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Research

System Studies in PA: Development of Process Influence Diagram (PID) for SFR-1 Repository Near-Field + Far-Field

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May 2001

ISSN 1104-1374
ISRN SKI-R-01/30-SE

SKI perspective

Background

As part of the licence for SFR-1 a renewed safety assessment should be carried out at least each ten years for the continued operation of the SFR-1 repository. SKB is currently engaged in the SAFE project to evaluate the performance of the repository system. SKI is currently preparing for its review of this renew safety assessment.

Purpose of the project

SKI work has so far been focused on the construction of a new Process Influence Diagram (PID) for the SFR repository, including the far-field. Another task is the testing of the software program SPARTA (developed by QuantiSci for SKI) on real PIDs. The program will serve as a tool for development and updating of PIDs and for scenario analysis. Assigning influence levels to the SFR PID is also a part of this task.

Results and continued work

The PID that now has been set up for the SFR repository is based on a list of FEPs (Features, Events and Processes) describing the future evolution of the repository system. This FEP-list together with the PID, that has been prepared using the software program SPARTA and the SPARTA program itself, make a powerful tool for scrutinise the development of the SFR-1 system.

The PID for SFR is not final product but must be updated whenever new knowledge and understanding of the repository system is gained.

Effect on SKI's work

This project forms an essential part of the SKI's review of SKB's project SAFE for SFR-1.

Project information

Responsible at SKI has been Benny Sundström.

SKI ref. 14.9-991358/99209 (and SKI ref. 14.9-980661/98144).

Relevant SKI report is: SKI Report 95:26, SITE-94, Systems Analysis, Scenario Construction and Consequence Analysis Definition for SITE-94, Neil A.Chapman, Johan Andersson, Peter Robinson, Kristina Skagius, Clas-Otto Wene, Marie Wiborgh, Stig Wingefors, June 1995.

Final report within the project: System studies in PA: Development of process influence diagram (PID) for SFR-1 repository. Near-field + far-field, MSCI-9916, M. Stenhouse, W. Miller, N. Chapman August 2000.

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May 2001

SKI Project Number 99209

Summary

Scenario development is a key component of the performance assessment (PA) process for radioactive waste disposal, the primary objective being to ensure that all relevant factors associated with the future evolution of the repository system are properly considered in PA. As part of scenario development, a list of features, events and processes (FEPs) are identified and assembled, representing the Process System, with interactions/influences between FEPs incorporated in a Process Influence Diagram (PID).

This report documents the technical work conducted between 1997 and the end of 1999 under the Systems Studies Project. The overall objective of this project has been the construction of a PID for the SFR-1 repository (final repository for reactor waste), this PID being the first stage in the identification of scenarios to describe future evolution of this repository.

The PIDs discussed in this report have been created using two software applications: existing commercial software (Business Modeller, Infotool AB. Stockholm, Sweden) and, more recently, a newly developed software tool SPARTA (Enviros QuantiSci, Henley, U.K.). Although the focus of this report is on the application of SPARTA to PID development, it is important to document the work carried out prior to SPARTA being available, in order to provide a complete record of the entire SFR-1 PID development effort as well as preserving the context of the multi-year project.

Following a description of the different disposal sections of the SFR-1 and the various near-field barriers, the sequential development (i.e. near-field of Silo, BMA, BLA, BTF sections; far-field; integrated near-field + far-field) of the PID for SFR-1 repository system using Business Modeller is described. Owing to the complexity of the repository, in terms of number of both different disposal sections (Silo, BLA, BMA, BTF) and barriers associated with each section, the two-dimensional (2D) PID created for SFR-1 using Business Modeller is visually complex and potentially difficult to interpret. Primarily for this reason, the need for an alternative approach was recognised in 1996 and the decision was taken to develop new software for this purpose. Following a consensus on the specific requirements of the new software, a first version of SPARTA became available towards the end of 1998, with subsequent versions being released during 1999.

SPARTA is used to generate a three-dimensional (3D) PID consisting of a series of layers, each underlying layer providing additional (more detailed) information about the Process System. The uppermost layer or diagram may be regarded as a top-level view of the repository system (near-field, far-field and biosphere). In the PID developed for SKI, underlying layers or diagrams often have some physical meaning, *e.g.* sections of the repository (Silo, BLA, BMA, BTF sections, repository zone), or barriers of a section (e.g. for the Silo - backfill, reinforced shell, porous grout or mortar, waste package). Other layers contain groups of related FEPs, *e.g.* geochemical FEPs. A total of 95 drawings, typically consisting of 6-8 FEPs each, describe the SFR-1 repository system.

The two PIDs developed for the SFR-1 repository provide different representations of the near-field and far-field of the repository system; the first PID being two-dimensional

and the later one three-dimensional. Despite the different approaches, the primary objective of constructing each PID has been the same: firstly, to ensure that all FEPs relevant to the future evolution of the repository system are considered, and secondly, that all "essential" Influences are identified so that they may be incorporated in the subsequent modelling of the system's evolution.

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1 Introduction to Project

1.1 Process System and Process Influence Diagram

Scenario development is a key component of the performance assessment (PA) process for radioactive waste disposal (NEA, 1992), the primary objective being to ensure that all relevant factors associated with the future evolution of the repository system are properly considered in PA. As part of scenario development, a list of features, events and processes (FEPs) are identified and assembled in a Process System, with interactions/influences between FEPs incorporated in a Process Influence Diagram (PID) (Chapman et al., 1995). This organised assembly is required to describe the performance of the disposal system (near-field, far-field and biosphere), including radionuclide release and migration, so that its behaviour can be predicted from a given set of external conditions. A scenario is then defined by a specific set of external conditions which influences the FEPs in the Process System. For each scenario, FEPs and their interactions/influences can be used to identify what modelling or calculations are necessary to determine the consequences of that scenario.

This report documents the technical work conducted between 1997 and the end of 1999 under the Systems Studies Project. The overall objective of this project has been the construction of a PID for the SFR-1 repository (final repository for reactor waste), this PID being the first stage in the identification of scenarios. In order to facilitate construction of the PID, as well as enabling editing and manipulation of the various elements of these diagrams, a software tool, SPARTA, was developed independently. This development, concurrent with the Systems Studies Project, is reported elsewhere (Jack and Hiller, 1999). However, since it was appreciated that the software tool would only become available during 1999, it had been important to proceed with PID development prior to 1999, using existing software, in order to maintain the capability for scenario development work associated with the PA of SFR-1.

Ultimately, therefore, the PIDs discussed in this report have been created using two software applications: the existing commercial software and the newly developed code SPARTA. Although the focus of this report is on the application of SPARTA to PID development, it is important to document the work carried out prior to SPARTA being available, in order to provide a complete record of the entire SFR-1 PID development effort as well as preserving the context of the multi-year project. As discussed in this report, the fact that the resultant PIDs have been constructed in entirely different ways has offered the opportunity to compare the products of the different approaches.

1.2 Phases of Project

As stated above, this project has been underway since 1997 and has been conducted in various stages, as discussed below and reported in several internal SKI reports. In order to document overall progress and achievements, these different stages are covered in this report.

The initial (1997) project work under this project focussed on the development of a near-field PID for the Silo section of the SFR-1 repository (Stenhouse and Chapman, 1998), via:

- identification, screening and categorisation of near-field FEPs; and
- construction of a general PID for the Silo section of the SFR-1 repository only, using existing software, available commercially (Business Modeller; Infotool Data AB, Stockholm, Sweden).

Subsequently, as reported in Stenhouse *et al.* (1998), the bulk of the 1998 input to the Systems Studies Project involved:

- extension of the existing PID for the Silo to accommodate all sections of the repository (the near-field of SFR-1 comprises five independent sections in total: one Silo, two BTF vaults, one BLA vault and one BMA vault, as discussed in *Sections 2.1* and *2.2*;
- similar treatment of the far-field, *i.e.*;
  - identification, screening and categorisation of FEPs applicable to the far-field of the SFR-1 repository;
  - construction of the far-field section of the PID;
- combination of near-field and far-field to produce the reference case PID for the SFR-1 repository.

The bulk of the 1999 work made use of SPARTA to construct a different type of PID, but for the same repository system. As newer versions of the code were released, the opportunity became available to make use of additional features in the software, incorporated to improve flexibility and speed of PID construction. Thus, to a large extent, the creation of this independent PID fulfilled the important requirement of providing in-depth testing and demonstration of the software capabilities.

1.3 Layout of Report

Discussion of the stages in the project described above are laid out in this report essentially in sequence. *Section 2* of this report is devoted to a short summary of the key features of the disposal concepts for the SFR-1 repository system. *Section 3* deals with the compilation and review of FEPs appropriate to the near- and far-fields. *Section 4* provides a brief summary of the construction of the Reference Case PID comprising near-field and far-field of the SFR-1 repository using the existing software, Business Modeller. *Section 5* covers the more recent PID construction using SKI's code SPARTA, developed specifically for this purpose.

Finally, *Section 6* discusses the achievements of the 3-year project as well as identifying ways in which the most recent version of the PID can be made more powerful.

2 Waste Disposal Concepts for SFR-1 Repository

As a basis for developing the PID, a brief description of the SFR-1 repository and its components is provided here.

The waste intended for SFR-1 arises mainly from the operation and maintenance of nuclear power plants and comprises low- and intermediate-level waste with a small inventory of long-lived radionuclides (Andersson *et al*., 1994). This waste , generated through the operation of nuclear reactors, consists of filters, ion-exchange resins, and general scrap for which recycling is not an option. The repository is also expected to take similar types of waste arising from the use of radioisotopes in medicine, industry and research.

There are 4 separate types of disposal section within the SFR-1 repository, *viz.*

- the Silo, containing metallic, organic and inorganic wastes immobilised in concrete and bitumen;
- *BMA* rock vault/tunnel section, also containing wastes immobilised in bitumen or cement;
- *BLA* rock vault/tunnel section, containing wastes in steel containers or containing wastes immobilised in bitumen or cement;
- two *BTF* rock vaults, for concrete tanks containing ion exchange resin wastes as well as the ashes from waste incineration.

About 70% of the radioactivity of the repository is housed in the Silo (Bo Strömberg, personal communication).

2.1 Silo Near-Field: Engineered Barriers

The near-field barriers of the Silo of SFR-1, discussed in detail in Stenhouse and Chapman (1998) and shown in *Figure 1*, comprise:

- *the waste package*: the waste itself immobilised in concrete or bitumen, within steel drums, and with a concrete overpack;
- an intimate mix of *porous concrete* or grout (mortar) surrounding the waste packages within the Silo structure (shell);
- the *shell* constructed using reinforced concrete;
- a *backfill layer*, between Silo and rock, consisting of:
  - bentonite/sand (base),

  - sand plus bentonite-sand (top),
  - bentonite only (around the Silo shell);
- *near-field rock* surrounding the Silo, with an additional layer of crushed rock above the bentonite-sand on top of the Silo.

2.2 Near-Field Barriers of Other Sections of Repository

The equivalent near-field barriers for the disposal concepts for the BTF, BMA and BLA sections of the SFR-1 repository are shown in *Figures 2A*, *3A* and *4A*. In fact, the individual engineered barriers for each of these sections of the repository system are quite similar to those of the Silo, although there are distinct differences, the main one being that the tunnel/vault sections of SFR-1 do not contain bentonite or bentonite-sand as an engineered barrier. *Figures 2B*, *3B* and *4B*, identify the corresponding conceptual barriers to be incorporated in the respective near-fields of each section of the repository.

Table 1 summarises the near-field barriers for each area and is useful for comparison purposes when extending the Silo near-field to include the other near-field areas of the SFR-1 repository. For example, using Business Modeller, these other areas may be generated by duplicating the Silo near-field PID, followed by removal of those section(s) or specific FEPs which do not apply to the BTF, BMA or BLA sections. Thus, for example, FEPs relating to bentonite and the "mortar" component of the PID may be removed from the corresponding BTF, BMA and BLA sections. Similar to the Silo, *Table 1* indicates that some of the backfill barriers have a composite nature.

Table 1 *Near-field barriers included in near-field PID.*

Barrier	**Composition**			
	Silo	**BTF**	**BMA**	**BLA**
Waste + container	yes	yes	yes	yes
Porous concrete	Mortar, including reinforced honeycomb	no	no	no
Shell	Reinforced concrete	concrete or permeable concrete	concrete	concrete base only
Backfill	Bentonite or sand-bentonite or sand	crushed rock?	sand or crushed rock?	crushed rock?
Near-field rock	Yes (including crushed rock)	yes	yes	yes

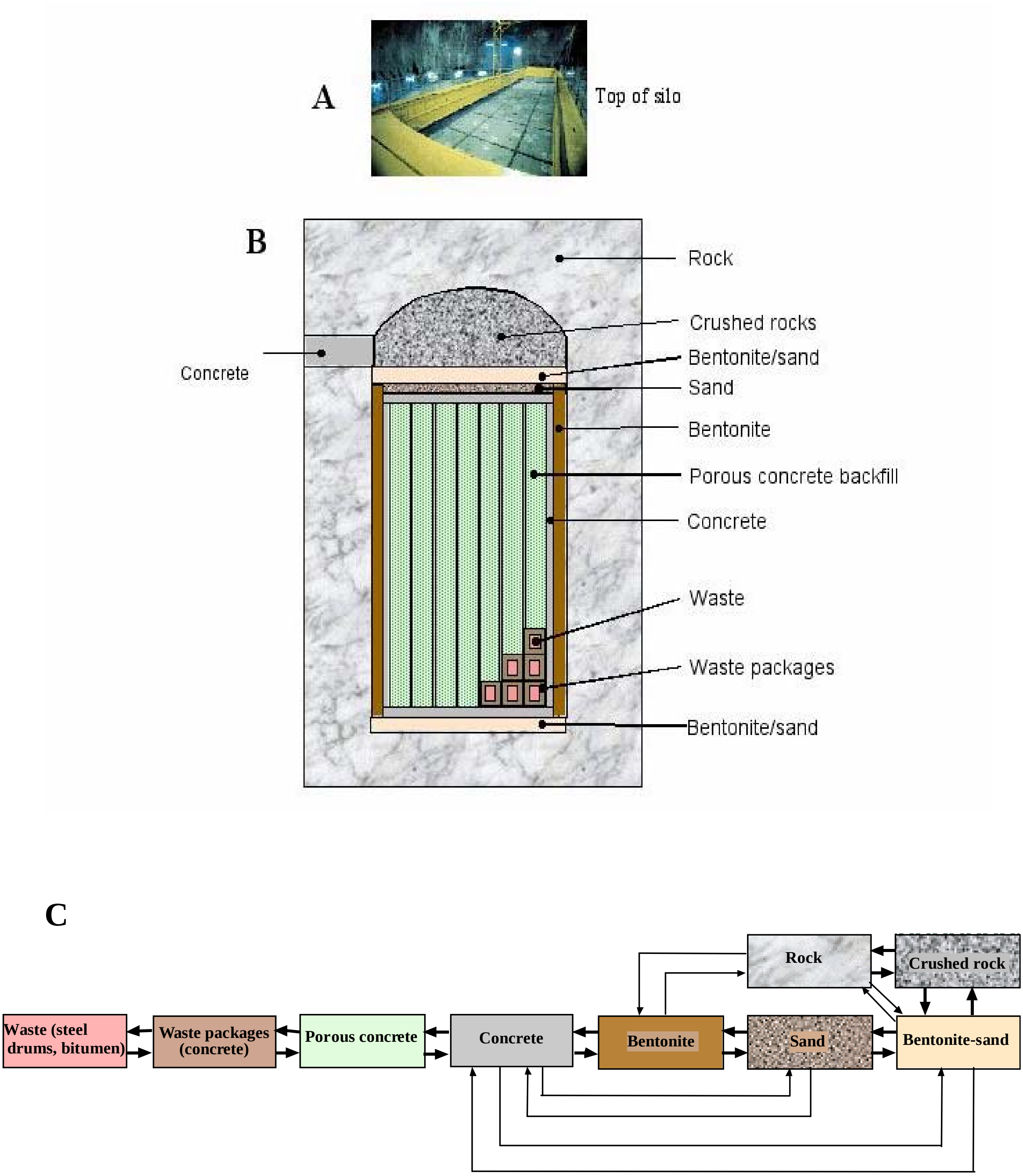

Figure 1 *The Silo concept for radioactive waste disposal (based on an original drawing provided by B. Sundström, Swedish Nuclear Inspectorate.* ***A****: photograph, Swedish Nuclear Fuel and Waste Management Co.;* ***B****: disposal system;* ***C****: modular approach of Process System.*

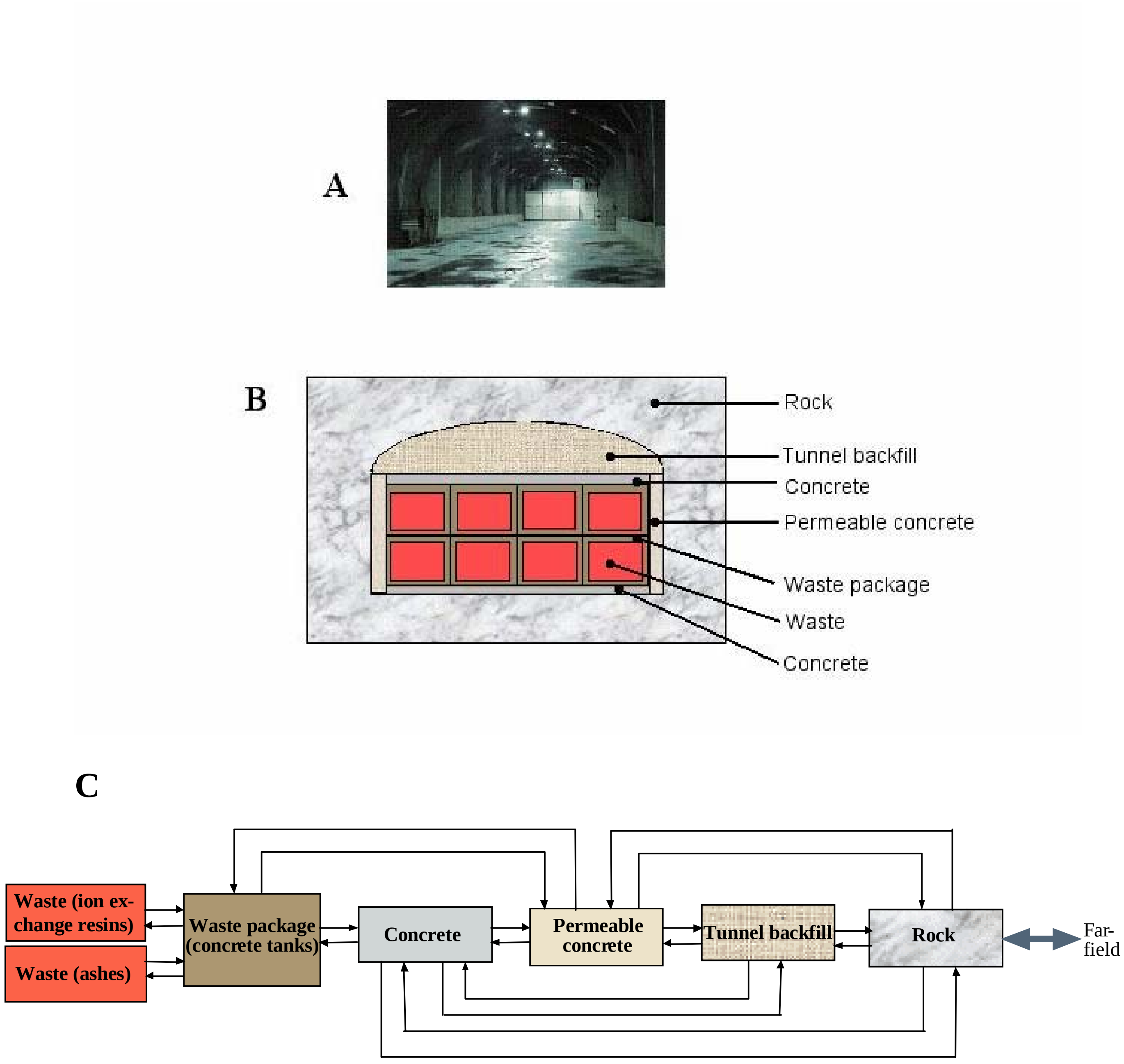

Figure 2 *The BTF concept for radioactive waste disposal (based on an original drawing provided by B. Sundström, Swedish Nuclear Inspectorate. A: photograph, Swedish Nuclear Fuel and Waste Management Co.; B: disposal system; C: modular approach of Process System.*

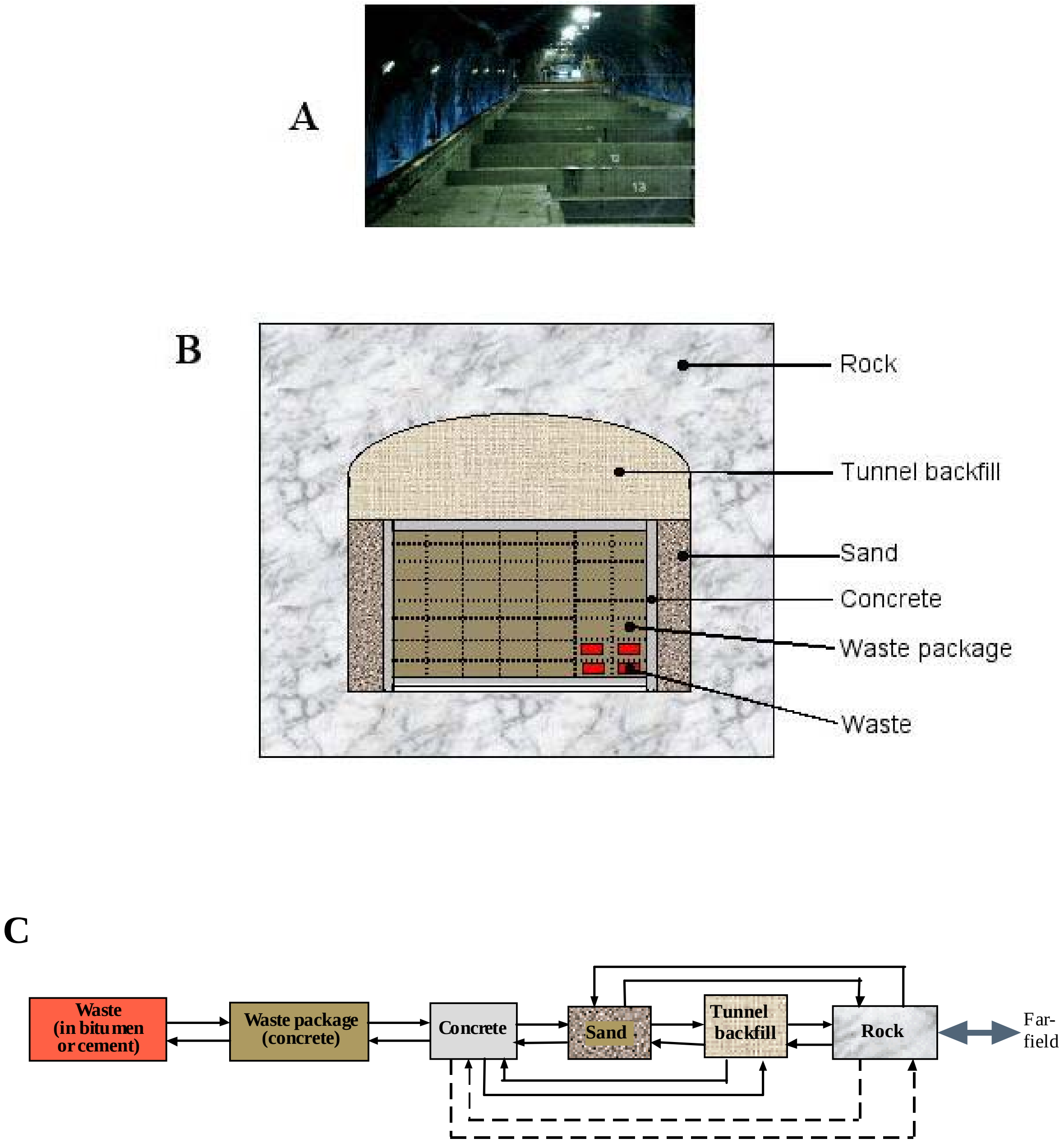

Figure 3 *The BMA concept for radioactive waste disposal (based on an original drawing provided by B. Sundström, Swedish Nuclear Inspectorate. A: photograph, Swedish Nuclear Fuel and Waste Management Co.; B: disposal system; C: modular approach of Process System.*

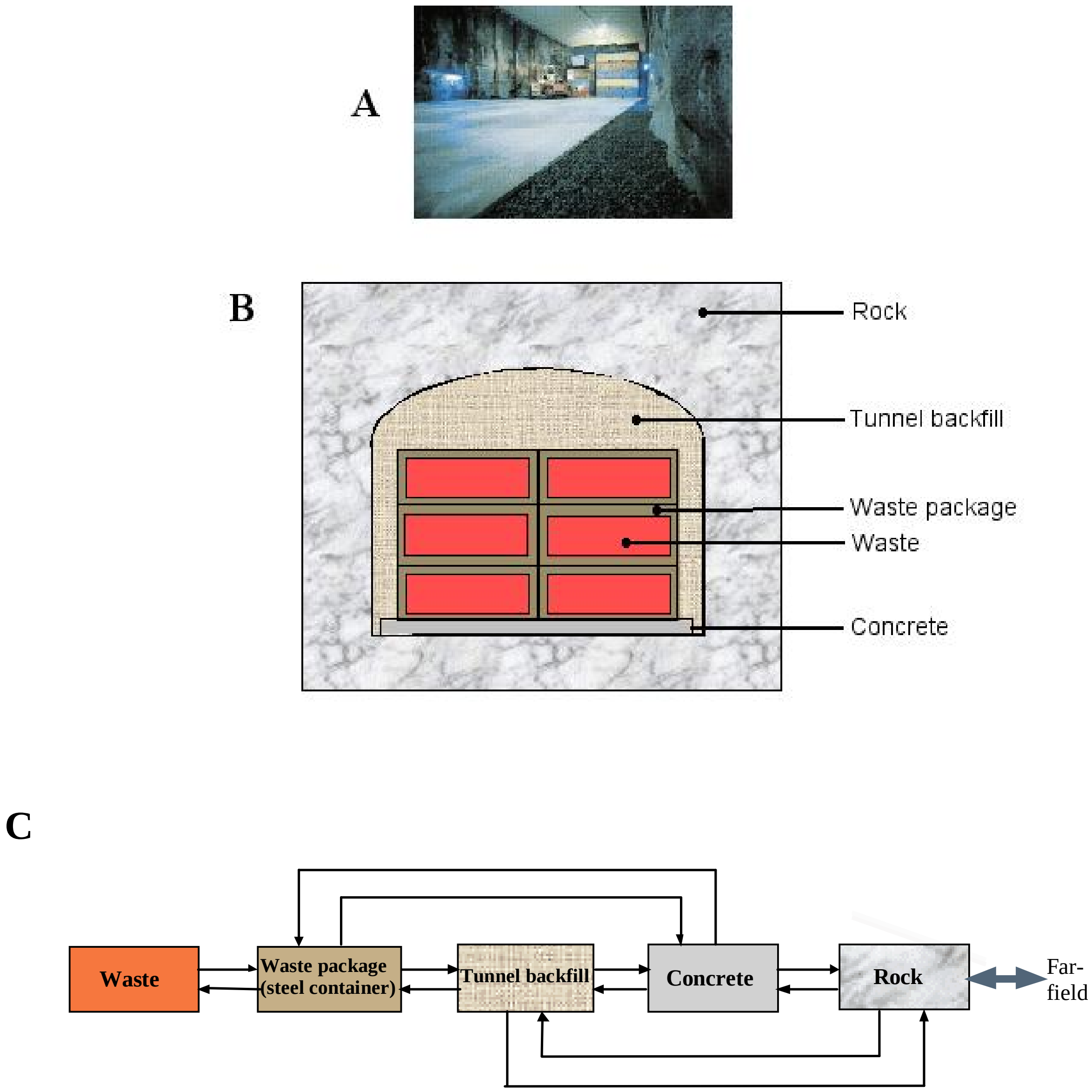

Figure 4 *The BLA concept for radioactive waste disposal (based on an original drawing provided by B. Sundström, Swedish Nuclear Inspectorate. A: photograph, Swedish Nuclear Fuel and Waste Management Co.; B: disposal system; C: modular approach of Process System.*

3 Preparation of Near-Field FEP list for SFR-1

3.1 Identification of Near-Field FEPs

Preparation of the initial near-field FEP list focussed on the Silo component of SFR-1, which, as well as containing about 70% total activity of the repository, can be considered as having the greatest number of barriers or near-field components. However, the compilation and review of FEPs was carried out in such a way that all barriers of the near-field systems for the suite of disposal concepts within SFR-1 and SFL 3-5 could be accommodated.

An initial objective was to ensure that all FEPs relevant to the radioactive waste disposal concept were identified and incorporated in the PID. Thus, an appropriate starting point was the international set of FEPs compiled from individual radioactive waste disposal management programmes. This 'raw' FEP List contains approximately 1580 entries of which the major portion (~ 1265 entries) was used as the basis for auditing the SKI FEP list as part of SITE-94 (Stenhouse *et al*. 1993). The FEP lists added to the original compilation are those for Kristallin I (Nagra, 1994) and the SFL 3-5 series developed by Eng *et al.* (1995). The latter, however, was used only for comparison purposes and is not included in *Appendix A* (see below).

As discussed in Andersson (1989), "the safety analysis of a radioactive waste repository involves the consideration of all possible relevant Features, Events and Processes, FEPs, that could, directly or indirectly, influence the release and transport of radionuclides from the repository". Furthermore, each FEP should be examined in terms of its cause, likelihood of occurrence, consequences and interaction with other FEPs (Andersson, 1989). Such an approach was also considered an appropriate basis for preparing the FEP list for PID development in this project.

Some obvious differences are expected in the series of FEPs associated with the disposal of long-lived L/ILW, compared with those for HLW disposal as described in SITE-94 (Chapman *et al*., 1995), especially since cement/concrete plays a significant role in a repository for long-lived L/ILW. Nevertheless, it became apparent that many of the FEPs for HLW and long-lived L/ILW, as discussed below, were quite similar.

3.1.1 Methodology for Preparing PID FEP List

The methodology adopted for producing a working FEP list for the PID relevant to low- and intermediate-level reactor waste disposal in the SFR-1 involved five stages, *viz.*

1. Using the compilation of national/international FEP lists as a starting point.

2. Identifying from this list those FEPs which are relevant to the near-field.

3. Identifying and eliminating duplicates *etc.* and screening out irrelevant FEPs (*e.g.* those exclusive to HLW).

4. Assigning FEPs from the reduced set to recognisable near-field categories.

5. Rationalising FEPs of different categories to obtain a working set of PID FEP titles.

Appendix A contains, in spreadsheet form, the compilation of 'near-field' FEPs (512) obtained at the end of Stage 2 above. Additionally in this Appendix, the letters shown in the second column of the spreadsheet tables were used to allow (most of) the irrelevant FEPs to be screened out in Stage 3. The justifications for exclusion and the corresponding letter codes are shown in *Table 2*.

Table 2 *Explanation of Screening Codes.*

Code	Meaning
H	FEP is only relevant to HLW disposal
NR	not relevant to current disposal concept
? or V	FEP is too vague to be useful
sub	a ‘sub-FEP' of a 'parent FEP'; the latter being specific enough to be included by itself
E	'external FEP' or EFEP, or at least external to the near-field and far-field system
R	repeat FEP, the link to the original entry being provided in the last column
G	FEP is too general; more specific sub-FEPs are included

Additional letters added as descriptors, but not used for screening purposes, were *T* to denote *time dependency*, and *P* to denote *properties* or a *parameter*.

3.1.2 Categorisation of Near-field FEPs

The resulting reduced series of FEPs from Stage 3 was still rather large and unwieldy. Consequently, to manage this list better, the FEPs were sorted according to the individual components of the near-field barrier system, *viz.*

- *WC* comprising
  - W = WASTE: the waste form, which is inside an outer container or drum. The waste form comprises both the waste itself and its encapsulation/ immobilisation matrix, if any, and
  - C = CANISTER: the steel container/drum in which the waste form is emplaced;

- *M* = MORTAR: the porous grout or concrete used to backfill compartments of the silo.
- *S* = SHELL: the reinforced concrete structure of the silo itself.
- *B* = BUFFER: the buffer (*e.g.* bentonite, bentonite-sand, or sand) around the silo or the backfill used to fill disposal vaults or tunnels.
- *N* = NEAR-FIELD ROCK: taken as the repository zone in which waste form, container, and buffer/backfill are emplaced; refers generically to the host rock from which the disposal caverns are constructed.[1]

The sorted FEPs are shown in *Appendix B* with additional information to identify the relevance of each FEP to the sections of the SFR-1 repository.

3.1.3 Rationalisation of Near-field FEPs

The final stage in the process was to 'rationalise' the sorted and reduced set of FEPs. Given that the FEP lists compiled in Stage 1 represent a range of waste disposal concepts, the categories identified should be considered as generic in the first instance.

Thus, the FEPs sorted by category in *Appendix B* represent a heterogeneous mixture of FEPs which, having been abstracted from lists of individual countries, do not necessarily provide consistency in either the level of detail or interpretation. For example, some of the FEPs in the lists describe possible interactions between processes rather than the processes themselves.

Review of the reduced and categorised FEPs was able to generate a smaller set of FEPs for incorporation in the PID. It should be emphasised that FEP boxes within a PID are normally simplified to a certain extent, thereby keeping the number of boxes to a manageable level to allow ease of visual inspection. Hence, each FEP box may represent a combination of several FEPs which were individually identified in the original FEP list. It is important, however, that each FEP in *Appendix B* is incorporated in the PID and this requirement is the major reason for conducting the rationalisation.

Specifically, the rationalisation process involved:

- treating some FEPs as influences. Several FEPs in *Appendix B* are relevant to the PID but more as influences (*i.e.* interactions between FEP boxes) rather than as individual features, events or processes. For example, thermal effects, would involve a link to temperature. It should be noted, however, that the distinction between what constitutes a FEP and what is an interaction is, to some extent, arbitrary and is not necessarily consistent.
- renaming some FEPs to more representative titles so that they can be used in different parts of the process system, in keeping with a modular approach.

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[1] The letter codes, *W*, *C*, *M*, *S*, *B* and *N* appear in the PID showing the individual FEPs and their interactions/influences.

- grouping FEPs under one title, *e.g. Water chemistry* (speciation, pH, *etc.*).

The end product, shown in *Appendix C*, is the list of FEPs to be incorporated in the PID.[2] Although FEPs for long-lived L/ILW waste disposal are not directly applicable to the SITE-94 FEP list (specific to spent fuel disposal), comparisons are possible on the basis of 'equivalent' FEPs; for example, when FEPs relate to a barrier of the engineered barrier system but are not necessarily specific to the material used. Thus, subsequent comparison of the FEPs in *Appendix C* with those of SITE-94 indicated that many of the FEPs were essentially the same or certainly comparable in both lists.

3.2 Preparation of Far-Field FEP List

A process similar to that discussed above was carried out to generate the list of far-field FEPs. *Appendix D* contains, in spreadsheet form, the list of 'far-field' FEPs (547) abstracted from the original compilation. Additionally in this Appendix, the letters shown in the second column of the spreadsheet tables were used to allow duplicates and most of the irrelevant FEPs to be screened out (Stage 3). The basic reasons for exclusion and the corresponding letter codes are similar to those used for the near-field FEPs (see *Table 2*) and the resultant list of screened FEPs is shown in the second column of *Appendix E*.

Again, a rationalisation process similar to that discussed in *Section 3.1.3* was carried out on the screened far-field FEPs, *i.e.*

- re-naming some FEPs to more representative titles to conform with those FEPs in the near-field rock component of the process system, in keeping with a modular approach (the original name and new FEP title are shown in *Appendix D*).
- grouping FEPs under one title, *e.g. Properties of rock* (fracture, hydrogeological and physical properties).

In addition, in order to maintain a degree of uniformity in the PID between the near-field (particularly the near-field rock barrier) and the far-field, some FEPs from the near-field rock category were added to the far-field FEP list, resulting in the more detailed working list of far-field FEPs shown in the fourth (right-hand) column of *Appendix E* and also, for completeness, in *Appendix F*[3].

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[2] Some deletions (of FEPs), as a result of Workshop discussions (Stenhouse et al., 2000), are recorded in *Appendix C*.

[3] Similar to the near-field FEPs, some FEP titles were either renamed or deleted following one of the SKI PID Workshops (Stenhouse et al., 2000); these are shown in *Appendix F*.

4 Development of PID for SFR-1 Repository Using Business Modeller

As discussed in *Section 1.2*, the complete PID for both near-field and far-field of the SFR-1 repository was developed in stages. Although the focus of this report is the application of SPARTA to PID development, the earlier work involving the existing software is summarised below in order to establish the sequence and context of PIDs generated within the Systems Studies Project. The order in which the PIDs are discussed in this section reflects the different stages of development.

4.1 Construction of Near-Field PIDs

4.1.1 Development of Near-field PID for Silo

As stated in *Section 1*, a Process System is the organised assembly of all the FEPs required to describe the near-field disposal system performance, including radionuclide release/migration from the near-field, so that radionuclide release can be predicted with at least some degree of determinism from a given set of external conditions imposed on the Process System.

The Process System for the SFR-1 repository is represented by boxes which describe the features, events or processes (FEP boxes for, *e.g.* radioactive decay, degradation of barrier components, such as reinforced steel or waste matrix, *etc.*) which make up the waste disposal system, linked together by interactions between FEPs, or Influences. The end product is a Process Influence Diagram (PID).

The first step in constructing a PID is to identify the system to be defined. Briefly, as discussed in *Section 2*, the waste disposal concept for the SFR-1 Silo is shown in *Figure 1A*, and comprises:

- radioactive wastes; various wasteforms (cement and bitumen matrices) in steel canisters with concrete overpacks; backfilled with cementitious grout; all within a reinforced concrete silo; sand and bentonite-sand backfill; the disposal volume located in relatively deep, crystalline host rock.

The component barrier regions corresponding to the disposal system of the Silo, i.e. *Figure 1A*, are shown schematically in *Figure 1B*. Once the FEPs relevant to each barrier are specified, integrated and organised into regions of the PID, interactions between FEPs are identified and represented in the diagram by lines connecting the interacting FEPs, with an arrow showing the direction of the interaction/Influence.

The software package Business Modeller developed by the Swedish Institute for Systems Development and released commercially by Infotool Data AB (Stockholm, Sweden), was used to draw the Influence Diagram. Generally, the main properties/features of each barrier, along with processes which act upon these properties and the transport pathways in the barrier, feed towards the bottom right-hand corner where the FEP box "*Transport and release of nuclides"* for each region, or barrier, is situated. These *"Transport and release..."* FEPs are key links within the PID.

Extracts of the PID developed for the Silo of the disposal system are shown in *Annexe I* Approximately one page represents a single barrier of the multi-barrier disposal system. One main difference between this PID and one for vitrified HLW or spent fuel, is the need to accommodate different types of waste (L/ILW); in particular, separate FEP boxes for metal and organic wastes. This approach allows the relative importance of certain processes, for example, gas generation, to be reflected accurately in the level of significance, *i.e.* Importance Level, attached to corresponding Influences.

It can be seen from the different pages of *Annexe I*, that the FEPs and Influences for each near-field barrier are structured in a similar way, since many of the FEP titles were designed to be appropriate to more than one component of the disposal system as depicted in *Figure 1B.* The main links between the different barriers typically involve FEP boxes for *Mechanical stress*, *Temperature*, *Water movement*, *Water chemistry* and, of course, *Transport and release of radionuclides*.

Each Influence on the diagram has been assigned a unique code identifier, using a letter to identify each near-field barrier:

W	waste;
C	matrix + container;
M	mortar and the Silo honeycomb of internal cells (porous grout);
S	reinforced concrete shell (Silo only);
B	backfill: bentonite or sand-bentonite;
N	near-field rock/disturbed rock zone.

Some Influence identifiers include the letter "T" (*e.g.* WT2 or ST2) to denote those Influences which are related to transport and release of radionuclides. These Influences are depicted in the PIDs via heavier, patterned lines. The numbers in parentheses following the Influence identifier, *e.g.* M33 (0), refer to Importance Levels (ILs) which were tentatively assigned initially, and subsequently audited/revised following a Workshop organised specifically for this purpose (Stenhouse *et al.*, 2000). A full list of near-field Influences for the Business Modeller PID, together with Influence number, is provided in *Appendix G*.

4.1.2 Near-Field PIDs for BTF, BMA and BLA Sections

Separate near-field PIDs were created for the BTF, BMA and BLA sections of the SFR-1 repository. Although not included in this report, these PIDs are similar to the PID for the Silo section. Owing to memory constraints associated with Business Modeller and the desire to maintain clarity, these sections were created separately and remain separate diagrams. However, in an integrated near-field comprising all disposal sections, links/Influences between the different areas of the repository, including the Silo, will exist via the interconnecting tunnels/shafts in the integrated near-field and far-field, as discussed in *Section 4.3*.

4.2 Construction of Far-Field PID

The PID for the far-field component of the Process System was constructed in a similar way to that of the near-field rock barrier of the near-field PID, though incorporating a slightly different set of FEPs. For the far-field PID, the external boundary conditions were provided by the following external FEPs, or EFEPs:

- Climate change;
- Erosion of the surface;
- Uplift/subsidence.

Note that the FEPs *Seismic activity*, and *Saline or fresh groundwater intrusion* were included in the far-field, although these FEPs could be considered external to the Process System (EFEPs).

The resultant PID, which for continuity includes the near-field rock zone as well as the far-field, are shown in *Annexe II*. The list of Influences which appear in this diagram is provided in *Appendix H*. Note that the corresponding letter code identifier for the far-field is *G*. Similarly, the letter code for Influences originating from external FEPs is *E*.

4.3 Integrated Near- and Far-Field PID

The final stage in the development of the full PID involved the development of an integrated near-field and far-field diagram. At this stage, owing to memory constraints of Business Modeller and the need for clarity, together with the fact that the new code, SPARTA, was now available for testing, a <u>near-field + far-field</u> PID was constructed only at an upper hierarchic level to show the inter-relationships between (only) two distinct near-field sections and the far-field. This diagram is shown in *Figure 5*. Note that in *Figure 5*, the FEP "*Shaft and tunnel seal degradation*" lies outside the two near-field components represented; this positioning is intended to reflect the repository layout in which interconnecting shafts/tunnels will exist between different parts of the repository.

In fact, as discussed in the next section, the approach used to generate the PID section shown in *Figure 5* is similar to that adopted in the SPARTA code, where different hierarchic levels of the PID are presented separately. This approach is considered advisable when the level of detail in the PID is excessive.

SFR 1 REPOSITORY: NEAR FIELD + FAR FIELD
UPPER HIERARCHIC LEVEL
(2 near-field components shown)
SKI/PID L/ILW/NF+FF/Version 1.2 (12/05/2000)

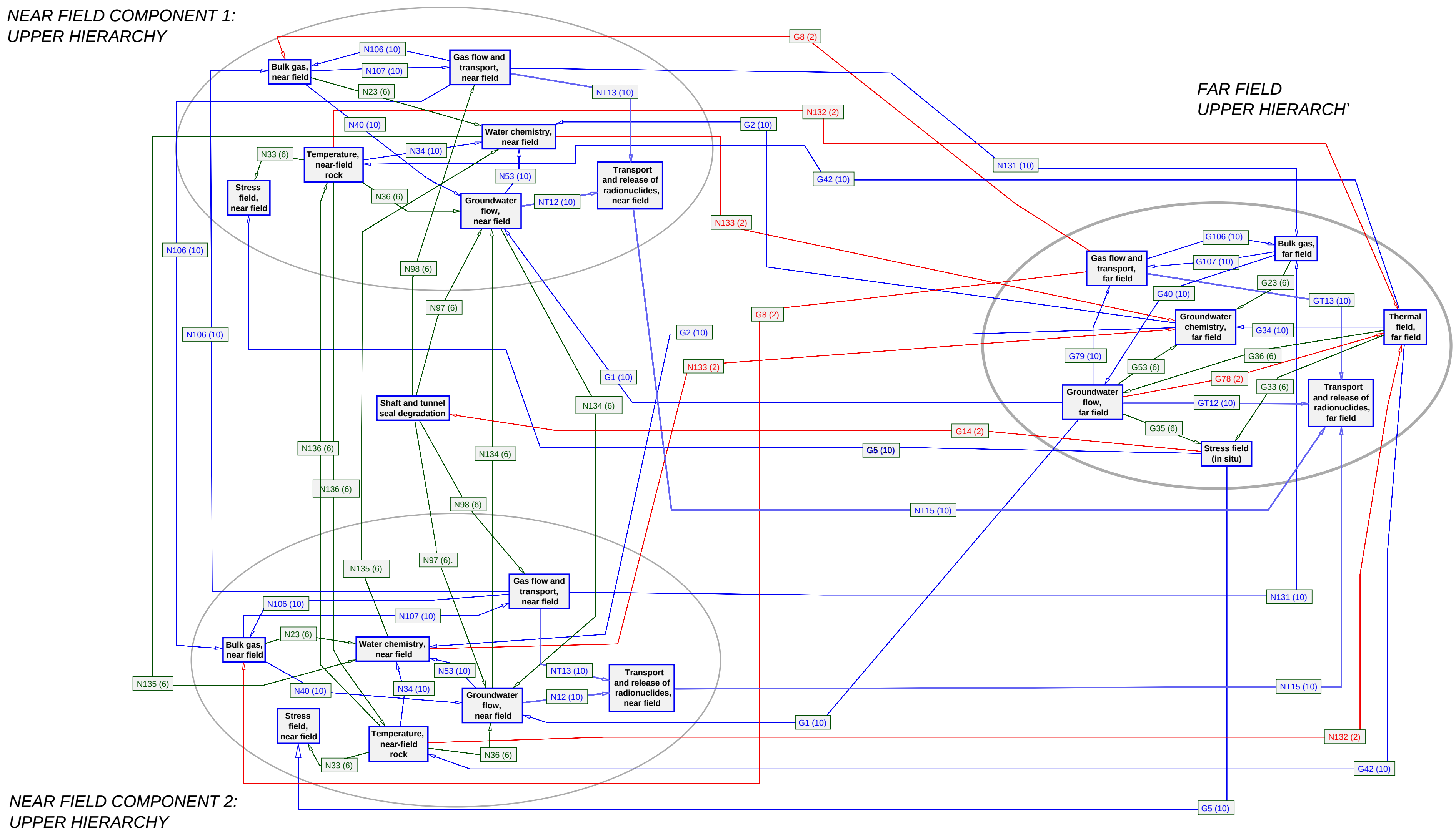

Figure 5 Process Influence Diagram for two near-field and the far-field components of the SFR-1 repository: upper hierarchic level only.

5 Development of PID for SFR-1 Using SPARTA

Owing to the number of different sections (Silo, BLA, BMA, BTF) of the repository and the number of barriers associated with each section, the two-dimensional (2D) PID created for SFR-1 using Business Modeller is visually complex. Thus, information on FEPs and Influences is difficult to impart to those not intimately familiar with either the software or PIDs.

Primarily for this reason, the need for a different approach was recognised in 1996 and steps taken at that time to develop new software that would accommodate this different approach. Following a consensus on the specific requirements of the new software, a first version of SPARTA became available towards the end of 1998, with subsequent versions being released during 1999.

5.1 Description of Hierarchical Approach

The objective of the PID remains the same, i.e. to provide a systematic way of ensuring that all features, events and processes are considered for the repository system being studied. Similarly, FEPs are represented in the same way, via a box with a name signifying the FEP title.

The hierarchical or three-dimensional (3D) PID consists of a series of layers, where the uppermost layer or diagram can be regarded as an overview of the repository system; principally near-field, far-field and biosphere. Each layer constitutes a separate drawing and each drawing typically consists of 6-8 'boxes'.

Within the hierarchical structure, upper-level layers comprise groupings of FEPs designated as "super-FEPs". Note that the term “super-FEP” is purely an arbitrary one, being used generally to signify an underlying structure to that FEP. In the PID developed for SKI, some such layers or diagrams often have some physical meaning, *e.g.* in the case of the SFR-1 repository, individual

- components of the system (biosphere, far-field, near-field);
- sections of repository (Silo, BLA, BMA, BTF sections, repository zone);
- barriers of a section (e.g. for the Silo - backfill, reinforced shell, porous grout or mortar, waste package).

Other layers contain groups of related FEPs, e.g. the “super-FEP” Geochemistry contains FEPs such as Groundwater composition, Sorption, Precipitation/Dissolution, Microbial activity, and Colloid generation.

As one "descends" the PID structure, i.e. examines the underlying structure, the level of detail needed to describe the elements of the repository system increases and eventually, the lowermost levels of this PID consist of "individual" features, events or processes[4], and are similar to small sections of the 2D PID. Although in the discussion below, all boxes are referred to as FEPs, the distinction between groups of FEPs, or super-FEPs, and individual FEPs should be appreciated.

The principal advantages of such an approach are that:

- development of a PID is to some extent intuitive as one can start from a fairly simple, superficial-level diagram (biosphere, far-field and near-field) and gradually add detail in a logical fashion as one becomes more familiar with the disposal system;
- each diagram of the PID is much simpler in appearance, typically consisting of about 4-8 FEP boxes;
- the structure beneath certain super-FEPs, *i.e.* the underlying FEPs and Influences, is in many cases identical, which offers the opportunity to duplicate those parts of the PID, using SPARTA.

Added to the above advantages is the large supporting database (see next section), which results in a flexible, yet powerful, software tool. The only apparent drawback of the 3D PID is, of course, the inability to view the entire PID at one time; however, given a complex PID such as that for the SFR-1 repository, this should not be regarded necessarily as a disadvantage.

Two examples of drawings are provided here: *Figure 6*, showing the individual barriers of the Silo section, and *Figure 7*, containing the individual FEPs within the *Transport and Release of Radionuclides* drawing for the Silo Waste Package.

5.2 Description of SPARTA Code and SPARTA PIDs

SPARTA was developed for SKI by QuantiSci (Jack and Hillier, 1999) to facilitate the construction of 3D PIDs. FEPs, or groups of FEPs are represented by boxes, and Influences by lines connecting boxes, similar to the basic components of a regular 2D PID.

However, in the 3D structure, Influences can extend over several drawings. To enable Influences to be properly recorded, therefore, lines called "*Connections*" are physically added to drawings. By way of an analogy, the layers of a 3D PID may be looked upon as separate floors of a building, FEPs may be considered as rooms within a floor, and Connections correspond to the wiring which links different rooms and different floors.

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[4] The term "individual" to FEPs is also an arbitrary one since decisions may subsequently be made to subdivide an individual FEP into two or more detailed FEPs. In such a case, the original "individual" FEP becomes one with structure, *i.e.* a super-FEP.

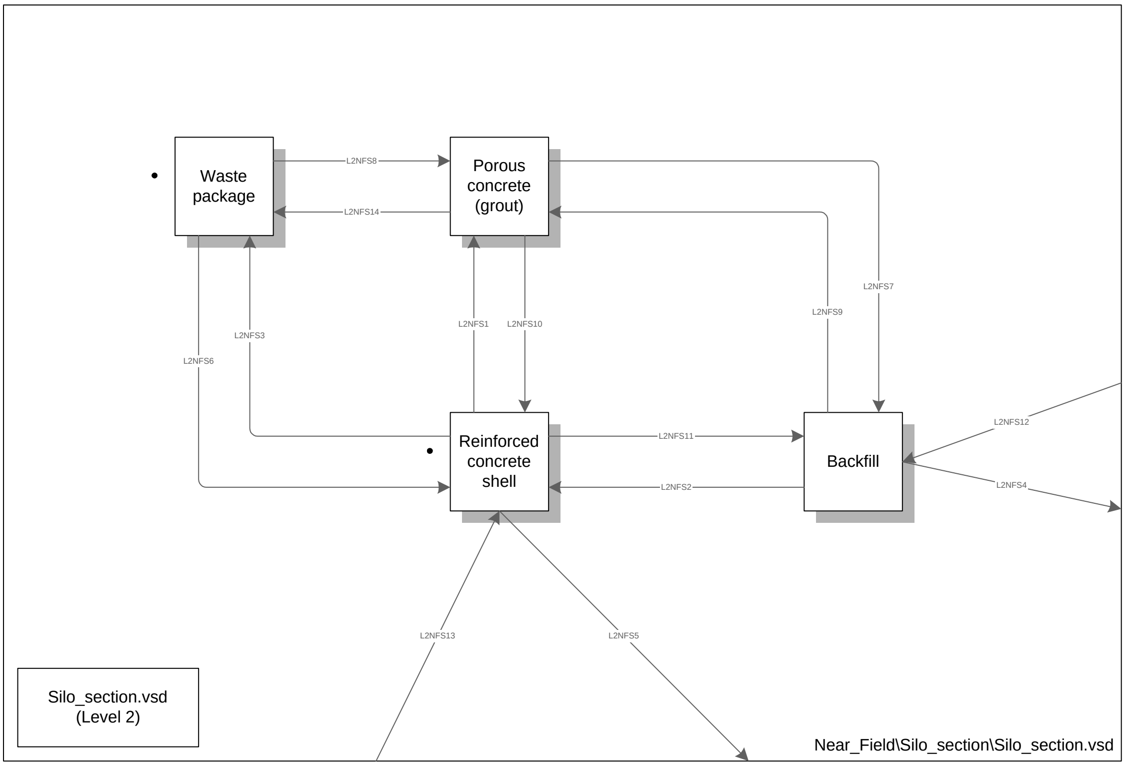

Figure 6 *SFR-1 PID: Individual barriers of the Silo section of the SFR-1 repository.*

Note: Lines extending from FEPs to the boundary of the drawing (*Reinforced concrete shell* in *Figure 6* above) connect Influences from that drawing to one or more other drawings.

Using SPARTA, each drawing consists of a rectangular boundary within which boxes, or FEPs are added. Connections between FEPs in the same drawing are obtained by direct lines between the FEPs concerned. Connections between FEPs in different drawings, on the other hand, are achieved by inserting lines from the FEPs concerned to the boundary of the drawing (see *Figure 6*).

The power of SPARTA lies in the supporting databases which store information on FEPs and Influences as well as incorporating links to more detailed documents, *e.g.* detailed FEP descriptions contained in a FEP Encyclopaedia (Miller *et al.*, 1998). The code also allows searches of FEPs and Influences in the form of key words or key fragments of words.

For FEPs, the type of information recorded includes:

- FEP title;
- drawing in which FEP is contained;
- description of FEP (with option of hyperlink to FEP Encyclopaedia (Miller *et al.*, 1998);

- classification (*e.g.* geological, hydrogeological, mechanical, chemical/geochemical);
- time dependency, if any.

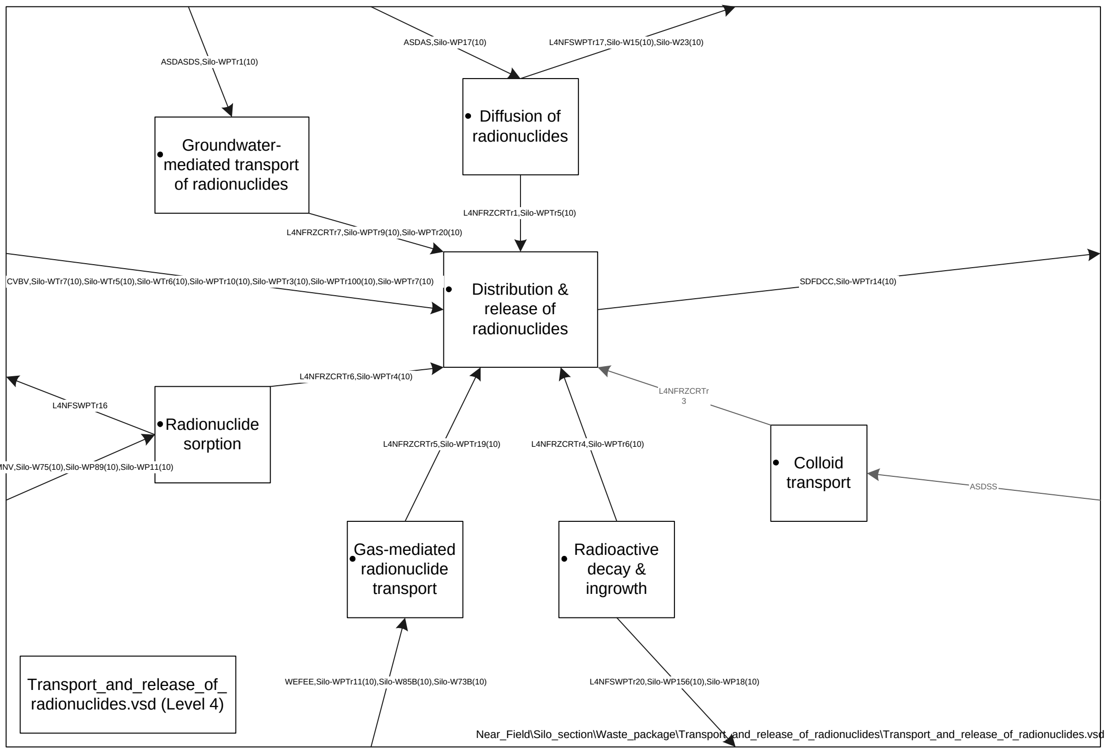

Figure 7 *SFR-1 PID: Silo: Waste Package: Transport and release of radionuclides.*

Note: Lines extending from FEP boxes to the boundary connect influences from one drawing to the next; text coding attached to individual lines identifies specific Influences.

- general comments, which may be used for audit purposes;
- creator's ID and date and time of FEP creation;
- unique identifiers for database records.

The type of information for Influences is similar to the above, with the exception of classification and time dependency, but with additional input of identifying those FEPs (starting and ending) which are linked.

5.3 Construction of SPARTA PID for SFR-1

5.3.1 Stages in Development of Current PID

As is the case for 2D PIDs, the development process is an iterative one, benefiting from feedback from various sources. The original intention had been to "convert" the Business Modeller 2D PID to a 3D version. Thus, the first PID developed using SPARTA contained the same FEP names as the 2D PID, part of which is shown in *Annexe I*. Subsequently, largely as the result of two Workshops held in 1999, one focusing on the PID (including Influences and Importance Levels), and the other on the use of SPARTA, the structure of the current PID was redefined to show a certain degree of consistency in names among different sections.
Preliminary Importance Levels (IL) were assigned to Influences based on the following arbitrary criteria:

- IL=10: Influence must be included or taken into consideration in the current context;
- IL=2: Influence is not considered important in the current context and can be ignored;
- IL=6: Influence may be important - requires second opinion.

"Current context" in the above criteria refers to the reference case Central Scenario in which only the expected evolution of the repository system is addressed.

The current PID with Importance Levels for Influences has not been formally audited. Rather, individual sections of the PID were examined by external reviewers familiar with Process System Models and the use of PIDs.[5]

5.3.2 Presentation of the Current PID

The drawings of the current PID for the SFR-1 repository, comprising full near-field (Silo, BMA, BLA and BTF sections, as well as near-field rock zone and far-field) are contained in *Annexe III*. The main features of this PID are:

- detailed drawings generated for far-field and near-field components only, the biosphere and external FEPs, or EFEPs, being considered separately;
- a total of 95 drawings;
- a total of 584 "FEPs" (including super-FEPs);
- 2100 Influences.

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[5] Far-field and near-field rock zone: Matt White (QuantiSci); Silo section: David Savage (Quintessa); BMA section: Peter Robinson (QuantiSci); BTF section: Randy Arthur (Monitor Scientific).

Although the PID is substantial in terms of the number of FEPs and Influences, closer examination of the individual drawings shows that the structure of individual engineered barriers is similar, making the overall structure more easy to comprehend. Thus, approximately 30 FEPs/super-FEPs exist for each barrier and most of these FEPs are linked in an identical way.

5.4 Comments on Current SPARTA PID

It is appropriate at this stage to provide a few comments on the current PID constructed using SPARTA.

Firstly, it should be re-emphasised that the current PID and its contents have not undergone a formal audit. Rather, sections of the PID have been reviewed in detail combined with the fact that there is a significant overlap between the information contained in the 2D PID, which was audited, and the 3D PID. However, the immediate purpose of the existing PID was as a tool to help identify research and development needs for SKI over a one- to two-year period. In this context, the PID was used successfully at a January Workshop for such a purpose (Stenhouse *et al.*, 2000; also discussed in *Section 6*).

As stated above, the current PID includes detailed treatment of the near-field and far-field only, in keeping with the scope of the project. Other components of the repository system, which are being treated elsewhere, are the biosphere and EFEPs, or scenario-generating FEPs. For the purposes of the January Workshop, EFEPs relevant to the Central Scenario, *i.e.* expected evolution of the repository system, were included in the PID.

Some of the FEPs/super-FEPs contained in the existing SPARTA-generated PID have different titles from those used to generate the 2D PID, the latter being listed in *Appendices C* and *F*. This situation has arisen primarily because the current PID was created independently of the 2D PID and is no longer an exact representation of the original PID. In addition, as a result of discussions at the various Workshops (2 in 1999, 1 in 2000), it was recognised that, particularly for cementitious barriers, some additional, more detailed FEP titles were desirable, particularly for the cementitious barriers, to ensure that specific processes were treated, e.g. *Sulphate attack* (on cement) and *Degradation of superplasticisers* (effect on *Release and transport of radionuclides*). Thus, the current near-field and far-field FEP lists are shown in *Appendices I* and *J*, with FEPs identified either as true FEPs or groups of FEPs.

6 Summary of Project

Two detailed PIDs have been prepared as part of the performance assessment of the SFR-1 repository. Each diagram provides a different representation of the near-field and far-field of the repository system; the first PID being two-dimensional and the later one three-dimensional. Despite the different approaches, the primary objective of constructing each PID has been the same: to ensure firstly, that all features, events and processes relevant to the future evolution of the repository system are considered, and secondly, that all "essential" Influences are identified so that they may be incorporated in some form in the modelling of the system's evolution.

As mentioned in *Section 5.4*, the 3D PID was used at an SFR-1 Safety Assessment Workshop held in January, 2000 (Stenhouse *et al*., 2000), to guide the Rock and Vault Clearing Houses - groups of experts focussing on specific parts of the repository system. The objective of this Workshop was to identify key issues which needed to be considered in depth prior to performance assessment calculations. Each Clearing House was expected to:

- scope the information available within their area of responsibility;
- identify key questions and issues currently relating to SFR-1 safety (known uncertainties);
- review activities to be undertaken (review/scoping calculations/in-depth treatments);
- allocate review tasks and timetable;
- indicate and scope the relevant R&D required to address the key questions and issues;
- define any input requirements from other Clearing Houses.

The SPARTA-generated PID provided a successful basis by which the Rock and Vault Clearing Houses structured these tasks.

6.1 Recommendations

Currently, because of time constraints, the information contained in SPARTA's database for the SFR-1 PID is limited to the basic input required by SPARTA, together with a few, select comments on FEP descriptions. External review and an understanding/appreciation of the PID would therefore benefit from entries in the additional descriptive data fields accommodated by SPARTA. In addition, hyperlinks embedded in the FEP input information within the SPARTA PID, would allow links to individual FEP descriptions in the FEP Encyclopaedia, thereby enhancing the usefulness of the PID. These additions would allow the full potential of the new software to be realised.

With regard to other repository systems, owing to the amount of preparative work carried out prior to constructing the PIDs, *i.e.* FEP identification, compilation and selection, much of the information base is available for transfer to other repository systems, particularly where cementitious barriers are a significant component. In this context, the 3D PID for SFR-1 can be readily adapted to the deep repository for spent nuclear fuel, SFL 2, and to the deep repository for long-lived low- and intermediate-level waste, SFL 3-5.

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Appendix A: *Compilation of Near-Field FEPs from International FEP List*

FEPs from the following lists appear in this appendix (corresponding code in parentheses)[6]:

- Atomic Energy of Canada Ltd. (*AECL*): spent fuel disposal; Goodwin *et al*. (1991).
- Department of the Environment, U.K. (*DOE*): L/ILW waste disposal; Thorne (1992).
- International Atomic Energy Agency (*IAEA*): IAEA (1981).
- Nagra, Switzerland (*PGA*): vitrified HLW disposal; Project Gewähr (1985).
- SKI/SKB (*SKI*): spent fuel disposal; Andersson (1989).
- Sandia National Laboratories, U.S.A. (*SNL*): HLW disposal; Cranwell *et al.* (1982).
- U.K. Nirex Ltd. (*UKN*): L/ILW disposal; Hodgkinson and Sumerling (1989).
- Department of the Environment, U.K. (*HMIP*); L/ILW disposal; Miller and Chapman (1992).
- Nagra Kristallin I (*NAGRA*): vitrified HLW disposal; Nagra (1994).

[6] A list of over 1500 FEPS was compiled in Stenhouse *et al.* (1993). In this compilation, the FEP list of Nuclear Energy Agency (NEA, 1992) was included, but is identical to that of U.K. Nirex Ltd. (UKN) above. This current, reduced set of near-field FEPs does not include FEPs from the list prepared by Eng *et al.* (1994), which was compiled but used only for comparison purposes.

CODE	Screen	FEP NAME	SEE
AECL1.1	P	Backfill characteristics	
AECL1.2	T	Backfill evolution	
AECL1.3	R	Biological activity	DOE1.6.6
AECL1.4	?	Boundary conditions	
AECL1.5	sub	Buffer additives	AECL1.6
AECL1.6	P	Buffer characteristics	
AECL1.7	T	Buffer evolution	
AECL1.8	R	Cave ins	DOE1.4.4
AECL1.9	V	Chemical gradients	
AECL1.10		Chemical interactions (expected)	
AECL1.11	T	Chemical interactions (long-term)	
AECL1.12	?	Chemical interactions (other)	
AECL1.13	T	Chemical kinetics	
AECL1.14	E	Climate change	
AECL1.15		Colloids	
AECL1.16		Complexation by organics	
AECL1.17	V	Concrete	
AECL1.18		Container corrosion products	
AECL1.19	T	Container failure (early)	
AECL1.20	T	Container failure (long-term)	
AECL1.21	?	Container failure (other long-term processes)	
AECL1.22		Container healing	
AECL1.23	sub	Containers - partial corrosion	
AECL1.24		Convection	
AECL1.25	?	Correlation	
AECL1.26	R	Corrosion	DOE1.1.1
AECL1.27	?	Coupled processes	
AECL1.28	R	Criticality	DOE1.3.2
AECL1.29		Diffusion	
AECL1.30		Dispersion	
AECL1.31	E	Earthquakes	
AECL1.32		Electrochemical gradients	
AECL1.33	R	Evolution of buffer	AECL1.7
AECL1.34		Excessive hydrostatic pressures	
AECL1.35	E	Explosions	
AECL1.36	E	Faulty buffer emplacement	
AECL1.37		Formation of cracks	
AECL1.38	R	Formation of gases	DOE1.2
AECL1.39	?	Galvanic coupling	
AECL1.40		Geochemical pump	
AECL1.41	E	Glaciation	
AECL1.42	E	Global effects	
AECL1.43	P	Hydraulic conductivity	
AECL1.44	P	Hydraulic head	
AECL1.45	?	Hydride cracking	
AECL1.46	NR	Hydrothermal alteration	

CODE	Screen	FEP NAME	SEE
AECL1.47	E	Improper operation	
AECL1.48	E	Incomplete closure	
AECL1.49	E	Incomplete filling of containers	
AECL1.50	?	Interfaces (boundary conditions)	
AECL1.51	E	Intrusion (animal)	
AECL1.52	E	Intrusion (human)	
AECL1.53	P	Inventory	
AECL1.54	P	Other wastes (other than vitrified HLW)	
AECL1.55	T	Long-term physical stability	
AECL1.56	?	Long-term transients	
AECL1.57	?	Methylation	
AECL1.58	R	Microbes	DOE1.6.6
AECL1.59	R	Microorganisms	DOE1.6.6
AECL1.60	E	Monitoring and remedial activities	
AECL1.61	?	Mutation	
AECL1.62	E	Percolation in shafts	
AECL1.63	sub	Pitting	DOE1.1.1
AECL1.64	E	Preclosure events	
AECL1.65	R	Precipitation and dissolution	DOE1.6.5
AECL1.66		Pseudo-colloids	
AECL1.67		Radiation damage	
AECL1.68	R	Radioactive decay	DOE1.3.1
AECL1.69		Radiolysis	
AECL1.70	E	Recharge groundwater	
AECL1.71		Reflooding	
AECL1.72	E	Retrievability	
AECL1.73	E	Sabotage and improper operation	
AECL1.74	T	Seal evolution	
AECL1.75		Seal failure	
AECL1.76	R	Sorption	DOE2.4.5
AECL1.77	sub	Sorption: non-linear	
AECL1.78		Source terms (expected)	
AECL1.79	?	Source terms (other)	
AECL1.80		Speciation	DOE1.6.5
AECL1.81	?	Stability	
AECL1.82	H	Stability of glass	
AECL1.83	NR	Swelling pressure	
AECL1.84	?	Temperature rises (unexpected effects)	
AECL1.85	T	Time dependence	
AECL1.86	R	Transport in gases or of gases	DOE2.4.11
AECL1.87	?	Uncertainties	
AECL1.88	sub	Uniform corrosion	DOE1.1.1
AECL1.89	?	Unmodelled design features	
AECL1.90	R	Unsaturated transport	DOE1.5.2
AECL1.91	?	Vault geometry	
AECL2.42	R	Methane	UKN1.2.13

CODE	Screen	FEP NAME	SEE
DOE1.1.1		*Structural container metal corrosion*	
DOE1.1.1.1	sub	Structural container metal corrosion: Localised	
DOE1.1.1.2	sub	Structural container metal corrosion: Bulk	
DOE1.1.1.3	sub	Structural container metal corrosion: Crevice	
DOE1.1.1.4	sub	Structural container metal corrosion: Stress corrosion cracking	
DOE1.1.2		*Physical degradation of concrete*	
DOE1.1.2.1	sub	Cracking	
DOE1.1.2.2	sub	Sealing of cracks	
DOE1.1.2.3	sub	Pore blockage	
DOE1.1.2.4	sub	Alkali-aggregate reaction	
DOE1.1.2.5	sub	Cement-sulphate reaction	
DOE1.1.3		*Chemical degradation of concrete*	
DOE1.1.3.1	sub	Changes in pore water composition, pH, Eh	
DOE1.1.3.2	sub	Exchange capacity exceeded	
DOE1.1.3.3	sub	Alkali-aggregate reaction	
DOE1.1.3.4	sub	Cement-sulphate reaction	
DOE1.1.4	H	*Degradation of wastes (vitrified glass)*	
DOE1.1.4.1	sub	Metal corrosion	
DOE1.1.4.2	sub	Leaching	
DOE1.1.4.3	sub	Complex formation	
DOE1.1.4.4	sub	Colloid formation	
DOE1.1.4.5	sub	Microbial degradation of organic wastes	
DOE1.1.4.6	sub	Microbial corrosion	
DOE1.1.4.7	sub	Radiolysis	
DOE1.2.1		*Hydrogen [production] by metal corrosion*	
DOE1.2.1.1	sub	Structural steel	
DOE1.2.1.2	sub	Container steel	
DOE1.2.1.3	sub	Waste steel	
DOE1.2.1.4	sub	Waste Magnox	
DOE1.2.1.5	sub	Waste aluminium	
DOE1.2.1.6	sub	Waste Zircalloy	
DOE1.2.1.7	sub	Waste other metals	
DOE1.2.1.8	sub	Effects of microbial growth on concrete	
DOE1.2.2		*Methane and carbon dioxide [production] by microbial degradation*	
DOE1.2.2.1	sub	Cellulosics	
DOE1.2.2.2	sub	Other susceptible organic materials	
DOE1.2.2.3	sub	Aerobic degradation	
DOE1.2.2.4	sub	Anaerobic degradation	
DOE1.2.2.5	sub	Effects of temperature	
DOE1.2.2.6	sub	Effects of lithostatic pressure	
DOE1.2.2.7	sub	Effects of microbial growth on properties of concrete	
DOE1.2.2.8	sub	Effects of biofilms	
DOE1.2.2.9	sub	Effects of hydrogen from metal corrosion	
DOE1.2.2.10	sub	Inhibition due to the pressure of toxic materials	
DOE1.2.2.11	sub	Carbonate/bicarbonate exchange with concrete	
DOE1.2.2.12	sub	Energy and nutrient control of metabolism	
DOE1.2.2.13	sub	Effects of radiation on microbial populations	
DOE1.2.3		Gas generation from concrete	

CODE	**Screen**	**FEP NAME**	**SEE**
DOE1.2.4		*Active gases*	
DOE1.2.4.1	sub	Tritiated hydrogen	
DOE1.2.4.2	sub	Active methane and carbon dioxide	
DOE1.2.4.3	sub	Other active gases	
DOE1.2.5		Toxic gases	
DOE1.2.6		*Gas transport*	
DOE1.2.6.1	sub	In the waste container	
DOE1.2.6.2	sub	In the vaults between containers	
DOE1.2.6.3	sub	Between vaults	
DOE1.2.6.4	sub	In the near-field, including up and around access shafts and adits	
DOE1.2.6.5	sub	Into and through the far-field	
DOE1.2.7		*Flammability*	
DOE1.2.7.1	sub	Fires	
DOE1.2.7.2	sub	Explosions	
DOE1.3.1		Radioactive decay and ingrowth	
DOE1.3.2		Nuclear criticality	
DOE1.4.1		Canister or container movement	
DOE1.4.2		Changes in in situ stress field	
DOE1.4.3		Embrittlement	
DOE1.4.4		*Subsidence/collapse*	
DOE1.4.4.1	sub	Repository induced	
DOE1.4.4.2	sub	Natural	
DOE1.4.5		Rock creep	
DOE1.4.6		Fracturing	
DOE1.5.1		*Changes in moisture content*	
DOE1.5.1.1	sub	Due to dewatering	
DOE1.5.1.2	sub	Due to stress relief	
DOE1.5.2		*Groundwater flow (unsaturated conditions)*	
DOE1.5.2.1	sub	Initial conditions	
DOE1.5.2.2	sub	Due to gas production	
DOE1.5.3	sub	Groundwater flow (saturated conditions)	
DOE1.5.4		*Transport of chemically active substances into the near-field*	
DOE1.5.4.1	sub	Inorganic ions	
DOE1.5.4.2	sub	Humic and fulvic acids	
DOE1.5.4.3	sub	Microbes	
DOE1.5.4.4	sub	Organic complexes	
DOE1.5.4.5	sub	Colloids	
DOE1.6.1	V	Differential elastic response	
DOE1.6.2	V	Non-elastic response	
DOE1.6.5		*Chemical changes*	
DOE1.6.5.1	sub	Metal corrosion	
DOE1.6.5.2	sub	Concrete degradation	
DOE1.6.5.3	sub	Waste degradation	
DOE1.6.5.4	sub	Gas production	
DOE1.6.5.5	sub	Complex formation	
DOE1.6.5.6	sub	Colloid production	
DOE1.6.5.7	sub	Solubility	
DOE1.6.5.8	sub	Sorption	
DOE1.6.5.9	sub	Species equilibrium	

CODE	Screen	FEP NAME	SEE
DOE1.6.6		*Microbiological effects*	
DOE1.6.6.1	sub	Cellulose degradation	
DOE1.6.6.2	sub	Microbial activity	
DOE1.6.6.3	sub	Microbial product reactions	
DOE2.1.1	E	Meteorite impact	
DOE2.4.1		Advection	
DOE2.4.2		*Diffusion*	
DOE2.4.2.1	sub	Bulk	
DOE2.4.2.2	sub	Matrix	
DOE2.4.2.3	sub	Surface	
DOE2.4.3		Hydrodynamic dispersion	
DOE2.4.4		*Solubility constraints*	
DOE2.4.4.1	sub	Effects of pH and Eh	
DOE2.4.4.2	sub	Effects of ionic strength	
DOE2.4.4.3	sub	Naturally-occurring complexing agents	
DOE2.4.4.4	sub	Complexing agents formed in the near-field	
DOE2.4.4.5	sub	Naturally-occuring colloids	
DOE2.4.4.6	sub	Colloids formed in the near-field	
DOE2.4.4.7	sub	Major ions migrating from the near-field	
DOE2.4.4.8	sub	Effects of microbial activity	
DOE2.4.5		*Sorption*	
DOE2.4.5.1	sub	Linear	
DOE2.4.5.2	sub	Non-linear	
DOE2.4.5.3	sub	Reversible	
DOE2.4.5.4	sub	Irreversible	
DOE2.4.5.5	sub	Effects of pH and Eh	
DOE2.4.5.6	sub	Effects of ionic strength	
DOE2.4.5.7	sub	Effects of naturally-occurring organic complexing agents	
DOE2.4.5.8	sub	Effects of naturally-occuring inorganic complexing agents	
DOE2.4.5.9	sub	Effects of complexing agents formed in the near-field	
DOE2.4.5.10	sub	Effects of naturally-occurring colloids	
DOE2.4.5.11	sub	Effects of colloids formed in the near-field	
DOE2.4.5.13	sub	Effects of microbial activity	
DOE2.4.7		*Organic colloid transport*	
DOE2.4.10		Isotopic dilution	
DOE2.4.11		*Gas Transport*	
DOE2.4.11.1		Solution	
DOE2.4.11.2		Gas phase	
DOE2.4.12		Gas-induced groundwater transport	
DOE2.4.13		*Thermally induced groundwater transport*	
DOE2.4.13.1	sub	Repository-induced	

CODE	Screen	FEP NAME	SEE
IAEA1.12		Geochemical change	
IAEA1.13		*Fluid interactions*	
IAEA1.13.1	sub	Fluid interactions: Groundwater flow	
IAEA1.13.2	sub	Fluid interactions: Dissolution	
IAEA2.2	E	*Inadequate design*	
IAEA2.2.1	E	Inadequate design: Shaft seal failure	
IAEA2.2.2	E	Inadequate design: Exploration borehole seal failure	
IAEA2.3	E	Improper operation: Improper waste emplacement	
IAEA3.1		*Thermal effects*	
IAEA3.2	G	*Chemical effects*	
IAEA3.2.1		Chemical effects: Corrosion	
IAEA3.2.2		Chemical effects: Interactions of waste package and rock	
IAEA3.2.3		Chemical effects: Gas generation	
IAEA3.2.4		Chemical effects: Geochemical change	
IAEA3.3	G	*Mechanical effects*	
IAEA3.3.1		Mechanical effects: Canister movement	
IAEA3.3.2		Mechanical effects: Local fracturing	
IAEA3.4	G	*Radiological effects*	
IAEA3.4.1		Radiological effects: Material property changes	
IAEA3.4.2	R	Radiological effects: Radiolysis	AECL1.69
IAEA3.4.3		Radiological effects: Decay product gas generation	
IAEA3.4.4	R	Radiological effects: Nuclear criticality	DOE1.3.2
PGA3.1	H	Radiation damage of the matrix	
PGA3.2	R	Radiolysis	AECL1.69
PGA3.3	R	Nuclear criticality	DOE1.3.2
PGA3.4	R	Canister movement in backfill	DOE1.4.1
PGA3.6		Mechanical canister damage	
PGA3.7		*Differing thermal expansion*	
PGA3.12	G	*Geochemical changes*	
PGA3.12.1		Geochemical changes in backfill	
PGA3.12.2		Geochemical changes in host rock	
PGA3.13		Physico-chemical phenomena/effects (eg. colloid formation)	
PGA3.14	R	Microbiological phenomena/effects	DOE1.6.6
PGA3.15	R	Gas production	SKI1.2.4

CODE	Screen	FEP NAME	SEE
SKI1.1.1	R	Criticality	DOE1.3.2
SKI1.1.2		Radioactive decay; heat	
SKI1.1.3		Recoil of alpha-decay	
SKI1.1.4	R	Gas generation: He production	IAEA3.4.3
SKI1.2.1	R	Radiolysis	IAEA3.4.2
SKI1.2.2		H2/O2 explosions	
SKI1.2.3	H	Pb-I reactions	
SKI1.2.4		Gas generation	
SKI1.2.5	H	I, Cs-migration to glass surface	
SKI1.2.6	H	Solubility within fuel matrix	
SKI1.2.7		Recrystallization	
SKI1.2.8	P	Redox potential	
SKI1.2.9		Dissolution chemistry	
SKI1.3	H	Damaged or deviating fuel	
SKI1.4	H	Sudden energy release	
SKI1.5		Release of radionuclides from the failured canister	
SKI2.1.1	H	Chemical reactions (copper corrosion)	
SKI2.1.2		Coupled effects (electrophoresis)	
SKI2.1.3		Internal corrosion due to waste	
SKI2.1.4		Role of the eventual channeling within the canister	
SKI2.1.5	H	Role of chlorides in copper corrosion	
SKI2.1.6.1	H	Repository induced Pb/Cu electrochemical reactions	
SKI2.1.6.2		Natural telluric electrochemical reactions	
SKI2.1.7	sub	Pitting	DOE1.1.1
SKI2.1.8		Corrosive agents, Sulphides, oxygen etc	
SKI2.1.9	H	Backfill effects on Cu corrosion	
SKI2.1.10	R	Microbes	DOE1.6.6
SKI2.2	H	Creeping of copper	
SKI2.3.1		Thermal cracking	
SKI2.3.2		Electro-chemical cracking	
SKI2.3.3		Stress corrosion cracking	
SKI2.3.4	H	Loss of ductility	
SKI2.3.5		Radiation effects on canister	
SKI2.3.6		Cracking along welds	
SKI2.3.7.1		External stress	
SKI2.3.7.2		Hydrostatic pressure on canister	
SKI2.3.8		Internal pressure	
SKI2.4	H	Voids in the lead filling	
SKI2.5.1		Random canister defects - quality control	
SKI2.5.2		Common cause canister defects - quality control	
SKI3.1.1		Degradation of the bentonite by chemical reactions	
SKI3.1.2		Saturation of sorption sites	
SKI3.1.3		Effects of bentonite on groundwater chemistry	
SKI3.1.4		Colloid generation - source	
SKI3.1.5		Coagulation of bentonite	
SKI3.1.6		Sedimentation of bentonite	
SKI3.1.7		Reactions with cement pore water	
SKI3.1.8		Near field buffer chemistry	

