

**APPENDIX D**  
**OVERVIEW OF PERFORMANCE ASSESSMENT APPROACH**

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## **APPENDIX D**

### **OVERVIEW OF PERFORMANCE ASSESSMENT APPROACH**

Estimating future impacts on human health and the environment is an important aspect of the alternatives analysis for this environmental impact statement (EIS). Impacts would occur both during the short-term decommissioning period due to planned activities and accidents, and in the long-term future under the influence of natural processes. Potentially affected individuals include workers and the public at both on- and offsite locations. Constituents of concern include radionuclides and hazardous chemicals.

Because potential impacts would occur in the future and involve new actions at the site, direct measurement of impacts or projections based on current releases is not possible. Thus, the estimation of impacts is based on exposure scenario analysis using mathematical models. The scenarios comprise combinations of releases from a facility, transport through the environment, and exposure of individuals. In principle, scenarios may be constructed to cover the range of all possible impacts from small to large. In practice, a set of scenarios intended to represent the upper range of potential impacts was selected for analysis. Scenario analysis models predict contaminant release rates from facilities, contaminant movement rates through the environment, exposure point concentrations, and human receptor exposure and risk levels. The analysis considers both radionuclides and hazardous chemicals and addresses: (1) short-term impacts due to accidents and planned releases to the atmosphere and local surface waters during the decommissioning period of each alternative, and (2) longer-term impacts resulting from future slow or episodic releases of any remaining contamination.

The performance assessment objectives of this EIS are to:

- Obtain estimates of potential impacts on human health and the environment that provide valid insight into the comparative impacts of the EIS alternatives, and
- Understand the interdependence of facility designs and environmental processes on human health and the environment.

This appendix presents an introductory overview of the approach for estimating impacts on human health due to (1) releases during decommissioning actions, and (2) long-term releases resulting from natural processes or human intrusion. The introductory discussion on the approach to estimating long-term impacts addresses the general approach to long-term assessment modeling, the site conceptual model, the considerations that went into identification of receptor scenarios, and the types of modules and integrated models used for the long-term analysis.

More-detailed information on the methods used for analysis of impacts during decommissioning, along with results, are presented in Appendix I of this EIS. More-detailed information on the specific release, transport, or dose modules that are used in the long-term performance assessment is presented in Appendix G. More-detailed information on the hydrology modeling and erosion modeling that support the long-term performance assessment is presented in Appendices E and F, respectively. Finally, more-detailed information on long-term performance assessment scenarios, model input parameters, and results for specific scenarios for the Sitewide Close-In-Place Alternative and the No Action Alternative is presented in Appendix H.

#### **D.1 Summary of Performance Assessment Approach**

The initial effort in the development of the performance assessment involves identification of site characteristics relevant to the estimation of impacts. These characteristics, collectively identified as the site conceptual model, are those that determine movement and dilution rates in the atmosphere, groundwater, and surface waters. Once a site conceptual model has been developed, the performance assessment process may be

described as comprising three major steps. The first step involves combining information on site conditions, facility designs and release mechanisms, and regulatory guidance to identify exposure scenarios for analysis. The scenario development process considered a complete range of contributing processes and conditions, but only a limited set of scenarios, intended to represent the upper range of potential impacts, was selected for analysis. The following information sources were used to identify exposure scenarios:

- Site physical characteristics, such as meteorology and hydrology
- Estimates of contaminant release rates
- Local and regional activity and land use plan information that provides a basis for estimating future human activities and their locations
- Regulatory requirements or guidance that identify relevant performance objectives or requirements

An element of the scenario development process is identification of environmental pathways appropriate to each facility under consideration. In the case of the Western New York Nuclear Service Center (WNYNSC), multiple facilities, three areas of existing environmental contamination (North Plateau Groundwater Plume, Cesium Prong, and creek/stream sediment contamination) are present, and the set of scenarios includes one that analyzes impacts from single facilities and other scenarios (downstream water users) that analyze impacts from multiple facilities. Analyses that only include a single facility can be combined to estimate the consequences of situations where a single receptor may come in contact with contamination from multiple facilities or areas. Specific examples of such combination are presented in Appendix H of this EIS. The exposure point location for the scenarios evaluating impacts from multiple facilities was selected based on conservative evaluation of the intersection of environmental pathways for individual facilities (i.e., nearby plume centerlines were assumed to overlap even when there is some actual separation). Cumulative impacts estimated in this manner included all onsite facilities and sources associated with WNYNSC. No sources outside WNYNSC having measurable potential human health impacts on WNYNSC receptors have been identified.

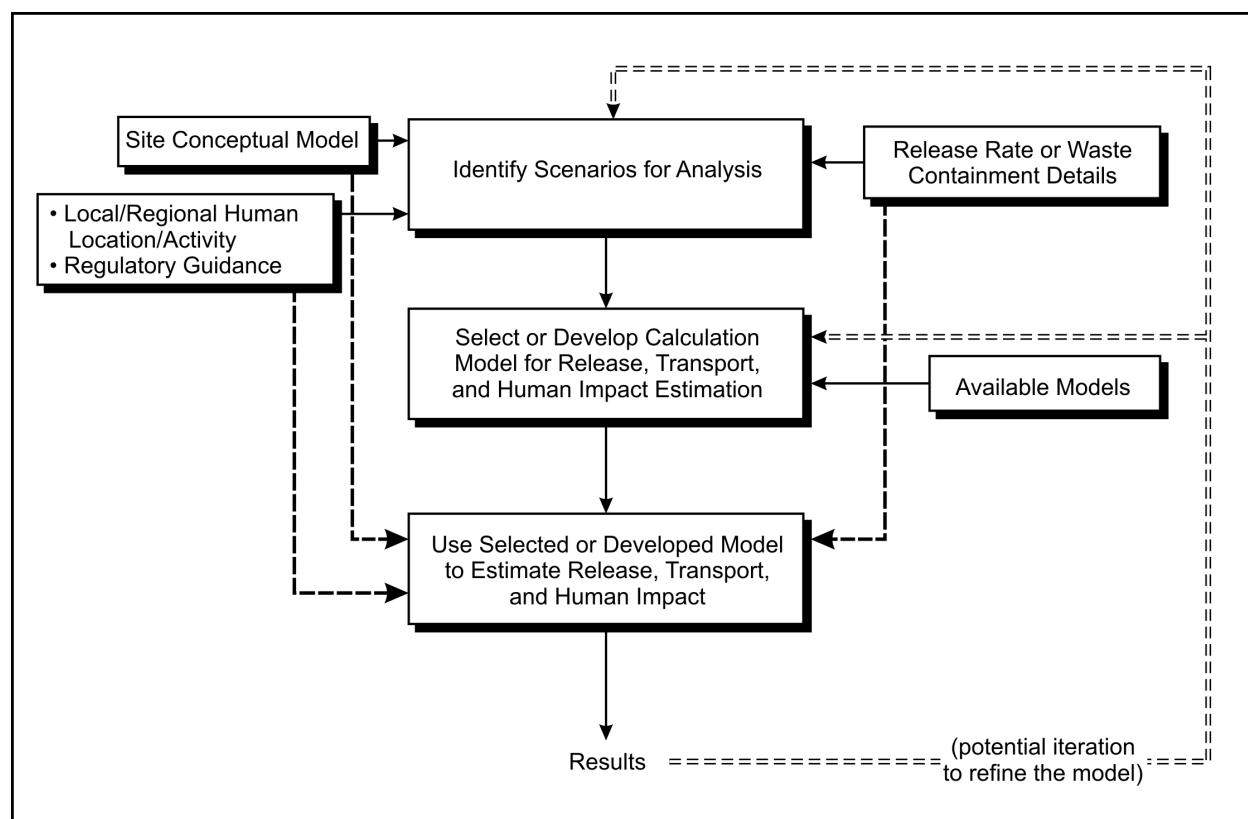
The second step was establishment of a method for performing calculations consistent with the integrated conceptual model developed in the first step. This step required review of existing models or analytical methods to determine if the basic requirements could be met using existing models or whether site- or project-specific models needed to be developed. Three requirements were used for selection, development, and use of models. The first requirement was to select and use models that strike a reasonable balance between analytic complexity and realistic modeling of site- and design-specific features. The second requirement was to be consistent in modeling processes across the site so that any variability in estimated impacts would be primarily due to differences in waste, barrier, or site properties, rather than differences in model features. The third requirement was to evaluate realistic, likely exposure scenarios that accurately reflected impacts of the alternatives.

