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FEP report for the safety evaluation SE-SFL

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Preface

This report is one of the main references for the evaluation of post-closure safety for a proposed repository concept for the repository for long-lived waste (SFL) in Sweden. The report describes the FEP processing that has been used in the safety evaluation for SFL, SE-SFL. The objective of the work was to establish a SE-SFL FEP catalogue, containing all FEPs that are needed to be considered in SE-SFL, within the context of the SKB FEP Database. This report and the resulting version of the SKB FEP Database containing the SE-SFL FEP catalogue form part of the SE-SFL safety evaluation.

The report is authored by Niko Marsic, SKB, who also developed the SE-SFL FEP Database and carried out all the FEP implementations in the database. The work described in this report was conducted by Niko Marsic and the SE-SFL project leader and FEP coordinator, Jenny Brandefelt, SKB, based on experience from the FEP work conducted in the safety assessments SR-PSU and SR-Site. Several other experts and generalists have been involved at specific stages of the work.

An earlier version of this report has been commented by Kristina Skagius (SKB). The current version of the report has been reviewed by Mike Thorne (Mike Thorne and Associates Ltd, UK) and Jordi Bruno (Amphos[21], Spain). The received comments are greatly appreciated.

Solna, September 2019

Jenny Brandefelt
Project leader SE-SFL

Summary

The repository for long-lived waste (SFL) is planned to be constructed for the final disposal of low- and intermediate-level waste from Swedish nuclear facilities. SKB is planning to take SFL into operation around year 2045. Possible solutions for management and disposal of the Swedish long-lived low- and intermediate-level waste were examined in the SFL concept study and an approach to further assessment of post-closure safety was proposed (Elfwing et al. 2013). The next step in the development of SFL is the present safety evaluation. The purpose of this evaluation is to evaluate conditions in the waste, the barriers, and the repository environs under which the repository concept has the potential to fulfil the regulatory requirements for post-closure safety. Moreover, an objective is to provide SKB with a basis for prioritizing areas in which the level of knowledge and efficiency of methods must be improved in order to perform a full safety assessment for SFL.

This report documents the processing of features, events and processes (FEPs) that has been carried out within the safety evaluation SE-SFL. The objective of the work was to establish a SE-SFL FEP catalogue within the context of the SKB FEP Database, which already contains FEP catalogues from the two most recent safety assessments of a KBS-3 repository for spent nuclear fuel, SR-Site and SR-Can, and also for the safety assessment of the low- and intermediate-level waste repository SFR, SR-PSU. The SE-SFL FEP catalogue is required to contain all FEPs that needed to be considered in SE-SFL. Due to the many similarities between the SFR repository and the proposed repository design for SFL, it was decided to use the SR-PSU FEP catalogue as a starting point for the FEP processing in SE-SFL.

By using similar systematic procedures and experience from the work establishing the SR-PSU and SR-Site FEP catalogues, a SE-SFL FEP catalogue has been developed and included in the SKB FEP Database. The FEP processing approach used in SE-SFL is however simplified compared with the work performed in SR-PSU and SR-Site. A copy of the SR-PSU FEP catalogue was used as a base for the SE-SFL preliminary FEP catalogue. Relevant changes were then made to the FEP catalogue to capture the differences between the SFR and SFL repositories. Other simplifications made in the analysis were in the audit work against the NEA FEP Database version 2.1, where only a subset of the NEA Project-specific FEPs (PFEPs) were included in the analysis. Also, the Interaction Matrices used in SR-PSU, were omitted from the analysis.

The main reason for using a simplified FEP processing approach in SE-SFL is that many details concerning the repository design and the site selection are still subject to discussion, and it is therefore not meaningful to perform an extensive analysis based on preliminary data at this stage. A more rigorous FEP analysis will be performed in a future full safety assessment for SFL.

The resulting SE-SFL FEP catalogue is divided into the main categories *initial state*, *internal processes*, *biosphere*, *external factors*, *system variables*, *methodology* and *site-specific factors*. The FEPs belonging to the main categories *internal processes* and *system variables* are subdivided into the SFL system components *waste form*, *concrete and steel packaging*, *BHA barriers*, *BHK barriers*, *plugs and other closure components*, and the *geosphere*. The *biospher*e FEPs are subdivided into *biosphere processes*, *biosphere subsystem components* and *biosphere variables*. The *external factors* are categorised as *climatic processes and effects*, *large-scale geological processes and effects*, *future human actions* and *other*.

Sammanfattning

Slutförvaret för långlivat avfall (SFL) planeras att uppföras för slutförvaring av långlivat låg- och medelaktivt avfall från svenska kärntekniska anläggningar. SKB planerar att ta SFL i drift runt år 2045. Elfwing et al. (2013) undersökte möjliga lösningar för slutligt omhändertagande av det svenska långlivade låg- och medelaktiva avfallet och föreslog ett system att analysera vidare med avseende på säkerheten efter förslutning. Föreliggande säkerhetsvärdering utgör nästa steg i utvecklingen av SFL. Syftet med utvärderingen är att undersöka under vilka betingelser med avseende på säkerhet efter förslutning, förvarets omgivningar, avfall, och barriärer som föreslaget koncept har möjlighet att uppfylla myndighetskraven.

I denna rapport redovisas det arbete som utförts inom säkerhetsvärderingen SE-SFL för att identifiera egenskaper, händelser och processer (eng. features, events, processes), FEPar, relevanta för SFL. Syftet med arbetet var att skapa en SE-SFL FEP-katalog inom ramen för SKB:s FEP-Databas som sedan tidigare innehåller FEP-kataloger för SR-PSU (den senaste säkerhetsanalysen för utbyggt SFR) samt SR-Site och SR-Can (de senast utförda säkerhetsanalyserna för det planerade KBS-3-förvaret för använt kärnbränsle). Ett krav är att SE-SFL FEP-katalogen skall innehålla alla FEPar som behöver hanteras i SE-SFL. På grund av de många likheterna mellan den preliminära förvarsdesignen för SFL och SFR-förvaret beslutades det att använda SR-PSU FEP-katalogen som utgångspunkt för FEP-arbetet i SE-SFL.

Genom att använda liknande systematiska procedurer och erfarenheter från arbetet med framtagandet av FEP-katalogerna för SR-PSU och SR-Site, har en SE-SFL FEP-katalog utvecklats och inkluderats i SKB:s FEP-Databas. FEP-metodiken som används i SE-SFL är emellertid förenklad jämfört med det arbete som utförts i SR-PSU och SR-Site. En kopia av SR-PSU FEP-katalogen användes som utgångspunkt för den preliminära SE-SFL FEP-katalogen. Relevanta ändringar gjordes sedan i FEP-katalogen för att fånga skillnaderna mellan SFR- och SFL-förvaren. Andra förenklingar som gjordes i analysen var i revisionsarbetet med NEA Project FEP Databas version 2.1, där endast en delmängd av FEParna inkluderades i analysen. Utöver detta utelämnades de interaktionsmatriser som användes i SR-PSU från analysen.

Huvudskälet till att använda en förenklad arbetsmetodik för FEP-analysen i SE-SFL är att många detaljer rörande förvarsutformningen och lokaliseringen av förvaret ännu inte är definitiva varför det i detta skede inte är meningsfullt att utföra en omfattande analys baserad på preliminära data. En mer noggrann FEP-analys kommer att utföras i en framtida fullständig säkerhetsbedömning för SFL.

Den slutliga versionen av SE-SFL FEP-katalogen innehåller FEPar indelade i huvudkategorierna *initialtillstånd*, *interna processer*, *biosfär*, *externa faktorer*, *systemvariabler*, *metodik* och *platsspecifika faktorer*. FEPar tillhörande huvudkategorierna *interna processer* och *systemvariabler* är indelade i SFL:s systemkomponenter *avfallsform*, *betong- och stålbehållare*, *BHA-barriärer*, *BHK-barriärer*, *pluggar och andra förslutningskomponenter* samt *geosfären*. FEParna för *biosfären* innefattar *biosfär-processer*, *delsystemkomponenter för biosfären* samt *biosfärsvariabler*. FEParna för *externa faktorer* kategoriseras som *klimatprocesser och effekter*, *storskaliga geologiska processer och effekter*, *framtida mänskliga handlingar* samt *övriga*.

Contents

1 Introduction

This report constitutes one of the main references supporting the safety evaluation for a proposed repository concept for the repository for long-lived waste (SFL) in Sweden. The purpose of the SFL safety evaluation (SE-SFL) is to provide input to the subsequent, consecutive steps in the development of SFL. These consecutive steps include further development of the design of the engineered barriers and the site-selection process for SFL. Further, the outcomes of SE-SFL can be used to prioritize areas in which the level of knowledge must be improved in order to perform a subsequent, full safety assessment for SFL. This chapter gives the background to the project and an overview of the safety evaluation. Moreover, the role of this report is described in the context of the evaluation.

1.1 Background

The Swedish power industry has been generating electricity by means of nuclear power for more than 40 years. The Swedish system for managing and disposal of the waste from operation of the reactors has been developed over that period. When finalised, this system will comprise three repositories: the repository for short-lived radioactive waste (SFR), the repository for long-lived waste (SFL), and the Spent Fuel Repository.

The system for managing radioactive waste is schematically depicted in Figure 1-1. SKB currently operates SFR at Forsmark in Östhammar municipality to dispose of low- and intermediate-level waste produced during operation of the various nuclear power plants, as well as to dispose waste generated during applications of radioisotopes in medicine, industry, and research. Further, SFR is planned to be extended to permit the disposal of waste from decommissioning of nuclear facilities in Sweden. The spent nuclear fuel is presently stored in the interim storage facility for spent nuclear fuel (Clab) in Oskarshamn municipality. Clab will be complemented by the Encapsulation Plant, together forming Clink. SKB has also applied to construct, possess and operate the Spent Fuel Repository at Forsmark in Östhammar municipality. The current Swedish radioactive waste management system also includes a ship and different types of casks for transport of spent nuclear fuel and other radioactive waste.

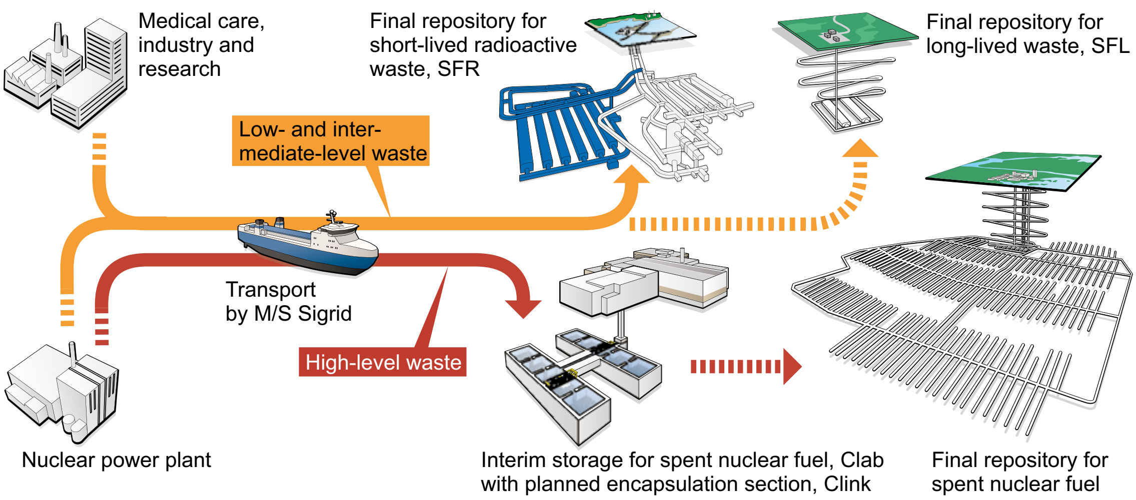

Figure 1-1. *The Swedish system for radioactive-waste management. Dashed arrows indicate future waste streams to facilities planned for construction.*

SFL will be used for disposal of the Swedish long-lived low- and intermediate-level waste. This comprises long-lived waste from the operation and decommissioning of the Swedish nuclear power plants, from early research in the Swedish nuclear programmes (legacy waste), from medicine, industry, and from research which includes the European Spallation Source (ESS) research facility. The long-lived low- and intermediate-level waste from the nuclear power plants consists of neutron-activated components and control rods and constitutes about one third of the waste planned for SFL. The rest originates mainly from the Studsvik site, where Studsvik Nuclear AB and Cyclife Sweden AB both produce and manage radioactive waste from medicine, industry and research. The legacy waste to be disposed of in SFL is currently managed by the company AB SVAFO.

A first preliminary repository concept for SFL was presented in the context of cost calculations for radioactive waste management (Plan 93; SKB 1993). Since the purpose of PLAN 93 was to give cost estimations no safety related analyses were discussed. The first quantification related to safety was presented in a pre-study of final disposal of long-lived low and intermediate level waste. The objective was to make a first preliminary and simplified assessment of the near-field as a barrier to radionuclide dispersion (Wiborgh 1995). In 1999, a preliminary safety assessment was presented that focussed on a quantitative analysis of the environmental impact for a reference scenario (SKB 1999c). The objective was to investigate the capacity of the facility to act as a barrier to the release of radionuclides and the importance of the repository location. The assessment was reviewed by the authorities (SKI/SSI 2001). One of the main comments was a lack of a clear account of the basis for the selection of the design and that no design alternatives had been considered.

Reflecting the comments from the authorities possible solutions for management and disposal of the Swedish long-lived low- and intermediate-level waste were examined in the SFL concept study (Elfwing et al. 2013). Among the considered alternatives a system was proposed as a basis for further assessment of post-closure safety. According to this concept, SFL is designed as a deep geological repository with two different sections:

- one waste vault, designed with a concrete barrier, BHK, for metallic waste from the nuclear power plants, and
- one waste vault, designed with a bentonite barrier, BHA, for the waste from Studsvik Nuclear AB, Cyclife Sweden AB and AB SVAFO.

A schematic illustration of SFL is displayed in Figure 1-2. In SE-SFL, it is assumed that the waste vaults are located at 500 m depth. BHK is approximately 135 m long and BHA is approximately 170 m long. Both vaults have a cross sectional area of approximately 20 × 20 m^2 (see further details in the **Initial state report**).

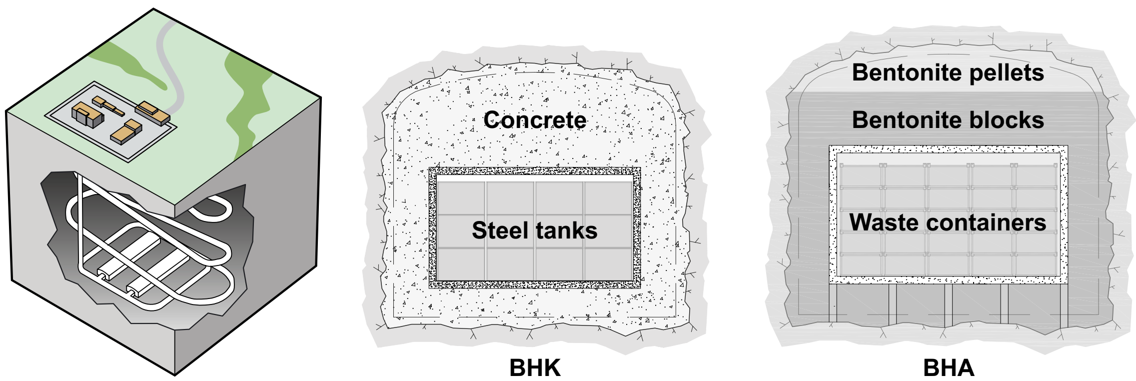

Figure 1-2. *Preliminary facility layout and the proposed repository concept for SFL (left), one waste vault for metallic waste from the nuclear power plants (BHK, centre) and one waste vault for waste from Studsvik Nuclear AB, Cyclife Sweden AB and AB SVAFO (BHA, right).*

1.2 The SE-SFL safety evaluation

There are two main objectives for SE-SFL. The first is to evaluate conditions in the waste, the barriers, and the repository environs under which the repository concept has the potential to fulfil the regulatory requirements for post-closure safety. The second is to provide SKB with a basis for prioritizing areas in which the level of knowledge and efficiency of methods must be improved in order to perform a full safety assessment for SFL. This is in line with the iterative safety analysis process that the SFL repository program follows, in which the results from post-closure safety analyses and related activities (e.g. information from a site selection process and development of numerical methods) are used to successively inform and improve the analysis. In accordance with the Nuclear Activities Act (1984:3), important research needs for the SFL programme that emerge as a result of SE-SFL will be reported in the research development and demonstration (RD&D) programme. An important aspect of this is to ensure that the industry has well founded information to support long-term planning.

The safety analysis methodology as applied in SE-SFL is a first evaluation of post-closure safety for the repository concept proposed by Elfwing et al. (2013) and is not part of a license application. As such, the methodology has been adapted to suit the needs of SE-SFL and thus differs from the methodology established by SKB for the most recent safety assessments for the extended SFR (SR-PSU; SKB 2015) and for the Spent Fuel Repository (SR-Site; SKB 2011a). This also implies that the regulatory requirements on the methodology have not been applied rigorously, which would be needed for a safety analysis that is part of a license application. The evaluation is intentionally simplified as compared with SR-Site and SR-PSU, and more focus is given to aspects connected to the further development of the repository concept and related analyses. This is also reflected in using the term safety evaluation in comparison to safety assessment. The differences between SE-SFL and a full safety assessment are described in more detail in Section 2.1 in the **Main report**. The adaption of the methodology for the purposes of SE-SFL is described in Section 2.5 in the **Main report**.

To the extent applicable, SE-SFL builds on knowledge from SR-PSU and SR-Site. There are commonalities regarding the waste, engineered barriers, bedrock, surface ecosystems and external conditions relevant to post-closure safety. For instance, SE-SFL and SR-Site both address timescales of one million years (see Section 2.3 in the **Main report**). A further similarity is the proposed depth of 300–500 m. There are similarities between SFR and SFL regarding the waste and waste packaging and the proposed engineered barriers.

In SE-SFL, a first evaluation of a suitable repository design for disposal of the ESS waste is carried out. Since the information regarding the ESS inventory is not yet as well defined as for the other waste streams, the protective capability of the different waste vaults in relation to this waste is analysed separately.

No site has yet been selected for SFL and therefore data from SKB's site investigation programmes for the Spent Fuel Repository and for the extension of SFR have been utilized in SE-SFL. In order to have a realistic and consistent description of a site for geological disposal of radioactive waste, data from the Laxemar site in Oskarshamn municipality (see Figure 1-3), for which a detailed and coherent dataset exists, is used. Based on an initial hydrogeological analysis for SE-SFL, the example location for the SFL repository was selected to be a volume part of what was earlier found most suitable for a potential Spent Fuel Repository within the Laxemar site (SKB 2011b).

SE-SFL is further developed in comparison to the previous assessments, which were mentioned in Section 1.1. Important improvements are an updated inventory and more elaborate account of internal and external processes. Moreover, the biosphere was in the preliminary assessment handled in a simplified manner, whereas it is handled in an elaborate way in SE-SFL. The availability of data from the Spent Fuel Repository site investigations also allows for more detailed representations of the geosphere. In general, SKB's experiences with safety analysis work have led to many developments since the late 1990s.

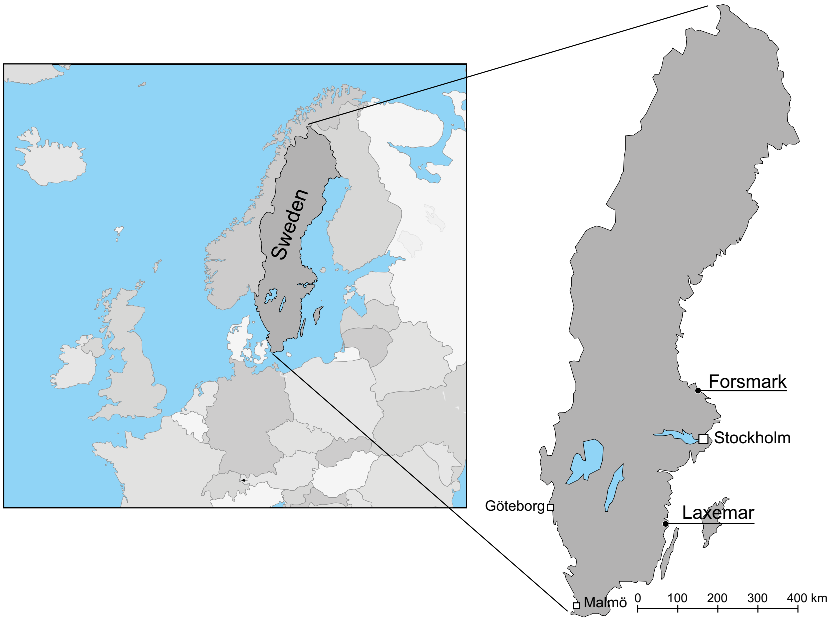

Figure 1-3. *Map showing the location of Laxemar and Forsmark. Data from the site investigations in Laxemar, along with the data from the SR-Site and SR-PSU assessments from Forsmark, are used in SE-SFL to obtain a coherent dataset of common conditions in Swedish crystalline bedrock and surface ecosystems.*

1.3 The SE-SFL report hierarchy

The **Main report** and main references in SE-SFL are listed in Table 1-1, also including the abbreviations by which they are identified in the text (abbreviated names in bold text). It can be noted that there are no dedicated process reports for SE-SFL. The SFR and SFL waste and repository concepts have many similarities, for instance the use of similar barrier materials and thus similar process interactions with the surrounding bedrock environment (see Section 2.5.4 in the **Main report**). Therefore, the descriptions of internal processes for the waste (SKB 2014f) and the barriers (SKB 2014g) in SR-PSU are used in SE-SFL. For the bedrock system, the descriptions of internal processes for the geosphere in SR-Site (SKB 2010c) and SR-PSU (SKB 2014h) are used. There are also several additional references, which include documents compiled within SE-SFL, for instance input data reports for the radionuclide transport and dose calculations (Shahkarami 2019, Grolander and Jaeschke 2019). But there are also references to documents that have been compiled outside of the project, either by SKB or other similar organisations, or are available in the scientific literature. In Figure 1-4, the hierarchy of the **Main report**, main references and additional references within SE-SFL is shown.

Table 1-1. Main references in SE-SFL and their abbreviations used in this report (shown in bold).

Abbreviation used when referenced in this report	Text in reference list
Main report	**Main report, 2019.** Post-closure safety for a proposed repository concept for SFL. Main report for the safety evaluation SE-SFL. SKB TR-19-01, Svensk Kärnbränslehantering AB.
Biosphere synthesis report	**Biosphere synthesis report, 2019.** Biosphere synthesis for the safety evaluation SE-SFL. SKB TR-19-05, Svensk Kärnbränslehantering AB.
Climate report	**Climate report, 2019.** Climate and climate-related issues for the safety evaluation SE-SFL. SKB TR-19-04, Svensk Kärnbränslehantering AB.
FEP report	**FEP report, 2019.** Features, events and processes for the safety evaluation SE-SFL. SKB TR-19-02, Svensk Kärnbränslehantering AB.
Initial state report	**Initial state report, 2019.** Initial state for the repository for the safety evaluation SE-SFL. SKB TR-19-03, Svensk Kärnbränslehantering AB.
Radionuclide transport report	**Radionuclide transport report, 2019.** Radionuclide transport and dose calculations for the safety evaluation SE-SFL. SKB TR-19-06, Svensk Kärnbränslehantering AB.

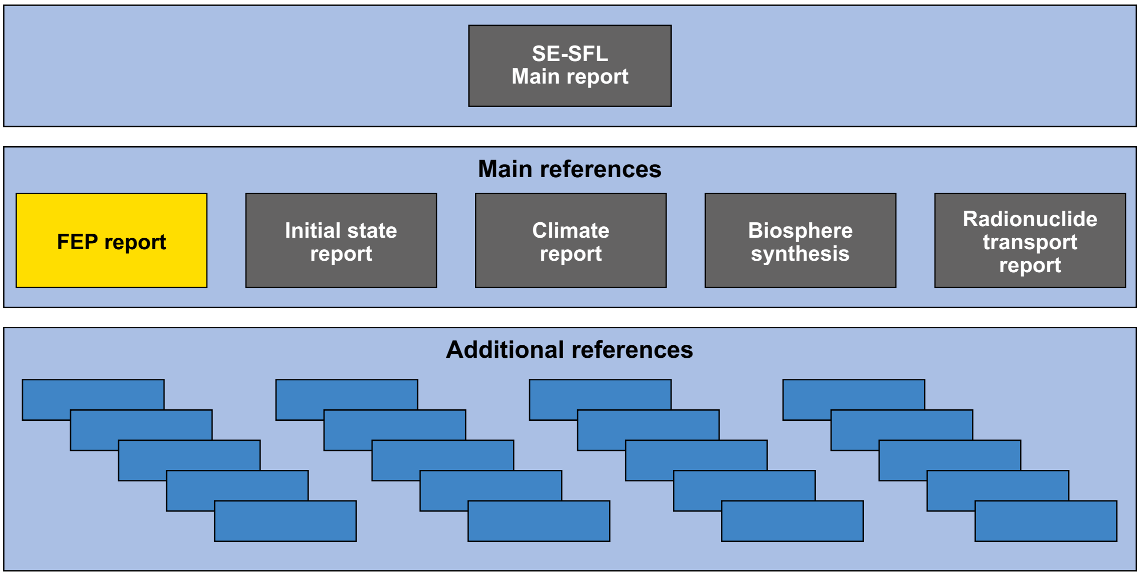

Figure 1-4. *The hierarchy of the Main report, main references and additional references in the safety evaluation of post-closure safety SE-SFL. The additional references either support the Main report or one or more of the main references.*

1.4 The role of this report in SE-SFL

This report documents the analysis and processing of features, events and processes (FEPs) that has been carried out within the safety evaluation SE-SFL. The evaluation of post-closure safety for the proposed repository concept for SFL is performed according to a methodology comprising nine main steps, which are carried out partly concurrently and partly consecutively. The detailed evaluation methodology is described in Chapter 2 in the **Main report**. The present report focusses on Step 1 in this methodology – Processing of features, events and processes influencing post-closure safety.

1.4.1 Objective and scope of the FEP processing

As part of each safety assessment conducted at SKB over the past two decades, a new FEP catalogue has been developed and included in the SKB FEP Database. The database was originally developed for the Spent Fuel Repository, and subsequently extended to include also SFR. In SE-SFL, this database has been further extended to include also SFL. The FEP processing work, including procedures for a systematic analysis of FEPs and documentation of the analysis in the FEP database, within each safety assessment is documented in separate FEP reports. In Table 1-2, the most recent safety assessments conducted at SKB are listed together with the analysed repository type (Spent Fuel Repository, SFR – for short-lived radioactive waste and SFL – for long-lived low- and intermediate-level waste) and references to the FEP and main reports, where applicable. The most recent assessment for each repository is marked in bold italics style. For a few frequently used references, Table 1-2 also includes the abbreviations by which they are identified in the text (abbreviated names in bold style).

Processing of FEPs involves:

- Identification of all factors that may influence post-closure safety for the proposed repository concept at the example location evaluated in SE-SFL.
- For each FEP identified it is decided if it needs to be included in the analysis.
- Documentation of the handling of each identified FEP in the SE-SFL FEP catalogue.

The SR-PSU FEP Database was used as a basis for the identification of all factors that may influence post-closure safety for the proposed repository concept at the example location for SE-SFL. The main reason for this choice is the similarities in the waste, waste packaging and technical barriers proposed. Further, the SR-PSU FEP Database, including the FEP catalogue and the collection of NEA PFEPs that were judged irrelevant for PSU, constitutes a complete set of currently known factors that can influence post-closure safety for a geological repository for radioactive waste. The procedures and sources used to identify relevant features, events and processes are described in Section 2.3.

The objective of the FEP processing in SE-SFL is two-fold; to make sure that all factors that may influence post-closure safety are identified, and, to document the handling of each FEP in the SE-SFL FEP catalogue. In this sense the SE-SFL FEP catalogue constitutes a "look-up-table" with a brief description of the handling of each FEP and references to relevant reports that detail the handling further. Further, FEPs are labelled either "considered" or "not considered", according to how they are handled in the safety evaluation. Considered FEPs have been taken into account in the reference evolution (**Main report**, Chapter 6), whereas non-considered FEPs have not been taken into account in SE-SFL. Some of the not-considered FEPs will be or may be considered in future safety assessments for SFL, indicating that the FEP was left out of the SE-SFL analysis due to the more limited scope of the safety evaluation compared with a full safety assessment, or that relevant data needed to handle the process adequately were missing. The classification of the SE-SFL FEPs is described in Sections 3.1 and 4.2.

Table 1-2. Safety assessments completed at SKB, listed in chronological order, where FEP reports and SKB FEP Databases were produced. The most recent assessment for each repository is marked in bold italics style. The abbreviations by which they are identified in the text are marked in bold style. All reports are available at www.skb.se.

