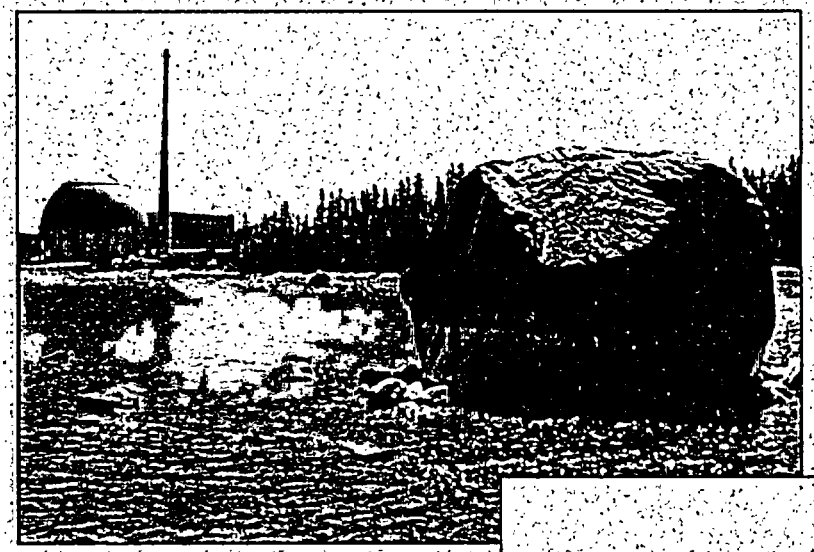
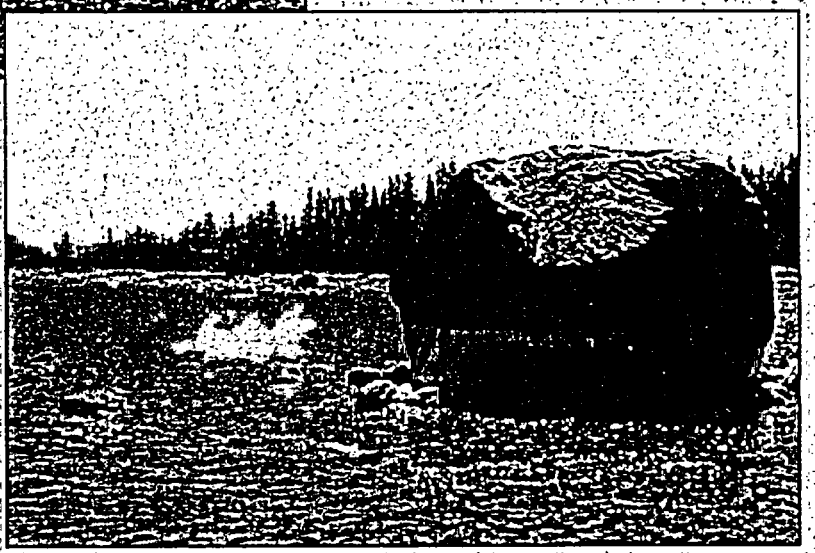
Big Rock Point Restoration Project

LICENSE TERMINATION PLAN





Revision 1

July 1, 2004

Prepared by Consumers Energy Company

Attachment 3
Consumers Energy
BIG ROCK POINT
Docket Numbers 50-155 and 72-043

Replacement Pages
Big Rock Point License Termination Plan
List of Revisions and Chapters 2, 4, 5, and 6

July 1, 2004

571 Pages

Big Rock Point License Termination Plan Revision 1

List of Revised Sections

Chapter	Section	Page	Revision
2	2.2.3	2-4	Revised second paragraph per RAI #32.
2	2.2.4.2	2-5	Revised the first paragraph per RAI #24.
2	2.2.4.2	2-5	Revised per RAI #25.
2	2.2.5.1	2-7	Revised area values per RAI #23.
2	2.2.5.2	2-8	Minor correction / clarification.
2	2.2.5.3	2-8	Revised area values per RAI #23.
2	2.2.5.3.b.1	2-8	Revised second paragraph per RAI #10.
2	2.2.5.3.b.4	2-11	Revised the second paragraph per RAI #11.
2	2.3.1.1.b	2-16	Revised the second paragraph per RAI #26.
2	2.3.1.3	2-16	Revised per RAI #27.
2	2.3.4.1.a	2-19	Revised per RAI #28.
2	2.3.4.1.a	2-20	Revised per RAI #29; added new Table 2-2, In-Situ Gamma Spectroscopy Efficiency for Standard Source Geometry.
2	2.4.3.4	2-27	Correction / clarification.
2	2.4.3.5	2-27	Revised title.
2	2.4.3.5	2-28	Revised per RAI #5.
2	2.4.3.5	2-28	Revised per RAI #5; added description entitled "Tritium Plume Change Due to Removal of Foundations".
2	2.4.3.6.a	2-29	Revised per RAI #2; added section entitled "Seasonal Fluctuations".
2	2.4.3.6.b	2-29	Revised per RAI #3; added section entitled "Lake Michigan Water Level Fluctuations".
2	2.4.3.6.c	2-30	Revised per RAI #1; added section entitled "Precipitation Effects".
2	2.4.5.1.a	2-34	Correction / clarification.
2	2.4.5.1.b	2-36	Revised per RAI #12.
2	2.4.5.1.c	2-38	Revised per RAI #24.
2	2.4.5.3.b	2-48	Correction / clarification.
2	2.4.5.3.c	2-49	Revised per RAI #6 and RAI #30.
2	2.4.5.3.c	2-49	Revised per RAI #9.

Big Rock Point License Termination Plan Revision 1

List of Revised Sections

Chapter	Section	Page	Revision
2	2.4.5.3.c	2-50	Revised per RAI #4.
2	Table 2-11	2-51	Revised per RAI #8. (This table was originally Table 2-10.)
2	Tables 2-12a, 2-12b, 2-12c	2-54	Revised per RAI #9; added new tables.
2	2.4.5.4	2-56	Revised per RAI #31.
2	Table 2-13	2-56	Corrected table.
2	2.4.6	2-57	Revised per RAI #7; added new Section 2.4.6, Radionuclide Migration.
2	Figure 2-4	2-64	Revised per RAI #30.
2	Figure 2-13	2-73	Added new figure per RAI #4.
2	Figure 2-14	2-74	Added new figure per RAI #4.
2	Figure 2-15	2-75	Added new figure per RAI #4.
2-D	Appendix	2D-2	Correction / clarification.
2-D	Table 2-D2	2D-5	Correction / clarification.
2-D	Table 2-D3	2D-6	Correction / clarification.
2-E	Survey Unit 8	2E-44	Correction / clarification.
2-F	New Appendix	2F-1	Added new appendix per RAI #1.
4	4.2.2.1	4-5	Correction / clarification.
4	4.2.2.2	4-6	Revised per RAI #5; added description tritium remediation efforts.
4	4.6	4-15	Revised per RAI #22.
4	4.7.1	4-15	Revised per RAI #22.
4	Appendix 4-A	4A-1	Correction / clarification.
4	Appendix 4-C-1	4C-1	Revised per RAI #22.
4	Appendix 4-C-2	4C-3	Revised per RAI #22.
4-D	New Appendix	4D-1	Revised per RAI #21; added Appendix 4-D, Average Soil Radionuclide Concentrations for Big Rock Point.
5	Table 5-1	5-8	Revised per RAI #35.
5	Table 5-2	5-11	Correction / clarification.
5	5.2.1.3	5-8	Revised per RAI #34.

Big Rock Point License Termination Plan Revision 1

List of Revised Sections

Chapter	Section	Page	Revision
5	5.3.6.2	5-20	Revised per RAI #34.
5	5.3.6.3	5-21	Correction / clarification.
5	5.3.6.3.2)	5-22	Revised per RAI #35.
5	5.4.2.1	5-24	Revised per RAI #10.
5	5.4.2.4	5-25	Revised per RAI #36.
5	5.4.2.5	5-26	Revised per RAI #13.
5	5.4.3.1	5-27	Revised per RAI #37.
5	5.4.3.5	5-30	Revised per RAI #33.
5	Table 5-8	5-30	Revised per RAI #38.
5	5.6.2	5-34	Revised per RAI #39.
5	Table 5-10	5-39	Updated Table 5-10.
6	6.7.2.2	6-20	Revised per RAI #33.
6	6.8.1	6-20	Correction / clarification.
6	Table 6-8	6-21	Revised per RAI #15 and correction / clarification.
6	6.8.2.1	6-21	Revised per RAI #14.
6	6.8.2.1	6-22	Revised per RAI #16 and RAI #33.
6	6.8.2.2	6-24	Correction / clarification.
6	6.8.2.3	6-25	Revised per RAI #17.
6	6.8.2.3 Table 6-11	6-27	Revised per RAI #18.
6	6.8.2.4	6-27	Revised per RAI #18.
6	6.9	6-28	Revised per RAI #19.
6	6.9.1	6-28	Revised per RAI #19.
6	6.9.2	6-28	Revised per RAI #19.
6	6.9.3	6-29	Revised per RAI #19.
6-H	New Appendix	6H-1	Revised per RAI #16
6-I	New Appendix	6I-1	Revised per RAI #16

TABLE OF CONTENTS

2.0 SITE CHARACTERIZATION 1

2.1 INTRODUCTION 1

2.2 HISTORICAL SITE ASSESSMENT SUMMARY 2
2.2.1 Overview 2
2.2.2 Site Description 2
2.2.3 Historical Site Assessment Methodology 3
2.2.4 Historical Review 4
2.2.5 Findings and Conclusions 7
2.2.6 Impacted Area - Non-Radiological Contamination 14

2.3 ANALYTICAL METHODS 15
2.3.1 Site Characterization Quality Assurance/Quality Control (QA/QC) 15
2.3.2 Initial Derived Concentration Guideline Level Values For Site Characterization Survey 18
2.3.3 Background Radioactivity in Soil and Water for Radionuclides of Potential Plant Origin 19
2.3.4 Measurement Instrumentation 19

2.4 ENVIRONMENTAL STATUS INVESTIGATION 22
2.4.1 Overview 22
2.4.2 Legacy Materials Evaluation 23
2.4.3 Hydrogeological Study 24
2.4.4 Characterization Survey 31
2.4.5 Characterization Survey Findings 33
2.4.6 Radionuclide Migration 57

2.5 REFERENCES 76

TABLES

2-1 Local Area Soil Cs-137 Background Radioactivity 19
2-2 In-Situ Gamma Spectroscopy Efficiency for Standard Source Geometry 21
2-3 BRP Detector Performance and Specification Data 21
2-4 Summary of Class 3 Survey Unit Findings 35
2-5 Summary of Class 2 Survey Unit Findings 37
2-6 Summary of Class 1, Group A Survey Unit Findings 41
2-7 Summary of Class 1, Group B Survey Unit Findings 44
2-8 Summary of Findings for Survey Unit 8 45
2-9 Summary of Drainage Ditch Survey Unit Findings 46
2-10 Summary of Discharge Canal Survey Unit Findings 47

2-11 Groundwater Monitoring Results of Investigation for Hard-to-Detect Radionuclides 51
2-12a Tritium Monitoring Well Historical Data (Well Installed in 1994) 54
2-12b Tritium Monitoring Well Historical Data (Well Installed in Post-Shutdown) 55
2-12c Tritium Monitoring Well Historical Data (Samples Beneath Containment Building) 56
2-13 Radionuclides Potentially Present in BRP Soil 56
2-14 Soil Sample Analyses for Hard-to-Detect Radionuclides 59

FIGURES

2-1 Big Rock Point Owner-Controlled Area 61
2-2 Big Rock Point Industrial Area 62
2-3 Legacy Materials Evaluation Survey Areas 63
2-4 Big Rock Point Groundwater Monitoring Wells 64
2-5 Vertical Profile A-A 65
2-6 Class 3 Survey Units 66
2-7 Class 2 Survey Units 67
2-8 Class 1, Group A Survey Units 68
2-9 Class 1, Group B Survey Units 69
2-10 Drainage Ditch Survey Unit 70
2-11 Discharge Canal Survey Unit 71
2-12 Data Point Locations for Determination of Radionuclide Fractions 72
2-13 Tritium Plume in Shallow Groundwater Zone 73
2-14 Tritium Plume in Intermediate Groundwater Zone 74
2-15 Tritium Plume in Bedrock Groundwater Zone 75

APPENDICES

Appendix 2-A Big Rock Point Site Legal Description 2A-1
Appendix 2-B Historical Site Assessment Event Data 2B-1
Appendix 2-C Legacy Materials Evaluation 2C-1
Appendix 2-D NaI Scanning Sensitivity for Open Land Survey 2D-1
Appendix 2-E Characterization Survey Results 2E-1
Appendix 2-F Big Rock Point Seasonal Groundwater Fluctuations and Generalized Flow Directions 2F-1

2.0 SITE CHARACTERIZATION

2.1 INTRODUCTION

The purpose of site characterization is to identify, quantify, and document residual radioactivity at the Big Rock Point (BRP) site. This effort includes the historical review and evaluation of all radiological and non-radiological materials that were either known or had the potential to impact the environment. The data quality objective (DQO) process is utilized to satisfy the following site characterization objectives:

1. Provide the information necessary for development of the site conceptual model used to demonstrate compliance with the radiological criteria for license termination;
2. Define the nuclide fractions for surrogate measurement of hard-to-detect (HTD) nuclides;
3. Identify the instrumentation, measurement performance criteria, and methods to be used for characterization survey and radioactivity analysis;
4. Establish the quality assurance requirements for sample collection, analysis, and record keeping;
5. Classify all areas of the BRP site property as impacted or non-impacted. Further define the initial classification of Impacted Areas as Class 1, 2, or 3; and
6. Provide information required to support the decision-making process necessary for potential environmental remediation and planning of the Final Status Survey (FSS).

The BRP site will have been returned to a Greenfield condition at the time of the FSS. All systems, components and buildings, with the exception of facilities supporting dry fuel storage, are scheduled for dismantlement and removal from the site. The scope of the characterization effort is therefore restricted to the residual radioactivity in site soils and groundwater. Evaluations of structures and components are included only as they pertain to known or potential environmental impacts.

Big Rock Point site characterization is a two-step process consisting of Historical Site Assessment (HSA) and Environmental Status Investigation (ESI). The HSA provides the foundation of the characterization effort. This study is a continuous chronological account and detailed evaluation of all historical events with the potential to have impacted the environment. Based on existing information, the HSA defines the Impacted and Non-Impacted Areas of the site and identifies known or potential sources of radioactivity in soils and groundwater.

The information established by the HSA provides the primary input for ESI planning. This step in the characterization process is the investigative survey, analysis, and evaluation of all soil and groundwater contamination within the site Impacted Area. ESI provides the planning and execution of all scoping, hydrogeological, characterization, and remediation surveys in support of license termination. The

evaluation resulting from this effort serves to define the current status of environmental contaminants at the site and provides the required input for development of the dose model. Site characterization is an iterative process that provides the information necessary for continuing dismantlement, returning the site to a Greenfield condition, and planning of final status surveys.

2.2 HISTORICAL SITE ASSESSMENT SUMMARY

2.2.1 Overview

The purpose of the BRP HSA is to identify and document the current radiological status of the site. The HSA defines the Impacted and Non-Impacted Areas of the site, identifies potential sources of contamination, and assesses the likelihood of contaminant migration. This study forms the basis for initial site area classifications and the characterization survey process. The HSA is limited to events that resulted in known or potential residual radioactivity impacting site soils and groundwater. All structures, systems, and components, with the exception of those supporting Independent Spent Fuel Storage Installation (ISFSI), are scheduled for dismantlement and offsite removal prior to license termination. The HSA was completed in 1999 and forms the basis for initial Impacted and Non-Impacted Area classifications and subsequent site characterization surveys [References 2-6 and 2-7]. An evaluation of potential non-radiological site contaminants, completed in 2002, is also included in this assessment [Reference 2-8]. The HSA was developed through directives established in the DQOs and follows the guidance provided in NUREG-1575 [Reference 2-27].

2.2.2 Site Description

2.2.2.1 Property Identification:

Big Rock Point Restoration Project
10269 US 31 North
Charlevoix, Michigan 49720
Consumers Energy's License No. DPR-6

2.2.2.2 Geographic Description

The site topography can be divided into two categories: (1) a narrow band of property parallel to the lake that is characterized by swampy areas between low beach ridges, and (2) inland areas where the terrain rises on a till plain to upland drumlins. The site stratigraphy consists of glacial deposits that overlay limestone bedrock. These deposits range from sandy gravel and cobble to clay till. A significant portion of inland site property is considered wetlands.

2.2.2.3 Surface and Ground Water Hydrology

Big Rock Point is located within a three to four square mile watershed that originates south of the property. Surface water, shallow groundwater, and the drinking water aquifer located beneath the clay till all flow north through the site and into Lake

Michigan. Stormwater runoff from high ground is diverted around the site-Protected Area. A drainage system consisting of catch basins and corrugated metal piping acts to remove stormwater away from buildings and parking areas toward Lake Michigan. An in-depth study of the site hydrogeology was conducted as an integral part of the ESI effort. This study is detailed in Section 2.4.3.

2.2.2.4 Industrial Area

The land area of potential radiological and non-radiological impact is that portion of the site where licensed activities took place. This location encompasses less than 0.1 km^2 (20 acres) and includes the Protected Area, the radwaste compound, and adjacent support structures and transport routes. Soils in these locations are coarse, of low fertility, and unsuitable for agricultural use. The upper 5 m (15 feet) of soil beneath this area is comprised of fill material and native soils ranging from coarse gravel and cobble to fine clayey sands. This upper soil strata is underlain by a thick and generally homogeneous layer of sandy clay that extends to bedrock. Two shallow groundwater bearing zones are typically encountered within 8.2 m (25 feet) of grade elevation. These water bearing zones originate from watershed hydraulic pressure resulting in the transportation of water above the clay layer and ultimately into Lake Michigan. Figure 2-1 shows the BRP Owner-Controlled Area. Figure 2-2 depicts the BRP Industrial Area.

2.2.3 Historical Site Assessment Methodology

The HSA is an extensive review of all historical plant documentation identifying events that were either known or had the potential to impact the environment. Investigation, physical inspection, and process knowledge were used to evaluate the event data and define site areas by radiological classification. Input information for this process included the following:

1. Review of Health Physics Logbook (1962 – 1999),
2. Response from employee/retiree questionnaires,
3. All corrective action records (1962 – 1999),
4. Personal interviews of past and present employees,
5. Decommissioning study performed in 1993 and 1994,
6. Radiological scoping surveys,
7. Investigations of historical anecdotes,
8. Physical walkdowns of site property,
9. Plant drawings,
10. Hazardous material assessments,
11. Records of polluting material spills, and
12. Waste shipment records (radiological, non-radiological and mixed waste).

Since buildings, foundations and equipment are to be removed from the site, the HSA review process focused on events that impacted or had the potential to impact the site environment (soils and groundwater). The HSA event summary provided in Appendix 2-B summarizes only those events that may have impacted site environs[1]. The HSA review of site Health Physics Logbook and Corrective Action records encompassed the entire time period from 1962 – 1999. The Health Physics Logbook is a 37-year account of continuous daily entries describing day-to-day radiological activities and site conditions. Corrective Action records document those occurrences or events that recognized safety-related deficiencies, identified undesirable conditions adverse to quality, or were reportable to regulatory agencies. Corrective Action documentation includes Deviation Reports, Event Reports, and Condition Reports. All supporting input documentation has been detailed in the HSA Supplemental Data.

Using the DQO process, an assessment of all input data was performed to define the current status of all contaminants in the BRP site environment. A Non-Impacted Area classification has been given to those areas with no evidence or reasonable potential for the presence of residual radioactivity. Areas that are known or suspected to contain residual radioactivity are classified as impacted. Where sufficient evidence exists, the classification of impacted was further profiled into the following sub-classifications: unlikely, potential, known, and potentially elevated. These initial area classifications were used as baseline data to aid in future ESI characterization survey planning.

2.2.4 Historical Review

2.2.4.1 Operation

The BRP Plant achieved initial criticality in September of 1962. The Nuclear Steam Supply System (NSSS) was a boiling water reactor designed by the General Electric Company. The turbine generator, also designed by General Electric, was rated to produce 75 MWe. The facility was originally operated as a research and development reactor, until commercial operations began in late 1962. The plant ceased operation on August 29, 1997. The BRP Plant has been permanently defueled and is currently undergoing dismantlement and return of the site to a Greenfield condition.

During BRP Plant operation, some events resulted in the contamination of structures and components inside buildings located in the Radiation Control Area. In addition, there were some occurrences that resulted in residual radioactivity outside of the buildings. Most occurrences were minor, resulting in minimal amounts of residual

[1] The first chronological entry for an event in the HSA Summary (Appendix 2-B) often lists dates of similar events that occurred later in the HSA review process. These subsequent dates for similar events are not identified as separate entries in the chronological listing unless a later event added important new information.

radioactivity. Upon discovery, events were documented and actions were taken to control and remove the contamination and to institute corrective actions to preclude future occurrences. These events are detailed in chronological order in Appendix 2-B.

2.2.4.2 Environmental Impact of Historical Fuel Failures

The review and evaluation of all HSA input data identified no occurrence of transuranic contamination of site soils. The following information provides a description of BRP design and operating history as it relates to the potential for transuranic contamination of site environs.

As with other nuclear plants of the era, BRP experienced significant fuel failures during the early years of operation. However, modifications to plant components and changes in reactor procedural operations minimized the potential for contamination resulting from failed fuel. The following factors have contributed to the minimization of fuel failures and absence of transuranics in the environment at the BRP site:

1. Big Rock Point was originally utilized as a research facility for reactor core performance testing and fuel irradiation evaluations. Early plant operation consisted of short criticality durations followed by test evaluations and subsequent core reconfiguration. This served to minimize the length of power operation associated with known fuel failures.
2. Fuel cladding design change from stainless steel to inconel early in the plant operational period (1960s).
3. Stainless steel replacements to the main condenser and primary system heat exchanger components reduced the scaling and subsequent fuel clad failures that result from poor heat transfer.
4. The pre-conditioning of fuel during start-up evolutions was procedurally established in the early 1970s. Fuel soaking prior to start-up removed oxygen from the coolant to maintain proper water chemistry and slower power escalations were found to reduce stress damage to fuel cladding.
5. Spent fuel was shipped offsite for testing and reprocessing throughout the 1960s and early 1970s. All fuel transport containers were loaded and sealed inside the Containment Building prior to offsite shipment.
6. The BRP Plant was constructed with the ability to maintain high purity reactor water chemistry. During operation, processed condensate was supplied to the reactor water feed pumps through high-capacity, deep-bed demineralizers. A primary system-processing loop also utilized deep bed demineralization to maintain ~3% cleanup flow through the reactor vessel. This large-capacity system maintained pure-water chemistry minimizing the presence of contaminants that potentially contribute to early fuel failure.

7. The NSSS steam drum was designed with cyclone separators to dry the steam supply to the turbine-generator and limit moisture and particulate carry-over. The off-gas system included a low velocity delay chamber for the removal of particulates and decay of short-lived nuclides prior to stack release. These system components remained intact and functional throughout the operational life of the plant and limited the ability of all particulate radionuclides, including transuranics to migrate into the environment.

8. The design of the BRP nuclear plant is relatively unique in that all routine handling of spent fuel during BRP refueling outages occurred inside the Containment Building. The spent fuel pool is located inside the Containment Building adjacent to the reactor vessel cavity. The spent fuel pool was used to store spent fuel, irradiated reactor core internals, and other miscellaneous irradiated components. The entire fuel handling system used to move spent fuel from the reactor vessel to the adjacent spent fuel pool was also located inside the Containment Building. Reviews of historical operational records have not identified any event that could have resulted in environmental transuranic contamination (soil or groundwater).

9. Additionally, reactor coolant piping did not exit the containment isolation boundary; only steam and liquid radioactive waste piping exited the Containment Building. This design significantly limits the areas that could have been exposed to transuranic contamination.

2.2.4.3 Initial Scoping Survey

In anticipation of decommissioning, a radiological scoping survey was performed in 1993 and early 1994. The initial scoping survey effort included the spectrographic analysis of grab samples taken in the Owner-Controlled Area, in-situ measurements of plant and background areas, and installation of nine groundwater monitoring wells. The scoping survey project was developed following the guidance of Draft NUREG/CR-5849[2]. Survey design, methodology, and findings are detailed in the BRP Decommissioning Plan [Reference 2-1]. Following this survey, Initial Derived Concentration Guideline Level (IDCGL) values were defined to provide conservative guidance for estimating remediation requirements. Initial Derived Concentration Guideline Levels were developed using the RESRAD v5.05 computer code based on the resident farmer scenario and the site release criteria of 25 mrem/yr[3]. The information resulting from the scoping survey contributed to development of the HSA. These data are summarized in Appendix 2-B, Data Event 49. The current radiological status of these survey areas is provided in Section 2.4.

[2] NUREG-1575 (MARSSIM) had not been published when the initial scooping survey was performed.
[3] Finalized DCGL values to demonstrate compliance with the radiological criteria for license termination are detailed in Chapter 6.

2.2.5 Findings and Conclusions

2.2.5.1 Data Review

A review of 37 years of historical plant documentation resulted in the identification of 63 operational events that were either known or had the potential to radiologically impact the environment. These events are summarized and listed in chronological order in Appendix 2-B. Investigation, physical inspection, and process knowledge were used in the evaluation of event data to determine the present radiological condition of the site. An evaluation to determine the current posture of all non-radiological site contaminants was also performed in this manner. This process resulted in the identification of those areas meeting the requirements of NUREG-1575 for Impacted and Non-Impacted Area classification.

Big Rock Point encompasses an area of 2.281 km^2 (563.7 acres). The Non-Impacted Area consists of 1.742 km^2 (430.4 acres) and is that portion of the Owner-Controlled property that has no evidence or reasonable potential for the presence of radioactivity resulting from plant operation. The remaining 0.539 km^2 (133.3 acres) of site property have been classified as impacted. These areas are known or have the potential to contain residual radioactivity. Figure 2-1 depicts the BRP site Impacted and Non-Impacted Areas.

2.2.5.2 Non-Impacted Area

The Non-Impacted Area of the BRP site ranges from low wetlands with standing water to mature forested uplands. Groundwater and surface water from the Lake Charlevoix watershed divide flow north into the Non-Impacted Area and then drain from this higher elevation through the Impacted Area into Lake Michigan. The property is generally inaccessible to motorized traffic and in most locations presents a challenge to foot travel. The Non-Impacted Area is mainly characterized by thick forest and uneven terrain. Dense vegetation is clearly visible in historical aerial photographs and indicates that the present terrain has remained relatively unchanged since plant construction.

The Non-Impacted Area served as a buffer zone for emergency planning purposes during power operations and was also used for the placement of dosimetry at site boundaries for environmental monitoring.

No other work activities have been conducted on this property and there is no historical data or process knowledge that would support classification of the area as impacted. The Non-Impacted property is part of a regional study that was conducted to establish the standard environmental radioactivity background value for soils similar in type to those found at BRP. No radioactivity other than the standard environmental background was identified within the Non-Impacted Area in the findings of this investigation. The Michigan Department of Environmental Quality (MDEQ) participated with BRP in this study. Michigan Department of Environmental

Quality split sample results support the BRP findings of this investigation (see Section 2.3.3). This region of the Owner-Controlled property meets the requirements of NUREG-1575 for Non-Impacted Area classification. The Non-Impacted Area is defined by the site legal description found in Appendix 2-A.

2.2.5.3 Impacted Area

The Impacted Property extends over a mile along the Lake Michigan shoreline and contains an area of 0.539 km^2 (133.3 acres). The majority of this property is remote from plant operational activities and has little probability to contain residual radioactivity. The locations of potential radiological concern are confined to the Industrial Area, an area of less than 0.1 km^2 (approximately 20 acres) that includes the Protected area, the Radwaste compound, and all material transport routes and storage locations. The following is a brief narrative of historical events that provide a description of the Impacted Area based upon location and the potential to contain residual radioactivity. Refer to Figure 2-2 for the area locations and buildings described below.

a. Areas Unlikely to Contain Residual Radioactivity

1. *Wooded Locations in Vicinity of the Protected Area*
Licensed activities are not known to have occurred in the wooded areas to the east and west of the protected area. Scoping surveys in these locations did not identify soil radioactivity above established environmental background levels. This area is classified Impacted only because of proximity to the Industrial Area.

2. *Area Along the Railroad Spur South of US Route 31*
Extensive surveys did not identify soil radioactivity above established environmental background levels in the soils of this area; however, concrete and asphalt construction debris were inadvertently moved to a small location within this region were found to have originated from a potentially contaminated area. A follow-up evaluation of this material identified a trace concentration of Co-60 fixed on a single olivine firebrick. Evaluation has determined the brick originated from the former incinerator site. This brick and all other construction debris were removed from the property.

b. Areas of Potential Residual Radioactivity

1. *Septic System Drain Field*
The drainfield is a mound system of approximately 3000 m^2 that is located immediately west of the Protected Area. The septic tanks and pumping station that supply the drainfield are within the Protected Area and located below grade about 20 meters south of the Screenhouse. In 1978, residual radioactivity was identified in the demineralized water system due to backflow through a check valve leading to the spent fuel pool. Demineralized water is

the make-up supply for the heating boiler and heating boiler blowdown water was routinely released to the septic system. In addition, residual radioactivity identified in the boiler sludge had the potential to impact boiler blowdown water.

In 1982 it was discovered that a sink in the Chemistry Lab presented a drain path to the septic system. This sink was designated for non-contaminated analyses; however, the possibility existed that contaminated liquids were drained to the septic system from this location. All conditions were corrected and the Septic Tanks were placed on a routine sampling regimen. The possibility of groundwater contamination resulting from septic drainfield effluent is considered remote because no contamination has been identified in the septic system as a result of the two events described above. Additionally, routine (semi-annually as a minimum) sampling of the septic system hold tanks initiated in 1978 has never indicated the presence of residual radioactivity.
(Appendix 2-B, Radiological Events 21, 28, 34, 39)

2. *Incinerator Site*
An incinerator was used for the burning of radiologically clean trash between the years of 1965 and 1978. The incinerator was a simple enclosure constructed of cement blocks that was located in the Protected Area approximately 40 meters west of the Containment Building. On several occasions throughout its operational history, ash from the incinerator was found to contain radioactivity above established environmental background levels.
(Appendix 2-B, Radiological Events 11,15,16,18,19,23)

3. Transport Routes and Staging Locations
All paved and unpaved open areas that have been identified as staging locations or transport routes for the movement of radioactive materials prior to final packaging for shipment are considered to be potentially contaminated.

Roadway West of Turbine Building
Resin and filter material used in the primary system were routinely transferred from an area immediately west of the Turbine Building, through the south gate of the Protected Area, and into the Radwaste Compound for storage and shipment preparation. Low-level wastes to be packed in containers for shipment in the Radwaste Compound were also transported along this route.

Paved Areas in Vicinity of the Radwaste Compound
The current Radwaste Building, constructed in 1981-1982, houses the vault waste storage area. Prior to this, the vault area was exposed to the environment. During preparation for construction of this building, residual radioactivity was discovered in the concrete, asphalt, vegetation, and soil in this area. Remediation of the area was completed prior to building construction.
(Appendix 2-B, Radiological Events 20,25,26,29,32,33,48)

Power Line Easement
The power line right-of-way has been used as a staging area for large volumes of discarded construction materials. Bulk materials presently located in this area include asphalt and concrete rubble, structural steel, and other miscellaneous debris. Some of this material may have originated from areas of known residual radioactivity. All construction debris has been removed from the area. Residual radioactivity was not identified. Cleanup efforts are detailed in Appendix 2-C. Radiological surveys conducted in this area did not identify soil radioactivity above established environmental background levels. (Appendix 2-B, Radiological Events 26,29,32,44,48,54,63)

Woods Road
The Woods Road is a narrow unimproved lane that extends approximately 300 meters from the western boundary of the Protected Area to the former weather station site. The station was constructed prior to plant operation and was used to collect weather data until January 1963. All that remains of the weather station are portions of the foundation. The Woods Road has been used as a materials transport route and several small locations along its length contain concrete rubble, wood pallets, paint chip refuse, and other miscellaneous debris; some of this material is known to have originated from inside the Protected Area. All debris of plant origin has been removed from this area [Sections 2.4.5.1(b), 2.4.5.1(c)]. Radiological surveys conducted in this area did not identify soil radioactivity above established environmental background levels.
(Appendix 2-B, Radiological Events 1,3,5,6)

Shoreline Near Screenhouse
An area of lake frontage extending from the Screenhouse toward the east parking lot has the potential to contain contaminated material. Cables, steel waste, and shards of asphalt and concrete have been identified in this area. In addition, dredgings from early Discharge Canal restoration work were stored in this area. These dredge spoils may have contained residual radioactivity from the Discharge Canal licensed release pathway. All construction debris has been removed from this area. No radioactivity above established environmental background levels was identified in conjunction with the construction debris removed from this area.
(Appendix 2-B, Radiological Events 4,9,10,12,14,38)

Construction Material Storage East of Protected Area
Physical inspection of an area 135 meters east of the Protected Area has identified two small locations that contain asphalt and concrete rubble. No radioactivity has been identified; however, a potential exists that this material may have originated from an area of known residual radioactivity.

4. Buildings
The HSA has been limited to site soils and groundwater; however, the occurrence of radiological events within or near site structures suggests the potential for residual radioactivity in soil.

Annex Building
A small quantity of the radioactive laboratory chemical, uranylacetate, was spilled inside the Annex Building in 1975. This chemical is not of plant origin and is commonly available from chemical suppliers. Materials of this type were commonly used at Public Affairs educational demonstrations. The spill was cleaned up. No evidence exists to indicate that this chemical has impacted the environment.

The original drainfield for the Annex was a temporary installation in use prior to connection with the site sanitary system. This drainfield was abandoned in place following connection to the main system. There is little or no potential for radionuclide contamination of groundwater from the abandoned Annex drainfield.

A shower was installed in the Annex in 1977 to support wholebody counting activities conducted in the Annex. While the Annex was located outside the radiologically controlled area, a pathway existed for potential residual radioactivity to have entered the site sanitary system as a result of this shower. However, radioactivity of plant origin has never been detected in the Annex or identified in routine analyses of the sanitary system holding tanks. (Appendix 2-B, Radiological Event 17)

Contaminated Warehouse
The Contaminated Warehouse is located in the southwest corner of the Protected Area. This building has been used to store salvageable materials with fixed residual radioactivity.

Butler Building
The Butler Building was once part of the Radwaste Compound. Low-level radwaste was compacted into barrels in this building for offsite disposal. A 1985 radiation survey documents fixed residual radioactivity on this structure. The Butler Building was subsequently moved into the Protected Area for use as a storage shed. It is presently located east of the QA/QC Warehouse. (Appendix 2-B, Radiological Event 33)

QA/QC Warehouse
The QA/QC Warehouse is located in the southwest corner of the Protected Area. This building was a locked and controlled storage location for contaminated equipment. A 1986 radiation survey of the building describes fixed residual radioactivity on areas of the concrete floor. Cleanup was completed and the building was released for general use in accordance with site procedures.
(Appendix 2-B, Radiological Event 35)

Gas Bottle Storage Shed
A decontamination area known as 'Room 121' is located on the southeast end of the Turbine Building. This room contains a floor sink that was used for cleaning highly contaminated objects. Records indicate that the sink overflowed on several occasions and that the radioactive effluent leaked

through a common wall with the Gas Bottle Storage Shed located outside the Radiologically Controlled Area (RCA). On each of these occasions the area was cleaned up and released for general use in accordance with plant procedures. The foundation and soils in this area may contain localized areas of residual radioactivity.
(Appendix 2-B, Radiological Events 40,41,43)

c. Areas of Soil and Groundwater that have been Known to Contain Residual Radioactivity

1. *Storm Water Drains*
Drains in the Protected Area divert stormwater run-off from building areas toward Lake Michigan. The north-south line along the railroad bed and the connecting east-west line to the west drainage ditch are known to have contained residual radioactivity at one time. Evaluation has showed this radioactivity originated from drainage of a contamination area west of the Turbine Building. The east-west drain line terminates in a collection barrel that holds sediment and allows supernatant to be released. The collection barrel is routinely sampled prior to release. Residual radioactivity has not been found in the liquid effluent; however, trace amounts of radioactivity have been found in the barrel sediment and in nearby ditch sediment originating from particulates deposited there prior to barrel installation.

Residual radioactivity was also found in the sediment of the east storm drain piping during investigation of the 1998 Service Water System event. The service water supplied sealing water to the condenser vacuum pumps and seal leak-off from the pumps was connected to the storm drain system. This event provided a flow pathway to the storm drain and radioactivity was found in the sediment of the east storm drain piping. Analyses of the storm drain liquid effluent did not identify residual radioactivity. The east storm drain line sediment was removed at the time of the event.
(Appendix 2-B, Radiological Events 52,53,57,58)

2. *Canal Dredgings*
Scoping surveys identified residual radioactivity at small fractions of IDCGLs in an area north of the Protected Area fence. This area extends from the Discharge Canal to the west drainage ditch and also includes the small section of beach near the tree line immediately east of the canal. The Discharge Canal has been dredged on several occasions prior to 1989 and it has been reported that dredge spoils were placed in this area. These spoils may have contained residual radioactivity from the Discharge Canal licensed release pathway.
(Appendix 2-B, Radiological Events 9,10,12,14,38)

3. *Roof Gravel Storage*
Trace amounts of residual radioactivity (less than 10% of the IDCGL) were identified in the gravel removed during renovation work on the Turbine Building roof. The gravel is stored beneath a tarpaulin in a location near the

northeast corner of the Containment Building. This location encompasses an area of approximately 10x10 meters.
(Appendix 2-B, Radiological Events 51,55)

4. *Turbine Building Track Alley*
A significant event involving a subsurface leak in a piping connection from the Condensate Storage Tank was recorded in 1984. An evaluation of this event concluded that approximately 20,000 gallons of radioactive condensate had been released to area soils beneath the Turbine Building. Shallow groundwater drains through this area towards the lake. Following extensive cleanup efforts, the NRC provided approval to allow the remaining contaminated soil to be left in place. This is the only onsite disposal utilized by BRP. Residual radioactivity was initially above IDCGLs, but has now decayed to less than the final site-specific DCGLs.
(Appendix 2-B, Radiological Events 24,30,42,46,47,56,60,61)

5. *Shallow Groundwater Monitoring Wells*
During decommissioning planning, nine shallow groundwater-monitoring wells were installed in 1994. These wells have been monitored by routine sampling and independent analysis. The two northern most wells have identified low levels of tritium. Tritium concentrations in non-potable water were initially above EPA drinking water guidelines for potable water, but decreased to below the guideline values over time. No other radionuclides have been detected. The tritium groundwater plume resulted from a Condensate Storage Tank leak that occurred in 1984. Other events within the potentially elevated area west of the Turbine Building may
also be a contributing factor for the identified tritium. Additional monitoring wells were installed during the Hydrogeological Assessment conducted in 2002. This study is summarized in Section 2.4.3.
(Appendix 2-B, Radiological Event 30)

d. Areas of Potentially Elevated Residual Radioactivity

Areas that have the potential to contain residual radioactivity levels above the IDCGLs are identified in Figure 2-2.

1. *Radwaste Vault Area*
Soil surrounding the vault in the Radwaste Compound may contain residual radioactivity. The classification of this area is based on recorded events, process knowledge of the methods used for the movement of radwaste, and previously identified residual radioactivity in this area.
(Appendix 2-B, Radiological Events20,26,29,32)

2. *Soils Below The Pipe Tunnel Floor*
The Pipe Tunnel is the location of the steam turbine exhaust and the main condenser. This location has been a known area of residual radioactivity throughout the history of the plant. A spent resin spill was recorded in this room. Standing water in the Pipe Tunnel resulting from steam and condensate leaks was common during the life of the plant. The open top

expansion ring surrounding the sphere is known to contain contaminated soil in this area and the expansion joints in the concrete flooring are suspected to present a contamination pathway to the soil below grade Core samples through the Pipe Tunnel floor show several areas of residual radioactivity greater than IDCGLs within the first 15 cm of soil below the floor. One local area (beneath a floor penetration) was above IDCGL for Co-60 in a sample extending from 30 to 60 cm depth.
(Appendix 2-B, Radiological Events 7,24,61)

3. *Area Immediately West of the Turbine Building*
Three large surface-mounted tanks and piping associated with the Liquid Radwaste Processing System are located in this area. The Liquid Radwaste Processing System is contained in a subsurface concrete structure adjacent to the Turbine Building foundation wall. Off-gas piping and the spent resin sluice line are also located below grade in this vicinity. Several events resulting from tank overflows and piping leaks have been documented in this area. This area was also a transfer point for the movement of highly contaminated filters and spent resin. Resin spills have occurred and the soil in this area has been remediated on several occasions.
(Appendix 2-B, Radiological Events ,8,13,22,27,30,36,37,45,46,49,61,62)

2.2.6 Impacted Area - Non-Radiological Contamination

The Non-Radiological HSA reviewed the historical impact of site activities, including decommissioning waste management, involving hazardous and regulated materials that have the potential to impact the environment. This study was developed following the DQO process. Applicable guidelines for scoping and site characterization from the Environment Protection Agency's (EPA) Preliminary Assessment and Remedial Investigation/Feasibility Study (RI/FS) Processes and guidelines found in NUREG-1575 were used as a resource in the development of this document [Reference 2-27].

The Non-Radiological HSA is an indepth review of historical plant documentation that identified non-radiological events that were known or had the potential to impact the environment. Environmental impact is defined as adverse effect to site soil, water, plants and animals. Further information was then used as the basis to evaluate the presence and extent of non-radiological contamination at BRP. This information includes the following:

- Interviews of present employees,
- Corrective action records,
- Shift Supervisor Logbooks,
- Radiological HSA,
- Physical walkdowns of site property,
- Waste characterizations,
- Environmental assessments,

- Laboratory analysis reports,
- Hazardous waste review reports,
- Hazardous/regulated waste generation reports,
- BRP Environmental Logs,
- BRP Asbestos Abatement Sampling and Daily Logs, and
- BRP Lead Shielding Accountability Logbook.

An evaluation was performed to determine if any events required further investigation or action to allow final unrestricted release of the site. It was determined that there is no environmental contamination at BRP due to non-radiological activities involving hazardous and regulated substances [Reference 2-8]. Response and cleanup to those events that did, or had the potential, to impact the site were completed per applicable regulatory requirements. Further investigation and additional remediation efforts regarding these past incidents are not needed. As the decommissioning process continues and buildings are dismantled, scoping samples in the gravel and soil beneath structures that pose the highest non-radiological risk to the environment may be considered to confirm no impact has occurred. These locations include the Screenhouse, Containment Building, Turbine Building, I&C Lab, Track Alley, and underground storage tank areas.

2.3 ANALYTICAL METHODS

2.3.1 Site Characterization Quality Assurance/Quality Control (QA/QC)

The site characterization process followed the applicable portions of the Consumers Energy Quality Program Description for Nuclear Power Plants [Reference 2-14]. This is the controlling document outlining quality assurance requirements for the BRP site. Decommissioning administrative procedures are designed to ensure compliance with applicable quality assurance requirements. Specific QA/QC requirements for site characterization are documented in the BRP Site Characterization Survey Plan [Reference 2-12]. These requirements are summarized below.

2.3.1.1 Sample Collection and Measurement Quality Control

a. Sample collection, preparation, and analyses are performed by qualified technicians. The process for sample collection and analysis, as defined by the BRP Site Characterization Survey Plan, includes the following tasks:
   - Verification of survey unit grid identification number, date, and time of the survey on the survey unit plan,
   - Collection techniques for samples,
   - Completion of a Chain of Custody form for each sample group,
   - Performance of daily instrument functional checks,

- Verification of spectroscopy input parameters including sample mass, location designation, geometry, date, etc., and
- Evaluation of spectroscopy output for the identification of all energy peaks.

b. Measurement Instrumentation
The quality control requirements for all site measurement instrumentation are specified by BRP administrative procedures [Reference 2-10]. In addition, instruments are controlled by procedures specific to their operation. QA/QC information concerning site characterization radiological measurement instrumentation is provided in Section 2.3.4.

Big Rock Point utilizes a vendor to validate the operation, efficiency calibration, and radioactive measurement process for laboratory gamma spectroscopy instrumentation. Big Rock Point receives annual cross-check samples from this vendor containing an isotopic mix of unknown radionuclide concentrations in geometries appropriate for gamma spectroscopy analysis. The samples are analyzed at the BRP site and the results returned to the vendor for program quality validation. In addition, all site technicians who are qualified to operate gamma spectroscopy equipment for characterization or final status surveys are required to demonstrate proficiency utilizing gamma spectroscopy equipment on an annual basis. The acceptance criterion for proficiency testing is specified in NRC Inspection Manual, Procedure 84750 [Reference 2-26]. Documentation of instrument proficiency is maintained by the BRP Radiation Protection and Environmental Services Department.

2.3.1.2 Survey Unit Data Validation

The data quality of analytical measurements of defined survey units was verified by one of two established methods. The first method requires an independent laboratory analysis and measurement comparison with BRP results on splits of randomly selected samples. The alternate method allows the comparison of independent laboratory analyses with BRP measurements of the same randomly selected sample to verify data quality. The acceptance criteria for measurement comparisons are established by evaluations performed using the two-tailed paired t-test at the 95% confidence level or by NRC Inspection Manual, Procedure 84750.

All data validation results are documented and maintained in accordance with quality requirements established by the BRP Site Characterization Survey Plan. Samples collected in support of the site characterization effort are documented and stored onsite in the event they are required for future evaluation.

2.3.1.3 Staff Training and Qualification Requirements

Staff training consists of annual site-specific General Employee Training, annual Basic Radiation Worker training, and training on specific procedures for personnel conducting or supervising characterization surveys. This training includes procedures covering the use of radioactivity measurement instrumentation, soil and groundwater sampling, chain of custody requirements and sample preparation and analysis. Task qualification is obtained upon a satisfactory demonstration of

proficiency in the implementation of procedural requirements. Site characterization-specific tasks are defined in the RP&ES (Radiation Protection and Environmental Services) OJT (on-the-job training) Manual and listed in the Practical Factor Task Lists (PSTL) [Reference 2-11]. The operation of instrumentation used in performing characterization surveys is also included on the PSTL. Training and evaluation of specific tasks are required prior to independent performance of the task.

The extent of training required is commensurate with the scope and complexity of the task and the education and experience of the individual. Training on new procedures or significant procedure revisions consists of required reading by affected personnel as a minimum. Classroom training will be utilized for new procedures, procedure revisions, or new programs where required. Training documentation and personnel qualifications are maintained in accordance with approved RP&ES Department procedures. Specific information on procedures and training for final status surveys is provided in LTP Section 5.8.2.3.

2.3.1.4 Data Reviews

Site characterization utilizes the DQO process to establish quality requirements for the design of characterization surveys, development of HSA, performance of background studies, and various engineering analyses supporting instrument usage and the measurement of radioactivity. Following the BRP Site Characterization Survey Plan, reviews of survey unit files and other applicable data are conducted to ensure that all required information has been obtained and that DQOs have been met. Survey design and evaluation in accordance with stated DQOs is addressed in Section 2.4.4.1. As formal characterization survey results are received and processed, an individual file is created for each survey unit containing the following documents:

- Index of surveys performed,
- Survey design,
- Survey unit description, history brief, and summary findings,
- Master activity data sheet,
- Annotated survey area maps indicating sample data point locations,
- Sampling and analysis reports of in-situ gamma and/or laboratory spectroscopy data for each individual survey,
- NaI scan survey data where applicable,
- Identification of individuals performing surveys and laboratory measurements,
- Dose contributions, limit calculations, and statistical evaluations where applicable, and
- Documentation and results of investigations and unusual findings or conditions.

Surveys other than formal characterization surveys (such as surveys in support of remediation activities, or various readiness and turnover surveys, as applicable), may be filed separately with documentation that differs from the above, as directed by plant procedures.

Each laboratory and in-situ spectroscopy analysis receives a review for accuracy by a qualified technician and the Site Characterization Supervisor or his designate. This review verifies the correct date, time, sample number, sample mass, location, and detector geometry/efficiency. The review also ensures that the MDA requirements for specified radionuclides are verified and that all unidentified or anomalous peaks are accounted for. The reviewers document this evaluation by initialing and dating each printout.

2.3.1.5 Document and Records Control

Site characterization records include survey analysis data/computer printouts, completed procedures, log books, HSA records, supporting engineering analyses, and other pertinent information relating to site areas. Documents associated with site characterization are maintained and controlled by site characterization personnel until finalized. Finalized characterization records are then sent to BRP Document Control for storage in accordance with site procedures.

2.3.1.6 Program Review and Self-Assessment

The radiological site characterization program is reviewed annually, as a minimum, by the Site Characterization Supervisor or designate and documented as an RP&ES Department self assessment. Additional periodic reviews by independent subject matter experts are also performed as deemed necessary.

2.3.2 Initial Derived Concentration Guideline Level Values for Site Characterization Survey

Initial area classification, survey design, and requirements for remediation efforts in early phases of the decommissioning process have required a working knowledge of allowable activity concentration limits. The IDCGL values were developed to benchmark estimated guideline limits for radioactivity in soil and provide the information necessary to support characterization planning and the evaluation of survey findings.

A site conceptual model was established using default input values to the RESRAD modeling code. The IDCGL values resulting from this evaluation were based on the resident farmer scenario with the drinking water pathway excluded, and a release criterion of 25mrem/year [Reference 2-20]. Finally, preliminary nuclide fractions were determined for the surrogate measurement of HTD isotopes, and IDCGLs for the surrogates were adjusted downward to account for the assumed presence of the HTD radionuclides.

The IDCGLs have since been replaced with final site-specific DCGLs. Site-specific measurements resulting from radiological survey and hydrogeological assessment have provided the information necessary for development of finalized DCGL values and radionuclide fractions. The methods and findings for development of final DCGL values are detailed in Chapter 6, *Compliance with the Radiological Criteria for License Termination*. Finalized radionuclide fractions are provided in Section 2.4.5.7.

2.3.3 Background Radioactivity in Soil and Water for Radionuclides of Potential Plant Origin

A regional study was conducted to determine the standard background radioactivity concentration of gamma emitting radionuclides in soil [Reference 2-3]. A survey was conducted in the BRP Non-Impacted Area and at Fisherman's Island State Park, a coastal region approximately ten kilometers (six miles) south of the plant site. Split samples were shared with the MDEQ. Fisherman's Island has been determined to contain soils of similar type and range as those present at BRP. The Non-Impacted and Fisherman's Island Area surveys were designed in accordance with DQOs and followed the guidance of NUREG-1575. An evaluation of regional scoping data determined that 37 sample points were more than sufficient to satisfy the DQOs for the surveys conducted in this study. Cs-137 was the only radionuclide other than naturally occurring radionuclides identified in soil analyses. Data are summarized in the table below. Michigan Department of Environmental Quality results support the BRP findings.