The third step of the performance assessment process was the actual calculation of release and transport rates and impact estimates using the selected models and appropriate input parameters. Input data were selected in a systematic procedure that considers the available site characterization data, surrogate data from similar sites, and regulatory guidance. Calculation results were examined to determine reasonableness of predicted release rates, transport, and impacts. The computer codes and models used in the long-term performance assessment were verified through a process that included the development of test cases and comparison of the results of model calculations with the results developed using alternate models and hand calculations. (See Appendix G, Section G.1, of the EIS.) Sensitivity analyses were conducted to determine more-important model and input parameters.

The performance assessment process is summarized on **Figure D–1**. The large text boxes aligned downward along the center of the figure represent the three major steps of the performance assessment process. The figure also shows the use of information about regulatory requirements, local human activity, site characteristics, and waste release or containment design during both the scenario development step (Step 1) and calculation step (Step 3).

Application of the first two steps of this process (identify scenarios and select calculation methods) for estimating short-term (decommissioning period) impacts is discussed in Section D.2.

Section D.3 discusses application of the first two steps of this process for estimating long-term impacts, as well as the approach to sensitivity analyses, which are particularly important to long-term performance assessments.



**Figure D–1 Performance Assessment Flow Diagram**

## D.2 Short-term Performance Assessment

The decommissioning period is the approximately 5- to-60-year period during which remediation, stabilization, and closure activities would be performed. During this time, workers would be present on site, public access to the site would be limited, and contaminant releases to the environment would be controlled. This section describes development of exposure scenarios for the public and selection of models for the short-term period under alternatives evaluated in this EIS.

### D.2.1 Short-term Performance Assessment Exposure Scenarios

During the decommissioning period, planned releases to the atmosphere and surface water would impact offsite individuals. Estimates of the impacts due to these releases were developed based on consideration of the

nature of proposed activities and on the release rate, rates of movement through and dilution in the environment, and potential receptor locations and activities. This section describes these analysis elements and summarizes their combination into scenarios selected for analysis.

#### **D.2.1.1 Site Conceptual Model**

Site characteristics relevant to estimation of decommissioning-period impacts are those that determine movement through, and dilution that would occur over, the relatively short decommissioning period. Potential pathways considered for analysis include atmospheric dispersion, dispersion via groundwater and surface water, and dispersion resulting from erosion leading to exposure of waste to potential dispersion by means of the atmosphere or water. Dispersion in the short term was determined to be by means of movement and dilution in the atmosphere and surface waters. Details are presented in Chapter 3 and Appendix I of this EIS.

The approach for characterizing surface water hydrology involved review of annual maximum, minimum, and average flow rate conditions and selection of conditions representative of average flows. This information is used in predicting downstream concentration of contaminants released from the site and is part of the information used in evaluation of erosion and erosion impacts. The information collected on surface hydrology is presented in Chapter 3.

Meteorological characteristics were monitored at an onsite weather station, as well as at weather stations located in the site vicinity. Windspeed frequency, direction and stability class, precipitation rates, and extreme wind occurrences were recorded as reported in Chapter 3. Site topography was measured and recorded on the West Valley Demonstration Project (WVDP) and U.S. Geological Survey maps. This information, in conjunction with the atmospheric dispersion calculation model described in Appendix I, constitutes the site model for dispersion in the atmosphere. Useful information derived from the model included released material concentrations, their locations, and the highest contaminant concentration.

The configuration of watersheds and the network of gullies and creeks draining the site and their paths to Lake Erie were mapped. Topography, rates of precipitation, and groundwater flow were characterized. Flow rates of on- and offsite creeks were measured at important site locations (WVNS 1993). For the decommissioning period, releases to Erdman Brook would be controlled. The flow path and recorded rates through Erdman Brook, Franks Creek, Buttermilk Creek, and Cattaraugus Creek to Lake Erie, in conjunction with the assumed complete dilution of contaminants in the creeks, constitute the surface water flow conceptual model. Useful information derived from the model included released material concentrations at locations in the creeks and Lake Erie.

Other possible transport processes involving groundwater or erosion would occur over longer periods of time. Historical measurements, as well as the groundwater flow analysis discussed in Appendix E indicate that, because of decay and geochemical retardation, the groundwater flow path would not contribute significantly to decommissioning-period impacts. Similar erosion measurements and the erosion analysis discussed in Appendix F show that erosion would not contribute to decommissioning-period impacts. Groundwater and erosion would, however, be considered as part of the long-term performance assessment.

#### **D.2.1.2 Short-term Performance Assessment Release Rates**

Contaminant release rates to the atmosphere and surface waters were directly estimated in engineering design studies for each alternative. This information is presented in the referenced technical reports and summarized in Appendix I. Releases can be radiological in nature (e.g., hydrogen-3 [tritium] and cesium-137) or involve nonradiological materials. Estimation of ionizing radiation flux during radioactive material transportation was based on material and package physical and radiological characteristics using standard methods (Chen et al. 2002).

### **D.2.1.3 Short-term Performance Assessment Human Receptors**

Receptors that must be considered in the short-term impact analysis are those outside the WNYNSC boundary. The U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA) would maintain access controls during the decommissioning period so there is no potential for a recurring onsite receptor. The locations and activities of receptors were selected considering the proposed activities, conceptual model of the site, current demography, and regulatory guidance.

For the atmospheric pathway, application of dispersion analysis and comparison with known residences indicate that the point of maximum concentration occurs in the north-northeast direction near WNYNSC. Thus, receptors for the atmospheric pathway are an individual at the north-northeast boundary; a member of the Seneca Nation of Indians (a potentially sensitive population) located near Gowanda, New York; and the general population out to a distance of 80 kilometers (50 miles) from the site.

For the surface water pathway, a set of three offsite locations was selected to evaluate potential impacts. The first location, near the confluence of Buttermilk and Cattaraugus Creeks, is the location of highest contaminant concentration in surface water outside the WNYNSC boundary. The second location, in Cattaraugus Creek near Gowanda, New York, is the location of the Seneca Nation of Indians, a potentially sensitive population. The final location, the Lake Erie water source for the surrounding population out to a distance of 80 kilometers (50 miles), combines the impact of water intake points located near Sturgeon Point and in the Niagara River. For transportation activities, populations were selected on a transportation-route-specific basis using routing models (Johnson and Michelhaugh 2000) and incorporating current census data.

Consistent with past practice in EIS analyses and regulatory guidance<sup>1</sup> (ICRP 1984, NRC 2006), receptor characteristics are those of the general population, a hypothetical individual located so as to receive the maximum calculated dose, and the average member of the critical group (AMCG). The AMCG is one of a group of individuals reasonably expected to receive the greatest exposure for the set of applicable circumstances. For these individuals, inhalation, drinking water intake, and fish consumption rates and gardening practices are selected to produce an estimate that is expected to reasonably bound potential impacts, but not represent an overly conservative worst-case estimate.

### **D.2.1.4 Summary of Short-term Performance Assessment Exposure Scenarios**

For the decommissioning period, two environmental pathways (air and surface water combinations of release and transport mechanisms) have been identified. Eight scenarios are analyzed for each alternative (see Appendix I of this EIS).

## **D.2.2 Selection of Short-term Performance Assessment Calculation Model**

For estimation of impacts during the short-term period (decommissioning period), standard models incorporating past practice for EIS analyses were selected. For releases of chemical (nonradiological) constituents to the atmosphere, meteorological dispersion modeling procedures described in Appendix K of this EIS were used to generate concentrations per unit source and deposition per unit source values and, therefore, contaminant concentrations as a function of distance and direction. The Industrial Source Complex atmospheric dispersion model was used for these calculations. For hydrologic releases, concentrations of nonradiological constituents in Cattaraugus Creek were calculated by assuming the total quantity released would be mixed into the total flow of Cattaraugus Creek without any allowances for absorption or deposition.

