M-32

Department of Energy
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P.O. Box 191
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July 28, 1999

Mr. Jack D. Parrott, Project Manager
U.S. Nuclear Regulatory Commission
MST8F37
Washington, DC 20555

SUBJECT: Draft Chapter 6 (Receptor Characteristics and Parameters) of Methods for Long-Term Performance Assessments in the Strategic Decision on Closure of the West Valley Site

Reference: Letter (65991), J. E. Hammelman to D. W. Sullivan, "Draft Chapter 6 (Receptor Characteristics and Parameters) of Methods for Long-Term Performance Assessments in the Strategic Decision on Closure of the West Valley Site," dated July 13, 1999

Dear Mr. Parrott:

Enclosed please find the subject document for your review and comment. This document was revised based on earlier input from U.S. Nuclear Regulatory Commission.

If you have any questions, contact Dan Sullivan of my staff at (716) 942-4016.

Sincerely,

Barbara A. Mazurowski

Barbara A. Mazurowski, Director
West Valley Demonstration Project

Enclosure: Subject Document

cc: P. J. Bembia, NYSERDA, WV-17, w/o enc.
J. E. Hammelman, SAIC, w/o enc.

DWS:071 - 66042 - 451.5.2e

DWS/brb

ATTACHMENT 1

file / TJ / Herman / Dan

Science Applications International Corporation
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July 13, 1999

Mr. D. W. Sullivan
West Valley Demonstration Project
U.S. Department of Energy
P.O. Box 191
WV-37
West Valley, NY 14171-0191

Subject: Draft Chapter 6 (Receptor Characteristics and Parameters) of *Methods for Long-Term Performance Assessments in the Strategic Decision on Closure of the West Valley Site*

Dear Dan:

The attached draft of the receptor characteristics chapter of the long-term performance assessment document addresses comments discussed in our recent teleconference. The chapter presents the rationale and methods used to select site-specific receptors for the West Valley EIS long-term radiological impact analysis. While there are currently no applicable standards for selection of on-site receptors at West Valley, the proposed receptors were selected consistent with past practice and potentially relevant guidance. The presentation to the NRC on May 3, 1999 was developed from an earlier draft of the material in this chapter. The chapter was revised to address issues raised during the presentation. Please call ([703] 318-4628) if I can provide additional information or clarification.

Sincerely,

SCIENCE APPLICATIONS
INTERNATIONAL CORPORATION

James E Hammelman

James E. Hammelman
Project Manager

cc: P. Bembia, NYSERDA

ATTACHMENT I

RECEPTOR CHARACTERISTICS AND PARAMETERS

6. IDENTIFICATION OF RECEPTORS

Estimating human health impacts involves analyzing releases from a facility, transport through the environment and exposure of an individual to potentially hazardous materials. This chapter focuses on locations and activity patterns of individuals potentially exposed to radionuclides present at the West Valley site. The method, rationale and results of the receptor selection process are presented in this chapter. Site conditions and radionuclide inventories are described in Chapters 3 and 4, development of environmental pathways and exposure scenarios are discussed in Chapters 5 and 7 and evaluation of release modes is described in Chapters 8, 9, 10, 11 and 12. Data and analyses presented in these chapters indicated that the primary environmental transport modes for long-term impacts are release to groundwater via dissolution and partitioning and release to surface water via groundwater discharge or erosional collapse.

Objectives for environmental analyses conducted under the National Environmental Policy Act (NEPA) include discussion of direct and indirect effects (Ref. 1, Section 1502.16) and of consistency of effects with national environmental standards (Ref. 1, Section 1504.1). The analyses focus on expected conditions but consider reasonably foreseeable events even if their probability of occurrence is small (Ref. 1, Section 1502.22). This introduces the concept of two classes of receptors, one class defined for conditions expected to occur and a second class defined for conditions not expected to occur. Although details of applicable site-specific environmental standards have not been established in final form, it is expected that these standards will include criteria for protection of members of the general public under the assumption that institutional controls are in place and of individuals under the assumption that institutional controls have failed. These expected standards can also be viewed as addressing conditions expected to occur and conditions not expected to occur.

Section 6.1 presents background information relevant to identification of receptors at West Valley. Section 6.2 presents principles for development of site-specific receptors, including review of past practice related to receptors for environmental analyses and identifies locations and activity patterns for generic and site-specific receptor types. Section 6.3 presents a summary of the results of receptor selection, identifying site-specific receptors for each alternative and for each waste management area (WMA). Section 6.4 summarizes dose calculation procedures for exposure to contaminated media, identifying the parameter values that characterize receptor activities.

6.1 INTRODUCTION

The location of receptors and the activity patterns characterizing these individuals are important elements in determining human health impacts due to exposure to either residual contamination or to releases from a disposal facility. The purposes of this chapter are to: (1) identify locations of receptors used in performance assessments (PA) for conditions both expected to occur and not expected to occur, (2) identify sets of activities for each type of receptor, (3) summarize equations and parameter values used to calculate dose to an individual due to exposure to a given concentration of a radionuclide in an environmental media and (4) summarize locations and activities for on-site receptors at each of the waste management areas (WMA) on the West Valley site.

Information on elements of exposure scenarios other than receptor locations and activities, for example release modes, and environmental transport mechanisms is provided to the extent necessary to support understanding of the description of receptor activities and associated dose impacts. Primary release modes include diffusional, partitioning-limited and solubility-limited release to groundwater and erosional collapse release to surface water, while environmental transport mechanisms include groundwater and surface water flow, atmospheric dispersion and direct radiation.

The expected conditions are that institutional control of the Western New York Nuclear Services Center (the Center), that is, the "site", or portions of the site would be maintained indefinitely during the post-implementation phases of Alternatives II (On-Premises Storage), III (In-Place Stabilization) and IV (No Action: Monitoring and Maintenance). Conditions that are not expected to occur include loss of institutional control of the site for these alternatives. The expected condition for Alternative I is presence of residual contamination levels consistent with free release of the site while the expected condition for Alternative V (Discontinue Operations) is immediate (year 2000) loss of institutional control with the potential for reoccupation of the site. Complete descriptions of activities comprising the alternatives were presented in Chapter 3 of the Draft Environmental Impact Statement (DEIS) (Ref. 2).

6.2 IDENTIFICATION OF RECEPTOR LOCATIONS AND ACTIVITIES

A three-step process was used to identify site-specific receptors. First, a set of principles was developed to guide selection of receptors. Development of these principles was based primarily on review of existing regulations, past practice and guidance but also considered site-specific conditions. Some of the referenced guidance is relevant but not necessarily applicable to the West Valley project and site. Second, the principles were applied to develop four generic receptors. The generic receptors are characterized by a range of activities consistent with reasonable interpretation of past practice. Third, site-specific information was combined with the generic receptor types to identify site-specific receptors. Site-specific information includes directions and velocities of flow of groundwater and surface water, distribution of population around the site and the 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 second step superimposed the generic receptors on the environmental pathways and population distributions in light of local site conditions. The site-specific receptors were developed both for conditions that are expected to occur and for conditions that are not expected to occur.

6.2.1 Principles for Selection of Receptors

A set of principles that guides identification of generic and site-specific receptors has been developed. These principles are consistent with that practice and the conditions present at the West Valley site. These principles are:

- Evaluate the health of members of the general public.
- Evaluate the health of an individual who indirectly contacts radioactive waste at some time after closure of the site under the assumption of failure of institutional controls.
- It is not possible to protect an individual who directly contacts radioactive waste.
- Identify generic receptors based on review and interpretation of prior analysis performed by the NRC and DOE and on principles applied in environmental and safety analyses.
- Evaluate modes of release of radioactive material and behavior of natural and engineered barriers based on physical processes.
- Analyze impacts based on realistic conditions and regional and site characteristics.

The first and second principles have their bases in generally applicable environmental regulations.

The third principle has its basis in the inherent hazard of radioactive waste and may be demonstrated, in part, through consideration of concentration and dose limits promulgated in environmental protection regulations. The content of the first three principles depends in part on the juxtaposition of direct and indirect contact and on the role of site conditions, receptor activities and facility designs in determining the likelihood of contact with waste-bearing material.