Table 2-1. Local Area Soil Cs-137 Background Radioactivity (pCi/g)

Radionuclide	Mean	Median	Sigma	Range
Cs-137	0.52	0.48	0.79*	0.0 – 1.9

*Log transform of Standard Deviation for Non-impacted site sample set (log-normal distribution)

Background concentrations of radioactive materials in water are below the minimum detection limits for environmental samples in the vicinity of BRP. Residual radioactivity in groundwater and surfacewater has not been identified above MDA levels, achievable by commercial laboratory analysis [Reference 2-9]. Table 2-11 identifies observed minimum detection levels (designated by < signs) for groundwater.

2.3.4 Measurement Instrumentation

2.3.4.1 a. Survey Location Instrumentation

The site grid plan has been referenced to longitude/latitude coordinate locations by licensed survey and confirmed by Global Positioning System (GPS) measurement [Reference 2-17]. Use of GPS to identify data point locations for radiological evaluation is restricted to random sampling in only Class 3 areas where large areas, rough terrain, or heavy vegetation made intensive licensed land survey for grid plan identifications impractical. Class 1 and Class 2 areas identifying residual radioactivity have been directly tied to the site grid plan by licensed land survey to facilitate exact survey data point replication. Use of the GPS system requires functional and operational checks to meet the following acceptance criteria:

- Functional check comparisons to the site grid plan control point must be performed before and after each workday use. Acceptance criteria are ± 10 meters.
- Operational checks to determine triangulation accuracy are required prior to each field measurement. Acceptance criteria are ± 10 meters.

b. Gamma Spectroscopy
Gamma spectroscopy is the primary method of radionuclide identification for the characterization of soil and groundwater at the BRP site. Gamma spectroscopy is routinely performed in the field and in the laboratory for qualitative and quantitative radionuclide measurement.

1. Laboratory Spectroscopy
The BRP laboratory maintains two gamma spectrometers. Each counting system utilizes a one-liter Marinelli beaker geometry for soil analyses. Groundwater measurements are conducted using a volume of three liters in a four-liter Marinelli beaker geometry. Detector systems were calibrated for each measurement geometry using National Institute of Standards and Technology (NIST) mixed gamma sources. Both detectors are manufactured by Princeton Gamma-Tech Inc., and operate on the VMS Genie platform manufactured by Canberra Industries. Table 2-3 summarizes BRP laboratory instrument specifications.

2. In-Situ Spectroscopy
In-situ gamma spectroscopy is conducted using a p-type coaxial germanium detector manufactured by Canberra Industries. The unit is controlled by a separate electronics module and laptop computer interface. The system is calibrated by In-Situ Object Counting System (ISOCS) software. ISOCS uses a combination of Monte Carlo N-particle modeling calculations and discrete ordinate attenuation computations to derive a set of polynomial coefficients that describe the detector/source efficiency data. The user interfaces these coefficients through ISOCS to develop measurement efficiencies for the geometry selected.

The standard source geometry for open land survey is a truncated cone 15 cm in depth with a surface diameter of 14.14 meters. Other cone thicknesses (depth of activity) may be utilized if laboratory or down-hole analysis of soil corings indicate different thickness. The detector is collimated to 90° and secured in a fixed jig arrangement with 5 cm of lead shielding. Source to detector distance is 7.07 meters.

Efficiency values for standard source soil geometry measurements performed by In-Situ gamma spectroscopy are provided in Table 2-2 below:

Table 2-2. In-Situ Gamma Spectroscopy Efficiency for Standard Source Geometry

Energy (KeV)	Massimetric Efficiency (cps / γps per gram)
50	5.40E-04
65	1.99E-03
80	3.70E-03
100	5.51E-03
120	6.70E-03
200	8.17E-03
400	7.32E-03
500	6.85E-03
1000	5.92E-03
2000	5.01E-03

Alternate geometry calibrations may be performed as required to provide radionuclide measurements of smaller survey areas. Accuracy of this counting system has been verified by empirical measurement [Reference 2-2].

Table 2-3. BRP Detector Performance and Specification Data

	Relative Efficiency *	Diameter	Length	End Window
Detector #1	9.7%	47mm	27mm	5mm
Detector #6	44.1%	67mm	60mm	5mm
In-Situ	40%	62mm	57.5mm	5mm

*Efficiency relative to the 1.33 MeV photopeak of Co-60 for a cylindrical NaI(Tl) detector 7.65 cm diameter by 7.65 cm in length, with a source-detector distance of 25 cm.

MDA determinations for both laboratory and portable counting systems have software controlled count times that maintain maximum environmental MDA values for all radionuclides of interest at fractional levels of the IDCGL release criteria. Algorithms used in MDA calculations for these two systems vary slightly in approach; however, both result in values equivalent to Currie MDA calculations at the 95% confidence level [Reference 2-15]:

$$MDA = Ld / KVT$$

where: Ld (limit of detection) $= (3) + (4.65)\sqrt{background}$

K = proportionality constant relating detector response to activity concentration

V = mass (or volume) of the sample

T = counting time

c. Surface Scanning
The evaluation of open land areas requires a detection methodology of sufficient sensitivity for the identification of small areas of potentially elevated activity. Big Rock Point scanning measurements are performed by passing a 2" x 2" NaI(Tl) (Sodium Iodide) gamma scintillation detector in gross count rate mode across the land surface under investigation [Reference 2-5]. The centerline of the detector is maintained at a source to detector distance of less than 10 cm above the surface and moved from side to side in a 1-meter wide pattern at a rate of 0.5 m/sec, while advancing forward approximately 0.125 m/sec. This serpentine scan pattern is designed to cross each survey cell (one square meter) four times in eight seconds with a maximum separation of less than 50 cm between any path. The audible signal is monitored for detectable increases in count rate. An observed count rate increase results in further investigation to verify findings and define the level and extent of residual radioactivity.

This method represents the Stage 1 and Stage 2 surface scanning process for land areas defined in NUREG-1507 and is the basis for calculation of the scanning detection sensitivity (scan MDC). The sensitivity of this counting system has been verified by empirical measurements. Alternate methods of sufficient sensitivity for the identification of small areas of elevated radioactivity may be used where appropriate. Survey methodology, counting geometry and Scan MDC calculations are detailed in Appendix 2-D.

2.4 ENVIRONMENTAL STATUS INVESTIGATION

2.4.1 Overview

The ESI builds on the foundational information developed in the HSA by physical inspection, measurement, and data analysis to further define the status of contaminants in the BRP Impacted Area. The result of this effort provides the information required for development of the site conceptual model, initial classification of Impacted Areas as Class 1, 2, or 3, and support of the decision-making process necessary for remediation and FSS planning. This task was accomplished through survey and investigation of soil and groundwater utilizing the following methods:

1. Legacy Materials Evaluation - to identify and define locations of abandoned or poorly documented underground piping and evaluate areas for the presence of subsurface legacy material,
2. Hydrogeological Study – to define the movement of water and migration of mobile contaminants through subsurface geology and provide the information necessary for development of the dose model, and
3. Radiological Survey and Spectroscopy Analysis - to characterize the location, concentration, and distribution of radionuclide contaminants in soil and groundwater.

To facilitate the ESI, licensed land surveyors have prepared the site plan by establishing a reference grid system. Based on HSA information and process knowledge, the site Impacted Area has been sectioned into preliminary survey units of similar residual radioactivity levels. These initial survey units are comprised of one or more 10 x 10 meter areas known as survey grids. Each survey grid is identified by a unique location code. Using a rectangular coordinate system with the southwest corner as origin, survey grids can be further defined in 1 x 1 meter areas known as survey cells. Permanent control points in the environment allow replication of the site grid system and verification of field locations during ESI surveys. Identification markers have been placed around the site at pre-determined intervals. These markers bear a numerical reference to provide survey point correlation with site map designations, United States Geological Survey (USGS) monuments, and latitude/longitude coordinates.

Survey units are identified by reference to the site grid plan. The southwest corner of each area represents the identifying origin of each survey unit. The nomenclature for identification of radiological surveys is described by the following:

NNT_iC Example: $15A_i1$

Where:

- NN – Survey unit number (e.g., 15)
- T – Survey type (A-Characterization, B-Post Remediation, C-Final Status Survey)
- i – Survey iteration (1,2,3 ...) or alternate identification as defined by survey package
- C – Survey unit initial classification (1,2,3 ...)

The site grid plan coordinated with reproducible field locations facilitates survey management and design, ensures accurate location of survey measurements, and permits the replication of survey areas for remediation and measurement verification as necessary.

2.4.2 Legacy Materials Evaluation

Achieving a Greenfield condition at the time of the FSS requires the removal of all sub-surface structures and relevant materials of plant origin. Ground Penetrating Radar (GPR) was used to evaluate the presence of buried non-native objects around the site Industrial Area. The purpose of the GPR survey was to define abandoned or poorly documented subsurface piping and to locate underground legacy materials of plant origin. Areas of the Owner-Controlled property were selected for GPR investigation based on the information provided by HSA findings, plant process knowledge, and physical walkdowns of the site. All valid, positive indications of subsurface materials were evaluated by excavation, inspection, and radiological measurement during the performance of this survey [Reference 2-13].

2.4.2.1 Survey Instrumentation

A Geophysical Survey Systems, Sir System 2 test instrument was used to perform the GPR study. Instrument sensitivity under site-specific soil conditions was sufficient to define anomalies to depths up to 3 meters (10 feet). Items were detected on site at the following depths:

- Ceramic Tile – 1.63 meters.
- Concrete – 2.0 meters.
- Corrugated metal drain piping - > 5 meters.

2.4.2.2 Survey Methodology

Potential locations of subsurface legacy material were considered to be regions of poorly documented or abandoned piping systems and fringe areas that may have been used for material storage. Grid track lines were marked out with 1.5 meter (5-foot) spacings in the areas to be surveyed. Position markers were placed on the GPR data profiles at each grid crossing for location reference. The survey was performed by passing the GPR antenna along the track lines at a slow walking speed. The GPR computer identified and recorded all subsurface anomalies and provided this information on a scale drawing of the survey area. Anomaly indications identified by the system were referenced to the site grid plan.

2.4.2.3 Survey Results

Construction debris consisting of concrete, asphalt, and miscellaneous scrap materials were identified and removed from survey areas along the shoreline and the former 138kV power line easement. In addition, two sections of drainage piping were recorded in Survey Unit 12, north of the Protected Area (see Figure 2-3). The piping locations have been documented and these systems are scheduled for excavation and removal prior to the FSS. Residual radioactivity was not identified in excavated materials or contact soils in any survey performed in this study.

The investigation of legacy materials around the BRP site is an ongoing process that will continue during the dismantlement and subsurface equipment removal activities. Detailed results of the GPR survey investigation are provided in Appendix 2-C.

2.4.3 Hydrogeological Study

A Hydrogeological Assessment of the BRP Industrial Area was completed in the spring of 2002. The project was conducted to evaluate existing documentation regarding the movement of groundwater in the Owner-Controlled Area and provide additional field investigations for detailed identification of the hydrogeological conditions within the Industrial Area. This study also resulted in the identification of soil and groundwater engineering properties required for input to the dose model (see Chapter 6) and provides the information necessary to define the movement of contaminants though the subsurface geology. Chapter 8, *Supplement to the Environmental Report,* contains additional information regarding BRP site hydrology.

2.4.3.1 Methods

The Hydrogeological Assessment was based on a review of existing site data, including the results of several previous site investigations, as well as a series of recent test borings and piezometer wells completed in the Industrial Area. The historical investigations utilized include those conducted by Zumberge (1959), The Traverse Group (1994) and Radian, Inc. (1999) [References 2-29, 2-22, and 2-19]. Additional test borings and piezometer well installations in the Industrial Area were conducted by Otwell Mawby, P.C. (2002) [Reference 2-18]. Individual geologic and groundwater bearing units were identified based primarily on visual examination of samples obtained during the drilling, while the engineering properties of several of the units were determined from laboratory testing of representative samples collected during field investigations. An analysis of the hydraulic heads in piezometer wells completed in different groundwater bearing units identified at the site was performed to assess the groundwater flow conditions at the site. A site plan drawing denoting the locations of the piezometer wells and soil borings is provided in Figure 2-4.

The physical (engineering) properties of the unsaturated and saturated soil materials were determined through laboratory testing of representative samples obtained from the individual layers. The laboratory methods used for the evaluation of physical properties were conducted following established ASTM procedures.

The horizontal groundwater flow directions in the groundwater bearing zones identified at the site were determined from the observed hydraulic heads measured in a minimum of three piezometer wells installed in each respective zone. Similarly, vertical groundwater flow direction(s) between the different groundwater bearing units (i.e., within the intervening aquitards) was determined from the observed hydraulic head differences measured in nested groups of piezometers installed at three locations. The horizontal groundwater flow velocity (v_H) for any given groundwater bearing zone and vertical groundwater flow velocity (V_v) within any given aquitard were determined from the following relationships:

$v_H = k^* i_H / n_E$,
where k = layer specific average hydraulic conductivity (cm/sec),
i_H = layer specific horizontal hydraulic gradient (dimensionless), and
n_E = layer specific effective porosity (dimensionless).
$v_V = k^* i_V / n_E$,
where k = layer specific average hydraulic conductivity (cm/sec),
i_V = layer specific vertical hydraulic gradient (dimensionless), and
n_E = layer specific effective porosity (dimensionless).

2.4.3.2 Site Geology and Hydrology

The results of the drilling and well installation work confirm that this portion of the site is underlain by recent unconsolidated deposits having a total thickness ranging from 12 to 24 meters (40 to 80 feet). This cover material is underlain by fractured limestone bedrock. While the surface elevation in the Industrial Area remains relatively constant at 130 to 131 meters (590 to 593 feet) msl, the variation in cover

thickness results from a pronounced north to south decrease in the bedrock elevations at the site. A cross-section of the Industrial Area subsurface geology is provided in Figure 2-5.

The unconsolidated cover material consists of several units that are laterally continuous across the site. These units comprise a thin upper zone composed chiefly of granular sand and gravel (Units 6a, 6b; 2.4 to 3.7 meters [8-12 feet] thick), and a much thicker lower zone composed of a series of units containing a higher proportion of clay and silt (Units 2, 3, and 5; 10 to 25 meters [32-76 feet] thick). In addition, a thin sand layer (Unit 4; 2-5 feet thick) is also present in this lower zone at depths of 6 to 7.5 meters (20 to 25 feet). A similar sequence of units, including the intermediate depth sand layer, was reported in an earlier study conducted approximately 305 meters (1000 feet) west of the main power station area, indicating that the unconsolidated deposits found in the main power station area are continuous over a wide area.

The bedrock materials obtained from the north and south sides of the site reveal similar lithologies consisting of gray brown limestone with abundant natural fractures. Because the pronounced decrease in bedrock elevations from north to south across the site is greater than the regional bedrock tile (i.e., 40 feet per mile), the bedrock strata encountered on the south side of the site are inferred to be from a slightly lower stratigraphic zone than those encountered on the north side of the site.

2.4.3.3 Groundwater

A total of three groundwater bearing zones have been identified at the site. These include the lower portion of the near-surface sand and gravel layer (Unit 6a, 6b; e.g., bottom 1 to 1.5 meters [3-5 feet]), the intermediate depth sand layer (Unit 4) and the underlying fractured limestone bedrock (Unit 1). The uppermost groundwater bearing zone is unconfined, while the other two zones are confined. The inferred entry point for groundwater found in the uppermost zone is located south of the main power station area in the undeveloped portion of the BRP site. Much of this area is low, wetland type terrain and a significant portion of the precipitation falling in this area likely infiltrates into the soil and enters the shallow groundwater zone. The groundwater entry points for the other two units are also located to the south, at varying distances from the main power station area. The groundwater flow in all three of these units is northerly into Lake Michigan.

The lowermost bedrock aquifer (Unit 1) consists of separate upper and lower bedrock zones. The lower bedrock zone encountered on the south side of the site (piezometer well 1D) is characterized by primarily horizontal groundwater flow from the source area northward toward Lake Michigan. Due to the irregular bedrock topography, the upper bedrock zone encountered on the north side of the site (piezometer wells 2D and 3D) is apparently isolated from the groundwater source area, located to the south, by low permeability unconsolidated sediments and is assumed to receive groundwater vertically from the lower bedrock zone.

The near-surface location of the two upper groundwater bearing units would prevent their use as sources of drinking water. The limited thickness of these same two units would also prevent their use as sources of non-potable water for irrigation or other purposes. The fractured bedrock zone is considered to be the main drinking water aquifer at the site, as well as a potential source of non-potable water.

2.4.3.4 Groundwater Movement

Horizontal groundwater movement in all three water bearing zones moves northward though the main power station area and into Lake Michigan. Analysis of hydraulic head contour maps provides additional quantitative information regarding horizontal groundwater flow. The shallow aquifer yields a horizontal flow direction of N0°E to N9°E with a horizontal hydraulic gradient of 0.015. The intermediate aquifer flow direction is N20W with a horizontal gradient value of 0.028. It was not possible to construct a contour map for the lower bedrock aquifer due to the different completion depths of the bedrock piezometers; however, horizontal hydraulic gradients for the upper and lower bedrock aquifer zones were estimated from the bedrock piezometer well data. Data indicates that the bedrock aquifer flows north into Lake Michigan with an estimated horizontal gradient value of 0.019 (see Section 2.4.3.6.a for additional information).

Vertical groundwater movement was evaluated by investigation of hydraulic head differences using nested piezometer well pairs installed at three locations across the site (PZ-1, PZ-2, and PZ-3). Comparison of the hydraulic heads in the nested piezometer wells indicates that vertical head differences occur at all three locations. At the locations south of the Containment Building (PZ-1 and PZ-2), the head differences from nested wells indicate upward directed vertical components of flow above the intermediate sand unit and downward vertical flow components below the intermediate sand unit. At the location north of the Containment Building (PZ-3 location), the head differences from nested wells indicate downward vertical flow components both above and below the intermediate sand unit. Vertical hydraulic gradient data vary in magnitude both above and below the intermediate sand layer. The overall downward vertical gradient in the area north of the containment sphere indicates the potential for downward migration of mobile constituents from the surface or shallow aquifer zones to the bedrock groundwater bearing zone.

2.4.3.5 Tritium Movement and Effect of Building Foundations on Groundwater Flow

Analysis of groundwater and aquifer flow parameters has resulted in identification of three primary pathways for interaction among groundwater zones due to the horizontal and vertical flow patterns for radionuclides released from or carried by the condensate leak that occurred in 1984. At the time it occurred, the leak generated a hydraulic head sufficient to charge the groundwater zones with tritium; pathways associated with tritium migration are discussed below.

The first pathway primarily involves the shallow groundwater zone (Unit 6b of LTP Figure 2-5). Two sub-paths are identified: unobstructed flow to the north (travel time to the lake approximately 330 days), and travel initially to the west around foundation obstructions, followed by continued movement to the north (travel time to the lake,

approximately three years). Once north of Containment, both sub-paths are affected by interaction of the downward vertical gradient that causes migration of a portion of the water across the underlying confining aquitard (Unit 5 of Figure 2-5). However, because the horizontal gradient continues northward, any water carrying potential contamination would be at or beyond the northern limits of the site (at their discharge point to Lake Michigan) before mixing with upper portions of the bedrock aquifer would occur.

A portion of flow from this pathway interacts with building foundations and includes water that was trapped in a subsurface vault beneath the Turbine Building, is the major source term for the tritium observed in monitoring wells since they were installed in 1994. Remediation of this source is discussed in LTP Section 4.2.2.2.

The second pathway is via the upper aquitard zone (Unit 5 of Figure 2-5). The vertical gradient within this aquitard is neutral between the Turbine and Containment Buildings. Movement is predominantly northward within this zone. The zone is deep enough to be influenced only by the Containment and radwaste vault foundations. Movement is at a rate of only approximately two meters/year (6.5 feet/year) due to its low permeability. This low permeability also limits the quantity of water it could have accepted in 1984. Consequently, this aquitard is not considered a significant contributor with regard to potential radionuclide transport.

The third pathway includes the intermediate groundwater zone and the lower aquitard zone (Units 4 and 3, respectively, of Figure 2-5). Only the Containment foundation reaches a sufficient depth (approximately 10 meters or 35 feet) to offer a means of water and tritium transfer from the upper zones, although there may also have been some transfer this deep from the hydraulic head of the 1984 leak. The downward vertical gradient north of Containment offers additional means of transfer from the upper zones. Rate of movement within the intermediate sand is rapid, with water reaching the lake from the Turbine Building leak location in approximately 200 days. With respect to that initial incident, this rapid horizontal flow is not likely to have allowed significant mixing with the potable aquifer below prior to aquifer discharge to the lake. However, slow leakage from the vault below the Turbine Building since that time may well account for the continued observation of low tritium concentrations in the potable aquifer since that time.

Excavation of foundations will result in removal of the primary source term of radioactivity (tritium) that gives rise to the currently observed levels of tritium in groundwater at the plant site. LTP Sections 2.4.5.3.c and 4.2.2.2 discuss the trapped subsurface source term of tritium that is determined to have given rise to the tritium plumes illustrated by Figures 2-13 through 2-15. As discussed in LTP Section 4.2.2.2, essentially all this source term was removed prior to the end of 2003.

Tritium transferred to the bedrock aquifer must pass through the aquitard above it (Unit 3 of Figure 2-5). Since the downward gradient through the aquitard above the bedrock aquifer is approximately 7.5 meters/year (25 feet/year) and the aquitard is approximately 7.5 meters (25 feet) thick, removal of this source term should result in significant reduction of tritium from its current level of 900 to 1,000 pCi/l (see Table 2-12) in the bedrock aquifer prior to site release.

2.4.3.6 Water Level Fluctuations

a. *Seasonal Fluctuations*

Based on monitoring results, it has been determined that all three groundwater bearing units exhibit slight seasonal variations in hydraulic head most likely due to corresponding seasonal changes in the amount of precipitation and/or recharge to the groundwater bearing unit. The seasonal variations result in increased hydraulic heads occurring in the spring/early summer and decreased heads in the late fall/winter. The magnitude of the seasonal change is estimated at 0.12 meters (0.4 feet) for the shallow groundwater zone and approximately 0.3 meters (1.0 foot) for the intermediate and bedrock groundwater zones. Evaluation of the hydraulic head data also shows a longer-term net decrease in the heads resulting from regional declines in precipitation and/or increases evapotranspiration. The longer-term component is evident from the observed hydraulic head decrease from March 2002 to March 2003. The magnitude of this longer-term decline is estimated at approximately 0.3 meters (1.0 foot) in the shallow groundwater zone and greater than 0.3 meters (1.0 foot) in the intermediate and bedrock zones. Overall declines in hydraulic head for the intermediate zone may have been additionally affected by dewatering operations within this zone during demolition and removal of the underground solid radioactive waste vaults occurring between December 2002 and March 2003.

General gradients and flow directions for the three groundwater zones do not change with seasonal level variations. It is important to note that the trend for Lake Michigan elevations reflect a similar seasonal variation as the three groundwater bearing units (see section below). Also, Lake Michigan elevations are consistently less than the hydraulic heads recorded for site piezometer wells, confirming that all three groundwater bearing units flow to Lake Michigan. Maps showing seasonal groundwater piezometric fluctuations and generalized flow directions toward Lake Michigan for the two upper groundwater-bearing units are provided in Appendix 2-F. While flow direction is known to be northerly based on data collected from the bedrock wells, a potentiometric map for the bedrock aquifer was not generated due to piezometer wells in this unit being completed in slightly different strata.

b. *Lake Michigan Water Level Fluctuations*

Surface water levels in the Great Lakes, including Lake Michigan, undergo periodic fluctuations on several time scales ranging from seasonal to several years. According to records for the period of time from 1918 to 2003, maintained by the U.S. Army Corps of Engineers (USACE), the annual variation in Lake Michigan levels has a magnitude of approximately 0.3 meters (1.0 foot), with the maximum occurring in June-July and the minimum occurring in December-January [Reference 2-23]. The seasonally averaged Lake Michigan levels for the same period (i.e., 1918 to 2003) have varied from a maximum of 582.0 feet msl (1986) to a low of 576.5 feet msl (1964), indicating an overall

magnitude of 1.7 meters (5.5 feet) for the longer period variations. Low lake level episodes in the mid-1930s, mid-1960s and the present, separated by intervening periods of higher lake levels indicate a roughly 30-year periodicity for the longer period fluctuations.

The seasonal water level fluctuations are caused by annual variation in precipitation and evaporation, while the longer period water level fluctuations are caused by variation in regional weather patterns over multiple years. The seasonal and long-term weather variations that cause the periodic lake level fluctuations produce corresponding changes in the groundwater elevations and/or piezometric elevations in aquifers connected to the lakes, including those identified at the site. Thus, precipitation increases and/or decreases in evaporative losses result in higher lake and groundwater elevations, while precipitation decreases and/or increases in evaporation have the opposite effect. The seasonal and long-term fluctuations in the levels are not expected to significantly change the hydraulic gradients in the adjacent groundwater-bearing units because the differential between the hydraulic heads within the groundwater zones and lake level remain relatively constant. Thus, the flow directions and rates identified in the respective groundwater-bearing units at the site, which depend on the hydraulic gradients, are expected to remain approximately constant, and the fate and transport of the impacted groundwater at the site are unlikely to be affected by the seasonal and long-term water level fluctuations. Appendix 2-F provides potentiometric data for onsite wells and Lake Michigan levels from March 2002 through March 2003.

Although localized groundwater level changes near the Turbine Building may have caused fluctuations in the rate of contaminant release from the sub-floor vault, these cyclical changes have not altered the northerly direction of groundwater flow in all three water-bearing units.

The magnitude of water level changes due to tidal effects in the Great Lakes are considered negligible compared to changes caused by other factors (e.g., weather). Thus, the U.S. Army Corp of Engineers does not keep records of Great Lakes water level fluctuations due to tidal effects. Short-term water level changes caused by wind do occur in Lake Michigan and are referred to as seiches. Seiches can result in lake level changes of up to 1 meter (3 feet) over a period of a few hours. Such changes may induce short-term transient changes in the hydraulic gradients in adjacent groundwater-bearing units. However, given the short duration and relative low frequency of occurrence of seiches, they are not expected to affect the long-term fate and transport of impacted groundwater at the site.

c. Precipitation Effects

The shallow groundwater zone is unconfined and, therefore, is the only groundwater-bearing unit that could potentially receive recharge from precipitation at the site. Presently, much of the site industrial area is covered by impervious surfaces, such as buildings and pavement, which limit precipitation at the site from directly entering the shallow zone by infiltration. Infiltration of

precipitation into the shallow groundwater zone over this area is not normally as important a recharge source as is shallow groundwater seepage flow from the south side of the site.

The wide unpaved areas on the north side of the site distribute infiltration evenly across the site in the east-west direction. Therefore, additional recharge entering the shallow groundwater zone in this area either from increased precipitation or due to future site greenfield condition is unlikely to alter the overall northward flow of shallow groundwater. Although increased recharge by precipitation may increase hydraulic heads in the shallow zone in the short term, any effect on radionuclides (tritium) in groundwater other than a slight decrease of concentration in the shallow zone itself is expected to be minimal. This is because concentrations of tritium currently remaining in the shallow groundwater zone have decreased to very low levels (see LTP Section 2.4.5.3.c).

2.4.4 Characterization Survey

Characterization surveys are the measurement process that identify, quantify, and document residual radioactivity in impacted areas of the BRP site. Over 1100 representative samples of soil and groundwater have been collected and analyzed from the 27 survey locations that form the Impacted Area. These surveys include:

- Primary survey – sample point locations selected by statistically based survey design,
- Supporting survey – knowledge-based judgmental data point locations to further investigate the radiological status of suspect areas,
- Deep core profiles – judgmental or systematic data point locations to define the vertical and lateral extent of subsurface residual radioactivity, and
- Groundwater survey – locations determined by hydrogeological study and the evaluation of subsurface contaminant migration.

2.4.4.1 Survey Design And Radiological Measurement

Initial survey units were developed for areas of analogous residual radioactivity through information established by HSA, process knowledge, and scoping survey data. Survey units follow the site grid plan and provide reproducible field point locations by reference correlation to local control points, USGS monuments, and latitude/longitude coordinates. Survey designs were performed in accordance with NUREG-1575 guidance; detailed survey design information is provided in Appendix 2-E for each survey unit. The DQO process was utilized to satisfy the following characterization survey design objectives:

1. Identify, quantify, and document residual radioactivity in soil, surface water, and groundwater at the BRP site,
2. Determine the extent of residual radioactivity within the survey unit; locate and define any areas of elevated activity,

3. Establish initial classification of site areas as Class 1, Class 2, or Class 3 in accordance NUREG-1575 guidance,
4. Provide the information necessary to define the nuclides of interest for evaluation and identify distribution fractions for surrogate measurement of HTD radionuclides, and
5. Provide the information required to support the decision-making process necessary for structural dismantlement, remediation, and planning of the FSS.

The primary method of survey unit evaluation utilizes laboratory gamma spectroscopy performed on soil samples collected at locations determined by survey design. The evaluation of HTD nuclides was performed by surrogate measurement, as defined in Section 2.3.2. All characterization surveys were conducted to include radionuclide-specific measurements without background reference area consideration. Although not excluded from gross count rate and dose rate measurements, naturally occurring radionuclides are excluded from nuclide-specific dose and DCGL analyses when identified on a nuclide-specific basis by gamma spectroscopy. The fallout radioisotope Cs-137 is not considered to be a naturally occurring radionuclide, and therefore was not excluded from dose or DCGL considerations.

In applicable locations of low background activity where soil sampling capabilities were limited by the presence of subsurface piping or electrical power hazards, in-situ gamma spectroscopy was used in combination with laboratory soil analyses to evaluate portions of the survey unit. In these cases, laboratory sample point locations follow the guidance of NUREG/CR-5849 and laboratory soil analyses were performed to support in-situ gamma evaluations [Reference 2-28]. Where personnel safety hazards exist and in-situ measurements are not feasible, survey designs were modified to permit sample collection at available locations. Survey unit sampling and measurements were conducted in the following method:

a. Primary Survey
   Primary surveys were performed to develop a comprehensive evaluation of the survey unit and provide input for follow-up survey investigations as required by survey design. Wherever practical, primary survey designs were based on the measurement requirements of the Sign Test with sample size defined by calculation of the relative shift. The relative shift was developed using IDCGL values (see Section 2.3.2) with Type I and Type II decision error limits of 0.05. The location and spacing of sample points for primary surveys were based on the following area designations identified by HSA.

   - Areas of 'Potential', 'Known', or 'Potentially Elevated' Radioactivity
     Random start systematic sample point locations - sample point spacing defined by square grid pattern requirements.
   - Areas Designated 'Unlikely' to Contain Residual Radioactivity
     Random number generated sample point locations - no spacing requirements.

b. Supporting Survey
Supporting surveys were conducted to further investigate suspect areas, identify trends, and define the concentration and boundary of existing area residual radioactivity. Sample point locations were judgmentally selected through information developed in the primary survey, HSA findings, process knowledge, and evaluation of contaminant migration pathways. Supporting investigations include surveys of increased intensity for the evaluation of surface and subsurface soils. Deep core profile sampling was performed in areas with the potential to contain residual radioactivity below grade. Deep core surveys were conducted to identify and quantify the vertical and lateral extent of subsurface residual radioactivity in the survey unit.

c. Post Remediation Survey
Post remediation surveys were conducted for specific survey units where radiological cleanup efforts have been performed. These surveys were radionuclide-specific evaluations designed and conducted in accordance with NUREG-1575 methodology. Post remediation surveys were performed with sufficient intensity to define the current radiological status of the remediated area and evaluate the effectiveness of the cleanup effort. These surveys excluded real-time measurements associated with remediation control efforts that were performed during the cleanup process.

d. Scan Survey
Scanning for the identification of areas of elevated activity was generally not performed during the characterization survey process. Scanning opportunities in and around the Industrial Area are greatly limited by accessibility, and elevated background activity originating from the Containment Building, Radwaste Processing Area, and the storage of radioactive materials around the site.

e. Surface and Groundwater Survey
Surface and subsurface waters are routinely monitored in accordance with the BRP Radiological Environmental Monitoring Program (REMP) (see Chapter 8). In addition, the Hydrogeological Assessment, conducted in 2002, provided an evaluation of groundwater movement through the site subsurface geology. This evaluation identified migration pathways of potential contaminants in groundwater within the Industrial Area. The Hydrogeological Assessment and associated radiological measurements performed in this study provide sufficient information to define the range, concentration, and migration of contaminants in subsurface hydrology. This evaluation is detailed in Sections 2.4.3 and 2.4.5.3.

2.4.5 Characterization Survey Findings

2.4.5.1 Radiological Status of Impacted Land Areas

A characterization of the BRP Impacted Area has been conducted. Survey findings are summarized by initial area classification. Additional information detailing the description, history, survey design, and sample point analyses of individual survey units is provided in Appendix 2-E.

For purposes of characterization, Cs-137 levels within the range identified in the background study discussed in Section 2.3.3 were not considered to indicate residual radioactivity. Any other radionuclide of potential plant origin, detected at any level, was considered indicative of residual radioactivity from plant sources.

a. Class 3 Areas
Class 3 areas are considered unlikely to contain residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the IDCGL value. Survey Units 13, 14, 15(3), 15(4), 17, 18, and 59 are Class 3 areas. Table 2-4 summarizes survey data for Class 3 areas. Figure 2-6 identifies locations of Class 3 areas.

The Class 3 survey units are outlying areas that were remote from normal plant operational activities. Survey Units 13 and 14 are pristine sections of Lake Michigan shoreline that encompass the open area from the upland vegetation line (ordinary high water mark) to the waters edge. The remaining Class 3 survey units are generally heavily forested with occasional wetland areas. Exceptions to this are the open field areas of the power-line easement in Survey Unit 17 and the former rail supply connection in Survey Unit 59.

Survey Unit 13
Survey Unit 13 is a lakefront area approximately 100 meters east of the plant discharge release pathway. Due to recent near record lows in Lake Michigan water level, additional shoreline is exposed for surveys conducted in this area. Three samples taken in this area identified trace levels of Co-60 at concentrations of ≤0.1pCi/g. The location of this survey unit is near the plant Discharge Canal where licensed radioactive liquid releases occurred; the levels of radionuclides identified in these surveys are consistent with contaminant migration that would result from wind, current and wave action in this area.

Survey Unit 14
Survey Unit 14 is a narrow expanse of shoreline in the northwest section of the Owner-Controlled property. Radiological surveys conducted in Survey Unit 19 did not identify soil radioactivity above environmental background levels.

Survey Units 15(3), and 15(4)
These survey units are located along the Woods Road west of the Protected Area. A small location of construction debris identified by the HSA in both Survey Units 15(3) and 15(4) was investigated. Residual radioactivity was not identified in this material or in surrounding area soils. All waste material has been cleaned up and removed from the area.

Survey Unit 17
The power-line easement along the southern boundary of Survey Unit 17 was known to contain debris consisting of concrete, asphalt, and other miscellaneous construction materials. This area was investigated and all debris has been removed for offsite disposal. Radiological surveys conducted in Survey Unit 17 did not identify soil or construction material radioactivity above environmental background levels.

Survey Unit 18
Survey Unit 18 is a large wooded area in the southwest quadrant of the Impacted Area. Radiological surveys conducted in Survey Unit 18 did not identify soil radioactivity above environmental background levels.

Survey Unit 59
Survey Unit 59 is west of the former railroad spur in an extension of the Owner-Controlled property separated from the main site by US Route 31. Radiologically clean soil was stored on this survey unit. However, a small amount of construction debris from other areas also was moved inadvertently to this area. Upon investigation, all construction material was found to be radiologically clean with the exception of a single olivine firebrick containing a fixed concentration of 0.06 pCi/g of Co-60. All construction debris has been removed from the area. The primary survey and extensive follow-up investigations in Survey Unit 59 have not identified radioactivity in soil above environmental background levels.

Table 2-4. Summary of Class 3 Survey Unit Findings

Survey	Data Points	Radionuclides	Mean (pCi/g)	Max. (pCi/g)
$13A_1$	20	Cs-137	0.36	0.97
		Co-60	0.07	0.10
$14A_1$	20	Cs-137	0.16	0.40
$15(3)A_1$	2	Cs-137	0.12	0.12
$15(3)A_2$	25	Cs-137	0.38	1.05
$15(4)A_1$	9	Cs-137	0.16	0.64
$15(4)A_2$	25	Cs-137	0.23	0.43
$17A_1$	20	Cs-137	0.57	1.59
$17A_2$	5	Cs-137	0.38	0.48
$17A_3$	3	Cs-137	0.06	0.06
$17A_{pl}$	7	Cs-137	0.53	1.43
$18A_1$	20	Cs-137	0.60	1.00
$59A_1$	36	Cs-137	0.31	0.72
$59A_2$	6	Cs-137	0.37	0.49
$59A_3$	10	Cs-137	0.26	0.47
$59A_{sd}$	67	Cs-137	0.26	0.62

pl – power line
sd – supplemental data

b. Class 2 Areas

Class 2 areas have, or had prior to remediation, a potentially known residual radioactivity, but are not expected to exceed the IDCGL value. Survey Units 12, 15(1), 15(2), 16, and 19 are considered Class 2 areas. Table 2-5 summarizes survey data for the Class 2 areas. Figure 2-7 depicts the locations of Class 2 Survey Units.

Class 2 survey units at BRP are generally located within the plant Industrial Area. These locations serve as buffer regions to Class 1 areas and generally were used for the staging, transport, and storage of radioactive materials prior to final packaging for offsite shipment.

Survey Units 12 and 16

Survey Units 12 and 16 are located north and east of the Protected Area along the Lake Michigan shoreline. Residual radioactivity may be present in subsurface storm drain piping located in this area. Soils in contact with drain piping will obtain evaluation during drain pipe removal.

The Legacy Materials Evaluation identified subsurface construction debris and abandoned stormwater piping in Survey Unit 12. Construction debris was also identified in Survey Unit 16. All waste materials have been removed from the area and locations of abandoned piping are scheduled for excavation and removal. No residual radioactivity was detected in materials removed; however, radiological surveys have identified trace concentrations of residual radioactivity in the soils of both survey units (see Table 2-5). Residual radioactivity present above the high watermark is from the Discharge Canal dredging projects performed to maintain the lake water discharge release pathway. Residual radioactivity below the high watermark is consistent with expectations for direct migration of permitted discharge radioactivity that results from wind, current, and wave action along the shoreline while radioactive effluents are being discharged.

There are no indications that any radioactivity has entered groundwater or surface water due to the presence of dredged materials in Survey Units 12 and 16. No radioactive material concentrations at or above DCGLs have been detected here (see Appendix 2-E data tabulations). A nested set of piezometric wells (PZ3D, PZ3Mb and PZ3Ma) are installed within Survey Unit 12, and only tritium has been detected in any of these wells.

Lack of leaching from the dredged spoil deposits is not surprising given the exposed location of the Discharge Canal within the surf-impacted area of the shoreline. Storm surf routinely washes and scours the materials present within the canal. Most soluble or otherwise migratory activity is expected to have been removed by these mechanisms prior to dredging.

Survey Unit 15(1)

The plant septic drainfield is contained in Survey Unit 15(1). The drainfield is a mound-type pump back system that receives effluent from holding tanks located in the Protected Area. Radiological surveys conducted in Survey Unit 15(1) did not identify soil radioactivity above environmental background levels. Although

the potential exists that residual radioactivity may be present in subsurface areas of the drainfield, radioactivity concentrations requiring remediation are considered very unlikely based on HSA findings. An evaluation for subsurface residual radioactivity will be performed when this system is removed from service.

Survey Unit 15(2)
Survey Unit 15(2) is a long, narrow region of property that parallels the shoreline south of Survey Unit 14. A small area of construction debris was identified along the Woods Road in this area. The material was cleaned up and removed from this area. Radiological surveys conducted in Survey Unit 15(2) did not identify soil radioactivity above environmental background levels.

Survey Unit 19
This area was used as a transport and staging location for the movement of radioactive materials to the Radwaste Building. A road improvement project was conducted in portions of this survey unit following final plant shutdown to pave areas north of the Radwaste Building and surface the roadway to the ISFSI. Primary surveys conducted in this area were performed in phases to investigate areas scheduled for construction (trenching, digging, road surfacing) prior to soil disturbance and road surfacing. Radiological surveys conducted in Survey Unit 19 did not identify soil radioactivity above environmental background levels.

Table 2-5. Summary of Class 2 Survey Unit Findings

Survey	Data Points	Radionuclide	Mean (pCi/g)	Max. (pCi/g)
$12A_1$	18	Cs-137	0.61	1.83
$12A_2$	25	Cs-137	0.26	1.48
		Co-60	0.16	0.18
$12A_{deepcore1}$	4	Cs-137	0.08	0.08
$12A_{deepcore2}$	4	Cs-137	0.52	1.56
$12A_{deepcore3}$	15	Cs-137	0.12	0.20
$12A_{gpr}$	4	Cs-137	0.25	0.29
$15(1)A_1$	25	Cs-137	0.22	1.20
$15(2)A_1$	44	Cs-137	0.18	1.06
$15(2)A_2$	25	Cs-137	0.22	0.53
$16A_1$	22	Cs-137	0.41	1.38
		Co-60	0.10	0.13
$19A_1$	79	Cs-137	0.18	0.45
$19A_2$	26	Cs-137	0.15	0.31
$19A_3$	25	Cs-137	0.61	1.10
		Co-60	0.12	0.12
$19A_{deepcore}$	4	Cs-137	0.22	0.35
$19A_{deepcore}$	2	nd	-	-
$19A_{td}$	15	nd	-	-

td - trenching & digging
nd - non-detect

c. Class 1 Areas

Class 1 areas are defined as locations that have, or had prior to remediation, a potential or known residual radioactivity above the IDCGL value. Big Rock Point Class 1 survey units have been assembled into subcategories of corresponding historical status and radioactivity concentration as discussed below. Tables 2-6, 2-7, and 2-8 summarize survey data for the Class 1 areas. Figure 2-8 depicts the locations of Class 1 Survey Units.

Twenty-one soil samples from the site areas of highest soils contamination levels were analyzed for transuranics and other hard-to-detect (HTD) radionuclides (Section 2.4.5.4). The samples represented both a wide distribution of site areas and include both surface and subsurface samples from these areas. No transuranics were detected in any of these samples above minimum detection levels. Subsequently, analysis of dose consequences at the minimum detection levels in soil for all HTD nuclides were determined (see LTP Section 6.7.2.2). It was found that at minimum detection levels or below, the sum of all HTD radionuclides provide total dose equal to less than 10% of the 10 CFR 20, Subpart E, limit of 25 mrem/y.

1. Class 1, Group A

This group includes material transport and waste storage areas with radioactivity concentration levels less than 50% of IDCGL values. Survey Units 1, 2, 3, 4, 6, 7, 9, 10, 11, and 15(2R) are Class 1, Group A areas. These survey units meet one or more of the following criteria:

- Scan surveys precluded due to elevated background activity resulting from operational systems or material storage,
- Proximity to areas scheduled for soil remediation,
- Proximity to areas scheduled for excavation and removal of contaminated subsurface systems (including storm drain system), or
- Areas previously requiring soil remediation

Table 2-6 summarizes survey data for Class 1, Group A areas. Figure 2-8 indicates locations of Class 1, Group A Survey Units.

Survey Unit 15(2R)

Survey Unit 15(2R) is an area of 18 m^2 along the south edge of the Woods Road within the boundaries of Survey Unit 15(2). This location was a storage area for small quantities of miscellaneous refuse and construction debris. Surveys conducted during removal of this material identified residual radioactivity in approximately two crumbling red bricks. All refuse and construction debris have been removed from the area. A post-remediation survey was conducted and confirmatory measurements were performed by representatives of the MDEQ and the NRC.

Survey Units 1 and 2

These survey units are located near the southwest boundary of the protected area adjacent to the transport route used to move spent resin and filter material from the Protected Area to the Radwaste Building. Structures in this

area include the QA/QC Warehouse and Butler Building located in Survey Unit 1, and the Maintenance Complex located in Survey Unit 2. Subsurface structures and equipment include building foundations, plumbing connections, storm drain and fire protection piping, fiber optics, and electrical conduit.

Remediation efforts have been conducted in the Butler Building and the QA/QC Warehouse to remove fixed residual radioactivity resulting from radioactive material storage. Subsurface residual radioactivity is not indicated by the HSA and was not identified by characterization surveys in these areas. Soils in contact with building foundations will receive further evaluation during structure removal.

Survey Units 3 and 4
Survey Units 3 and 4 are located along the northwest boundary of the Protected Area adjacent to the transport route used to move spent resin and filter material from the Protected Area to the Radwaste Building. Survey Unit 4 borders the Containment Building access at the Equipment Lock. No permanent buildings exist in these locations. Subsurface structures and equipment include storm drain piping, electrical conduit, Service Water and Fire Protection System piping. Survey Unit 4 borders the footing and foundations of the Containment Building and Equipment Lock. Subsurface soil residual radioactivity is not indicated by HSA and was not identified by characterization surveys conducted in this area.

Survey Unit 9
Survey Unit 9 is located in the northeast corner of the Protected Area and contains the Screenhouse. This area encompasses the water intake location for circulating water, service water, and fire water supply. Subsurface structures and equipment include the following:

- Intake structure and Screenhouse foundation,
- Diesel storage tanks (2) southeast of the Screenhouse (emergency generator and fire pump fuel supply),
- Diesel storage tank north of the Turbine Building (plant heating boiler fuel supply),
- Batch release pipe for radioactive liquid discharge,
- Transformer station and associated underground conduit, and
- Electrical power supply, instrumentation conduit, and condenser cooling water, service water, well water, fire protection, storm drain, and compressed air system piping.

The liquid batch release pipe used to release liquid radioactive waste effluent to the Discharge Canal passes through this survey unit. Soils in contact with the subsurface piping of this system will receive further evaluation during piping excavation and removal. Limited amounts of residual radioactivity have been identified in Survey Unit 9. Table 2-6 provides results of soil analyses from this area.

Survey Units 6, 7, and 10
Survey Units 6, 7, and 10 primarily consist of open paved areas that provide a transport pathway to the main gate at the east boundary of the Protected Area. The New Access Control Building is a temporary structure located in Survey Units 6 and 7 that is the access point for entry into the Turbine and Containment Buildings. The Security Building, located near the east gate in Survey Unit 7, is the security checkpoint for entrance into the Protected Area and also contains the Operations Monitoring Station and portal radiation monitors for exiting personnel. Subsurface systems and equipment include storm drain and fire protection piping, electrical conduit, the liquid radioactive release piping, and well water piping. In addition, Survey Unit 10 is the connecting point for circulating water and service water piping in the Turbine Building.

Trace levels of Co-60 (significantly less than the IDCGL) were identified in several surface samples taken along the former railroad grade in Survey Unit 6. Subsurface residual radioactivity is not indicated in these areas by HSA and was not identified in characterization surveys. Samples obtained in areas remote from the railroad bed did not identify soil radioactivity above established environmental background levels.

Survey Unit 11
Survey Unit 11 is located east of the former rail grade near the southern boundary of the Impacted Area and encompasses the Radwaste Building and the Mixed Low-Level Waste Storage Building.

Subsurface materials and equipment in this survey unit include the following:

- Radwaste storage vaults,
- Electrical supply conduit,
- Storm drain piping, and
- Remote security camera and motion sensor relay communication.

The Radwaste Building was used for the temporary storage and staging of contaminated material prior to offsite shipment as radioactive waste. The HSA has identified contamination events occurring in this location and documents a significant cleanup of the area conducted in 1981 prior to Radwaste Building construction. Supporting surveys included deep core soil sampling at locations encompassing the storage vaults. Residual radioactivity was identified only at levels well below the IDCGLs in this area.

Table 2-6. Summary of Class 1, Group A Survey Unit Findings

Survey	Data Points	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$1A_1$	23	Cs-137	0.16	0.37
		Co-60**	0.11	0.11
$1A_{1\ deepcore1}$	4	nd	-	-
$2A_1$	20	Cs-137	0.24	0.92
$2A_{1\ deepcore1}$	11	nd	-	-
$3A_1$	17	Cs-137	0.34	2.13
		Co-60**	0.28	0.28
$3A_2$	2	nd	-	-
$3A_{deepcore1}$	9	Cs-137	-	0.17
$3A_{deepcore2}$	3	nd	-	-
$3A_{deepcore3}$	9	Cs-137	-	0.06
		Co-60	Nd	-
$4A_1$	22	Cs-137	0.22	0.74
$4A_2$	17	Cs-137	0.05	0.07
		Co-60**	0.27	0.27
$4A_3$	10	Cs-137	0.57	1.22
		Co-60	0.06	0.07
$4A_4$	4	Cs-137*	0.17	0.17
$4A_{deepcore1}$	22	Cs-137**	0.08	0.08
$4A_{deepcore2}$	12	Cs-137**	0.10	0.10
$6A_1$	18	Cs-137	0.09	0.20
		Co-60	0.08	0.16
$6A_2$	4	Cs-137	0.09	0.09
$6A_{deepcore1}$	5	nd	-	-
$6A_{deepcore2}$	2	nd	-	-
$7A_1$	15	Cs-137	0.10	0.20
$7A_{deepcore1}$	6	nd	-	-
$9A_1$	22	Cs-137	0.19	0.33
		Co-60**	0.04	0.04
$9A_{deepcore1}$	19	Cs-137	0.09	0.14
		Co-60	Nd	-
$10A_1$	21	Cs-137	0.22	0.52
$11A_1$	25	Cs-137	0.17	0.40
		Co-60**	0.48	0.64
$11A_{deepcore1}$	6	Co-137**	0.28	0.43
$11A_{deepcore2}$	33	Cs-137	0.09	0.93
		Co-60**	0.19	0.24
$15(2R)B_1$	19	Cs-137	0.75	2.03
$15(2R)B_{deepcore1}$	5	Cs-137	0.06	0.08

*nd – non-detect
**Radioactivity identified in a limited number of samples, details of survey analyses are provided in Appendix 2-E.

2. Class 1, Group B
   Class 1, Group B, category includes survey units with identified residual radioactivity above IDCGL values. Survey Units 5(1), 5(2), and 8 are considered Class 1, Group B areas. Tables 2-7 and 2-8 summarize survey data for these areas. Survey unit locations are shown on Figure 2-9.

   Survey Units 5(1), 5(2), and 8 represent connecting regions within the Protected Area that encompass the Containment Building, Turbine Building, and adjacent tank storage area to the west. These locations contain subsurface equipment, piping, and structures that currently remain operational and continue to support the spent fuel pool and ongoing decontamination and dismantlement activities. Primary surveys in these areas were limited due to worker safety requirements and plant systems still in use. The characterization of areas beneath buildings was conducted by coring through building structures and concrete foundations to obtain soil samples.

   Survey Units 5(1) and 5 (2)
   The Liquid Radwaste Vaults and Storage Tanks are located in Survey Units 5(1) and 5(2). These survey units are bisected by a remnant of the former Chesapeake and Ohio Railroad spur. The following structures are included in this area:

   - Stack,
   - Condensate storage tank,
   - Demineralized water tank,
   - Waste hold tanks, and
   - Subsurface radwaste processing tanks, equipment, and interconnecting piping.