CODE	Screen	FEP NAME	SEE
SKI3.1.9	R	Radiolysis	IAEA3.4.2
SKI3.1.10		Interactions with corrosion products and waste	
SKI3.1.11		Redox front	
SKI3.1.12		Pertubed buffer material chemistry	
SKI3.1.13		Radiation effects on bentonite	
SKI3.2.1		*No entry [Swelling of bentonite?]*	
SKI3.2.1.1		Swelling of bentonite into tunnels and cracks	
SKI3.2.1.2		Uneven swelling of bentonite	
SKI3.2.2	R	Movement of canister in buffer/backfill	DOE1.4.1
SKI3.2.3		Mechanical failure of buffer/backfill	
SKI3.2.4	T	Erosion of buffer/backfill	
SKI3.2.5		Thermal effects on the buffer material	
SKI3.2.6	sub	Diffusion - surface diffusion	DOE2.4.2
SKI3.2.7		Swelling of corrosion products	
SKI3.2.8		Preferential pathways in the buffer/backfill	
SKI3.2.9		Flow through buffer/backfill	
SKI3.2.10		Soret effect	
SKI3.2.11		Backfill material deficiencies	
SKI3.2.12		Gas transport in bentonite	
SKI4.1.1		Oxidizing conditions	
SKI4.1.2		pH-deviations	
SKI4.1.3		Colloids, complexing agents	
SKI4.1.4	R	Sorption	DOE2.4.5
SKI4.1.5	sub	Matrix diffusion	DOE2.4.2
SKI4.1.6		Reconcentration	
SKI4.1.7		Thermochemical changes	
SKI4.1.8		Change of groundwater chemistry in nearby rock	
SKI4.1.9		Complexing agents	
SKI4.2.1	R	Mechanical failure of repository	DOE1.4.4
SKI4.2.2.1		Excavation/backfilling effects on nearby rock	
SKI4.2.2.2		Hydraulic conductivity change - Excavation/backfilling effect	
SKI4.2.2.3		Mechanical effects - Excavation/backfilling effects	
SKI4.2.3		Extreme channel flow of oxidants and nuclides	
SKI5.1		Saline (or fresh) groundwater intrusion	
SKI5.2	E	Non-sealed repository	
SKI5.3	E	Stray materials left	
SKI5.4	E	Decontamination materials left	
SKI5.11	T	Degradation of hole- and shaft seals	
SKI5.14		Resaturation	
SKI5.23		Changed hydrostatic pressure on canister	
SKI5.39	E	Postclosure monitoring	
SKI5.43	E	Methane intrusion	
SKI5.44	R	Solubility and precipitation	DOE2.4.4
SKI5.45		Colloid generation and transport	
SKI6.2	R	Gas transport	DOE2.4.11
SKI6.4		Dispersion	
SKI6.5		Dilution	
SKI7.4		Chemical toxicity of wastes	
SKI7.5	R	Isotopic dilution	DOE2.4.10

CODE	Screen	FEP NAME	SEE
SNL6.1	R	Subsidence and Caving	DOE1.4.4
SNL6.2	T	Shaft and Borehole Seal Degradation	
UKN1.2.13		Natural gas intrusion	
UKN1.6.1	R	Advection and dispersion	DOE2.4.1
UKN1.6.2	R	Diffusion	DOE2.4.2
UKN1.6.4	R	Gas mediated transport	DOE2.4.12
UKN1.6.5		Multiphase flow and gas driven flow	
UKN1.6.6	P	Solubility limit	
UKN1.6.7	R	Sorption (linear/non-linear, reversible/irreversible)	DOE2.4.5
UKN1.6.8		Dissolution, precipitation and crystalisation	
UKN1.6.9		Colloid formation, dissolution and transport	
UKN1.6.10		Complexing agents	
UKN1.6.13		Mass, isotopic and species dilution	DOE2.4.10
UKN1.6.14		Chemical gradients (electrochemical effects and osmosis)	
UKN1.7.6	?	Chemical transformations	
UKN1.7.7	R	Microbial interactions	DOE1.6.6
UKN2.1.6		Material defects, e.g. early canister failure	
UKN2.1.10		Thermal effects (eg. concrete hydration)	
UKN2.2.2	E	Inadequate backfill or compaction, voidage	
UKN2.2.3	E	Co-disposal of reactive wastes (deliberate)	
UKN2.2.4	E	Inadvertant inclusion of undesirable materials	
UKN2.2.5		Heterogeneity of waste forms (chemical, physical)	
UKN3.1.5		Induced chemical changes (solubility, sorption, species equilibrium, mineralisation)	
UKN3.2.1	R	Metallic corrosion (pitting/uniform, internal and external agents, gas generatio	DOE1.6.5
UKN3.2.2		Interactions of host materials and gr/w with repository materials (eg, concrete carbonation,sul	
UKN3.2.3		Interactions of waste and repository materials with host materials (eg. electrochemical, corrosi	
UKN3.2.5		Cellulosic degradation	
UKN3.2.6		Introduced complexing agents and cellulosics	DOE1.5.4
UKN3.2.7	R	Microbiological effects (on corrosion/degradation, on solubility/complexatio	DOE1.6.6
UKN3.3.1	R	Canister or container movement	DOE1.4.1
UKN3.3.3	R	Embrittlement and cracking	DOE1.4.3
UKN3.3.6		Gas effects (pressuration, disruption, explosion, fire)	
UKN3.4.1	R	Radiolysis	AECL1.69
UKN3.4.2	E	Material property changes	
UKN3.4.3	R	Nuclear criticality	DOE1.3.2
UKN3.4.4	R	Radioactive decay and ingrowth (chain decay)	DOE1.3.1

CODE	Screen	FEP NAME	SEE
HMIP1.1	G	*Chemical/physical degradation*	
HMIP1.1.1	R	Container metal corrosion	DOE1.1.1
HMIP1.1.2	R	Physico-chemical degradation of concrete	DOE1.1.2
HMIP1.1.3		Physico-chemical degradation of wastes and transport to the far-field	
HMIP1.1.4		Electrical effects of metal corrosion	
HMIP1.2	G	*Gas production, transport and flammability*	
HMIP1.2.1	R	Hydrogen by metal corrosion	DOE1.2.1
HMIP1.2.2	R	Methane and carbon dioxide by microbial degradation	DOE1.2.2
HMIP1.2.3	R	Gas generation from concrete	DOE1.2.3
HMIP1.2.4	R	Radioactive gases	DOE1.2.4
HMIP1.2.5	R	Chemotoxic gases	DOE1.2.5
HMIP1.2.6	R	Gas transport	DOE1.2.6
HMIP1.2.7	R	Flammability	DOE1.2.7.1
HMIP1.2.8		Thermo-chemical effects	
HMIP1.3	G	*Radiation phenomena*	
HMIP1.3.1	R	Radioactive decay and ingrowth	DOE1.3.1
HMIP1.3.2	R	Nuclear criticality	AECL1.69
HMIP1.4	G	*Structural integrity*	
HMIP1.4.1		Waste-form and backfill consolidation	
HMIP1.4.2	R	Vault collapse	DOE1.4.4
HMIP1.5	G	*Hydrogeological effects*	
HMIP1.5.1	E	Desaturation (pumping) effects	
HMIP1.5.2		Disturbed zone (hydromechanical) effects	
HMIP1.5.3		Gas production (unsaturated flow)	
HMIP1.5.4		Saturated groundwater flow	
HMIP1.5.5	R	Transport of chemically active substances into the near-field	DOE1.5.4
HMIP1.6	G	*Thermal Effects*	
HMIP1.6.1		Rock-mass changes (thermal effects)	
HMIP1.6.2		Hydrogeological changes (thermal effects)	
HMIP1.6.3		Chemical changes (thermal effects)	
HMIP1.6.4		Transport (diffusion) effects (thermal effects)	

CODE	Screen	FEP NAME	SEE
NAGRA0.1	R	Radioactive decay	DOE1.3.1
NAGRA0.2	R	Speciation (including gases/volatiles)	AECL1.80
NAGRA1.2	R	Radionuclide inventory	AECL1.53
NAGRA1.4	H	Void space	
NAGRA1.8	R	Heat output (radionuclide decay heat)	SKI1.1.2
NAGRA1.10	R	Radiation damage	AECL1.67
NAGRA1.13		Selective leaching	
NAGRA1.14		Coprecipitates/solid solutions	
NAGRA1.15		Elemental solubility limits	
NAGRA1.16		Solute transport resistance	
NAGRA1.17		Iron corrosion products	
NAGRA1.20	R	Radionuclide source term	AECL1.78
NAGRA1.21	R	Colloid formation	HMIP1.6.9
NAGRA1.22	R	Microbial activity	DOE1.6.6
NAGRA1.23	R	Radiolysis	AECL1.69
NAGRA1.24	R	He gas production	IAEA3.4.3
NAGRA1.25	E	Quality control	
NAGRA2.1	H	Cast steel canister	
NAGRA2.2	P	Canister thickness	
NAGRA2.3		Corrosion on wetting	
NAGRA2.4	R	Oxic corrosion	DOE1.1.1
NAGRA2.5		Microbially mediated corrosion	
NAGRA2.6	sub	Anoxic corrosion	
NAGRA2.7	sub	Localised corrosion	
NAGRA2.8	T	Total corrosion rate	
NAGRA2.9	sub	Stress corrosion cracking	
NAGRA2.10	?	Canister (other effects)	
NAGRA2.11		Radiation shielding	
NAGRA2.12a		Canister failure (alternative modes)	
NAGRA2.12b		Canister failure (reference)	
NAGRA2.13		Residual canister (crack/hole effects)	
NAGRA2.14		Chemical buffering (canister corrosion products)	
NAGRA2.15	R	Radionuclide sorption and co-precipitation	DOE2.4.5
NAGRA2.16	R	Hydrogen production	DOE1.2.1
NAGRA2.17		Effect of hydrogen on corrosion	
NAGRA2.18		Corrosion products (physical effects, including volume increase)	
NAGRA2.19		Canister temperature	
NAGRA2.20		Radionuclide transport	
NAGRA2.21	E	Quality control	
NAGRA2.22	E	Mis-sealed canister	
NAGRA3.1		Bentonite emplacement and composition	
NAGRA3.2		Thermal evolution	

CODE	Screen	FEP NAME	SEE
NAGRA3.3	R	Bentonite saturation	SKI5.14
NAGRA3.4		Bentonite swelling pressure	
NAGRA3.5	P	Bentonite plasticity	
NAGRA3.6	T	Bentonite corrosion/colloid formation	
NAGRA3.7		Canister sinking	
NAGRA3.8		Buffer impermeability	
NAGRA3.9		Bentonite porewater chemistry	
NAGRA3.10		Radionuclide retardation	
NAGRA3.11		Colloid filtration	
NAGRA3.12		Mineralogical alteration	
NAGRA3.13		Bentonite cementation	
NAGRA3.14		Canister/bentonite interaction	
NAGRA3.15		Gas permeability	
NAGRA3.16		Radionuclide transport through buffer	
NAGRA3.17	R	Microbial activity	DOE1.6.6
NAGRA3.18		Elemental solubility/precipitation	
NAGRA3.19	R	Radiolysis	AECL1.69
NAGRA3.20		Interaction bewteen canisters	
NAGRA3.21	E	Inhomogeneities	
NAGRA3.22	E	Quality control	
NAGRA3.23	E	Poor emplacement of buffer	
NAGRA3.24		Organics/contamination of bentonite	
NAGRA3.25		Interaction with cement components	
NAGRA4.1	G	Excavation-disturbed zone (EDZ)	
NAGRA4.2		Natural radionuclides/elements	
NAGRA4.3	R	Desaturation/resaturation of excavation-disturbed zone	SKI5.14
NAGRA4.4		Effect of bentonite swelling on excavation-disturbed zone	
NAGRA4.5		Geochemical alteration	
NAGRA4.6		Groundwater chemistry	
NAGRA4.7		Water flow at the bentonite/host rock interface	
NAGRA4.8		Radionuclide migration	
NAGRA4.9	R	Radionuclide retardation	NAGRA3.10
NAGRA4.10		Elemental solubility	
NAGRA4.11	R	Gas transport/dissolution	DOE1.2.6
NAGRA4.12	R	Colloids	AECL1.15
NAGRA4.13		Radionuclide release from excavation-disturbed zone	
NAGRA4.15	G	TRU silos (siting)	
NAGRA4.16	P	Access tunnels and shafts	
NAGRA4.17	P	Shaft and tunnel seals	
NAGRA4.18		Oil or organic fluid spill	
NAGRA4.19		TRU silos high pH plume	

Appendix B: *Reduced List of Near-Field Barrier FEPs: Sorted by Category*

Reduced List of Near-Field Barrier FEPs: Sorted by Category

NEAR-FIELD FEPs: WASTE PACKAGE (WASTE + CANISTER)					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Container corrosion products					Evolving properties of container
Container failure (early)					Evolving properties of container
Container failure (long-term)					Evolving properties of container
Container healing					Evolution of container
Inventory					Evolving radionuclide inventory
Other wastes (other than vitrified HLW)					Inventory
Structural container metal corrosion					Evolving properties of container
Physical degradation of concrete					Evolving properties of cement matrix
Chemical degradation of concrete					Degradation of concrete
Hydrogen [production] by metal corrosion					Gas generation in waste package
Methane and carbon dioxide [production] by microbial degradation					Gas generation in waste package
Gas generation from concrete					Gas generation in waste package
Active gases					Gas generation in waste package
Toxic gases					Gas generation in waste package
Canister or container movement					Mechanical stress distribution in waste package
Embrittlement					Evolving properties of container
Fracturing					Evolving properties of container
Radiological effects: Material property changes					Radiation effects on mortar/shell
Radiological effects: Decay product gas generation					Radiation effects on mortar/shell
Mechanical canister damage					Evolving properties of container
Release of radionuclides from the failured canister					Transport and release of nuclides from waste package

NEAR-FIELD FEPs: WASTE PACKAGE (WASTE + CANISTER)					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Internal corrosion due to waste					Evolving properties of container
Role of the eventual channeling within the canister					Evolving properties of container
Radiation effects on canister					
Cracking along welds					Evolving properties of container
External stress					Mechanical stress distribution in waste package
Hydrostatic pressure on canister					Mechanical stress distribution in waste package
Internal pressure					Mechanical stress distribution in waste package
Random canister defects - quality control					Evolving properties of container
Common cause canister defects - quality control					Evolving properties of container
Interactions with corrosion products and waste					via Water chemistry in waste package
Changed hydrostatic pressure on canister					Mechanical stress distribution in waste package
Chemical toxicity of wastes					
Heterogeneity of waste forms (chemical, physical)					
Cellulosic degradation					Degradation of organic waste/ion exchange resins
Introduced complexing agents and cellulosics					via Water chemistry
Physico-chemical degradation of wastes [and transport to the far-field]					Degradation of waste
Electrical effects of metal corrosion					via Evolution of waste package
Waste-form and backfill consolidation					
Selective leaching					Water chemistry in waste package
Iron corrosion products					Evolving properties of container
Canister thickness					Evolving properties of container
Corrosion on wetting					Evolving properties of container
Microbially mediated corrosion					Evolving properties of container
Total corrosion rate					Evolving properties of container
Radiation shielding					Evolving properties of container
Canister failure (alternative modes)					Evolving properties of container
Canister failure (reference)					Evolving properties of container
Residual canister (crack/hole effects)					Evolving properties of container
Chemical buffering (canister corrosion products)					Water chemistry in waste package
Effect of hydrogen on corrosion					Evolving properties of container

NEAR-FIELD FEPs: MORTAR (Porous concrete) and SHELL (Reinforced con

FEP NAME	SILO	BLA	BMA	BTF	FEP TITLE / COMMENT
Corrosion products (physical effects, including volume increase)					Evolving properties of container
Canister temperature					Evolving properties of container
Canister sinking					
Canister/bentonite interaction					
Interaction between canisters					Evolving properties of container
Backfill characteristics					Properties of mortar/shell
Backfill evolution					Degradation of mortar/shell
Buffer characteristics					Properties of mortar/shell
Buffer evolution					Degradation of mortar/shell
Fracturing					Degradation of mortar/shell
Geochemical changes in backfill					Degradation of mortar/shell
Degradation of the bentonite by chemical reactions					Degradation of mortar/shell
Effects of bentonite on groundwater chemistry					via Water chemistry in mortar/shell
Coagulation of bentonite					
Sedimentation of bentonite					
Reactions with cement pore water					
Near field buffer chemistry					Water chemistry in mortar/shell
Pertubed buffer material chemistry					Water chemistry in mortar/shell
Radiation effects on bentonite					Radiation effects on mortar/shell
Swelling of bentonite [created]					
Swelling of bentonite into tunnels and cracks					
Uneven swelling of bentonite					
Mechanical failure of buffer/backfill					Degradation of mortar/shell
Erosion of buffer/backfill					Degradation of mortar/shell
Thermal effects on the buffer material					Thermal effects on the mortar/concrete
Preferential pathways in the buffer/backfill					Transport and release of nuclides from mortar/shell
Flow through buffer/backfill					Water movement in and through mortar/shell
Backfill material deficiencies					Properties of mortar/shell
Gas transport in bentonite					Gas flow and transport in mortar/shell

NEAR-FIELD FEPs: MORTAR (Porous concrete) and SHELL (Reinforced concrete)					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Waste-form and backfill consolidation					
Bentonite emplacement and composition					Properties of mortar/shell
Thermal evolution					Temperature
Bentonite swelling pressure					
Bentonite plasticity					
Bentonite corrosion/colloid formation					Colloid generation and transport in mortar/shell
Buffer impermeability					Properties of mortar/shell
Bentonite porewater chemistry					Water chemistry in mortar/shell
Colloid filtration					Colloid generation and transport in mortar/shell
Mineralogical alteration					Degradation of mortar/shell
Bentonite cementation					Degradation of mortar/shell
Gas permeability					Gas flow and transport in mortar/shell
Radionuclide transport through buffer					Transport and release of nuclides from mortar/shell
Organics/contamination of bentonite					Properties of mortar/shell
Interaction with cement components					Water chemistry in mortar/shell
Effect of bentonite swelling on excavation-disturbed zone					
Water flow at the bentonite/host rock interface					

NEAR-FIELD FEPs: BACKFILL (sand/bentonite and bentonite)					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Backfill characteristics					Properties of backfill
Backfill evolution					Degradation/alteration of backfill
Buffer characteristics					Properties of backfill
Buffer evolution					Degradation/alteration of backfill
Fracturing					Degradation/alteration of backfill
Geochemical changes in backfill					Degradation/alteration of backfill
Degradation of the bentonite by chemical reactions					Degradation/alteration of backfill
Effects of bentonite on groundwater chemistry					via Water chemistry in backfill
Coagulation of bentonite					Degradation/alteration of backfill
Sedimentation of bentonite					Degradation/alteration of backfill
Reactions with cement pore water					Water chemistry in backfill
Near field buffer chemistry					Water chemistry in backfill
Pertubed buffer material chemistry					Water chemistry in backfill
Radiation effects on bentonite					Radiation effects on backfill
Swelling of bentonite [created]					Bentonite swelling in backfill
Swelling of bentonite into tunnels and cracks					Bentonite swelling in backfill/Properties backfill
Uneven swelling of bentonite					Bentonite swelling in backfill/Properties backfill
Mechanical failure of buffer/backfill					Degradation/alteration of backfill
Erosion of buffer/backfill					Degradation/alteration of backfill
Thermal effects on the buffer material					Thermal effects on the backfill material
Preferential pathways in the buffer/backfill					Transport and release of nuclides from backfill

NEAR-FIELD FEPs: BACKFILL (sand/bentonite and bentonite)					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Flow through buffer/backfill					Water movement in and through backfill
Backfill material deficiencies					Properties of backfill
Gas transport in bentonite					Gas flow and transport in backfill
Waste-form and backfill consolidation					
Bentonite emplacement and composition					Properties of backfill
Thermal evolution					Temperature of backfill
Bentonite swelling pressure					Properties of backfill
Bentonite plasticity					Properties of backfill
Bentonite corrosion/colloid formation					Colloid generation and transport in backfill
Buffer impermeability					Degradation/alteration of backfill
Bentonite porewater chemistry					Water chemistry in backfill
Colloid filtration					Colloid generation and transport in backfill
Mineralogical alteration					Degradation/alteration of backfill
Bentonite cementation					Degradation/alteration of backfill
Gas permeability					Gas flow and transport in backfill
Radionuclide transport through buffer					Transport and release of nuclides from backfill
Organics/contamination of bentonite					Properties of backfill
Interaction with cement components					via Water chemistries
Effect of bentonite swelling on excavation-disturbed zone					via Mechanical stress distribution in backfill
Water flow at the bentonite/host rock interface					Water movement in and through backfill

NEAR-FIELD FEPs: NEAR-FIELD ROCK					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Reflooding					Resaturation state of near-field rock
Seal evolution					Shaft and tunnel seal degradation
Seal failure					Shaft and tunnel seal degradation
Changes in situ stress field					Stress field in near-field rock
Subsidence/collapse					Cave-in
Rock creep					Creeping of rock mass in near-field
Geochemical changes in host rock					Properties or Degradation/alteration of near-field rock
Change of groundwater chemistry in nearby rock					Water chemisrty in near-field rock
Excavation/backfilling effects on nearby rock					Excavation effects on near-field rock
Degradation of hole- and shaft seals					Shaft and tunnel seal degradation
Shaft and Borehole Seal Degradation					Shaft and tunnel seal degradation
Desaturation (pumping) effects					Resaturation state of near-field rock
Disturbed zone (hydromechanical) effects					Stress field in near-field rock
Transport of chemically active substances into the near-field					via Groundwater chemistry (far field)
Natural radionuclides/elements					via Groundwater chemistry (far field)
Effect of bentonite swelling on excavation-disturbed zone					Stress field in near-field rock
Water flow at the bentonite/host rock interface					Groundwater flow through near-field rock
Radionuclide release from excavation-disturbed zone					Transport and release of nuclides from near-field rock
Access tunnels and shafts					
Shaft and tunnel seals					
Oil or organic fluid spill					
TRU silos high pH plume					via Water chemistry

NEAR-FIELD FEPs: GENERAL					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Chemical interactions (expected)					Water chemistry
Chemical interactions (long-term)					Water chemistry
Chemical kinetics					Water chemistry
Colloids					Colloid generation and transport
Complexation by organics					Water chemistry
Convection					Water movement
Diffusion					Diffusion
Dispersion					Groundwater flow
Electrochemical gradients					Electrochemical gradients
Excessive hydrostatic pressures					Stress field
Formation of cracks					Fast pathways
Long-term physical stability					Degradation
Precipitation and dissolution					Precipitation/dissolution
Pseudo-colloids					Colloid generation and transport
Radiation damage					Radiation effects
Radiolysis					Radiolysis
Speciation					Water chemistry
Time dependence					
Gas transport					Gas flow and transport
Flammability					
Radioactive decay and ingrowth					Radioactive decay and ingrowth
Nuclear criticality					
Changes in moisture content					Resaturation state
Groundwater flow (unsaturated conditions)					Groundwater flow
Transport of chemically active substances into the near-field					via Water chemistry (far field)
Chemical changes					Water chemistry

NEAR-FIELD FEPs: GENERAL					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Microbiological effects					via Microbial activity
Advection					Groundwater flow
Diffusion					Diffusion
Hydrodynamic dispersion					Groundwater flow
Solubility constraints					Precipitation/dissolution
Sorption					Sorption
Organic colloid transport					Colloid generation and transport
Isotopic dilution					via Water chemistry
Gas Transport					Gas flow and transport
Solution					Water chemistry
Gas phase					Gas generation
Gas-induced groundwater transport					via Gas pressure
Thermally induced groundwater transport					via Temperature
Geochemical change					Degradation / Alteration
Thermal effects					via Temperature
Chemical effects: Corrosion					Degradation
Chemical effects: Interactions of waste package and rock					via Water chemistry
Chemical effects: Gas generation					via Gas generation
Mechanical effects: Local fracturing					Mechanical stress
Differing thermal expansion					Mechanical stress
Physico-chemical phenomena/effects (eg. colloid formation)					
Radioactive decay; heat					via Evolving radionuclide inventory
Recoil of alpha-decay					Recoil from alpha decay
Gas generation: He production					Gas generation
H2/O2 explosions					
Pb-I reactions					
Recrystallization					Precipitation/dissolution
Redox potential					Redox front

NEAR-FIELD FEPs: GENERAL					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Dissolution chemistry					Precipitation/dissolution
Coupled effects (electrophoresis)					via Electrochemical gradients
Natural telluric electrochemical reactions					via Electrochemical gradients
Corrosive agents, Sulphides, oxygen etc					Water chemistry
Thermal cracking					Degradation
Electro-chemical cracking					Degradation
Stress corrosion cracking					Degradation
Saturation of sorption sites					Sorption
Colloid generation - source					Colloid generation and transport
Redox front					Redox front
Swelling of corrosion products					Mechanical stress distribution
Soret effect					
Oxidizing conditions					Water chemistry
pH-deviations					Water chemistry
Colloids, complexing agents					Colloid generation and transport
Reconcentration					Precipitation/dissolution
Thermochemical changes					
Complexing agents					Water chemistry
Hydraulic conductivity change - Excavation/backfilling effect					
Mechanical effects - Excavation/backfilling effects					
Extreme channel flow of oxidants and nuclides					Fast pathways
Saline (or fresh) groundwater intrusion					
Resaturation					Resaturation state
Colloid generation and transport					Colloid generation and transport

NEAR-FIELD FEPs: GENERAL					
FEP NAME	**SILO**	**BLA**	**BMA**	**BTF**	**FEP TITLE / COMMENT**
Dispersion					Groundwater flow
Dilution					Water chemistry
Natural gas intrusion					
Multiphase flow and gas driven flow					Gas flow and Groundwater flow
Solubility limit					Precipitation/dissolution
Dissolution, precipitation and crystalisation					Precipitation/dissolution
Colloid formation, dissolution and transport					Colloid generation and transport
Complexing agents					Water chemistry
Mass, isotopic and species dilution					Water chemistry
Chemical gradients (electrochemical effects and osmosis)					Water chemistry
Material defects, e.g. early canister failure					Properties
Thermal effects (eg. concrete hydration)					via Temperature
Induced chemical changes (solubility, sorption, species equilibrium, mineralisation)					via Water chemistries
Interactions of host materials and groundwater with repository material (eg, concrete carbonation,sulphate attack)					via Water chemistries
Interactions of waste and repository materials with host materials (eg. electrochemical, corrosive agents)					via Water chemistries
Gas effects (pressuration, disruption, explosion, fire)					
Thermo-chemical effects					
Gas production (unsaturated flow)					Gas generation
Coprecipitates/solid solutions					Precipitation/dissolution
Elemental solubility limits					Precipitation/dissolution
Solute transport resistance					Water chemistry
Radionuclide transport					Transport and release of radionuclides
Radionuclide retardation					Anion exclusion
Elemental solubility/precipitation					Precipitation/dissolution
Geochemical alteration					Degradation / alteration
Groundwater chemistry					Precipitation/dissolution
Radionuclide migration					Transport and release of radionuclides
Elemental solubility					Precipitation/dissolution

Appendix C: *FEP List for Near-Field PID for L/ILW Disposal*[7]

FEP Title	Silo	BMA	BLA	BTF
Alteration/weathering of flow paths in near-field rock	Y	Y	Y	Y
Anion exclusion				
in mortar [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y			
in shell [*as above*]	Y	Y	Y	Y
in backfill [*as above*]	Y	Y	Y	Y
in near-field rock [*as above*]	Y	Y	Y	Y
Bentonite swelling in backfill	Y			
Cave-in (near-field rock)	Y	Y	Y	Y
Change in radionuclide inventory [*changed to "Evolving radionuclide inventory"]*	Y	Y	Y	Y
Colloid generation in waste package	Y	Y	Y	Y
Colloid generation and transport in				
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Creeping of rock mass in near-field [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
Degradation/alteration of				
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
Degradation of cell walls (mortar/shell)	Y			
Degradation of inorganic waste	Y	Y	Y	Y
Degradation of metal waste	Y	Y	Y	Y
Degradation of organic waste	Y	Y	Y	Y
Degradation of rock reinforcement and grout	Y	Y	Y	Y
Degradation of steel reinforcement in shell	Y	Y	Y	Y
Differential thermal expansion of near-field barriers [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
Diffusion through				
and in waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Dispersion in				
backfill [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Electrochemical effects in waste package [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y

7 Amendments (deletions) made since the original list was prepared, e.g. as a result of Workshop discussions (Stenhouse et al., 2000, are identified by underscoring/italics.

FEP Title	Silo	BMA	BLA	BTF
Electrochemical gradients in				
mortar [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y			
shell [*as above*]	Y	Y	Y	Y
backfill [*as above*]	Y	Y	Y	Y
near-field rock [*as above*]	Y	Y	Y	Y
Evolving properties of				
bitumen matrix	Y	Y	Y	Y
cement matrix	Y	Y	Y	Y
container including degradation/corrosion	Y	Y	Y	Y
Excavation effects on near-field rock	Y	Y	Y	Y
Fast pathways in near-field rock				
[*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
Fault movements and activation				
[*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
Filtration in backfill (bentonite, bentonite-sand)	Y			
Gas flow and transport in				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Gas generation (bulk gas formation) in				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Groundwater flow through near-field rock	Y	Y	Y	Y
Matrix diffusion in				
mortar [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y			
shell [*as above*]	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Mechanical stress distribution in				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
Microbial activity in				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Precipitation/dissolution in				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Properties of				
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Radiation effects on				

mortar [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y			
shell [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
backfill [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y

FEP Title	Silo	BMA	BLA	BTF
Radioactive decay in waste	Y	Y	Y	Y
Radioactive decay and ingrowth of nuclides in				
waste package	Y			
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Radiolysis in				
waste package [*subsequently deleted for BMA, BLA and BTF following Workshop*]	Y	Y	Y	Y
mortar [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y			
shell [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
backfill [*as above*]	Y	Y	Y	Y
near-field rock [*as above*]	Y	Y	Y	Y
Radionuclide reconcentration in near-field rock [*subsequently deleted following Workshop]*	Y	Y	Y	Y
Recoil of alpha decay [*subsequently deleted following Workshop (Stenhouse et al., 2000)*]	Y	Y	Y	Y
Redox front/Redox heterogeneity in				
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Release from L/ILW waste	Y	Y	Y	Y
Resaturation/Resaturation state of				
waste package	Y			
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Shaft and tunnel seal degradation	Y	Y	Y	Y
Sorption on				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Stress field in near-field rock	Y	Y	Y	Y
Temperature of				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Transport and release of nuclides from				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Water chemistry in				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y
backfill	Y	Y	Y	Y
near-field rock	Y	Y	Y	Y
Water movement in and through				
waste package	Y	Y	Y	Y
mortar	Y			
shell	Y	Y	Y	Y

backfill	Y	Y	Y	Y
near-field rock (see Groundwater flow)	Y	Y	Y	Y

Appendix D: *Compilation of Far-Field FEPs from International FEP List*

FEPs from the following lists appear in this appendix (corresponding code in parentheses)[8]:

- Atomic Energy of Canada Ltd. (*AECL*): spent fuel disposal; Goodwin *et al*. (1991).
- Department of the Environment, U.K. (*DOE*): L/ILW waste disposal; Thorne (1992).
- International Atomic Energy Agency (*IAEA*): IAEA (1981).
- Nagra, Switzerland (*PGA*): vitrified HLW disposal; Project Gewähr (1985).
- SKI/SKB (*SKI*): spent fuel disposal; Andersson (1989).
- Sandia National Laboratories, U.S.A. (*SNL*): HLW disposal; Cranwell *et al.* (1982).
- U.K. Nirex Ltd. (*UKN*): L/ILW disposal Hodgkinson and Sumerling (1989).
- Department of the Environment, U.K. (*HMIP*); L/ILW disposal; Miller and Chapman (1992).
- Nagra Kristallin I (*NAGRA*): vitrified HLW disposal; Nagra (1994).

[8] A list of over 1500 'raw' FEPS (applicable to near-and far-fields) was compiled in Stenhouse *et al.* (1993). In this compilation, the FEP list of Nuclear Energy Agency (NEA, 1992) was included, but is identical to that of U.K. Nirex Ltd. (UKN) above. This current, reduced set of far-field FEPs (this Appendix) does not include FEPs from the list prepared by Eng *et al.* (1994), which was compiled but used only for comparison purposes.

CODE	Screen	FEP NAME	SEE
AECL1.3	R	Biological activity	AECL2.43
AECL1.4	?	Boundary conditions	
AECL1.9	G	Chemical gradients	
AECL1.10	G	Chemical interactions (expected)	
AECL1.11	G	Chemical interactions (long-term)	
AECL1.12	G	Chemical interactions (other)	
AECL1.13	G	Chemical kinetics	
AECL1.14	R	Climate change	AECL2.8
AECL1.15	G	Colloids	
AECL1.16	G	Complexation by organics	
AECL1.24	sub	Convection	DOE2.2.11
AECL1.27	?	Coupled processes	
AECL1.28	H	Criticality	
AECL1.29	R	Diffusion	AECL2.15
AECL1.30	R	Dispersion	AECL2.17
AECL1.31	E	Earthquakes	
AECL1.32		Electrochemical gradients	
AECL1.34	sub	Excessive hydrostatic pressures	AECL2.33
AECL1.37	sub	Formation of cracks	PGA2.6
AECL1.38	R	Formation of gases	AECL2.26
AECL1.40	?	Geochemical pump	
AECL1.41	sub	Glaciation	AECL2.8
AECL1.42	?	Global effects	
AECL1.43	sub	Hydraulic conductivity	AECL2.33
AECL1.44	sub	Hydraulic head	AECL2.33
AECL1.46	E	Hydrothermal alteration	
AECL1.50	?	Interfaces (boundary conditions)	
AECL1.51	E	Intrusion (animal)	
AECL1.52	E	Intrusion (human)	
AECL1.55	?	Long-term physical stability	
AECL1.56	?	Long-term transients	
AECL1.58	R	Microbes	AECL2.43
AECL1.59	R	Microorganisms	AECL2.43
AECL1.60	E	Monitoring and remedial activities	
AECL1.64	E	Preclosure events	
AECL1.65	R	Precipitation and dissolution	AECL2.46
AECL1.66	sub	Pseudo-colloids	AECL2.9
AECL1.68	R	Radioactive decay	AECL2.48
AECL1.69	?	Radiolysis	
AECL1.70	R	Recharge groundwater	HMIP2.2.1
AECL1.71	E	Reflooding	
AECL1.72	E	Retrievability	
AECL1.73	E	Sabotage and improper operation	
AECL1.76	R	Sorption	AECL2.58
AECL1.77	sub	Sorption: non-linear	AECL2.58
AECL1.80	sub	Speciation	SKI4.19
AECL1.81	?	Stability	
AECL1.84	?	Temperature rises (unexpected effects)	
AECL1.85	?	Time dependence	
AECL1.86	R	Transport in gases or of gases	AECL2.26
AECL1.87	?	Uncertainties	
AECL1.90	sub	Unsaturated transport	AECL2.55
AECL2.1	E	Blasting and vibration	
AECL2.2	E	Bomb blast	
AECL2.3	E	Borehole - well	
AECL2.4	E	Borehole seal failure/open boreholes	
AECL2.5	E	Boreholes - exploration	

CODE	Screen	FEP NAME	SEE
AECL2.6	E	Boreholes - unsealed	
AECL2.7	E	Cavitation	
AECL2.8	B	Climate change	
AECL2.9		Colloid formation	
AECL2.10	sub	Complexation by organics	SKI4.1.9
AECL2.11	?	Conceptual model - hydrology	
AECL2.12	?	Correlation	
AECL2.14	sub	Dewatering	AECL2.55
AECL2.15		Diffusion	
AECL2.16	sub	Discharge zones	HMIP2.2.1
AECL2.17		Dispersion	
AECL2.18	sub	Drought	HMIP2.2.1
AECL2.19	E	Earthmoving	
AECL2.20	sub	Earthquakes	NAGRA9.5
AECL2.21	B	Erosion	
AECL2.22	E	Explosion	
AECL2.23	R	Faulting	PGA2.6
AECL2.24	sub	Flood	HMIP2.2.1
AECL2.25	sub	Fulvic acid	SKI4.1.9
AECL2.26		Gases and gas transport	
AECL2.27	R	Geothermal gradient effects	DOE2.2.11
AECL2.28	sub	Glaciation	AECL2.8
AECL2.29	sub	Greenhouse effect	AECL2.8
AECL2.30	R	Groundwater - evolution	NAGRA5.8
AECL2.31	R	Groundwater composition change	NAGRA5.8
AECL2.32	sub	Humic acid	SKI4.1.9
AECL2.33		Rock properties (hydrogeological)	
AECL2.34	E	Intrusion (magmatic)	
AECL2.35	E	Intrusion (mines)	
AECL2.36	sub	Isostatic rebound	IAEA1.14
AECL2.37	E	Magmatic activity	
AECL2.38	E	Magnetic poles	
AECL2.39		Matrix diffusion	
AECL2.40	E	Metamorphic activity	
AECL2.41	E	Meteorite	
AECL2.42	sub	Methane	AECL2.26
AECL2.43		Microbes	
AECL2.44	E	Mines	
AECL2.45	E	Ozone layer	
AECL2.46		Radionuclide precipitation - dissolution	
AECL2.47	sub	Pseudo-colloids	AECL2.9
AECL2.48		Radioactive decay	
AECL2.49	NR	Radiolysis, radiation damage	
AECL2.50	R	Recharge groundwater	HMIP2.2.1
AECL2.51		Rock properties	
AECL2.52	E	Rock properties - undetected features	
AECL2.53	E	Sabotage	
AECL2.54	sub	Salinity effects on flow	SKI5.1
AECL2.55		Saturation	
AECL2.56	E	Shaft seal failure	
AECL2.57	E	Solution mining	
AECL2.58		Sorption	
AECL2.59	sub	Sorption - non-linear	AECL2.58
AECL2.60	sub	Speciation	SKI4.1.9

CODE	Screen	FEP NAME	SEE
AECL2.61	sub	Topography - current	AECL2.21
AECL2.62	sub	Topography - future	AECL2.21
AECL2.63	?	Turbulence	
AECL2.64	?	Uncertainties	
AECL2.65	sub	Unsaturated rock	AECL2.55
AECL2.66	E	Vault closure (incomplete)	
AECL2.67	S	Vault heating effects	DOE2.2.11
AECL2.68	E	Vulcanism	
AECL2.69	E	Wells	
AECL2.70	E	Wells (high demand)	
DOE1.2.4.1	sub	Tritiated hydrogen	AECL2.26
DOE1.2.4.2	sub	Active methane and carbon dioxide	AECL2.26
DOE1.2.4.3	sub	Other active gases	AECL2.26
DOE1.2.5	sub	Toxic gases	AECL2.26
DOE1.2.6.5	sub	Gas flow into and through the far-field	AECL2.26
DOE1.3.1	R	Radioactive decay and ingrowth	AECL2.48
DOE1.3.2	H	Nuclear criticality	
DOE1.4.2		Changes in situ stress field	
DOE1.4.4.2	sub	Natural rock subsidence	IAEA1.14
DOE1.4.5	sub	Rock creep	AECL2.51
DOE1.4.6	sub	Fracturing	PGA2.6
DOE1.5.1.1	sub	Moisture loss due to dewatering	AECL2.55
DOE1.5.1.2	sub	Moisture loss due to stress relief	AECL2.55
DOE1.5.2.1	sub	Groundwater flow initial conditions	DOE2.4.1
DOE1.5.2.2	sub	Groundwater flow due to gas production	DOE2.4.1
DOE1.5.3	sub	Groundwater flow (saturated conditions)	DOE2.4.1
DOE1.6.3	G	*Fracture changes*	
DOE1.6.3.1	sub	Aperture	DOE2.2.7.3
DOE1.6.3.2	sub	Length	DOE2.2.7.3
DOE1.6.4	G	*Hydrological changes*	
DOE1.6.4.1	sub	Fluid pressure	DOE2.4.1
DOE1.6.4.2	sub	Density	DOE2.4.1
DOE1.6.4.3	sub	Viscosity	DOE2.4.1
DOE1.6.5.7	sub	Solubility	NAGRA5.8
DOE1.6.5.8	R	Sorption	AECL2.58
DOE2.1.1	E	Meteorite impact	
DOE2.2.1	sub	*Regional tectonic*	IAEA1.14
DOE2.2.1.1	sub	Uplift	IAEA1.14
DOE2.2.1.2	sub	Subsidence	IAEA1.14
DOE2.2.1.3	sub	Lateral and/or vertical flexure	IAEA1.14
DOE2.2.2	E	*Magmatic*	
DOE2.2.2.1	E	Intrusive	
DOE2.2.2.2	E	Extrusive	
DOE2.2.2.3	E	Hydrothermal	
DOE2.2.3	E	*Metamorphism*	
DOE2.2.3.1	E	Contact	
DOE2.2.3.2	E	Regional	
DOE2.2.3.3	E	Dislocation	
DOE2.2.4	E	Diagenesis	
DOE2.2.5	E	Diapirism	
DOE2.2.6	R	*Seismicity*	NAGRA9.5
DOE2.2.6.1	sub	Repository-induced	NAGRA9.5
DOE2.2.6.2	sub	Externally-induced	NAGRA9.5
DOE2.2.6.3	sub	Natural	NAGRA9.5

CODE	Screen	FEP NAME	SEE
DOE2.2.7	R	*Faulting/fracturing*	PGA2.6
DOE2.2.7.1	sub	Activation	PGA2.6
DOE2.2.7.2	sub	Generation	PGA2.6
DOE2.2.7.3		Fracture properties	
DOE2.2.8	sub	Major incision	PGA2.6
DOE2.2.9	sub	Weathering	AECL2.21
DOE2.2.10	sub	Effects of natural gases	AECL2.26
DOE2.2.11		Geothermal effects	
DOE2.3.1	sub	Variation in groundwater recharge	HMIP2.2.1
DOE2.3.2	sub	Groundwater losses (e.g. evaporation)	HMIP2.2.1
DOE2.3.3	R	*Rock property changes*	AECL2.51
DOE2.3.3.1	sub	Porosity	AECL2.51
DOE2.3.3.2	sub	Permeability	AECL2.51
DOE2.3.3.3	sub	Microbial pore blocking	AECL2.43
DOE2.3.3.4	sub	Channel formation/closure	DOE2.2.7.3
DOE2.3.4	R	*Groundwater flow*	DOE2.4.1
DOE2.3.4.1	sub	Darcy	DOE2.4.1
DOE2.3.4.2	sub	Non-Darcy	DOE2.4.1
DOE2.3.4.3	R	Intergranular (matrix)	AECL2.39
DOE2.3.4.4	sub	Fracture	DOE2.4.1
DOE2.3.4.5	sub	Effects of solution channels	DOE2.4.1
DOE2.3.4.6	R	Unsaturated	AECL2.55
DOE2.3.5	?	*Salinity*	
DOE2.3.5.1	sub	Effects of differences in salinity	SKI5.1
DOE2.3.5.2	sub	Effects at the saline-freshwater interface	SKI5.1
DOE2.3.5.3	?	Implications of evaporite deposits/minerals	
DOE2.3.6	sub	Variations in groundwater temperature	DOE2.2.11
DOE2.4.1		Groundwater flow (advection)	
DOE2.4.2	R	*Diffusion*	AECL2.15
DOE2.4.2.1	sub	Bulk	AECL2.15
DOE2.4.2.2	R	Matrix	AECL2.39
DOE2.4.2.3	sub	Surface	AECL2.15
DOE2.4.3	R	Hydrodynamic dispersion	AECL2.17
DOE2.4.4	sub	*Solubility constraints*	NAGRA5.8
DOE2.4.4.1	sub	Effects of pH and Eh	NAGRA5.8
DOE2.4.4.2	sub	Effects of ionic strength	NAGRA5.8
DOE2.4.4.3	sub	Naturally-occurring complexing agents	SKI4.1.9
DOE2.4.4.4	sub	Complexing agents formed in the near-field	SKI4.1.9
DOE2.4.4.5	R	Naturally-occuring colloids	AECL2.9
DOE2.4.4.6	R	Colloids formed in the near-field	AECL2.9
DOE2.4.4.7	sub	Major ions migrating from the near-field	NAGRA5.8
DOE2.4.4.8	R	Effects of microbial activity	AECL2.43
DOE2.4.5	R	*Sorption*	AECL2.58
DOE2.4.5.1	sub	Linear	AECL2.58
DOE2.4.5.2	sub	Non-linear	AECL2.58
DOE2.4.5.3	sub	Reversible	AECL2.58
DOE2.4.5.4	sub	Irreversible	AECL2.58
DOE2.4.5.5	sub	Effects of pH and Eh	NAGRA5.8
DOE2.4.5.6	sub	Effects of ionic strength	NAGRA5.8
DOE2.4.5.7	R	Naturally-occurring organic complexing agents	SKI4.1.9
DOE2.4.5.8	sub	Naturally-occuring inorganic complexing agents	SKI4.1.9
DOE2.4.5.9	sub	Complexing agents formed in the near-field	SKI4.1.9

CODE	Screen	FEP NAME	SEE
DOE2.4.5.10	sub	Effects of naturally-occurring colloids	AECL2.9
DOE2.4.5.11	sub	Effects of colloids formed in the near-field	AECL2.9
DOE2.4.5.12	sub	Major ions migrating from the near-field	NAGRA5.8
DOE2.4.5.13	R	Effects of microbial activity	AECL2.43
DOE2.4.6	sub	Fracture mineralisation	DOE2.2.7.3
DOE2.4.7	sub	*Organic colloid transport*	AECL2.9
DOE2.4.7.1	sub	Porous media	AECL2.9
DOE2.4.7.2	sub	Fractured media	AECL2.9
DOE2.4.7.3	sub	Effects of pH and Eh	NAGRA5.8
DOE2.4.7.4	sub	Effects of ionic strength	NAGRA5.8
DOE2.4.8	sub	*Inorganic colloid transport*	AECL2.9
DOE2.4.8.1	sub	Porous media	AECL2.9
DOE2.4.8.2	sub	Fractured media	AECL2.9
DOE2.4.8.3	sub	Effects of pH and Eh	NAGRA5.8
DOE2.4.8.4	sub	Effects of ionic strength	NAGRA5.8
DOE2.4.9	sub	Transport of radionuclides bound to microbes	AECL2.43
DOE2.4.10	sub	Isotopic dilution	NAGRA5.8
DOE2.4.11	G	*Gas Transport*	AECL2.26
DOE2.4.11.1	sub	Solution	AECL2.26
DOE2.4.11.2	sub	Gas phase	AECL2.26
DOE2.4.12	sub	Gas-induced groundwater transport	AECL2.26
DOE2.4.13	sub	*Thermally induced groundwater transport*	DOE2.2.11
DOE2.4.13.1	sub	Repository-induced	DOE2.2.11
DOE2.4.13.2	sub	Naturally-induced	DOE2.2.11
DOE2.4.14	sub	Biogeochemical changes	AECL2.43
DOE3.1.1.1	sub	Precipitation (climate)	AECL2.8
DOE3.1.1.3	sub	Sea level rise	HMIP2.2.1
DOE3.1.1.6	sub	Potential evaporation	AECL2.8
DOE3.1.2	sub	*Glacial/interglacial cycling*	AECL2.8
DOE3.1.2.1	sub	Precipitation (climate)	HMIP2.2.1
DOE3.1.2.3	sub	Sea level changes (rise/fall)	HMIP2.2.1
DOE3.1.2.6	sub	Seasonally frozen ground	HMIP2.2.1
DOE3.1.2.7	sub	Permanently frozen ground	HMIP2.2.1
DOE3.1.2.8	sub	Glaciation	AECL2.8
DOE3.1.2.9	sub	Deglaciation	AECL2.8
DOE3.1.2.10	R	Potential evaporation	HMIP2.2.1
DOE3.1.3	sub	*Exit from glacial/interglacial cycling*	AECL2.8
DOE3.1.3.1	sub	Greenhouse gas induced	AECL2.8
DOE3.1.3.2	sub	Other causes	AECL2.8
DOE3.2.1	R	*Generalised denudation*	AECL2.21
DOE3.3.3	R	Groundwater recharge	HMIP2.2.1
DOE3.3.4.5	R	Effects of sea level change	HMIP2.2.1
DOE3.5.3	R	Groundwater discharge to wells or springs	HMIP2.2.1
DOE3.5.4	R	Groundwater discharge to freshwaters	HMIP2.2.1
DOE3.5.5	R	Groundwater discharge to estuaries	HMIP2.2.1
DOE3.5.6	R	Groundwater discharge to coastal waters	HMIP2.2.1
DOE4.1.1	E	*Investigation borehole seal*	
DOE4.1.1.1	E	Failure	
DOE4.1.1.2	E	Degradation	
DOE4.1.2	E	*Shaft or access tunnel seal*	
DOE4.1.2.1	E	Failure	
DOE4.1.2.2	E	Degradation	

CODE	**Screen**	**FEP NAME**	**SEE**
DOE4.1.3	R	*Subsidence*	IAEA1.14
DOE4.1.3.1	R	Fault/fracture induction	PGA2.6
DOE4.2.1	E	Deliberate recovery of wastes or associated materials	
DOE4.2.2	E	Malicious intrusion	
DOE4.2.3	E	Exploratory drilling	
DOE4.2.4	E	Exploitation drilling	
DOE4.2.5	E	Geothermal energy production	
DOE4.2.6	E	Resource mining	
DOE4.2.7	E	Tunnelling	
DOE4.2.8	E	Construction of underground storage/disposal facilities	
DOE4.2.12	E	Groundwater abstraction	
DOE4.2.13	E	Underground weapons testing	
IAEA1.1	R	Climatic change	AECL2.8
IAEA1.2	R	Hydrological change	HMIP2.2.1
IAEA1.3	sub	Sea level change	HMIP2.2.1
IAEA1.6	sub	Glacial erosion	AECL2.21
IAEA1.8	E	Sedimentation	
IAEA1.9	E	Diagenesis	
IAEA1.10	E	Diapirism	
IAEA1.11	R	Faulting/seismicity	NAGRA9.5
IAEA1.12	R	Geochemical change	NAGRA5.8
IAEA1.13	?	*Fluid interactions*	
IAEA1.13.1	sub	Fluid interactions: Groundwater flow	DOE2.4.1
IAEA1.13.2	sub	Fluid interactions: Dissolution	AECL2.46
IAEA1.13.3	E	Fluid interactions: Brine pockets	
IAEA1.14	B	*Uplift/Subsidence*	
IAEA1.14.1	sub	Uplift/Subsidence: Orogenic	IAEA1.14
IAEA1.14.2	sub	Uplift/Subsidence: Epirogenic	IAEA1.14
IAEA1.14.3	sub	Uplift/Subsidence: Isostatic	IAEA1.14
IAEA1.15	E	*Undetected features*	
IAEA1.15.1	E	Undetected features: Faults, shear zones	
IAEA1.15.2	E	Undetected features: Breccia pipes	
IAEA1.15.3	E	Undetected features: Lava tubes	
IAEA1.15.4	E	Undetected features: Intrusive dykes	
IAEA1.15.5	E	Undetected features: Gas or brine pockets	
IAEA1.16[.1]	E	Magmatic activity: Extrusive	
IAEA1.17	E	Meteorite impact	
IAEA2.1	E	*Undetected past intrusion*	
IAEA2.1.1	E	Undetected past intrusion: Boreholes	
IAEA2.1.2	E	Undetected past intrusion: Mine shafts	
IAEA2.2	E	*Inadequate design*	
IAEA2.2.1	E	Inadequate design: Shaft seal failure	
IAEA2.2.2	E	Inadequate design: Exploration borehole seal failure	
IAEA2.3	E	Improper operation: Improper waste emplacement	
IAEA2.4	E	*Transport agent introduction (TAI)*	
IAEA2.4.1	E	TAI: Irrigation	
IAEA2.4.2	E	TAI: Reservoirs	
IAEA2.4.3	E	TAI: Intentional artificial groundwater recharge or withdrawal	
IAEA2.4.4	E	TAI: Chemical liquid waste disposal	
IAEA2.5	R	Climatic change (including climate control)	AECL2.8
IAEA2.6	R	Large-scale hydrological change	HMIP2.2.1

CODE	Screen	FEP NAME	SEE
IAEA2.7	E	*Intentional intrusion*	
IAEA2.7.1	E	Intentional intrusion: War	
IAEA2.7.2	E	Intentional intrusion: Sabotage	
IAEA2.7.3	E	Intentional intrusion: Waste recovery	
IAEA2.8	E	*Inadvertent future intrusion*	
IAEA2.8.1	E	Inadvertent future intrusion: Exploratory drilling	
IAEA2.8.2	E	Inadvertent future intrusion: Archaeological exhumation	
IAEA2.8.3	E	Inadvertent future intrusion: Resource mining (mineral, water, hydrocarbon, geothermal, salt,	
IAEA3.1	R	*Thermal effects*	DOE2.2.11
IAEA3.1.1	sub	Thermal effects: Differential elastic response	DOE2.2.11
IAEA3.1.2	sub	Thermal effects: Non-elastic response	DOE2.2.11
IAEA3.1.3	sub	Thermal effects: Fluid pressure, density, viscosity changes	DOE2.2.11
IAEA3.1.4	sub	Thermal effects: Fluid migration	DOE2.2.11
IAEA3.2.3	R	Chemical effects: Gas generation	AECL2.26
IAEA3.2.4	R	Chemical effects: Geochemical change	NAGRA5.8
IAEA3.3.2	R	Mechanical effects: Local fracturing	PGA2.6
PGA1.1	R	Climate changes	AECL2.8
PGA1.2	sub	Sea-level changes	HMIP2.2.1
PGA1.4	E	Sedimentation	
PGA1.5	sub	Tectonic crustal movements	IAEA1.14
PGA1.6	E	Magma intrusion	
PGA1.7	E	Volcanism	
PGA1.8	E	Diapirism	
PGA1.9	E	Diagenesis	
PGA1.10	E	Metamorphosis	
PGA1.11	sub	Weathering, mineralisation	AECL2.21
PGA1.12	R	Groundwater changes	NAGRA5.8
PGA2.1	E	Earthquakes	
PGA2.2	E	Volcanic eruption	
PGA2.3	E	Meteor impact	
PGA2.4	E	Flooding with extreme erosion	
PGA2.5	E	Hurricane, storms	
PGA2.6		Movements at faults	
PGA2.7	sub	Formation of new faults	PGA2.6
PGA3.13	G	Physico-chemical phenomena/effects (eg. colloid formation)	
PGA3.14	R	Microbiological phenomena/effects	AECL2.43
PGA3.16	E	Failure of shaft sealing	
PGA4.1	E	Direct alterations in hydrogeology	
PGA4.2	E	Injection of liquid waste	
PGA4.3	E	*Drilling*	
PGA4.3.1	E	Drilling: in sediments	
PGA4.3.2	E	Drilling: in host rock	
PGA4.4	E	Geothermal energy production in crystalline rock	

CODE	Screen	FEP NAME	SEE
SKI4.1.1	?	Oxidizing conditions	
SKI4.1.2	?	pH-deviations	
SKI4.1.3	G	Colloids, complexing agents	
SKI4.1.4	R	Sorption	AECL2.58
SKI4.1.5	R	Matrix diffusion	AECL2.39
SKI4.1.6	sub	Reconcentration	AECL2.46
SKI4.1.7	G	Thermochemical changes	
SKI4.1.8	R	Change of groundwater chemistry in nearby rock	NAGRA5.8
SKI4.1.9		Complexing agents	
SKI4.2.1	E	Mechanical failure of repository	
SKI4.2.2.1	sub	Excavation/backfilling effects on nearby rock	AECL2.33
SKI4.2.2.2	sub	Hydraulic conductivity change - excavation effect	AECL2.33
SKI4.2.2.3	sub	Mechanical effects - backfilling effects	AECL2.33
SKI4.2.3	sub	Extreme channel flow of oxidants and nuclides	DOE2.2.7.3
SKI4.2.4	sub	Thermal buoyancy	DOE2.2.11
SKI4.2.5	R	Changes of groundwater flow	DOE2.4.1
SKI4.2.6	R	Faulting	PGA2.6
SKI4.2.7	sub	Thermo-hydro-mechanical effects	DOE2.2.11
SKI4.2.8	sub	Enhanced rock fracturing	PGA2.6
SKI4.2.9	sub	Creeping of rock mass	AECL2.51
SKI4.2.10	sub	Chemical effects of rock reinforcement	NAGRA5.8
SKI5.1		Saline (or fresh) groundwater intrusion	
SKI5.9	E	Unsealed boreholes and/or shafts	
SKI5.11	E	Degradation of hole- and shaft seals	
SKI5.12	E	Future boreholes and undetected past boreholes	
SKI5.13	E	Volcanism	
SKI5.15	E	Earthquakes	
SKI5.16	R	Uplift and subsidence	IAEA1.14
SKI5.17	sub	Permafrost	AECL2.8
SKI5.18	sub	Enhanced groundwater flow	DOE2.4.1
SKI5.19	E	Effect of plate movements	
SKI5.20	E	Changes of the magnetic field	
SKI5.22	sub	Accumulation of gases under permafrost	AECL2.26
SKI5.24	sub	Stress changes of conductivity	AECL2.33
SKI5.25	R	Dissolution of fracture fillings/precipitations	AECL2.46
SKI5.29	E	Meteorite	
SKI5.30	E	Underground test of nuclear devices	
SKI5.31	sub	Change in sealevel	HMIP2.2.1
SKI5.33	E	Waste retrieval, mining	
SKI5.34	E	Geothermal energy production	
SKI5.35	E	Other future uses of crystalline rock	
SKI5.36	E	Reuse of boreholes	
SKI5.39	E	Postclosure monitoring	
SKI5.40	E	Unsuccessful attempt of site improvement	
SKI5.41	E	Water producing well	
SKI5.42	sub	Glaciation	AECL2.8
SKI5.43	E	Methane intrusion	
SKI5.44	R	Solubility and precipitation	AECL2.46
SKI5.45	R	Colloid generation and transport	AECL2.9
SKI5.46	sub	Groundwater recharge/discharge	HMIP2.2.1

CODE	Screen	FEP NAME	SEE
SKI6.1	E	Undetected fracture zones	
SKI6.2	R	Gas transport	AECL2.26
SKI6.3	R	Far field hydrochemistry - acids, oxidants, nitrate	NAGRA5.8
SKI6.4	R	Dispersion	AECL2.17
SKI6.5	sub	Dilution	AECL2.17
SKI6.6	sub	Weathering of flow paths	DOE2.2.7.3
SKI6.11	E	Intruding dykes	
SKI6.12	E	Undetected discontinues	
SKI6.13	sub	Geothermally induced flow	DOE2.2.11
SKI6.14	E	Tectonic activity - large scale	
SNL2.4	R	Sea-Level Variations	HMIP2.2.1
SNL2.8	R	Regional Subsidence or Uplift	IAEA1.14
SNL3.1	E	Diapirism	
SNL3.2	R	Seismic Activity	NAGRA9.5
SNL3.3	E	Volcanic Activity	
SNL3.4	E	Magmatic Activity	
SNL3.5	E	Formation of Dissolution Cavities	
SNL3.6	sub	Formation of Interconnected Fracture Systems	DOE2.2.7.3
SNL3.7	R	Faulting	PGA2.6
SNL4.1	E	Inadvertent Intrusions: Explosions	
SNL4.2	E	Inadvertent Intrusions: Drilling	
SNL4.3	E	Inadvertent Intrusions: Mining	
SNL4.4	E	Inadvertent Intrusions: Injection Wells	
SNL4.5	E	Inadvertent Intrusions: Withdrawal Wells	
SNL6.1	R	Subsidence and Caving	IAEA1.14
SNL6.2	E	Shaft and Borehole Seal Degradation	
SNL6.3	sub	Thermally Induced Stress/Fracturing in Host Rock	DOE1.4.2
SNL6.4	sub	Excavation-Induced Stress/Fracturing in Host Rock	DOE1.4.2
UKN1.1.1	E	Meteorite Impact	
UKN1.2.1	E	Plate movement/tectonic change	
UKN1.2.3	E	Magmatic activity (intrusive, extrusive)	
UKN1.2.4	E	Metamorphic activity	
UKN1.2.5	E	Diagenesis	
UKN1.2.6	R	Uplift and subsidence (e.g. orogenic, isostatic)	IAEA1.14
UKN1.2.7	E	Diapirism	
UKN1.2.8	R	Seismicity	NAGRA9.5
UKN1.2.9	sub	Fault activation	PGA2.6
UKN1.2.10	sub	Fault generation	PGA2.6
UKN1.2.11	R	Rock heterogeneity affecting water flow	AECL2.33
UKN1.2.12	E	Undetected features (e.g. faults, fracture networks, shear zones, brecciation, gas pockets)	
UKN1.2.13	E	Natural gas intrusion	
UKN1.3.4	R	Sea-level rise/fall	HMIP2.2.1
UKN1.3.5	sub	Periglacial effects (eg. permafrost, high seasonality)	AECL2.8
UKN1.3.6	sub	Glaciation	AECL2.8
UKN1.3.7	sub	No ice age	AECL2.8
UKN1.5.3	R	Recharge to groundwater	HMIP2.2.1
UKN1.5.4	R	Groundwater discharge	HMIP2.2.1
UKN1.5.5	R	Groundwater flow (Darcy, non-Darcy, intergranular fracture, channelling and	DOE2.4.1
UKN1.5.6	R	Groundwater conditions (saturated/unsaturated)	AECL2.55

CODE	Screen	FEP NAME	SEE
UKN1.5.7	R	Saline or freshwater intrusion	SKI5.1
UKN1.5.8	sub	Effects at saline-freshwater interface	SKI5.1
UKN1.5.9	R	Natural thermal effects	DOE2.2.11
UKN1.6.1	G	Advection and dispersion	AECL2.17
UKN1.6.2	R	Diffusion	AECL2.15
UKN1.6.3	R	Matrix diffusion	AECL2.39
UKN1.6.4	R	Gas mediated transport	AECL2.26
UKN1.6.5	sub	Multiphase flow and gas driven flow	AECL2.26
UKN1.6.6	R	Solubility limit	AECL2.46
UKN1.6.7	R	Sorption (linear/non-linear, reversible/irreversible)	AECL2.58
UKN1.6.8	sub	Dissolution, precipitation and crystalisation	AECL2.46
UKN1.6.9	R	Colloid formation, dissolution and transport	AECL2.9
UKN1.6.10	R	Complexing agents	SKI4.1.9
UKN1.6.11	sub	Fracture mineralisation and weathering	DOE2.2.7.3
UKN1.6.13	sub	Mass, isotopic and species dilution	AECL2.17
UKN1.6.14	sub	Chemical gradients	NAGRA5.8
UKN1.7.6	?	Chemical transformations	
UKN1.7.7	R	Microbial interactions	AECL2.43
UKN2.1.1	E	Undetected past intrusions, (eg. boreholes, mining)	
UKN2.1.2	E	Investigation borehole seal failure and degradation	
UKN2.1.3	E	Shaft or access tunnel seal failure and degradation	
UKN2.1.5	sub	Dewatering of host rock	AECL2.55
UKN2.3.2	E	Malicious intrusion, e.g. sabotage, act of war	
UKN2.3.3	E	Exploratory drilling	
UKN2.3.4	E	Exploitation drilling	
UKN2.3.5	E	Geothermal energy production	
UKN2.3.6	E	Resource mining	
UKN2.3.7	E	Tunnelling	
UKN2.3.8	E	Underground construction	
UKN2.3.10	E	Injection of liquid wastes	
UKN2.3.11	E	Groundwater abstraction	
UKN2.3.12	E	Underground nuclear testing	
UKN3.1.1	sub	Differential elastic response	DOE1.4.2
UKN3.1.2	sub	Non-elastic response	DOE1.4.2
UKN3.1.3	sub	Host rock fracture aperture changes	DOE2.2.7.3
UKN3.1.4	G	Induced hydrological changes	AECL2.33
UKN3.1.5	G	Induced chemical changes	NAGRA5.8
UKN3.2.4	R	Non-radioactive solute plume in geosphere	NAGRA5.20
UKN3.3.2	R	Changes in in-situ stress field	DOE1.4.2
UKN3.3.4	R	Subsidence/collapse	IAEA1.14
UKN3.3.5	sub	Fracturing	PGA2.6
UKN3.3.6	G	Gas effects	AECL2.26
UKN3.4.3	H	Nuclear criticality	
UKN3.4.4	R	Radioactive decay and ingrowth (chain decay)	AECL2.48

CODE	Screen	FEP NAME	SEE
HMIP2.1	G	*Geological*	
HMIP2.1.1	E	Regional tectonic	
HMIP2.1.2	E	Magmatic activity	
HMIP2.1.3	E	Metamorphism	
HMIP2.1.4	E	Diagenesis	
HMIP2.1.5	E	Diapirism	
HMIP2.1.6	R	Seismicity	NAGRA9.5
HMIP2.1.7	R	Faulting/fracturing	PGA2.6
HMIP2.1.8	E	Major incision	
HMIP2.1.9	sub	Effects of natural gases	AECL2.26
HMIP2.2	*G*	*Hydrogeological*	
HMIP2.2.1		Geometry and driving forces of the flow system	
HMIP2.2.2	R	Rock property changes	AECL2.51
HMIP2.2.3	R	Groundwater flow	DOE2.4.1
HMIP2.3	G	*Transport and Geochemical*	
HMIP2.3.1	R	Advection	DOE2.4.1
HMIP2.3.2	R	Diffusion	AECL2.15
HMIP2.3.3	R	Hydrodynamic dispersion	AECL2.17
HMIP2.3.4	sub	Solubility constraints	AECL2.46
HMIP2.3.5	R	Sorption including ion-exchange	AECL2.58
HMIP2.3.6	R	Changes in sorptive surfaces	AECL2.58
HMIP2.3.7	?	Changes in groundwater chemistry and flow	
HMIP2.3.8	R	Colloid transport	AECL2.9
HMIP2.3.9	sub	Transport of radionuclides bound to microbes	AECL2.43
HMIP2.3.10	sub	Transport of active gases	AECL2.26
HMIP2.3.11	sub	Gas induced groundwater transport	AECL2.26
HMIP2.3.12	sub	Thermal effects on hydrochemistry	DOE2.2.11
HMIP2.3.13	sub	Biogeochemical changes	AECL2.43
HMIP2.4	G	*Geomorphology*	
HMIP2.4.1	sub	Generalised denudation	AECL2.21
HMIP2.4.2	sub	Localised denudation	AECL2.21
HMIP5.1.1	E	Loss of integrity of borehole seals	
HMIP5.1.2	E	Loss of integrity of shaft or access tunnel seals	
HMIP5.2.1	E	Meteorite impact	
HMIP5.2.2	E	Deliberate intrusion	
HMIP5.2.3	E	Malicious intrusion	
HMIP5.2.4	E	Accidental intrusion	
NAGRA0.1	R	Radioactive decay	AECL2.48
NAGRA0.2	sub	Speciation (including gases/volatiles)	SKI4.19
NAGRA1.14	sub	Coprecipitates/solid solutions	AECL2.46
NAGRA1.15	sub	Elemental solubility limits	AECL2.46
NAGRA1.16	?	Solute transport resistance	
NAGRA1.21	sub	Colloid formation	AECL2.9
NAGRA1.22	R	Microbial activity	AECL2.43
NAGRA4.6	R	Groundwater chemistry	NAGRA5.8
NAGRA4.7	?	Water flow at the bentonite/host rock interface	
NAGRA4.8	?	Radionuclide migration	
NAGRA4.9	?	Radionuclide retardation	
NAGRA4.10	sub	Elemental solubility	AECL2.46
NAGRA4.11	sub	Gas transport/dissolution	AECL2.26
NAGRA4.12	sub	Colloids	AECL2.9

CODE	Screen	FEP NAME	SEE
NAGRA5.1	?	Low permeability domain effective	
NAGRA5.2	?	Water-conducting features (types)	
NAGRA5.3	sub	Groundwater flow in low permeability domain	DOE2.4.1
NAGRA5.4	sub	Groundwater flowpath	DOE2.4.1
NAGRA5.5	?	Radionuclide transport through low permeability domain	
NAGRA5.6	R	Matrix diffusion	AECL2.39
NAGRA5.7	sub	Mineralogy	AECL2.51
NAGRA5.8		Groundwater chemistry	
NAGRA5.9	R	Sorption	AECL2.58
NAGRA5.10	sub	Non-linear sorption	AECL2.58
NAGRA5.11	R	Intrusion of saline groundwater	SKI5.1
NAGRA5.12	sub	Density-driven groundwater flow (thermal)	DOE2.2.11
NAGRA5.13	sub	Geothermal regime	DOE2.2.11
NAGRA5.14	R	Regional stress regime	DOE1.4.2
NAGRA5.15	sub	Natural colloids	AECL2.9
NAGRA5.16	G	Solubility limits/colloid formation	
NAGRA5.17	sub	Gas pressure effects	AECL2.26
NAGRA5.18	R	Hydraulic gradient changes (magnitude, direction)	HMIP2.2.1
NAGRA5.19	R	Influx of oxidising water	SKI5.1
NAGRA5.20		TRU alkaline or organic plume	
NAGRA5.21	sub	Organics	SKI4.1.9
NAGRA5.22	R	Microbial activity	AECL2.43
NAGRA5.23	sub	Dilution of radionuclides in groundwater	AECL2.17
NAGRA5.24	sub	Geogas	AECL2.26
NAGRA5.25	E	Exploratory boreholes	
NAGRA6.1	?	MCWF effective hydraulic properties	
NAGRA6.2	?	Water-conducting features (types)	
NAGRA6.3	sub	Groundwater flow in low permeability domain	DOE2.4.1
NAGRA6.4	sub	Groundwater flowpath in major water-conducting faults	DOE2.4.1
NAGRA6.5	sub	Radionuclide transport in major water-conducting faults	DOE2.4.1
NAGRA6.6	R	Matrix diffusion	AECL2.39
NAGRA6.7	sub	Mineralogy	AECL2.51
NAGRA6.8	R	Groundwater chemistry	NAGRA5.8
NAGRA6.9	R	Sorption	AECL2.58
NAGRA6.10	sub	Non-linear sorption	AECL2.58
NAGRA6.11	R	Intrusion of saline groundwater	SKI5.1
NAGRA6.12	sub	Density-driven groundwater flows (thermal)	DOE2.2.11
NAGRA6.13	sub	Geothermal regime	DOE2.2.11
NAGRA6.14	R	Regional stress regime	DOE1.4.2
NAGRA6.15	sub	Natural colloids	AECL2.9
NAGRA6.16	?	Solubility limits/colloid formation	
NAGRA6.17	v	Gas pressure effects	AECL2.26
NAGRA6.18	R	Hydraulic gradient changes (magnitude, direction)	HMIP2.2.1
NAGRA6.19	R	Influx of oxidising water	SKI5.1
NAGRA6.20	R	TRU alkaline or organics plume	NAGRA5.20
NAGRA6.21	sub	Organics	SKI4.1.9
NAGRA6.22	R	Microbial activity	AECL2.43
NAGRA6.23	sub	Dilution of radionuclides in groundwater	AECL2.17
NAGRA6.24	sub	Geogas	AECL2.26

CODE	Screen	FEP NAME	SEE
NAGRA7.1	?	Higher-permeability domain effective hydraulic properties	
NAGRA7.2	E	Mesozoic sedimentary cover	
NAGRA7.3	E	Permo-Carboniferous Trough	
NAGRA7.4	R	Groundwater flow	DOE2.4.1
NAGRA7.5	R	Boundary conditions for flow	HMIP2.2.1
NAGRA7.6	sub	Groundwater flow path	DOE2.4.1
NAGRA7.7	?	Dilution of radionuclides in HPD	
NAGRA7.8	R	Groundwater chemistry	NAGRA5.8
NAGRA7.9	R	Radionuclide sorption	AECL2.58
NAGRA7.10	R	Stress regime	DOE1.4.2
NAGRA7.11	R	Erosion	AECL2.21
NAGRA7.12	sub	Hydraulic gradient	AECL2.33
NAGRA7.13	sub	Density-driven groundwater flows	AECL2.33
NAGRA9.1	E	Regional horizontal movements	
NAGRA9.2	sub	Regional vertical movements	IAEA1.14
NAGRA9.3	sub	Movements along major faults	PGA2.6
NAGRA9.4	sub	Movements along small-scale faults	PGA2.6
NAGRA9.5	B	Seismic activity	
NAGRA9.6	sub	Stress-changes - hydrogeological effects	DOE1.4.2
NAGRA9.7	R	Erosion/denudation	AECL2.21
NAGRA9.8	E	Basement alteration	
NAGRA9.9	E	Magmatic activity (volcanism and plutonism)	
NAGRA9.10	E	Hydrothermal activity	
NAGRA9.11	E	Extraterrestrial events	
NAGRA10.4	sub	Future climatic conditions	AECL2.8
NAGRA10.6	sub	Glacial climate	AECL2.8
NAGRA10.7	sub	Warmer climate - arid	AECL2.8
NAGRA10.8	sub	Warmer climate - seasonal humid	AECL2.8
NAGRA10.9	sub	Warmer climate - equable humid	AECL2.8
NAGRA10.13	sub	Permafrost	AECL2.8
NAGRA10.14	sub	Glacial erosion/sedimentation	AECL2.21
NAGRA10.15	sub	Glacial-fluvial erosion/sedimentation	AECL2.21
NAGRA10.16	sub	Ice-sheet effects (loading, melt water recharge)	HMIP2.2.1
NAGRA11.1	E	Exploratory drilling	
NAGRA11.2	E	Mining activities	
NAGRA11.3	E	Geothermal exploitation	
NAGRA11.4	E	Liquid waste injection	
NAGRA11.5	E	Deep groundwater abstraction	
NAGRA11.6	E	Water management schemes	
NAGRA11.7	E	Groundwater pollution	
NAGRA11.9	E	Human-induced climate change	

Appendix E: *Reduced List of Far-Field FEPs: Sorted by Category*[9]

FEP NAME FROM RAW FEPs LIST	FEP TITLE/COMMENT
Sorted/reduced list from Appendix A FEPs	
Electrochemical gradients	Electrochemical gradients
Climate change	Climate change / BOUNDARY CONDITION [=B]
Colloid formation	Colloid generation and transport
Diffusion	Diffusion
Dispersion	Dispersion
Erosion	Erosion of the surface / BOUNDARY CONDITION [=B]
Gases and gas transport	Gas generation & Gas pressure & Gas flow and transport
Rock properties (hydrogeological)	Properties of rock
Matrix diffusion	Matrix diffusion
Microbes	Microbial activity
Radionuclide precipitation - dissolution	Precipitation/dissolution & Radionuclide reconcentration
Radioactive decay	Radioactive decay and ingrowth
Rock properties - physical	Properties of rock
Saturation	Hydraulic saturation/unsaturation
Sorption	Sorption
Changes in situ stress field	Stress field (in situ)
Fracture properties	Properties of rock
Geothermal effects	Thermal field
Groundwater flow (advection)	Groundwater flow
Uplift/Subsidence	Uplift/subsidence
Movements at faults	Fault movement and activation
Complexing agents	Groundwater chemistry
Saline (or fresh) groundwater intrusion	Saline (or fresh) groundwater intrusion
Geometry and driving forces of the flow system	Geometry and driving force
Groundwater chemistry	Groundwater chemistry
TRU alkaline or organic plume	Groundwater chemistry
Seismic activity	Seismic activity
	Additional FEPs from near-field PID
	Anion exclusion
	Transport and release of radionuclides
	Fast pathways
	Recoil of alpha decay
	Redox front
	Radiolysis
	Alteration/weathering of flowpaths

[9] Some of the above FEPs in the right-hand column were either renamed or deleted following discussions at one of the SKI PID Workshops (Stenhouse et al., 2000), as shown in *Appendix F*.

Appendix F: *FEP List for Far-Field PID for SFR-1*

Alteration/weathering of flow paths
Anion exclusion [*subsequently deleted following Workshop discussions (Stenhouse et al., 2000)*]

Climate change (BOUNDARY CONDITION)
Colloid generation and transport

Diffusion
Dispersion

Electrochemical gradients [*subsequently deleted following Workshop discussions (Stenhouse et al., 2000)*]
Erosion of surface (BOUNDARY CONDITION)

Fast pathways [*subsequently deleted following Workshop discussions (Stenhouse et al., 2000)*]
Fault movement and activation [*subsequently renamed "Rock movement/collapse"*]

Gas generation [*subsequently renamed "Bulk gas"*]
Gas flow and transport
Gas pressure (bulk gas formation) [*incorporated in "Bulk gas"; see above*]
Geometry and driving force of flow system [*renamed "Geometry/driving forces for groundwater flow"*]
Groundwater chemistry
Groundwater flow

Hydraulic saturation/unsaturation

Matrix diffusion
Microbial activity

Precipitation/dissolution
Properties of rock (physical + hydrogeological)

Radioactive decay and ingrowth of nuclides
Radiolysis [*subsequently deleted following Workshop discussions (Stenhouse et al., 2000)*]
Radionuclide reconcentration [*subsequently deleted following Workshop discussions (Stenhouse et al., 2000)*]
Recoil of alpha decay [*subsequently deleted following Workshop discussions Stenhouse et al., 2000)*]
Redox front/Redox heterogeneity

Saline (or fresh) groundwater intrusion
Seismic activity
Sorption
Stress field (*in situ*)

Thermal field
Transport and release of nuclides

Uplift/subsidence (BOUNDARY CONDITION)

Appendix G: *Influences in the Reference Case L/ILW Near- Field Section of PID*

NOTE: Codes in bold type signify Influences directly related to the transport of radionuclides. All such Influences are given an Importance Level of 10.