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<sup>1</sup> While regulatory guidance was used to help inform the selection of potential receptors, this analysis is intended to meet National Environmental Policy Act (NEPA) requirements and is not a regulatory compliance analysis.

For estimation of impacts due to radioactive material releases, the GENII computer code (PNNL 2007), an integrated dose-estimation model incorporating the most recent developments in dose assessment methods and exposure modes, was selected. The GENII code uses physiologic models and procedures recommended in *1990 Recommendations of the International Commission on Radiological Protection* (ICRP 1991) and Federal Guidance Reports 12 and 13 (EPA 1993, 1999) to estimate internal and external dose conversion factors. GENII estimates impacts of atmospheric and surface water releases on individuals and populations. Exposure through a spectrum of pathways, including inhalation; direct external; and ingestion of crops, animal products, and soil, may be evaluated in the analysis. For estimation of impacts due to transportation activities, the RADTRAN 5 computer code (Neuhauser et al. 2000), a dose estimation model that considers normal operation and accident conditions, was selected.

### **D.3 Long-term Performance Assessment**

The long-term period is the time extending from the end of the decommissioning period out to the distant future. The following sections describe the approach for estimation of long-term impacts, including scenario development, model selection, and the approach to understanding uncertainty.

#### **D.3.1 Long-term Performance Assessment Exposure Scenarios**

Scenario development and analysis for long-term performance assessment is more complex than for short-term performance assessment because more physical processes are involved and transport pathways are more complicated for post-closure conditions. These long-term processes include a variety of mechanisms for contaminant release to groundwater, as well as erosion that can release buried materials. In addition, there is a wider range of potential receptors that could come into contact with released contaminants. While most of the receptors are located outside the boundaries of any area where control is retained, it is also necessary to consider intrusion within the boundaries when considering long periods of time. Addressing additional contaminant transport mechanisms and additional receptors is an integral part of scenarios for long-term performance assessment. The analysis period for long-term performance assessment for decommissioning activities cited as a regulatory requirement (DOE 1999, NRC 2006) is 1,000 years. However, the U.S. Nuclear Regulatory Commission (NRC) WVDP Decommissioning Policy Statement (*67 Federal Register* [FR] 5003) states that an evaluation of reasonably foreseeable impacts requires that an analysis of impacts beyond 1,000 years should be provided. Additionally, DOE recommends (DOE 1999) that the magnitude of peak impacts be identified, even if the peak impact is projected to occur after tens of thousands of years. Analysis in this EIS identifies the magnitude and time of peak impact.

##### **D.3.1.1 Site Conceptual Model**

Site conceptual model characteristics include consideration of physical conditions and natural processes, both current and evolving, including long-term disruptive processes that serve as a basis for quantifying contaminant release and transportation processes that could lead to human health impacts. In development of the site conceptual model, consideration was given to processes occurring at the regional and local scales. Consistent with NRC guidance (NRC 2000), site conditions arising from extreme global-scale climatic changes (including human-induced climate change), whose adverse effects would invalidate the scenarios and receptors of the performance assessment and greatly exceed site-specific effects resulting from residual contamination, are not considered in the long-term performance assessment. The impact of natural cycling (periods of wetter or dryer conditions) is addressed through sensitivity analyses. The conceptual model serves to identify site-specific natural processes and human-related activities that can lead to contaminant release, transport, and human exposure and thus play an important role in scenario development. To facilitate model development, conditions were categorized as: (1) currently occurring or (2) disruptive processes occurring gradually or in specific episodes over a long-term period. Disruptive processes include earthquakes, tornadoes, floods, and erosion.

The conceptual model development approach for both current and disruptive conditions included environmental data collection and documentation, data review, development of a representation of contributing environmental processes, and development of mathematical descriptions of the processes to allow quantitative analysis.

### **Current Site Conditions**

Description of current conditions includes characterization of existing contamination and consideration of geologic, hydrologic, and atmospheric processes. The two important existing sources of environmental contamination involve groundwater and surface soil. A plume of contaminated groundwater, termed the “North Plateau Plume,” extends in a northeasterly direction from a historical source below the Main Plant Process Building. An area of soil contamination, termed the “Cesium Prong,” extends in a northwesterly direction from a historical source at the main plant stack.

The approach for geologic conditions included review of structures and stratigraphy at regional and local scales and development of a model view of site stratigraphy and of site strata interfacing with larger-scale features. The results of this activity are useful in understanding current groundwater flow paths and in evaluating potential future paths. The information collected and analyzed is documented in Chapter 3 and Appendix E of this EIS.

The approach for characterizing surface water hydrology involved review of annual maximum, minimum, and average flow rate conditions and selection of conditions representative of average flows. This information was used in predicting downstream concentration of contaminants released from the site and was part of the information used in evaluation of erosion and erosion impacts. The information collected on surface hydrology is presented in Chapter 3.

The approach for developing an understanding of groundwater hydrology was to review existing geohydrologic characterizations and available data, develop a three-dimensional model of site conditions calibrated to observed pressure levels, and use the results of three-dimensional modeling about groundwater flow direction and velocity as input conditions for one-dimensional models appropriate for long-term impact analysis. The results of the three-dimensional groundwater analysis and characterization are presented in Appendix E.

The approach for meteorological transport was to summarize data in a joint frequency distribution and use a Gaussian plume model to estimate dispersion factors used to predict downwind concentrations of released contaminants at various distances and directions from the site. The results of this information are presented in Chapter 3 and Appendix K of this EIS.

### **Potential Disruptive Processes**

Disruptive events occurring at the site include earthquakes, tornadoes, floods, and erosion. The approach adopted for characterization of both earthquakes and tornadoes was development of a hazard curve depicting exceedance probability as a function of event severity.

The most recent estimate of site seismic hazard risk was conducted by the URS Corporation (URS 2004) using the U.S. Geological Survey National Seismic Hazard Maps (USGS 2002). This information is presented in Chapter 3.

For tornadoes, the damage area per unit-path-length method was applied to an area within 160 kilometers (100 miles) of the site (Fujita 1979). Detailed results are presented in this EIS and summarized in the form of a plot of windspeed against that windspeed’s exceedance frequency.



The flood and erosion analysis was based on rainfall data collected over the past 30 years, including estimation of probable maximum precipitation and precipitation for storms with return periods of 2, 10, and 100 years (WVNS 1993), and on statistically generated daily precipitation histories covering periods up to 100 years (USDA 1995). For floods, stream levels were estimated for each of these storm magnitudes and compared with present stream channels configurations.

For erosion, site-specific, long-term unmitigated erosion rates were estimated using a landscape evolution model calibrated to reproduce historical long-term erosion at the site and a simplified single gully model intended to place an upper bound on potential local-scale impacts not captured by the landscape evolution model. Where gullies are postulated to impact a specific waste management area, area-specific gully erosion rates were used to estimate human health impacts. The erosion site model results are presented in Appendix F of this EIS, and the gully model is discussed in Appendix G.

### **D.3.1.2 Long-term Performance Assessment Release Rates and Environmental Transport Pathways**

The approach to identification of long-term release mechanisms includes characterization of the waste inventory and facility-engineered barriers, review of the site physical characteristics, and development of a list of processes that could transport contaminants from the facility into the surrounding environment. The approach was applied for each of the EIS alternatives. The procedure was applied both for conditions where institutional controls are assumed to be in place and for disruptive processes, including those that would occur in the absence of institutional control (e.g., effects on intruders and unmitigated erosion effects).

Estimation of contamination release rates and identification of environmental transport pathways involve cataloguing of the processes that remove contamination from the source and the mechanisms that move contamination through the environment to the receptor. Potential release mechanisms from the source include direct contact by humans, plants, or animals; evaporation to the atmosphere; dissolution in surface water or groundwater; and entrainment in wind, surface water, or groundwater. Following release from the source, primary transport pathways include dispersion in the atmosphere, surface water, or groundwater; transfer to plants or animals; and, finally, transfer to humans.