The fourth principle is based on the authority and analyses of federal and state agencies charged with enforcement of environmental regulations and on the need to provide a basis for comparison with regulatory requirements and prior analyses of similar facilities.

Guidance and past practice relevant to identification of receptors for the West Valley performance assessment includes information related to facilities operating under normal conditions, to facilities undergoing decommissioning and to low-level radioactive waste (LLW) disposal facilities. 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 (Ref. 1) 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 (Ref. 3) for assessment of impacts to normal operation (expected conditions) 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 operation of fuel reprocessing plants (Ref. 4) also directs consideration of doses to populations out to 80 kilometers (50 miles). More recent guidance for controlling impacts of normal operations (Ref. 5 and 6) focuses on limiting doses to the average member of the critical group (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 (Ref. 7) directs federal decision-makers to identify and address high and adverse environmental impacts that disproportionately affect minority and low-income populations.

Standards for termination of NRC licenses (Ref. 5) provide dose limits for exposure to residual contamination for an average member of the critical group (AMCG) where this individual is representative of the group reasonably expected to receive the greatest dose. Supporting guidance (Ref. 8) provides methods and additional details for generic screening scenarios (Ref. 8, Chapter 3) and procedures for development of site-specific scenarios (Ref. 8, Appendix C). For screening scenarios, the AMCG occupies the site and is in direct contact with residual contamination (Ref. 8, p 10). 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 transport of contaminants (Ref. 8, p C-2). Guidance developed for analysis of impacts of residual contamination at Department of Energy sites (Ref. 9) provides dose limit criteria and methods for analysis of residential farmer 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.

NRC analysis of generic LLW disposal sites is presented in the Environmental Impact Statement on 10 CFR Part 61, Licensing Requirements for Land Disposal of Radioactive Waste (Ref. 10 and 11). Reasonable assurance of protection of public health and safety is provided by specification of dose limits for off-site receptors and by specification of performance objectives for on-site intruders, workers and site stability. NRC guidance (Ref. 12, p 3-58) identifies the off-site receptor as the AMCG located at the disposal site boundary. On-site 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 (Ref. 10, p 4-13). Waste stability and layering are assumed to be effective in reducing contact with waste for only a limited period of time (Ref. 10, p 4-14). 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) (Ref. 11, p G-60). As long as a 1 to 2 meter (3 to 6 feet) cap was maintained over the waste, direct contact with the waste was considered very unlikely (Ref. 11, p G-60). 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 (Ref. 11, p G-61). 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 requiring a commercial operation to perform the work (Ref. 11, p G-61). 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 (Ref. 11, p G-76). An additional intrusion scenario considered more recently (Ref. 13, p 4-18) involves short-term exposure related to drilling a well through the waste disposal facility.

Guidance provided for performance assessment of DOE LLW disposal facilities (Ref. 14, p 3-13) 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 (Ref. 15). 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 (Ref. 15, p 12). In the post-drilling scenario, contaminated cuttings from the borehole are distributed onto soil on which a home and garden are located (Ref. 15, p 13).

The fifth and sixth principles have their bases in environmental and safety analyses conducted under NEPA. Analyses based on realistic conditions is recommended in DOE guidance (Ref.16) and in general CEQ guidance (Ref. 1) that analyses should be based on credible scientific evidence and not conjecture.

6.2.2 Identification of Generic Receptors

A set of four generic receptors has been developed based on the principles described above. The general locations and activities of the receptors were selected to span the range of conditions reasonably expected to occur. The generic receptor types proposed for the West Valley analysis have characteristics similar to the four intruders used in the 10 CFR Part 61 analyses and the residential farmer used in NRC 10 CFR Part 20 license termination and DOE residual contamination analyses. These are the home construction, discovery, residential agriculture and drilling intruders.

Locations of generic receptors are determined based on receptor selection principles 1 and 2. Given the first receptor selection principle, impacts should be estimated for receptors representing the population surrounding the site. For the conditions occurring at West Valley, these population receptors will not directly contact radioactive material but could contact surface water indirectly contaminated by releases from site facilities. Given the second receptor selection principle, it is reasonable to propose an on-site receptor whose activities are consistent with the capabilities of an individual who establishes a residence on the site. Thus, each of the four types of individual receptors may be located on or off the site, as long as activities of the receptor are consistent with the form or concentration of contamination at that location.

The range of activities and degree of contact of receptors with radioactive material is determined by consideration of principles 3, 4, 5 and 6. 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 or discovery could directly contact contaminated soil or radioactive waste if physical separation was not provided but is not likely to do so if direct contact requires construction capabilities greater thar. :equired to build a home (Ref. 11). 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 (Ref. 11); could not recognize the hazard given industrial-technical capability and could continue to function given that institutional control of government agencies had failed. Thus, the home construction receptor excavates a limited volume of soil to a depth less than three meters (10 feet) but does not have the capability to remove large quantities of soil or rock. The generic discovery receptor is the same as the home construction receptor with the exception that the hazard is recognized and the exposure time is limited. Modes of exposure for these receptors include inhalation of airborne contaminated material and exposure to direct radiation.

In the case of a residential agricultural receptor, past practice (Ref. 9 and Ref. 11) indicates that presence of a 1 to 2 meter thick cap prevents direct contact with radioactive material. The residential agriculture receptor may contact near-surface radioactive waste, soil with residual contamination or have access to soil, groundwater or surface water contaminated by releases from a site facility. Based on past practice (Ref. 8, 9 and 11), modes of exposure related to residential agricultural activities include inhalation of contaminated air, ingestion of contaminated groundwater, surface water, crops, animal products, fish and soil; and exposure to direct radiation.

In the case of use of well water for domestic purposes, past practice has located the well away from the release point (Ref. 11) and has provided realistic representation of dilution in infiltration and mixing in an aquifer serving the well (Ref. 9 and 11). Given that the receptor is not capable of large-scale disruption of the site, credit for function of passive elements of engineered barriers 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 and function of sub-surface 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, hydraulic conductivity of cements and grout increase with time, approaching that of soil and hydraulic conductivity of surface layers of caps increase with time approaching that of native soil. Consistent with evaluation of material properties (Ref. 17) and guidance (Ref. 12), lifetimes of engineered barriers are less than 500 years. Chemical properties of natural materials, such as adsorptive capacity are however not expected to decrease with time. Engineered disposal facilities include infiltration drainage layers and sub-surface groundwater diversion structures that decrease productivity of wells inside the facility relative to wells located outside of the facility. Thus, it is reasonable to propose that wells will be located outside of the engineered barrier system. However, it is reasonable to consider the transient effects of construction of a well inside the barrier system. If engineered barriers would not affect the productivity of a well, the location of the well would not be influenced by presence of the barrier but could be influenced by the hydraulic conductivity of the native soil. Thus, the well drilling receptor has two variations. In the first variation, site conditions or facility designs do not limit productivity of the well and the well may be located anywhere on the site. In the second variation, site conditions of facility designs limit the productivity of the well and the well is located outside of the facility barriers. Both variations evaluate indirect contact with waste in a drilling operation located at the facility. Included in this interpretation is that analyses conditioned on loss of institutional control begin after 100 years and that intruder barriers last 500 years.

6.2.3 Site-Specific Receptors

Characteristics of the four generic receptors were modified using site-specific conditions to develop a set of site-specific receptors. The residential agricultural scenario discussed above is proposed both for on-site and off-site individuals and for the population out to 80 kilometers (50 miles). The extension to off-site individuals and the population introduces consideration of fish and drinking water consumption rates. Consumption rates for aquatic products are proposed based on site-specific conditions. Because Buttermilk Creek is of relatively low flow and high-suspended sediment content, fish are not available to a receptor located on this creek. Fish consumption at the 75th percentile of the general population (Ref. 8, p 3.9-6 and p 6.1-17) is proposed for a Cattaraugus Creek receptor while consumption at a subsistence level is proposed for the member of the Seneca Nation located on Cattaraugus Creek. The subsistence level is the 95th percentile surveyed for members of the Mohawk Nation using Lake Ontario (Ref. 18). Fish consumption for members of the surrounding population is proposed as 0.1 kilograms per year based on survey of fish production from Lake Erie (Ref. 19). Off-site residential agricultural receptors are proposed to obtain drinking water and crop irrigation water from contaminated surface water. Drinking water consumption rates are 2 liters/d (2 quarts/d), corresponding to the 88th percentile of national consumption rates (Ref. 8, p 3.6-2). For on-site receptors, aquifer conditions on the north plateau allow access to groundwater through a domestic well but hydraulic conductivity on the south plateau is low enough to preclude use of a well for domestic purposes. These considerations are summarized in Table 6-1. Additional parameter values characterizing each type of receptor are presented in Section 6.4.

