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# Use of GIS and 3D Modeling for Development and Conceptualization of a Performance Assessment Model for Decommissioning of a Complex Site

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## ABSTRACT

Geographic Information Systems (GIS) and 3D geospatial modeling were employed to facilitate development and conceptualization of a performance assessment (PA) model that will be used to evaluate the health impacts of residual radioactivity at a former nuclear materials processing facility site in New York. Previous operations have resulted in a number of different sources of radiological contamination that must be assessed during site decommissioning.

A performance assessment model is being developed to estimate radiological dose to potential receptors through the simulation of the release and transport of radionuclides, and exposure to residual contamination for hundreds to thousands of years in the future. A variety of inputs are required to parameterize the performance assessment model, such as: distance from the waste to surface water bodies, thickness of geologic units for saturated transport, saturated thickness of the geologic units, and spatial and temporal average of percent of waste that is saturated. GIS and 3D modeling are used to analyze and abstract aleatoric uncertainty associated with the dimensionality of the geologic system into epistemic uncertainty for one- and two-dimensional process models for flow and transport of radionuclides.

Three-dimensional geospatial modeling was used to develop the geologic framework and the geometrical representation of the residual contamination within the geologic framework. GIS was used in the initial development and parameterization of the transport pathways, to provide spatial context to the PA model, and to link it to the 3D geologic framework and contamination geometry models. Both the GIS and 3-D modeling were used to interpret the results of runs of the PA model.

## INTRODUCTION

The West Valley site located near Buffalo, New York, was the location of the reprocessing of commercial spent nuclear fuel. Previous operations have resulted in a number of different sources of radiological contamination that must be assessed during site decommissioning including: below-grade high-level waste storage tanks, process buildings and wastewater lagoons, a groundwater plume of primarily Sr-90, surface contamination of soil with Cs-137, and waste disposal areas. The Department of Energy (DOE) currently has authority over the materials at the West Valley site.[1] The NRC is a cooperating agency with DOE in the development of the decommissioning environmental impact statement (EIS) for West Valley. The NRC is

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developing a performance assessment model in order to risk-inform its review of DOE's PA used in the EIS decision making process and to provide a confirmatory analysis.

A performance assessment model is designed to estimate radiological dose to potential receptors through the simulation of the release and transport of radionuclides, and exposure to residual contamination in the future. The location of receptors with respect to the contamination can be limited by ongoing controls at the site, or in the case of no institutional controls, by the availability of natural resources (e.g., water). The radiological dose to both onsite and offsite receptors can be limited by transport through the geologic system, particularly for shorter-lived radionuclides or for those with strong sorption.

The radiological sources and the geologic system in which the material is present is three-dimensional. Because a performance assessment model must simulate a large number of processes from waste release to eventual uptake by receptors, computational burdens can become excessive. A performance assessment model must strike an appropriate balance between representing enough of the key features and characteristics of a site to provide a reasonable risk assessment with the computational burden imposed by explicitly representing those key features and characteristics. Also, the complexity of the models in most cases should not exceed the level of information available to constrain and support the models. In this paper, techniques to represent system variability, mostly resulting from the three-dimensional hydrogeologic system, as epistemic uncertainty in more simple one- and two-dimensional transport models are presented.

## DATA ANALYSIS AND MODEL DEVELOPMENT

Even though a performance assessment model is usually a highly-abstracted representation of the actual system, they can be data intensive and complex. The amount of information that is available to support a performance assessment can be quite variable from extensive to limited. Integration, visualization, and interpretation of data can be difficult when it is distributed throughout technical reports. GIS and 3D modeling may be valuable tools in the development of a PA model whether the amount of supporting information is limited or extensive.

The software package GoldSim, developed by GoldSim Technology Group LLC of, Issaquah, WA, is being used to develop the PA model for the West Valley site. Built-in GoldSim transport elements (pipes) that can take into account radioactive decay and ingrowth, adsorption, dispersion, advection, and matrix diffusion (for fractured flow) were used to model contaminant migration. The properties of transport pathways (e.g., length and geologic materials) can have a strong influence on which types of radionuclides dominate the risk at a given site. Mining Visualization System (MVS) from CTech Development Corporation in Huntington Beach, CA was used to construct a 3D geologic framework for the West Valley site, from well bore data supplied by DOE. Eleven stratigraphic layers were modeled, along with the groundwater table. MVS was also used to build a geometrical representation of the residual contamination of numerous radionuclides within the geologic framework.

GIS was used in the initial development and parameterization of the transport pathways, to provide spatial context to the PA model, and to link it to the 3D geologic framework and

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contamination geometry models. GIS analysis was performed using ArcView 3.2a with the Spatial Analyst 2.0a extension, both are products of Environmental Systems Research Institute, Inc. of Redlands, CA. The modeled horizons of each geologic unit and the groundwater table were exported from MVS for use in the GIS application. The GIS software was also used to model and map the spatial variability of terrain attributes and other properties considered when building the PA model. This aided in the conceptualization and selection of the areas to be represented by transport elements in the PA model. Once the final area represented by each element was decided upon, statistics of all properties stored in the GIS were calculated for each polygon using overlay analysis and the distance between transport elements was calculated. These statistics were used in an iterative process for setting parameters in the PA model.