   Residual radioactivity is present as the result of tank overfilling, piping leaks, and staging of radioactive waste that took place in this area. A narrow band of low topography that was formerly present along the railroad bed once provided a drainage pathway for the accumulation of contaminants in this location. The HSA details radiological events and subsequent soil remediation efforts that took place in this area. Later, rails and ties were removed at the western edge of these survey units. Following removal of contaminated soil and railroad ballast, clean fill was used to return excavated areas to proper grade. Samples taken from Survey Units 5(1) and 5(2) have identified elevated levels of residual radioactivity in surface and subsurface soils. Some of the subsurface samples contain residual radioactivity remaining below the clean fill.

   Survey Unit 8 – Pipe Tunnel
   The Pipe Tunnel is a defined area within the Turbine Building that annexes Containment at the NSSS piping penetration. This area is approximately 186 square meters in size and is the former location of the steam condenser. The soil beneath the condenser and inside the sphere expansion ring is

isolated within a vault structured with concrete walls and flooring. All remaining areas beneath the Pipe Tunnel are open to the environment. This area contains subsurface piping that currently remains in service to support continued operation of the spent fuel pool. Recent testing in 2001 validated the piping integrity of this system. The Pipe Tunnel was maintained as a contaminated area during plant power operations. Seal failures identified in flooring expansion joints and drain line connections have provided transport pathways to the soil immediately below the floor. All Pipe Tunnel floor seals were repaired following condenser removal in 2001. Surveys conducted in this area have identified elevated levels of Co-60, consistent with the primary system contamination events identified in the HSA. Survey results are summarized in Table 2-8.

Survey Unit 8 - Turbine Building
Samples collected in the eastern portion of the Turbine Building did not identify soil radioactivity above environmental background levels. This location was maintained as a radiologically clean area and contained the building heating and cooling unit, uninterruptible power supply (UPS) battery station, and the machine shop. Office space annexed to this region was outside the RCA.

Radioactivity concentrations at IDCGL values were identified in the western portion of the Turbine Building. The residual radioactivity was located in a narrow area adjacent to the west wall. This radioactivity results from the condensate piping leak that occurred in 1984. The depth of residual radioactivity identified in this area is consistent with the findings of the investigation conducted following this event.

Survey Unit 8 - Containment Building
The Containment Building is a steel sphere resting on a concrete base pad that extends approximately 10.5 meters below grade. The northward movement of groundwater through the Industrial Area provides a potential pathway for the migration of mobile contaminants in this area. Four sample locations were selected traversing the sphere at varying elevations to evaluate potential soil and groundwater residual radioactivity beneath the Containment Building. Samples were collected through subsurface steel and concrete to the maximum depth permitted by the soil media. With the exception of tritium, samples did not identify radioactivity above established environmental background levels in this area. Groundwater sampling is discussed in Section 2.4.5.3.

Table 2-7. Summary of Class 1, Group B Survey Unit Findings

Summary Findings for Survey Units 5(1) and 5(2)

Survey	Data Points	Radionuclides*	Mean (pCi/g)	Max. (pCi/g)
$5(1)A_1$	33	Cs-137	3.26	12.74
		Co-60	0.54	0.73
$5(1)A_2$	13	Cs-137	0.45	1.09
		Co-60	nd	-
$5(1)A_3$	7	Cs-137	0.06	0.07
		Co-60	nd	-
$5(1)B_1$	23	Cs-137	1.81	16.59
		Co-60	0.16	0.76
$5(1)_{deepcore1}$	21	Cs-137	0.06	0.09
		Co-60	nd	-
$5(1)_{deepcore2}$	25	Cs-137	1.21	$12.94_{(15\text{-}30\ cm)}$
		Co-60	0.19	0.47
$5(1)_{deepcore3}$	1	nd	-	-
$5(1)_{deepcore4}$	5	Cs-137	0.30	0.79
		Co-60	0.17	0.17
$5(1)_{deepcore5}$	8	Cs-137	2.22	6.41
		Co-60	0.36	0.66
$5(2)A_1$	26	Cs-137	0.28	1.39
		Co-60	0.20	0.42
$5(2)A_2$	7	Cs-137	0.04	0.04
$5(2)B_1$	6	Cs-137	2.29	5.25
		Co-60	0.07	0.09
$5(2)_{deepcore1}$	16	Cs-137	1.15	2.73
		Co-60	nd	-
$5(2)_{deepcore2}$	12	Cs-137	0.79	2.72
		Co-60	0.31	0.98
$5(2)_{deepcore3}$	19	Cs-137	2.87	30.70
		Co-60	1.96	7.50
$5(2)_{deepcore4}$	19	Cs-137	0.25	0.67
		Co-60	0.54	1.45
$5(2)_{deepcore5}$	3	Cs-137	nd	-
		Co-60	nd	-

*nd – non-detect

Table 2-8. Summary Of Findings For Survey Unit 8

Survey	Data Points	Radionuclides*	Mean (pCi/g)	Max. (pCi/g)
Turbine Bldg. $A_{Deepcore\ 1}$	14	nd	-	-
Pipe Tunnel $A_{Deepcore\ 2}$	33	Cs-137	1.27	12.60
		Co-60	4.84	105.90[D]
		Mn-54**	1.77	8.68
Turbine Bldg. $A_{Deepcore\ 3}$	58	Cs-137	1.22	5.29
		Co-60	0.15	0.17
Sphere $A_{Deepcore\ 4}$	9	H-3	Liquid Only See Table 2-11	-

*nd - non-detect
**Mn-54 identified in 6 samples only; decayed to ~81 pCi/g as of October, 2002

2.4.5.2 Radiological Status of Surface Water

Surface water flows northward and is directed by stormwater convey areas on both the east and west sides of the Industrial Area. Surface water enters Lake Michigan at the west drainage ditch and at the plant Discharge Canal in the Impacted Area of the BRP site.

a. Drainage Ditch
The Drainage Ditch is located just west of the Protected Area (see Figure 2-10). It is a seasonal stream approximately a meter wide that extends approximately 370 meters from the northern boundary of the Non-Impacted Area. Surface waters from wetland elevations to the south accumulate in low areas along the railroad grade and flow north into the Industrial Area. Runoff is diverted around the Protected Area to the Drainage Ditch and discharges directly into Lake Michigan at the east boundary of Survey Unit 14. The Drainage Ditch also receives water from a series of catch basins and corrugated metal piping that act to remove stormwater away from buildings and parking lots in the Industrial Area.

Routine sampling has not identified radioactivity in the liquid effluents of storm water piping or Drainage Ditch water. A primary survey has been conducted of the Drainage Ditch Area. Trace levels of residual radioactivity have been identified in the sediment of stormwater piping in the Protected Area and in Drainage Ditch soils near where the storm pipe discharges to the ditch. Further information detailing survey design and sample point analysis is provided in Appendix 2-E. Table 2-9 summarizes survey data for the Drainage Ditch.

Table 2-9. Summary of Drainage Ditch Survey Unit Findings

Survey	Data Points	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$Stream_1$	19	Cs-137	0.13	0.32
		Co-60*	0.11	0.17

*Co-60 detected in 2 samples only

b. Discharge Canal
The plant Discharge Canal enters Lake Michigan north of the Owner-Controlled Area and extends from the Screenhouse to the normal beach contour line. This area is approximately 600 m^2 in size and includes the submerged area from the Discharge Canal bottom to the water's edge. Normal water depths in the Discharge Canal range from 1.2 to 2.4 meters (4 to 7 feet); however, current near-record lows in Lake Michigan water levels have greatly reduced this depth. Figure 2-11 indicates the Discharge Canal location.

The Discharge Canal bottom consists of a layer of dense cobble resting on a base of hard clay. The cobble is estimated to be between 15 and 90 cm thick. Variations in surface water depth and movement have resulted in minor locations of sediment build-up in backwater eddies and areas of low flow. Structures and equipment in this area include the following:

- Liquid batch release pipe located next to the Screenhouse weir at the point of effluent discharge,
- Stormwater discharge piping approximately ten meters north of the Screenhouse,
- Liquid process monitor intake piping that traverses the Discharge Canal approximately eight meters from the Screenhouse, and
- The concrete floor and foundation footings of the Screenhouse.

The Discharge Canal is the licensed release pathway for liquid effluents. Environmental monitoring of effluents, surface waters and sediment is performed in accordance with site procedures. Radioactivity originating from licensed liquid release is present in this area. Characterization surveys have identified elevated levels of radioactivity concentrated in areas of sediment located below the water's surface. Table 2-10 summarizes survey data for the Discharge Canal.

Additional information detailing survey design and sample point analyses is provided in Appendix 2-E.

Table 2-10. Summary of Discharge Canal Survey Unit Findings

Survey	Data Points	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$CanalA_1$	18	Cs-137	0.61	1.90
		Co-60	0.38	2.68
		Mn-54*	0.12	0.23
$CanalA_2$	17	Cs-137	1.39	3.31
		Co-60	2.87	17.74
		Mn-54	0.32	1.04

*Mn-54 detected in 3 samples only.

2.4.5.3 Radiological Status of Groundwater

a. Historical Investigation

As part of decommissioning studies, a scoping survey was performed in 1994 that included the installation of nine groundwater monitoring wells. Well installations were screened between 6.5 and 8 meters (20 and 25 feet) below grade and placed at locations selected to encompass all areas with the potential for groundwater contamination. Well water sampling is performed in accordance with the BRP REMP and applicable procedures. Monitoring well analyses have provided baseline information on waterborne radioactivity levels (undetectable for all radionuclides but tritium) and tritium migration.

Investigations conducted in 1999 involved a series of 28 additional test borings around the Industrial Area. This investigation was conducted to identify areas of subsurface soil residual radioactivity and provide additional geological information. Test boring sites were selected to bound locations in the Industrial Area with the potential to contain subsurface soil radioactivity. Additional data point locations were selected in observed contaminant migration pathways. The test borings were performed by continuous sampling using the split-spoon, hollow-stem auger method. Boring depths in many cases approached 16.4 meters (50 feet) below grade or until soil media refusal. The test borings did not penetrate the bedrock aquifer and were carefully sealed and grouted upon completion to prevent introducing a mechanism for vertical transport. Samples from the test borings analyzed for radioactivity and soil properties were evaluated and documented during this study.

b. Survey Design

In 2001 a hydrogeologic study was initiated for the BRP site. This project was conducted to satisfy the following objectives:

1. Identify, define, and document existing geologic and hydrogeologic conditions in the Industrial Area,
2. Review and evaluate historical hydrogeological data,
3. Determine the direction and rate of groundwater flow (vertical and horizontal) in the Industrial Area,

4. Assess the potential for groundwater migration between aquifer zones,
5. Collect samples of soil and groundwater representative of varying conditions in all defined geologic strata,
6. Identify radioactivity concentrations in subsurface soil and groundwater, .
7. Acquire the information necessary to identify radioactivity trends and contaminant migration pathways, and
8. Establish the information necessary for development of the site conceptual model, including engineering properties of soil and groundwater within the Industrial Area.

A sample collection plan was developed to establish drilling methods, sampling technique, and data point locations for piezometer test wells. Locations representative of hydrogeological conditions within the Industrial Area were chosen based on regional knowledge, historical documentation, and the techniques required for gradient measurements. Big Rock Radiation Protection personnel then reviewed these regions and well sites were selected to span locations of the Industrial Area with the potential to contain radioactivity. Input to the well site selection process included the following:

- Historical Site Assessment event data,
- Environmental scoping surveys,
- Radioactivity identified in monitoring well analyses, and
- Observed contaminant migration pathways.

Samples were collected by hollow-stem, split-spoon auger. Shallow groundwater elevations were cased and grouted in place, , to prevent seepage communication between geological strata. Drilling was then continued by advancing the auger through the casing for the investigation of lower elevations. This process resulted in the successfully installation of 13 test wells screened in three groundwater zones. Sample point locations are provided in Figure 2-4.

Additional groundwater samples for this study were collected beneath the Containment Building structure in Survey Unit 8. Data point locations were selected to bisect the building at four sites perpendicular to groundwater flow. Samples were collected by coring through the steel Containment Building shell and concrete base pad at elevations between 185 and 189 meters (565 and 575 feet) msl. Sample point locations are provided in Appendix 2-E, Survey Unit 8.

The results of the hydrogeological assessment provided the following information:

- Two shallow water bearing zones were identified above the potable aquifer,
- Flow direction of all groundwater is northward into Lake Michigan,

- The intermediate water-bearing zone is under artesian conditions. Vertical groundwater flow is directed upward above the intermediate zone in all areas south of the Turbine Building,
- Downward gradients exist in shallow water bearing zones north of containment,
- Building foundations present a barrier to shallow groundwater flow, and
- Shallow water bearing zones do not have sufficient depth and yield for potable water usage.

c. Radiological Status

Well water samples were analyzed for gamma emitting radionuclides and the presence of tritium. Samples both with and without elevated tritium concentrations were further investigated by independent laboratory analysis for other HTD radionuclides with the potential to originate from plant activities. All water samples were collected and sent for analysis without preservation; sample preservation was performed at the vendor laboratory facilities as required by accepted industry methods. Vendor laboratories contracted for BRP radionuclide measurements are in accordance with HASL-300[References 2-16, 2-24, and 2-21]. Test well results for radionuclides of potential plant origin are provided in Table 2-11.

Sample analyses identified tritium as the only radionuclide present in groundwater at BRP. Sampling events detailing variations in tritium concentrations over time are provided in Tables 2-12a, 2-12b, 2-12c, and corresponding figures.

Tritium concentrations were found in all three groundwater zones north of the Turbine Building in a narrow corridor less than 100 meters wide. This corridor extends approximately 140 meters to the site boundary at Lake Michigan. The location of highest tritium concentrations is along the foundation centerlines of the Turbine and Containment Buildings. Tritium concentrations decrease at test well locations north of the Containment Building when compared with shallow well analyses south of Containment, validating a transport pathway in the direction of groundwater flow as discussed below.

Separate tritium plume maps for the shallow, intermediate and bedrock groundwater zones are provided in Figures 2-13, 2-14, and 2-15, respectively. These plume maps are based on the measured activities in groundwater samples collected from wells screened on the respective zones; wells used for constructing the maps are indicated on each figure. The measured groundwater activity values used to construct the plume location maps for the three zones are indicated on these figures. For purposes of plume map construction, the plume boundary for each zone coincides with the location of the 1000 pCi/l tritium concentration isopleth. The general horizontal

groundwater flow direction in each zone is also indicated on each map. While the horizontal groundwater flow direction in the bedrock aquifer has been shown to be northerly, the exact azimuthal direction of flow in this unit has not been determined (see LTP Section 2.4.3.6).

The source of groundwater contamination originated from the condensate leak beneath the Turbine Building that occurred in 1984 (see Section 2.2.5.3). Shallow groundwater below the Turbine Building is held in place above a dense layer of thick clay and the deep foundation walls of this building provide a mechanism for confinement. Characterization efforts have identified a sub-floor vault below the Turbine Building that was constructed to support the weight of the steam turbine and generator. This sub-floor vault is constructed of concrete (1m thick) and is filled with sand; it is an integral part of the building foundation that forms a sealed enclosure of approximately 360 m^3. It is postulated the 1984 condensate leak temporarily raised the water table in the area below the Turbine Building and forced contaminated water around piping penetrations into the sub-floor vault. The sub-floor vault area has held the condensate water in place and has intermittently released small amounts into the environment as a result of localized fluctuations in water table conditions.

The 1984 condensate system leak encompassed an area in which the majority of other soil contaminants have been found, and therefore, provides a tracking indicator for the water migration pathway that other radionuclides would follow. Because radionuclides other than tritium would move at different rates, HTD analyses have not focused on a single position within the groundwater plume. Instead, analyses have been performed directly beneath the building foundations (SC-1, SC-2, SC-3, and SC-5 locations), in intermediate groundwater zone (PZ-5S), and at a more distant location north of the Industrial Area fence near the shoreline in Survey Unit 12 (PZ-3Ma and PZ-3D) (see Figure 2-4 and Table 2-11). In addition, gamma and HTD analyses for the most soluble radionuclides potentially present at BRP (C-14, Sr-90, Tc-99, and I-129) were performed at seven well locations that did not show detectable tritium. An evaluation of most soluble HTD radionuclides was chosen to provide the best indication possible for the migration of radionuclides from soil.

No HTD groundwater or soil analyses (Tables 2-11 and 2-14, respectively) identify the presence of any HTD radionuclide other than tritium. In all, 16 groundwater samples were analyzed for C-14, Sr-90, and I-129: seven samples in combination with the larger list of HTD radionuclides (including transuranics) from the tritium plume area, and nine samples with only these nuclides of highest solubility (two within the plume in monitoring wells MW-5 and MW-6, and the remainder at well locations outside the plume area). Tritium concentrations (Table 2-11) in all monitoring well locations have been reduced to levels below the EPA drinking water standard of 20,000 pCi/l. Details of the tritium remediation process are provided in LTP Section 4.2.2.2.

Table 2-11. Groundwater Monitoring Results of Investigation for Hard-to-Detect Radionuclides

Well Identification Code	PZ-1S pCi/l	PZ-2S pCi/l	PZ-3S pCi/l	PZ-4S pCi/l	PZ-5S pCi/l	PZ-6S pCi/l	PZ-1M pCi/l	PZ-2M pCi/l	PZ-3Ma pCi/l	PZ-3Mb pCi/l
Sample Date	3/13/02	3/13/02	3/12/02	3/12/02	10/16/02	3/13/02	10/16/02	10/16/02	10/16/02	10/16/02
BRP Gamma Analysis	< MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA
Independent Laboratory										
H-3	< 177*	< 177*	< 177*	< 177*	2650	< 177*	< 177*	< 177*	2060	808
Mn-54					< 3.54				< 3.13	
Co-60					< 3.51				< 3.72	
Zn-65					< 6.98				< 7.49	
Ag-110m					< 3.5				< 3.08	
Cs-137					< 3.02				< 2.9	
Cs-134					< 3.4				< 3.57	
Eu-152					< 9.05				< 8.66	
Eu-154					< 9.9				< 8.7	
Eu-155					< 9.94				< 10	
Am-241										
Hard to detect										
C-14	< 5.8	< 5.8	< 5.8	< 5.8	<46.5	< 5.8			<47	
Fe-55					< 140				<132	
Ni-59					< 46.3				<92.6	
Ni-63					< 170				<146	
Sr-90	< 0.5	< 0.5	< 0.5	< 0.5	<0.67	< 0.6			<0.67	
Tc-99	< 1.9	< 2	< 1.9	< 2.4	<6.14	< 2.1			<7.58	
I-129	< 0.6	< 0.6	< 0.6	< 0.5	<2.09	< 0.6			<6.68	
Am-241					<0.22				<0.43	
Cm-243/244					<0.22				<0.18	
Pu-238					<0.22				<0.20	
Pu-239/240					<0.38				<0.35	
Pu-241					<12.4				<13.7	

Blank entries indicate no analysis performed
* Sample collection date 10/16/02

Table 2-11. Groundwater Monitoring Results of Investigation for Hard-to-Detect Radionuclides (continued)

Well Identification Code	MW-1 pCi/l	MW-2 pCi/l	MW-3 pCi/l	MW-4 pCi/l	MW-5 pCi/l	MW-6 pCi/l	MW-7 pCi/l	MW-8 pCi/l	MW-9 pCi/l
Sample Date	4/17/02	4/17/02	4/17/02	4/17/02	4/17/02	4/17/02	4/17/02	10/29/97	4/17/02
BRP Gamma	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA
Independent Laboratory									
H-3	< 141	< 141	< 164	< 164	2860	5150	< 164	< 706	357
Mn-54	<4.4	<3.64	<3.19	<1.62	<1.52	<3.02	<3.15		<1.10
Co-60	<3.36	<3.01	<2.71	<1.93	<3.81	<3.51	<3.94		<2.38
Zn-65	<2.56	<4.14	<4.87	<4.19	<3.75	<2.78	<3.89		<4.14
Ag-110m									
Cs-137	<4.01	<3.73	<2.08	<1.93	<2.94	<3.30	<4.23		<1.40
Cs-134	<3.01	<3.49	<4.00	<2.65	<3.43	<4.10	<4.85		<1.77
Eu-152									
Eu-154									
Eu-155									
Am-241									
Hard to detect									
C-14					< 5.8*	< 5.8*			
Fe-55									
Ni-59									
Ni-63									
Sr-90					< 0. 5*	< 0.7*			
Tc-99					< 2.3*	< 1.9*			
I-129					< 0.6*	< 0.6*			
Am-241									
Cm-243/244									
Pu-238									
Pu-239/240									
Pu-241									

Blank entries indicate no analysis performed
* Sample collection date 3/13/02

Table 2-11. Groundwater Monitoring Results of Investigation for Hard-to-Detect Radionuclides (continued)

Well Identification Code	PZ-1D pCi/l	PZ-2D pCi/l	PZ-3D pCi/l	Sphere 1 pCi/l	Sphere 2 pCi/l	Sphere 3 pCi/l	Sphere 5 pCi/L
Sample Date	3/13/02	3/13/02	6/3/02				
BRP Gamma	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA	<MDA
Independent Laboratory							
H-3	< 177	< 177	1560	12692	3290	32000	23725
Mn-54			< 1.8	< 1.1	< 1.9	< 4.8	< 2.1
Co-60			< 2.1	< 1.6	< 2.2	< 3.9	< 2.9
Zn-65			< 6.7	< 3.9	< 5.1	< 5.3	< 7.2
Ag-110m			< 2.5	< 1.8	< 3	< 3.5	< 3.2
Cs-137			< 4	< 1.5	< 2.8	< 2.7	< 1.6
Cs-134			< 3.4	< 2.1	< 3.6	< 4.7	< 3.7
Eu-152			< 11	< 5.2	< 10	< 12	< 12
Eu-154			< 10	< 3.2	< 8.2	< 8.4	< 7.9
Eu-155			< 13.4	< 9.1	< 15	< 21	< 12
Am-241			<48	<9.9	< 11	< 21.2	< 18
Hard to detect							
C-14	< 5.8	<5.8	< 5.9	< 7.5	< 8.9	< 5.8	< 7
Fe-55			< 27	< 103	< 99	< 106	< 108
Ni-59			< 185	< 96	< 123	< 203	< 184
Ni-63			< 18	< 11.8	< 15.1	< 19.4	< 17.6
Sr-90	< 0.6	< 0.5	< 0.5	< 0.4	< 0.5	< 0.4	< 0.4
Tc-99	< 4.3	< 4.3	< 3	< 3	< 3.4	< 3.8	< 3.5
I-129	< 0.6	< 0.5	< 0.7	< 0.6	< 0.6	< 0.6	< 0.7
Am-241			< 0.4	< 0.5	< 0.8	< 0.1	< 0.6
Cm-243/244			< 0.3	< 0.2	< 0.2	< 0.1	< 0.3
Pu-238			< 0.06	< 0.1	< 0.1	< 0.2	< 0.1
Pu-239/240			< 0.03	< 0.1	< 0.1	< 0.2	< 0.1
Pu-241			< 12	< 67	< 29	<96	< 42

< indicates less than MDA value
Blank entries indicate no analysis performed
* Sample collection date 10/16/02
^ Tritium analysis on 1/8/02 of 3,290 pCi/l used for dose calculation (see Chapter 6)
^^Tritium analysis on 10/16/02 of 32,000 pCi/l used for dose calculation (see Chapter 6)

Table 2-12a. Tritium Monitoring Well Historical Data (in pCi/l) (Well Installed in 1994)

Date Sampled	MW #1	MW #2	MW #3	MW #4	MW #5	MW #6	MW #7	MW #8	MW #9
08/24/94	<1250	<1250	<1250	<1250	11,300	40,600	<1250	<1250	<1250
09/07/94	<504	<504	<503	<503	10,500	27,000	<502	<503	<522
04/26/96					23,800	46,900			
07/30/96	<721				23,200	16,000	<721	<721	536
10/17/96	<804	<804		<804	22,600	22,300	<804	<804	<804
04/30/97	<149	<149	<149		22,700	36,800	<149	<149	<149
10/29/97	<706	<706			14,400	24,700	<706	<706	<706
04/22/98	<602	<602	<602		13,900	9,100	<602		<602
10/27/98	<524	<524		<524	15,800	23,100	<524		628
03/14/99	<523	<523		<523	10,500	13,900	<523		<523
07/14/99	184	<150		<150	10,100	2,730	<150		598
10/22/99	<183	<183	<183	<183	16,500	1,900	<183		510
04/29/00	<175	<157	<157	<157	17,392	5,276	<157		430
10/12/00		<156	<156	<156			<156		
10/25/00	191				26,000	5,057			
03/23/01					9,600	5,160			
04/20/01	170	<186		<186	8,820	5,280	<186		
10/11/01	<168	<168	<168	<168	9,160	2,420	<168		422
03/13/02					3,860	1,747			
04/17/02	<141	<141	<164	<164	2,860	5,150	<164		357
10/10/02	<150	<150	<146	<146	4,910	4,320	<146		<150
04/23/03	188	<133	<133	<133	3,490	2,960	<133		269
10/09/03		<169	<169	<169	4,870	5,080	<169		349
12/03/03						2,326			341
05/12/04	<157	<154			4,081	1,362	<154		324

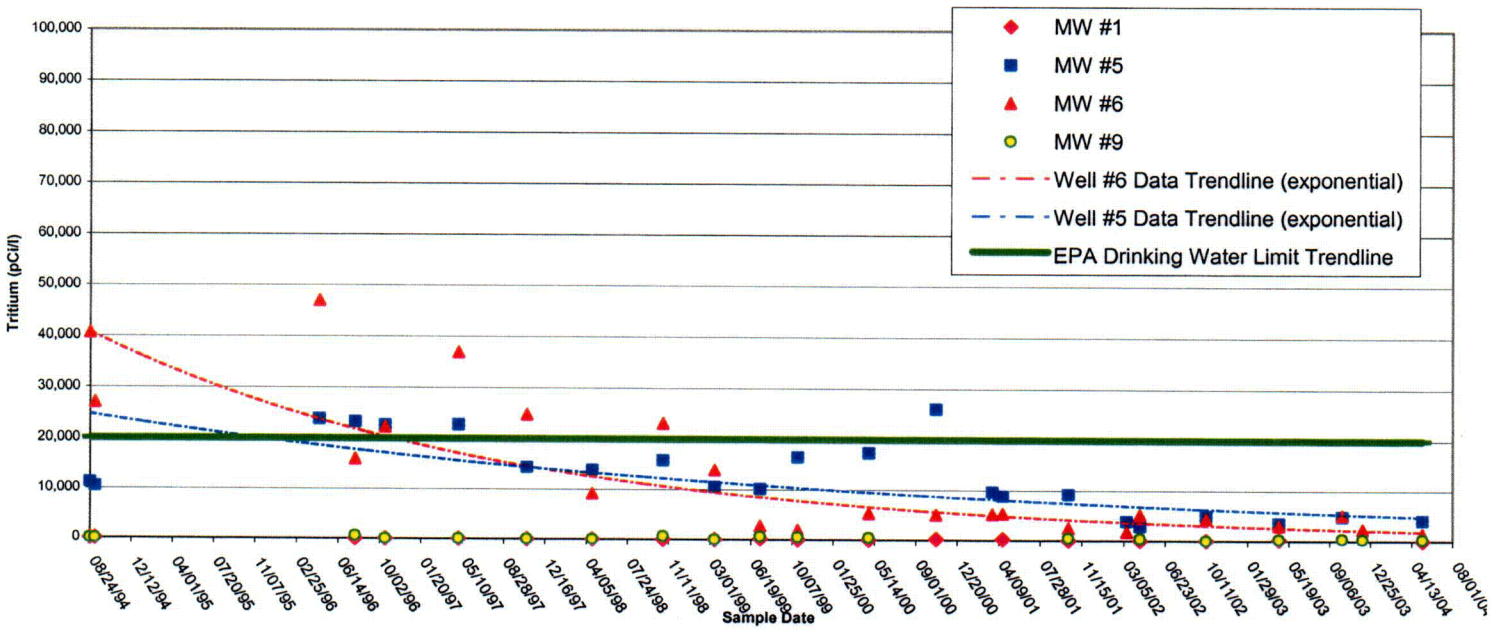


Table 2-12b. Tritium Monitoring Well Historical Data (Wells Installed in Post-Shutdown)

Date Sampled	PZ-1D	PZ-1M	PZ-1S	PZ-2D	PZ-2M	PZ-2S	PZ-3D	PZ-3Ma	PZ-3Mb	PZ-3S	PZ-4S	PZ-5S	PZ-6S
01/28/02				<126			290						
02/05/02	<96												
03/13/02	<96		<96	<96		<96	1,423			<96	<96	957	<96
05/06/02		<97			<97			2,105	595				
06/03/02							1,560						
10/15/02	<177	<177	<177	<177	<177	<177	768	2,060	808	<177	<177	2,650	<177
04/24/03	<163		<163	<163	<163	<163	798	3,165	383	<163	<163	1,069	<163
11/05/03	<174		<174	<174	<174		919	3,342	380			737	<174
12/03/03							942	3,183	361			315	
05/12/04					<154		373	2,667	279		<154	892	

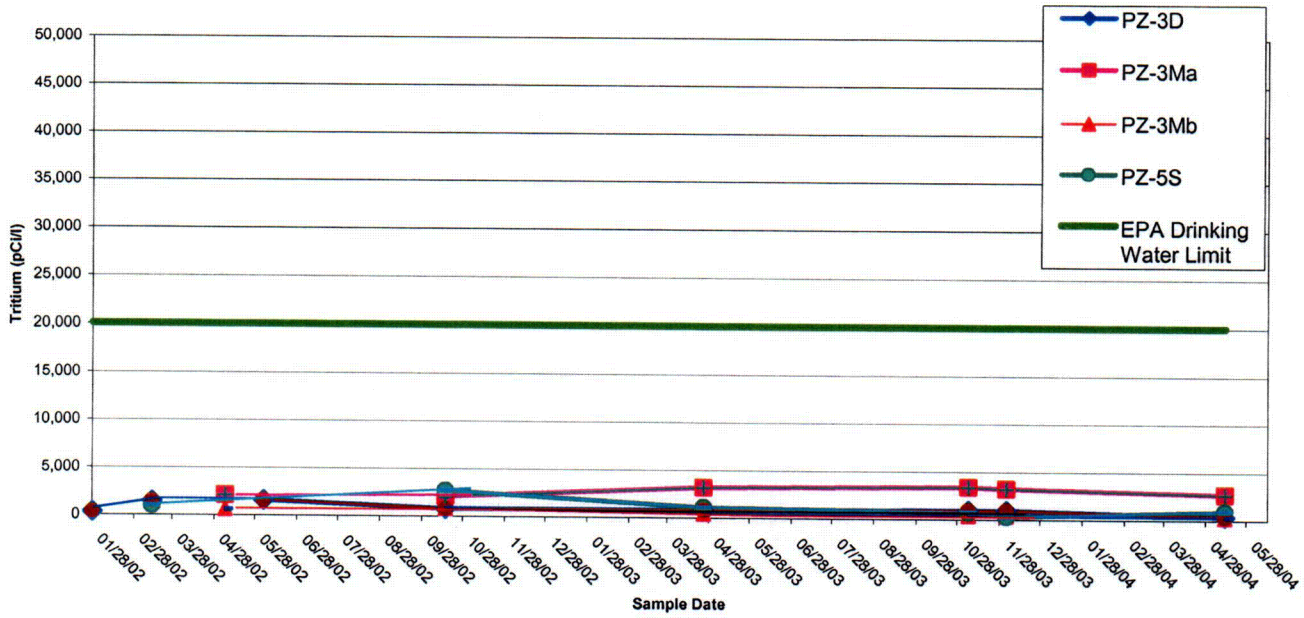


Table 2-12c. Tritium Monitoring Well Historical Data (Samples Beneath Containment Building)

Date Sampled	SC-1	SC-2	SC-3	SC-5
12/14/01			32,000	
12/17/01				20,400
01/08/02		3,290		
01/10/02	5,420			
03/21/02	12,692	2,653		
03/25/02			22,473	23,725
04/01/04				22,669
04/29/04			15,290	
04/30/04				19,307

^ Tritium analysis on 1/8/02 of 3,290 pCi/l used for dose calculation (see Chapter 6)
^^Tritium analysis on 10/16/02 of 32,000 pCi/l used for dose calculation (see Chapter 6)

2.4.5.4 Radionuclide Fractions for Surrogate Measurement of HTD Contaminants in Soil

An investigation was conducted for the identification of all radionuclides potentially present in BRP soils and groundwater. This study resulted in development of the 24 radionuclide suite presented in Table 2-13 below. Further details of this evaluation are provided in Chapter 6, Section 6.4.1.

Table 2–13. Radionuclides Potentially Present in BRP Soil

H-3*	Ni-63	Cs-134	Pu-239
C-14	Zn-65	Cs-137	Pu-240
Mn-54	Sr-90	Eu-152	Pu-241
Fe-55	Tc-99	Eu-154	Am-241
Ni-59	Ag-110m	Eu-155	Cm-243
Co-60	I-129	Pu-238	Cm-244

*Radioactivity measurements were performed on dry samples; H^3 analyses of soil samples were not conducted in this study.

This suite of potential BRP radionuclides was the basis used for the analyses of characterization soil samples to define the actual radionuclides present in BRP soils and develop nuclide ratio's for the surrogate measurement of HTD contaminants. Areas representative of the highest activity set of survey units were used for this study. These survey units were represented by 389 soil samples encompassing an area of 6,500 m^2 (Figure 2-12). All survey data from these areas were evaluated with no samples excluded. Selected soil samples from the most highly contaminated areas in this data set were selected for further evaluation in order to provide the most probable identification of HTD nuclides. This selection resulted in the independent laboratory analysis of 21 soil samples for the presence of the radionuclides defined in Table 2-13. These samples included surface samples, deep core samples, and activity profiles to depths up to 1.8 m.

Vendor laboratories contracted for BRP radionuclide measurements are HASL-300 compliant. Radionuclide analyses were conducted by accepted industry methods to the lowest MDA values achievable by standard commercial laboratory. Laboratory results are provided in Table 2-14. Samples from each site area having significant soil contamination are represented. Grid designations and soil sample depths are indicated in the table. The only HTD radionuclides (including transuranic radionuclides) detected were Fe-55 and Sr-90.

The ratio of Fe-55 to Co-60 for the single sample that identified the presence of Fe-55 is 0.47. Use of MDA values for all samples of the study with Co-60 concentration greater than 2.5 pCi/g (five samples) gives a surrogate ratio of 3.07. The higher of the surrogate ratios (3.07), derived using MDAs and the one actual value, has been conservatively chosen for use. Since Fe-55 is not a significant contributor to dose (DCGL = 358,000 pCi/g), the surrogate ratio would not give a dose equivalent to that of Co-60 unless it approached a level equal to the ratio of DCGLs, or 111,500 pCi/g. Thus, the dose from Fe-55 is insignificant (less than 0.01% to dose calculated for Co-60 alone), even at this higher surrogate ratio.

The ratio of Sr-90 to Cs-137 for the two samples showing the presence of Sr-90 is 0.20. Use of MDA values for all samples in the surrogate study with Cs-137 concentration greater than 2.5 pCi/g (ten samples) gives a surrogate ratio of 0.012. The more conservative value of 0.020, as originally calculated, has been retained for use.

It is notable that all samples showing positive HTD results are samples with significant surrogate concentrations. No samples with less than 2.5 pCi/g Co-60 (16 samples) have shown positive indications of Fe-55, and no samples with less than 2.5 pCi/g Cs-137 (11 samples) have shown positive indication of Sr-90. This suggests that the surrogate radionuclides have not separated to any significant degree from the relevant HTD companion, and since the samples represent all contaminated site areas, that the derived ratios are suitable for site-wide use.

2.4.6 Radionuclide Migration

Groundwater tritium is the only radionuclide at Big Rock Point with significant potential for offsite migration. The tritium plume, originating from approximately 20,000 gallons of condensate water that leaked from underground piping in 1984, is discussed in Section 2.2.5 (items c.4 and c.5). Radionuclides other than tritium from that leak have remained fixed in soil within a few meters of the original point of leakage. Only Cs-137 and Co-60 remain detectable in soils of the Industrial Area. Other radionuclides originally present (Mn-54, I-131, and Ag-110m) have decayed to nondetectable levels.

Initial concentration of tritium in condensate water at the time of the leak is estimated to have been approximately 2 mCi/l. Groundwater monitoring wells were installed in 1994 to investigate onsite groundwater radioactivity levels. These monitoring wells, and wells installed later (beginning in 2002) as part of the plant's hydrogeologic study, have shown tritium to be the only radionuclide present in groundwater. Original 1994 monitoring wells MW-5 and MW-6, near the northern fence line, have

shown the historically highest levels of onsite tritium since installation. Levels have decreased significantly over time, as shown in Table 2-12 and corresponding figures. Newer monitoring wells, PZ-3MA, PZ-3MB, and PZ-3D are located slightly north of the site fence, and PZ-5S is just inside the fence. Each of these wells is laterally between wells MW-5 and MW-6. These newer wells show that the maximum concentration is present at 8-10 meters (29-32 feet) depth. Concentrations are running about a factor of three lower in the deep (14.0-15.5 meters/46-51 foot depth) and shallow (2.5-4.0 meters/8-13 foot depth) groundwater strata.

No offsite impact of tritium migration has been observed. Each of the three groundwater strata join Lake Michigan within several hundred feet of shore. Tritium background in Lake Michigan (based on environmental monitoring program background samples at Ludington, Michigan) is below 200 pCi/l. Tritium concentrations higher than background have not been present in Lake Michigan water samples for many years at or near the BRP site (samples include discharge canal, plant intake, ¼ mile east, and ¼ mile west of the site discharge). Thus, the groundwater plume has a negligible effect on lake water concentration.

Any radioactivity remaining after site release, other than the existing low-level plume of tritium, is unlikely to migrate offsite by land and water erosion mechanisms. The relatively flat surface of the site Industrial Area, along with the final site greenfield condition, will ensure that there is minimal erosion from either wind or water sources.

Table 2-14. Soil Sample Analyses for Hard-to-Detect Radionuclides

Grid Location	318	318	318	269	269	250	250	250	266	266
Sample Depth	0–15cm	0–15cm	0–15cm	0–15cm	0–15cm	0–30cm	30-60 cm	60-90 cm	0–15 cm	30-60 cm
Gamma:	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Mn-54	< 0.010	< 0.010	< 0.020	0.110	0.030	1.140	0.236	0.028	< 0.040	< 0.19
Co-60	0.03	0.02	< 0.02	6.43	1.91	80.7	15.6	< 0.1	5.17	0.12
Zn-65	< 0.03	< 0.01	< 0.04	< 0.09	< 0.07	0.33*	< 0.238	< 0.073	< 0.09	< 0.047
Ag-110m	< 0.02	< 0.01	< 0.05	< 0.02	< 0.02	< 0.04	< 0.073	< 0.026	< 0.05	< 0.022
Cs-134	< 0.01	0.01*	< 0.02	< 0.04	< 0.02	< 0.06	< 0.064	< 0.024	< 0.04	< 0.02
Cs-137	3.56	4.01	4.18	0.2	0.26	3.8	0.77	< 0.03	21.7	0.97
Eu-152	< 0.05	< 0.01	< 0.05	< 0.03	< 0.05	< 0.08	< 0.16	< 0.058	< 0.06	< 0.056
Eu-154	< 0.03	< 0.01	< 0.04	< 0.02	< 0.03	< 0.06	< 0.18	< 0.091	< 0.05	< 0.063
Eu-155	< 0.07	< 0.02	< 0.07	< 0.04	< 0.06	< 0.1	< 0.13	< 0.052	< 0.09	< 0.06
Am-241	< 0.08	< 0.02	< 0.07	< 0.05	< 0.07	< 0.22	< 0.416	< 0.031	< 0.14	< 0.058
Non Gamma:	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
C-14	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 1.54	< 1.48	< 0.47	< 1.68
Fe-55	< 51	< 49	< 31	< 48	< 45	38	< 3.66	< 3.75	< 36	< 3.34
Ni-59	< 2	< 1.9	< 2	< 2	< 2.4	< 2.4	< 1.65	< 4.29	< 2.3	< 1.53
Ni-63	< 0.25	< 0.24	< 0.24	< 0.37	< 0.25	< 0.39	< 2.98	< 2.62	< 0.4	< 1.97
Sr-90	< 0.02	< 0.04	< 0.04	< 0.02	< 0.02	0.13	< 0.095	< 0.11	< 0.06	< 0.11
Tc-99	< 0.26	< 0.16	< 0.34	< 0.23	< 0.18	< 0.33	< 1.94	< 2.8	< 0.2	< 2.53
I-129	< 0.26	< 0.24	< 0.25	< 0.24	< 0.28	< 0.24	< 0.28	< 0.26	< 0.25	< 0.33
Pu-238	< 0.02	< 0.01	< 0.01	< 0.02	< 0.01	< 0.01	< 0.17	< 0.15	< 0.02	< 0.154
Pu-239/240	< 0.01	< 0.01	< 0.01	< 0.02	< 0.01	< 0.01	< 0.32	< 0.19	< 0.02	< 0.20
Pu-241	< 8.9	< 9.4	< 7.6	< 8.4	< 7.3	< 7.2	< 5.4	< 6.03	< 8.9	< 7
Cm-243/244	< 0.04	< 0.08	< 0.03	< 0.05	< 0.02	< 0.06	< 0.06	< 0.06	< 0.15	< 0.0189
Am-241	< 0.04	< 0.08	< 0.08	< 0.07	< 0.09	< 0.03	< 0.024	< 0.019	< 0.08	< 0.019

< indicates less than MDA values. *Excluded due to short half-life

Table 2-14. Soil Sample Analyses for Hard-to-Detect Radionuclides (continued)

Grid Location Sample Depth	266 60-90 cm	266 0-15cm	266 0-15cm	266 0-15cm	211 0-15cm	248 0-15cm	248 0-15cm	247 0-15cm	247 0-15cm	228 0-15cm	Canal sediment 0-15cm
Gamma:	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
Mn-54	<0.026	< 0.031	< 0.045	<0.041	<0.010	<0.010	< 0.010	< 0.010	< 0.020	< 0.010	0.203
Co-60	<0.1	< 0.042	< 0.046	<0.034	<0.02	0.56	0.3	0.5	0.58	0.51	8.27
Zn-65	<0.067	< 0.072	< 0.108	<0.084	<0.05	<0.03	< 0.03	< 0.03	< 0.05	< 0.03	< 0.173
Ag-110m	<0.029	< 0.028	< 0.049	<0.033	<0.01	<0.04	< 0.03	< 0.03	< 0.04	< 0.03	< 0.0586
Cs-134	<0.029	< 0.028	< 0.039	<0.029	<0.02	<0.02	< 0.01	< 0.02	< 0.02	< 0.02	< 0.0494
Cs-137	<0.309	< 0.032	0.111	<0.1	<0.01	14.0	10.2	25.7	13.36	8.14	2.19
Eu-152	<0.068	< 0.083	< 0.127	<0.082	<0.03	<0.07	< 0.04	< 0.06	< 0.07	< 0.06	< 0.126
Eu-154	<0.091	< 0.095	< 0.148	<0.107	<0.02	<0.05	< 0.03	< 0.05	< 0.05	< 0.04	< 0.136
Eu-155	<0.092	< 0.100	< 0.116	<0.089	<0.04	<0.08	< 0.07	< 0.1	< 0.11	< 0.08	< 0.0934
Am-241	<0.160	< 0.165	< 0.061	<0.186	<0.07	<0.19	< 0.07	< 0.12	< 0.08	< 0.14	< 0.0518
Non-gamma:	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
C-14	<1.44	< 1.68	< 1.55	<3.81	<0.47	<0.47	< 0.47	< 0.47	< 0.47	< 0.47	< 1.12
Fe-55	<3.24	< 3.78	< 3.77	<3.99	<38	<37	< 35	< 41	< 37	< 31	< 1.70
Ni-59	<2.64	< 2.13	< 4.28	<1.38	<2	<2.8	< 2.1	< 2.4	< 2.5	< 2.4	< 14.2
Ni-63	<2.05	< 2.47	< 2.18	<2.55	<0.25	<0.4	< 0.39	< 0.9	< 0.39	< 0.42	< 3.14
Sr-90	<0.103	< 0.0994	< 0.118	<0.117	<0.3	<0.6	< 0.06	< 0.04	< 0.1	0.04	< 0.592
Tc-99	<2.05	< 1.92	< 2.63	<1.97	<0.14	<0.23	< 0.11	< 0.29	< 0.24	< 0.13	< 3.31
I-129	<0.282	< 0.033	< 0.297	<0.361	<0.23	<0.24	< 0.24	< 0.25	< 0.26	< 0.27	<.0.332
Pu-238	<0.149	< 0.144	< 0.121	<0.125	<0.04	<0.02	< 0.03	< 0.04	< 0.05	< 0.06	< 0.0737
Pu-239/240	<0.366	< 0.187	< 0.25	<0.147	<0.03	<0.03	< 0.03	< 0.04	< 0.05	< 0.04	< 0.165
Pu-241	<0.229	< 5.43	< 6.03	<4.82	<8.6	<8.4	< 6.7	< 5.2	< 7.1	< 9.6	< 0.324
Am-241	<0.020	< 0.051	< 0.023	<0.019	<0.03	<0.04	< 0.13	< 0.2	< 0.07	< 0.29	< 9.65
Cm-243/244	<0.063	< 0.075	< 0.057	<0.061	<0.06	<0.04	< 0.06	< 0.13	< 0.08	< 0.64	< 0.185

< indicates less than MDA values

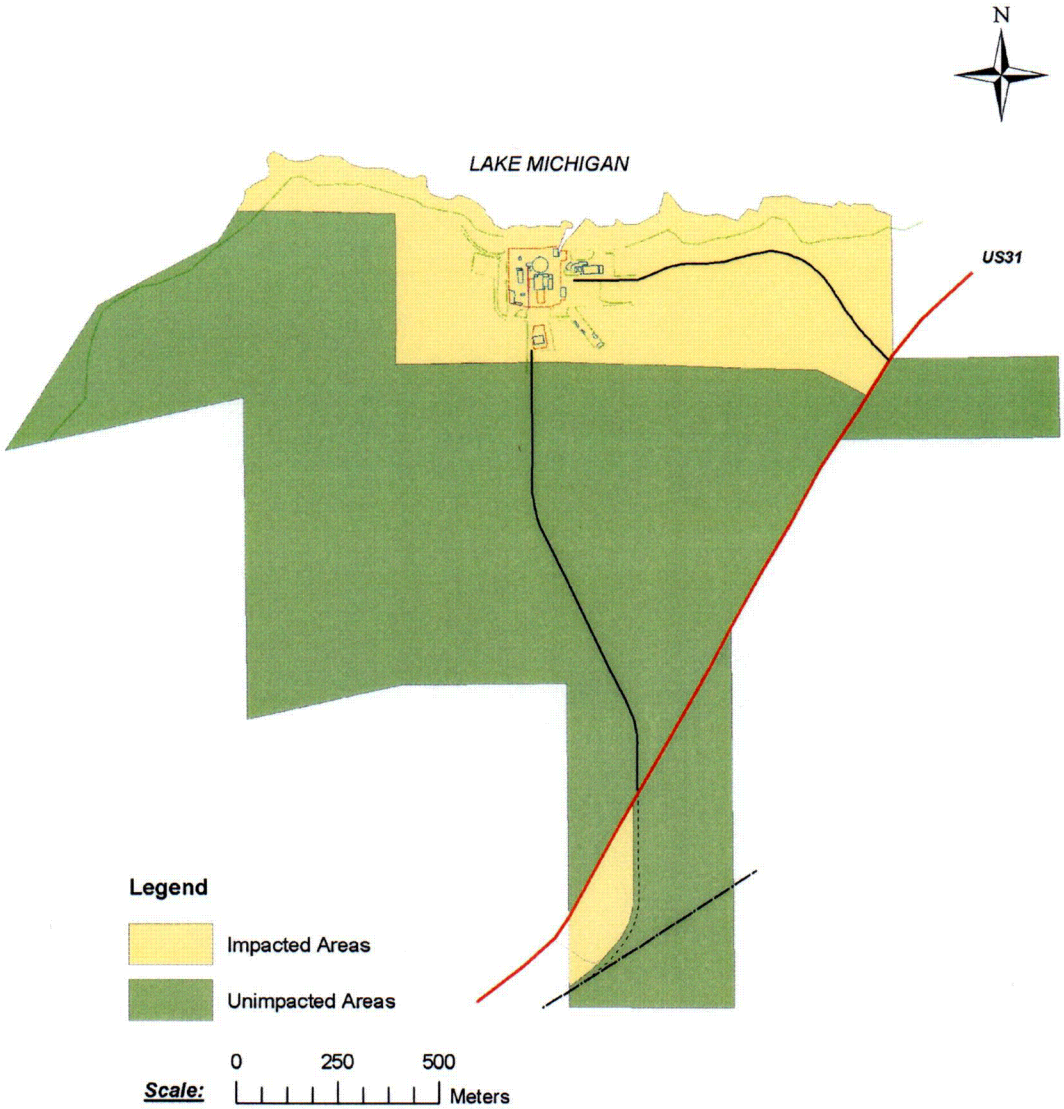
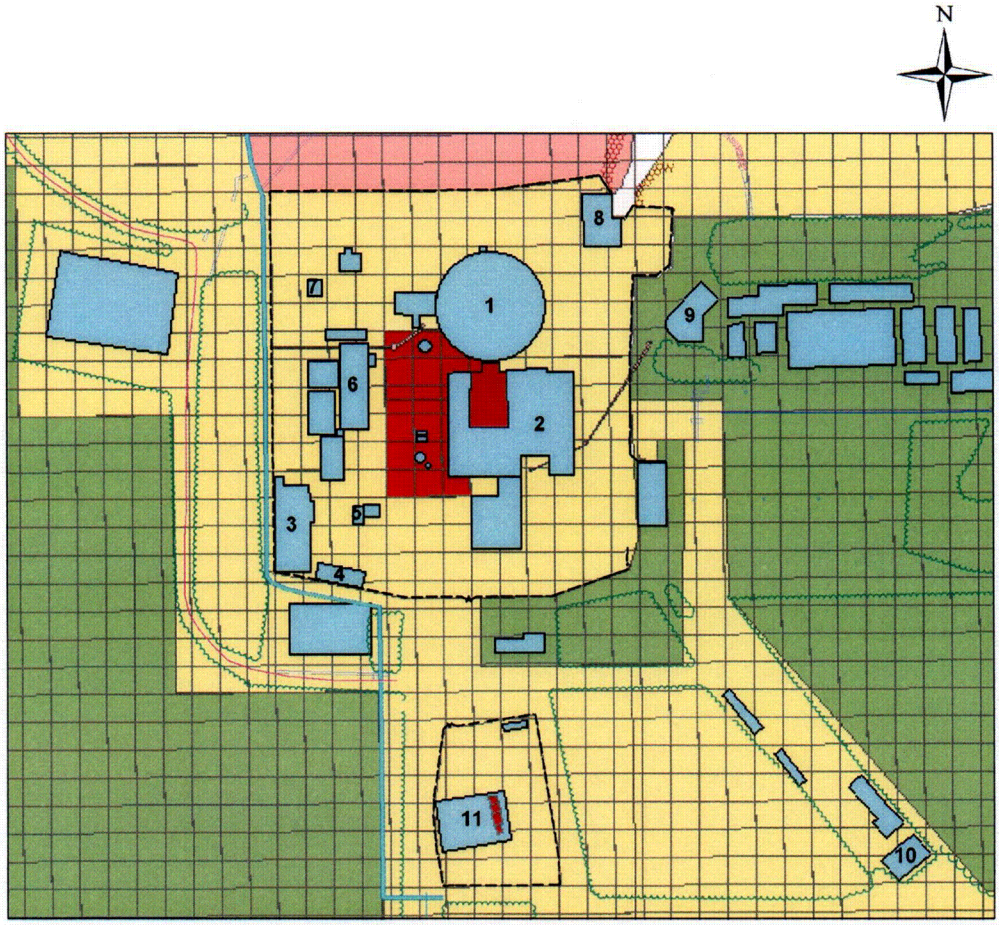