Safety assessment	Repository	References
SR 97	Spent Fuel Repository	**SKB, 1999a.** Deep repository for spent nuclear fuel. SR 97 – Post-closure safety. Main report – Vol. I, Vol. II and Summary. SKB TR-99-06, Svensk Kärnbränslehantering AB. **SKB, 1999b.** SR 97. Processes in the repository evolution. SKB TR-99-07, Svensk Kärnbränslehantering AB. **Pers K, Skagius K, Södergren S, Wiborgh M, Hedin A, Morén L, Sellin P, Ström A, Pusch R, Bruno J, 1999.** SR 97 – Identification and structuring of process. SKB TR-99-20, Svensk Kärnbränslehantering AB.
SAFE	SFR	**SKB, 2001.** Project SAFE. Scenario and system analysis. SKB R-01-13, Svensk Kärnbränslehantering AB.
SR-Can	Spent Fuel Repository	**SKB, 2006a.** Long-term safety for KBS-3 repositories at Forsmark and Laxemar – a first evaluation. Main report of the safety assessment SR-Can. SKB TR-06-09, Svensk Kärnbränslehantering AB. **SKB, 2006b.** FEP report for the safety assessment SR-Can. SKB TR-06-20, Svensk Kärnbränslehantering AB.
SAR-08	SFR	**SKB, 2008.** Project SFR 1 SAR-08. Update of priority of FEPs from Project SAFE. SKB R-08-12, Svensk Kärnbränslehantering AB.
SR-Site	***Spent Fuel Repository***	**SKB, 2011a.** Main report of the SR-Site project. SKB TR-11-01, Svensk Kärnbränslehantering AB. **SKB, 2010a.** FEP report for the safety assessment SR-Site. SKB TR-10-45, Svensk Kärnbränslehantering AB. **SKB, 2010b.** Components, processes and interactions in the biosphere. SKB R-10-37, Svensk Kärnbränslehantering AB.

Safety assessment	Repository	References
SR-PSU	***SFR***	**SKB, 2015.** Safety analysis for SFR. Long-term safety. Main report for the safety assessment SR-PSU. Revised edition. SKB TR-14-01, Svensk Kärnbränslehantering AB. **SKB, 2014b.** FEP report for the safety assessment SR-PSU. SKB TR-14-07, Svensk Kärnbränslehantering AB. **SKB, 2014c.** Handling of biosphere FEPs and recommendations for model development in SR-PSU. SKB R-14-02, Svensk Kärnbränslehantering AB. **SKB, 2014d.** Biosphere synthesis report for the safety assessment SR-PSU. SKB TR-14-06, Svensk Kärnbränslehantering AB.
SE-SFL	***SFL***	**Main report, 2019.** Post-closure safety for a proposed repository concept for SFL. Main report for the safety evaluation SE-SFL. SKB TR-19-01, Svensk Kärnbränslehantering AB. **FEP report, 2019.** Features, events and processes for the safety evaluation SE-SFL. SKB TR-19-02, Svensk Kärnbränslehantering AB.

1.4.2 Participating experts

The procedures applied for developing the SE-SFL FEP catalogue were similar to those used for the SR-PSU (SKB 2014b) and SR-Site FEP catalogues (SKB 2010a). Decisions during the FEP audit and processing stages regarding the treatment of FEPs were made by several groups of SKB experts in the different FEP categories and system components, guided by the corresponding decisions made in SR-PSU and SR-Site. Table 1-3 shows the names of the participating experts in the SE-SFL FEP audit and processing. The name of the expert responsible for each FEP category is underlined.

Table 1-3. Experts participating in the FEP audit and processing. Names in italic show the expert responsible for the FEP category.

Main category	System component	Participating experts
Initial state		*Jenny Brandefelt*
Internal processes	Waste form	*Klas Källström*, Kastriot Spahiu, Björn Herschend, Johannes Johansson, Katrin Ahlford, Jenny Brandefelt
Internal processes	Concrete and steel packaging	*Klas Källström*, Per Mårtensson, Björn Herschend, Katrin Ahlford, Jenny Brandefelt
Internal processes	BHK barriers	*Henrik von Schenck*, Per Mårtensson, Ola Wessely, Maria Lindgren (Kemakta), Jenny Brandefelt
Internal processes	BHA barriers	*Patrik Sellin*, Ola Wessely, Jenny Brandefelt
Internal processes	Plugs and other closure components	*Patrik Sellin*, Per Mårtensson, Henrik von Schenck, Ola Wessely, Jenny Brandefelt
Internal processes	Geosphere	*Patrik Vidstrand*, Björn Gylling, Ignasi Puigdomenech, Raymond Munier, Diego Mas-Ivars, Birgitta Kalinowski, Jenny Brandefelt
Biosphere		*Ulrik Kautsky*, Peter Saetre, Olle Hjerne, Eva Andersson, Jenny Brandefelt
External factors		*Jens-Ove Näslund*, Diego Mas-Ivars, Patrik Vidstrand, Eva Andersson, Thomas Hjerpe (ÅF), Jenny Brandefelt
Methodology		*Jenny Brandefelt*
Site-specific factors		*Jenny Brandefelt*, Johannes Johansson, Björn Herschend, Kastriot Spahiu

1.5 Structure of this report

This report comprises six chapters and two appendices. Following is a brief description of the contents:

Chapter 1 – Introduction. This chapter describes the background and the role of the report. Furthermore, a list of participating experts is provided and definitions of abbreviations are given.

Chapter 2 – FEP processing procedures and prerequisites. In this chapter, the prerequisites for the work and an overview of the different activities undertaken during the establishment of the SE-SFL FEP catalogue are given.

Chapter 3 – FEP audit. In this chapter, the SE-SFL FEP audit procedure is described in detail, including the audits against the SR-PSU FEP list and the NEA PFEPs.

Chapter 4 – FEP processing. In this chapter, the different procedures applied for the further processing of the FEPs identified through the SE-SFL FEP audit are described.

Chapter 5 – The SE-SFL FEP catalogue. In this chapter, the establishment of the SE-SFL FEP catalogue within the framework of the SKB FEP Database together with files documenting the FEP processing results is described. The content of the SE-SFL FEP catalogue and the information it provides are described.

Chapter 6 – Concluding remarks. This chapter gives some concluding remarks regarding the FEP analysis conducted in SE-SFL.

Appendix 1 – Complete list of FEP records in the SE-SFL FEP catalogue. This appendix contains a complete list of all 281 FEPs included in the SE-SFL catalogue. For each FEP, the following information is shown: the FEP ID, FEP name, main category, system component/subcategory, and handling status in SE-SFL.

Appendix 2 – Complete list of NEA Project-specific FEPs considered in the SE-SFL FEP analysis. This appendix contains a complete list of all 553 NEA Project-specific FEPs (see Section 3.3) that were considered in the SE-SFL FEP analysis. For each FEP, the following information is shown: the FEP ID, FEP name, audit step number where the FEP was screened out or taken into account by augmenting the SE-SFL FEP catalogue, and motivation for screening.

1.6 Abbreviations used in this report

In Table 1-4, explanations of the most important abbreviations used in this report, is given.

Table 1-4. Explanations to used abbreviations.

Term or abbreviation	Description
BHA	Vault for legacy waste from the early research in the Swedish nuclear programmes, and smaller amounts of waste from medicine, industry and research.
BHK	Vault for reactor internals
DGR	Deep Geological Repository
FEPs	Features, Events and Processes
IFEP List	NEA International FEP List
PFEP List	NEA Project-specific FEP List
NEA	Nuclear Energy Agency
IAEA	International Atomic Energy Agency
IGSC	Integration Group for the Safety Case
OECD	Organisation for Economic Co-operation and Development
RWMO	Radioactive Waste Management Organisation
SFR	Repository for short-lived radioactive waste
SFL	Repository for long-lived radioactive waste
SKB	Swedish Nuclear Fuel and Waste Management Company
FileMaker™	Software used for developing and managing the SKB FEP Database
Initial state	The state of the SFL repository and its environs immediately after closure.
QA	Quality assurance
Repository and its environs	Broadly defined as the deposited radioactive waste and the surrounding packaging, the engineered barriers surrounding the waste packages, the host rock and the biosphere in proximity to the repository.
Waste form	The physical and chemical form after treatment and/or conditioning. (IAEA 2007)
Waste package	Includes waste form and packaging
Waste packaging	The outer barrier protecting the waste form. Includes the assembly of components (e.g. absorbant materials, spacing structures, radiation shielding, service equipment, etc.) (IAEA 2007)
Waste type	In order to systematically classify the waste, different waste types have been defined and a code system developed.
Waste vault	Part of repository where waste is disposed
System component	A physical component of the repository and its environs
AB SVAFO	Company managing the Swedish legacy waste. Originally formed by Sydkraft, Vattenfall, Forsmark and OKG. Now owned by Forsmarks Kraftgrupp AB, Ringhals AB and OKG AB.

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 SE-SFL FEP catalogue. The development procedure is described in more detail in the following chapters together with the results from the various steps.

2.1 System definition

The system analysed in SE-SFL, i.e. the repository and its environs, comprises the deposited radioactive waste and the packaging, the engineered barriers surrounding the waste packages, the geosphere and the biosphere in proximity to the repository.

In the database, the system is divided into several system components. It should be noted that these definitions were set up primarily to facilitate the auditing procedure and the development of the SE-SFL part of the SKB FEP Database. Therefore, all these definitions are not necessarily relevant in subsequent treatments of FEPs in the safety evaluation, e.g. through modelling.

2.1.1 System boundary

The repository and its environs comprise the disposed radioactive waste, the engineered barriers surrounding the waste packages, the geosphere and the biosphere in the proximity of the repository. In general, a strict boundary definition is neither necessary nor indeed possible, and the same boundaries are not necessarily relevant to all parts of the safety evaluation.

To be able to distinguish between FEPs belonging to the system analysed in SE-SFL 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 of Laxemar developed for the site-selection process for the Spent Fuel Repository (SKB 2009), i.e. an area of the order of 100–300 km^2 above the repository, is regarded as internal and part of the system that is represented within the analysis, whereas the biosphere on a larger scale is regarded as external. The analysis of the biosphere extends downward to the bedrock surface. 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. Climate and climate-related issues, such as development of permafrost and ice-sheets, are external factors. The *effects* on the repository and its environs, e.g. freezing in the bedrock and repository, are regarded as internal to the system.
- Roughly the portion of the geosphere included in the site-descriptive model of Laxemar developed for the site-selection process for the Spent Fuel Repository (SKB 2009) 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 that does not affect the performance and safety of the disposal system is regarded as internal to the system. Issues related to the characteristics and behaviour of future society at large are regarded as external factors.
- Future human actions that may influence the post-closure safety of the repository, e.g. extraction of geothermal heat, are regarded as external factors.

2.1.2 System components

The proposed deep geological repository concept for SFL comprises two waste vaults. One vault (BHK) would be for metallic waste from the nuclear power plants and designed with a concrete barrier. The other vault (BHA) would have a bentonite barrier and accommodate the waste from Studsvik Nuclear AB, Cyclife Sweden AB and AB SVAFO. This includes waste from medicine, industry and research as well as the legacy waste. In addition, all or some of the waste from the

European Spallation Source (ESS) could be placed here. ESS is a multi-disciplinary research facility based on the world's most powerful neutron source, currently under construction in Lund, Sweden. However, due to uncertainties in radionuclide composition, it is not yet clear whether BHK or BHA will be best suited for disposal of the ESS waste.

The system analysed is divided into the following system components:

- *Waste form.*
- *Concrete and steel packaging.*
- *BHK barriers.*
- *BHA barriers.*
- *Plugs and other closure components.*
- *Geosphere.*
- *Biosphere.*

A brief description of each system component is given below. More detailed descriptions are provided in the **Main report** and the main references.

Waste form. In BHK, this system component comprises the long-lived low- and intermediate-level metallic waste from the nuclear power plants, which typically consists of neutron-activated components from within or close to the reactor core. Conditioning material is also included in this system component.

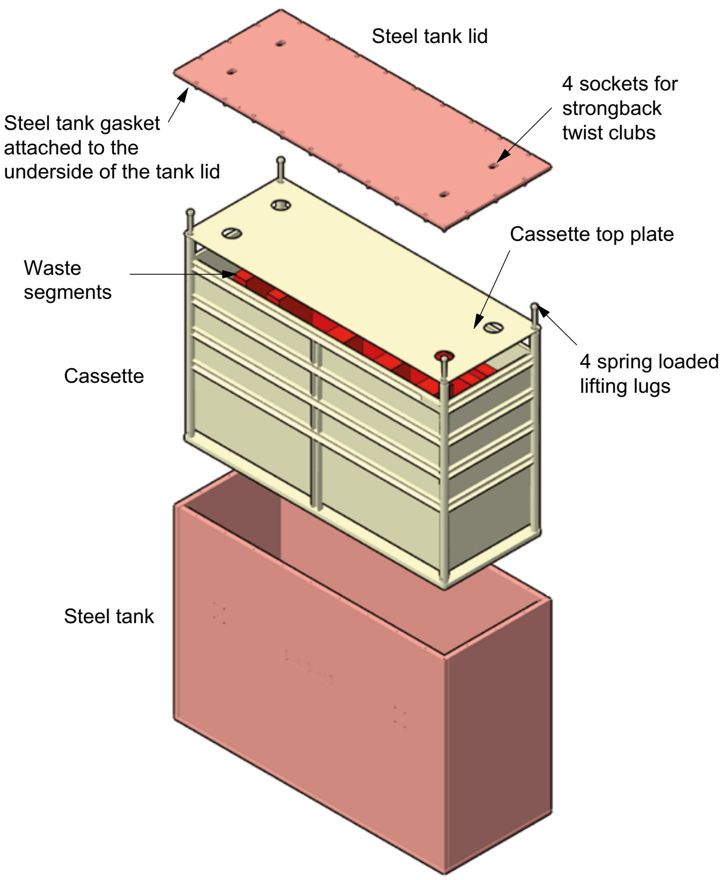

***Figure 2-1.** Schematic illustration of the steel tank for neutron activated components disposed in BHK. The steel tank has external dimensions 3.3 × 1.3 × 2.3 m^3 (length × width × height). The waste is placed in a cassette which is placed in the tank. A lid is bolted to the tank. The thickness of the steel walls is chosen to comply with the requirements determined by the radioactivity and dose rate of the waste. The figure is a copy of Figure 3-1 in the **Initial state report**.*

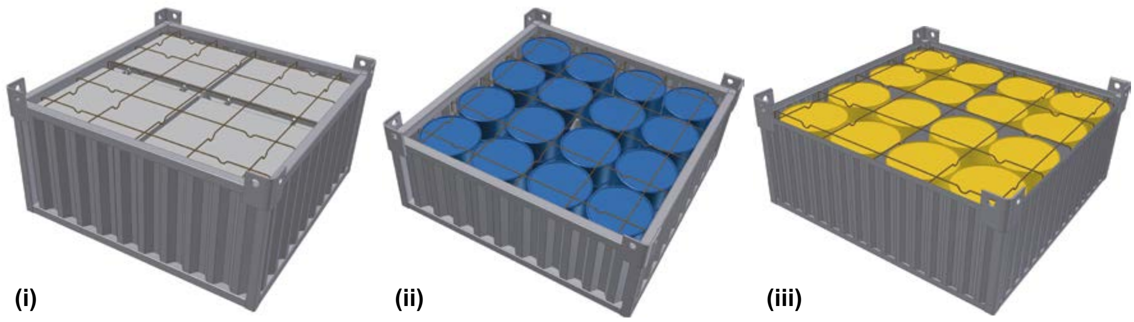

***Figure 2-2.** 3D-view of waste packaging disposed in BHA, loaded with (i) standard moulds, (ii) standard 200-litre drums, and (iii) 280-litre protection drums. Reinforcement bars that will stabilise the future grout on top of the moulds are also shown. The figure is a copy of Figures 3-3 (i), 3-5 (ii) and 3-7 (iii) in the **Initial state report**.*

In BHA, this system component comprises previous and future waste from research carried out at the Studsvik site as well as waste from decommissioning. Furthermore, waste from the early research in the Swedish nuclear programmes (legacy waste), and waste collected from other producers of radioactive materials in Sweden such as medicine, industry and research is included. Conditioning material is also included in this system component in BHA. Some of the legacy waste currently stored at Studsvik is stored in 200-litre drums, which have recently been placed in new 280 litre protection drums. For this waste, the inner drum is also included in the waste form.

The outer boundary of this system component is defined as the interface between the waste form and the packaging (**Initial state report**).

Concrete and steel packaging. This system component comprises all packaging materials used in SFL, with the exception of the inner packaging for some of the waste in BHA. For BHK, the plan is to use the same large steel tanks that are used today for storage of the core components from maintenance of the nuclear power plants. Cassettes loaded with waste are placed inside the steel tanks and a lid is bolted to the tank. Both the cassettes and the steel tanks are made of carbon steel, see Figure 2-1.

For BHA, the current plan is to dispose of the waste in packaging for standard moulds, standard 200-litre drums and 280-litre protection drums, see Figure 2-2. The design is similar for the three types of waste packaging and consists of a welded framework of square tubes, with sides made of corrugated steel panels that are designed to withstand the forces from grouting of the inner waste packages. The waste packaging is made of steel and is assumed to be filled with grout to the top of the waste packaging. No steel lid will be used. The grout surface will be level with the top of the steel frame. Reinforcement bars will be placed on top of the moulds to prevent cracking of the top-most layer of the grout (**Initial state report**).

BHK barriers. This system component comprises all engineered barriers in the BHK vault, except for the waste packages, and comprises a concrete barrier in the form of six separate caissons. When the waste packages have been placed in the caisson, the space between the waste packages will be filled with grout to stabilise the stack of waste packages and to reduce the void, see Figure 2-3 for dimensions. In addition, the grout will stabilise the waste packages themselves and improve the strength of the structure by reducing the deformations caused by the external forces on the walls, floor and lid of the caisson during backfill and re-saturation of the repository. The grout also contributes to the high alkalinity in the vault and thus also to the passivation of steel components in the waste packages, which thereby reduces the corrosion rate. The space between the concrete caissons and the bedrock walls, on all sides, is to be backfilled with concrete. Bentonite plugs will be installed at each end of the vault. The length of the BHK vault is approximately 134 m.

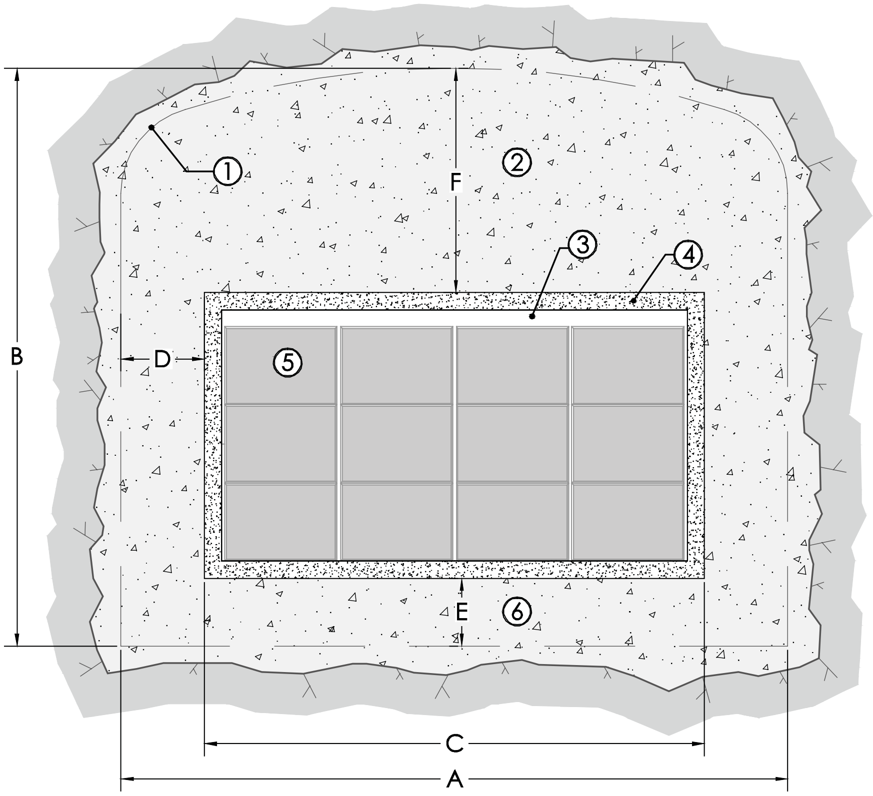

*Figure 2-3. Schematic cross-sectional layout of BHK from Elfwing et al. (2013). Legend: (1) Theoretical tunnel contour, (2) Concrete backfill, (3) Grout, (4) Reinforced concrete structure (0.5 m), (5) Steel tanks, (6) Concrete. Approximate dimensions: A = 20.6 m, B = 19.6 m, C = 15 m, D = 2.8 m, E = 2.4 m, F = 8.8 m. The figure is a copy of Figure 4-1 in the **Initial state report**.*

The primary safety function of this repository vault is retardation. This is achieved by limiting the flow of groundwater through the waste and further by limiting the diffusive transport of substances to and from the waste. Finally, the concrete and grout provide a high sorption capacity for many radionuclides and also maintain high pH and a favourable chemical environment in the repository. The design of the waste vault along with dimensions is described in Elfwing et al. (2013).

An illustration of the cross section of the vault including the main components and dimensions of the engineered BHK barrier system are shown in Figure 2-3 (**Initial state report**).

BHA barriers. This system component comprises all engineered barriers in the BHA vault, except for the waste packages, and comprises a concrete structure in which the waste is deposited. The bottom of the structure consists of a reinforced concrete base slab which is placed on granite pillars, standing on the floor of the vault. A concrete wall structure is cast onto the base slab, and, at closure, a concrete lid is placed on top of the structure. The purpose of the concrete structure is to provide radiation protection during the operational phase and, after closure, also to contribute to high alkalinity in the vault and constitute a chemical barrier that enhances sorption of radionuclides in the vault.

When the waste packages have been placed in the concrete structure, the void between the waste packages will be filled with grout to stabilise the entire stack of waste packages and to reduce the voidage. In addition, the grout will stabilise the individual waste packages and improve the strength of the structure by reducing the deformations caused by the external forces on the walls, floor and lid during backfill and re-saturation of the repository. The grout also contributes to the high alkalinity in the vault and thus also to the passivation of steel components in the waste packages, which thereby reduces the corrosion rate. The concrete walls, lid, grout and the floor, constitute chemical barriers that enhance sorption of radionuclides in the vault. The length of the BHA vault is approximately 170 m.

The concrete structure will be entirely surrounded by a thick layer of high-quality bentonite, see Figure 2-4 for dimensions. It will function as a low permeability medium enclosing the waste. The bedrock walls and ceilings will be lined with shotcrete, as required. Bentonite blocks will be placed beneath the base slab as well as on the sides and on top of the concrete structure. The top part of the vault will be filled with bentonite pellets. No bentonite will be placed in the vault until the time of closure. The thick bentonite layer constitutes the main barrier that primarily reduces the flow of water through the repository but also increases the sorption capacity for radionuclides in the vault.

The primary safety function of this repository vault is retardation. The barriers limit the flow of groundwater through the waste and thus, make diffusion the predominant transport process for radionuclides. The design of the waste vault along with dimensions is described in Elfwing et al. (2013).

An illustration of the cross section of the vault including the main components and dimensions of the engineered BHA barrier system are shown in Figure 2-4.

Plugs and other closure components. This part of the system comprises the range of backfill materials (bentonite, concrete, crushed rock or boulders) and mechanical plugs used in the different parts of the system analysed, as described below.

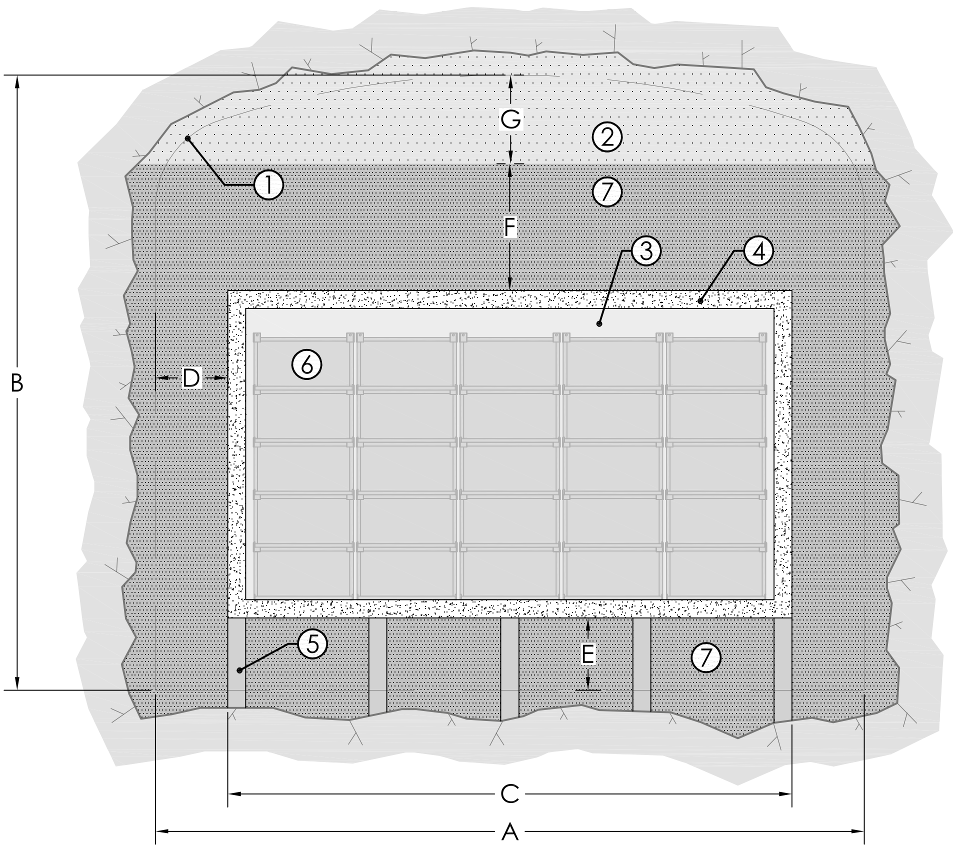

***Figure 2-4.** Schematic cross-sectional layout of BHA from Elfwing et al. (2013). Legend: (1) Theoretical tunnel contour, (2) Bentonite pellets, (3) Grout, (4) Concrete structure (0.5 m), (5) Granite pillars, (6) Waste packages, (7) Bentonite blocks. Approximate dimensions: A = 20.6 m, B = 18.5 m, C = 16 m, D = 2.3 m, E = 2.4 m, F = 4 m, G = 3.7 m. The figure is a copy of Figure 5-1 in the **Initial state report**.*

In a geological repository, the bedrock surrounding the waste vaults is part of the barrier system that will prevent the radioactive substances from reaching the biosphere. The tunnels that provide access to the waste vaults may impair the barrier function of the bedrock through the creation of open flow paths. These flow paths must be closed by installing closure components. The main purposes of the closure components are to:

- Reduce the axial water transport in the tunnels.
- Reduce the water flow from the tunnels to the waste vaults.
- Support the bedrock and thereby prevent collapse of the tunnel roof and walls.
- Prevent unauthorised access to the radioactive waste.

The closure components are schematically illustrated in Figure 2-5. At this stage, it is assumed that the design of the components and method for installation will not differ significantly between the different parts of the repository. However, future research and safety analysis will be required before a final design of the closure components can be presented for each of the individual parts of the repository (see the **Initial state report**).

Backfill. The space between the caissons and the bedrock will be filled with concrete (BHK) or bentonite (BHA) to further limit the water flow through the waste, contribute to high alkalinity and provide sorption sites for the radionuclides.

Sealing waste vaults. To seal the waste vaults, tunnel sections adjacent to the cavern are to be filled with bentonite and confined by mechanical plugs. The bentonite acts as a hydraulic seal to reduce the axial flow of groundwater through the waste vault. This solution is in accordance with previous investigations and concepts developed by SKB for the Spent Fuel Repository (Luterkort et al. 2012).

Closure of the tunnel system at repository level. The tunnels at repository level in connection with the sealed sections of the waste vaults are planned to be backfilled with crushed rock or a similar material. The tunnel sections where the sealing will be installed must have a limited *excavation damaged zone* (EDZ) to avoid a shortcut of the sealing. A limited and discontinuous EDZ can be achieved by using careful drilling and blasting techniques when excavating the tunnels.

Closure of access tunnel. The access tunnel is planned to be backfilled with crushed rock. In addition, a plug section will be installed, made up of a tight hydraulic section of bentonite to further reduce the groundwater flow through the waste, surrounded by concrete plugs as mechanical support, see Figure 2-6.

