Treatment of Seals and Sealing Systems in Total System Performance Assessment

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Total System Performance Assessments (TSPAs) for geologic disposal facilities (GDFs) generally assume that plugs and seals perform as expected during "normal evolution" in the post-closure period. In turn, the TSPA calculations show that the disposal system as a whole provides acceptable post-closure safety. Put another way, any intended post-closure safety function(s) of the plugs and seals – principally hydraulic isolation – is assumed to be fulfilled and to contribute to overall safety of the GDF. Uncertainty in seal performance in TSPAs is handled mainly through either parameter values for seal properties or alternative scenarios. Parameters representing seal properties are either conservatively kept constant over time or changed in a stepwise fashion. Changing properties over time are used to account for known, but often poorly constrained, processes. Some TSPAs, particularly those concerned with disposal concepts in low-permeability sedimentary host rock, consider scenarios that explicitly include a situation of poor seal performance. The bounding case of abandonment of a GDF before closure, i.e. before emplacement of final tunnel closures and shaft/access ramp seals, is also included in a number of TSPAs.

1 Introduction

A review has been undertaken to evaluate how sealing systems for deep or geologic disposal facilities (GDFs) have been considered in Total System Performance Assessments (TSPAs). The term TSPA is used here to emphasise the distinction between safety assessments for the performance of GDFs in their entirety and assessments or PAs for seals only, i.e. at a component scale. This review considers published TSPAs for a range of proposed, constructed and operational GDFs.

Given the objective of the review, it was considered desirable to cover as many examples of TSPAs as possible. It should be noted that the example for each country is the last published TSPA; in a number of cases, the TSPA is quite old and may not therefore represent the current programme position. The countries covered in the review and the associated Waste Management Organisation (WMO) and TSPA are listed below by host geological environment for the GDF:

- Crystalline host rock
  - Sweden - SKB SR-Site 2010, updated 2015 (SKB 2015), Spent Fuel (SF).
  - Finland - Posiva TURVA 2012 (Posiva 2012a), SF.
- Sedimentary non-evaporite host rock
  - France - ANDRA 2005 Argile (Andra 2005a,b), SF/high-level waste (HLW)/intermediate-level waste (ILW).
  - Switzerland - NAGRA Entsorgungsnachweis 2002, SGT-E2 (Nagra 2002, Poller et al. 2014), SF/HLW/ILW.

– Canada, OPG Deep Geological Repository (NWMO 2011), low-level waste (LLW) and ILW.
– Belgium - ONDRAF-NIRAS SAFIR2 (ONDRAF/NIRAS 2001), SF/HLW/ILW.

- Salt (evaporite) host rock
  – United States - USDOE Waste Isolation Pilot Plant (WIPP) Compliance Certification Application (USDOE 1996), updated 2004, 2009, and 2014, ILW.
  – Germany - GRS Vorläufige Sicherheitsanalyse für den Standort Gorleben – VSG 2012 (Larue et al. 2013, Rubel et al. 2014), SF/HLW/ILW.

2 Summary of Approaches

Overall, TSPA calculations for normal evolution scenarios generally assume that plugs and seals perform "as expected". In turn, the TSPA calculations show that each disposal system as a whole provides acceptable post-closure safety (e.g. SKB 2015, NWMO 2011, USDOE 2009). Put another way, any intended post-closure safety function(s) of the plugs and seals – principally hydraulic isolation – is fulfilled by expected performance and contributes to overall safety.

In reverse, TSPA calculations may be used to set design requirements for plug and seal performance – for example, what hydraulic conductivity is necessary to achieve a certain level of performance (e.g. Nagra 2002), and what levels of performance are achieved during normal evolution – for example, what is the radionuclide flux through a seal (e.g. Andra 2005b).

3 Treatment of Uncertainty

Treatment of uncertainty in seal performance in TSPAs can be categorised using the widely-used three-fold classification of parameter, model and scenario uncertainty (e.g. Crawford and Galson 2009; Figure 3-1). We provide examples of how uncertainty in seal system performance has been accounted for in TSPA via each of these means.

