[Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	5 and 6 (Select the number from "Areas of Technologies Requested")
Title	Contaminant Migration Modelling and Risk Assessment
Submitted by	UK National Nuclear Laboratory (NNL)

1. Overview of Technologies (features, specification, functions, owners, etc.)

Contaminant migration modelling and risk assessment provides an important tool, both in supporting the understanding of the site and interpretation of site data, as well as in assessing the impacts of current groundwater contamination and its future migration. Such modelling allows the effectiveness of groundwater management options (e.g. groundwater barriers or chemical treatments) to be assessed, including identification of any potential detrimental knock-on effects (e.g. groundwater barriers modifying the groundwater flow regime with potential unintentional impacts on contamination migration routes). Contaminant migration modelling and risk assessment can be used to support safety cases and to demonstrate consistency with regulatory requirements and criteria.

NNL has a comprehensive capability for assessing the extent of contamination migration and the risks posed by it and can be summarised as:

- Many years' experience in constructing reactive transport models for contaminant migration and models for risk assessment;
- Use of both in-house (e.g. TRAFFIC) and commercially available codes, e.g. TOUGHREACT, MODFLOW-SURFACT, PHAST, GoldSim;
- In-house high performance computing facilities for rapid results;
- Modelling capability underpinned by in-house capabilities in site characterisation, laboratory analysis, conceptual model development and review of international good practice.

Building on site characterisation and the development of conceptual models, NNL has decades of experience in extending these into a variety of finite element and finite difference computer models. These include reactive transport codes incorporating 2D or 3D groundwater flows through the local geological features and consider the migration behaviour of different elements in terms of their individual chemistry (e.g. sorption and solubility). These are underpinned by fundamental geochemical models such as PHREEQC and peer-reviewed chemical databases.

These models can be applied to assess historical, current and potential future contamination

areas. Such models need to be calibrated and provide an appropriate good fit to measured site data. The outputs from these models, providing simulated activity levels in the aqueous and solid phases (i.e. in groundwater and soils) can allow site operators to predict the arrival times of contamination at various locations (e.g. a site boundary) and determine appropriate mitigation or remediation responses.

The outputs from contamination migration modelling can then be used to inform risk assessment models, which determine the impacts of contamination through its interaction with the biosphere. The source term component of the assessment model describes the release of activity to the geosphere, e.g. due to leakage from a building. The geosphere component describes the transport of radionuclides from the source to the biosphere via the groundwater pathway, accounting for both unsaturated and saturated zones, including fast pathways, e.g. fractures in geological media or man-made features. The biosphere component of the assessment model represents areas of, for example, the coastal and marine environment (beach, water bodies and underlying sediment bodies) and the terrestrial environment (soils and surface waters, e.g. rivers and streams). The habits of exposure groups map to regions of the biosphere model and the corresponding radionuclide concentrations can be used as the basis of dose/risk calculations.

NNL Experience of Applying Contaminant Migration and Risk Assessment Models

A legacy waste storage facility at the Sellafield site comprises a series of water filled concrete waste silos, into which intermediate level wastes were consigned. During the 1970s, leakage of radioactivity to ground occurred and the possibility of renewed leakage during retrievals and decommissioning cannot be ruled out.

In order to address these concerns, NNL was contracted to undertake a radiological risk assessment to obtain:

- additional doses/risks to receptors associated with potential future leaks of activity to ground; and
- arrival times and plots of activity concentrations versus time at various selected locations for key radionuclides.

A two-phase approach was taken to the assessment modelling. The first phase involved the development of a groundwater flow and contaminant transport model using NNL's TRAFFIC code to inform the risk assessment model on groundwater pathways and velocities, to determine the extent of plume development (Figure 1). The second phase used outputs from this model to develop a risk assessment model using the GoldSim code to describe the transport of

radionuclides from the source, through the geosphere to the biosphere, to calculate doses and risks to exposed groups and to calculate groundwater concentrations and arrival times of key radionuclides. Separate GoldSim model runs were undertaken to investigate a number of leak scenarios and variant cases. An example GoldSim model of a geosphere system linking the source and the biosphere is shown in Figure 2.

An assessment of non-human biota ecological risk from ionising contaminants was also undertaken using the ERICA (Ecological Risk from Ionising Contaminants: Assessment and Management) Integrated Approach.

This work has built upon over 10 years of experience by NNL members of staff in conducting site characterisation studies, conceptual model development, groundwater flow and transport modelling and safety assessments in relation to land contamination at the Sellafield site. This supports decision making regarding land quality management.

The output from this particular study has been used in discussions with the regulators to determine the requirements for leak mitigation measures during retrievals from the silos.