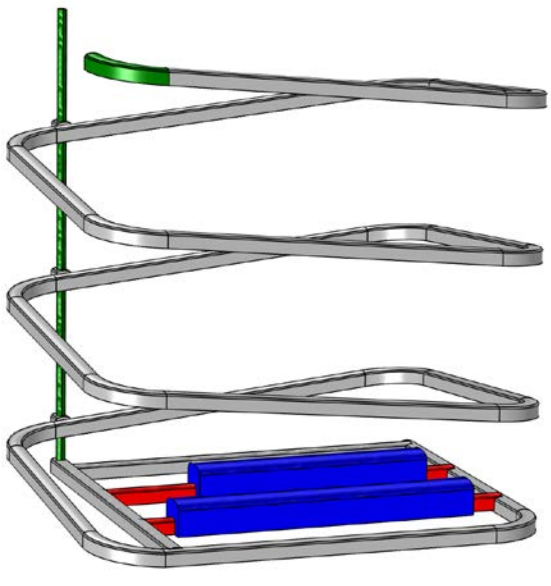

Figure 2-5. *Schematic illustration of the closure components in SFL: backfill of waste vaults (blue), sealing (red), backfill of access tunnels (grey) and closure plugs (green). The figure is a copy of Figure 6-1 in the* ***Initial state report****.*

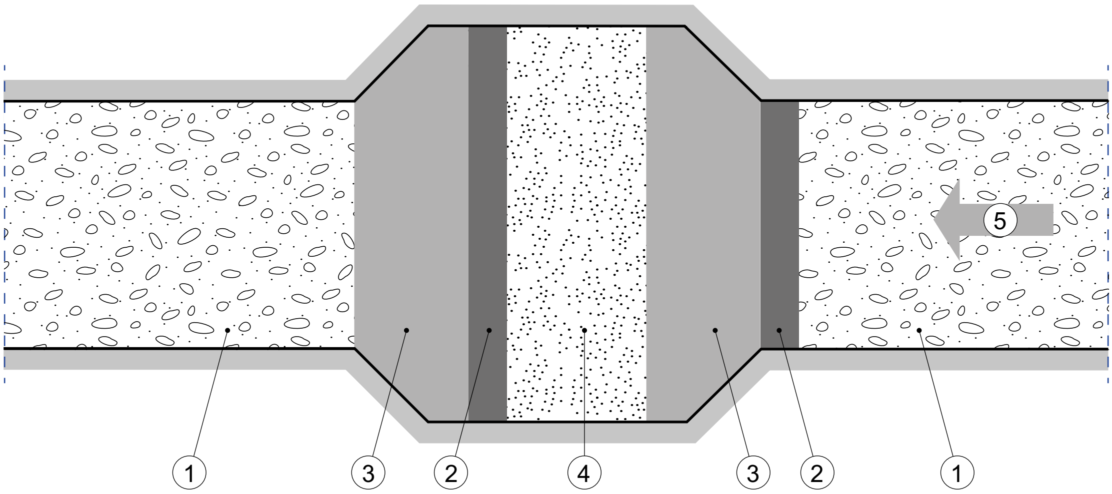

***Figure 2-6.** Schematic design of a sealing plug in the repository main tunnel (Luterkort et al. 2014). Legend: (1) Backfill of crushed rock or similar, (2) Retaining concrete walls, (3) Cast concrete, (4) Bentonite, (5) Backfill direction (from the waste vault and out), (6) Waste vault backfill material. The figure is a copy of Figure 6-2 in the **Initial state report**.*

Closure of the upper part of access tunnel. The first 50 m of the access tunnels are planned to be backfilled with boulders and a concrete plug will be cast to obstruct unintentional intrusion into the repository. Finally, the ground surface will be restored to match the surroundings.

Closure of shaft. The vertical shaft connecting different parts of the repository is planned to be plugged to restrict the flow of water. The suggested solution comprises a tight hydraulic section with bentonite surrounded by upper and lower concrete plugs for mechanical support.

Plugging of boreholes. In this safety evaluation of SFL, boreholes are not considered in the modelling of the hydrogeology or radionuclide transport. After the site-investigation program for SFL, it will be necessary to consider the presence of boreholes and to have a plan for plugging them.

Geosphere. This system component comprises the bedrock surrounding the repository. It also includes grout injected into fractures in the bedrock during construction of the repository to prevent water inflow to tunnels and other repository cavities. Upwards, the geosphere is bounded by the geosphere–biosphere interface, defined as the top of the weathered bedrock. For boundaries in the other directions, see Section 2.1.1 for definitions 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 Section 2.1.1 for definitions regarding system boundaries.

System variables. The various system components are also characterised by a number of *system variables*, both in terms of the initial states of these variables and their states during repository evolution. For the waste, packaging and the engineered barrier system components, the list of *system variables* has been adopted from SR-PSU (SKB 2014b). These are given in Chapter 7 of the **Initial state report**. The list of variables for the geosphere system component has also been adopted from SR-PSU (SKB 2014h). The biosphere system components are given in the **Biosphere synthesis report**. The initial state of the repository is described in the **Initial state report**. A description of the initial state of the geosphere and biosphere is provided in the SE-SFL **Main report**.

2.2 FileMaker™

FileMaker™ (part of the FileMaker™ Platform) is the name of the commercial database software package used for creating and maintaining the SKB FEP Database. FileMaker™ is a cross-platform relational database application from Claris International Inc. (formerly FileMaker™ Inc.), a subsidiary of Apple Inc. It integrates a database engine with a graphical user interface (GUI) and security features, allowing users to modify the database by dragging new elements into layouts, screens, or forms. It also has a native support for ODBC, SQL databases and includes scripting capabilities. FileMaker™ is available as both client and server applications. The SKB FEP Database is currently maintained using FileMaker™ Pro 18 Advanced, hereinafter referred to as FileMaker™. *Disclaimer: SKB is an independent entity and has not been authorized, sponsored, or otherwise affiliated with Claris. FileMaker™ is a trademark of Claris International Inc., registered in the U.S. and other countries.*

2.3 Overview of FEP processing procedure

The SE-SFL FEP processing procedures are similar, but simplified, to the procedures established in SR-PSU, as reported in the SR-PSU FEP report (SKB 2014b) and documented in the SR-PSU version of the SKB FEP Database. The procedure comprises the following steps:

1. Selection of FEP sources.
2. Creation of a SE-SFL preliminary FEP catalogue.
3. FEP audit.
4. FEP processing.
5. Establishment of the SE-SFL FEP catalogue.
6. Establishment of the SE-SFL FEP Database.

The procedure is also schematically illustrated in Figure 2-7 and summarised in the following sections.

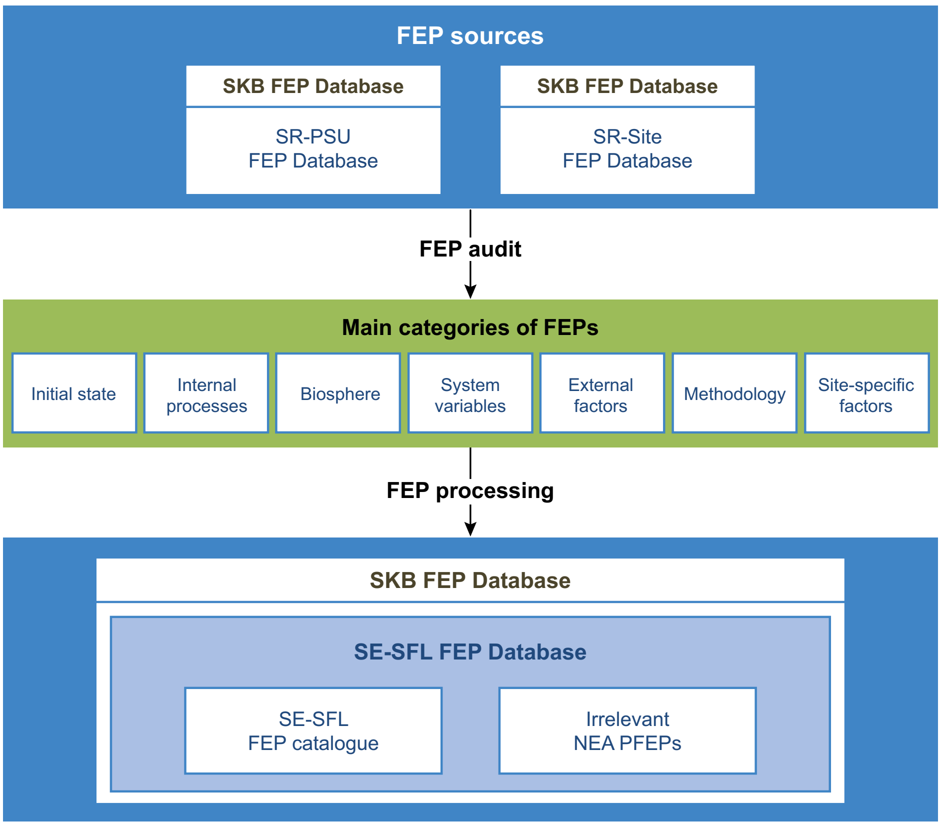

Figure 2-7. *Schematic illustration of the SE-SFL FEP processing procedure.*

2.3.1 FEP sources

As described in Section , the SR-PSU FEP Database was used as a basis for the identification of relevant features, events and processes influencing post-closure safety for the proposed repository concept at the example location for SE-SFL. Since both the SR-Site and SR-PSU FEP Databases were informed by the NEA FEP Database, see Section 2.3.2 and 2.4.1, the NEA FEP Database has not been screened in SE-SFL. The set of NEA PFEPs judged irrelevant in SR-PSU are also compared with the corresponding set of NEA PFEPs judged irrelevant in SR-Site. This is to make sure that all FEPs that are relevant for the proposed repository concept for SFL at the example location are included in SE-SFL.

In the most recent safety assessment for SFR, SR-PSU, Interaction Matrices were also used to identify FEPs and interactions between processes that affect the future evolution of the repository and its environs. This source of information is omitted in SE-SFL. The reason for this decision is to limit the FEP work effort within the safety evaluation. However, since the FEP analysis for SE-SFL is already informed by the work done for SR-PSU, which is very similar and is informed by the use of Interaction Matrices, this omission is not expected to limit the validity of the FEP analysis. In the future, when a full safety assessment is carried out for SFL, a more thorough analysis of the FEPs will be performed.

2.3.2 The NEA FEP Database

The NEA FEP Database is the outcome of work by the NEA FEP Database Working Group. The NEA has carried out activities related to the compilation and use of lists and databases of FEPs in safety and performance assessment studies of radioactive waste disposal facilities since the early 1990s. The database is a tool for supporting the national programmes for radioactive waste management organisations (RWMOs) in the identification, classification and screening of FEPs used in defining relevant scenarios for safety assessment analysis for deep geological repositories (DGRs). The NEA FEP Database is composed of two main parts:

- **The International FEP (IFEP) List** – a comprehensive and structured list of generic factors relevant to the assessment of long-term safety of nuclear waste repositories, which has been assembled through a long-term international collaboration. This forms a master list and classification scheme by which to examine the project-specific database entries. The list is intended to support national programmes in the production of their safety cases through the provision of a comprehensive and internationally accepted list of factors that may need to be considered when assessing the safety of DGRs. The NEA International FEP List has been revised over the years and the evolution of the IFEP List is summarised in Table 2-1.
- **The Project-specific FEP (PFEP) Lists** – a collection of FEP lists and database contents, with references, that have been compiled during repository safety assessment studies undertaken by various national organisations for different repository concepts and waste types. The lists are tailored to the specific geologies or disposal concepts of interest to the project and are therefore of less general applicability compared to the IFEP List. Every PFEP is mapped to one or more of the IFEPs.

The NEA FEP Database, which is used to store the IFEP and PFEP Lists, has also been updated several times over the years, see Table 2-2. The software allows each PFEP item to be related to one or more IFEPs.

Table 2-1. NEA International FEP releases (NEA 2019).

Version	Release year	Alternative name	Reference
1.0	2000	2000 IFEP List	NEA 2000
2.0	2015	2015 IFEP List	Not published
3.0	2019	2019 IFEP List	NEA 2019

Table 2-2. NEA FEP Database releases. (NEA 2019).

<table>
<tr><th>Standalone Database Version</th><th>Web Database Version</th><th>Release Year</th><th>IFEP List Version</th><th>Number of PFEP Lists</th><th>Notes</th></tr>
<tr><td>1.0</td><td>–</td><td rowspan="3">2000</td><td rowspan="5">1.0</td><td>7</td><td>Standalone version 1.0 was circulated for review and private use to members of the FEP Working Group.</td></tr>
<tr><td>1.1</td><td>–</td><td rowspan="2">8</td><td>Standalone version 1.1 was released publicly by the NEA on CD-ROM and for download. It is identical to 1.2 but with some restrictions on functionality.</td></tr>
<tr><td>1.2</td><td>–</td><td>Standalone version 1.2 was released to NEA FEP Working Group participants, who had funded its development. Included custom tools to assist in locating and examining FEPs and related information</td></tr>
<tr><td>2.0</td><td>–</td><td rowspan="2">2006</td><td rowspan="2">10</td><td>Standalone version 2.0 was not publicly released, but internally distributed for testing.</td></tr>
<tr><td>2.1</td><td>–</td><td>The restrictions on functionality in version 1.1 were removed.</td></tr>
<tr><td>–</td><td>2.0</td><td>2019</td><td>3.0</td><td>(1)</td><td>Web database version 2.0 has a modern graphical interface.</td></tr>
</table>

(1) At the time of publication of this report upload of PFEP lists was still underway.

Version 2.1 of the NEA FEP Database (NEA 2006) was used in the FEP processing in SR-PSU and SR-Site. Version 2.1 of the NEA FEP Database was completed in 2006 and contains 10 PFEP Lists from 6 different countries, three of which are from Swedish projects. The main features (i.e. waste type, host rock and engineered barrier system concept) of the repository concepts for each of these projects are given in Table 2-3.

Many of the projects in the NEA FEP Database version 2.1 are concerned with spent fuel or high-level waste. However, there are FEP lists available from other relevant and more recent national projects for low- and intermediate-level waste not included in the NEA FEP Database version 2.1. In Table 2-4, a summary is given of relevant project-specific FEP lists developed in national deep disposal programmes since 2006 (NEA 2013), i.e. after NEA FEP Database version 2.1 was released. These additional national PFEP lists have not been used in SE-SFL, but will be considered in a future full safety assessment, see further Section 3.4.2.

Version 3.0 of the NEA IFEP List was recently released (NEA 2019), and thus has not been utilized in the FEP analysis in SE-SFL. This version of the database includes a major revision of the IFEP List both in terms of its structure and its content in comparison with version 1.0 of the IFEP List. Consistent with many of the more recent PFEP Lists (e.g. those from Sweden, Finland and Japan), the new IFEP List is structured around a classification scheme based on external factors and disposal components (waste package, repository, geosphere and biosphere), rather than on the version 1.0 scheme that used external, environment and contaminant factors. Each FEP contains a description, category, commentary on its relevance to performance and safety, and mapping to related FEP(s) in version 1.0 of the IFEP List.

In addition, a major revision was also completed in 2019 to the NEA FEP Database which moves it to a web-based system (version 2.0) accessible from the public NEA website. This database has been designed to allow full version control and is intended to provide a home for all future releases of the IFEP and PFEP Lists.

Table 2-3. Projects included in the NEA PFEP Lists version 2.1 (NEA 2006).

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, copper 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	Vitrified 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[(1)] repository	Crystalline basement: SFR ca 60 m below seabed at Forsmark; SFL[(1)] 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[(1)] repository

[(1)] Earlier name of the Swedish Spent Fuel Repository that is used in the NEA FEP Database.

Table 2-4. Status of FEP lists in national deep disposal programmes (NEA 2013).

Country	Organisation	Updated FEP list or other relevant documents (post-2006)	References
Belgium	ONDRAF/NIRAS	Yes	Galson Sciences (2007) Wickham (2008)
Canada	NWMO	Yes	NWMO (2011)
Czech Republic	NRI	Yes	Vokál et al. (2010)
Finland	POSIVA	Yes	Gribi et al. (2007) Miller and Marcos (2007) Posiva (2010), Nummi et al. (2012)
France	ANDRA	No	–
Germany	Various	Yes	Beuth et al. (2012a) Beuth et al. (2012b) Buhmann et al. (2008) Wolf et al. (2012a) Wolf et al. (2012b)
Hungary	PURAM	No	–
Japan	JAEA	Yes	JAEA/ FEPC (2007)
Netherlands	NRG	No	–
Spain	ENRESA	No	–
Sweden	SKB	Yes	SKB (2010a, 2011a)
Switzerland	Nagra	Yes	Nagra (2008a, b, c, 2010)
UK	NDA/RWMD	No	–
USA	USDoE	Yes	US DOE (2009)

2.3.3 FEP audit

The FEP audit process consists of several consecutive steps starting with the creation of a SE-SFL preliminary FEP catalogue based on the contents of the SR-PSU FEP catalogue. Following that, FEP audit meetings were arranged where experts on the different FEP main categories and system components were engaged in discussions, see Table 1-3. In the final audit step, a review of the NEA PFEP Lists version 2.1 was carried out.

The purpose of these audits was to ensure that all factors relevant to SFL were identified and to classify all relevant factors as being related to the initial state of the repository and its environs, to internal system processes or to external factors. All other FEPs are characterised as general *methodological* issues or determined to be irrelevant for the system analysed in SE-SFL.

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

2.3.4 FEP processing

The FEP list produced during the FEP audit process described above was further processed by the involved experts in accordance with their different areas of expertise. The FEPs are divided into the main categories *initial state, internal processes, biosphere, external factors, system variables, methodology* and *site-specific factors*. The FEPs belonging to the main categories *internal processes* and *system variables* are subdivided into the SFL system components *waste form*, *concrete* and *steel packaging*, *BHA barriers, BHK barriers, plugs and other closure components*, and *geosphere*. The *biosphere* FEPs are subdivided into *biosphere processes, biosphere subsystem components* and *biosphere variables*. The *external factors* are categorised as *climatic processes and effects, large-scale geological processes and effects*, *future human actions* and *other*. During this work, the description and handling of each FEP within each of the categories was updated to match the work performed in SE-SFL.

The processing of FEPs and the results obtained are described further in Chapter 4.

2.3.5 Establishment of the SE-SFL FEP catalogue

Based on the FEP processing briefly described above, an SE-SFL FEP catalogue was established. This FEP catalogue contains all FEPs that have been considered relevant in SE-SFL and is thus fundamentally a subset of FEPs in the SKB FEP Database. The SE-SFL FEP catalogue contains the main FEP categories listed below. While the actual term used in the FEP database is in the singular, the correct inflection of the respective main category is used throughout this report to improve readability.

- *Initial state.*
- *Internal processes* in the system components *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components* and the *geosphere*.
- *System variables* in the system components *waste form*, *concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components* and the *geosphere*.
- *Biosphere*, comprising *biosphere processes*, *biosphere subsystem components* and *biosphere variables*.
- *External factors.*
- *Methodology.*
- *Site-specific factors.*

The *methodological* 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. FEPs categorised as *site-specific factors* represent issues that are specifically identified as relevant for the SE-SFL analysis or have the potential of being so in a future safety assessment.

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

2.4 Quality assurance aspects

2.4.1 The SKB FEP Database

The SKB FEP Database is used as a tool for documentation of the outcome of the different steps in the FEP processing procedure as the work proceeds. 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 PFEPs included in the NEA FEP Database version 1.2 (NEA 1999, 2000) and in version 2.1 (NEA 2006), the contents of the SR 97 Process report (SKB 1999b) in database format, the Interaction Matrices developed for the Spent Fuel Repository (KBS-3) (Pers et al. 1999), the Interaction Matrices developed for the existing SFR (SFR 1) (SKB 2001, 2008) and SR-PSU (SKB 2014b), as well as the resulting SR-Can (SKB 2006b), SR-Site (SKB 2010a) and SR-PSU FEP catalogues (SKB 2014b). In addition, the SKB FEP Database contains files created for documentation of the outcome of the FEP audits in SR-Can, in SR-Site and in SR-PSU, one for the result of the audit against the NEA PFEPs (NEA mapping) and one for the result of the audit against the Interaction Matrices (Matrix mapping).

In each of the SR-Site and SR-PSU FEP Databases, the complete list of PFEPs included in the NEA FEP Database version 2.1 is included. Each NEA PFEP belongs to one of the categories relevant or irrelevant to the specific safety assessment. The NEA PFEPs considered to be relevant to the specific safety assessment are mapped to FEPs defined and included in the FEP Database for that specific assessment. The NEA PFEPs considered to be irrelevant to the specific assessment, are included in a list of assessment-specific irrelevant NEA PFEPs. Thus, each of these databases constitutes a complete set of currently known factors that can influence post-closure safety for a geological repository for radioactive waste.

The overall structure of the SKB FEP Database is shown in Figure 2-8. For the purpose of clarity, the different parts of the SKB FEP Database can be defined as in Table 2-5. The dashed line separating the SR-Can and SR-Site FEP catalogues in Figure 2-8 is indicating that the SR-Site FEP catalogue constitutes a development of the SR-Can version. Similarly, the SR-PSU FEP catalogue used the SR-Site version as input together with the SFR 1 Interaction Matrices.

Table 2-5. Definition of the different parts in the SKB FEP Database.

Part	Description
SKB FEP Database	Comprises all separate FEP databases produced in safety assessments performed at SKB, i.e. the SR-Can, SR-Site, SR-PSU and SE-SFL FEP Databases (sometimes referred to as versions of the SKB FEP Database).
SR-Can FEP Database	Comprises the SR-Can FEP catalogue, SR-97 Process report, NEA mapping, Irrelevant NEA PFEPs and Matrix mapping.
SR-Site FEP Database	Comprises the SR-Site FEP catalogue (including Couplings), NEA mapping, Irrelevant NEA PFEPs and Matrix mapping.
SR-PSU FEP Database	Comprises the SR-PSU FEP catalogue (including Couplings), NEA mapping, Irrelevant NEA PFEPs and Matrix mapping.
SE-SFL FEP Database	Comprises the SE-SFL FEP catalogue, NEA mapping, and Irrelevant NEA PFEPs.
FEP catalogue	Contains all FEP records treated in the safety assessment. Some of the catalogues also include Couplings, see definition below.
NEA mapping	Contains all NEA PFEPs considered relevant to the safety assessment, including mapping to relevant SKB FEPs in the FEP catalogue.
Irrelevant NEA PFEPs	Contains all NEA PFEPs considered irrelevant to the safety assessment.
Matrix mapping	Contains matrix interactions and mapping to relevant SKB FEPs in the FEP catalogue.
Couplings	Comprises any of the following: Process diagrams and tables, FEP charts, AMF charts and tables, Interaction Matrices (IM). More details on Couplings are given in Section 3.4.1.

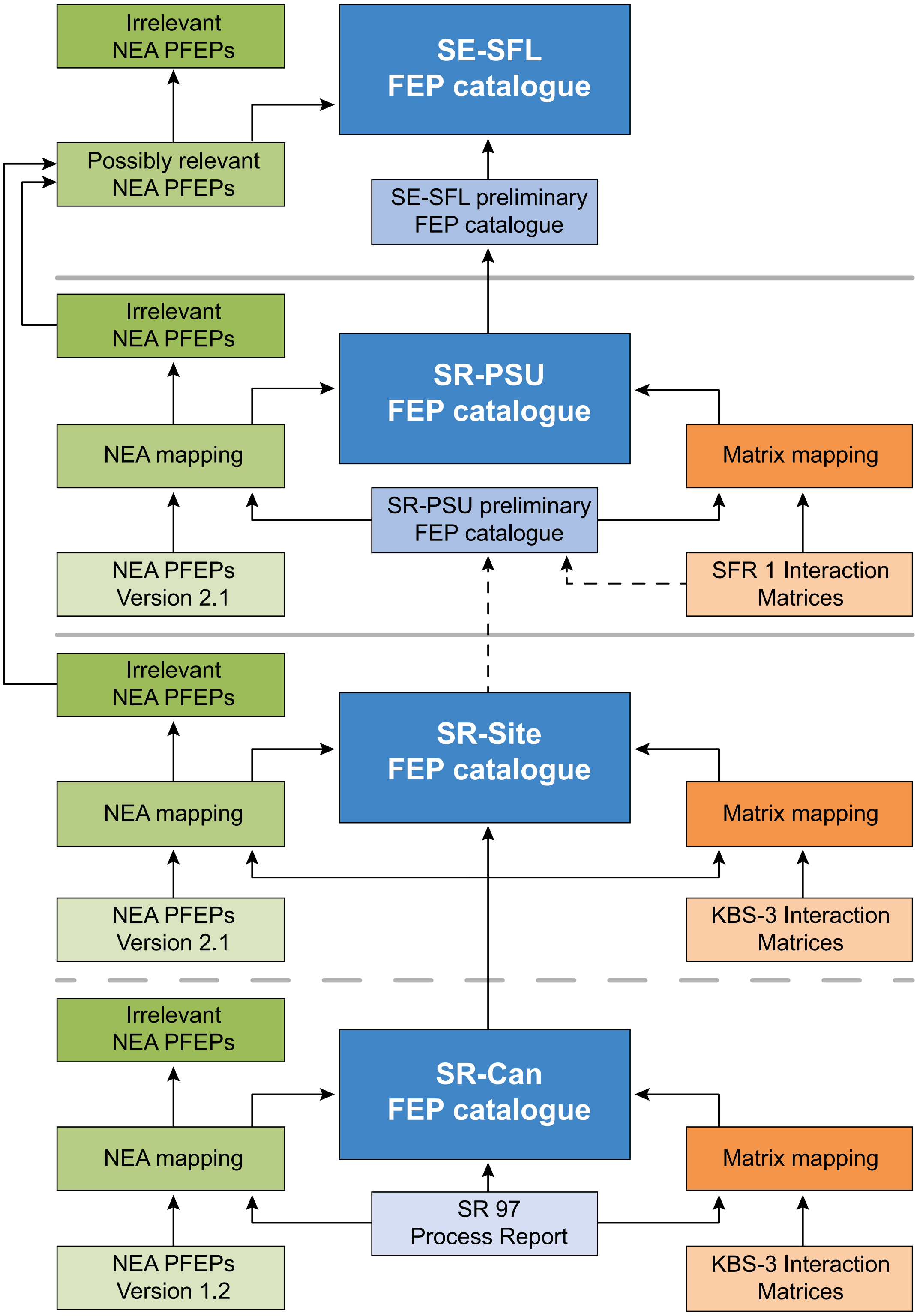

Figure 2-8. *Overall structure of the SKB FEP Database.*

To ensure a proper handling of the SKB FEP Database, routines for the development and management of it were defined and applied in the earlier safety assessments. These routines are summarised in the following sections and further addressed, where appropriate, in the following chapters.

2.4.2 Routines for FEP processing and documentation of results

The FEP audit in SE-SFL, described in Chapter 3, is carried out using a different approach compared with the audits performed in SR-PSU and SR-Site. In SR-PSU and SR-Site, the FEP audits were focused on a systematic comparison of the respective FEP catalogues with all PFEPs in the NEA FEP Database and the contents of the corresponding Interaction Matrices. In SE-SFL, however, the FEP audits were carried out with the main focus on screening the SR-PSU FEP list on relevance for SE-SFL. As for the audit against the NEA PFEPs, a simplified approach is used in SE-SFL compared with SR-PSU and SR-Site, with the intention of performing a more rigorous FEP audit procedure in a future full safety assessment for SFL. However, the comprehensive use of the FEPs from SR-PSU and SR-Site and the NEA PFEP Lists plus expert evaluation make it highly unlikely that a FEP of relevance to SFL might be overlooked. Therefore, because of the extensive FEP work that has been performed previously, the simplifications used in the SE-SFL FEP analysis will have a limited impact.

As a first audit step, a copy of all FEP records from the SR-PSU FEP catalogue was exported to a Microsoft Excel workbook, creating a SE-SFL preliminary FEP catalogue. The decision to export the FEPs from the FileMaker™ database and temporarily carry out the work in Excel was taken primarily for practical reasons as it simplifies the handling and editing of the FEPs during the audit and processing phases and also improves the overview of all data in the FEP catalogue, compared with performing the same tasks using FileMaker™. In addition, working with the FEPs in an Excel format makes it easier to distribute the FEPs among experts for further processing and eventually compiling the results of the FEP processing, preparing it for a final import back into the SKB FEP Database and SE-SFL FEP catalogue in FileMaker™.

The FEP audit was carried out in small groups involving both generalists and experts. After an initial screening of the SR-PSU FEP list, a list of SE-SFL FEPs was created and the FEPs were distributed to the relevant experts, according to their areas of expertise, for further processing. The experts were provided a list of FEPs relevant for the particular area of expertise they represented. The FEPs were distributed to the experts in a Microsoft Excel document and returned in the same format after completion of the FEP processing. In addition, the expert responsible for the documentation of the handling is identified in the appropriate FEP 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 again by the expert together with the SE-SFL project leader and the author of this report. 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 considered necessary, the document was returned to the experts for approval of the changes made.

Regarding the audit against the NEA PFEPs, the process was simplified compared with SR-PSU and SR-Site in the sense that the audit was only performed on a subset of all NEA PFEPs, namely the ones rejected in SR-PSU and SR-Site. However, the same rejection criteria for determining the relevance of a FEP for SE-SFL were used.

The FEP audit is described in more detail in Chapter 3.

2.4.3 Routines for management of the SKB FEP Database

Some general rules for the administration of the SKB FEP Database have been followed throughout the development work on the SE-SFL FEP Database. These are listed below.

- Only one person is allowed to make modifications to the structure and content of the database. For the SE-SFL project this person is Niko Marsic, SKB. For the previous safety assessments, SR-Can, SR-Site and SR-PSU, Kristina Skagius, SKB, was responsible for this work.
- Input of information to the database is required only to be made from a master document in Microsoft Excel format which is handled and supervised by Niko Marsic, SKB.
- The final official SE-SFL version of the FEP database is made available for download from the SKB website (www.skb.se) as a stand-alone, write-protected version. This is also the case for the earlier SR-Can, SR-Site and SR-PSU versions of the SKB FEP Database.

Before delivering the final current version of the SKB FEP Database, the content of the SE-SFL part of the database was checked. The corresponding checks of the SR-Can, SR-Site and SR-PSU parts of the database were made in SR-Can (SKB 2006b), SR-Site (SKB 2010a) and SR-PSU (SKB 2014b), respectively. The check was made to ensure that:

1. All SE-SFL FEP records contain the correct information regarding FEP ID, FEP name, Main category, System component.
2. All SE-SFL FEP records contain the correct information regarding Description and Handling.
3. All SE-SFL FEP records contain the correct information regarding References to SE-SFL reports.
4. All SE-SFL FEP records contain the correct information regarding Revision history and that all records are Signed and Approved.
5. All processes identified in main references and additional references, defined categories of *initial states*, defined *external factors*, and defined *system variables* have a corresponding FEP record in the SE-SFL FEP catalogue.
6. All NEA PFEPs in version 2.1 of the NEA FEP Database that were considered irrelevant for SFR in SR-PSU are included in the SE-SFL part of the SKB FEP Database.
7. All NEA PFEPs included in the SE-SFL part of the SKB FEP Database are flagged as Relevant or Irrelevant for the system analysed in SE-SFL.
8. All NEA PFEPs included in the SE-SFL part of the SKB FEP Database and flagged as Irrelevant for the system analysed in SE-SFL are associated with documentation justifying their omission.
9. All NEA PFEPs included in the SE-SFL part of the SKB FEP Database and flagged as Relevant for the system analysed in SE-SFL are associated with a documented description of their handling in SE-SFL.