The role of engineered barriers was evaluated for residual contamination and below-grade structures. For the site, descriptions of radionuclide inventories and facility closure designs are presented in waste characterization reports and technical reports, respectively. Release mechanisms and environmental transport pathways have been identified and evaluated (Case and Otis 1988; NRC 2000, 2006; Shippers and Harlan 1989). Due to the nature of previous fuel reprocessing operations and waste management practices at the site and the time since reprocessing, radionuclides are present in the waste in chemical forms that are both soluble and insoluble in water, but with negligible quantities of volatile forms. Thus, evaporative release through the unsaturated zone to the atmosphere would be negligible. For the Sitewide Close-In-Place Alternative, the residual contamination in the Main Plant Process Building, the Vitrification Facility, the Waste Tank Farm, the NRC [U.S. Nuclear Regulatory Commission]-Licensed Disposal Area (NDA), and the State-Licensed Disposal Area (SDA) would be located at depths greater than 3 meters (10 feet) below the current ground surface and under a rock and vegetation-covered tumulus with a maximum height of 9 meters (30 feet). Residual contamination at these depths is unlikely to be mobilized by human intrusion, burrowing animals, or vegetation or roots. Thus, assuming institutional control, transport by groundwater is the only mechanism for transport of contaminants from the waste form to the surrounding environment, and releases via diffusion and convective flow are the release mechanisms of concern. As discussed in Section D.3.1.3, forms of human intrusion are considered to provide additional perspective on potential impacts. Contaminants dissolved in groundwater may be transported to onsite wells or discharged to onsite surface water (Erdman Brook, Franks Creek, and Buttermilk Creek) that flows to Cattaraugus Creek and Lake Erie. Once the potentially contaminated water has been pumped from the ground or creek, it may be consumed as drinking water or used for crop irrigation. In the

case of crop irrigation, all the contributing pathways of the residential farmer scenario were applied. In addition, contamination in surface water is transferred to fish harvested and consumed by the surface water user. Hydraulic and chemical properties of engineered barriers were considered in the release rate estimation. Consistent with regulatory guidance (NRC 2000), hydraulic property values of barriers subject to degradation mechanisms, such as subsidence, cracking, or clogging, were assumed to degrade over time. Chemical properties, such as adsorptive capacity, were assumed to remain constant consistent with past practice (Kennedy and Strenge 1992, Yu et al. 1993) and the stability of sand and clay formations over geologic times (Rowe et al. 2004).

Disruptive processes that may occur at WNYNSC include earthquakes, tornadoes, floods, and erosion. The maximum historical earthquake observed at the site had a Modified Mercalli Intensity of V, which would produce minor damage to glassware and have no effects on waste-isolating engineered structures that would remain across the site under the Sitewide Close-in-Place Alternative. Any waste located below grade would not be affected by tornadoes. Site-specific analysis of flooding potential indicated that water levels for storms up to the probable maximum precipitation would not affect existing site facilities. Erosion is occurring at the site and could release radionuclides to the environment. Erosion processes are addressed in this EIS as an aspect of long-term performance assessment.

#### **D.3.1.3 Long-term Performance Assessment Human Receptors and Exposure Modes**

A two-step process was used to identify site-specific receptors. The first step involved establishment and use of a set of principles to select generic receptors. The second step was the application of site-specific information to the generic receptors to develop site-specific receptors. Both of these steps are discussed in the following paragraphs.

Principles established for the first step were based primarily on review of regulations, past practice, and guidance. Some of the referenced regulations or guidance are relevant but not directly applicable to the site and Project Premises. Receptors both inside and outside the current WNYNSC boundary were identified. Receptors outside the current WNYNSC boundary correspond to individuals who could actually be exposed to contamination released from the site, assuming the existing boundaries and institutional controls remain in place. Receptors inside the current WNYNSC boundary correspond to hypothetical individuals, whose location and activities are assumed for analytical purposes, including investigation of the upper bound of impacts. Site-specific information includes directions and velocities of groundwater and surface water flow, population distribution around the site, and physical conditions associated with the residual contamination or disposed waste. These physical conditions could include location of the waste in relation to environmental pathways and available land area or facility designs that limit accessibility of the waste.

The set of principles that guided identification of generic and site-specific receptors is consistent with the practice and conditions present at the site. These principles are:

- Provide a realistic to reasonably conservative evaluation of the long-term impact on the health of the general public.
- Provide estimation of the impact on individuals indirectly contacting radioactive waste at some time after closure of the site following the assumption of institutional control failure.
- Identify receptors based on review and interpretation of prior analysis performed by the NRC, U.S. Environmental Protection Agency, and DOE, and on principles applied in environmental and safety analyses.

The first and second principles have their bases in generally applicable environmental regulations. The third principle is based on the need to comply with regulations and guidance of Federal agencies charged with environmental analysis and the desire to conduct an analysis that provides insight into compliance with decommissioning dose criteria.

Guidance and past practice relevant to identification of receptors for the WNYNSC performance assessment include information related to facilities operating under normal conditions, facilities undergoing decommissioning, low-level radioactive waste disposal facilities, and facilities contaminated with hazardous waste (EPA 1991, 1995). The following paragraphs summarize guidance and practice for each of these cases.

NEPA directs that Federal plans shall be coordinated to protect human health and the environment, but does not identify specific human populations or limits to the analysis. Guidance promulgated by the Council on Environmental Quality (CEQ 1986) created under NEPA also does not identify specific populations, but does specify that data and analysis should be commensurate with the impacts of the action. Early guidance issued by the NRC (NRC 1977) for assessment of impacts of normal operations of nuclear reactors provides methods for estimation of doses to maximally exposed individuals and to the population out to 80 kilometers (50 miles). Guidance for assessment of impacts of fuel reprocessing plant operations (NRC 1975) also directs consideration of doses to populations out to 80 kilometers (50 miles). More recent guidance for controlling normal operations impacts (DOE 1995, NRC 2006) focuses on limiting doses to the AMCG. The AMCG is a member of the group reasonably expected to receive the greatest exposure to releases from the site. The range of activities of an exposed individual includes inhalation of contaminated air, ingestion of contaminated drinking water, establishment of a residence on or near contaminated material, and establishment of a garden on contaminated soil. In addition to these general considerations, Executive Order 12898 (February 11, 1994) directs Federal decisionmakers to identify and address high and adverse environmental impacts that disproportionately affect minority and low-income populations.

Standards for termination of NRC licenses (NRC 2006) address exposure to residual contamination for an AMCG where this individual is representative of the group reasonably expected to receive the greatest dose. Supporting guidance, which provides methods and additional details for generic screening scenarios and procedures for development of site-specific scenarios (NRC 2006), is useful when determining the scope of the long-term performance assessment for this EIS. For screening scenarios, the AMCG occupies the site and is in direct contact with residual contamination (NRC 2006). For site-specific scenarios, the AMCG and scenarios may be developed in light of planned future land use, physical characteristics that constrain site use, and realistic processes for contaminant transport (NRC 2006). Guidance developed for analysis of impacts of residual contamination at DOE sites (Yu et al. 1993) provides dose-limit criteria and methods for analysis of residential receptor exposure scenarios. For situations involving contamination of surface soil, the receptor is in direct contact with contaminated material. For situations involving subsurface contamination, the receptor contacts contaminated material indirectly through use of well water contaminated by percolation of precipitation through the waste material. Both NRC and DOE guidance discuss the range of activities of an exposed individual, including inhalation of contaminated material, use of contaminated drinking water, establishment of a residence on or near contaminated material, and establishment of a garden in contaminated soil.

The NRC's analysis of generic disposal sites is presented in the *Environmental Impact Statement on 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste"* (NRC 1981, 1982). Information supporting this analysis proves useful in identifying receptors and receptor habits. NRC guidance (NRC 2000) for sites where institutional controls are in effect identifies the offsite receptor as the AMCG located at the disposal site boundary. For unrestricted release of a site, the public receptor is not necessarily located at the disposal site boundary, but rather at a point determined to be the location of maximum exposure. Onsite intruders do not deliberately intrude into disposed waste, but do have contact with contaminated water in a well

scenario and direct contact with disposed material in home construction, discovery, and residential agriculture scenarios (NRC 1982). Waste stability and layering are assumed to be effective in reducing contact with waste for only a limited period of time (NRC 1982). A range of intrusion scenarios was considered prior to selection of the home construction, discovery, and residential agriculture scenarios. In the construction scenario, a worker excavated a foundation to a depth of 3 meters (10 feet) (NRC 1981). As long as a 1- to 2-meter (3- to 6-foot) cap was maintained over the waste, direct contact with the waste was considered very unlikely (NRC 1981). The residential agriculture scenario was initiated when a portion of the soil excavated in the construction scenario was distributed around the home and assumed available for cultivation of crops (NRC 1981). An alternative scenario was considered in which the waste cover was stripped away and the intruder lived directly on the waste. This scenario was judged unreasonable, as a commercial operation would be required to perform the work (NRC 1981). In the well water exposure scenario, the well was located at the boundary of the disposal facility at a distance of 40 meters (130 feet) from the release point of the contaminated water (NRC 1981). An additional intrusion scenario (Oztunali and Roles 1986) involves short-term exposure related to drilling a well through the waste disposal facility. For alternatives involving control of the site, initiation of intrusion scenarios is assumed to occur after 100 years (DOE 1999), following loss of institutional control. To provide perspective for regulatory analysis, impacts for intrusion scenarios were also estimated for the case of immediate loss of institutional controls.