Figure 2-1. Big Rock Point Owner-Controlled Area

C01



Scale: 0 25 50 100 Meters

Legend

UNLIKELY	KNOWN	Buildings and Structures
POTENTIAL	POTENTIALLY ELEVATED	Local Coordinate Grid

1. CONTAINMENT BUILDING (SPHERE)
2. TURBINE/SERVICE BUILDING
3. QA/QC BUILDING (WAREHOUSE)
4. CONTAMINATED WAREHOUSE
5. BUTLER BUILDING (FORMER BALER HOUSE)
6. MAINTENANCE BUILDING (FORMER SITE OF NEWKIRK WAREHOUSE)
7. FORMER SITE OF PLANT INCINERATOR
8. SCREENHOUSE
9. ANNEX BUILDING
10. SWAMP WAREHOUSE
11. RADIOACTIVE WASTE BUILDING

Figure 2-2. Big Rock Point Industrial Area

C02

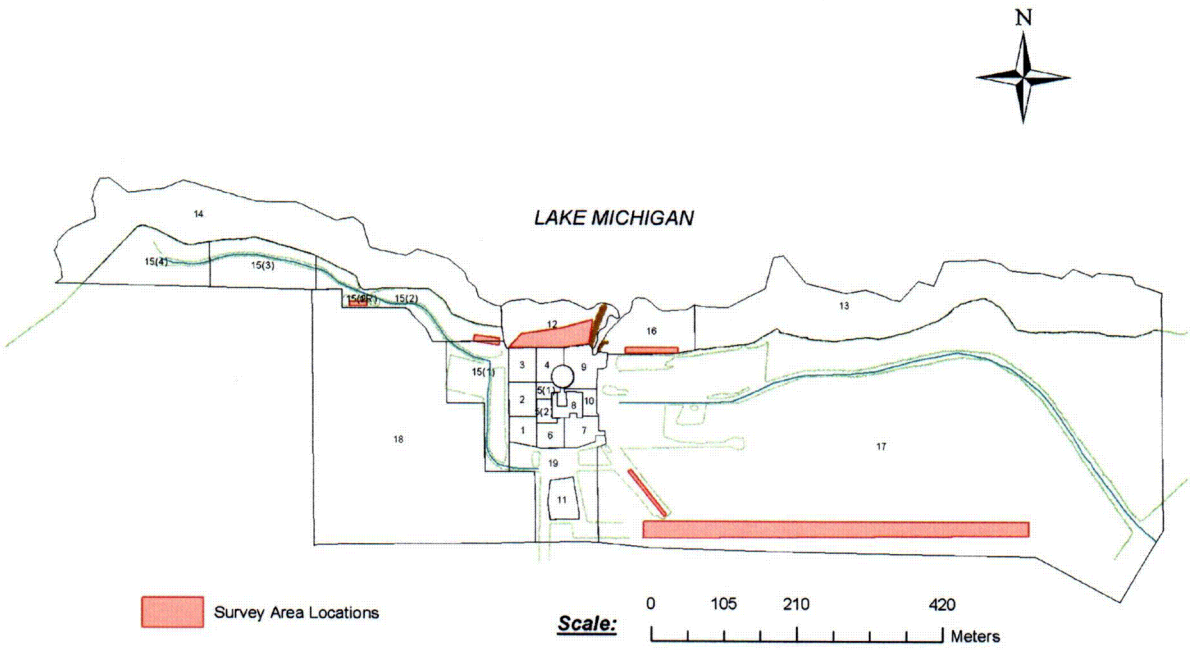


Figure 2-3. Legacy Materials Evaluation Survey Areas

C03

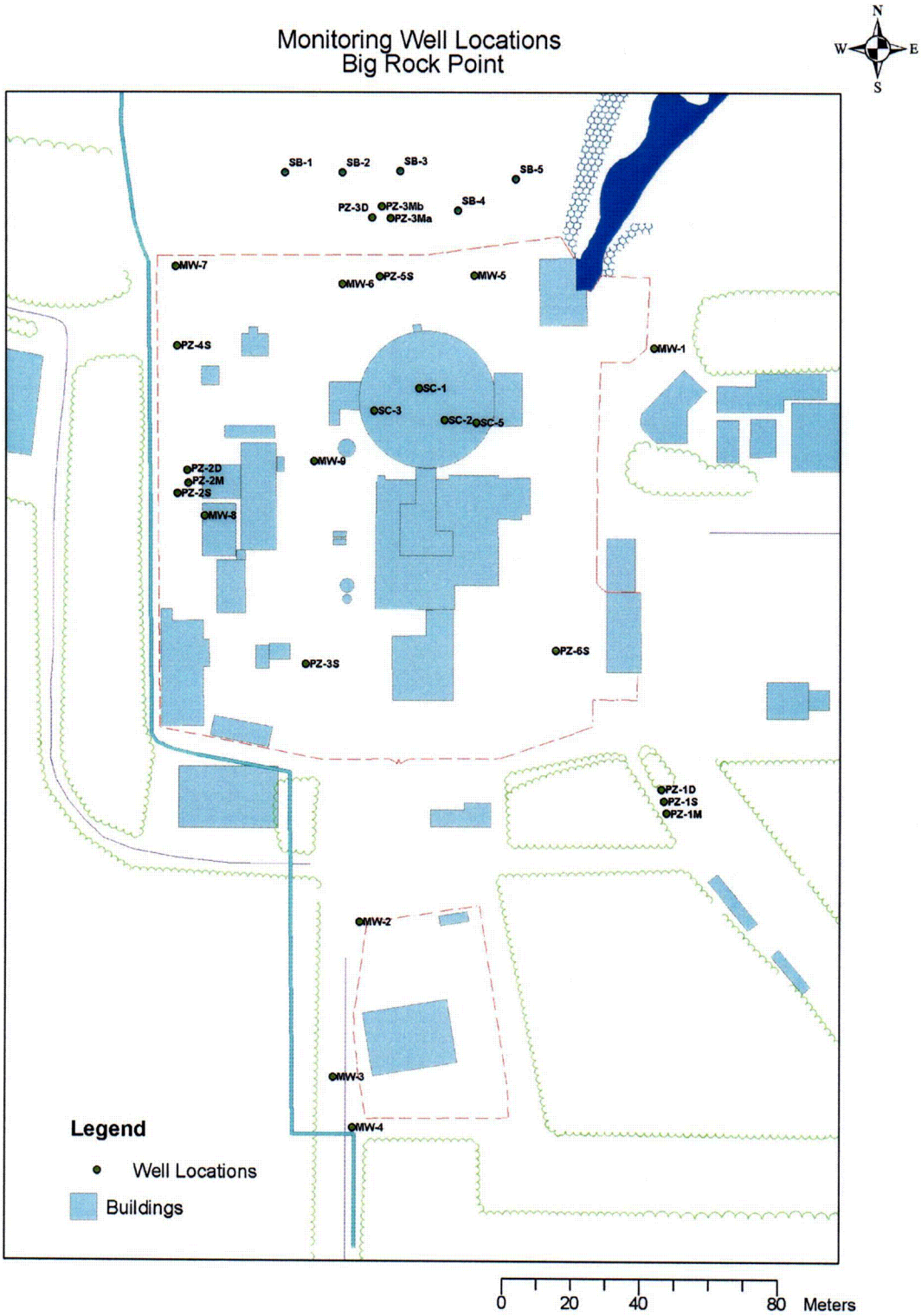
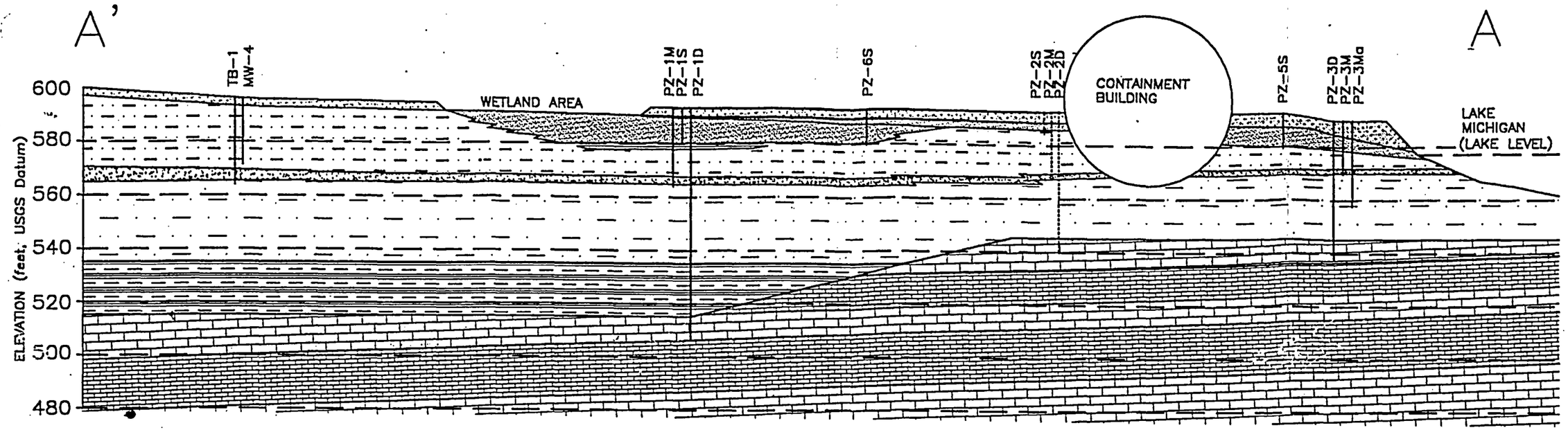


Figure 2-4. Big Rock Point Groundwater Monitoring Wells

C04



UNITS

SAND & GRAVEL FILL (6a)

NATIVE SAND,W/GRAVEL, OCCASIONAL CLAY LAYERS, WET AT BOTTOM (6b)

UNSORTED SAND, CLAY, GRAVEL (5)

SAND,FINE GRAINED, SATURATED (4)

SANDY CLAY W/SAND SEAMS, WET (3)

SILTY CLAY, DRY (2)

LIMESTONE BEDROCK (1)

NOTES:

1. BOUNDARIES BETWEEN GEOLOGICAL UNITS ARE INFERRED BASED ON LIMITED SUBSURFACE DATA.

2. WELLS SHOWN WITH DASHED LINES ARE PROJECTED ONTO VERTICAL PROFILE.

HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 40'

BIG ROCK POINT RESTORATION PROJECT CHARLEVOIX CO., MICHIGAN	**Figure 2-5.** VERTICAL PROFILE A–A'		
OTWELL MAWBY, P.C. Traverse City, Michigan	Date: 07/23/02	Job No.:	Scale: 1"=100'

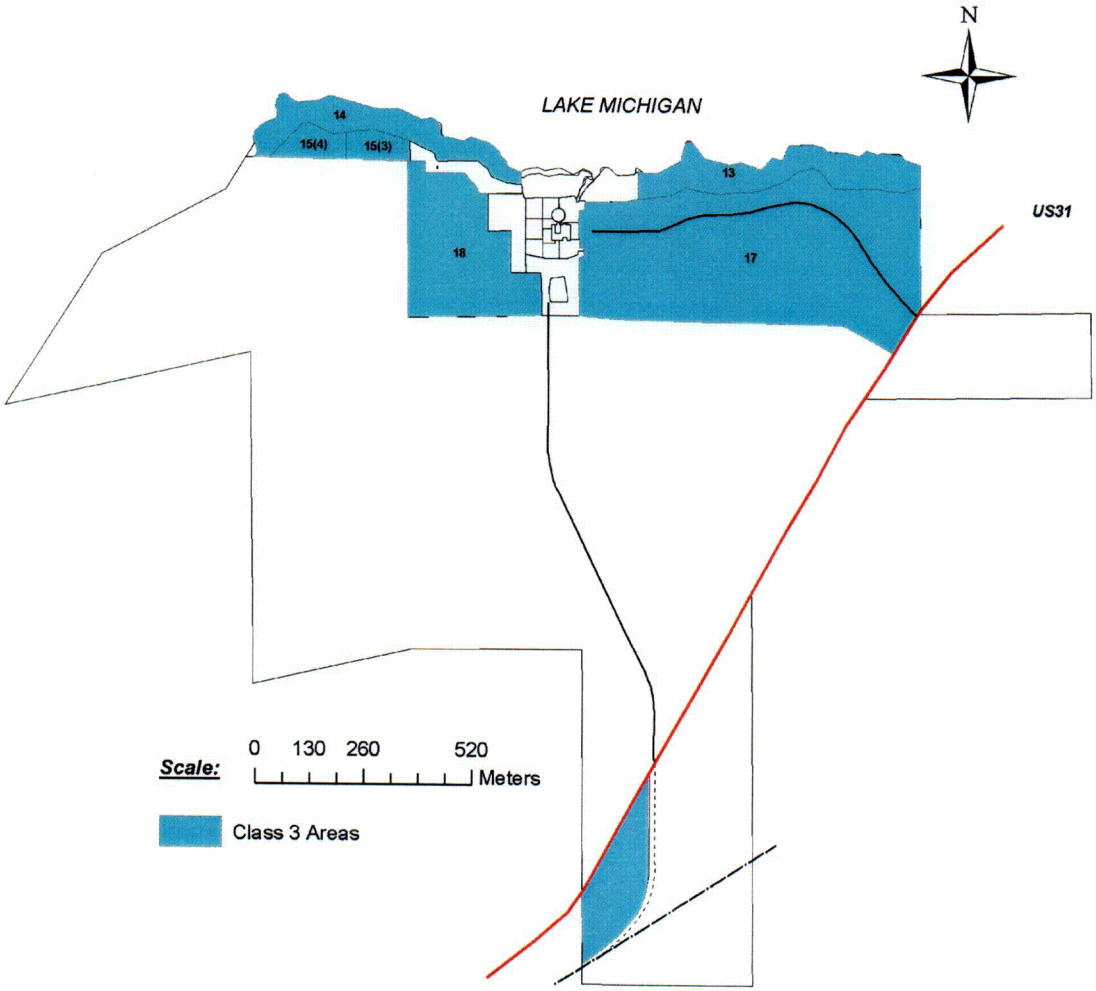


Figure 2-6. Class 3 Survey Units

C05

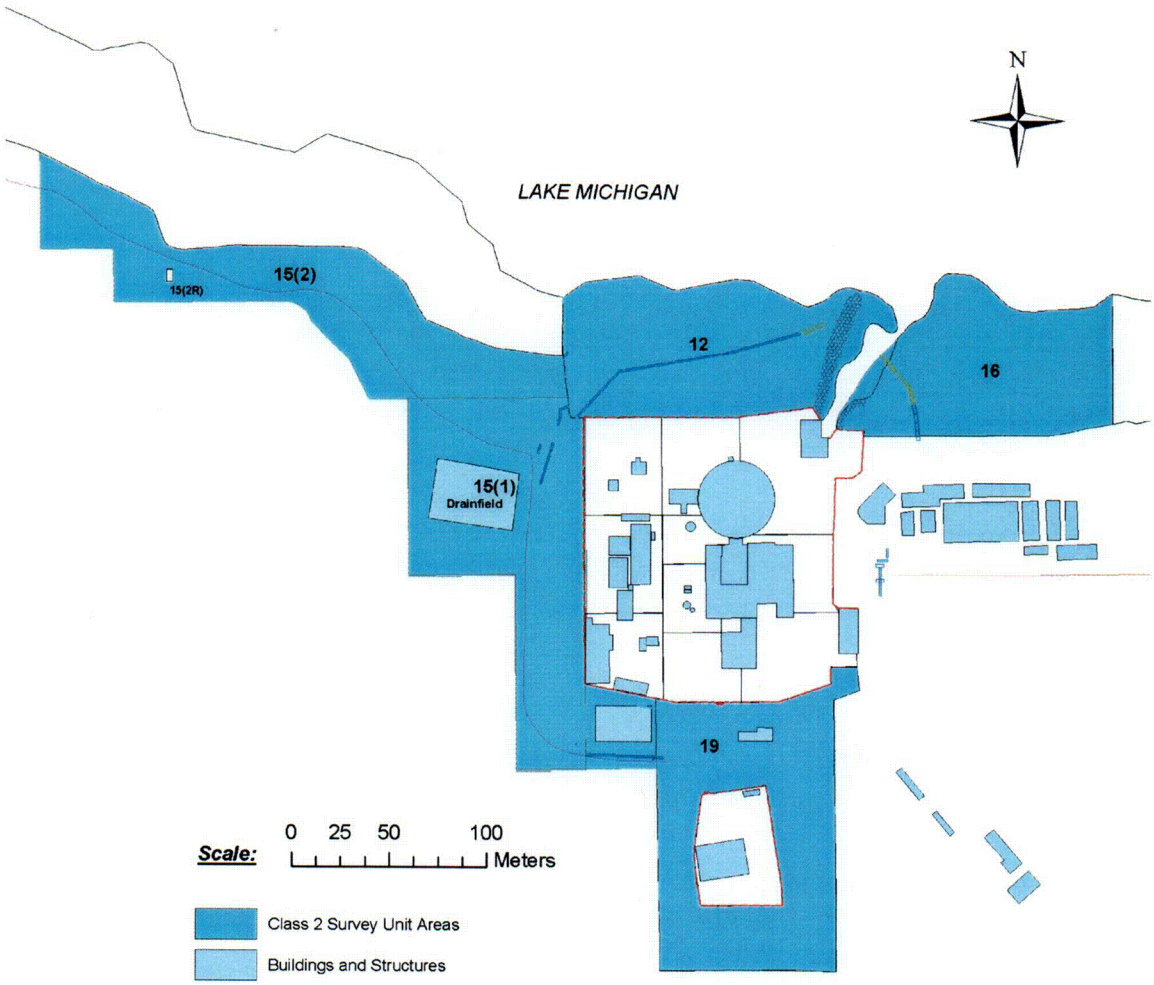


Figure 2-7. Class 2 Survey Units

C06-

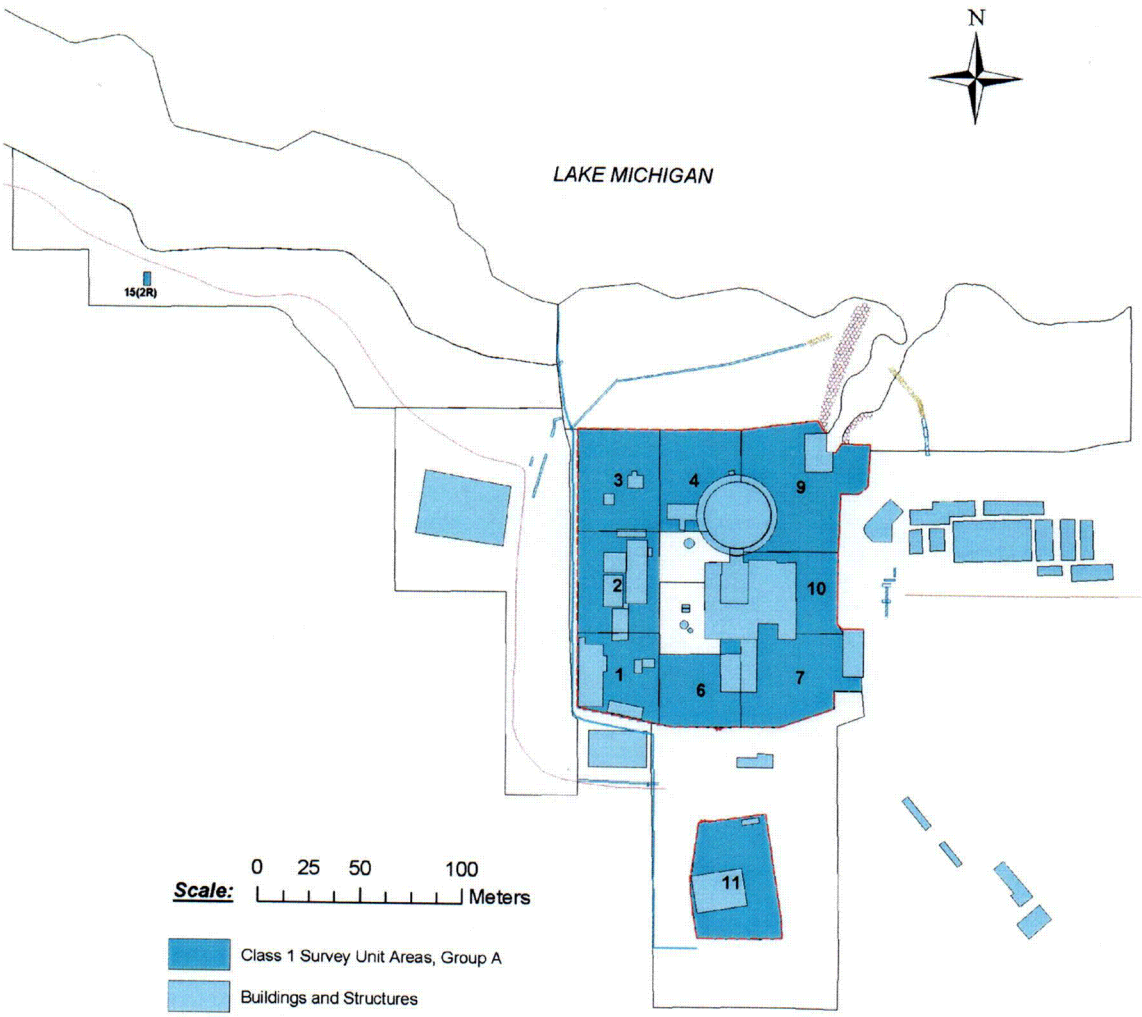


Figure 2-8. Class 1, Group A Survey Units

C07

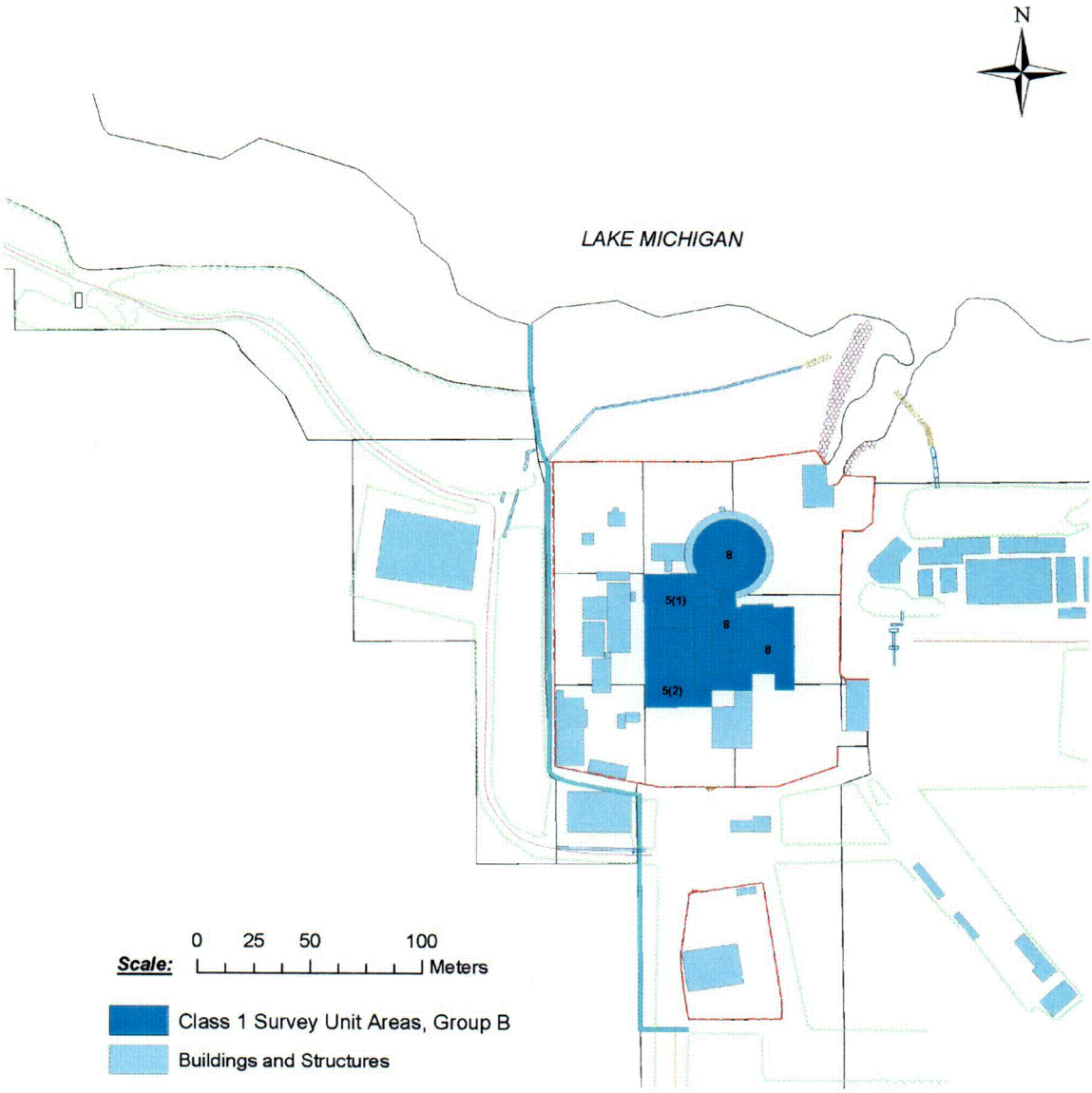
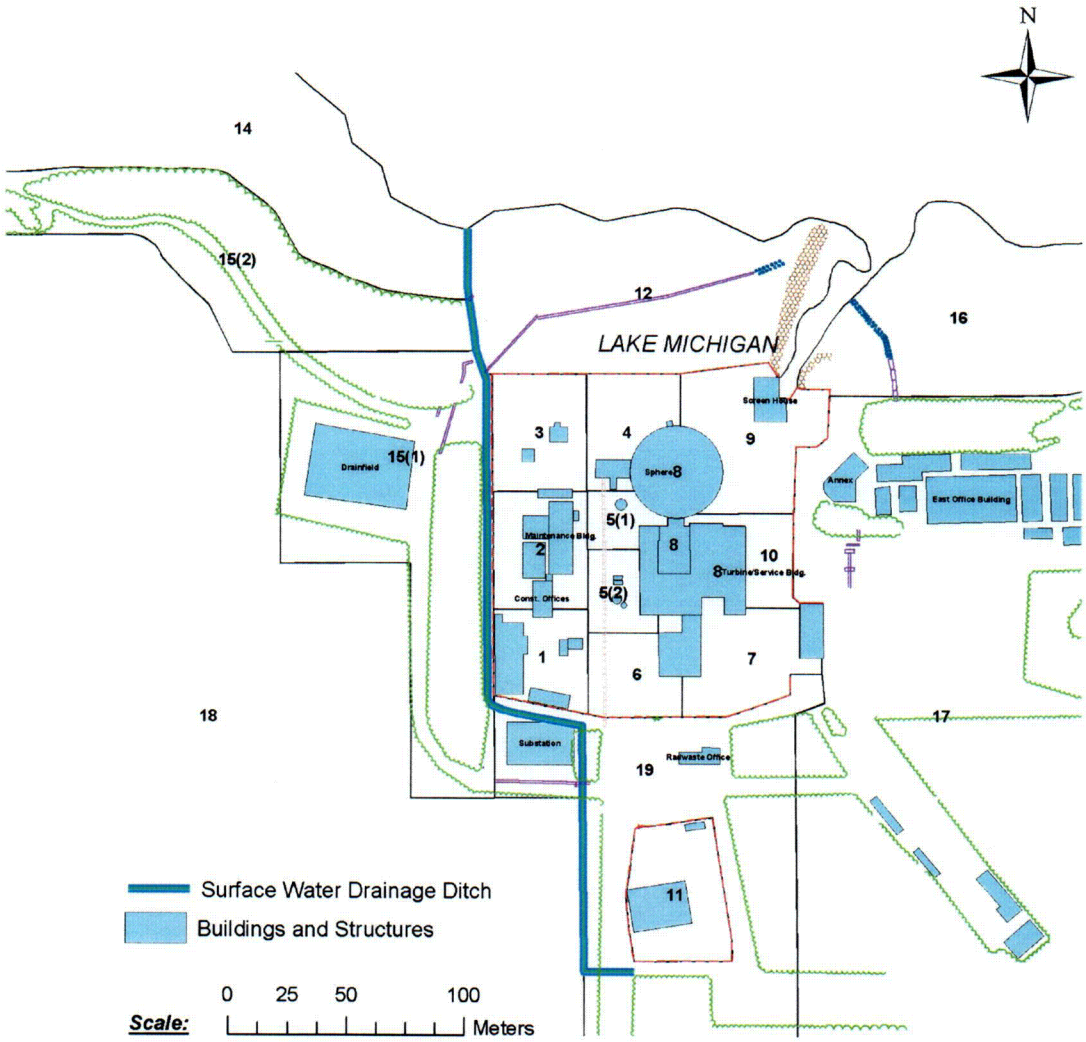


Figure 2-9. Class 1, Group B Survey Units

C08



Note: Survey points were collected in shaded area for surface water drainage ditch.

Figure 2-10. Drainage Ditch Survey Unit

C09

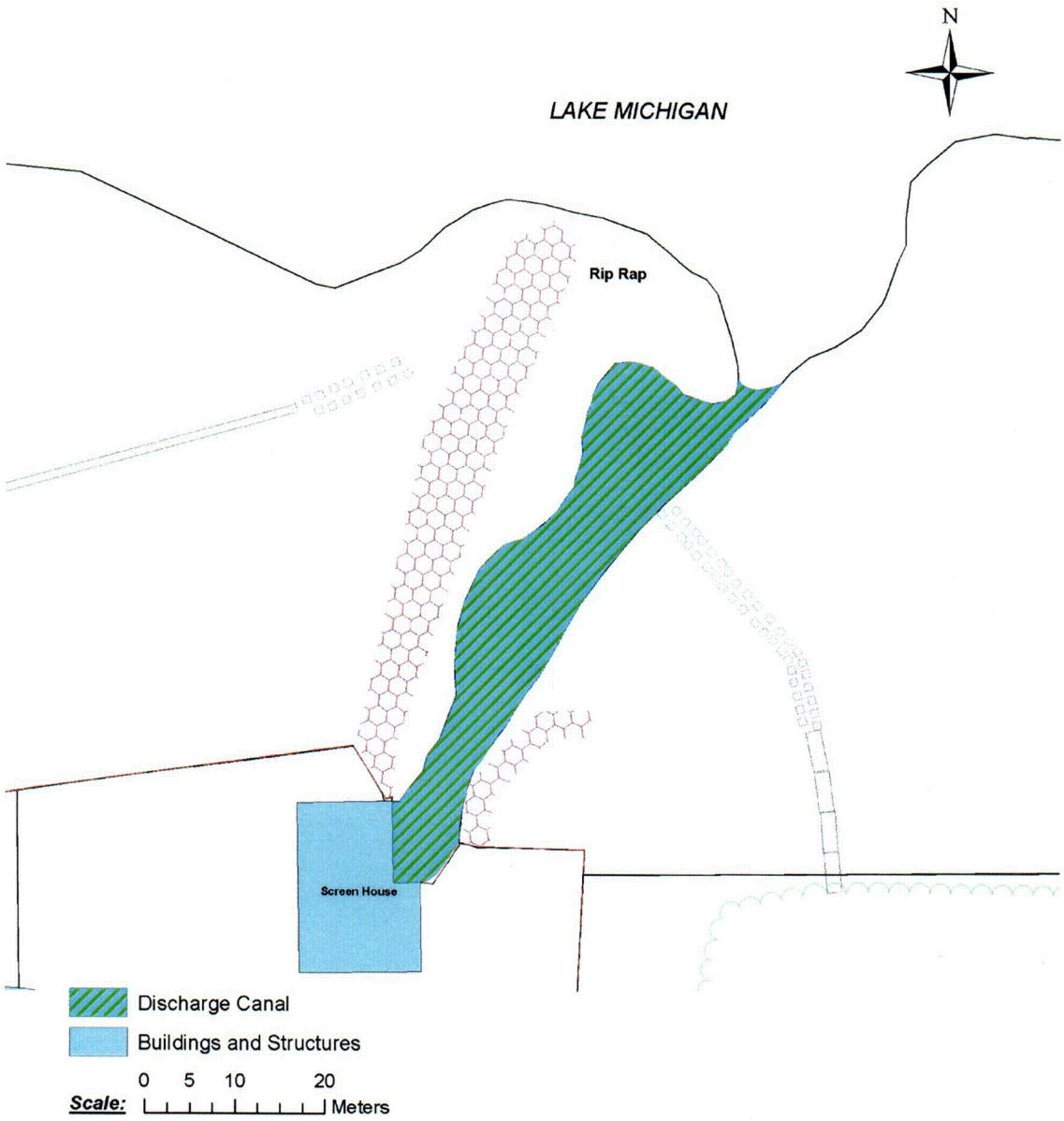


Figure 2-11. Discharge Canal Survey Unit

C10

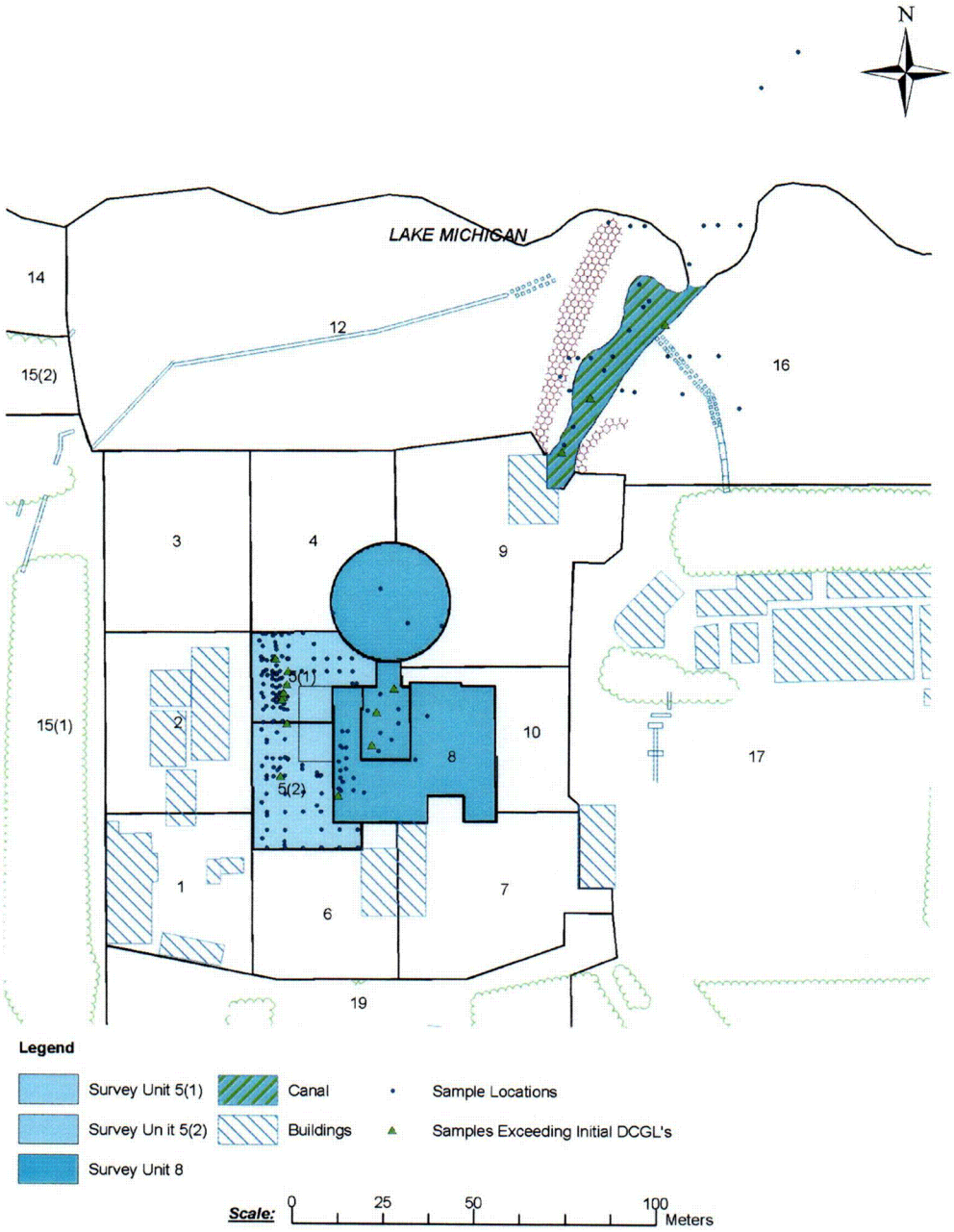


Figure 2-12. Data Point Locations for Determination of Radionuclide Fractions

C11

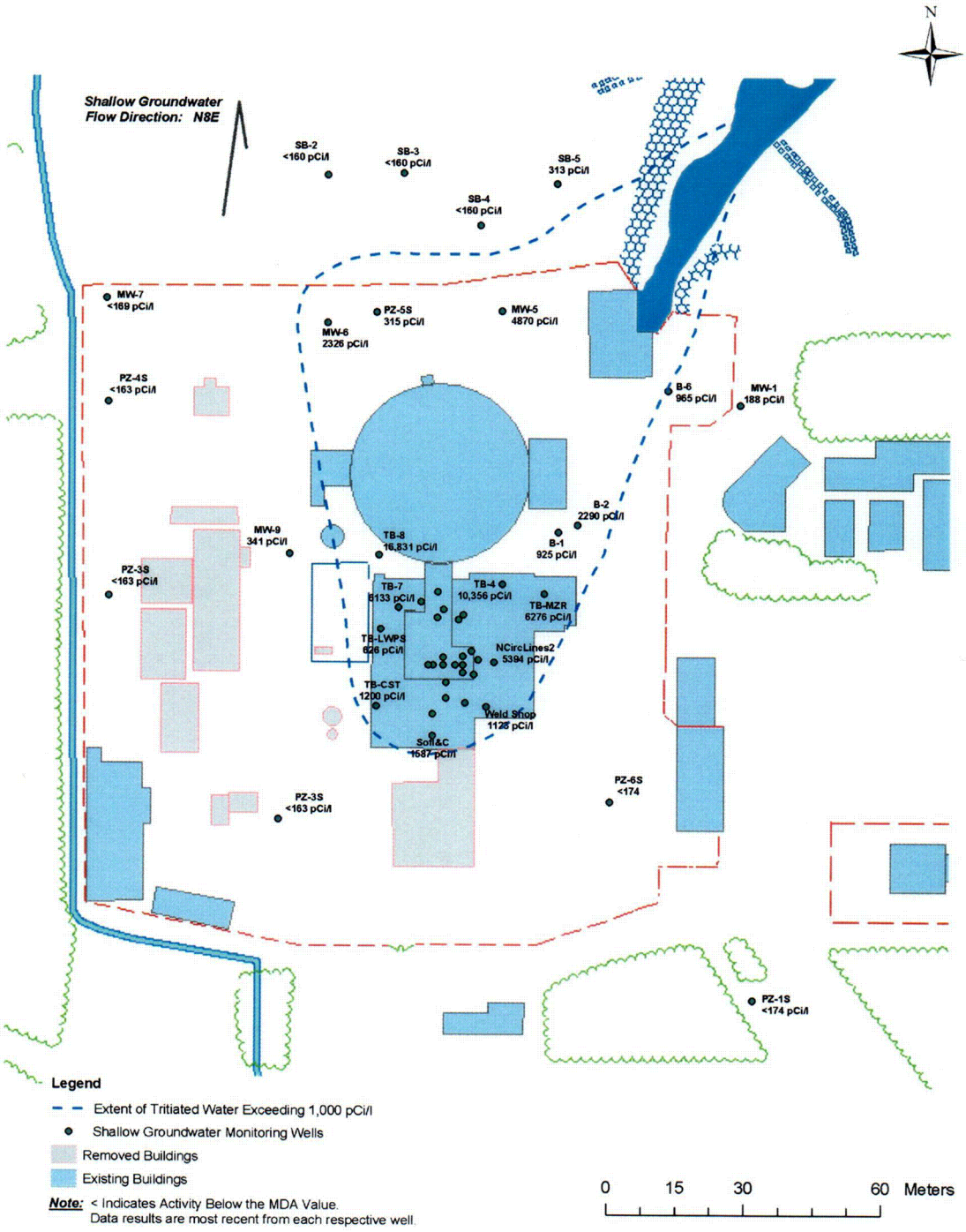


Figure 2-13. Tritium Plume in Shallow Groundwater Zone

C12

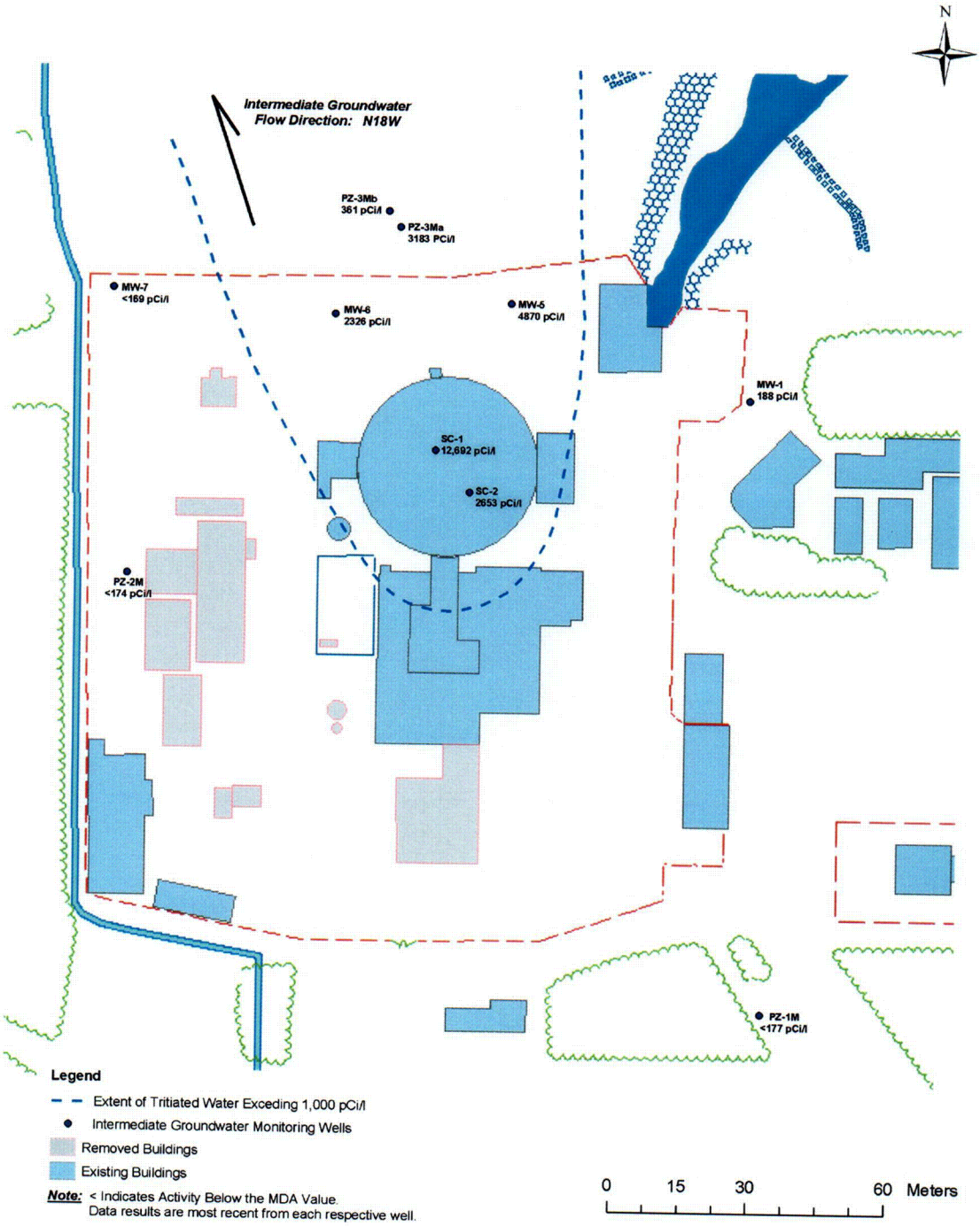


Figure 2-14. Tritium Plume in Intermediate Groundwater Zone

C13

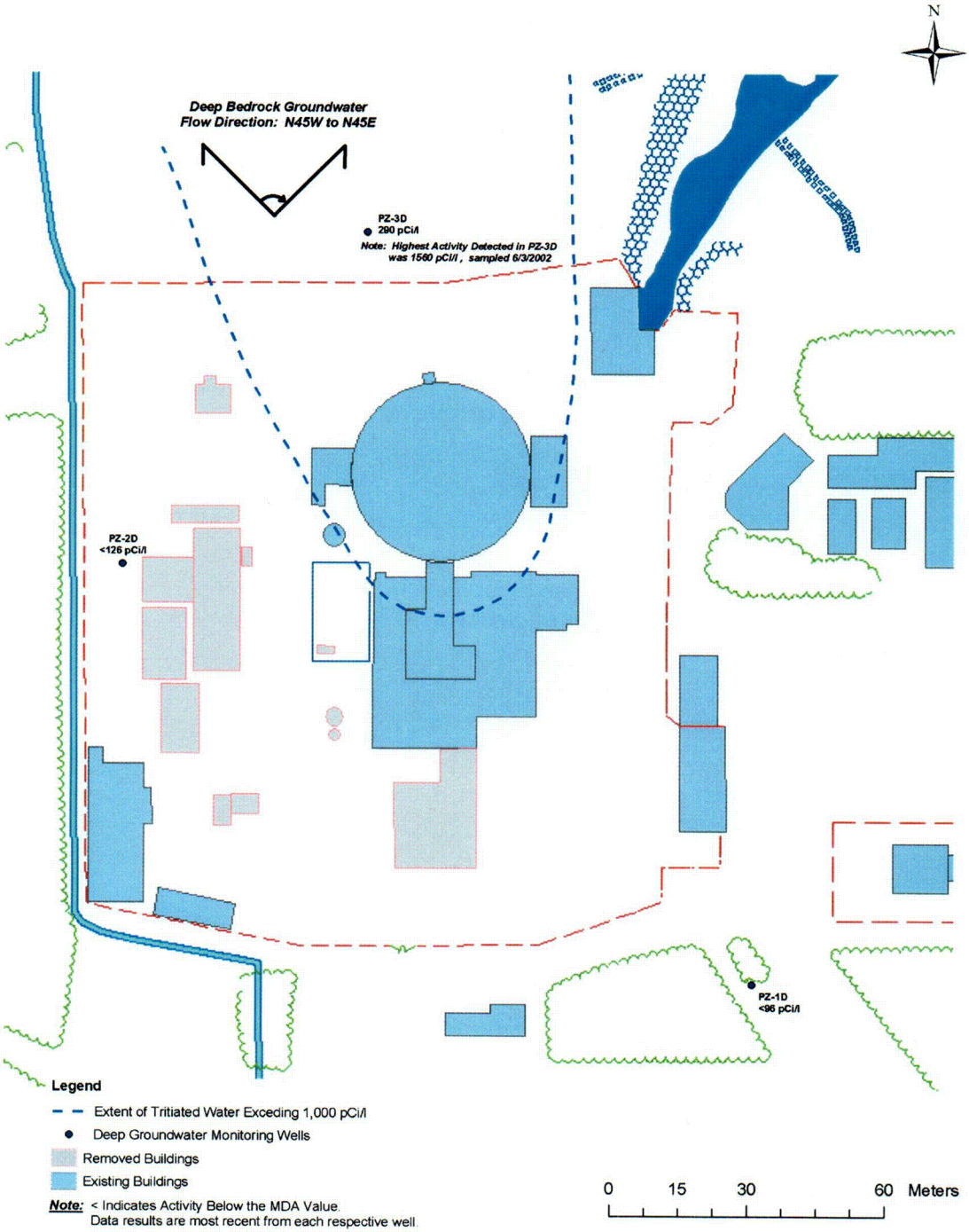


Figure 2-15. Tritium Plume in Bedrock Groundwater Zone

C14

2.5 REFERENCES

2-1 Big Rock Point Decommissioning Plan & Environmental Report, May 1995

2-2 Big Rock Point Engineering Analysis EA-BRP-DW-98-01, *Efficiency Confirmation of the Portable Gamma Spectrometer*, December 1998

2-3 Big Rock Point Engineering Analysis EA-BRP-SC-01-00, *Background Radioactivity in Soil*, June 2000

2-4 Big Rock Point Engineering Analysis EA-BRP-SC-01-01, *Derivation of Scaling Factors for Hard To Detect Nuclides In Soil*, July 2001

2-5 Big Rock Point Engineering Analysis EA-BRP-SC-02-01, *NA-I Scanning Sensitivity for Open Land Survey*, October 2002

2-6 Big Rock Point Historical Site Assessment, 1962-1999, May 2001

2-7 Big Rock Point Historical Site Assessment Supplemental Data

2-8 Big Rock Point Non-Radiological Historical Site Assessment, August 2002

2-9 Big Rock Point Off-Site Dose Calculation Manual

2-10 Big Rock Point Procedure D5.19, *Radiation Detection Instrumentation, Calibration Facility and Source Control*

2-11 Big Rock Point Radiation Protection and Environmental Services On-the-Job Training Manual, Revision 11, September 17, 2002

2-12 Big Rock Point Radiological Site Characterization Survey Plan

2-13 Consumers Energy NDT/Materials Testing Services, Ground Penetrating Radar Geophysical Survey, MAT Project 0000588, Revision 1, June 2001

2-14 Consumers Energy Quality Program Description for Nuclear Power Plants (Part 1) – Big Rock Point

2-15 Currie, Lloyd A., *Limits for Qualitative Detection and Qualitative Determination, Application to Radiochemistry*, Analytical Chemistry, 40:586, 1968

2-16 EML Procedures Manual (HASL-300), 28th Edition, February 1997

2-17 Garmin International, Inc., Olathe, Kansas USA, Garmin eTrex Summit Global Positioning System, User Manual, 190-00193-00, Revision B

2-18 Otwell Mawby, P.C., Consulting Engineers, Hydrogeological Evaluation of the Big Rock Point Restoration Project, November 2002

2-19 Radian International, Inc., 1991, *Big Rock Plant Core Borings Report*, 1991

2-20 RESRAD Calculation of Contamination Levels Equal to 25 mrem/hour at 5 Years Post-Shutdown, RAE/HP97019, August 1997

2-21 Standard Methods for Examination of Water and Wastewater 20th Edition (Table 7010:I)

2-22 Traverse Group, Well Installation and Subsurface Sampling Boring Logs, for Big Rock Point Power Plant, 1994

2-23 U.S. Army Corps of Engineers (USACE), Detroit District, Great Lakes Water Levels for Lake Michigan/Huron: 1918-2003, http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/historicdata/greatlakeshydrographs/

2-24 U.S. Environmental Protection Agency EPA/540-1-89/001, Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual, 1989

2-25 U.S. Environmental Protection Agency EPA-600/4-80-032, Prescribed Procedures for Measurement of Radioactivity in Drinking Water (Test Method 906.0 for Tritium)

2-26 U.S. Nuclear Regulatory Commission Inspection Manual, Inspection Procedure 84750, March 1994

2-27 U.S. Nuclear Regulatory Commission NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM),* December 1997

2-28 U.S. Nuclear Regulatory Commission NUREG/CR-5849, Section 4.2.3, *Open Land Surveys, Affected Areas*

2-29 Zumberge, J.H., *Geology and Hydrology of the Proposed Reactor Site at Big Rock Point, near Charlevoix, Michigan*, 1959

PROPERTY DESCRIPTIONS: Sheet 1 of 3

For: Consumers Energy (Big Rock Point): Date: January 15, 2003

Impacted Area #1: (Parcel includes Plant Facilities & Beachfront)
In the Township of Hayes, Charlevoix County, Michigan, COMMENCING at the corner common to Sections 7, 8, 17 & 18, Township 34 North, Range 7 West; thence along the line common to said Sections 7 & 8 North 0°05'57" West 2627.58 feet to the 1/4 corner common to said Sections 7 & 8, being the POINT OF BEGINNING of this description; thence along the East & West 1/4 line of said Section 7, (as monumented) South 77°55'17" West East 20.45 feet; thence North 0°00'33" West 1226.88 feet; thence North 88°13' 00" West 1268.76 feet to the shore of Lake Michigan; thence along said shore the following seven (7) courses: North 32°01'00" East 506.91 feet, South 77°00'20" East 1046.15 feet, South 78°06'52" East 1318.53 feet, South 90°00'00" East 1320.00 feet, North 70°00'00" East 660.00 feet, South 69°00'00" East 792.00, and North 71°00'00" East 35.53 feet; thence leaving said shore along the East 1/8 line, also being the East line of Government Lot 2, of said Section 8, South 0°04'35" East 1122.78 feet to the East & West 1/4 line of said Section 8; thence along said 1/4 line South 89°46'27" West 4004.74 feet to the POINT OF BEGINNING, being part of Government Lots 1 & 2 in Section 7 and Government Lots 2, 3 & 4 in Section 8, all in Township 34 North, Range 7 West and containing 125.006 acres within the perimeter of the courses herein described. Property includes all land to the water's edge of Lake Michigan lying Northwesterly and Northerly of the courses described as being along said shore. Subject to the rights of the public and of any governmental unit in any part thereof taken, used or deeded for street, road or highway purposes.