3 FEP audit

For the reasons discussed earlier, see Section 1.3.1, it was decided to use the SR-PSU FEP catalogue to serve as a basis for the establishment of the SE-SFL FEP catalogue described in this report.

The initial work during the FEP audit in SE-SFL, as described in the following sections, see also Figure 2-7, is different from that for the earlier safety assessments performed at SKB. Even though the SR-PSU and SR-Site FEP catalogues both were based on older versions of their respective FEP catalogues (i.e. the SR-PSU preliminary FEP catalogue and the SR-Can FEP catalogue respectively) in a similar way as now done for SE-SFL, the initial audit work then was focused on a systematic and comprehensive screening of the complete list of the NEA PFEPs in the NEA FEP Database version 2.1, where the FEPs were considered to be either relevant or irrelevant for the safety assessment. The FEP audits in SR-PSU and SR-Site were carried out following a set of general procedures and rules. In addition, a number of criteria were defined that had to be fulfilled in order to determine that a FEP was irrelevant for the actual system analysed (SR-PSU; SKB 2014b and SR-Site; SKB 2010a). These procedures, rules and criteria were then applied in the work and the results of the audit, as well as decisions made during the work, were documented in the FEP database (NEA mapping in Figure 2-8).

The following sections describe the procedures, rules and criteria used in the SE-SFL FEP audit work.

3.1 Classification of the SE-SFL FEPs

In the SE-SFL FEP catalogue, seven main categories are used to classify the FEPs, see Section 2.3.5. These are the same categories as were used in the FEP processing for SR-PSU (SKB 2014b) and SR-Site (SKB 2010a). A short description of each main category is given in the following sections.

3.1.1 Initial state

This category of FEPs is related either to the expected *initial state* of the system components with tolerances, or to deviations from the expected *initial state* outside tolerances. The deviations from the initial state follow from undetected mishaps, sabotage, failure to close the repository, etc. Each FEP related to the expected *initial state* is associated with the appropriate *system variables* and system components and is included in the description of the initial state for the system component in question. Each *system variable* constitutes a FEP record in the SE-SFL FEP catalogue. The evolution of the waste, waste packaging, engineered barriers as well as of the conditions of the repository environs as a result of operation and construction of the facility are taken into account in defining the initial state.

The initial state is defined as the expected state of the repository and its environs at closure, under the assumption that the repository is designed and constructed in accordance with the proposed repository concept and placed at the example location at approximately 500 m depth in the position in Laxemar assumed for SE-SFL. At closure the closure components are installed including backfilling and plugging of the vaults, tunnel system, shaft and boreholes. The repository is assumed to be closed in 2075 AD and, under these assumptions, the initial state of the repository is defined based on current estimates of the properties of the waste and the repository components at repository closure (see the **Initial state report**). The initial state of the repository environs is assumed to be similar to present-day conditions, as described by the site descriptive model for Laxemar (SKB 2009) and the **Biosphere synthesis report**. The site-descriptive model (SDM) for Laxemar is based on the site characterisation work performed during site investigations for the Spent Fuel Repository and includes data from the bedrock and the near-surface systems. A summary of the initial state of the repository and its environs is given in Chapter 4 of the **Main report**.

3.1.2 Internal processes

The FEPs belonging to the main category *internal processes* are subdivided into the SFL system components *waste form*, *concrete and steel packaging, BHA barriers, BHK barriers*, *plugs and other closure components*, and the *geosphere*. The FEPs in this category describe processes relevant to one or several of the system components defined for the SE-SFL safety evaluation, excluding the *biosphere*. *Biosphere* FEPs are handled as a separate category in the FEP catalogue, see below. Within a system component, each process is influenced by one or several of the *system variables* describing the state of the component, and the process, in turn, influences one or several of the *system variables*, see Section 3.1.3 below.

3.1.3 System variables

FEPs belonging to the main category *system variables* are subdivided into the SFL system components *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components*, and the *geosphere*. The *system variable* FEPs are used to characterise the system components, both in terms of the *initial state* of these variables and their states during repository evolution. In the same way as for the *internal processes*, the *biosphere* FEPs are excluded from the main category *system variables*. Instead, *biosphere* FEPs are handled as a separate main category in the FEP catalogue with their own processes and variables, see below.

3.1.4 Biosphere

Biosphere FEPs are treated separately (i.e. not included in the main categories *internal processes* or *system variables*) in the FEP catalogue for SE-SFL, which was also the case in SR-PSU. The *biosphere* FEPs are divided into the subsystems *biosphere processes, biosphere subsystem components* (divided into *physical components* and *boundary components*) and *biosphere variables*. The FEPs in this category describe a subsystem, a variable or a process relevant to one or several of the subsystems. A major work on the formulation of the *biosphere* FEPs was done in SR-PSU (SKB 2013), building on work done for SR-Site (SKB 2010b). This work also serves as a basis for the analysis of biosphere FEPs in SE-SFL. SKB (2013) contains general descriptions of the processes considered to be of importance for the safety assessment. In addition, it contains definitions of subsystems of the biosphere and variables needed to describe the evolution of the biosphere in relation to those aspects that are of importance for radionuclide accumulation and transport. For each *biosphere process, biosphere subsystem component* and *biosphere variable* defined in SKB (2013), a *biosphere* FEP has been included in the SE-SFL FEP catalogue. The *biosphere* FEPs and the handling of these in SE-SFL are described in the **Biosphere synthesis report**, where mainly the changes compared with SR-PSU are pointed out in the text.

3.1.5 External factors

The *external factor* FEPs are divided into the subcategories *climatic processes and effects, large-scale geological processes and effects, future human actions* and *other*. This is the same classification as is used in the NEA FEP Database and also in SKB's previous safety assessments, e.g. SR-PSU and SR-Site. This category comprises FEPs that act outside the boundary of the system analysed in SE-SFL.

The handling of climate-related issues is documented in the SE-SFL **Climate report** and the corresponding *climatic processes and effects* FEPs are included in the SE-SFL FEP catalogue.

The list of *external factor* FEPs defined in SR-PSU was considered relevant and complete also for SE-SFL and thus the same list of *external factor* FEPs is used.

3.1.6 Methodology

The *methodological* FEPs address issues relevant to the basic assumptions for the assessment and to the methodology used in it. These FEPs are of a 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-PSU (SKB 2014b) and SR-Site (SKB 2010a), also propagated to the SE-SFL FEP catalogue.

3.1.7 Site-specific factors

The *site-specific factor* FEPs represent issues that are specifically relevant to the selected site. The FEPs included in the SR-PSU FEP catalogue (SKB 2014b) are specific for the Forsmark site, where the SFR repository is placed, with proximity to the nuclear power plant at Forsmark and the power cable to Finland, Fenno-Skan. Since SE-SFL is based on data from the Laxemar site, the description of the corresponding FEPs used for Laxemar in SR-Can (SKB 2006b) were used instead with minor modifications. Depending on what site is selected for the SFL repository, these FEPs will be updated with relevant site-specific information in a future full safety assessment for SFL. It could be argued that it is not meaningful to define site-specific factors at this stage since no site has been selected yet. However, for the sake of comprehensiveness, these two FEPs were, as in SR-PSU (SKB 2014b) and SR-Site (SKB 2010a), also propagated to the SE-SFL FEP catalogue.

3.2 Audit against the SR-PSU FEP catalogue

3.2.1 First audit step

As a first step in the establishment of the SE-SFL FEP catalogue, a copy of all FEP records from the SR-PSU FEP catalogue was exported to a Microsoft Excel workbook, creating a SE-SFL preliminary FEP catalogue. This means that all FEPs in the SR-PSU FEP catalogue were considered for inclusion in the SE-SFL FEP catalogue.

3.2.2 Second audit step

During the second audit step, several expert meetings were arranged where the list of FEPs in the SE-SFL preliminary FEP catalogue was screened for relevance with respect to the proposed concept for SFL, see Table 1-3 for a list of participating experts. Typically, each meeting was dedicated to one of the main categories or system components. During the screening process the list of FEPs was changed accordingly, as described in detail below, to meet the requirements of SE-SFL.

There are many similarities in terms of the waste, the barriers and the repository surroundings between an extended SFR and the repository concept and location evaluated in SE-SFL. Therefore, most of the FEPs in the SR-PSU FEP catalogue were chosen for inclusion in the SE-SFL preliminary FEP catalogue.

Table 3-1, shows a comparison of the number of FEPs within each category of the SR-PSU FEP catalogue and SE-SFL preliminary FEP catalogue. The numbers in Table 3-1 are given both as a total for each main category (*"Total"*) and as a subtotal for each of the system components or subcategories (*"Sub"*) within each main category, where applicable. The table shows that for all main categories but two, namely *internal processes* and *system variables*, the number of FEPs is the same for SR-PSU and SE-SFL. Consequently, all these FEPs were considered relevant for SE-SFL, though it should be noted that even though these are the same FEPs (same FEP name), the description and handling could be different in the two FEP catalogues.

Due to the different types of packaging and the different engineered barriers in the waste vaults the system analysed in SE-SFL is divided into different system components for the purpose of FEP processing and the development of the FEP catalogue. As a consequence, the main categories *internal processes* and *system variables* are both subdivided into a number of system components. These all represent specific parts and functions of the repository, some of which are unique to the repository design and therefore differ for SFR and SFL. While the system components *waste form, concrete and steel packaging, plugs and other closure components* and *geosphere* are present in both SFR and SFL, the remaining system components dealing with the barriers are not. In SFR, system components representing the barriers in the Silo, BMA, BLA, BRT and BTF, respectively, are used. None of these is present in SFL. Instead, in SFL, system components for the barriers in BHA and BHK are used. Consequently, in the second audit step, the FEPs within the main categories *internal processes* and *system variables* corresponding to the BLA, BRT and BTF barriers were removed from the SE-SFL preliminary FEP catalogue. However, before removing any FEPs, it was ensured that all relevant *internal processes* as well as *system variables* defined in the SR-PSU FEP catalogue for the removed system components are represented in the SE-SFL preliminary FEP catalogue, for the system components BHA and BHK respectively.

Due to the similarities in barrier properties and function between two of the system components in SR-PSU and the two vaults in SE-SFL it was decided to re-use these FEPs with some minor modifications. Therefore, the FEPs for the system component *silo barriers* in the SR-PSU FEP catalogue were copied to corresponding FEPs for *BHA barriers* in the SE-SFL preliminary FEP catalogue. The same procedure was performed for the SR-PSU FEPs for the system component *BMA barriers*, which were copied to corresponding FEPs for *BHA barriers* in the SE-SFL preliminary FEP catalogue, as follows:

- Each FEP for the system component *silo barriers* in the SR-PSU FEP catalogue was copied to a corresponding FEP for *BHA barriers* in the SE-SFL preliminary FEP catalogue. The copy included FEPs in the main categories *internal processes* and *system variables*.
- The names of the FEPs were then changed from the SR-PSU FEP IDs SiBa*nn* (*internal processes*) and VarSi*nn* (*system variables*) to the SE-SFL FEP IDs BHABa*nn* (*internal processes*) and VarBHA*nn* (*system variables*), where *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.
- Each FEP for the system component *BMA barriers* in the SR-PSU FEP catalogue was copied to a corresponding FEP for *BHK barriers* in the SE-SFL preliminary FEP catalogue. The copy included FEPs in the main categories *internal processes* and *system variables*.
- The names of the FEPs were then changed from the SR-PSU FEP IDs BMABa*nn* (*internal processes*) and VarBMA*nn* (*system variables*) to the SE-SFL FEP IDs BHKBa*nn (internal processes*) and VarBHK*nn* (*system variables*), where *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.
- All other FEPs from the SR-PSU FEP catalogue that are kept in the SE-SFL preliminary FEP catalogue have retained their names and numbering.

Through the screening process of FEPs described above, the number of FEPs in the SE-SFL preliminary FEP catalogue decreased from 353 to a total number of 280 FEPs, see Table 3-1. The SE-SFL preliminary FEP catalogue was subject to further processing, as described in Chapter 4, aiming at establishing the final product, the SE-SFL FEP catalogue.

Table 3-1. Classification and number of FEPs in the SR-PSU FEP catalogue and the SE-SFL preliminary FEP catalogue.

SR-PSU FEP catalogue	No of FEPs		SE-SFL preliminary FEP catalogue	No of FEPs	
Main category ***System component or Subcategory***	**Sub**	**Total**	**Main category** ***System component or Subcategory***	**Sub**	**Total**
Initial state		5	Initial state		5
Internal processes		178	Internal processes		126
Waste form	*22*		*Waste form*	*22*	
Concrete and steel packaging	*16*		*Concrete and steel packaging*	*16*	
Plugs and other closure components	*21*		*Plugs and other closure components*	*21*	
Geosphere	*22*		*Geosphere*	*22*	
Silo barriers	*26*		*BHA barriers*	*26*	
BMA barriers	*19*		*BHK barriers*	*19*	
BLA barriers	*18*		–	–	
BRT barriers	*18*		–	–	
BTF barriers	*16*		–	–	
Biosphere		68	Biosphere		68
Biosphere processes	*50*		*Biosphere processes*	*50*	
Biosphere subsystem components	*12*		*Biosphere subsystem components*	*12*	
Biosphere variables	*6*		*Biosphere variables*	*6*	

SR-PSU FEP catalogue	No of FEPs		SE-SFL preliminary FEP catalogue	No of FEPs	
Main category ***System component or Subcategory***	**Sub**	**Total**	**Main category** ***System component or Subcategory***	**Sub**	**Total**
External factors		27	External factors		27
Climatic processes and effects	*7*		*Climatic processes and effects*	*7*	
Large-scale geological processes	*2*		*Large-scale geological processes*	*2*	
Future human actions	*17*		*Future human actions*	*17*	
Other	*1*		*Other*	*1*	
System variables		71	System variables		50
Waste form	*9*		*Waste form*	*9*	
Concrete and steel packaging	*7*		*Concrete and steel packaging*	*7*	
Plugs and other closure components	*7*		*Plugs and other closure components*	*7*	
Geosphere	*13*		*Geosphere*	*13*	
Silo barriers	*7*		*BHA barriers*	*7*	
BMA barriers	*7*		*BHK barriers*	*7*	
BLA barriers	*7*		–	–	
BRT barriers	*7*		–	–	
BTF barriers	*7*		–	–	
Methodology		2	Methodology		2
Site-specific factors		2	Site-specific factors		2
Total No of FEPs		**353**			**280**

3.3 Audit against the NEA Project-specific FEP (PFEP) Lists

Following the initial screening process of FEPs in the SE-SFL preliminary FEP catalogue, the audit work continued with a review of the PFEPs in the NEA FEP Database.

3.3.1 General auditing procedure and documentation of NEA PFEPs

At the start of the audit process against the NEA PFEPs, an export of all NEA PFEPs marked as irrelevant in SR-PSU and SR-Site was made to a Microsoft Excel workbook. The rest of the audit work, as well as the documentation of it, was then carried out in that same environment. This differs significantly from how the audit process of the NEA PFEPs was carried out in SR-PSU and SR-Site where a full mapping (including documentation) between the NEA PFEPs and the SKB FEPs was performed in FileMaker™.

The screening process of the NEA PFEPs was documented directly in the Excel workbook by a combination of colour coding and labelling of PFEPs. Justifications and relevant comments were made as to why a PFEP was determined either to be relevant or irrelevant to the SE-SFL safety evaluation. Since the naming of the NEA PFEPs in some instances can be misleading, the screening was based on the NEA PFEP description, rather than the PFEP name. Any associations outside the primary meaning of the PFEP that arose from consideration of the PFEP description were also documented.

3.3.2 Third audit step

In the third and final audit step, the list of NEA PFEPs that were considered irrelevant for SFR in SR-PSU was screened with focus on potential relevance for SE-SFL. A main assumption in SE-SFL is that the mapping of NEA PFEPs to SR-PSU FEPs is applicable also to the proposed repository concept for SFL. There may however be FEPs in the list of NEA PFEPs not mapped to SR-PSU FEPs that are relevant for the proposed repository concept for SFL. Therefore, the list of NEA PFEPs that were considered irrelevant for SFR in SR-PSU was screened for potential relevance in SE-SFL. As described in Section 2.4.1, the SR-PSU (and SR-Site) FEP Database each covers the complete list of NEA PFEPs. Thus, by the third and final audit step, the complete NEA PFEP List was covered in the FEP audits in SE-SFL.

The screening process was conducted in four consecutive sub-steps, here denoted *audit step 3a–3d*, each one reducing the number of possibly relevant PFEPs left for a final more in-depth analysis. The relevance of each NEA PFEP for the system analysed in SE-SFL was considered on the basis of pre-defined relevance criteria, as summarised in the list below. Essentially the same relevance criteria as used in the SR-PSU (SKB 2014b) and SR-Site (SKB 2010a) FEP processing were adopted but adapted to the system analysed in SE-SFL.

The PFEPs were screened out if one of the following relevance criteria was fulfilled:

- *Inadequately defined or too general.*
- *Irrelevant for long-term safety, safety assessment or the current safety evaluation.*
- *Considered irrelevant in both SR-Site and SR-PSU.*
- *Irrelevant for the actual geographical, geological setting or site-selection issues.*
- *Irrelevant for the actual repository design.*
- *Irrelevant for the actual waste form, waste package or waste packaging design.*

The relevance criteria are further discussed in the following sections. It should be emphasised that certain aspects given in a NEA PFEP description could be relevant for the system analysed in SE-SFL, even though the PFEP mainly relates to a system differing from the SFL system. Such examples are PFEPs related to e.g. bentonite barriers, corrosion and criticality in a spent fuel repository concept, which are all features and processes also relevant to the system analysed in SE-SFL.

It should also be noted that the general strategy in the screening of PFEP relevance was to judge PFEPs as relevant rather than to screen them out at an early stage, unless it was clearly obvious that they are irrelevant. By this approach, the final decision regarding the relevance of a PFEP 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.

The NEA PFEP Lists version 2.1 contain 1,671 PFEPs in total, of which 553 were considered irrelevant in SR-PSU, see Figure 3-1 and Figure 3-2.

Audit step 3a

In audit step 3a, the first sub-step of the third audit step, the PFEPs were screened out if one of the relevance criteria given in Table 3-2 was fulfilled. Of the 553 NEA PFEPs considered irrelevant in SR-PSU, 238 were screened out in audit step 3a and thus considered irrelevant in SE-SFL as well, see Figure 3-2. Table 3-2 shows the number of PFEPs screened out for each of the five relevance criteria used in audit step 3a. This leaves 315 NEA PFEPs for further relevance screening in audit step 3b of SE-SFL, see summary in Table 3-6.

Table 3-2. Screening criteria used in audit step 3a.

NEA PFEP relevance criteria for SE-SFL	No of PFEPs
The PFEP is defined by a heading without any description, but from the interpretation of the heading it is considered that the PFEP is covered by other NEA PFEPs	166
The PFEP is very general and covered by other more specific NEA PFEPs	57
Not necessary to consider in a safety assessment (IAEA 2012)	8
Not considered to be a FEP	5
Irrelevant for long-term safety	2
Total number of PFEPs screened out in audit step 3a	**238**

Audit step 3b

In audit step 3b, the PFEPs were screened out if they were considered irrelevant in both SR-Site and SR-PSU. However, as an additional precaution, the PFEPs screened out in audit step 3b were checked again to verify that the screening process in SR-Site was still valid for SE-SFL. Of the remaining 315 NEA PFEPs considered irrelevant in SR-PSU, 124 were screened out in audit step 3b and thus considered irrelevant in SE-SFL as well, see Table 3-3 and Figure 3-2. This leaves 191 NEA PFEPs for further relevance screening in audit step 3c of SE-SFL, see summary in Table 3-6.

Figure 3-1 shows the distribution of NEA PFEPs version 2.1 considered irrelevant in SR-Site and SR-PSU and also how these groups relate to each other within the total population of 1,671 NEA PFEPs. The size of the different circles and the overlap between them (intersection) is proportional to the number of PFEPs within each one of them. As illustrated in the figure, there is an overlap between the PFEPs screened out in SR-Site and SR-PSU, but there are also PFEPs that were uniquely screened out in each of the two safety assessments. If the first two sub-steps of audit step 3 had been carried out in the reverse order, the number of screened out PFEPs considered irrelevant in SR-Site as well as in SR-PSU would obviously have been 329 according to Figure 3-1. Now some of these PFEPs had already been screened out in audit step 3a, which is why the number of PFEPs screened out in audit step 3b is only 124, see Figure 3-2.

Table 3-3. Screening criteria used in audit step 3b.

NEA PFEP relevance criteria for SE-SFL	No of PFEPs
The PFEP was considered irrelevant in both SR-Site and SR-PSU	124
Total number of PFEPs screened out in audit step 3b	**124**

Audit step 3c

In audit step 3c, the PFEPs were screened out using criteria based on relevance for the actual geographical or geological setting, repository design, waste, waste package or waste packaging design. Of the remaining 191 NEA PFEPs considered irrelevant in SR-PSU, 104 were screened out in audit step 3c and thus considered irrelevant in SE-SFL as well, see Figure 3-2. Table 3-4 shows the number of PFEPs screened out for each of the six relevance criteria used in audit step 3c. This leaves 87 possibly relevant NEA PFEPs for a final more in-depth analysis in SE-SFL, see summary in Table 3-6.

During the sessions relating to Audit step 3c, a number of experts participated in the discussions and decision making in the screening process of NEA PFEPs. Those experts are listed in Section 1.3.2.

Table 3-4. Screening criteria used in audit step 3c.

NEA PFEP relevance criteria for SE-SFL	No of PFEPs
Irrelevant for the actual geographical setting	0
Irrelevant for the actual geological setting	0
Irrelevant for the current safety evaluation	1
Irrelevant for the actual repository design	11
Irrelevant for the actual waste	49
Irrelevant for the actual waste package design [(1)]	26
Irrelevant for the actual waste packaging design [(2)]	17
Total number of PFEPs screened out in audit step 3c	**104**

[(1)] Waste package design relates to waste and packaging.

[(2)] Waste packaging design relates to the packaging only.

Audit step 3d

In audit step 3d, the fourth and final sub-step, the PFEPs were screened out if one of the irrelevance criteria given in Table 3-5 was fulfilled. It can be noted that some of the screening criteria are the same in audit steps 3c and 3d. The reason is that due to the more complicated nature of these remaining PFEPs, also indicated by the fact that they had not easily been screened out in any of the earlier steps, they were in many cases subject to more profound analyses also involving other experts. Of the remaining 87 NEA PFEPs considered irrelevant in SR-PSU, 35 were considered irrelevant for SE-SFL in audit step 3d, see Figure 3-2.

Most of these PFEPs were screened out because they are defined for a different repository design including the use of copper canisters with or without a buffer surrounding. Many PFEPs are defined for waste forms not planned for SFL, e.g. spent nuclear fuel, other high-level waste or vitrified waste.

Some of the PFEPs could be screened out using criteria related to the site-selection process, e.g., areas with a potential for oil, gas or thermal heat production are excluded from being selected as locations for SFL. The potential for future human activities that may lead to disturbed performance conditions for SFL will also be a factor in the site-selection process for SFL.

Table 3-5 shows the number of PFEPs screened out for each of the three relevance criteria used in audit step 3d. Finally, a total of 52 PFEPs possibly relevant for SE-SFL remained after the FEP audit, see summary in Table 3-6. These NEA PFEPs were sent to further FEP processing as described in Section 4.1.

Table 3-5. Screening criteria used in audit step 3d.

NEA PFEP relevance criteria for SE-SFL	No of PFEPs
Considered irrelevant based on repository design issues	16
Considered irrelevant based on waste-form issues	12
Considered irrelevant based on site-selection issues	7
Total number of PFEPs screened out in audit step 3d	**35**

A summary of the results and screening criteria used in the different sub-steps of audit step 3 is shown in Table 3-6. For each sub-step, the table shows the total number of PFEPs screened out, the subtotal for each screening criterion used in the sub-step and the number of remaining PFEPs after the sub-step in question.

Table 3-6. Summary of results and screening criteria used in the different sub-steps of audit step 3.

NEA PFEP relevance criteria for SE-SFL	No of PFEPs		
Number of NEA PFEPs considered irrelevant in SR-PSU			**553**
Audit step 3a	**Sub**	**Total**	**Remaining**
The PFEP is defined by a heading only	*166*		
The PFEP is too general, covered by more specific PFEPs	*57*		
Irrelevant for safety assessment (IAEA 2012)	*8*		
Not considered as being a FEP	*5*		
Irrelevant for long-term safety	*2*		
Number of PFEPs screened out in audit step 3a		**238**	**315**
Audit step 3b			
The PFEP was considered irrelevant in SR-Site and SR-PSU	*124*		
Number of PFEPs screened out in audit step 3b		**124**	**191**
Audit step 3c			
Irrelevant for the actual geographical setting	*0*		
Irrelevant for the actual geological setting	*0*		
Irrelevant for the current safety evaluation	*1*		
Irrelevant for the actual repository design	*11*		
Irrelevant for the actual waste	*49*		
Irrelevant for the actual waste package design	*26*		
Irrelevant for the actual waste packaging design	*17*		
Number of PFEPs screened out in audit step 3c		**104**	**87**
Audit step 3d			
Considered irrelevant based on repository design	*16*		
Considered irrelevant based on waste form	*12*		
Considered irrelevant based on site-selection issues	*7*		
Number of PFEPs screened out in audit step 3d		**35**	**52**
Total number of remaining NEA PFEPs possibly relevant for SE-SFL			**52**

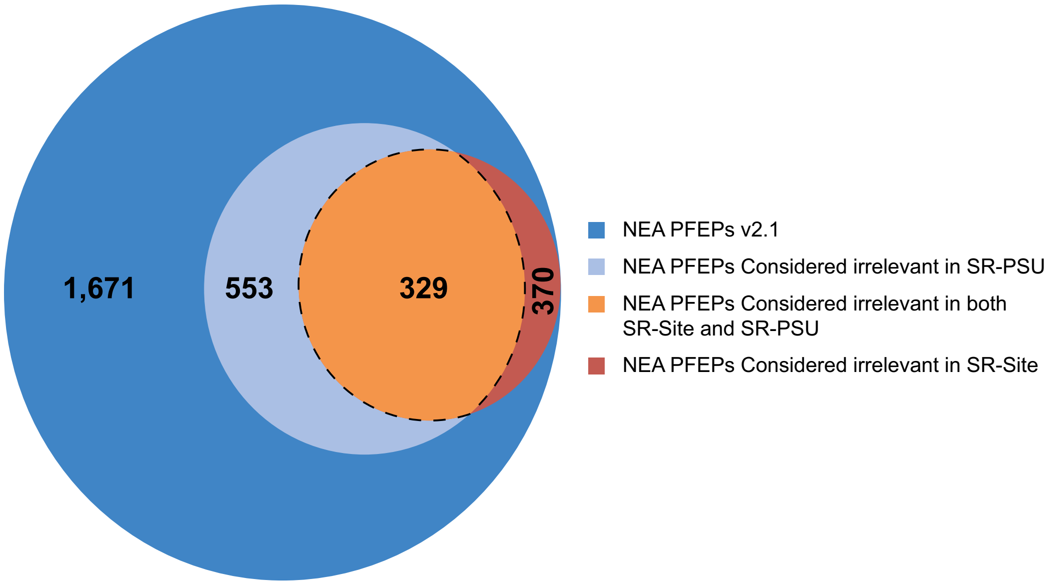

Figure 3-1. *Distribution of NEA PFEPs version 2.1 considered irrelevant in SR-Site and SR-PSU.*

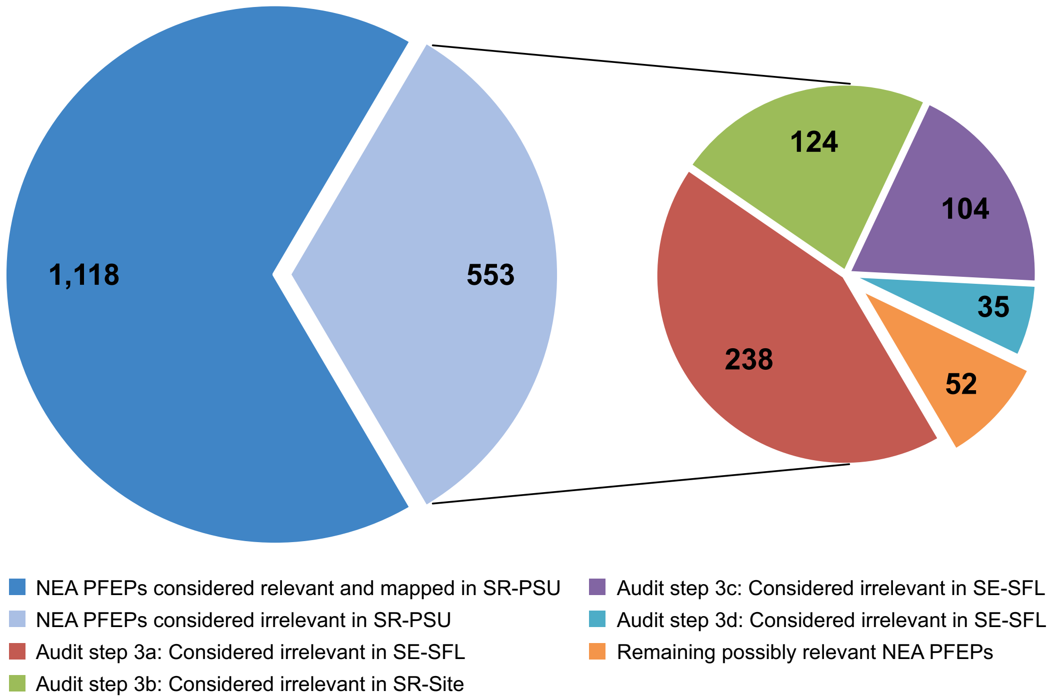

Figure 3-2. *Results from the screening process in audit steps 3a-3d, showing the distribution of the 553 NEA PFEPs considered irrelevant in SR-PSU, with respect to each audit step. The 52 remaining possibly relevant NEA PFEPs were sent to further processing, as described in Section 4.1.*

3.4 Information sources not used in the FEP analysis

3.4.1 Couplings in the SKB FEP Database

FEPs can also be coupled in several ways and on several levels. In the previous safety assessments carried out for the Spent Fuel Repository and SFR, the SKB FEP Database was used as a tool for documentation and visualisation of couplings between processes via variables and subcomponents. However, for SE-SFL this work has been omitted from the FEP analysis. The reason for this decision is to limit the FEP work effort within the safety evaluation. In the future, when a full safety assessment is carried out for SFL, a more thorough analysis of the FEPs will be performed. In the following sections the main characteristics of the influence tables, process diagrams, Interaction Matrices and charts included in the SKB FEP Database are given.