Alteration/weathering of flow paths in near-field rock
- N20 (10) Water chemistry, near-field rock
- N28 (10) Properties of near-field rock
- N47 (10) Colloid generation and transport in near-field rock
- N121 (10) Fast pathways in near-field rock

Bentonite swelling in backfill
- B116 (10) Gas flow and transport in backfill
- B117 (2) Degradation/alteration of backfill
- B124 (10) Properties of backfill
- B132 (2) Properties of near-field rock
- B133 (6) Stress field in near-field rock
- B145 (10) Bulk gas formation in backfill

Bulk gas formation in waste package
- C7 (10) Water movement in and through waste package
- C8 (10) Mechanical Stress Distribution in the waste package
- C13 (10) Gas flow and transport in waste package
- C51 (10) Bulk gas formation in mortar [NOT BTF/BLA/BMA]
- W65 (6) Evolving properties of cement matrix
- W78 (2) Evolving properties of bitumen matrix

Bulk gas formation in backfill
- B7 (10) Bulk gas formation in shell
- B10 (10) Gas flow and transport in backfill
- B38 (10) Water movement in and through backfill
- B65 (10) Water chemistry in backfill
- B70 (10) Bulk gas, near-field rock
- B91 (10) Mechanical stress distribution in backfill
- B140 (10) Bulk gas formation in mortar [NOT BTF/BLA/BMA]

Bulk gas formation in mortar [NOT BTF/BLA/BMA]
- M7 (10) Bulk gas formation in waste package
- M10 (10) Gas flow and transport in mortar
- M38 (10) Water movement in and through mortar
- M65 (10) Water chemistry in mortar
- M70 (10) Bulk gas formation in shell
- M83 (2) Mechanical Stress Distribution in the waste package
- M91 (2) Mechanical stress distribution in mortar
- M97 (10) Mechanical stress distribution in shell
- M102 (10) Bulk gas formation in backfill

Bulk gas formation in shell
- S7 (10) Bulk gas formation in mortar [NOT BTF/BLA/BMA]

S10 (10) Gas flow and transport in shell
S38 (10) Water movement in and through shell
S65 (10) Water chemistry in shell
S70 (10) Bulk gas formation in backfill
S91 (6) Mechanical stress distribution in shell
S97 (2) Mechanical stress distribution in backfill
S102 (2) Bulk gas, near-field rock

Bulk gas, near-field rock

N40 (10) Groundwater flow through near-field rock
N72 (10) Bulk gas formation in backfill
N107 (10) Gas flow and transport in near-field rock
N23 (6) Water chemistry, near-field rock
N73 (10) Bulk gas formation in shell

Cave-in

N64 (2) Properties of shell
N88 (10) Properties of near-field rock
N124 (10) Groundwater flow through near-field rock

Colloid generation and transport in near-field rock

NT5 (10) Transport and release of nuclides from near-field rock
N128 (2) Water chemistry, near-field rock

Colloid generation and transport in backfill

BT5 (10) Transport and release of nuclides from backfill
B131 (10) Colloid generation and transport in near-field rock
B158 (2) Water chemistry in backfill

Colloid generation and transport in mortar [NOT BTF/BLA/BMA]

MT5 (10) Transport and release of nuclides from mortar
M128 (2) Water chemistry in mortar
M131 (10) Colloid generation and transport in shell

Colloid generation and transport in shell

ST5 (10) Transport and release of nuclides from shell
S128 (2) Water chemistry in shell
S131 (10) Colloid generation and transport in backfill

Colloid generation in waste package

CT9 (10) Transport and release of nuclides from waste package
C128 (2) Water chemistry in waste package
C131 (10) Colloid generation and transport in mortar

Degradation/alteration of backfill

B12 (10) Water chemistry in backfill
B27 (10) Properties of backfill
B130 (10) Colloid generation and transport in backfill

Degradation of inorganic waste

WT7 (10) Release from L/ILW waste
W50 (2) Evolving properties of bitumen matrix
W52 (**2**) Gas generation in waste package
W57 (2) Evolving properties of cement matrix
W59 (10) Water chemistry in waste package
W61 (6) Microbial activity in waste package

Degradation of metal waste [NOT BTF/BMA]
WT5 (10) Release from L/ILW waste
W29 (6) Evolving properties of bitumen matrix
W31 (10) Gas generation in waste package
Degradation of metal waste (continued) [NOT BTF/BMA]
W34 (6) Evolving properties of cement matrix
W36 (10) Water chemistry in waste package
W38 (6) Microbial activity in waste package
Degradation of mortar [NOT BTF/BLA/BMA]
M12 (10) Water chemistry in mortar
M27 (10) Properties of mortar
Degradation of organic waste
WT6 (10) Release from L/ILW waste
W39 (2) Evolving properties of bitumen matrix
W41 (10) Gas generation in waste package
W45 (10) Evolving properties of cement matrix
W47 (10) Water chemistry in waste package
W48 (10) Microbial activity in waste package
Degradation of rock reinforcement and grout, near-field
N17 (6) Water chemistry, near-field rock
N46 (2) Colloid generation and transport in near-field rock
N86 (2) Gas generation in near-field rock
N87 (10) Properties of near-field rock
Degradation of shell
S12 (10) Water chemistry in shell
S27 (10) Properties of shell
Degradation of steel reinforcement in cell walls of shell [NOT BTF/BLA/BMA]
S84A (10) Gas generation in mortar
S104A (10) Degradation of mortar
S106A (10) Properties of mortar
S111A (10) Water chemistry in mortar
Degradation of steel reinforcement in shell
S84 (10) Gas generation in shell
S104 (10) Degradation of shell
S106 (10) Properties of shell
S111 (10) Water chemistry in shell
Diffusion through backfill
BT3 (10) Transport and release of nuclides from backfill
B44 (10) Water chemistry in backfill
Diffusion through mortar [NOT BTF/BLA/BMA]
MT3 (10) Transport and release of nuclides from mortar
M44 (10) Water chemistry in mortar
Diffusion through shell
S**T3** (10) Transport and release of nuclides from shell
S44 (10) Water chemistry in shell
Diffusion in and through waste package
CT5 (10) Transport and release of nuclides from waste package
C15 (10) Water chemistry in waste package
C23 (10) Water chemistry in mortar [NOT BTF/BLA/BMA]

Diffusion through near-field rock
NT8 (2) Transport and release of nuclides from near-field rock
N91 (6) Water chemistry, near-field rock
Dispersion in near-field rock
NT11 (2) Transport and release of nuclides from near-field rock

Evolving radionuclide inventory
WT3 (10) Release from L/ILW waste
Evolving properties of bitumen matrix
CT2 (2) Transport and release of nuclides from waste package
C42 (10) Mechanical Stress Distribution in the waste package
W51 (2) Degradation of inorganic waste
W77 (10) Gas generation in waste package
W79 (10) Microbial activity in waste package
W81 (6) Water chemistry in waste package
W84 (10) Water movement in and through waste package
W85 (10) Gas flow and transport in waste package
W86 (10) Colloid generation in waste package
W87 (2) Sorption on waste package
Evolving properties of cement matrix
CT1 (10) Transport and release of nuclides from waste package
C40 (10) Mechanical Stress Distribution in the waste package
W33 (2) Degradation of metal waste [NOT BTF/BMA]
W44 (2) Degradation of organic waste
W56 (2) Degradation of inorganic waste
W69 (10) Water chemistry in waste package
W72 (10) Water movement in and through waste package
W73 (10) Gas flow and transport in waste package
W74 (10) Colloid generation in waste package
W75 (10) Sorption on waste package
Evolving Properties of container
C6 (6) Gas generation in waste package
C14 (10) Sorption on waste package
C17 (10) Diffusion in and through waste package
C52 (2) Mechanical stress distribution in mortar [NOT BTF/BLA/BMA]
C53 (10) Water chemistry in mortar [NOT BTF/BLA/BMA]
CT10 (10) Transport and release of nuclides from waste package
CT12 (10) Colloid generation in waste package
C4 (10) Water chemistry in waste package
C9 (10) Water movement in and through waste package
C12 (10) Bulk gas formation in waste package
C35 (2) Microbial activity in waste package
C37 (6) Mechanical Stress Distribution in the waste package
Excavation effects on near-field rock
N54 (10) Properties of near-field rock
N99 (10) Stress field in near-field rock
N100 (6) Water chemistry, near-field rock
N126 (10) Fast pathways in near-field rock

Filtration in backfill (bentonite)
B151 (2) Properties of backfill
B152 (10) Colloid generation and transport in backfill

Gas generation in waste package
C5 (10) Bulk gas formation in waste package
C32 (10) Water chemistry in waste package
W5 (6) Degradation of metal waste [NOT BTF/BMA]
W42 (6) Degradation of organic waste
W54 (6) Degradation of inorganic waste

Gas flow and transport in backfill
BT11 (10) Transport and release of nuclides from backfill
B11 (10) Bulk gas formation in backfill

Gas flow and transport in mortar [NOT BTF/BLA/BMA]
MT11 (10) Transport and release of nuclides from mortar
M11 (10) Bulk gas formation in mortar

Gas flow and transport in shell
ST11 (10) Transport and release of nuclides from shell
S11 (10) Bulk gas formation in shell

Gas flow and transport in waste package
CT11 (10) Transport and release of nuclides from waste package
C48 (10) Water movement in and through waste package
C57 (10) Bulk gas formation in waste package

Gas flow and transport in near-field rock
NT13 (10) Transport and release of nuclides from near-field rock
N106 (10) Bulk gas in near-field rock
N131 (10) Bulk gas in far-field

Gas generation in shell
S86 (10) Bulk gas formation in shell

Groundwater flow through near-field rock
NT12 (10) Transport and release of nuclides from near-field rock
N53 (10) Water chemistry, near-field rock
N55 (2) Degradation/alteration of backfill
N60 (10) Water movement in and through backfill
N80 (10) Resaturation state of near-field rock
N82 (10) Colloid generation and transport in near-field rock

Matrix diffusion in near-field rock
NT9 (10) Transport and release of nuclides from near-field rock
N92 (2) Water chemistry, near-field rock

Mechanical Stress Distribution in the waste package
C36 (10) Evolving Properties of container
C39 (2) Evolving properties of cement matrix
C41 (2) Evolving properties of bitumen matrix

Mechanical stress distribution in backfill
B32 (10) Properties of backfill
B74 (2) Stress field in near-field rock
B80 (10) Mechanical stress distribution in shell

Mechanical stress distribution in mortar [NOT BTF/BLA/BMA]
M32 (6) Properties of mortar

M74 (6) Mechanical stress distribution in shell
M80 (10) Mechanical stress distribution in the waste package
M100 (6) Mechanical stress distribution in backfill

Mechanical stress distribution in shell
S32 (10) Properties of shell
S74 (6) Mechanical stress distribution in backfill
S80 (6) Mechanical stress distribution in mortar [NOT BTF/BLA/BMA]

Microbial activity in waste package
C20 (10) Water chemistry in waste package
C21 (10) Colloid generation in waste package
C31 (6) Sorption on waste package
C50 (2) Microbial activity in mortar [NOT BTF/BLA/BMA]

Microbial activity in waste package (continued)
C54 (10) Gas generation in waste package
W49 (10) Degradation of organic waste
W80 (6) Evolving properties of bitumen matrix

Microbial activity in mortar [NOT BTF/BLA/BMA]
M9 (2) Gas generation in mortar
M16 (6) Water chemistry in mortar
M48 (6) Colloid generation and transport in mortar
M55 (2) Sorption on mortar

Microbial activity in shell
S9 (2) Gas generation in shell
S16 (2) Water chemistry in shell
S48 (2) Colloid generation and transport in shell

Microbial activity, backfill
B9 (2) Gas generation backfill
B16 (6) Water chemistry in backfill
B48 (2) Colloid generation and transport in backfill

Microbial activity in near-field rock
N2 (2) Water chemistry, near-field rock
N45 (2) Colloid generation and transport in near-field rock
N74 (2) Properties of near-field rock

Precipitation/dissolution in backfill
BT1 (10) Transport and release of nuclides from backfill
BT9 (10) Colloid generation and transport in backfill
B23 (10) Water chemistry in backfill

Precipitation/dissolution in mortar [NOT BTF/BLA/BMA]
MT1 (10) Transport and release of nuclides from mortar
MT9 (10) Colloid generation and transport in mortar
M23 (10) Water chemistry in mortar

Precipitation/dissolution in shell
ST1 (10) Transport and release of nuclides from shell
ST9 (10) Colloid generation and transport in shell [NOT BTF/BLA/BMA]
S23 (10) Water chemistry in shell

Precipitation/dissolution in waste package
CT3 (10) Transport and release of nuclides from waste package
CT8 (6) Colloid generation in waste package
W89 (10) Sorption on waste package

W91 (10) Water chemistry in waste package

Precipitation/dissolution in near-field rock

NT6 (10) Transport and release of nuclides from near-field rock
NT10 (10) Colloid generation and transport in near-field rock
N12 (10) Water chemistry, near-field rock

Properties of backfill

B156 (10) Water chemistry in backfill
B150 (10) Filtration in backfill
B31 (10) Mechanical stress distribution in backfill
B35 (10) Water movement in and through backfill
B42 (10) Sorption on backfill
B45 (10) Diffusion through backfill
B66 (10) Gas flow and transport in backfill
B95 (6) Microbial activity, backfill
B96 (10) Colloid generation and transport in backfill
B115 (10) Bentonite swelling in backfill

Properties of mortar [NOT BTF/BLA/BMA]

M33 (2) Mechanical Stress Distribution in the waste package
M35 (10) Water movement in Microbial activity in waste package through mortar
M42 (10) Sorption on mortar
M45 (10) Diffusion through mortar
M89 (10) Degradation of steel reinforcement in mortar
M95 (6) Microbial activity in mortar
M96 (10) Colloid generation and transport in mortar
M118 (10) Water chemistry in mortar
M31 (10) Mechanical stress distribution in mortar
M66 (10) Gas flow and transport in mortar

Properties of near-field rock

N37 (10) Groundwater flow through near-field rock
N41 (10) Sorption on near-field rock
N44 (10) Colloid generation and transport in near-field rock
N48 (10) Matrix diffusion in near-field rock
N52 (10) Gas flow and transport in near-field rock
N67 (10) Water chemistry, near-field rock
N75 (10) Diffusion through near-field rock
N84 (10) Stress field in near-field rock
N112 (10) Dispersion in near-field rock
N113 (10) Cave-in

Properties of shell

S31 (10) Mechanical stress distribution in shell
S35 (10) Water movement in and through shell
S42 (10) Sorption on shell
S45 (10) Diffusion through shell
S66 (10) Gas flow and transport in shell
S89 (10) Degradation of steel reinforcement in shell
S95 (6) Microbial activity in shell
S96 (10) Colloid generation and transport in shell
S119 (10) Water chemistry in shell

Radioactive decay in waste
W7 (10) Radiolysis in waste package
W14 (10) Evolving radionuclide inventory
W16 (2) Radiolysis in mortar [NOT BTF/BLA/BMA]
W17 (2) Evolving Properties of container
W18 (2) Degradation of metal waste [NOT BTF/BMA]
W21 (2) Radiation effects on mortar [NOT BTF/BLA/BMA]
W22 (2) Degradation of metal waste [NOT BTF/BMA]
W24 (6) Microbial activity in waste package
W25 (2) Degradation of organic waste
W26 (2) Degradation of inorganic waste
W27 (2) Evolving properties of cement matrix
W28 (2) Evolving properties of bitumen matrix
Radioactive decay and ingrowth of nuclides in backfill
BT4 (10) Transport and release of nuclides from backfill
Radioactive decay and ingrowth of nuclides in matrix and container
CT6 (10) Transport and release of nuclides from waste package
C56 (6) Radiolysis in waste package
Radioactive decay and ingrowth of nuclides in mortar [NOT BTF/BLA/BMA]
MT4 (10) Transport and release of nuclides from mortar
Radioactive decay and ingrowth of nuclides in near-field rock
NT4 (10) Transport and release of nuclides from near-field rock
Radioactive decay and ingrowth of nuclides in shell
ST4 (10) Transport and release of nuclides from shell
S30 (10) Radiation effects on shell
S85 (2) Gas generation in shell
S115 (10) Radiolysis in shell
S107 (10) Recoil of alpha decay
Radiolysis in waste package
W8 (2) Water chemistry in waste package
W11 (2) Gas generation in waste package
Redox heterogeneity in backfill
B21 (10) Precipitation/dissolution in backfill
B75 (6) Colloid generation and transport in backfill
B85 (10) Water chemistry in mortar
Redox heterogeneity in mortar [NOT BTF/BLA/BMA]
M21 (10) Precipitation/dissolution in mortar
M75 (6) Colloid generation and transport in mortar
M85 (10) Water chemistry in mortar
Redox heterogeneity in near-field rock
N16 (10) Precipitation/dissolution in near-field rock
N94 (6) Colloid generation and transport in near-field rock
N103 (10) Water chemistry in near-field rock
Redox heterogeneity in shell
S21 (10) Precipitation/dissolution in shell
S75 (6) Colloid generation and transport in shell
S76(10) Water chemistry in shell
Release from L/ILW waste
WT1 (10) Transport and release of nuclides from waste package
WT4 (10) Evolving radionuclide inventory

Resaturation state of backfill
B40 (10) Water chemistry in backfill
B60 (10) Water movement in and through backfill
B61 (10) Diffusion through backfill
B114 (10) Bentonite swelling in backfill
Resaturation state of mortar [NOT BTF/BLA/BMA]
M40 (10) Water chemistry in mortar
M60 (10) Water movement in and through mortar
M61 (10) Diffusion through mortar
M103 (10) Degradation of steel reinforcement in mortar
Resaturation state of near-field rock
N30 (10) Water chemistry, near-field rock
N38 (10) Groundwater flow through near-field rock
N49 (10) Matrix diffusion in near-field rock
N85 (10) Gas flow and transport in near-field rock
Resaturation state of shell
S40 (10) Water chemistry in shell
S60 (10) Water movement in and through shell
S61 (10) Diffusion through shell
S103 (10) Degradation of steel reinforcement in shell
Resaturation of waste package
C40 (10) Water chemistry in waste package
C60 (10) Water movement in and through waste package
C61 (10) Diffusion through s waste package
C85 (10) Gas flow and transport in waste package
C100 (10) Degradation of cement matrix
C101 (10) Degradation of bitumen matrix
C102 (10) Degradation of metal waste
C103 (10) Degradation of organic waste
C104 (10) Degradation of inorganic waste

Shaft and tunnel seal degradation
N116 (6) Redox heterogeneity in near-field rock
N117 (2) Water movement in and through backfill
N97 (6) Groundwater flow, near-field
N98 (6) Gas flow and transport, near-field
Sorption on backfill
BT2 (10) Transport and release of nuclides from backfill
B159 (10) Water chemistry in backfill
Sorption on mortar [NOT BTF/BLA/BMA]
MT2 (10) Transport and release of nuclides from mortar
M76 (10) Water chemistry in mortar
Sorption on near-field rock
N129 (6) Water chemistry, near-field rock
NT16 (10) Transport and release of nuclides from near-field rock
Sorption on shell
ST2 (10) Transport and release of nuclides from shell
S90 (10) Water chemistry, near-field rock
Sorption on waste package
CT4 (10) Transport and release of nuclides from waste package

W90 (10) Water chemistry, waste package

Stress field in near-field rock

- N26 (10) Properties of near-field rock
- N83 (10) Mechanical stress distribution in backfill
- N125 (10) Cave-in
- N127 (2) Alteration/weathering of flow paths in near-field rock

Temperature of backfill

- B3 (2) Resaturation state of backfill
- B5 (2) Degradation/alteration of backfill
- B24 (10) Water chemistry in backfill
- B25 (2) Precipitation/dissolution in backfill
- B26 (10) Temperature of shell
- B39 (2) Water movement in and through backfill
- B47 (2) Diffusion through backfill
- B71 (2) Sorption on backfill
- B92 (2) Mechanical stress distribution in backfill
- B93 (10) Microbial activity, backfill
- B98 (2) Temperature of near-field rock
- B136 (2) Bentonite swelling in backfill
- B143 () Temperature of mortar [NOT BTF/BLA/BMA]

Temperature of mortar [NOT BTF/BLA/BMA]

- M3 (2) Resaturation state of mortar
- M5 (2) Degradation of mortar
- M87 (2) Degradation of steel reinforcement in cell walls
- M24 (10) Water chemistry in mortar
- M25 (6) Precipitation/dissolution in mortar
- M26 (10) Temperature in waste package
- M39 (2) Water movement in and through mortar
- M47 (2) Diffusion through mortar
- M71 (2) Sorption on mortar
- M72 (2) Matrix diffusion in mortar
- M92 (6) Mechanical stress distribution in mortar
- M93 (10) Microbial activity in mortar
- M98 (2) Temperature of shell
- M101 (2) Temperature of backfill

Temperature of shell

- S3 (2) Resaturation state of shell
- S5 (2) Degradation of shell
- S24 (10) Water chemistry in shell
- S25 (2) Precipitation/dissolution in shell
- S26 (10) Temperature of mortar [NOT BTF/BLA/BMA]
- S39 (2) Water movement in and through shell
- S47 (2) Diffusion through shell
- S71 (2) Sorption on shell
- S72 (2) Matrix diffusion in shell
- S87 (2) Degradation of steel reinforcement in shell
- S92 (2) Mechanical stress distribution in shell
- S93 (10) Microbial activity in shell
- S98 (2) Temperature of backfill

S101 (10) Temperature of near-field rock

Temperature in waste package

C2 (6) Precipitation/dissolution in waste package
C38 (2) Mechanical stress distribution in the waste package
C43 (2) Bulk gas formation in waste package
C44 (2) Diffusion in and through waste package
W9 (10) Water chemistry in waste package
W12 (2) Water movement in and through waste package
W13 (2) Evolving properties of container
W15 (6) Temperature of mortar [NOT BTF/BLA/BMA]
W20 (2) Sorption on waste package
W23 (10) Microbial activity in waste package
W32 (2) Degradation of metal waste [NOT BTF/BMA]
W43 (2) Degradation of organic waste
W53 (2) Degradation of inorganic waste
W62 (2) Evolving properties of cement matrix
W76 (2) Evolving properties of bitumen matrix

Temperature of near-field rock

N33 (2) Stress field in near-field rock
N34 (10) Water chemistry, near-field rock
N36 (2) Groundwater flow through near-field rock
N56 (10) Temperature of backfill
N68 (2) Sorption on near-field rock
N69 (2) Precipitation/dissolution in near-field rock
N70 (2) Diffusion through near-field rock
N71 (2) Matrix diffusion in near-field rock
N76 (2) Alteration/weathering of flow paths in near-field rock
N89 (10) Microbial activity in near-field rock
N132 (2) Thermal field, far-field

Transport and release of nuclides from backfill

BT15 (10) Transport and release of nuclides from near-field rock

Transport and release of nuclides from mortar [NOT BTF/BLA/BMA]

MT13 (10) Transport and release of nuclides from backfill
MT15 (10) Transport and release of nuclides from shell

Transport and release of nuclides from shell

ST13 (10) Transport and release of nuclides from near-field rock
ST15 (10) Transport and release of nuclides from backfill

Transport and release of nuclides from waste package

CT14 (10) Transport and release of nuclides from mortar [NOT BTF/BLA/BMA]

Transport and release of nuclides from near-field

NT15 (10) Transport and release of nuclides in far-field

Transport and release of nuclides from near-field rock

NT15 (10) Transport and release of nuclides from far-field

Water chemistry in backfill

B13 (10) Degradation/alteration of backfill
B14 (10) Microbial activity, backfill
B20 (10) Redox heterogeneity in backfill
B22 (10) Precipitation/dissolution in backfill
B41 (10) Sorption on backfill

B50 (10) Colloid generation and transport in backfill
B56 (6) Water chemistry in shell
B68 (10) Water chemistry, near-field rock
B141 (10) Water chemistry in mortar [NOT BTF/BLA/BMA]

Water chemistry in mortar [NOT BTF/BLA/BMA]

M2 (10) Evolving Properties of container
M13 (10) Degradation of mortar
M14 (10) Microbial activity in mortar
M20 (10) Redox heterogeneity in mortar
M22 (10) Precipitation/dissolution in mortar
M41 (10) Sorption on mortar
M50 (10) Colloid generation and transport in mortar
M56 (10) Water chemistry in waste package
M68 (10) Water chemistry in shell
M88 (10) Degradation of steel reinforcement in mortar
M99 (10) Water chemistry in backfill

Water chemistry in shell

S51 (10) Precipitation/dissolution in shell
S13 (10) Degradation of shell
S14 (10) Microbial activity in shell
S20 (10) Redox heterogeneity in shell
S22 (10) Precipitation/dissolution in shell
S68 (10) Water chemistry in backfill
S41 (10) Sorption on shell
S50 (10) Colloid generation and transport in shell
S56 (6) Water chemistry in mortar [NOT BTF/BLA/BMA]
S68 (10) Water chemistry in backfill
S88 (10) Degradation of steel reinforcement in shell
S99 (6) Water chemistry, near-field rock
S117 (10) Gas generation in shell

Water chemistry in waste package

C10 (10) Radiolysis in waste package
C16 (10) Water chemistry in mortar [NOT BTF/BLA/BMA]
C19 (10) Microbial activity in waste package
C11 (10) Sorption on waste package
C22 (10) Colloid generation in waste package
C27 (10) Precipitation/dissolution in waste package
C28 (10) Evolving properties of container
C33 (10) Electrochemical effects in waste package
C45 (10) Gas generation in waste package
C49 (10) Diffusion in and through waste package
W35 (10) Degradation of metal waste [NOT BTF/BMA]
W46 (10) Degradation of organic waste
W58 (10) Degradation of inorganic waste
W70 (10) Evolving properties of cement matrix
W82 (10) Evolving properties of bitumen matrix

Water chemistry, near-field rock

N1 (10) Microbial activity in near-field rock
N10 (10) Precipitation/dissolution in near-field rock
N13 (10) Sorption on near-field rock

N15 (10) Redox heterogeneity in near-field rock
N18 (10) Degradation of rock reinforcement and grout
N19 (10) Alteration/weathering of flow paths in near-field rock
N43 (10) Colloid generation and transport in near-field rock
N65 (10) Water chemistry in backfill
N66 (6) Water chemistry in shell
N95 (10) Shaft and tunnel seal degradation
N133 (2) Groundwater chemistry, far-field

Water movement in and through mortar [NOT BTF/BLA/BMA]

MT8 (10) Transport and release of nuclides from mortar
M34 (6) Water chemistry in mortar
M37 (2) Evolving properties of container
M67 (10) Water movement in and through waste package
M110 (10) Resaturation state of mortar

Water movement in and through waste package

CT7 (10) Transport and release of nuclides from waste package
C1 (2) Radiolysis in waste package
C3 (10) Water chemistry in waste package
C26 (6) Electrochemical effects in waste package
C47 (10) Bulk gas formation in waste package

Water movement in and through backfill

BT8 (10) Transport and release of nuclides from backfill
B34 (6) Water chemistry in backfill
B67 (10) Water movement in and through shell
B110 (10) Resaturation state of backfill
B113 (10) Resaturation state of shell
B139 (10) Water movement in and through mortar [NOT BTF/BLA/BMA]
B144 (10) Resaturation state of mortar [NOT BTF/BLA/BMA]
B157 (2) Groundwater flow through near-field rock

Water movement in and through shell

ST8 (10) Transport and release of nuclides from shell
S34 (10) Water chemistry in shell
S67 (10) Water movement in and through mortar [NOT BTF/BLA/BMA]
S110 (10) Resaturation state of shell
S113 (10) Resaturation state of mortar [NOT BTF/BLA/BMA]

Appendix H: *Influences in the Far-Field Section of PID for SFR-1*

NOTE: Codes in bold type signify Influences directly related to the transport of radionuclides. All such Influences are given an Importance Level of 10.

Alteration/weathering of flow paths in far-field rock
G20 (10) Groundwater chemistry, far-field rock
G28 (10) Properties of far-field rock
G47 (10) Colloid generation and transport in near-field rock
G121 (10) Fast pathways

Bulk gas, far-field rock
G23 (6) Water chemistry, far-field rock
G32 (10) Hydraulic saturation/unsaturation of far-field rock
G40 (10) Groundwater flow through far-field rock
G107 (10) Gas flow and transport in far-field rock

Climate change (External Boundary Condition)
E1 (6) Stress field (in situ)
E2 (10) Hydraulic saturation/unsaturation
E3 (2) Alteration/weathering of flowpaths
E4 (10) Groundwater flow
E5 (6) Thermal field

Colloid generation and transport in far-field rock
GT5 (10) Transport and release of nuclides from far-field rock
G128 (2) Groundwater chemistry, far-field rock

Diffusion of salt [*FEP, not included in Business Modeller PID, added after 1999 Workshop (Stenhouse et al., 2000)*]
G?? (10) Groundwater chemistry, far-field [*Influence not included in Business Modeller PID, added after 1999 Workshop (Stenhouse et al., 2000)*]

Diffusion through far-field rock
GT8 (2) Transport and release of nuclides from far-field rock
G91 (6) Water chemistry, far-field rock

Dispersion in far-field rock
GT11 (10) Transport and release of nuclides from far-field rock

Electrochemical gradients in far-field rock
GT10 (2) Transport and release of nuclides from far-field rock

Erosion of the surface (External Boundary Condition)
E6 (2) Redox heterogeneity
E7 (6) Stress field (in situ)
E8 (2) Groundwater chemistry

Fault movement

G54 (10) Properties of far-field rock
G99 (10) Stress field (in situ)
G100 (6) Water chemistry, far-field rock
G126 (10) Fast pathways in far-field rock

Gas flow and transport in far-field rock

GT13 (10) Transport and release of nuclides from far-field rock
G8 (2) Gas pressure (bulk gas) in near-field rock
G106 (10) Gas pressure (bulk gas) in far-field rock

Geometry/driving force for groundwater flow

G73 (6) Stress field (in situ)
G83 (10) Groundwater flow
G86 (2) Properties of rock

Groundwater chemistry in far-field

G1 (10) Microbial activity in far-field rock
G2 (10) Water chemistry, near-field rock
G8 (10) Radiolysis in far-field rock
G10 (10) Precipitation/dissolution in far-field rock
G11 (10) Microbial activity in far-field rock
G13 (10) Sorption on far-field rock
G15 (10) Redox heterogeneity in far-field rock
G19 (10) Alteration/weathering of flow paths in far-field rock
G43 (10) Colloid generation and transport in far-field rock

Groundwater flow through far-field

GT12 (10) Transport and release of nuclides from far-field rock
G1 (10) Groundwater flow through near-field rock
G35 (6) Stress field (in situ)
G53 (6) Water chemistry, far-field rock
G55 (6) Geometry/driving force for groundwater flow
G77 (10) Dispersion in far-field rock
G78 (2) Thermal field, far-field
G79 (10) Gas flow and transport in far-field rock
G80 (10) Hydraulic saturation/unsaturation of far-field rock
G81 (10) Matrix diffusion in far-field rock
G82 (10) Colloid generation and transport in far-field rock

Hydraulic saturation, far-field rock

G30 (10) Groundwater chemistry, far-field
G38 (10) Groundwater flow through far-field
G49 (10) Matrix diffusion, far-field
G85 (10) Gas flow and transport, far-field

Matrix diffusion in far-field rock

GT9 (10) Transport and release of nuclides from far-field rock
G92 (2) Water chemistry, far-field rock

Microbial activity in far-field rock

G3 (2) Water chemistry, far-field rock
G4 (2) Gas generation, far-field
G9 (2) Sorption on far-field rock

G45 (2) Colloid generation and transport in far-field rock
G74 (2) Properties of far-field rock

Precipitation/dissolution in far-field rock
GT1 (10) Radionuclide reconcentration in far-field rock
GT6 (10) Transport and release of nuclides from far-field rock
G12 (10) Water chemistry, far-field rock
Properties of far-field rock
G19 (2) Alteration/weathering of flowpaths, far-field
G37 (10) Groundwater flow through far-field rock
G41 (10) Sorption on far-field rock
G44 (10) Colloid generation and transport in far-field rock
G46 (10) Seismic activity
G48 (10) Matrix diffusion in far-field rock
Properties of far-field rock (continued)
G52 (10) Gas flow and transport in far-field rock
G67 (10) Water chemistry, far-field rock
G75 (10) Diffusion through far-field rock
G84 (10) Stress field (in situ)
G87 (6) Geometry/driving force for groundwater flow
G104 (10) Electrochemical gradients in far-field rock
G112 (10) Dispersion in far-field rock
G113 (10) Uplift/subsidence
G122 (10) Fast pathways in far-field rock

Radioactive decay and ingrowth of nuclides in far-field rock
GT4 (10) Transport and release of nuclides from far-field rock
G108 (10) Radiolysis in far-field rock
G109 (2) Gas generation in far-field rock
G111 (2) Recoil of alpha decay
Redox heterogeneity in far-field rock
G16 (10) Precipitation/dissolution in far-field rock
G93 (2) Properties of far-field rock
G94 (6) Colloid generation and transport in far-field rock

Salt (or fresh) groundwater intrusion
G58 (10) Groundwater flow
G59 (10) Groundwater chemistry
G61 (6) Properties of rock
G?? (10) Diffusion of salt [*FEP and Influence added after 1999 Workshop (Stenhouse et al., 2000)*]
Seismic activity
G27 (10) Properties of far-field rock
G101 (10) Fast pathways, far-field rock
G114 (10) Stress field (in situ)
Sorption on far-field rock
GT16 (10) Transport and release of nuclides from far-field rock
G129 (6) Water chemistry, far-field rock
Stress field, far-field (*in situ*)
G5 (10) Stress field in near-field rock

G14 (2) Shaft and tunnel seal degradation
G21 (6) Geometry/driving force for groundwater flow
G24 (10) Fault movement/activation
G25 (2) Fast pathways in far-field rock
G26 (6) Properties of far-field rock
G29 (10) Seismic activity
G125 (10) Uplift/subsidence
G127 (2) Alteration/weathering of flow paths in far-field rock

Thermal field, far-field
G33 (6) Stress field (*in situ*)
G34 (10) Water chemistry, far-field
G36 (6) Groundwater flow through far-field
G42 (10) Temperature of near-field rock
G68 (2) Sorption on far-field rock
G69 (2) Precipitation/dissolution in far-field rock
G70 (2) Diffusion through far-field rock
G71 (2) Matrix diffusion, far-field
G76 (2) Alteration/weathering of flow paths in far-field rock
G89 (10) Microbial activity, far-field

Transport and release of nuclides from far-field
GT13 (10) Transport and release of nuclides from far-field

Uplift/subsidence
E9 (10) Seismic activity
E10 (10) Fast pathways
E11 (10) Fault movement/activation
E12 (2) Properties of far-field rock
E13 (2) Groundwater flow through far-field rock

Appendix I: *FEPs From SPARTA PID for SFR-1 Repository: Near-Field*

FEPs From SPARTA PID for SFR-1 Repository: Near-Field

FEP Title	Nature of FEP		
	Super	*True*	*Level*
Repository zone			1
Crushed rock backfill			2
Near-field rock			2
Shafts and tunnels			2
BLA Section			1
Waste package			2
Concrete base			2
Backfill			2
BMA Section			1
Waste package			2
Concrete shell			2
Backfill			2
BTF Section			1
Waste package			2
Concrete shell			2
Backfill			2
Silo Section			1
Waste package			2
Porous concrete (grout)			2
Reinforced concrete shell			2
Backfill			2
Bentonite backfill			3
Sand-bentonite backfill			3
Sand backfill			3

FEP Title	Nature of FEP		Drawing	Repository zone			Relevant FEP from 2D PID
	"Super"	True	Level	NFR	S&T	CRB	
Cave-in		■	3	■			Cave-in
Excavation effects		■	3	■			Excavation effects on NFR
Gas pressure and flow		■	3	■	■	■	Gas pressure (bulk gas formation)
Geochemistry	■		3	■	■	■	*N/A*
Alkaline (pH) front		■	4	■	■	■	NOT INCLUDED
Alteration and weathering of flowpaths		■	4	■	■	■	Alteration/weathering of flowpaths
Degradation of shaft and tunnel seals		■	4		■		Shaft & tunnel seal degradation
Degradation and alteration of crushed rock backfill		■	4			■	Degradation/alteration of backfill
Colloid generation		■	4	■	■	■	Colloid generation and transport
Groundwater composition		■	4	■	■	■	Water chemistry
Microbial activtiy		■	4	■	■	■	Microbial activity
Precipitation and dissolution		■	4	■	■	■	Precipitation/dissolution
Redox heterogeneity		■	4	■	■	■	Redox front
Sulphate attack		■	4		■	■	NOT INCLUDED
Groundwater flow		■	3	■	■	■	Groundwater flow thruogh NFR
Rock properties FEPs	■		3	■	■	■	*N/A*
Fault activation		■	4	■			Fault movement and activation
Hydrogeological properties		■	4	■	■	■	Properties of NFR
Mechanical properties including stress field		■	4	■	■	■	Stress field in NFR
Mineralogy		■	4	■	■	■	Properties of NFR
Resaturation state		■	4	■	■	■	Resaturation state
Structural geometry properties		■	4	■	■	■	Properties of NFR
Thermal properties		■	4	■	■	■	Properties of NFR
Temperature and heat transfer		■	3	■	■	■	Temperature
Transport and release of radionuclides	■		3	■	■	■	*N/A*
Advective & dispersive transport of RN in groundwater		■	4	■	■	■	Transport & release of nuclides
Colloid transport		■	4	■	■	■	Colloid generation and transport
Diffusion		■	4		■		NOT INCLUDED IN NFR
Distribution & release of radionuclides		■	4	■	■	■	Transport & release of nuclides
Gas-mediated radionuclide transport		■	4	■	■	■	Gas flow and transport
Matrix diffusion		■	4	■			Matrix diffusion
Radioactive decay & ingrowth		■	4	■	■	■	Radioactive decay and ingrowth of nuclides
Radionuclide sorption		■	4	■	■	■	Sorption

NOTE: NFR=near-field rock; S&T=shafts and tunnels; CRB=crushed rock backfill.

FEP Title	Nature of FEP			WASTE PACKAGE				Relevant FEP from 2D PID
	"Super"	*True*	*Level*	*Silo*	*BLA*	*BMA*	*BTF*	
Chemistry FEPs			3					*N/A*
Colloid generation			4					Colloid generation and transport
Microbial activity			4					Microbial activity
Precipitation & dissolution			4					Precipitation/dissolution
Radiolysis			4					Radiolysis
Redox heterogeneity			4					NOT INCLUDED
Sulphate attack			4					NOT INCLUDED
Porewater composition			4					Water chemistry
Degradation of waste package			4					*N/A*
Corrosion of metallic waste			5					Corrosion of metal waste
Corrosion and degradation of waste container			5					Evolving properties of container
Degradation of inorganic waste			5					Degradation of inorganic waste
Degradation of organic waste			5					Degradation of organic waste
Degradation of bitumen matrix			5					Evolving properties of of bitumen matrix
Degradation of cement matrix			5					Evolving properties of cement matrix
Degradation of superplasticiser			5					NOT INCLUDED
Gas FEPs			3					*N/A*
Gas generation			4					Gas generation
Gas pressure and flow			4					Gas pressure (bulk gas formation)
Properties FEPs			3					*N/A*
Hydrogeological properties			4					Properties of WP
Mechanical properties including stress distribution			4					Mechanical stress distribution
Chemical comp. of waste, waste matrix + container			4					Properties of WP
Saturation state of waste package			4					Resaturation state
Structural geometry properties			4					Properties of WP
Thermal properties			4					Properties of WP
Temperature and heat transfer			3					Temperature
Transport and release of radionuclides			3					*N/A*
Water-mediated transport of radionuclides			4					Transport & release of nuclides
Colloid transport			4					Colloid generation and transport
Diffusion			4					Diffusion in and through WP
Distribution & release of radionuclides			4					Transport & release of nuclides
Gas-mediated radionuclide transport			4					Gas flow and transport
Radioactive decay & ingrowth			4					Radioactive decay and ingrowth of RN
Radionuclide sorption			4					Radionuclide sorption
Water flow in and through waste package			3					Water movement in and through WP

FEP Title	Nature of FEP			Silo backfill			Backfill			Relevant FEP from 2D PID
	Super	True	Level	*B*	*S-B*	*S*	*BLA*	*BMA*	*BTF*	
Gas pressure and flow			3/4							Gas pressure (bulk gas formation)
Geochemistry FEPs			3/4							*N/A*
Alkaline (pH) front			4/5							NOT INCLUDED
Colloid generation			4/5							Colloid generation and transport
Degradation and alteration			4/5							Degradation /alteration
Groundwater composition			4/5							Water chemistry
Microbial activity			4/5							Microbial activity
Precipitation & dissolution			4/5							Precipitation / dissolution
Redox heterogeneity			4/5							Redox front
Groundwater flow			3/4							Water movement in & through
Properties FEPs			3/4							*N/A*
Hydrogeological properties			4/5							Properties of NFR
Iechanical properties including stress distribution			4/5							Mechnical stress distribution
Mineralogy			4/5							Properties of NFR
Resaturation/saturation state			4/5							Resaturation state
Structural geometry			4/5							Properties of NFR
Swelling of bentonite			4/5							Swelling of bentonite
Thermal properties			4/5							Properties of NFR
Temperature and heat transfer			3/4							Temperature
Transport and release of radionuclides			3/4							*N/A*
Advective& dispersive transport of RN			4/5							Transport & release of nuclides
Colloid transport			4/5							Colloid generation and transport
Diffusion			4/5							Diffusion
Distribution & release of radionuclides			4/5							Transport & release of nuclides
Filtration			4/5							Filtration
Gas-mediated radionuclide transport			4/5							Gas flow and transport
Radioactive decay & ingrowth			4/5							Radioactive decay and ingrowth of RN
Radionuclide sorption			4/5							Radionuclide sorption

NOTES
Level=3/4 signifies Level 4 for Silo, LEvel 3 for other sections; similarly for Level 4/5.
Silo backfill: B=bentonite; S-B=sand-bentonite; S=sand.

Appendix J: *FEPs Included in SPARTA PID for SFR-1 Repository: Far-Field*

FEPs Included in SPARTA PID for SFR-1 Repository: Far-Field

FEP Title	Nature of FEP			Relevant FEP from 2D PID
	Super	True	Level	
Gas pressure and flow			1	Gas pressure (bulk gas formation)
Geochemistry			1	*N/A*
Alteration & weathering of flowpaths			2	Alteration & weathering of flowpaths
Colloid generation			2	Colloid generation and transport
Groundwater composition			2	Groundwater chemistry
Microbial activity			2	Microbial activity
Precipitation and dissolution			2	Precipitation and dissolution
Redox heterogeneity			2	Redox front
Salt or fresh water intrusion			2	Saline (or fresh) groundwater intrusion
Groundwater flow			1	Groundwater flow
Rock movement			1	Fault movement and activation
Rock properties FEPs			1	*N/A*
Hydraulic saturation/unsaturation			2	Hydraulic saturation/unsaturation
Hydrogeological properties			2	Properties of rock (physical+hydrogeological)
Mechanical properties including stress field			2	Stress field (in situ)
Mineralogy			2	Properties of rock (physical+hydrogeological)
Structural geometry properties			2	Properties of rock (physical+hydrogeological)
Thermal properties			2	Thermal field
Temperature and heat transfer			1	Thermal field
Transport and release of radionuclides			1	*N/A*
Advective and dispersive transport of radionuclides in groundwater			2	Dispersion
Colloid transport			2	Colloid generation and transport
Distribution and release of radionuclides			2	Transport and release of nuclides
Gas-mediated radionuclide transport			2	Gas flow and transport
Matrix diffusion			2	Matrix diffusion
Radioactive decay			2	Radioactive decay and ingrowth of nuclides
Radionuclide sorption			2	Sorption

2D PID FEPs NOT INCLUDED	Comment
Anion exclusion	Considered not relevant to far field of SFR-1
Diffusion	Considered not relevant to far field of SFR-1
Electrochemical gradients	Considered insignificant
Fast pathways	Included within "Structural geometry properties"
Gas generation	Considered not relevant to far field of SFR-1
Geometry and driving force of flow system	Included within "Hydrogeological properties"
Radiolysis	Considered insignificant
Radionuclide reconcentration	Considered insignificant
Recoil of alpha decay	Considered insignificant
Seismic activity	Considered EFEP
Uplift/subsidence	Considered EFEP

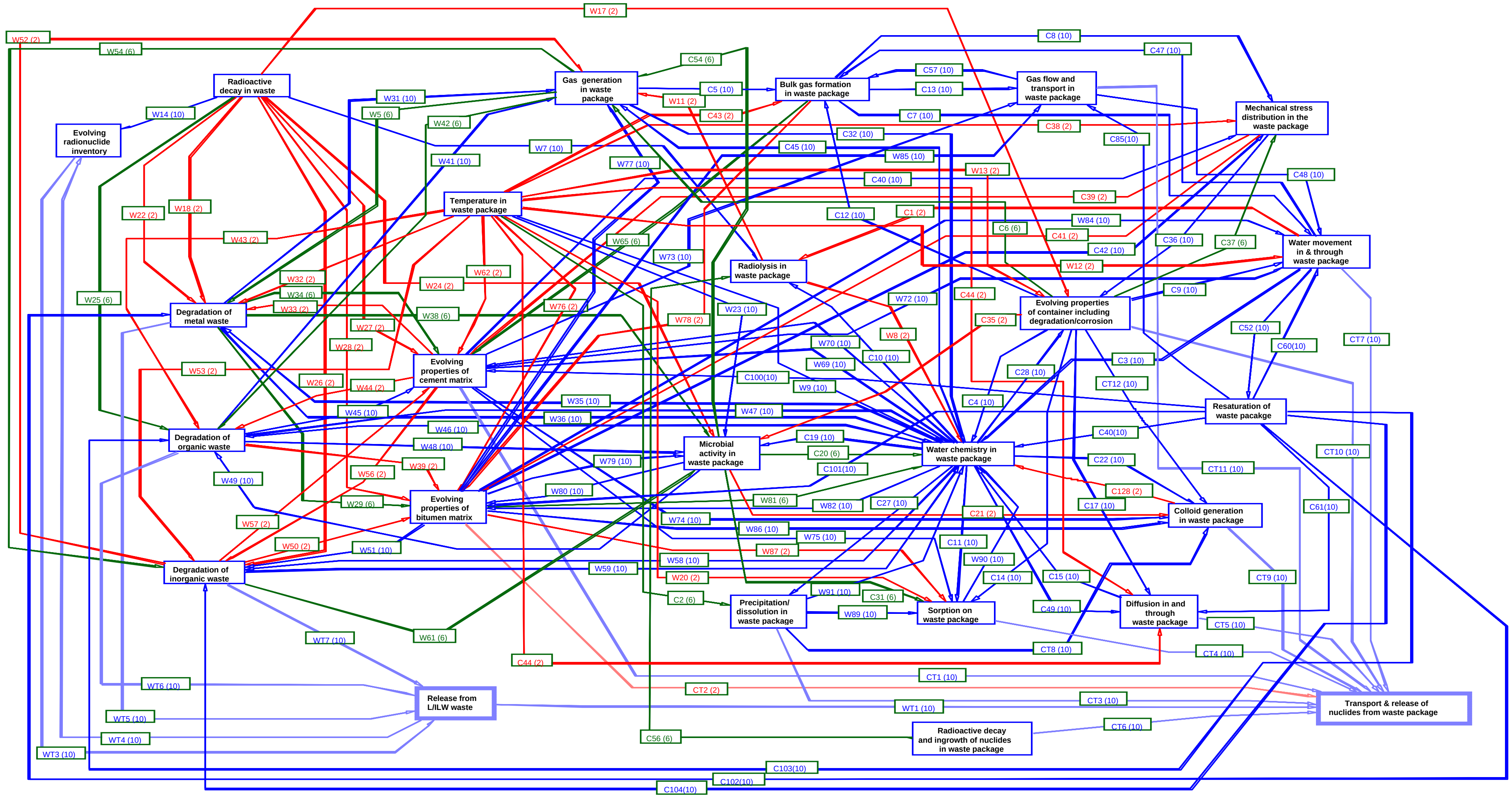
Annexe I: *Extracts of PID for Near-Field Section of Silo, SFR-1 Repository*

L/ILW REPOSITORY: SFR SILO
Waste+Matrix+Container (Waste Package)
Near-Field Reference Case PID

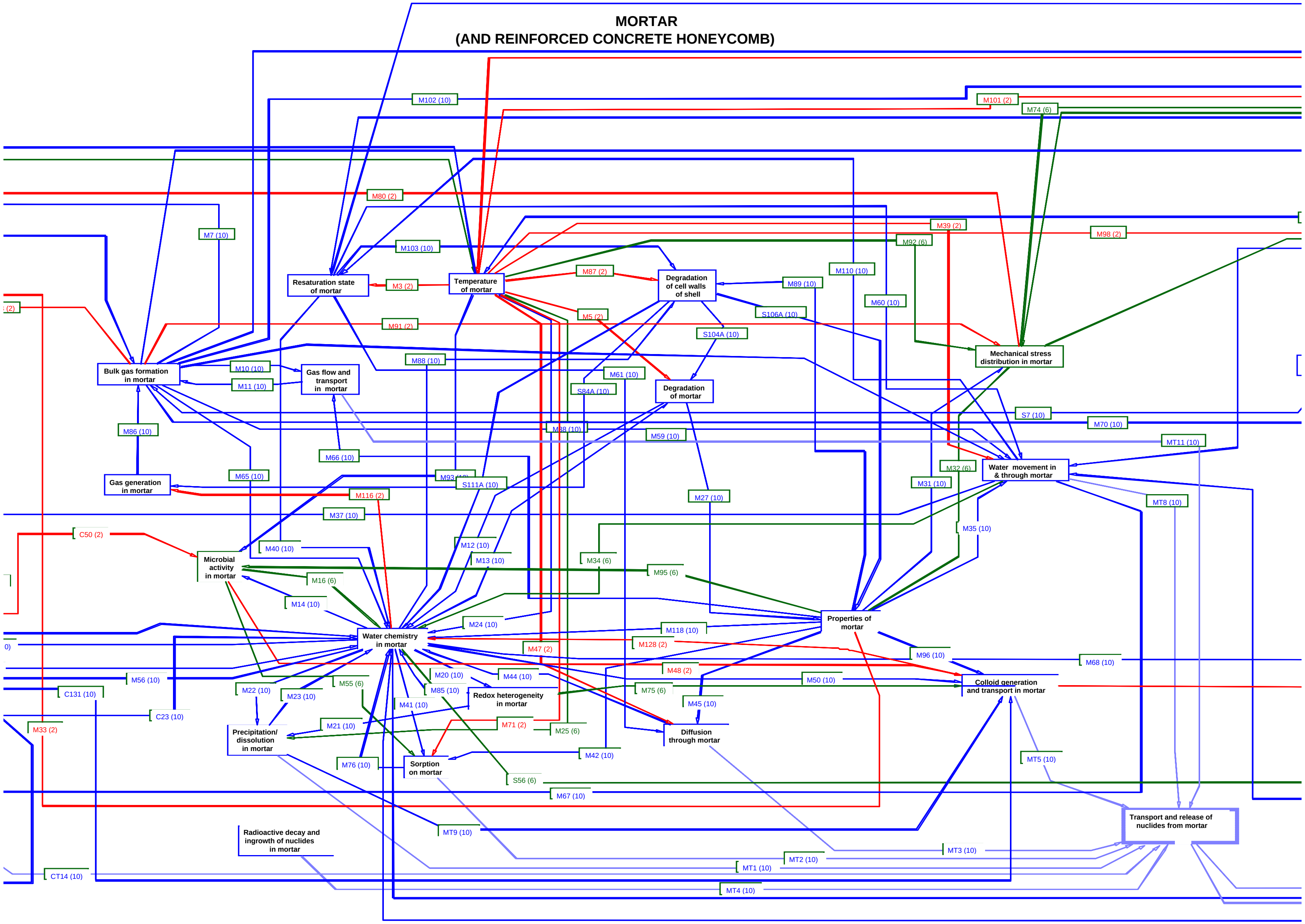
WASTE + MATRIX + STEEL DRUMS
+ CONCRETE (WASTE PACKAGE)

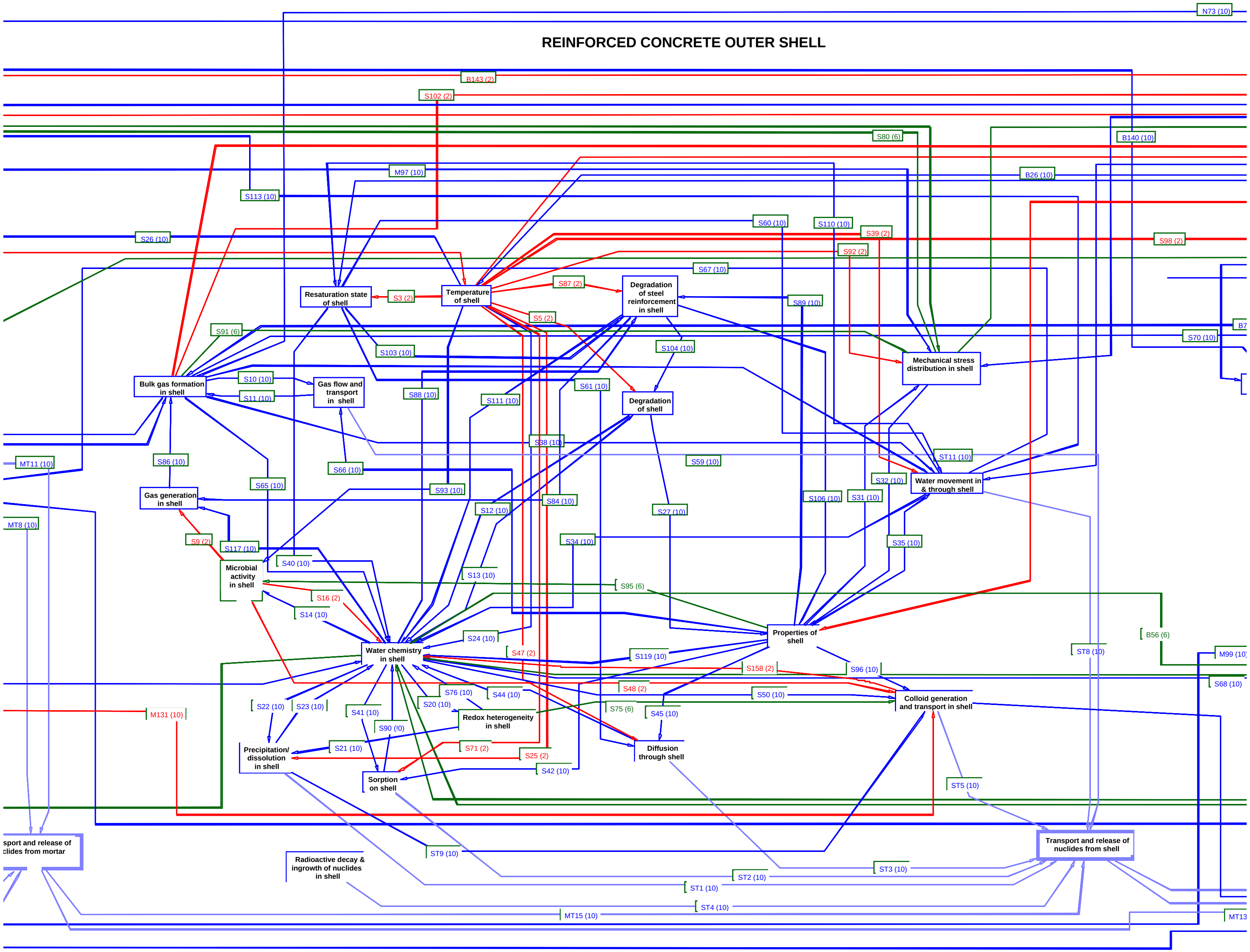
SKI PID L/ILW / SILO / 1.3 (12/04/2000)

KEY:
W63 (6) = Influence number (preliminary assignment of Importance Level in brackets)
W = waste+matrix,
C = container (concrete, steel), [C+W = waste package]
M = mortar

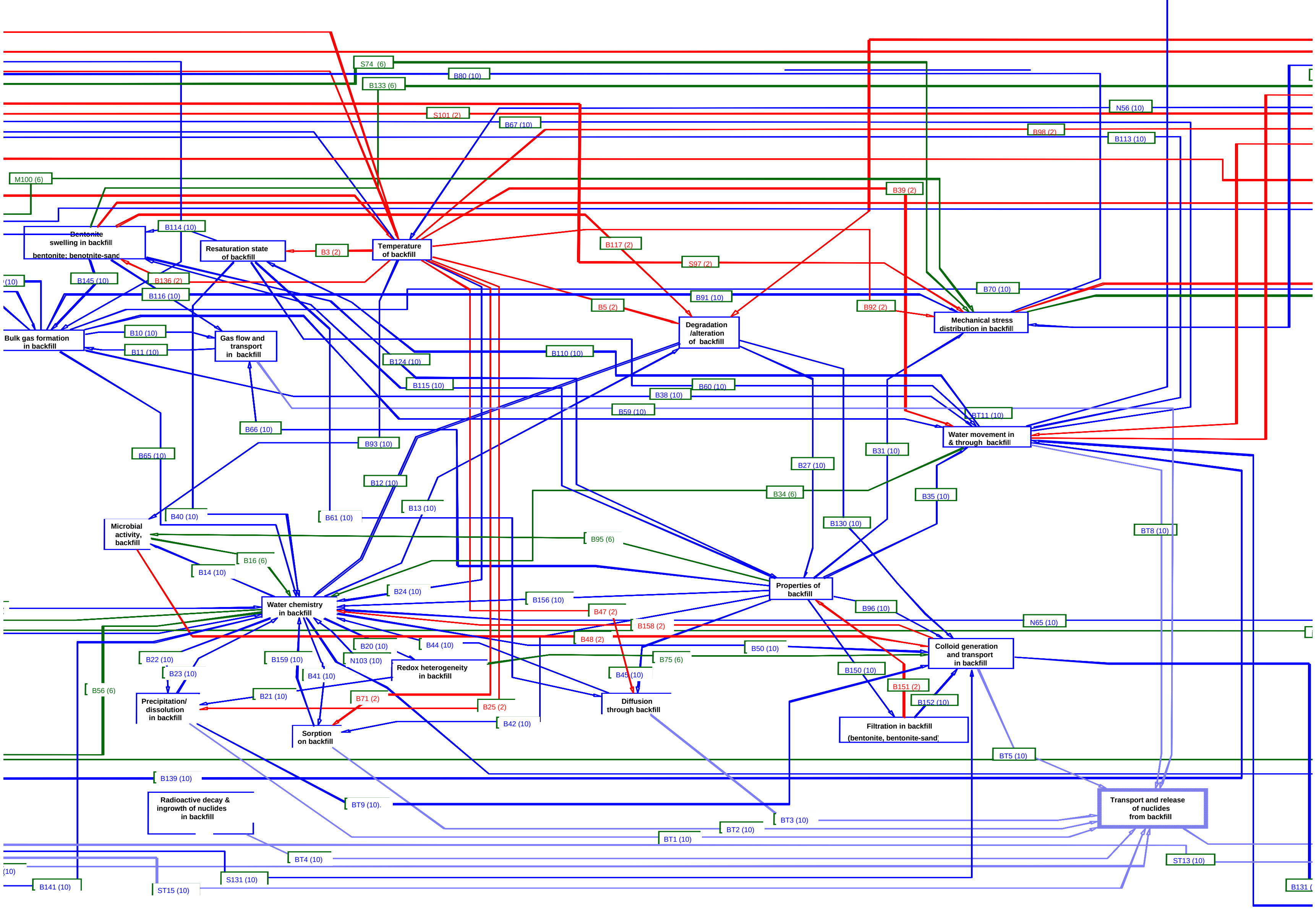


MORTAR
(AND REINFORCED CONCRETE HONEYCOMB)

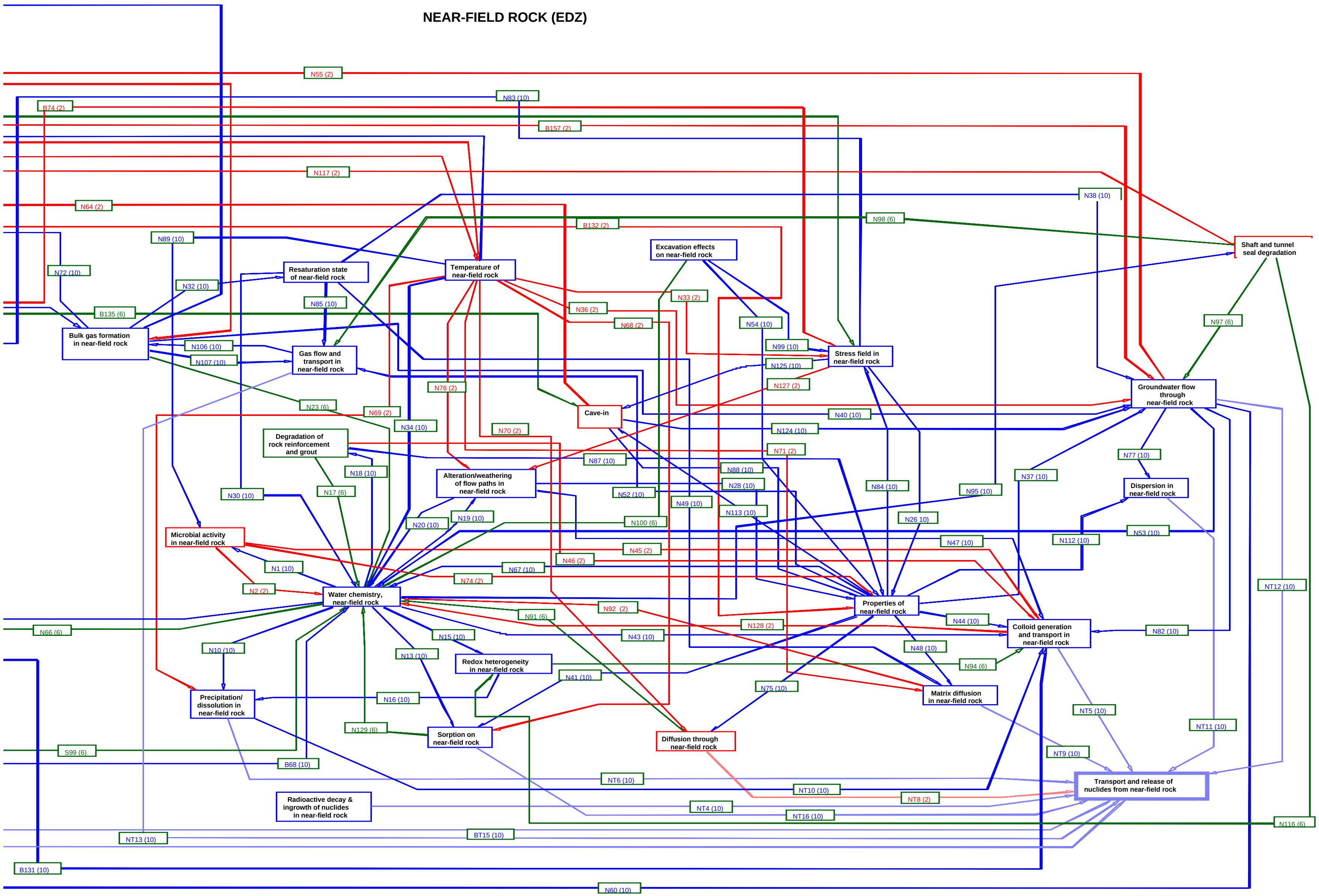



REINFORCED CONCRETE OUTER SHELL
N73 (10)
B143 (2)
S102 (2)
S80 (6)
B140 (10)
M97 (10)
B26 (10)
S113 (10)
S60 (10)
S110 (10)
S39 (2)
S98 (2)
S26 (10)
S92 (2)
S67 (10)
S87 (2)
Degradation of steel reinforcement in shell
S89 (10)
Resaturation state of shell
S3 (2)
Temperature of shell
S5 (2)
S91 (6)
S103 (10)
S104 (10)
S70 (10)
Mechanical stress distribution in shell
S10 (10)
Gas flow and transport in shell
Bulk gas formation in shell
S11 (10)
S88 (10)
S111 (10)
S61 (10)
Degradation of shell
S38 (10)
S59 (10)
ST11 (10)
MT11 (10)
S86 (10)
S66 (10)
S32 (10)
Water movement in & through shell
S65 (10)
S93 (10)
Gas generation in shell
S84 (10)
S106 (10)
S31 (10)
S12 (10)
S27 (10)
MT8 (10)
S9 (2)
S34 (10)
S35 (10)
S117 (10)
Microbial activity in shell
S40 (10)
S13 (10)
S95 (6)
S16 (2)
S14 (10)
B56 (6)
S24 (10)
Properties of shell
S47 (2)
ST8 (10)
M99 (10)
Water chemistry in shell
S119 (10)
S158 (2)
S96 (10)
S68 (10)
S76 (10)
S44 (10)
S48 (2)
S50 (10)
Colloid generation and transport in shell
S22 (10)
S23 (10)
S20 (10)
S75 (6)
S45 (10)
M131 (10)
S41 (10)
Redox heterogeneity in shell
S90 (10)
S21 (10)
S71 (2)
Diffusion through shell
Precipitation/ dissolution in shell
S25 (2)
S42 (10)
Sorption on shell
ST5 (10)
sport and release of clides from mortar
Transport and release of nuclides from shell
ST9 (10)
Radioactive decay & ingrowth of nuclides in shell
ST3 (10)
ST2 (10)
ST1 (10)
ST4 (10)
MT15 (10)
MT13

BACKFILL (BENTONITE / BENTONITE-SAND / SAND)



NEAR-FIELD ROCK (EDZ)



Annexe II: ***Extracts of PID for Near-Field Rock Zone and Far-Field Sections of Silo, SFR-1 Repository***

Annexe II-2

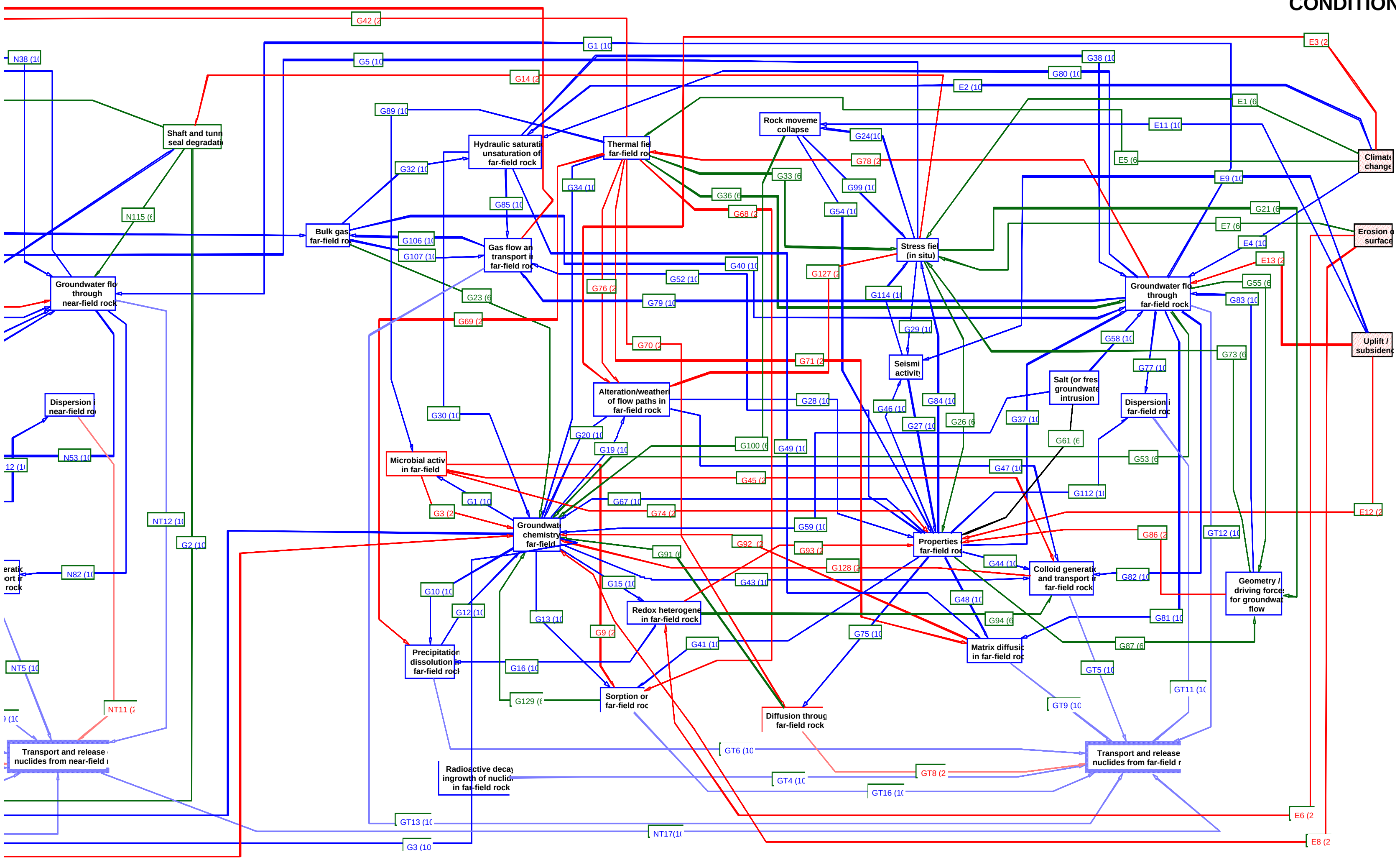
SKI PID L/ILW / FAR FIELD Version 1.2 (12/05/2000)

L/ILW REPOSITORY: SFR
Far-Field PID
(including Near-Field Rock zo

KEY:
G63 (6) = Influence number
(Importance Level in brackets)
N=near-field rock,
G=far-field rock
E=external influence

FAR-FIEL

EXTERNA BOUNDAR CONDITION



Annexe III: *Reference Case PID for SFR-1 Repository: Individual Drawings from SPARTA*

Layout of Drawings

The PID drawings for the SFR-1 repository system created using SPARTA are presented in this Annexe in the following sequence:

LEVEL 0

System Level (SFR-1 Repository System)

LEVEL 1

External FEPs [1]

Geosphere-Biosphere Interface [1]

Far Field

Near Field

LEVEL 2

(Far Field)	Groundwater chemistry
	Rock properties
	Transport and release of radionuclides
(Near Field)	Repository zone
	Silo section
	BLA section
	BTF section
	BMA section

LEVEL 3

(Repository zone)	Near-field rock
	Shafts and tunnels
	Crushed rock backfill
(Silo section)	Backfill
	Reinforced concrete shell
	Porous concrete (grout)
	Waste package
(BLA section)	Backfill
	Concrete base
	Waste package
(BTF section)	Roof backfill
	Concrete shell
	Waste package
(BMA section)	Backfill
	Concrete shell

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[1] The FEPs provided in this drawing should be viewed as preliminary, as a separate effort is being devoted to this topic. Similarly, the Geosphere-Biosphere Interface and Biosphere are being treated independently.

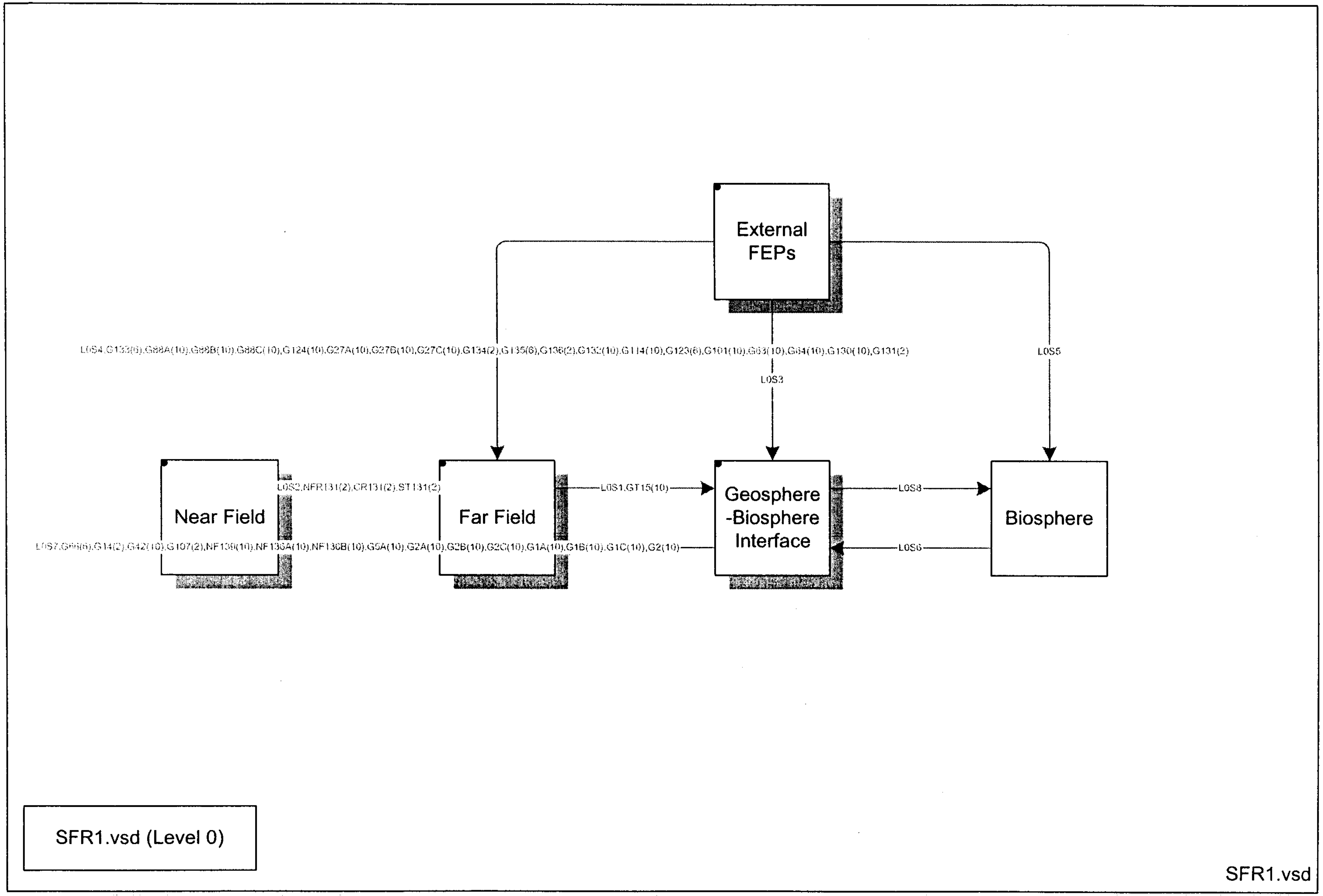
Layout of Drawings (continued)

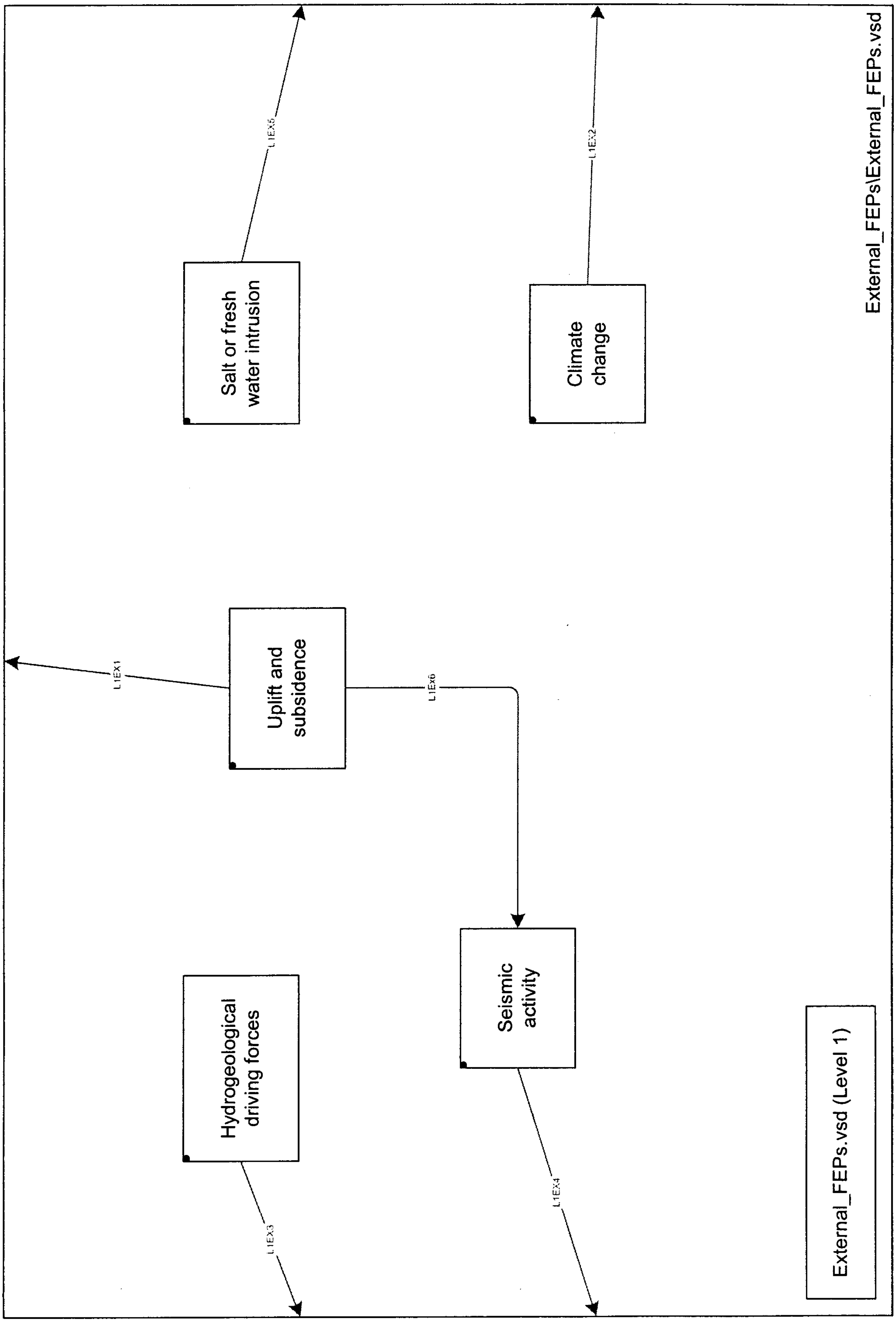
	LEVEL 4
(Repository zone/Near-field rock)	Geochemistry
	Rock properties
	Transport and release of radionuclides
(Repository zone/Shafts & tunnels)	Geochemistry
	Rock properties
	Transport and release of radionuclides
(Repository zone/Crushed rock) backfill)	Geochemistry
	Rock properties
	Transport and release of radionuclides
(Silo-Backfill)	Bentonite
	Sand-bentonite
	Sand
(Silo-Reinforced concrete shell)	Geochemistry
	Gas FEPs
	Properties of barrier
	Transport and release of radionuclides
(Silo-Porous concrete - grout)	Geochemistry
	Properties of porous concrete
	Transport and release of radionuclides
(Silo-Waste package)	Chemistry
	Gas FEPs
	Properties of waste package
	Transport and release of radionuclides
(BLA-Backfill)	Geochemistry
	Properties of backfill
	Transport and release of radionuclides
(BLA-Concrete base)	Geochemistry
	Properties of concrete base
	Transport and release of radionuclides
(BLA -Waste package)	Chemistry
	Gas FEPs
	Properties of waste package
	Transport and release of radionuclides
(BTF-Roof backfill)	Geochemistry
	Properties of roof backfill
	Transport and release of radionuclides
(BTF-Concrete shell)	Geochemistry
	Properties of concrete shell
	Transport and release of radionuclides
(BTF -Waste package)	Chemistry
	Gas FEPs
	Properties of waste package
	Transport and release of radionuclides

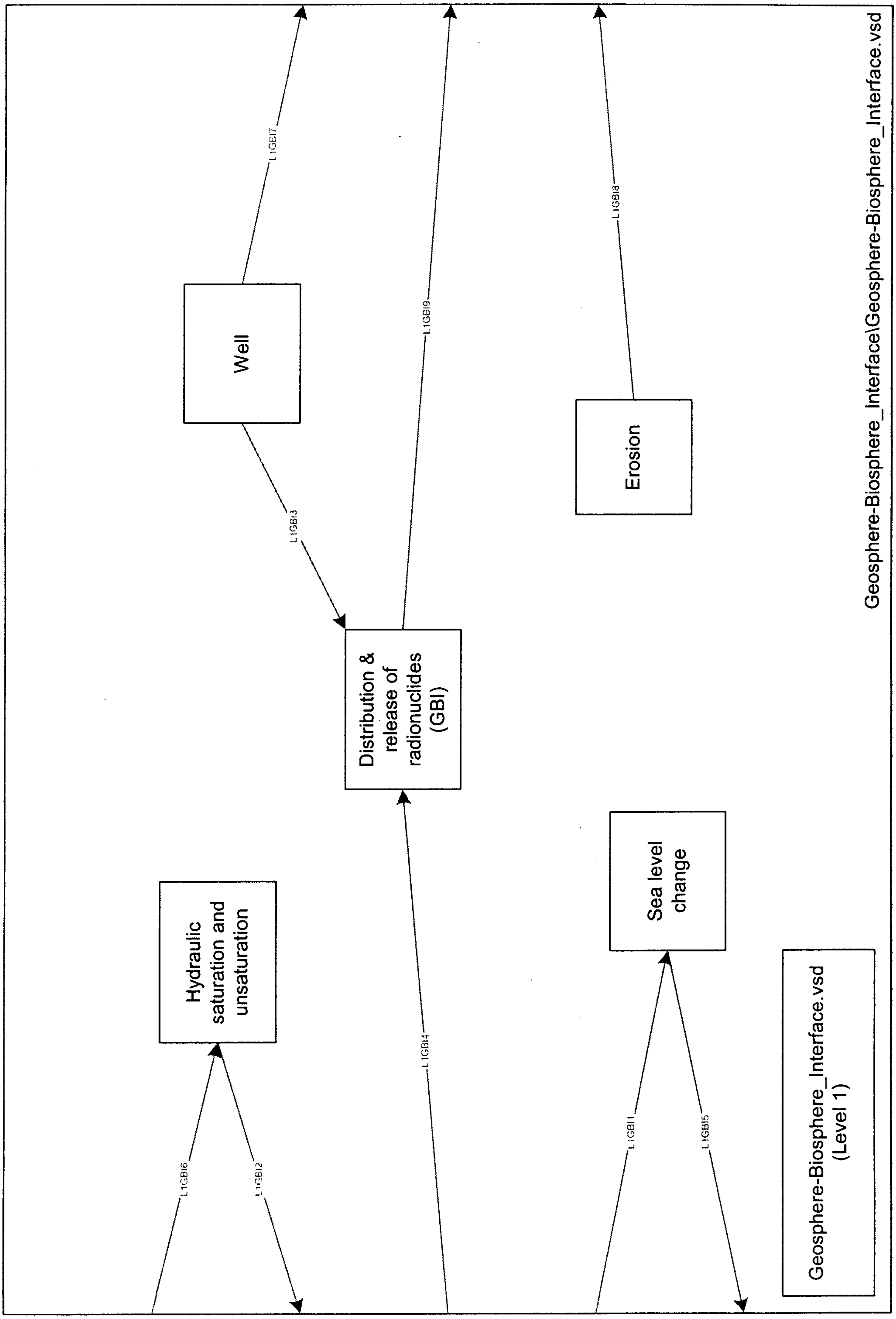
Layout of Drawings (continued)

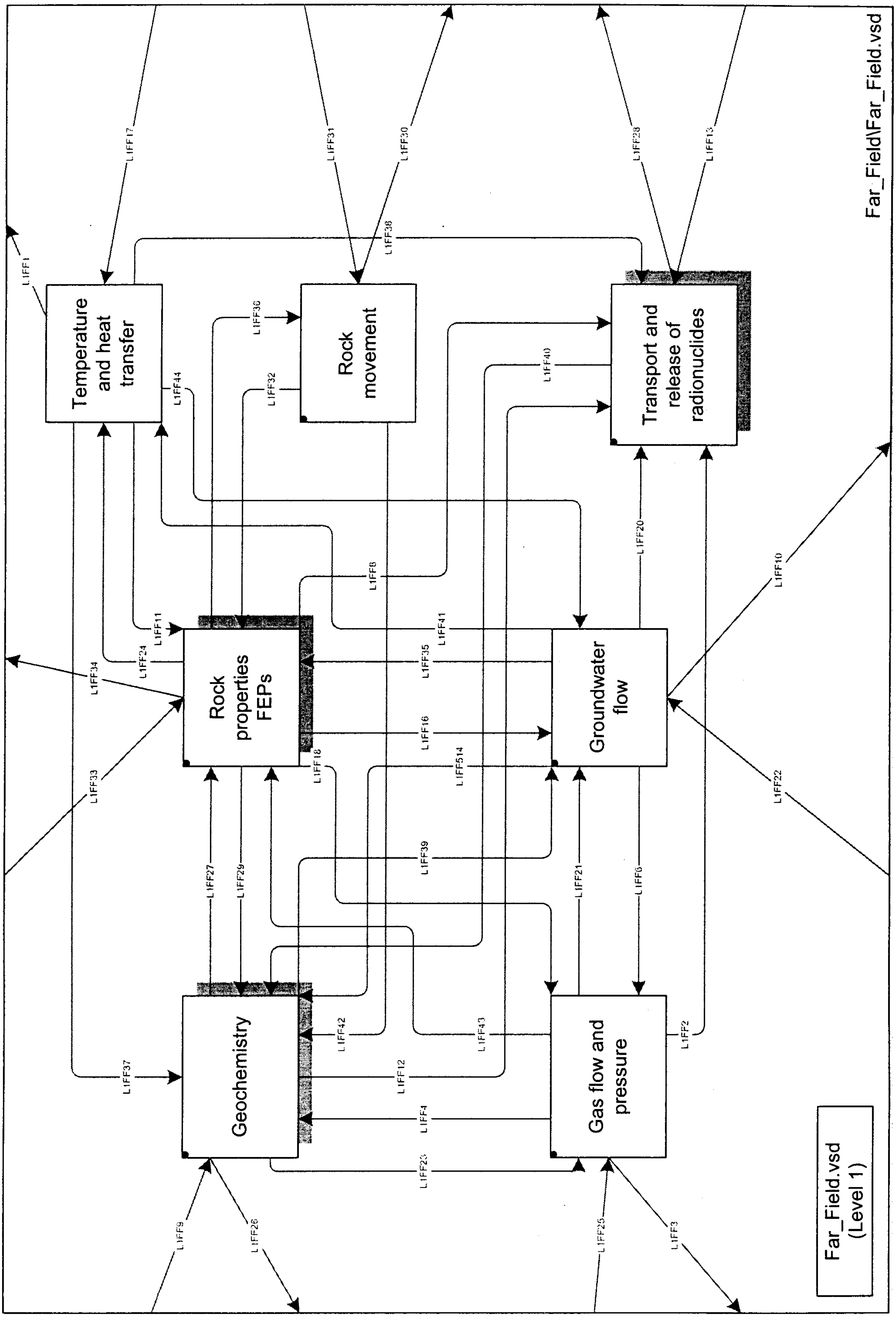
	LEVEL 4
(BMA-Backfill)	Geochemistry
	Properties of backfill
	Transport and release of radionuclides
(BMA-Concrete shell)	Geochemistry
	Properties of concrete shell
	Transport and release of radionuclides
(BMA -Waste package)	Chemistry
	Gas FEPs
	Properties of waste package
	Transport and release of radionuclides

	LEVEL 5
(Silo: Bentonite backfill)	Geochemistry
	Properties of bentonite backfill
	Transport and release of radionuclides
(Silo: Sand-bentonite backfill)	Geochemistry
	Properties of sand-bentonite backfill
	Transport and release of radionuclides
(Silo: Sand backfill)	Geochemistry
	Properties of sand backfill
	Transport and release of radionuclides
(Silo-Waste package-Chemistry)	Degradation of waste package
(BLA-Waste package-Chemistry)	Degradation of waste package
(BTF-Waste package-Chemistry)	Degradation of waste package
(BMA-Waste package-Chemistry)	Degradation of waste package