Impacted Area #2 (Parcel Lying South of Highway U.S.-31):
In the Township of Hayes, Charlevoix County, Michigan, COMMENCING at the 1/4 corner common to Sections 8 & 17, Township 34 North, Range 7 West; thence along the North & South 1/4 line of said section 17 South 0°00'29" East 2655.11 feet to the center 1/4 corner of said Section 17; thence along the East & West 1/4 line of said section North 89°19'18" West 1338.35 feet to the West 1/8 line of said section; thence along said 1/8 line North 0°02'04" East 176.36 feet to the POINT OF BEGINNING of this description; thence continuing along said 1/8 line North 0°02'04" East 526.92 feet to the Southeasterly line of Highway U.S.-31; thence along said highway line on a curve to the left 773.41 feet, (the radius of said curve being 5804.63, the central angle being 7°38'03" and the chord bears North 33°33'14" East 772.84 feet); thence continuing along said highway line North 29°44'13" East 207.80 feet; thence South 0°05'06" East 626.63 feet; thence along a curve to the right 477.88 feet, (the radius of said curve being 585.54 feet, the central angle being 46°45'40" and the chord bears South 23°17'44" West 464.73 feet); thence South 46°40'34" West 344.33 feet; thence South 57°35'47" West 115.13 feet to the POINT OF BEGINNING, being a part of the East 1/2 of the Northwest 1/4 of Section 17, Township 34 North, Range 7 West and containing 8.266 acres. Subject to the rights of the public and of any governmental unit in any part thereof taken, used or deeded for street, road or highway purposes.

John E. Ferguson, P.S. No.24595

STATE of MICHIGAN
JOHN E. FERGUSON
LAND SURVEYOR
24595
REGISTERED LAND SURVEYOR

PROPERTY DESCRIPTIONS: Sheet 2 of 3

For: Consumers Energy (Big Rock Point):
Date: January 15, 2003

Non-Impacted Area Lying North & East of Highway U.S.-31:
In the Township of Hayes, Charlevoix County, Michigan, BEGINNING at the corner common to Sections 7, 8, 17 & 18, Township 34 North, Range 7 West; thence along the line common to said Sections 7 & 18 South 77°40'53" West 1282.91 feet to the East 1/8 line of said Section 7; thence along said 1/8 line North 0°07'19" West 2632.85 feet to the East & West 1/4 line of said Section 7, (as monumented); thence along said 1/4 line, also being the South line of Government Lots 2 & 3 of said Section 7, South 77°44'18" West 1969.87 feet to the shore of Lake Michigan; thence along said shore the following three (3) courses: North 32°42'00" East 1411.30 feet, North 62°13'00" East 1100.00 feet, and North 32°01'00" East 293.09 feet; thence leaving said shore South 88°13'00" East 1268.76 feet; thence South 0°00'33" East 1226.88 feet to the East & West 1/4 line of said Section 7; thence along said 1/4 line North 77°55'17" East 20.45 feet to the 1/4 corner common to said Sections 7 & 8; thence along the East & West 1/4 line of said Section 8, North 89°46'27" East 4004.74 feet to the Southeast corner of Government Lot 2 of said section; thence continuing along said 1/4 line North 89°46'27" East 1334.91 feet to the East 1/4 corner of said Section 8; thence along the East line of said section South 0°13'00" East 665.64 feet to the South line of the North 1/2 of the North 1/2 of the Southeast 1/4 of said Section 8; thence along the aforementioned line South 89°54'06" West 1932.81 feet to the Northwesterly line of Highway U.S.-31; thence along said highway line South 29°44'13" West 3661.53 feet; thence continuing along said highway line on a curve to the right 475.89 feet, (the radius of said curve being 5604.63, the central angle being 4°51'54" and the chord bears South 32°10'10" West 475.75 feet) to the West 1/8 line of said Section 17; thence along said 1/8 line North 0°02'04" East 1598.21 feet to the line common to said Sections 8 & 17; thence along said section line North 89°49'18" West 1336.25 feet to the POINT OF BEGINNING, being the East 1/2 of the Southeast 1/4, Part of Government Lots 1 & 2, all of Government Lot 3 in Section 7, the Southwest 1/4, Part of the Southeast 1/4 in Section 8, and part of the East 1/2 of the Northwest 1/4 of Section 17, all in Township 34 North, Range 7 West and containing 383.664 acres within the perimeter of the courses herein described. Property includes all land to the water's edge of Lake Michigan lying Northwesterly and Northerly of the courses described as being along said shore. Subject to the rights of the public and of any governmental unit in any part thereof taken, used or deeded for street, road or highway purposes.

John E. Ferguson, P.S. No.24595

STATE of MICHIGAN
JOHN E. FERGUSON
LAND SURVEYOR
24595
REGISTERED LAND SURVEYOR

PROPERTY DESCRIPTIONS: Sheet 3 of 3

For: Consumers Energy (Big Rock Point):
Date: January 15, 2003

Non-Impacted Area Lying South of Highway U.S.-31:
In the Township of Hayes, Charlevoix County, Michigan, BEGINNING at the 1/4 corner common to Sections 8 & 17, Township 34 North, Range 7 West; thence along the North & South 1/4 line of said Section 17 South 0°00'29" East 2655.11 feet to the center 1/4 corner of said Section 17; thence along the East & West 1/4 line of said section North 89°19'18" West 1338.35 feet to the West 1/8 line of said section; thence along said 1/8 line North 0°02'04" East 176.36 feet; thence North 57°35'47" East 115.13 feet; thence North 46°40'34" East 344.33 feet; thence along a curve to the left 477.88 feet, (the radius of said curve being 585.54 feet, the central angle being 46°45'40" and the chord bears North 23°17'44" East 464.73 feet); thence North 00°05'06" West 626.63 feet to the Southeasterly line of Highway U.S.-31; thence along said highway line North 29°44'13" East 1280.47 feet to the line common to said Sections 8 & 17; thence continuing along said highway line North 29°44'13" East 345.30 feet to the North & South 1/4 line of said Section 8; thence along said 1/4 line South 0°09'18" East 300.19 feet to the POINT OF BEGINNING, being part of Part of the Southeast 1/4, Southwest 1/4 in Section 8, and part of the East 1/2 of the Northwest 1/4 of Section 17, all in Township 34 North, Range 7 West and containing 46.699 acres. Subject to the rights of the public and of any governmental unit in any part thereof taken, used or deeded for street, road or highway purposes.

John E. Ferguson, P.S. No.24595

STATE of MICHIGAN
JOHN E. FERGUSON
LAND SURVEYOR
24595
REGISTERED LAND SURVEYOR

Radiological Event History

The following list is a summary of historical events that were either known, or had the potential, to impact the environment. Many of these events were evaluated and resolved through the corrective action process at the time of each occurrence. Documentation and further details surrounding these events can be found in the Historical Site Assessment (HSA) Supplemental Data.

1960's 1. A Bechtel construction crew reportedly buried non-contaminated welding equipment on the beach after the plant was completed. No location given.
Data from Historical Site Assessment Questionnaire.

1960's 2. Radwaste Tanks and Resin Disposal Tanks were overfilled on many occasions, often with water standing on the floor. The Valve Pit at the back northwest door of the Turbine Building had resin spills in it.
Historical Site Assessment Questionnaire.

1960's 3. Construction waste may have been buried west of the Discharge Canal near the beach in the construction staging area.
Historical Site Assessment Questionnaire.

1960's 4. Old steel cables and solid steel waste were buried or dumped along the east side of the Discharge Canal.
Historical Site Assessment Questionnaire.

1960's 5. Construction debris has been identified in areas along the Woods Road. These locations contain wooden pallets and paint chips that are suspected to originate from the Protected Area.
Historical Site Assessment Questionnaire.

1960's 6. Construction materials were stored in a temporary lay down areas near the Big Rock and the old weather tower.
Historical Site Assessment Questionnaire.

12-1-62 7. The Pipe Tunnel was flooded with approximately 2 inches of water. It is suspected that this water was from the Condensate System. Leaks of this type have occurred throughout the operational life of the plant. Some of this contaminated water may have entered the gravel filled expansion cavity that surrounds the Containment Building or through floor expansion joints into the sand below the building.
HP logbook entry 12-1-62

8-8-63 8. A water leak was identified at a flange of the Waste Hold Tank. These outdoor tanks are a part of the Radwaste Clean-up System and are located west of the Turbine Building. It is likely that contaminated water may have entered the ground below the tanks.
HP logbook entry dated 8-8-63.
Historical Site Assessment Questionnaire.

8-6-64 9. Discharge Canal dredging was completed 8-18-64. The discharge canal is the effluent pathway for the radwaste batch release of contaminated water. Based upon employee interviews and the results of scoping surveys, it is suspected that dredging spoils may have been stored on the narrow strip of land north of the protected area and on the beach northeast of the Discharge Canal.
HP logbook entries dated 8-6-64, 8-18-64.
Historical Site Assessment Questionnaires.
Safety Evaluation for renewal of dredging permit 5-11-87.
Evaluation of Radiological Impact of Discharge Canal Dredging 4-13-89.

11-13-64 10. Contamination was identified on top of the Canal Process Monitor intake piping during a maintenance work evolution. The source of contamination is believed to have originated from this licensed release pathway.
HP logbook entry dated 11-13-64.

6-8-65 11. Twelve logbook entries reference the incinerator and identify contamination in the ash. Used for burning clean trash, the incinerator was a simple enclosure constructed of cement block. Some of the ashes that were removed from the incinerator have contained low levels of contamination. The incinerator was in operation between 1965 and 1978. In December of 1978 it was dismantled, surveyed for contamination and released as clean trash. There is a potential that contamination may be present in the soil at this location.
HP logbook dated: 6-8-65, 9-10-70, 9-11-70, 6-12-73, 10-23-73, 4-29-74, 3-23-76, 7-1-76, 5-16-77, 4-17-78, 12-8-78, 12-21-78.
Historical Site Assessment Questionnaires.

10-3-72 12. Canal dredging is in process.
HP logbook entry 10-3-72.

7-25-73 13. Contaminated material is discovered in a temporary shelter near the stack base. No further entries refer to this storage location and it is probable that this temporary storage area was cleaned up shortly after discovery. The potential exists for soil and pavement in this area to be contaminated as a result of this event.
HP logbook entry 7-25-73.

10-3-73 14. Canal dredging is in progress.
HP logbook entry 10-3-73.

10-23-73 15. Ash removed from the incinerator was found to be contaminated. The ashes were disposed of as radwaste.
HP logbook entry 10-23-73.

4-29-74 16. Ten barrels of contaminated ashes were removed from the incinerator as radwaste.
HP logbook entry 4-29-74.

8-18-75 17. Uranylacetate was spilled in the Annex Building. The Public Affairs Department likely used this radioactive chemical during presentations. The area was cleaned up following the spill.
HP logbook entry 8-18-75.

3-23-76 18. Contamination was found in 8 barrels of ashes from the incinerator. The barrels were taken to the radwaste area for shipment.
HP logbook entry 3-23-76.

7-1-76 19. Contamination was identified in 8 barrels of incinerator ash. The ash was released as radwaste.
HP logbook entry 7-1-76.

2-21-77 20. The radwaste transfer cask liner was banged against the cask during the transfer of spent filters. Contaminated debris was spilled on the ground by the open air Radwaste Vault in the Radwaste Compound. The liner read 2.3 Rem/hr. Clean up efforts included the removal of contaminated snow. It is likely that contamination remained on the ground in this area.
HP logbook entry 2-21-77.

8-20-78 21. Contamination was found in demineralized water collected at the chemistry lab and Machine Shop sample location. The source of contamination is suspected to have originated from a remote piping cross connection that established demineralized water as an alternate source for spent fuel pool make-up. The cross connect was removed, and in later years this contamination was reduced to trace levels found only in sample locations at lower elevations in the sphere. Many plant systems that are connected to the demineralized water supply have drain connections that may have provided a contamination release pathway. The investigation following this event could not identify a radioactivity release to the environment. This system is now surveyed on a routine basis.
HP logbook entry 8-20-78.

9-28-78 22. The Waste Hold Tank was found overflowing to the asphalt below the tanks.
HP logbook entries 9-28-78 and 9-29-78.

12-8-78 23. The Incinerator was in the process of being dismantled by contractors. No contamination was identified during removal.
HP logbook entries 12-8-78 and 12-21-78

11-20-81 24. Approximately 10 cubic feet of contaminated resin were spilled at the north end of the Pipe Tunnel in the Turbine Building. The spill was an operational error resulting from improper valve line up. Clean up efforts included the removal of the top 3-5 inches of gravel from the expansion joint area between the Pipe Tunnel and the Sphere. Over the course of the next several days the area was decontaminated and resurveyed several times. Fields of 2-3 Rem/hr were recorded at contact with the floor. It is suspected that contamination remains in the sphere expansion area and may have also migrated through the floor expansion joints to the environment below.

HP logbook entries 11-20-80(2 log entries), 11-23-80(2 log entries), 11-24-80 (two log entries), Table 3.1-2 Big Rock Point Nuclear Plant Decommissioning Plan. Deviation Report D-BRP-80-60.

4-22-81 25. Loose contamination was found in a normally clean area of the Baler House (Butler Building). The baling area at this time was a 12 by 22 foot building located in the Radwaste Compound. This building was the location for the compaction and barreling of low level waste. Soils in this area are potentially contaminated.
HP logbook (2 log entries) 4-22-81.

8-17-81 26. Elevated contamination levels were identified while preparing for construction of the new Radwaste Building. Asphalt, dirt and vegetation with significant contamination levels were removed and placed in barrels for shipment. Large slabs of concrete were taken inside the turbine building and decontaminated. These blocks were then moved to their current storage location at the power line south and east of the Swamp Warehouse. This was a long-term project that continued on until November 9, 1981. A total of 90 drums of sand, cement, and blacktop were shipped offsite as radioactive waste.
HP logbook entries 8-17-81, 8-22-81, 8-25-81, 8-30-81, 8-31-81, 9-1-81, 9-2-81, 9-3-81, 9-4-81, 9-11-81, 9-15-81, 9-16-81, 10-8-81, 10-9-81, 10-12-81, 10-30-81, 11-2-81, 11-3-81, 11-4-81,11-5-81, 11-6-81, 11-9-81.
Table 3.1-2 Big Rock Point Nuclear Plant Decommissioning Plan.
Internal Correspondence GLF-81-27.
Historical Site Assessment Questionnaire.

11-5-82 27. Contamination was identified in asphalt rubble located near the Stack Base. The following events have occurred in the vicinity of the Stack Base that could have resulted in the contamination of this area: temporary contaminated material storage area, resin sluicing and pumping, numerous Waste Hold Tank leaks and overflows, Condensate Storage Tank leaks. This area was also the transfer point for the movement of radwaste filters casks to the Radwaste Building.
HP logbook entries11-5-82 and 7-25-73.

11-16-82 28. A transport pathway was identified between the Chemistry Lab sink and the septic system. This sink was used for the disposal of non-contaminated water samples. Modifications were made to correct this situation in December 1982. There is a potential that this sink may have been used for the disposal of contaminated waste. The septic tanks and drain field (liquid, sludge and soil) were sampled for suspected contamination. This and subsequent investigations and analyses have never identified radioactive contamination. The septic tanks are presently sampled and analyzed three times per year.
HP logbook 11-16-82, Specification field change SFC 82-050.

11-24-82 29. Contaminated blocks of cement from the radwaste vaults were moved to the northeast corner of the Contaminated Materials Warehouse. The cement had fixed contamination levels of 100 to 800 cpm. These blocks may have been stored along the power line at the time the contamination was discovered.
HP logbook entry 1-24-82.

5-31-84 30. Water was found weeping through the wall of the Radwaste Pump Room. The water originated from a leak in a two-inch aluminum line below the Turbine Building floor. It was calculated that approximately 20,000 gallons of condensate system water had leaked into the soil. A section of the floor in the southwestern corner of the turbine building was cut out and eight barrels of contaminated soil were removed and shipped as low-level radwaste. On August 16, 1985, Consumers Power requested NRC approval to retain the remaining contaminated soil. Total activity estimated at 1.4E-7 μCi/g; nuclides present in 1984 included Mn-54, Cs-137, Co-60 and Ag-110m. The NRC granted approval on May 8, 1986. Voids were replaced by clean fill and the concrete floor was repaired. It is estimated that 5300 cubic feet of contaminated soil remained at this location The summary section of this engineering study made the following conclusion: "Retaining the contaminated soil on-site with approximately 8 inches of concrete covering (turbine building floor) would result in no discernable impact on either the environment or on occupational and public health. The total activity is expected to be undetectable within seven years."
HP logbook entries 5-31-84, 7-10-84 (2 log entries), 7-11-84 (two log entries), 7-12-84, 7-18-84, and 7-25-84.
Engineering Analysis performed in August of 1985 "Justification for Retaining Contaminated Soil On-Site" E-BRP-84-05
Big Rock Point Nuclear Plant Decommissioning Plan Table 3.1-2.
Historical Site Assessment Questionnaire.
Event Report E-BRP-84-05.
Action Item Record A-BRP-84-20.

9-5-84 31. Contamination is discovered in a small quantity of soil during a free release evaluation of equipment from the temporary resin shed south of the Stack Base. This contamination was likely the result of a spill during spent resin pumping activities.
HP logbook entry 9-5-84.
Historical Site Assessment Questionnaire.

11-9-84 32. Concrete blocks from the radwaste vault were found with activity levels of 100 to 500cpm. These are likely from the storage location along the power line. (Related events 26 and 29.)
HP logbook entry 11-9-84.

7-29-85 33. In July of 1985 the "Butler Building" (formerly the Baler House) was evaluated for radioactivity. Fixed contamination of 300 cpm was found on the north window of this 12 by 22 foot metal building. The building was moved to a location directly east of the QA/QC warehouse inside the protected area and is now used for materials storage.
HP logbook entry dated 7-29-85.
Historical Site Assessment Questionnaire

9-30-86 34. Contaminated sludge was found in the heating boiler during a maintenance evolution. The source of this activity is believed to have originated from contaminated demineralized water make-up. (Related event 21). Frisking performed on samples of the sludge detected 160 cpm over background and

gamma analysis identified measurable levels of Co-60, Cs-134 and Cs-137. The sludge was removed and the area was decontaminated. A pathway existed for liquid drains from this system to have reached the environment. A new heating boiler was installed in 1990 and system drains are now batched by licensed effluent release.
HP logbook entries 9-30-86, 10-1-86, 10-2-86, 10-3-86, 10-6-86, 10-10-86, 10-11-86.

10-25-86 35. Contamination was found on the concrete floor under the pipe rack in the QA/QC warehouse. The contamination was limited to the locked storage area in the south quarter of the building. Fixed activity levels greater than 50,000 cpm were identified. A major clean-up effort was undertaken that involved chipping out contaminated sections of the floor. The room was then released as a radiologically clean area.
HP logbook entries dated 10-25-86, 10-27-86, 10-28-86, 10-29-86, 10-30-86, 12-22-86, 12-23-86, 3-27-87, 10-2-87, 10-5-87, 10-7-87, 10-14-87, 10-15-87, and 10-19-87.

2-13-87 36. Approximately 25 gallons of water is estimated to have leaked from the #1 Waste Hold Tank vent line due to overfilling. Less than one gallon was estimated to have reached the environment. Soil samples taken after this event identified 1.2E-5 ⊠Ci/gm of Co-60, 3.4E-5 ⊠Ci/gm of Cs-137, and 2.0E-6 ⊠Ci/gm of Mn-54. Two and a half fifty-five gallon drums of soil were removed from the area below the tank. The pit was approximately 3 feet long and 2 ½ feet deep when soil levels reached <100 cpm above background and the clean-up effort was terminated.
HP logbook entries 2-13-87 (2 log entries), 2-14-87,
Table 3.1-2 Big Rock Point Nuclear Plant Decommissioning Plan.
Deviation Report D-BRP-87-56.
Historical Site Assessment Questionnaire.
Internal Correspondence JLB 87-64.

3-11-87 37. A decontamination of the Waste Hold Tank was performed. This may be the result of the overflow recorded in event 36.
HP logbook entry dated 3-11-87 (2 log entries).

3-17-87 38. The Discharge Canal was dredged. A direct frisk of dredge spoils identified only background activity levels. The refuse was likely placed on the elevated stretch of property between the beach and the protected area fence that is north of the Containment Building. (Related events 9, 12, 14)
HP logbook entry dated 3-17-87.

6-30-87 39. Maintenance removes sludge from the heating boiler water-box. Gamma isotopic analysis identified a Cs-137 activity of 1.60E-6 ⊠Ci/cc of sludge. During the process of clean-out approximately 500 gallons of heating boiler water was inadvertently released to the septic system.
HP logbook entry 6-30-87.
Table 3.1-2 Big Rock Point Nuclear Plant Decommissioning Plan.
Internal Correspondence WMH-01 & WDB 87-05.
Historical Site Assessment Questionnaire.

6-29-88 40. Contaminated water leached through a cement wall on the west side of the Room 121 into the compressed gas bottle storage area. Water analysis identified an activity level of 3.59E-5 ⊠Ci/ml. The area was decontaminated and released as radiologically clean.
HP logbook entry 6-29-88.
Internal Correspondence RLB 88-12.

7-8-88 41. Moisture was again found at the seam of the wall in the gas bottle storage area. Smears of the area did not identify radioactive contamination.
HP logbook entry 7-8-88.

2-24-89 42. Drain line integrity is questioned in the floor drain of the Condensate Demineralizer Room (between cation and anion tanks). Maintenance personnel may have punctured the drain while attempting to unplug the line. Soil contamination is suspected below the concrete flooring.
*Internal Correspondence TAM 89-04, JLB 89*23.*

9-21-89 43. The floor sink inside the Room 121 decontamination area was found flooded up to the curb and water leaked out into the gas bottle storage area (related events 40 & 41). The area was cleaned up and released as radiologically clean.
HP logbook entries 9-21-89, 9-25-89, 9-26-89.

9-19-91 44. A truckload of rip/rap and a concrete pad were frisked and released for storage along the power line behind the Swamp Warehouse. This material was likely from the canal dredging area.
HP logbook (two entries) 9-19-91.

8-13-93 45. The #1 Waste Hold Tank was overfilled and leaked to the ground. The area was boundaried off and decontaminated. (Related events 8, 22, 36, 37).
HP logbook (two entries) 8-13-93.
Deviation Report D-BRP-93-048.

11-27-93 46. The overhead supply line to the Condensate Storage Tank was found leaking near the Turbine Building. A temporary cover was constructed to keep out rain and snow. Two 55-gallon barrels of low activity soil were removed from the leak area. On June 6, 1994 further clean up resulted in the removal of an additional barrel of soil.
HP logbook 11-27-93 (two logbook entries), 11-29-93 (two logbook entries), 12-1-93, Table 3.1-2 Big Rock Point Nuclear Plant Decommissioning Plan.
Deviation Report D-BRP-93-065.
Historical Site Assessment Questionnaire.

1-6-94 47. A leaking union was discovered on a section of the demineralized water transfer line located immediately west of the southern end of the Turbine Building. Snow and ice in the area below the piping leak was collected. The logbook entry gave no activity results for the samples. The leak was repaired on the same day as it occurred.
HP logbook (two entries) 1-6-94
Historical Site Assessment Questionnaire.

6-27-94 48. Contractors removed asphalt and dirt from the Radwaste Compound in preparation for pouring a new cement slab in front of the loading bay. This asphalt and dirt were released to the power line storage area behind the Swamp Warehouse. This location from which these materials came was once a contamination area.
HP logbook entries 6-27-94, 6-30-94

8-18-94 49. In August of 1994 the Decommissioning Planning Team had nine groundwater- monitoring wells installed. Gamma isotopic analyses of water samples collected from these wells showed no detectable reactor generated activity, however, an analysis for Tritium identified low level contamination in the two wells (wells 5 & 6) closest to the lake. The Tritium is believed to have originated from the Condensate Storage Tank leak (event 30) that occurred in May of 1984. The Tritium concentration is a factor of 500 lower than the level of the original leak and it is likely that this represents the tail of the groundwater plume moving toward Lake Michigan. Routine activity monitoring of groundwater has been added to the plant's Radiological Environmental Monitoring Program.

As part of Decommissioning Planning, an initial site Scoping Survey was also performed. This survey identified contaminated soil in the following two locations:

Area 1 - The edge of the asphalt directly west of the resin disposal tank plugs. Approximately 5-10 square meters. Nuclide activity levels in this area ranged from 4.7 to 13 pCi/gm of Co-60, and 2.8 to 100 pCi/gm of Cs-137. This is believed to have originated from the 1990 resin transfer work and the numerous spills and overflows of the Waste Hold Tanks that occurred over the years.

Area 2 - Approximately 5-10 square meters of soil west of the acid tank containment wall contained contamination levels up to 48 pCi/gm of Co-60 and 70 pCi/gm of Cs-137. This activity suspected to have originated from the 1984 Condensate Storage Tank leak and other spills and overflows of the Waste Hold Tanks.

Clean up efforts were conducted at the completion of the Scoping Survey.
Deviation Report D-BRP-94-073 & D-BRP-94-073B.

11-12-94 50. An activity analysis was performed on the storm drain effluent that empties into the west drainage ditch. Samples were taken from the eroded area near the drain and from nearby sediment and vegetation. The results of these analyses could not be located. However, it is known that radioactivity was limited to sediment passing through the drain and not to liquid effluent, and that a barrel was installed to collect sediment at the outfall of the drain.
HP logbook entry 11-12-94

6-6-95 51. Gravel containing Cs-137 was identified during repair of the Turbine Building roof. The gravel contained Cs-137 at soil background levels. The gravel is being stored under a tarp northwest of the sphere.
HP logbook (two entries) 6-6-95.
Internal Correspondence RAE HP97-008.

9-14-95 52. Heavy rains flooded an area below the stack base. The storm drain at this location had been sealed due to ongoing resin transfer work and the seal was removed to allow flow to the west drainage ditch. A gamma analysis of the drain discharge to the drainage ditch identified radioactive contamination. No activity could be identified in additional samples taken of the sediment collection barrel and creek discharge to the lake.
HP logbook entry dated 9-14-95

8-23-96 53. Contamination was found (15 μCi/gm) in the collection barrel sediment of the storm drain discharge at the west drainage ditch. Samples were taken after a spent resin transfer evolution west of the Turbine Building. This location is the storm water collection source for the storm drain. An investigation identified the following known sources of contamination in this area:

- Spills or the migration of contamination during spent resin and filter cask transfer
- Waste Hold Tank overfills
- Contamination resulting from past leaks in area piping

Condition Report C-BRP-96-778.

9-16-96 54. Two loads of blacktop were removed from an area near the stack base. Both loads were frisked and identified no activity above background levels. These two loads were released to the storage area along the power line behind the Swamp Warehouse. An additional load evaluated on the following day contained numerous areas of surface contamination ranging from 1,000 to 10,000 cpm. The contaminated pieces were segregated and taken to the Radwaste Building. The remaining asphalt was released to the power line storage area.
HP logbook entries 9-16-96, 9-17-96.

11-18-96 55. Roof repair was performed on the Turbine Building (Related event 51). Gravel from this location was removed and placed in the storage location northwest of the Containment Building. The average activity of the gravel stored in this area is 0.72 μCi/gm Cs-137, and 0.07 μCi/gm Co-60.
HP logbook entry 11-18-96.
Internal Correspondence RAE HP97-008.

3-13-97 56. Contamination was found in the soil below a cracked floor drain near the caustic tank in the Condensate Pump Room. This room is located in the Turbine Building north of Track Alley. Samples collected identified Cs-137, Mn-54, Sb-124, and Cs-134. Area clean up efforts were performed and the drain has been plugged to prevent further use. Soils in this location are expected to contain low levels of contamination.
HP logbook entry 3-13-97.
Condition Report C-BRP-97-0174.

3-98 57. An investigation of a system process monitor alarm event identified contamination (Co-60 and Mn-54) in the sediment of the east storm drain. For a brief period, radioactive contaminants were introduced into the Service Water System that provides supply water to many radiologically clean systems. The contaminants entered through an improperly seated condenser warming line and were the result of wave-suspended radioactivity that was previously discharged to the lake in permitted releases. The sediment radioactivity is likely to have originated from the condenser vacuum pump which uses sealing water from the Service Water System and discharges to the storm drain. Sediment activity levels in the drain piping were approximately 0.8 pCi/gm. No activity was identified in the samples taken from other connecting sections of drain system. The entire length of this drain line has been decontaminated and is now monitored on a routine basis by the Operational Health Physics Department. Any potential piping leaks in this system would have presented a release pathway to the environment.
Condition Report C-BRP-98-056 and WR 117526

5-99 58. Trace levels of contamination were found in the east storm drain piping during a follow-up survey to CR-BRP-98-056 (Related event 57). This activity is likely to be wash out from the earlier event of March of 1998. An effort has been made to seal plant outflow piping to the storm drains and this system is now monitored in the Annual Survey. The Planning and Scheduling Department has been notified that removal of storm drains will be a requirement for license termination.
Condition Report C-BRP-99-0183

No Date 59. Anti-Contamination clothing in a yellow radwaste disposal bag was found in a void under the asphalt near the Equipment Lock Area. No contaminated materials were present in the bag. This void may be the result of wash out that was caused by modifications that were made to the Alternate Shutdown Building drainage. No further information is known concerning the origin of the radwaste disposal bag.
Historical Site Assessment Questionnaire

No Date 60. Floor drain in shop had activity.
Historical Site Assessment Questionnaire

No Date 61. The integrity of all under ground piping is suspect due to inadequate cathodic protection. There is a potential of soil contamination in areas near underground piping carrying radioactive fluids.
Historical Site Assessment Questionnaire

No Date 62. There was a spill during a resin shipment that occurred prior to sealing the storm drains at the Stack Base.
Historical Site Assessment Questionnaire

No Date 63. Old steel from inside the sphere was stored in the area where the Swamp Warehouse is presently located. The steel was from plant modifications that were made over the years and is believed to contain low levels of contamination.
Historical Site Assessment Questionnaire

Ground Penetrating Radar Survey

The ground penetrating radar (GPR) survey was conducted using a Geophysical Survey Systems, Sir System 2 test instrument for the investigation of potential subsurface anomalies. The sensitivity of this instrument under site-specific soil conditions was sufficient to define anomalies to a depth of 10 feet. Survey findings were evaluated for valid positive anomalies and trending. Backhoe excavation and hand digging were then used to investigate the locations of positive indication. Coarse vegetation (small trees and brush) and sharp elevation changes due to rough terrain precluded GPR survey in some areas. Where these conditions were present, investigations were performed by exploratory excavation and the direct movement of soil by hand digging or heavy earth moving equipment.

All unearthed construction materials were removed and evaluated under existing procedures for materials release. Gamma spectroscopy was judgmentally performed on samples of soil found in direct contact with excavated debris at suspect locations. Radioactivity resulting from plant operational activities was not identified at any survey location in this investigation. The findings of this evaluation are detailed below by individual area survey.

Survey Unit 12
Survey unit 12 is a flat, grassy strip of level terrain located directly north of the plant between the Protected Area fence and Lake Michigan. Historical photographs identify this area as the location used for concrete batch production and material staging during plant construction. The investigation of GPR anomalies in this area resulted in the retrieval of large pieces of concrete and wooden scaffold planking. Additional miscellaneous unearthed debris included nails, rebar, metal bands, and an empty crushed burn barrel. All of this material was excavated from the original construction level elevation. This elevation is presently located approximately 3 to 6 feet below current grade. Based on historical data and the unique properties of soil layers identified in this survey unit, the elevation change is believed to result from the contour grading of lake bottom dredge sediment that was deposited in this area. The sediment fill originated from the initial excavation and construction of the discharge canal.

It was common practice in the construction industry to dispose of unwanted building debris by onsite burial during final site grading. The construction rubble excavated during the GPR survey is typical of the building materials used during plant construction. In addition to construction debris, the GPR survey identified two separate systems of undefined piping in this survey unit:

1. A piping segment was identified in the eastern portion of the survey unit extending from the Protected Area to the beach. This section of piping is an alternate branch of the storm drain system that was abandoned as a result of reoccurring sand blockage along the lakeshore.

2. The GPR survey also identified a trend of north/south anomalies in the central portion of the survey unit. Follow-up excavations led to the discovery of a run of clay tile set in drain stone. This line is suspected to have been used for water drainage during placement of the lake bottom dredging sediment that had been removed for construction of the discharge canal. Proximity to system piping still in use precluded removal of the drain tile at this time of discovery.

Survey Unit 15(2)
The staging and storage of materials in this area during plan construction is clearly identified in historical photographic records. This location is an undisturbed beach ridge comprised of a covering of cobles over hard clay. No subsurface anomalies were identified; however, a small volume of scrap metal and miscellaneous construction material were found on the beach surface. This material was removed from the area for disposal.

Survey Unit 16
An evaluation of a beach area near the tree line in the southwest section of Survey Unit 16 was conducted. Soils at this location are comprised of shallow gravelly sand typical of the soil layers found in survey unit 12. The soil layer covers a base of cobbles and clay. It is obvious from the topography and vegetation that this region has been graded. Vehicle barricades bisect the survey area approximately 75 feet east of the security fence. The GPR survey and follow-up anomaly investigation revealed only naturally occurring rock formations west of the vehicle barricades. An investigation of suspect anomalies east of the barricades is planned prior to Final Status survey.

Sections of tile, asphalt, concrete, and crane cable were visible near the ordinary waterline. These materials were likely placed on the beach as riprap for shoreline protection against wave action and high water levels. All construction debris has been removed from the area for disposal.

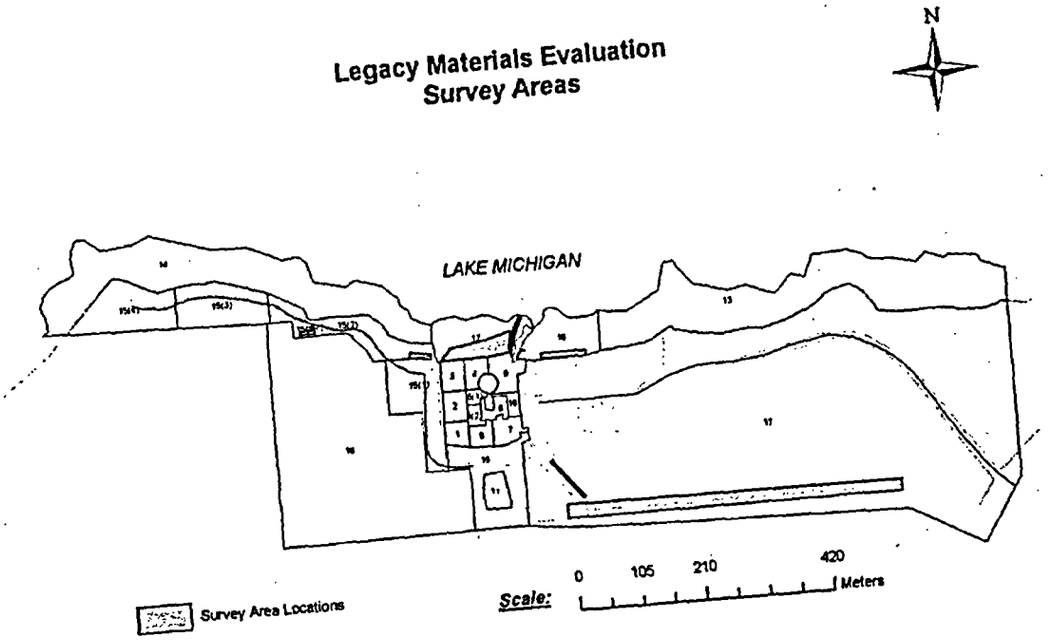
Dredge spoils from the Canal were placed in this area on several occasions. The spoils originate from the discharge canal dredging that was conducted to remove sand build-up created by wind and wave action. The shallow gravelly sand, and grading visible in this area are believed to result from the dredging projects.
Survey Unit 17 – Paved Drive
The survey area in unit 17 is the paved transport route to the Swamp Warehouse and former 138kV power line easement. This 300-foot section of roadway was developed prior to power operations at the time of original site construction.

Individual soil layers in the survey area were clearly defined by GPR as fill material, native soil, and water table strata. Power cable and\or storm drain crossings were identified at 2 locations. The soil below the roadway fill material appears undisturbed. No significant anomalies were identified in the survey and exploratory excavation was unnecessary. All cable, piping, and road surface materials have been scheduled for removal prior to Final Status Survey.

Survey Unit 17 – 138 kV Power Line Easement
During site preparation for original plant construction, an easement supporting 138 kV power distribution was created to supply electrical service to the Emmet County Substation near Petoskey, Michigan. The easement begins near the former plant substation in the Industrial area and traverses the owner-controlled property eastward approximately 400 meters to highway US Highway 31. This area, originally heavily wooded, was logged and smooth graded for power line construction. Area grading resulted in mounded embankments of excess soil spaced against the tree line on either side of the easement. These mounded areas contain large pieces of concrete, asphalt rubble, and other miscellaneous debris as documented by historical information and physical inspection.

A GPR survey could not be conducted in this area due to coarse vegetation and uneven terrain; however, investigation was performed by a thorough excavation of all suspect areas. Using a backhoe and front loader, all mounds were graded to an approximate 5-inch thickness and inspected for the presence of man-made materials. Construction debris and miscellaneous scrap materials were only found on mound surfaces. The mounds all appear to have been created by deposition of soil from the original easement grading. Soil layers beneath the mounds appear to have remained undisturbed. All materials retrieved were removed from the area.

Legacy Materials Evaluation Survey Areas



NaI Scanning For Open Land Survey

Big Rock Point is required to perform the survey and analysis of all area soils to ensure that potential residual radioactivity levels meet the regulatory requirements for license termination and unrestricted site release. Site history and characterization activities to date have identified Cs-137 and Co-60 as the predominant potential contaminants associated with Big Rock Point. Other radioactive contaminants of plant origin, including the HTD (hard-to-detect) radionuclides, are present at levels much lower than those of Cs-137 and Co-60. Soil sampling analyses have demonstrated that measurements of Cs-137 and Co-60 can be used as surrogates for estimating levels of other radionuclides with the potential to be present in soils at Big Rock Point.

The evaluation of open land areas for unrestricted release must include a detection methodology of sufficient sensitivity for the identification of small areas of potentially elevated activity within a survey unit. This engineering analysis considers the following two survey methods:

1. Surface Scan (continuous monitoring), or
2. Static Measurement (discrete measurement)

This study establishes the detector, counting geometry, and minimum detectable concentration (MDC) values for scanning and defines the methods used to identify small areas of potentially elevated levels of radioactivity in land area surveys. Measurement methodologies follow the guidance provided in NUREG-1507 and NUREG-1575 [References 2 and 3).

ANALYSIS INPUTS:

1. Bicron NaI scintillation probe specifications
2. MicroShield radioactive source modeling [Reference 1]

ANALYSIS:

Surface Scan
Surface Scanning measurements for Big Rock Point open land areas are performed by passing a 2" x 2" NaI (Sodium Iodide) gamma scintillation detector across the land surface under investigation. The centerline of the detector is maintained 10 cm above the surface and moved from side to side in a 1 meter wide pattern at a rate of 0.5 m/sec, while advancing forward approximately 0.125 m/sec. The resulting serpentine scan pattern crosses each square meter area 4 times in 8 seconds with a maximum separation of less than 50 cm between any path. The audible signal is monitored for detectable increases in count rate. An observed count rate increase results in further investigation to verify findings and define the level and extent of contamination. This method represents the Stage 1 and Stage 2 scanning process defined in NUREG-1507 and is the basis for calculations of the scanning detection sensitivity (Scan MDC).

Measurement sensitivity
An *a priori* determination of scanning sensitivity is performed to ensure that the measurement system is able to detect concentrations of radioactivity at levels below the regulatory release limit. Expressed in terms of Scan MDC, this sensitivity is the lowest concentration of radioactivity for a given background that the measurement system is able to detect at a specified performance level. The MDC value for Surface Scanning is developed in the following steps:

1. Minimum Detectable Count Rate surveyor ($MDCR_s$)
The $MDCR_s$ is the minimum detectable count rate above a given background that the scanning instrument and measurement technique are expected to identify at a specified level of performance. Scanning is conducted by the following two stages of measurement technique:

- Stage 1 scanning
The detector is in motion for initial identification of potential areas of elevated activity. Based on the scanning progression of 1 square meter per 8 seconds, an observation interval of 2 seconds exists for measurement evaluation. The specified performance level for Stage 1 scanning defines the count rate above a given background that results in a 95% probability of being correctly identified when present and a 60% probability of being falsely identified when not present (α =0.6, β = 0.05).

- Stage 2 Scanning
Following identification of a potential area of elevated activity in the Stage 1 scanning process; further investigation is conducted by increasing the observation interval for measurement of the suspect area to 4 seconds. The specified performance level for Stage 2 scanning defines the count rate above a given background that results in a 95% probability of being correctly identified when present and a 20% probability of being falsely identified when not present (α =0.2, β = 0.05).

The $MDCR_s$ is determined for Stage 1 and Stage 2 scanning based on the following relationship:

$$MDCR_s = d' \frac{\sqrt{B_i}}{\sqrt{p}} \bullet \frac{60}{i}$$

Where : d'= Index of sensitivity: Stage1 d' = 1.38 (α =0.6, β = 0.05)
Stage2 d' = 2.48 (α =0.2, β = 0.05)

i = Observation interval: Stage 1 (2 seconds)
Stage 2 (4 seconds)
B_i = Background count rate in the interval i
p = Surveyor efficiency of 0.5

The longer observation interval of Stage 2 scanning increases measurement sensitivity and permits an improvement in the level of specified performance. Stage 2 scanning provides more conservative (higher) values of $MDCR_s$ as detailed in Tables 1 and 2. The Stage 2 scanning $MDCR_s$ is the basis value used for development of the Scan MDC.

2. Detector Rating

The detector rating is the manufacturer rated value of detector cpm response to delivered μR/hr exposure. The detector used in this counting system has a Cs-137 rated value of 1200cpm/μR/hr. To determine the rating value for other nuclides of interest, a calculation of the relative detector response is required. This value is the product of the fluence rate and the probability of interaction for each nuclide. The detector rating for the additional nuclide of interest (cpm/μR/hr) is the product of the manufacturer Cs-137 rated value and the relative detector response ratio at each energy. The rating values for additional nuclides of interest are defined by the following:

Fluence Rate $F = \dfrac{\mu R/hr}{(E\gamma)(\mu_{en}/\rho)_{air}}$

Where: $E\gamma$ = nuclide of interest energy (kev)

μ_{en}/ρ = mass energy absorption coefficient for air at $E\gamma$

Probability of Interaction $P = 1 - e^{-(1/\sigma\tau)_{NaI}\,(x)\,(\sigma\tau)_{NaI}}$

Where: $(1/\sigma\tau)_{NaI}$ = mass attenuation coefficient for NaI at the nuclide energy

(x) = thickness of the NaI crystal (cm)

$\sigma\tau_{NaI}$ = density of NaI g(cm^3)

Relative Detector Response = Fluence Rate . Probability of Interaction

Detector Rating For Additional Nuclides

$$\text{cpm} / \mu\text{R/hr}_{\text{new energy}} = \text{Cs-137}_{\text{rated}} \cdot \frac{\text{RDR}_{@\,\text{new energy}}}{\text{RDR}_{@\,\text{rated energy}}}$$

Where: Cs-137 $_{rated}$ = 1200cpm/ μR/hr

RDR = Relative Detector Response

Detector rating values for Big Rock Point nuclides of interest are detailed in Table 2-D1.

Table 2-D1
Detector Rating

Energy kev	μ_{en}/ρ air	μ/ρ NaI	Fluence (F)	Probability (P)	F * P	Det. Rating
661.6	2.93E-02	7.77E-02	5.16E-02	7.65E-01	3.95E-02	1200
1173.2	2.70E-02	5.38E-02	3.15E-02	6.33E-01	2.00E-02	607
1332.5	2.63E-02	5.01E-02	2.86E-02	6.07E-01	1.73E-02	527
		Detector Rating cpm/μR/hr				
			Cs-137	Co-60*		
			1200	565		

* Weighted sum based on exposure rate$_{model}$ contribution at energies of 1173.2 and 1332.5 kev

3. Minimum Detector Exposure Rate (MDER)
The MDER is the minimum level of exposure rate delivered to the detector in a given background that the counting system is able to identify at the specified level of performance. This value is a ratio of the $MDCR_s$ and the detector rating for the nuclide of interest.

$$\text{MDER} = \frac{MDCRs}{Detector \quad Rating \quad cpm/\mu R/hr}$$

4. Scan MDC
Finally, the Scan MDC is the product of the minimum detectable exposure rate and the modeled exposure/activity.

$$\text{Scan MDC} = \text{MDER} \cdot \frac{pCi/g}{\mu R/hr}_{\text{Exposure/Activity model}}$$

Final derivation of the Scan MDC is developed using the Microshield modeling code (ref. 1) to define the exposure/activity model. The source of potential elevated activity for identification by the scanning process is considered to be distributed for an area of approximately 0.25 square meters (0.28 meter radius). A given concentration of the source nuclide of interest is modeled to the measurement system geometry resulting in a known delivered exposure rate to the detector. Modeled exposure to source concentration values are provided later in this Appendix.

Results
For a distributed source geometry of 0.15 meters depth and 0.28 meters radius in typical Big Rock Point background levels of 4000 cpm to 6500 cpm, Scan MDC values range from 2.91 to 3.71 pCi/g for Cs-137 and 1.51 to 1.93 pCi/g for Co-60. Stage 1 and Stage 2 $MDCR_s$, MDER, and Scan MDC values are detailed for various background activity levels in Tables 2-D2 and 2-D3.