Table 6-1. Site-Specific Intake Parameter Values for Drinking Water and Fish Consumption

Location	Pathway		
	Water Independent	Drinking Water (L/d)	Fish Consumption (kg/yr)
On-site, North Plateau	Yes	2	0
On-site, South Plateau	Yes	0	0
Cattaraugus Creek (near site)	Yes	2	21
Cattaraugus Creek (Seneca Indian)	Yes	2	50
Buttermilk Creek	Yes	2	0
Population	Yes	2	0.1

An element of the West Valley site analysis includes consideration of buildings or disposal areas left in an unstable state, a condition not contemplated in the prior NRC analyses. In response to this condition, the generic intruder was extended to include individuals entering buildings or waste areas where exposure to high levels of direct radiation could occur.

6.3 WASTE MANAGEMENT AREA-SPECIFIC RECEPTORS

This section summarizes the rationale for selection of off-site and on-site, WMA-specific receptors for each alternative and the results of this selection. In some cases, one can determine from consideration of exposure scenario characteristics and parameter values that analysis of a particular scenario would result in no impact. For example, for the residential agricultural scenario, if residual contamination was more than 0.9 meters below the surface and groundwater use did not cause secondary contamination at the surface, then crops would not be contaminated and the receptor would receive no dose from eating food from a garden. Also, for the home construction and discovery scenarios, if waste were greater than 3 meters below the surface the activity would not disturb the waste and no exposure would occur. These considerations were applied in selection of WMA-specific receptors. In order to facilitate presentation of results, off-site and on-site receptors are discussed separately.

6.3.1 Off-Site Receptors

Review of the distribution of population around the site identified individuals living along Cattaraugus Creek and members of the surrounding population out to 80 kilometers using water drawn from Lake Erie as off-site receptors potentially affected by releases from site facilities. Because buried waste associated with the site does not exist at these locations, occurrence of the home construction, discovery and drilling scenarios would have no adverse impacts. Thus, off-site individuals and members of the general population are residential agricultural receptors for all alternatives both for conditions expected to occur and for conditions that are not expected to occur. Off-site individuals considered in the analysis include an AMCG living on Cattaraugus Creek near the confluence with Buttermilk Creek and a member of the Seneca Nation living on Cattaraugus Creek near Gowanda. Locations of these individuals and the population out to 80 kilometers are shown on Figure 6-1.

6.3.2 On-Site Receptors

Under Alternative I (Removal), no waste would remain on site and the Center would be released for unrestricted use. Thus, the home construction, discovery and drilling scenarios would not result in exposure to buried contamination and the potential hazard remaining at the site would be estimated through consideration of the residential agricultural and drinking water scenarios. The allowable residual contamination that would apply for Alternative I are those that would result in a dose less than 25 mrem/yr. Actual levels of residual contamination needed to meet this level of dose would be established during the remediation phase of the project. These levels would be area- and radionuclide-specific and can only be estimated at this time. Representative levels for WMA-specific radionuclide distributions were presented in Appendix E of the DEIS (Ref. 2).

Under Alternative II for conditions expected to occur, portions of the site would be remediated to free-release conditions and the hazard remaining at these areas would be estimated through consideration of the residential agricultural and drinking water scenarios. As in the case of Alternative I, the free-released areas are presumed decontaminated to levels below those producing a dose of 25 mrem/yr. Also under Alternative II, the Retrievable Storage Area (RSA) and Radwaste Treatment System (RTS) drum cell would be retained for storage and not have on-site receptors for expected conditions. All waste

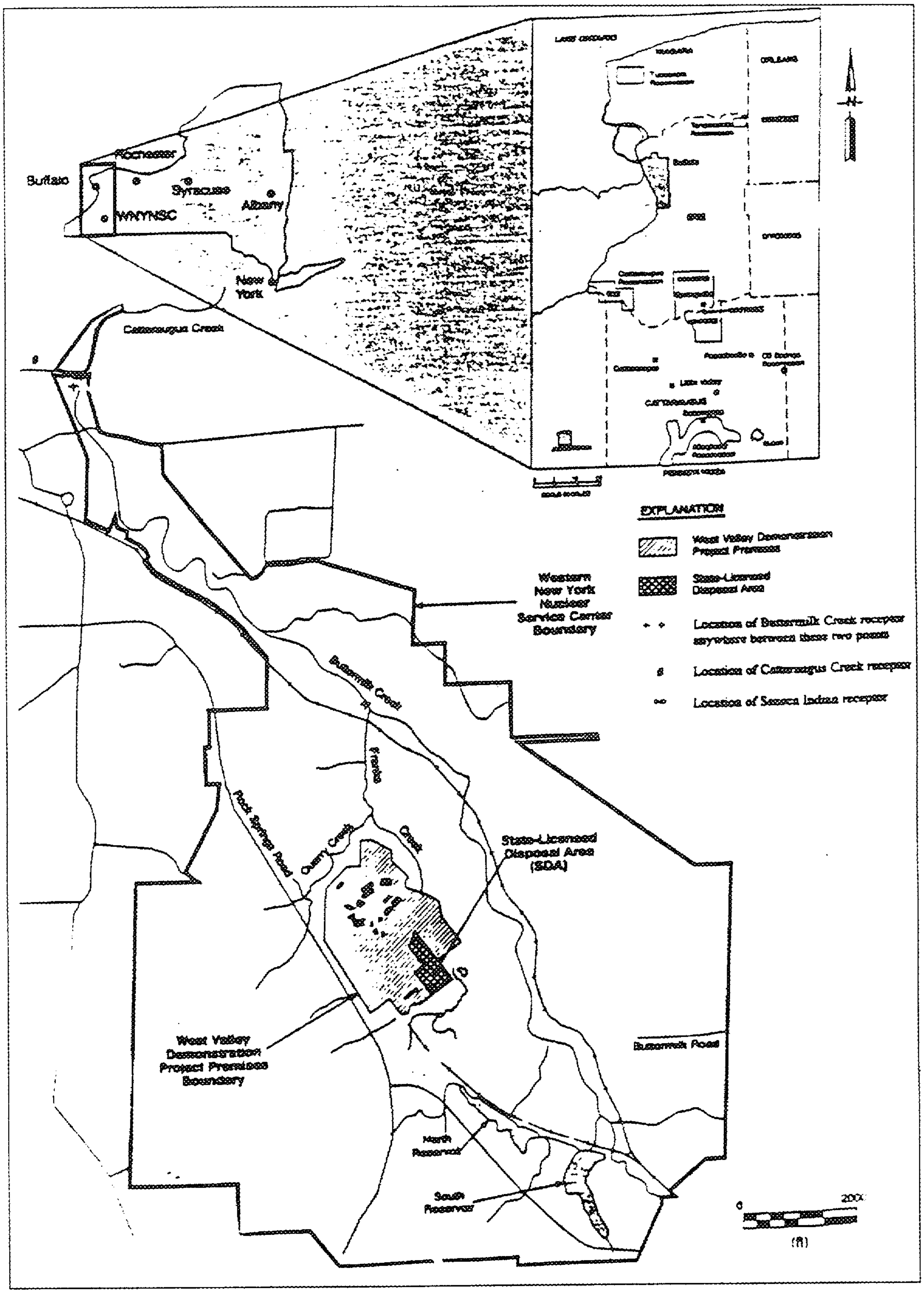

Figure 6-1. Population within 80 km (50 miles) of the Western New York Nuclear Service Center

excavated from other site facilities would be stored in above ground retrievable storage areas on the Project Premises. For conditions not expected to occur, institutional control could be lost and receptors could contact waste or groundwater contaminated with leachate from stored waste. Because the storage facilities would be above ground buildings, the home construction and drilling scenarios on top of these facilities would not occur. The residential agricultural, discovery and drinking water scenarios could occur at locations immediately adjacent to the waste.