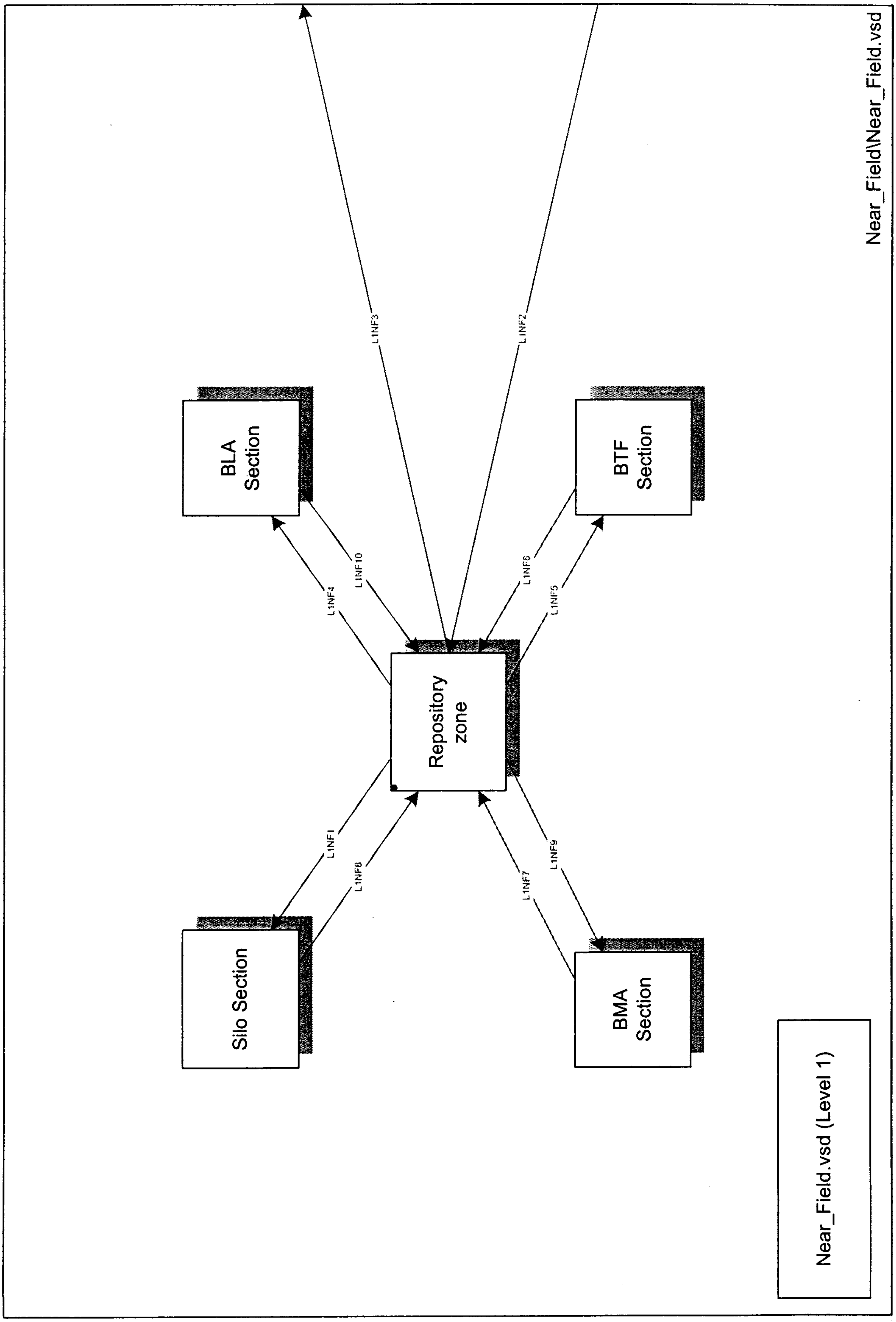

External FEPs
Near Field
Far Field
Geosphere -Biosphere Interface
Biosphere
L0S4,G133(6),G88A(10),G88B(10),G88C(10),G124(10),G27A(10),G27B(10),G27C(10),G134(2),G135(6),G136(2),G132(10),G114(10),G123(6),G101(10),G63(10),G64(10),G130(10),G131(2)
L0S3
L0S5
L0S2,NFR131(2),CR131(2),ST131(2)
L0S1,GT15(10)
L0S8
L0S6
L0S7,G66(6),G14(2),G42(10),G107(2),NF139(10),NF136A(10),NF136B(10),G5A(10),G2A(10),G2B(10),G2C(10),G1A(10),G1B(10),G1C(10),G2(10)
SFR1.vsd (Level 0)
SFR1.vsd

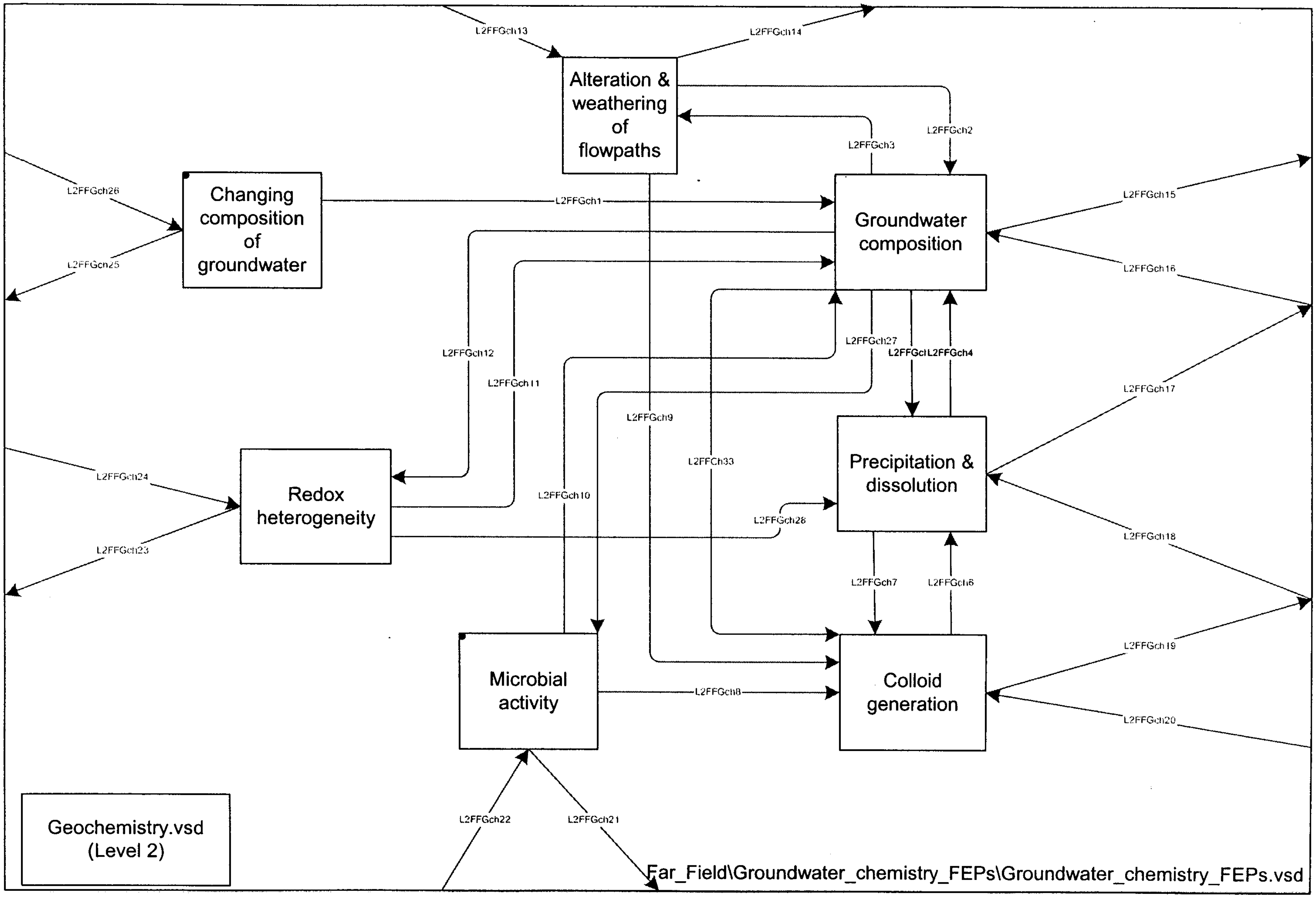

External_FEPs\External_FEPs.vsd
Salt or fresh water intrusion
Climate change
Uplift and subsidence
Seismic activity
Hydrogeological driving forces
L1EX5
L1EX2
L1EX1
L1Ex6
L1EX3
L1EX4
External_FEPs.vsd (Level 1)


Geosphere-Biosphere_Interface\Geosphere-Biosphere_Interface.vsd
Well
Distribution & release of radionuclides (GBI)
Erosion
Hydraulic saturation and unsaturation
Sea level change
Geosphere-Biosphere_Interface.vsd (Level 1)
L1GBI7
L1GBI3
L1GBI9
L1GBI8
L1GBI4
L1GBI6
L1GBI2
L1GBI1
L1GBI5



Far_Field\Far_Field.vsd
Temperature and heat transfer
Rock movement
Transport and release of radionuclides
Rock properties FEPs
Groundwater flow
Geochemistry
Gas flow and pressure
Far_Field.vsd (Level 1)
L1FF1
L1FF17
L1FF31
L1FF30
L1FF38
L1FF28
L1FF13
L1FF36
L1FF32
L1FF44
L1FF40
L1FF8
L1FF20
L1FF10
L1FF11
L1FF24
L1FF34
L1FF41
L1FF35
L1FF16
L1FF18
L1FF514
L1FF33
L1FF22
L1FF27
L1FF29
L1FF39
L1FF21
L1FF6
L1FF42
L1FF43
L1FF2
L1FF37
L1FF12
L1FF4
L1FF23
L1FF9
L1FF26
L1FF25
L1FF3


Near_Field\Near_Field.vsd
BLA Section
BTF Section
Repository zone
Silo Section
BMA Section
L1NF1
L1NF2
L1NF3
L1NF4
L1NF5
L1NF6
L1NF7
L1NF8
L1NF9
L1NF10
Near_Field.vsd (Level 1)


Alteration & weathering of flowpaths
Changing composition of groundwater
Groundwater composition
Redox heterogeneity
Precipitation & dissolution
Microbial activity
Colloid generation
Geochemistry.vsd (Level 2)
Far_Field\Groundwater_chemistry_FEPs\Groundwater_chemistry_FEPs.vsd
L2FFGch1
L2FFGch2
L2FFGch3
L2FFGch4
L2FFGch6
L2FFGch7
L2FFGch8
L2FFGch9
L2FFGch10
L2FFGch11
L2FFGch12
L2FFGch13
L2FFGch14
L2FFGch15
L2FFGch16
L2FFGch17
L2FFGch18
L2FFGch19
L2FFGch20
L2FFGch21
L2FFGch22
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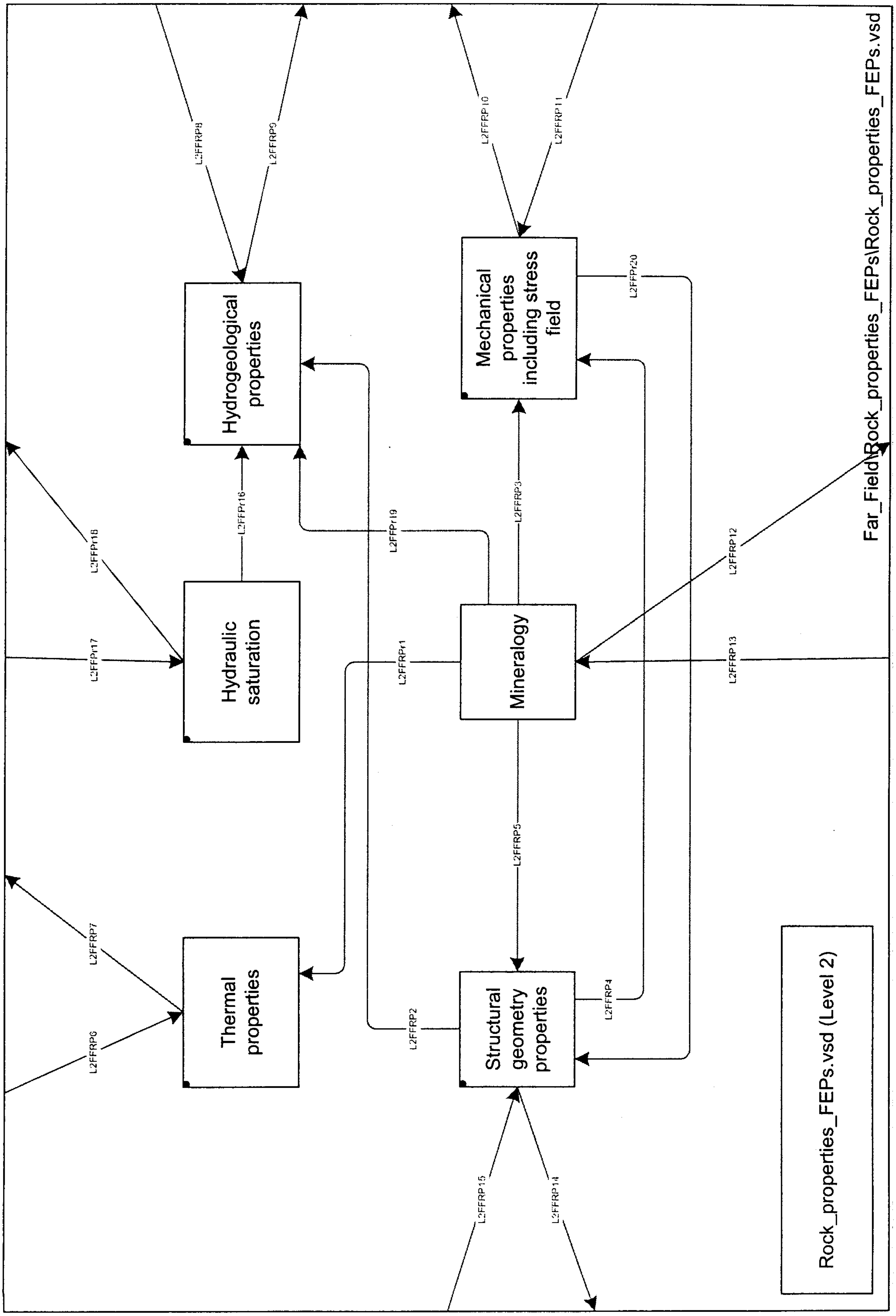
L2FFGch28
L2FFCh33


Far_Field\Rock_properties_FEPs\Rock_properties_FEPs.vsd
Hydrogeological properties
Mechanical properties including stress field
Hydraulic saturation
Mineralogy
Thermal properties
Structural geometry properties
Rock_properties_FEPs.vsd (Level 2)
L2FFRP8
L2FFRP9
L2FFRP10
L2FFRP11
L2FFPr20
L2FFPr16
L2FFPr19
L2FFRP3
L2FFRP12
L2FFPr18
L2FFPr17
L2FFPr1
L2FFRP13
L2FFRP5
L2FFRP7
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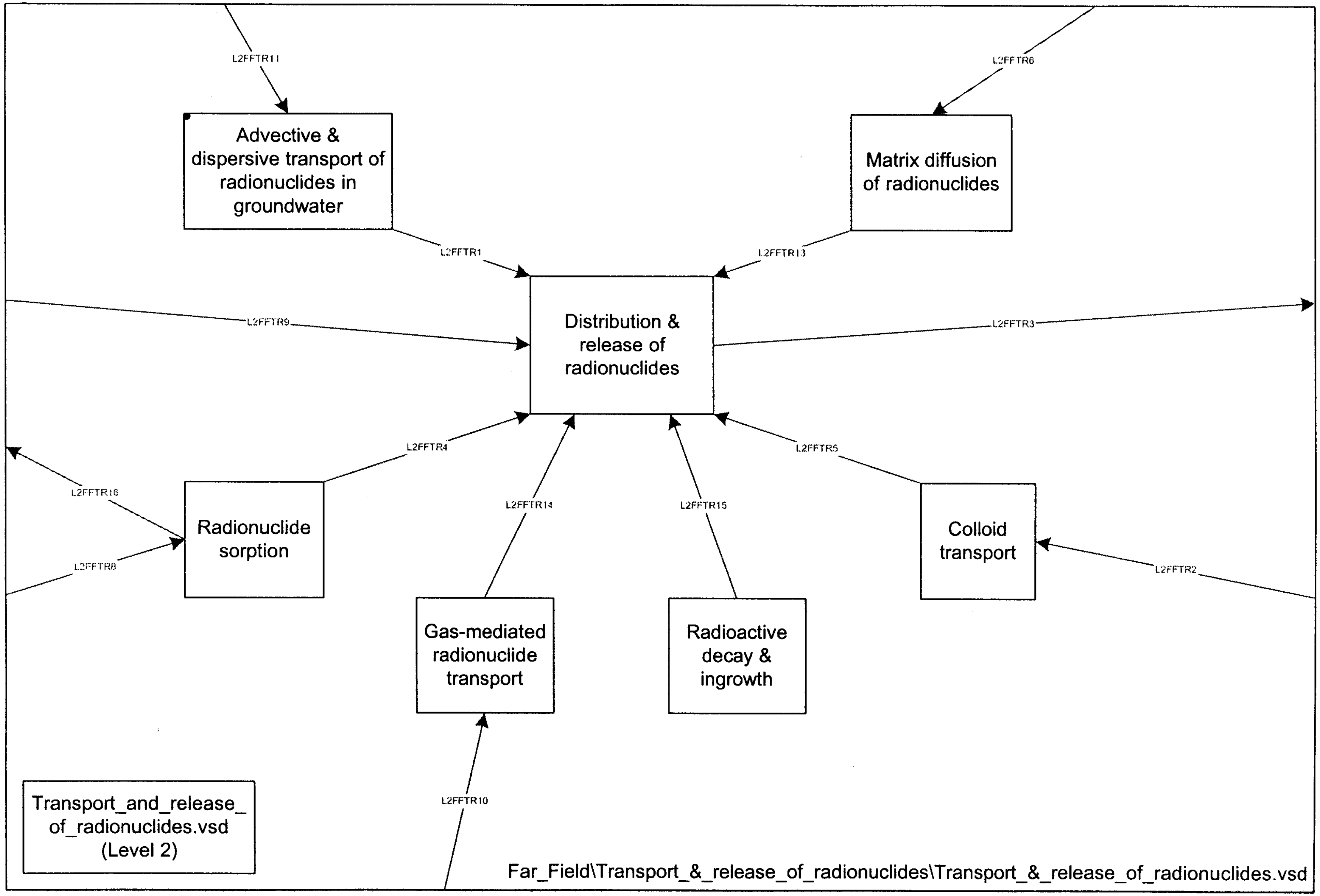
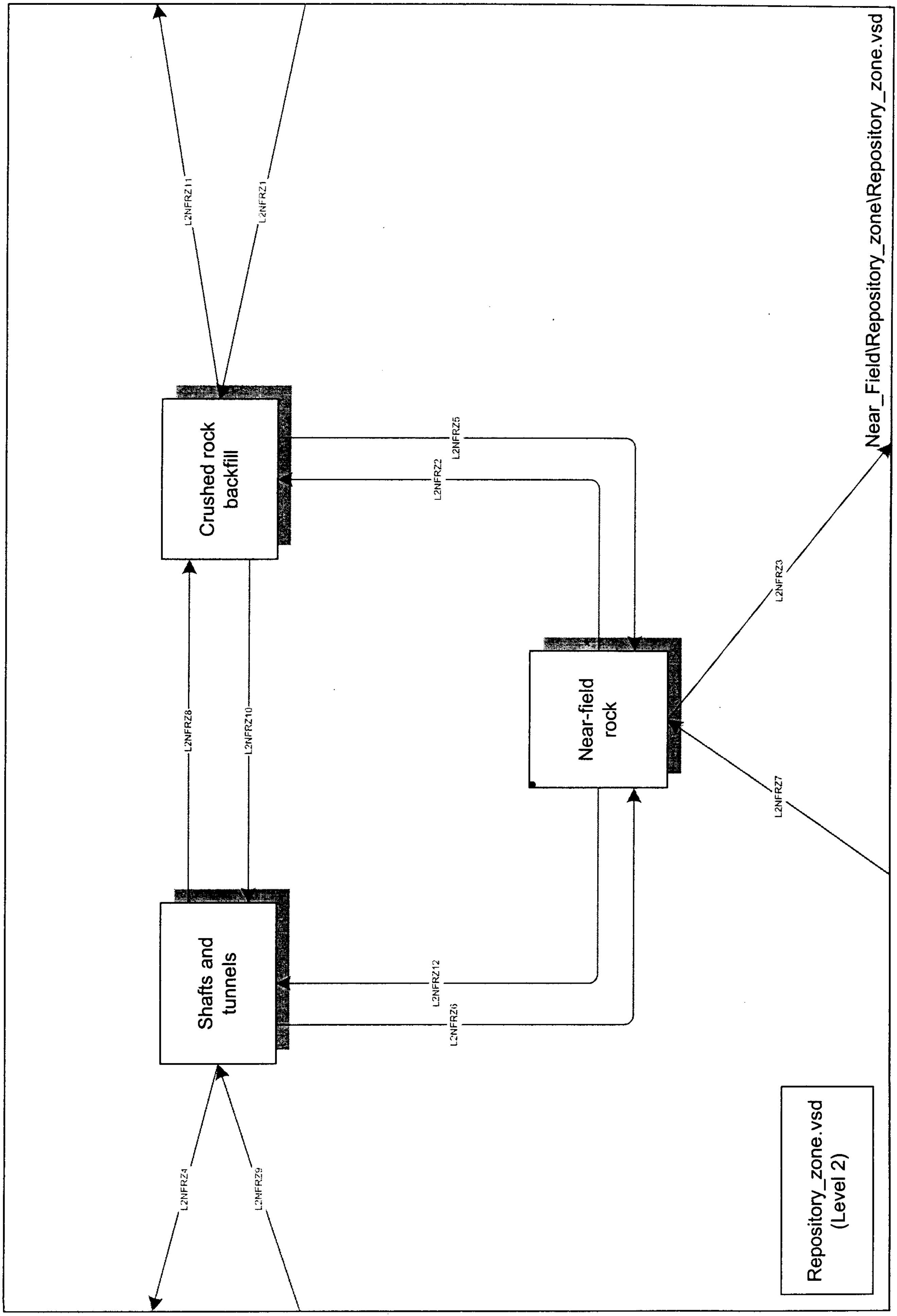
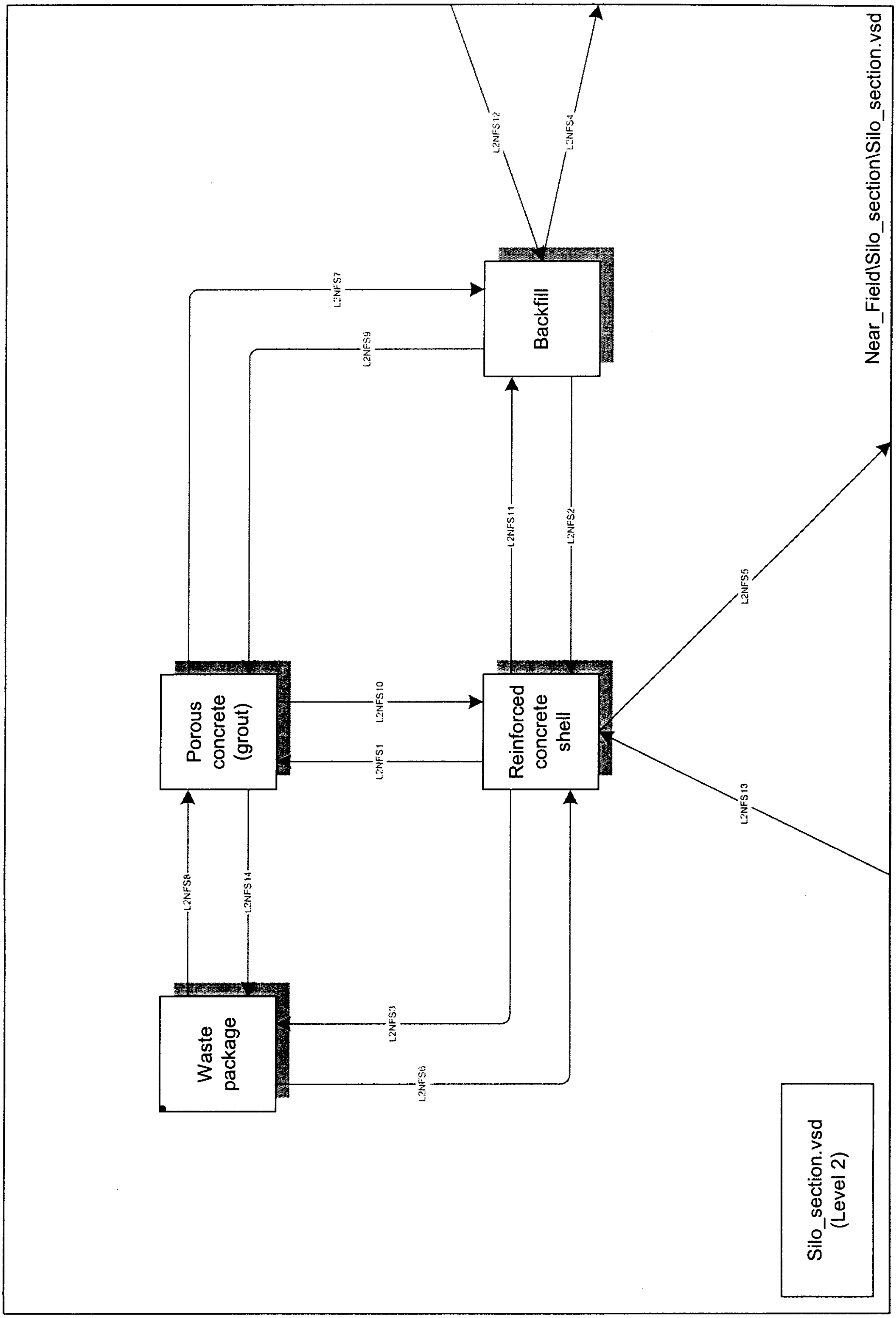
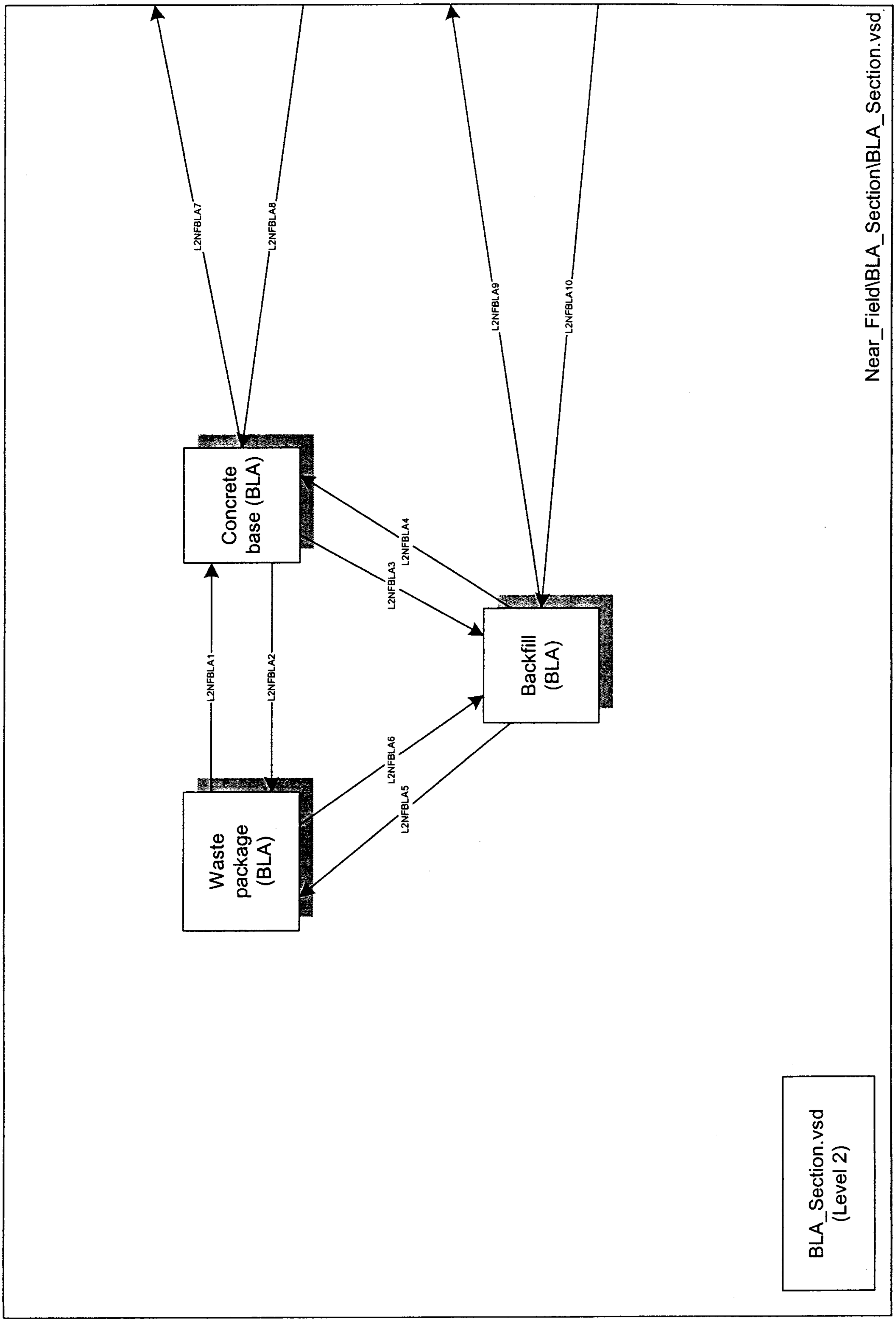
L2FFRP4
L2FFRP15
L2FFRP14


Advective & dispersive transport of radionuclides in groundwater
Matrix diffusion of radionuclides
L2FFTR11
L2FFTR6
L2FFTR1
L2FFTR13
L2FFTR9
Distribution & release of radionuclides
L2FFTR3
L2FFTR4
L2FFTR5
L2FFTR16
L2FFTR14
L2FFTR15
Radionuclide sorption
Colloid transport
L2FFTR8
L2FFTR2
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
L2FFTR10
Transport_and_release_of_radionuclides.vsd (Level 2)
Far_Field\Transport_&_release_of_radionuclides\Transport_&_release_of_radionuclides.vsd

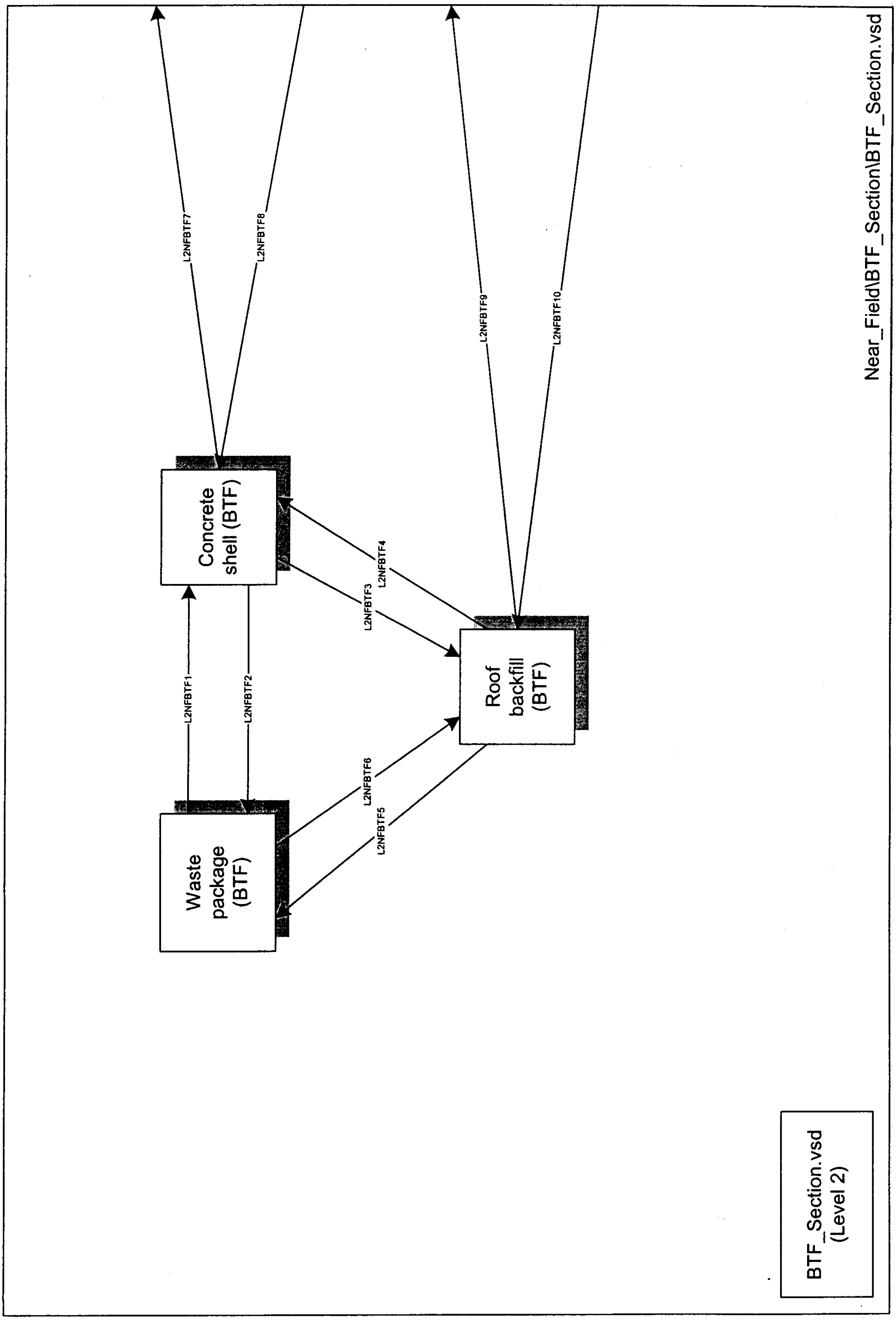

Near_Field\Repository_zone\Repository_zone.vsd
Crushed rock backfill
Near-field rock
Shafts and tunnels
L2NFRZ11
L2NFRZ1
L2NFRZ5
L2NFRZ2
L2NFRZ3
L2NFRZ8
L2NFRZ10
L2NFRZ7
L2NFRZ12
L2NFRZ6
L2NFRZ4
L2NFRZ9
Repository_zone.vsd
(Level 2)

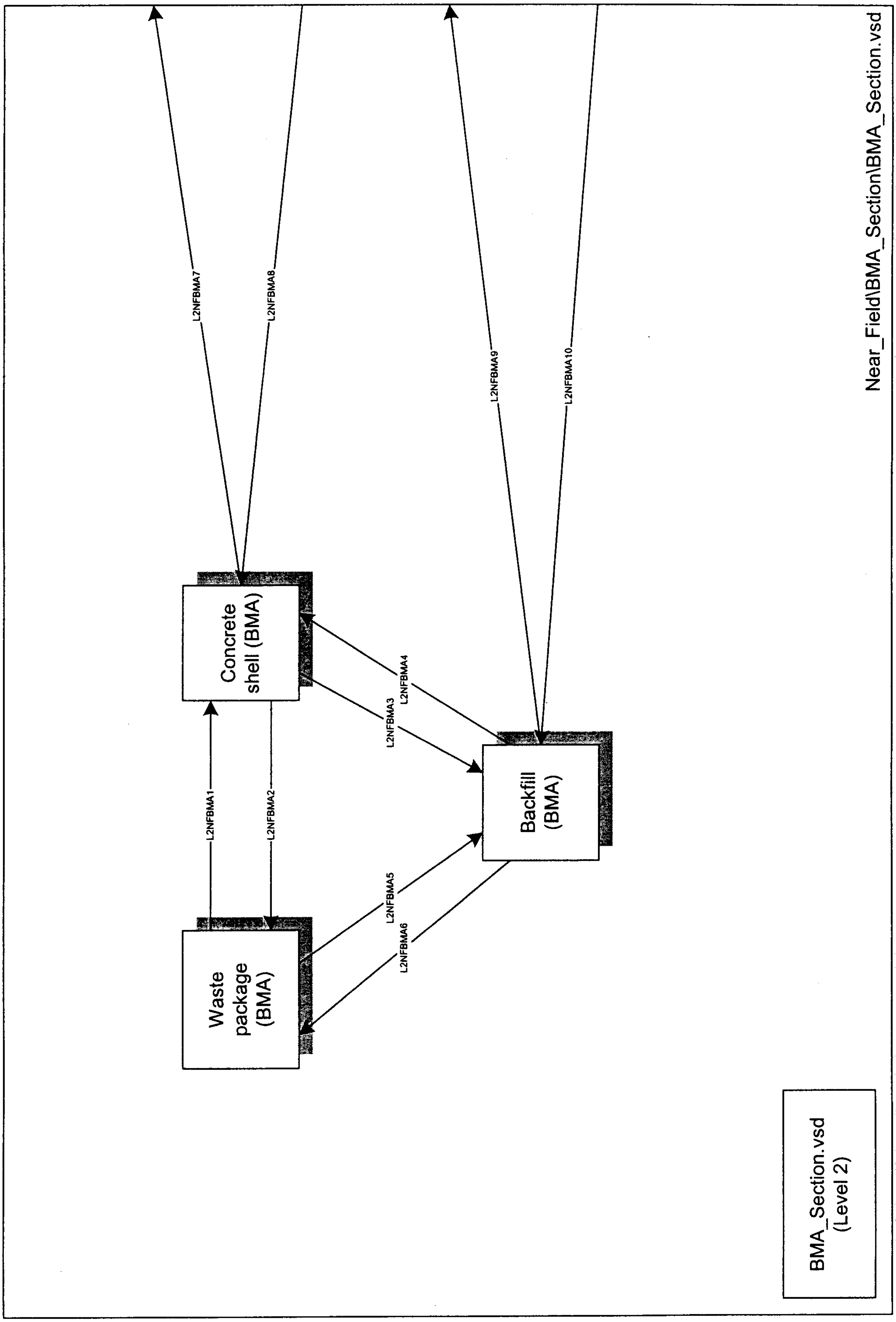


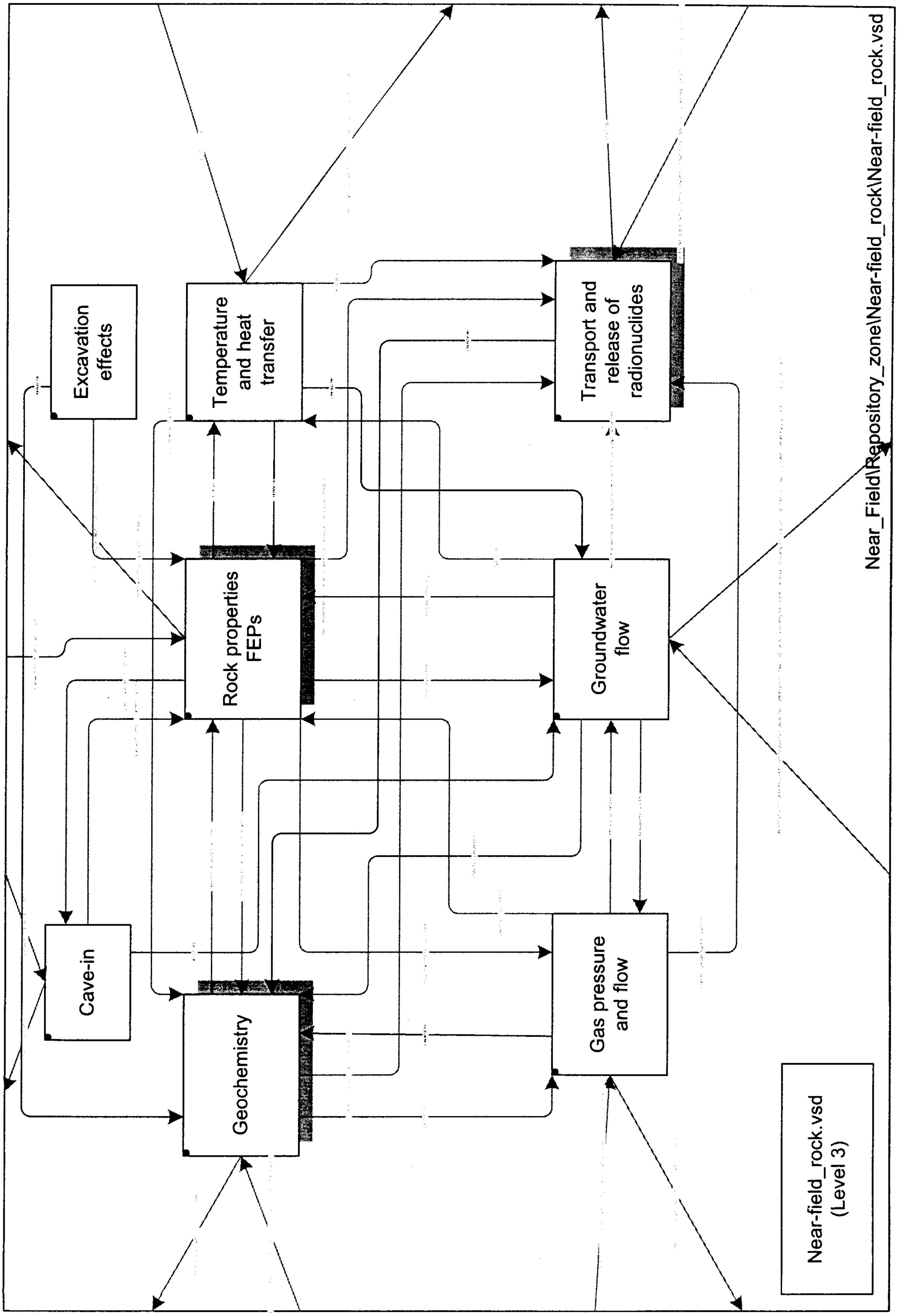
Near_Field\Silo_section\Silo_section.vsd
Backfill
Porous concrete (grout)
Reinforced concrete shell
Waste package
Silo_section.vsd (Level 2)
L2NFS1
L2NFS2
L2NFS3
L2NFS4
L2NFS5
L2NFS6
L2NFS7
L2NFS8
L2NFS9
L2NFS10
L2NFS11
L2NFS12
L2NFS13
L2NFS14



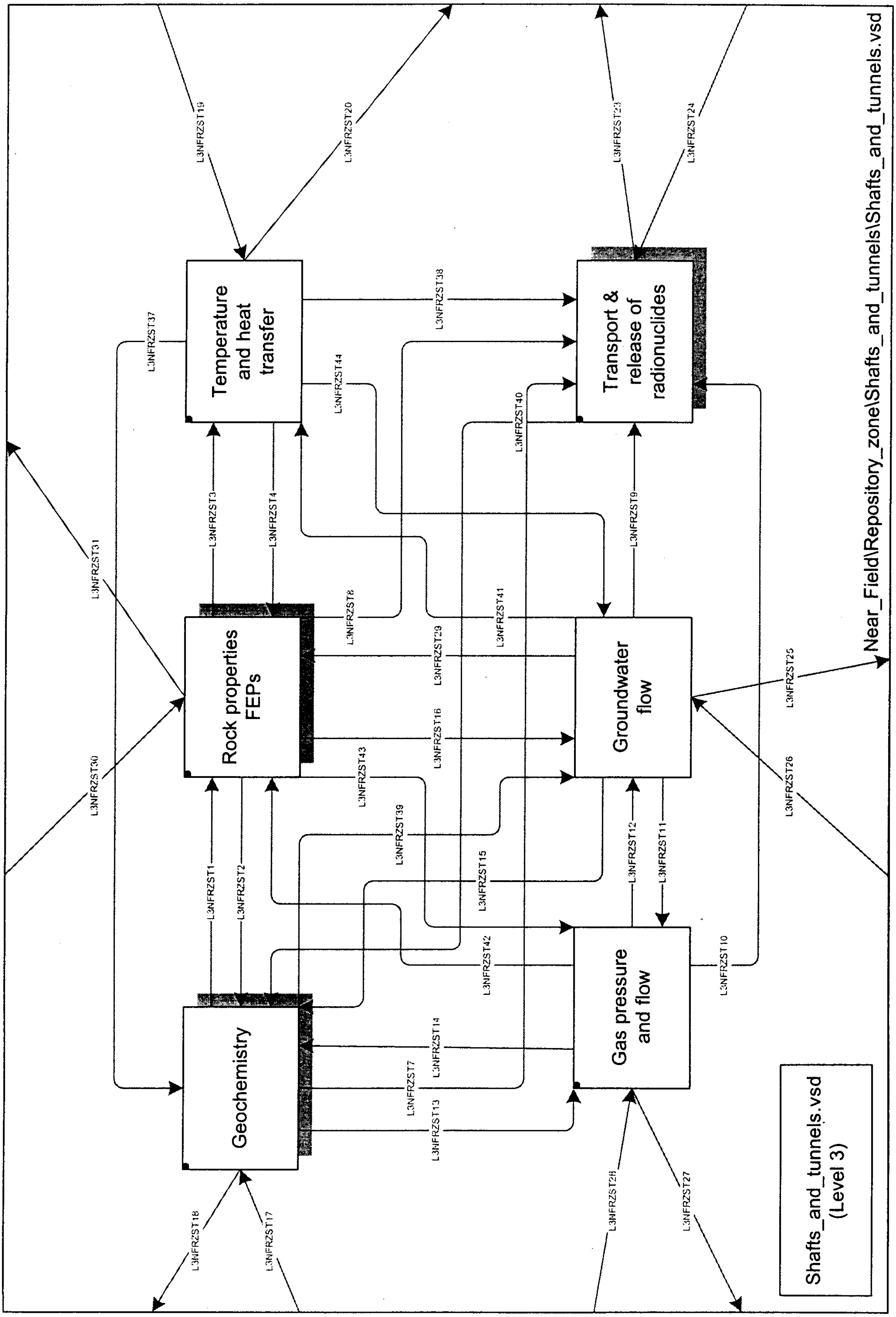
Near_Field\BLA_Section\BLA_Section.vsd
Concrete base (BLA)
Backfill (BLA)
Waste package (BLA)
L2NFBLA1
L2NFBLA2
L2NFBLA3
L2NFBLA4
L2NFBLA5
L2NFBLA6
L2NFBLA7
L2NFBLA8
L2NFBLA9
L2NFBLA10
BLA_Section.vsd (Level 2)

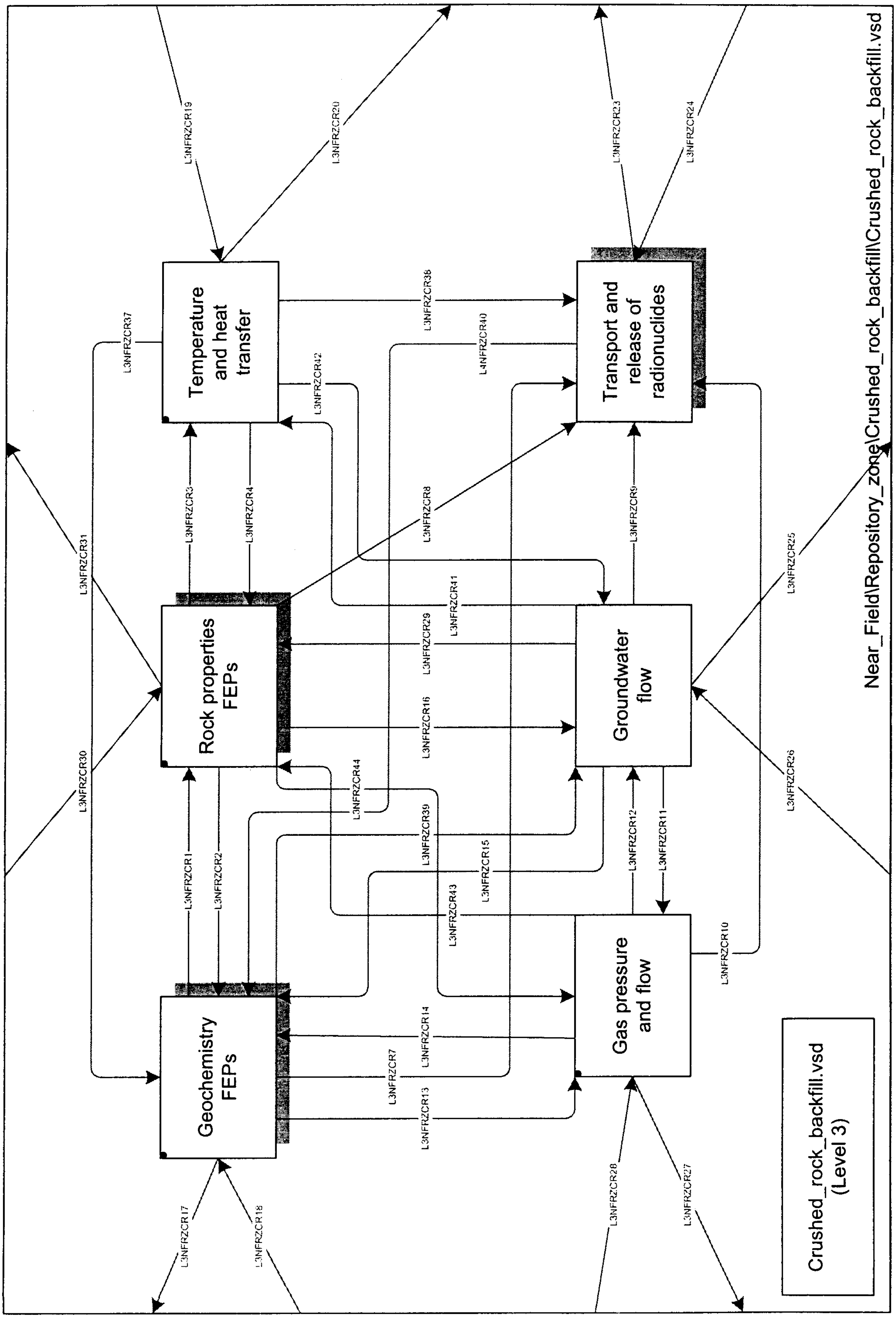

Near_Field\BTF_Section\BTF_Section.vsd
Concrete shell (BTF)
Waste package (BTF)
Roof backfill (BTF)
L2NFBTF1
L2NFBTF2
L2NFBTF3
L2NFBTF4
L2NFBTF5
L2NFBTF6
L2NFBTF7
L2NFBTF8
L2NFBTF9
L2NFBTF10
BTF_Section.vsd (Level 2)

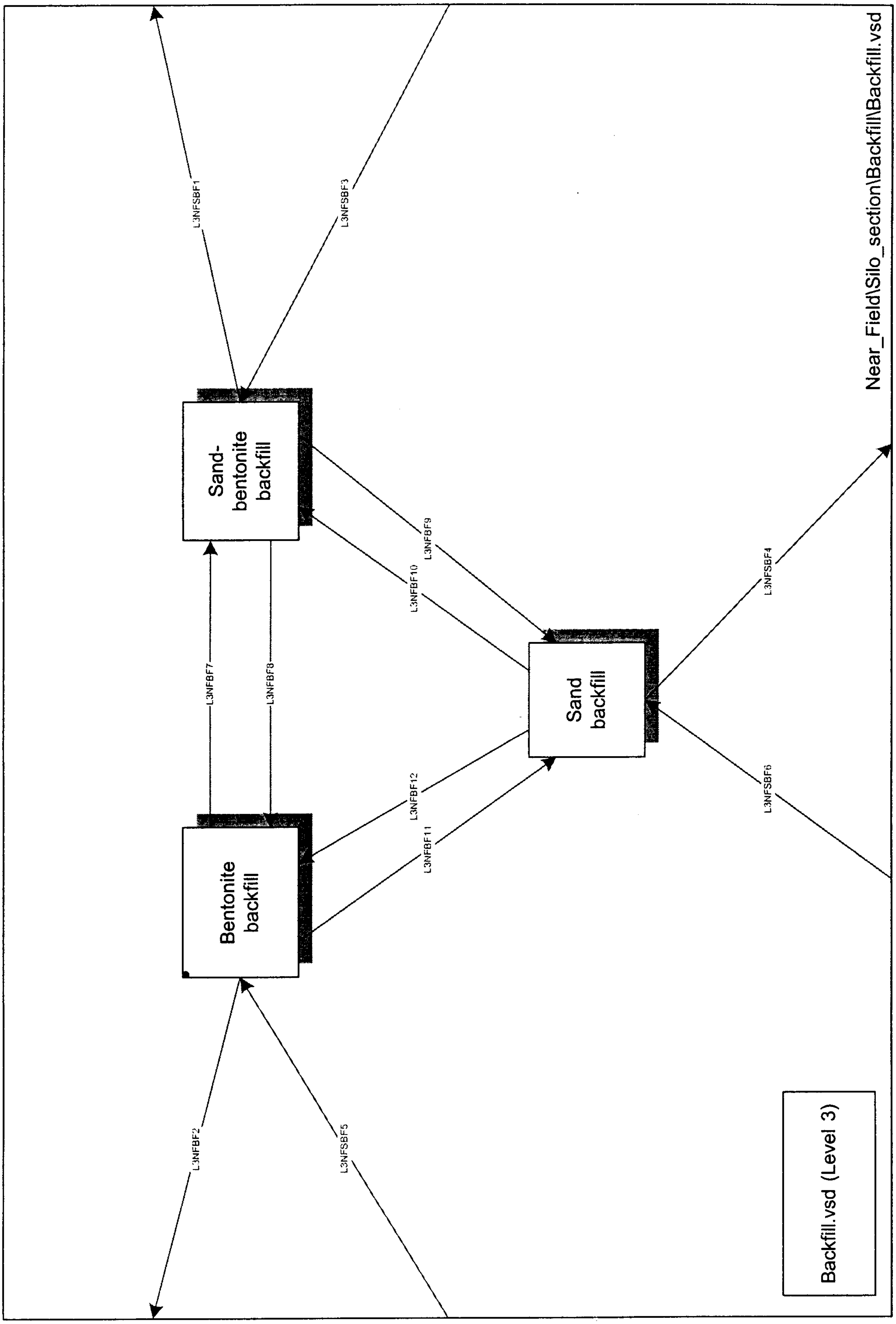

Near_Field\BMA_Section\BMA_Section.vsd
Waste package (BMA)
Concrete shell (BMA)
Backfill (BMA)
L2NFBMA1
L2NFBMA2
L2NFBMA3
L2NFBMA4
L2NFBMA5
L2NFBMA6
L2NFBMA7
L2NFBMA8
L2NFBMA9
L2NFBMA10
BMA_Section.vsd
(Level 2)

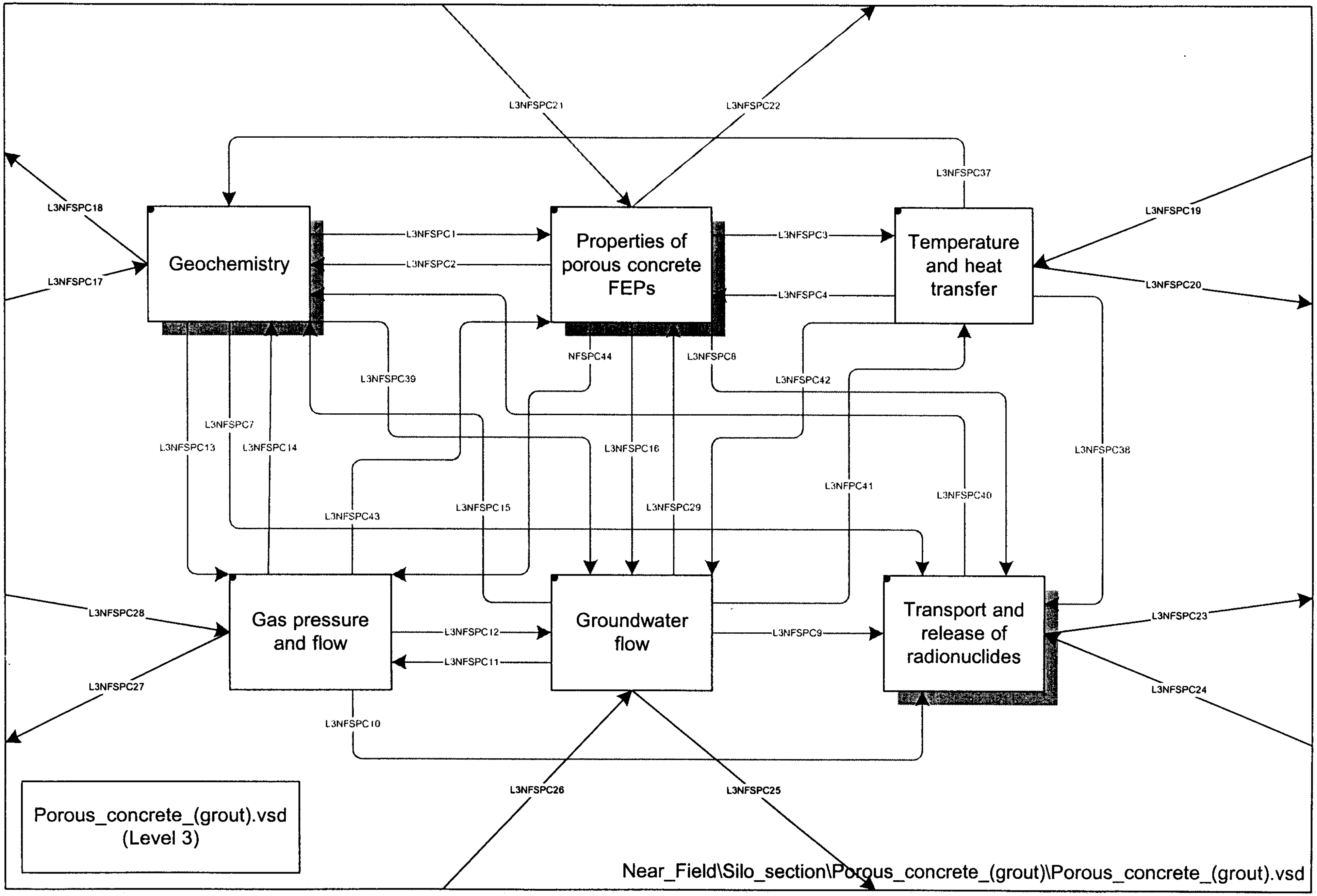


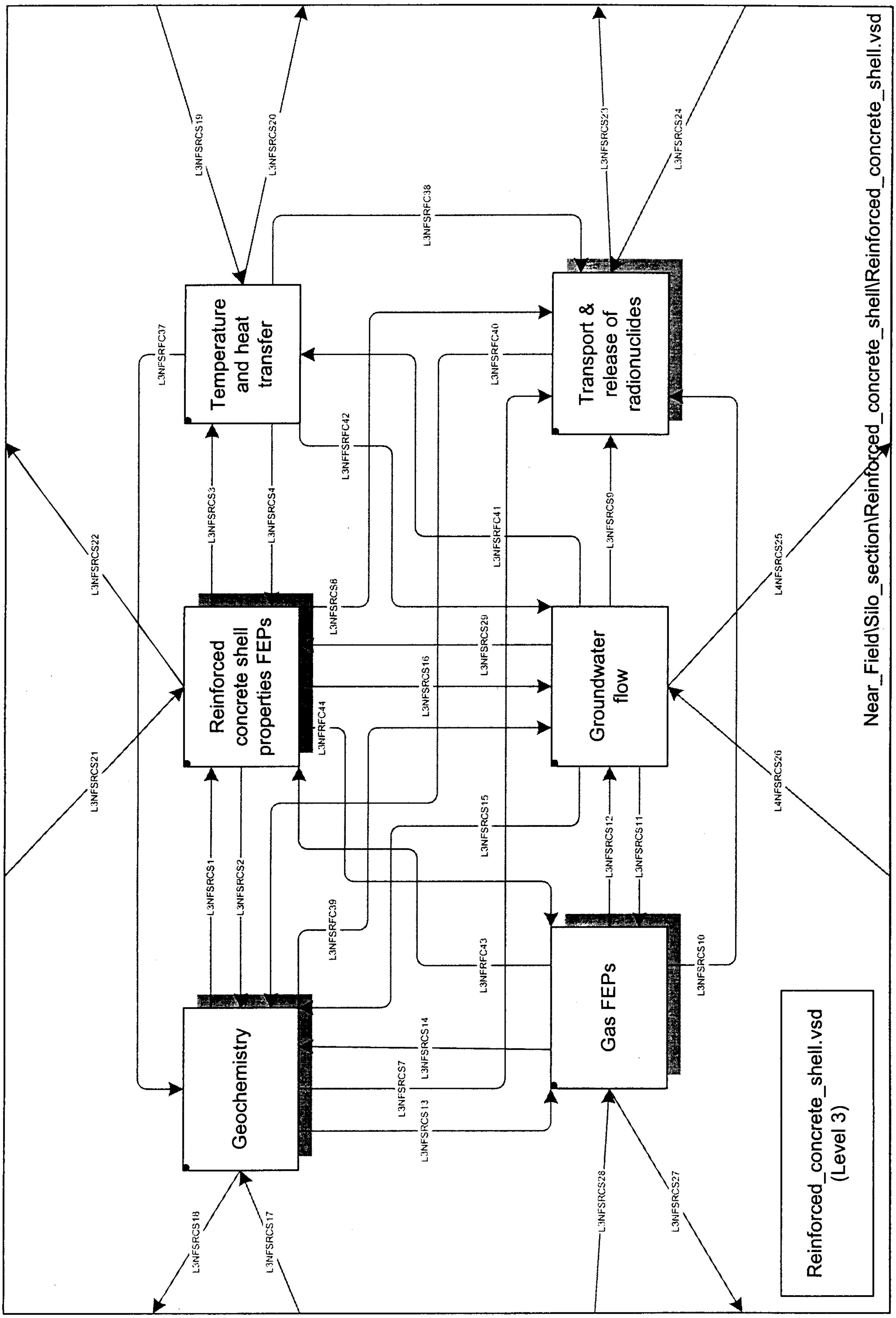
Excavation effects
Temperature and heat transfer
Transport and release of radionuclides
Rock properties FEPs
Groundwater flow
Cave-in
Geochemistry
Gas pressure and flow
Near-field_rock.vsd (Level 3)
Near_Field\Repository_zone\Near-field_rock\Near-field_rock.vsd

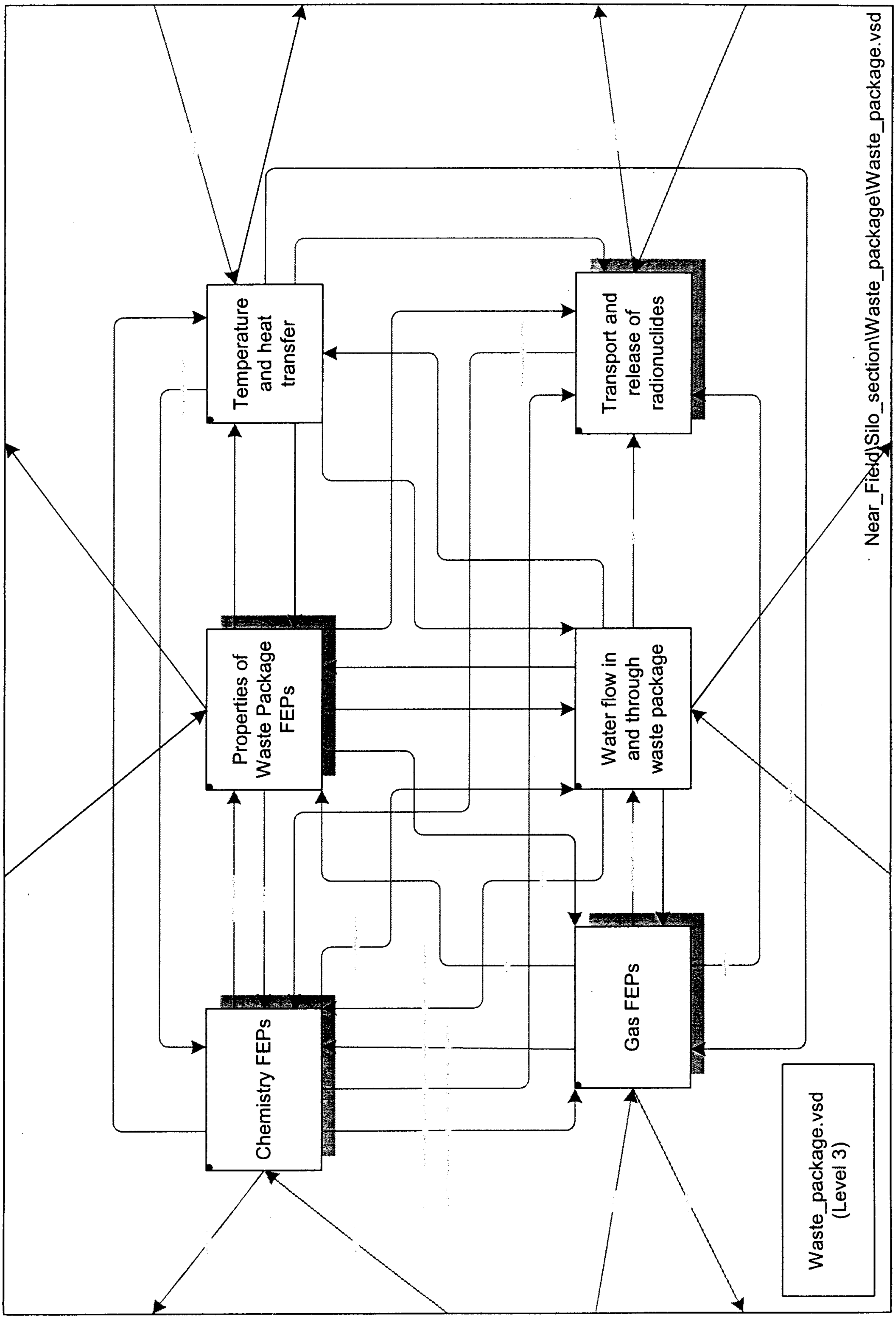

Temperature and heat transfer
Transport & release of radionuclides
Rock properties FEPs
Groundwater flow
Geochemistry
Gas pressure and flow
Shafts_and_tunnels.vsd (Level 3)
Near_Field\Repository_zone\Shafts_and_tunnels\Shafts_and_tunnels.vsd
L3NFRZST19
L3NFRZST20
L3NFRZST23
L3NFRZST24
L3NFRZST37
L3NFRZST38
L3NFRZST44
L3NFRZST40
L3NFRZST3
L3NFRZST4
L3NFRZST9
L3NFRZST31
L3NFRZST8
L3NFRZST41
L3NFRZST29
L3NFRZST25
L3NFRZST16
L3NFRZST30
L3NFRZST43
L3NFRZST39
L3NFRZST26
L3NFRZST12
L3NFRZST11
L3NFRZST1
L3NFRZST2
L3NFRZST15
L3NFRZST42
L3NFRZST10
L3NFRZST14
L3NFRZST7
L3NFRZST13
L3NFRZST18
L3NFRZST17
L3NFRZST28
L3NFRZST27

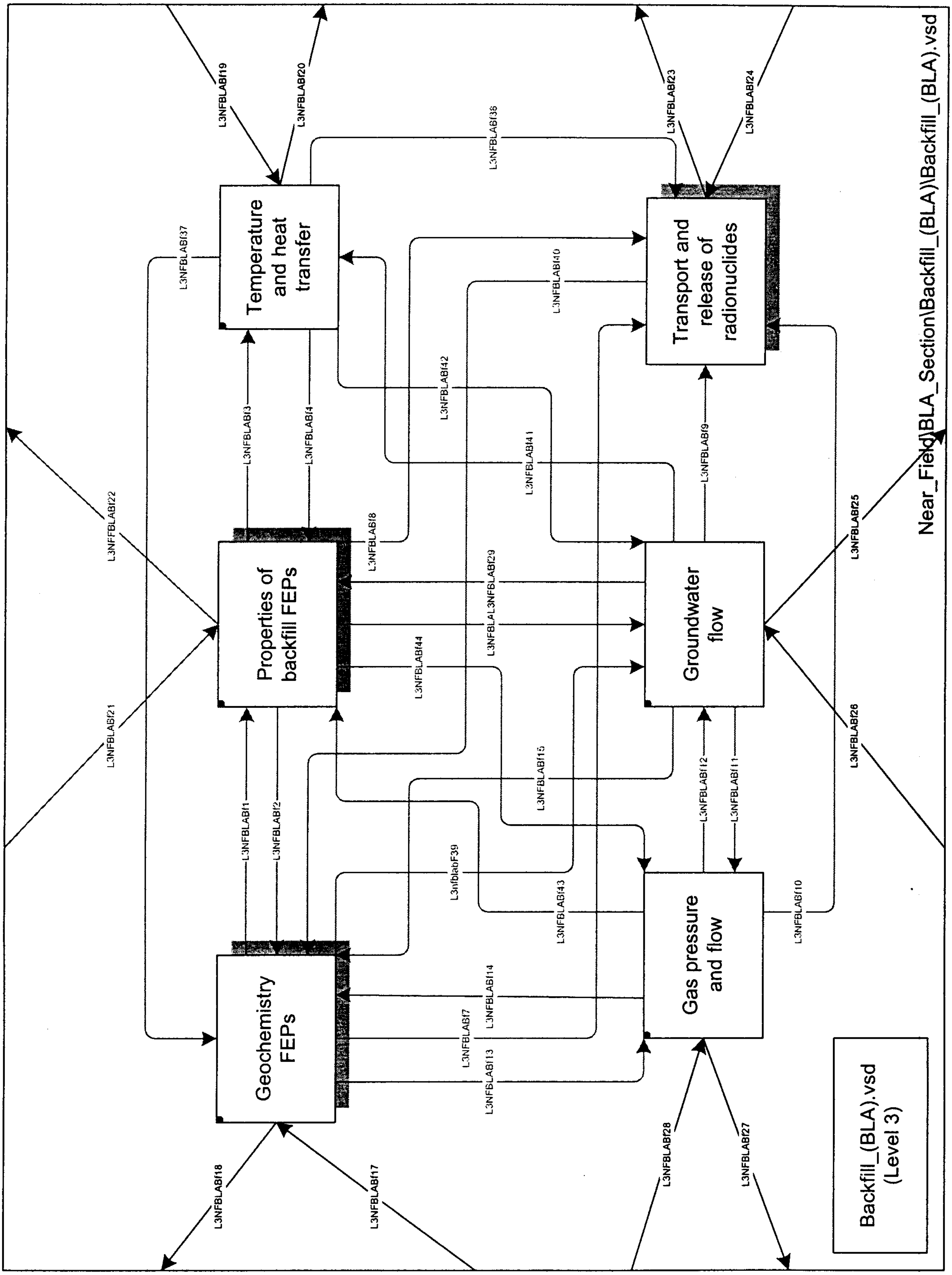

Temperature and heat transfer
Transport and release of radionuclides
Rock properties FEPs
Groundwater flow
Geochemistry FEPs
Gas pressure and flow
Crushed_rock_backfill.vsd (Level 3)
Near_Field\Repository_zone\Crushed_rock_backfill\Crushed_rock_backfill.vsd
L3NFRZCR1
L3NFRZCR2
L3NFRZCR3
L3NFRZCR4
L3NFRZCR7
L3NFRZCR8
L3NFRZCR9
L3NFRZCR10
L3NFRZCR11
L3NFRZCR12
L3NFRZCR13
L3NFRZCR14
L3NFRZCR15
L3NFRZCR16
L3NFRZCR17
L3NFRZCR18
L3NFRZCR19
L3NFRZCR20
L3NFRZCR23
L3NFRZCR24
L3NFRZCR25
L3NFRZCR26
L3NFRZCR27
L3NFRZCR28
L3NFRZCR29
L3NFRZCR30
L3NFRZCR31
L3NFRZCR37
L3NFRZCR38
L4NFRZCR40
L3NFRZCR39
L3NFRZCR41
L3NFRZCR42
L3NFRZCR43
L3NFRZCR44


Near_Field\Silo_section\Backfill\Backfill.vsd
Backfill.vsd (Level 3)
Sand-bentonite backfill
Bentonite backfill
Sand backfill
L3NFSBF1
L3NFSBF3
L3NFBF2
L3NFSBF5
L3NFBF7
L3NFBF8
L3NFBF9
L3NFBF10
L3NFBF11
L3NFBF12
L3NFSBF4
L3NFSBF6

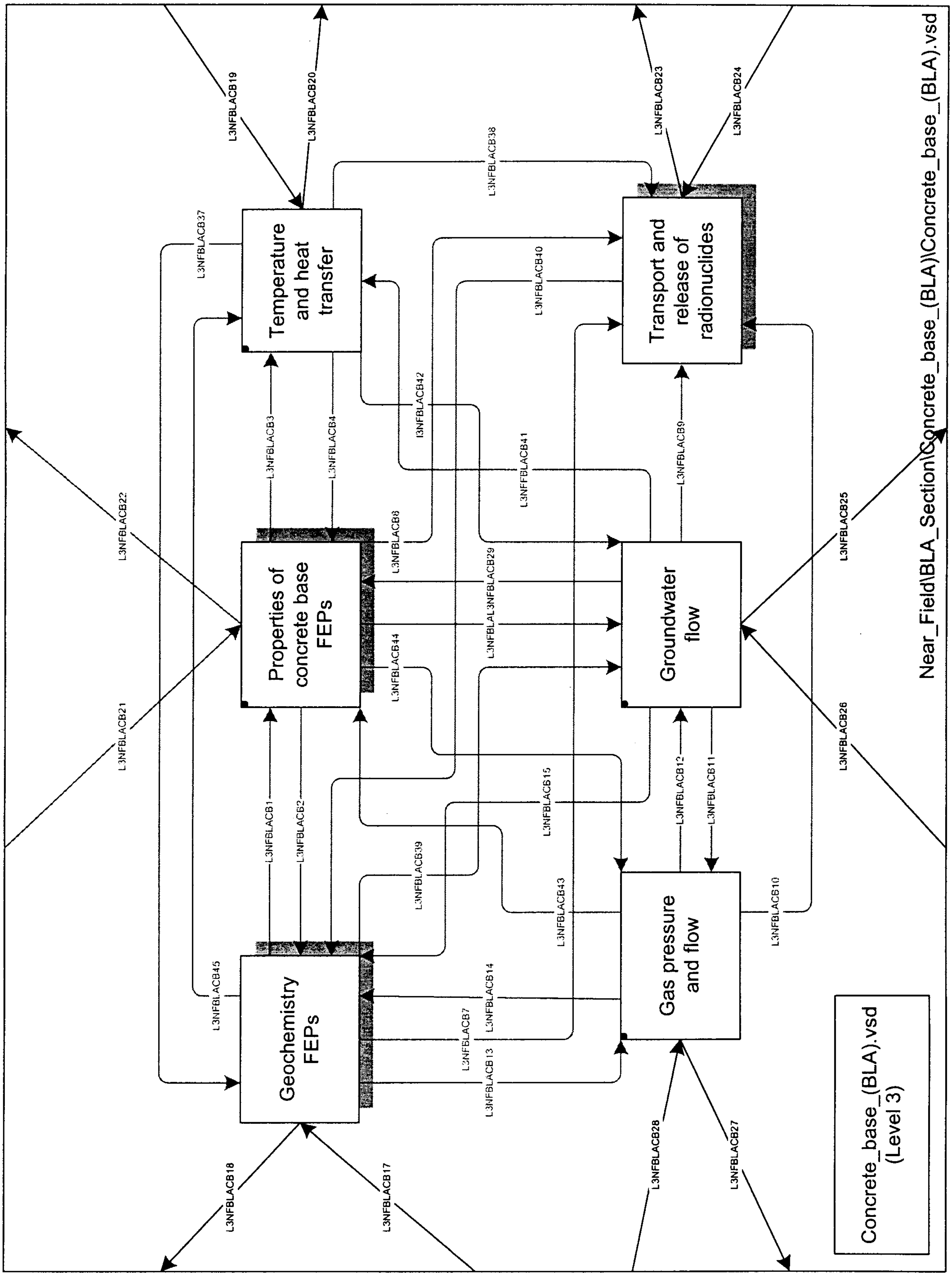

Geochemistry
Properties of porous concrete FEPs
Temperature and heat transfer
Gas pressure and flow
Groundwater flow
Transport and release of radionuclides
L3NFSPC1
L3NFSPC2
L3NFSPC3
L3NFSPC4
L3NFSPC7
L3NFSPC8
L3NFSPC9
L3NFSPC10
L3NFSPC11
L3NFSPC12
L3NFSPC13
L3NFSPC14
L3NFSPC15
L3NFSPC16
L3NFSPC17
L3NFSPC18
L3NFSPC19
L3NFSPC20
L3NFSPC21
L3NFSPC22
L3NFSPC23
L3NFSPC24
L3NFSPC25
L3NFSPC26
L3NFSPC27
L3NFSPC28
L3NFSPC29
L3NFSPC37
L3NFSPC38
L3NFSPC39
L3NFSPC40
L3NFPC41
L3NFSPC42
L3NFSPC43
NFSPC44
Porous_concrete_(grout).vsd
(Level 3)
Near_Field\Silo_section\Porous_concrete_(grout)\Porous_concrete_(grout).vsd


Near_Field\Silo_section\Reinforced_concrete_shell\Reinforced_concrete_shell.vsd
Reinforced_concrete_shell.vsd
(Level 3)
Temperature and heat transfer
Transport & release of radionuclides
Reinforced concrete shell properties FEPs
Groundwater flow
Geochemistry
Gas FEPs
L3NFSRCS1
L3NFSRCS2
L3NFSRCS3
L3NFSRCS4
L3NFSRCS7
L3NFSRCS8
L3NFSRCS9
L3NFSRCS10
L3NFSRCS11
L3NFSRCS12
L3NFSRCS13
L3NFSRCS14
L3NFSRCS15
L3NFSRCS16
L3NFSRCS17
L3NFSRCS18
L3NFSRCS19
L3NFSRCS20
L3NFSRCS21
L3NFSRCS22
L3NFSRCS23
L3NFSRCS24
L4NFSRCS25
L4NFSRCS26
L3NFSRCS27
L3NFSRCS28
L3NFSRCS29
L3NFSRFC37
L3NFSRFC38
L3NFSRFC39
L3NFSRFC40
L3NFSRFC41
L3NFFSRFC42
L3NFRFC43
L3NFRFC44


Temperature and heat transfer
Transport and release of radionuclides
Properties of Waste Package FEPs
Water flow in and through waste package
Chemistry FEPs
Gas FEPs
Near_Field\Silo_section\Waste_package\Waste_package.vsd
Waste_package.vsd (Level 3)



Near_Field\BLA_Section\Backfill_(BLA)\Backfill_(BLA).vsd
Temperature and heat transfer
Transport and release of radionuclides
Properties of backfill FEPs
Groundwater flow
Geochemistry FEPs
Gas pressure and flow
Backfill_(BLA).vsd (Level 3)
L3NFBLABf1
L3NFBLABf2
L3NFBLABf3
L3NFBLABf4
L3NFBLABf7
L3NFBLABf8
L3NFBLABf9
L3NFBLABf10
L3NFBLABf11
L3NFBLABf12
L3NFBLABf13
L3NFBLABf14
L3NFBLABf15
L3NFBLABf17
L3NFBLABf18
L3NFBLABf19
L3NFBLABf20
L3NFBLABf21
L3NFFBLABf22
L3NFBLABf23
L3NFBLABf24
L3NFBLABf25
L3NFBLABf26
L3NFBLABf27
L3NFBLABf28
L3NFBLAL3NFBLABf29
L3NFBLABf36
L3NFBLABf37
L3nfblabF39
L3NFBLABf40
L3NFBLABf41
L3NFBLABf42
L3NFBLABf43
L3NFBLABf44


Near_Field\BLA_Section\Concrete_base_(BLA)\Concrete_base_(BLA).vsd
Concrete_base_(BLA).vsd
(Level 3)
Temperature and heat transfer
Transport and release of radionuclides
Properties of concrete base FEPs
Groundwater flow
Geochemistry FEPs
Gas pressure and flow
L3NFBLACB1
L3NFBLACB2
L3NFBLACB3
L3NFBLACB4
L3NFBLACB8
L3NFBLACB9
L3NFBLACB10
L3NFBLACB11
L3NFBLACB12
L3NFBLACB13
L3NFBLACB14
L3NFBLACB15
L3NFBLACB17
L3NFBLACB18
L3NFBLACB19
L3NFBLACB20
L3NFBLACB21
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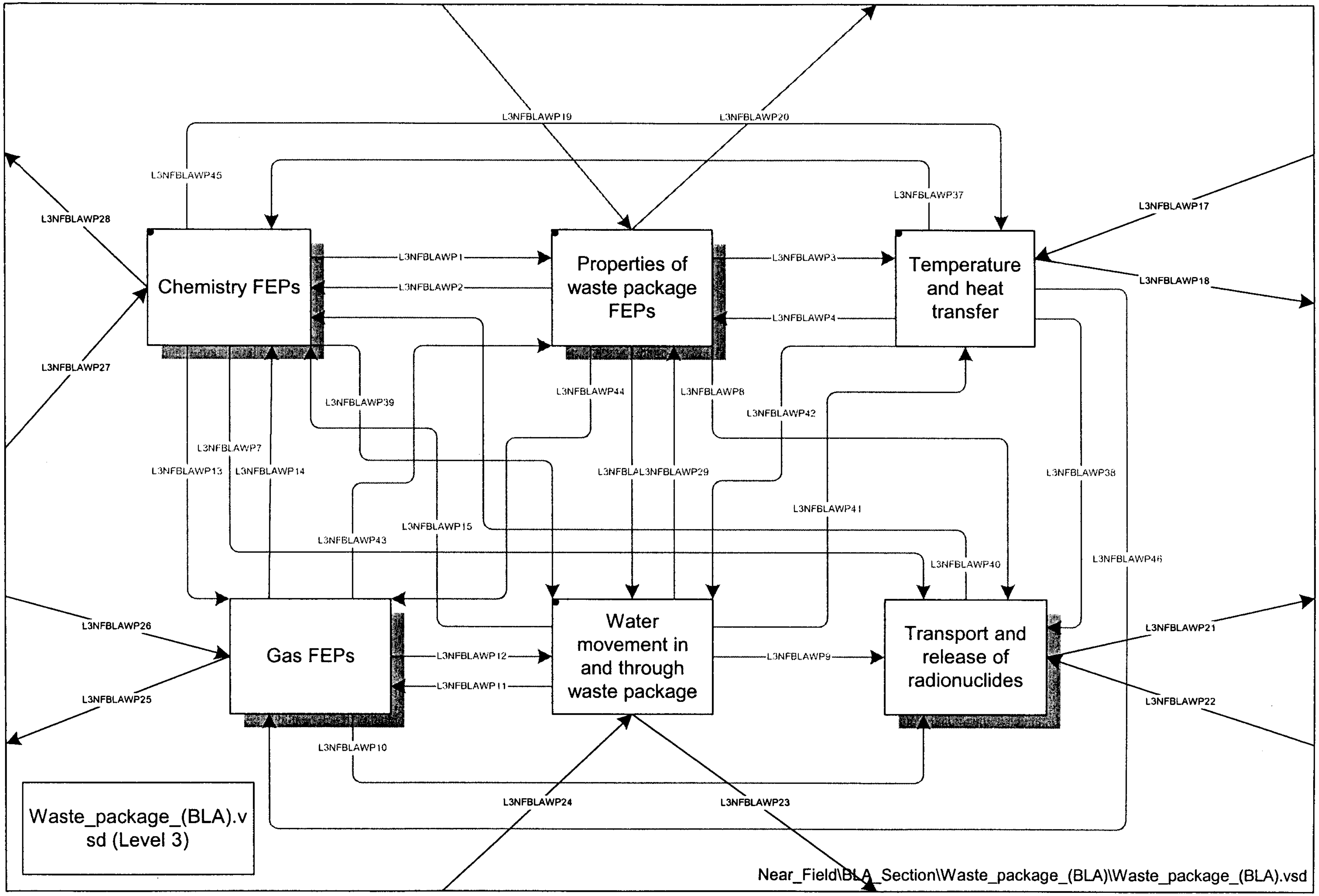
L3NFBLACB23
L3NFBLACB24
L3NFBLACB25
L3NFBLACB26
L3NFBLACB27
L3NFBLACB28
L3NFBLACB29
L3NFBLAL3NFBLACB29
L3NFBLACB37
L3NFBLACB38
L3NFBLACB39
L3NFBLACB40
L3NFFBLACB41
l3NFBLACB42
L3NFBLACB43
L3NFBLACB44
L3NFBLACB45
L3NFBLACB7