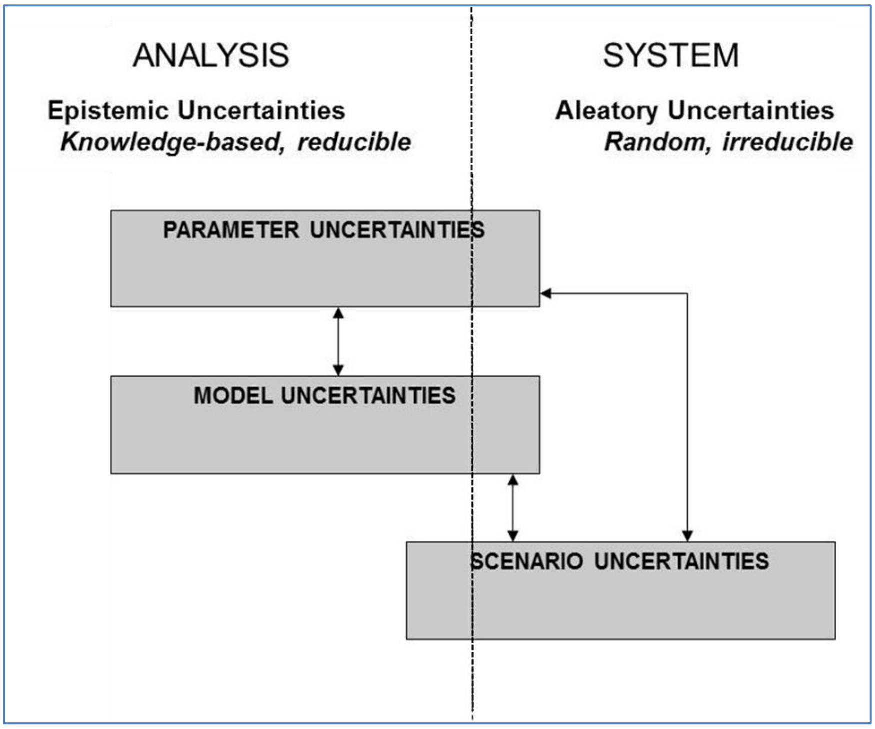

Figure 3-1. Classification and nature of uncertainties in TSPAs (Crawford and Galson 2009).

3.1 Parameter Uncertainty

Both deterministic uncertainty analyses and probabilistic calculations have been used to take account of uncertainty in the properties of seals. For example, the Reference Case groundwater flow modelling in the Finnish TSPA includes a calculation that incorporates a 0.1-m-thick crown space in disposal tunnels with a high hydraulic conductivity (10^{-3} m/s) (Posiva 2012b). The WIPP TSPA is a probabilistic assessment that samples the permeability of a concrete room seal (USDOE 1996; Figure 3-2). The parameter values for the analyses may be based on supporting modelling and/or expert judgement. The properties are either conservatively kept constant over time (e.g. USDOE 1996) or are changed in a stepwise fashion (e.g. Larue et al. 2013). Changing properties over time are used to account for known, but often poorly constrained, processes such as concrete degradation, salt compaction, and clay swelling. The potential for sudden change may drive scenario definition rather than be captured as parameter variation within the same scenario.

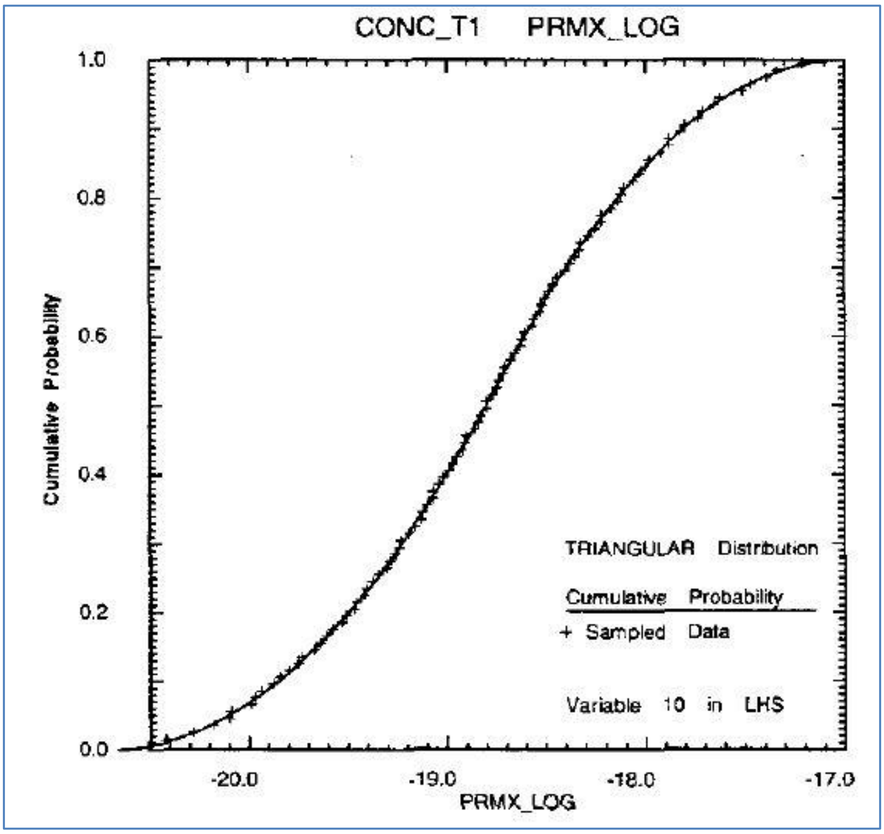

Figure 3-2. Cumulative probability function for the hydraulic permeability of concrete in a panel (room) closure (seal) at the Waste Isolation Pilot Plant (USDOE 1996).