Under alternatives III and IV for conditions expected to occur, portions of the site would be remediated to free-release conditions and the hazard remaining at these areas would be estimated through consideration of residential agricultural scenarios and drinking water scenarios. As in the cases of Alternatives I and II, the free-released areas are presumed decontaminated to levels below those producing a dose of 25 mrem/yr. Under Alternatives III and IV for conditions expected to occur, a government agency would maintain control of areas having disposed or stored wastes and exposure of on-site individuals could not occur at these locations.

Under Alternatives III and IV for conditions not expected to occur and Alternative V for conditions expected to occur, individuals could gain access to the site and build a home, raise a garden, and drill a well. Thus, the home construction, discovery, residential agricultural, and drilling scenarios could occur in differing combinations at each WMA for each of these three alternatives. Because site facilities are presumed left in unstabilized condition for Alternatives IV and V and some degree of isolation is provided by disposal facility designs for Alternative III, the characteristics of the base scenarios are varied to conform to the WMA-specific conditions. The following paragraphs describe the details of application of each scenario to these cases.

The generic home construction and discovery scenarios presume that residual surface contamination or waste buried to a depth of less than three meters is disturbed by excavation activity. These conditions apply and the scenarios are evaluated at the LLWTF for Alternative II and V, the NDA and SDA for Alternatives IV and V and the north plateau plume for Alternatives III, IV and V. Under Alternative III, design features at each WMA provide three or more meters of separation and occurrence of the scenario would yield no impact. Under Alternatives IV and V, unsecured buildings or tanks are left in place at WMAs 1 (process building), 3 (HLW tanks) and 9 (RTS drum cell). In these cases, the conditions of the home construction and discovery scenarios do not apply and a WMA specific discovery is evaluated. At the process building, the receptor tours the building and spends five minutes in each room, accumulated direct exposure during this time. At HLW tank 8D-2, the receptor removes a riser cover and views the tank contents for five minutes, experiencing direct exposure. At the lag storage buildings and the RTS drum cell, the receptor tours the building for five hours and is exposed to direct radiation. These considerations are summarized in Tables 6-2 and 6-3 for the home construction and discovery receptors, respectively.

The generic residential agricultural scenario presumes the presence of either near-surface soil contamination, contact of near-surface soil with contaminated groundwater, or secondary contamination of surface soil through use of contaminated irrigation water. Secondary contamination of soil with irrigation water can occur on the north plateau where well productivity may be high but does not occur on the south plateau where well productivity is low. Under Alternative III on the north plateau, releases occur by contamination of infiltrating groundwater and the residential agricultural scenario is initiated by use of irrigation water. The use of slurry walls around the process building, HLW tanks and Lagoon 1 and the configuration of caps result in placement of the wells outside of the engineered barriers. This variation of the residential agricultural scenario is evaluated for north plateau facilities. Under Alternative III at the NDA and SDA on the south plateau, the thickness of the caps and absence of wells result in no impact for this scenario. At the RTS drum cell on the south plateau, the presence of a near-

Table 6-2. Variations of the Standard Home Construction Intruder Scenario

Waste Management Area – Facility	Alternative IIIA[a] (In-Place Stabilization [Backfill]) (Possible after 100 Years)	Alternative IIIB[b] (In-Place Stabilization [Rubble]) (Possible after 100 Years)	Alternative IV (No Action: Monitoring and Maintenance) (Possible after 100 Years)	Alternative V (Discontinue Operations) (Year 2000)
1 – Process Building	Scenario credible after 500 years/No impact: Excavation depth[c]	Scenario credible after 500 years/No impact: Excavation depth	Scenario not credible/ Building construction[d]	Scenario not credible/ Building construction
2 – LLWTF Lagoons	Scenario credible after 500 years/No impact: Excavation depth	Scenario credible after 500 years/No impact: Excavation depth	✓[e]	✓
3 – HLW Storage Tanks	Scenario credible after 500 years/No impact: Excavation depth	Scenario credible after 500 years/No impact: Excavation depth	Scenario credible/No impact: Excavation depth	Scenario credible/No impact: Excavation depth
3 – Vitrification Facility	Scenario credible after 500 years/No impact: Excavation depth	Scenario credible after 500 years/No impact: Excavation depth	Scenario not credible/ Building construction	Scenario not credible/ Building construction
5 – Waste Storage Area	Scenario not credible/No stored or buried waste[f,a]	Scenario not credible/No stored or buried waste[f,b]	Scenario not credible/ Building construction	Scenario not credible/ Building construction
LLW Disposal Facility	—[f]	Scenario credible after 500 years/No impact: Excavation depth[g]	—	—
North Plateau Groundwater Plume	✓	✓	✓	✓
7 – NDA	Scenario credible/ No impact: Excavation depth	Scenario credible/ No impact: Excavation depth	✓	✓
8 – SDA	Scenario credible/ No impact: Excavation depth	Scenario credible/ No impact: Excavation depth	✓	✓
9 – RTS Drum Cell	Scenario credible/ No impact: Excavation depth.	Scenario credible/No impact: Excavation depth	Scenario not credible/ Building construction[g]	Scenario not credible/ Building construction

a. Under Alternative IIIA, stored waste from WMA 5 would be disposed of in the process building (see WMA 1). Tents and buildings would be disposed of off site.

b. Under Alternative IIIB, stored waste from WMA 5 would be disposed of in a new LLW disposal facility that would be converted into a tumulus (see LLW Disposal Facility). Tents and buildings would be disposed of off site.

c. Scenario credible after 500 years/No impact: Excavation depth. Scenario credible after concrete has degraded (500 years), but there would be no impact because the excavation would not intersect the waste.

d. Scenario not credible/Building construction. It was considered unreasonable to assume that an individual would construct on top of a building (Alternatives II, IV, and V).

e. ✓. The standard exposure pathways for this scenario apply (i.e., direct exposure to waste contaminated soil and dust inhalation [see Section 3.3]).

f. —. The new LLW disposal facility would be built only under Alternative IIIB.

g. This would apply also to Alternative II; the same actions would be done for the RTS drum cell under Alternatives II and IV.

Table 6-3. Variations of the Discovery Intruder Scenario[a]

Waste Management Area – Facility	Alternative IIIA[b] (In-Place Stabilization [Backfill]) (Possible after 100 Years)	Alternative IIIB[c] (In-Place Stabilization [Rubble]) (Possible after 100 Years)	Alternative IV (No Action: Monitoring and Maintenance) (Possible after 100 Years)	Alternative V (Discontinue Operations) (Year 2000)
1 – Process Building	Scenario credible after 500 years/No impact: Excavation depth[d]	Scenario credible after 500 years/No impact: Excavation depth	Direct access scenario credible[e]: Intruder tours building and spends 5 minutes in each room.	Direct access scenario credible: Intruder tours building and spends 5 minutes in each room.
2 – LLWTF Lagoons	Construction scenario credible after 500 years/No impact: Excavation depth	Construction Scenario credible after 500 years/No impact: Excavation depth	✓[f]	✓
3 – HLW Storage Tanks	Construction scenario credible after 500 years/No impact: Excavation depth	Construction scenario credible after 500 years/No impact: Excavation depth	Direct access scenario credible[e]: Intruder exposed for 5 minutes while viewing tank contents from a riser.	Direct access scenario credible: Intruder exposed for 5 minutes while viewing tank contents from a riser.
3 – Vitrification Facility	Construction scenario credible after 500 years/No impact: Excavation depth	Construction scenario credible after 500 years/No impact: Excavation depth	Direct access scenario credible[e]: Intruder tours building for 5 hours.	Direct access scenario credible: Intruder tours building for 5 hours.
5 – Waste Storage Area	Scenario not credible/ No stored or buried waste	Scenario not credible/No stored or buried waste	Direct access scenario credible: Intruder tours waste storage facilities for 5 hours	Direct access scenario credible: Intruder tours waste storage facilities for 5 hours
LLW Disposal Facility	—[g]	Scenario credible/No impact: Excavation depth	—	—
North Plateau Groundwater Plume	✓	✓	✓	✓
7 – NDA	Construction scenario credible/No impact: Excavation depth	Construction Scenario credible/No impact: Excavation depth	Scenarios credible[h]: Intruder excavates into special hole 27, encounters two solvent tanks, and is exposed for 5 hours	Scenarios credible: Intruder excavates into special hole 27, encounters two solvent tanks, and is exposed for 5 hours.
8 – SDA	Construction scenario credible/No impact: Excavation depth	Construction scenario credible/No impact: Excavation depth	Scenarios credible: Intruder excavates into trench 4 and is exposed for 5 hours	Scenarios credible: Intruder excavates into trench 4 and is exposed for 5 hours.
9 – RTS Drum Cell	Construction scenario credible/No impact: Excavation depth	Construction scenario credible/No impact: Excavation depth	Direct access scenario credible: Intruder exposed for 5 hours while touring RTS drum cell[i]	Direct access scenario credible: Intruder exposed for 5 hours while touring RTS drum cell