**Site Description**

The PA model simulates release, transport, and exposure to contaminants from the sources considered to most likely cause the largest risks. Figure 1 provides a photograph of the site. The West Valley site is characterized by North and South plateau areas divided hydrogeologically by a small stream named Erdmann Brook. Both plateaus are comprised of a series of glacial/fluvio-glacial units overlying Upper Devonian bedrock. The North plateau is comprised primarily of a permeable sand and gravel unit underlain by a much less permeable lavery till layer. Contaminants are expected to migrate vertically to the sand and gravel unit, then transport horizontally to discharge into a series of streams. Primary sources for the North Plateau are the High-Level Waste (HLW) tanks, lagoons, process building, and the Sr-90 plume. Properties of the North Plateau are such that a receptor could use groundwater from the sand and gravel unit for domestic or irrigation purposes. The South Plateau has very little of the sand and gravel unit. Instead the top geologic layer from the ground surface is the weathered Lavery Till, underlain by the unweathered Lavery Till. Groundwater travels primarily horizontally through the weathered lavery till and its properties are such that it is not expected that receptors will use it as a source of water. Primary sources of potential contamination for the South Plateau are the NRC-licensed Disposal Area (NDA) and the State-licensed Disposal Area (SDA). Primary groundwater transport directions are shown by the red arrows; however, these transport directions can be temporally and spatially variable.

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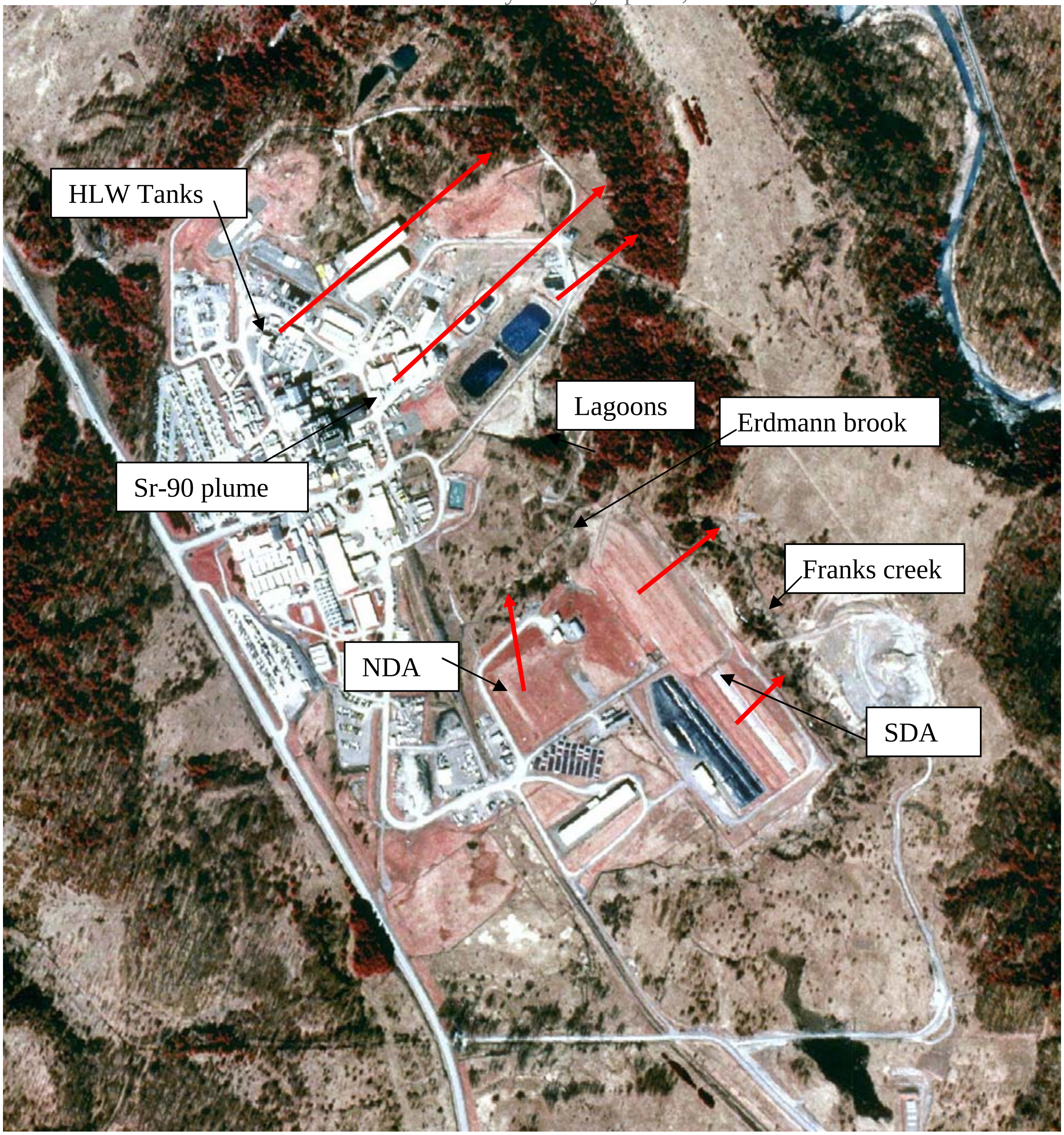


Fig.1. Photograph of the West Valley site

**GIS Model Description**

MVS [3] was used to construct a 3-D geologic framework model for the site from stratigraphic contacts recorded in well bore data supplied by DOE. A total of 294 boreholes contained geologic information for the site. Initially eleven stratigraphic layers were modeled as kriged hierarchical surfaces using the Krig_3D_Geology method provided in the software. The units of primary interest for this study were the sand and gravel layer, the surficial unit of the North Plateau; the weathered Lavery Till, the surficial unit of the South Plateau; and the unweathered Lavery Till, the unit underlying surficial deposits. A subset of the geologic framework model

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was created containing only these three layers. The water table level was generated for the North and South Plateaus from the average of all water level measurements taken over the period 1995-2003. There were 52 groundwater wells for the sand and gravel unit (North Plateau) and 15 wells for the weathered Lavery Till unit (South Plateau).