Given that the receptor is not capable of large-scale site disruption, credit for function of passive elements of engineered barriers under the Sitewide Close-In-Place Alternative is reasonable and consistent with NEPA guidance that arbitrary elements of analysis be avoided. This credit would include physical separation enforced by presence of thick caps; inability to move drilling equipment over the large, irregular rip rap comprising the apron and deck of engineered caps; and effectiveness of subsurface flow diversion structures. These principles also imply that physical processes, such as desiccation, cracking, and erosion, are considered in determining the degree of credit for function of passive barriers. Thus, the hydraulic conductivity of cements and grout increases with time, approaching that of soil, and hydraulic conductivity of surface layers of caps increases with time, approaching that of native soil. Consistent with material property evaluation (Atkinson and Hearne 1984), the stability of sand and clay formations over geologic times (Rowe et al. 2004), and regulatory guidance (NRC 2000), lifetimes of cement-based engineered barriers are less than 500 years. For this analysis, existence of the tank vault and placement of strong grout in the tank supports selection of a 500-year lifetime for the intruder barrier at the Waste Tank Farm (WSMS 2009). For other subsurface engineered barriers, including grouts, slurry walls, and tumulus drainage layers, a 100-year life is assumed. Specific engineered barrier parameters used for specific analyses are identified in Appendix H, Section H.2.2, of this EIS. Chemical properties of natural materials, such as adsorptive capacity, are, however, not expected to decrease with time, consistent with the long lifetimes observed for sand and clay formations in the environment (NRC 2000). Engineered disposal facilities include infiltration drainage layers and subsurface groundwater diversion structures that decrease productivity of wells inside the facility relative to wells located outside the facility. Because of the cap design incorporating large rock, it is reasonable to propose that wells under the Sitewide Close-In-Place Alternative be located outside the engineered barrier system for the Main Plant Process Building, the Vitrification Facility, the Waste Tank Farm, the NDA, and the SDA. The premise that properly selected, quarried, and placed rock can have long service life is supported by reference to analog sites for chemical weathering of rock and adherence to design and construction principles described in regulatory guidance (NRC 2002). The design thickness of the rock layers of the cap is approximately 1.14 meters (3.75 feet). Data from natural analogs include reported rates of weathering for the foreland boundary of a glacier of 1.6 millimeters per 1,000 years for gneiss surfaces and negligible weathering for quartz layers over approximately 9,700 years (Owen et al. 2007). The cap design is expected to consider both normal conditions and extreme events, and incorporate defense in depth of flow control and diversion structures to produce a robust design. In the case of well water use for domestic purposes, past practice has located the well away from the release point (NRC 1981) and has provided realistic representation of dilution in infiltration and mixing in an aquifer serving the well (NRC 1981, Yu et al. 1993).

Guidance provided for performance assessment of DOE low-level radioactive waste disposal facilities (Case and Otis 1988) specifies that impacts should be evaluated for the surrounding population out to a distance of 80 kilometers (50 miles), a maximally exposed individual located at the boundary of the site, and an intruder located at the disposal facility. More-detailed guidance related to intruder scenarios has also been provided (Kennedy and Peloquin 1988). The guidance directs evaluation of the home construction, discovery, and residential agriculture scenarios developed by the NRC and supplements these scenarios with well-drilling and post-drilling residential agriculture scenarios (Kennedy and Peloquin 1988). In the post-drilling scenario, contaminated cuttings from the borehole are distributed onto soil on which a home and garden are located (Kennedy and Peloquin 1988).

For evaluation of risk of exposure to hazardous chemicals, regulatory guidance (EPA 1995) recommends that analysis should reflect reasonably anticipated future land use. Thus, for free release of site areas, receptors would be residential farmer receptors located on site. For agency control of site areas, receptors would be residential farmer receptors located off site.

### **Receptors Outside the Current Western New York Nuclear Service Center Boundary**

Site-specific receptors outside the current WNYNSC boundary would be either actual individuals currently living near the site or individuals whose locations and activities could reasonably be extrapolated from current conditions. At the site, these receptors correspond to the AMCG living at offsite locations. These receptors include individuals living near the confluence of Buttermilk and Cattaraugus Creeks, a member of the Seneca Nation of Indians living on Cattaraugus Creek near Gowanda, and the general population out to a distance of 80 kilometers (50 miles) using water from eastern Lake Erie. Five municipal water intakes are located in Lake Erie and the Niagara River, and the dose to individuals in the general population is characterized by two receptors: one with no dilution of Cattaraugus Creek water (e.g., Sturgeon Point water user) and one with dilution due to the east channel of the Niagara River (e.g., North Tonawanda water user). The five water intakes serve a population extending beyond the 80-kilometer (50-mile) limit generally applied in NEPA analysis. Water use characteristics of these four individual receptors used for dose analysis are summarized in **Table D-1**. For each of the receptors, drinking water consumption corresponds to the 95<sup>th</sup> percentile of the national distribution of drinking water consumption rates (EPA 1999). For the Cattaraugus Creek and Seneca Nation receptors, fish consumption corresponds to the 95<sup>th</sup> percentile of national and subsistence fish consumption rates (EPA 1999), respectively. The subsistence consumption rate is consistent with results of American Indian subsistence fishing on Lake Ontario (Forti et al. 1993). For the general population, fish consumption rates correspond to the average of fish yields for eastern Lake Erie (NYSDEC 1998). Each individual is assumed to cultivate a garden irrigated with potentially contaminated lake water and consume crop and animal products at rates recommended in regulatory guidance (Beyeler et al. 1998). The fish consumption rates for the four individual receptors are also presented in Table D-1.

**Table D-1 Intake Parameter Values for Drinking Water and Fish Consumption by Receptors  
Outside Current Western New York Nuclear Service Center Boundary**

<i>Location</i>	<i>Pathway</i>	
	<i>Drinking Water (liters per day)</i>	<i>Fish Consumption (kilograms per year)</i>
Cattaraugus Creek (near Buttermilk Creek)	2.35	9
Cattaraugus Creek (Seneca Indian)	2.35	62
Lake Erie/Niagara River water users <sup>a</sup>	2.35	0.1

<sup>a</sup> The same fish consumption rate is assumed for both undiluted (e.g., Sturgeon Point) and diluted (e.g., North Tonawanda) water users.

Note: To convert liters to gallons, multiply by 0.264; kilograms to pounds, multiply by 2.2046.

## Receptors Inside the Current Western New York Nuclear Service Center Boundary

A set of four site receptors inside the current WNYNSC boundary was developed and screened based on the principles and information described above. The general locations and activities of the receptors were selected to span the range of conditions that could occur if site control were lost. Since documentation supporting regulatory guidance was used to influence the selection of receptors, the site receptors have characteristics similar to the residential agriculture receptor used in NRC license termination analysis (NRC 2006), the intruders used in Title 10 of the *Code of Federal Regulations* (CFR), Part 61, analyses, and DOE residual contamination analyses (Yu et al. 1993). These are the home construction, well-drilling, and residential farmer receptors. Additionally, to address direct exposure resulting from erosion, a resident located opposite the exposed waste along one of the creeks within the WNYNSC boundary was selected. The nature of the contamination and environmental transport pathways and receptor behavior combine to produce sets of exposure modes for each receptor. Conditions of these exposure scenarios are consistent with guidance recommendations (EPA 1991, 1999) developed for evaluation of risk of exposure to hazardous chemicals.