a. Either a revised construction scenario, where the exposure pathways would be direct exposure to waste and contaminated soil and dust inhalation, or a scenario where the individual comes into direct contact with the waste and receives an external radiation dose. The scenario with the greater impact is presented.

b. Under Alternative IIIA, stored waste from WMA 5 would be disposed of in the process building (see WMA 1). Tents and buildings would be disposed of off site.

c. Under Alternative IIIB, stored waste from WMA 5 would be disposed of in a new LLW disposal facility that would be converted into a tumulus (see LLW Disposal Facility). Tents and buildings would be disposed of off site.

d. Construction scenario credible after 500 years/No impact: Excavation depth. Scenario credible after concrete has degraded (500 years); but there would be no impact because the excavation would not intersect the waste.

e. The construction scenario not credible because it was considered unreasonable to assume that an intruder would construct on top of a building, concrete vault, or steel tanks; however, an intruder could gain direct access.

f. ✓. The standard exposure pathways for this scenario apply .

g. —. The new LLW disposal facility would be built only under Alternative IIIB.

h. Scenarios credible: both construction and direct access scenarios are credible; the direct access scenario had the greater impact.

i. This would apply also to Alternative II; the same actions would be done for the RTS drum cell under Alternatives II and IV.

surface horizontal flow path may result in contamination of near-surface soil, and the residential agricultural scenario is evaluated for this case. For Alternatives IV and V on the north plateau, infiltration through unsecured facilities can contaminate groundwater that is used for irrigation of surface soil. The irrigation well is located immediately adjacent to the facility. This variation of the residential agricultural scenario is evaluated for the process building, LLWTF, HLW tanks and the lag storage facilities. Under Alternatives IV and V on the south plateau, caps are not in place and movement of groundwater through a near-surface horizontal flow path can contaminate soil. This variation of the residential agricultural scenario is evaluated for the NDA, SDA and RTS drum cell. These considerations are summarized in Table 6-4.

Two variations of the drilling scenario have been developed. In the first version, a well-drilling worker is exposed to direct radiation from contaminated material in a cuttings pond. In the second version, an individual uses water from the well as a source of drinking water. Under Alternative III, the drilling version is applied to all areas, including the north and south plateaus. Because wells on the south plateau have low productivity, the drinking water version is applied only on the north plateau. Under Alternatives IV and V on the north plateau, buildings are left unstabilized and drilling through the intact or collapsed building is considered unreasonable. However, water contaminated by leachate from the facility could be pumped from a well adjacent to the facility. Under Alternatives IV and V at the SDA and NDA on the south plateau, the drilling version could occur but low well productivity would preclude occurrence of the drinking water version. Under alternative IV and V at the RTS drum cell on the south plateau, presence of the intact or collapsed building renders the drilling version unlikely and low well productivity precludes occurrence of the drinking water version. These considerations are summarized in Table 6-5.

6.4 VALUES FOR PARAMETERS CHARACTERIZING RECEPTOR ACTIVITIES

Separate computer codes were developed to estimate dose impacts for the on-premises intruder, erosional collapse, and groundwater release scenarios. Each code presumed that soil or waste radionuclide inventories were known at a specified initial time. The on-premises intruder construction, discovery, and drilling scenarios did not involve environmental transport and dose calculations were thus initiated with specified initial radionuclide inventories and volumes. The on-premises intruder residential agriculture scenario could be initiated either by a user-specified soil concentration in the on-premises intruder code or by a soil concentration calculated using the integrated groundwater release codes. The erosional collapse scenarios and groundwater release scenario codes calculated concentrations of radionuclides at user-specified locations for environmental media including groundwater, surface water, and soil. Using time-dependent environmental media concentrations, all three codes calculated doses for user-selected time intervals for a user-selected timeframe. The following sections describe methods used to calculate dose for on-premises intruder, drinking water and fish ingestion, and on- and off-site residential farmer scenarios. Dose conversion factor data used in all calculations are summarized in Table 6-6 and partition coefficient data used in the residential agricultural calculations are presented in Table 6-7. Parameter values specific to each scenario are presented in the relevant section.

6.4.1 On-Premises Intruder Dose Estimation Methods

On-premises intruders included home construction, home construction/discovery, drilling, and residential farmer scenarios and specialized discovery scenarios appropriate to specific WMAs. The following paragraphs describe scenario conditions and dose estimation parameter values for each scenario. Parameter values used in these calculations are summarized in Table 6-8. These values are consistent with those used in studies performed to support updating of NRC's radioactive waste disposal impact analysis methods (Ref. 13).

Table 6-4. Variations of the Residential Agricultural Intruder Scenario

Waste Management Area – Facility	Alternative IIIA[a] (In-Place Stabilization [Backfill]) (Possible after 100 Years)	Alternative IIIB[b] (In-Place Stabilization [Rubble]) (Possible after 100 Years)	Alternative IV (No Action: Monitoring and Maintenance) (Possible after 100 Years)	Alternative V (Discontinue Operations) (Year 2000)
1 – Process Building	✓[c]	✓	✓	✓
2 – LLWTF Lagoons	✓	✓	✓	✓
3 – HLW Storage Tanks	✓	✓	✓	✓
3 – Vitrification Facility	✓	✓	✓	✓
5 – Waste Storage Area	Scenario credible/No impact[a]	Scenario credible/No impact[b]	✓	✓
LLW Disposal Facility	—[d]	✓	—	—
North Plateau Groundwater Plume	✓	✓	✓	✓
7 – NDA	Scenario credible/ No impact: Root depth; no water supply[e]	Scenario credible/ No impact: Root depth; no water supply[e]	Scenario credible/ no water supply[f]	Scenario credible/ no water supply
8 – SDA	Scenario credible/ No impact: Root depth; no water supply	Scenario credible/ No impact: Root depth; no water supply	Scenario credible/ no water supply	Scenario credible/ no water supply
9 – RTS Drum Cell	Scenario credible/ no water supply	Scenario credible/ no water supply	Scenario credible/ no water supply[g]	Scenario credible/ no water supply

a. Under Alternative IIIA, stored waste from WMA 5 would be disposed of in the process building (see WMA 1). Tents and buildings would be disposed of off site.

b. Under Alternative IIIB, stored waste from WMA 5 would be disposed of in a new LLW disposal facility that gets converted into a tumulus (see LLW Disposal Facility). Tents and buildings would be disposed of off site.

c. ✓. The standard exposure pathways for this scenario apply (i.e., drinking contaminated groundwater, eating food grown in soil contaminated by contaminated groundwater, dust inhalation, and direct exposure to radiation from a nearby facility [see Section 3.3).

d. —. The new LLW disposal facility would be built only under Alternative IIIB.

e. Scenario credible/No impact: Root depth; No water supply. The scenario would be credible, but there would be no impact because the engineered cap (3 meters) is thicker than the root depth (0.9 m) and because wells completed in the Lavery till are not productive enough to sustain an adequate water supply.

f. Scenario credible: No water supply. The scenario would be credible because a garden could be grown in contaminated soil but wells completed in the Lavery till are not productive enough to sustain an adequate water supply.

g. This would apply also to Alternative II; the same actions would be done for the RTS drum cell under Alternatives II and IV.