Figure 2 shows the resulting five-layer 3-D model. The modeled horizons of the three primary geologic units and the potentiometric surface for both the North and South plateaus were exported from MVS as point shapefiles for use in the ArcView 3.2a GIS application.[4] The point shapefiles contained the XYZ coordinates for the center of each grid cell in the geologic framework model. All subsequent GIS analysis was performed using ArcView and the Spatial Analyst extension.[5] Each shapefile was converted to a raster grid representing the elevation of that surface, resulting in surfaces for the land surface, bottom of the sand and gravel water table, the bottom of the sand and gravel unit, the water table level in the weathered Lavery Till, the bottom of the weathered Lavery Till, and the bottom of the unweathered Lavery Till. Flow direction grids were calculated for each water table surface and then sinks in the surfaces were identified and filled. The flow direction grids were recalculated and used to calculate flow accumulation grids. The flow accumulation grids were used to determine the contributing area for each of the main catchments found on the site. A drainage shapefile was used to mask out the grid cells on each potentiometric surface which were intersected by drainage features. For each PA model element, a point shapefile was created from the vertices of the polygon shapefile outlining the element and a uniform grid of points within the element. The point shapefiles were used as pour points for creating flow paths along the potentiometric surface underlying each PA model element. Map algebra was used to calculate a thickness grid for the saturated and unsaturated zones within the sand and gravel and weathered Lavery Till units, and the unweathered Lavery Till.

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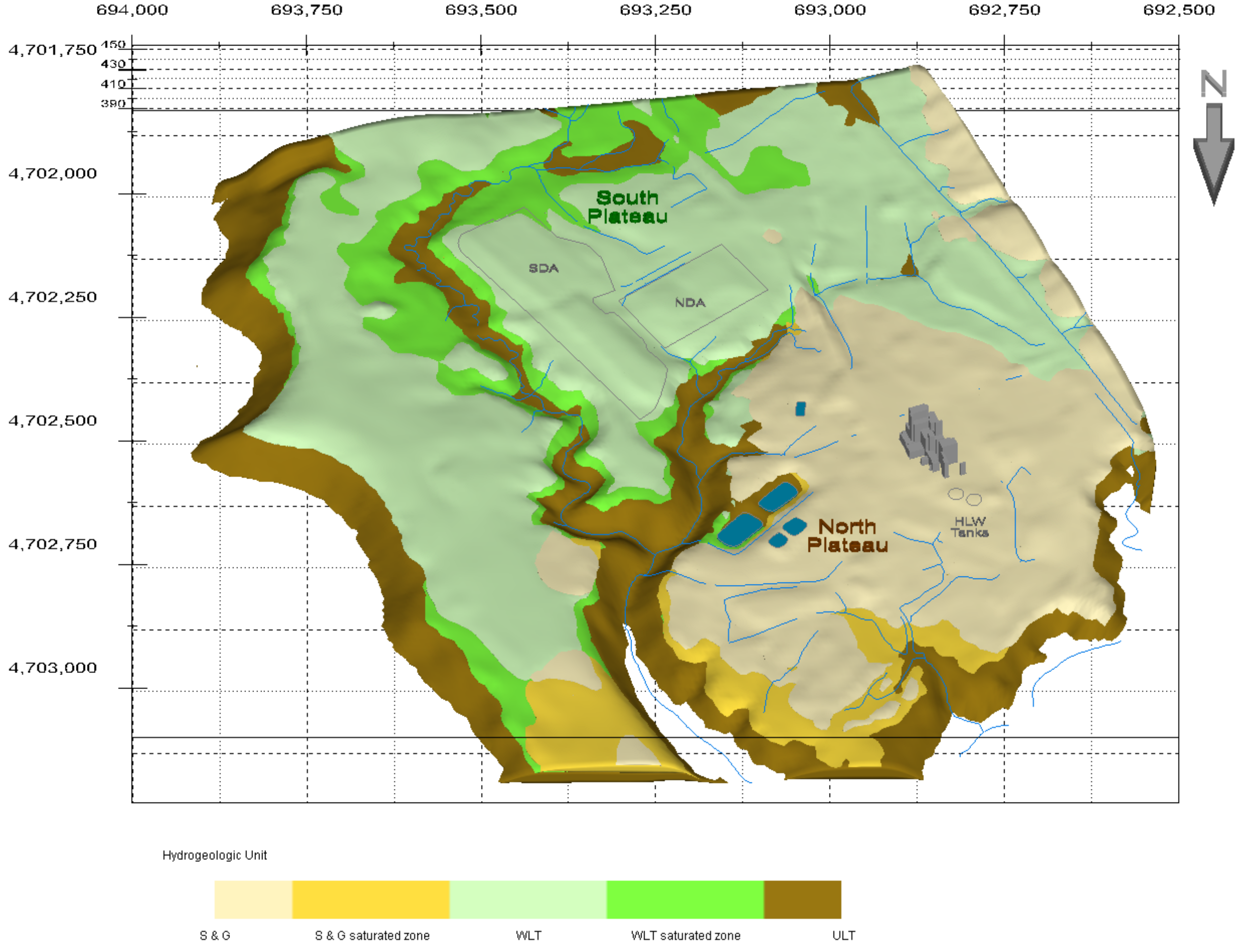


Fig.2. Hydrogeology at the West Valley site

MVS was used to model the geometry of residual contamination of numerous radionuclides within the North Plateau portion of the geologic framework model. The contaminants modeled were gross beta, Sr-90, Tc-99, Tritium, Np-237, Pu-238, Pu-239, Pu-241, U-234, U-235, and U-238. Soil contamination was modeled for 1993, 1997, and 1998 and groundwater contamination was modeled for 1994, 1997, and 1998. Not all contaminants were measured in each year. The contamination data were normalized with respect to Sr-90, allowing for radioactive decay since the time of release. The model element shapefiles were draped over the contamination models for further assessment of the assignment of these elements. Polygon shapefiles were created in the GIS to cover the spatial extent of the area represented by each transport element. The GIS software was also used to model and map the spatial variability of terrain attributes and other properties considered when building the PA model. This aided in the conceptualization and selection of the areas to be represented by transport elements in the PA model.