Chemistry FEPs
Properties of waste package FEPs
Temperature and heat transfer
Gas FEPs
Water movement in and through waste package
Transport and release of radionuclides
L3NFBLAWP1
L3NFBLAWP2
L3NFBLAWP3
L3NFBLAWP4
L3NFBLAWP7
L3NFBLAWP8
L3NFBLAWP9
L3NFBLAWP10
L3NFBLAWP11
L3NFBLAWP12
L3NFBLAWP13
L3NFBLAWP14
L3NFBLAWP15
L3NFBLAWP17
L3NFBLAWP18
L3NFBLAWP19
L3NFBLAWP20
L3NFBLAWP21
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L3NFBLAWP23
L3NFBLAWP24
L3NFBLAWP25
L3NFBLAWP26
L3NFBLAWP27
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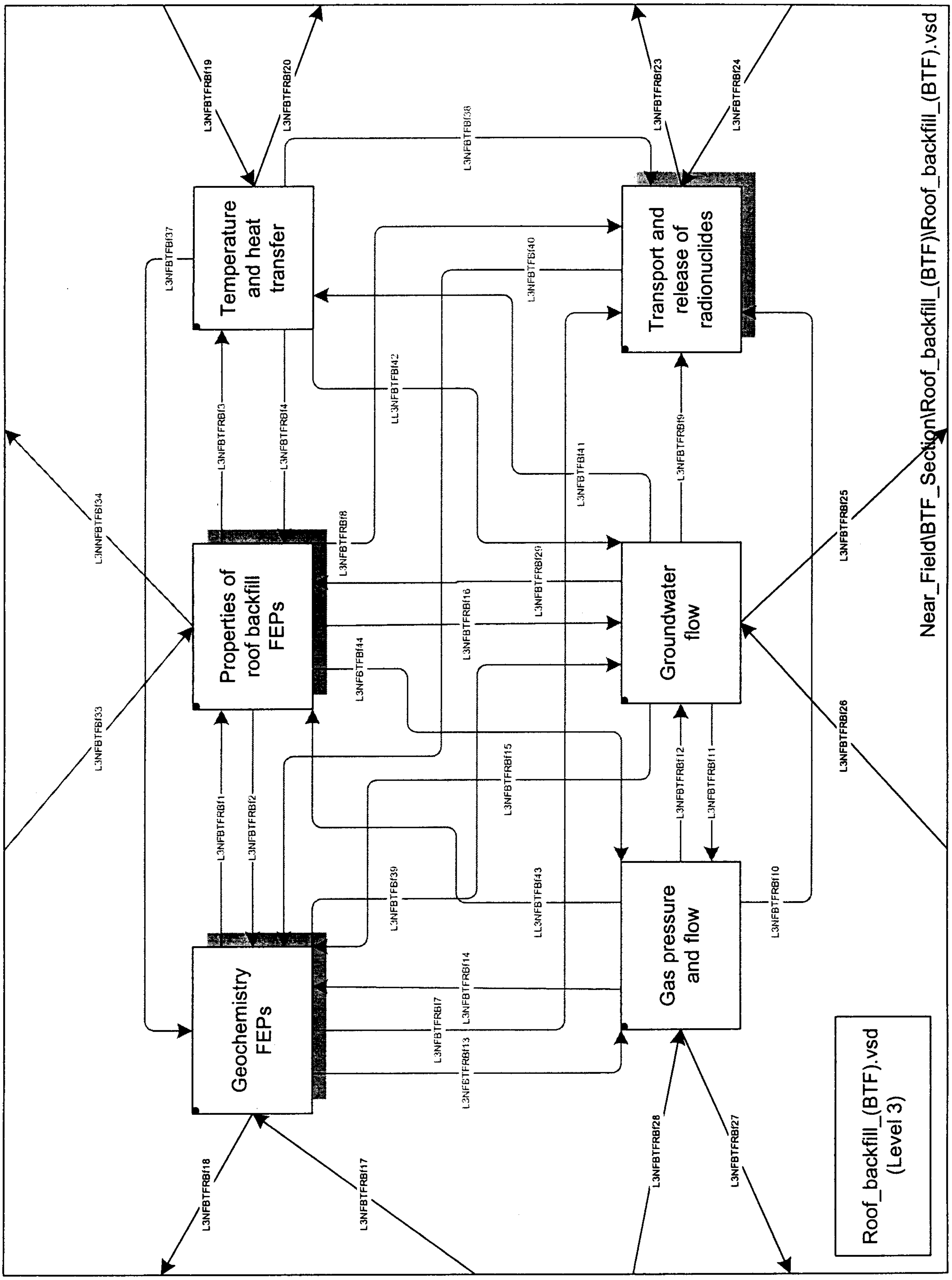
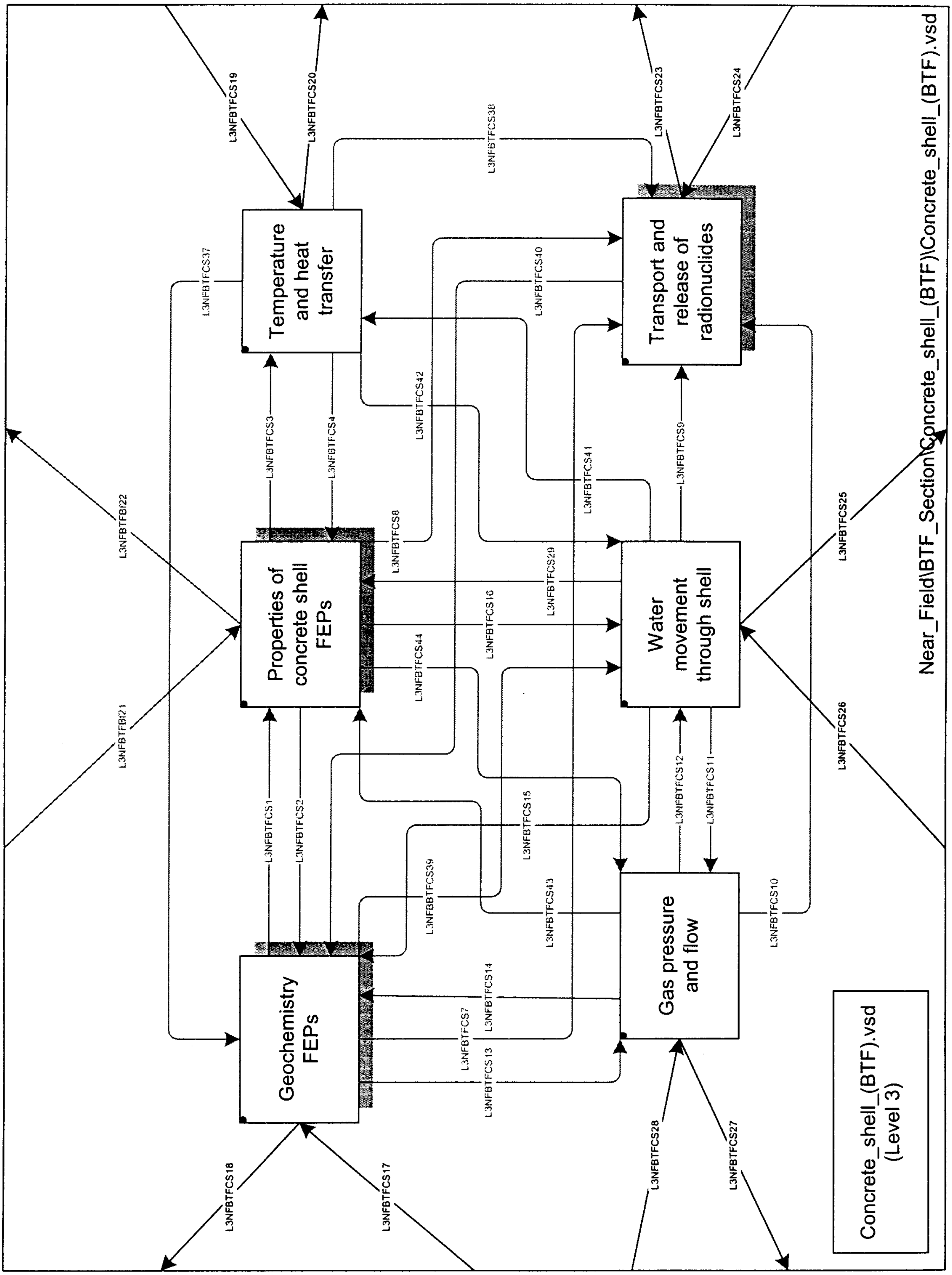
L3NFBLAWP37
L3NFBLAWP38
L3NFBLAWP39
L3NFBLAWP40
L3NFBLAWP41
L3NFBLAWP42
L3NFBLAWP43
L3NFBLAWP44
L3NFBLAWP45
L3NFBLAWP46
Waste_package_(BLA).vsd (Level 3)
Near_Field\BLA_Section\Waste_package_(BLA)\Waste_package_(BLA).vsd


Temperature and heat transfer
Transport and release of radionuclides
Properties of roof backfill FEPs
Groundwater flow
Geochemistry FEPs
Gas pressure and flow
Near_Field\BTF_Section\Roof_backfill_(BTF)\Roof_backfill_(BTF).vsd
Roof_backfill_(BTF).vsd (Level 3)


Near_Field\BTF_Section\Concrete_shell_(BTF)\Concrete_shell_(BTF).vsd
Concrete_shell_(BTF).vsd
(Level 3)
Temperature and heat transfer
Transport and release of radionuclides
Properties of concrete shell FEPs
Water movement through shell
Geochemistry FEPs
Gas pressure and flow
L3NFBTFCS1
L3NFBTFCS2
L3NFBTFCS3
L3NFBTFCS4
L3NFBTFCS7
L3NFBTFCS8
L3NFBTFCS9
L3NFBTFCS10
L3NFBTFCS11
L3NFBTFCS12
L3NFBTFCS13
L3NFBTFCS14
L3NFBTFCS15
L3NFBTFCS16
L3NFBTFCS17
L3NFBTFCS18
L3NFBTFCS19
L3NFBTFCS20
L3NFBTFBI21
L3NFBTFBI22
L3NFBTFCS23
L3NFBTFCS24
L3NFBTFCS25
L3NFBTFCS26
L3NFBTFCS27
L3NFBTFCS28
L3NFBTFCS29
L3NFBTFCS37
L3NFBTFCS38
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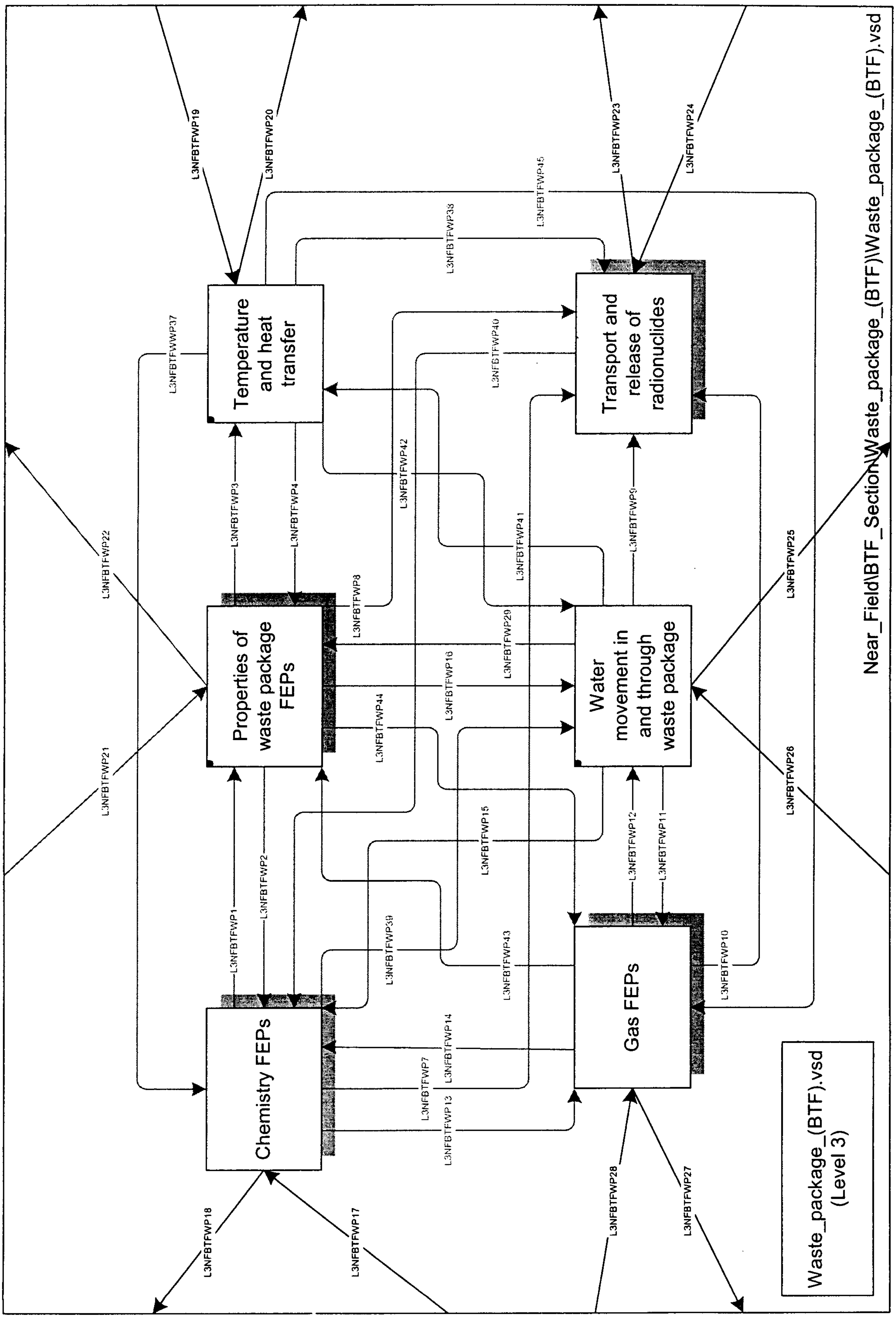
L3NFBTFCS41
L3NFBTFCS42
L3NFBTFCS43
L3NFBTFCS44



Temperature and heat transfer
Properties of waste package FEPs
Chemistry FEPs
Transport and release of radionuclides
Water movement in and through waste package
Gas FEPs
Waste_package_(BTF).vsd (Level 3)
Near_Field\BTF_Section\Waste_package_(BTF)\Waste_package_(BTF).vsd
L3NFBTFWP1
L3NFBTFWP2
L3NFBTFWP3
L3NFBTFWP4
L3NFBTFWP7
L3NFBTFWP8
L3NFBTFWP9
L3NFBTFWP10
L3NFBTFWP11
L3NFBTFWP12
L3NFBTFWP13
L3NFBTFWP14
L3NFBTFWP15
L3NFBTFWP16
L3NFBTFWP17
L3NFBTFWP18
L3NFBTFWP19
L3NFBTFWP20
L3NFBTFWP21
L3NFBTFWP22
L3NFBTFWP23
L3NFBTFWP24
L3NFBTFWP25
L3NFBTFWP26
L3NFBTFWP27
L3NFBTFWP28
L3NFBTFWP29
L3NFBTFWWP37
L3NFBTFWP38
L3NFBTFWP39
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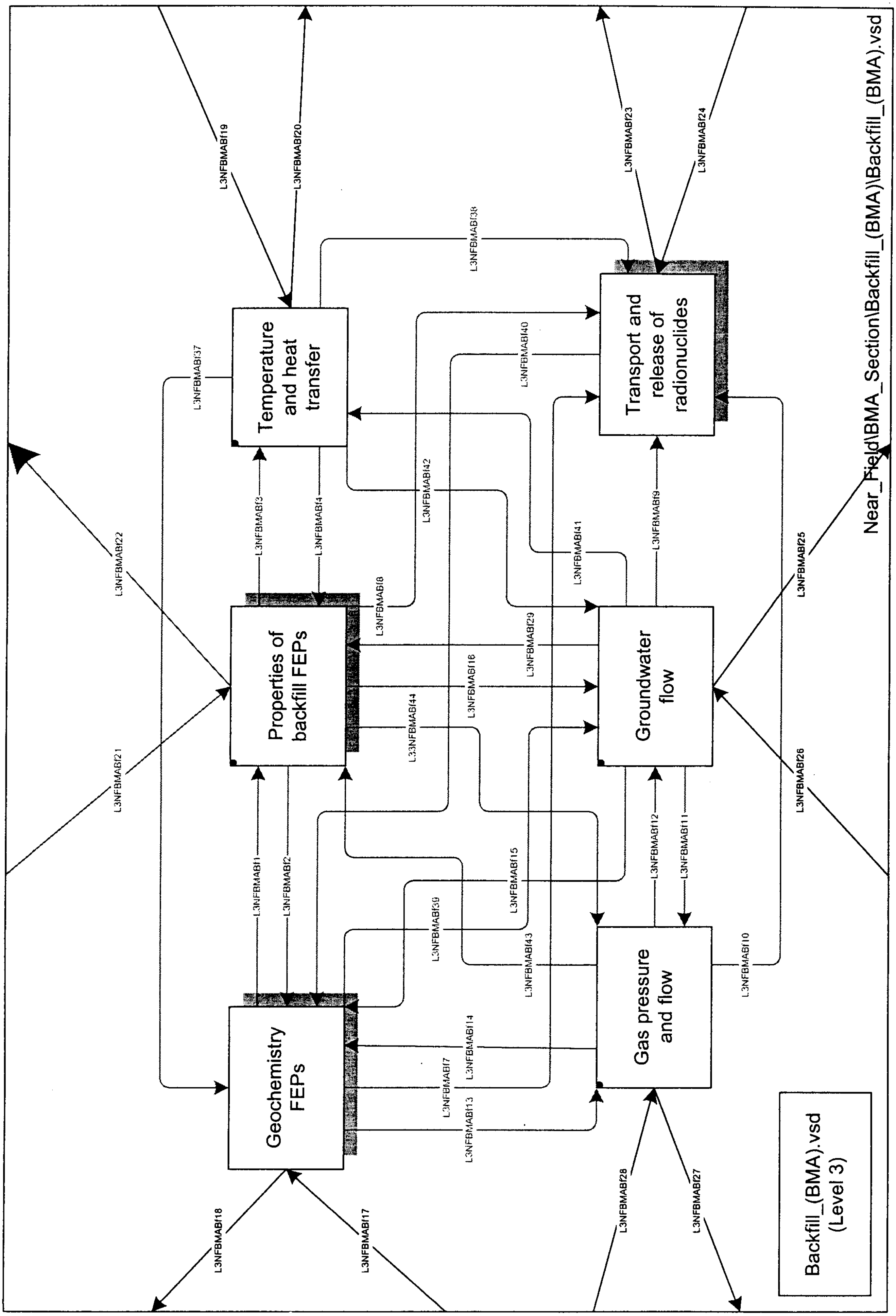
L3NFBTFWP44
L3NFBTFWP45



Near_Field\BMA_Section\Backfill_(BMA)\Backfill_(BMA).vsd
Backfill_(BMA).vsd
(Level 3)
Temperature and heat transfer
Transport and release of radionuclides
Properties of backfill FEPs
Groundwater flow
Geochemistry FEPs
Gas pressure and flow
L3NFBMABf1
L3NFBMABf2
L3NFBMABf3
L3NFBMABf4
L3NFBMABf7
L3NFBMABf8
L3NFBMABf9
L3NFBMABf10
L3NFBMABf11
L3NFBMABf12
L3NFBMABf13
L3NFBMABf14
L3NFBMABf15
L3NFBMABf16
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L3NFBMABf28
L3NFBMABf29
L3NFBMABf37
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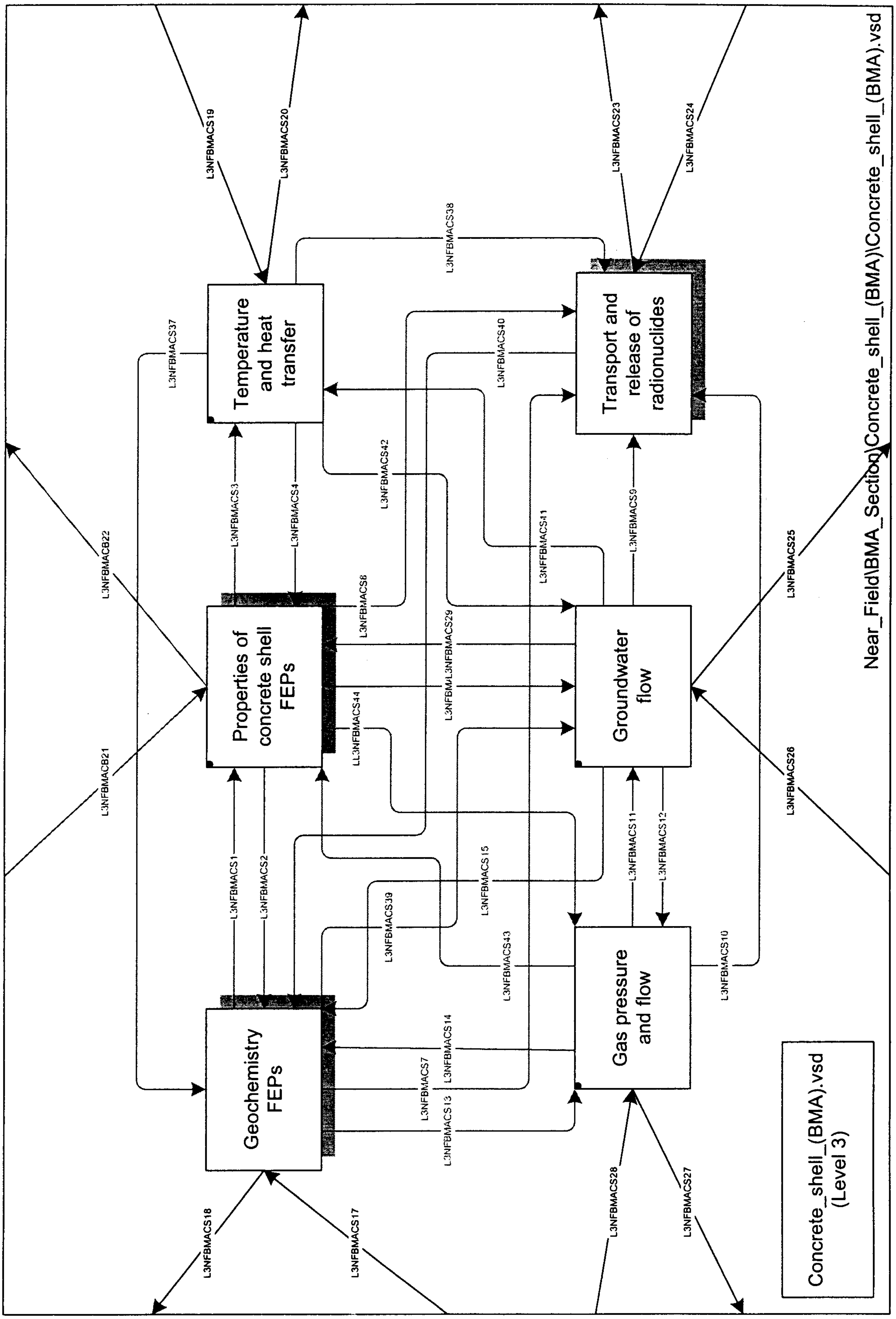
L3NFBMABf40
L3NFBMABf41
L3NFBMABf42
L3NFBMABf43
L33NFBMABf44


Near_Field\BMA_Section\Concrete_shell_(BMA)\Concrete_shell_(BMA).vsd
Temperature and heat transfer
Transport and release of radionuclides
Properties of concrete shell FEPs
Groundwater flow
Geochemistry FEPs
Gas pressure and flow
Concrete_shell_(BMA).vsd (Level 3)
L3NFBMACS1
L3NFBMACS2
L3NFBMACS3
L3NFBMACS4
L3NFBMACS7
L3NFBMACS8
L3NFBMACS9
L3NFBMACS10
L3NFBMACS11
L3NFBMACS12
L3NFBMACS13
L3NFBMACS14
L3NFBMACS15
L3NFBMACS17
L3NFBMACS18
L3NFBMACS19
L3NFBMACS20
L3NFBMACB21
L3NFBMACB22
L3NFBMACS23
L3NFBMACS24
L3NFBMACS25
L3NFBMACS26
L3NFBMACS27
L3NFBMACS28
L3NFBM/L3NFBMACS29
L3NFBMACS37
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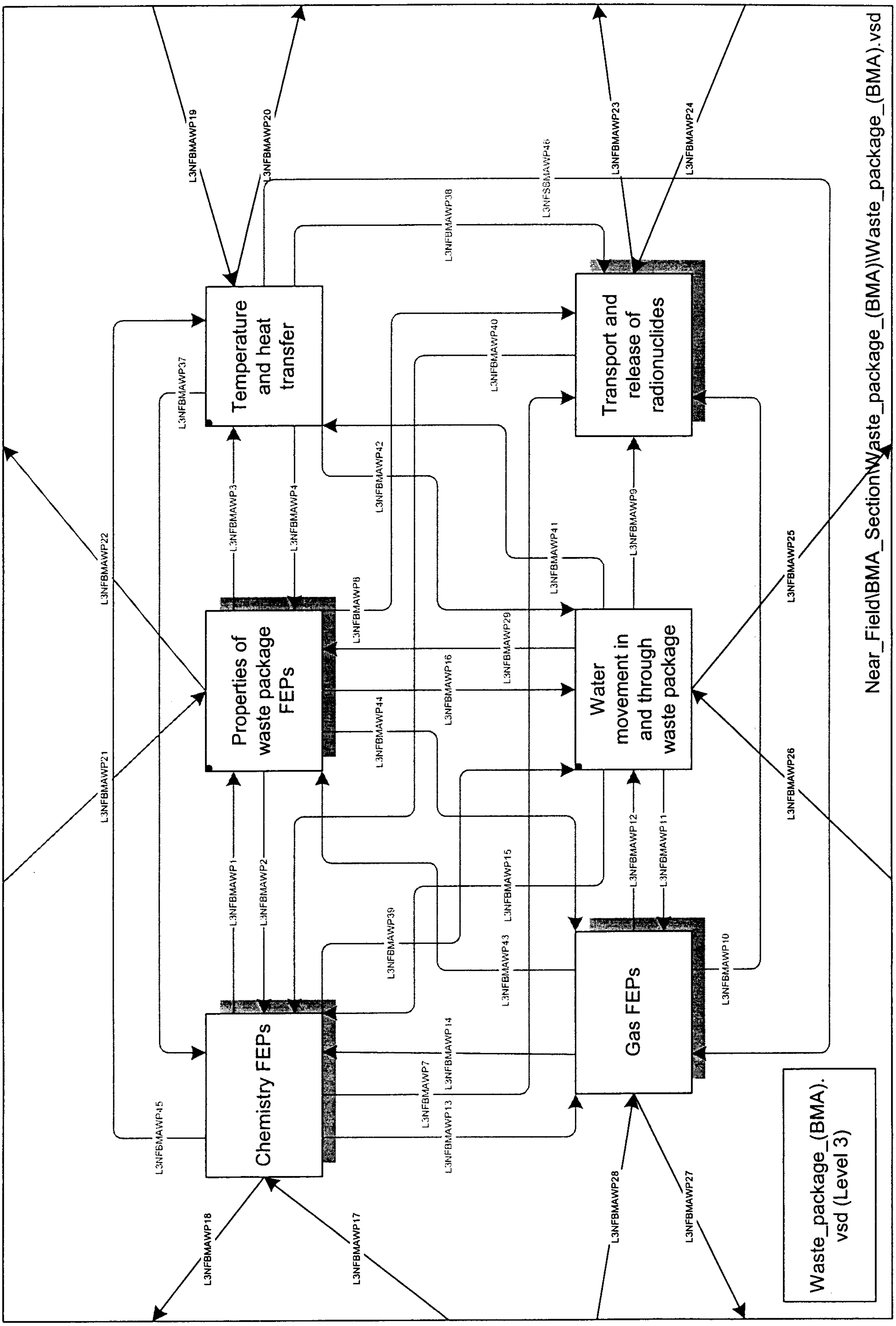
L3NFBMACS43
LL3NFBMACS44


Near_Field\BMA_Section\Waste_package_(BMA)\Waste_package_(BMA).vsd
Temperature and heat transfer
Transport and release of radionuclides
Properties of waste package FEPs
Water movement in and through waste package
Chemistry FEPs
Gas FEPs
Waste_package_(BMA).vsd (Level 3)
L3NFBMAWP1
L3NFBMAWP2
L3NFBMAWP3
L3NFBMAWP4
L3NFBMAWP7
L3NFBMAWP8
L3NFBMAWP9
L3NFBMAWP10
L3NFBMAWP11
L3NFBMAWP12
L3NFBMAWP13
L3NFBMAWP14
L3NFBMAWP15
L3NFBMAWP16
L3NFBMAWP17
L3NFBMAWP18
L3NFBMAWP19
L3NFBMAWP20
L3NFBMAWP21
L3NFBMAWP22
L3NFBMAWP23
L3NFBMAWP24
L3NFBMAWP25
L3NFBMAWP26
L3NFBMAWP27
L3NFBMAWP28
L3NFBMAWP29
L3NFBMAWP37
L3NFBMAWP38
L3NFBMAWP39
L3NFBMAWP40
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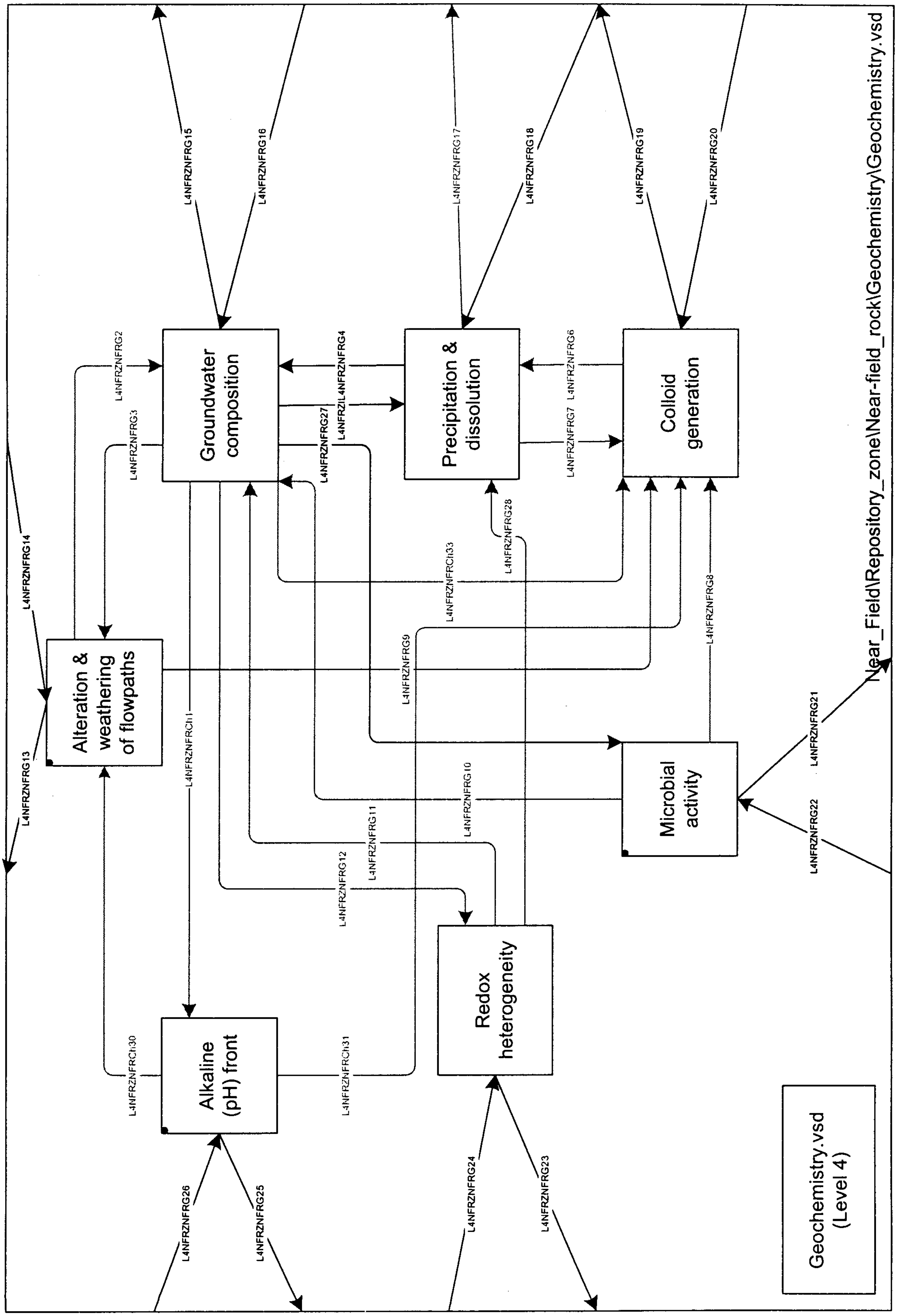
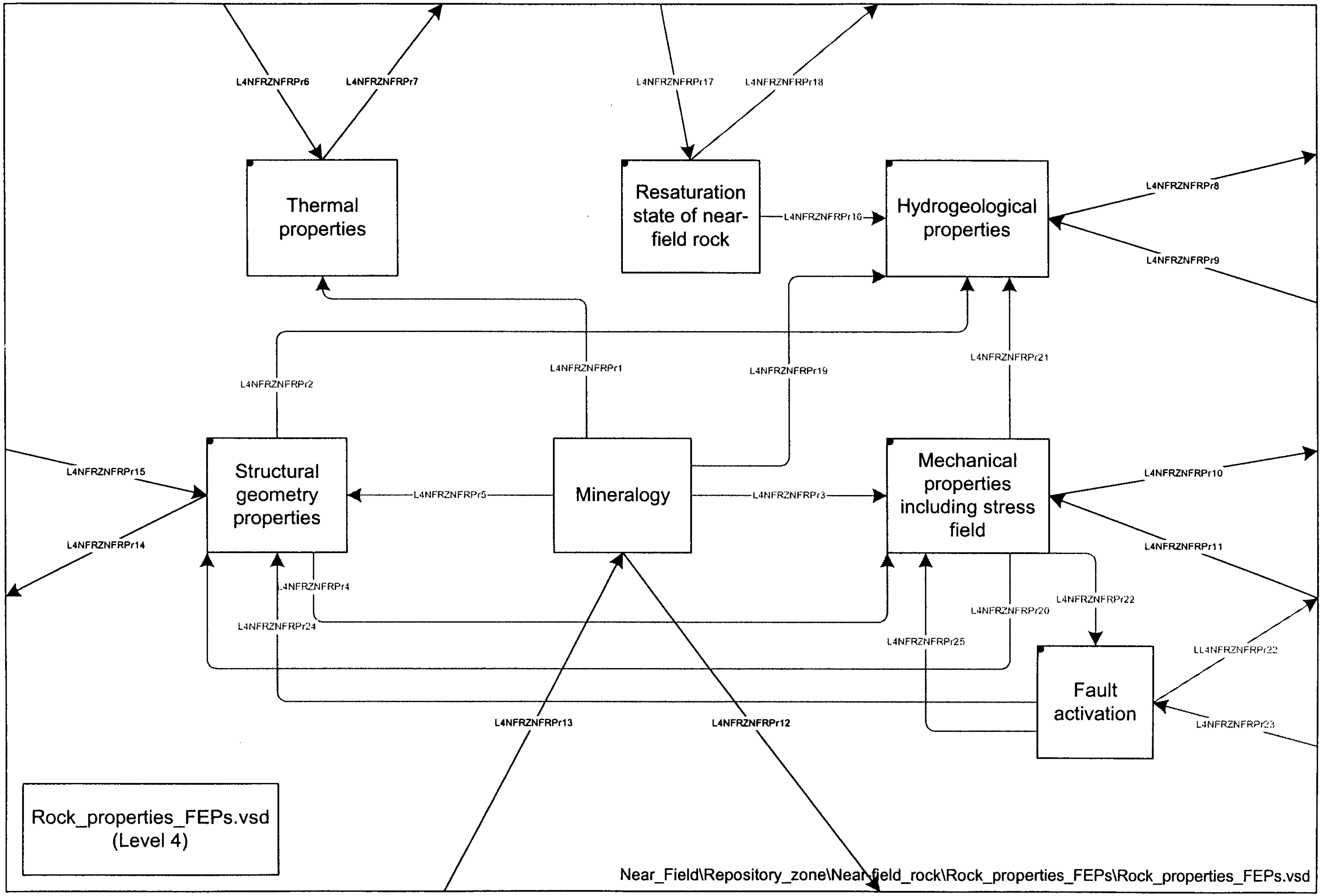
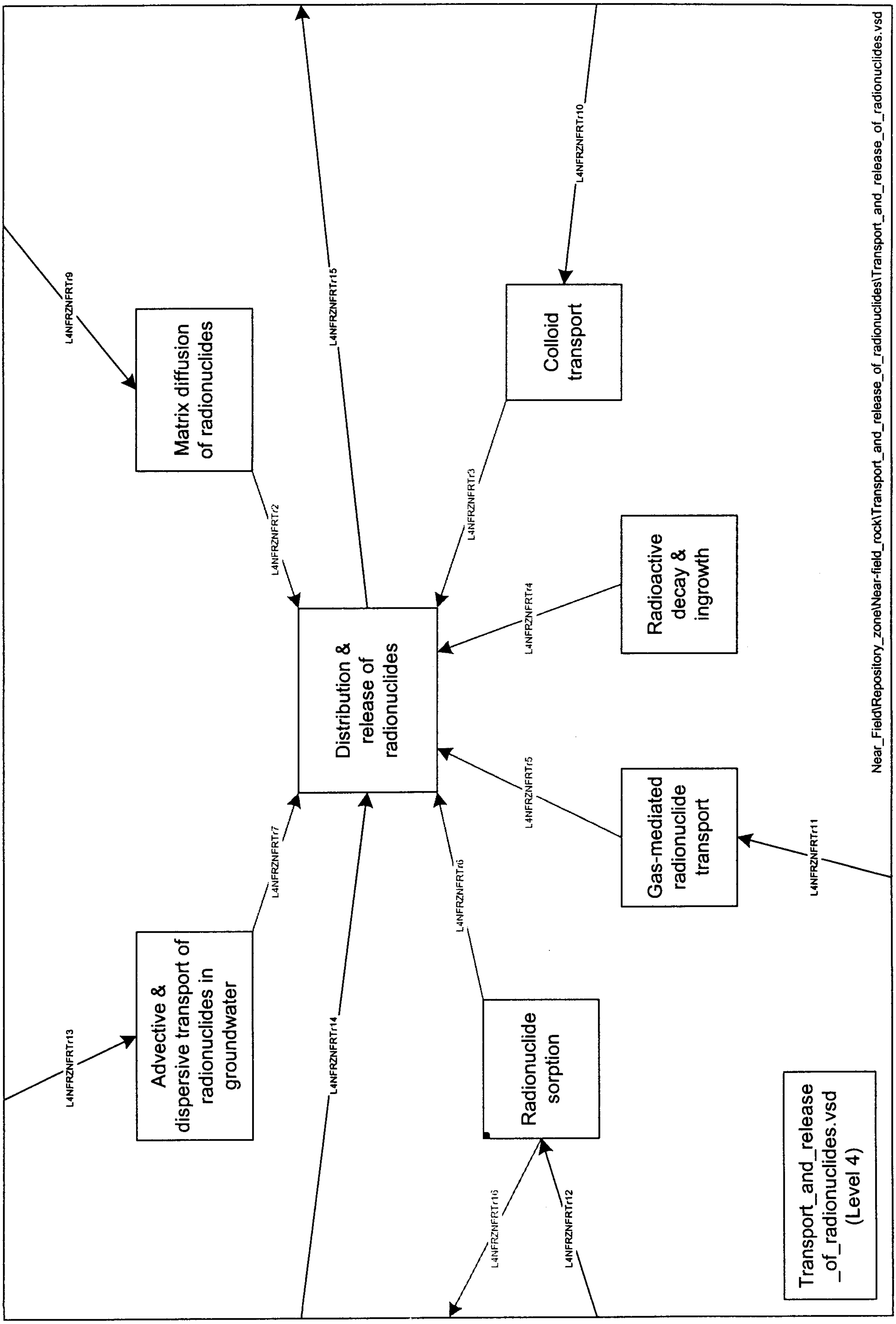
L3NFBMAWP45
L3NFSBMAWP46

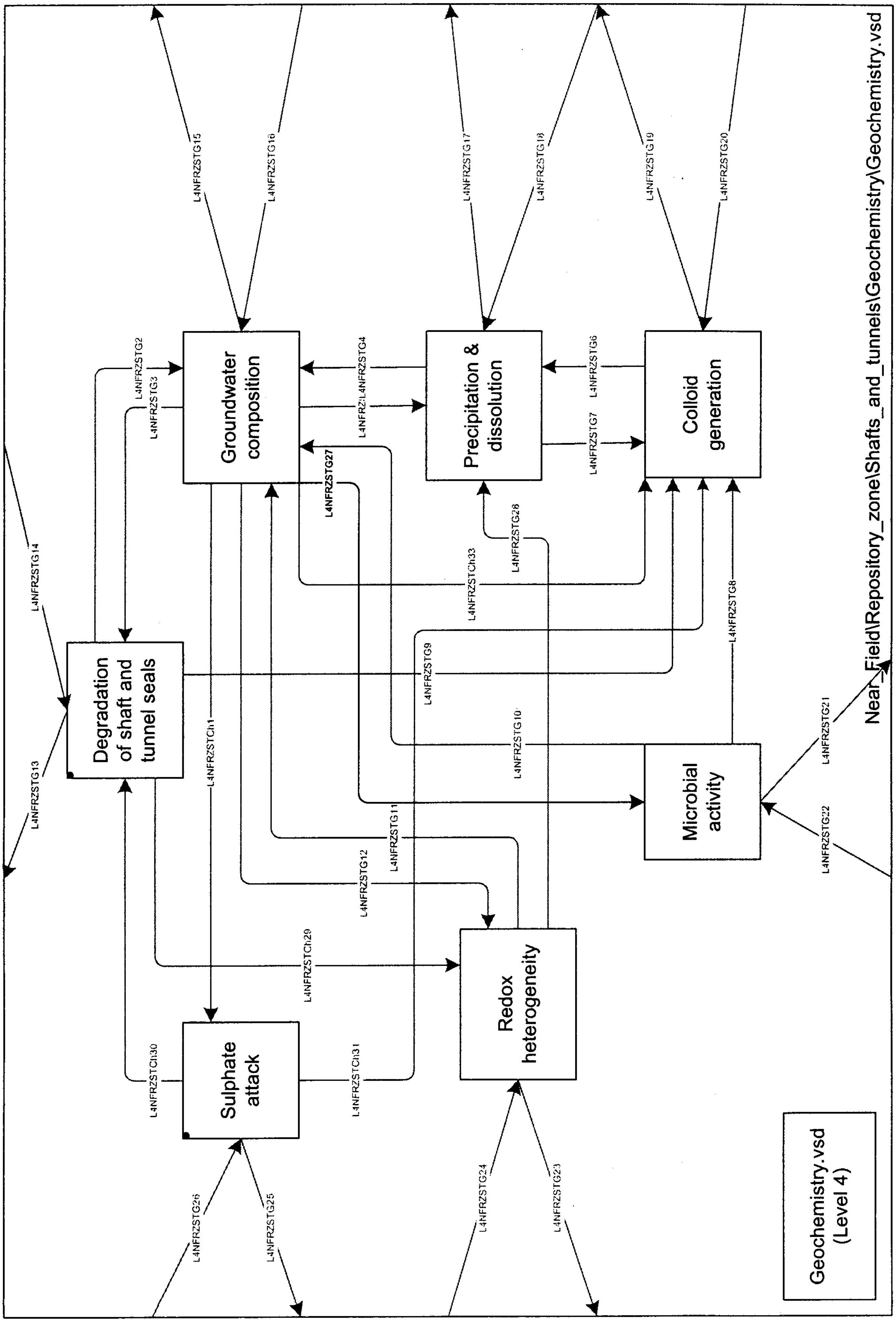


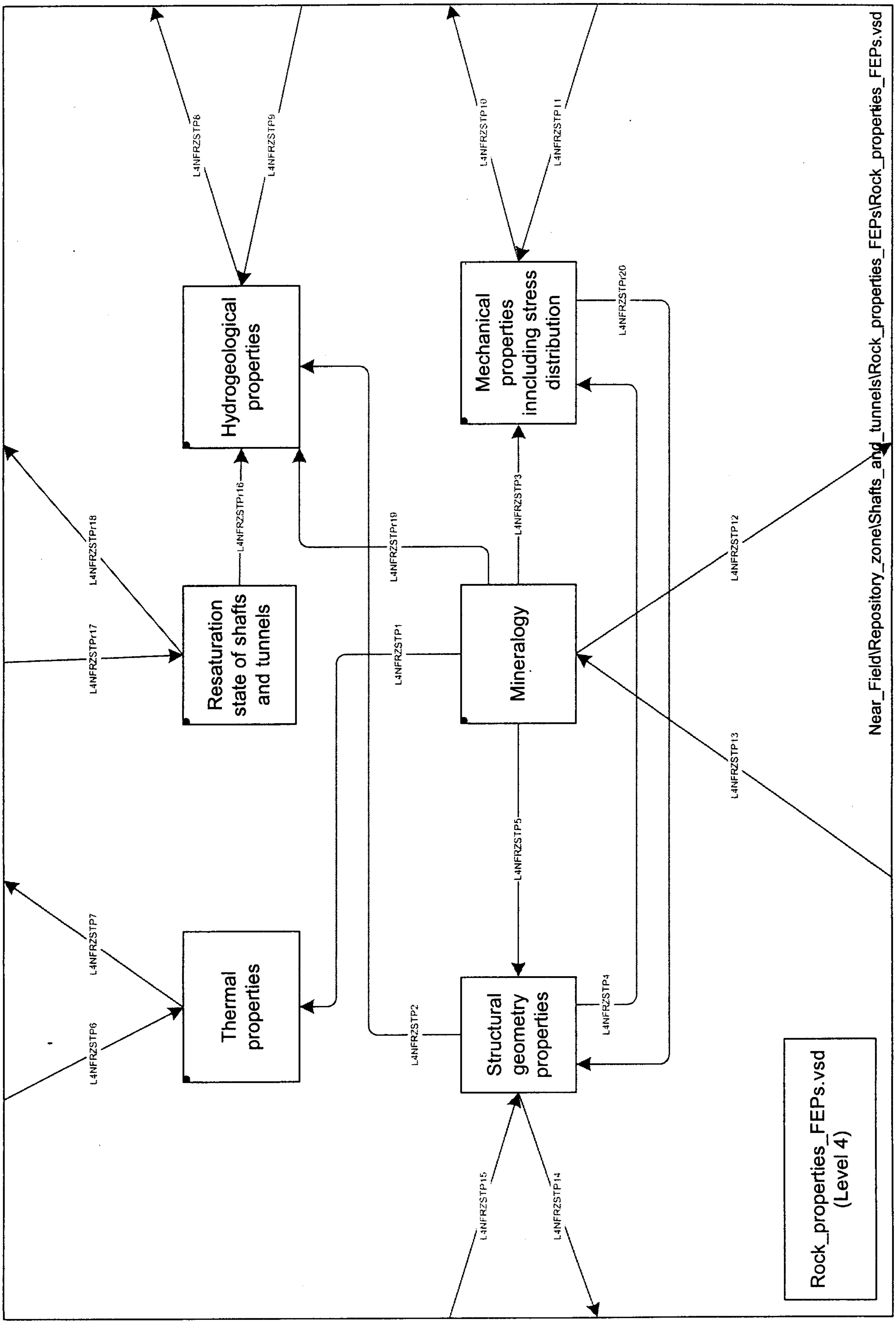
Near_Field\Repository_zone\Near-field_rock\Geochemistry\Geochemistry.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Alteration & weathering of flowpaths
Microbial activity
Redox heterogeneity
Alkaline (pH) front
Geochemistry.vsd (Level 4)
L4NFRZNFRG2
L4NFRZNFRG3
L4NFRZNFRG4
L4NFRZNFRG6
L4NFRZNFRG7
L4NFRZNFRG8
L4NFRZNFRG9
L4NFRZNFRG10
L4NFRZNFRG11
L4NFRZNFRG12
L4NFRZNFRG13
L4NFRZNFRG14
L4NFRZNFRG15
L4NFRZNFRG16
L4NFRZNFRG17
L4NFRZNFRG18
L4NFRZNFRG19
L4NFRZNFRG20
L4NFRZNFRG21
L4NFRZNFRG22
L4NFRZNFRG23
L4NFRZNFRG24
L4NFRZNFRG25
L4NFRZNFRG26
L4NFRZNFRG27
L4NFRZNFRG28
L4NFRZNFRCh30
L4NFRZNFRCh31
L4NFRZNFRCh33

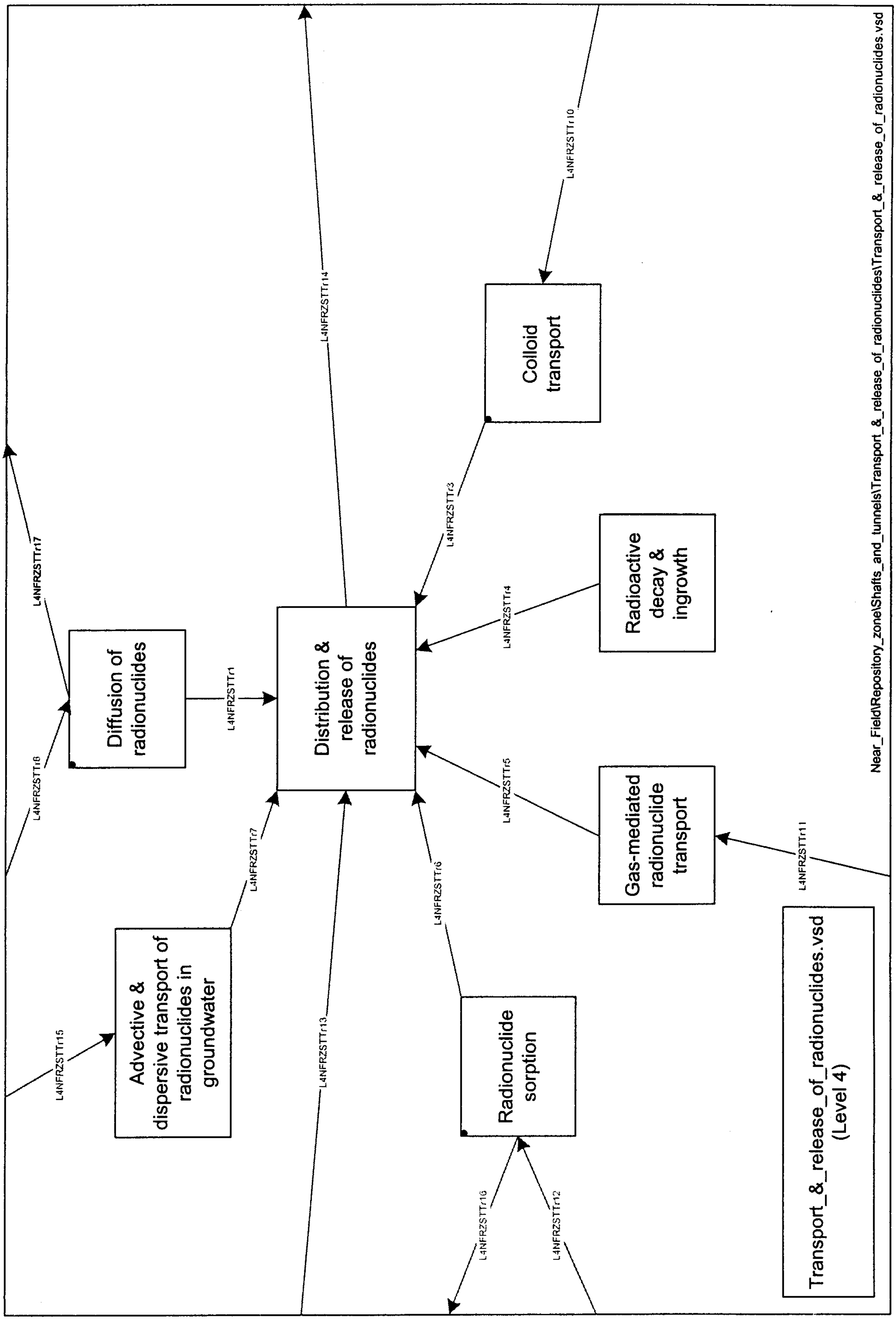

Thermal properties
Resaturation state of near-field rock
Hydrogeological properties
Structural geometry properties
Mineralogy
Mechanical properties including stress field
Fault activation
L4NFRZNFRPr6
L4NFRZNFRPr7
L4NFRZNFRPr17
L4NFRZNFRPr18
L4NFRZNFRPr16
L4NFRZNFRPr8
L4NFRZNFRPr9
L4NFRZNFRPr1
L4NFRZNFRPr2
L4NFRZNFRPr19
L4NFRZNFRPr21
L4NFRZNFRPr15
L4NFRZNFRPr14
L4NFRZNFRPr5
L4NFRZNFRPr3
L4NFRZNFRPr10
L4NFRZNFRPr11
L4NFRZNFRPr4
L4NFRZNFRPr24
L4NFRZNFRPr20
L4NFRZNFRPr22
L4NFRZNFRPr25
LL4NFRZNFRPr22
L4NFRZNFRPr23
L4NFRZNFRPr13
L4NFRZNFRPr12
Rock_properties_FEPs.vsd (Level 4)
Near_Field\Repository_zone\Near_field_rock\Rock_properties_FEPs\Rock_properties_FEPs.vsd

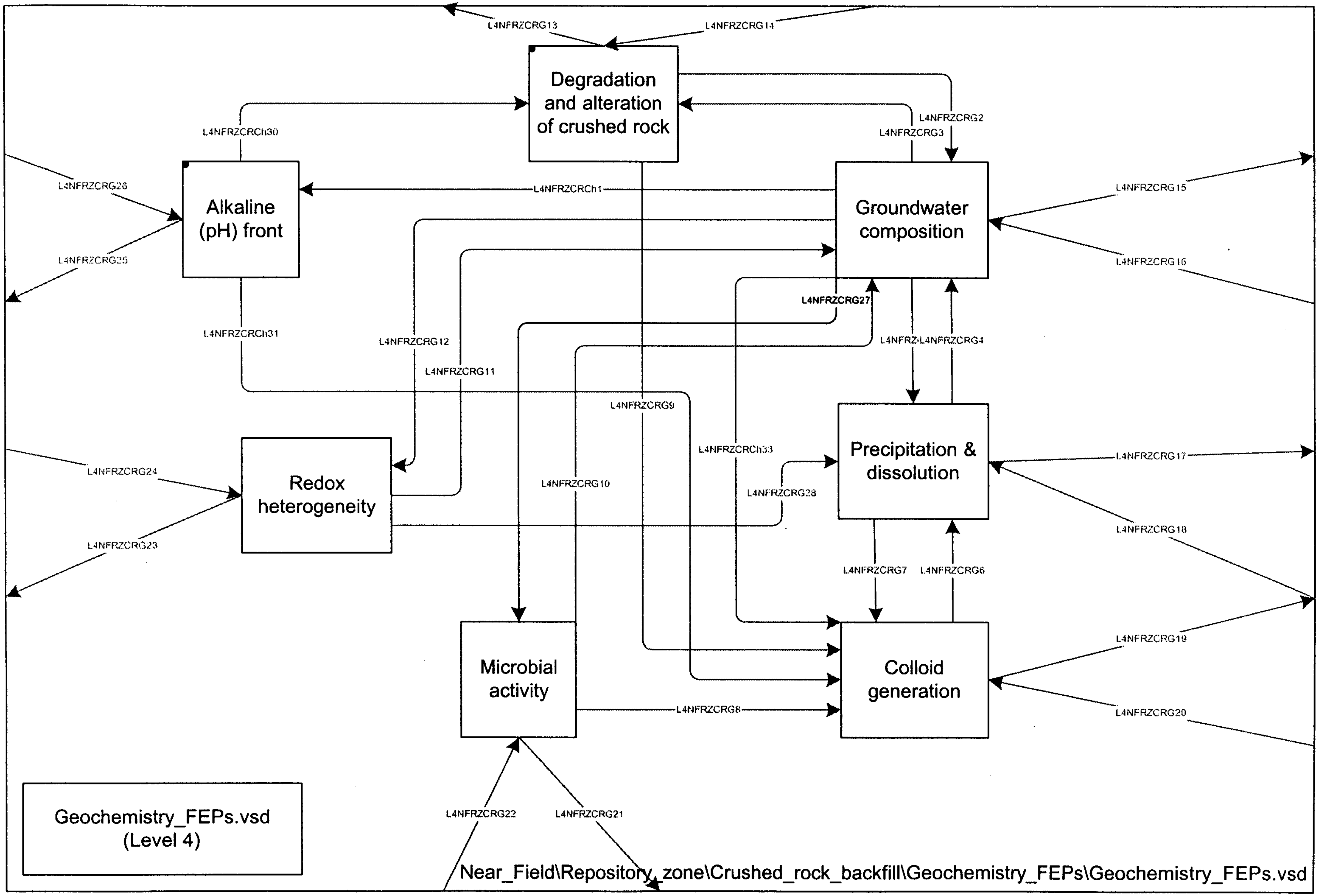


Matrix diffusion of radionuclides
Colloid transport
Radioactive decay & ingrowth
Distribution & release of radionuclides
Gas-mediated radionuclide transport
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
Transport_and_release _of_radionuclides.vsd (Level 4)
L4NFRZNFRTr2
L4NFRZNFRTr3
L4NFRZNFRTr4
L4NFRZNFRTr5
L4NFRZNFRTr6
L4NFRZNFRTr7
L4NFRZNFRTr9
L4NFRZNFRTr10
L4NFRZNFRTr11
L4NFRZNFRTr12
L4NFRZNFRTr13
L4NFRZNFRTr14
L4NFRZNFRTr15
L4NFRZNFRTr16
Near_Field\Repository_zone\Near-field_rock\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd

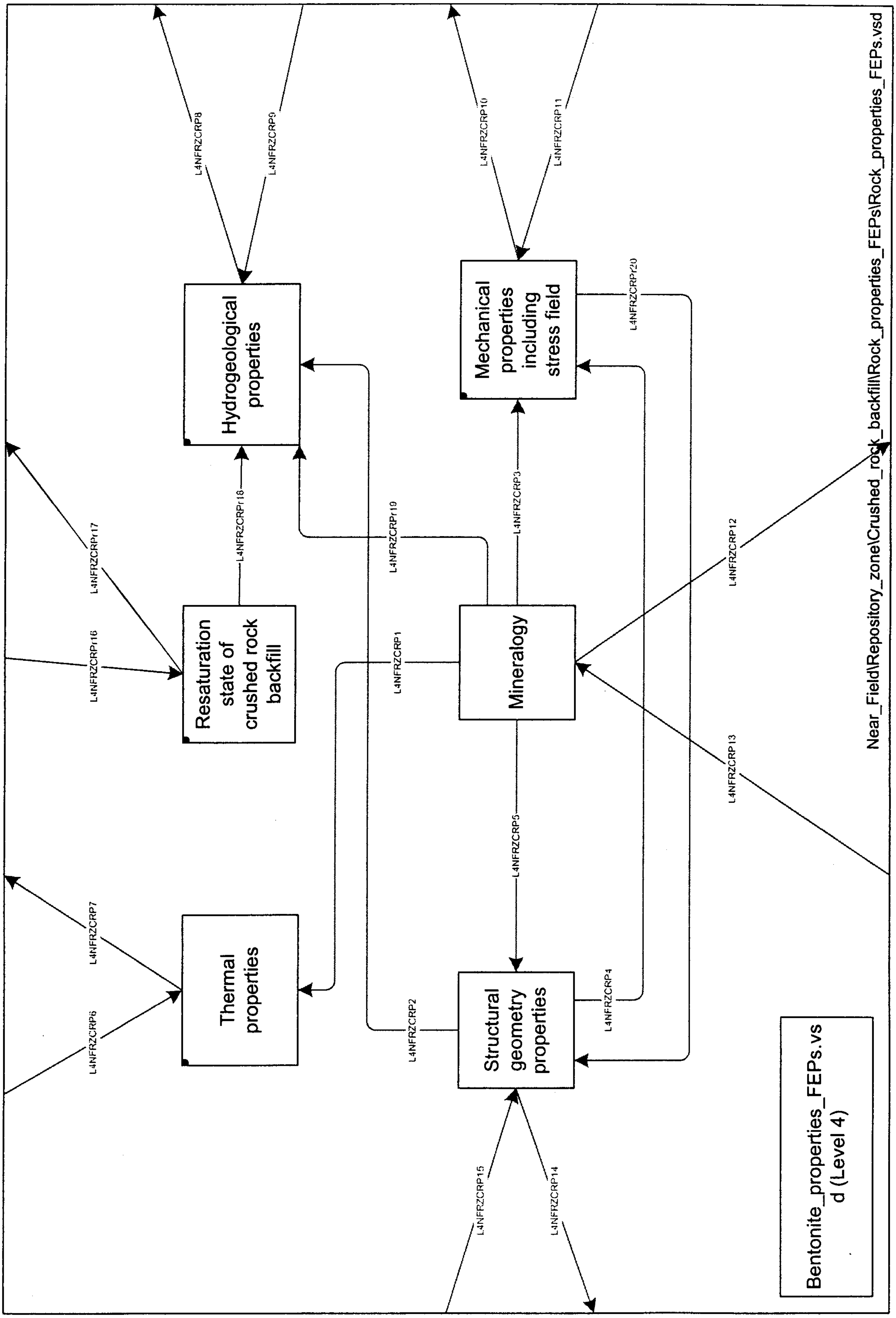

Near_Field\Repository_zone\Shafts_and_tunnels\Geochemistry\Geochemistry.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation of shaft and tunnel seals
Microbial activity
Redox heterogeneity
Sulphate attack
Geochemistry.vsd (Level 4)
L4NFRZSTG15
L4NFRZSTG16
L4NFRZSTG17
L4NFRZSTG18
L4NFRZSTG19
L4NFRZSTG20
L4NFRZSTG14
L4NFRZSTG13
L4NFRZSTG2
L4NFRZSTG3
L4NFRZSTG4
L4NFRZSTG6
L4NFRZSTG7
L4NFRZSTG27
L4NFRZSTG28
L4NFRZSTCh33
L4NFRZSTG8
L4NFRZSTG9
L4NFRZSTG10
L4NFRZSTG21
L4NFRZSTG22
L4NFRZSTCh1
L4NFRZSTG11
L4NFRZSTG12
L4NFRZSTCh29
L4NFRZSTCh30
L4NFRZSTCh31
L4NFRZSTG26
L4NFRZSTG25
L4NFRZSTG24
L4NFRZSTG23

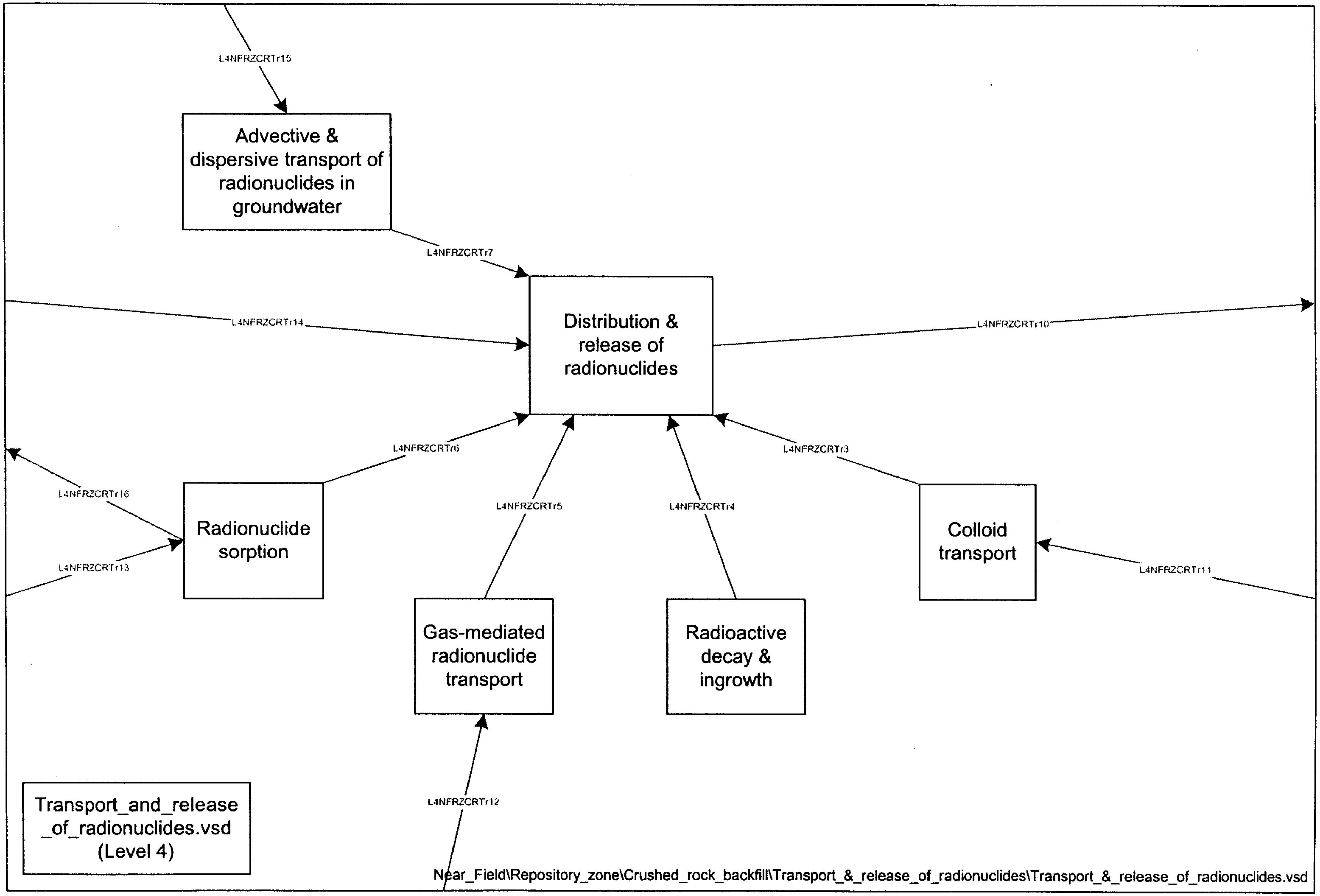

Near_Field\Repository_zone\Shafts_and_tunnels\Rock_properties_FEPs\Rock_properties_FEPs.vsd
Hydrogeological properties
Mechanical properties inncluding stress distribution
Resaturation state of shafts and tunnels
Mineralogy
Thermal properties
Structural geometry properties
Rock_properties_FEPs.vsd (Level 4)
L4NFRZSTP1
L4NFRZSTP2
L4NFRZSTP3
L4NFRZSTP4
L4NFRZSTP5
L4NFRZSTP6
L4NFRZSTP7
L4NFRZSTP8
L4NFRZSTP9
L4NFRZSTP10
L4NFRZSTP11
L4NFRZSTP12
L4NFRZSTP13
L4NFRZSTP14
L4NFRZSTP15
L4NFRZSTP16
L4NFRZSTP17
L4NFRZSTP18
L4NFRZSTP19
L4NFRZSTP20

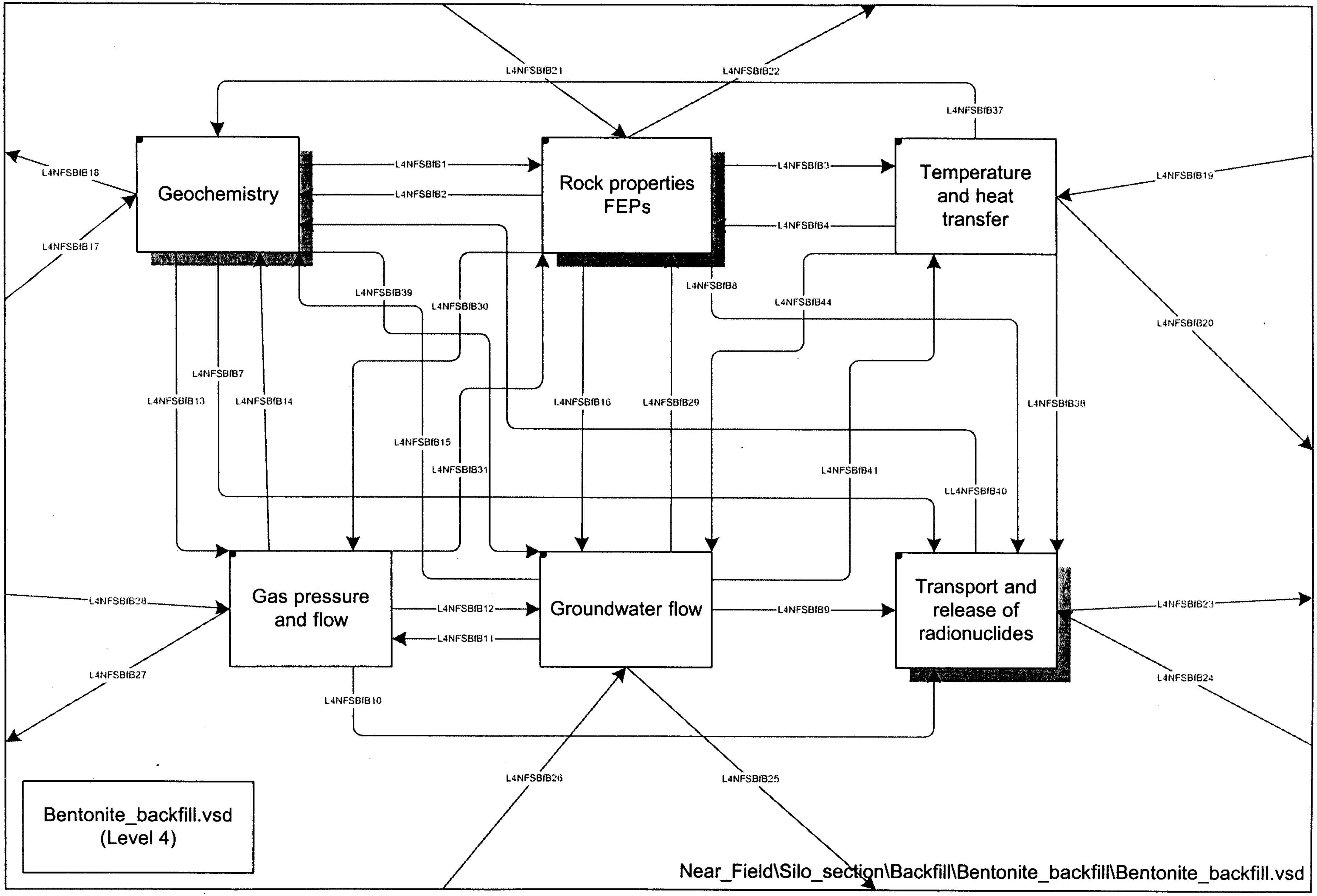

Near_Field\Repository_zone\Shafts_and_tunnels\Transport_&_release_of_radionuclides\Transport_&_release_of_radionuclides.vsd
Transport_&_release_of_radionuclides.vsd
(Level 4)
Diffusion of radionuclides
Distribution & release of radionuclides
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
L4NFRZSTTr1
L4NFRZSTTr3
L4NFRZSTTr4
L4NFRZSTTr5
L4NFRZSTTr6
L4NFRZSTTr7
L4NFRZSTTr8
L4NFRZSTTr10
L4NFRZSTTr11
L4NFRZSTTr12
L4NFRZSTTr13
L4NFRZSTTr14
L4NFRZSTTr15
L4NFRZSTTr16
L4NFRZSTTr17

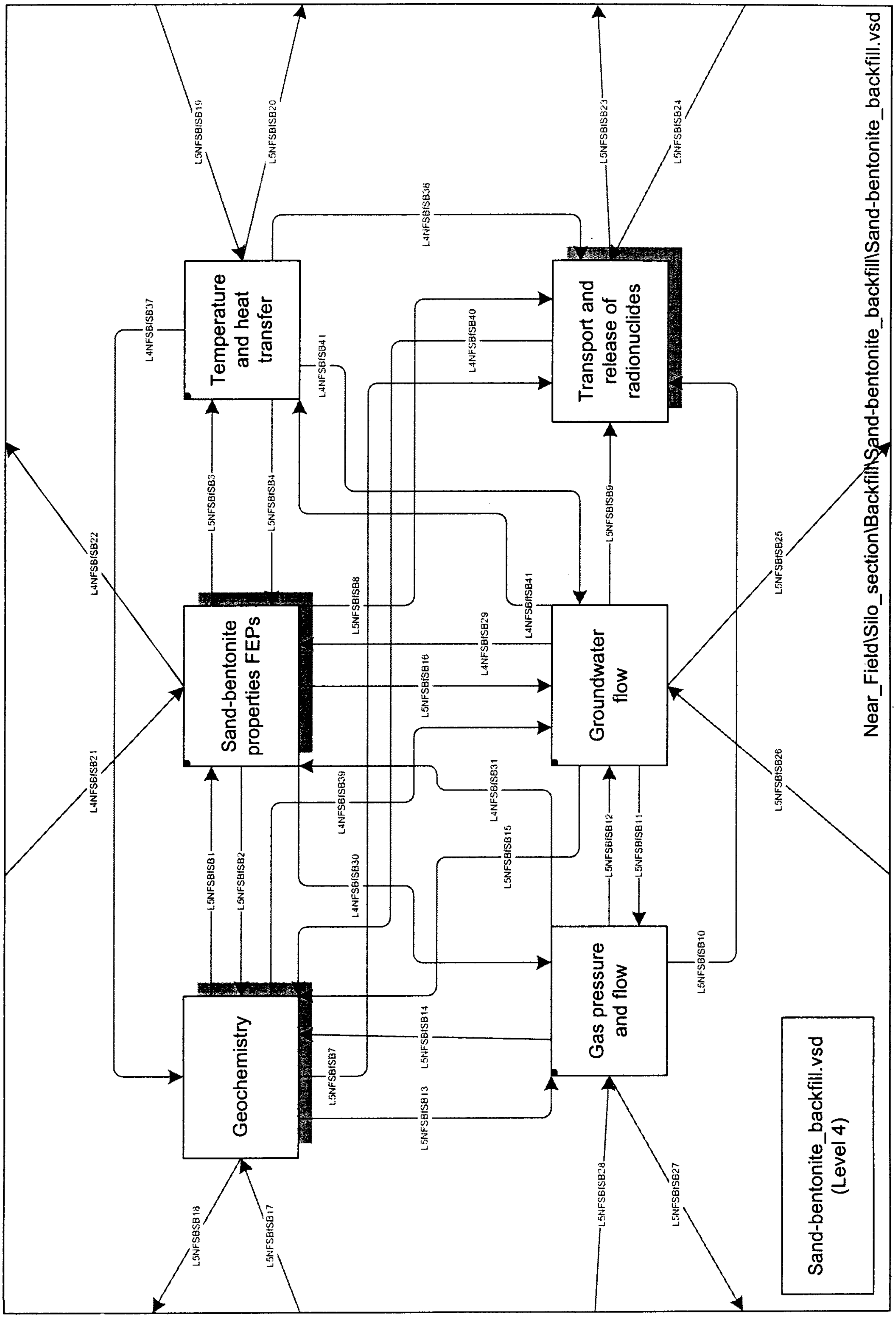


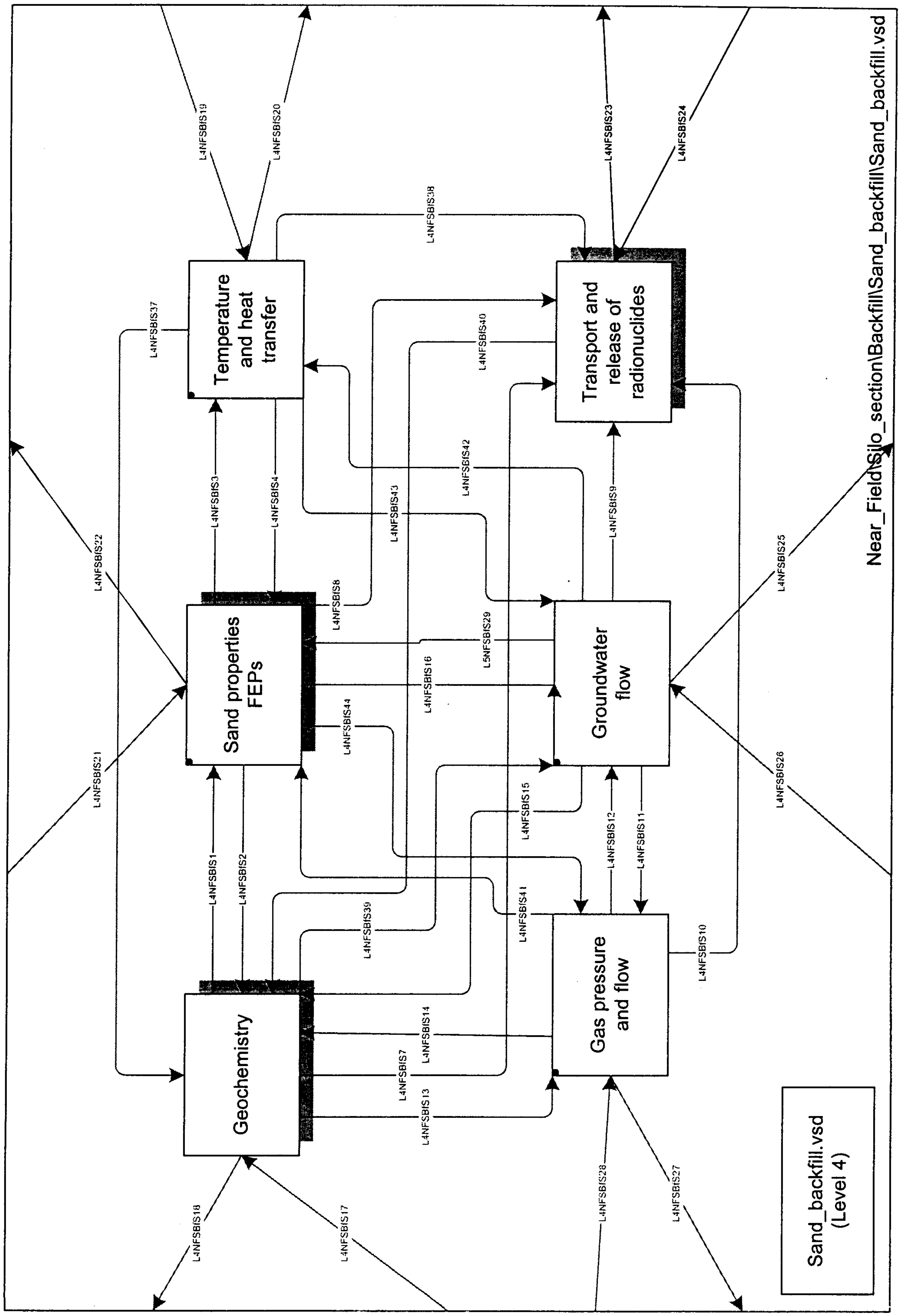
L4NFRZCRG13
L4NFRZCRG14
Degradation and alteration of crushed rock
L4NFRZCRCh30
L4NFRZCRG2
L4NFRZCRG3
L4NFRZCRG26
Alkaline (pH) front
L4NFRZCRCh1
Groundwater composition
L4NFRZCRG15
L4NFRZCRG25
L4NFRZCRG16
L4NFRZCRG27
L4NFRZCRCh31
L4NFRZCRG12
L4NFRZL4NFRZCRG4
L4NFRZCRG11
L4NFRZCRG9
L4NFRZCRCh33
Precipitation & dissolution
L4NFRZCRG17
L4NFRZCRG24
Redox heterogeneity
L4NFRZCRG10
L4NFRZCRG28
L4NFRZCRG18
L4NFRZCRG23
L4NFRZCRG7
L4NFRZCRG6
L4NFRZCRG19
Microbial activity
Colloid generation
L4NFRZCRG8
L4NFRZCRG20
Geochemistry_FEPs.vsd (Level 4)
L4NFRZCRG22
L4NFRZCRG21
Near_Field\Repository_zone\Crushed_rock_backfill\Geochemistry_FEPs\Geochemistry_FEPs.vsd

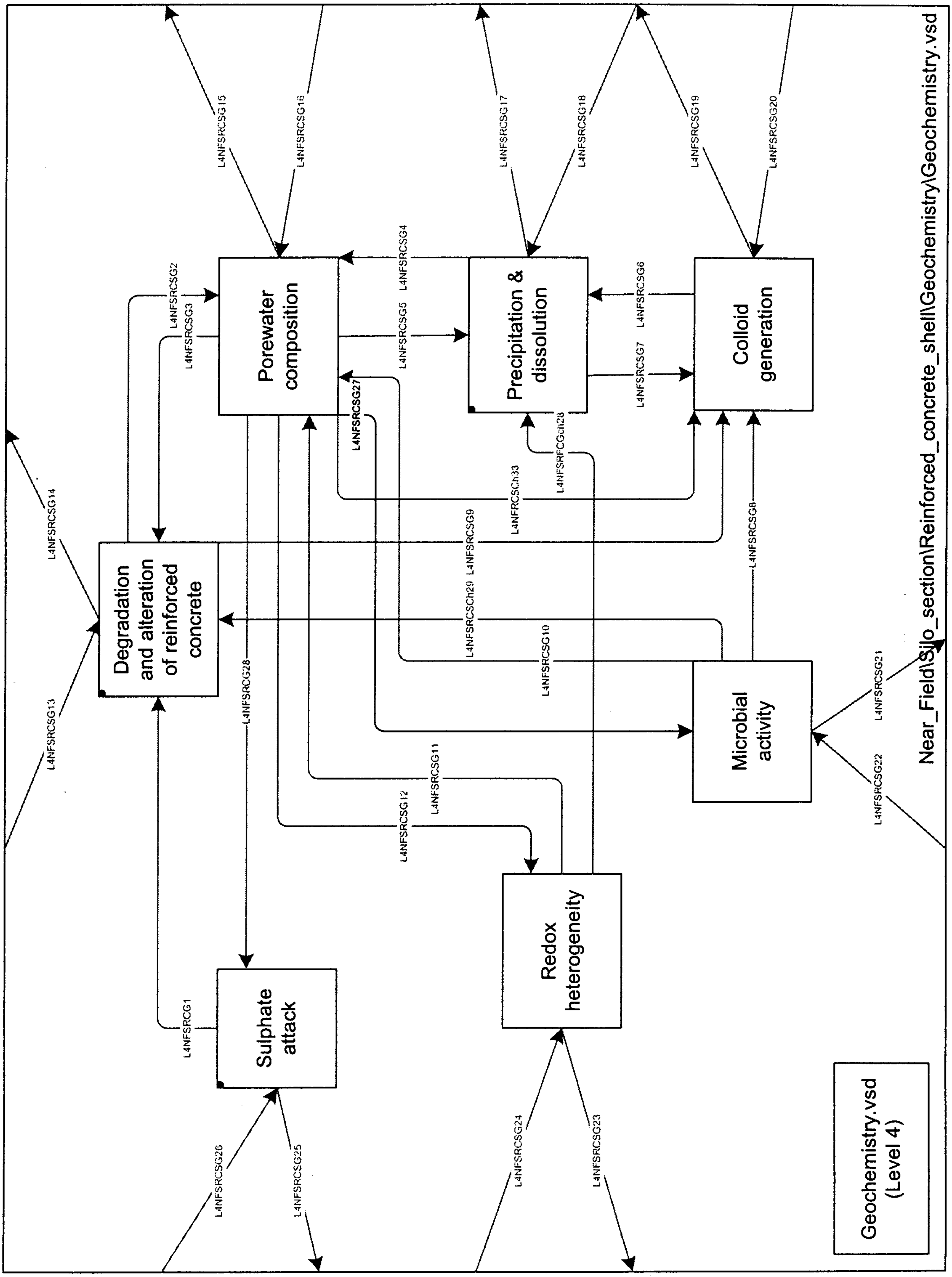

Near_Field\Repository_zone\Crushed_rock_backfill\Rock_properties_FEPs\Rock_properties_FEPs.vsd
Bentonite_properties_FEPs.vsd (Level 4)
Hydrogeological properties
Mechanical properties including stress field
Resaturation state of crushed rock backfill
Mineralogy
Thermal properties
Structural geometry properties
L4NFRZCRP1
L4NFRZCRP2
L4NFRZCRP3
L4NFRZCRP4
L4NFRZCRP5
L4NFRZCRP6
L4NFRZCRP7
L4NFRZCRP8
L4NFRZCRP9
L4NFRZCRP10
L4NFRZCRP11
L4NFRZCRP12
L4NFRZCRP13
L4NFRZCRP14
L4NFRZCRP15
L4NFRZCRP16
L4NFRZCRP17
L4NFRZCRP18
L4NFRZCRP19
L4NFRZCRP20