Couplings have been used and described within several SKB safety assessments and reported in the SR-Can FEP report (SKB 2006b), SR-Site FEP report (2010a), and in the SR-PSU FEP report (2014b).

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, and are included in the SKB FEP Database for SR-Site and SR-PSU. 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 SR-Site and SR-PSU FEP catalogues.

Interaction Matrices

Interaction Matrices offer an alternative way to process diagrams to illustrate couplings between variables and processes and are used as a tool to identify FEPs and interactions between processes that affect the future evolution of the repository and its environs and must be considered in quantitative analyses of the system. Interaction Matrices for each system component in the repository, as well as for the geosphere and the biosphere, are included in the SKB FEP Database for SR-Site and SR-PSU. As for the process diagrams, the Interaction Matrices are automatically generated based on the influence tables. This is further described in the SR-Site FEP report (2010a), and in the SR-PSU FEP report (2014b).

The basic principle of an Interaction Matrix is to list the variables defining the properties and conditions in the physical components of the system studied along the principal 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. The internal processes act directly between two variables in a clock-wise manner.

FEP charts and Assessment Model Flow charts (AMF)

FEP charts are used to provide an overview of the relationship between *initial state* factors, variables, processes and the safety functions of the repository. They aid an expert in analysing the system qualitatively, and are used, in combination with other sources, for scenario selection and analysis in safety assessments. A FEP chart is included in the SR-Site version of the SKB FEP Database. The items in the FEP chart are linked to process FEPs in the SR-Site FEP catalogue and the links are displayed in process tables. These process tables summarise the handling of each process in the assessment. The process tables are accessed through the process FEP records in the FEP catalogue. This is further described in the SR-Site FEP report (SKB 2010a).

Assessment model flow charts, AMFs, are used to give an overview of the models used in the evaluation of repository evolution, the dependencies/interactions between them, and data used in the modelling. AMFs and tables that provide links between the process FEPs in the process tables and the modelling activities described by the AMF are included in the SR-Site version of the SKB FEP Database (SKB 2010a).

3.4.2 Other FEP lists

Many of the projects in the NEA FEP Database version 2.1 are concerned with spent fuel or high-level waste. However, there are FEP lists available from other relevant and more recent national projects for low- and intermediate-level waste not included in the NEA FEP Database version 2.1. In Table 2-4, a summary is given of relevant project-specific FEP lists developed in national deep disposal programmes since 2006 (NEA 2013), i.e. after NEA FEP Database version 2.1 was released.

In the FEP analysis carried out within the most recent safety assessment for the SFR repository, SR-PSU (PSAR), some of the new FEP lists were checked against the content of the already established SR-PSU FEP catalogue. The following FEP lists were included in the analysis:

- *NEA International FEP List version 3.0* (NEA 2019), described in Section 2.3.2.
- *Posiva's LILW repository* (Nummi et al. 2012), which is the FEP list for Posiva's safety case in support of the construction licence application for a geologic disposal facility situated at Olkiluoto, limited to the repository for the low and intermediate level waste.
- *OPG's LILW repository* (NWMO 2011), which is the FEP list for the post-closure safety assessment for Ontario Power Generation's proposed deep geologic repository for low and intermediate level waste at the Bruce nuclear site in Canada. It should be noted that the geological environment at the Bruce site differs significantly from the Forsmark site. The OPG repository is planned to be located in Ordovician age sediments overlaid by Silurian sediments. This important difference was kept in mind when comparing the FEP lists.
- *Posiva's SNF and LILW repositories* (unpublished FEP-list), which is the preliminary version of the FEP list for SC-OLA, which is Posiva's safety case in support of the operating licence application for a geologic disposal facility situated at Olkiluoto. This facility comprises a repository for disposal of spent nuclear fuel based on the KBS-3V design and a repository for the low and intermediate level waste arising from the operation and decommissioning of the encapsulation plant for the spent nuclear fuel.

The review did not result in any changes made to the SR-PSU FEP catalogue and no formal documentation of the outcome of the review was added to the SKB FEP database.

In SE-SFL, it was decided not to use the additional more recent national project FEP lists in the FEP analysis. In the future, when a full safety assessment is carried out for SFL, the NEA IFEP List together with all relevant national project FEP lists, not necessarily included in the NEA FEP Database, will be considered in the analysis. Since the NEA IFEP List version 3.0 has undergone a major revision both in terms of its structure and its content in comparison with the 2000 IFEP List, see section 2.3.2, in future safety assessments it may be relevant to reconsider the structure of the SKB FEP Database and in particular the mapping made to other project-specific FEP lists (PFEPs). Also, since the new NEA IFEP List was only recently released, it is considered adequate at this stage to wait for any updates that might follow before performing a revision of the SKB FEP database.

4 FEP processing

The results of the FEP audit against the SR-PSU FEP catalogue and the PFEPs in the NEA FEP Database, described in Chapter 3, are documented in two separate Microsoft Excel workbooks. These workbooks were used as intermediate storage to support and simplify the audit and processing work on the FEPs before the result was imported back into the SE-SFL FEP Database. The different procedures applied for the further processing of the audit results are described in this chapter.

4.1 Processing results for the NEA PFEPs

The possibly relevant NEA PFEPs remaining after the third and final audit step were discussed together with the involved experts from different disciplines, see Table 1-3. The FEPs were then distributed to the experts for further processing and a final screening for relevance to SE-SFL. Depending on the outcome of the processing, the NEA PPEP is treated as follows:

- If the PFEP is considered irrelevant to SE-SFL and screened out during this stage of the FEP processing, this is commented on accordingly in the Microsoft Excel workbook using the wording *"Considered irrelevant in SE-SFL"*, followed by a motivation as to why the FEP is considered irrelevant.

If the FEP is considered relevant to SE-SFL, the FEP is treated in one of the following two ways:

- If the PFEP is already covered by existing FEPs in the SE-SFL FEP catalogue, this is commented on accordingly in the Microsoft Excel workbook using the wording *"Included in the SE-SFL FEP catalogue"* and the SE-SFL FEPs of relevance are referenced by their FEP ID and FEP name.
- If the PFEP in not covered by any existing FEP in SE-SFL FEP catalogue, this is commented on accordingly in the Microsoft Excel workbook using the wording *"New FEP added to the SE-SFL FEP catalogue"* and the new SE-SFL FEP is referenced by the FEP ID and FEP name. The new FEP is then added to the SE-SFL FEP catalogue together with the required FEP record information, provided by the expert; FEP ID, FEP name, Description and Handling.

A total of 52 PFEPs possibly relevant for SE-SFL were remaining after the FEP audit. Of the 52 PFEPs, it was concluded that 11 PFEPs are irrelevant and 41 are relevant for SE-SFL. However, 32 of the relevant PFEPs are already covered by one or more existing FEPs in the SE-SFL preliminary FEP catalogue see Table 4-1. The other 9 PFEPs all concern the criticality process, which is the initiation of sustained nuclear (fission) chain reactions in the repository. This may occur if a sufficient mass and appropriate density of fissile material can accumulate in one place. It also requires the presence of a suitable amount and type of moderator material. Criticality, if it were to occur, would affect the radionuclide inventory and the thermal output and, in extreme cases, might damage the integrity of the engineered barriers and the bedrock. It is not likely that criticality will occur in SFL but the potential for it to happen still needs to be analysed and the amount of fissile material that can be disposed determined. A new FEP (WM23) in the main category *internal processes* and system component *waste form* was therefore added to the SE-SFL preliminary FEP catalogue, see Table 4-2, and this is the only FEP added to the SE-SFL preliminary FEP catalogue because of the audit against the NEA PFEPs. This also concluded the work on establishing the final product, the SE-SFL FEP catalogue. The SE-SFL FEP catalogue was then further processed with respect to the information regarding the description and handling of each FEP. This work is described in detail in Section 4.2.

Finally, the compiled results from the FEP processing of the NEA PFEPs, i.e. the notes on handling and motivation, was documented in the two Microsoft Excel workbooks and imported back into the SE-SFL FEP Database.

A complete list of all 553 NEA PFEPs that were considered in the SE-SFL FEP analysis is provided in Table A2-1 in Appendix 2. For each FEP the following information is shown: the FEP ID, FEP name, and audit step number where the FEP was screened out.

Table 4-1. Screening criteria used in processing of NEA PFEPs.

NEA PFEP relevance criteria for SE-SFL	No of PFEPs
Considered relevant. Already covered by other FEPs in the SE-SFL preliminary FEP catalogue	32
Considered relevant. Not yet covered by other FEPs in the SE-SFL preliminary FEP catalogue	9
Considered irrelevant in SE-SFL	11

Table 4-2. NEA PFEP added to the SE-SFL FEP catalogue.

FEP record field	Value
FEP ID	WM23
FEP name	Criticality
Main category	Internal processes
System component	Waste form

4.2 Processing results for the SE-SFL FEP catalogue

The SE-SFL FEP catalogue was treated in a similar way to the list of NEA PFEPs in the FEP processing. Based on the results from the FEP audit, subsets of the SE-SFL FEP catalogue were filtered out and distributed in Excel format to relevant experts as listed in Table 1-3. The description and handling of each FEP included in the SE-SFL FEP catalogue was updated, or if necessary completely re-written, by the experts according to the conditions in the SFL repository and treatment in SE-SFL. Many FEPs are handled in the same manner as in SR-PSU, but for others the handling is simplified in SE-SFL.

In the SE-SFL FEP catalogue, all FEPs are labelled according to how they are handled in the safety evaluation. The labelling is documented using a separate field (*Handling status in SE-SFL*) in the FEP record where one of the labels *Considered* or *Not considered* is stored for each FEP. The definitions of FEP handling status in SE-SFL, used during the labelling process are described below.

FEPs labelled *"Considered in SE-SFL"* fall into one of the following categories:

- FEP taken into account in the reference evolution that are judged to be of negligible importance for the radionuclide transport and dose calculations.
- FEP taken into account in the reference evolution and included in the radionuclide transport and dose calculations.

FEPs labelled *"Not considered in SE-SFL"* fall into one of the following categories:

- FEP considered irrelevant for post-closure safety for the proposed repository concept.
- FEP may be relevant to post-closure safety, but has not been considered in SE-SFL.

The handling status is mainly used for sorting FEPs in the SE-SFL FEP catalogue and to clearly show how the FEP is handled in the analysis. A more detailed description of the handling is found in a separate field (*Handling*) in the FEP record.

There are a number of FEPs which for different reasons are *Not considered in SE-SFL*. In many cases, it is stated that the not-considered FEP will be or may be considered in future safety assessments for SFL, indicating that the FEP was left out of the SE-SFL analysis due to the more limited scope of the safety evaluation compared with a full safety assessment, or that relevant data needed to handle the process adequately were missing. In a few cases, where a FEP is clearly irrelevant for SE-SFL, it was still decided to keep it in the SE-SFL FEP catalogue for the sake of comprehensiveness relative to SR-PSU and for future reference to show that the process was not overlooked in the analysis.

Finally, the compiled results from the FEP processing of the SE-SFL FEP catalogue were imported back into the SE-SFL FEP catalogue in the SE-SFL FEP Database, within the SKB FEP Database. In Table 5-1, the classification and number of FEPs in the final SE-SFL FEP catalogue, is shown. A complete list of FEP records in the SE-SFL FEP catalogue is provided in Table A1-1 in Appendix 1.

In the following sections, the FEP processing is described for each of the main categories in the SE-SFL FEP catalogue.

4.2.1 Initial state FEPs

The five *initial state* FEPs in the SE-SFL FEP catalogue are related either to the expected initial state with acceptable variations/tolerances or to deviations from the expected initial state outside those tolerances. Each FEP related to the expected initial state is associated with the appropriate *system variables* and system component and included in the description of the initial state for the system component of relevance. This is described in the SR-PSU **Initial state report** (SKB 2014e) and in the **Initial state report**. Each variable constitutes a FEP record in the SE-SFL FEP catalogue. The *initial state* FEPs are not system specific, but are related to more general considerations and deviations, and are included in the SE-SFL FEP catalogue with the FEP IDs, ISGen*nn*, where IS denotes *initial state*, Gen denotes general characteristics of and deviations in the initial state and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

In the further processing, it was decided to exclude all the SE-SFL *initial state* FEPs from the scenario selection. The five FEPs, listed below, are therefore labelled *Not considered* in SE-SFL:

- *ISGen01 – Major mishaps/accidents/sabotage*, is related to severe perturbations like fire, explosions, sabotage and severe flooding. 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.
- *ISGen02 – Effects of phased operation*. This may be considered in future safety assessments for SFL if phased operation is relevant.
- *ISGen03 – Incomplete closure*, concerns the effects of an abandoned, not completely sealed repository or open monitoring boreholes. This will be considered in future safety assessments for SFL.
- *ISGen04 – Monitoring activities*, is related to effects detrimental to safety after repository closure caused by monitoring activities. This FEP was excluded from further analysis because this type of monitoring will not be accepted.
- *ISGen05 – Design deviations – Mishaps*, concerns undetected design deviations and mishaps during manufacturing, transportation, deposition and repository operations etc. This will be considered in future safety assessments for SFL.

The handling of the *initial state* in SE-SFL is described in the **Initial state report** and documented in the SE-SFL FEP Database.

4.2.2 Internal process FEPs

There are 127 FEPs belonging to the main category *internal processes*. These are subdivided into the SFL system components *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components*, and the *geosphere*. Each FEP in this category describes a process relevant to one or several of the system components defined for the SE-SFL safety evaluation, excluding the *biosphere*, see Section 4.2.4. The various system components are also characterised by a number of *system variables*, see Section 4.2.3. Within a system component, each process is influenced by one or several of the *system variables* describing the state of the component, and the process, in turn, influences one or several of the *system variables*.

Since the SFR and SFL waste packaging, technical barriers and other repository concepts have many similarities, the descriptions of *internal processes* for the *waste form* (SKB 2014f) and the *barriers* (SKB 2014g) in SR-PSU are used also in SE-SFL. For the bedrock system, the descriptions of *internal processes* for the *geosphere* in SR-Site (SKB 2010c) and SR-PSU (SKB 2014h) are used.

In the following sections, a compilation of all FEPs that are *Not considered in SE-SFL*, is given for each of the system components in SFL.

Waste form

There are 23 FEPs included for the system component *waste form* in the SE-SFL FEP catalogue. These are the same FEPs as defined in SR-PSU, with the addition of *WM23* that concerns criticality. One of the FEPs is labelled *Not considered in SE-SFL*:

- *WM13 – Colloid formation and transport.* Will be considered in future safety assessments for SFL.

The *waste form* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, WM*nn*, where WM denotes *waste form* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

Concrete and steel packaging

There are 16 FEPs included for the system component *concrete and steel packaging* in the SE-SFL FEP catalogue. These are the same FEPs as defined in SR-PSU. In the radionuclide transport modelling, the potential impact of the concrete and steel packaging on the water flow is neglected. Five of the FEPs are labelled *Not considered in SE-SFL*:

- *Pa03 – Water uptake and transport during unsaturated conditions.* It is assumed this process is not affected by the presence of the packaging.
- *Pa04 – Water transport under saturated conditions.* It is assumed this process is not affected by the presence of the packaging.
- *Pa05 – Fracturing/deformation.* It is assumed this process is not affected by the presence of the packaging.
- *Pa06 – Advective transport of dissolved species.* It is assumed this process is not affected by the presence of the packaging.
- *Pa07 – Diffusive transport of dissolved species.* It is assumed this process is not affected by the presence of the packaging.

The *concrete and steel packaging* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Pa*nn*, where Pa denotes *concrete and steel packaging* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

BHA barriers

There are 26 FEPs included for the system component *BHA barriers* in the SE-SFL FEP catalogue. These are the same FEPs as defined in SR-PSU. Two of the FEPs are labelled *Not considered in SE-SFL*:

- *BHABa07 – Mechanical processes.* No mechanical analysis has been performed within SE-SFL. This will be considered in future safety assessments for SFL.
- *BHABa19 – Montmorillonite colloid release.* Process neglected. It will be considered in future safety assessments for SFL.

The *BHA barriers* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, BHABa*nn*, where BHABa denotes *BHA barriers* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

BHK barriers

There are 19 FEPs included for the system component *BHK barriers* in the SE-SFL FEP catalogue. These are the same FEPs as defined in SR-PSU. All *BHK barrier* FEPs are labelled *Considered in SE-SFL*.

The *BHK barriers* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, BHKBa*nn*, where BHKBa denotes *BHK barriers* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

Plugs and other closure components

There are 21 FEPs included for the system component *plugs and other closure components* in the SE-SFL FEP catalogue. These are the same FEPs as defined in SR-PSU. Three of the FEPs are labelled *Not considered in SE-SFL*:

- *Pg06 – Piping/erosion.* The process is neglected in SE-SFL. It will be considered in future safety assessments for SFL, when a better description of the closure of SFL is presented.
- *Pg15 – Montmorillonite transformation.* The process is neglected in SE-SFL. It will be considered in future safety assessments for SFL, when a more detailed description of the closure of SFL becomes available.
- *Pg16 – Montmorillonite colloid release.* The process is neglected in SE-SFL. It will be considered in future safety assessments for SFL, when a more detailed description of the closure of SFL becomes available.

The *plugs and other closure components* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Pg*nn*, where Pg denotes *plugs and other closure components* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

Geosphere

There are 22 FEPs included for the system component *geosphere* in the SE-SFL FEP catalogue. These are the same FEPs as defined in SR-PSU. Five of the FEPs are labelled *Not considered in SE-SFL*:

- *Ge05 – Deformation of intact rock.* This will be considered in future safety assessments for SFL.
- *Ge06 – Displacements along existing fractures.* This will be considered in future safety assessments for SFL.
- *Ge07 – Fracturing.* This will be considered in future safety assessments for SFL.
- *Ge09 – Erosion and sedimentation in fractures.* This will be considered in future safety assessments for SFL.
- *Ge21 – Earth currents.* Earth currents are not accounted for in SE-SFL. They will be considered in future safety assessments for SFL.

The *geosphere* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Ge*nn*, where Ge denotes *geosphere* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

4.2.3 System variable FEPs

There are 50 FEPs belonging to the main category *system variables*. In the same way as for *internal processes*, these FEPs are subdivided into the SFL system components *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components*, and the *geosphere*. Within a system component, each process is influenced by one or several of the *system variables* describing the state of the component, and the process, in turn, influences one or several of the *system variables*. The FEPs are used to characterise the system components, both in terms of the initial state of these variables and their states during repository evolution. The *biosphere* FEPs are excluded from the main category *system variables* in the same way as they are from the *internal processes*. Instead, the *biosphere* FEPs are handled as a separate main category in the FEP catalogue with their own processes and variables, see below.

Since the SFR and SFL waste and repository concepts have many similarities, the *system variables* given for the *waste form* and *packaging* (SKB 2014f) and the engineered *barriers* (SKB 2014g) in the SR-PSU are used also in SE-SFL and the initial state of these system components is described in the **Initial state report**. For the bedrock system, the *system variables* of *internal processes* for the *geosphere* in SR-Site (SKB 2010c) and SR-PSU (SKB 2014h) are used. A description of the initial state of the *geosphere* and *biosphere* is provided in the **Main report** in the present report. Each *system variable* in these reports is also associated with a FEP record in the SE-SFL FEP catalogue.

The following *system variables* are defined for all system components, i.e. *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components*, and the *geosphere*:

- *Gas variables.*
- *Geometry.*
- *Hydrological variables.*
- *Material composition.*
- *Mechanical stresses.*
- *Temperature.*
- *Water composition.*

For the *waste form*, two additional FEPs are defined for the radionuclide inventory and radiation intensity. For the *geosphere*, the number of system variable FEPs is larger with slightly different and more detailed definitions, but they essentially cover the same topics.

The *system variable* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, VarYYY*nn*, where Var denotes *system variable*, YYY denotes the system component (where WM – *waste form*, Pa – *concrete and steel packagin*g, BHK – *BHK barriers*, BHA – *BHA barriers*, Pg – *plugs and other closure components* and Ge – *geosphere*) and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

For all *system variabl*e FEPs defined for the system components *waste form, concrete and steel packaging, BHK barriers, BHA barriers* and *plugs and other closure components*, the FEP description and handling are identical to SR-PSU. These FEPs are all included in the description of repository evolution.

For the *system variable* FEPs defined for the *geosphere*, the handling is missing in SR-PSU so a comparison with SE-SFL FEPs is not possible. However, all but one *system variable* FEPs are considered in SE-SFL and are included in the description of repository evolution. The *system variable* FEPs labelled *Not considered in SE-SFL* is:

- *VarGe07 – Rock stresses,* as a function of time and space. A 3D stress field based on a geological history model is needed to assess the spatial and temporal stress variability and its consequences in terms of fracture and deformation zone reactivation as well as potential for fracture generation and propagation under subsequent external loads. Since this aspect is strongly site-dependent and no site has been selected for SFL, this analysis has been omitted at this stage but will be considered in future safety assessments for SFL.

4.2.4 Biosphere FEPs

In the safety assessment SR-PSU (SKB 2014b, c) a major effort was directed to the formulation of *biosphere* FEPs. That work is essentially transferred to SE-SFL. The *biosphere* FEPs and the handling of these in SE-SFL are described in the **Biosphere synthesis report**, where mainly the minor changes compared with SR-PSU are pointed out in the text.

A systematic approach is needed for the identification of FEPs in complex systems such as ecosystems. The interaction matrix (IM) is a practical tool to display identified components and pathways that may potentially affect radionuclide transport, accumulation and exposure. When constructing an IM, the major components of the system (in the case of the biosphere, an ecosystem), are listed along the lead diagonal of the matrix. The dynamics of the system are then described in terms of processes acting between the major components. Processes are displayed as off-diagonal elements in the matrix and represent direct interactions between two components that will result in a change in at least one of the components. In the biosphere IM developed for SR-PSU (SKB 2013), 12 *biosphere subsystem components* (divided into 10 *physical components* and 2 *boundary components*), 6 *biosphere variables*, and 50 *biosphere processes* are identified, i.e. in total 68 *biosphere* FEPs.

To illustrate the nature of these processes they have been grouped into six subcategories, namely:

- *Biological processes.*
- *Processes related to human behaviour.*
- *Chemical, mechanical and physical processes.*
- *Transport processes.*
- *Radiological and thermal processes.*
- *Landscape development processes.*

In the **Biosphere synthesis report**, these process categories are defined, and key processes are briefly described. In addition, features of the physical components are also briefly described. A detailed description of all processes and variables is given in SKB (2013), where also the IM is described.

Not all processes between the components in the IM are expected to be quantitatively important for transport and accumulation of radionuclides from a repository in the bedrock at the assessment site. Thus, of the 50 initially identified processes, 46 were considered relevant and sufficient to consider for a safety assessment off the repository, see Table A1-1 in Appendix 1. All processes, considered as well as those not considered, have a record in the SE-SFL FEP catalogue. For the FEPs *Not considered in SE-SFL*, the reason for exclusion is justified in the FEP record. The identification of relevant FEPs and model development has been going on in parallel at SKB for the last 20 years and thus knowledge of important FEPs has been considered in the development and improvements of the radionuclide model for the biosphere. However, to incorporate all 46 FEPs into the radionuclide transport model would result in a very complex model. Instead, many of the FEPs are included in supporting modelling used to derive parameter values for the radionuclide model. A mapping of identified biosphere FEPs to the different modelling activities has been performed showing that all the relevant FEPs are included in one or more modelling activities. All SE-SFL *biosphere* FEPs are identical to those in SR-PSU, except for three (*Bio09, Bio11* and *Bio20*, see descriptions below) which were reconsidered after review. Two of the FEPs were changed from *Not considered in SR-PSU* to being *Considered in SE-SFL*:

- *Bio11 – Movement induced by organisms,* which was included since filter feeders can dominate the benthic biomass in the model area and cannot generally be ruled out in marine areas.
- *Bio20 – Change of pressure,* which affects the water level in the enclosed bays and thus also the water circulation.

One FEP (*Bio09*) that was *considered* in SR-PSU was changed to *Not considered in SE-SFL*. The four *biosphere process* FEPs that are labelled *Not considered in SE-SFL* are:

- *Bio09 – Intrusion* (of organism), which is not relevant at several 100 m depth for organisms other than humans and thus is excluded from the FEP list of the biosphere. For humans this FEP is handled in *future human actions*, see Section 4.2.5.
- *Bio23 – Loading,* is the exertion of force caused by the weight of material on the underlying bedrock. This process was excluded since it is not important to consider for a repository located where the regolith is thin. Ice load affects the geosphere directly.
- *Bio44 – Irradiation* (by ionising radiation), is the process whereby an object is exposed to radiation and absorbs energy. This process was excluded since the expected radionuclide levels at the surface are too low to affect regolith and water in regolith by irradiation.
- *Bio46 – Radiolysis*, is the disintegration of molecules caused by radiation. This process was excluded since the expected radionuclide levels are too low to affect regolith and water in regolith by irradiation.

The SE-SFL *biosphere process* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Bio*nn*, where Bio denotes *biosphere processes* and *nn* is a two-digit serial number. Similarly, the *biosphere subsystem component* FEPs are given the FEP IDs, CompBio*nn*, and lastly, the *biosphere variable* FEPs are given the FEP IDs, VarBio*nn*, see Table A1-1 in Appendix 1.

4.2.5 External factor FEPs

The 27 SE-SFL FEPs belonging to the main category *external factors* are subdivided into the following four subcategories:

- *Climatic processes and effects.*
- *Large-scale geological processes and effects.*
- *Future human actions.*
- *Other.*

The same division was used in the FEP analysis in SR-PSU (SKB 2014b) and in SR-Site (SKB 2010a). In the following sections, each of the subcategories is discussed.

Climatic processes and effects

The handling of climate and climate-related issues is documented in the SE-SFL **Climate report**. The identification of climate-related issues to evaluate in SE-SFL is based on the corresponding identification performed in SR-Site (see Section 1.2 in SKB 2010d) and SR-PSU (see Section 1.2 in SKB 2014i). The motivation for this procedure is the commonality with the Spent Fuel Repository in terms of repository depth and analysis period and with SFR in terms of technical barriers, waste packaging and radionuclide inventory.

The following climate-related issues have been identified in SE-SFL as potentially having an impact on repository safety (see Chapter 3 in the **Main report**):

- The development of hydrostatic pressures, including pressure gradients, associated with ice-sheet development affecting repository structures.
- The maximum permafrost and ground-freezing depth.
- Variations in groundwater fluxes during glacial cycles affecting the transport of radionuclides to the surface.
- The possible penetration of dilute groundwater to repository depth during glacial phases and extended periods of temperate climate conditions, potentially causing erosion of buffer and backfill.
- The potential for glacially induced faulting affecting repository structures.
- The potential impacts of global warming on the surface ecosystems.

The same seven *climatic processes and effects* FEPs as were defined for SR-PSU are included in the SE-SFL FEP catalogue, see list of FEPs 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, and thus reduce the number of FEPs in the SR-PSU FEP catalogue (therefore also the gap in the FEP numbering, see below).

All *climatic processes and effects* FEPs are labelled *Considered in SE-SFL*. For some of the FEPs, a full safety assessment for SFL will include more aspects of the FEP.

- *Cli02 – Climate forcing,* deals with the forcing conditions that influence the evolution of global, regional and local climate. These include the atmospheric greenhouse effect and orbital insolation variations.
- *Cli03 – Climate evolution,* deals with the future climate evolution and thus climate change as compared with the present. Natural and human-induced changes are included.
- *Cli05 – Development of permafrost,* deals with permafrost development under various climate assumptions.
- *Cli06 – Ice-sheet dynamics and hydrology,* deals with ice-sheet dynamics and hydrology during future periods of glaciation at the repository site.
- *Cli08 – Glacial isostatic adjustment,* deals with the response of the solid Earth to the growth and decay of continental ice sheets.

- *Cli09 – Shore-level changes,* deals with shore-level changes due to isostasy and eustasy. Isostasy is the response of the solid Earth to loading or unloading by ice or water, and/or unloading and loading due to denudation and sedimentation. Eustasy refers to changes in sea-level arising from changes in ocean water volume, due to mass exchange between continental ice masses and the oceans and density changes associated with changes in ocean temperature and salinity, and, the spatial distribution of ocean water changes.
- *Cli10 – Denudation,* deals with the combined effect of all weathering and erosion processes, referred to as denudation. The downwearing of the Earth's surface by exogenic processes is accomplished by weathering, erosion, and transportation of material.