Once the final area represented by each element was decided upon and the shapefiles edited, statistics of all properties stored in the GIS were calculated for each polygon using overlay analysis and the distance between transport elements was calculated. For each model element statistics were generated of the area of each geologic unit underlying the element; the minimum, maximum, and mean thickness of the unit within the area covered by the element; the area of the

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element contributing to each catchment; and the minimum, maximum, and mean flow length to each catchment calculated from the pour points in the shapefile described above. These statistics were used in an iterative process for setting parameters in the PA model. Both the GIS and 3-D modeling will be used to help interpret results from the PA model. Maps will be created to illustrate the estimated contributions to dose of each area represented in the PA model as model parameters were manipulated. Animations will be generated to visualize how each area's contribution is projected to change over time.

**PA Model Description**

The performance assessment model has been developed to assess the risk from release of radioactivity from a variety of waste management areas to onsite and offsite receptors. The model contains over 2000 GoldSim elements, prohibiting a complete description of the total model here. GoldSim elements can range from cells to represent release and environmental transport, to stochastic parameter distributions, to expression elements which are essentially mathematical equations. It should be noted that the PA model is revised and edited as risk insights are developed and more information about the site and its characteristics become available. The current version of the PA model is considered a beta version for evaluation. The main features of the model and its general organization are provided here. The model can be used to estimate radiological impacts to different types of receptors (e.g., resident, farmer, recreational user [onsite or offsite], intruders [acute or chronic]) through multiple exposure pathways. Parameter and model uncertainty were included through the use of more than 700 stochastic elements. The model is composed of three main parts: 1) source term and near-field release, 2) saturated zone and surface water flow, and 3) dose assessment. The model contains information about radionuclide inventory, decay chains, and fluid and geologic material properties.

Figure 3 is a simplified conceptual picture of the basic components used to simulate release and transport of radionuclides through the environment in the PA model. Six main waste management areas (sources) are represented in the model (HLW tanks, lagoons, process building, Sr-90 plume, NDA, SDA). Each source may have unique characteristics in terms of the geology, transport pathways, engineered features to contain or limit the release of contamination, and the distribution of contamination, that would result in deviations from the basic conceptual representation provided in Figure 3. The description that follows is consistent with Figure 3.

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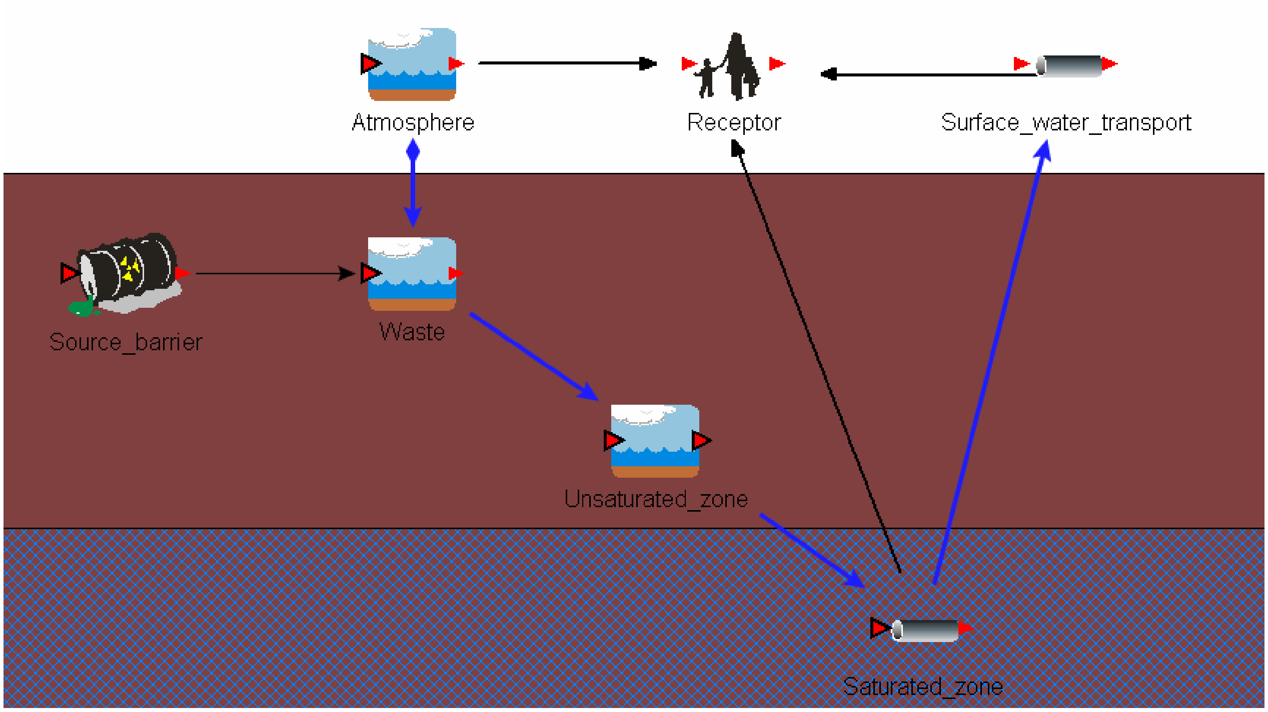