Table 6-5. Variations of the Drilling Intruder Scenario

Waste Management Area – Facility	Alternative IIIA[a] (In-Place Stabilization [Backfill]) (Possible after 100 Years)	Alternative IIIB[b] (In-Place Stabilization [Rubble]) (Possible after 100 Years)	Alternative IV (No Action: Monitoring and Maintenance) (Possible after 100 Years)	Alternative V (Discontinue Operations) (Year 2000)
1 – Process Building	Drilling and consumption scenarios credible after 500 years[c]	Drilling and consumption scenarios credible after 500 years	Drilling scenario not credible[d]/Consumption well located outside area boundary	Drilling scenario not credible[d]/Consumption well located outside area boundary
2 – LLWTF Lagoons	Drilling and consumption scenarios credible after 500 years	Drilling and consumption scenarios credible after 500 years	✓[e]	✓
3 – HLW Storage Tanks	Drilling and consumption scenarios credible after 500 years	Drilling and consumption scenarios credible after 500 years	Drilling scenario not credible[d]/Consumption well located outside area boundary	Drilling scenario not credible[d]/Consumption well located outside area boundary
3 – Vitrification Facility	Drilling and consumption scenario credible after 500 years	Drilling and consumption scenario credible after 500 years	Drilling scenario not credible[d]/Consumption well located outside area boundary	Drilling scenario not credible[d]/Consumption well located outside area boundary
5 – Waste Storage Area	Scenarios credible/ No impact: Waste inventory[f,a]	Scenarios credible/ No impact: Waste inventory[f,b]	Drilling scenario not credible[d]/Consumption well located outside area boundary	Drilling scenario not credible[d]/Consumption well located outside area boundary
LLW Disposal Facility	—[g]	Drilling and consumption scenarios credible after 500 years	—	—
North Plateau Groundwater Plume	✓	✓	✓	✓
7 – NDA	Drilling scenario credible after 500 years/No consumption scenario, low well productivity	Drilling scenario credible after 500 years/No consumption scenario, low well productivity	Drilling scenario credible/ No consumption scenario, low well productivity	Drilling scenario credible/ No consumption scenario, low well productivity
8 – SDA	Drilling scenario credible after 500 years/No consumption scenario, low well productivity	Drilling scenario credible after 500 years/No consumption scenario, low well productivity	Drilling scenario credible/ No consumption scenario, low well productivity	Drilling scenario credible/ No consumption scenario, low well productivity
9 – RTS Drum Cell	Drilling scenario credible after 500 years/No consumption scenario, low well productivity	Drilling scenario credible after 500 years/No consumption scenario, low well productivity	Drilling scenario not credible/No consumption scenario, low well productivity[h]	Drilling scenario not credible/No consumption scenario, low well productivity[h]

a. Under Alternative IIIA, stored waste from WMA 5 would be disposed of in the process building (see WMA 1). Tents and buildings would be disposed of off site.

b. Under Alternative IIIB, stored waste from WMA 5 would be disposed of in a new LLW disposal facility that gets converted into a tumulus (see LLW Disposal Facility). Tents and buildings would be disposed of off site.

c. Scenarios credible after 500 years. Concrete in monoliths, tanks, overlying a tumulus, and in engineered caps was assumed to degrade after 500 years. Well location determined by well productivity inside of or adjacent to the facility.

d. Scenario not credible/Drilling wells. It is unreasonable to assume that an individual would drill into a building, a concrete vault, or steel tanks with void space.

e. ✓. The standard exposure pathways for drilling and consumption scenarios would apply (i.e., direct exposure to waste contaminated soil or use of drinking water).

f. Scenario credible/No impact: Waste inventory. There is no waste inventory below the surface that could be accessed by drilling.

g. —. The new LLW disposal facility is not built under Alternatives IIIA, IV, or V; only under Alternative IIIB.

h. This would apply also to Alternative II; the same actions would be done for the RTS drum cell under Alternatives II and IV.

Table 6-6. Dose Conversion and Fish Bioaccumulation Factors

Nuclide	Fish Bioaccumulation Factor[1] (pCi/kg/pCi/L)	Dose Conversion Factors				
		Ingestion[2] (rem/Ci)	Inhalation[2] (rem/Ci)	External		RESRAD Unit Dose Factor[4] (rem/yr/pCi/g)
				Soil Volume[3] (rem/yr/pCi/cm^3)	Soil Surface[3] (rem/yr/Ci/m^2)	
H-3	1.0	63	63	0	0	8.8×10^{-11}
C-14	4,600	2,100	2,100	0	1.9	1.7×10^{-9}
Co-60	330	1.0×1.0^{4}	3.0×10^{4}	0.010	2.7×10^{5}	0.013
Ni-63	100	540	3,000	0	0	0.015
Se-79	170	8,300	8,900	1.2×10^{-8}	2.4	0.015
Sr-90	50	$1.3 \text{x} 10^{5}$	2.3×10^{5}	1.5×10^{-5}	650	0.0026
Tc-99	15	1,300	840	7.8×10^{-8}	9.1	3.9×10^{-5}
Cd-113m	200	1.5×10^{5}	1.4×10^{6}	4.1×10^{-7}	31	0.0021
Sn-121m	3,000	1,300	8,900	1.2×10^{-6}	570	0.01
Sn-126	3,000	1.7×10^{4}	7.4×10^{4}	0.017	5.1×10^{5}	0.015
Sb-125	200	2,400	9,800	0.001	3.9×10^{4}	0.0016
I-129	50	2.8×10^{5}	1.8×10^{5}	8.1×10^{-6}	3,000	9.1×10^{-4}
Cs-137	2,000	5.4×10^{4}	3.2×10^{4}	0.0021	6.5×10^{4}	0.0028
Pm-147	25	950	3.4×10^{4}	3.1×10^{-8}	4.0	0.015
Sm-151	25	340	2.9×10^{4}	6.2×10^{-10}	0.60	0.015
Eu-154	25	9,100	2.6×10^{5}	0.0048	1.4×10^{5}	0.0016
Tl-207	25	0	0	1.2×10^{-5}	440	SLP[5]
Tl-208	25	0	0	0.005	1.3×10^{5}	SLP
Pb-209	100	210	90	4.8×10^{-7}	35	SLP
Pb-210	100	5.1×10^{6}	1.3×10^{7}	1.5×10^{-6}	290	0.0049
Pb-211	100	440	8,000	1.9×10^{-4}	5,900	SLP
Pb-212	100	4.1×10^{4}	1.6×10^{5}	4.4×10^{-4}	1.7×10^{4}	SLP
Pb-214	100	580	6,700	8.4×10^{-4}	2.9×10^{4}	SLP
Bi-210	15	5,900	1.9×10^{5}	2.3×10^{-6}	120	SLP
Bi-211	15	0	0	1.6×10^{-4}	5,300	SLP
Bi-212	15	990	1.7×10^{4}	7.3×10^{-4}	2.1×10^{4}	SLP
Bi-213	15	680	1.4×10^{4}	4.8×10^{-4}	1.5×10^{4}	SLP
Bi-214	15	240	5,800	6.1×10^{-3}	1.6×10^{5}	SLP
Po-210	500	1.6×10^{6}	8.0×10^{6}	3.3×10^{-8}	1	SLP
Po-213	500	0	0	0	0	SLP
Po-214	500	0	0	3.2×10^{-7}	9.5	SLP
Po-215	500	0	0	6.4×10^{-7}	20	SLP
Po-216	500	0	0	6.5×10^{-8}	1.9	SLP
Po-218	500	0	0	3.5×10^{-8}	1	SLP
At-217	25	0	0	1.1×10^{-6}	35	SLP

(1) From Reference 20
(2) Calculated using GENII (Ref. 21) except for nuclides not in GENII database; Sm-151, short-lived Tl, Pb, Bi, Po, At, and Fr isotopes; estimates for these from Reference 22.
(3) From Reference 23.
(4) Calculated using RESRAD Ref. 9)
(5) SLP = short-lived progeny, contributions to residential farmer doses from these radionuclides are reported by RESRAD with the doses of the parent radionuclides.