Locations of receptors are determined based on receptor selection Principles 1 and 2 discussed earlier in this section and site-specific conditions. Given Principle 2, it is reasonable to propose an onsite receptor whose activities are consistent with the capabilities of an individual who establishes a residence on the site. Each of the individual receptors may be located on site on the plateaus or along Buttermilk Creek, but location and activities are constrained by topography, groundwater availability, and waste form location. In particular, direct intrusion into buried waste is assumed to not occur in the erosion case, because erosion-driven exposure of the waste involves development of steep slopes and concentrated flow as the rim of the creek moves into the contaminated area. These conditions are less favorable to utilization than settling of nearby areas outside of the creek channel. For erosion scenarios, intrusion involves a hiker walking along the contaminated creek bank and coming into direct contact with waste for a limited period of time.

### Home Construction Receptor

The ability of the receptor to directly contact radioactive material is related to the excavation capability of the individual and the degree of separation afforded by the nature of the residual contamination or by the disposal facility design. The receptor selection principles and past practice indicate that an individual involved in home construction could directly contact contamination if physical separation is not provided, but is not likely to do so if direct contact requires construction capabilities greater than those required to build a home (NRC 1981). Selection of this type of individual is reasonable in light of the low probabilities that an industrial concern would excavate large quantities of cement, rock, and soil to contact waste; could not recognize the hazard, given industrial-technical capability; and could continue to function, given that institutional control of government agencies had failed (NRC 1981). Thus, the home construction receptor excavates a limited volume of soil to a depth of less than three meters (10 feet), but does not have the capability to remove large quantities of soil or rock. Exposure modes for the home constructor include inhalation of airborne contaminated material and exposure to direct radiation. In the course of excavating the home foundation, contaminated material may be removed from the excavation and serve to initiate residential farmer exposure modes. Occurrence of this scenario is reasonable for the Low-Level Waste Treatment Facility, the NDA, and the SDA for the No Action Alternative but is precluded by placement of a thick cap for these four facilities for the Sitewide Close-In-Place Alternative.

### Well-drilling Receptor

Even though contamination may be located in an area having little available water due to natural conditions or placement of engineered barriers, it is reasonable to consider the transient effects of construction of a well inside the barrier system. In this case, an individual has direct contact with waste in a drilling operation located at the facility, but does not consume water from the well. Exposure modes for the well driller include

inhalation of fugitive dust and external exposure to material deposited in a well cuttings pond. Subsequent to drilling activity completion, contaminated material may be removed from the cuttings pond and distributed on the ground surface to initiate residential exposure modes. Occurrence of this scenario is possible for all facilities for the No Action Alternative and for the Low-Level Waste Treatment Facility for the Sitewide Close-In-Place Alternative.

**Residential Farmer Receptor**

In the case of a residential farmer receptor, past practice (Yu et al. 1993, NRC 1981) indicates that presence of a 3-meter-thick (10-foot-thick) cap prevents direct contact with radioactive material. The residential agriculture receptor may contact near-surface soil with residual contamination, or have access to soil, groundwater, or surface water contaminated by releases from a site facility. For facilities stabilized in place, direct contact with contamination derived from that waste is unlikely due to depth of cover of the waste form, and exposure via residential agriculture would require contact with potentially contaminated groundwater or surface water. Drinking and irrigation water wells with adequate productivity could be located on the North Plateau between the individual waste management areas and groundwater discharge to Erdman Brook. Site data and the three-dimensional site-wide groundwater model indicate that the Kent recessional sequence is unsaturated below the North and South Plateaus, indicating that this unit is not a reasonable source of domestic or irrigation water. The degree of saturation and directions of flow in the Kent recessional sequence are discussed in Appendix E, Section E.3.7.1. Due to size and flow regularity, surface water used by onsite receptors would likely come from Buttermilk Creek. Based on past practice (EPA 1991, 1999; NRC 1981, 2006; Yu et al. 1993), exposure modes related to residential agriculture activities include inhalation of contaminated air; ingestion of contaminated groundwater, surface water, crops, animal products, and soil; and exposure to direct radiation. For this EIS analysis of onsite receptors, these exposure modes have been extended to include hiking in an area contaminated by groundwater discharge to a creek and consumption of deer (selected to represent exposure resulting from hunting activities in the area) contaminated by consumption of vegetation growing in the contaminated groundwater discharge area.

**Residential Receptor (Erosion)**

Although establishment of a residence or farm immediately in an area of active erosion is unlikely, establishment of a residence adjacent to such an area is possible. The primary exposure mode related to such a residence is exposure to direct radiation from areas exposed as a result of erosion along creekbeds. This receptor does not grow crops on the actively eroding area. For this EIS analysis, this exposure mode has been extended to include hiking in the area of exposed waste.

The assumed contaminated drinking water and fish consumption rates for receptors inside the current WNYNSC boundary (the receptors discussed in the previous paragraphs) are presented in **Table D–2**.

**Table D–2 Intake Parameter Values for Drinking Water and Fish Consumption by Receptors  
Inside the Western New York Nuclear Service Center Boundary**

<i>Receptor</i>	<i>Pathway</i>	
	<i>Drinking Water<sup>a</sup> (liters per day)</i>	<i>Fish Consumption (kilograms per year)</i>
North Plateau resident farmer	2.35	0
North/South Plateau well driller/worker	0	0
Buttermilk Creek resident farmer	2.35	9

<sup>a</sup> Drinking water rates are 95<sup>th</sup> percentile rates.

Note: To convert liters to gallons, multiply by 0.264; kilograms to pounds, multiply by 2.2046.

#### **D.3.1.4 Summary of Long-term Performance Assessment Exposure Scenarios**

Based on combinations of release mechanism, environmental transport pathway, and receptor location and behavior, three types of exposure scenarios have been developed. These are groundwater release, erosion release, and direct intrusion scenarios. The types of contamination initiating these scenarios are residual contamination of near-surface soil and groundwater and residual contamination of below-grade soil and structures.

##### **Residual Contamination of Near-surface Soil**

For residual contamination in surface soil, combinations of release mechanisms, environmental transport pathways, and exposure modes have been identified, screened, and developed into standard exposure scenarios (NRC 2006; Yu et al. 1993, 1994). This scenario, termed “residential farmer,” has been adopted for this analysis, but extended to include deer consumption and recreational hiking for onsite receptors. Due to the nature of the alternatives, the residential farmer scenario is widely applied.

##### **Existing Contamination of Groundwater**

Due to a historical unplanned release of acidic wastewater from the nuclear fuel reprocessing plant, a plume of contaminated groundwater with activity concentration dominated by strontium-90 has developed to the northeast of the plant. Use of this contaminated water would initiate all of the residential exposure modes described above for the residential farmer receptor.

##### **Residual Contamination of Below-Grade Soil and Structures**

For residual contamination of below-grade soil and structures, analysis of site and facility conditions identified three site-specific release mechanisms: partitioning into groundwater, entrainment in surface water runoff (erosion), and direct intrusion. Analysis of environmental conditions identified three primary environmental transport pathways: transport in groundwater to onsite wells, transport in groundwater to surface water, and transport in surface water. For each alternative and each facility, the groundwater release mechanism initiates scenarios affecting an onsite farmer (transport of contaminated groundwater to onsite wells) and five users of surface water (Buttermilk Creek; Cattaraugus Creek near Buttermilk Creek; Cattaraugus Creek near Gowanda, New York [Seneca Nation]; Lake Erie and Niagara River). For each alternative and each facility, erosion initiates an additional five scenarios affecting an onsite resident/recreational hiker and surface water users on Buttermilk Creek; Cattaraugus Creek near Buttermilk Creek; Cattaraugus Creek near Gowanda, New York (Seneca Nation); and Lake Erie/Niagara River (population). Thus, for each alternative and each facility, a basic set of 5 erosion release scenarios is considered. For each alternative and each facility, a set of 2 direct intrusion scenarios (home construction and well drilling) is considered. While a total of 12 basic scenarios are considered, some may be eliminated due to waste depth or other considerations for a specific alternative. The combinations of release mechanism and receptor location are summarized in **Table D-3**.