Table 2-D2
Stage 1 Scan MDC In Varying Backgrounds

Background				CPM	MDER µR/hr		Scan MDC pCi/g	
	d'	i	s_i	$MDCR_{surveyor}$	Cs-137	Co-60	Cs-137	Co-60
2000	1.38	2	11.27	478.05	0.40	0.85	1.62	0.84
2500	1.38	2	12.60	534.47	0.45	0.95	1.81	0.94
3000	1.38	2	13.80	585.48	0.49	1.04	1.98	1.03
3500	1.38	2	14.91	632.40	0.53	1.12	2.14	1.11
4000	1.38	2	15.93	676.06	0.56	1.20	2.29	1.19
4500	1.38	2	16.90	717.07	0.60	1.27	2.43	1.26
5000	1.38	2	17.82	755.86	0.63	1.34	2.56	1.33
5500	1.38	2	18.69	792.75	0.66	1.40	2.69	1.40
6000	1.38	2	19.52	828.00	0.69	1.47	2.81	1.46
6500	1.38	2	20.31	861.81	0.72	1.53	2.92	1.52
7000	1.38	2	21.08	894.34	0.75	1.58	3.03	1.57
7500	1.38	2	21.82	925.73	0.77	1.64	3.14	1.63
8000	1.38	2	22.54	956.09	0.80	1.69	3.24	1.68
8500	1.38	2	23.23	985.52	0.82	1.74	3.34	1.73
9000	1.38	2	23.90	1,014.09	0.85	1.79	3.44	1.78
10000	1.38	2	25.20	1,068.94	0.89	1.89	3.62	1.88
10500	1.38	2	25.82	1,095.34	0.91	1.94	3.71	1.93
11000	1.38	2	26.42	1,121.12	0.93	1.98	3.80	1.97
11500	1.38	2	27.02	1,146.31	0.96	2.03	3.89	2.02
12000	1.38	2	27.60	1,170.97	0.98	2.07	3.97	2.06
12500	1.38	2	28.17	1,195.12	1.00	2.12	4.05	2.10
13000	1.38	2	28.73	1,218.78	1.02	2.16	4.13	2.14
13500	1.38	2	29.27	1,242.00	1.04	2.20	4.21	2.19
14000	1.38	2	29.81	1,264.79	1.05	2.24	4.29	2.23
14500	1.38	2	30.34	1,287.18	1.07	2.28	4.36	2.27
15000	1.38	2	30.86	1,309.18	1.09	2.32	4.44	2.30
Modeled Exposure (µR/hr) @ 5 pCi/g								
	Cs-137	1.23E+00						
	Co-60	5.03E+00						

Table 2-D3
Stage 2 Scan MDC In Varying Backgrounds

Background				CPM	MDER µR/hr		Scan MDC pCi/g	
	d'	i	s_i	$MDCR_{surveyor}$	Cs-137	Co-60	Cs-137	Co-60
2000	2.48	4	28.64	607.47	0.51	1.08	2.06	1.07
2500	2.48	4	32.02	679.18	0.57	1.20	2.30	1.20
3000	2.48	4	35.07	744.00	0.62	1.32	2.52	1.31
3500	2.48	4	37.88	803.61	0.67	1.42	2.72	1.41
4000	2.48	4	40.50	859.10	0.72	1.52	2.91	1.51
4500	2.48	4	42.95	911.21	0.76	1.61	3.09	1.60
5000	2.48	4	45.28	960.50	0.80	1.70	3.26	1.69
5500	2.48	4	47.49	1,007.38	0.84	1.78	3.42	1.77
6000	2.48	4	49.60	1,052.17	0.88	1.86	3.57	1.85
6500	2.48	4	51.63	1,095.14	0.91	1.94	3.71	1.93
7000	2.48	4	53.57	1,136.48	0.95	2.01	3.85	2.00
7500	2.48	4	55.45	1,176.37	0.98	2.08	3.99	2.07
8000	2.48	4	57.27	1,214.95	1.01	2.15	4.12	2.14
8500	2.48	4	59.04	1,252.34	1.04	2.22	4.25	2.20
9000	2.48	4	60.75	1,288.65	1.07	2.28	4.37	2.27
10000	2.48	4	64.03	1,358.35	1.13	2.40	4.61	2.39
10500	2.48	4	65.61	1,391.90	1.16	2.46	4.72	2.45
11000	2.48	4	67.16	1,424.65	1.19	2.52	4.83	2.51
11500	2.48	4	68.67	1,456.67	1.21	2.58	4.94	2.56
12000	2.48	4	70.14	1,488.00	1.24	2.63	5.04	2.62
12500	2.48	4	71.59	1,518.68	1.27	2.69	5.15	2.67
13000	2.48	4	73.01	1,548.76	1.29	2.74	5.25	2.73
13500	2.48	4	74.40	1,578.26	1.32	2.79	5.35	2.78
14000	2.48	4	75.77	1,607.22	1.34	2.84	5.45	2.83
14500	2.48	4	77.11	1,635.67	1.36	2.89	5.55	2.88
15000	2.48	4	78.42	1,663.63	1.39	2.94	5.64	2.93
Modeled Exposure (µR/hr) @ 5 pCi/g								
	Cs-137	1.23E+00						

Bicron Detector Specifications

002

Models: G1/G1LE/G2/G3
NaI(Tl) Scintillation Probes

G1 Features

- 1" x 1" CRYSTAL
- HIGH GAMMA SENSITIVITY

G1LE Features

- LOW ENERGY GAMMA
- DETECTION
- ^{125}I EFFICIENCY >90%

GENERAL: The probes described on this data sheet use NaI(Tl) scintillators to detect gamma and x-ray energies. The energy range and the count rate (efficiency/sensitivity) desired determine which probe to use in a given application.

G2/G3 Features

- 2" x 2" CRYSTAL (G2)
- 3" x 3" CRYSTAL (G3)
- RUGGED CONSTRUCTION
- SINGLE MHV CONNECTOR
- HIGH GAMMA SENSITIVITY

When matched with the single channel analyzers of the ANALYST or LABTECH, these probes can discriminate between low and high energy sources or detect low energy radiation while reducing background counting rate.

The G1 is a compact, lightweight, general purpose probe useful for detecting small changes in background.

The G1LE has a thin crystal and entrance window (aluminum or beryllium) for enhanced detection of ^{125}I and other low energy sources.

The G2 is a ruggedly built probe with a larger scintillation crystal than the G1 for greater sensitivity. In turn, the G3 has a still larger volume for sensitivity greater than the G2.

The G1, G1LE, G2 and G3 are compatible with portable survey meters, analyzers, and scalers which accept scintillation probes. These include the Bicron ANALYST, SURVEYOR M, SURVEYOR MS, LABTECH and FRISK-TECH.

HARSHAW BICRON RADIATION MEASUREMENT PRODUCTS

BICRON • 6801 Cochran Road • Solon, OH 44139
Phone: (216)248-7400 • (800)472-5656
Fax: (216)349-8581
BICRON Technologies Vertriebs-GmbH
Viktoriastrasse 5 • 5632 Wermelskirchen 1 • Germany
Phone: 49-2196-3097 • Fax: 49-2196-8518

Saint-Gobain/Norton Industrial Ceramics Corporation

Bicron Detector Specifications

Models: G1/G1LE/G2/G3 Specifications

	G1 Probe	G1LE Probe	G2 Probe	G3 Probe
Radiation Detected	Gamma >60 keV	Gamma, 10-60 keV	Gamma >60 keV	Gamma >60 keV
	NaI(Tl)	NaI(Tl)	NaI(Tl)	
Crystal Dimensions	1" x 0.97"	1" x 0.04"	2" x 2"	
Housing Material	Aluminum	Aluminum	Aluminum	
Housing Thickness	0.13" side wall 0.07" end	0.13" side wall	0.02"	
Window Density	N/A	6.9 mg/cm² Al 23 mg/cm² Be	N/A	N/A
Photomultiplier Tube	1.125" dia., 11 stage, selected, bialkali cathode	1.125" dia., 11 stage, selected, bialkali cathode	2.0" dia., 10 stage, selected, bialkali cathode	3.0" dia., 10 stage, selected, bialkali cathode
Magnetic Shield	Conetic foil	Conetic foil	Mu-metal	
Operating Voltage	Variable	Variable	Variable	
Maximum Voltage	1500 V	1500 V	1500 V	
Voltage Divider Termination	Single MHV	Single MHV	Single MHV (others available)	
Total Impedence	110 meg	110 meg	110 meg (other ratings available)	
Pulse Height Resolution	8.5% or better for ^{137}Cs (663 keV)	20% or better for ^{125}I (35 keV)	8.5% or better for ^{137}Cs (663 keV)	
Relative Sensitivity	300 kcpm/mR/h for ^{137}Cs	375 kcph/mR/h for ^{125}I	1200 kcpm/mR/h for ^{137}Cs	
Efficiency	46% for ^{137}Cs	99% for ^{125}I	74% for ^{137}Cs	
	-40° to +50°C	-40° to +50°C	-40° to +50°C	
	10°C per hour	10°C per hour	10°C per hour	
	7.9" x 1.37" 20 x 3.5 cm	7.1" x 1.37" 18 x 3.5 cm	8.37" x 2.3" 21.3 x 5.8 cm	9.87" x 3.25" (max) 25.1 x 8.3 cm
Weight	9.8 oz 278 g	7.5 oz 213 g	1.79 lb 0.81 kg	4.0 lb 1.81 kg

* Efficiency is defined as that percentage of a well collimated beam incident on the center face of the detector which is counted by the detector.

APPLICATION NOTES:

G1.5 and G2LE model probes are also available. The G1.5 uses a 1.5" diameter by 1" thick crystal to provide a larger sensitive area and more efficiency than the G1.

The G2LE is a 2" diameter version of the G1LE, and, like the G1LE, is optimized for ^{125}I detection. The optional beryllium window for the G1LE and G2LE provides greater low energy efficiency.

Bicron's capabilities in NaI(Tl) and organic scintillators enable us to offer a wide variety of scintillation probes. Versatile detection systems result from combining these probes with Bicron's ANALYST, LABTECH, FRISK-TECH, or SURVEYOR M & MS Instruments.

Manufacturer reserves right to alter specifications.

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MicroShield Model

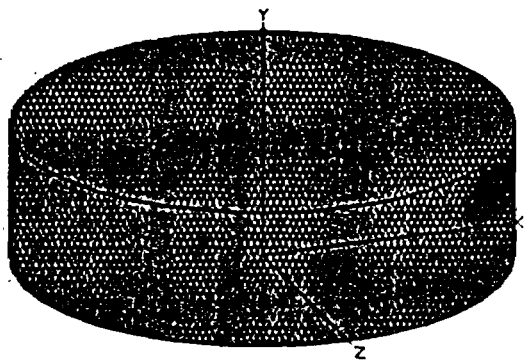
Cs-137

MicroShield v5.03 (5.03-00060)
Consumers Energy

Page : 1
DOS File: CS137@28.MS5
Run Date: October 15, 2002
Run Time: 11:45:47 AM
Duration: 00:00:00

File Ref:
Date:
By:
Checked:

Case Title: Scan MDC
Description: Cs-137 uniform concentration, 28 cm radius
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	15.0 cm	5.9 in
Radius	28.0 cm	11.0 in

Dose Points

	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ba-137m	2.7960e-007	1.0345e+004	7.5680e-006	2.8002e-001
Cs-137	2.9556e-007	1.0936e+004	8.0000e-006	2.9600e-001

Buildup
The material reference is : Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	2.142e+02	3.852e-05	4.667e-05	3.209e-07	3.888e-07
0.0322	3.952e+02	7.408e-05	9.030e-05	5.962e-07	7.267e-07
0.0364	1.438e+02	4.101e-05	5.350e-05	2.330e-07	3.040e-07
0.6616	9.309e+03	3.553e-01	6.330e-01	6.889e-04	1.227e-03
TOTALS:	1.006e+04	3.555e-01	6.332e-01	6.900e-04	1.229e-03

MicroShield Model

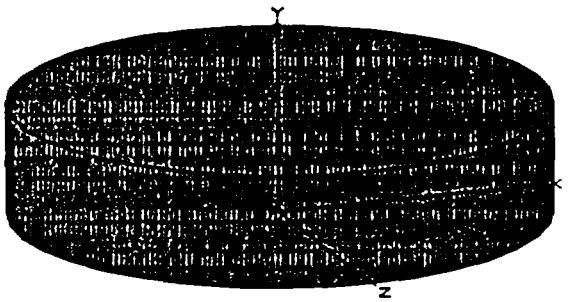
Scan Co-60

MicroShield v5.03 (5.03-00060)
Consumers Energy

'e : 1
: File: CO60@28.MS5
. Date: October 15, 2002
. Time: 12:10:15 PM
'ation: 00:00:00

File Ref:
Date:
By:
Checked:

Case Title: Scan MDC
Description: C0-60 uniform concentration, 28 cm radius
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	15.0 cm	5.9 in
Radius	28.0 cm	11.0 in

Dose Points

	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.0012:

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Co-60	2.9556e-007	1.0936e+004	8.0000e-006	2.9600e-001

Buildup
The material reference is : Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial	10

Results

ıergy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
.6938	1.784e+00	7.244e-05	1.272e-04	1.399e-07	2.456e-07
.1732	1.094e+04	8.782e-01	1.335e+00	1.569e-03	2.386e-03
.3325	1.094e+04	1.035e+00	1.523e+00	1.795e-03	2.643e-03
TALS:	2.187e+04	1.913e+00	2.858e+00	3.364e-03	5.029e-03

References

1. MicroShield v5.03
   Grove Engineering
   15215 Shady Grove Road
   Rockville, Maryland 20850

2. NUREG-1507, Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions
   U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001
   Office of Nuclear Regulatory Research

3. NUREG-1575, Multi-Agency Radiation Survey And Site Investigation Manual U. S. Nuclear Regulatory Commission Washington, DC 20555-0001

4. Harshaw Bicron Radiation Measurement Products
   6081 Cochran Road Solon, OH 44139

Characterization Summary

Radiological surveys conducted in support of site characterization are designed by directives established through the Data Quality Objective (DQO) process and follow the guidance provided in NUREG-1575. Survey design information contained in this Appendix follows the applicable guidance provided in NUREG-1575. The Big Rock Point Impacted Area is 0.540 km^2 (133.3 acres) in size and currently consists of 27 survey units. The characterization survey process has identified less than 1% of this area to contain residual radioactivity of plant origin. Four survey units (Discharge Canal, 5(1), 5(2), and 8) qualify as complex locations containing one or more of the following:

- Identified contaminant levels requiring remediation,
- Previous soil remediation and backfill within the survey unit,
- Subsurface contamination,
- Subsurface components currently supporting containment ventilation or continued operation of the fuel pool, or
- Geomorphologic conditions requiring complex sampling techniques (Discharge Canal).

Measurement instrumentation and methods used for the performance of characterization surveys are detailed in Sections 2.3.4.and 2.4.4.1. This appendix defines the radiological status of Impacted area soils and provides the characterization survey findings of individual survey units to include:

- Physical description and brief history of the survey unit,
- Current radiological status,
- Data summary,
- The primary survey design and summary of all supporting surveys,
- Maps defining the survey unit and identifying sample point locations, and
- Survey results.

Survey Unit 1

Description

Survey Unit 1 is an area of approximately 1,600 m^2 that occupies the southwest corner of the Protected Area. The Butler Building, Contaminated Warehouse, Calibration Shack, and the QA/QC Warehouse are located in this area. Subsurface structures and equipment in Survey Unit 1 include building foundations, plumbing connections, fiber optics, and electrical conduit.

History

The HSA identifies this survey as potentially containing residual radioactivity . This location is adjacent to the transport route that was used to move spent resin and filter material from the Protected Area to the Radwaste Compound. Buildings located in this area have been used for the storage of contaminated materials. The Butler Building and the QA/QC Warehouse have undergone remediation following the discovery of fixed structural contamination.

Radiological Status

Radioactivity of potential plant origin was not identified in Survey Unit 1 above Initial Derived Concentration Guideline Levels (IDCGLs). Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified in soil analyses. The radiological status of this survey unit is Class 1 based on proximity to the following area locations:

- Contaminated materials transport pathways,
- Areas of known soil contamination scheduled for excavation and subsurface component removal,
- Locations scheduled for soil remediation, and
- Buildings and foundations scheduled for demolition and removal of contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.038
Standard Deviation (&)	0.076

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{\text{DCGL} - \text{LBGR}}{\sigma} = \frac{5.11 - 2.5}{0.076} = 34$$

   With ƒ and ƀ error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   Survey unit dimensions 40 x 50 meters

Random Numbers 0.82, 0.31
X = (0.82)(40 m) = 32.8m
Y = (0.31)(50 m) = 15.5 m

$$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{1600/14} = 10.7 \text{ m spacing}$$

As a conservative measure 20 samples were collected using 10 meter spacing. For data points falling outside the survey unit or where obstructions prohibited sample collection, alternate sample locations were identified by the random selection process.

Supporting Surveys

One deep-core profile was obtained in survey grid 363 as shown on the following page. Sampling was performed to a depth of 2.4 m by a mechanically driven 3-inch diameter split-spoon hollow stem auger. The sample data point was judgmentally selected based on location availability due to subsurface piping, fiber optics, and electrical power supply.

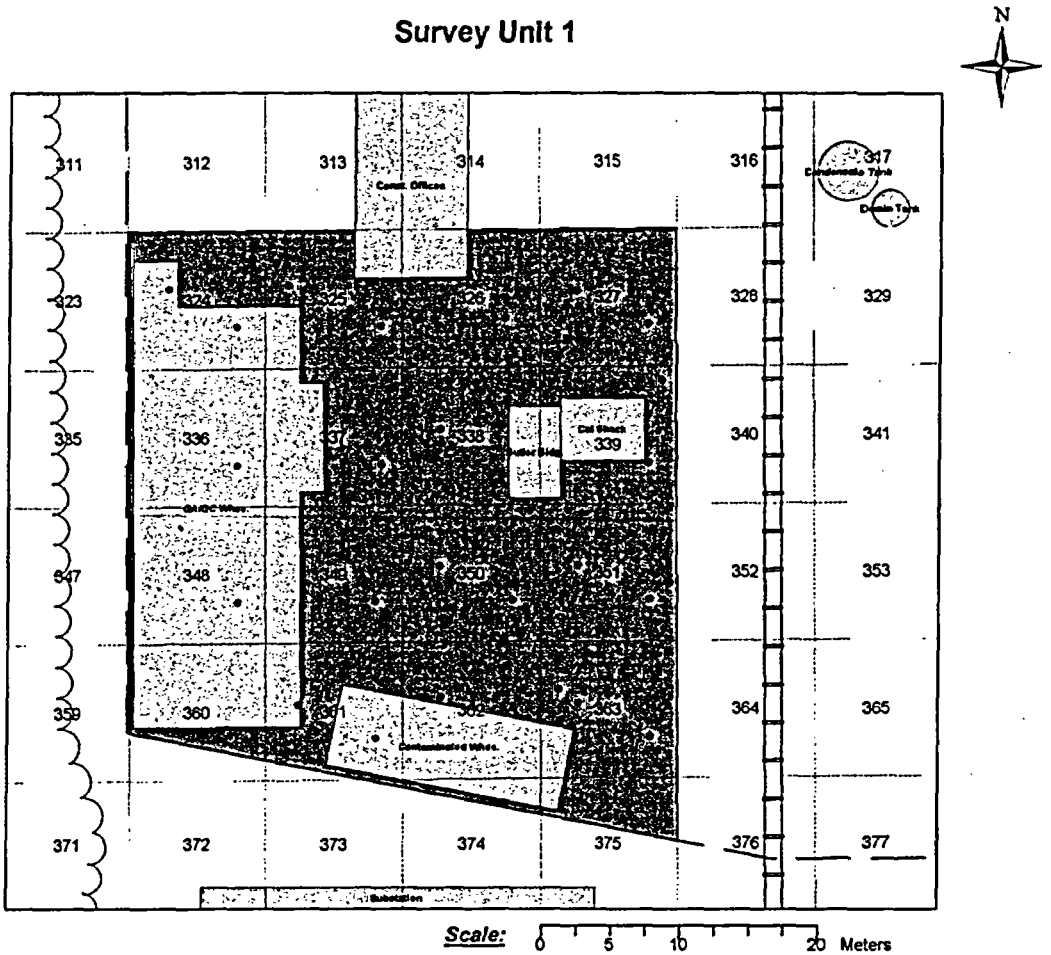
Data Summary

Survey Unit 1

Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$1A_1$	23	Cs_{137}	0.16	0.37
		Co_{60}**	0.11	0.11
$1A_{1\ deepcore1}$	4	nd	-	-

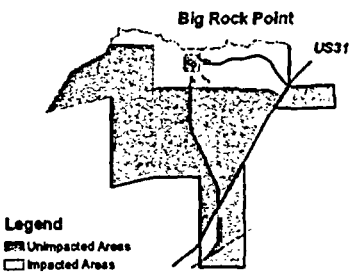
* nd indicates non detect
** Activity detected in one sample only

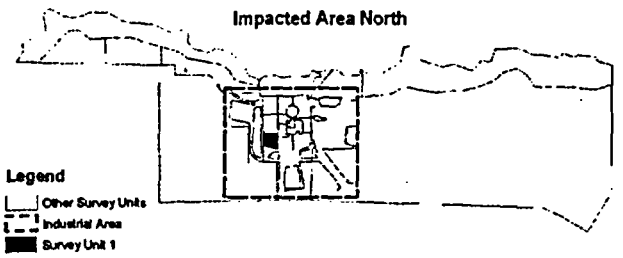
Survey Unit 1



Legend

- Survey Unit 1
- Numbered Local Coordinate Grid
- Buildings
- Soil Sample Locations





Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
1A	324	(3.0,5.8)	0.00-0.15	0.07		nd	0.04	nd	0.18
1A	324	(8.0,3.0)	0.00-0.15	nd	0.04	nd	0.02	nd	0.19
1A	325	(1.8,6.0)	0.00-0.15	0.05		nd	0.04	nd	0.18
1A	325	(8.5,3.0)	0.00-0.15	0.07		nd	0.04	nd	0.18
1A	326	(7.5,3.5)	0.00-0.15	0.33		0.11		nd	0.28
1A	327	(2.8,5.5)	0.00-0.15	0.26		nd	0.03	nd	0.17
1A	327	(8.0,3.0)	0.00-0.15	0.06		nd	0.04	nd	0.19
1A	336	(8.0,3.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.17
1A	337	(8.5,3.0)	0.00-0.15	0.07		nd	0.05	nd	0.16
1A	338	(2.8,5.5)	0.00-0.15	0.28		nd	0.04	nd	0.19
1A	339	(8.0,3.0)	0.00-0.15	0.37		nd	0.08	nd	0.30
1A	339	(9.0,9.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.16
1A	348	(8.0,3.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.21
1A	349	(8.0,3.0)	0.00-0.15	nd	0.26	nd	0.05	nd	0.19
1A	350	(2.8,5.5)	0.00-0.15	0.36		nd	0.04	nd	0.18
1A	350	(8.0,3.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.23
1A	351	(2.8,5.5)	0.00-0.15	0.03		nd	0.04	nd	0.17
1A	351	(8.0,3.0)	0.00-0.15	nd	0.03	nd	0.03	nd	0.15
1A	361	(2.4,5.5)	0.00-0.15	0.05		nd	0.03	nd	0.17
1A	361	(8.0,3.0)	0.00-0.15	0.08		nd	0.04	nd	0.18
1A	362	(2.8,6.0)	0.00-0.15	0.09		nd	0.03	nd	0.17
1A	363	(2.8,5.5)	0.00-0.15	0.18		nd	0.10	nd	0.32
1A	363	(8.0,3.0)	0.00-0.15	0.18		nd	0.10	nd	0.33
$1A_{deepcore1}$	363	(1.3,6.5)	0.00-0.90	0.03		nd	0.07	nd	0.21
$1A_{deepcore1}$	363	(1.3,6.5)	0.90-1.20	nd	0.08	nd	0.09	nd	0.35
$1A_{deepcore1}$	363	(1.3,6.5)	1.20-180	nd	0.05	nd	0.11	nd	0.41
$1A_{deepcore1}$	363	(1.3,6.5)	1.80-240	nd	0.03	nd	0.05	nd	0.25

[a] nd indicates non detect, MDA reported

[b] No entry in MDA columns is provided when residual radioactivity is detected.

Survey Unit 2

Description

Survey Unit 2 is approximately 2000 m^2 and occupies the west–central section of the Protected Area. This area contains the Maintenance/Construction Complex (MCC). Subsurface structures and equipment in Survey Unit 2 include the MCC building foundation, plumbing connections, fiber optics, electrical conduit runs, and a section of the site Fire Protection System piping.

History

The HSA identifies this survey unit to potentially contain radioactive contamination in area soils. Survey Unit 2 is adjacent to the transport route used to move spent resin and filter material from the Protected Area to the Radwaste Compound. The MCC has not been used for the storage of contaminated materials and equipment.

Radiological Status

Residual radioactivity was not identified in Survey Unit 2 above established background concentrations. Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified in deep-core sample analyses. The radiological status of this survey unit is Class 1 based on proximity to the following area locations:

- Contaminated material transport pathways,
- Areas of known soil contamination scheduled for excavation and subsurface component removal,
- Locations scheduled for soil remediation, and
- Buildings and foundations scheduled for demolition and removal of contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.014
Standard deviation (σ)	0.025

The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{\text{DCGL} - \text{LBGR}}{\sigma} = \frac{5.11 - 2.5}{0.025} = 104$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   Survey unit dimensions 40 x 50 meters
   Random Numbers 0.60, 0.13
   X = (0.60)(40 m) = 24 m
   Y = (0.13)(50 m) = 6.5 m

   Sample Spacing $L = \sqrt{Area/N} = \sqrt{2000/14} = 11.9$ meters

   As a conservative measure 20 samples were collected using 10 meter spacing. For data points falling outside the survey unit or where obstructions prohibited sample collection, alternate sample locations were identified by the random selection process described above.

Supporting Surveys
A deep-core profile survey was conducted in survey grids 224 and 3129. Sampling was performed to a maximum depth of 2.4 meters by split-spoon, hollow-stem auger. Sample point locations were judgmentally selected based on historical data, process knowledge and the potential to contain subsurface radioactivity of plant origin. Sample point locations for deep-core profiles are limited in this survey unit due to the safety concerns associated underground systems and power supplies that remain in service.

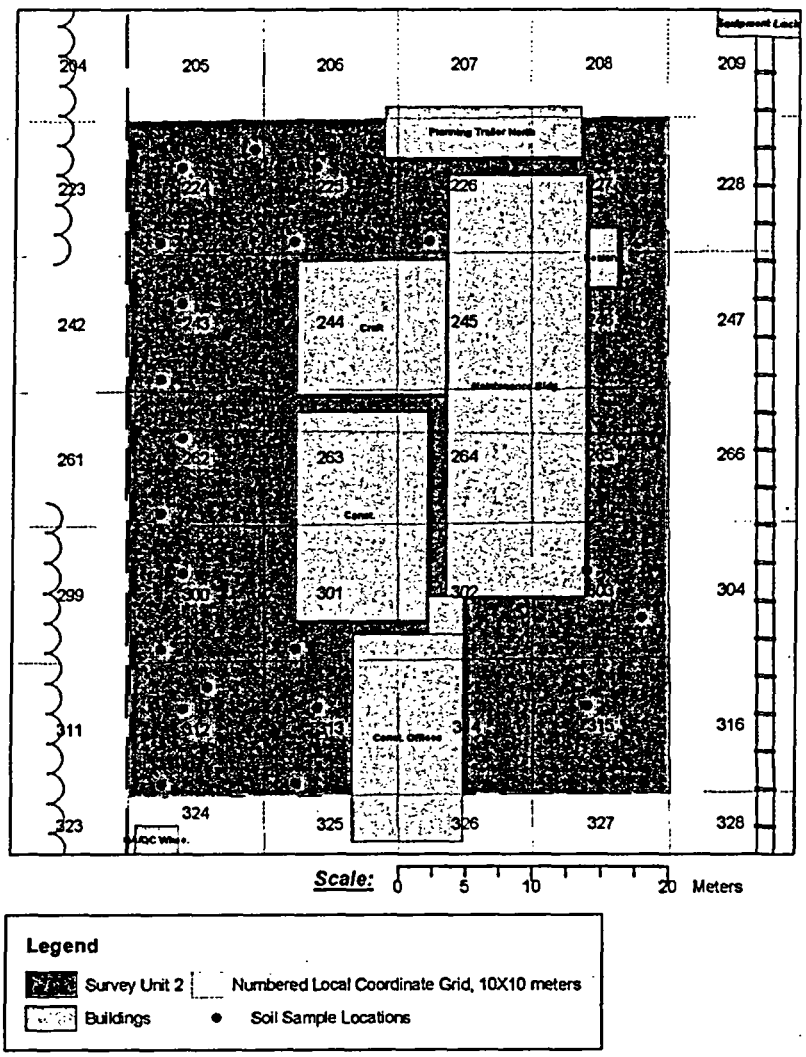
Data Summary

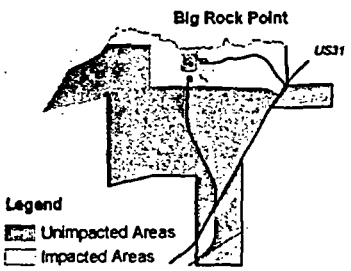
Survey Unit 2

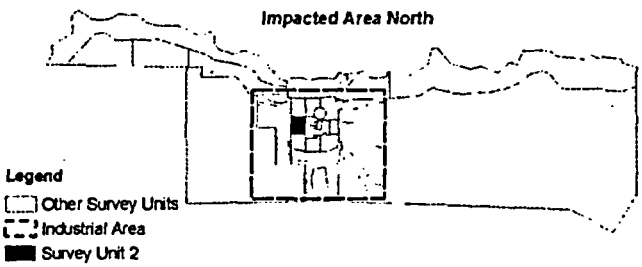
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$2A_1$	20	Cs_{137}	0.24	0.92
$2A_{1\ deepcore1}$	11	nd	-	-

* nd indicates non detect

Survey Unit 2







Survey Results

Survey	Grid	Coordinate (x,y) (m)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
2A	224	(2.4,0.9)	0.00-0.15	0.92		nd	0.08	nd	0.27
2A	224	(4.0,6.5)	0.00-0.15	0.18		nd	0.13	nd	0.26
2A	225	(2.4,0.9)	0.00-0.15	0.14		nd	0.08	nd	0.28
2A	225	(4.0,6.5)	0.00-0.15	nd	0.13	nd	0.13	nd	0.23
2A	226	(2.4,0.9)	0.00-0.15	0.10		nd	0.11	nd	0.16
2A	243	(2.4,0.9)	0.00-0.15	0.33		nd	0.13	nd	0.22
2A	243	(4.0,6.5)	0.00-0.15	0.08		nd	0.10	nd	0.17
2A	262	(2.4,0.9)	0.00-0.15	nd	0.03	nd	0.03	nd	0.17
2A	262)	(4.0,6.5)	0.00-0.15	0.29		nd	0.09	nd	0.33
2A	300	(2.4,0.9)	0.00-0.15	nd	0.03	nd	0.03	nd	0.15
2A	300	(4.0,6.5)	0.00-0.15	0.06		nd	0.04	nd	0.18
2A	301	(2.4,0.9)	0.00-0.15	0.39		nd	0.11	nd	0.21
2A	303	(4.0,6.5)	0.00-0.15	0.04		nd	0.11	nd	0.27
2A	303	(8.0,3.0)	0.00-0.15	0.15		nd	0.10	nd	0.24
2A	312	(2.4,0.9)	0.00-0.15	0.03		nd	0.04	nd	0.20
2A	312	(4.0,6.5)	0.00-0.15	0.03		nd	0.04	nd	0.19
2A	313	(2.4,0.9)	0.00-0.15	0.15		nd	0.05	nd	0.20
2A	313	(4.0,6.5)	0.00-0.15	0.83		nd	0.06	nd	0.26
2A	315	(4.0,6.5)	0.00-0.15	0.19		nd	0.04	nd	0.18
2A	315	(4.0,6.5)	0.00-0.15	nd		nd	0.06	nd	0.24
$2A_{deep\ core1}$	224	(9.4,7.8)	0.00-0.15	nd	.08	nd	0.08	nd	0.27
$2A_{deep\ core1}$	224	(9.4,7.8)	0.60-1.20	nd	0.08	nd	0.07	nd	0.38
$2A_{deep\ core1}$	224	(9.4,7.8)	1.20-1.80	nd	0.04	nd	0.04	nd	0.18
$2A_{deep\ core1}$	224	(9.4,7.8)	1.80-2.40	nd	0.07	nd	0.08	nd	0.37
$2A_{deep\ core1}$	224	(9.4,7.8)	2.40-3.00	nd	0.05	nd	0.07	nd	0.35
$2A_{deep\ core1}$	224	(9.4,7.8)	3.00-3.60	nd	0.07	nd	0.09	nd	0.38
$2A_{deep\ core1}$	312	(2.4,0.9)	0.00-0.15	nd	0.09	nd	0.10	nd	0.28
$2A_{deep\ core1}$	312	(2.4,0.9)	0.60-1.20	nd	0.06	nd	0.13	nd	0.34
$2A_{deep\ core1}$	312	(2.4,0.9)	1.20-1.80	nd	0.03	nd	0.04	nd	0.15
$2A_{deep\ core1}$	312	(2.4,0.9)	1.80-2.40	nd	0.08	nd	0.11	nd	0.38
$2A_{deep\ core1}$	312	(2.4,0.9)	240 – 300	nd	0.04	nd	0.05	nd	0.27

[a] nd indicates non detect, MDA reported
[b] No entry in MDA columns is provided when residual radioactivity is detected.

Survey Unit 3

Description

Survey Unit 3 is approximately 2000 m^2 and occupies the northwestern section of the Protected Area. Subsurface structures and equipment located in this area include electrical conduit, storm drains, Fire Protection System piping and Post Incident System piping.

History

The HSA identifies this survey unit to potentially contain radioactive contamination in area soils. Survey Unit 3 is adjacent to the transport route used to move spent resin and filter material from the Protected Area to the Radwaste Compound. A trash incineration site for the burning of radiologically clean refuse was formerly located in this area. Radioactivity identified in incinerator ash has been documented by the HSA .

The Alternate Shutdown Building was dismantled and removed from this area in 2001 to prepare for construction of the transport pathway that will be used to move spent fuel to the ISFSI storage pad. Characterization surveys supporting this construction effort ($3A_2$ and $3A_3$) were conducted prior to road surfacing and have been included in the Survey Results table.

Radiological Status

Residual radioactivity was not identified in Survey Unit 3 above the IDCGL values. Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified above trace values in deep-core sampling analyses. The radiological status of this survey unit is Class 1 based on proximity to the following area locations:

- Contaminated material transport pathways,
- Areas of known soil contamination scheduled for excavation and subsurface component removal,
- Locations scheduled for soil remediation, and
- Buildings and foundations scheduled for demolition and removal of contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60
Mean value (pCi/g)	0.086	0.013
Standard deviation (σ)	0.177	0.038

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{DCGL_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{DCGL_{Co}}\right)^2} = \sqrt{\left(\frac{0.177_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{0.0379_{Co}}{4.99_{Co}}\right)^2}$$

$\sigma = 0.036$

Using the Unity Rule, the DCGL weighted sum is 1.0. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1-0.5}{0.036} = 13.8$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

Survey unit dimensions 40 x 50 meters
Random Numbers 0.69, 0.47
X = (0.69)(40 m) = 27.6 m
Y = (0.47)(50 m) = 23.5 m

$$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{2000/14} = 11.9 \text{ meters}$$

As a conservative measure 17 samples were collected using 10 meter spacing. Sampling was prohibited in grids 206 and 207 due to subsurface obstruction.

Supporting Surveys

Supporting surveys include those conducted in support of ASD Building removal ($3A_{deepcore3}$, $3A_{deepcore2}$),and ISFSI road construction ($3A_2$, $3A_{deepcore\ 1}$). Deep core sampling was performed to a maximum depth of 6.6 meters. Sample point locations were judgmentally selected based on historical data, process knowledge and the potential to contain subsurface radioactivity of plant origin. Sample point locations for deep-core profiles are limited in this survey unit due to the safety concerns associated underground systems and power supplies that remain in service.

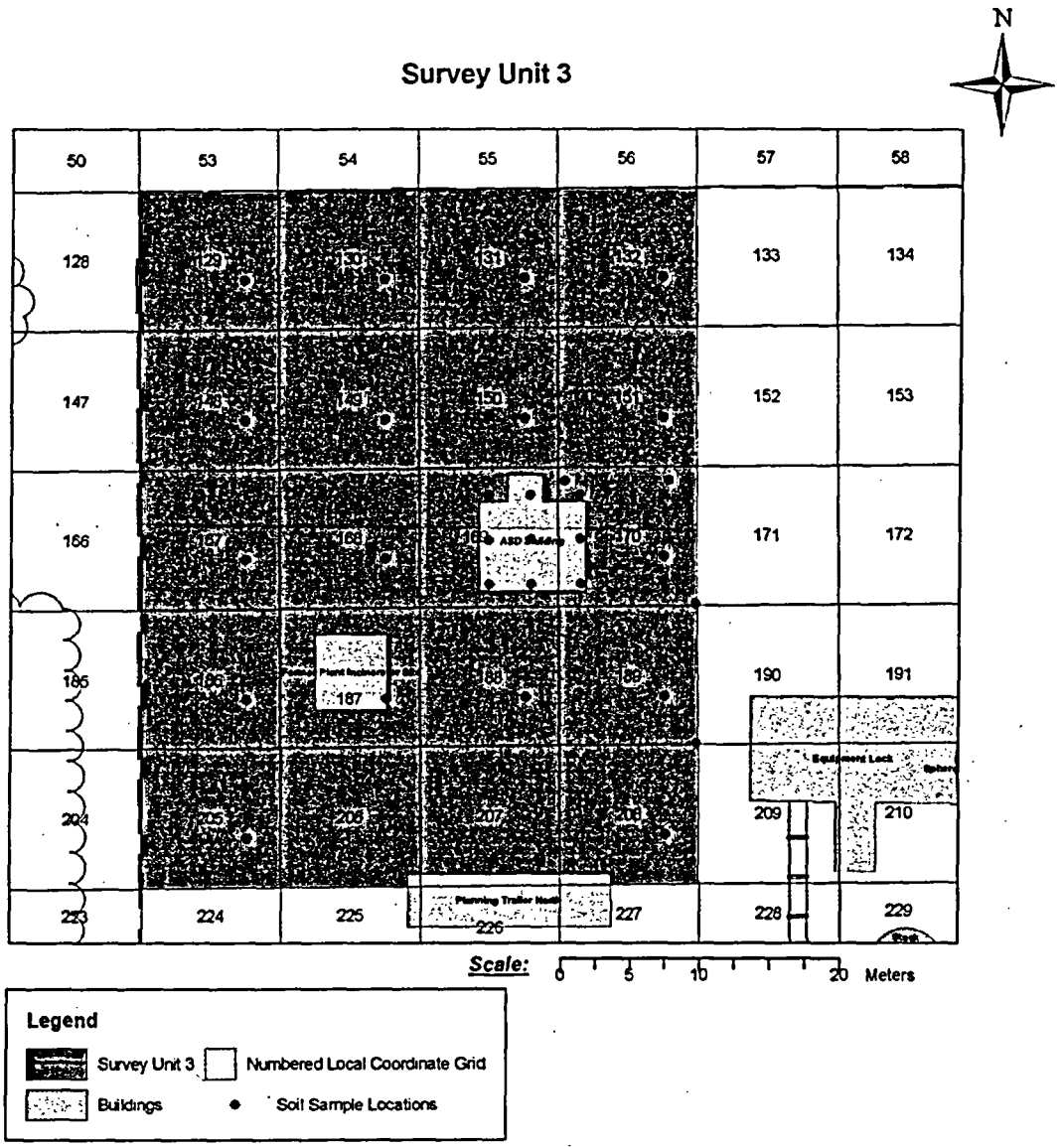
Data Summary

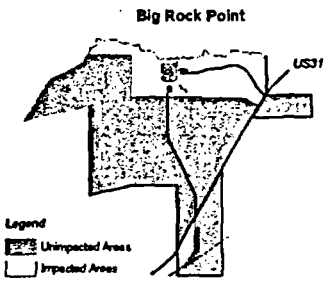
Survey Unit 3

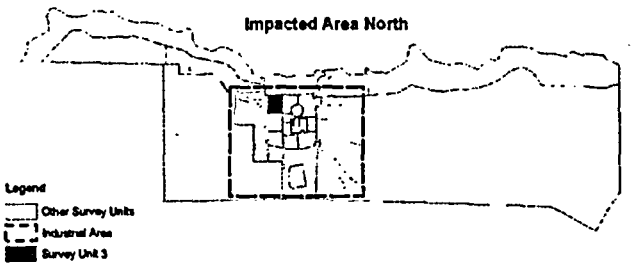
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$3A_1$	17	Cs_{137}	0.34	2.13
		Co_{60}**	0.28	0.28
$3A_2$	2	nd	-	-
$3A_{deepcore1}$	9	Cs-137	-	0.17
$3A_{deepcore2}$	3	nd	-	-
$3A_{deepcore3}$	9	Cs-137	-	0.06

* nd indicates non detect
** *Activity identified in one sample only*

Survey Unit 3







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$3A_1$	129	(7.6,3.5)	0.00-0.15	nd	0.15	nd	0.04	nd	0.26
$3A_1$	130	(7.6,3.5)	0.00-0.15	0.21		nd	0.09	nd	0.31
$3A_1$	131	(7.6,3.5)	0.00-0.15	0.32		nd	0.12	nd	0.22
$3A_1$	132	(7.6,3.5)	0.00-0.15	0.30		nd	0.06	nd	0.31
$3A_1$	148	(7.6,3.5)	0.00-0.15	0.08		nd	0.08	nd	0.27
$3A_1$	149	(7.6,3.5)	0.00-0.15	0.18		nd	0.07	nd	0.31
$3A_1$	150	(7.6,3.5)	0.00-0.15	nd	0.08	nd	0.09	nd	0.15
$3A_1$	151	(7.6,3.5)	0.00-0.15	0.07		nd	0.06	nd	0.30
$3A_1$	167	(7.6,3.5)	0.00-0.15	0.11		nd	0.08	nd	0.31
$3A_1$	168	(7.6,3.5)	0.00-0.15	nd	0.09	nd	0.12	nd	0.24
$3A_1$	170	(7.6,3.5)	0.00-0.15	0.16		nd	0.08	nd	0.32
$3A_1$	186	(7.6,3.5)	0.00-0.15	nd	0.14	nd	0.13	nd	0.25
$3A_1$	187	(7.6,3.5)	0.00-0.15	0.08		nd	0.07	nd	0.28
$3A_1$	188	(7.6,3.5)	0.00-0.15	nd	0.07	nd	0.11	nd	0.19
$3A_1$	189	(7.6,3.5)	0.00-0.15	0.31		nd	0.13	nd	0.18
$3A_1$	205	(7.6,3.5)	0.00-0.15	0.11		nd	0.06	nd	0.16
$3A_1$	208	(7.6,3.5)	0.00-0.15	2.13		0.28		nd	0.41
$3A_2$ [c]	189	(9.9,0.1)	0.00-0.15	nd	0.04	nd	0.05	nd	0.26
$3A_2$ [c]	170	(9.9,0.1)	0.00-0.15	nd	0.05	nd	0.05	nd	0.21
$3A_{deepcore1}$	170	(0.5,9.0)	0.00-0.20	0.06		nd	0.05	nd	0.22
$3A_{deepcore1}$	170	(0.5,9.0)	0.30-0.75	0.06		nd	0.05	nd	0.25
$3A_{deepcore1}$	170	(0.5,9.0)	1.05-1.50	nd	0.04	nd	0.06	nd	0.25
$3A_{deepcore1}$	170	(0.5,9.0)	1.80-2.25	nd	0.05	nd	0.06	nd	0.26
$3A_{deepcore1}$	170	(0.5,9.0)	2.55-2.70	0.17		nd	0.04	nd	0.21
$3A_{deepcore1}$	170	(0.5,9.0)	2.55-2.70	0.12		nd	0.05	nd	0.21
$3A_{deepcore1}$	170	(0.5,9.0)	3.3-4.5	nd	0.04	nd	0.02	nd	0.15
$3A_{deepcore1}$	170	(0.5,9.0)	4.5-5.1	nd	0.04	nd	0.04	nd	0.17
$3A_{deepcore1}$	170	(0.5,9.0)	5.4-6.6	nd	0.03	nd	0.04	nd	0.17
$3A_{deepcore2}$	189	(9.9,0.1)	0.15-30	nd	0.04	nd	0.05	nd	0.24
$3A_{deepcore2}$	189	(9.9,0.1)	0.30-0.45	nd	0.04	nd	0.06	nd	0.28
$3A_{deepcore2}$	189	(9.9,0.1)	0.45-0.60	nd	0.05	nd	0.07	nd	0.32
$3A_{deepcore3}$	169/170	[d]	0.00-0.60	nd	0.05	nd	0.05	nd	0.20
$3A_{deepcore3}$	169/170	[d]	0.00-0.60	nd	0.05	nd	0.05	nd	0.21
$3A_{deepcore3}$	169/170	[d]	0.00-0.60	nd	0.05	nd	0.05	nd	0.25
$3A_{deepcore3}$	169/170	[d]	0.00-0.60	nd	0.06	nd	0.04	nd	0.23
$3A_{deepcore3}$	169/170	[d]	0.00-0.60	nd	0.05	nd	0.05	nd	0.21
$3A_{deepcore3}$	169/170	[d]	0.00-0.60	0.03		nd	0.05	nd	0.23
$3A_{deepcore3}$	170	(1.6,1.6) [e]	0.60-0.75	nd	0.06	nd	0.06	nd	0.28
$3A_{deepcore3}$	169	(8.0,1.6) [e]	0.60-0.75	0.06		nd	0.05	nd	0.29
$3A_{deepcore3}$	169	(5.0,1.6) [e]	0.60-0.75	nd	0.05	nd	0.06	nd	0.22
$3A_{deepcore3}$	169	(5.0,4.8) [e]	0.60-0.75	nd	0.04	nd	0.04	nd	0.23
$3A_{deepcore3}$	169	(8.0,4.8) [e]	0.60-0.75	nd	0.03	nd	0.05	nd	0.18
$3A_{deepcore3}$	170	(1.6,4.8) [e]	0.60-0.75	0.06		nd	0.05	nd	0.25
$3A_{deepcore3}$	170	(1.6,8.0) [e]	0.60-0.75	nd	0.04	nd	0.05	nd	0.22
$3A_{deepcore3}$	169	(8.0,8.0) [e]	0.60-0.75	nd	0.04	nd	0.04	nd	0.26
$3A_{deepcore3}$	169	(5.0,8.0) [e]	0.60-0.75	nd	0.05	nd	0.06	nd	0.25

[a] nd indicated non detect, MDA reported
[b] No entry in MDA columns is provided when residual radioactivity is detected
[c] Survey Unit 3, portion of road construction survey
[d] Excavation Soil Fill For ASD Building Removal
[e] Base Elevation Survey During ASD Building Removal

Survey Unit 4

Description
Survey Unit 4 is approximately 1600 m^2 in size and occupies the north-central section of the Protected Area. Subsurface structures located in this area include electrical conduit, Fire Protection System piping, Post Incident System piping, and footings and foundations of the Equipment Lock and Containment Building.

History
The HSA identifies this survey unit to residual radioactivity in area soils. The Equipment Lock is the point of transfer for radiologically contaminated equipment and materials from the Containment Sphere. Survey Unit 4 is also adjacent to the transport route used for movement of spent resin and filter material from the Protected Area to the Radwaste Compound.

Radiological Status
Radioactivity of potential plant origin was not identified in Survey Unit 4 above the IDCGL value. Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified above trace values in deep-core sampling analyses. The radiological status of this survey unit is Class 1 based on proximity to the following area locations:

- Contaminated material transport pathways,
- Areas of known soil contamination scheduled for excavation and subsurface component removal,
- Locations scheduled for soil remediation, and
- Buildings and foundations scheduled for demolition and removal of contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60
Mean value (pCi/g)	0.720	0.043
Standard deviation (&)	0.127	0.003

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{DCGL_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{DCGL_{Co}}\right)^2} = \sqrt{\left(\frac{0.127_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{0.003_{Co}}{4.99_{Co}}\right)^2}$$

$\sigma = 0.025$

For the Unity Rule the DCGL for the weighted sum is 1.0. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL .

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1-0.5}{0.025} = 20$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 40 X 50 meters
   Random Numbers 0.59, 0.99
   X = (0.59)(40 m) = 23.6 m
   Y = (0.99)(50 m) = 49.5 m

   Sample Spacing $L = \sqrt{Area/N} = \sqrt{1616/14} = 10.7$ meters

   As a conservative measure 22 samples were collected using 8.7 meter spacing.

Supporting Surveys
Supporting surveys were conducted during soil preparation for construction of the loading dock annex to the Equipment Lock ($4A_3$, $4A_4$). Additional surveys were also performed ($4A_2$) prior to construction of the ISFSI road using systematic sampling. Sample point locations for deep-core profiles are limited in this survey unit due to the safety concerns associated with underground systems and power supplies that remain in service.