The *climatic processes and effects* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Cli*nn*, where Cli denotes *climatic processes and effects* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

Large-scale geological processes and effects

Large-scale geological processes and effects are covered by two FEPs in the SE-SFL FEP catalogue. These FEPs are the same as those defined for SR-PSU and SR-Site and the descriptions provided in SR-PSU (SKB 2014h) and in the SR-Site geosphere process report (SKB 2010c, Sections 4.1.2 and 4.1.3) also apply for SE-SFL. Both FEPs are labelled *Not considered in SE-SFL*:

- *LSGe01 – Mechanical evolution of the Shield* concerns the geological history of the Baltic Shield and its consequences for the current mechanical conditions of the Baltic Shield.
- *LSGe02 – Earthquakes.* The layout of the repository and its geographic location, i.e. the local properties of the geosphere, will to a very large degree steer the outcome of a safety assessment. As both the layout and siting are still at a conceptual stage, there is no defendable rationale for engaging in any advanced seismic hazard analyses. In particular, the spatio-temporal variability of the magnitude-frequency relations needs to be addressed over a glacial cycle. This is a major undertaking that did not fit into the scope of this assessment.

The *large-scale geological processes and effects* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, LSGe*nn*, where LSGe denotes *large-scale geological processes and effects* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

Future human actions (FHA)

In SE-SFL, the same list of 17 *future human actions* FEPs was used as was defined in the SR-PSU FEP catalogue and reported in SKB (2014a). No further analysis was performed for these FEPs and all FEPs are labelled *Not considered in SE-SFL* but they are still defined as FEPs in the SE-SFL FEP catalogue. The justification for excluding these FEPs from further analysis is documented in the respective FEP records. For most FEPs, it is stated that it either may, or will, be considered in future safety assessments for SFL. For two of the FEPs, it is considered unlikely for the event to have any effect on the repository and the following FEPs are therefore labelled *Not considered in SE-SFL*:

- *FHA14 – Landfill,* is related to the construction of a dump or landfill. It is considered unlikely that releases at a landfill would have an impact at the repository depth.
- *FHA15 – Bombing or blasting, explosions and crashes,* is related to deliberate or accidental explosions and crashes near the repository. Due to the large depth of SFL, explosions and crashes are considered highly unlikely to have any effect on the repository.

Detailed analysis of the potential effects of *future human actions* on post-closure safety for SFL will be performed in future full safety assessments. The *future human actions* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, FHA*nn*, where FHA denotes *future human actions* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

Other

As in the SR-PSU FEP catalogue, there is only one SE-SFL FEP included in the subcategory *other* and it deals with meteorite impact. This FEP is labelled *Considered in SE-SFL*, but is not handled in SE-SFL. The motivation for this is that there is very little likelihood that a meteorite big enough to damage the repository will impact the Earth. The probability that the impact will occur on the repository site is very low. Moreover, such an impact would cause great damage to the local and regional biosphere, humans included. These direct effects of a meteorite impact are judged to be far more serious than any possible radiological consequences.

The *other* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Oth*nn*, where Oth denotes *other* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1.

4.2.6 Methodology FEPs

In spite of there being a large number of NEA PFEPs related to basic assumptions for the assessment and to the *methodology* adopted for the assessment, only two *methodology* FEPs are included in the SE-SFL FEP catalogue. The reason is that most of the NEA FEPs are of 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. The *methodological* FEPs are included in the SE-SFL FEP catalogue with the FEP IDs, Meth*nn*, where Meth denotes *methodology* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1. These are the same as in the SR-PSU and SR-Site FEP catalogues, with some differences in the handling of the assessment methodology. Both *methodological* FEPs are labelled *Considered in SE-SFL*.

The handling of the *methodological* FEPs in SE-SFL is described in the **Main report** and documented in the SE-SFL FEP catalogue in the SKB FEP Database.

4.2.7 Site-specific factor FEPs

FEPs categorised as *site-specific factors* represent issues that are specifically identified as relevant for the SE-SFL analysis or have the potential of being so in a future safety assessment. Only two *site-specific factor* FEPs are included in the SE-SFL FEP catalogue and have the FEP IDs, SiteFact*nn*, where SiteFact denotes *site-specific factors* and *nn* is a two-digit serial number, see Table A1-1 in Appendix 1. These are the same FEPs as in the SR-PSU FEP catalogue and both are labelled *Not considered in SE-SFL*:

- *SiteFact02 – Construction of nearby rock facilities.* This will be considered in future safety assessments for SFL.
- *SiteFact03 – Nearby nuclear power plant.* This will be considered in future safety assessments for SFL, provided that the repository is located close to a nuclear power plant.

The handling of *site-specific factors* in SE-SFL is described in the **Main report** and documented in the SE-SFL FEP catalogue in the SKB FEP Database.

4.3 Summary of FEP processing

A summary of the SE-SFL FEP processing procedure is given in Table 5-1, where the classification and number of FEPs in the final SE-SFL FEP catalogue is specified. For each category, numbers are given in terms of the subtotals (for the subcategories), number of FEPs *Considered in SE-SFL*, *Not considered in SE-SFL* and the total number of FEPs.

In total, the SE-SFL FEP catalogue comprises 281 FEP records, of which 234 are labelled *Considered in SE-SFL* and 47 are labelled *Not considered in SE-SFL*.

5 The SE-SFL FEP catalogue

Based on the FEP processing conducted in SE-SFL, a SE-SFL FEP catalogue was established. The resulting FEP catalogue contains all FEPs defined for the SE-SFL safety evaluation. The SE-SFL FEP catalogue is included in the SKB FEP Database together with files documenting the FEP processing results. The SKB FEP Database also encompasses the SR-PSU FEP Database, as well as the SR-Site, SR-Can and SR 97 FEP Databases, see Section 2.4.1 and Figure 2-8. The content of the SE-SFL FEP catalogue together with the features of the SE-SFL version of SKB FEP Database and the information it provides are described in this chapter. A digital version of the SKB FEP Database (i.e. a FileMaker™ database) is available for download from the SKB web page together with instructions on how to navigate in the database.

5.1 Classification of the SE-SFL FEPs

The SE-SFL FEP catalogue contains FEPs in the following main categories:

- *Initial state.*
- *Internal processes* with the system components *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components* and the *geosphere*.
- *System variables* for the system components *waste form, concrete and steel packaging, BHA barriers, BHK barriers, plugs and other closure components* and the *geosphere*.
- *Biosphere*, comprising *biosphere processes*, *biosphere subsystem components* and *biosphere variables*.
- *External factors.*
- *Methodology.*
- *Site-specific factors.*

To illustrate the nature of the *biosphere processes* they are in turn grouped into the following six subcategories:

- *Biological processes.*
- *Processes related to human behaviour.*
- *Chemical, mechanical and physical processes.*
- *Transport processes.*
- *Radiological and thermal processes.*
- *Landscape development processes.*

The SE-SFL FEPs belonging to the main category *external factors* are subdivided into the following four subcategories:

- *Climatic processes and effects.*
- *Large-scale geological processes and effects.*
- *Future human actions.*
- *Other.*

In total, the SE-SFL FEP catalogue comprises **281 FEP records**. In Table 5-1, the classification and number of FEPs in the final SE-SFL FEP catalogue, is shown. For each category, numbers are given in terms of the subtotals (for the subcategories), number of FEPs *Considered in SE-SFL*, *Not considered in SE-SFL* and the total number of FEPs.

A complete listing of the SE-SFL FEP catalogue is provided in Table A1-1 in Appendix 1. For practical reasons, only the FEP ID, FEP name, main category, system component or subcategory and a short note on handling, are shown in the table. The full descriptions and handlings can be very extensive for some FEPs, which makes the inclusion of these fields unpractical. The complete information for each FEP is however present in the SE-SFL FEP catalogue.

Table 5-1. Classification and number of FEPs in the final SE-SFL FEP catalogue. For each category, numbers are given in terms of the subtotal (for the subcategories), number of *Considered*, *Not considered* and the total number of FEPs.

SE-SFL FEP catalogue	No of FEPs			
Main category ***System component or Subcategory***	**Sub**	**Considered**	**Not considered**	**Total**
Initial state		0	5	5
Internal processes		111	16	127
Waste form	*23*	*22*	*1*	
Concrete and steel packaging	*16*	*11*	*5*	
Plugs and other closure components	*21*	*18*	*3*	
Geosphere	*22*	*17*	*5*	
BHA barriers	*26*	*24*	*2*	
BHK barriers	*19*	*19*	*0*	
System variables		49	1	50
Waste form	*9*	*9*	*0*	
Concrete and steel packaging	*7*	*7*	*0*	
Plugs and other closure components	*7*	*7*	*0*	
Geosphere	*13*	*12*	*1*	
BHA barriers	*7*	*7*	*0*	
BHK barriers	*7*	*7*	*0*	
Biosphere		64	4	68
Biosphere processes	*50*	*46*	*4*	
Biosphere subsystem components	*12*	*12*	*0*	
Biosphere variables	*6*	*6*	*0*	
External factors		8	19	27
Climatic processes and effects	*7*	*7*	*0*	
Large-scale geological processes	*2*	*0*	*2*	
Future human actions	*17*	*0*	*17*	
Other	*1*	*1*	*0*	
Methodology		2	0	2
Site-specific factors		0	2	2
Sum		**234**	**47**	**281**

5.2 The SE-SFL FEP record information

In the SE-SFL FEP catalogue, each FEP is represented by a FEP record containing the following fields of information:

- **FEP ID** – contains a unique identification of the FEP.
- **FEP name** – contains a short name describing the FEP.
- **Main category** – contains the main category to which the FEP belongs.
- **Subcategory** – contains the subcategory, where applicable, to which the FEP belongs, as described in Section 5.1.
- **Handling status in SE-SFL** – contains a label showing the handling status of the FEP, i.e. *Considered* or *Not considered*, as described in Section 4.2.
- **Description** – contains a detailed description of the FEP.
- **Handling** – contains a detailed description of the handling of the FEP in SE-SFL.
- **Reference** – contains references with section pointers and hyperlinks to reports (main report and any number of main references and supporting reports) where more extensive documentation of the FEP and its handling are found.
- **Revision** – contains information about the changes and revisions made to the FEP.

An example of a SE-SFL FEP record in the SKB FEP Database is given in Figure 5-1 and Figure 5-2.

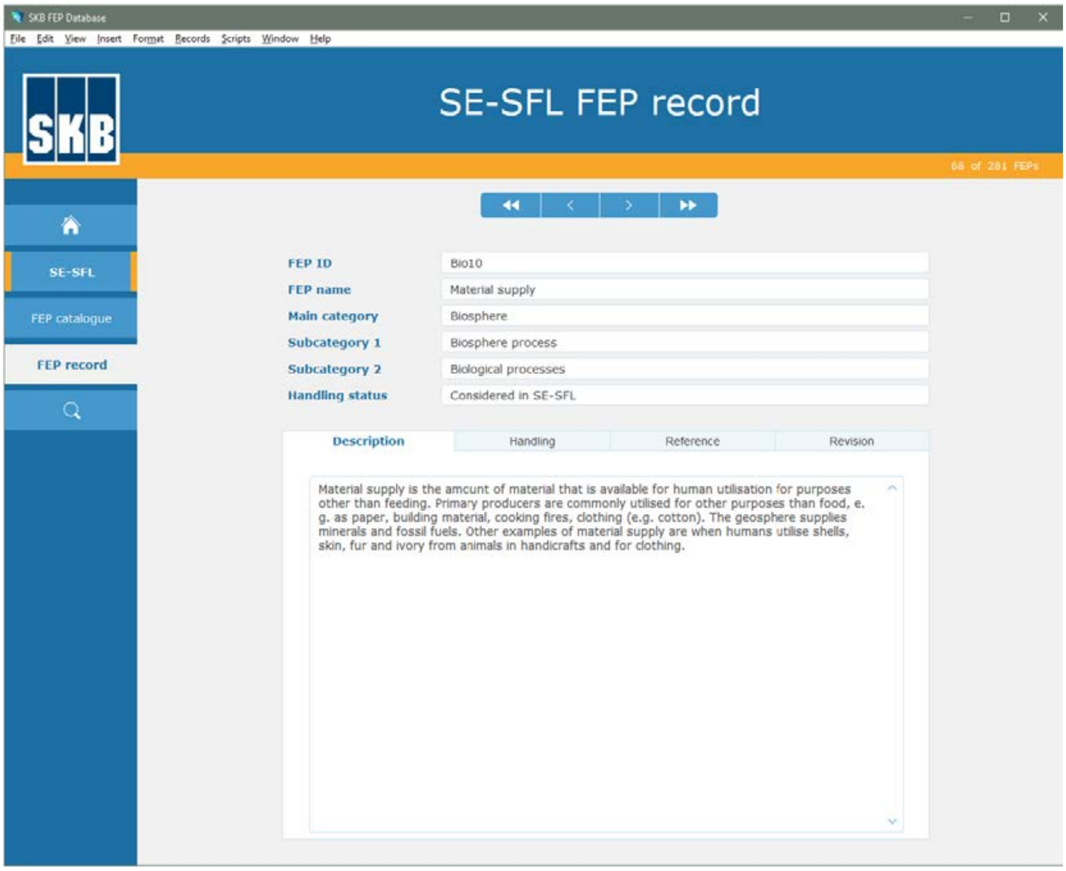

Figure 5-1. *Information available from a FEP record in the SE-SFL FEP catalogue.*

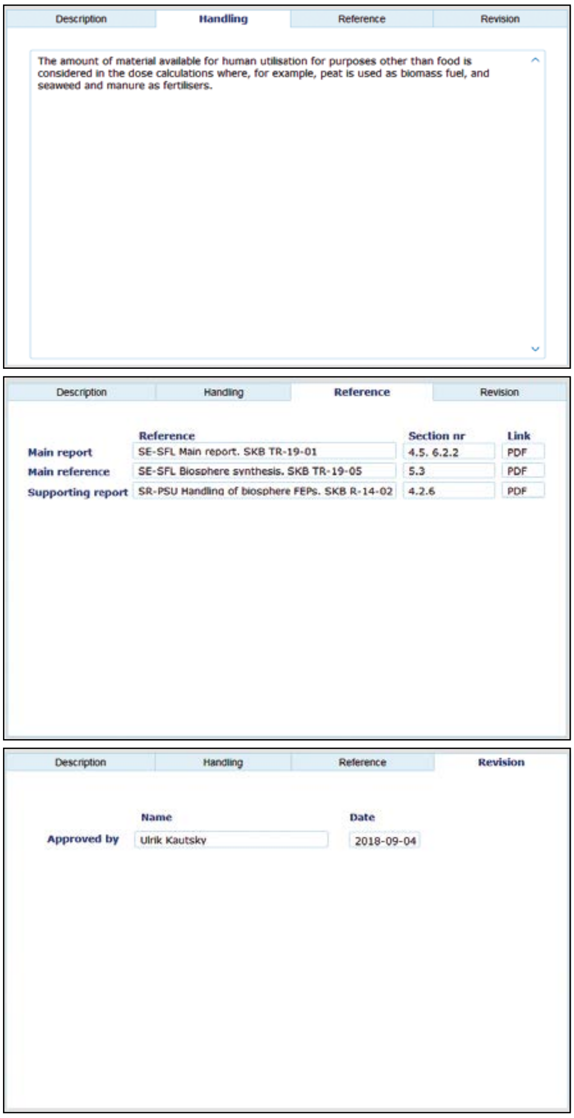

Figure 5-2. *Close-up view of tabs showing information regarding Handling, Reference and Revision available from a FEP record in the SE-SFL FEP catalogue.*

5.3 The SE-SFL version of the SKB FEP Database

In parallel to the development of the SE-SFL FEP catalogue, a major update of the layout and functionality in the SKB FEP Database was conducted. The work focused on the SE-SFL version of the SKB FEP Database, whereas the other older versions, SR-PSU, SR-Site and SR-Can, were left unchanged and will therefore not be further discussed here. It is however planned to update the layouts in all other versions of the SKB FEP Database in the future so that the visual appearance as well as the user experience is made consistent throughout the database.

When the SKB FEP Database is started, the Home screen is opened, see Figure 5-3. The Home screen can be accessed from every layout in the SE-SFL FEP Database through the Home button present at the top of the navigation panel on the left-hand side of the screen.

The Home screen layout has been reorganised so that each database, or version, i.e. SR-Can, SR-Site, SR-PSU and SE-SFL, of the SKB FEP Database now is assigned to a separate button found in the navigation panel, see Figure 5-3. In the navigation panel, there are also buttons for downloading the database from the SKB website and for accessing general information about the database. In addition to the buttons for opening each of the databases, it is also possible to click an active object directly in the main figure showing the overall structure of the SKB FEP Database, which will open the selected part of the database directly.

By clicking the SE-SFL button, the SE-SFL FEP Database main screen is opened, see Figure 5-4. In the navigation panel, the user can choose between opening the full SE-SFL FEP catalogue, see Figure 5-5, or a single SE-SFL FEP record, see Figure 5-1. The SE-SFL FEP catalogue can also be opened directly by selecting the related rectangle in the main figure.

Using the button bar at the top of the main screen of the SE-SFL FEP catalogue, the user can select specific main categories or subcategories of FEPs to be listed. For each FEP listed on the main screen, the *FEP ID, FEP name, Main category, Subcategory* and *Handling status* is shown, see Figure 5-5. A specific FEP record is accessed by clicking the info button to the right of each FEP. In Section 5.2, the information available from a SE-SFL FEP record is described and an example FEP record is shown in Figure 5-1 and Figure 5-2.

The Search screen is accessed by clicking the search button at the bottom of the navigation panel, see Figure 5-7. The user is provided full flexibility to perform searches using all information fields available in the FEP records, see Figure 5-1 and Figure 5-2. The *FEP ID, FEP name, Main category, Subcategory*, and *Handling status* fields are dropdown menus that aid the user during the search procedure. It is however also possible to enter an optional search string in these dropdown menus. The *Description, Handling, Reference* and *Revision* fields can be used for free text search entries.

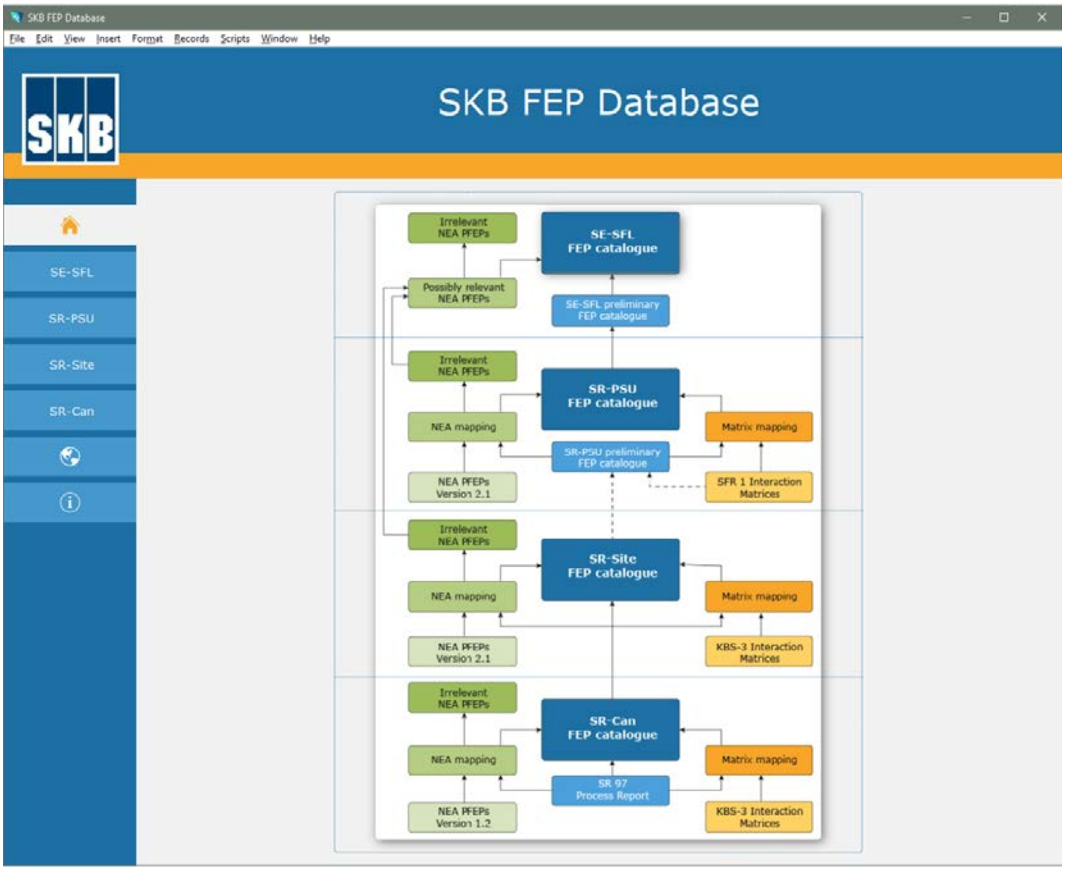

Figure 5-3. *The SKB FEP Database Home screen.*

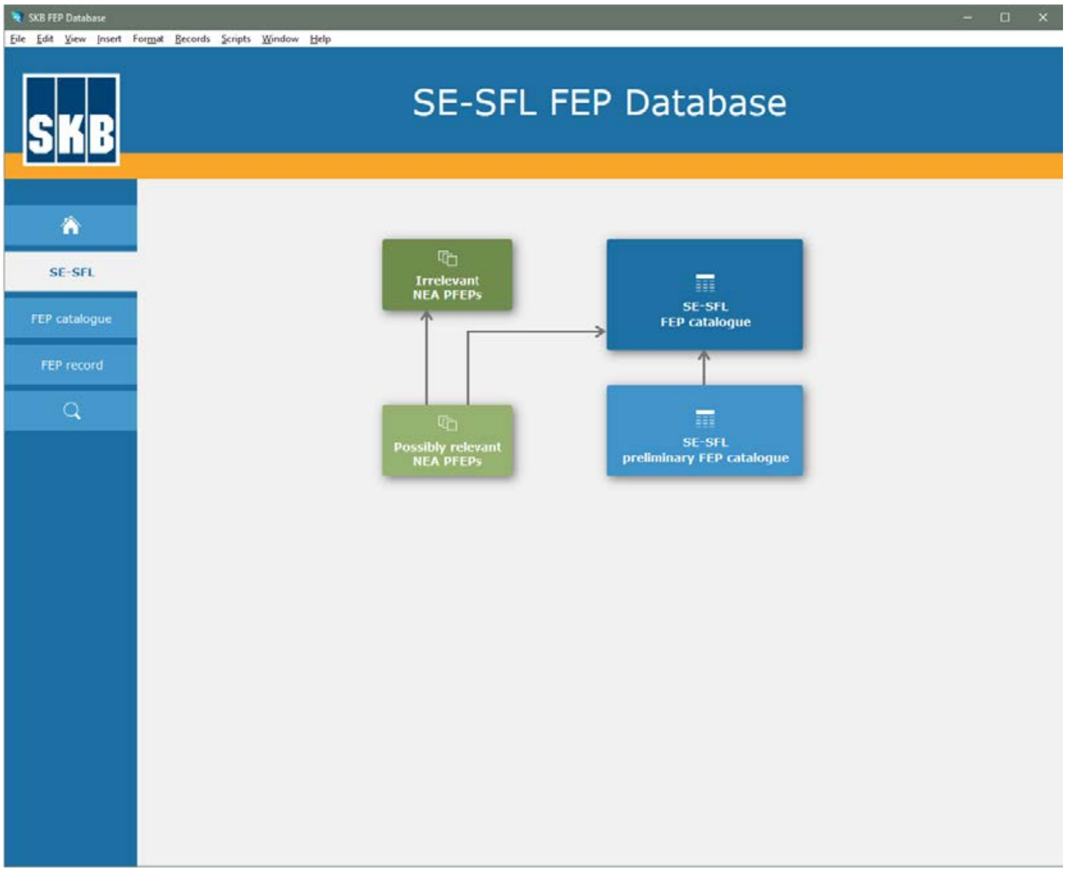

Figure 5-4. The SE-SFL FEP Database main screen.

Figure 5-5. List of selected FEPs in the SE-SFL FEP catalogue.

Figure 5-6. *Pop-up window showing available FEP categories to be listed in the SE-SFL FEP catalogue.*

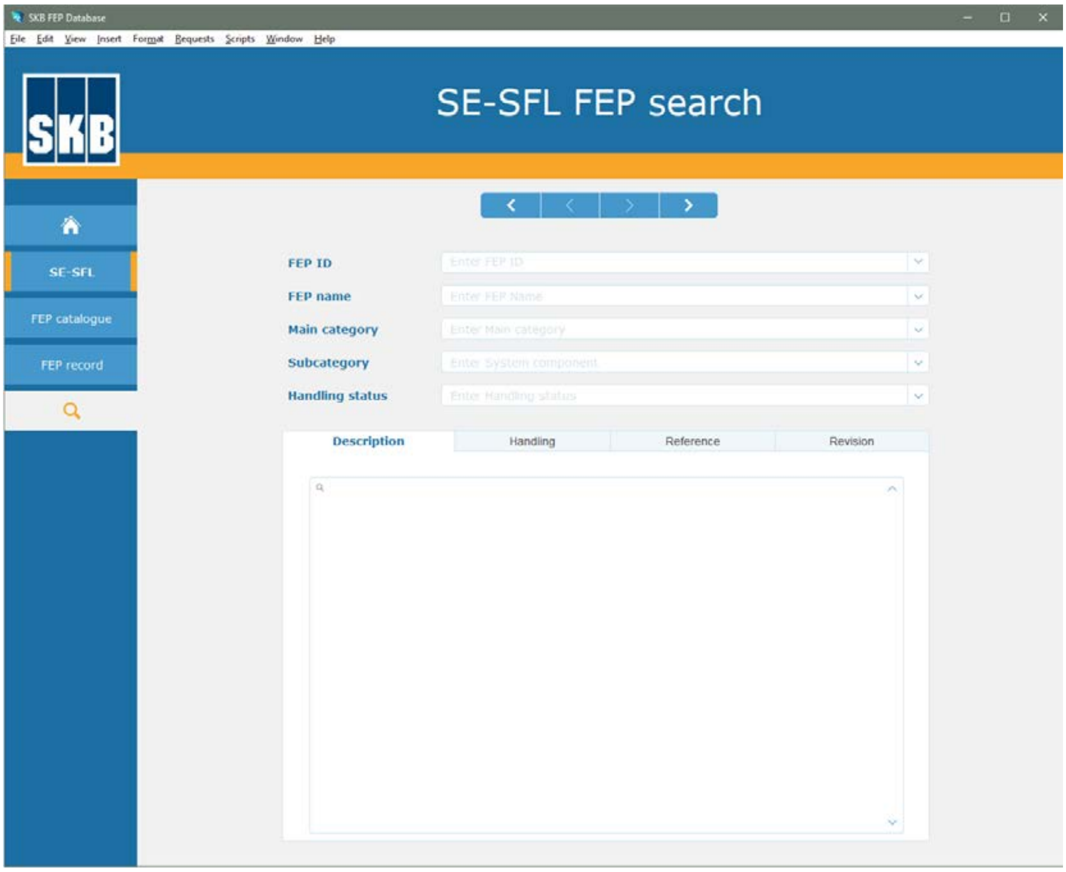

Figure 5-7. *Search options available from the Search screen in the SE-SFL FEP catalogue.*

6 Concluding remarks

Based on the FEP analysis conducted in SE-SFL, a SE-SFL FEP catalogue has been established within the framework of the SKB FEP Database. The SE-SFL FEP catalogue is the first version established for the SFL repository. The resulting FEP catalogue contains all FEPs defined for the SE-SFL safety evaluation and is included in the SKB FEP Database together with files documenting the FEP processing results. The SKB FEP Database also encompasses the SR-PSU version, as well as the SR-Site, SR-Can and SR 97 FEP Databases. A digital version of the SKB FEP Database (i.e. a FileMaker™ database) is available for download from the SKB web page together with instructions on how to navigate in the FEP database.

The FEP processing work in SE-SFL has been conducted in a systematic way, building on the FEP analysis conducted in the recent safety assessments carried out for the extended SFR, SR-PSU, and the Spent Fuel Repository, SR-Site. Similar, but simplified, procedures and experience from the work with the SR-PSU FEP catalogue have been applied. A simplified audit against the PFEPs in the NEA international FEP database was conducted, but without performing the mapping between NEA PFEPs and the SE-SFL FEP catalogue. However, in the future, when a full safety assessment is carried out for SFL, a more thorough analysis of the FEPs will be performed and all relevant national FEP lists will be considered in the analysis.

In summary, this analysis and FEP processing supports our view that the SE-SFL FEP catalogue contains all FEPs needed to be considered in the SE-SFL assessment. It is therefore concluded that the objectives of the FEP analysis in SE-SFL have been fulfilled.

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SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.
SKBdoc documents will be submitted upon request to document@skb.se.
In the FEP database, references in the text to SKB reports are given as SKB report numbers.

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Appendix 1

In Table A1-1, a complete list of FEP records in the SE-SFL FEP catalogue is shown. The FEP list is a product of the audit and processing described in Chapters 3 and 4 respectively. The audit against the SR-PSU FEP catalogue is described in Section 3.2 and the FEP processing results for the SE-SFL catalogue are described in Section 4.2 and 4.3 and summarised in Chapter 5. The definitions of FEP handling status in SE-SFL, used during the labelling process are also described in Section 4.2.