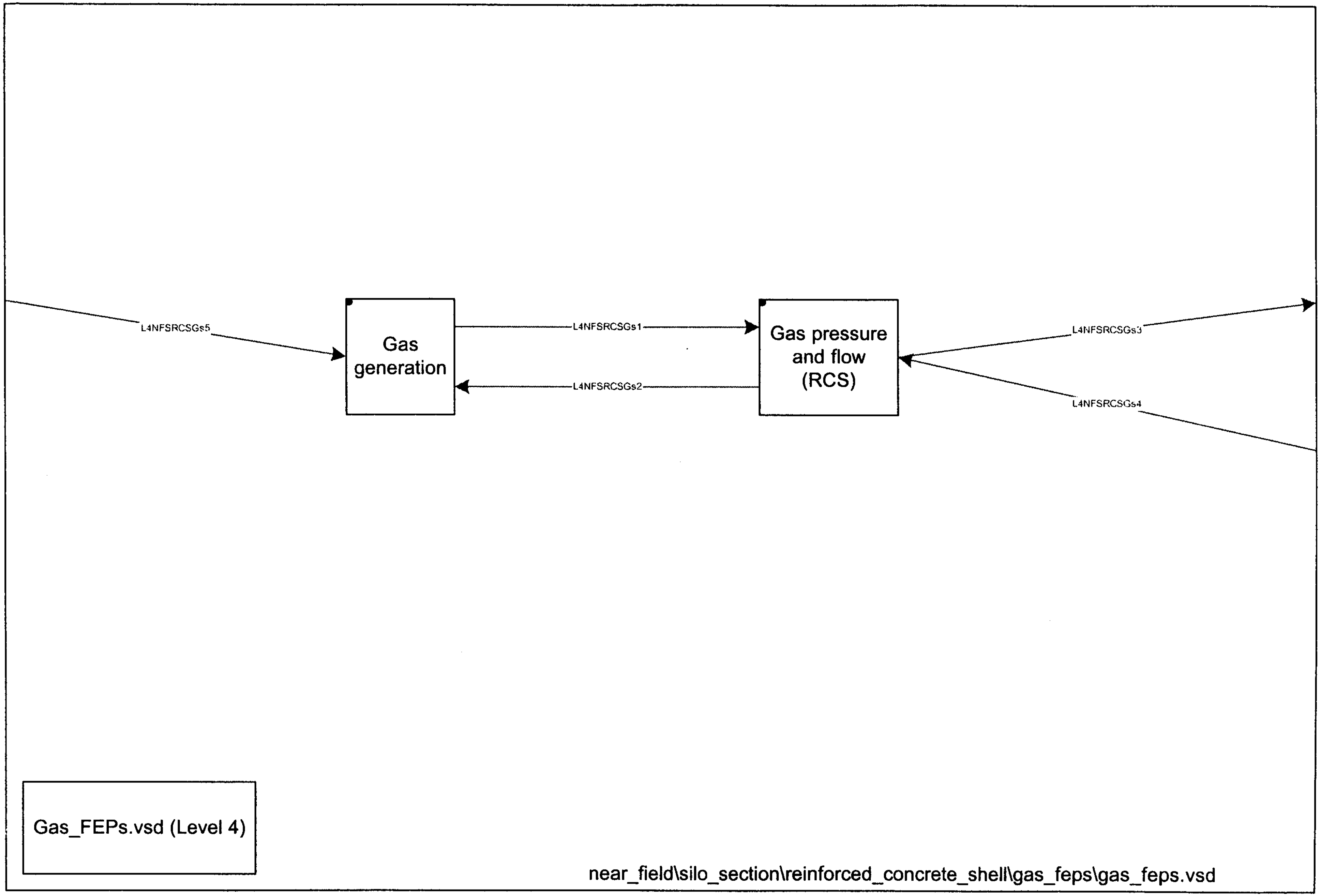

Advective & dispersive transport of radionuclides in groundwater
Distribution & release of radionuclides
Radionuclide sorption
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
Transport_and_release_of_radionuclides.vsd (Level 4)
Near_Field\Repository_zone\Crushed_rock_backfill\Transport_&_release_of_radionuclides\Transport_&_release_of_radionuclides.vsd
L4NFRZCRTr15
L4NFRZCRTr7
L4NFRZCRTr14
L4NFRZCRTr10
L4NFRZCRTr6
L4NFRZCRTr3
L4NFRZCRTr16
L4NFRZCRTr5
L4NFRZCRTr4
L4NFRZCRTr13
L4NFRZCRTr11
L4NFRZCRTr12

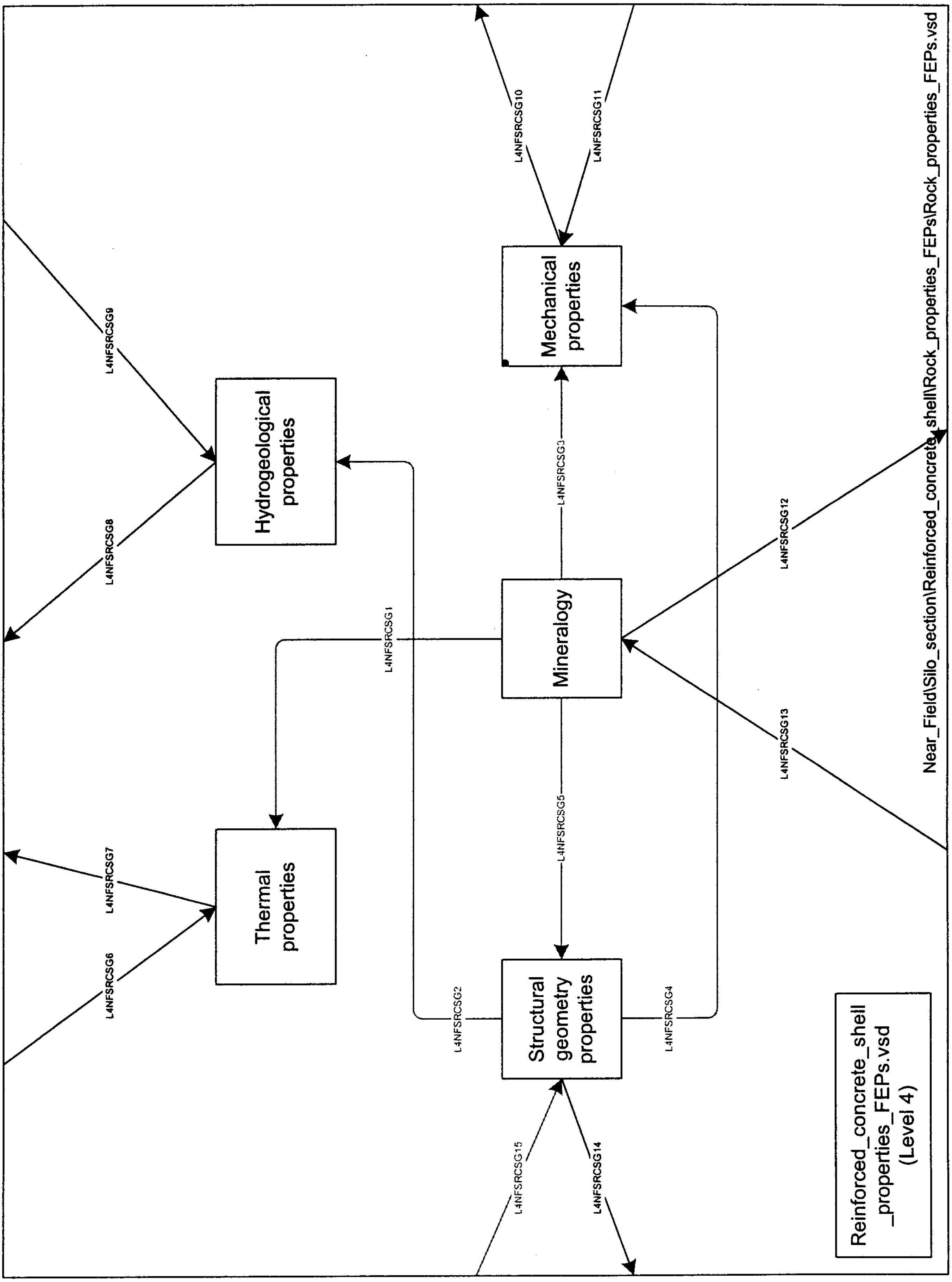

Geochemistry
Rock properties FEPs
Temperature and heat transfer
Gas pressure and flow
Groundwater flow
Transport and release of radionuclides
L4NFSBfB1
L4NFSBfB2
L4NFSBfB3
L4NFSBfB4
L4NFSBfB7
L4NFSBfB8
L4NFSBfB9
L4NFSBfB10
L4NFSBfB11
L4NFSBfB12
L4NFSBfB13
L4NFSBfB14
L4NFSBfB15
L4NFSBfB16
L4NFSBfB17
L4NFSBfB18
L4NFSBfB19
L4NFSBfB20
L4NFSBfB21
L4NFSBfB22
L4NFSBfB23
L4NFSBfB24
L4NFSBfB25
L4NFSBfB26
L4NFSBfB27
L4NFSBfB28
L4NFSBfB29
L4NFSBfB30
L4NFSBfB31
L4NFSBfB37
L4NFSBfB38
L4NFSBfB39
LL4NFSBfB40
L4NFSBfB41
L4NFSBfB44
Bentonite_backfill.vsd (Level 4)
Near_Field\Silo_section\Backfill\Bentonite_backfill\Bentonite_backfill.vsd


Near_Field\Silo_section\Backfill\Sand-bentonite_backfill\Sand-bentonite_backfill.vsd
Temperature and heat transfer
Transport and release of radionuclides
Sand-bentonite properties FEPs
Groundwater flow
Geochemistry
Gas pressure and flow
Sand-bentonite_backfill.vsd (Level 4)

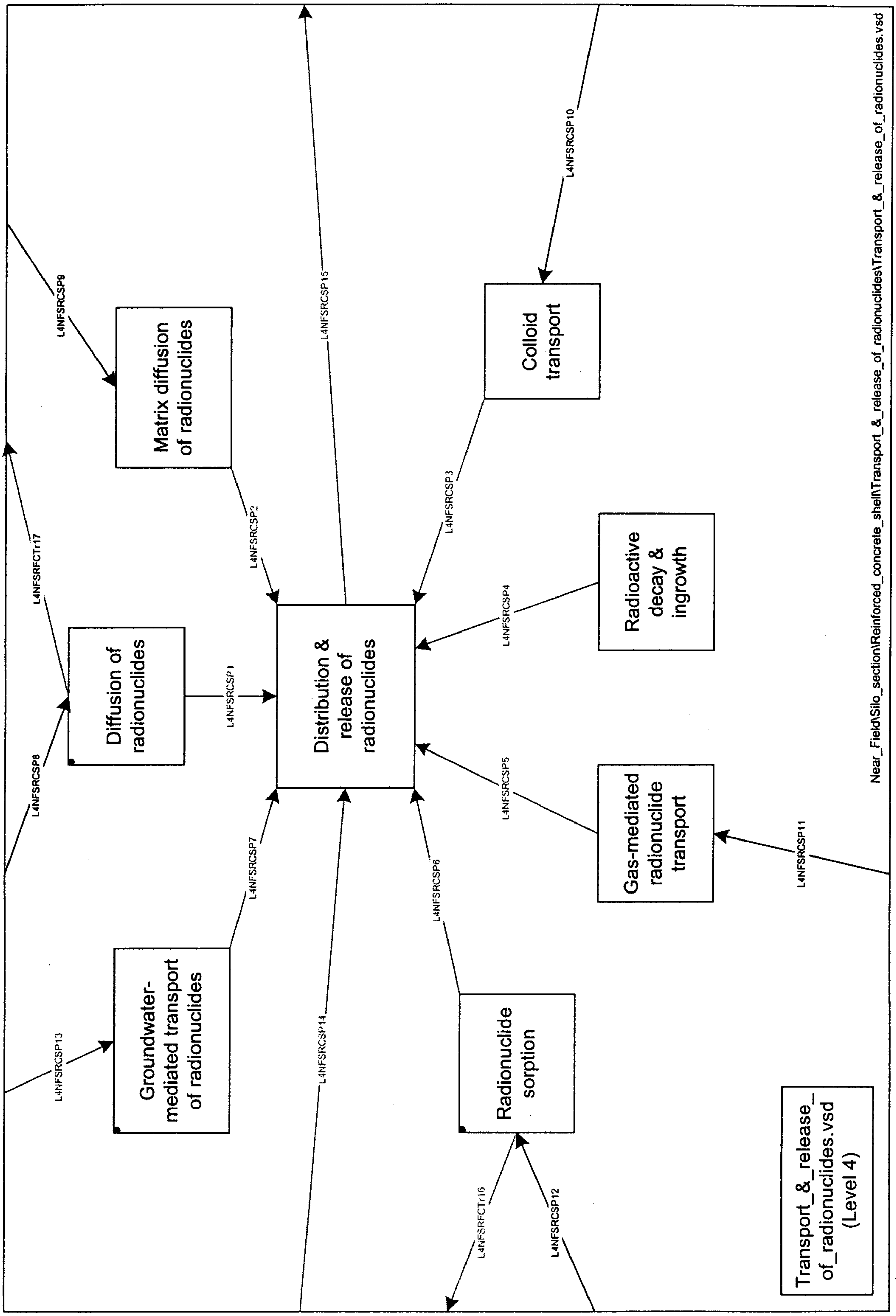

Near_Field\Silo_section\Backfill\Sand_backfill\Sand_backfill.vsd
Sand_backfill.vsd
(Level 4)
Temperature and heat transfer
Transport and release of radionuclides
Sand properties FEPs
Groundwater flow
Geochemistry
Gas pressure and flow
L4NFSBIS19
L4NFSBIS20
L4NFSBIS23
L4NFSBIS24
L4NFSBIS38
L4NFSBIS37
L4NFSBIS40
L4NFSBIS42
L4NFSBIS3
L4NFSBIS4
L4NFSBIS43
L4NFSBIS9
L4NFSBIS22
L4NFSBIS25
L4NFSBIS8
L5NFSBIS29
L4NFSBIS16
L4NFSBIS44
L4NFSBIS21
L4NFSBIS26
L4NFSBIS15
L4NFSBIS12
L4NFSBIS11
L4NFSBIS1
L4NFSBIS2
L4NFSBIS41
L4NFSBIS39
L4NFSBIS10
L4NFSBIS14
L4NFSBIS7
L4NFSBIS13
L4NFSBIS18
L4NFSBIS17
L4NFSBIS28
L4NFSBIS27


Near_Field\Silo_section\Reinforced_concrete_shell\Geochemistry\Geochemistry.vsd
Porewater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of reinforced concrete
Microbial activity
Sulphate attack
Redox heterogeneity
Geochemistry.vsd (Level 4)
L4NFSRCG1
L4NFSRCSG2
L4NFSRCSG3
L4NFSRCSG4
L4NFSRCSG5
L4NFSRCSG6
L4NFSRCSG7
L4NFSRCSG8
L4NFSRCSG9
L4NFSRCSG10
L4NFSRCSG11
L4NFSRCSG12
L4NFSRCSG13
L4NFSRCSG14
L4NFSRCSG15
L4NFSRCSG16
L4NFSRCSG17
L4NFSRCSG18
L4NFSRCSG19
L4NFSRCSG20
L4NFSRCSG21
L4NFSRCSG22
L4NFSRCSG23
L4NFSRCSG24
L4NFSRCSG25
L4NFSRCSG26
L4NFSRCSG27
L4NFSRCG28
L4NFSRCSCh29
L4NFRCSCh33

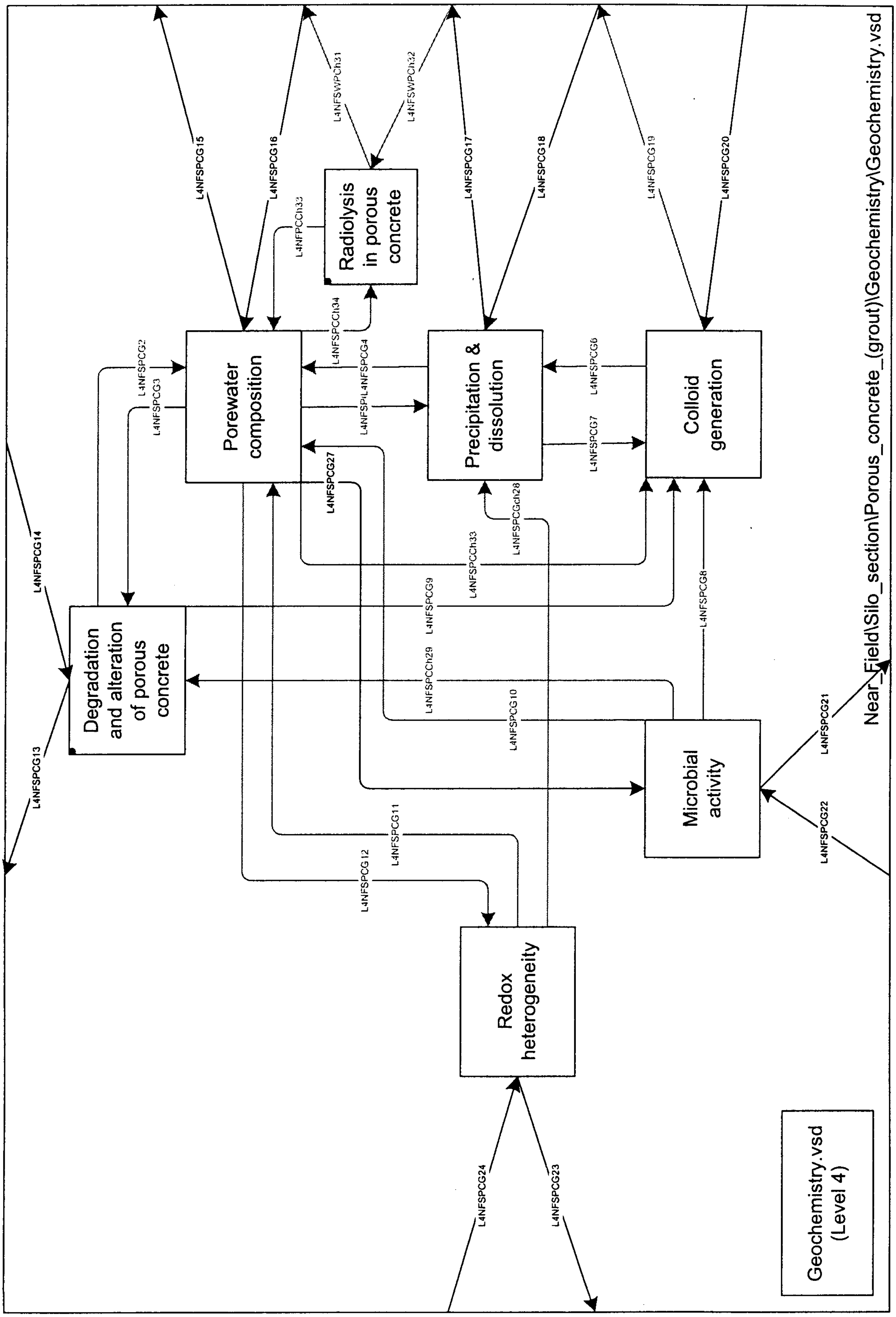

L4NFSRCSGs5
Gas generation
L4NFSRCSGs1
L4NFSRCSGs2
Gas pressure and flow (RCS)
L4NFSRCSGs3
L4NFSRCSGs4
Gas_FEPs.vsd (Level 4)
near_field\silo_section\reinforced_concrete_shell\gas_feps\gas_feps.vsd

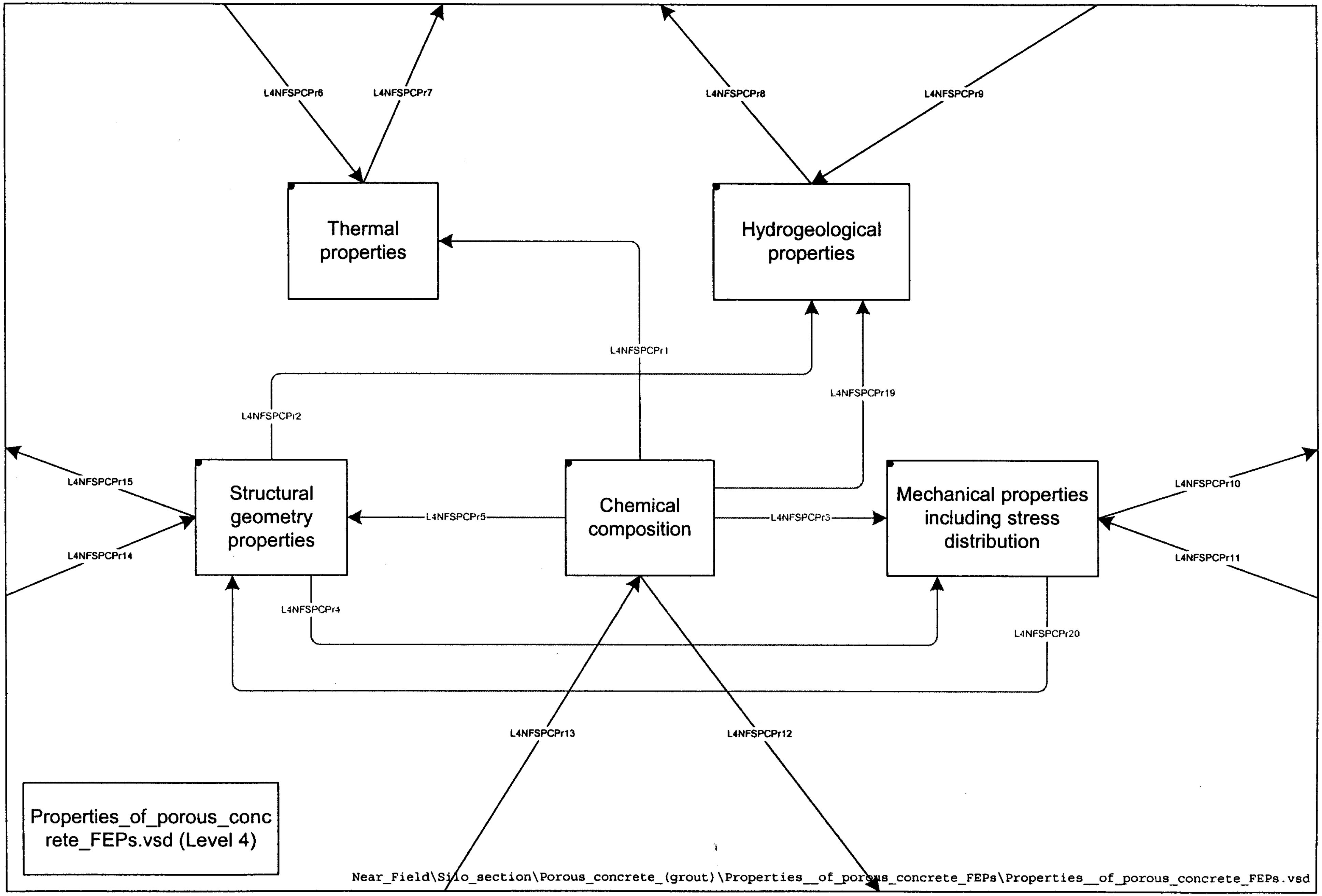


Near_Field\Silo_section\Reinforced_concrete_shell\Rock_properties_FEPs\Rock_properties_FEPs.vsd
Hydrogeological properties
Mechanical properties
Mineralogy
Thermal properties
Structural geometry properties
Reinforced_concrete_shell _properties_FEPs.vsd (Level 4)
L4NFSRCSG1
L4NFSRCSG2
L4NFSRCSG3
L4NFSRCSG4
L4NFSRCSG5
L4NFSRCSG6
L4NFSRCSG7
L4NFSRCSG8
L4NFSRCSG9
L4NFSRCSG10
L4NFSRCSG11
L4NFSRCSG12
L4NFSRCSG13
L4NFSRCSG14
L4NFSRCSG15

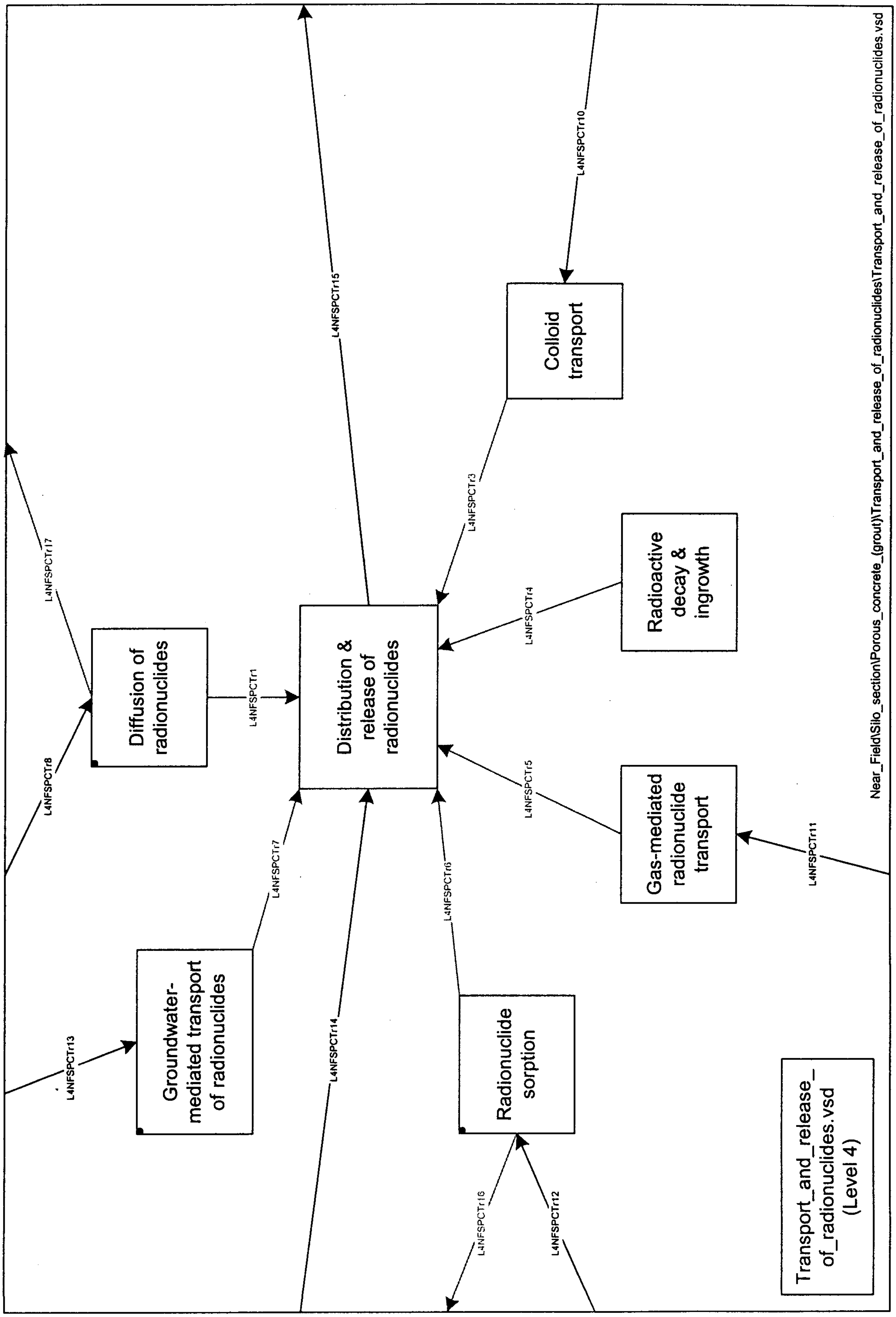


Distribution & release of radionuclides
Diffusion of radionuclides
Matrix diffusion of radionuclides
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
Radionuclide sorption
Groundwater-mediated transport of radionuclides
L4NFSRCSP1
L4NFSRCSP2
L4NFSRCSP3
L4NFSRCSP4
L4NFSRCSP5
L4NFSRCSP6
L4NFSRCSP7
L4NFSRCSP8
L4NFSRCSP9
L4NFSRCSP10
L4NFSRCSP11
L4NFSRCSP12
L4NFSRCSP13
L4NFSRCSP14
L4NFSRCSP15
L4NFSRFCTr16
L4NFSRFCTr17
Transport_&_release_of_radionuclides.vsd (Level 4)
Near_Field\Silo_section\Reinforced_concrete_shell\Transport_&_release_of_radionuclides\Transport_&_release_of_radionuclides.vsd


Near_Field\Silo_section\Porous_concrete_(grout)\Geochemistry\Geochemistry.vsd
Porewater composition
Radiolysis in porous concrete
Precipitation & dissolution
Colloid generation
Degradation and alteration of porous concrete
Microbial activity
Redox heterogeneity
Geochemistry.vsd (Level 4)
L4NFSPCG15
L4NFSPCG16
L4NFSWPCh31
L4NFSWPCh32
L4NFSPCG17
L4NFSPCG18
L4NFSPCG19
L4NFSPCG20
L4NFPCCh33
L4NFSPCCh34
L4NFSPCG2
L4NFSPCG3
L4NFSPCG4
L4NFSPL4NFSPCG4
L4NFSPCG6
L4NFSPCG7
L4NFSPCG27
L4NFSPCGch28
L4NFSPCCh33
L4NFSPCG14
L4NFSPCG9
L4NFSPCG8
L4NFSPCCh29
L4NFSPCG10
L4NFSPCG13
L4NFSPCG21
L4NFSPCG22
L4NFSPCG11
L4NFSPCG12
L4NFSPCG24
L4NFSPCG23



Thermal properties
Hydrogeological properties
Structural geometry properties
Chemical composition
Mechanical properties including stress distribution
L4NFSPCPr1
L4NFSPCPr2
L4NFSPCPr3
L4NFSPCPr4
L4NFSPCPr5
L4NFSPCPr6
L4NFSPCPr7
L4NFSPCPr8
L4NFSPCPr9
L4NFSPCPr10
L4NFSPCPr11
L4NFSPCPr12
L4NFSPCPr13
L4NFSPCPr14
L4NFSPCPr15
L4NFSPCPr19
L4NFSPCPr20
Properties_of_porous_concrete_FEPs.vsd (Level 4)
Near_Field\Silo_section\Porous_concrete_(grout)\Properties__of_porous_concrete_FEPs\Properties__of_porous_concrete_FEPs.vsd



Near_Field\Silo_section\Porous_concrete_(grout)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
Transport_and_release_of_radionuclides.vsd (Level 4)
Diffusion of radionuclides
Distribution & release of radionuclides
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
Groundwater-mediated transport of radionuclides
Radionuclide sorption
L4NFSPCTr1
L4NFSPCTr3
L4NFSPCTr4
L4NFSPCTr5
L4NFSPCTr6
L4NFSPCTr7
L4NFSPCTr8
L4NFSPCTr10
L4NFSPCTr11
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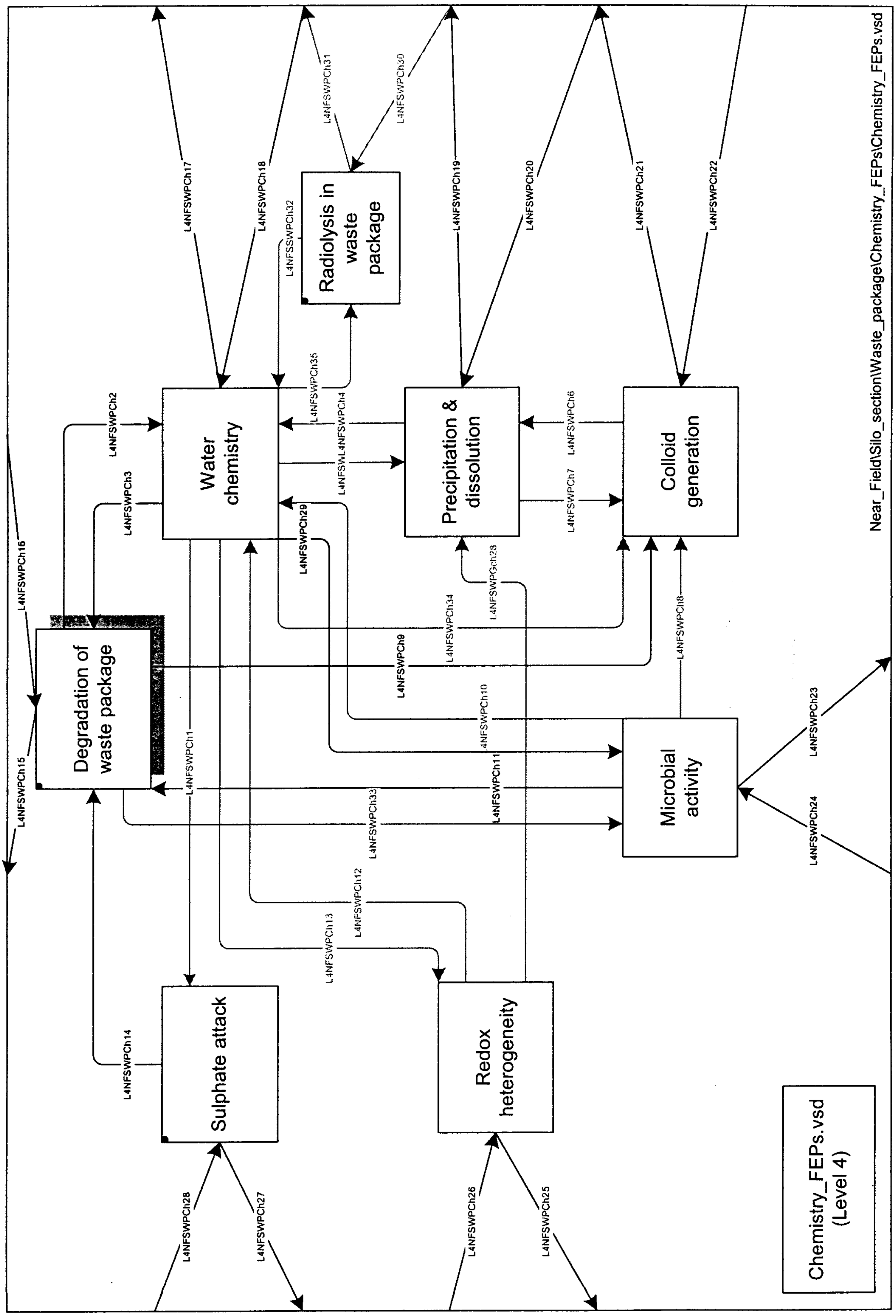
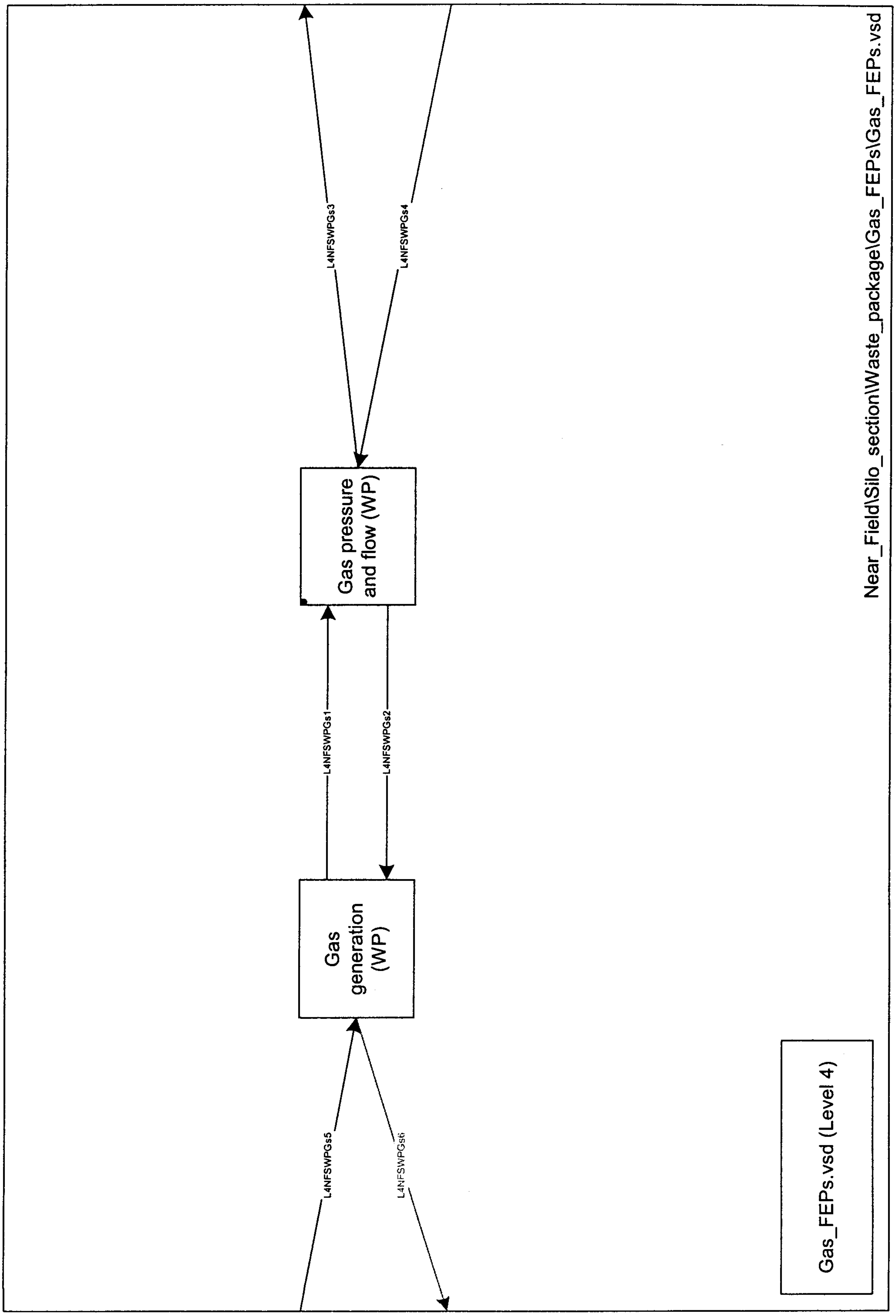
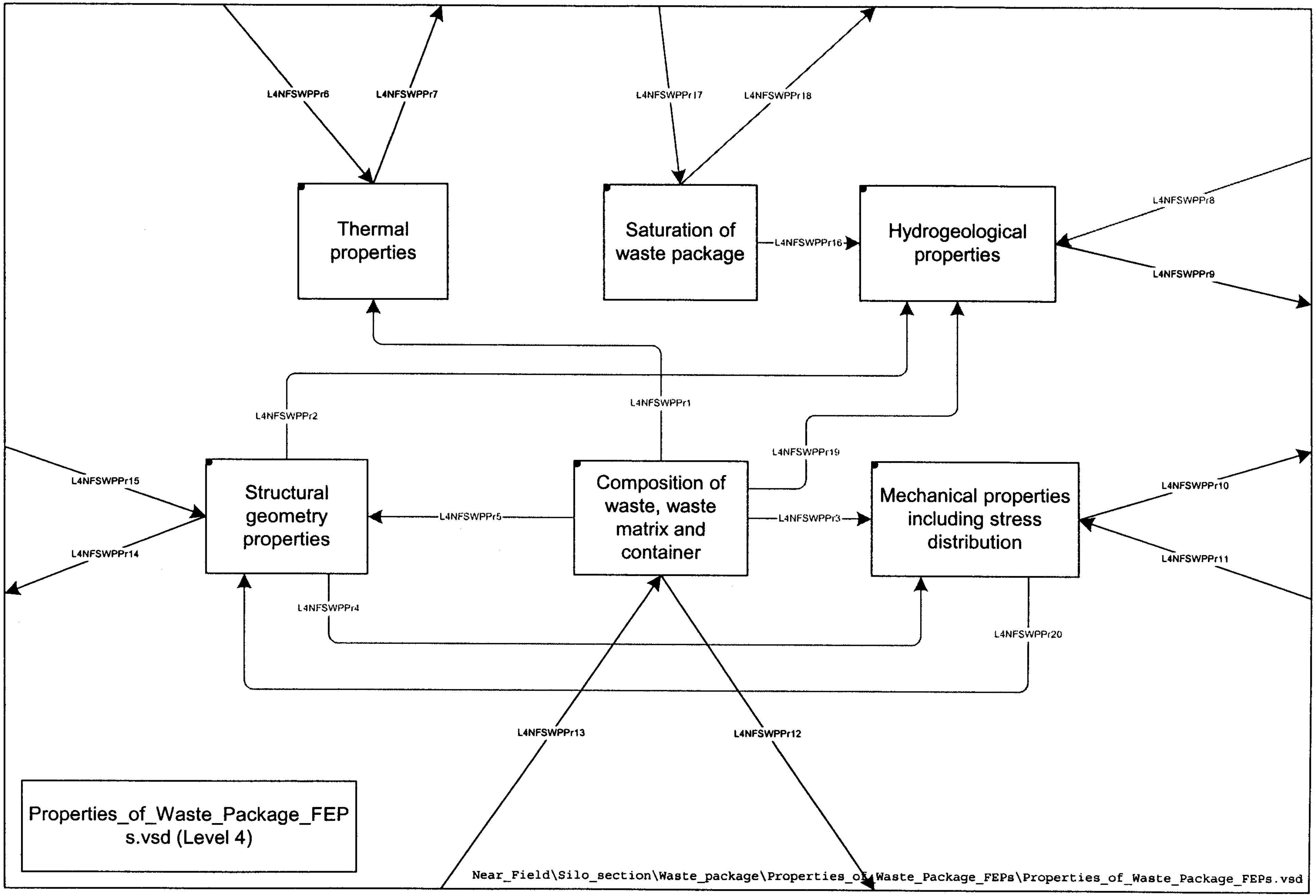
L4NFSPCTr14
L4NFSPCTr15
L4NFSPCTr16
L4NFSPCTr17

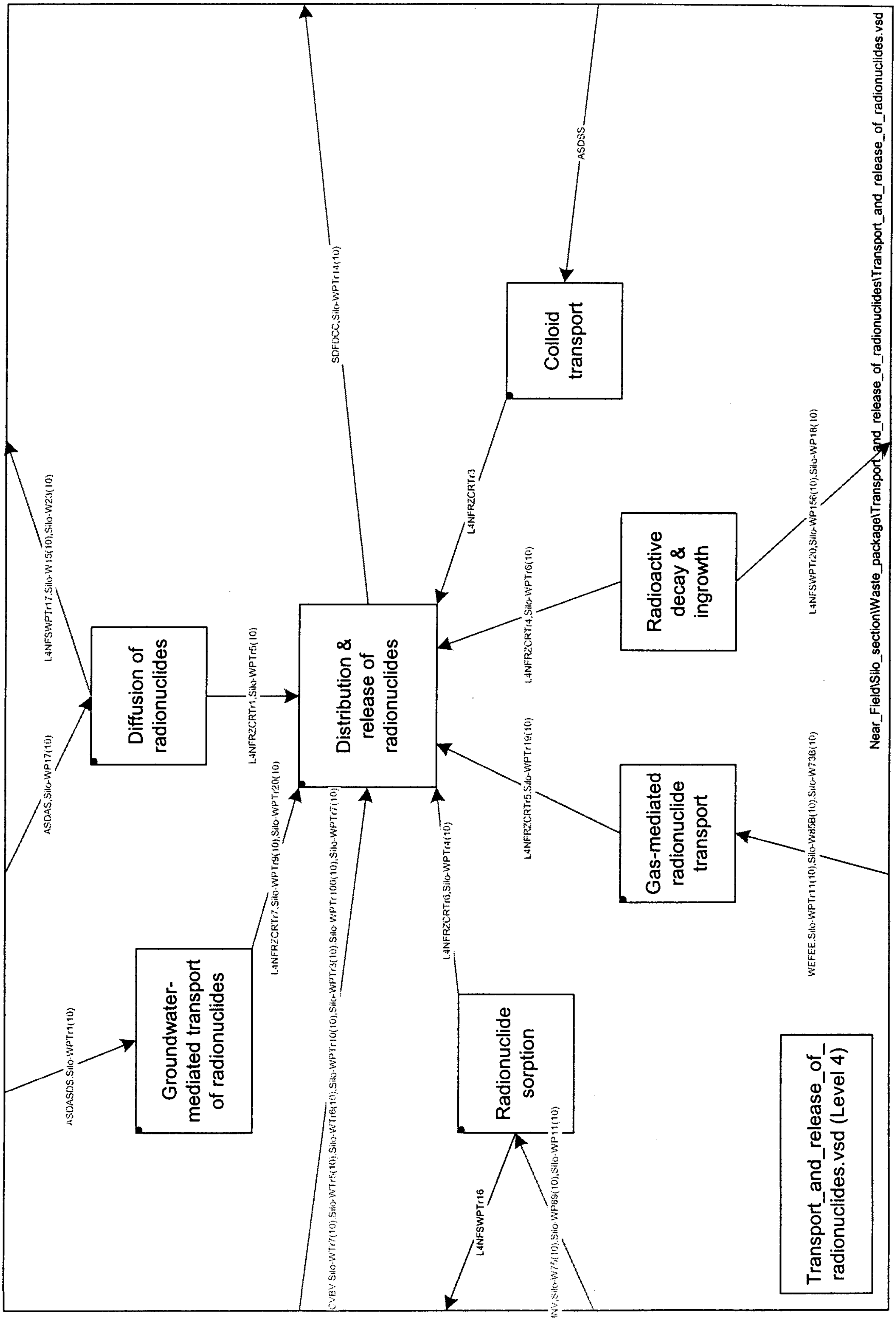


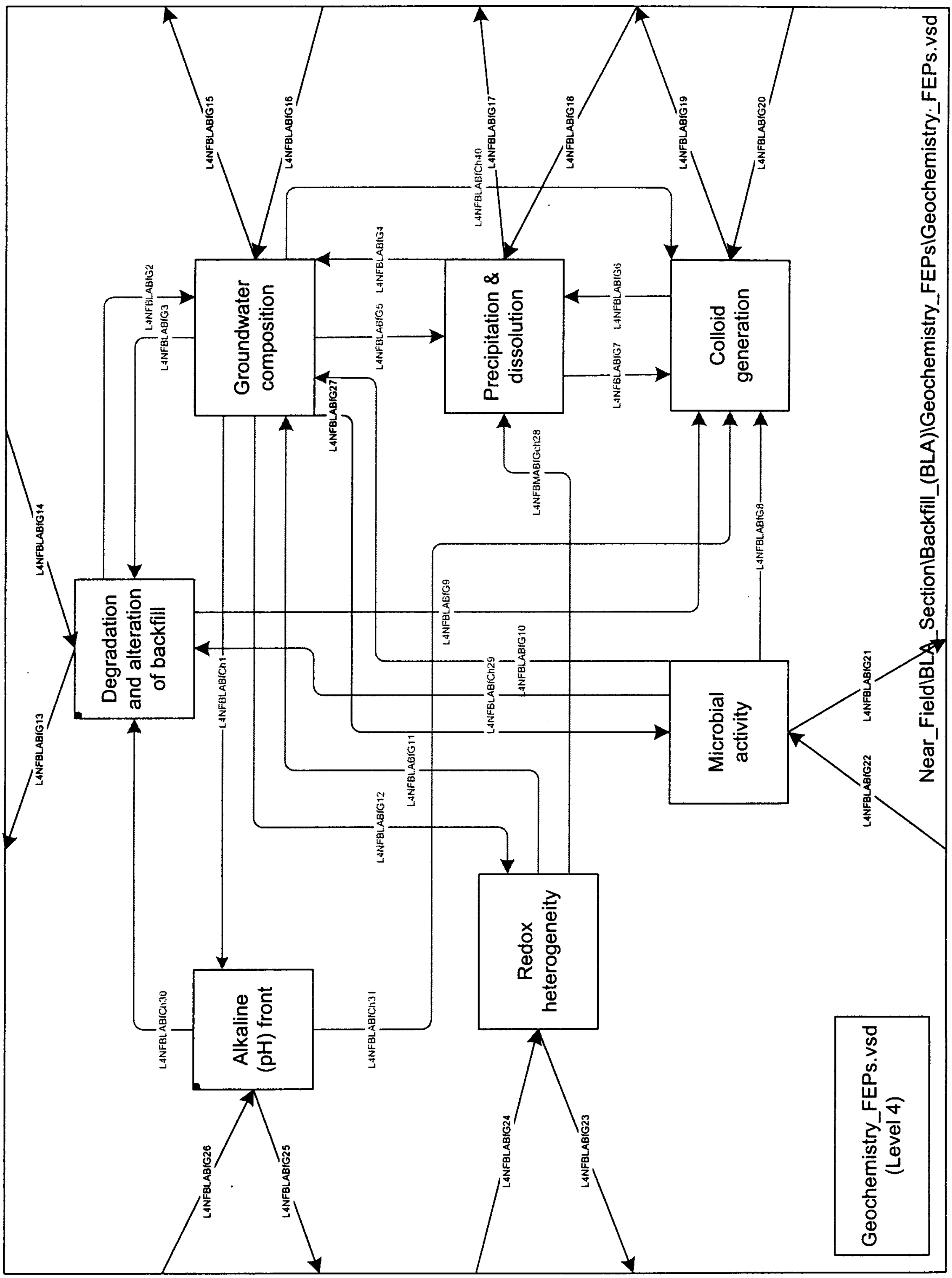
Water chemistry
Radiolysis in waste package
Precipitation & dissolution
Colloid generation
Degradation of waste package
Microbial activity
Sulphate attack
Redox heterogeneity
L4NFSWPCh1
L4NFSWPCh2
L4NFSWPCh3
L4NFSWL4NFSWPCh4
L4NFSWPCh6
L4NFSWPCh7
L4NFSWPCh8
L4NFSWPCh9
L4NFSWPCh10
L4NFSWPCh11
L4NFSWPCh12
L4NFSWPCh13
L4NFSWPCh14
L4NFSWPCh15
L4NFSWPCh16
L4NFSWPCh17
L4NFSWPCh18
L4NFSWPCh19
L4NFSWPCh20
L4NFSWPCh21
L4NFSWPCh22
L4NFSWPCh23
L4NFSWPCh24
L4NFSWPCh25
L4NFSWPCh26
L4NFSWPCh27
L4NFSWPCh28
L4NFSWPGch28
L4NFSWPCh29
L4NFSWPCh30
L4NFSWPCh31
L4NFSSWPCh32
L4NFSWPCh33
L4NFSWPCh34
L4NFSWPCh35
Near_Field\Silo_section\Waste_package\Chemistry_FEPs\Chemistry_FEPs.vsd
Chemistry_FEPs.vsd
(Level 4)



Near_Field\Silo_section\Waste_package\Gas_FEPs\Gas_FEPs.vsd
Gas pressure and flow (WP)
Gas generation (WP)
L4NFSWPGs1
L4NFSWPGs2
L4NFSWPGs3
L4NFSWPGs4
L4NFSWPGs5
L4NFSWPGs6
Gas_FEPs.vsd (Level 4)


Thermal properties
Saturation of waste package
Hydrogeological properties
Structural geometry properties
Composition of waste, waste matrix and container
Mechanical properties including stress distribution
L4NFSWPPr1
L4NFSWPPr2
L4NFSWPPr3
L4NFSWPPr4
L4NFSWPPr5
L4NFSWPPr6
L4NFSWPPr7
L4NFSWPPr8
L4NFSWPPr9
L4NFSWPPr10
L4NFSWPPr11
L4NFSWPPr12
L4NFSWPPr13
L4NFSWPPr14
L4NFSWPPr15
L4NFSWPPr16
L4NFSWPPr17
L4NFSWPPr18
L4NFSWPPr19
L4NFSWPPr20
Properties_of_Waste_Package_FEPs.vsd (Level 4)
Near_Field\Silo_section\Waste_package\Properties_of_Waste_Package_FEPs\Properties_of_Waste_Package_FEPs.vsd


Colloid transport
ASDSS
SDFDCC,Silo-WPTr14(10)
L4NFRZCRTr3
L4NFSWPTr17,Silo-W15(10),Silo-W23(10)
Diffusion of radionuclides
L4NFRZCRTr1,Silo-WPTr5(10)
Distribution & release of radionuclides
L4NFRZCRTr4,Silo-WPTr6(10)
Radioactive decay & ingrowth
L4NFSWPTr20,Silo-WP156(10),Silo-WP18(10)
Near_Field\Silo_section\Waste_package\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
ASDAS,Silo-WP17(10)
L4NFRZCRTr5,Silo-WPTr19(10)
Gas-mediated radionuclide transport
WEFEE,Silo-WPTr11(10),Silo-W858(10),Silo-W738(10)
L4NFRZCRTr7,Silo-WPTr9(10),Silo-WPTr20(10)
CVBV,Silo-WT7(10),Silo-WTr5(10),Silo-WTr6(10),Silo-WPTr10(10),Silo-WPTr3(10),Silo-WPTr100(10),Silo-WPTr7(10)
L4NFRZCRTr6,Silo-WPTr4(10)
ASDASDS,Silo-WPTr1(10)
Groundwater-mediated transport of radionuclides
Radionuclide sorption
L4NFSWPTr16
BNMNV,Silo-W75(10),Silo-WP89(10),Silo-WP11(10)
Transport_and_release_of_radionuclides.vsd (Level 4)



Near_Field\BLA_Section\Backfill_(BLA)\Geochemistry_FEPs\Geochemistry_FEPs.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of backfill
Microbial activity
Alkaline (pH) front
Redox heterogeneity
Geochemistry_FEPs.vsd (Level 4)
L4NFBLABfG2
L4NFBLABfG3
L4NFBLABfG4
L4NFBLABfG5
L4NFBLABfG6
L4NFBLABfG7
L4NFBLABfG8
L4NFBLABfG9
L4NFBLABfG10
L4NFBLABfG11
L4NFBLABfG12
L4NFBLABfG13
L4NFBLABfG14
L4NFBLABfG15
L4NFBLABfG16
L4NFBLABfG17
L4NFBLABfG18
L4NFBLABfG19
L4NFBLABfG20
L4NFBLABfG21
L4NFBLABfG22
L4NFBLABfG23
L4NFBLABfG24
L4NFBLABfG25
L4NFBLABfG26
L4NFBLABfG27
L4NFBLABfCh1
L4NFBMABfGh28
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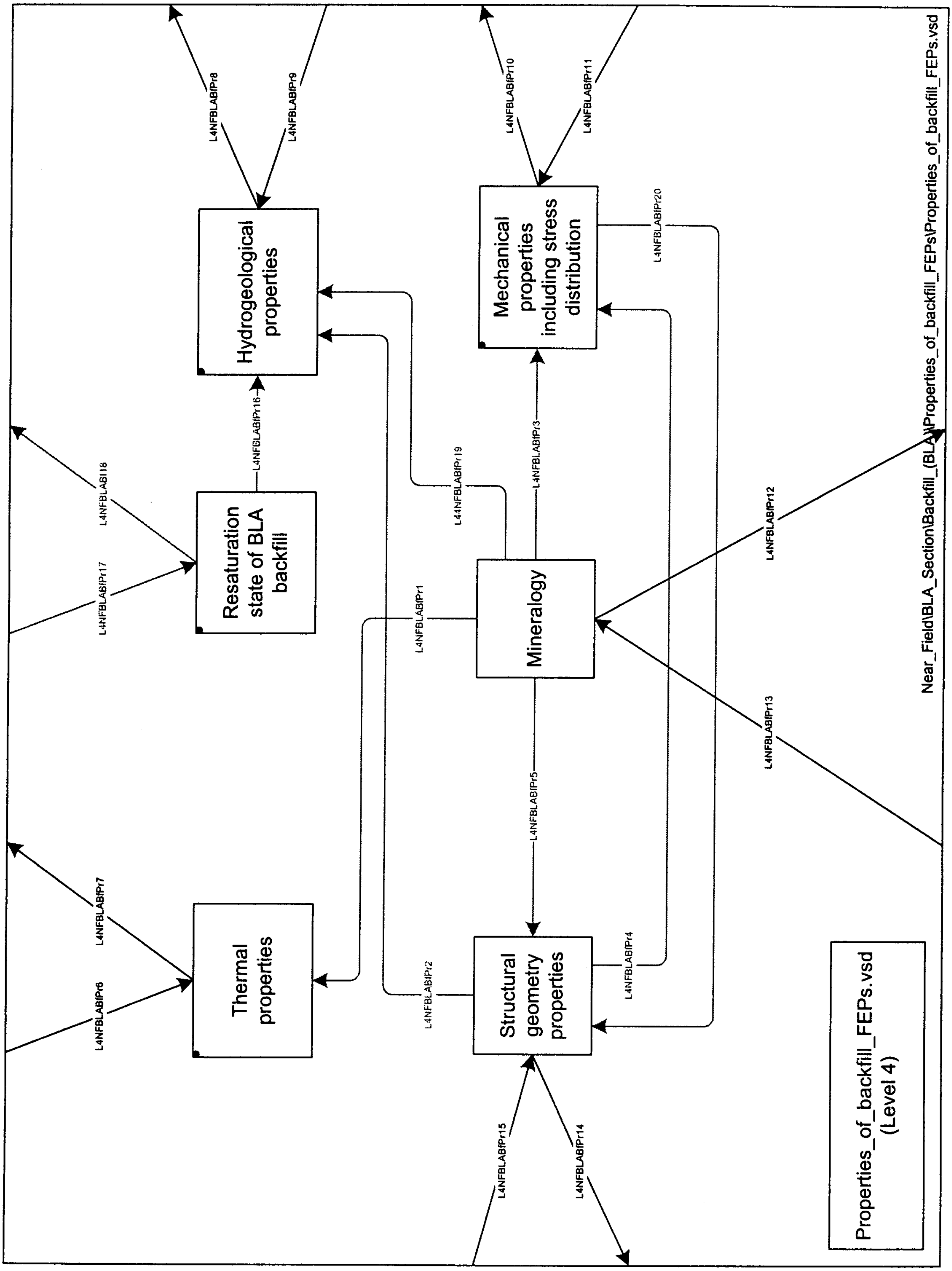
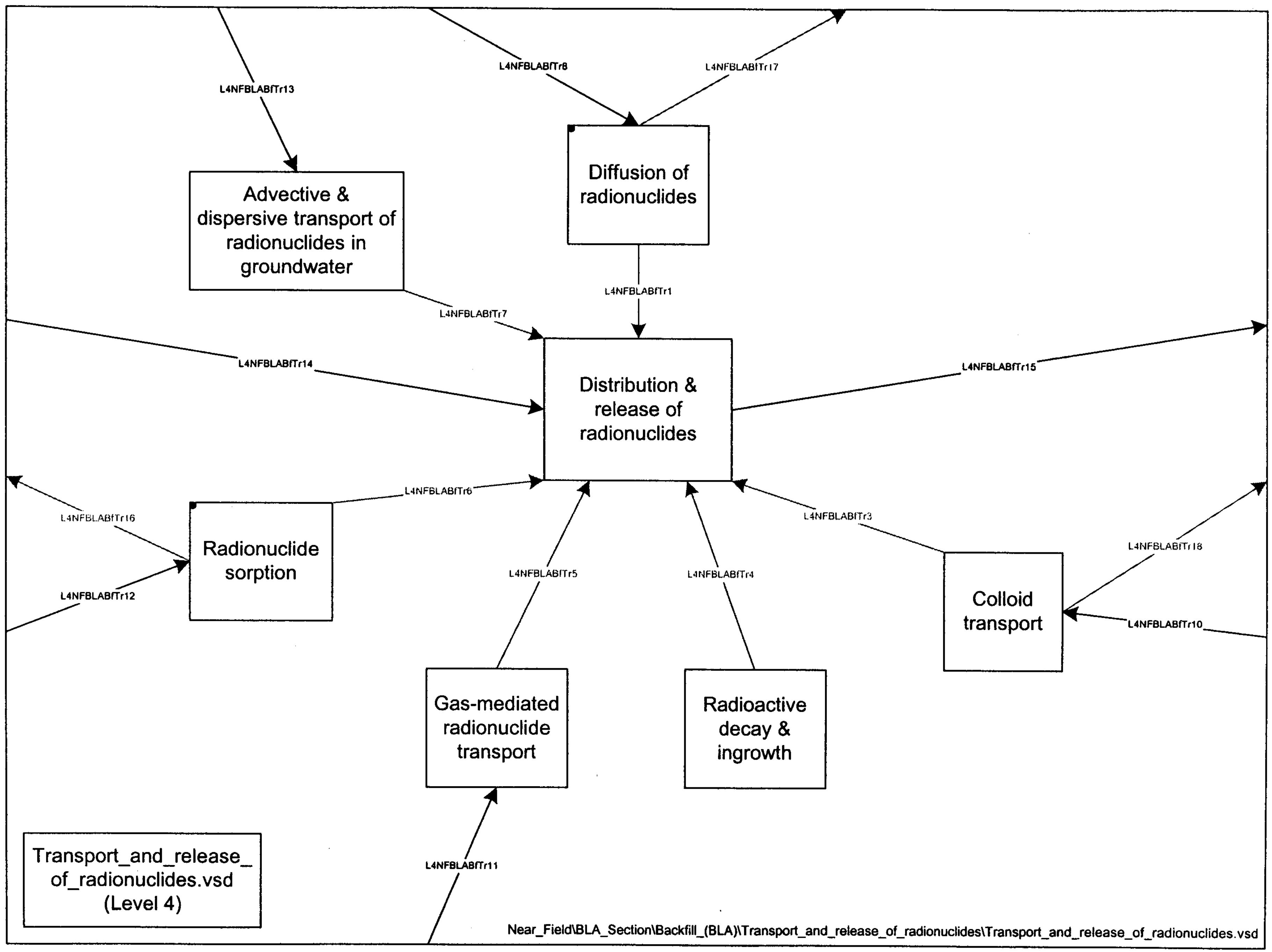
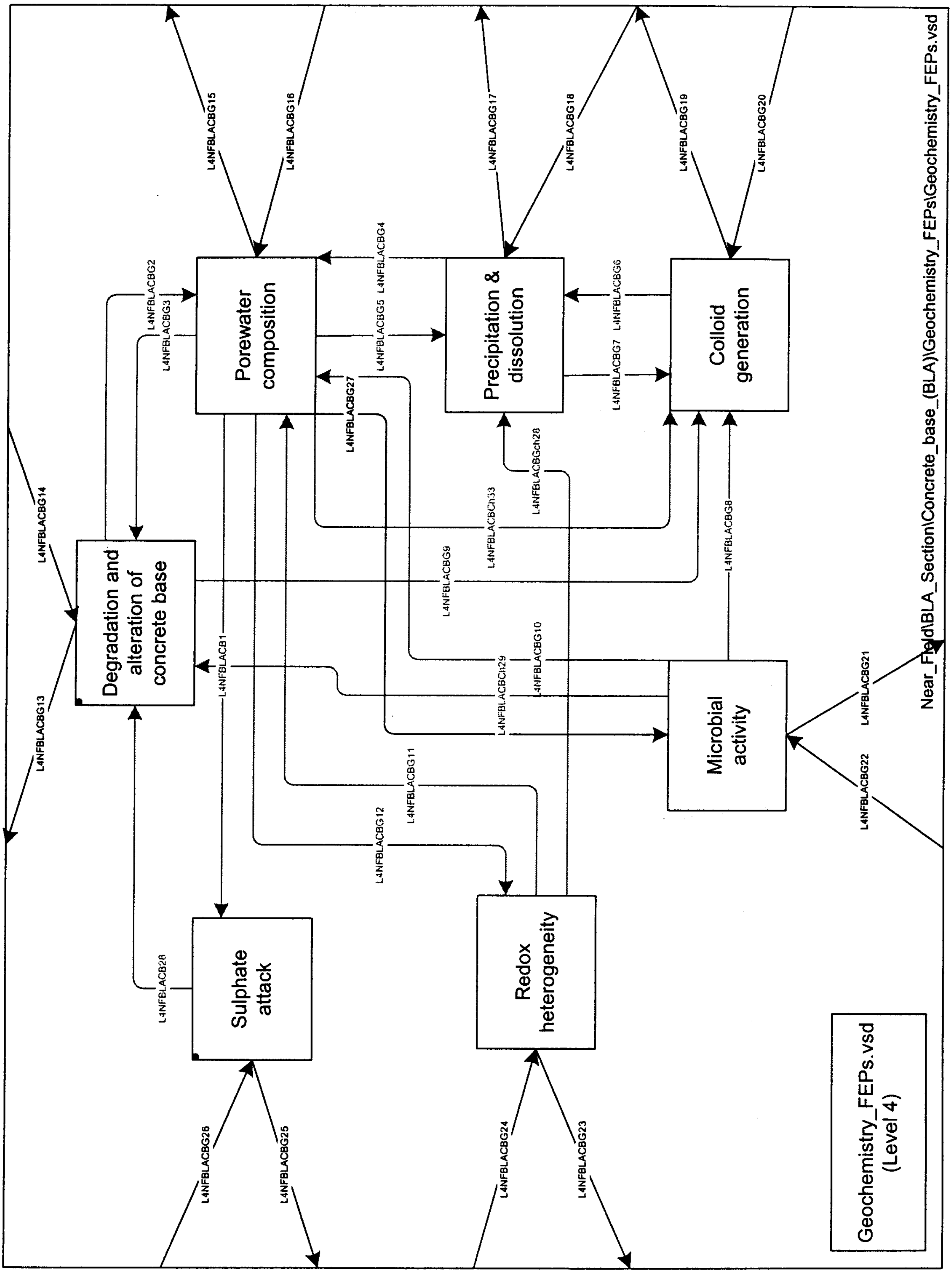
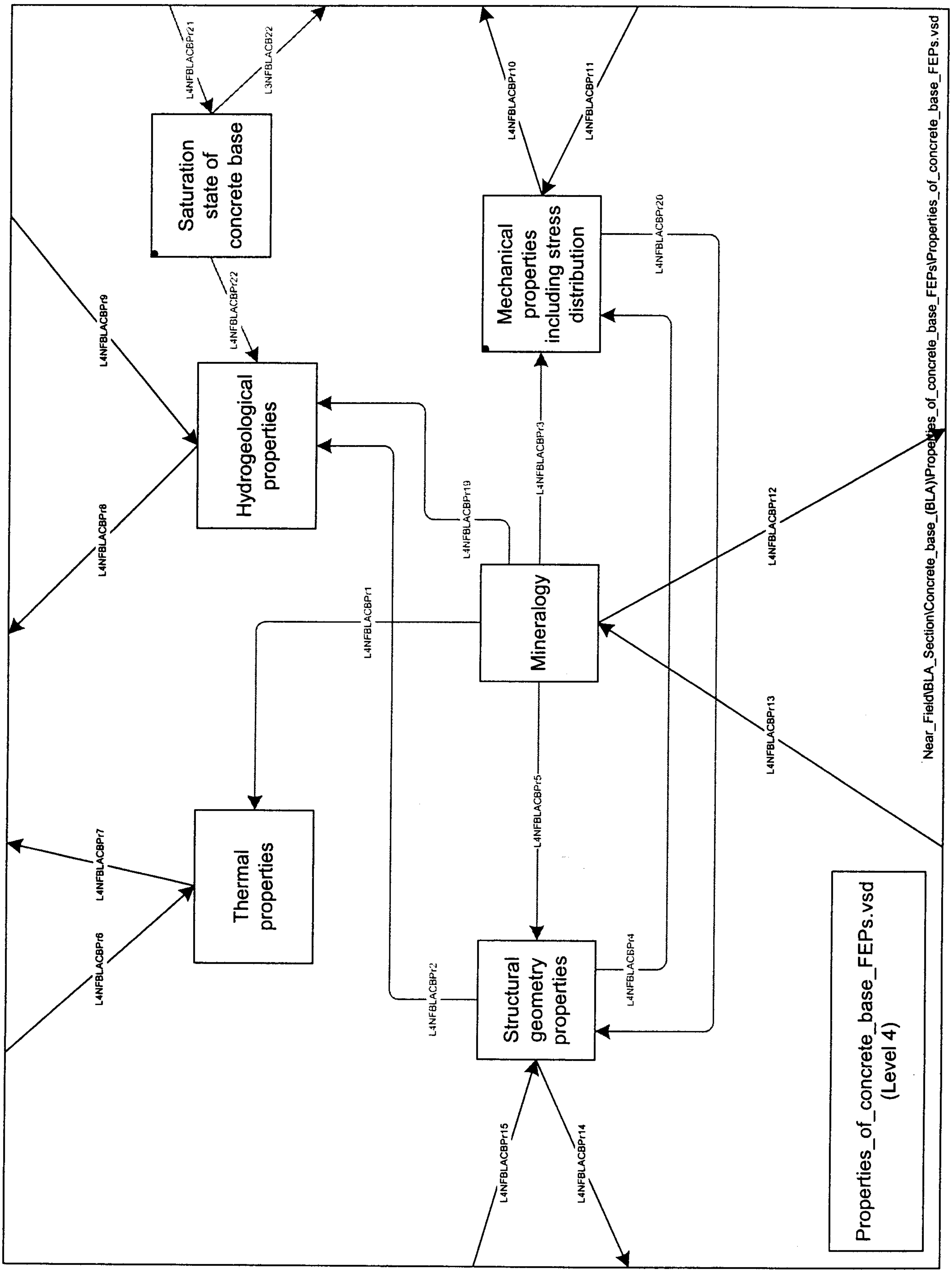
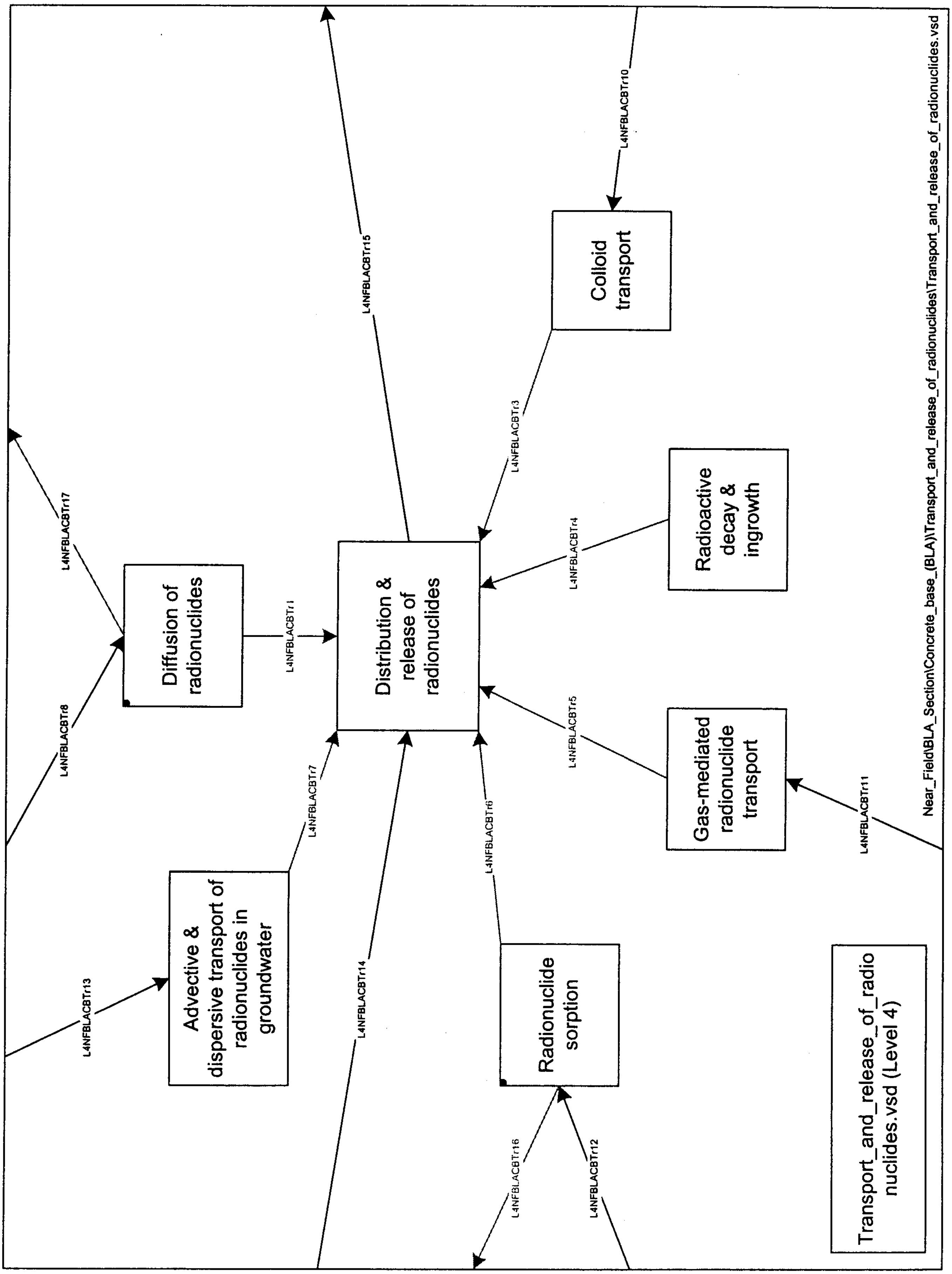
L4NFBLABfCh30
L4NFBLABfCh31
L4NFBLABfCh40


Hydrogeological properties
Mechanical properties including stress distribution
Resaturation state of BLA backfill
Mineralogy
Thermal properties
Structural geometry properties
L4NFBLABfPr8
L4NFBLABfPr9
L4NFBLABfPr10
L4NFBLABfPr11
L4NFBLABfPr20
L4NFBLABfPr16
L44NFBLABfPr19
L4NFBLABfPr3
L4NFBLABI18
L4NFBLABfPr17
L4NFBLABfPr1
L4NFBLABfPr12
L4NFBLABfPr13
L4NFBLABfPr5
L4NFBLABfPr7
L4NFBLABfPr6
L4NFBLABfPr2
L4NFBLABfPr4
L4NFBLABfPr15
L4NFBLABfPr14
Near_Field\BLA_Section\Backfill_(BLA)\Properties_of_backfill_FEPs\Properties_of_backfill_FEPs.vsd
Properties_of_backfill_FEPs.vsd (Level 4)


Advective & dispersive transport of radionuclides in groundwater
Diffusion of radionuclides
Distribution & release of radionuclides
Radionuclide sorption
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
L4NFBLABfTr1
L4NFBLABfTr3
L4NFBLABfTr4
L4NFBLABfTr5
L4NFBLABfTr6
L4NFBLABfTr7
L4NFBLABfTr8
L4NFBLABfTr10
L4NFBLABfTr11
L4NFBLABfTr12
L4NFBLABfTr13
L4NFBLABfTr14
L4NFBLABfTr15
L4NFBLABfTr16
L4NFBLABfTr17
L4NFBLABfTr18
Transport_and_release_of_radionuclides.vsd (Level 4)
Near_Field\BLA_Section\Backfill_(BLA)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd


Porewater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of concrete base
Microbial activity
Sulphate attack
Redox heterogeneity
Geochemistry_FEPs.vsd (Level 4)
Near_Field\BLA_Section\Concrete_base_(BLA)\Geochemistry_FEPs\Geochemistry_FEPs.vsd
L4NFBLACB1
L4NFBLACBG2
L4NFBLACBG3
L4NFBLACBG4
L4NFBLACBG5
L4NFBLACBG6
L4NFBLACBG7
L4NFBLACBG8
L4NFBLACBG9
L4NFBLACBG10
L4NFBLACBG11
L4NFBLACBG12
L4NFBLACBG13
L4NFBLACBG14
L4NFBLACBG15
L4NFBLACBG16
L4NFBLACBG17
L4NFBLACBG18
L4NFBLACBG19
L4NFBLACBG20
L4NFBLACBG21
L4NFBLACBG22
L4NFBLACBG23
L4NFBLACBG24
L4NFBLACBG25
L4NFBLACBG26
L4NFBLACBG27
L4NFBLACBGch28
L4NFBLACBCh29
L4NFBLACBCh33
L4NFBLACB28


Saturation state of concrete base
Hydrogeological properties
Mechanical properties including stress distribution
Mineralogy
Thermal properties
Structural geometry properties
L4NFBLACBPr21
L3NFBLACB22
L4NFBLACBPr22
L4NFBLACBPr9
L4NFBLACBPr8
L4NFBLACBPr10
L4NFBLACBPr11
L4NFBLACBPr20
L4NFBLACBPr19
L4NFBLACBPr3
L4NFBLACBPr1
L4NFBLACBPr12
L4NFBLACBPr13
L4NFBLACBPr5
L4NFBLACBPr7
L4NFBLACBPr6
L4NFBLACBPr2
L4NFBLACBPr4
L4NFBLACBPr15
L4NFBLACBPr14
Near_Field\BLA_Section\Concrete_base_(BLA)\Properties_of_concrete_base_FEPs\Properties_of_concrete_base_FEPs.vsd
Properties_of_concrete_base_FEPs.vsd
(Level 4)