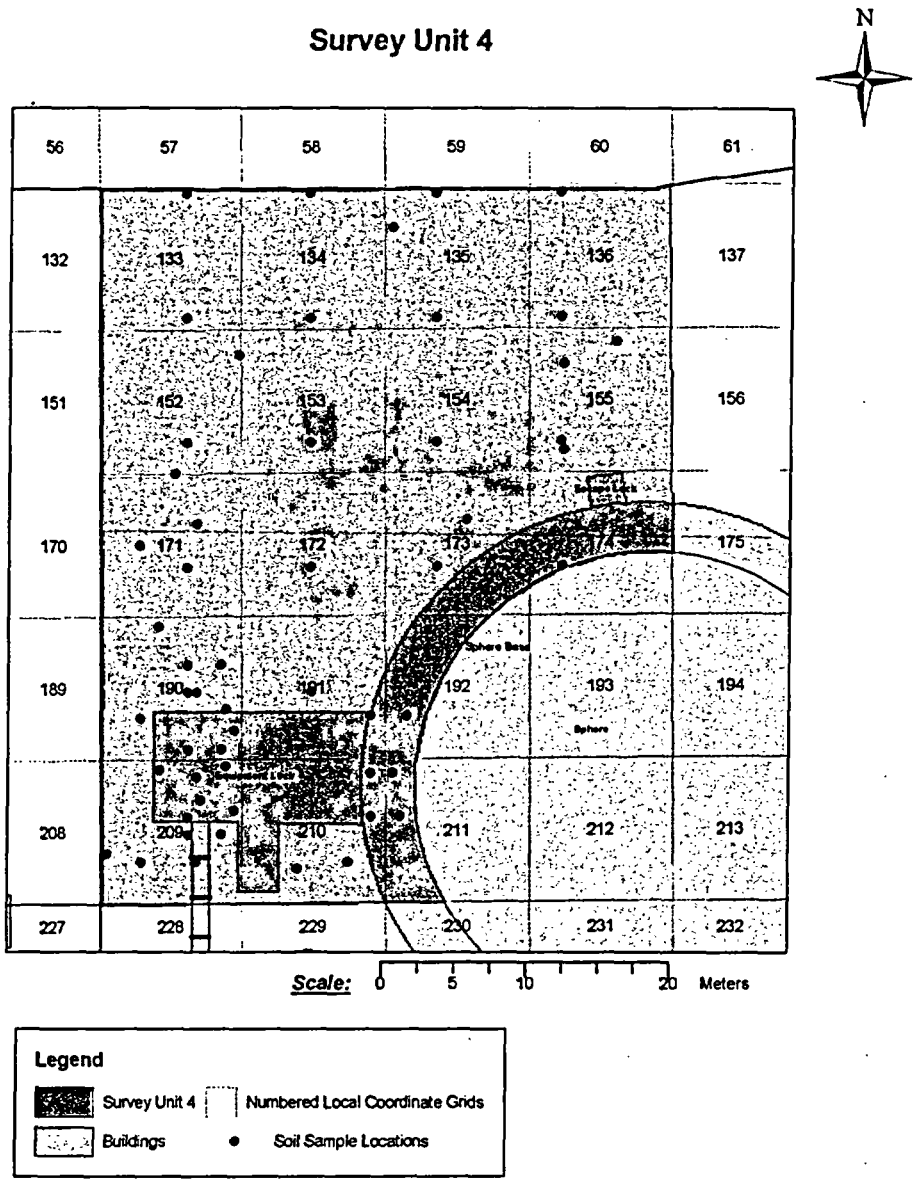
Data Summary

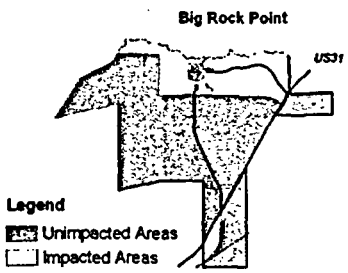
Survey Unit 4

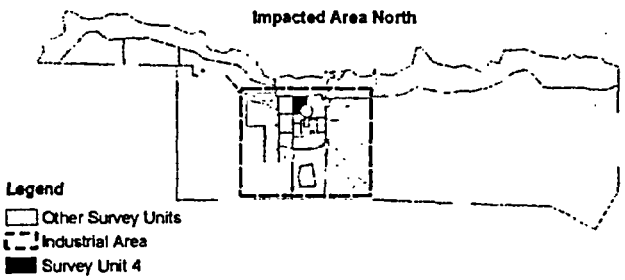
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$4A_1$	22	Cs-137	0.22	0.74
$4A_2$	17	Cs_{137}	0.05	0.07
		Co_{60}*	0.27	0.27
$4A_3$	10	Cs_{137}	0.57	1.22
		Co_{60}	0.06	0.07
$4A_4$	4	Cs-137*	0.17	0.17
$4A_{deepcore\ 1}$	22	Cs-137*	0.08	0.08
$4A_{deepcore\ 2}$	12	Cs-137*	0.10	0.10

* Activity identified in one sample only

Survey Unit 4







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$4A_1$	133	(6.2,9.5)	0.00-0.15	0.15		nd	0.09	nd	0.40
$4A_1$	134	(4.9,9.5)	0.00-0.15	0.28		nd	0.05	nd	0.21
$4A_1$	135	(3.6,9.5)	0.00-0.15	0.18		nd	0.06	nd	0.22
$4A_1$	136	(2.3,9.5)	0.00-0.15	0.20		nd	0.09	nd	0.37
$4A_1$	133	(6.2,0.8)	0.00-0.15	0.27		nd	0.04	nd	0.22
$4A_1$	134	(4.9,0.8)	0.00-0.15	0.34		nd	0.12	nd	0.33
$4A_1$	135	(3.6,0.8)	0.00-0.15	nd	0.11	nd	0.07	nd	0.40
$4A_1$	136	(2.3,0.8)	0.00-0.15	nd	0.05	nd	0.04	nd	0.19
$4A_1$	152	(6.2,2.1)	0.00-0.15	nd	0.07	nd	0.10	nd	0.42
$4A_1$	153	(4.9,2.1)	0.00-0.15	0.20		nd	0.04	nd	0.18
$4A_1$	154	(3.6,2.1)	0.00-0.15	0.74		nd	0.13	nd	0.38
$4A_1$	155	(2.3,2.1)	0.00-0.15	0.20		nd	0.10	nd	0.44
$4A_1$	171	(6.2,3.4)	0.00-0.15	nd	0.04	nd	0.05	nd	0.21
$4A_1$	172	(4.9,3.4)	0.00-0.15	0.08		nd	0.08	nd	0.33
$4A_1$	173	(3.6,3.4)	0.00-0.15	0.13		nd	0.09	nd	0.35
$4A_1$	174	(2.3,3.4)	0.00-0.15	0.10		nd	0.12	nd	0.31
$4A_1$	190	(6.2,4.7)	0.00-0.15	nd	0.06	nd	0.07	nd	0.38
$4A_1$	191	(4.9,4.7)	0.00-0.15	0.03		nd	0.09	nd	0.20
$4A_1$	209	(6.2,6.0)	0.00-0.15	nd	0.04	nd	0.05	nd	0.21
$4A_1$	210	(3.9,2.4)	0.00-0.15	nd	0.05	nd	0.04	nd	0.23
$4A_1$	210	(7.4,2.8)	0.00-0.15	nd	0.07	nd	0.09	nd	0.32
$4A_1$	155	(6.2,9.0)	0.00-0.15	nd	0.05	nd	0.03	nd	0.20
$4A_2$	209	(2.9,2.9)	0.00-0.15	nd	0.05	nd	0.07	nd	0.29
$4A_2$	209	(4.2,9.3)	0.00-0.15	nd	0.05	nd	0.07	nd	0.30
$4A_2$	190	(2.9,2.9)	0.00-0.15	nd	0.05	nd	0.07	nd	0.26
$4A_2$	190	(4.2,9.3)	0.00-0.15	nd	0.04	nd	0.05	nd	0.26
$4A_2$	171	(2.9,5.0)	0.00-0.15	nd	0.04	nd	0.06	nd	0.29
$4A_2$	171	(6.9,6.5)	0.00-0.15	nd	0.04	nd	0.06	nd	0.29
$4A_2$	152	(5.4,0.0)	0.00-0.15	nd	0.05	nd	0.06	nd	0.29
$4A_2$	152	(9.9,8.2)	0.00-0.15	nd	0.05	nd	0.06	nd	0.29
$4A_2$	190	(6.2,6.6)	0.00-0.15	0.04		nd	0.06	nd	0.26
$4A_2$	190	(8.6,6.6)	0.00-0.15	nd	0.05	nd	0.06	nd	0.31
$4A_2$	190	(6.8,4.7)	0.00-0.15	nd	0.04	nd	0.06	nd	0.26
$4A_2$	190	(6.2,0.7)	0.00-0.15	0.07		0.27		nd	0.33
$4A_2$	190	(8.6,0.7)	0.00-0.15	nd	0.05	nd	0.05	nd	0.28
$4A_2$	209	(6.8,8.8)	0.00-0.15	nd	0.05	nd	0.06	nd	0.25
$4A_2$	209	(6.2,4.8)	0.00-0.15	nd	0.05	nd	0.06	nd	0.29
$4A_2$	209	(8.6,4.8)	0.00-0.15	nd	0.05	nd	0.06	nd	0.27
$4A_2$	209	(6.8,2.9)	0.00-0.15	0.04		nd	0.05	nd	0.27

[a] nd indicates non detect, MDA reported
[b] No entry in MDA columns is provided when residual radioactivity is detected

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
$4A_3$	210	(9.0,9.0)	0.00-0.15	1.22		0.15		nd	0.29
$4A_3$	210	(9.0,6.0)	0.00-0.15	0.63		0.63		nd	0.34
$4A_3$	211	(0.5,9.0)	0.00-0.15	0.71		0.05		nd	0.26
$4A_3$	192	(1.5,3.0)	0.00-0.15	nd	0.04	nd	0.05	nd	0.26
$4A_3$	211	(1.0,6.0)	0.00-0.15	0.16		0.19		nd	0.21
$4A_3$	210	(9.0,9.0)	0.15-0.30	0.11		nd	0.07	nd	0.22
$4A_4$	209	(9.5,6.5)	0.80-0.95	nd	0.05	nd	0.06	nd	0.25
$4A_4$	209	(8.9,9.5)	0.80-0.95	0.17		nd	0.05	nd	0.26
$4A_4$	190	(9.5,2.0)	0.80-0.95	nd	0.05	nd	0.05	nd	0.25
$4A_4$	190	(8.9,3.5)	0.80-0.95	nd	0.05	nd	0.04	nd	0.24
$4A_{deepcore1}$	209	(7.1,7.2)	0.60-1.20	nd	0.07	nd	0.07	nd	0.41
$4A_{deepcore1}$	173	(5.7,6.7)	0.60-1.20	nd	0.05	nd	0.05	nd	0.17
$4A_{deepcore1}$	135	(0.6,7.1)	0.00-0.60	0.08		nd	0.04	nd	0.22
$4A_{deepcore1}$	173	(5.7,6.7)	0.00-0.60	nd	0.10	nd	0.09	nd	0.40
$4A_{deepcore1}$	209	(7.1,7.2)	0.00-0.60	nd	0.05	nd	0.06	nd	0.33
$4A_{deepcore1}$	209	(7.1,7.2)	0.00-0.60	nd	0.06	nd	0.09	nd	0.32
$4A_{deepcore1}$	135	(0.6,7.1)	1.20-1.80	nd	0.08	nd	0.03	nd	0.40
$4A_{deepcore1}$	173	(5.7,6.7)	1.20-1.80	nd	0.06	nd	0.05	nd	0.24
$4A_{deepcore1}$	209	(7.1,7.2)	1.20-1.80	nd	0.06	nd	0.06	nd	0.32
$4A_{deepcore1}$	135	(0.6,7.1)	1.80-2.40	nd	0.03	nd	0.03	nd	0.15
$4A_{deepcore1}$	173	(5.7,6.7)	1.80-2.40	nd	0.06	nd	0.11	nd	0.32
$4A_{deepcore1}$	209	(7.1,7.2)	1.80-2.40	nd	0.08	nd	0.08	nd	0.28
$4A_{deepcore1}$	135	(0.6,7.1)	2.40-3.00	nd	0.06	nd	0.10	nd	0.39
$4A_{deepcore1}$	173	(5.7,6.7)	2.40-3.00	nd	0.07	nd	0.07	nd	0.38
$4A_{deepcore1}$	209	(7.1,7.2)	2.40-3.00	nd	0.05	nd	0.07	nd	0.36
$4A_{deepcore1}$	173	(5.7,6.7)	3.00-3.60	nd	0.03	nd	0.05	nd	0.21
$4A_{deepcore1}$	209	(7.1,7.2)	3.00-3.60	nd	0.08	nd	0.11	nd	0.36
$4A_{deepcore1}$	135	(0.6,7.1)	3.60-4.20	nd	0.04	nd	0.04	nd	0.27
$4A_{deepcore1}$	173	(5.7,6.7)	3.60-4.20	nd	0.06	nd	0.11	nd	0.42
$4A_{deepcore1}$	135	(0.6,7.1)	4.20-4.80	nd	0.04	nd	0.04	nd	0.23
$4A_{deepcore1}$	209	(7.1,7.2)	4.20-4.80	nd	0.08	nd	0.10	nd	0.41
$4A_{deepcore1}$	209	(7.1,7.2)	4.80-5.40	nd	0.08	nd	0.13	nd	0.40
$4A_{deepcore2}$	155	(2.5,7.5)	0.00-0.60	nd	0.04	nd	0.04	nd	0.17
$4A_{deepcore2}$	155	(2.5,1.5)	0.00-1.20	0.10		nd	0.06	nd	0.23
$4A_{deepcore2}$	209	(0.5,3.5)	0.30-0.75	nd	0.04	nd	0.05	nd	0.23
$4A_{deepcore2}$	209	(0.5,3.5)	1.05-1.50	nd	0.04	nd	0.04	nd	0.28
$4A_{deepcore2}$	155	(2.5,1.5)	1.20-1.80	nd	0.05	nd	0.05	nd	0.23
$4A_{deepcore2}$	209	(0.5,3.5)	1.80-2.25	nd	0.03	nd	0.05	nd	0.21
$4A_{deepcore2}$	155	(2.5,1.5)	1.80-2.70	nd	0.04	nd	0.06	nd	0.20
$4A_{deepcore2}$	209	(0.5,3.5)	2.25-3.00	nd	0.04	nd	0.06	nd	0.24
$4A_{deepcore2}$	155	(2.5,1.5)	3.00-4.20	nd	0.04	nd	0.04	nd	0.20
$4A_{deepcore2}$	209	(0.5,3.5)	3.30-3.75	nd	0.03	nd	0.05	nd	0.20
$4A_{deepcore2}$	209	(0.5,3.5)	4.05-4.44	nd	0.03	nd	0.04	nd	0.17
$4A_{deepcore2}$	155	(2.5,1.5)	4.20-5.25	nd	0.04	nd	0.06	nd	0.25

[a] nd indicates non detect, MDA reported
[b] No entry in MDA columns is provided when residual radioactivity is detected

Survey Unit 5(1)

Description
Survey Unit 5(1) is an area of approximately 600 m^2 located at the southwest edge of the Containment Building. This location encompasses the Stack and the northern section of the Liquid Radwaste Vault. The Liquid Radwaste Vault is a subsurface concrete structure that contains the equipment used by the Liquid Radwaste Processing System. The roof of this structure is located at grade elevation and is composed of concrete covered by asphalt paving. Additional subsurface structures include, the Stack base, Radwaste System piping, fiber optics, electrical conduit, and the footings and foundations of the Equipment Lock, Containment Building and Turbine Building.

History
The HSA has identified radioactivity in this survey unit for localized areas of soil in close proximity to the former rail bed. This location was the transfer point for the removal of primary system resin and filters through disposal access hatches in the Liquid Radwaste Vault. Waste material was then routed to the Radwaste Building in preparation for shipment.

A contaminant migration pathway is known to have existed near the storage tank location in adjacent Survey Unit 5(2). The low topography formerly present along the rail bed once provided a storm water runoff pathway from the tank area into Survey Unit 5(1). Documented radiological events describe a number of piping leaks and spills that are known to have entered Survey Unit 5(1) through this drainage pathway.

Cleanup efforts have been conducted in this survey unit on several occasions. Following the removal of contaminated soil, clean fill was used to return remediated locations to proper grade. As a result, activity depth profiles conducted in these areas have identified an increase in activity near the base elevation of former soil removal locations. This activity is believed to result from contamination left in place during the remediation process

Radiological Status
Survey Unit 5(1) is relatively small and complex survey area. The Stack and Liquid Radwaste Processing System currently remain in service. As a result, building foundations, subsurface piping, and electrical power hazards limit the extent of soil sampling in many locations. Although trace values of Mn-54 were identified in two of the scoping survey samples used for design of the primary survey, Mn-54 was not identified in any subsequent characterization survey conducted in Survey Unit 5(1). Elevated concentrations of Cs-137 were identified in several samples taken along the rail bed, a former contaminant migration pathway. Further characterization of these areas will continue as systems and equipment are removed from the site.

The results of characterization analyses to date indicate that cleanup efforts may be required following the removal of road surfacing along an area east of the rail bed. This location was paved to satisfy the engineering requirements for movement of spent fuel to the ISFSI. The asphalt paving is scheduled to be removed following dismantlement of the Stack and Liquid Radwaste Processing System.

Excavation will be required for the removal of subsurface structures and equipment in this area. Characterization surveys are scheduled to continue during this excavation and remediation efforts will be conducted as necessary to satisfy the requirements for final status surveys. Survey Unit 5(1) is designated as Class 1.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60	Mn-54
Mean value (pCi/g)	2.62	0.61	0.049
Standard deviation (σ)	5.11	1.11	0.09

   Applying the Unity Rule,

$$\sigma_{UR} = \sqrt{\left(\frac{\sigma_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{4.99_{Co}}\right)^2 + \left(\frac{\sigma_{Mn}}{474_{Mn}}\right)^2}$$

$$\sigma_{UR} = \sqrt{\left(\frac{5.11}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{1.11}}{4.99_{Co}}\right)^2 + \left(\frac{0.09}{474_{Mn}}\right)^2}$$

$$\sigma_{UR} = 1.02$$

   For the Unity Rule the DCGL for the weighted sum is 1.0. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1-0.5}{1.02} = 0.49$$

   With α and β error levels of 0.05, the Sign Test requires 136 sample data points.

   A sample size of this magnitude was considered impractical for the primary survey of this complex area. A target value of 50 data points was selected for sample location and spacing determination. Due to inaccessible areas of this survey unit, only 33 data points were available for sampling within the survey unit. This sample size was considered sufficient to develop an initial comprehensive evaluation of the survey unit and provide the necessary input for the design of follow-up supporting surveys.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid, pattern with the southwest corner of the survey unit as origin.
   Bounding survey unit dimensions 30 X 30 meters
   Random Numbers 0.11, 0.99
   X = (0.11)(30 m) = 3.4 m
   Y = (0.23)(30 m) = 6.9 m

$$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{600/50} = 3.5 \text{ meters}$$

Supporting Surveys

Supporting surveys $5(1)A_2$ and $5(1)A_3$ were conducted prior to construction of the ISFSI road. Real time measurements performed during roadway construction identified elevated contamination levels in a suspect area along the former railroad grade. A remediation of this area was conducted; however, the extent of cleanup was limited to the amount of soil disturbance required for removal of the rail bed and surface preparation for construction of the roadway ($5(1)B_1$).

Deep-core sampling was conducted in five survey efforts to investigate the extent of potential subsurface contamination. The maximum survey depth was approximately six meters. Sample point locations were judgmentally selected based on historical data, process knowledge, survey analyses, and location availability due to subsurface obstructions and equipment.

Data Summary

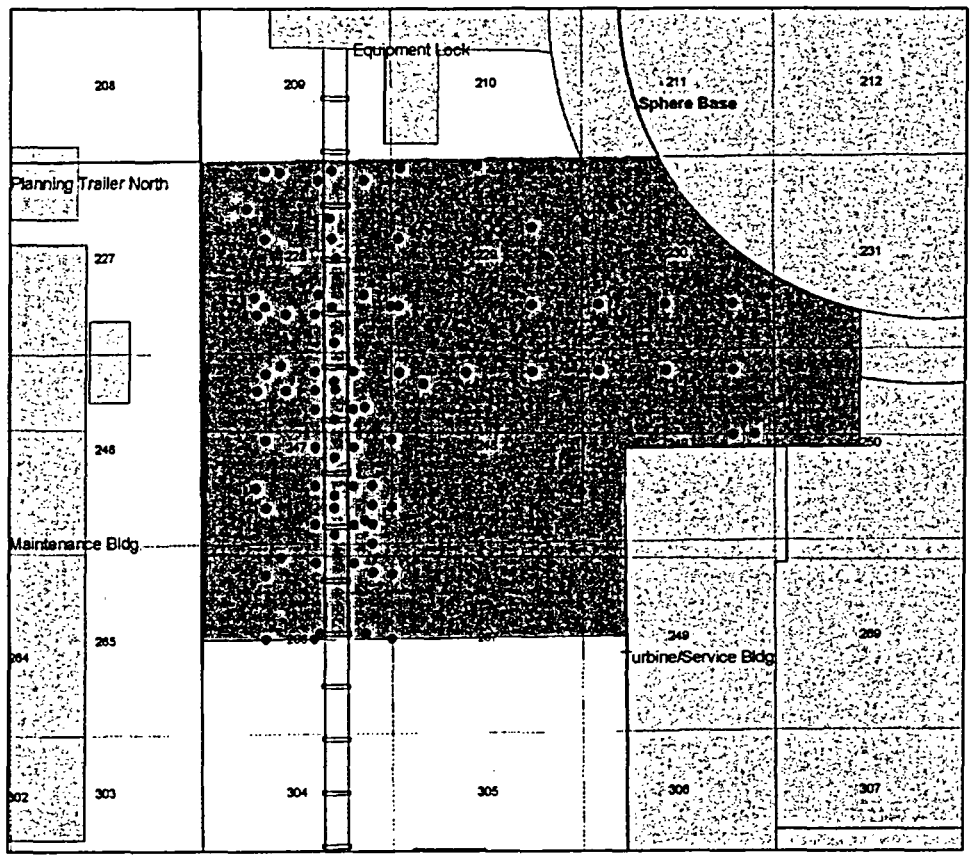
The data tabulated below reflects the current status of the survey unit. Data analyses for samples collected from locations that were later remediated have been excluded. The results of survey analyses for all samples collected in each individual survey of Survey Unit 5(1) are included in the survey results table.

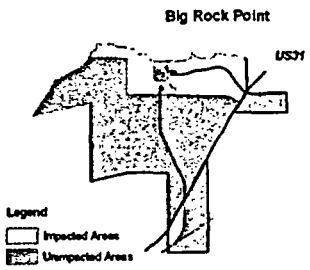
Survey Unit 5(1)

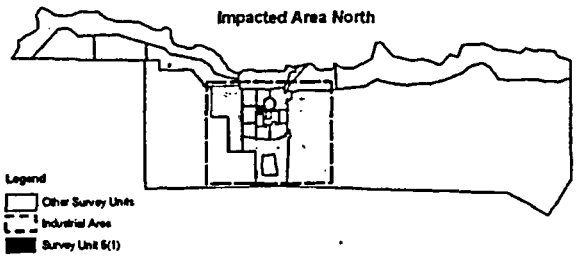
Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$5(1)A_1$	33	Cs_{137}	3.26	12.74
		Co_{60}	0.54	0.73
$5(1)A_2$	13	Cs_{137}	0.45	1.09
		Co_{60}	nd	nd
$5(1)A_3$	7	Cs_{137}	0.06	0.07
		Co_{60}	nd	nd
$5(1)B_1$	23	Cs_{137}	1.81	16.59
		Co_{60}	0.16	0.76
$5(1)_{deepcore1}$	21	Cs_{137}	0.06	0.09
		Co_{60}	nd	nd
$5(1)_{deepcore2}$	25	Cs_{137}	1.21	12.94 ***
		Co_{60}	0.19	0.47
$5(1)_{deepcore3}$	1	nd	-	-
$5(1)_{deepcore4}$	5	Cs_{137}	0.30	0.79
		Co_{60} **	0.17	0.17
$5(1)_{deepcore5}$	8	Cs_{137}	2.22	6.41
		Co_{60}	0.36	0.66

*nd indicates non detect
**Co-60 detected in only one sample
***Sample taken at (15-30 cm)

Survey Unit 5(1)







Survey Results

Survey [c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
5(1)A_1	266	(3.4,5.0)	0.0-0.15	nd*	0.11	nd	0.08	nd	0.42
5(1)A_1	266	(5.9,5.0)	0.0-0.15	nd	0.12	nd	0.07	nd	0.39
5(1)A_1	266	(3.4,8.4)	0.0-0.15	nd	0.06	nd	0.10	nd	0.39
5(1)A_1	267	(0.0,5.0)	0.0-0.15	nd	0.06	nd	0.06	nd	0.40
5(1)A_1	267	(0.0,8.4)	0.0-0.15	nd	0.07	nd	0.06	nd	0.38
5(1)A_1	247	(3.4,1.9)	0.0-0.15	nd	0.11	nd	0.09	nd	0.41
5(1)A_1	247	(3.4,5.4)	0.0-0.15	3.10		0.43		nd	0.42
5(1)A_1	247	(3.4,8.9)	0.0-0.15	nd	0.09	nd	0.02	nd	0.39
5(1)A_1	248	(0.0,1.9)	0.0-0.15	nd	0.04	nd	0.03	nd	0.19
5(1)A_1	248	(0.0,5.4)	0.0-0.15	0.21		nd	0.13	nd	0.37
5(1)A_1	248	(0.4,8.9)	0.0-0.15	12.74		0.7		nd	0.42
5(1)A_1	248	(3.9,8.9)	0.0-0.15	nd	0.08	nd	0.09	nd	0.42
5(1)A_1	248	(7.4,8.9)	0.0-0.15	nd	0.04	nd	0.05	nd	0.18
5(1)A_1	249	(7.9,5.5)	0.0-0.15	nd	0.09	nd	0.08	nd	0.41
5(1)A_1	249	(9.0,5.5)	0.0-0.15	0.33		nd	0.12	nd	0.36
5(1)A_1	249	(0.9,8.9)	0.0-0.15	nd	0.05	nd	0.11	nd	0.38
5(1)A_1	249	(4.4,8.9)	0.0-0.15	nd	0.11	nd	0.10	nd	0.42
5(1)A_1	249	(7.9,8.9)	0.0-0.15	nd	0.05	nd	0.04	nd	0.23
5(1)A_1	228	(3.4,2.4)	0.0-0.15	nd	0.08	nd	0.08	nd	0.30
5(1)A_1	228	(6.9,2.4)	0.0-0.15	8.03		0.73		nd	0.43
5(1)A_1	228	(3.4,5.9)	0.0-0.15	nd	0.05	nd	0.05	nd	0.20
5(1)A_1	228	(6.9,5.9)	0.0-0.15	nd	0.04	nd	0.04	nd	0.18
5(1)A_1	228	(3.4,9.4)	0.0-0.15	nd	0.09	nd	0.10	nd	0.40
5(1)A_1	228	(6.9,9.4)	0.0-0.15	nd	0.06	nd	0.09	nd	0.37
5(1)A_1	229	(0.0,2.4)	0.0-0.15	4.50		0.28		nd	0.37
5(1)A_1	229	(7.4,2.4)	0.0-0.15	nd	0.11	nd	0.09	nd	0.40
5(1)A_1	229	(0.4,5.9)	0.0-0.15	0.17		nd	0.06	nd	0.27
5(1)A_1	229	(7.4,6.4)	0.0-0.15	0.17		nd	0.09	nd	0.43
5(1)A_1	229	(0.5,9.5)	0.0-0.15	nd	0.11	nd	0.10	nd	0.42
5(1)A_1	229	(4.5,9.6)	0.0-0.15	nd	0.08	nd	0.05	nd	0.34
5(1)A_1	230	(0.9,2.4)	0.0-0.15	0.12		nd	0.05	nd	0.21
5(1)A_1	230	(4.4,2.4)	0.0-0.15	nd	0.05	nd	0.11	nd	0.38
5(1)A_1	230	(7.9,2.4)	0.0-0.15	nd	0.05	nd	0.10	nd	0.33
5(1)A_1	*247*	*(6.9,8.9)*	*0.0-0.15*	*1.66*		*0.20*		*nd*	*0.31*
5(1)A_1	*247*	*(5.9,5.4)*	*0.0-0.15*	*0.97*		*0.14*		*nd*	*0.26*
5(1)A_1	*247*	*(7.0,1.9)*	*0.0-0.15*	*2.65*		*0.17*		*nd*	*0.34*
5(1)A_1	*266*	*(6.9,8.5)*	*0.0-0.15*	*nd*	*0.07*	*nd*	*0.10*	*nd*	*0.35*

[a] nd indicates non detect, MDA provided
[b] No entry in MDA columns is provided when residual radioactivity is detected
[c] Italicized entries indicate samples that were collected prior to remediation

Survey [c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
5(1)A_2	266	(4.2,9.3)	0.0-0.15	nd	0.05	nd	0.06	nd	0.33
5(1)A_2	266	(6.2,5.3)	0.0-0.15	0.18		nd	0.07	nd	0.27
5(1)A_2	266	(8.6,5.3)	0.0-0.15	nd	0.04	nd	0.07	nd	0.28
5(1)A_2	247	(2.9,2.9)	0.0-0.15	nd	0.05	nd	0.07	nd	0.28
5(1)A_2	247	(4.2,9.3)	0.0-0.15	0.08		nd	0.07	nd	0.29
5(1)A_2	247	(8.6,7.1)	0.0-0.15	1.09		nd	0.07	nd	0.27
5(1)A_2	228	(2.9,2.9)	0.0-0.15	nd	0.07	nd	0.04	nd	0.26
5(1)A_2	228	(4.2,9.3)	0.0-0.15	nd	0.05	nd	0.07	nd	0.26
5(1)A_2	228	(6.2,8.9)	0.0-0.15	nd	0.05	nd	0.07	nd	0.29
5(1)A_2	228	(8.6,8.9)	0.0-0.15	nd	0.04	nd	0.06	nd	0.22
5(1)A_2	228	(6.8,7.0)	0.0-0.15	nd	0.05	nd	0.06	nd	0.23
5(1)A_2	228	(6.2,3.0)	0.0-0.15	nd	0.04	nd	0.06	nd	0.35
5(1)A_2	228	(8.6,3.0)	0.0-0.15	nd	0.06	nd	0.07	nd	0.26
5(1)A_2	*228*	*(6.8,1.1)*	*0.0-0.15*	*1.72*		*0.14*		*nd*	*0.29*
5(1)A_2	*247*	*(6.2,7.1)*	*0.0-0.15*	*nd*	*0.06*	*nd*	*0.05*	*nd*	*0.27*
5(1)A_2	*247*	*(6.8,5.2)*	*0.0-0.15*	*4.42*		*0.42*		*nd*	*0.43*
5(1)A_2	*247*	*(6.2,1.2)*	*0.0-0.15*	*0.17*		*nd*	*0.07*	*nd*	*0.26*
5(1)A_2	*247*	*(8.6,1.2)*	*0.0-0.15*	*4.72*		*0.61*		*nd*	*0.41*
5(1)A_2	*266*	*(6.8,9.3)*	*0.0-0.15*	*nd*	*0.06*	*nd*	*0.06*	*nd*	*0.28*
5(1)A_2	*266*	*(9.9,8.9)*	*0.0-0.15*	*5.68*		*0.48*		*nd*	*0.42*
5(1)A_2	*266*	*(9.9,9.3)*	*0.0-0.15*	*nd*	*0.04*	*nd*	*0.06*	*nd*	*0.28*
5(1)A_3	247	(3.0,8.0)	0.90-1.05	nd	0.04	nd	0.04	nd	0.27
5(1)A_3	247	(4.5,8.0)	0.90-1.05	nd	0.04	nd	0.05	nd	0.25
5(1)A_3	247	(6.0,8.0)	0.90-1.05	nd	0.03	nd	0.04	nd	0.23
5(1)A_3	228	(3.0,2.0)	0.90-1.05	nd	0.05	nd	0.05	nd	0.25
5(1)A_3	228	(4.5,2.0)	0.90-1.05	nd	0.05	nd	0.05	nd	0.25
5(1)A_3	228	(6.0,2.0)	0.90-1.05	nd	0.04	nd	0.06	nd	0.24
5(1)A_3 [d]	d	d	0.00-1.00	0.06		nd	0.06	nd	0.24
5(1)B_1	266	(6.0,9.0)	0.30-0.45	2.66		0.47		nd	0.38
5(1)B_1	266	(8.0,9.0)	0.30-0.45	0.72		0.20		nd	0.28
5(1)B_1	266	(9.0,8.5)	0.30-0.45	0.94		0.02		nd	0.28
5(1)B_1	247	(7.0,0.5)	0.30-0.45	0.36		0.05		nd	0.32
5(1)B_1	247	(6.0,1.0)	0.30-0.45	2.19		0.16		nd	0.35
5(1)B_1	247	(8.0,1.0)	0.30-0.45	0.91		0.07		nd	0.31
5(1)B_1	247	(7.0,2.5)	0.30-0.45	0.24		nd	0.06	nd	0.31
5(1)B_1	247	(6.0,3.0)	0.30-0.45	0.48		0.11		nd	0.24
5(1)B_1	247	(8.0,3.0)	0.30-0.45	1.26		0.07		nd	0.32
5(1)B_1	247	(7.0,4.5)	0.30-0.45	0.25		nd	0.06	nd	0.30

[a] nd indicates non detect, MDA provided

[b] No entry in MDA columns is provided when residual radioactivity is detected

[c] Italicized entries indicate samples that were collected prior to remediation

[d] Composite sample

Survey [c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
5(1)B_1	247	(6.0,5.0)	0.30-0.45	0.66		0.10		nd	0.30
5(1)B_1	247	(8.0,5.0)	0.30-0.45	0.49		nd	0.08	nd	0.27
5(1)B_1	247	(7.0,6.5)	0.30-0.45	0.07		nd	0.05	nd	0.27
5(1)B_1	247	(6.0,7.0)	0.30-0.45	0.22		0.06		nd	0.31
5(1)B_1	247	(8.0,7.0)	0.30-0.45	0.41		0.03		nd	0.22
5(1)B_1	247	(7.0,8.5)	0.30-0.45	0.13		nd	0.06	nd	0.22
5(1)B_1	247	(6.0,9.0)	0.30-0.45	0.70		0.06		nd	0.28
5(1)B_1	247	(8.0,9.0)	0.30-0.45	0.77		nd	0.09	nd	0.26
5(1)B_1	247	(9.0,0.0)	0.30-0.45	3.17		0.18		nd	0.35
5(1)B_1	247	(9.0,1.0)	0.30-0.45	1.19		0.05		nd	0.29
5(1)B_1	247	(9.0,2.0)	0.30-0.45	5.53		0.14		nd	0.39
5(1)B_1	247	(9.0,3.0)	0.30-0.45	16.59		0.76		nd	0.42
5(1)B_1	228	(7.0,0.5)	0.30-0.45	1.58		0.16		nd	0.27
5(1)$A_{deepcore1}$	*247*	*(7.1,8.1)*	*0.60-1.20*	*5.00*		*0.23*		*nd*	*0.42*
5(1)$A_{deepcore1}$	248	(1.7,8.3)	0.0-0.60	nd	0.05	nd	0.04	nd	0.19
5(1)$A_{deepcore1}$	228	(7.1,4.9)	0.0-0.60	nd	0.04	nd	0.04	nd	0.19
5(1)$A_{deepcore1}$	247	(7.1,8.1)	0.60-1.20	0.09		nd	0.08	nd	0.39
5(1)$A_{deepcore1}$	248	(1.7,8.3)	0.60-1.20	nd	0.08	nd	0.08	nd	0.31
5(1)$A_{deepcore1}$	228	(7.1,4.9)	0.60-1.20	nd	0.04	nd	0.04	nd	0.22
5(1)$A_{deepcore1}$	247	(7.1,8.1)	1.20-1.80	0.04		nd	0.04	nd	0.20
5(1)$A_{deepcore1}$	248	(1.7,8.3)	1.20-1.80	nd	0.06	nd	0.06	nd	0.29
5(1)$A_{deepcore1}$	228	(7.1,4.9)	1.20-1.80	nd	0.06	nd	0.08	nd	0.36
5(1)$A_{deepcore1}$	247	(7.1,8.1)	1.80-2.40	0.05		nd	0.06	nd	0.29
5(1)$A_{deepcore1}$	228	(7.1,4.9)	1.80-2.40	nd	0.05	nd	0.10	nd	0.35
5(1)$A_{deepcore1}$	248	(1.7,8.3)	1.80-3.00	nd	0.02	nd	0.06	nd	0.22
5(1)$A_{deepcore1}$	247	(7.1,8.1)	2.40 - 3.00	nd	0.06	nd	0.10	nd	0.34
5(1)$A_{deepcore1}$	228	(7.1,4.9)	2.40 - 3.00	nd	0.03	nd	0.04	nd	0.21
5(1)$A_{deepcore1}$	247	(7.1,8.1)	3.00 - 3.60	nd	0.03	nd	0.04	nd	0.19
5(1)$A_{deepcore1}$	228	(7.1,4.9)	3.00 - 3.90	nd	0.06	nd	0.09	nd	0.39
5(1)$A_{deepcore1}$	248	(1.7,8.3)	3.00 - 5.10	nd	0.05	nd	0.08	nd	0.31
5(1)$A_{deepcore1}$	247	(7.1,8.1)	3.60 - 4.20	nd	0.04	nd	0.04	nd	0.23
5(1)$A_{deepcore1}$	228	(7.1,4.9)	3.90 - 4.20	nd	0.08	nd	0.13	nd	0.39
5(1)$A_{deepcore1}$	247	(7.1,8.1)	4.20 - 4.80	nd	0.03	nd	0.04	nd	0.23
5(1)$A_{deepcore1}$	248	(1.7,8.3)	5.10 - 6.00	nd	0.06	nd	0.08	nd	0.36
5(1)$A_{deepcore1}$	228**	(7.1,4.9)	0.0-0.60	nd	0.07	nd	0.05	nd	0.26
5(1)$A_{deepcore2}$	248	(0.0,5.4)	0.15-0.30	12.94		0.47		nd	0.43
5(1)$A_{deepcore2}$	248	(0.4,8.9)	0.15-0.30	1.14		0.10		nd	0.29

[a] nd indicates non detect, MDA provided

[b] No entry in MDA columns is provided when residual radioactivity is detected

[c] Italicized entries indicate samples that were collected prior to remediation

Survey [c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g) Activity [a]	MDA [b]	Co-60 (pCi/g) Activity [a]	MDA [b]	Am-241 (pCi/g) Activity [a]	MDA [b]
5(1)$A_{deepcore2}$	228	(6.9,2.4)	0.15-0.30	0.10		nd	0.07	nd	0.42
5(1)$A_{deepcore2}$	229	(0.4,2.4)	0.15-0.30	0.13		nd	0.09	nd	0.42
5(1)$A_{deepcore2}$	229	(0.4,5.9)	0.15-0.30	nd	0.10	nd	0.09	nd	0.38
5(1)$A_{deepcore2}$	229	(7.4,6.4)	0.15-0.30	nd	0.10	nd	0.07	nd	0.43
5(1)$A_{deepcore2}$	230	(0.9,2.4)	0.15-0.30	0.08		0.03		nd	0.20
5(1)$A_{deepcore2}$	247	(7.0,1.9)	0.30-0.60	0.24		nd	0.05	nd	0.23
5(1)$A_{deepcore2}$	248	(0.0,5.4)	0.30-0.60	1.92		0.15		nd	0.38
5(1)$A_{deepcore2}$	248	(0.4,8.9)	0.30-0.60	1.91		0.30		nd	0.35
5(1)$A_{deepcore2}$	228	(6.9,2.4)	0.30-0.60	0.27		nd	0.08	nd	0.35
5(1)$A_{deepcore2}$	230	(0.9,2.4)	0.30-0.60	0.10		nd	0.09	nd	0.41
5(1)$A_{deepcore2}$	228	(6.9,2.4)	0.60-0.75	0.53		0.06		nd	0.31
5(1)$A_{deepcore2}$	247	(7.0,1.9)	0.60-0.90	0.35		nd	0.06	nd	0.24
5(1)$A_{deepcore2}$	248	(0.0,5.4)	0.60-0.90	0.64		nd	0.06	nd	0.28
5(1)$A_{deepcore2}$	248	(0.4,8.9)	0.60-0.90	1.27		0.20		nd	0.31
5(1)$A_{deepcore2}$	248	(0.0,5.4)	0.90-1.20	2.99		0.19		nd	0.39
5(1)$A_{deepcore2}$	248	(0.4,8.9)	0.90-1.20	0.32		nd	0.09	nd	0.32
5(1)$A_{deepcore2}$	248	(0.0,5.4)	1.20-1.50	0.34		nd	0.07	nd	0.23
5(1)$A_{deepcore2}$	248	(0.4,8.9)	1.20-1.50	0.29		nd	0.07	nd	0.23
5(1)$A_{deepcore2}$	248	(0.0,5.4)	1.20-1.80	1.58		0.20		nd	0.33
5(1)$A_{deepcore2}$	248	(0.4,8.9)	1.20-1.80	0.33		nd	0.12	nd	0.42
5(1)$A_{deepcore2}$	248	(0.0,5.4)	1.80-2.10	0.06		nd	0.08	nd	0.37
5(1)$A_{deepcore2}$	248	(0.4,8.9)	1.80-2.10	0.17		nd	0.05	nd	0.24
5(1)$A_{deepcore2}$	248	(0.4,8.9)	2.10 - 2.40	0.12		nd	0.06	nd	0.22
5(1)$A_{deepcore2}$	*247*	*(7.0,1.9)*	*0.15-0.30*	*0.71*		*0.06*		*nd*	*0.29*
5(1)$A_{deepcore2}$	*247*	*(6.9,5.4)*	*0.15-0.30*	*0.18*		*nd*	*0.05*	*nd*	*0.21*
5(1)$A_{deepcore2}$	*247*	*(6.9,8.9)*	*0.15-0.30*	*0.09*		*nd*	*0.04*	*nd*	*0.18*
5(1)$A_{deepcore3}$	228	(2.5,7.5)	0.0-0.73	nd	0.05	nd	0.05	nd	0.25
5(1)$A_{deepcore4}$	249	(7.9,5.5)	0.30-0.60	nd	0.03	nd	0.04	nd	0.23
5(1)$A_{deepcore4}$	229	(0.4,2.4)	0.30-0.60	0.79		0.17		nd	0.23
5(1)$A_{deepcore4}$	249	(7.9,5.5)	0.60-0.90	nd	0.03	nd	0.04	nd	0.19
5(1)$A_{deepcore4}$	229	(0.4,2.4)	0.60-0.90	0.08		nd	0.06	nd	0.24
5(1)$A_{deepcore4}$	229	(0.4,2.4)	0.90-1.20	0.03		nd	0.05	nd	0.19
5(1)$A_{deepcore5}$	228	(8.6,8.9)	0.15-0.30	0.07		nd	0.06	nd	0.31
5(1)$A_{deepcore5}$	228	(8.6,3.0)	0.15-0.30	0.18		0.19		nd	0.30
5(1)$A_{deepcore5}$	247	(8.6,1.2)	0.30-0.45	6.41		0.24		nd	0.42
5(1)$A_{deepcore5}$	228	(8.6,8.9)	0.30-0.45	nd	0.06	nd	0.06	nd	0.26

[a] nd indicates non detect, MDA provided

[b] No entry in MDA columns is provided when residual radioactivity is detected

[c] Italicized entries indicate samples that were collected prior to remediation

Survey [c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
5(1)$A_{deepcore5}$	228	(8.6,3.0)	0.30-0.45	nd	0.04	nd	0.05	nd	0.23
5(1)$A_{deepcore5}$	228	(8.6,3.0)	0.45-0.60	nd	0.05	nd	0.08	nd	0.24
5(1)$A_{deepcore5}$	228	(8.6,8.9)	0.45-0.90	nd	0.05	nd	0.06	nd	0.26
5(1)$A_{deepcore5}$	228	(8.6,8.9)	0.90-1.05	nd	0.06	nd	0.06	nd	0.29
5(1)$A_{deepcore5}$	*247*	*(8.6,1.2)*	*0.15-0.30*	*32.8*		*0.66*		*nd*	*0.43*

[a] nd indicates non detect, MDA provided

[b] No entry in MDA columns is provided when residual radioactivity is detected

[c] Italicized entries indicate samples that were collected prior to remediation

Survey Unit 5(2)

Description
Survey Unit 5(2) is an area of approximately 800 m^2 located immediately west of the Turbine Building. This location encompasses the Waste Hold Tanks, Condensate Storage Tank, Demineralized Water Tank, and the northern section of the Liquid Radwaste Vault area. The Liquid Radwaste Vault is a subsurface concrete structure that contains the equipment used for liquid radwaste processing. The roof of this structure is located at grade elevation and is composed of concrete covered with asphalt paving. Additional subsurface structures include, the Stack foundation, Liquid Radwaste Processing System piping, fiber optics, electrical conduit, and Turbine Building and storage tank foundations.

History
The HSA has identified radioactivity in this survey unit for localized areas of soil in close proximity to the former rail bed. Both Survey Units 5(1) and 5(2) share similar operational histories and contain components of the Liquid Radwaste Processing System. This location is a transfer point for the removal of primary system resin and filters through disposal access hatches in the Liquid Radwaste Vault. Waste material was then routed to the Radwaste Building in preparation for shipment.

A contaminant migration pathway existed along the rail grade in this survey unit. The low topography formerly present at this location provided a storm water runoff pathway from the tank area into Survey Unit 5(1). Documented radiological events describe a number of piping leaks and spills that are known to have occurred in this area. Remediation efforts have been conducted in this survey unit on several occasions.

Following the removal of contaminated soil, clean fill was used to return remediated locations to proper grade. As a result, activity depth profiles conducted in these areas have identified an increase in activity near the base elevation of soil removal locations. This activity is believed to result from contamination left in place during the remediation process.

Radiological Status
Survey Unit 5(2) is a relatively small and complex survey area. The Liquid Radwaste Processing System remains in service at this time; therefore, building foundations, subsurface piping, and electrical power hazards limit the extent of soil sampling in many locations.

Although trace values of Mn-54 were identified in one of the scoping survey samples used for design of the primary survey, Mn-54 was not identified in any subsequent characterization survey conducted in Survey Unit 5(2). Elevated concentrations of Cs-137 were identified in several samples taken near railroad grade along the former storm water runoff pathway.

The results of characterization analyses to date indicate that remediation may be required following the removal of the road surface east of the rail bed. This location was paved to satisfy the engineering requirements for movement of spent fuel to the ISFSI. The asphalt paving is scheduled for removal following demolition of the Stack and the Liquid Radwaste Processing System.

Excavation will be required for the removal of subsurface structures and equipment in this area. Characterization surveys are scheduled to continue during this process and remediation efforts will be conducted as necessary to satisfy the requirements for final status surveys. This survey unit is considered a Class 1 Area.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60	Mn-54
Mean value (pCi/g)	2.14	0.69	0.043
Standard deviation (&)	1.40	1.24	0.106

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{4.99_{Co}}\right)^2 + \left(\frac{\sigma_{Mn}}{474_{Mn}}\right)^2}$$

$$\sigma = \sqrt{\left(\frac{1.40}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{1.24}}{4.99_{Co}}\right)^2 + \left(\frac{.106}{474_{Mn}}\right)^2}$$

$$\sigma = 0.37$$

For the Unity Rule, the DCGL for the weighted sum is 1.0. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1 - 0.5}{0.37} = 1.3$$

With ⬆ and ⬇ error levels of 0.05, the Sign Test requires 21 sample data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid, pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 30 X 30 meters
   Random Numbers 0.14, 0.43
   X = (0.14)(30 m) = 4.2 m
   Y = (0.43)(35 m) = 15.2 m

$$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{600/21} = 5.3 \text{ meters}$$

As a conservative measure 26 samples were collected using 5 meter spacing.

Supporting Surveys

Supporting survey 5(2)A_2, was conducted to provide a radiological evaluation of area soils prior to construction of the ISFSI road. Historical documentation and real time measurements performed during roadway construction identified elevated contamination levels in an area along the former railroad grade. A remediation of this area was conducted; however, the extent of cleanup was limited to the amount of soil disturbance required for removal of the rail bed and preparation of the surface required for construction of the roadway (Survey 5(2)B_1).

Deep-core sampling was conducted in five survey efforts to investigate the extent of potential subsurface contamination. The maximum survey depth was approximately 14 meters. Sample point locations were judgmentally selected based on historical data, process knowledge, survey analyses, and location availability due to subsurface obstructions of systems and equipment.

Data Summary

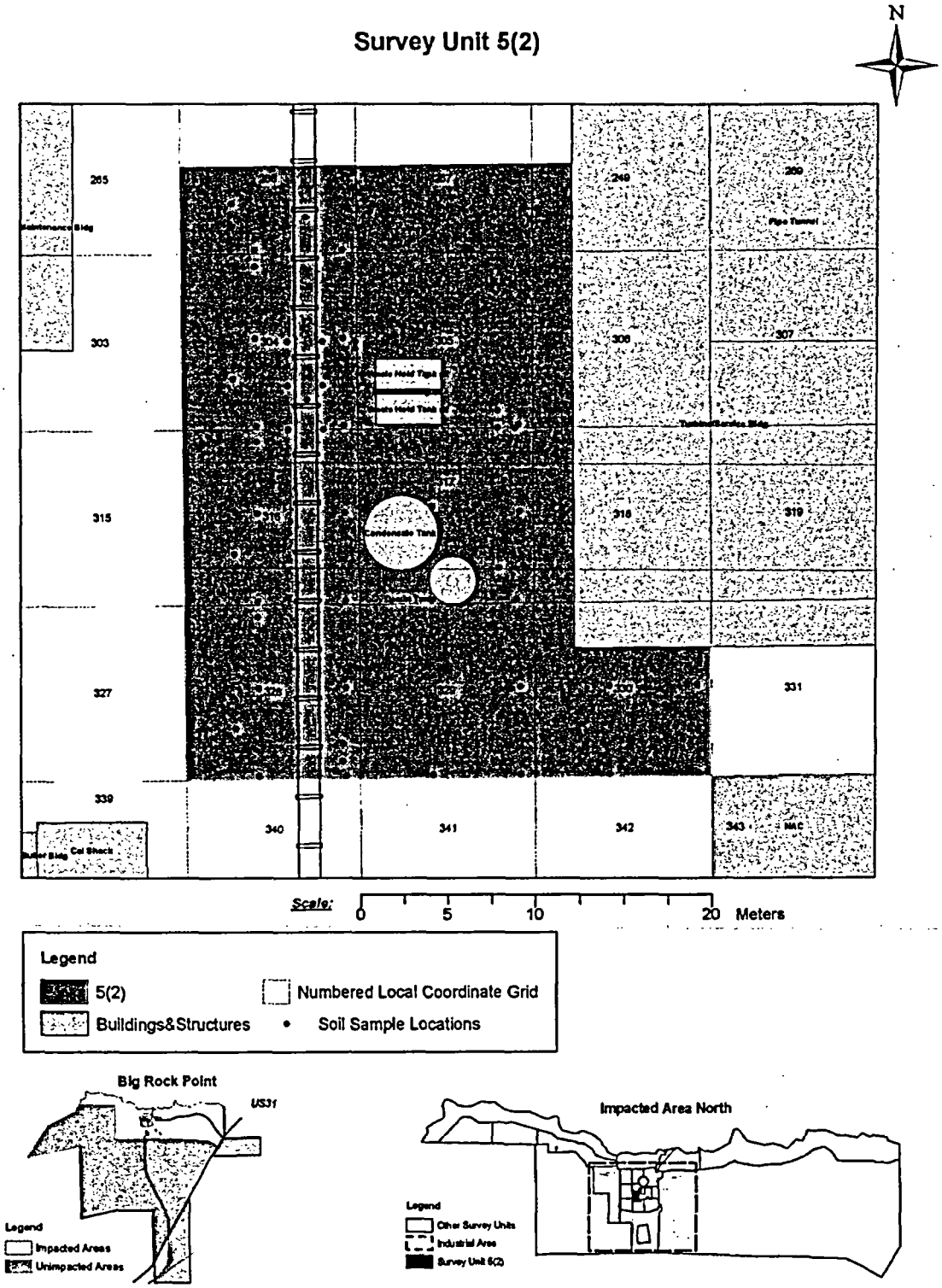
The data tabulated below reflects the current status of the survey unit. Data analyses for samples collected from locations that were later remediated have been excluded. The results of survey analyses for all samples collected in each individual survey of Survey Unit 5(2) are included in the Survey Results table.