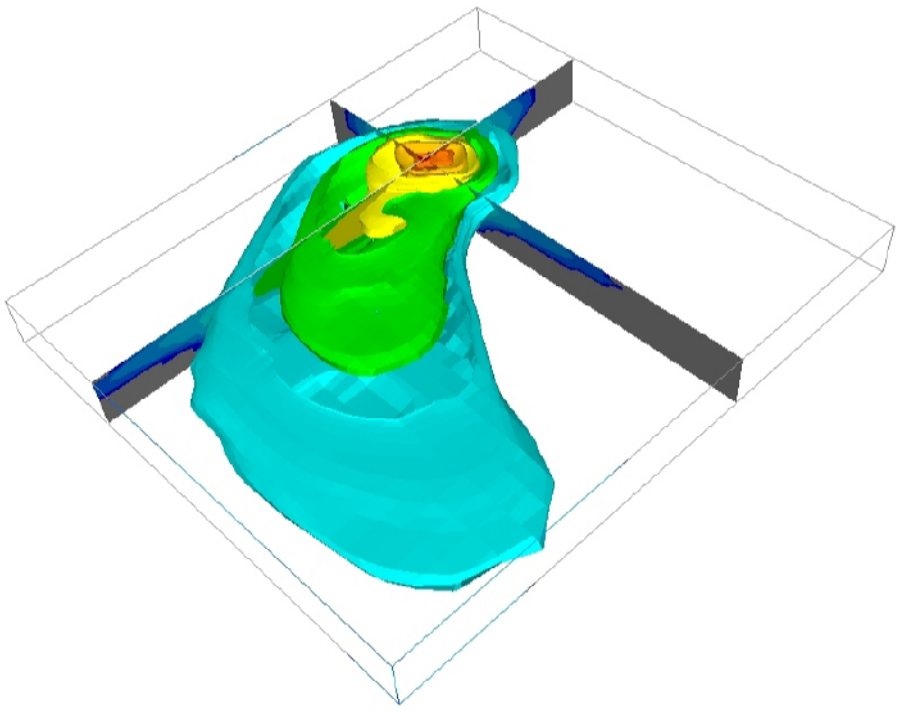

Figure 1 – Contaminant transport model output

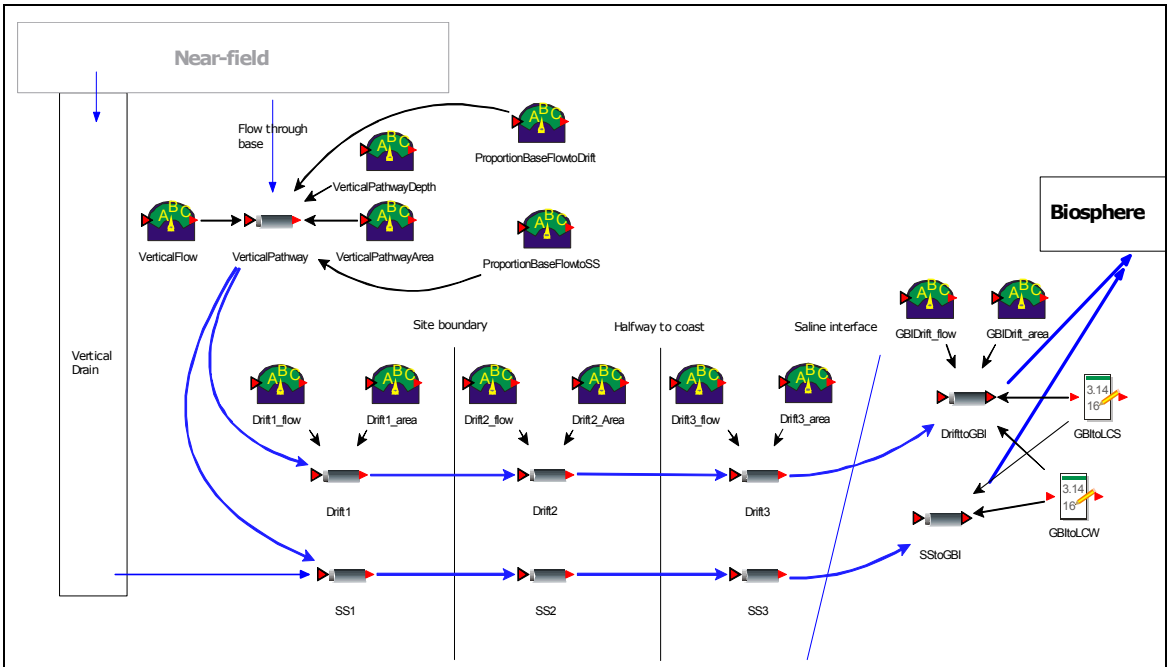

Figure 2 – Example GoldSim Geosphere Model Linking Source to Biosphere

Review of International Good Practice for Groundwater Modelling and Risk Assessment

On behalf of Sellafield Ltd, NNL undertook a review of worldwide/international good practice for groundwater modelling and risk assessment for radiologically contaminated land. The review involved the identification of good practice based on guidance documents and case studies. The findings of the review were used as a basis to assess the consistency of methods used in a previous Sellafield contaminated land assessment. This review focused on the numerical models of contaminant fate and transport and environmental risk assessment models.

2. Notes (Please provide following information if possible.)

- Technology readiness level (including cases of application, not limited to nuclear industry, time line for application)

TRL 9. Models have been applied and validated at a number of UK and international nuclear sites.

- Challenges

Modelling techniques – Requires development of a robust conceptual model, supported by site data, and management of uncertainties in data and understanding of processes.

- Others (referential information on patent if any)