For groundwater release scenarios, onsite receptors are residential farmer receptors consuming drinking water, garden products, and deer and engaging in recreation at rates consistent with their location. For erosion release scenarios, onsite receptors are residents living near waste exposed by erosion who engage in recreational hiking and are exposed via direct radiation, inhalation, and inadvertent soil ingestion pathways. For direct intrusion scenarios, workers are exposed via direct radiation, and inhalation pathways. For residential farmer scenarios initiated by direct intrusion, receptors are subject to the exposure modes listed above for onsite residential farmer receptors. For both groundwater and erosion release scenarios, offsite receptors consume fish and drinking water and are subject to the balance of residential farmer pathways listed above for onsite receptors. Characterization of the exposure modes for these receptors is summarized in **Table D-4** and described in more detail in Appendix G.



**Table D-3 Summary of Exposure Scenarios**

<i>Release Mechanism</i>	<i>Location</i>
Partitioning to groundwater	North or South Plateau Buttermilk Creek Cattaraugus Creek (near site) Cattaraugus Creek (Seneca Nation of Indians) Lake Erie (population)
Entrainment in surface water (erosion)	North or South Plateau (recreational hiker) Buttermilk Creek Cattaraugus Creek (near site) Cattaraugus Creek (Seneca Nation of Indians) Lake Erie (population)
<b>Direct Intrusion</b> Home construction Well drilling	North or South Plateau North or South Plateau

**Table D-4 Summary of Receptor Exposure Modes <sup>a</sup>**

<i>Release and Transport Mode, Receptor Location</i>	<i>Exposure Mode</i>						
	<i>Drinking Water Consumption</i>	<i>Fish Consumption</i>	<i>Residential with Agriculture <sup>b</sup></i>	<i>Residential without Agriculture</i>	<i>Deer Consumption</i>	<i>Recreational Hiking</i>	<i>Worker Inhalation &amp; External Exposure</i>
<b>Groundwater to groundwater</b>							
North Plateau	Y	N	Y	N	Y	Y	N
South Plateau	N	N	Y	N	Y	Y	N
<b>Groundwater to groundwater and surface water</b>							
Buttermilk Creek	Y	Y	Y	N	N	N	N
Cattaraugus Creek	Y	Y	Y	N	N	N	N
Seneca Nation of Indians	Y	Y	Y	N	N	N	N
Sturgeon Point	Y	Y	Y	N	N	N	N
Niagara River	Y	Y	Y	N	N	N	N
<b>Erosion to surface water</b>							
Buttermilk Creek	Y	Y	Y	N	N	N	N
Cattaraugus Creek	Y	Y	Y	N	N	N	N
Seneca Nation of Indians	Y	Y	Y	N	N	N	N
Sturgeon Point	Y	Y	Y	N	N	N	N
Niagara River	Y	Y	Y	N	N	N	N
<b>Erosion with adjacent residence</b>							
North Plateau	N	N	N	Y	N	Y	N
South Plateau	N	N	N	Y	N	Y	N
<b>Intrusion</b>							
Home construction worker	N	N	N	N	N	N	Y
Home construction resident	Y	N	Y	N	N	N	N
Well-drilling worker	N	N	N	N	N	N	Y
Well-drilling resident	Y	N	Y	N	N	N	N

<sup>a</sup> Y = Yes, combination of release, transport, and exposure modes and receptor location occurs.

N = No, combination of release, transport, and exposure modes and receptor location does not occur.

<sup>b</sup> Inhalation and direct exposure are subpaths for the residential agriculture scenario.

In addition to the set of basic scenarios that analyze impacts of releases from individual facilities, combination scenarios were constructed to evaluate cumulative impacts of all facilities for each receptor. Locations of onsite receptors for cumulative impacts were identified by conservative evaluation of intersection of groundwater flow paths for individual facilities. Because groundwater flow paths to surface water for all facilities reach Buttermilk Creek, cumulative impacts on surface water users would be the sum of impacts of each facility.

### **D.3.2 Selection of Long-term Performance Assessment Calculation Models**

Analysis of scenarios involves selection, development, and use of computerized mathematical models applied for radionuclides and hazardous chemicals. The models produce estimates of dose, Hazard Index, and risk to individuals and populations due to releases from individual facilities. The results can be added for multiple facilities to provide a cumulative dose, Hazard Index, and risk. For scenarios involving contact with surface water contaminated by groundwater releases or by erosion collapse, the cumulative impact was calculated as the sum of impacts due to releases from individual facilities. For scenarios involving onsite contact with contaminated groundwater, cumulative dose, Hazard Index, and risk were estimated as the sum of impacts due to intersecting groundwater paths from multiple facilities. Direction of groundwater flow and locations of intersecting groundwater flow paths were identified using hydrologic analysis results, described in Appendix E. The following subsections discuss the approach for selection, development, and some aspects of mathematical model use. Estimates of dose, Hazard Index, and risk developed using mathematical models are presented in Appendix H.

#### **D.3.2.1 Review of Existing Models and Conceptual Alternatives**

The primary objectives for estimation of human health impacts (dose, Hazard Index, and risk) are to provide a basis for choice among alternative courses of action. Mathematical models used for these purposes should:

- Have a basis in observable physical processes and standard scientific principles that allows reasonable projection over time
- Use consistent technical approaches that do not introduce bias favoring specific actions
- Provide reasonable representation of site-specific conditions
- Allow for development of demonstrably conservative estimates when used in a deterministic manner
- Allow verification of estimates

The first step in selection of models for release, transport, and human health impact analysis was identification of the site-specific conditions important in estimation of health impacts. This includes specification of environmental conditions, facility designs, and exposure scenarios specific to WNYNSC as described in Section D.3.1. Environmental conditions important to estimation of human health impacts of facilities stabilized in place include groundwater flow directions and velocities and erosion locations and rates. Facility design considerations specific to WNYNSC facilities include layering of engineered barriers, time-dependence of engineered barriers physical properties, and nonuniform vertical and radial distributions of contaminants. The layered design of engineered barriers supports the objective of minimizing early releases to realize reduction in concentration due to decay of radionuclides and degradation of hazardous chemicals. Under these circumstances, diffusive, dispersive, and advective releases are of interest. Nonuniform vertical or radial distribution of concentration introduces the need for distributed parameter representation of transport mechanisms.

The second step in selection of mathematical models was review of the technical literature and regulatory guidance to identify existing models meeting site-specific requirements. Guidance on the approach to human health impact modeling and the appropriate types of performance assessment models has been published (Case and Otis 1988; EPA 1991, 1999; Kozak et al. 1990; Kozak et al. 1993; NRC 2000, 2006). For analysis of low-level radioactive waste facilities, formal analysis of uncertainty was recommended, an iterative approach was anticipated, limits to the required level of detail were recognized, and use of particular models or codes was not endorsed (NRC 2000). Particular models applicable to performance assessment include those addressing facility release rates (Icenhour and Tharp 1995, NRC 1993), groundwater transport (Codell et al. 1982; Pigford et al. 1980; van Genuchten and Alves 1982), and integration of release rate, groundwater transport, and exposure (Kennedy and Strenge 1992, Yu et al. 1993).

The referenced models were evaluated for their ability to simulate the site-specific scenarios and closure designs developed for WNYNSC facilities. In general, no single model for groundwater release scenarios addressed the combination of waste form conditions and engineered barriers specified for site facilities, and no models addressed erosion scenarios. Thus, for groundwater release scenarios, the approach selected for analysis of site facilities was development of site-specific release models combined with referenced groundwater transport (van Genuchten and Alves 1982) and exposure models (Yu et al. 1993, EPA 1991) to produce the integrated codes required for estimation of human health impacts. For erosion scenarios, the approach selected was to couple a site-calibrated landscape evolution model with a site-specific integrated release and exposure model that combined the site-specific release rate with a referenced exposure model (Yu et al. 1993).