Table A1-1. Complete list of FEP records in the SE-SFL FEP catalogue.

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
ISGen01	Major mishaps/accidents/sabotage	Initial state	General	**Not considered in SE-SFL**
ISGen02	Effects of phased operation	Initial state	General	**Not considered in SE-SFL**
ISGen03	Incomplete closure	Initial state	General	**Not considered in SE-SFL**
ISGen04	Monitoring activities	Initial state	General	**Not considered in SE-SFL**
ISGen05	Design deviations - Mishaps	Initial state	General	**Not considered in SE-SFL**
WM01	Radioactive decay	Internal process	Waste form	Considered in SE-SFL
WM02	Radiation attenuation/heat generation	Internal process	Waste form	Considered in SE-SFL
WM03	Radiolytic decomposition of organic material	Internal process	Waste form	Considered in SE-SFL
WM04	Water radiolysis	Internal process	Waste form	Considered in SE-SFL
WM05	Heat transport	Internal process	Waste form	Considered in SE-SFL
WM06	Phase changes/freezing	Internal process	Waste form	Considered in SE-SFL
WM07	Water uptake and transport during unsaturated conditions	Internal process	Waste form	Considered in SE-SFL
WM08	Water transport under saturated conditions	Internal process	Waste form	Considered in SE-SFL
WM09	Fracturing	Internal process	Waste form	Considered in SE-SFL
WM10	Advective transport of dissolved species	Internal process	Waste form	Considered in SE-SFL
WM11	Diffusive transport of dissolved species	Internal process	Waste form	Considered in SE-SFL
WM12	Sorption/uptake	Internal process	Waste form	Considered in SE-SFL
WM13	Colloid formation and transport	Internal process	Waste form	**Not considered in SE-SFL**
WM14	Dissolution, precipitation and recrystallisation	Internal process	Waste form	Considered in SE-SFL
WM15	Degradation of organic materials	Internal process	Waste form	Considered in SE-SFL
WM16	Water uptake/swelling	Internal process	Waste form	Considered in SE-SFL
WM17	Microbial processes	Internal process	Waste form	Considered in SE-SFL
WM18	Metal corrosion	Internal process	Waste form	Considered in SE-SFL
WM19	Gas formation and transport	Internal process	Waste form	Considered in SE-SFL
WM20	Speciation of radionuclides	Internal process	Waste form	Considered in SE-SFL
WM21	Transport of radionuclides in the water phase	Internal process	Waste form	Considered in SE-SFL
WM22	Transport of radionuclides in the gas phase	Internal process	Waste form	Considered in SE-SFL
WM23	Criticality	Internal process	Waste form	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
Pa01	Heat transport	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa02	Phase changes/freezing	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa03	Water uptake and transport during unsaturated conditions	Internal process	Concrete and steel packaging	**Not considered in SE-SFL**
Pa04	Water transport under saturated conditions	Internal process	Concrete and steel packaging	**Not considered in SE-SFL**
Pa05	Fracturing/deformation	Internal process	Concrete and steel packaging	**Not considered in SE-SFL**
Pa06	Advective transport of dissolved species	Internal process	Concrete and steel packaging	**Not considered in SE-SFL**
Pa07	Diffusive transport of dissolved species	Internal process	Concrete and steel packaging	**Not considered in SE-SFL**
Pa08	Sorption/uptake	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa09	Colloid transport and filtering	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa10	Dissolution, precipitation and recrystallisation	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa11	Microbial processes	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa12	Metal corrosion	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa13	Gas formation and transport	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa14	Speciation of radionuclides	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa15	Transport of radionuclides in the water phase	Internal process	Concrete and steel packaging	Considered in SE-SFL
Pa16	Transport of radionuclides in the gas phase	Internal process	Concrete and steel packaging	Considered in SE-SFL
BHKBa01	Heat transport	Internal process	BHK barriers	Considered in SE-SFL
BHKBa02	Phase changes/freezing	Internal process	BHK barriers	Considered in SE-SFL
BHKBa03	Water uptake and transport during unsaturated conditions	Internal process	BHK barriers	Considered in SE-SFL
BHKBa04	Water transport under saturated conditions	Internal process	BHK barriers	Considered in SE-SFL
BHKBa05	Gas transport/dissolution	Internal process	BHK barriers	Considered in SE-SFL
BHKBa06	Mechanical processes	Internal process	BHK barriers	Considered in SE-SFL
BHKBa07	Advection and dispersion	Internal process	BHK barriers	Considered in SE-SFL
BHKBa08	Diffusion	Internal process	BHK barriers	Considered in SE-SFL
BHKBa09	Sorption on concrete/shotcrete	Internal process	BHK barriers	Considered in SE-SFL
BHKBa10	Colloid stability, transport and filtering	Internal process	BHK barriers	Considered in SE-SFL
BHKBa11	Concrete degradation	Internal process	BHK barriers	Considered in SE-SFL
BHKBa12	Aqueous speciation and reactions	Internal process	BHK barriers	Considered in SE-SFL
BHKBa13	Microbial processes	Internal process	BHK barriers	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
BHKBa14	Metal corrosion	Internal process	BHK barriers	Considered in SE-SFL
BHKBa15	Gas formation	Internal process	BHK barriers	Considered in SE-SFL
BHKBa16	Speciation of radionuclides	Internal process	BHK barriers	Considered in SE-SFL
BHKBa17	Transport of radionuclides in the water phase	Internal process	BHK barriers	Considered in SE-SFL
BHKBa18	Transport of radionuclides in the gas phase	Internal process	BHK barriers	Considered in SE-SFL
BHABa01	Heat transport	Internal process	BHA barriers	Considered in SE-SFL
BHABa02	Phase changes/freezing	Internal process	BHA barriers	Considered in SE-SFL
BHABa03	Water uptake and transport during unsaturated conditions	Internal process	BHA barriers	Considered in SE-SFL
BHABa04	Water transport under saturated conditions	Internal process	BHA barriers	Considered in SE-SFL
BHABa05	Gas transport/dissolution	Internal process	BHA barriers	Considered in SE-SFL
BHABa06	Piping/erosion	Internal process	BHA barriers	Considered in SE-SFL
BHABa07	Mechanical processes	Internal process	BHA barriers	**Not considered in SE-SFL**
BHABa08	Advection and dispersion	Internal process	BHA barriers	Considered in SE-SFL
BHABa09	Diffusion	Internal process	BHA barriers	Considered in SE-SFL
BHABa10	Sorption (including ion exchange of major ions)	Internal process	BHA barriers	Considered in SE-SFL
BHABa11	Alteration of impurities	Internal process	BHA barriers	Considered in SE-SFL
BHABa12	Colloid transport and filtering	Internal process	BHA barriers	Considered in SE-SFL
BHABa13	Concrete degradation	Internal process	BHA barriers	Considered in SE-SFL
BHABa14	Dissolution/precipitation	Internal process	BHA barriers	Considered in SE-SFL
BHABa15	Aqueous speciation and reactions	Internal process	BHA barriers	Considered in SE-SFL
BHABa16	Osmosis	Internal process	BHA barriers	Considered in SE-SFL
BHABa17	Montmorillonite transformation	Internal process	BHA barriers	Considered in SE-SFL
BHABa18	Iron-bentonite interaction	Internal process	BHA barriers	Considered in SE-SFL
BHABa19	Montmorillonite colloid release	Internal process	BHA barriers	**Not considered in SE-SFL**
BHABa20	Microbial processes	Internal process	BHA barriers	Considered in SE-SFL
BHABa21	Cementation in bentonite	Internal process	BHA barriers	Considered in SE-SFL
BHABa22	Metal corrosion	Internal process	BHA barriers	Considered in SE-SFL
BHABa23	Gas formation	Internal process	BHA barriers	Considered in SE-SFL
BHABa24	Speciation of radionuclides	Internal process	BHA barriers	Considered in SE-SFL
BHABa25	Transport of radionuclides in the water phase	Internal process	BHA barriers	Considered in SE-SFL
BHABa26	Transport of radionuclides in the gas phase	Internal process	BHA barriers	Considered in SE-SFL
Pg01	Heat transport	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg02	Phase changes/freezing	Internal process	Plugs and other closure components	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
Pg03	Water uptake and transport during unsaturated conditions	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg04	Water transport under saturated conditions	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg05	Gas transport/dissolution	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg06	Piping/erosion	Internal process	Plugs and other closure components	**Not considered in SE-SFL**
Pg07	Mechanical processes	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg08	Advection and dispersion	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg09	Diffusion	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg10	Sorption (including ion-exchange of major ions)	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg11	Alteration of impurities in bentonite	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg12	Dissolution, precipitation, recrystallisation and clogging in backfill	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg13	Aqueous speciation and reactions	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg14	Osmosis	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg15	Montmorillonite transformation	Internal process	Plugs and other closure components	**Not considered in SE-SFL**
Pg16	Montmorillonite colloid release	Internal process	Plugs and other closure components	**Not considered in SE-SFL**
Pg17	Microbial processes	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg18	Degradation of rock bolts, reinforcements and concrete	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg19	Speciation of radionuclides	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg20	Transport of radionuclides in the water phase	Internal process	Plugs and other closure components	Considered in SE-SFL
Pg21	Transport of radionuclides in the gas phase	Internal process	Plugs and other closure components	Considered in SE-SFL
Ge01	Heat transport	Internal process	Geosphere	Considered in SE-SFL
Ge02	Freezing	Internal process	Geosphere	Considered in SE-SFL
Ge03	Groundwater flow	Internal process	Geosphere	Considered in SE-SFL
Ge04	Gas flow/dissolution	Internal process	Geosphere	Considered in SE-SFL
Ge05	Deformation of intact rock	Internal process	Geosphere	**Not considered in SE-SFL**
Ge06	Displacements along existing fractures	Internal process	Geosphere	**Not considered in SE-SFL**
Ge07	Fracturing	Internal process	Geosphere	**Not considered in SE-SFL**
Ge09	Erosion and sedimentation in fractures	Internal process	Geosphere	**Not considered in SE-SFL**
Ge10	Advective transport/mixing of dissolved species	Internal process	Geosphere	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
Ge11	Diffusive transport in the rock mass	Internal process	Geosphere	Considered in SE-SFL
Ge12	Speciation and sorption	Internal process	Geosphere	Considered in SE-SFL
Ge13	Reactions groundwater/rock matrix	Internal process	Geosphere	Considered in SE-SFL
Ge14	Dissolution/precipitation of fracture-filling minerals	Internal process	Geosphere	Considered in SE-SFL
Ge15	Microbial processes	Internal process	Geosphere	Considered in SE-SFL
Ge16	Degradation of grout	Internal process	Geosphere	Considered in SE-SFL
Ge17	Colloidal processes	Internal process	Geosphere	Considered in SE-SFL
Ge19	Methane hydrate formation	Internal process	Geosphere	Considered in SE-SFL
Ge20	Salt exclusion	Internal process	Geosphere	Considered in SE-SFL
Ge21	Earth currents	Internal process	Geosphere	**Not considered in SE-SFL**
Ge22	Speciation of radionuclides	Internal process	Geosphere	Considered in SE-SFL
Ge23	Transport of radionuclides in the water phase	Internal process	Geosphere	Considered in SE-SFL
Ge24	Transport of radionuclides in the gas phase	Internal process	Geosphere	Considered in SE-SFL
Bio01	Bioturbation	Biosphere	Biological processes	Considered in SE-SFL
Bio02	Consumption	Biosphere	Biological processes	Considered in SE-SFL
Bio03	Death	Biosphere	Biological processes	Considered in SE-SFL
Bio04	Decomposition	Biosphere	Biological processes	Considered in SE-SFL
Bio05	Excretion	Biosphere	Biological processes	Considered in SE-SFL
Bio06	Food supply	Biosphere	Biological processes	Considered in SE-SFL
Bio07	Growth	Biosphere	Biological processes	Considered in SE-SFL
Bio08	Habitat supply	Biosphere	Biological processes	Considered in SE-SFL
Bio09	Intrusion	Biosphere	Biological processes	**Not considered in SE-SFL**
Bio10	Material supply	Biosphere	Biological processes	Considered in SE-SFL
Bio11	Movement	Biosphere	Biological processes	Considered in SE-SFL
Bio12	Particle release/trapping	Biosphere	Biological processes	Considered in SE-SFL
Bio13	Primary production	Biosphere	Biological processes	Considered in SE-SFL
Bio14	Stimulation/inhibition	Biosphere	Biological processes	Considered in SE-SFL
Bio15	Uptake	Biosphere	Biological processes	Considered in SE-SFL
Bio16	Anthropogenic release	Biosphere	Processes related to human behaviour	Considered in SE-SFL
Bio17	Material use	Biosphere	Processes related to human behaviour	Considered in SE-SFL
Bio18	Species introduction/extermination	Biosphere	Processes related to human behaviour	Considered in SE-SFL
Bio19	Water use	Biosphere	Processes related to human behaviour	Considered in SE-SFL
Bio20	Change of pressure	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
Bio21	Consolidation	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio22	Element supply	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio23	Loading	Biosphere	Chemical, mechanical and physical processes	**Not considered in SE-SFL**
Bio24	Phase transitions	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio25	Physical properties change	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio26	Reactions	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio27	Sorption/desorption	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio28	Water supply	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio29	Weathering	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio30	Wind stress	Biosphere	Chemical, mechanical and physical processes	Considered in SE-SFL
Bio31	Acceleration	Biosphere	Transport processes	Considered in SE-SFL
Bio32	Convection	Biosphere	Transport processes	Considered in SE-SFL
Bio33	Covering	Biosphere	Transport processes	Considered in SE-SFL
Bio34	Deposition	Biosphere	Transport processes	Considered in SE-SFL
Bio35	Export	Biosphere	Transport processes	Considered in SE-SFL
Bio36	Import	Biosphere	Transport processes	Considered in SE-SFL
Bio37	Interception	Biosphere	Transport processes	Considered in SE-SFL
Bio38	Relocation	Biosphere	Transport processes	Considered in SE-SFL
Bio39	Resuspension	Biosphere	Transport processes	Considered in SE-SFL
Bio40	Saturation	Biosphere	Transport processes	Considered in SE-SFL
Bio41	Radioactive decay	Biosphere	Radiological and thermal processes	Considered in SE-SFL
Bio42	Exposure	Biosphere	Radiological and thermal processes	Considered in SE-SFL
Bio43	Heat storage	Biosphere	Radiological and thermal processes	Considered in SE-SFL
Bio44	Irradiation	Biosphere	Radiological and thermal processes	**Not considered in SE-SFL**
Bio45	Light-related processes	Biosphere	Radiological and thermal processes	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
Bio46	Radiolysis	Biosphere	Radiological and thermal processes	**Not considered in SE-SFL**
Bio47	Radionuclide release	Biosphere	Radiological and thermal processes	Considered in SE-SFL
Bio48	Change in rock surface location	Biosphere	Landscape development processes	Considered in SE-SFL
Bio49	Sea-level change	Biosphere	Landscape development processes	Considered in SE-SFL
Bio50	Thresholding	Biosphere	Landscape development processes	Considered in SE-SFL
VarWM01	Geometry	System variable	Waste form	Considered in SE-SFL
VarWM02	Radiation intensity	System variable	Waste form	Considered in SE-SFL
VarWM03	Temperature	System variable	Waste form	Considered in SE-SFL
VarWM04	Hydrological variables	System variable	Waste form	Considered in SE-SFL
VarWM05	Mechanical stresses	System variable	Waste form	Considered in SE-SFL
VarWM06	Radionuclide inventory	System variable	Waste form	Considered in SE-SFL
VarWM07	Material composition	System variable	Waste form	Considered in SE-SFL
VarWM08	Water composition	System variable	Waste form	Considered in SE-SFL
VarWM09	Gas variables	System variable	Waste form	Considered in SE-SFL
VarPa01	Geometry	System variable	Concrete and steel packaging	Considered in SE-SFL
VarPa02	Temperature	System variable	Concrete and steel packaging	Considered in SE-SFL
VarPa03	Hydrological variables	System variable	Concrete and steel packaging	Considered in SE-SFL
VarPa04	Mechanical stresses	System variable	Concrete and steel packaging	Considered in SE-SFL
VarPa05	Material composition	System variable	Concrete and steel packaging	Considered in SE-SFL
VarPa06	Water composition	System variable	Concrete and steel packaging	Considered in SE-SFL
VarPa07	Gas variables	System variable	Concrete and steel packaging	Considered in SE-SFL
VarBHK01	Geometry	System variable	BHK barriers	Considered in SE-SFL
VarBHK02	Temperature	System variable	BHK barriers	Considered in SE-SFL
VarBHK03	Hydrological variables	System variable	BHK barriers	Considered in SE-SFL
VarBHK04	Mechanical stresses	System variable	BHK barriers	Considered in SE-SFL
VarBHK05	Material composition	System variable	BHK barriers	Considered in SE-SFL
VarBHK06	Water composition	System variable	BHK barriers	Considered in SE-SFL
VarBHK07	Gas variables	System variable	BHK barriers	Considered in SE-SFL
VarBHA01	Geometry	System variable	BHA barriers	Considered in SE-SFL
VarBHA02	Temperature	System variable	BHA barriers	Considered in SE-SFL
VarBHA03	Hydrological variables	System variable	BHA barriers	Considered in SE-SFL
VarBHA04	Mechanical stresses	System variable	BHA barriers	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
VarBHA05	Material composition	System variable	BHA barriers	Considered in SE-SFL
VarBHA06	Water composition	System variable	BHA barriers	Considered in SE-SFL
VarBHA07	Gas variables	System variable	BHA barriers	Considered in SE-SFL
VarPg01	Geometry	System variable	Plugs and other closure components	Considered in SE-SFL
VarPg02	Temperature	System variable	Plugs and other closure components	Considered in SE-SFL
VarPg03	Hydrological variables	System variable	Plugs and other closure components	Considered in SE-SFL
VarPg04	Mechanical stresses	System variable	Plugs and other closure components	Considered in SE-SFL
VarPg05	Material composition	System variable	Plugs and other closure components	Considered in SE-SFL
VarPg06	Water composition	System variable	Plugs and other closure components	Considered in SE-SFL
VarPg07	Gas variables	System variable	Plugs and other closure components	Considered in SE-SFL
VarGe01	Temperature in bedrock	System variable	Geosphere	Considered in SE-SFL
VarGe02	Groundwater flow	System variable	Geosphere	Considered in SE-SFL
VarGe03	Groundwater pressure	System variable	Geosphere	Considered in SE-SFL
VarGe04	Gas phase flow	System variable	Geosphere	Considered in SE-SFL
VarGe05	Repository geometry	System variable	Geosphere	Considered in SE-SFL
VarGe06	Fracture and pore geometry	System variable	Geosphere	Considered in SE-SFL
VarGe07	Rock stresses	System variable	Geosphere	**Not considered in SE-SFL**
VarGe08	Matrix minerals	System variable	Geosphere	Considered in SE-SFL
VarGe09	Fracture minerals	System variable	Geosphere	Considered in SE-SFL
VarGe10	Groundwater composition	System variable	Geosphere	Considered in SE-SFL
VarGe11	Gas composition	System variable	Geosphere	Considered in SE-SFL
VarGe12	Structural and stray materials	System variable	Geosphere	Considered in SE-SFL
VarGe13	Saturation	System variable	Geosphere	Considered in SE-SFL
CompBio01	Geosphere (Boundary condition)	Biosphere	Biosphere component	Considered in SE-SFL
CompBio02	Regolith	Biosphere	Biosphere component	Considered in SE-SFL
CompBio03	Water in regolith	Biosphere	Biosphere component	Considered in SE-SFL
CompBio04	Surface waters	Biosphere	Biosphere component	Considered in SE-SFL
CompBio05	Gas and local atmosphere	Biosphere	Biosphere component	Considered in SE-SFL
CompBio06	Primary producers	Biosphere	Biosphere component	Considered in SE-SFL
CompBio07	Decomposers	Biosphere	Biosphere component	Considered in SE-SFL

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
CompBio08	Filter feeders	Biosphere	Biosphere component	Considered in SE-SFL
CompBio09	Herbivores	Biosphere	Biosphere component	Considered in SE-SFL
CompBio10	Carnivores	Biosphere	Biosphere component	Considered in SE-SFL
CompBio11	Humans	Biosphere	Biosphere component	Considered in SE-SFL
CompBio12	External conditions (Boundary condition)	Biosphere	Biosphere component	Considered in SE-SFL
VarBio01	Geometry	Biosphere	Biosphere variable	Considered in SE-SFL
VarBio02	Material composition	Biosphere	Biosphere variable	Considered in SE-SFL
VarBio03	Radionuclide inventory	Biosphere	Biosphere variable	Considered in SE-SFL
VarBio04	Stage of succession	Biosphere	Biosphere variable	Considered in SE-SFL
VarBio05	Temperature	Biosphere	Biosphere variable	Considered in SE-SFL
VarBio06	Water composition	Biosphere	Biosphere variable	Considered in SE-SFL
Cli02	Climate forcing	External factor	Climatic processes and effects	Considered in SE-SFL
Cli03	Climate evolution	External factor	Climatic processes and effects	Considered in SE-SFL
Cli05	Development of permafrost	External factor	Climatic processes and effects	Considered in SE-SFL
Cli06	Ice-sheet dynamics and hydrology	External factor	Climatic processes and effects	Considered in SE-SFL
Cli08	Glacial isostatic adjustment	External factor	Climatic processes and effects	Considered in SE-SFL
Cli09	Shore-level changes	External factor	Climatic processes and effects	Considered in SE-SFL
Cli10	Denudation	External factor	Climatic processes and effects	Considered in SE-SFL
LSGe01	Mechanical evolution of the Shield	External factor	Large-scale geological processes and effects	**Not considered in SE-SFL**
LSGe02	Earthquakes	External factor	Large-scale geological processes and effects	**Not considered in SE-SFL**
FHA01	State of knowledge	External factor	Future human actions	**Not considered in SE-SFL**
FHA02	Societal development	External factor	Future human actions	**Not considered in SE-SFL**
FHA03	Technical development	External factor	Future human actions	**Not considered in SE-SFL**
FHA04	Heat storage	External factor	Future human actions	**Not considered in SE-SFL**
FHA05	Heat pump system	External factor	Future human actions	**Not considered in SE-SFL**
FHA06	Geothermal energy	External factor	Future human actions	**Not considered in SE-SFL**

FEP ID	FEP name	Main category	System component / subcategory	Handling status in SE-SFL
FHA07	Heating/cooling plant	External factor	Future human actions	**Not considered in SE-SFL**
FHA08	Drilled well	External factor	Future human actions	**Not considered in SE-SFL**
FHA09	Water management	External factor	Future human actions	**Not considered in SE-SFL**
FHA10	Altered land use	External factor	Future human actions	**Not considered in SE-SFL**
FHA11	Drilling	External factor	Future human actions	**Not considered in SE-SFL**
FHA12	Underground constructions	External factor	Future human actions	**Not considered in SE-SFL**
FHA13	Quarry	External factor	Future human actions	**Not considered in SE-SFL**
FHA14	Landfill	External factor	Future human actions	**Not considered in SE-SFL**
FHA15	Bombing or blasting, explosions and crashes	External factor	Future human actions	**Not considered in SE-SFL**
FHA16	Hazardous waste facility	External factor	Future human actions	**Not considered in SE-SFL**
FHA17	Contamination with chemical substances	External factor	Future human actions	**Not considered in SE-SFL**
Oth01	Meteorite impact	External factor	Other	Considered in SE-SFL
Meth01	Assessment basis	Methodology	General	Considered in SE-SFL
Meth02	Assessment methodology	Methodology	General	Considered in SE-SFL
SiteFact02	Construction of nearby rock facilities	Site-specific factor	General	**Not considered in SE-SFL**
SiteFact03	Nearby nuclear power plant	Site-specific factor	General	**Not considered in SE-SFL**

Appendix 2

In Table A2-1, a complete list of the 553 NEA Project-specific FEPs considered in the SE-SFL FEP analysis is shown. In the table, the PFEP ID and name are shown, together with information about where the PFEP was screened in the FEP analysis and the motivation for screening in SE-SFL. The FEP audit and processing procedures are described in Chapters 3 and 4, respectively. The audit against NEA Project-specific FEP (PFEP) Lists is described in Section 3.3 and the FEP processing results for the NEA PFEPs are described in Section 4.1.

Table A2-1. Complete list of NEA Project-specific FEPs considered in the SE-SFL FEP analysis.