Transport_and_release_of_radio nuclides.vsd (Level 4)
Near_Field\BLA_Section\Concrete_base_(BLA)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
Distribution & release of radionuclides
Diffusion of radionuclides
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
L4NFBLACBTr1
L4NFBLACBTr3
L4NFBLACBTr4
L4NFBLACBTr5
L4NFBLACBTr6
L4NFBLACBTr7
L4NFBLACBTr8
L4NFBLACBTr10
L4NFBLACBTr11
L4NFBLACBTr12
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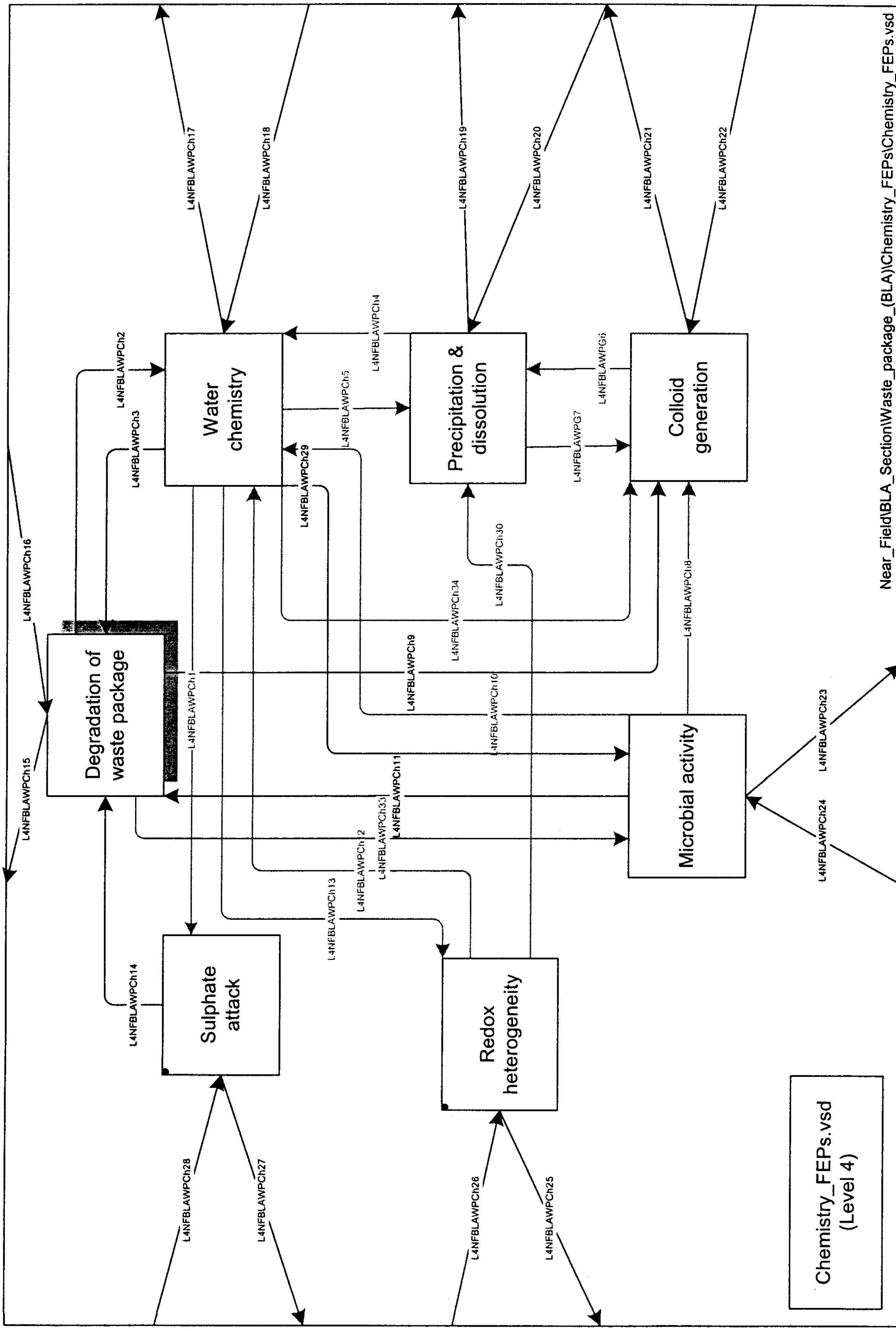
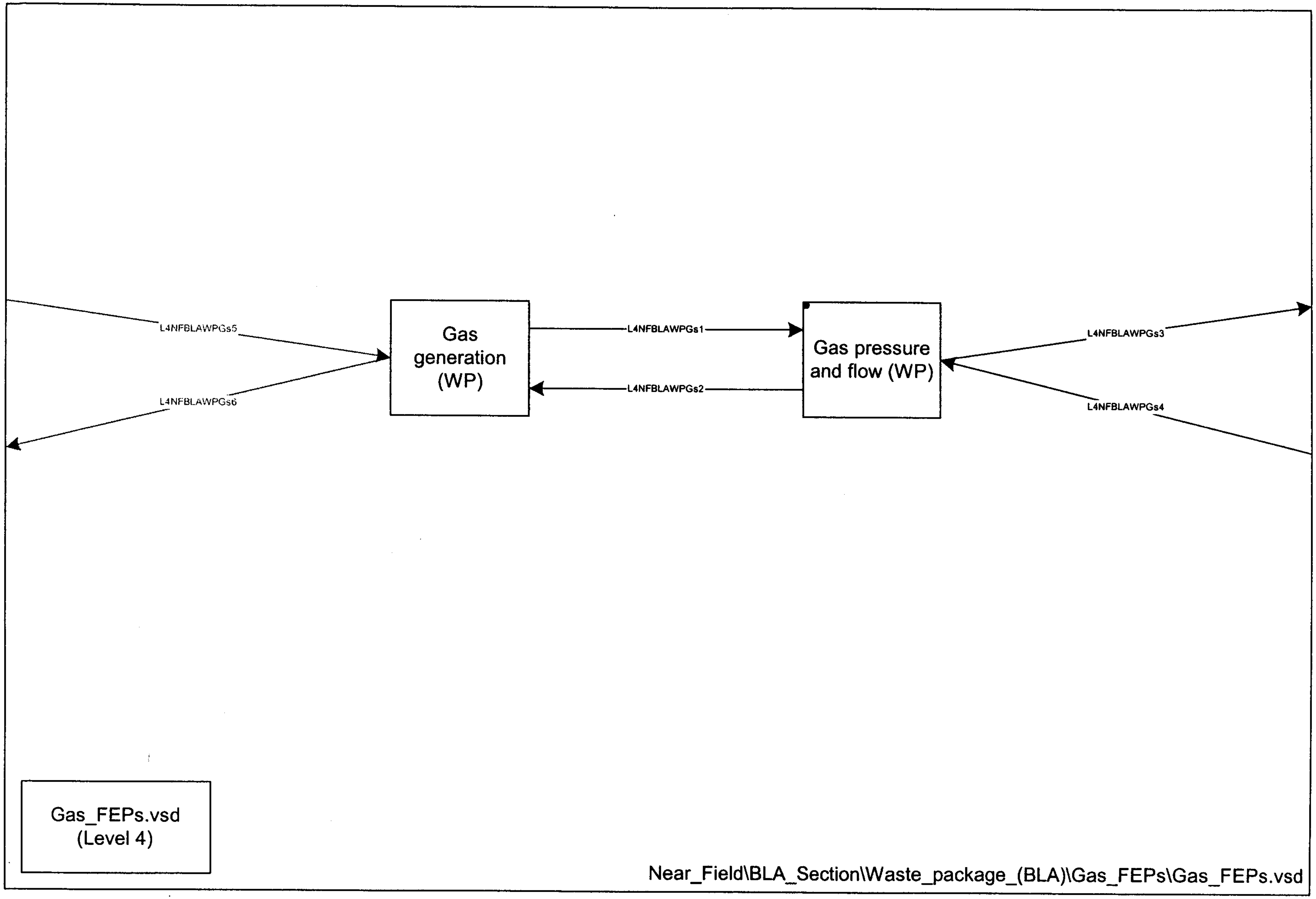
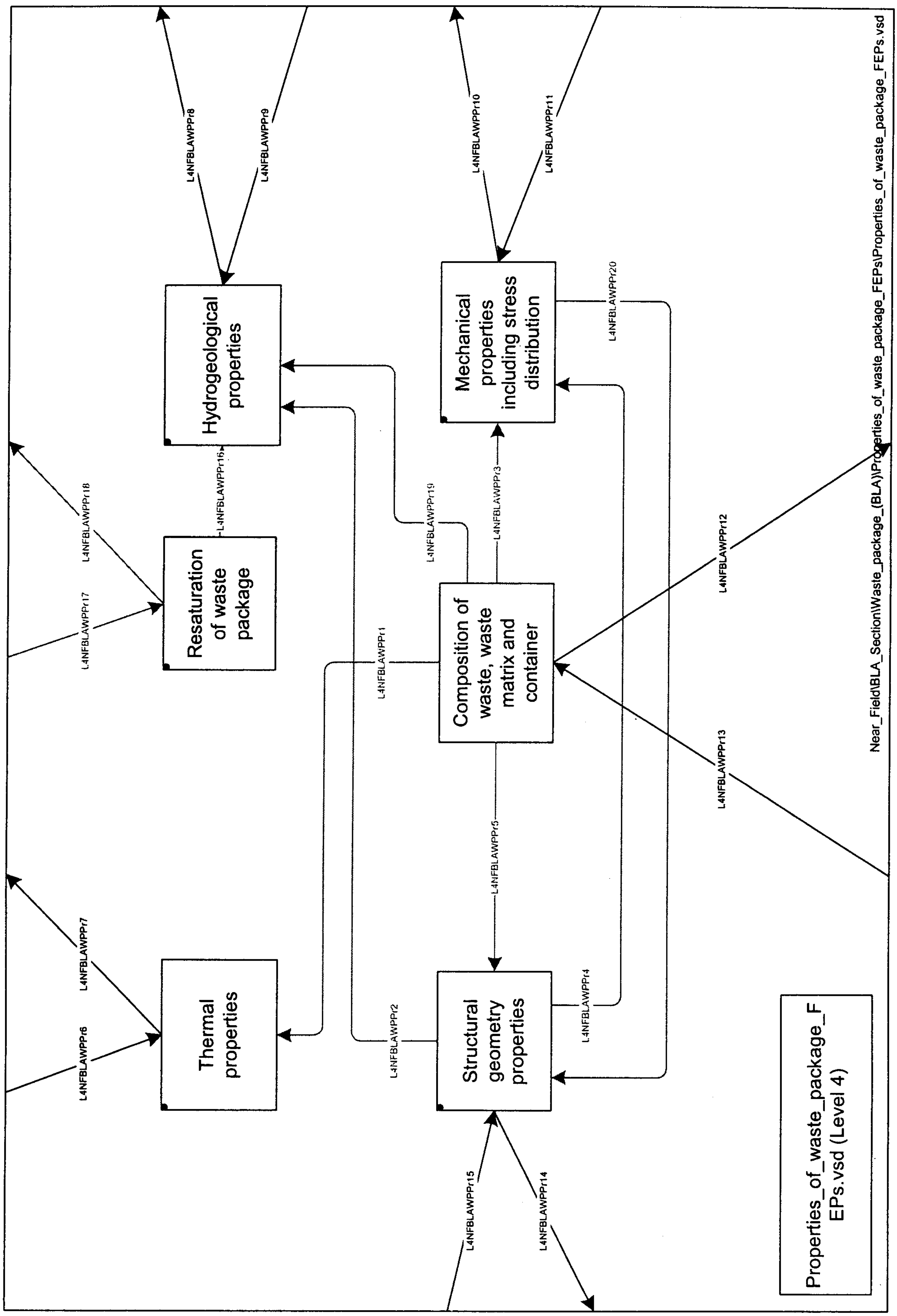
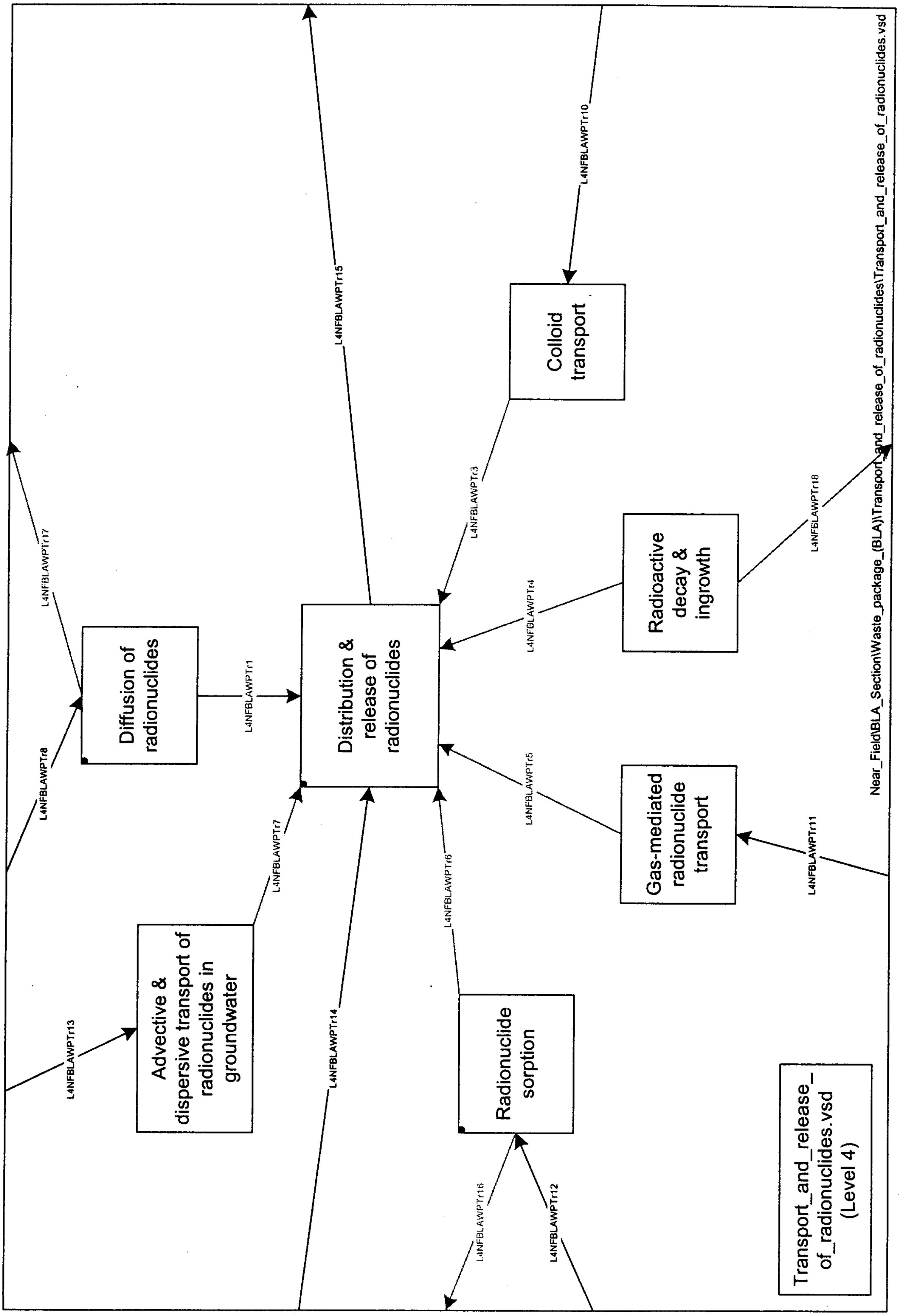
L4NFBLACBTr14
L4NFBLACBTr15
L4NFBLACBTr16
L4NFBLACBTr17

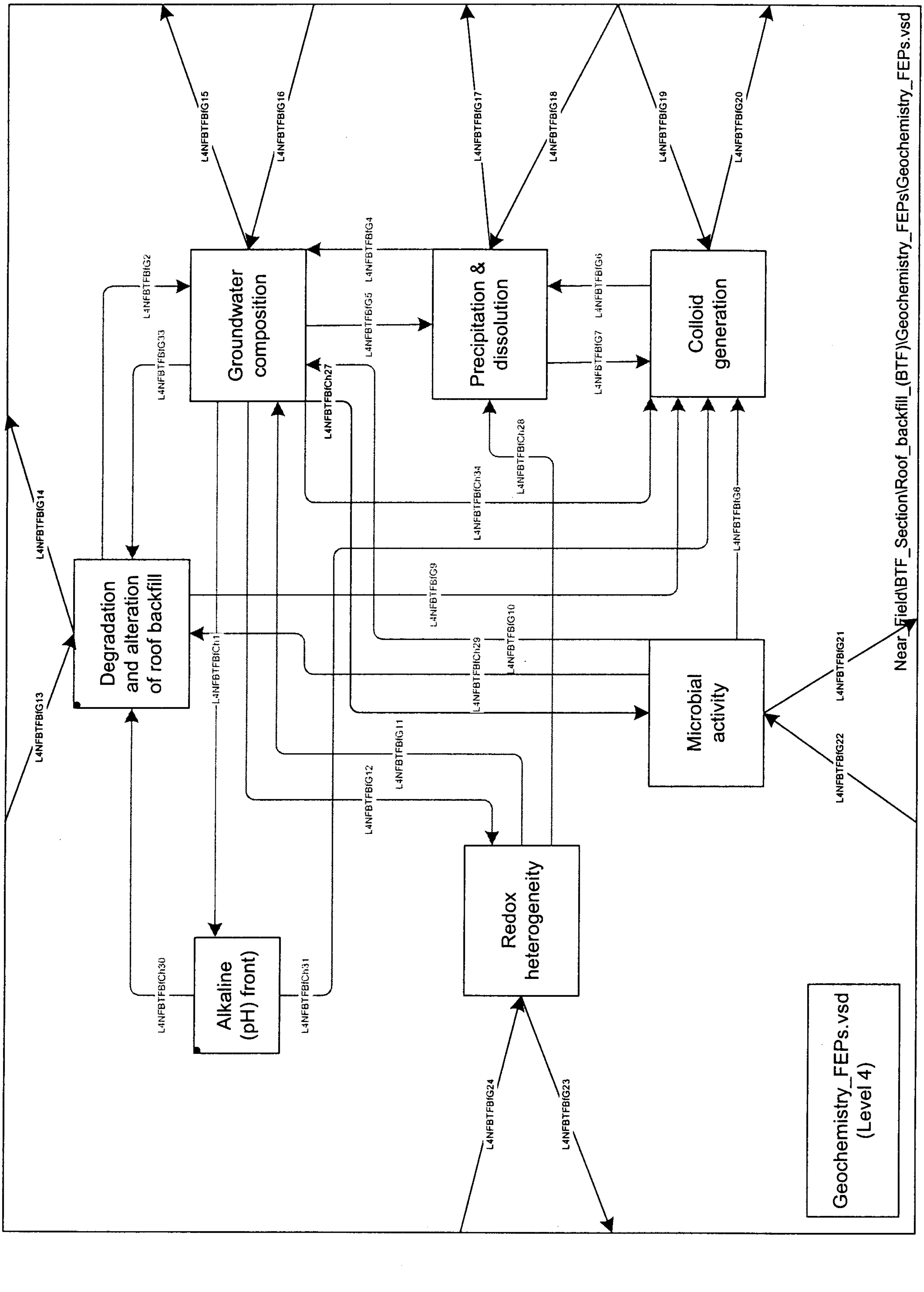

Water chemistry
Precipitation & dissolution
Colloid generation
Degradation of waste package
Microbial activity
Sulphate attack
Redox heterogeneity
L4NFBLAWPCh1
L4NFBLAWPCh2
L4NFBLAWPCh3
L4NFBLAWPCh4
L4NFBLAWPCh5
L4NFBLAWPCh8
L4NFBLAWPCh9
L4NFBLAWPCh10
L4NFBLAWPCh11
L4NFBLAWPCh12
L4NFBLAWPCh13
L4NFBLAWPCh14
L4NFBLAWPCh15
L4NFBLAWPCh16
L4NFBLAWPCh17
L4NFBLAWPCh18
L4NFBLAWPCh19
L4NFBLAWPCh20
L4NFBLAWPCh21
L4NFBLAWPCh22
L4NFBLAWPCh23
L4NFBLAWPCh24
L4NFBLAWPCh25
L4NFBLAWPCh26
L4NFBLAWPCh27
L4NFBLAWPCh28
L4NFBLAWPCh29
L4NFBLAWPCh30
L4NFBLAWPCh33
L4NFBLAWPCh34
Near_Field\BLA_Section\Waste_package_(BLA)\Chemistry_FEPs\Chemistry_FEPs.vsd
Chemistry_FEPs.vsd
(Level 4)



Gas generation (WP)
Gas pressure and flow (WP)
L4NFBLAWPGs1
L4NFBLAWPGs2
L4NFBLAWPGs3
L4NFBLAWPGs4
L4NFBLAWPGs5
L4NFBLAWPGs6
Gas_FEPs.vsd (Level 4)
Near_Field\BLA_Section\Waste_package_(BLA)\Gas_FEPs\Gas_FEPs.vsd


Hydrogeological properties
Mechanical properties including stress distribution
Resaturation of waste package
Composition of waste, waste matrix and container
Thermal properties
Structural geometry properties
Properties_of_waste_package_FEPs.vsd (Level 4)
Near_Field\BLA_Section\Waste_package_(BLA)\Properties_of_waste_package_FEPs\Properties_of_waste_package_FEPs.vsd
L4NFBLAWPPr1
L4NFBLAWPPr2
L4NFBLAWPPr3
L4NFBLAWPPr4
L4NFBLAWPPr5
L4NFBLAWPPr6
L4NFBLAWPPr7
L4NFBLAWPPr8
L4NFBLAWPPr9
L4NFBLAWPPr10
L4NFBLAWPPr11
L4NFBLAWPPr12
L4NFBLAWPPr13
L4NFBLAWPPr14
L4NFBLAWPPr15
L4NFBLAWPPr16
L4NFBLAWPPr17
L4NFBLAWPPr18
L4NFBLAWPPr19
L4NFBLAWPPr20


Transport_and_release_of_radionuclides.vsd (Level 4)
Diffusion of radionuclides
Distribution & release of radionuclides
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
L4NFBLAWPTr1
L4NFBLAWPTr3
L4NFBLAWPTr4
L4NFBLAWPTr5
L4NFBLAWPTr6
L4NFBLAWPTr7
L4NFBLAWPTr8
L4NFBLAWPTr10
L4NFBLAWPTr11
L4NFBLAWPTr12
L4NFBLAWPTr13
L4NFBLAWPTr14
L4NFBLAWPTr15
L4NFBLAWPTr16
L4NFBLAWPTr17
L4NFBLAWPTr18
Near_Field\BLA_Section\Waste_package_(BLA)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd



Near Field\BTF_Section\Roof_backfill_(BTF)\Geochemistry_FEPs\Geochemistry_FEPs.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of roof backfill
Microbial activity
Alkaline (pH) front)
Redox heterogeneity
Geochemistry_FEPs.vsd (Level 4)
L4NFBTFBfG15
L4NFBTFBfG16
L4NFBTFBfG17
L4NFBTFBfG18
L4NFBTFBfG19
L4NFBTFBfG20
L4NFBTFBfG2
L4NFBTFBfG33
L4NFBTFBfG4
L4NFBTFBfG5
L4NFBTFBfG6
L4NFBTFBfG7
L4NFBTFBfCh27
L4NFBTFBfCh28
L4NFBTFBfCh34
L4NFBTFBfG14
L4NFBTFBfG13
L4NFBTFBfG8
L4NFBTFBfG9
L4NFBTFBfG10
L4NFBTFBfCh29
L4NFBTFBfCh1
L4NFBTFBfG11
L4NFBTFBfG12
L4NFBTFBfG21
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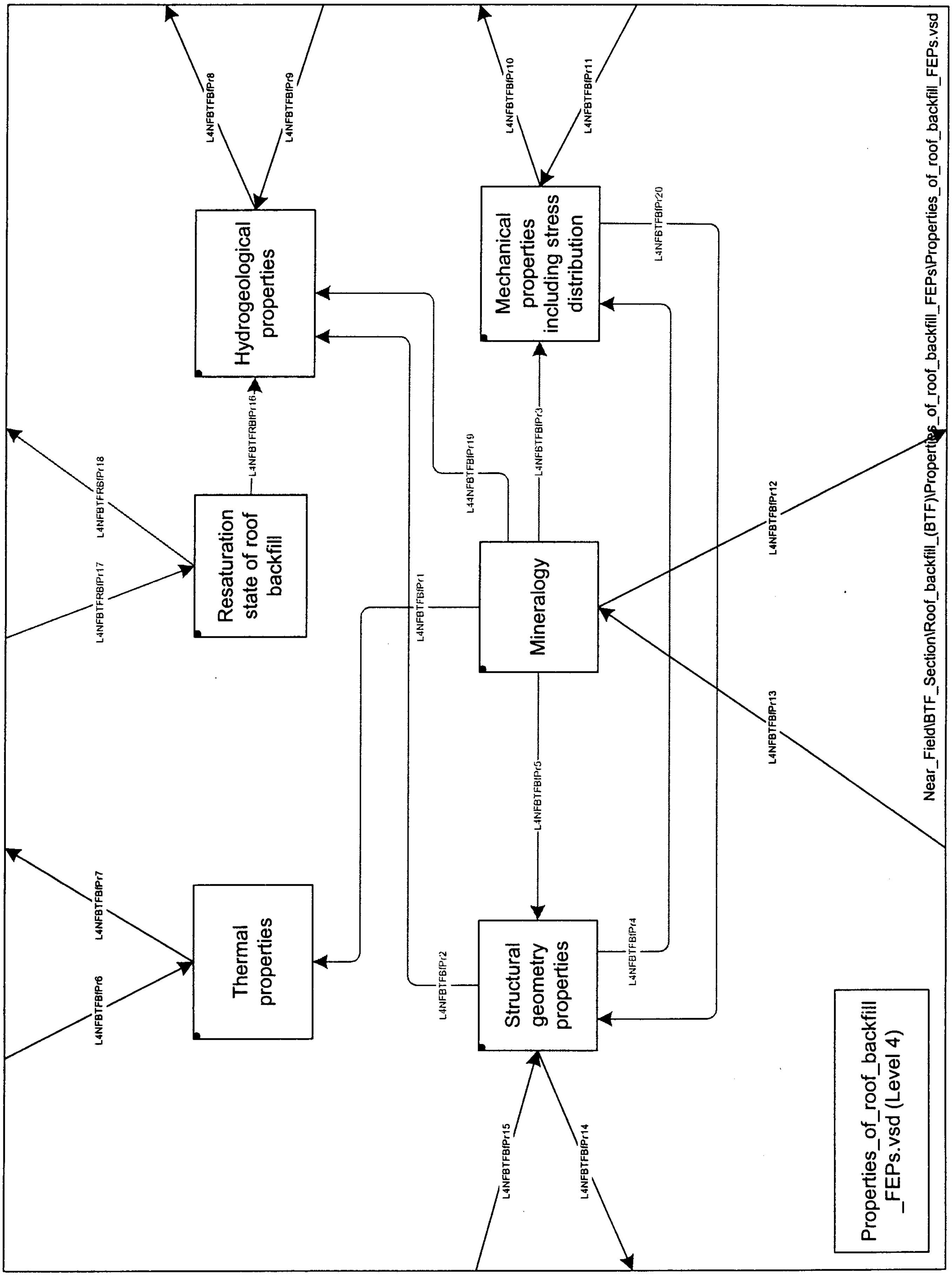
L4NFBTFBfG24
L4NFBTFBfG23



Hydrogeological properties
Mechanical properties including stress distribution
Resaturation state of roof backfill
Mineralogy
Thermal properties
Structural geometry properties
Properties_of_roof_backfill_FEPs.vsd (Level 4)
Near_Field\BTF_Section\Roof_backfill_(BTF)\Properties_of_roof_backfill_FEPs\Properties_of_roof_backfill_FEPs.vsd
L4NFBTFBfPr8
L4NFBTFBfPr9
L4NFBTFBfPr10
L4NFBTFBfPr11
L4NFBTFBfPr20
L4NFBTFRBfPr16
L4NFBTFRBfPr18
L4NFBTFRBfPr17
L44NFBTFBfPr19
L4NFBTFBfPr3
L4NFBTFBfPr1
L4NFBTFBfPr12
L4NFBTFBfPr13
L4NFBTFBfPr5
L4NFBTFBfPr7
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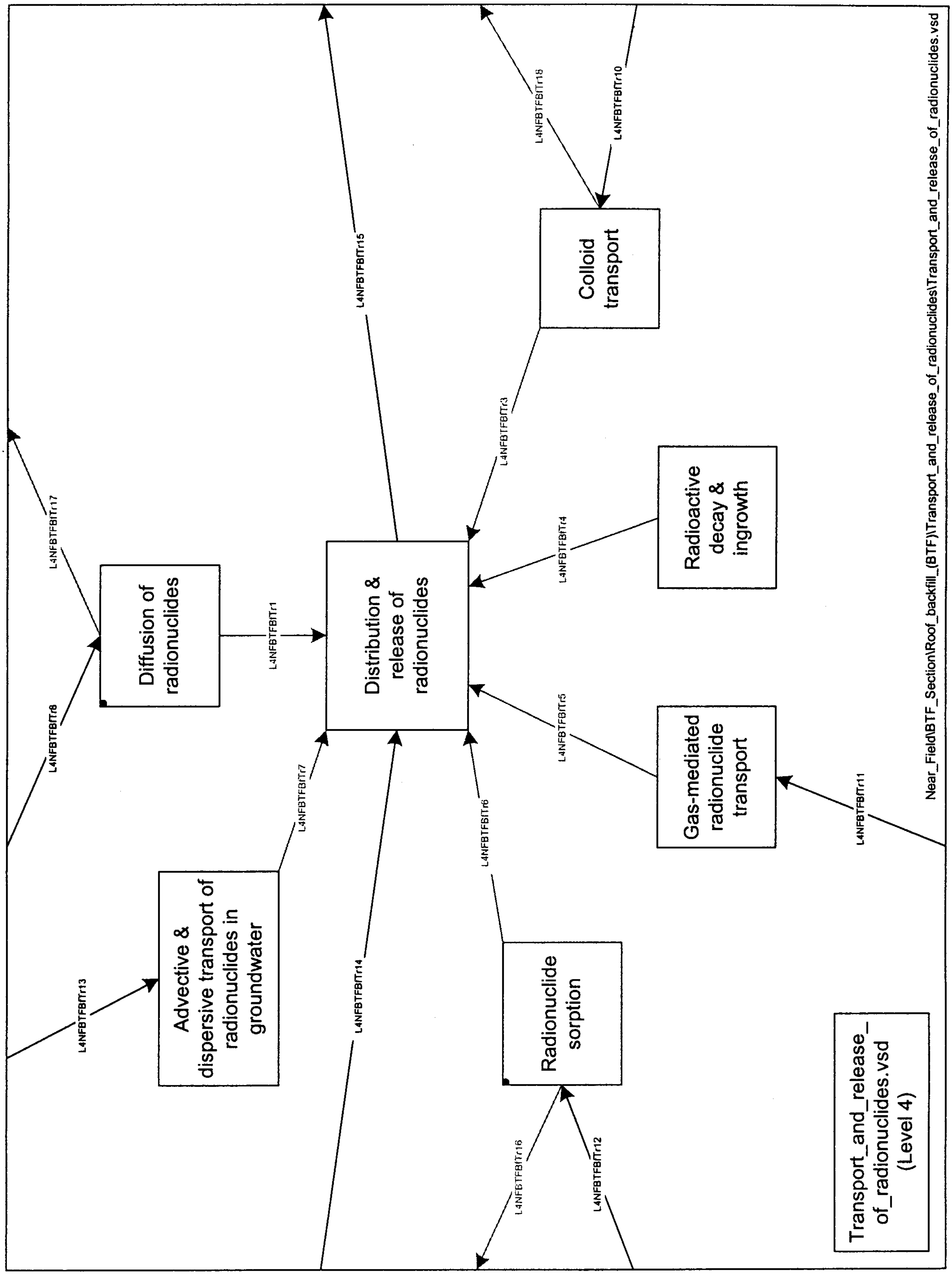
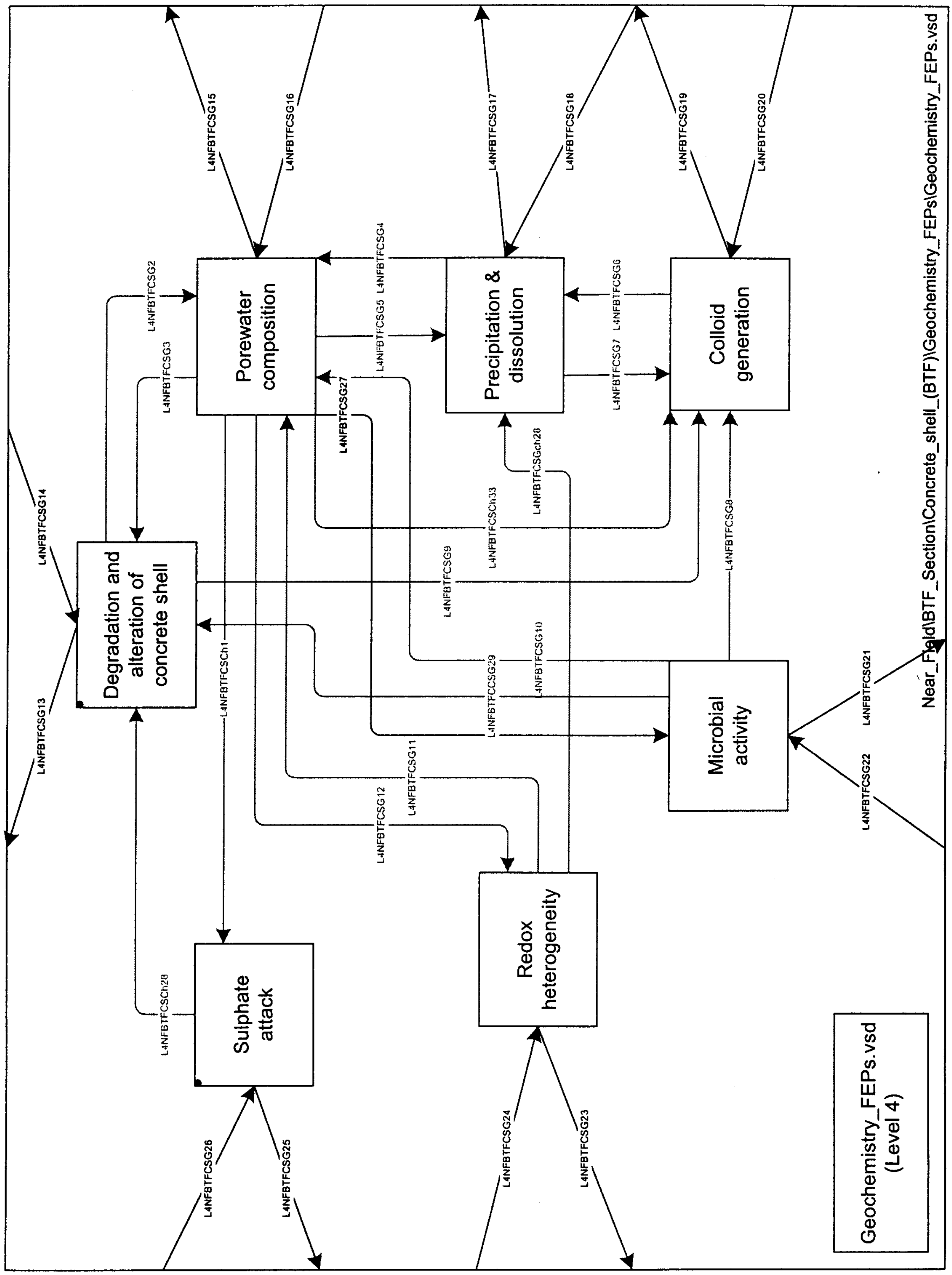
L4NFBTFBfPr4
L4NFBTFBfPr15
L4NFBTFBfPr14


Near_Field\BTF_Section\Roof_backfill_(BTF)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
Diffusion of radionuclides
Distribution & release of radionuclides
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
Transport_and_release_of_radionuclides.vsd (Level 4)
L4NFBTFBfTr1
L4NFBTFBfTr3
L4NFBTFBfTr4
L4NFBTFBfTr5
L4NFBTFBfTr6
L4NFBTFBfTr7
L4NFBTFBfTr8
L4NFBTFBfTr10
L4NFBTFBfTr11
L4NFBTFBfTr12
L4NFBTFBfTr13
L4NFBTFBfTr14
L4NFBTFBfTr15
L4NFBTFBfTr16
L4NFBTFBfTr17
L4NFBTFBfTr18



Porewater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of concrete shell
Microbial activity
Redox heterogeneity
Sulphate attack
Geochemistry_FEPs.vsd (Level 4)
Near_Field\BTF_Section\Concrete_shell_(BTF)\Geochemistry_FEPs\Geochemistry_FEPs.vsd
L4NFBTFCSG2
L4NFBTFCSG3
L4NFBTFCSG4
L4NFBTFCSG5
L4NFBTFCSG6
L4NFBTFCSG7
L4NFBTFCSG8
L4NFBTFCSG9
L4NFBTFCSG10
L4NFBTFCSG11
L4NFBTFCSG12
L4NFBTFCSG13
L4NFBTFCSG14
L4NFBTFCSG15
L4NFBTFCSG16
L4NFBTFCSG17
L4NFBTFCSG18
L4NFBTFCSG19
L4NFBTFCSG20
L4NFBTFCSG21
L4NFBTFCSG22
L4NFBTFCSG23
L4NFBTFCSG24
L4NFBTFCSG25
L4NFBTFCSG26
L4NFBTFCSG27
L4NFBTFCSGch28
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L4NFBTFCSCh1
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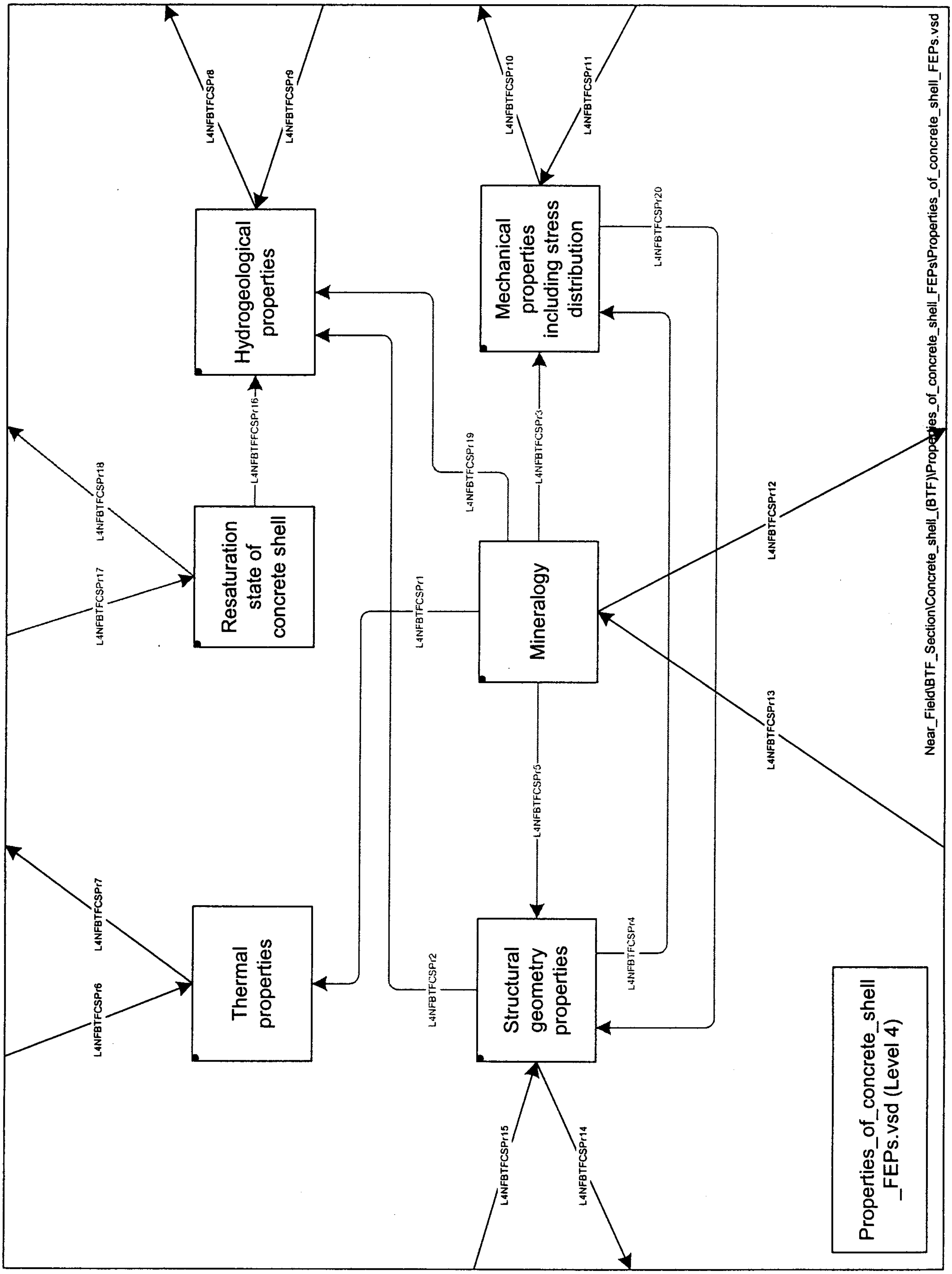
L4NFBTFCSCh33


Hydrogeological properties
Mechanical properties including stress distribution
Resaturation state of concrete shell
Mineralogy
Thermal properties
Structural geometry properties
Properties_of_concrete_shell_FEPs.vsd (Level 4)
Near_Field\BTF_Section\Concrete_shell_(BTF)\Properties_of_concrete_shell_FEPs\Properties_of_concrete_shell_FEPs.vsd
L4NFBTFCSPr1
L4NFBTFCSPr2
L4NFBTFCSPr3
L4NFBTFCSPr4
L4NFBTFCSPr5
L4NFBTFCSPr6
L4NFBTFCSPr7
L4NFBTFCSPr8
L4NFBTFCSPr9
L4NFBTFCSPr10
L4NFBTFCSPr11
L4NFBTFCSPr12
L4NFBTFCSPr13
L4NFBTFCSPr14
L4NFBTFCSPr15
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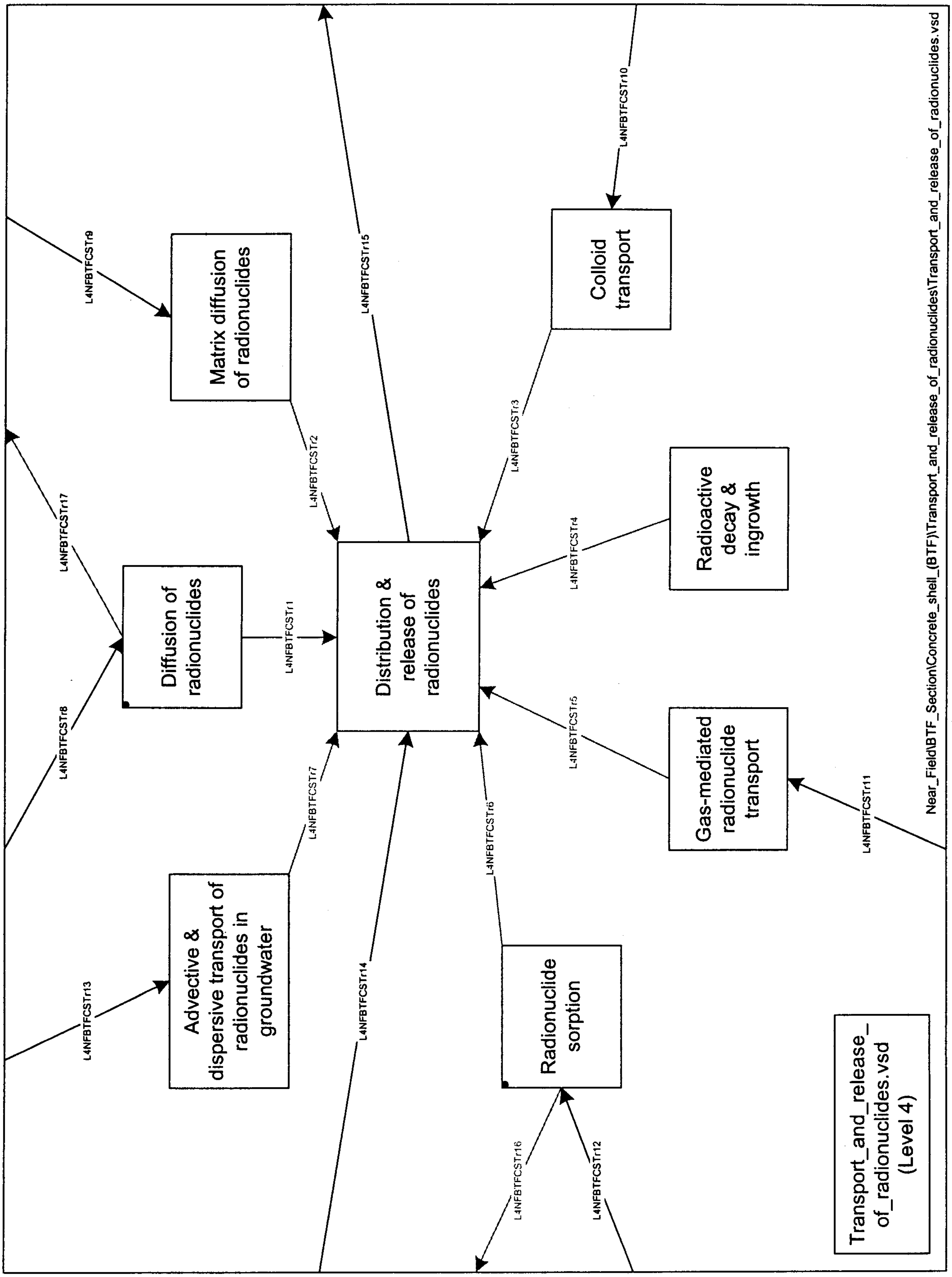
L4NFBTFCSPr18
L4NFBTFCSPr19
L4NFBTFCSPr20


Near_Field\BTF_Section\Concrete_shell_(BTF)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
Transport_and_release_of_radionuclides.vsd (Level 4)
Distribution & release of radionuclides
Diffusion of radionuclides
Matrix diffusion of radionuclides
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
Radionuclide sorption
Advective & dispersive transport of radionuclides in groundwater
L4NFBTFCSTr1
L4NFBTFCSTr2
L4NFBTFCSTr3
L4NFBTFCSTr4
L4NFBTFCSTr5
L4NFBTFCSTr6
L4NFBTFCSTr7
L4NFBTFCSTr8
L4NFBTFCSTr9
L4NFBTFCSTr10
L4NFBTFCSTr11
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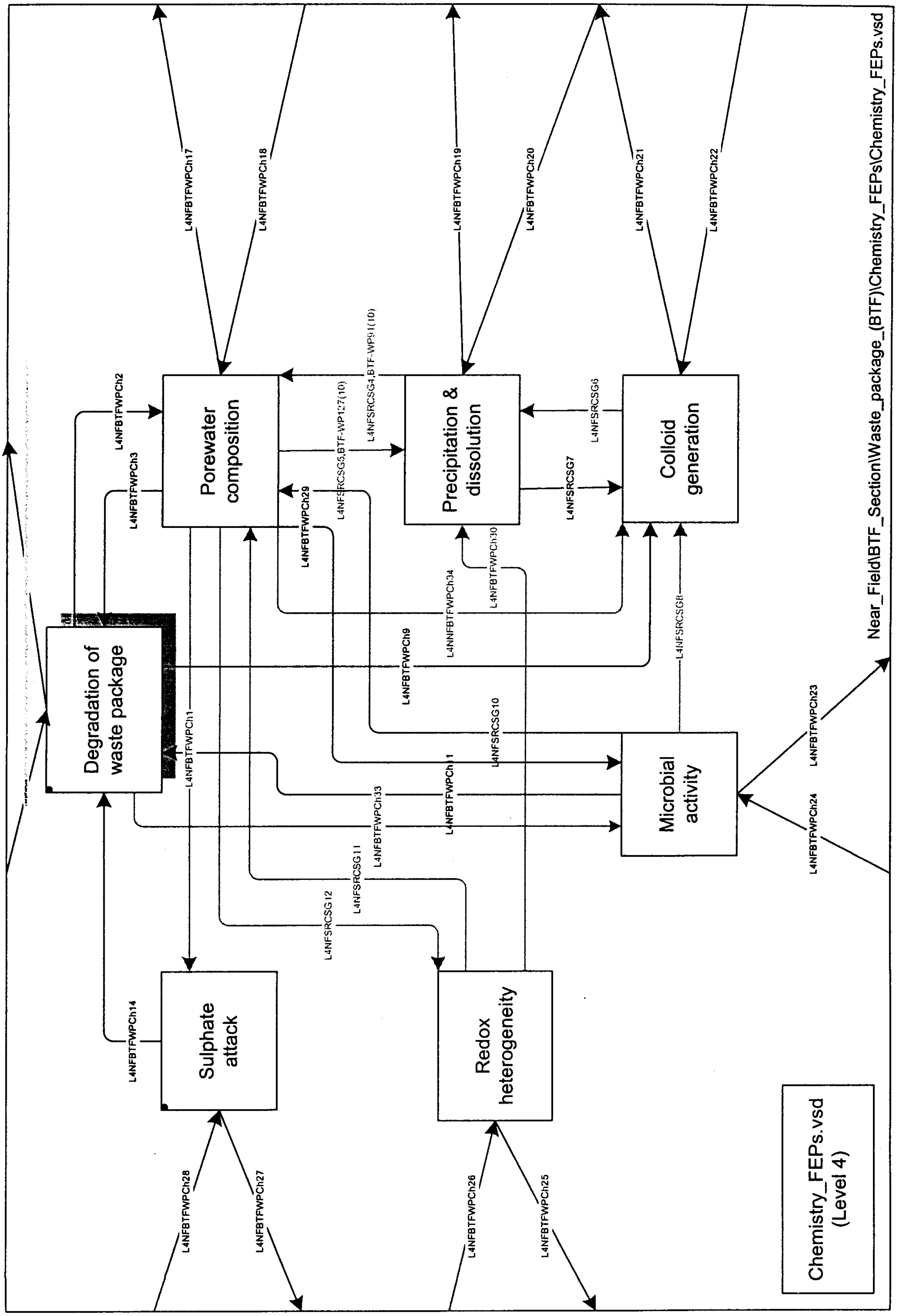
L4NFBTFCSTr16
L4NFBTFCSTr17



Near_Field\BTF_Section\Waste_package_(BTF)\Chemistry_FEPs\Chemistry_FEPs.vsd
Degradation of waste package
Porewater composition
Precipitation & dissolution
Colloid generation
Microbial activity
Sulphate attack
Redox heterogeneity
Chemistry_FEPs.vsd (Level 4)
L4NFBTFWPCh17
L4NFBTFWPCh18
L4NFBTFWPCh19
L4NFBTFWPCh20
L4NFBTFWPCh21
L4NFBTFWPCh22
L4NFBTFWPCh2
L4NFBTFWPCh3
L4NFSRCSG4,BTF-WP91(10)
L4NFSRCSG5,BTF-WP127(10)
L4NFSRCSG6
L4NFSRCSG7
L4NFBTFWPCh29
L4NFBTFWPCh30
L4NFBTFWPCh34
L4NFSRCSG8
L4NFBTFWPCh9
L4NFSRCSG10
L4NFBTFWPCh1
L4NFBTFWPCh11
L4NFBTFWPCh33
L4NFBTFWPCh23
L4NFBTFWPCh24
L4NFSRCSG11
L4NFSRCSG12
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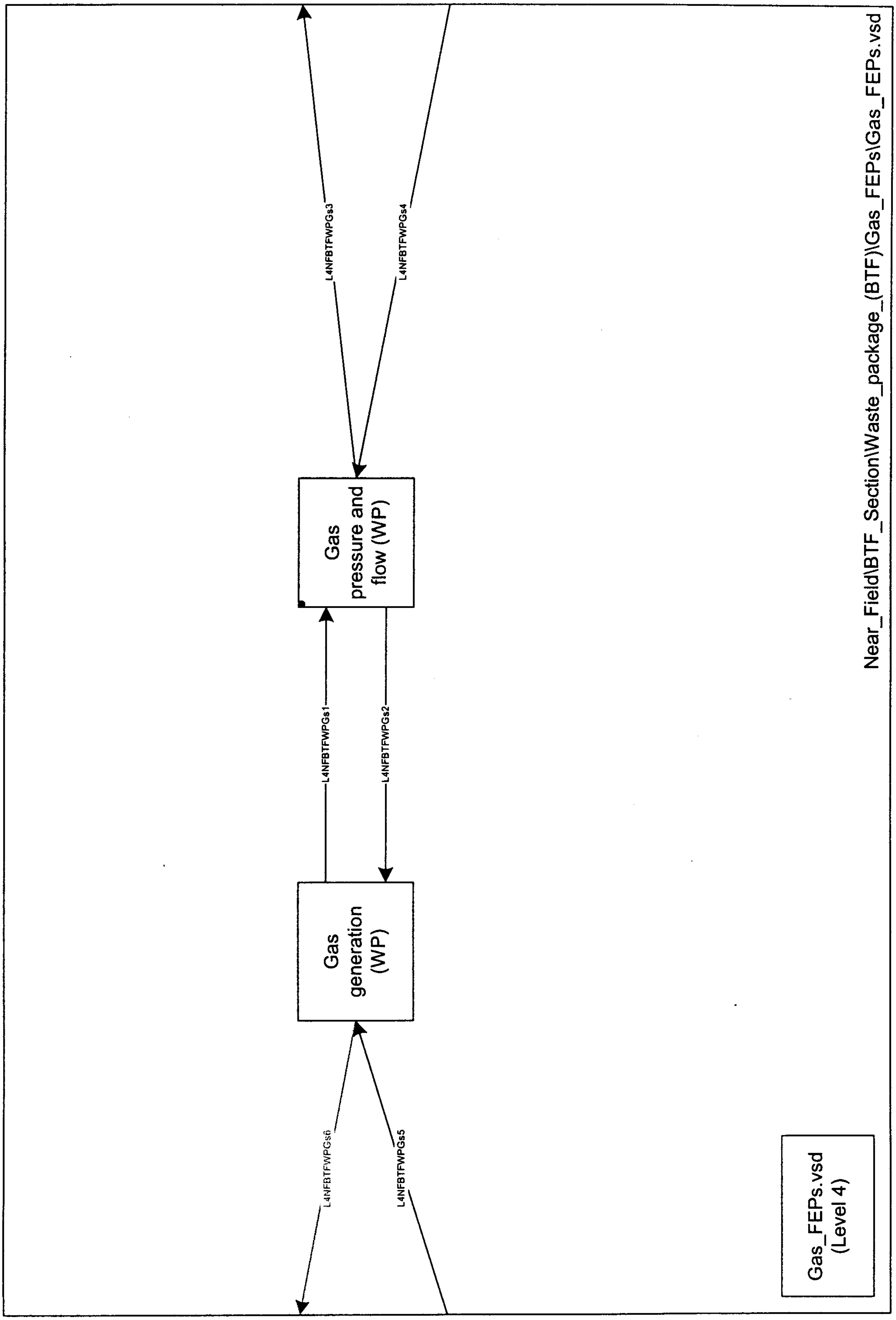
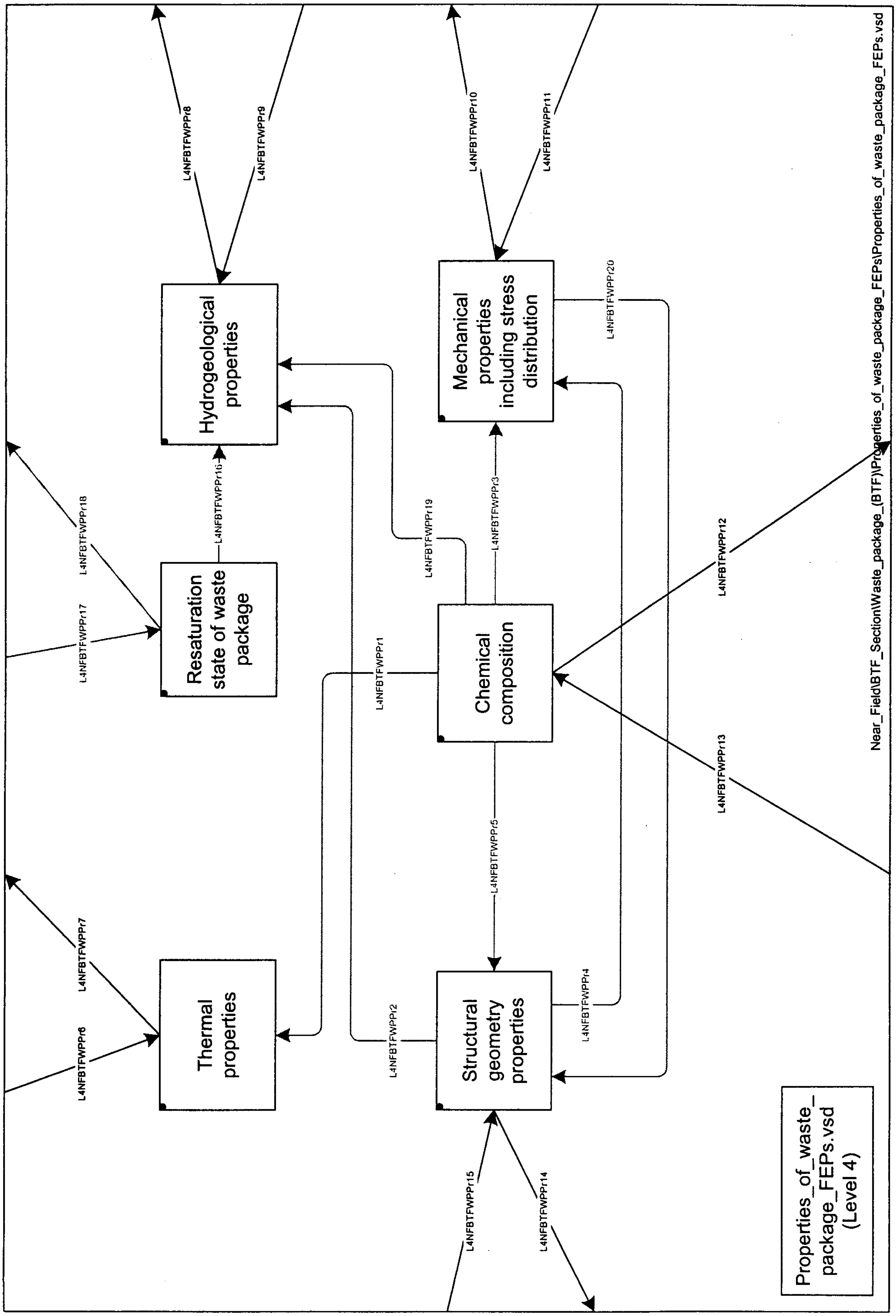
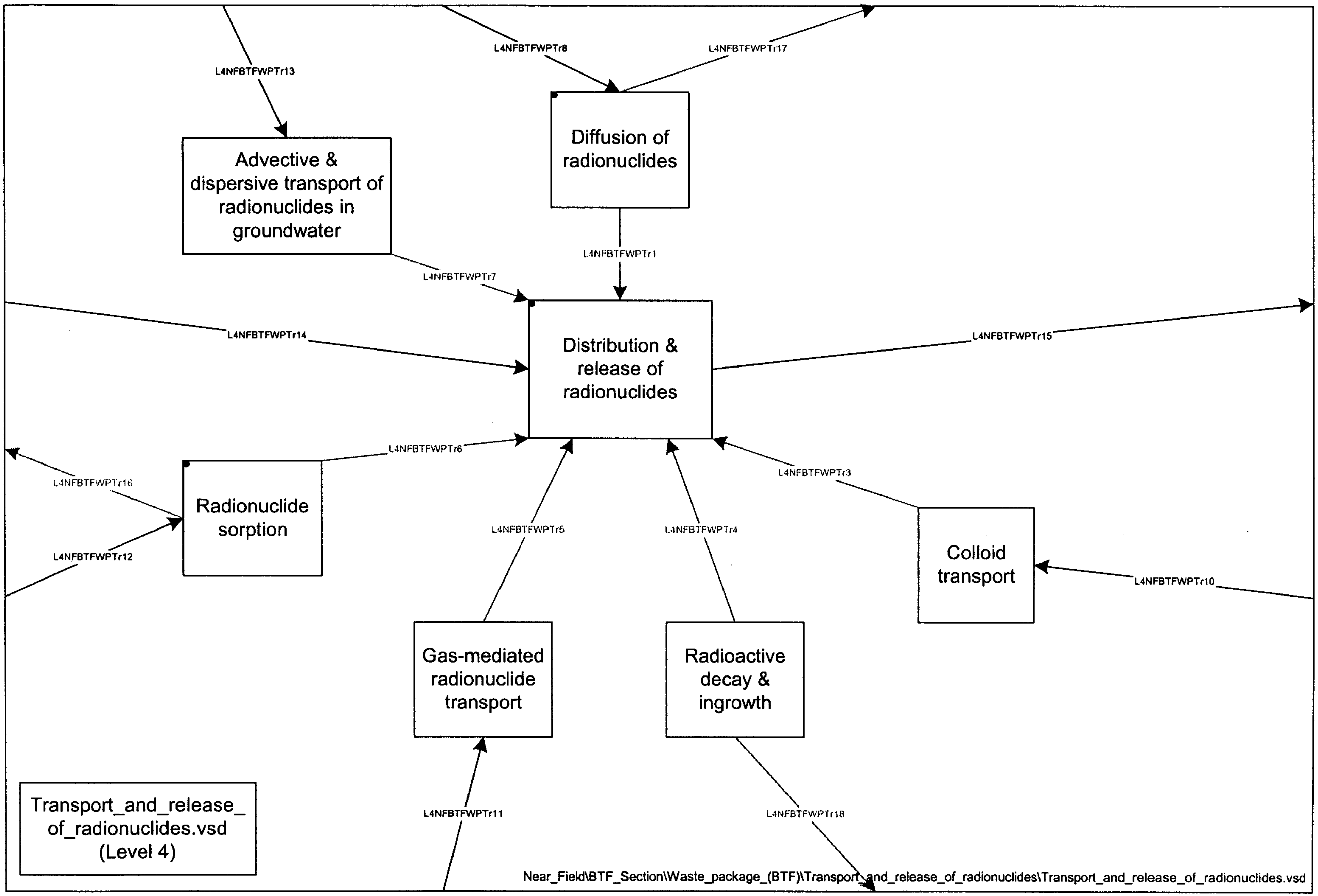
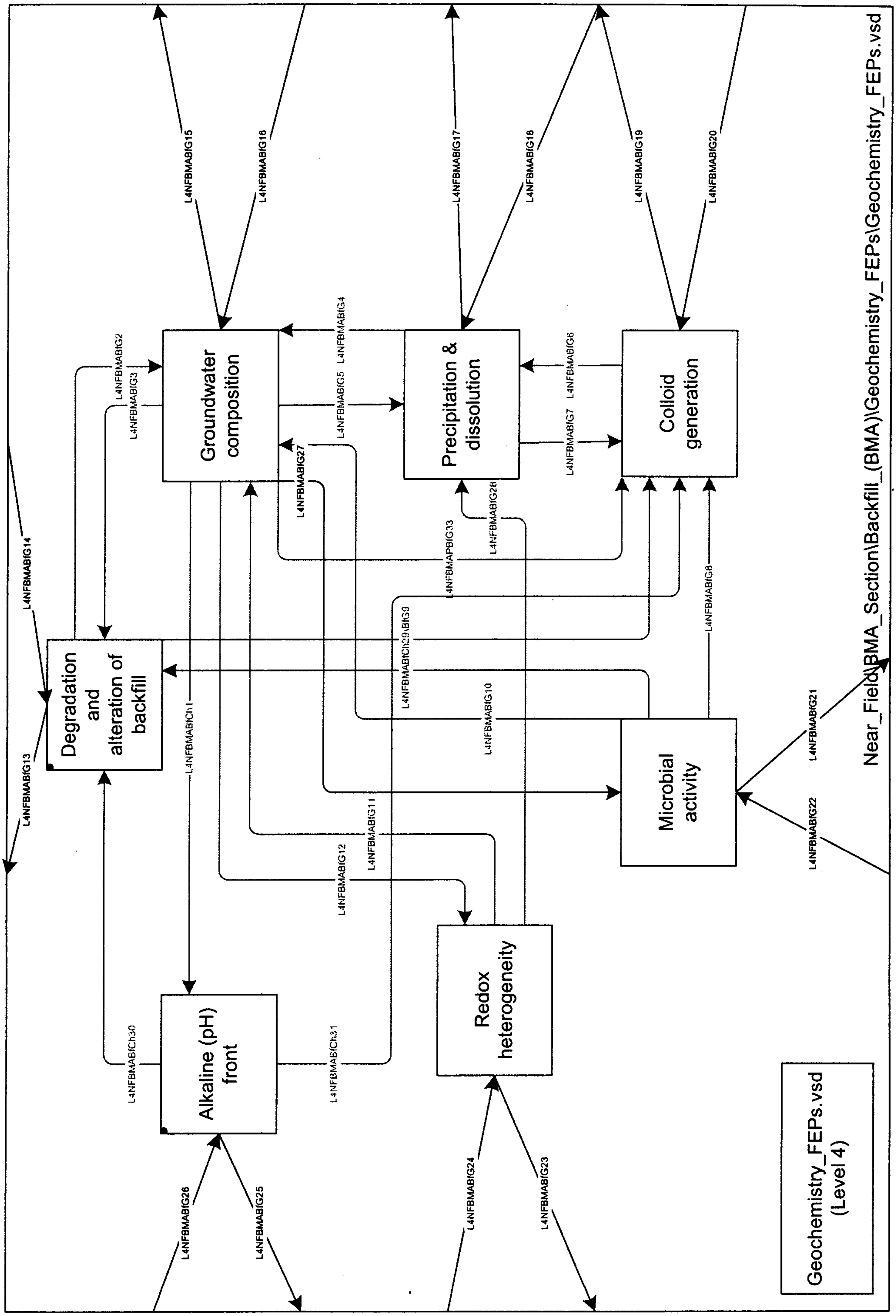
L4NFBTFWPCh26
L4NFBTFWPCh25

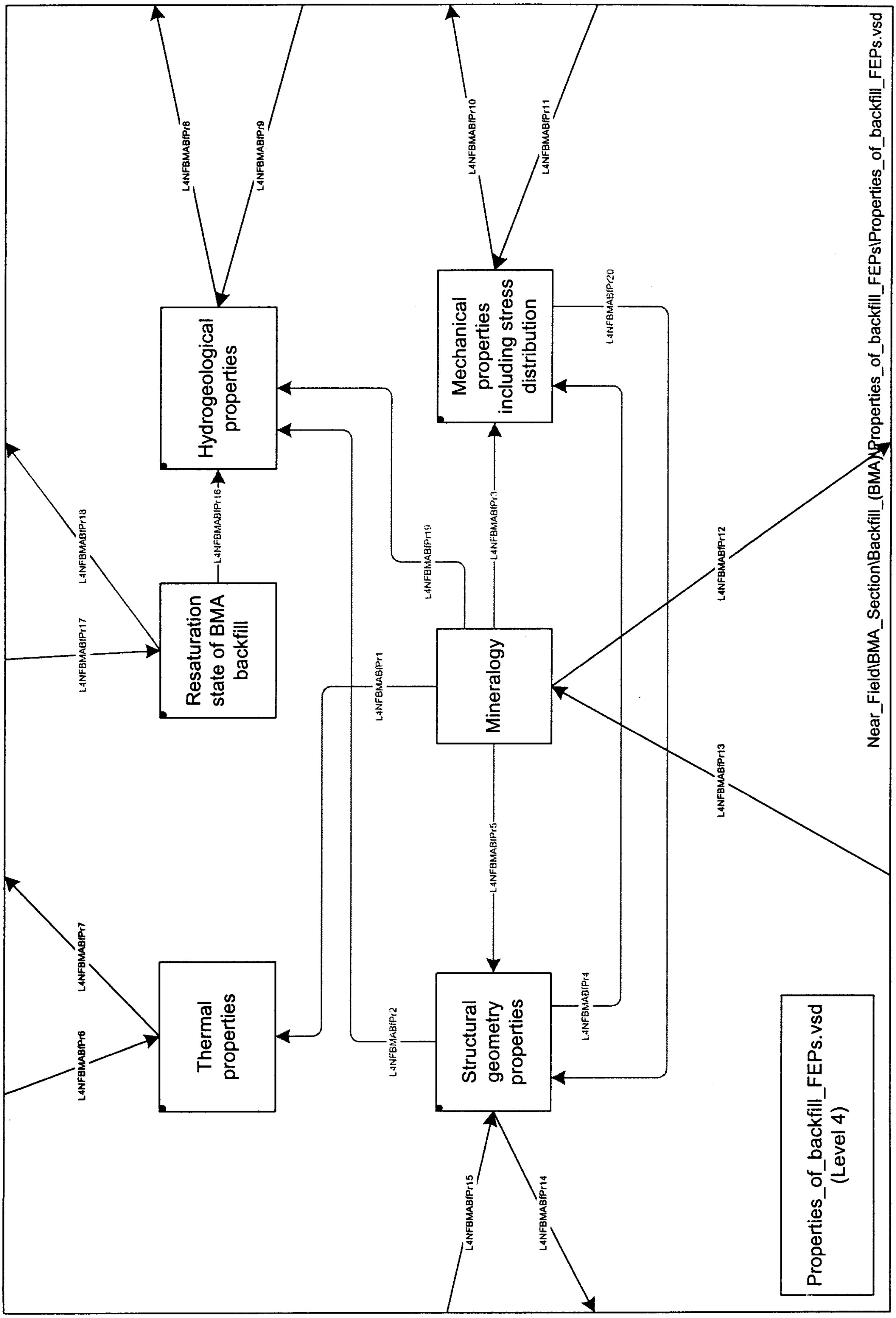

Near_Field\BTF_Section\Waste_package_(BTF)\Gas_FEPs\Gas_FEPs.vsd
Gas pressure and flow (WP)
Gas generation (WP)
L4NFBTFWPGs1
L4NFBTFWPGs2
L4NFBTFWPGs3
L4NFBTFWPGs4
L4NFBTFWPGs5
L4NFBTFWPGs6
Gas_FEPs.vsd (Level 4)

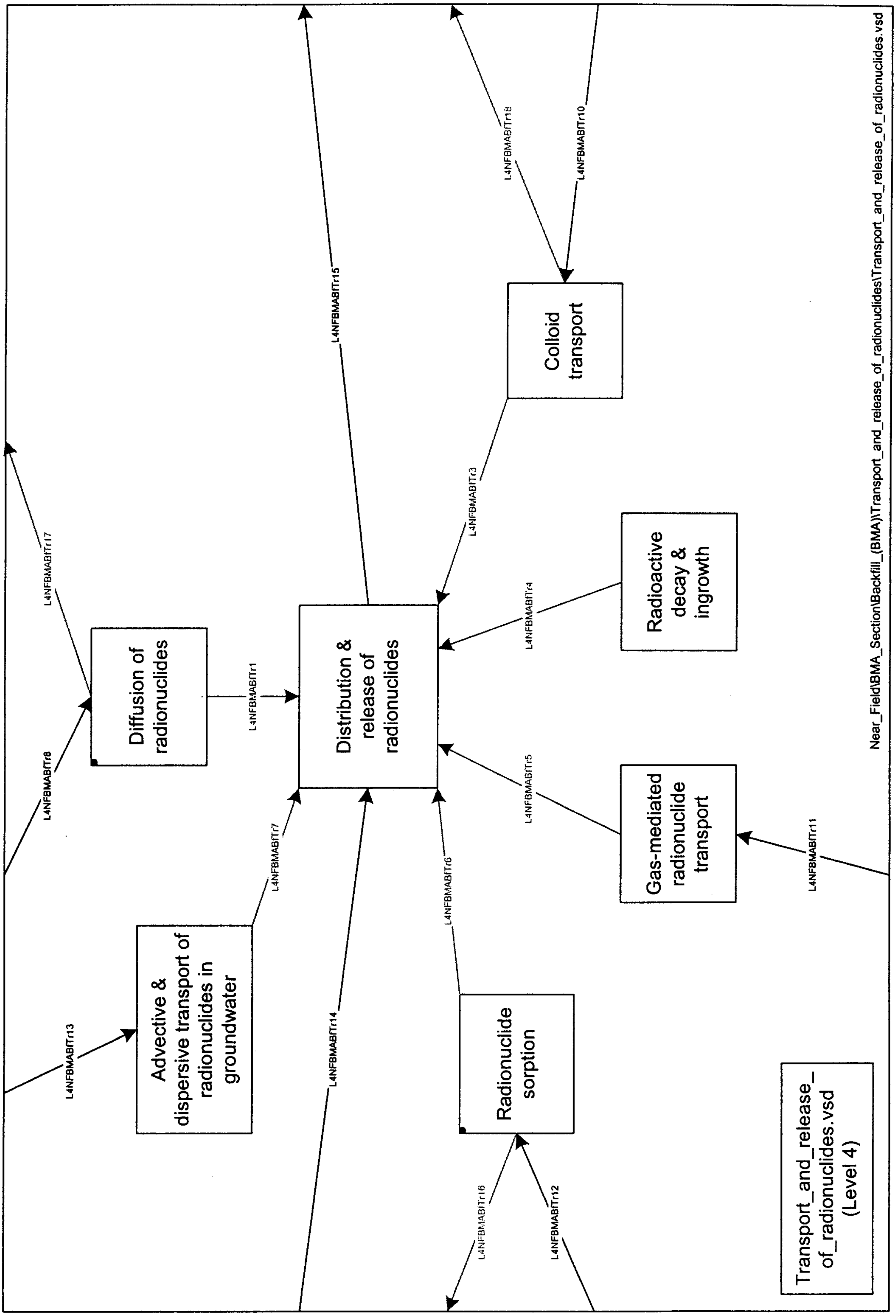

Hydrogeological properties
Mechanical properties including stress distribution
Resaturation state of waste package
Chemical composition
Thermal properties
Structural geometry properties
Properties_of_waste_package_FEPs.vsd (Level 4)
Near_Field\BTF_Section\Waste_package_(BTF)\Properties_of_waste_package_FEPs\Properties_of_waste_package_FEPs.vsd
L4NFBTFWPPr1
L4NFBTFWPPr2
L4NFBTFWPPr3
L4NFBTFWPPr4
L4NFBTFWPPr5
L4NFBTFWPPr6
L4NFBTFWPPr7
L4NFBTFWPPr8
L4NFBTFWPPr9
L4NFBTFWPPr10
L4NFBTFWPPr11
L4NFBTFWPPr12
L4NFBTFWPPr13
L4NFBTFWPPr14
L4NFBTFWPPr15
L4NFBTFWPPr16
L4NFBTFWPPr17
L4NFBTFWPPr18
L4NFBTFWPPr19
L4NFBTFWPPr20

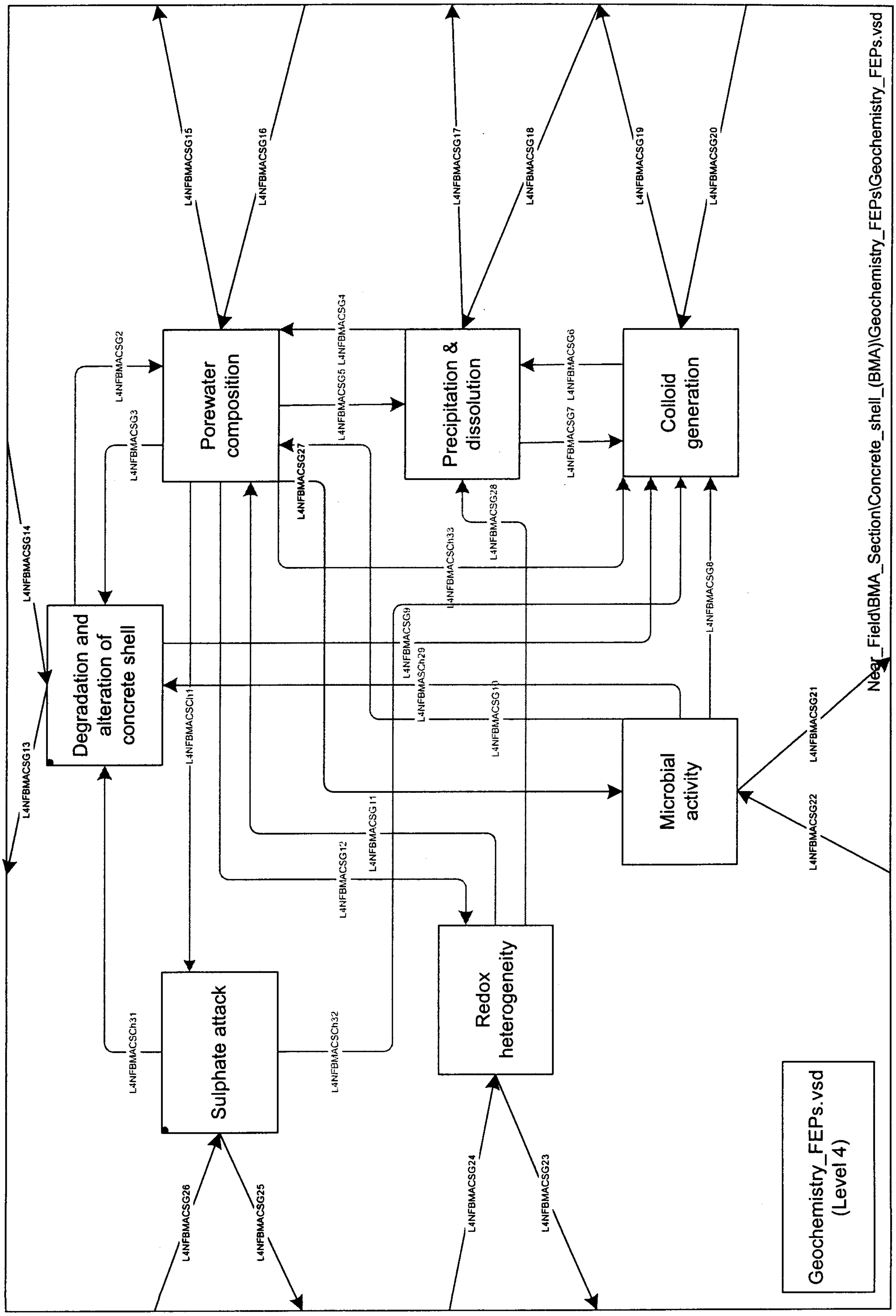


Advective & dispersive transport of radionuclides in groundwater
Diffusion of radionuclides
Distribution & release of radionuclides
Radionuclide sorption
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
L4NFBTFWPTr13
L4NFBTFWPTr8
L4NFBTFWPTr17
L4NFBTFWPTr1
L4NFBTFWPTr7
L4NFBTFWPTr14
L4NFBTFWPTr15
L4NFBTFWPTr6
L4NFBTFWPTr16
L4NFBTFWPTr12
L4NFBTFWPTr5
L4NFBTFWPTr4
L4NFBTFWPTr3
L4NFBTFWPTr10
L4NFBTFWPTr11
L4NFBTFWPTr18
Transport_and_release_of_radionuclides.vsd (Level 4)
Near_Field\BTF_Section\Waste_package_(BTF)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd

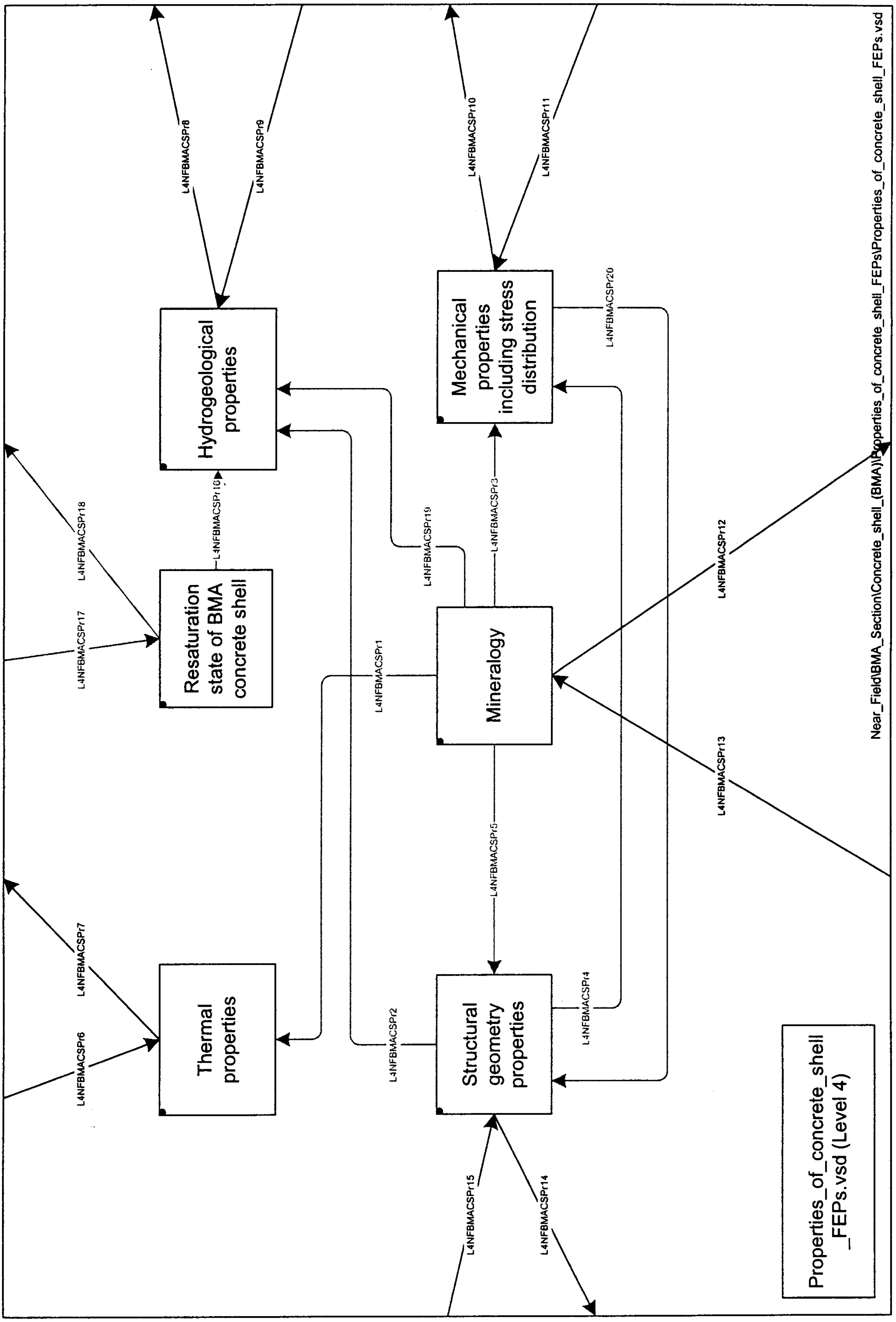

Near_Field\BMA_Section\Backfill_(BMA)\Geochemistry_FEPs\Geochemistry_FEPs.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of backfill
Microbial activity
Alkaline (pH) front
Redox heterogeneity
Geochemistry_FEPs.vsd
(Level 4)
L4NFBMABfG2
L4NFBMABfG3
L4NFBMABfG4
L4NFBMABfG5
L4NFBMABfG6
L4NFBMABfG7
L4NFBMABfG8
L4NFBMABfG10
L4NFBMABfG11
L4NFBMABfG12
L4NFBMABfG13
L4NFBMABfG14
L4NFBMABfG15
L4NFBMABfG16
L4NFBMABfG17
L4NFBMABfG18
L4NFBMABfG19
L4NFBMABfG20
L4NFBMABfG21
L4NFBMABfG22
L4NFBMABfG23
L4NFBMABfG24
L4NFBMABfG25
L4NFBMABfG26
L4NFBMABfG27
L4NFBMABfG28
L4NFBMAPBfG33
L4NFBMABfCh1
L4NFBMABfCh29\BfG9
L4NFBMABfCh30
L4NFBMABfCh31


Properties_of_backfill_FEPs.vsd (Level 4)
Near_Field\BMA_Section\Backfill_(BMA)\Properties_of_backfill_FEPs\Properties_of_backfill_FEPs.vsd
Hydrogeological properties
Mechanical properties including stress distribution
Resaturation state of BMA backfill
Mineralogy
Thermal properties
Structural geometry properties
L4NFBMABfPr1
L4NFBMABfPr2
L4NFBMABfPr3
L4NFBMABfPr4
L4NFBMABfPr5
L4NFBMABfPr6
L4NFBMABfPr7
L4NFBMABfPr8
L4NFBMABfPr9
L4NFBMABfPr10
L4NFBMABfPr11
L4NFBMABfPr12
L4NFBMABfPr13
L4NFBMABfPr14
L4NFBMABfPr15
L4NFBMABfPr16
L4NFBMABfPr17
L4NFBMABfPr18
L4NFBMABfPr19
L4NFBMABfPr20

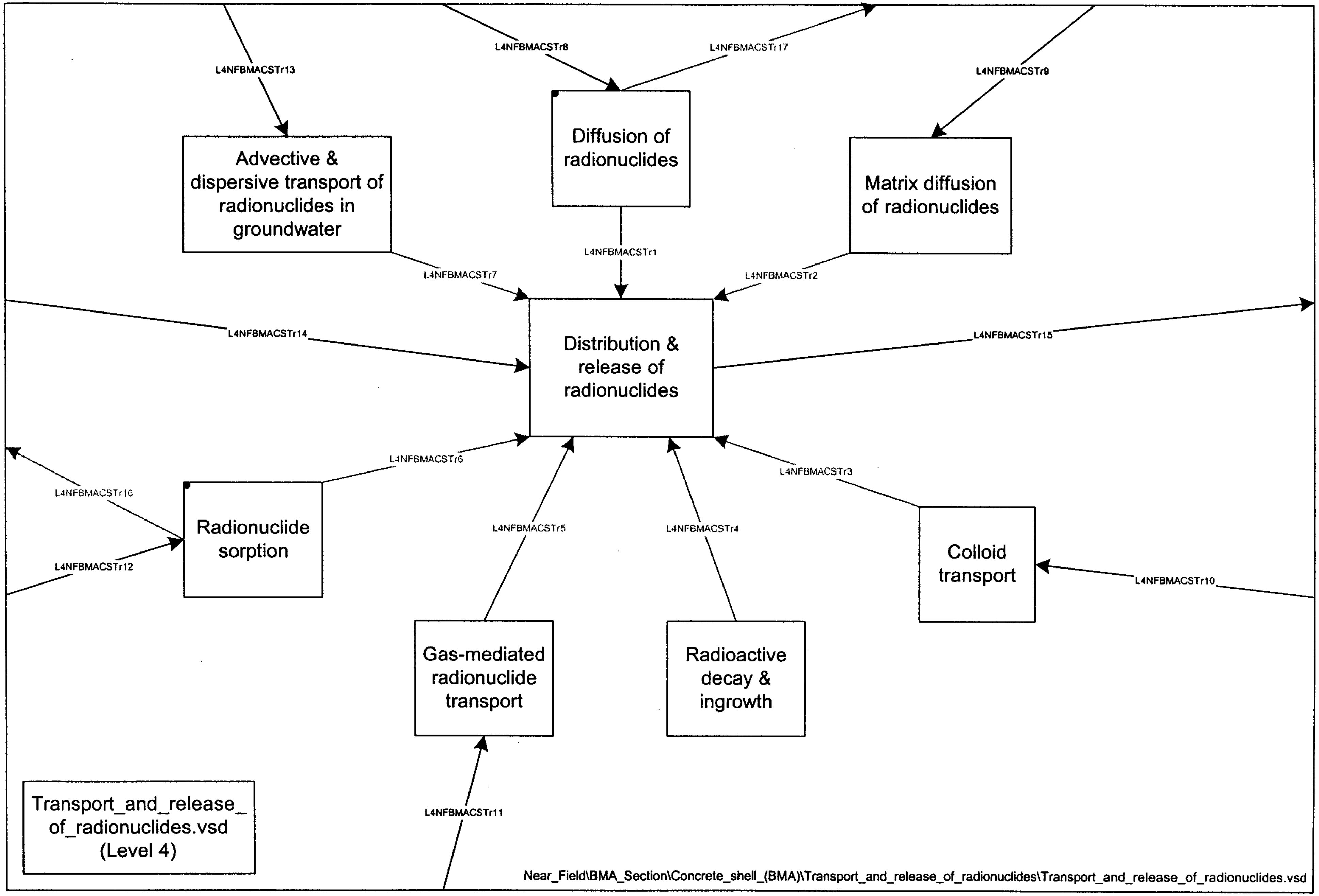

Transport_and_release_of_radionuclides.vsd (Level 4)
Near_Field\BMA_Section\Backfill_(BMA)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
Diffusion of radionuclides
Distribution & release of radionuclides
Colloid transport
Radioactive decay & ingrowth
Gas-mediated radionuclide transport
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
L4NFBMABfTr1
L4NFBMABfTr3
L4NFBMABfTr4
L4NFBMABfTr5
L4NFBMABfTr6
L4NFBMABfTr7
L4NFBMABfTr8
L4NFBMABfTr10
L4NFBMABfTr11
L4NFBMABfTr12
L4NFBMABfTr13
L4NFBMABfTr14
L4NFBMABfTr15
L4NFBMABfTr16
L4NFBMABfTr17
L4NFBMABfTr18