Fig.3. Simplified conceptual diagram of the main components of the PA model

Releases from the source may be controlled by engineered features (e.g., engineered cap, cements, slurry walls) that are represented by failure time distributions and controlled release rates (bound waste degradation rates). After material is made available for environmental transport, the concentration of radionuclides in the source region is calculated based on partitioning between the fluid and solid phases, application of solubility limits, and calculation of advective and diffusive fluxes. Gaseous species can diffuse through overlying soil to the atmosphere, where environmental concentrations are calculated that receptors are potentially exposed to. Transport via the water pathway occurs from the source vertically through the unsaturated zone (if present). Radionuclides fluxes from the unsaturated zone enters the saturated zone where transport occurs horizontally through the aquifer and to surface water. Receptors may potentially be exposed to withdrawals from the saturated zone at any point along the pathway, withdrawals from the surface water bodies, or directly to the surface water bodies depending on the receptor and exposure scenario. Contaminated water entering the saturated zone from the unsaturated zone is diluted by clean water flowing through the aquifer. The model simulates radionuclide transport given information about groundwater and surface water movement. The PA model does not calculate hydraulic gradients based on modeled precipitation or infiltration. Instead, information about groundwater movement is based on site-specific information about the speed of groundwater flow in the area and an assumption that the contaminants will be well-mixed over the relatively thin geologic units (i.e., the well screen length will be consistent with the saturated thickness of the transport units). Water is assumed to flow from the area under the waste through a stream tube in the saturated zone toward a surface stream. Water flow through the saturated zone is modeled as flow through underground stream tubes (pipe elements). The flow of water through the tubes is represented by the flow velocity (a stochastic parameter based on hydraulic gradients and hydraulic conductivities developed from

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site measurements) multiplied by the lateral area of the stream tube, where the lateral area of the stream tube is represented by the characteristic length of the waste on the surface multiplied by the estimated depth over which contaminants will be mixed in the aquifer.

A variety of exposure pathways are represented in the model depending on the scenario selected. Select main exposure pathways include: drinking contaminated groundwater, consuming plants grown in a garden using contaminated irrigation water, inadvertent soil ingestion, consumption of fish caught in a stream, consumption of deer that have ingested contaminated water, consumption of milk, eggs, and beef from animals raised with contaminated water and fodder and direct radiation exposure to the garden and field soils. The dose analysis is based on the concentrations of contaminants calculated by the model multiplied by the appropriate dose conversion factors that relate environmental concentrations to receptor doses for each pathway. The dose conversion factors used in the model are from Federal Guidance Report 11 and 12.[6, 7] The environmental concentrations of radionuclides in the model were calculated with submodels developed by NRC staff. The submodel to calculate receptor dose due to specific uptake pathways was borrowed extensively from a model created by John Tauxe of Neptune and Company.[8]

## ANALYSIS

The focus of this paper is on the use of GIS for development of the site conceptual model, analysis of the characterization data of the site, and abstraction of that information for use in the performance assessment model. The main outputs developed from the GIS and 3D geologic modeling were: a conceptual representation of the hydrogeologic system, hydrogeologic unit thicknesses (saturated and unsaturated) at each waste management area, the flowpaths and their lengths to the surface water bodies, and the catchment area of each source potentially contributing to the flowpath. Figure 4 provides a image from the GIS modeling showing each waste management area (GIS PA model elements), the projected flow paths based on current information, and the fraction of each waste management area that may contribute to the flowpath.

The actual waste management areas are three-dimensional objects embedded in a three-dimensional geologic system. The challenge is developing a performance assessment model that is computationally efficient while preserving the uncertainty and variability in the data. The approach for development of this performance assessment model is to abstract the variability in the information as uncertainty. This approach is expected to overestimate the uncertainty, preserve the mean risk generated with the probabilistic analysis, and allow for computational efficiency. This approach would not work if a deterministic analysis was being used. The rectangular shape at the bottom of Figure 4, which is a plan view of the NDA, shows two colors representing the portions of the disposal area that are expected to have different flow paths. In the PA model, sampled variables were defined to determine which flowpath would be simulated in a given probabilistic realization. The flowpath length from the portion of the area that is active in a realization is then sampled from a distribution that was developed from the plan view area of the source and the projected distances from the source to the relevant stream segment. This approach was taken to maintain the model, which is already fairly complex, as simple as possible. While the variability of the system would not be preserved within a realization, over the full probabilistic simulation the impact of the variability should be represented.