Table 6-6. Dose Conversion and Fish Bioaccumulation Factors (Continued)

Nuclide	Dose Conversion Factors					
	Fish Bioaccumulation Factor[1] (pCi/kg/pCi/L)	Ingestion[2] (rem/Ci)	Inhalation[2] (rem/Ci)	External		RESRAD Unit Dose Factor[4] (rem/yr/pCi/g)
				Soil Volume[3] (rem/yr/pCi/cm^3)	Soil Surface[3] (rem/yr/Ci/m^2)	
Rn-219	0	0	0	1.9×10^{-4}	6,400	SLP
Rn-220	0	0	0	1.4×10^{-6}	45	SLP
Rn-222	0	0	0	1.5×10^{-6}	46	SLP
Fr-221	25	0	0	9.6×10^{-5}	3,500	SLP
Ra-223	70	5.5×10^{5}	7.5×10^{6}	3.8×10^{-4}	1.5×10^{4}	SLP
Ra-224	70	3.3×10^{5}	2.9×10^{6}	3.2×10^{-5}	1,100	SLP
Ra-225	70	3.1×10^{5}	7.5×10^{6}	6.9×10^{-6}	1,500	SLP
Ra-226	70	1.1×10^{6}	7.9×10^{6}	2.0×10^{-5}	750	0.046
Ra-228	70	1.2×10^{6}	4.2×10^{6}	0	0	0.0076
Ac-225	25	9.5×10^{4}	1.0×10^{7}	4.0×10^{-5}	1,800	SLP
Ac-227	25	1.4×10^{7}	6.7×10^{9}	3.1×10^{-7}	18	0.01
Ac-228	25	2,100	2.9×10^{5}	0.0037	1.1×10^{5}	SLP
Th-227	100	3.6×10^{4}	1.6×10^{7}	3.3×10^{-4}	1.2×10^{4}	SLP
Th-228	100	3.8×10^{5}	3.1×10^{8}	5.0×10^{-6}	270	0.0023
Th-229	100	3.5×10^{6}	1.7×10^{9}	2.0×10^{-4}	1.0×10^{4}	0.0046
Th-230	100	5.3×10^{5}	2.6×10^{8}	7.6×10^{-7}	88	7.3×10^{-4}
Th-231	100	1,300	770	2.3×10^{-5}	2,200	SLP
Th-232	100	2.8×10^{6}	1.1×10^{9}	3.3×10^{-7}	64	0.015
Th-234	100	1.3×10^{4}	3.3×10^{4}	1.5×10^{-5}	970	SLP
Pa-231	11	1.1×10^{7}	8.6×10^{8}	1.2×10^{-4}	4,800	0.014
Pa-233	11	3,300	8,600	6.4×10^{-4}	2.3×10^{4}	SLP
Pa-234m	11	0	0	5.6×10^{-5}	1,800	SLP
U-232	50	1.3×10^{6}	1.3×10^{7}	5.6×10^{-7}	120	0.0075
U-233	50	2.7×10^{5}	7.1×10^{6}	8.7×10^{-7}	84	1.8×10^{-4}
U-234	50	2.6×10^{5}	7.1×10^{6}	2.5×10^{-7}	87	1.7×10^{-4}
U-235	50	2.5×10^{5}	6.7×10^{6}	4.5×10^{-4}	1.7×10^{4}	6.5×10^{-4}
U-236	50	2.5×10^{5}	6.7×10^{6}	1.3×10^{-7}	76	8.7×10^{-5}
U-238	50	2.3×10^{5}	6.2×10^{6}	6.5×10^{-8}	64	2.2×10^{-4}
Np-237	250	3.9×10^{6}	4.9×10^{8}	4.9×10^{-5}	3,400	0.0023
Pu-238	250	3.8×10^{6}	4.6×10^{8}	9.5×10^{-8}	98	4.7×10^{-4}
Pu-239	250	4.3×10^{6}	5.1×10^{8}	1.8×10^{-7}	43	5.3×10^{-4}
Pu-240	250	4.3×10^{6}	5.1×10^{8}	9.2×10^{-8}	94	5.3×10^{-4}
Pu-241	250	8.6×10^{4}	1.0×10^{7}	3.7×10^{-9}	0.2	1.7×10^{-5}
Am-241	250	4.5×10^{6}	5.2×10^{8}	2.7×10^{-5}	3,200	5.7×10^{-4}
Cm-243	250	2.9×10^{6}	3.5×10^{8}	3.6×10^{-4}	1.5×10^{4}	0.014
Cm-244	250	2.3×10^{6}	2.7×10^{8}	7.9×10^{-8}	100	7.9×10^{-4}

(1) From Reference 20
(2) Calculated using GENII (Ref. 21) except for nuclides not in GENII database; Sm-151, short-lived Tl, Pb, Bi, Po, At, and Fr isotopes; estimates for these from Reference 22.
(3) From Reference 23.
(4) Calculated using RESRAD (Ref. 9)
(5) SLP = short-lived progeny, contributions to residential farmer doses from these radionuclides are reported by RESRAD with the doses of the parent radionuclides.

Table 6-7. Values of Distribution Coefficients for Surface Soil for Residential Agricultural Scenarios

Element	Distribution Coefficient (ml/g)
H	1
C	5
Sr	5
Tc	1
I	1
Cs	40
Eu	245
Ra	500
Ac	450
Th	3,200
Pa	550
U	10
Np	5
Pu	550
Am	1,900
Cm	4,000

Table 6-8. Parameter Values for Home Construction/Discovery and Drilling Intruder Scenarios

Exposure Pathway	Assumed Rates	Applicable Receptors
Dust Inhalation and Direct Exposure	Breathing rate of 8,400 m^3/year[a]	All off-site and on-site receptors
	Dust loading rate of 0.258 mg/m^3	Residential construction/discovery intruder
	Residential construction time of 500 hours[b]	Residential construction intruder
	Discovery construction time of 6 hours[b]	Discovery (construction-type) intruder
	Dimensions of home excavation: 20 m × 10 m × 3 m[b]	Residential construction/discovery intruder
Exposure to Drilling Mud	Dimensions of drill hole 0.2 m diameter × 6 m deep[b]	Drilling intruder
	Dimensions of mud pond 2.4 m × 2.7 m × 1.2 m[b]	
	Exposure time of 6 hours[b]	

a. Value from Reference 8.
b. Assumptions consistent with Reference 13.

6.4.1.1 *Home Construction and Home Construction/Discovery Scenarios*

The home construction and home construction/discovery scenario specified that a worker excavated a foundation over a burial area. If the burial was less than 3 meters below the surface, the excavation intercepted the waste. The work generated contaminated airborne dust which was inhaled by the worker and exposed the worker to direct radiation from material in the floor and walls of the excavation. The excavation was assumed to be 30 m wide, 10 m long, and 3 m deep. Dose due to inhalation of a given radionuclide was estimated as:

$$D_{inh} = 1.0 \times 10^{-15} \times M_{load} \times BR \times T_{build} \times C_{soil} \times DCF_{inh} \qquad (6\text{-}1)$$

where:

D_{inh} = inhalation dose, rem
M_{load} = mass loading of dust in the air, mg/m^3
BR = breathing rate, m^3/yr
T_{build} = time spent in the excavation, yr
C_{soil} = radionuclide concentration in the soil, pCi/g
DCF_{inh} = dose conversion factor for inhalation, rem/Ci.

Direct external dose was estimated as:

$$D_{ext} = N_s \times DEN_{soil} \times C_{soil} \times T_{build} \times DCF_{extv} \qquad (6\text{-}2)$$

where:

D_{ext} = external dose, rem
N_s = number of surfaces
DEN_{soil} = soil density, g/cm^3
DCF_{extv} = dose conversion factor for external radiation from to a volume source, (rem/yr)/(pCi/cm^3)

and other variables are as defined above. This estimate is conservation because five surfaces were considered and the dose factors are for semi-infinite media not corrected for the finite size of the excavation or decrease in concentration with distance below the surface. The construction-discovery and construction scenarios differed only in the amount of time spent in the excavation, that is, only in the value of the T_{build} parameter. Parameter values used to estimate dose are summarized in Table 6-8.