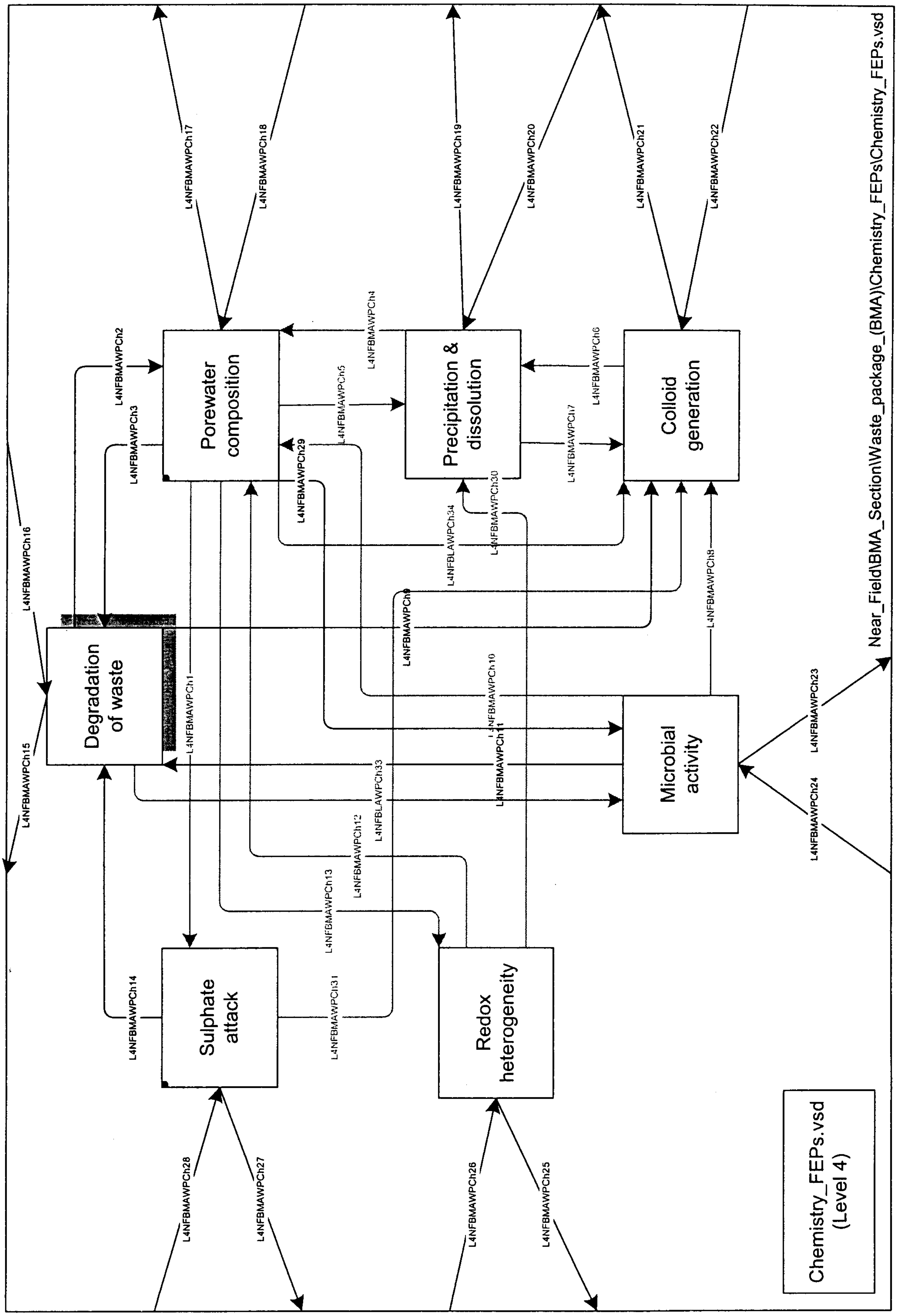


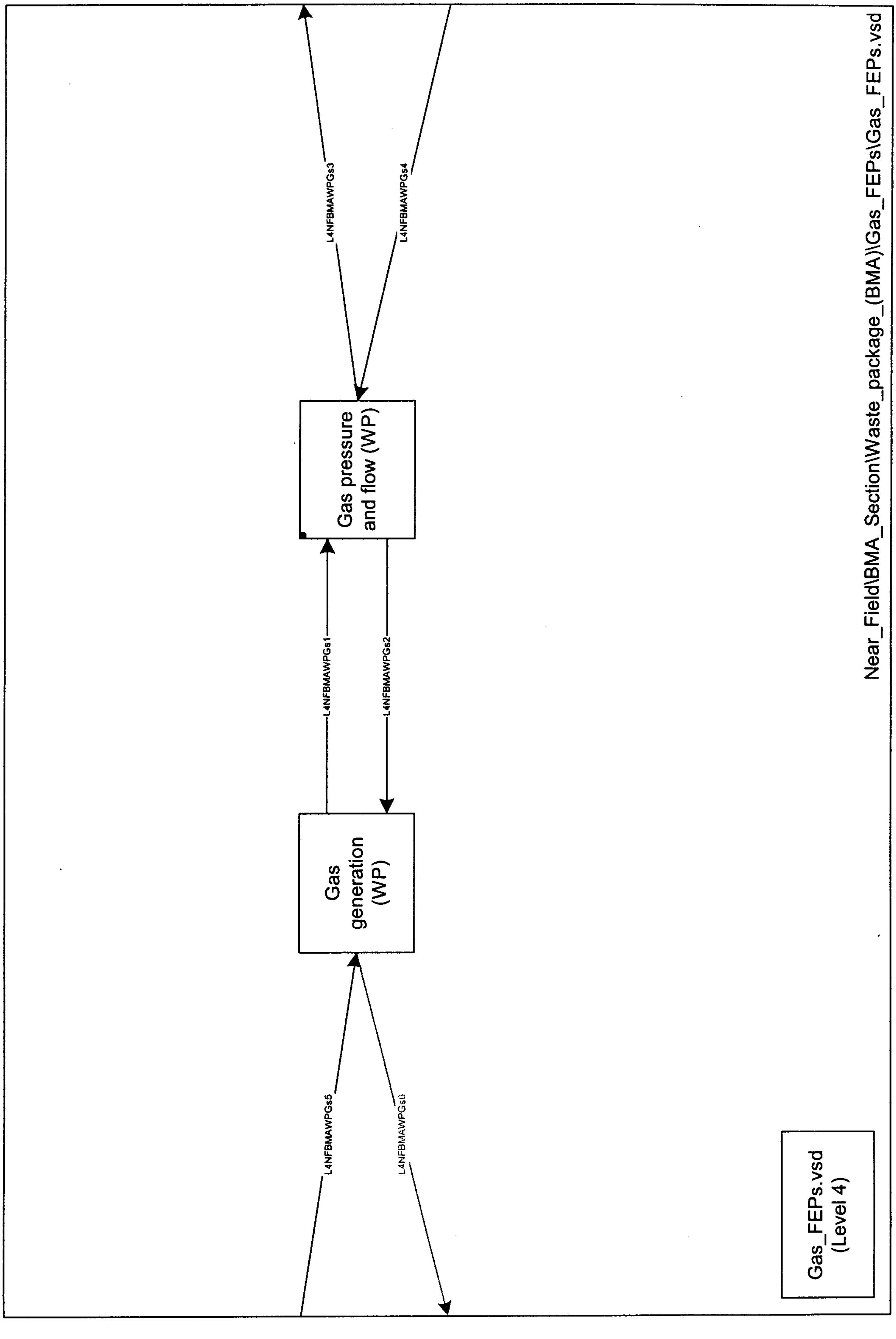
Near_Field\BMA_Section\Concrete_shell_(BMA)\Geochemistry_FEPs\Geochemistry_FEPs.vsd
Porewater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of concrete shell
Microbial activity
Sulphate attack
Redox heterogeneity
Geochemistry_FEPs.vsd (Level 4)
L4NFBMACSG2
L4NFBMACSG3
L4NFBMACSG4
L4NFBMACSG5
L4NFBMACSG6
L4NFBMACSG7
L4NFBMACSG8
L4NFBMACSG9
L4NFBMACSG10
L4NFBMACSG11
L4NFBMACSG12
L4NFBMACSG13
L4NFBMACSG14
L4NFBMACSG15
L4NFBMACSG16
L4NFBMACSG17
L4NFBMACSG18
L4NFBMACSG19
L4NFBMACSG20
L4NFBMACSG21
L4NFBMACSG22
L4NFBMACSG23
L4NFBMACSG24
L4NFBMACSG25
L4NFBMACSG26
L4NFBMACSG27
L4NFBMACSG28
L4NFBMASCh29
L4NFBMACSCh1
L4NFBMACSCh31
L4NFBMACSCh32
L4NFBMACSCh33



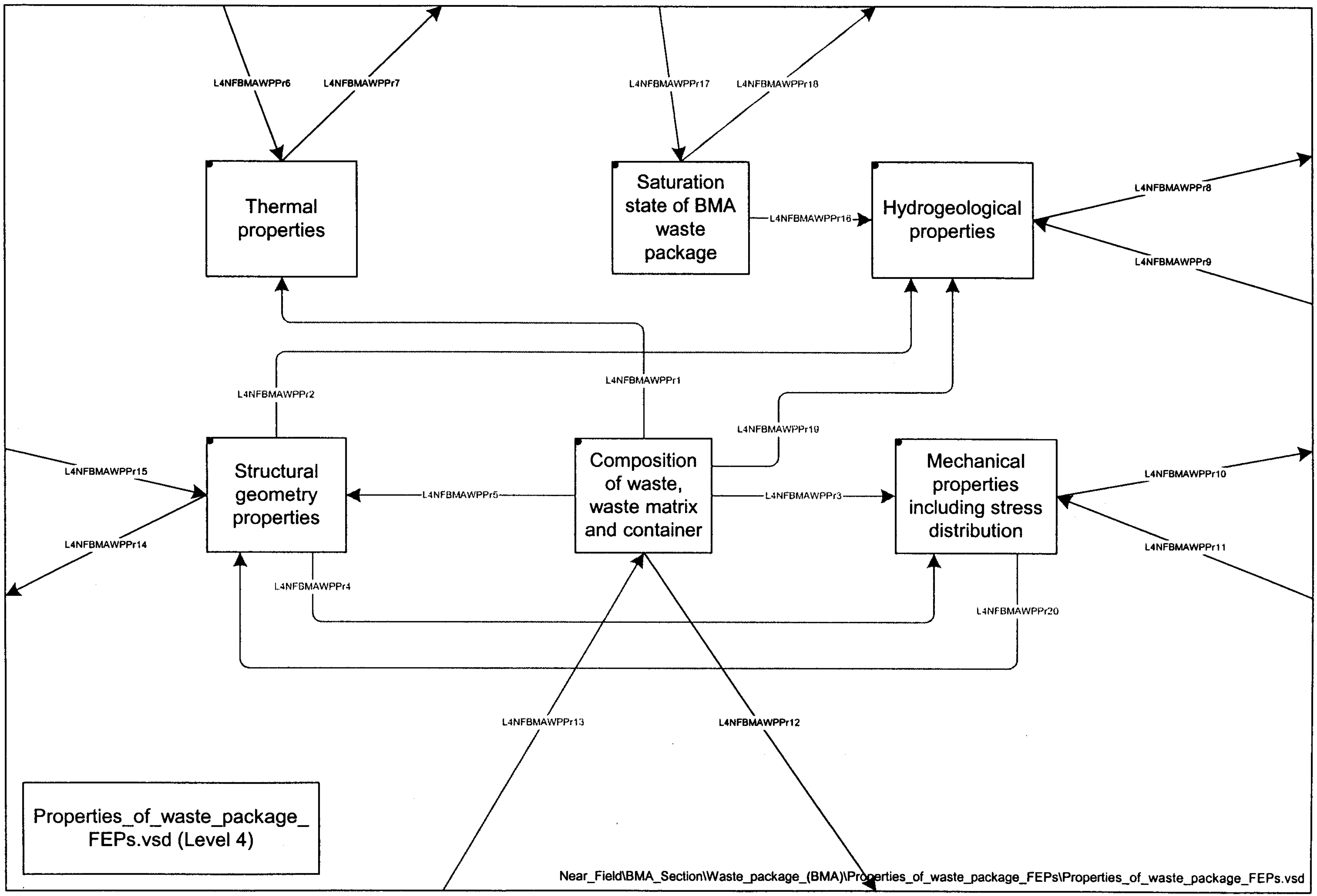
Hydrogeological properties
Mechanical properties including stress distribution
Resaturation state of BMA concrete shell
Mineralogy
Thermal properties
Structural geometry properties
L4NFBMACSPr1
L4NFBMACSPr2
L4NFBMACSPr3
L4NFBMACSPr4
L4NFBMACSPr5
L4NFBMACSPr6
L4NFBMACSPr7
L4NFBMACSPr8
L4NFBMACSPr9
L4NFBMACSPr10
L4NFBMACSPr11
L4NFBMACSPr12
L4NFBMACSPr13
L4NFBMACSPr14
L4NFBMACSPr15
L4NFBMACSPr16
L4NFBMACSPr17
L4NFBMACSPr18
L4NFBMACSPr19
L4NFBMACSPr20
Near_Field\BMA_Section\Concrete_shell_(BMA)\Properties_of_concrete_shell_FEPs\Properties_of_concrete_shell_FEPs.vsd
Properties_of_concrete_shell_FEPs.vsd (Level 4)

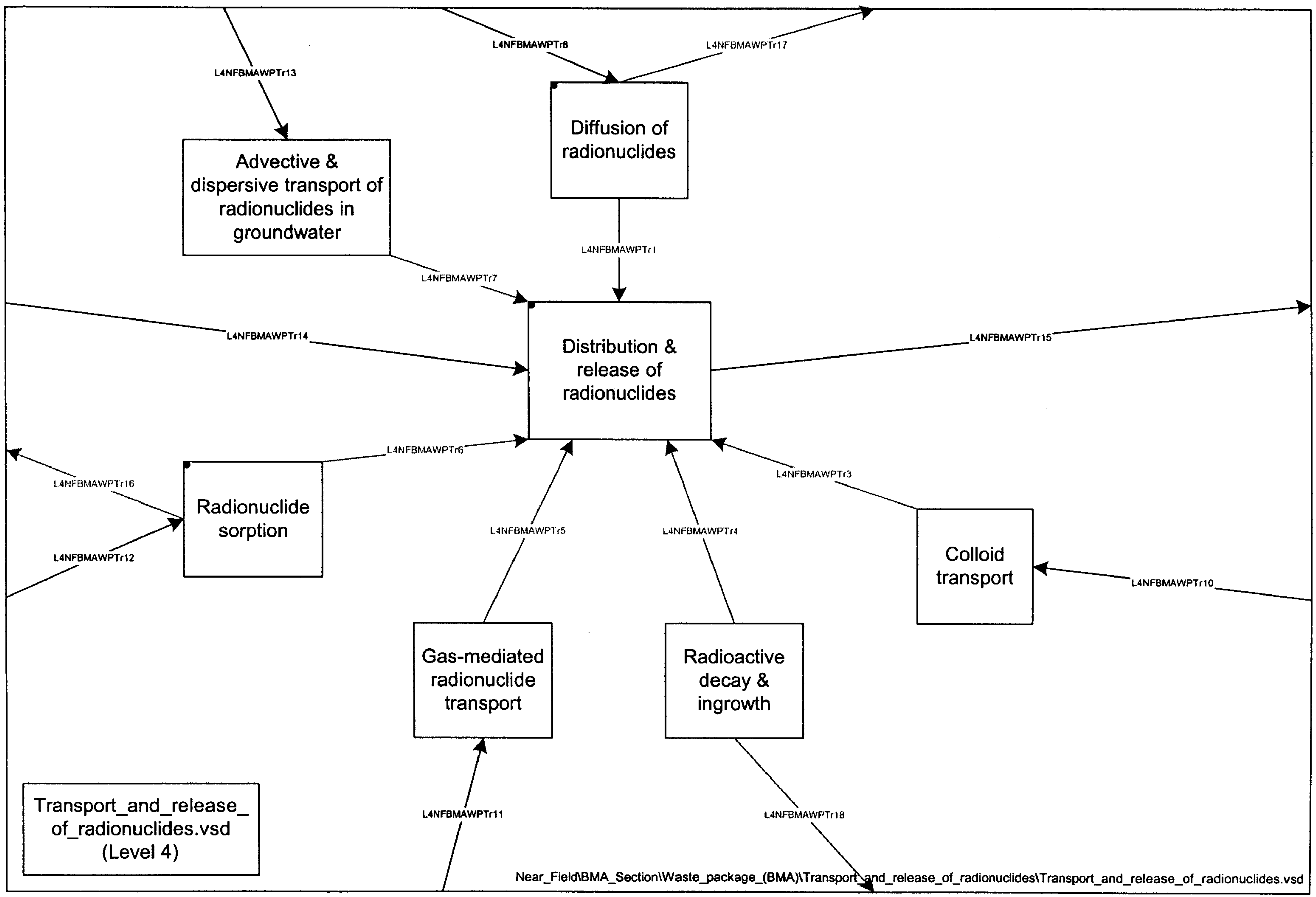

Advective & dispersive transport of radionuclides in groundwater
Diffusion of radionuclides
Matrix diffusion of radionuclides
Distribution & release of radionuclides
Radionuclide sorption
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
Transport_and_release_of_radionuclides.vsd (Level 4)
L4NFBMACSTr1
L4NFBMACSTr2
L4NFBMACSTr3
L4NFBMACSTr4
L4NFBMACSTr5
L4NFBMACSTr6
L4NFBMACSTr7
L4NFBMACSTr8
L4NFBMACSTr9
L4NFBMACSTr10
L4NFBMACSTr11
L4NFBMACSTr12
L4NFBMACSTr13
L4NFBMACSTr14
L4NFBMACSTr15
L4NFBMACSTr16
L4NFBMACSTr17
Near_Field\BMA_Section\Concrete_shell_(BMA)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd

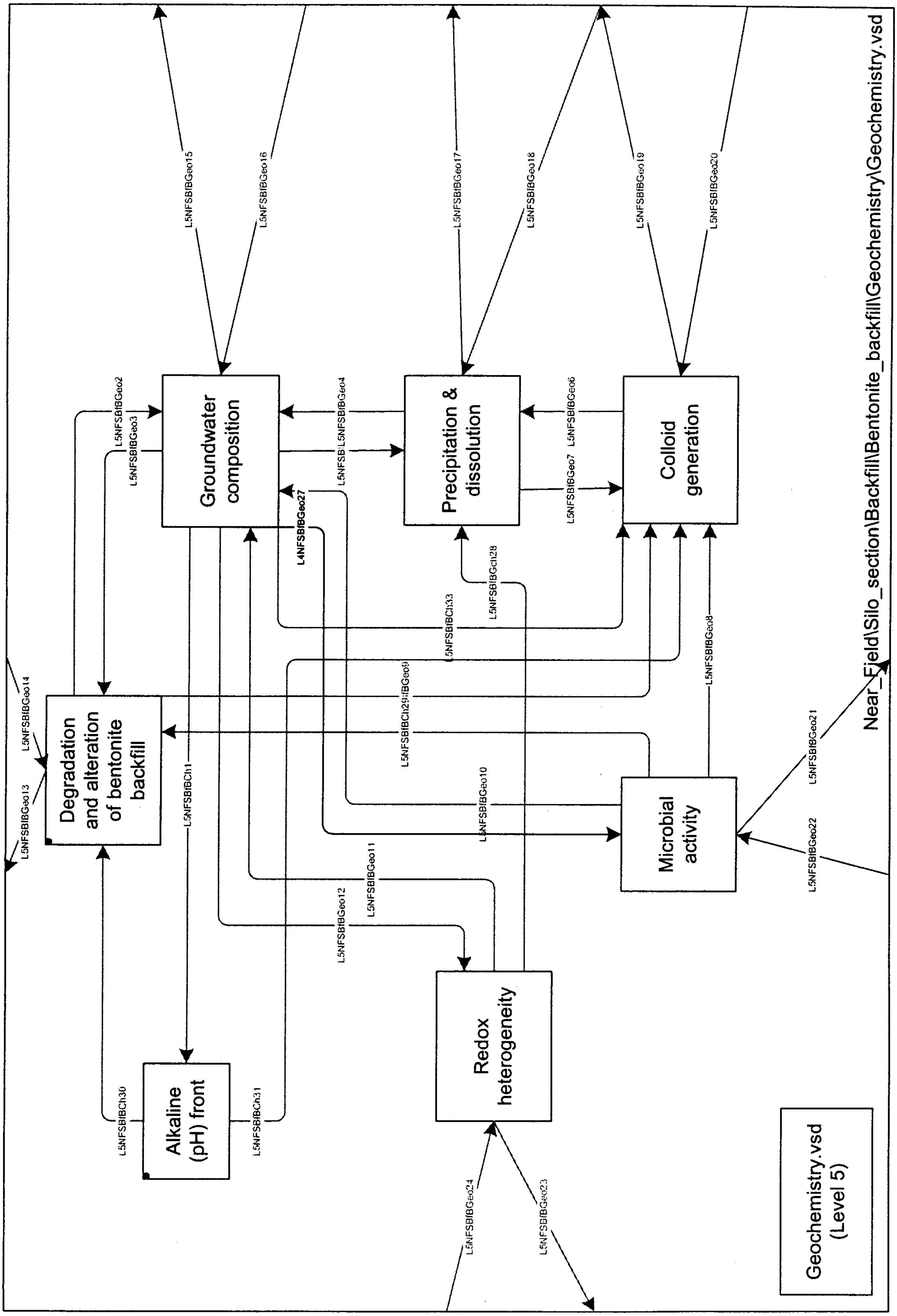

Porewater composition
Precipitation & dissolution
Colloid generation
Degradation of waste
Microbial activity
Sulphate attack
Redox heterogeneity
Chemistry_FEPs.vsd (Level 4)
Near_Field\BMA_Section\Waste_package_(BMA)\Chemistry_FEPs\Chemistry_FEPs.vsd
L4NFBMAWPCh1
L4NFBMAWPCh2
L4NFBMAWPCh3
L4NFBMAWPCh4
L4NFBMAWPCh5
L4NFBMAWPCh6
L4NFBMAWPCh7
L4NFBMAWPCh8
L4NFBMAWPCh9
L4NFBMAWPCh10
L4NFBMAWPCh11
L4NFBMAWPCh12
L4NFBMAWPCh13
L4NFBMAWPCh14
L4NFBMAWPCh15
L4NFBMAWPCh16
L4NFBMAWPCh17
L4NFBMAWPCh18
L4NFBMAWPCh19
L4NFBMAWPCh20
L4NFBMAWPCh21
L4NFBMAWPCh22
L4NFBMAWPCh23
L4NFBMAWPCh24
L4NFBMAWPCh25
L4NFBMAWPCh26
L4NFBMAWPCh27
L4NFBMAWPCh28
L4NFBMAWPCh29
L4NFBMAWPCh30
L4NFBMAWPCh31
L4NFBLAWPCh33
L4NFBLAWPCh34

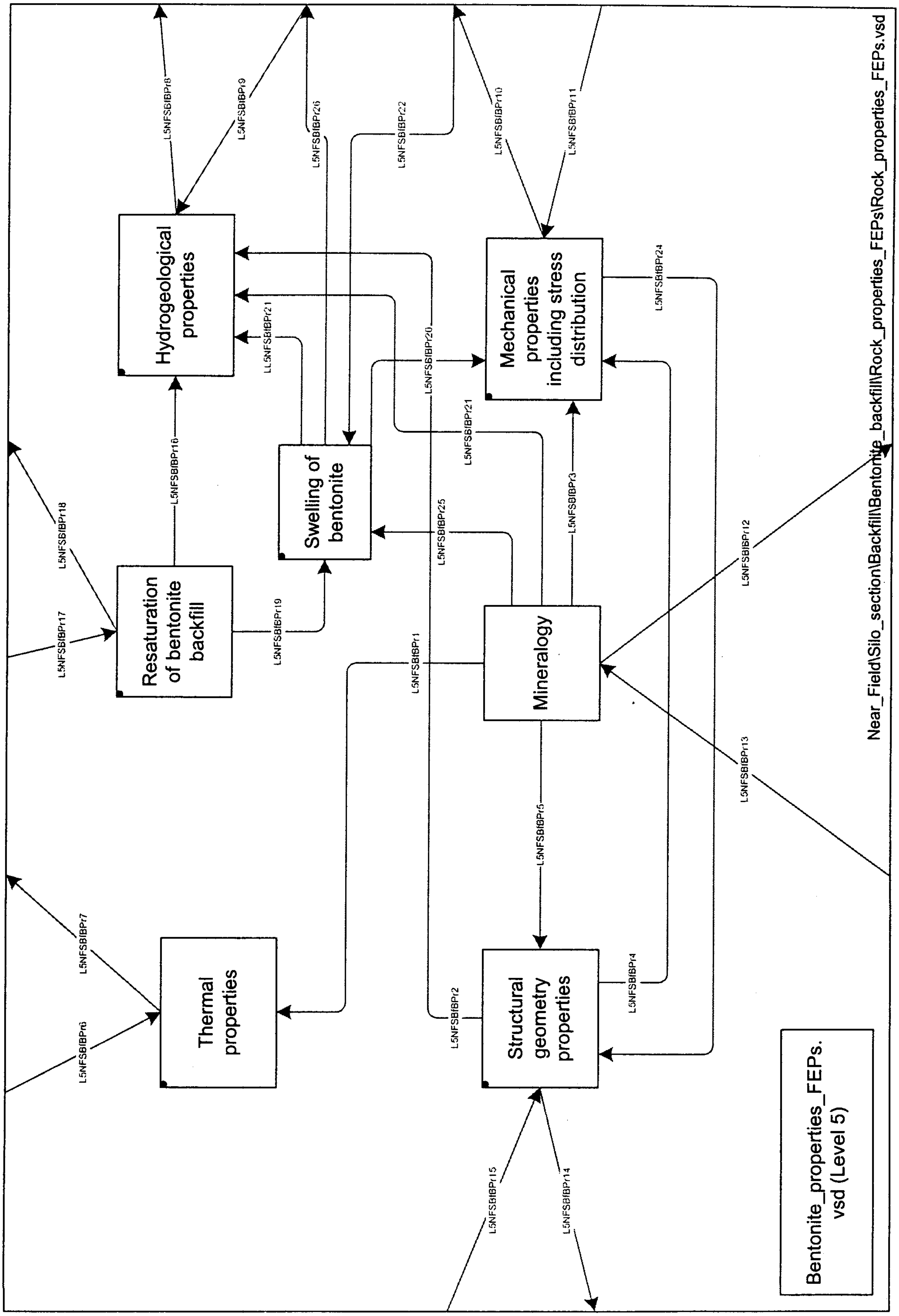


Near_Field\BMA_Section\Waste_package_(BMA)\Gas_FEPs\Gas_FEPs.vsd
Gas_FEPs.vsd
(Level 4)
Gas generation (WP)
Gas pressure and flow (WP)
L4NFBMAWPGs1
L4NFBMAWPGs2
L4NFBMAWPGs3
L4NFBMAWPGs4
L4NFBMAWPGs5
L4NFBMAWPGs6


Thermal properties
Saturation state of BMA waste package
Hydrogeological properties
Structural geometry properties
Composition of waste, waste matrix and container
Mechanical properties including stress distribution
L4NFBMAWPPr1
L4NFBMAWPPr2
L4NFBMAWPPr3
L4NFBMAWPPr4
L4NFBMAWPPr5
L4NFBMAWPPr6
L4NFBMAWPPr7
L4NFBMAWPPr8
L4NFBMAWPPr9
L4NFBMAWPPr10
L4NFBMAWPPr11
L4NFBMAWPPr12
L4NFBMAWPPr13
L4NFBMAWPPr14
L4NFBMAWPPr15
L4NFBMAWPPr16
L4NFBMAWPPr17
L4NFBMAWPPr18
L4NFBMAWPPr19
L4NFBMAWPPr20
Properties_of_waste_package_FEPs.vsd (Level 4)
Near_Field\BMA_Section\Waste_package_(BMA)\Properties_of_waste_package_FEPs\Properties_of_waste_package_FEPs.vsd


L4NFBMAWPTr13
L4NFBMAWPTr8
L4NFBMAWPTr17
Diffusion of radionuclides
Advective & dispersive transport of radionuclides in groundwater
L4NFBMAWPTr1
L4NFBMAWPTr7
L4NFBMAWPTr14
Distribution & release of radionuclides
L4NFBMAWPTr15
L4NFBMAWPTr6
L4NFBMAWPTr16
Radionuclide sorption
L4NFBMAWPTr12
L4NFBMAWPTr5
L4NFBMAWPTr4
L4NFBMAWPTr3
Colloid transport
L4NFBMAWPTr10
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Transport_and_release_of_radionuclides.vsd (Level 4)
L4NFBMAWPTr11
L4NFBMAWPTr18
Near_Field\BMA_Section\Waste_package_(BMA)\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd


Near_Field\Silo_section\Backfill\Bentonite_backfill\Geochemistry\Geochemistry.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of bentonite backfill
Microbial activity
Alkaline (pH) front
Redox heterogeneity
Geochemistry.vsd (Level 5)
L5NFSBfBGeo15
L5NFSBfBGeo16
L5NFSBfBGeo17
L5NFSBfBGeo18
L5NFSBfBGeo19
L5NFSBfBGeo20
L5NFSBfBGeo2
L5NFSBfBGeo3
L5NFSBfBGeo4
L5NFSBfBGeo6
L5NFSBfBGeo7
L4NFSBfBGeo27
L5NFSBfBCh28
L5NFSBfBCh33
L5NFSBfBGeo8
L5NFSBfBCh29
L5NFSBfBGeo9
L5NFSBfBGeo10
L5NFSBfBGeo11
L5NFSBfBGeo12
L5NFSBfBCh1
L5NFSBfBGeo13
L5NFSBfBGeo14
L5NFSBfBGeo21
L5NFSBfBGeo22
L5NFSBfBCh30
L5NFSBfBCh31
L5NFSBfBGeo23
L5NFSBfBGeo24



Hydrogeological properties
Mechanical properties including stress distribution
Swelling of bentonite
Resaturation of bentonite backfill
Mineralogy
Thermal properties
Structural geometry properties
Bentonite_properties_FEPs. vsd (Level 5)
Near_Field\Silo_section\Backfill\Bentonite_backfill\Rock_properties_FEPs\Rock_properties_FEPs.vsd
L5NFSBfBPr1
L5NFSBfBPr2
L5NFSBfBPr3
L5NFSBfBPr4
L5NFSBfBPr5
L5NFSBfBPr6
L5NFSBfBPr7
L5NFSBfBPr8
L5NFSBfBPr9
L5NFSBfBPr10
L5NFSBfBPr11
L5NFSBfBPr12
L5NFSBfBPr13
L5NFSBfBPr14
L5NFSBfBPr15
L5NFSBfBPr16
L5NFSBfBPr17
L5NFSBfBPr18
L5NFSBfBPr19
L5NFSBfBPr20
L5NFSBfBPr21
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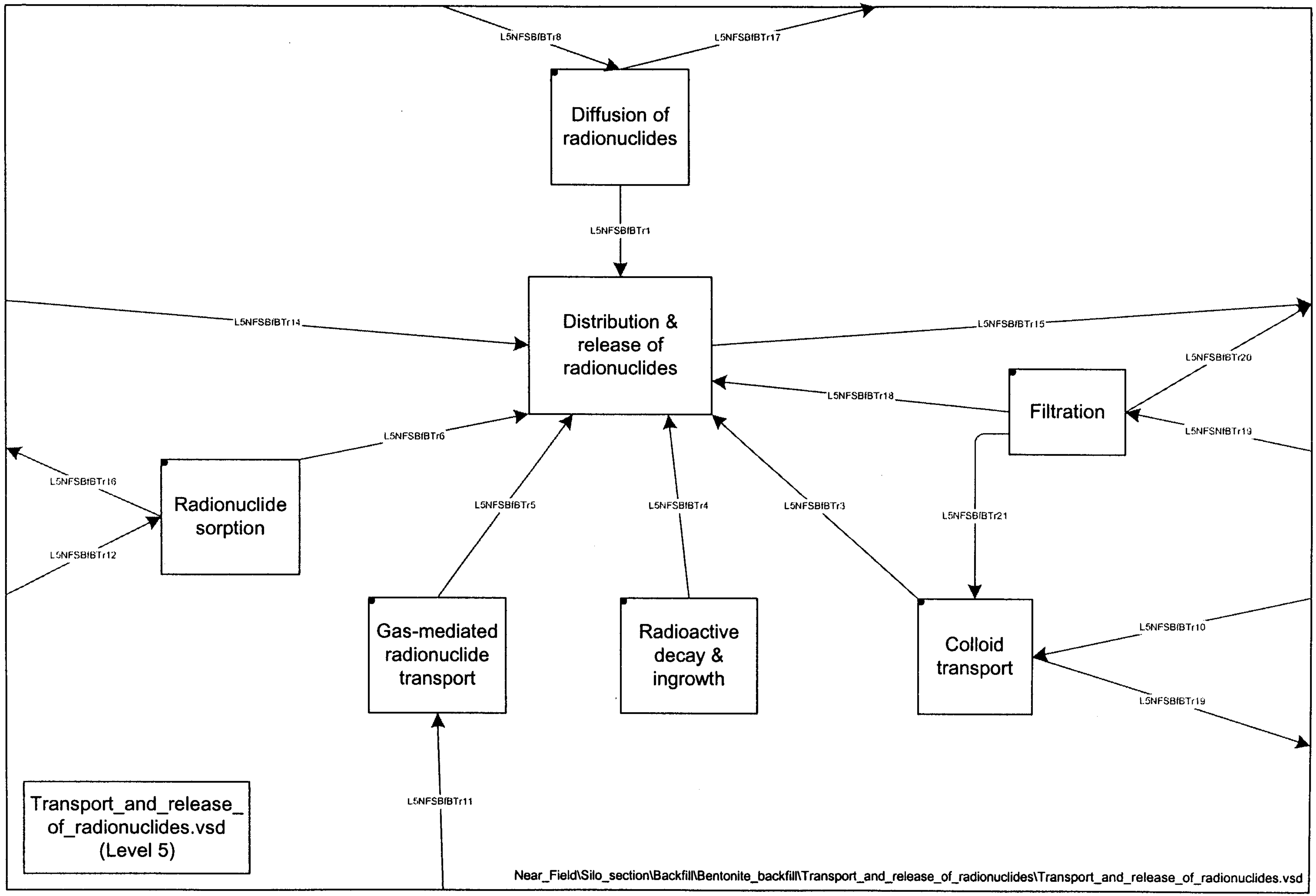
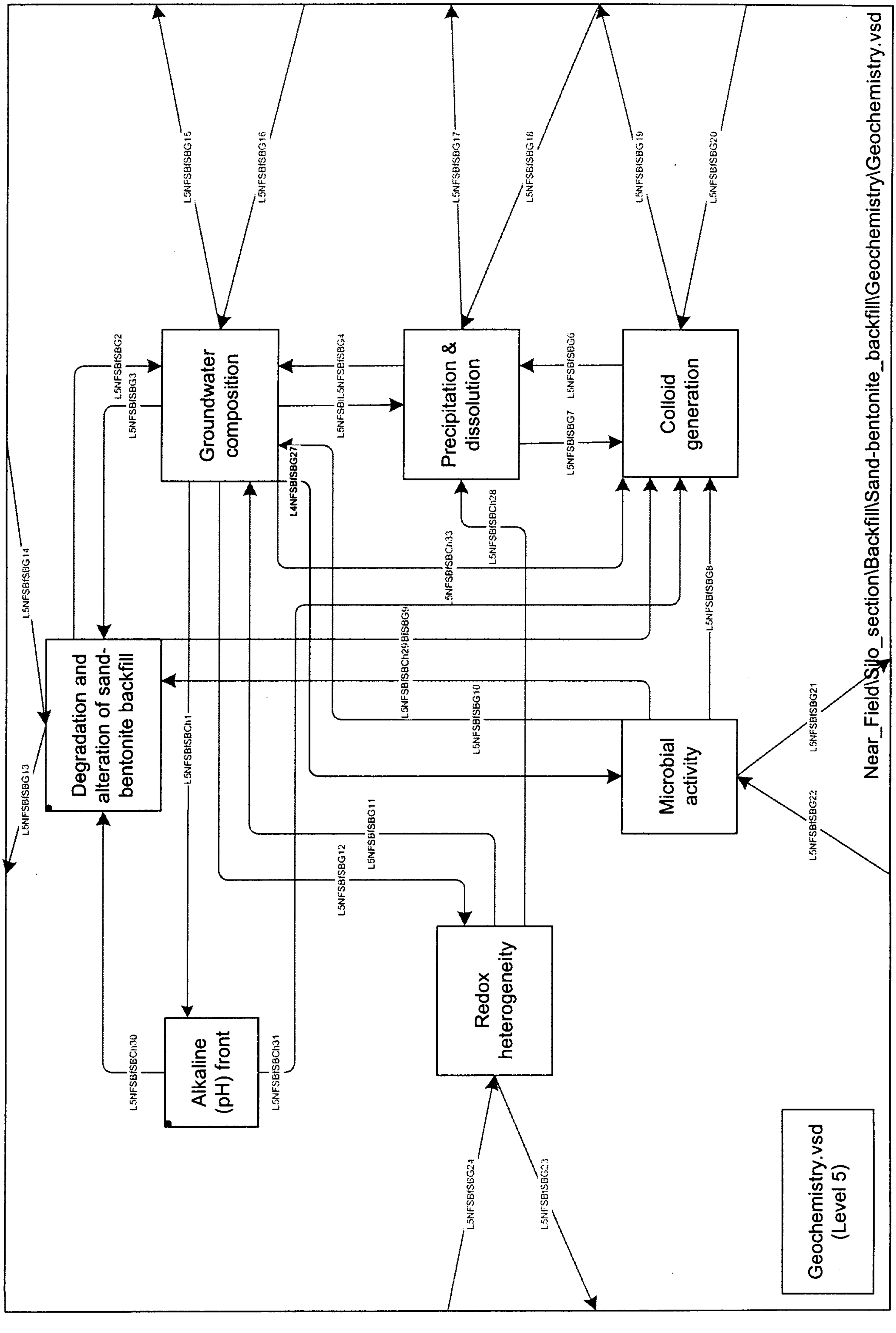
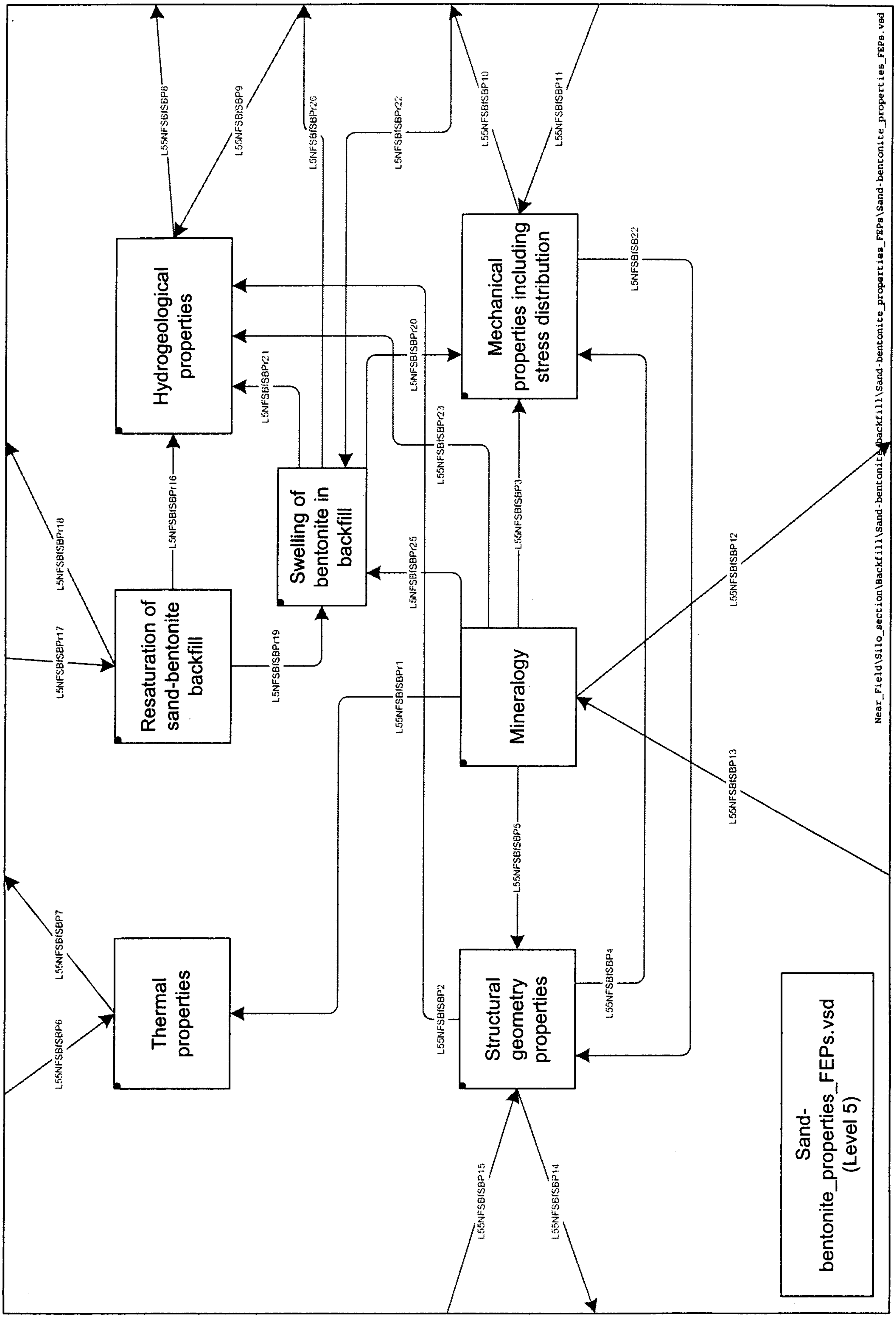
L5NFSBfBPr22
L5NFSBfBPr24
L5NFSBfBPr25
L5NFSBfBPr26

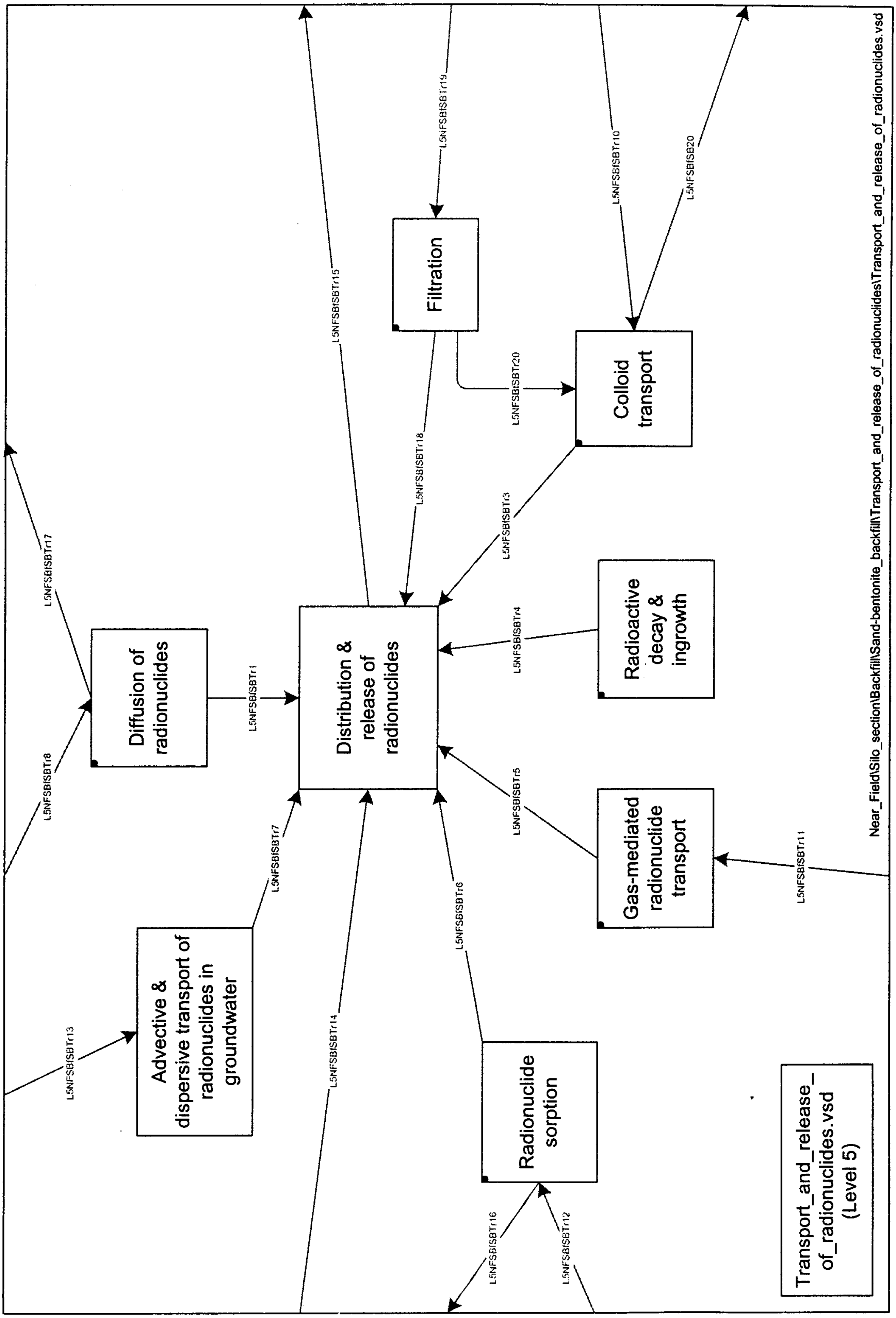


L5NFSBfBTr8
L5NFSBfBTr17
Diffusion of radionuclides
L5NFSBfBTr1
L5NFSBfBTr14
Distribution & release of radionuclides
L5NFSBfBTr15
L5NFSBfBTr20
L5NFSBfBTr18
Filtration
L5NFSNfBTr13
L5NFSBfBTr6
L5NFSBfBTr16
Radionuclide sorption
L5NFSBfBTr12
L5NFSBfBTr5
L5NFSBfBTr4
L5NFSBfBTr3
L5NFSBfBTr21
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
L5NFSBfBTr10
L5NFSBfBTr19
L5NFSBfBTr11
Transport_and_release_of_radionuclides.vsd (Level 5)
Near_Field\Silo_section\Backfill\Bentonite_backfill\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd



Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of sand-bentonite backfill
Microbial activity
Alkaline (pH) front
Redox heterogeneity
Geochemistry.vsd (Level 5)
Near_Field\Silo_section\Backfill\Sand-bentonite_backfill\Geochemistry\Geochemistry.vsd


Hydrogeological properties
Mechanical properties including stress distribution
Swelling of bentonite in backfill
Resaturation of sand-bentonite backfill
Mineralogy
Thermal properties
Structural geometry properties
Sand-bentonite_properties_FEPs.vsd (Level 5)
Near_Field\Silo_section\Backfill\Sand-bentonite backfill\Sand-bentonite_properties_FEPs\Sand-bentonite_properties_FEPs.vsd
L55NFSBISBP8
L55NFSBISBP9
L5NFSBISBPr26
L5NFSBISBPr22
L55NFSBISBP10
L55NFSBISBP11
L55NFSBISB22
L5NFSBISBPr20
L5NFSBISBPr21
L55NFSBISBPr23
L5NFSBISBPr16
L5NFSBISBPr18
L55NFSBISBP3
L5NFSBISBPr25
L55NFSBISBP12
L5NFSBISBPr17
L5NFSBISBPr19
L55NFSBISBPr1
L55NFSBISBP13
L55NFSBISBP5
L55NFSBISBP7
L55NFSBISBP6
L55NFSBISBP4
L55NFSBISBP2
L55NFSBISBP15
L55NFSBISBP14


Distribution & release of radionuclides
Diffusion of radionuclides
Advective & dispersive transport of radionuclides in groundwater
Radionuclide sorption
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
Colloid transport
Filtration
Transport_and_release_of_radionuclides.vsd (Level 5)
Near_Field\Silo_section\Backfill\Sand-bentonite_backfill\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd
L5NFSBfSBTr1
L5NFSBfSBTr3
L5NFSBfSBTr4
L5NFSBfSBTr5
L5NFSBfSBTr6
L5NFSBfSBTr7
L5NFSBfSBTr8
L5NFSBfSBTr10
L5NFSBfSBTr11
L5NFSBfSBTr12
L5NFSBfSBTr13
L5NFSBfSBTr14
L5NFSBfSBTr15
L5NFSBfSBTr16
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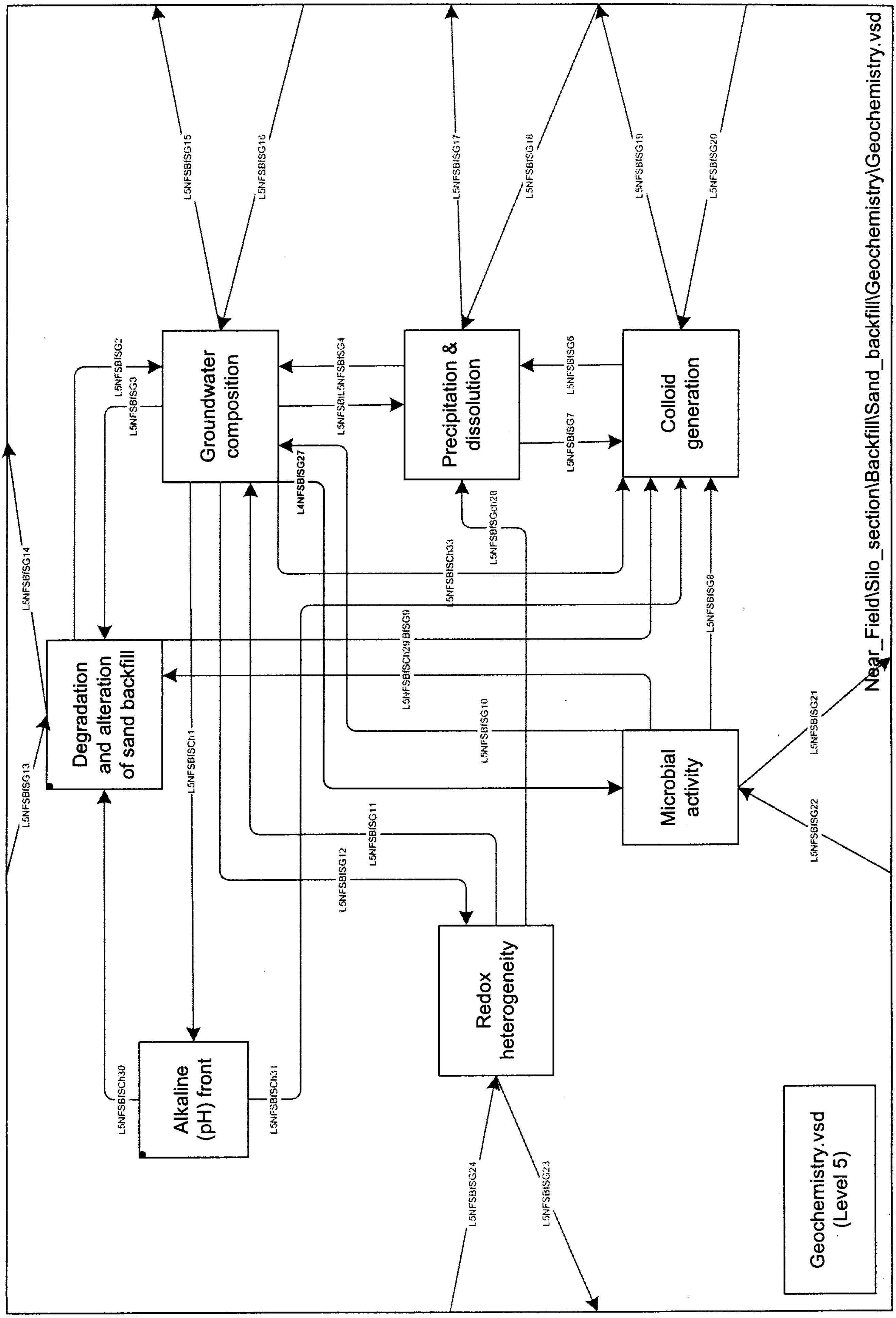
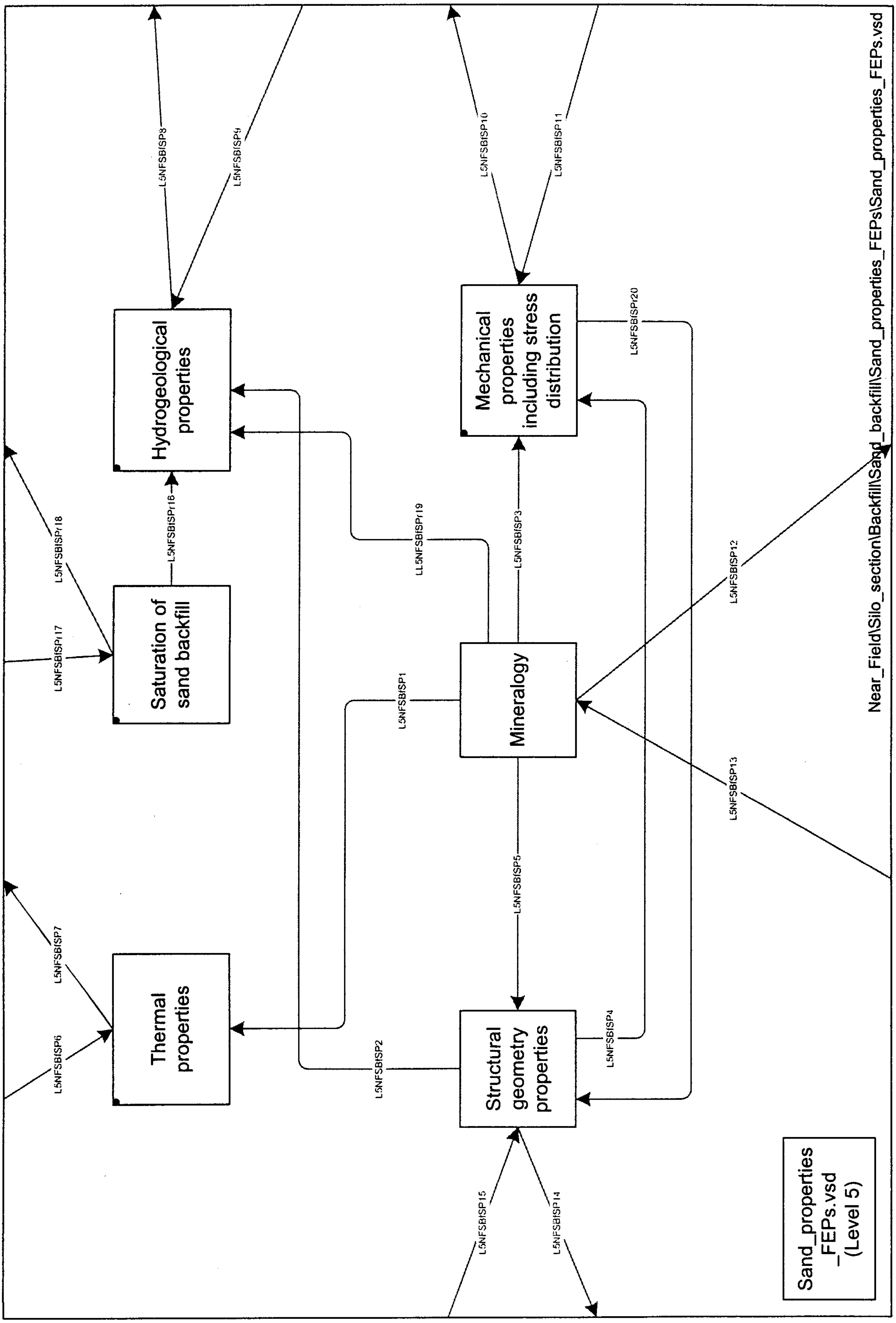
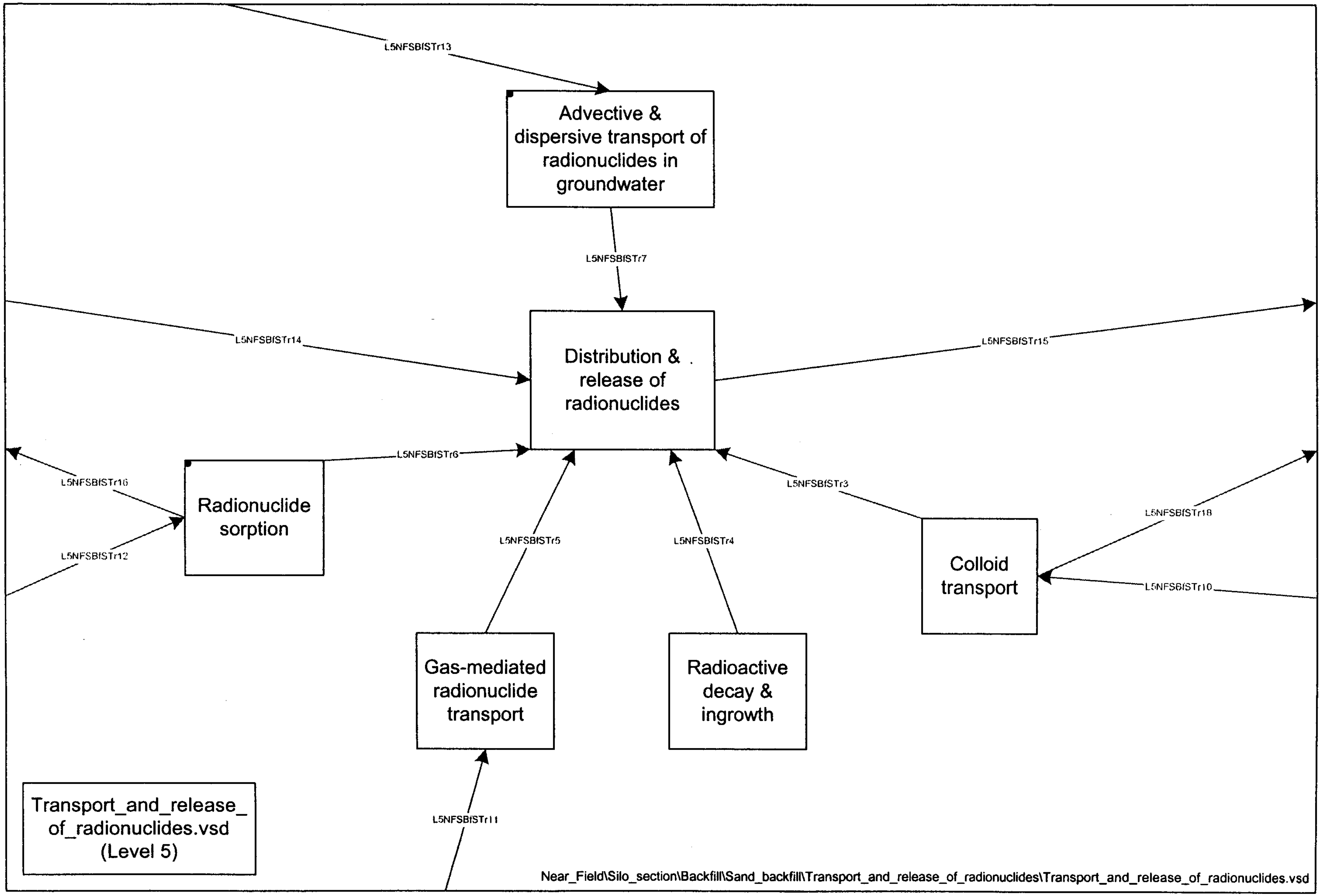
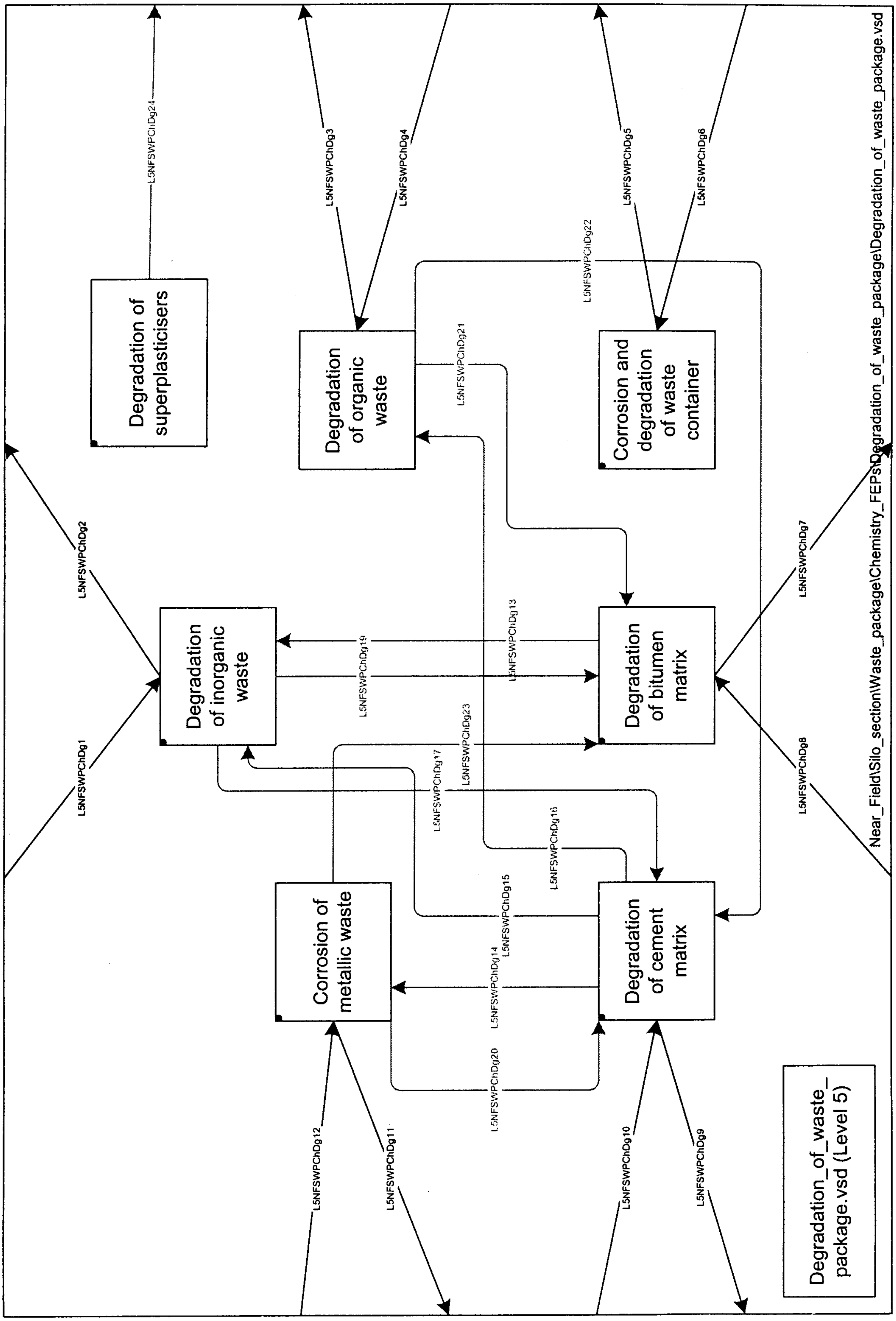
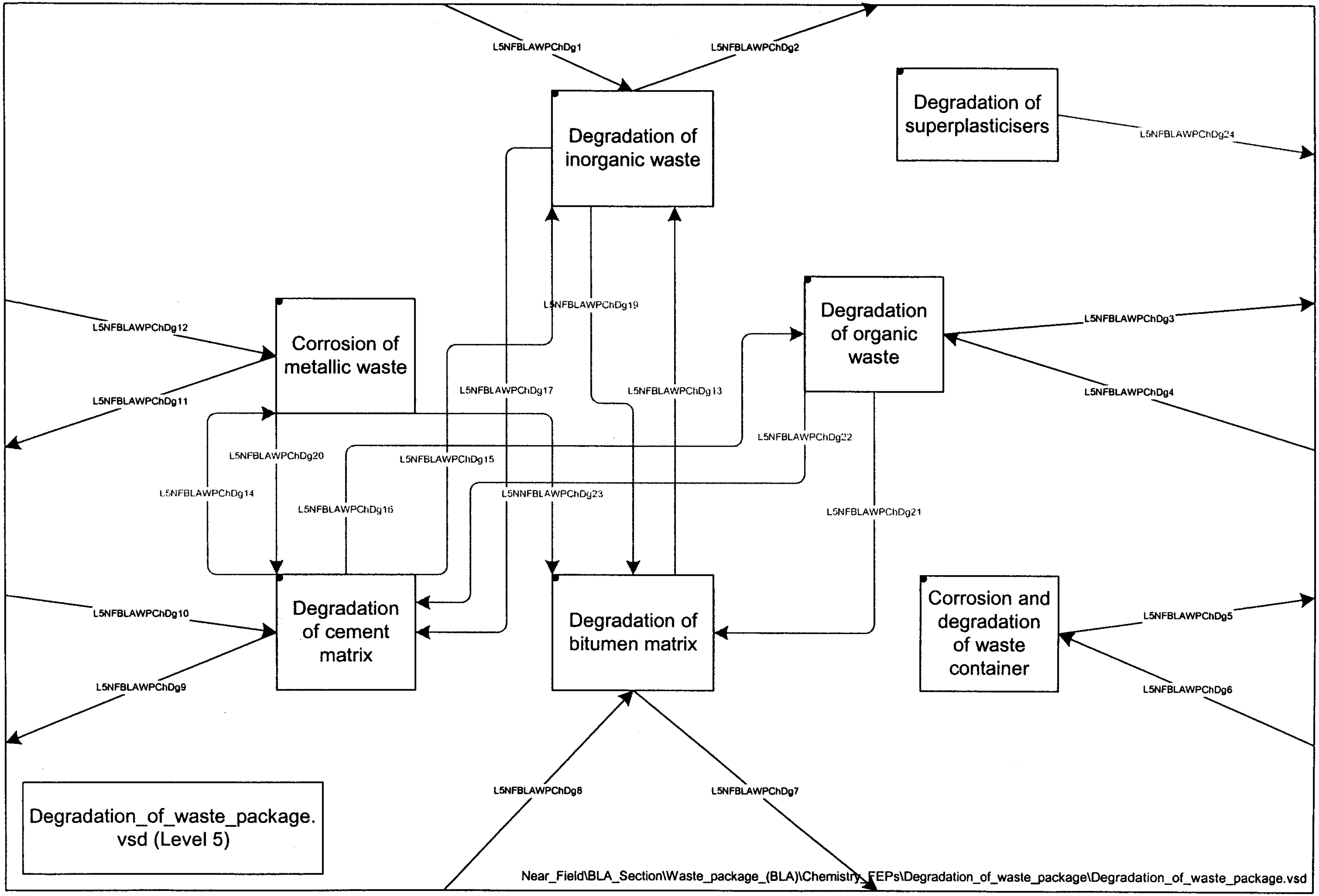
L5NFSBfSBTr20
L5NFSBfSB20


Near_Field\Silo_section\Backfill\Sand_backfill\Geochemistry\Geochemistry.vsd
Groundwater composition
Precipitation & dissolution
Colloid generation
Degradation and alteration of sand backfill
Microbial activity
Alkaline (pH) front
Redox heterogeneity
Geochemistry.vsd (Level 5)
L5NFSBISG2
L5NFSBISG3
L5NFSBIL5NFSBISG4
L5NFSBISG6
L5NFSBISG7
L5NFSBISG8
L5NFSBISCh29 BISG9
L5NFSBISG10
L5NFSBISG11
L5NFSBISG12
L5NFSBISG13
L5NFSBISG14
L5NFSBISG15
L5NFSBISG16
L5NFSBISG17
L5NFSBISG18
L5NFSBISG19
L5NFSBISG20
L5NFSBISG21
L5NFSBISG22
L5NFSBISG23
L5NFSBISG24
L4NFSBISG27
L5NFSBISGch28
L5NFSBISCh1
L5NFSBISCh30
L5NFSBISCh31
L5NFSBISCh33


Hydrogeological properties
Mechanical properties including stress distribution
Saturation of sand backfill
Mineralogy
Thermal properties
Structural geometry properties
Sand_properties _FEPs.vsd (Level 5)
Near_Field\Silo_section\Backfill\Sand_backfill\Sand_properties_FEPs\Sand_properties_FEPs.vsd
L5NFSB\SP1
L5NFSB\SP2
L5NFSB\SP3
L5NFSB\SP4
L5NFSB\SP5
L5NFSB\SP6
L5NFSB\SP7
L5NFSB\SP8
L5NFSB\SP9
L5NFSB\SP10
L5NFSB\SP11
L5NFSB\SP12
L5NFSB\SP13
L5NFSB\SP14
L5NFSB\SP15
L5NFSB\SP16
L5NFSB\SP17
L5NFSB\SP18
LL5NFSB\SP19
L5NFSB\SP20


L5NFSBfSTr13
Advective & dispersive transport of radionuclides in groundwater
L5NFSBfSTr7
L5NFSBfSTr14
Distribution & release of radionuclides
L5NFSBfSTr15
L5NFSBfSTr6
L5NFSBfSTr16
Radionuclide sorption
L5NFSBfSTr12
L5NFSBfSTr5
L5NFSBfSTr4
L5NFSBfSTr3
L5NFSBfSTr18
Colloid transport
L5NFSBfSTr10
Gas-mediated radionuclide transport
Radioactive decay & ingrowth
L5NFSBfSTr11
Transport_and_release_of_radionuclides.vsd (Level 5)
Near_Field\Silo_section\Backfill\Sand_backfill\Transport_and_release_of_radionuclides\Transport_and_release_of_radionuclides.vsd


Degradation_of_waste_package.vsd (Level 5)
Near_Field\Silo_section\Waste_package\Chemistry_FEPs\Degradation_of_waste_package\Degradation_of_waste_package.vsd
Degradation of superplasticisers
Degradation of organic waste
Corrosion and degradation of waste container
Degradation of inorganic waste
Degradation of bitumen matrix
Corrosion of metallic waste
Degradation of cement matrix
L5NFSWPChDg1
L5NFSWPChDg2
L5NFSWPChDg3
L5NFSWPChDg4
L5NFSWPChDg5
L5NFSWPChDg6
L5NFSWPChDg7
L5NFSWPChDg8
L5NFSWPChDg9
L5NFSWPChDg10
L5NFSWPChDg11
L5NFSWPChDg12
L5NFSWPChDg13
L5NFSWPChDg14
L5NFSWPChDg15
L5NFSWPChDg16
L5NFSWPChDg17
L5NFSWPChDg19
L5NFSWPChDg20
L5NFSWPChDg21
L5NFSWPChDg22
L5NFSWPChDg23
L5NFSWPChDg24



Degradation of inorganic waste
Degradation of superplasticisers
Corrosion of metallic waste
Degradation of organic waste
Degradation of cement matrix
Degradation of bitumen matrix
Corrosion and degradation of waste container
Degradation_of_waste_package. vsd (Level 5)
Near_Field\BLA_Section\Waste_package_(BLA)\Chemistry_FEPs\Degradation_of_waste_package\Degradation_of_waste_package.vsd
L5NFBLAWPChDg1
L5NFBLAWPChDg2
L5NFBLAWPChDg24
L5NFBLAWPChDg12
L5NFBLAWPChDg11
L5NFBLAWPChDg19
L5NFBLAWPChDg3
L5NFBLAWPChDg17
L5NFBLAWPChDg13
L5NFBLAWPChDg4
L5NFBLAWPChDg20
L5NFBLAWPChDg15
L5NFBLAWPChDg22
L5NFBLAWPChDg14
L5NFBLAWPChDg16
L5NNFBLAWPChDg23
L5NFBLAWPChDg21
L5NFBLAWPChDg10
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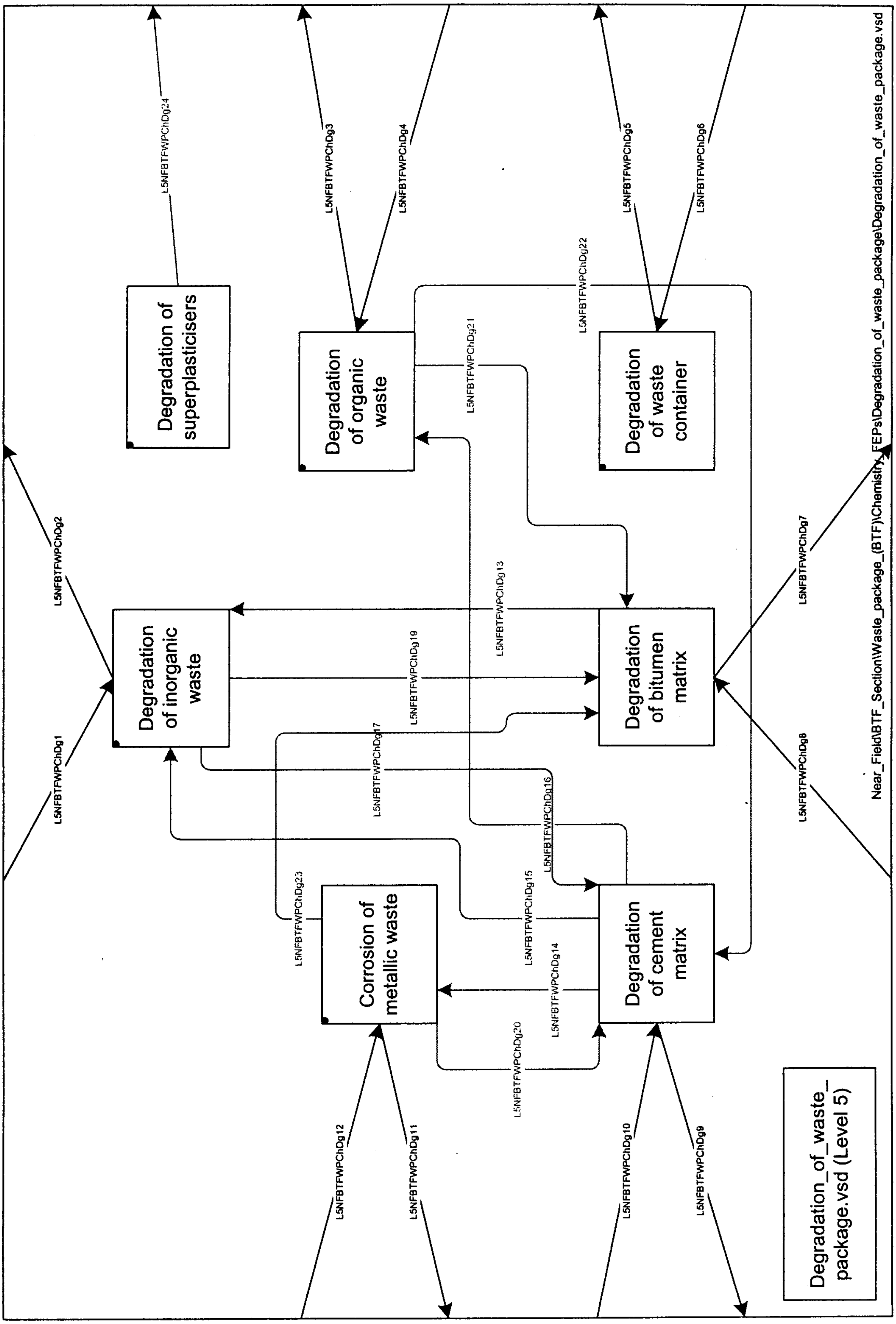
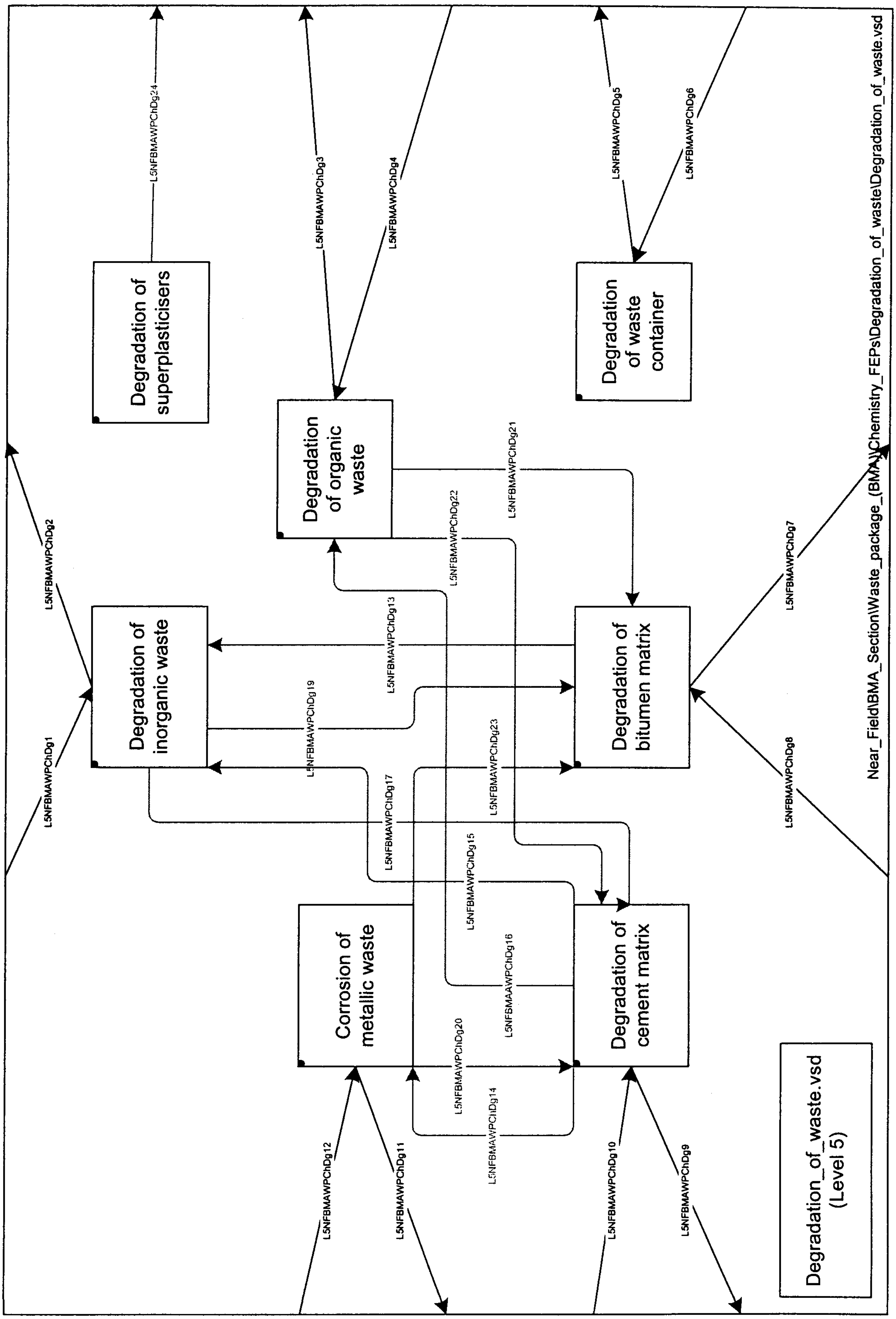
L5NFBLAWPChDg7



Degradation of superplasticisers
Degradation of organic waste
Degradation of waste container
Degradation of inorganic waste
Degradation of bitumen matrix
Corrosion of metallic waste
Degradation of cement matrix
Degradation_of_waste_package.vsd (Level 5)
Near_Field\BTF_Section\Waste_package_(BTF)\Chemistry_FEPs\Degradation_of_waste_package\Degradation_of_waste_package.vsd
L5NFBTFWPChDg1
L5NFBTFWPChDg2
L5NFBTFWPChDg3
L5NFBTFWPChDg4
L5NFBTFWPChDg5
L5NFBTFWPChDg6
L5NFBTFWPChDg7
L5NFBTFWPChDg8
L5NFBTFWPChDg9
L5NFBTFWPChDg10
L5NFBTFWPChDg11
L5NFBTFWPChDg12
L5NFBTFWPChDg13
L5NFBTFWPChDg14
L5NFBTFWPChDg15
L5NFBTFWPChDg16
L5NFBTFWPChDg17
L5NFBTFWPChDg19
L5NFBTFWPChDg20
L5NFBTFWPChDg21
L5NFBTFWPChDg22
L5NFBTFWPChDg23
L5NFBTFWPChDg24


Degradation of superplasticisers
Degradation of organic waste
Degradation of waste container
Degradation of inorganic waste
Degradation of bitumen matrix
Corrosion of metallic waste
Degradation of cement matrix
Degradation_of_waste.vsd (Level 5)
Near_Field\BMA_Section\Waste_package_(BMA)\Chemistry_FEPs\Degradation_of_waste\Degradation_of_waste.vsd
L5NFBMAWPChDg1
L5NFBMAWPChDg2
L5NFBMAWPChDg3
L5NFBMAWPChDg4
L5NFBMAWPChDg5
L5NFBMAWPChDg6
L5NFBMAWPChDg7
L5NFBMAWPChDg8
L5NFBMAWPChDg9
L5NFBMAWPChDg10
L5NFBMAWPChDg11
L5NFBMAWPChDg12
L5NFBMAWPChDg13
L5NFBMAWPCIIDg14
L5NFBMAWPChDg15
L5NFBMAAWPChDg16
L5NFBMAWPChDg17
L5NFBMAWPChDg19
L5NFBMAWPChDg20
L5NFBMAWPChDg21
L5NFBMAWPChDg22
L5NFBMAWPChDg23
L5NFBMAWPChDg24