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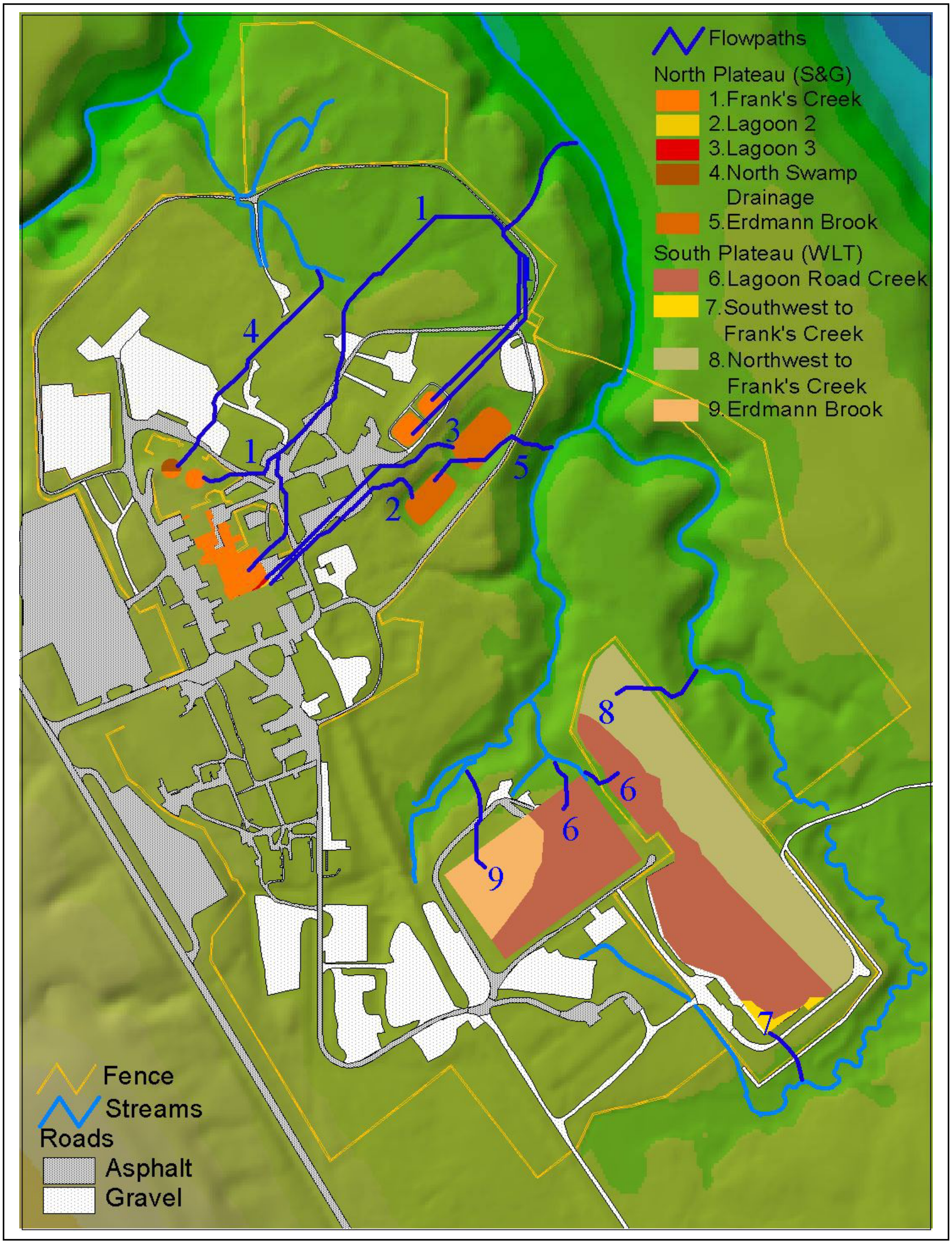


Fig.4. Projected flowpaths and contributing areas from the waste management areas

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The projected variability in geologic unit thicknesses at each waste management area from the 3D geologic modeling were abstracted into the PA model as probability distributions that determine the length of the transport cells for the unsaturated zone in each realization. In some waste management areas, a fraction of the source is projected to be saturated while the remainder is unsaturated. The variability in the saturation state of the source is represented in a model using an approach analogous to that described above for flowpath length. Stochastic parameters are used to sample the saturation state of the material. If the parameter indicates the source is saturated, then the thickness of the unsaturated transport cells is sampled to be very thin, effectively bypassing the unsaturated zone. Utilization of this approach required a combination of logic statements and stochastic elements in the performance assessment model.

## RESULTS

Table I provides a summary of the hydrogeologic unit thicknesses for various PA areas. In some instances, the data was developed for more areas than were explicitly modeled in the PA. For example, the thickness information for the lagoons (provided as 5 lagoons from the GIS modeling) was abstracted as a single distribution that encompassed the information for all lagoons (represented as one lagoon in the PA model with the cumulative inventory of all lagoons). In addition, whereas the data from the 3D geologic modeling was provided in the form of minimum, maximum, range, mean, and standard deviation, in some cases distributions were assigned that would overestimate the uncertainty in the data. Interpretation of the data from the 3D geologic modeling may have suggested a truncated normal distribution is the appropriate choice, but a uniform distribution was assigned in the PA model to account for uncertainty in the analysis with the 3D geologic modeling.

Table II provides the summary of flowpath information including the main catchments and the area of the source contributing to the catchment developed with the GIS modeling and abstracted in the performance assessment model. The column in Table II labeled *Figure ID* references the flowpaths shown on Figure 4. Some waste management areas (e.g., the HLW tanks, the NDA, SDA) are expected to have flowpaths in multiple directions through the aquifer to the surface water system. In addition, the flowpath lengths can be substantially different from different areas of an individual source. Roughly two thirds of the fractional area of the source for HLW tank 8D-1 is expected to have a mean flowpath length that is about half of the remaining area. The impact of the variability on the PA model results was evaluated by performing simulations with uncertainty in the variables such as flowpath, flowpath length, and geologic unit thicknesses sampled, and the results compared to simulations where those parameters were fixed at constant values but all other parameters were sampled from identical distributions as in the first simulation.

Preliminary model results comparing a typical PA model developed without the use of GIS and 3D modeling (that may have over-simplified the transport pathways) with the PA model developed with these tools shows the contribution geologic variability and uncertainty can have on simulation of radiological impacts from residual contamination have been developed.