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
A 1.04	Boundary conditions	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.09	Chemical gradients	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.15	Concrete	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.25	Coupled processes	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.34	Formation of cracks	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.39	Global effects	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.47	Interfaces (boundary conditions)	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.51	Long-term physical stability	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.52	Long-term transients	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.54	Microbes	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.55	Microorganisms	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.78	Stability	Audit step 3a	Too general, covered by other NEA PFEPs
A 1.83	Time dependence	Audit step 3a	Too general, covered by other NEA PFEPs
A 2.32	Groundwater composition	Audit step 3a	Too general, covered by other NEA PFEPs
A 3.070	Intrusion (deliberate)	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
A 3.085	Recycling	Audit step 3a	Too general, covered by other NEA PFEPs
A 3.103	Surface water bodies	Audit step 3a	Too general, covered by other NEA PFEPs
E GEN-00	General FEPs	Audit step 3a	Not considered to be a FEP
E SFL-00	FEPs specific to the SFL repository	Audit step 3a	Too general, covered by other NEA PFEPs
E SFR-00	FEPs specific to the SFR repository	Audit step 3a	Not considered to be a FEP
H 1.4.1	Waste-form and backfill consolidation	Audit step 3a	Too general, covered by other NEA PFEPs
H 1.6.3	Thermal effects: Chemical and microbiological changes	Audit step 3a	Too general, covered by other NEA PFEPs
H 2.2.3	Groundwater flow	Audit step 3a	Too general, covered by other NEA PFEPs
H 5.2.2	Deliberate intrusion	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
H 5.2.3	Malicious intrusion	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
I 008a	Archaeology (a find during construction)	Audit step 3a	Irrelevant for long-term safety
I 008b	Archaeology (a find during post-closure period)	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
I 011a	Backfill (properties)	Audit step 3a	Not considered to be a FEP
I 039	Vault chemical interactions	Audit step 3a	Too general, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
I 165	Interfaces (boundary conditions)	Audit step 3a	Too general, covered by other NEA PFEPs
I 167	Intrusion (human/deliberate)	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
I 337	Water contacting waste in vault	Audit step 3a	Too general, covered by other NEA PFEPs
J 2.3.02	Electro-chemical cracking	Audit step 3a	Heading only, covered by other NEA PFEPs
J 3.1.08	Near field buffer chemistry	Audit step 3a	Heading only, covered by other NEA PFEPs
J 3.1.09	Radiolysis	Audit step 3a	Heading only, covered by other NEA PFEPs
J 3.1.11	Redox front	Audit step 3a	Too general, covered by other NEA PFEPs
J 3.1.12	Perturbed buffer material chemistry	Audit step 3a	Heading only, covered by other NEA PFEPs
J 4.1.01	Oxidizing conditions	Audit step 3a	Too general, covered by other NEA PFEPs
J 4.1.02	Ph-deviations	Audit step 3a	Too general, covered by other NEA PFEPs
J 4.1.03	Colloids, complexing agents	Audit step 3a	Heading only, covered by other NEA PFEPs
J 4.1.07	Thermochemical change	Audit step 3a	Too general, covered by other NEA PFEPs
J 4.2.02.2	Hydraulic conductivity change - Excavation/backfilling effect	Audit step 3a	Heading only, covered by other NEA PFEPs
J 4.2.02.3	Mechanical effects - Excavation/backfilling effects	Audit step 3a	Heading only, covered by other NEA PFEPs
J 4.2.05	Changes in groundwater flow	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.07	Poorly designed repository	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.08	Poorly constructed repository	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.10	Accidents during operation	Audit step 3a	Irrelevant for long-term safety
J 5.18	Enhanced groundwater flow	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.19	Effect of plate movements	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.21	Future boreholes and undetected past boreholes	Audit step 3a	Heading only, covered by other NEA PFEPs
J 5.24	Stress changes of conductivity	Audit step 3a	Heading only, covered by other NEA PFEPs
J 5.25	Dissolution of fracture fillings/ precipitations	Audit step 3a	Heading only, covered by other NEA PFEPs
J 5.38	Explosions	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.40	Unsuccessful attempt of site improvement	Audit step 3a	Too general, covered by other NEA PFEPs
J 5.46	Groundwater recharge/discharge	Audit step 3a	Heading only, covered by other NEA PFEPs
J 6.03	Far field hydrochemistry - acids, oxidants, nitrate	Audit step 3a	Too general, covered by other NEA PFEPs
J 6.08	Human-induced climate change	Audit step 3a	Too general, covered by other NEA PFEPs
J 6.12	Undetected discontinuities	Audit step 3a	Heading only, covered by other NEA PFEPs
J 6.14	Tectonic activity - large scale	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
J 7.01	Accumulation in sediments	Audit step 3a	Heading only, covered by other NEA PFEPs
J 7.02	Accumulation in peat	Audit step 3a	Heading only, covered by other NEA PFEPs
J 7.03	Intrusion into accumulation zone in the biosphere	Audit step 3a	Heading only, covered by other NEA PFEPs
J 7.06	Missing	Audit step 3a	Not considered to be a FEP
K 0.2	Speciation	Audit step 3a	Too general, covered by other NEA PFEPs
M 1.6.05	Multiple-phase flow and gas-driven flow	Audit step 3a	Heading only, covered by other NEA PFEPs
M 1.7.05	Pedogenesis	Audit step 3a	Too general, covered by other NEA PFEPs
M 1.7.06	Chemical transformation	Audit step 3a	Too general, covered by other NEA PFEPs
M 1.7.07	Microbial interactions	Audit step 3a	Too general, covered by other NEA PFEPs
M 1.7.08	Ecological change (e.g. Forest fire cycles)	Audit step 3a	Too general, covered by other NEA PFEPs
M 1.7.09	Ecological response to climate (e.g. Desert formation)	Audit step 3a	Too general, covered by other NEA PFEPs
M 2.1.04	Stress field changes, setting, subsidence or caving	Audit step 3a	Heading only, covered by other NEA PFEPs
M 2.1.07	Common cause failures	Audit step 3a	Heading only, covered by other NEA PFEPs
M 2.1.09	Design modification	Audit step 3a	Not considered to be a FEP
M 2.2.01	Radioactive waste disposal error	Audit step 3a	Too general, covered by other NEA PFEPs
M 2.3.02	Malicious intrusion	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
M 2.4.06	Land-use changes	Audit step 3a	Too general, covered by other NEA PFEPs
M 3.2.04	Non-radioactive solute plume in geosphere	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.1	Extra-terrestrial	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.1.1	Meteorite impact	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.1.2	Solar insolation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2	Geological	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.1	Plate movement/tectonic change	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.10	Fault generation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.11	Rock heterogeneity	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.12	Undetected features	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.13	Natural-gas intrusion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.2	Changes in the Earth’s magnetic field	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
N 1.2.3	Magmatic activity	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.4	Metamorphic activity	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.5	Diagenesis	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.6	Uplift and subsidence	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.7	Diapirism	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.8	Seismicity	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.2.9	Fault activation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3	Climatological	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.1	Precipitation, temperature and soil water balance	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.2	Extremes of precipitation, snow melt and associated flooding	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.3	Coastal surge, storms and hurricanes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.4	Sea-level rise/fall	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.5	Periglacial effects	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.6	Glaciation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.3.7	No ice age	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4	Geomorphological	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.1	Land slide	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.10	Frost weathering	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.2	Denudation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.3	River, stream, channel erosion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.4	River meander	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.5	Freshwater sediment transport and deposition	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.6	Coastal erosion and estuarine development	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.7	Marine sediment transport and deposition	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.8	Solifluction	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.4.9	Chemical denudation and weathering	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
N 1.5	Hydrological	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.1	River flow and lake-level changes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.2	Site flooding	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.3	Recharge to groundwater	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.4	Groundwater discharge	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.5	Groundwater flow	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.6	Groundwater conditions	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.7	Saline or freshwater intrusion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.8	Effects at saline-freshwater interface	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.5.9	Natural thermal effects	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6	Transport and geochemical	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.1	Advection and dispersion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.10	Complexing agents	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.11	Fracture mineralisation and weathering	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.12	Accumulation in soils and organic debris	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.13	Mass, isotopic and species dilution	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.14	Chemical gradients	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.2	Diffusion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.3	Matrix diffusion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.4	Gas-mediated transport	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.5	Multiphase flow and gas-driven flow	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.6	Solubility limit	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.7	Sorption	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.8	Dissolution, precipitation and crystallisation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.6.9	Colloid formation, dissolution and transport	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7	Ecological	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
N 1.7.1	Plant uptake	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.10	Plant and animal evolution	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.2	Animal uptake	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.3	Uptake by deep-rooting species	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.4	Soil and sediment bioturbation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.5	Pedogenesis	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.6	Chemical transformations	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.7	Microbial interactions	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.8	Ecological change	Audit step 3a	Heading only, covered by other NEA PFEPs
N 1.7.9	Ecological response to climate (e.g. Desert formation)	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1	Design and construction	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.1	Undetected past intrusions	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.10	Thermal effects	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.2	Investigation borehole seal failure and degradation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.3	Shaft or access tunnel seal failure and degradation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.4	Stress field changes, settling, subsidence or caving	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.5	Dewatering of host rock	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.6	Material defects	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.7	Common cause failures	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.8	Poor quality construction	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.1.9	Design modification	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2	Operation and closure	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.1	Radioactive waste disposal error	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.10	Poor closure	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.11	Post-closure monitoring	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.12	Effects of phased operation	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
N 2.2.2	Inadequate backfill or compaction, voidage	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.3	Co-disposal of reactive wastes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.4	Inadvertent inclusion of undesirable materials	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.5	Heterogeneity of waste forms	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.6	Accidents during operation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.7	Sabotage	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.8	Repository flooding during operation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.2.9	Abandonment of unsealed repository	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3	Post-closure sub-surface activities (intrusion)	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.1	Recovery of repository materials	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.10	Injection of liquid wastes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.11	Groundwater abstraction	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.12	Underground nuclear testing	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.2	Malicious intrusion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.3	Exploratory drilling	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.4	Exploitation drilling	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.5	Geothermal energy production	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.6	Resource mining	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.7	Tunnelling	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.8	Underground construction	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.3.9	Archaeological investigation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4	Post-closure surface activities	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.1	Loss of records	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.10	Quarrying, near-surface extraction	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.2	Dams and reservoirs, built/drained	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.3	River rechannelled	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
N 2.4.4	Irrigation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.5	Altered soil or surface water chemistry	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.6	Land-use changes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.7	Agricultural and fisheries practice changes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.8	Demographic change, urban development	Audit step 3a	Heading only, covered by other NEA PFEPs
N 2.4.9	Anthropogenic climate change	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.1	Thermal	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.1.1	Differential elastic response	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.1.2	Non-elastic response	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.1.3	Host rock fracture aperture changes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.1.4	Induced hydrological changes (fluid pressure, density convection, viscosity)	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.1.5	Induced chemical changes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2	Chemical	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.1	Metallic corrosion	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.2	Interactions of host materials and groundwater with repository material	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.3	Interactions of waste and repository materials with host materials	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.4	Non-radioactive solute plume in geosphere	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.5	Cellulosic degradation	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.6	Introduced complexing agents and cellulosics	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.2.7	Microbiological effects	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.3	Mechanical	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.3.1	Canister or container movement	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.3.2	Changes in in-situ stress field	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.3.3	Embrittlement and cracking	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.3.4	Subsidence/collapse	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.3.5	Fracturing	Audit step 3a	Heading only, covered by other NEA PFEPs

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
N 3.3.6	Gas effects	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.4	Radiological	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.4.1	Radiolysis	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.4.2	Material property changes	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.4.3	Nuclear criticality	Audit step 3a	Heading only, covered by other NEA PFEPs
N 3.4.4	Radioactive decay and ingrowth	Audit step 3a	Heading only, covered by other NEA PFEPs
S 027	Distribution and release of nuclides from the geosphere	Audit step 3a	Too general, covered by other NEA PFEPs
S 062	Properties of bentonite buffer	Audit step 3a	Too general, covered by other NEA PFEPs
S 064	Properties of far-field rock	Audit step 3a	Too general, covered by other NEA PFEPs
S 065	Properties of near-field rock	Audit step 3a	Too general, covered by other NEA PFEPs
S 066	Properties of tunnel backfill	Audit step 3a	Too general, covered by other NEA PFEPs
S 101	Water chemistry, bentonite buffer	Audit step 3a	Too general, covered by other NEA PFEPs
S 103	Water chemistry in near-field rock	Audit step 3a	Too general, covered by other NEA PFEPs
S 104	Water chemistry, tunnel backfill	Audit step 3a	Too general, covered by other NEA PFEPs
W 1.050	Soil development	Audit step 3a	Too general, covered by other NEA PFEPs
W 1.072	Natural ecological development	Audit step 3a	Too general, covered by other NEA PFEPs
W 2.072	Exothermic reactions	Audit step 3a	Too general, covered by other NEA PFEPs
W 2.097	Chemical gradients	Audit step 3a	Too general, covered by other NEA PFEPs
W 2.100	Enhanced diffusion	Audit step 3a	Too general, covered by other NEA PFEPs
W 3.012	Deliberate drilling intrusion	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
W 3.018	Deliberate mining intrusion	Audit step 3a	Not necessary to consider in Safety assessment (IAEA 2012)
A 1.10	Chemical interactions	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 1.46	Incomplete filling of containers	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 1.58	Other waste (other than used fuel)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 1.82	Temperature rises (unexpected effects)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 2.36	Intrusion (magmatic)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 2.39	Magmatic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 2.42	Metamorphic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 2.44	Methane	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 2.67	Turbulence	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
A 2.72	Volcanism	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
H 2.1.2	Magmatic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
H 2.1.3	Regional metamorphism	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
H 2.1.5	Diapirism	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
H 4.3.2	Land and surface water use: Estuarine	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 004	Animals (intrusion)/ plants (root uptake)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 013	Bedrock fracture	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 025	Buffer (plugging by bitumen, slime molds, waste degradation products, etc.)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 032	Capillary rise in soil	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 034	Void formation (cave-ins, cavitation-outside the vault)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 057	Weather (hurricanes and tornadoes)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 062c	Concrete performance (incorrect modelling)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 062d	Concrete (degradation: natural, artificial)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 091	Water-table changes	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 093	Differential settling (inside IRUS)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 098	Drain gutters plug	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 105	Erosion (of sand ridge by wind)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 130	Gas (from waste containing a gas cylinder)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 178	Surface water bodies (flooding of Lake 233)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 195	Monitoring program - criteria and response	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 252	Remediation of other sites	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 280	Soil slumping	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 313	Turbulence (groundwater flow)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 322	Volcanic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
I 328	Swelling pressure(bales)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
J 1.2.03	Pb-I reactions	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
J 2.1.06.1	Repository induced Pb/Cu electrochemical reactions	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
J 2.4	Voids in the lead filling	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
J 5.06	Co-storage of other waste	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
J 5.13	Volcanism	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
J 5.23	Changed hydrostatic pressure on canister	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
J 6.11	Intruding dykes	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.01	Waste product (glass)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.02	Radionuclide inventory	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.03	Stainless steel fabrication flask	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.04	Void space	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.05	Glass cracking and surface area	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.06	Glass recrystallisation	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.07	Phase separation	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.09	Glass temperature	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.10	Radiation damage	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.11a	Glass alteration/dissolution	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.11b	Congruent dissolution	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.12	Rate of glass dissolution	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.13	Selective leaching	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.14	Coprecipitates/solid solutions	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.17	Iron corrosion products	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.18	Precipitation of silicates/silica gel	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.19	Radionuclide release from glass	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.21	Colloid formation	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.22	Microbial activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 1.25	Quality control	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
K 4.14	HLW panels (siting)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 4.15	TRU silos (siting)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 4.19	TRU silos cementitious plume	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 5.14	Regional stress regime	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 6.14	Regional stress regime	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 7.02	Mesozoic sedimentary cover	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 7.03	Permo-carboniferous trough	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 7.04	Groundwater flow	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 7.10	Stress regime	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 8.01	Present-day biosphere	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 8.19	Surface water flow (river Rhine)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 8.20	Groundwater flow (alluvium of Rhine valley)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 8.26	Surface water bodies	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.01	Regional horizontal movements	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.02	Regional vertical movements	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.03	Movements along major faults	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.04	Movements along small-scale faults	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.08	Basement alteration	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.09	Magmatic activity (volcanism and plutonism)	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K 9.10	Hydrothermal activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K S1.1	Waste Form and Packaging	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K S1.3	Host geology	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K S1.4	Local and Regional Surface Environment	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
K S1.5	Geographical location	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
M 1.2.03	Magmatic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
M 1.2.04	Metamorphic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
M 1.2.07	Diapirism	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
M 1.2.14	Decrease of plasticity of the clay	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
M 1.5.06	Ground water conditions	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
M 1.6.09	Colloid formation, dissolution and transport	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
M 2.1.12	Excavation effects	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
S 085	Sorption on filling material	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.002	Brine reservoirs	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.006	Salt deformation	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.007	Diapirism	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.013	Volcanic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.014	Magmatic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.015	Metamorphic activity	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.016	Shallow dissolution	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.017	Lateral dissolution	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.018	Deep dissolution	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.019	Solution chimneys	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.020	Breccia pipes	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.021	Collapse breccias	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.033	Groundwater geochemistry	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 1.065	Estuaries	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.009	Backfill physical composition	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.010	Backfill chemical composition	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.020	Salt creep	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.021	Changes in the stress field	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.023	Subsidence	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.024	Large-scale rock fracturing	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
W 2.025	Disruption due to gas effects	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.026	Pressurization	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.032	Consolidation of waste	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.033	Movement of containers	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.036	Consolidation of seals	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.040	Brine inflow	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.052	Radiolysis of brine	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 2.075	Chemical degradation of backfill	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 3.032	Waste-induced borehole flow	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 3.034	Borehole-induced solution and subsidence	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
W 3.052	Estuarine water use	Audit step 3b	Considered irrelevant in both SR-Site and SR-PSU
A 1.02	Backfill evolution	Audit step 3c	Irrelevant for the actual waste
A 1.07	Buffer evolution	Audit step 3c	Irrelevant for the actual waste
A 1.20	Container healing	Audit step 3c	Irrelevant for the actual repository design
A 1.31	Excessive hydrostatic pressures	Audit step 3c	Irrelevant for the actual waste
A 1.42	Hydride cracking	Audit step 3c	Irrelevant for actual waste packaging design
A 1.43	Hydrothermal alteration	Audit step 3c	Irrelevant for the actual waste
A 1.75	Source terms (expected)	Audit step 3c	Irrelevant for the actual waste
A 1.76	Source terms (other)	Audit step 3c	Irrelevant for the actual waste
A 1.79	Stability of UO_2	Audit step 3c	Irrelevant for the actual waste
A 2.33	Groundwater - evolution	Audit step 3c	Irrelevant for the actual waste
A 2.71	Vault heating effects	Audit step 3c	Irrelevant for the actual waste
A 3.113	Vault heating effects	Audit step 3c	Irrelevant for the actual waste
E SFL-06	Colloids and particles in the canister	Audit step 3c	Irrelevant for the actual repository design
E SFL-07	Corrosion of the copper shell	Audit step 3c	Irrelevant for actual waste packaging design
E SFL-09	Corrosion of the cast-iron insert	Audit step 3c	Irrelevant for actual waste packaging design
E SFL-10	Canister corrosion prior to wetting	Audit step 3c	Irrelevant for actual waste packaging design
E SFL-11	Creeping of the metal in the canister	Audit step 3c	Irrelevant for the actual repository design
E SFL-13	Degradation of the spent fuel elements	Audit step 3c	Irrelevant for the actual waste
E SFL-14	Different thermal expansion and contraction of the near-field barriers	Audit step 3c	Irrelevant for the actual waste
E SFL-15	Diffusion in and through the canister	Audit step 3c	Irrelevant for actual waste package design

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
E SFL-18	Failure of the copper shell	Audit step 3c	Irrelevant for actual waste packaging design
E SFL-19	Failure of the cast-iron insert	Audit step 3c	Irrelevant for actual waste packaging design
E SFL-21	Spent fuel dissolution and conversion	Audit step 3c	Irrelevant for the actual waste
E SFL-22	Gap and grain boundary release	Audit step 3c	Irrelevant for the actual waste
E SFL-27	Radionuclide accumulation at the spent fuel surface	Audit step 3c	Irrelevant for the actual waste
E SFL-29	Internal gas pressure	Audit step 3c	Irrelevant for actual waste package design
E SFL-30	Mechanical impact on the canister	Audit step 3c	Irrelevant for actual waste package design
E SFL-37	Radiolysis inside the canister prior to wetting	Audit step 3c	Irrelevant for actual waste package design
E SFL-39	Reduced mechanical strength of the canister	Audit step 3c	Irrelevant for actual waste packaging design
E SFL-40	Radionuclide release from the spent fuel matrix	Audit step 3c	Irrelevant for the actual waste
E SFL-47	Thermal degradation of the buffer and backfill	Audit step 3c	Irrelevant for the actual waste
E SFL-48	Total release from the fuel elements	Audit step 3c	Irrelevant for the actual waste
E SFL-49	Radionuclides release and transport from the canister	Audit step 3c	Irrelevant for the actual waste
E SFL-56	Water turnover in the copper shell	Audit step 3c	Irrelevant for actual waste package design
E SFL-57	Water turnover in the cast-iron insert	Audit step 3c	Irrelevant for actual waste package design
H 1.6.1	Thermal effects: Rock-mass changes	Audit step 3c	Irrelevant for the actual waste
H 1.6.2	Thermal effects: Hydrogeological changes	Audit step 3c	Irrelevant for the actual waste
H 1.6.4	Thermal effects: Transport (diffusion) effects	Audit step 3c	Irrelevant for the actual waste
I 072	Modelling (SYVAC/NSURE adequacy)	Audit step 3c	Irrelevant for the current safety evaluation.
J 1.1.03	Recoil of alpha-decay	Audit step 3c	Irrelevant for the actual waste
J 1.2.05	I, Cs-migration to fuel surface	Audit step 3c	Irrelevant for the actual waste
J 1.2.06	Solubility within fuel matrix	Audit step 3c	Irrelevant for the actual waste
J 1.2.09	Dissolution chemistry	Audit step 3c	Irrelevant for the actual waste
J 1.3	Damaged or deviating fuel	Audit step 3c	Irrelevant for the actual waste
J 1.4	Sudden energy release	Audit step 3c	Irrelevant for the actual waste
J 1.5	Release of radionuclides from the failed canister	Audit step 3c	Irrelevant for the actual waste
J 2.1.01	Chemical reactions (copper corrosion)	Audit step 3c	Irrelevant for the actual repository design
J 2.1.03	Internal corrosion due to waste	Audit step 3c	Irrelevant for the actual repository design
J 2.1.04	Role of the eventual channelling within the canister	Audit step 3c	Irrelevant for actual waste package design
J 2.1.05	Role of chlorides in copper corrosion	Audit step 3c	Irrelevant for actual waste packaging design
J 2.1.09	Backfill effects on Cu corrosion	Audit step 3c	Irrelevant for actual waste packaging design

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
J 2.2	Creeping of copper	Audit step 3c	Irrelevant for actual waste packaging design
J 2.3.01	Thermal cracking	Audit step 3c	Irrelevant for actual waste package design
J 2.3.03	Stress corrosion cracking	Audit step 3c	Irrelevant for actual waste packaging design
J 2.3.04	Loss of ductility	Audit step 3c	Irrelevant for actual waste packaging design
J 2.3.05	Radiation effects on canister	Audit step 3c	Irrelevant for actual waste packaging design
J 2.3.06	Cracking along welds	Audit step 3c	Irrelevant for actual waste packaging design
J 2.3.07.2	Hydrostatic pressure on canister	Audit step 3c	Irrelevant for the actual repository design
J 2.3.08	Internal pressure	Audit step 3c	Irrelevant for actual waste package design
J 2.5.01	Random canister defects - quality control	Audit step 3c	Irrelevant for actual waste packaging design
J 2.5.02	Common cause canister defects - quality control	Audit step 3c	Irrelevant for actual waste packaging design
J 4.2.04	Thermal buoyancy	Audit step 3c	Irrelevant for the actual waste
K 1.16	Solute transport resistance	Audit step 3c	Irrelevant for the actual waste
K 1.20	Radionuclide source term	Audit step 3c	Irrelevant for the actual waste
K 2.01	Cast-steel canister	Audit step 3c	Irrelevant for actual waste package design
K 2.02	Canister thickness	Audit step 3c	Irrelevant for actual waste packaging design
K 2.10	Other canister degradation processes	Audit step 3c	Irrelevant for actual waste package design
K 2.12a	Canister failure (alternative modes)	Audit step 3c	Irrelevant for actual waste package design
K 2.12b	Canister failure (reference)	Audit step 3c	Irrelevant for actual waste package design
K 2.20	Radionuclide transport	Audit step 3c	Irrelevant for actual waste package design
K 2.21	Quality control	Audit step 3c	Irrelevant for actual waste package design
K 2.22	Mis-sealed canister	Audit step 3c	Irrelevant for actual waste package design
K 3.07	Canister sinking	Audit step 3c	Irrelevant for the actual repository design
K 3.11	Colloid filtration	Audit step 3c	Irrelevant for actual waste package design
K 3.12a	Mineralogical alteration - short term	Audit step 3c	Irrelevant for the actual waste
K 3.13	Bentonite cementation	Audit step 3c	Irrelevant for the actual waste
K S1.2	Waste Emplacement and Repository	Audit step 3c	Irrelevant for the actual repository design
M 2.1.06	Material defects (e.g. Early canister failure)	Audit step 3c	Irrelevant for actual waste package design
M 3.1.04	Induced hydrological changes	Audit step 3c	Irrelevant for the actual waste
M 3.3.01	Canister or container movement	Audit step 3c	Irrelevant for the actual repository design
S 011	Corrosion of copper canister	Audit step 3c	Irrelevant for actual waste package design
S 016	Creeping of steel/copper	Audit step 3c	Irrelevant for actual waste package design
S 019	Degradation of fuel elements	Audit step 3c	Irrelevant for the actual waste
S 022	Differential thermal expansion of near-field barriers	Audit step 3c	Irrelevant for the actual waste
S 034	Failure of copper canister	Audit step 3c	Irrelevant for actual waste package design

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
S 035	Failure of steel vessel	Audit step 3c	Irrelevant for actual waste package design
S 038	Fuel dissolution and conversion	Audit step 3c	Irrelevant for the actual waste
S 039	Gap and grain boundary release	Audit step 3c	Irrelevant for the actual waste
S 050	I, Cs-migration to fuel surface	Audit step 3c	Irrelevant for the actual waste
S 063	Properties of failed canister	Audit step 3c	Irrelevant for actual waste package design
S 068	Radiation effects on canister	Audit step 3c	Irrelevant for the actual repository design
S 072	Radiolysis prior to wetting	Audit step 3c	Irrelevant for the actual waste
S 075	Reduced mechanical strength	Audit step 3c	Irrelevant for actual waste package design
S 076	Release from fuel matrix	Audit step 3c	Irrelevant for the actual waste
S 090	Temperature, canister	Audit step 3c	Irrelevant for the actual repository design
S 095	Total release from fuel elements	Audit step 3c	Irrelevant for the actual waste
S 105	Water turnover, copper canister	Audit step 3c	Irrelevant for actual waste package design
S 106	Water turnover, steel vessel	Audit step 3c	Irrelevant for actual waste package design
W 2.016	Radiological effects on containers	Audit step 3c	Irrelevant for the actual waste
W 2.028	Nuclear explosions	Audit step 3c	Irrelevant for the actual waste
W 2.029	Thermal effects on material properties	Audit step 3c	Irrelevant for the actual waste
W 2.030	Thermally-induced stress changes	Audit step 3c	Irrelevant for the actual waste
W 2.031	Differing thermal expansion of repository components	Audit step 3c	Irrelevant for the actual waste
W 2.043	Convection	Audit step 3c	Irrelevant for the actual waste
A 1.26	Criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
A 1.33	Faulty buffer emplacement	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
A 1.69	Retrievability	FEP processing	Considered irrelevant in SE-SFL. Retrievability of disposed nuclear waste after repository closure is prohibited by the Swedish Act on Nuclear Activities (1984:3).
A 2.52	Radiation effects	FEP processing	Included in the SE-SFL FEP catalogue
A 3.002	Alkali flats	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the geological setting in Sweden.
E SFL-01	Swelling of the bentonite buffer	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-02	Changes in the spent fuel radionuclide inventory	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of spent nuclear fuel.
E SFL-03	Chemical alteration of the buffer and backfill	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
E SFL-04	Coagulation of bentonite	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
E SFL-05	Colloid behaviour in the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-08	Corrosion of the metal non-fuel waste parts	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of spent nuclear fuel.

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
E SFL-12	Criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
E SFL-16	Dilution of the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-17	Erosion of the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-20	Groundwater flow through the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-23	Gas escape from the canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
E SFL-24	Gas flow through the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-25	Gas generation in the canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
E SFL-26	Gas generation in the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-28	Radionuclide interaction with corrosion products	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
E SFL-31	Mechanical impact on the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-33	Movement of the canister in the buffer	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters surrounded by buffer material.
E SFL-34	Preferential transport pathways in the canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
E SFL-35	Radiation effects on the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-36	Radiation effects on the canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
E SFL-41	Radionuclide release from the metal non-fuel parts	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of spent nuclear fuel.
E SFL-42	Hydraulic resaturation of the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-43	Sedimentation of the buffer and backfill	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
E SFL-44	Soret effect in the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-45	Swelling of the tunnel backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-46	Temperature of the near-field	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-50	Radionuclides release and transport from the buffer and backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-51	Expansion of solid corrosion products	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
E SFL-52	Evolving water chemistry in the canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
E SFL-53	Evolving water chemistry in the buffer	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-54	Evolving water chemistry in the backfill	FEP processing	Included in the SE-SFL FEP catalogue
E SFL-55	Evolving water chemistry in the near-field rock	FEP processing	Included in the SE-SFL FEP catalogue
H 1.3.2	Nuclear criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
I 002	Alkali flats	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the geological setting in Sweden.
I 081	Criticality event	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
J 1.1.01	Criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
J 1.1.04	Gas generation: He production	Audit step 3d	Considered irrelevant in SE-SFL. Irrelevant for the actual waste.
J 2.1.08	Corrosive agents, Sulphides, oxygen etc	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
J 3.1.13	Radiation effects on bentonite	FEP processing	Included in the SE-SFL FEP catalogue
J 3.2.02	Movement of canister in buffer/backfill	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters surrounded by buffer material.
J 3.2.10	Soret effect	FEP processing	Included in the SE-SFL FEP catalogue
J 4.2.10	Chemical effects of rock reinforcement	FEP processing	Included in the SE-SFL FEP catalogue
J 5.03	Stray materials left	Audit step 3d	Considered irrelevant in SE-SFL. Stray materials are of no concern in this repository, because of the complex and broad composition of the waste.
K 0.4	Nuclear criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
K 1.15	Elemental solubility limits	FEP processing	Considered irrelevant in SE-SFL. The current repository design does not include glass.
K 1.24	He-gas production	Audit step 3d	Considered irrelevant in SE-SFL. Irrelevant for the actual waste.
K 2.13	Residual canister (crack/hole effects)	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
K 3.02	Thermal evolution	FEP processing	Included in the SE-SFL FEP catalogue
K 3.18	Elemental solubility/precipitation	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
K 4.17	Shaft and tunnel seals	FEP processing	Included in the SE-SFL FEP catalogue

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
M 1.5.09	Natural thermal effects	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that the repository will not be located in a thermally active area.
M 2.2.03	Co-disposal of reactive wastes (deliberate)	Audit step 3d	Considered irrelevant in SE-SFL. Irrelevant for the actual waste.
M 2.3.01	Recovery of repository materials	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
M 2.3.06	Resource mining	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that future human activities will not lead to disturbed performance conditions.
M 2.3.11	Ground water abstraction	FEP processing	Included in the SE-SFL FEP catalogue
M 3.3.03	Embrittlement and cracking	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of high level waste.
M 3.4.03	Nuclear criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
S 012	Corrosion of metal parts	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of spent nuclear fuel.
S 013	Corrosion of steel vessel	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters (in which these steel vessels are placed).
S 014	Corrosion prior to wetting	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of spent nuclear fuel.
S 017	Criticality	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
S 040	Gas escape from canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
S 045	Gas generation, canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
S 053	Internal pressure	FEP processing	Included in the SE-SFL FEP catalogue
S 058	Movement of canister in buffer/backfill	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters surrounded by buffer material.
S 067	Radiation effects on buffer/backfill	FEP processing	Included in the SE-SFL FEP catalogue
S 077	Release from metal parts	Audit step 3d	Considered irrelevant in SE-SFL. The SFL repository is not planned to include storage of spent nuclear fuel.
S 080	Resaturation of tunnel backfill	FEP processing	Included in the SE-SFL FEP catalogue
S 083	Soret effect	FEP processing	Included in the SE-SFL FEP catalogue
S 088	Swelling of tunnel backfill	FEP processing	Included in the SE-SFL FEP catalogue
S 089	Temperature, bentonite buffer	FEP processing	Included in the SE-SFL FEP catalogue

PFEP ID	PFEP name	Screened in	Motivation for screening in SE-SFL
S 102	Water chemistry, canister	Audit step 3d	Considered irrelevant in SE-SFL. The current repository design does not include copper canisters.
W 2.014	Nuclear criticality: heat	New FEP	New FEP added to the SE-SFL FEP catalogue (WM23 - Criticality/Waste form)
W 2.017	Radiological effects on seals	FEP processing	Included in the SE-SFL FEP catalogue
W 2.054	Helium gas production	Audit step 3d	Considered irrelevant in SE-SFL. Irrelevant for the actual waste.
W 2.067	Localized reducing zones	FEP processing	Considered irrelevant in SE-SFL. Not relevant for the current repository design.
W 2.093	Soret effect	FEP processing	Included in the SE-SFL FEP catalogue
W 3.004	Oil and gas exploitation	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that future human activities will not lead to disturbed performance conditions.
W 3.009	Enhanced oil and gas recovery	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that sites with a potential for oil or gas production are excluded from the site selection for SFL.
W 3.013	Potash mining	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that future human activities will not lead to disturbed performance conditions.
W 3.025	Oil and gas extraction	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that future human activities will not lead to disturbed performance conditions.
W 3.028	Enhanced oil and gas production	Audit step 3d	Considered irrelevant in SE-SFL. The selection of site will ensure that sites with a potential for oil or gas production are excluded from the site selection for SFL.

SKB is responsible for managing spent nuclear fuel and radioactive waste produced by the Swedish nuclear power plants such that man and the environment are protected in the near and distant future.

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