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A Generic Water Balance Model for a Trench Repository

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1. Introduction

A simple and effective model and a GoldSim [1] template program, by which a probabilistic safety assessment of a conceptual trench type repository system for low-level radioactive waste (LILW) disposal can be carried out, have been extended from a previous study [2] by adopting a water balance in and around the trench, as described in Fig. 1.

To quantify the exposure dose rates from the nuclide release and transport through the various pathways possible in the near- and far-fields of the LILW repository system, various scenarios are to be conveniently simulated in a straightforward manner and extensively with this GoldSim model, part of which is shown in Fig. 2, as similarly developed for other various types of repositories in previous studies [3-11]. Through this study, a result from four scenario cases, each of which is or is not associated with water balance, are compared to each other to see what happens in different cases in which an overflow over a trench rooftop, stochastic rainfall on the trench cover, and an unsaturated flow scheme under the trench bottom are combined. The other two latter elements vary periodically owing to stochastic behavior of the time series data for the past rain-fall records.

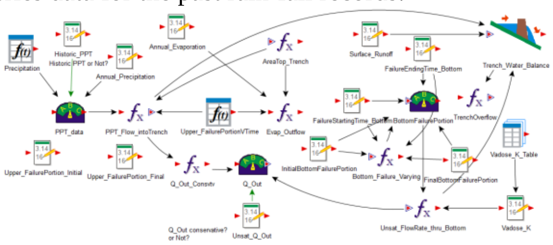

Fig. 1. Construction of a GoldSim Model.

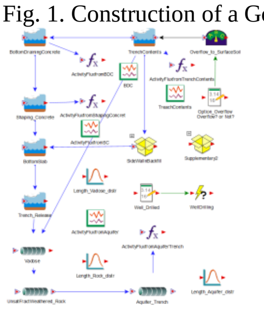

Fig. 2. Water balance modeling in and around the trench.

2. Nuclide Transport Scenario and Modeling

The 200*l* storage drum packages for LILW, which amounts to a total of 125,000 packages, are assumed to be disposed of in a trench with multiple concrete barriers and then buffered and grouted with concrete. Impervious and multilayered trench covers for preventing water infiltration and some erosion, as well as nuclide release, are considered to be placed on the rooftop.

In such GoldSim modeling, a trench and its surrounding concrete barriers and geological media are discretized into several compartments. The waste is to be disposed of in multiple concrete barrier boxes in the trench, and the inside is buffered by filling concrete.

For trench-type repositories at the surface or possibly at a subsurface depth, once leakage from a damaged radioactive waste package occurs through tiny holes, the nuclides will commonly spread out into the buffer material surrounding the waste, and then into other possible barrier regions in and around the trench before being transported into the biosphere through various pathways in the natural far-field area.

In the case of transport into porous soil and weathered rock media under the trench, both of which are unsaturated, an aquifer that probably exists in the far-field area of the repository could be one of the main pathways, through which the nuclides finally reach the human environment, by passing over the geosphere-biosphere interfaces for exposure to human bodies.

Through this study, the four scenarios for nuclide release and transport are mainly considered conservative cases, under which nuclides are released by groundwater that normally flows along their own preferential pathways after release from the repository, as well as several possible cases that are described in detail in a previous study [2].

Unlike this previous study, both the upward overflow pathway through the cover and stochastic time series precipitation data scheme based on historic rainfall records from the past couple of years are newly included. To this end a water balance model was introduced, as shown in Fig. 1, which includes a new pathway, “overflow” and an unsaturated flow based on Darcy’s law instead of a fixed input. Unlike the conventional pathways for two normal side and base pathways, all of which simultaneously reach the unsaturated vadose zone under the trench for farther far-field transport, an overflow path over a trench rooftop is suggested only for transport directly into the surface soil bypassing all geological media involved including an aquifer pathway. However, all nuclide releases from the trenches are transported and reach the biosphere in the long run.