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Table I. Hydrogeologic Unit Thicknesses in Meters for Various PA Areas

| PA Area | Hydrogeologic Unit | Min | Max | Range | Mean | Std Dev |
|---|---|---|---|---|---|---|
| Lagoon 2 | Sand and Gravel - Unsaturated Zone: | 0.00 | 0.03 | 0.03 | 0.00 | 0.00 |
| | Sand and Gravel - Saturated Zone: | 0.00 | 0.03 | 0.03 | 0.00 | 0.01 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unweathered Lavery Till: | 18.52 | 20.87 | 2.35 | 19.55 | 0.50 |
| Lagoon 3 | Sand and Gravel - Unsaturated Zone: | 0.00 | 0.02 | 0.02 | 0.00 | 0.00 |
| | Sand and Gravel - Saturated Zone: | 0.00 | 0.02 | 0.02 | 0.00 | 0.00 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 1.99 | 1.99 | 0.14 | 0.36 |
| | Unweathered Lavery Till: | 19.27 | 21.18 | 1.91 | 20.19 | 0.40 |
| Lagoon 4 | Sand and Gravel - Unsaturated Zone: | 2.75 | 3.92 | 1.17 | 3.28 | 0.30 |
| | Sand and Gravel - Saturated Zone: | 2.25 | 4.27 | 2.01 | 3.56 | 0.50 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |
| | Unweathered Lavery Till: | 19.52 | 20.99 | 1.47 | 20.03 | 0.35 |
| Lagoon 5 | Sand and Gravel - Unsaturated Zone: | 3.24 | 4.62 | 1.38 | 3.73 | 0.35 |
| | Sand and Gravel - Saturated Zone: | 2.67 | 4.74 | 2.07 | 3.82 | 0.52 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.37 | 0.37 | 0.04 | 0.09 |
| | Unweathered Lavery Till: | 18.04 | 19.97 | 1.93 | 19.00 | 0.51 |
| Lagoon 6 | Sand and Gravel - Unsaturated Zone: | 0.30 | 1.02 | 0.71 | 0.51 | 0.17 |
| | Sand and Gravel - Saturated Zone: | 0.90 | 1.33 | 0.43 | 1.12 | 0.11 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unweathered Lavery Till: | 23.31 | 25.17 | 1.86 | 24.40 | 0.50 |
| HLW Tank 8D-1 | Sand and Gravel - Unsaturated Zone: | 2.87 | 3.84 | 0.97 | 3.44 | 0.25 |
| | Sand and Gravel - Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unweathered Lavery Till: | 16.43 | 18.28 | 1.85 | 17.38 | 0.50 |
| HLW Tank 8D-2 | Sand and Gravel - Unsaturated Zone: | 3.57 | 5.03 | 1.47 | 4.22 | 0.43 |
| | Sand and Gravel - Saturated Zone: | 0.00 | 0.06 | 0.06 | 0.01 | 0.01 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unweathered Lavery Till: | 17.28 | 19.80 | 2.52 | 18.58 | 0.67 |
| NDA | Sand and Gravel - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Sand and Gravel - Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till - Unsaturated Zone: | 1.10 | 3.93 | 2.83 | 2.38 | 0.62 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 3.27 | 3.27 | 1.33 | 0.69 |
| | Unweathered Lavery Till: | 16.90 | 27.91 | 11.01 | 23.18 | 2.62 |
| SDA | Sand and Gravel - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Sand and Gravel - Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 6.20 | 6.20 | 3.05 | 1.34 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 3.83 | 3.83 | 0.79 | 0.93 |
| | Unweathered Lavery Till: | 7.87 | 31.30 | 23.42 | 21.97 | 5.86 |
| Process Building | Sand and Gravel - Unsaturated Zone: | 2.33 | 4.70 | 2.37 | 3.40 | 0.52 |
| | Sand and Gravel - Saturated Zone: | 1.93 | 4.33 | 2.39 | 3.30 | 0.35 |
| | Weathered Lavery Till - Unsaturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Weathered Lavery Till -Saturated Zone: | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Unweathered Lavery Till: | 10.49 | 14.73 | 4.23 | 11.47 | 0.84 |

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Table II. Summary of Flow Path and Source Information from GIS Modeling

| From | To | Figure ID | Contributing Area (m^2) | Length, min | Length, max | Length, mean | Length, Std Dev |
|---|---|---|---|---|---|---|---|
| Lagoon 2 | Erdman Brook | 5 | 1809 | 146.61 | 210.55 | 180.19 | 16.535 |
| Lagoon 3 | Erdman Brook | 5 | 2538 | 56.699 | 122.91 | 92.255 | 15.097 |
| Lagoon 4 | Frank's Creek | 1 | 792 | 403.01 | 443.99 | 421.97 | 9.4768 |
| Lagoon 5 | Frank's Creek | 1 | 531 | 359.35 | 395.04 | 376.98 | 9.7957 |
| Tank 8D1 | Frank's Creek | 1 | 126 | 692.29 | 706.78 | 699.39 | 4.2164 |
| Tank 8D1 | N Swamp Drainage | 4 | 243 | 273.59 | 308.56 | 287.41 | 9.6769 |
| Tank 8D2 | Frank's Creek | 1 | 378 | 652.35 | 686.81 | 671.63 | 8.5009 |
| Main Plant | Frank's Creek | 1 | 3420 | 627.96 | 740.51 | 685.27 | 22.967 |
| Main Plant | Lagoon 3 | 3 | 99 | 258.89 | 297.59 | 270.96 | 10.473 |
| Main Plant | Lagoon 2 | 2 | 27 | 211.71 | 218.95 | 215.12 | 2.9713 |
| NDA | Lagoon Creek | 6 | 13167 | 15.728 | 367.1 | 164.9 | 87.18 |
| NDA | Erdman Brook | 9 | 7533 | 86.61 | 208.37 | 140.74 | 26.904 |
| SDA | Lagoon Creek | 6 | 22788 | 19.971 | 385.74 | 224.27 | 97.862 |
| SDA | SW to Frank's | 7 | 873 | 70.669 | 124.88 | 98.132 | 15.322 |
| SDA | NW to Frank's | 8 | 25137 | 58.669 | 494.38 | 234.96 | 107.93 |