6.4.1.2 *Drilling Intruders*

An individual residing on site could construct a well for domestic use. In the scenario developed to investigate this activity, the driller completing the well is assumed to indirectly exposed by waste brought to the surface with the drilling mud. The mud is deposited in a pond and is covered by two feet of water while the driller remains in the vicinity for 6 hours. The activity brought to the surface is:

$$A = 1.0 \times 10^{+6} \times \pi \times R^2_{well} \times Z_{waste} \times DEN_{waste} \times C_{waste} \qquad (6\text{-}3)$$

where:

A = activity of a radionuclide deposited to the pond, pCi
R_{well} = radius of the well, m

Z_{waste} = thickness of waste horizon intersected by the well, m
DEN_{waste} = density of the waste, g/cm^3
C_{waste} = radionuclide concentration in the waste, pCi/g

The activity is conservatively assumed to be distributed at the upper surface of the mud layer, below the overlying pond water.

The shielding of the pond water reduces dose by a factor of approximately 75. The dose to a receptor near the pond is estimated as:

$$D_{drill} = 1.0 \times 10^{-12} \times (A/A_p) \times (1.0/75.0) \times T_{drill} \times DCF_{exts} \quad (6\text{-}4)$$

where:

D_{drill} = dose during the drilling activity, rem
A_p = area of the pond, m^2
T_{drill} = time of exposure near the pond, yr
DCF_{exts} = dose conversion factor for external radiation from a surface source, (rem/yr)/(Ci/m^2)

and A is as defined above. Parameter values for this scenario are summarized in Table 6-8.

6.4.1.3 Residential Farmer

An on-premises intruder could build a residence and farm a garden in soil contaminated by reprocessing plant operation or contact with contaminated groundwater or surface water. In these case impacts were estimated as:

$$D_{farm} = C_{soil} \times DCF_{farm} \quad (6\text{-}5)$$

where:

D_{farm} = dose to a residential farmer, rem/yr
C_{soil} = radionuclide concentration in soil, pCi/g
DCF_{farm} = unit dose factor reflecting dose through 6 residential farm pathways, (rem/yr)/(pCi/g)

The unit dose factor is estimated using the RESRAD (Version 5.82) computer code (Ref. 9) and the conditions and parameter values presented in Section 6.4.3 below.

6.4.1.4 Site-Specific Intruder Discovery Scenarios

Alternatives considered for closure of the Center include cases in which facilities would be abandoned or left with ineffective engineered barriers. In these cases, the standard discovery scenario was supplemented with site- and WMA-specific scenarios appropriate to the individual WMA. For the process building, an individual was assumed to enter and tour the building, spending 5 minutes in each room. For the HLW tanks, an individual was assumed to gain access to a tank 8D-2 riser and be exposed to direct radiation for 5 minutes while viewing the contents of the tank. At the lag storage building and additions and at the RTS drum cell, individuals were assumed exposed to direct radiation for 5 hours while walking through these waste storage areas. At the NDA and SDA, individuals were assumed to excavate into near-surface waste and be directly exposed for 5 hours.

6.4.2 Drinking Water and Fish Ingestion Dose Estimates

On-premises intruders could drill wells and use contaminated groundwater for drinking water purposes. Similarly, on-site (Buttermilk Creek) or off-site (Cattaraugus Creek, Seneca Indian, or Lake Erie) surface water users could use drink contaminated surface water or consume fish grown in contaminated surface water. Drinking water doses for these potential receptors due to individual radionuclides were estimated as:

$$D_{dw} = C_w \times IR_w \times DCF_{ing} \qquad (6\text{-}6)$$

where:

D_{dw} = dose due to drinking water, rem/yr
C_w = concentration of the radionuclide in the groundwater or surface water, Ci/m^3
IR_w = drinking water ingestion rate, m^3/yr
DCF_{ing} = dose conversion factor for ingestion, rem/Ci

Drinking water intake rate was taken as 0.73 m^3/yr while dose conversion factors for individual radionuclides were those presented in Table 6-6.

Dose from a given radionuclide due to ingestion of fish was estimated as:

$$D_{fish} = 1.0 \times 10^{-3} \times C_{sw} \times B_{fish} \times IR_{fish} \times DCF_{ing} \qquad (6\text{-}7)$$

where:

D_{fish} = dose due to ingestion of fish, rem/yr
C_{sw} = radionuclide concentration in the surface water, Ci/m^3
B_{fish} = radionuclide bioaccumulation factor in fish, (pCi/kg)/(pCi/L)
IR_{fish} = fish ingestion rate, kg/yr
DCF_{ing} = dose conversion factor for ingestion, rem/Ci

Fish ingestion rates are presented in Table 6-1. Values for bioaccumulation and dose conversion factors were those presented in Table 6-6.

6.4.3 Residential Agriculture Dose Estimates

Following free release of site facilities or in the case of loss of institutional control; on-premises, on-site, and off-site individuals could come into contact with soil contaminated due to releases from site facilities. Activities of these individuals could include use of contaminated groundwater and establishment of a residence and garden on contaminated soil. Doses due to consumption of contaminated well or surface water are estimated as described in Section 6.4.2. This section describes development of dose estimates due to use or contact with contaminated soil.

The RESRAD computer code (Ref. 9) is designed to calculate annual doses to an individual who establishes a home on contaminated soil and is exposed to direct radiation, raises and consumes crops, raises livestock and consumes beef and milk, inhales contaminated soil, and inadvertently ingests contaminated soil. Doses calculated with the RESRAD code vary in direct proportion to the concentration of radionuclides in the soil. As stated above, the site-specific on-Premises intruder, erosional collapse, and integrated groundwater release codes calculated soil concentrations of parent and daughter radionuclides at specified locations in a time-dependent manner. The approach for estimation of long-term performance residential agricultural dose is to use RESRAD to calculate unit dose factors for 6 pathways and use these unit dose factors in conjunction with the soil concentrations calculated with the site specific codes. Because the site-specific codes calculate drinking water dose independently and calculate soil concentrations for all radionuclides in a time-varying manner, the water independent RESRAD scenario was used to calculate the unit dose factors incorporated into the long-term performance assessment codes. The site-specific codes estimate dose for each radionuclide as:

$$D_{farm} = C_{soil} \times DCF_{farm} \tag{6-8}$$

where:

D_{farm} = residential agriculture dose, rem/yr
C_{soil} = contaminated soil concentration
DCF_{farm} = RESRAD unit dose factor, (rem/yr)/(pCi/g).

The unit dose factors are those presented in Table 6-6. Although soil and geohydrologic conditions vary across the site, sensitivity runs demonstrated that the single set of unit dose factors was appropriate for both north and south plateau locations. Parameter values used to generate the individual radionuclide RESRAD unit dose factors are summarized in Table 6-9. The values are intended to be site specific but consistent with regulatory guidance (Ref. 8).

Table 6-9. RESRAD Parameters for Long-Term Performance Assessment

Parameter	Value[a]
Area of contaminated zone	10,000m²
Cover depth	0 m
Thickness of contaminated zone	1 m
Thickness of uncontaminated zone	1 m
Consumption rates	
fruits, vegetables and grain	160 kg/yr
leafy vegetables	14 kg/yr
milk	92 L/yr
meat and poultry	63 kg/yr
Inhalation rate	8,400 m³/yr
Mass loading for inhalation	0.0002 mg/m³
Occupancy and shielding factor, external gamma	0.60
Occupancy factor, inhalation	0.45
Depth of soil mixing layer	0.15 m
Depth of roots	0.9 m
Soil erosion rate	0.00001 m/yr
Soil effective porosity	0.25
Water table drop rate	0
Precipitation rate	1.01 m/yr
Length of contaminated zone parallel to aquifer flow	100 m
Soil density	2.1 g/cm³
Soil total porosity	0.30
Soil hydraulic conductivity; unsaturated soil	66 m/yr
Soil hydraulic conductivity; saturated soil	132 m/yr
Saturated soil hydraulic gradient	0.03
Evaportranspiration coefficient	0.50
Runoff coefficient	0.30

a. Separate radionuclide-specific values were used for north plateau and south plateau. In general, the most conservative (i.e., lowest) values from a variety of sources were used.

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