#### **D.3.2.2 Site-specific Models**

Integrated human health impact estimation models were constructed using modules that addressed: (1) release from the storage/disposal configuration (release module), (2) transport through groundwater and surface water (groundwater transport module), and (3) human health impacts resulting from consumption or use of contaminated water (human health impact module). In addition, each integrated model includes an executive routine that controls data input and output and calculation flow. Flow of groundwater through and around the waste form was estimated using three-dimensional near-field flow models described in Appendix E. A set of eight integrated models (four for radionuclides and four for hazardous chemicals) was developed for the analysis of site facilities. Each set of four uses differing types of release, and groundwater transport modules, but common human health impact modules. Two additional integrated codes (one for radionuclides and one for hazardous chemicals) were developed for analysis of erosion collapse release scenarios. A single integrated code was developed for analysis of radiological impacts of direct intrusion into waste. Only the integrated groundwater release models use the groundwater flow, release, or transport modules. Each of these modules is discussed in the following paragraphs. The five release modules are discussed first, followed by a discussion of the groundwater transport module and then the human health impact module. The discussion of the individual modules is followed by a short discussion of how the modules are assembled into integrated codes for long-term dose prediction. Further details on the equations used in the modules and the nature of integrated codes are presented in Appendix G of this EIS.

#### **Near-field Flow Models**

For groundwater release scenarios, a set of models was developed to reflect the site-specific configuration of the aquifer and the engineered barrier system determining groundwater flow around and through the waste system. These three-dimensional near-field flow models simulate performance of the combination of a slurry wall, tumulus, waste form, and aquifer using the STOMP [Subsurface Transport Over Multiple Phases] computer code (White and Oostrom 2000). The tumulus comprises a drainage layer and a central core with a low-permeability upper layer and lower block of backfill soil or grout. More-specific information on the near-field flow models is presented in Appendix E of this EIS.

## Site-specific Release Modules

Four modules for releases to groundwater and a single model for erosive release to surface water were developed. In each groundwater case, whether the contamination is in unsaturated or saturated zones, the rate of groundwater movement through the waste is estimated using the near-field flow models described in Appendix E of this EIS. The release modules were developed to address the more complex geometries over short distances and different materials that are part of the waste confinement systems. The release modules are as follows:

- A distributed-parameter, layered cylindrical-geometry release model was developed to predict release of radionuclides or hazardous chemicals in the horizontal, but not vertical, direction from waste solidified in a tank. In this model, a central cylindrical core representing the waste form is encircled by layers representing a grout-filled annulus and a slurry wall. Each system element has adsorptive properties, but the annular grout and slurry wall layers are initially free of contamination. The model allows for advection as well as diffusion as small amounts of the groundwater flow through the waste form and then mix with the majority of the groundwater that flows around the slurry wall. The model allows for variation in the contaminant concentration with radial position and may be used in an iterative manner to represent vertical distribution of contaminants. This model uses finite difference methods to solve mass balances and predict the concentration of a contaminant entering the groundwater downstream of the engineered structure. This particular model is most appropriate for analysis of the Waste Tank Farm when there is a solid waste form within the tank and engineered barriers around the waste.
- A lumped-parameter model with layered, rectangular symmetry was developed to predict rate of release from contaminated soil or stabilized waste located in the saturated zone. The model comprises three layers: the waste form and two adsorptive layers downstream of the waste form. This module predicts releases from the engineered structure, assuming equilibrium partitioning of radionuclides or hazardous chemicals between the solid and pore water phases of the waste form. Contaminant concentration varies in steps within the waste form, and release occurs by advection but not diffusion. The mass balances allow an analytical solution, and this release model is applicable to below-grade portions of the Main Plant Process Building, the NDA, and the SDA.
- A distributed-parameter, layered rectangular-geometry release module was developed to simulate release in the vertical direction from portions of the Main Plant Process Building and Waste Tank Farm. The model represents downward percolation of precipitation through an upper adsorptive barrier, waste form, and lower adsorptive barrier. Water exiting this engineered system flows horizontally through an aquifer. The model represents spatial distribution of concentration of radionuclides or hazardous chemicals, advective and diffusive transport, and time-dependence of physical properties. This module uses finite difference methods to solve the mass balance equations.
- A distributed-parameter rectangular flow tube model was developed to simulate release from contaminated soil and groundwater; that is, future development of a groundwater plume. The model represents spatial distribution of concentration of radionuclides or hazardous chemicals, as well as advective and diffusive transport, and allows simulation of a slurry wall within the contaminated area. This module uses finite difference methods to solve mass balance equations.
- An erosion model was developed that predicts the release of below-grade waste into surface streams. The release rates are based on horizontal and vertical distribution of radionuclides or hazardous chemicals in a rectangular cell. For this EIS, erosion rates are predicted by a simplified gully model that draws its starting point from topography established by the use of the CHILD [Channel-Hillslope Integrated Landscape Development] landscape evolution model. The CHILD model was calibrated by reproducing a close approximation of the current topography from a topography estimated to have

been present following the last glacial retreat a little over 15,000 years ago. The simplified single gully release model allows investigation of local-scale features that may not be captured by the landscape evolution model.

### Groundwater Transport Module

For releases from localized sources, a single one-dimensional groundwater transport module was developed that predicts changes in soil and groundwater contaminant concentrations at various distances and times using the parameters of groundwater velocity, soil adsorption properties, and contaminant decay rate. This model utilizes an analytic solution to the contaminant transport equation in conjunction with the principle of superposition to represent a time series of releases. This module is linked with one of the groundwater release modules discussed earlier to predict downgradient contaminant concentration as a function of position and time. As described above, for releases from spatially distributed sources such as the North Plateau Groundwater Plume, a finite-difference solution to the one-dimensional contaminant transport equation is applied. Initial concentration of contaminants in the aquifer is specified as model input.

### Human Health Impact Module

For both radioactive and hazardous chemical constituents, a human health impact module was developed that calculated dose and risk (radionuclides) or Hazard Index and risk (hazardous chemicals) from contact with and use of contaminated soil and water. The human health impact module allows for the consumption of contaminated water, crops, and livestock as well as fish raised in contaminated water. It also allows for the siting of a house in contaminated soil. Estimation of human health impacts of deer consumption and recreational hiking are included in the model.

### Integrated Models

The various modules are combined to develop sets of integrated release, transport, and exposure models. **Table D-5** summarizes the combinations of modules composing the sets of integrated models that represent the capabilities on the integrated long-term performance assessment models. The finite-difference cylindrical, analytic rectangular, and finite-difference rectangular modules all involve release to groundwater and groundwater transport to either a well or surface water. The plume model involves release to either a groundwater well or surface water. The erosion model simulates direct release to surface water, while the intruder model does not involve transport to groundwater or surface water. Further information on the capabilities of specific integrated models is presented in Appendix G of this EIS. Information on which models are used for specific analyses is presented in Appendix H, where the results of specific analyses are presented.

**Table D-5 Summary of Integrated Release/Transport/Exposure Models**

Model	Release Module					Groundwater Transport Module	Health Impact Module
	Finite-Difference Cylindrical	Analytical Rectangular	Finite-Difference Rectangular	Erosion	Direct Intrusion		
Plume			Yes			Yes	Yes
Tank <sup>a</sup>	Yes	Yes	Yes			Yes	Yes
Above-grade monolith <sup>a</sup>		Yes	Yes			Yes	Yes
Below-grade monolith		Yes				Yes	Yes
Erosion				Yes		No	Yes
Intruder					Yes	Yes	Yes

<sup>a</sup> The tank and tumulus models have two versions, one with a distributed-parameter source and one with a lumped-parameter source.

### **D.3.2.3 Approach to Addressing Long-term Performance Assessment Uncertainty**

Evaluation of uncertainty involves consideration of contributions from model structure, model parameters, and scenario elements (Draper et al. 1999). Because probability distributions of model structure (i.e., uncertainty of appropriate model structure), receptor behavior, and some model parameters are not available for both groundwater and erosion scenarios, a comprehensive probabilistic evaluation is not practical. Thus, a combination of conservative assumptions and sensitivity analyses were applied to investigate uncertainty associated with dose estimates. As a first step in the process, the nature of the model was reviewed to identify fidelity to the physical system represented by the model. As a second step, literature of sensitivity and uncertainty analysis was reviewed to survey the current understanding of model sensitivity and uncertainty. The next step comprised review of site-specific environmental conditions, closure designs, and models to select a set of sensitivity cases. Results of deterministic sensitivity analysis are presented in Appendix H of this EIS.

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