Figure 4 provides a plot for one of the sources at the site (closed HLW tanks containing residual contamination). The mean result, as well as the $5^{th}$ and $95^{th}$ percentile curves are shown on the figure for each simulation. The solid lines represent the mean result for each probabilistic simulation. The dashed lines are the $5^{th}$ and $95^{th}$ percentile of dose for each simulation. The results have been normalized (to a value of 1.0) by the peak of the mean result for the case of the GIS and 3D geologic modeling derived parameters being sampled stochastically. In the case where the geologic variability was not being represented, stochastic parameter distributions associated with geologic variability were set to small values about their mean in order to preserve the Latin Hypercube Sampling between the two simulations. All other stochastic parameter distributions were identical between the simulations. The simulations were performed with 250 realizations for each case. For the case with geologic uncertainty and variability represented, the peak mean result is larger and there is a broader range of variability compared to the case with no geologic uncertainty and variability. The mean curve reflects the contribution from more than 30 radionuclides and their decay chains, if applicable. The peak mean dose for more weakly sorbing contaminants (e.g., Tc-99) is more influenced by geologic variability than for more strongly sorbing contaminants (e.g., Pb-210), evident by the larger reduction in the variability at around year 2000 in the two simulations compared to the variability at year 10,000.

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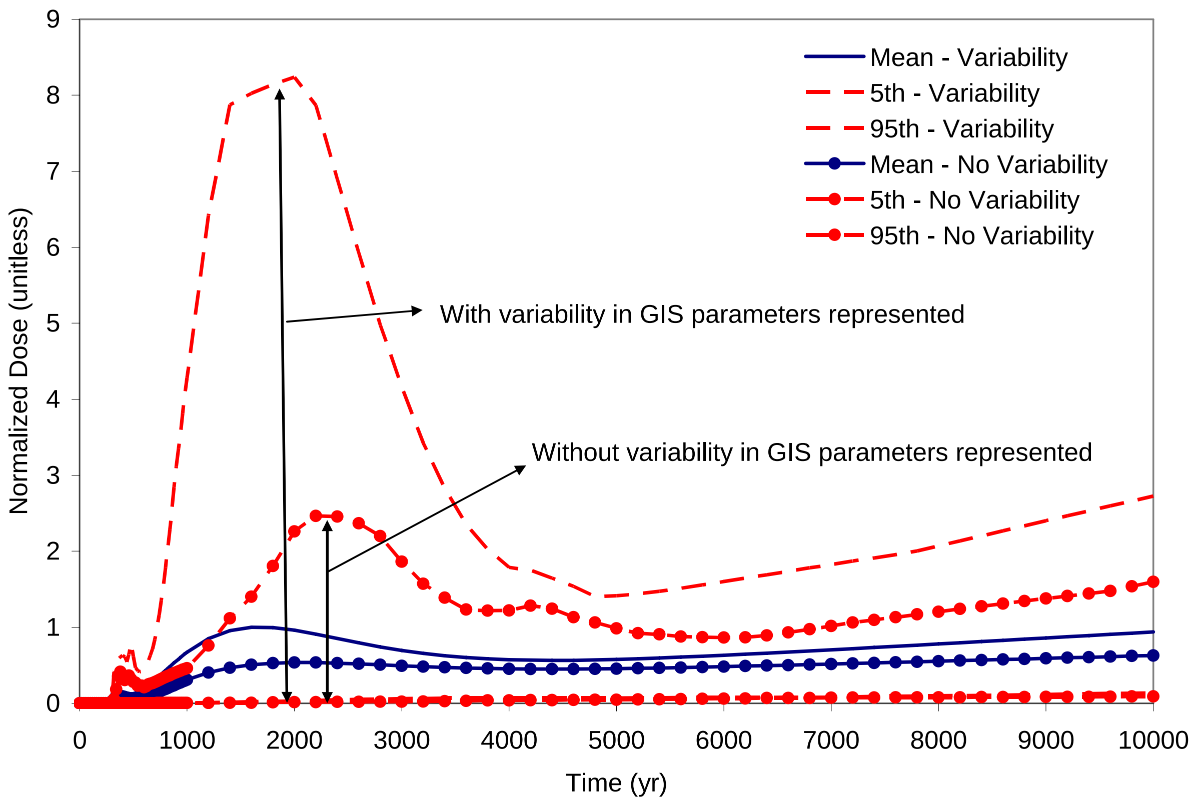


Fig. 4. PA model response with and without variability represented in model parameters derived from GIS and 3D geologic modeling.

## CONCLUSION

The use of GIS greatly facilitated the development and conceptualization of a performance assessment model that will be used to evaluate the health impacts of residual radioactivity at a former nuclear materials processing facility site in New York. GIS was used to develop the geologic framework and the geometrical representation of the residual contamination with respect to the receptors within the geologic framework. Preliminary model results comparing a typical PA model developed without the use of GIS that may have over-simplified the transport pathways with the PA model developed with GIS shows the important contribution geologic variability and uncertainty can have on simulation of radiological impacts from residual contamination. GIS was used to convert aleatoric uncertainty associated with three-dimensional transport systems into epistemic uncertainty for simpler one- and two-dimensional abstractions. The simpler abstractions allowed for computational practicality while providing the analyst the opportunity to evaluate the importance of geologic variability in the stochastic performance assessment model. In addition from a practical perspective, the level of effort involved with developing the PA model using the GIS data visualization and interpretation tool was considerably less compared with developing a PA model by extracting information from technical reports.

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