3.2 Model uncertainty

Alternative model configurations or conceptual uncertainty in the modelling of features, events and processes might be captured through sets of analyses specified to address model uncertainty. For example, Poller et al. (2014) used flow modelling to assess the impact of alternative arrangements and performance of seals (Figure 3-3). The flow calculations were then used in a radionuclide release and transport model and biosphere dose conversion factors applied to calculate individual effective dose rates. However, no instances of “top-level” TSPA modelling of actual processes leading to changes of plugs and seal properties during a calculation were found in the review. For example, coupled processes relevant to seal system performance are not directly accounted for in TSPA.

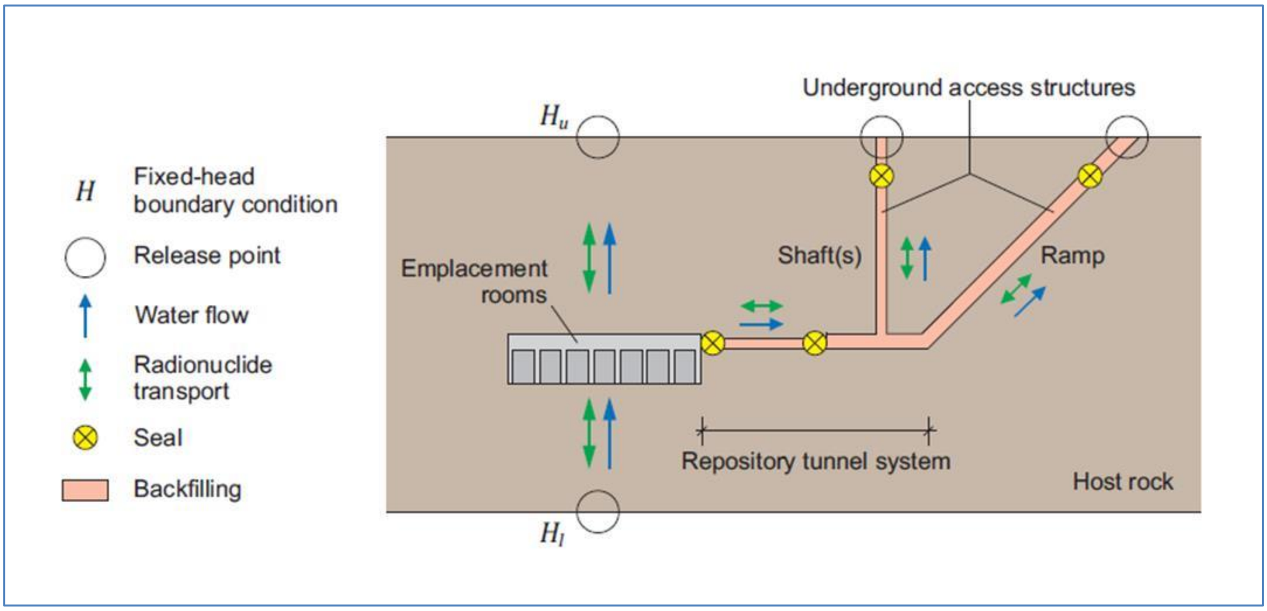

Figure 3-3. Possible access routes considered in modelling for a GDF for HLW and/or L/ILW in clay in Switzerland (Poller et al. 2014).

3.3 Scenario uncertainty

Some TSPAs, particularly those concerned with disposal concepts in low-permeability sedimentary host rock, consider scenarios that explicitly include a situation of poor seal performance. In such scenarios, however, advective migration of radionuclides generally remains limited, because virtually no water enters the disposal areas owing to the low hydraulic conductivity of the host rock (e.g. ONDRAF/NIRAS 2001, NWMO 2011). The bounding case of abandonment of a GDF before closure, i.e. before emplacement of final tunnel closures and shaft/access ramp seals, is included in a number of TSPAs (e.g. Andra 2005b). In the case of the Swedish TSPA for disposal of spent fuel in a crystalline host rock, the abandonment calculation is considered as a Future Human Action scenario (SKB 2015).

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