3. Illustration

Table 1. Scenario Scheme

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Overflow	yes	yes	no	no
TS rainfall	yes	yes	yes	no
Unsat. Flow	Darcy	fixed	fixed	fixed

Illustrative cases for a comparison among these four scenarios are compared in Table 1.

The long-term confinement and release of nuclides from a near-field engineered barrier system rely on reliable waste packages, a concrete buffer, and concrete barriers of the trench. The case of imaginary failure events for the rooftop and bottom of a trench are also postulated, as shown in Fig. 3, which might be expected in view of the long-term performance of the repository.

A set of rainfall data are brought from the past historic records as time series data, as shown in Fig. 4 (left), which are also needed for the water inflow rate into the trench, as well as input for the overflow calculation from the water balance model, as shown in Fig. 4 (right).

The total dose rates of the farming exposure group evaluated from each of the four scenarios are plotted together in Fig. 5. The results from a normal case with an overflow (Scenario 1), which shows the highest peak value, is compared with the other three scenarios.

An overflow case with stochastic rainfall time-series data is adopted for Scenarios 1 and 2. A fixed unsaturated flow rate instead of Darcy's flow scheme in consideration of the water balance is used only for normal scenario 1. For Scenario 4, a fixed precipitation rate instead of time-series rainfall data was solely used. This is why, unlike the other three curves, fluctuation along the curve is not observed for this scenario.

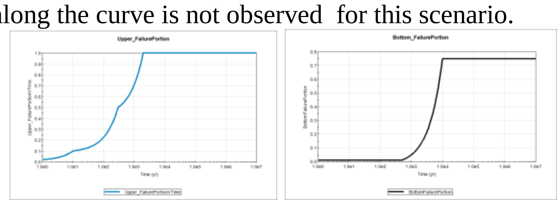

Fig. 3. Failure portion as a function of time: upper cover (left) and trench bottom (right).

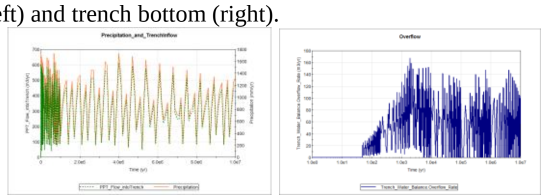

Fig. 4. Annual precipitation and inflow (left) and trench overflow output (right).

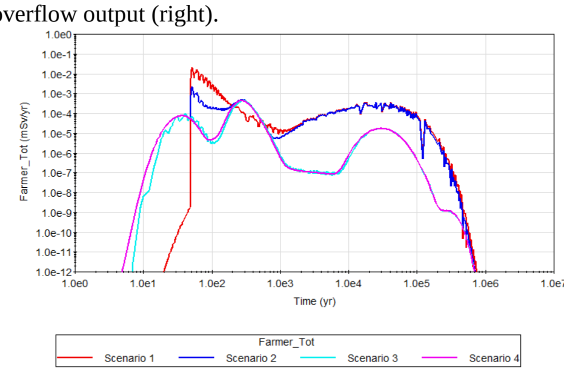

Fig. 5. Comparison of total dose rate to the farming exposure group among four scenarios.

4. Conclusions

A simple and effective model previously developed [2, 3] for a safety assessment of a conceptual trench repository system, in which an LILW that arises from a nuclear power plant and other sources, has been extended with a water balance scheme in and around the trench using rainfall time series data. This program is ready for a total system performance assessment and is able to deterministically and probabilistically evaluate the nuclide release from a repository and farther transport into the geosphere and biosphere under various scenarios that can occur after a failure of waste packages with associated uncertainty. An illustration conducted through a study with a new water balance scheme shows the possibility of a stochastic evaluation associated with the stochastic behavior and various pathways that happen around the trench repository.

Despite the conceptual design of a trench type LILW repository system, all parameter values associated with the repository system were assumed, and the generic model developed through this study should be helpful not only for a safety assessment of the repository, but also for the design feedback of its performance.

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