Survey Unit 5(2)

Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
5(2)A_1	26	Cs_{137}	0.28	1.39
		Co_{60}	0.20	0.42
5(2)A_2	7	Cs_{137}	0.04	0.04
5(2)B_1	6	Cs_{137}	2.29	5.25
		Co_{60}	0.07	0.09
$5(2)_{deepcore1}$	16	Cs_{137}	1.15	2.73
		Co_{60}	nd	nd
$5(2)_{deepcore2}$	12	Cs_{137}	0.79	2.72
		Co_{60}	0.31	0.98
$5(2)_{deepcore3}$	19	Cs_{137}	2.87	30.70
		Co_{60} **	1.96	7.50
$5(2)_{deepcore4}$	19	Cs_{137}	0.25	0.67
		Co_{60} **	0.54	1.45
$5(2)_{deepcore5}$	3	Cs_{137}	nd	nd
		Co_{60}	nd	nd

* nd indicates non detect
** Co-60 detected in a limited number of samples

Survey Unit 5(2)



Survey Results

Survey	Grid	Coordinate (x,y)	Depth (meters)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
5(2)A_1	266	(4.2,0.2)	0.00-0.15	nd	0.12	nd	0.10	nd	0.40
5(2)A_1	266	(9.2,0.2)	0.00-0.15	1.39		0.42		nd	0.34
5(2)A_1	304	(4.2,5.2)	0.00-0.15	nd	0.08	nd	0.06	nd	0.37
5(2)A_1	304	(9.2,5.2)	0.00-0.15	0.45		0.26		nd	0.27
5(2)A_1	304	(4.2,0.2)	0.00-0.15	nd	0.08	nd	0.08	nd	0.40
5(2)A_1	304	(9.2,0.2)	0.00-0.15	0.06		0.13		nd	0.31
5(2)A_1	305	(9.2,0.2)	0.00-0.15	0.19		0.08		nd	0.21
5(2)A_1	316	(4.2,5.2)	0.00-0.15	0.11		nd	0.15	nd	0.35
5(2)A_1	316	(9.2,5.2)	0.00-0.15	0.10		0.15		nd	0.32
5(2)A_1	317	(4.2,5.5)	0.00-0.15	0.14		nd	0.07	nd	0.24
5(2)A_1	317	(9.2,5.2)	0.00-0.15	0.22		0.14		nd	0.21
5(2)A_1	316	(4.2,0.2)	0.00-0.15	nd	0.08	nd	0.08	nd	0.37
5(2)A_1	316	(9.2,0.2)	0.00-0.15	0.10		nd	0.05	nd	0.20
5(2)A_1	317	(4.2,0.2)	0.00-0.15	0.19		nd	0.12	nd	0.41
5(2)A_1	317	(9.0,0.2)	0.00-0.15	nd	0.13	nd	0.11	nd	0.28
5(2)A_1	328	(4.2,5.2)	0.00-0.15	nd	0.09	nd	0.08	nd	0.35
5(2)A_1	328	(9.2,5.2)	0.00-0.15	nd	0.03	nd	0.05	nd	0.19
5(2)A_1	329	(9.2,5.2)	0.00-0.15	nd	0.10	nd	0.10	nd	0.39
5(2)A_1	330	(4.2,5.2)	0.00-0.15	nd	0.04	nd	0.05	nd	0.21
5(2)A_1	330	(9.2,5.2)	0.00-0.15	nd	0.09	nd	0.06	nd	0.43
5(2)A_1	328	(4.2,0.2)	0.00-0.15	nd	0.07	nd	0.09	nd	0.38
5(2)A_1	328	(9.2,0.2)	0.00-0.15	nd	0.10	nd	0.10	nd	0.42
5(2)A_1	329	(4.2,0.2)	0.00-0.15	nd	0.12	nd	0.06	nd	0.36
5(2)A_1	329	(9.2,0.2)	0.00-0.15	0.09		nd	0.09	nd	0.39
5(2)A_1	330	(4.2,0.2)	0.00-0.15	nd	0.07	nd	0.10	nd	0.42
5(2)A_1	330	(9.2,0.2)	0.00-0.15	nd	0.09	nd	0.06	nd	0.39
5(2)A_2	328	(2.9,2.9)	0.00-0.15	nd	0.04	nd	0.06	nd	0.28
5(2)A_2	328	(4.2,9.3)	0.00-0.15	nd	0.04	nd	0.05	nd	0.25
5(2)A_2	316	(2.9,2.9)	0.00-0.15	nd	0.04	nd	0.05	nd	0.23
5(2)A_2	316	(4.2,9.3)	0.00-0.15	0.04		nd	0.05	nd	0.24
5(2)A_2	304	(2.9,2.9)	0.00-0.15	nd	0.04	nd	0.06	nd	0.26
5(2)A_2	304	(4.2,9.3)	0.00-0.15	nd	0.04	nd	0.05	nd	0.27
5(2)A_2	266	(2.9,2.9)	0.00-0.15	nd	0.04	nd	0.07	nd	0.28
5(2)B_1	304	(6.0,0.0)	0.30-0.45	0.98		nd	0.06	nd	0.31
5(2)B_1	304	(8.0,0.0)	0.30-0.45	5.25		nd	0.07	nd	0.41
5(2)B_1	304	(6.0,2.5)	0.30-0.45	0.09		nd	0.07	nd	0.30

[a] nd indicates non detect, MDA provided
[b] No entry in MDA columns is provided when residual radioactivity is detected

Survey	Grid	Coordinate (x,y)	Depth (meters)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
5(2)B_1	304	(8.0,2.5)	0.30-0.45	1.87		nd	0.07	nd	0.35
5(2)B_1	304	(6.0,5.0)	0.30-0.45	1.18		0.09		nd	0.32
5(2)B_1	304	(8.0,5.0)	0.30-0.45	4.30		0.04		nd	0.36
5(2)$A_{deepcore1}$	304	(7.1,1.7)	0 - 0.30	1.68		nd	0.08	nd	0.26
5(2)$A_{deepcore1}$	304	(7.1,1.7)	0.60-1.80	2.73		nd	0.08	nd	0.38
5(2)$A_{deepcore1}$	304	(7.1,1.7)	1.80-2.40	0.10		nd	0.06	nd	0.23
5(2)$A_{deepcore1}$	304	(7.1,1.7)	2.40-3.60	nd	0.04	nd	0.07	nd	0.26
5(2)$A_{deepcore1}$	304	(7.1,1.7)	3.60-4.20	nd	0.04	nd	0.07	nd	0.33
5(2)$A_{deepcore1}$	304	(7.1,1.7)	4.20-4.80	nd	0.08	nd	0.13	nd	0.38
5(2)$A_{deepcore1}$	304	(7.1,1.7)	4.80-5.40	nd	0.03	nd	0.04	nd	0.24
5(2)$A_{deepcore1}$	304	(7.1,1.7)	10.2-10.8	nd	0.04	nd	0.11	nd	0.36
5(2)$A_{deepcore1}$	304	(7.1,1.7)	11.7-12.3	nd	0.07	nd	0.09	nd	0.39
5(2)$A_{deepcore1}$	304	(7.1,1.7)	13.2-13.8	nd	0.03	nd	0.06	nd	0.24
5(2)$A_{deepcore1}$	266	(7.1,2.1)	0 - 0.30	0.10		nd	0.04	nd	0.24
5(2)$A_{deepcore1}$	266	(7.1,2.1)	0.60-1.20	nd	0.10	nd	0.06	nd	0.35
5(2)$A_{deepcore1}$	266	(7.1,2.1)	1.20-2.40	nd	0.05	nd	0.05	nd	0.20
5(2)$A_{deepcore1}$	266	(7.1,2.1)	2.40-3.00	nd	0.07	nd	0.08	nd	0.40
5(2)$A_{deepcore1}$	266	(7.1,2.1)	3.00-3.60	nd	0.30	nd	0.04	nd	0.18
5(2)$A_{deepcore1}$	266	(7.1,2.1)	3.60-4.20	nd	0.06	nd	0.09	nd	0.39
5(2)$A_{deepcore2}$	266	(9.2,0.2)	0.15-0.30	0.41		0.18		nd	0.32
5(2)$A_{deepcore2}$	266	(9.2,0.2)	0.30-0.60	0.21		nd	0.13	nd	0.40
5(2)$A_{deepcore2}$	266	(9.2,0.2)	0.60-0.90	nd	0.11	nd	0.12	nd	0.34
5(2)$A_{deepcore2}$	304	(9.2,5.2)	0.15-0.30	0.60		0.19		nd	0.25
5(2)$A_{deepcore2}$	304	(9.2,5.2)	0.30-0.60	0.16		0.08		nd	0.27
5(2)$A_{deepcore2}$	304	(9.2,5.2)	0.60-0.90	0.22		0.16		nd	0.29
5(2)$A_{deepcore2}$	304	(9.2,0.2)	0.15-0.30	1.39		0.14		nd	0.23
5(2)$A_{deepcore2}$	304	(9.2,0.2)	0.30-0.60	1.81		0.50		nd	0.33
5(2)$A_{deepcore2}$	304	(9.2,0.2)	0.60-0.90	2.72		0.98		nd	0.41
5(2)$A_{deepcore2}$	316	(9.2,5.2)	0.15-0.30	0.16		nd	0.13	nd	0.43
5(2)$A_{deepcore2}$	316	(9.2,5.2)	0.30-0.60	0.80		0.27		nd	0.34
5(2)$A_{deepcore2}$	316	(9.2,5.2)	0.60-0.90	0.21		nd	0.11	nd	0.38
5(2)$A_{deepcore3}$	266	(9.9,4.6)	0.00-0.30	30.70		7.5		nd	0.43
5(2)$A_{deepcore3}$	266	(9.9,4.6)	0.30-0.60	0.89		0.15		nd	0.26
5(2)$A_{deepcore3}$	266	(9.9,4.6)	0.60-0.90	0.41		0.11		nd	0.23
5(2)$A_{deepcore3}$	266	(9.9,4.6)	0.90-1.20	0.11		nd	0.05	nd	0.21
5(2)$A_{deepcore3}$	266	(9.9,4.6)	1.20-1.50	0.06		nd	0.05	nd	0.21
5(2)$A_{deepcore3}$	266	(9.9,4.6)	1.50-1.80	0.04		nd	0.05	nd	0.22
5(2)$A_{deepcore3}$	304	(9.9,5.0)	0.60-0.90	0.13		nd	0.07	nd	0.21

[a] nd indicates non detect, MDA provided
[b] No entry in MDA columns is provided when residual radioactivity is detected

Survey	Grid	Coordinate (x,y)	Depth (meters)	Cs-137 (pCi/g) Activity [a]	MDA [b]	Co-60 (pCi/g) Activity [a]	MDA [b]	Am-241 (pCi/g) Activity [a]	MDA [b]
5(2)A$_{deepcore3}$	304	(9.9,5.0)	0.90-1.20	0.07		nd	0.05	nd	0.18
5(2)A$_{deepcore3}$	304	(9.9,5.0)	1.20-1.50	0.10		0.07		nd	0.19
5(2)A$_{deepcore3}$	304	(9.9,5.0)	1.50-1.80	0.05		nd	0.04	nd	0.19
5(2)A$_{deepcore3}$	304	(9.9,5.0)	1.80-2.10	nd	0.05	nd	0.05	nd	0.23
5(2)A$_{deepcore3}$	304	(9.9,4.6)	0.30-0.60	1.14		nd	0.06	nd	0.25
5(2)A$_{deepcore3}$	304	(9.9,4.6)	0.60-0.90	0.72		nd	0.07	nd	0.31
5(2)A$_{deepcore3}$	317	(8.0,2.0)	0.45-0.60	nd	0.06	nd	0.06	nd	0.29
5(2)A$_{deepcore3}$	317	(8.0,2.0)	0.60-0.90	nd	0.04	nd	0.05	nd	0.20
5(2)A$_{deepcore3}$	317	(8.0,2.0)	0.90-1.20	nd	0.03	nd	0.04	nd	0.20
5(2)A$_{deepcore3}$	317	(8.0,2.0)	1.20-1.50	nd	0.04	nd	0.06	nd	0.26
5(2)A$_{deepcore3}$	317	(8.0,2.0)	1.50-1.80	nd	0.04	nd	0.05	nd	0.21
5(2)A$_{deepcore3}$	317	(8.0,2.0)	1.80-2.10	nd	0.04	nd	0.05	nd	0.21
5(2)A$_{deepcore4}$	305	(4.0,2.0)	0.00-0.30	0.67		1.45		nd	0.23
5(2)A$_{deepcore4}$	305	(4.0,2.0)	0.30-0.60	0.15		0.33		nd	0.21
5(2)A$_{deepcore4}$	305	(4.0,2.0)	0.60-0.90	nd	0.08	nd	0.13	nd	0.19
5(2)A$_{deepcore4}$	305	(4.0,3.0)	0.60-0.90	nd	0.05	nd	0.10	nd	0.19
5(2)A$_{deepcore4}$	305	(4.0,3.0)	0.90-1.20	nd	0.05	nd	0.12	nd	0.16
5(2)A$_{deepcore4}$	305	(4.0,3.0)	1.20-1.50	nd	0.07	nd	0.11	nd	0.17
5(2)A$_{deepcore4}$	305	(4.0,3.0)	1.50-1.80	nd	0.07	nd	0.10	nd	0.21
5(2)A$_{deepcore4}$	305	(8.0,0.0)	0.30-0.60	nd	0.08	nd	0.11	nd	0.20
5(2)A$_{deepcore4}$	305	(8.0,0.0)	0.60-0.90	nd	0.08	nd	0.13	nd	0.24
5(2)A$_{deepcore4}$	305	(8.0,1.0)	0.30-0.60	0.33		0.20		nd	0.16
5(2)A$_{deepcore4}$	305	(8.0,1.0)	0.60-0.90	0.11		nd	0.13	nd	0.17
5(2)A$_{deepcore4}$	305	(9.0,0.0)	0.00-0.30	0.41		0.18		nd	0.18
5(2)A$_{deepcore4}$	305	(9.0,0.0)	0.30-0.60	nd	0.12	nd	0.10	nd	0.19
5(2)A$_{deepcore4}$	305	(9.0,0.0)	0.60-0.90	nd	0.08	nd	0.07	nd	0.16
5(2)A$_{deepcore4}$	305	(9.0,1.0)	0.30-0.60	nd	0.09	nd	0.13	nd	0.15
5(2)A$_{deepcore4}$	328	(9.0,1.0)	0.30-0.60	0.11		nd	0.12	nd	0.16
5(2)A$_{deepcore4}$	328	(9.0,2.0)	0.00-0.30	0.15		nd	0.13	nd	0.23
5(2)A$_{deepcore4}$	328	(9.0,2.0)	0.30-0.60	nd	0.08	nd	0.13	nd	0.20
5(2)A$_{deepcore4}$	328	(9.0,2.0)	0.60-0.90	0.10		nd	0.11	nd	0.24
5(2)A$_{deepcore5}$	304	(2.9,2.9)	0.15-0.30	nd	0.05	nd	0.06	nd	0.25
5(2)A$_{deepcore5}$	304	(2.9,2.9)	0.30-0.60	nd	0.04	nd	0.05	nd	0.30
5(2)A$_{deepcore5}$	304	(2.9,2.9)	0.60-0.75	nd	0.05	nd	0.07	nd	0.29

[a] nd indicates non detect, MDA provided
[b] No entry in MDA columns is provided when residual radioactivity is detected

Survey Unit 6

Description
Survey Unit 6 is an area of approximately 1500 m^2 in size that occupies the south-central section of the Protected Area. This area encompasses the New Access Control Building and the former location of the site electrical substation. Subsurface structures and equipment include the Liquid Radwaste Processing discharge line, storm drains, Well Water System piping electrical conduit, and Fire Protection System piping.

History
The HSA has identified this survey unit to potentially contain radioactive contamination in area soils. This area was once the transport route for movement of radioactive waste to the Radwaste Building for temporary storage and shipment preparation.

Radiological Status
Residual radioactivity was identified in this survey unit at a fraction of the IDCGL (0.2 pCi/g Co-60). Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified in deep-core sampling analyses. The radiological status of this survey unit is Class 1 based on proximity to the following:

- Contaminated material transport pathways,
- Areas of known soil contamination scheduled for excavation and subsurface component removal,
- Locations scheduled for soil remediation, and
- Buildings and foundations scheduled for demolition and removal of contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60
Mean value (pCi/g)	0.16	0.056
Standard deviation (&)	0.048	0.020

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{4.99_{Co}}\right)^2} = \sqrt{\left(\frac{.048}{5.11_{Cs}}\right)^2 + \left(\frac{.020}{4.99_{Co}}\right)^2}$$

σ = 0.010

For the Unity Rule the DCGL for the weighted sum is 1.0. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1 - 0.5}{0.01} = 50$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 40 X 50 meters
   Random Numbers 0.00, 0.76
   X = (0.00)(40 m) = 0.0 m
   Y = (0.76)(50 m) = 38.0 m

   Sample Spacing $L = \sqrt{Area/N} = \sqrt{1500/14} = 10.3$ meters

   As a conservative measure, 18 samples were collected by random start coordinate location and 9.2 meter spacing.

Supporting Surveys

Supporting survey $6A_2$ was conducted to provide further investigation of potential soil contamination prior to construction of the ISFSI road. Deep core sampling was conducted in two survey efforts to investigate the extent of subsurface contamination. The maximum sample depth was approximately 2.7 meters. Sample point locations were judgmentally selected based on historical data, process knowledge, and location availability due to subsurface obstruction.

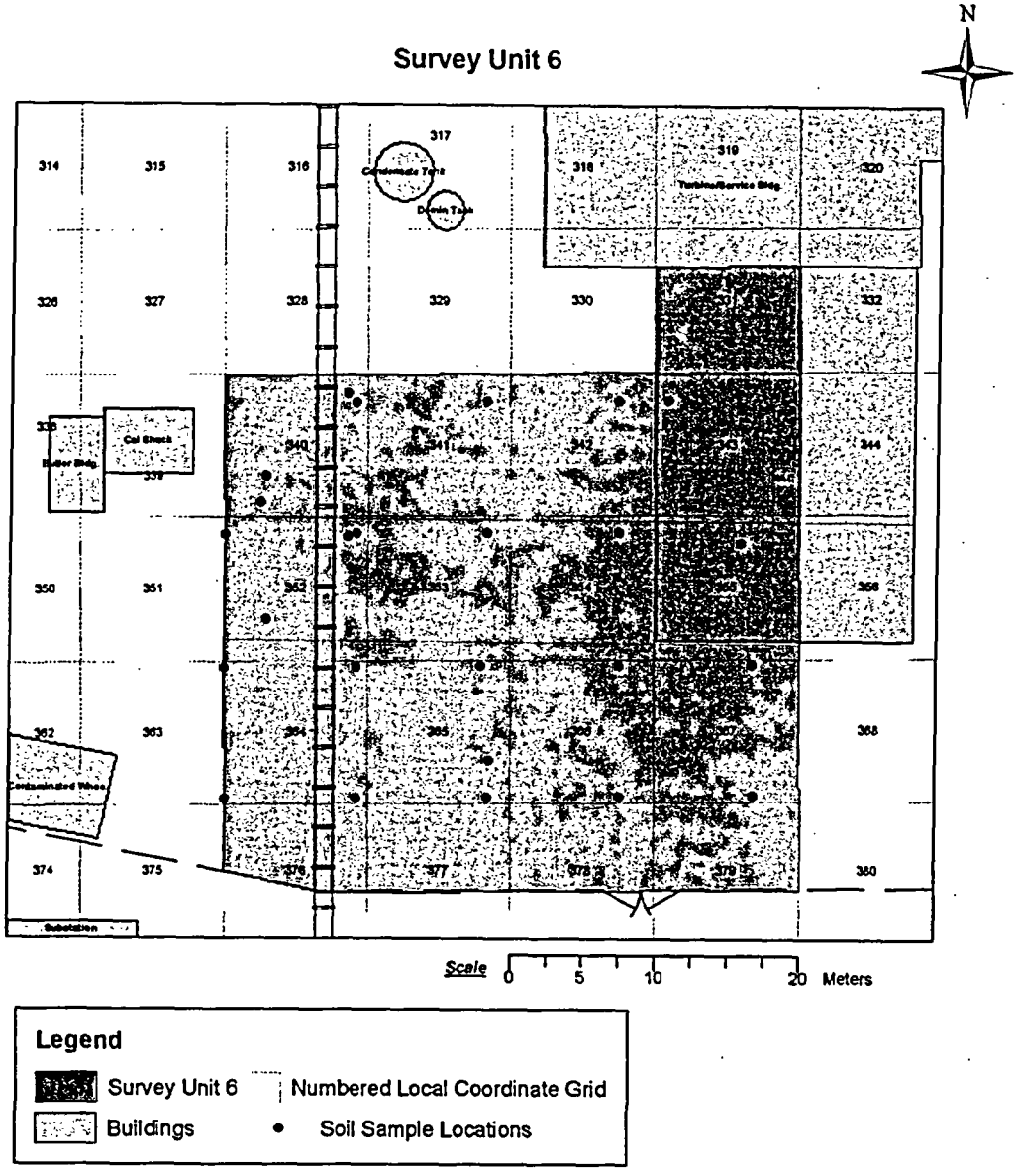
Data Summary

Survey Unit 6

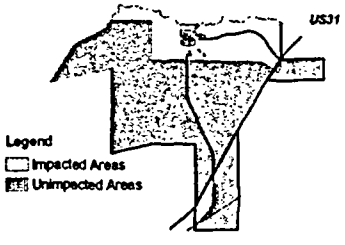
Survey	Data Points	Radionuclide*	Mean (pCi/g)	Max. Value (pCi/g)
$6A_1$	18	Cs_{137}	0.09	0.20
		Co_{60} **	0.08	0.16
$6A_2$	4	Cs_{137}	0.09	0.09
$6A_{deepcore1}$	5	nd	-	-
$6A_{deepcore2}$	2	nd	-	-

* nd denotes no activity detected
** Co-60 detected in 3 samples only

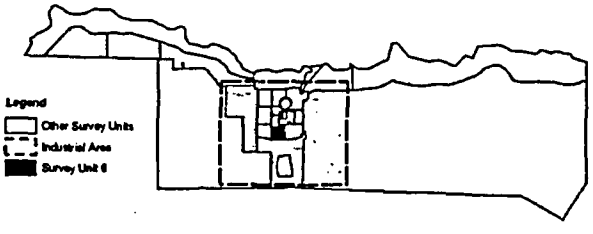
Survey Unit 6



Big Rock Point



Impacted Area North



Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$6A_1$	340	(9.2,8.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.18
$6A_1$	341	(8.4,8.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.20
$6A_1$	342	(7.6,8.0)	0.00-0.15	nd	0.05	nd	0.05	nd	0.20
$6A_1$	352	(0.0,8.8)	0.00-0.15	0.17		0.04		nd	0.24
$6A_1$	352	(9.2,8.8)	0.00-0.15	0.04		nd	0.03	nd	0.19
$6A_1$	353	(8.4,8.8)	0.00-0.15	nd	0.03	nd	0.05	nd	0.16
$6A_1$	354	(7.6,8.8)	0.00-0.15	0.06		nd	0.04	nd	0.20
$6A_1$	364	(0.0,9.6)	0.00-0.15	0.07		0.05		nd	0.24
$6A_1$	364	(9.2,9.6)	0.00-0.15	0.20		0.16		nd	0.27
$6A_1$	365	(8.0,9.6)	0.00-0.15	0.03		nd	0.05	nd	0.19
$6A_1$	366	(7.6,9.6)	0.00-0.15	0.08		nd	0.04	nd	0.24
$6A_1$	367	(6.8,9.6)	0.00-0.15	0.11		nd	0.05	nd	0.22
$6A_1$	364	(0.0,0.4)	0.00-0.15	0.13		nd	0.05	nd	0.19
$6A_1$	364	(9.2,0.4)	0.00-0.15	0.12		nd	0.06	nd	0.23
$6A_1$	365	(8.4,0.4)	0.00-0.15	0.03		nd	0.05	nd	0.20
$6A_1$	366	(7.6,0.4)	0.00-0.15	nd	0.04	nd	0.03	nd	0.19
$6A_1$	367	(6.8,0.4)	0.00-0.15	nd	0.04	nd	0.04	nd	0.20
$6A_1$	340	(9.2,8.0)	0.15-0.30	nd	0.03	nd	0.03	nd	0.18
$6A_2$	352	(2.9,2.9)	0.00-0.15	nd	0.05	nd	0.04	nd	0.30
$6A_2$	352	(8.6,8.6)	0.00-0.15	nd	0.05	nd	0.07	nd	0.24
$6A_2$	340	(2.9,2.9)	0.00-0.15	nd	0.05	nd	0.05	nd	0.23
$6A_2$	340	(8.6,8.6)	0.00-0.15	0.09		nd	0.06	nd	0.26
$6A_{deepcore1}$	355	(6.0,8.0)	0.00-0.45	[c]					
$6A_{deepcore1}$	355	(6.0,8.0)	0.45-1.70	nd	0.06	nd	0.11	nd	0.19
$6A_{deepcore1}$	343	(1.0,8.0)	0.00-0.60	[c]					
$6A_{deepcore1}$	343	(1.0,8.0)	0.60-1.20	nd	0.06	nd	0.07	nd	0.15
$6A_{deepcore1}$	343	(1.0,8.0)	1.20-1.80	nd	0.07	nd	0.07	nd	0.17
$6A_{deepcore1}$	343	(1.0,8.0)	1.80-2.40	nd	0.05	nd	0.07	nd	0.16
$6A_{deepcore1}$	343	(1.0,8.0)	2.40-2.70	nd	0.05	nd	0.07	nd	0.16
$6A_{deepcore2}$	341	(8.4,8.0)	0.60-0.90	nd	0.04	nd	0.05	nd	0.24
$6A_{deepcore2}$	341	(8.4,8.0)	0.90-1.05	nd	0.07	nd	0.07	nd	0.33

[a] nd indicates non detect, MDA provided

[b] No entry in MDA columns is provided when residual radioactivity is detected

[c] Sample was not obtained for analysis (surface gravel).

Survey Unit 7

Description
Survey Unit 7 is an area of approximately 2200 m^2 that occupies the southeast section of the Protected Area. This area contains a portion of the New Access Control Building and the former site electrical substation. Subsurface structures and equipment include the Liquid Radwaste Processing discharge line, storm drains, well water piping, electrical conduit, and Fire Protection System piping.

History
The HSA has identified this survey unit to potentially contain radioactive contamination in area soils. This area is adjacent to the transport route for movement of radioactive waste to the Radwaste Building. This area is also a connecting pathway for the transport of radioactive materials to the Protected Area main gate.

Radiological Status
Residual radioactivity was not identified above background levels in any survey performed in this area. Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified in deep-core sampling analyses. The radiological status of this survey unit is Class 1 based on proximity to the following area locations:

- Contaminated material transport pathways,
- Areas of known soil contamination scheduled for excavation and subsurface component removal,
- Locations scheduled for soil remediation, and
- Buildings and foundations scheduled for demolition and removal of contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.21
Standard deviation (&)	0.23

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.23} = 11.1$$

   With ⬆ and ⬇ error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

Bounding survey unit dimensions 60 X 60 meters
Random Numbers 0.467, 0.76
X = (0.467)(60 m) = 28.0 m
Y = (0.575)(60 m) = 34.5 m

Sample Spacing $L = \sqrt{Area/N} = \sqrt{2200/14} = 12.5$ meters

As a conservative measure, 15 samples were collected by random start coordinate location and 10.5 meter spacing.

Supporting Surveys

One deep core survey was conducted investigate the potential presence of subsurface contamination. The maximum sample depth was approximately 2.25 meters. Sample point locations were judgmentally selected to identify potential areas of contamination using historical information, process knowledge, and location availability based on subsurface obstructions.

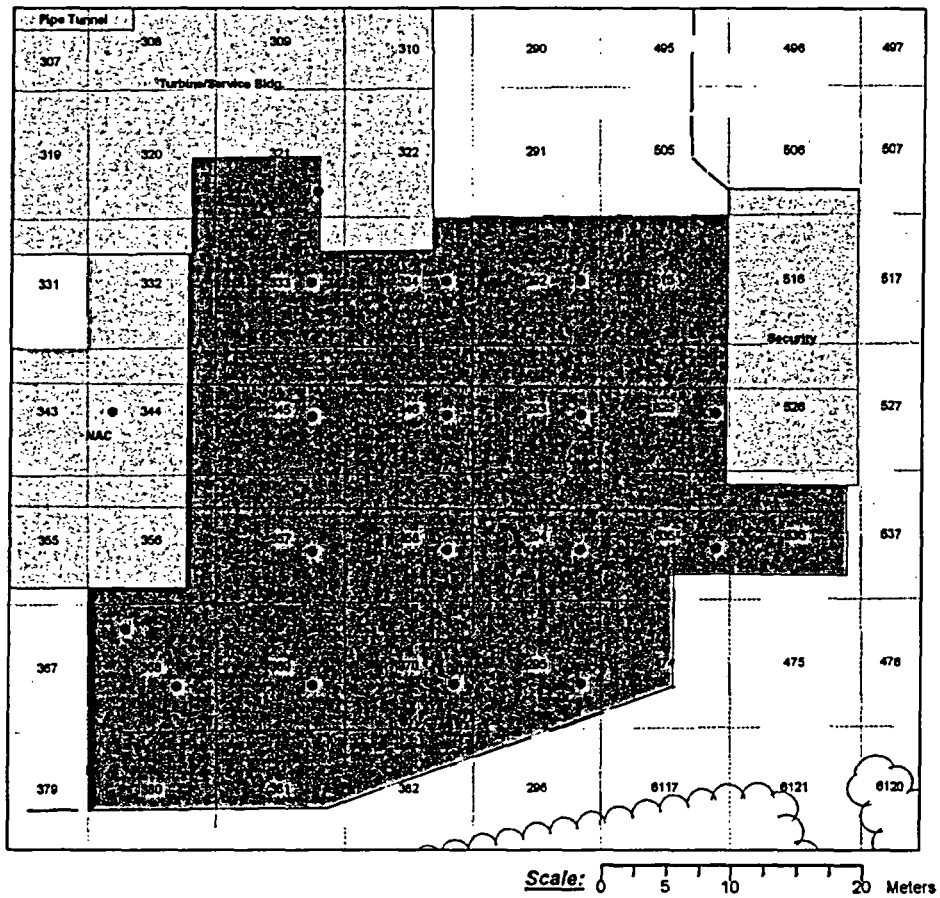
Data Summary

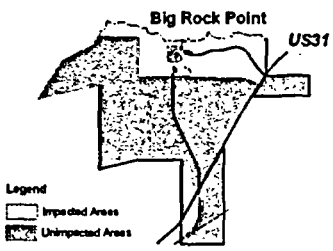
Survey Unit 7

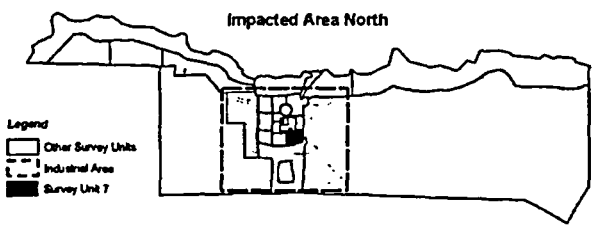
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$7A_1$	15	Cs_{137}**	0.10	0.20
$7A_{deepcore1}$	6	nd	-	-

* nd indicates non detect
** Radioactivity detected in 3 samples only

Survey Unit 7







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$7A_1$	333	(7.5,5.0)	0.00-0.15	nd	0.04	nd	0.04	nd	0.18
$7A_1$	334	(8.0,5.0)	0.00-0.15	nd	0.04	nd	0.05	nd	0.24
$7A_1$	292	(8.5,5.0)	0.00-0.15	nd	0.04	nd	0.05	nd	0.25
$7A_1$	345	(7.5,4.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.17
$7A_1$	346	(8.0,4.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.21
$7A_1$	293	(8.5,4.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.18
$7A_1$	525	(9.0,4.5)	0.00-0.15	nd	0.05	nd	0.05	nd	0.21
$7A_1$	357	(7.5,4.0)	0.00-0.15	nd	0.04	nd	0.05	nd	0.24
$7A_1$	358	(8.0,4.0)	0.00-0.15	nd	0.04	nd	0.05	nd	0.20
$7A_1$	294	(8.5,4.0)	0.00-0.15	nd	0.03	nd	0.04	nd	0.21
$7A_1$	535	(9.0,4.0)	0.00-0.15	0.20		nd	0.05	nd	0.27
$7A_1$	368	(7.0,3.5)	0.00-0.15	0.06		nd	0.05	nd	0.20
$7A_1$	369	(7.5,3.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.20
$7A_1$	370	(8.5,3.5)	0.00-0.15	nd	0.03	nd	0.03	nd	0.16
$7A_1$	295	(8.5,3.5)	0.00-0.15	0.04		nd	0.04	nd	0.20
$7A_{deepcore1}$	321	(8.0,2.0)	0.00-0.60	nd	0.06	nd	0.09	nd	0.15
$7A_{deepcore1}$	321	(8.0,2.0)	0.60-1.20	nd	0.05	nd	0.09	nd	0.19
$7A_{deepcore1}$	344	(2.0,5.0)	0.00-0.45	[c]					
$7A_{deepcore1}$	344	(2.0,5.0)	0.45-1.05	nd	0.07	nd	0.03	nd	0.20
$7A_{deepcore1}$	344	(2.0,5.0)	1.05-2.70	nd	0.07	nd	0.11	nd	0.24
$7A_{deepcore1}$	368	(3.0,8.0)	0.00-0.40	[c]					
$7A_{deepcore1}$	368	(3.0,8.0)	0.40-1.60	nd	0.06	nd	0.10	nd	0.19
$7A_{deepcore1}$	368	(3.0,8.0)	1.60-2.25	nd	0.06	nd	0.08	nd	0.16

[a] nd indicates non detect, MDA provided

[b] No entry in MDA columns is provided when residual radioactivity is detected

[c] Sample was not obtained for analysis (surface gravel).

Survey Unit 8

Description

Survey Unit 8 is approximately 2800 m^2 in size and encompasses the area beneath the Turbine Building and Containment Building. The concrete base pad supporting the Containment Building extends over 10 meters below grade.

Subsurface structures and equipment in these areas are extensive. During plant operation these buildings housed all components and interconnecting systems necessary for power generation. A significant amount of subsurface piping and electrical conduit continues to support systems that currently remain in operation.

History

The eastern section of the Turbine Building (also known as the Service Building Annex) was utilized for office space and has always been maintained as a non-radiological area. The HSA has identified residual radioactivity at two locations in soils beneath the Turbine Building floor:

1. Pipe Tunnel – resulting from the migration of contaminants through concrete expansion joints in the floor, and
2. Track Alley - originating from a former subsurface condensate piping leak.

The Pipe Tunnel expansion joints were sealed and the flooring surface in this area has been reinforced to support the removal of heavy equipment and materials from the Containment Building prior to demolition. Remediation efforts were conducted in 1984 after discovery of a condensate piping leak in Track Alley. Following the removal of contaminated soil, clean fill was used to return the remediated area to proper grade.

Radiological Status

- Residual radioactivity was not identified in soil samples collected beneath the Containment Building above established background levels.
- Surveys conducted in the Turbine Building identified residual radioactivity at IDCGL values in the western portion of Track Alley. Soil analyses in this area verify the results of remediation efforts identified in historical documentation.
- Residual Radioactivity was not identified in the eastern section of the Turbine Building above established background levels.
- Analyses of soil sampled collected beneath the Pipe Tunnel floor yielded residual radioactivity (Co-60) above the IDCGL. The Pipe Tunnel is a segregated section in the northern area of the Turbine Building that annexes the Containment Building.

A significant amount of excavation will be required for the removal of subsurface structures and components in Survey Unit 8. Characterization surveys are scheduled to continue during this process and remediation efforts will be conducted as necessary to satisfy the requirements for final status survey. It is expected that this survey unit will be subdivided into smaller areas for evaluation at the time of the Final Status Survey. The radiological status of Survey Unit 8 is Class 1.

Primary Survey Design

Fire Protection System, Liquid Radwaste Processing System, and other systems supporting continued operation of the Spent Fuel Pool remain in service at this time. As a result, sampling in this area was restricted due to potential breach of operational systems, embedded piping, or electrical power by the boring process required for sample collection. In addition, ongoing decommissioning activities in these areas limit the extent of available sample point locations. A primary survey design based on a systematic sampling approach and the statistical requirements of the Sign Test were not possible in this survey unit.

Sample points were selected at locations of greatest probability to identify radioactivity and define the lateral and vertical extent of potential contaminant migration. Sample size was determined by location availability. The data point selection process was based on documented historical events, process knowledge, and identified contaminant migration pathways defined by hydrogeological evaluation. Samples were collected by mechanically boring through structural steel and concrete and then coring the soil below with specialized sampling equipment. This process has resulted in the collection of 114 samples in four area survey iterations.

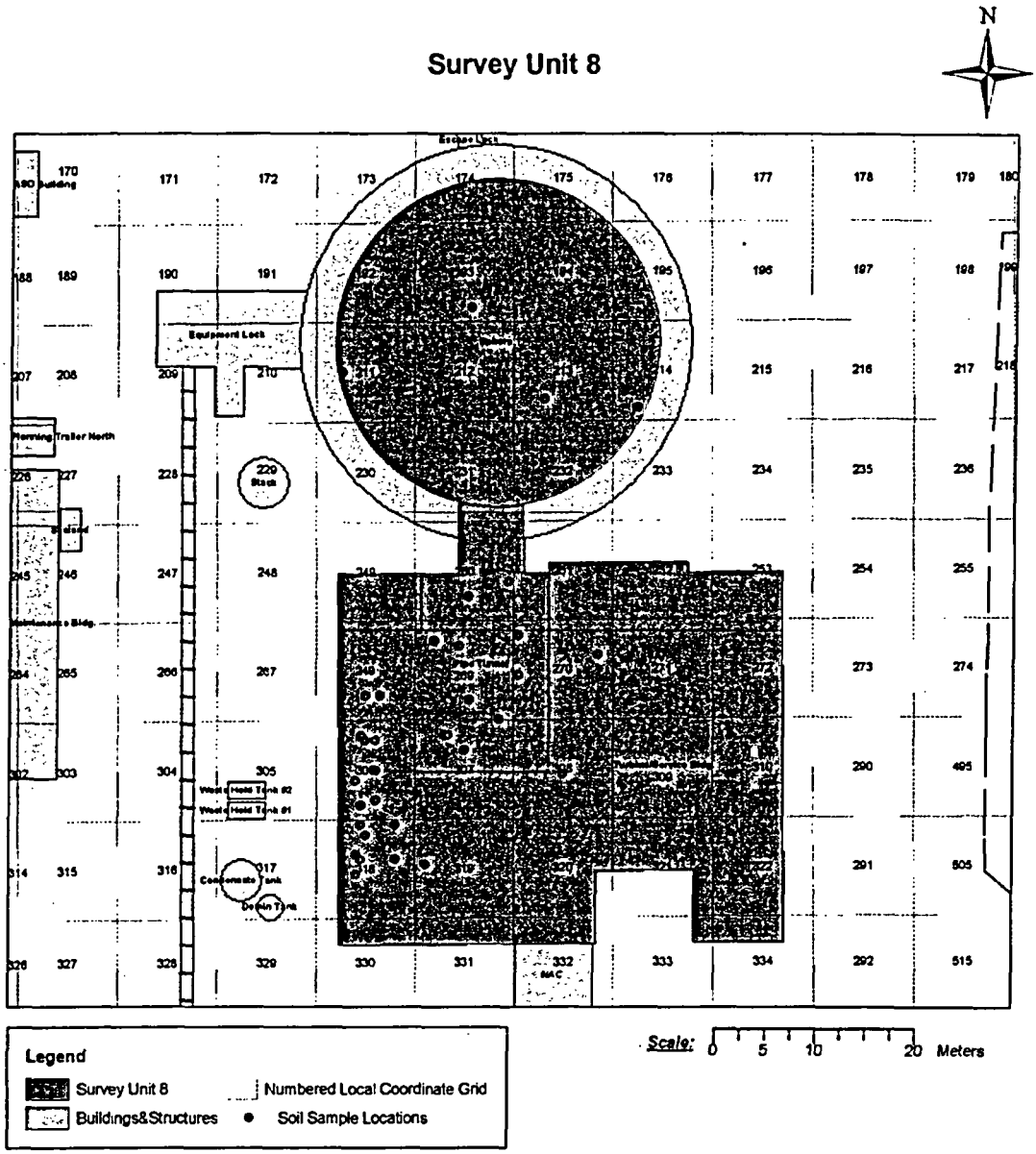
Data Summary

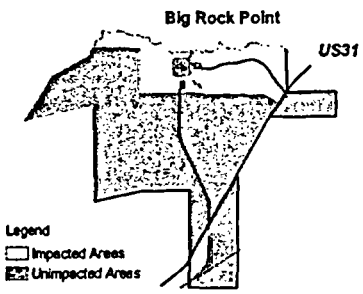
Survey Unit 8

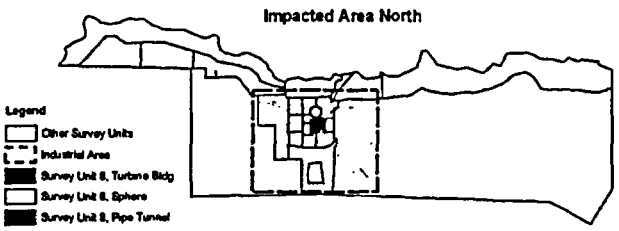
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$8A_{Deepcore\ 1}$ Turbine Bldg.	14	nd	-	-
$8A_{Deepcore\ 2}$ Pipe Tunnel	33	Cs_{137}	1.27	12.60
		Co_{60}	4.84	105.90
		Mn_{54}**	1.77	8.68
$8A_{Deepcore\ 3}$ Turbine Bldg.	58	Cs_{137}	1.22	5.29
		Co_{60}	0.15	0.17
$8A_{Deepcore\ 4}$ Containment	9	nd	-	-

* nd indicates non detect
** Radioactivity detected in one sample only

Survey Unit 8







Survey Results

Survey	Grid	Coordinate [c] (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Mn-54 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
Pipe Tunnel											
8 deepcore 2	250	(5.5,2.5)	0.00-0.30	nd	0.05	0.08		nd	0.06	nd	0.26
8 deepcore 2	250	(5.5,2.5)	0.30-0.60	nd	0.05	0.10		nd	0.06	nd	0.29
8 deepcore 2	250	(5.5,2.5)	0.60-0.90	nd	0.05	nd	0.08	nd	0.07	nd	0.23
8 deepcore 2	250	(9.5,4.0)	0.00-0.30	4.07		105.90		8.68		nd	0.63
8 deepcore 2	250	(9.5,4.0)	0.30-0.60	0.60		15.50		0.92		nd	0.43
8 deepcore 2	250	(9.5,4.0)	0.60-0.90	0.05		0.19		0.03		nd	0.30
8 deepcore 2	269	(2.0,8.0)	0.00-0.30	0.08		0.32		nd	0.07	nd	0.29
8 deepcore 2	269	(2.0,8.0)	0.30-0.60	0.05		0.44		nd	0.07	nd	0.25
8 deepcore 2	269	(2.0,8.0)	0.60-0.90	0.39		3.19		0.17		nd	0.40
8 deepcore 2	269	(2.0,8.0)	0.90-1.20	0.10		0.82		nd	0.07	nd	0.31
8 deepcore 2	269	(2.0,8.0)	1.20-1.50	0.06		0.25		nd	0.05	nd	0.27
8 deepcore 2	269	(2.0,8.0)	1.50-1.80	nd	0.05	0.17		nd	0.04	nd	0.27
8 deepcore 2	269	(2.0,8.0)	1.80-2.10	0.02		0.22		nd	0.06	nd	0.27
8 deepcore 2	269	(4.5,7.5)	0.00-0.15	nd	0.06	0.59		nd	0.11	nd	0.32
8 deepcore 2	269	(4.5,7.5)	0.30-0.60	nd	0.05	0.28		nd	0.08	nd	0.28
8 deepcore 2	269	(4.5,7.5)	0.60-0.90	0.11		0.44		0.09		nd	0.34
8 deepcore 2	269	(4.5,7.5)	0.90-1.20	nd	0.08	0.23		nd	0.08	nd	0.29
8 deepcore 2	269	(4.5,7.5)	1.20-1.50	0.26		8.78		0.73		nd	0.43
8 deepcore 2	269	(4.5,7.5)	1.50-1.80	nd	0.07	nd	0.1	nd	0.05	nd	0.32
8 deepcore 2	269	(4.5,7.5)	1.80-2.10	nd	0.06	0.09		nd	0.06	nd	0.25
8 deepcore 2	269	(4.5,7.5)	2.10-2.40	nd	0.04	0.09		nd	0.05	nd	0.22
8 deepcore 2	269	(5.5,2.0)	0.00-0.15	nd	0.05	0.43		nd	0.07	nd	0.22
8 deepcore 2	269	(5.5,2.0)	0.30-0.60	nd	0.04	0.20		nd	0.07	nd	0.23
8 deepcore 2	269	(8.5,0.0)	0.00-0.15	nd	0.07	1.10		nd	0.10	nd	0.34
8 deepcore 2	269	(8.5,0.0)	0.30-0.60	nd	0.05	0.26		nd	0.07	nd	0.24
8 deepcore 2	270	(0.5,4.5)	0.00-0.15	0.10		1.34		nd	0.12	nd	0.34
8 deepcore 2	270	(0.5,4.5)	0.30-0.60	0.06		0.62		nd	0.10	nd	0.28
8 deepcore 2	270	(0.5,8.5)	0.00-0.15	nd	0.05	0.33		nd	0.08	nd	0.24
8 deepcore 2	270	(0.5,8.5)	0.30-0.60	nd	0.05	0.24		nd	0.07	nd	0.26
8 deepcore 2	307	(3.0,8.5)	0.00-0.15	0.54		0.29		nd	0.08	nd	0.28
8 deepcore 2	307	(3.3,8.5)	0.00-0.15	12.60		2.10		nd	0.07	nd	0.43
8 deepcore 2	307	(5.0,7.0)	0.00-0.15	nd	0.04	0.52		nd	0.08	nd	0.28
8 deepcore 2	307	(5.0,7.0)	0.30-0.60	nd	0.06	nd	0.12	nd	0.06	nd	0.33

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] Datapoint locations are further defined in individual survey file drawings and floor plans

Survey	Grid	Coordinate [c]	Depth (m)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Mn-54 (pCi/g) Activity [a]	Mn-54 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
Turbine/Service Building											
8 deepcore 1	306	(6.0,8.0)	0.00-0.30	nd	0.09	nd	0.13	nd	0.07	nd	0.24
8 deepcore 1	306	(6.0,2.0)	0.00-0.60	nd	0.10	nd	0.06	nd	0.14	nd	0.38
8 deepcore 1	319	(1.0,5.5)	0.00-0.60	nd	0.06	nd	0.1	nd	0.02	nd	0.19
8 deepcore 1	319	(1.0,5.5)	0.60-2.20	nd	0.06	nd	0.09	nd	0.05	nd	0.16
8 deepcore 1	319	(1.0,5.5)	2.20-3.10	nd	0.07	nd	0.07	nd	0.06	nd	0.15
8 deepcore 1	319	(1.0,5.5)	3.10-3.70	nd	0.06	nd	0.09	nd	0.05	nd	0.19
8 deepcore 1	308	(5.0,4.5)	0.00-0.90	nd	0.08	nd	0.10	nd	0.09	nd	0.20
8 deepcore 1	308	(5.0,4.5)	0.90-2.13	nd	0.05	nd	0.08	nd	0.06	nd	0.15
8 deepcore 1	308	(5.0,4.5)	2.13-2.75	nd	0.05	nd	0.04	nd	0.04	nd	0.26
8 deepcore 1	308	(5.0,4.5)	2.75-3.30	nd	0.04	nd	0.05	nd	0.03	nd	0.29
8 deepcore 1	270	(8.5,6.5)	0.00-0.80	nd	0.10	nd	0.11	nd	0.08	nd	0.21
8 deepcore 1	270	(8.5,6.5)	0.80-2.75	nd	0.05	nd	0.11	nd	0.07	nd	0.18
8 deepcore 1	270	(8.5,6.5)	2.75-3.50	nd	0.05	nd	0.08	nd	0.05	nd	0.18
8 deepcore 1	306	(6.0,5.0)	0.00-0.30	nd	0.17	nd	0.21	nd	0.14	nd	0.37
8 deepcore 3	318	(5.0,8.5)	0.00-0.30	0.86		nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	318	(5.0,8.5)	0.30-0.60	3.05		0.17		nd	0.05	nd	0.36
8 deepcore 3	318	(4.5,6.0)	0.00-0.30	nd	0.04	nd	0.05	nd	0.04	nd	0.26
8 deepcore 3	318	(4.5,6.0)	0.30-0.60	0.07		nd	0.06	nd	0.04	nd	0.28
8 deepcore 3	318	(4.5,6.0)	0.60-0.90	4.77		nd	0.09	nd	0.06	nd	0.43
8 deepcore 3	318	(4.5,6.0)	0.90-1.20	2.10		nd	0.05	nd	0.04	nd	0.32
8 deepcore 3	318	(4.0,6.5)	0.00-0.30	nd	0.04	nd	0.07	nd	0.04	nd	0.23
8 deepcore 3	318	(4.0,6.5)	0.30-0.60	0.05		nd	0.05	nd	0.04	nd	0.26
8 deepcore 3	318	(4.0,6.5)	0.60-0.90	4.58		nd	0.07	nd	0.03	nd	0.38
8 deepcore 3	318	(4.0,6.5)	0.90-1.20	2.25		0.13		nd	0.05	nd	0.37
8 deepcore 3	318	(4.0,6.5)	1.20-1.40	0.84		nd	0.07	nd	0.04	nd	0.31
8 deepcore 3	318	(4.0,4.5)	0.00-0.30	nd	0.04	nd	0.06	nd	0.03	nd	0.25
8 deepcore 3	318	(4.0,4.5)	0.30-0.60	nd	0.05	nd	0.05	nd	0.04	nd	0.27
8 deepcore 3	318	(4.0,4.5)	0.60-0.90	5.29		nd	0.04	nd	0.05	nd	0.37
8 deepcore 3	318	(4.0,4.5)	0.90-1.20	1.00		nd	0.06	nd	0.05	nd	0.28
8 deepcore 3	318	(4.0,4.5)	1.20-1.50	0.60		nd	0.08	nd	0.04	nd	0.29
8 deepcore 3	318	(4.0,4.5)	1.50-1.80	0.15		nd	0.06	nd	0.04	nd	0.23
8 deepcore 3	318	(4.0,4.5)	1.80-2.10	nd	0.04	nd	0.04	nd	0.03	nd	0.23
8 deepcore 3	318	(8.0,6.0)	0.00-0.30	0.04		nd	0.05	nd	0.03	nd	0.20
8 deepcore 3	318	(8.0,6.0)	0.30-0.60	nd	0.03	nd	0.06	nd	0.02	nd	0.30
8 deepcore 3	318	(8.0,6.0)	0.60-0.90	nd	0.05	nd	0.06	nd	0.04	nd	0.30
8 deepcore 3	318	(8.0,6.0)	0.90-1.20	nd	0.05	nd	0.06	nd	0.03	nd	0.23
8 deepcore 3	318	(8.0,6.0)	1.20-1.50	nd	0.05	nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	318	(8.0,6.0)	1.50-1.80	nd	0.04	nd	0.05	nd	0.03	nd	0.25
8 deepcore 3	318	(8.0,9.5)	0.00-0.30	nd	0.04	nd	0.04	nd	0.04	nd	0.27

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] Datapoint locations are further defined in individual survey file drawings and floor plans

Survey	Grid	Coordinate [c]	Depth (m)	Cs-137 (pCi/g) Activity [a]	Cs-137 (pCi/g) MDA [b]	Co-60 (pCi/g) Activity [a]	Co-60 (pCi/g) MDA [b]	Mn-54 (pCi/g) Activity [a]	Mn-54 (pCi/g) MDA [b]	Am-241 (pCi/g) Activity [a]	Am-241 (pCi/g) MDA [b]
Turbine/Service Building (cont.)											
8 deepcore 3	318	(8.0,9.5)	0.30-0.60	nd	0.04	nd	0.05	nd	0.04	nd	0.25
8 deepcore 3	318	(8.0,9.5)	0.60-0.90	0.10		nd	0.05	nd	0.05	nd	0.24
8 deepcore 3	318	(8.0,9.5)	0.90-1.20	0.10		nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	318	(8.0,9.5)	1.20-1.50	nd	0.05	nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	318	(8.0,9.5)	1.50-1.80	nd	0.04	nd	0.06	nd	0.04	nd	0.25
8 deepcore 3	318	(8.0,9.5)	1.80-2.10	nd	0.04	nd	0.05	nd	0.03	nd	0.25
8 deepcore 3	306	(4.5,1.5)	0.00-0.30	0.04		nd	0.06	nd	0.04	nd	0.27
8 deepcore 3	306	(4.5,1.5)	0.30-0.60	nd	0.06	nd	0.08	nd	0.05	nd	0.34
8 deepcore 3	318	(4.5,9.5)	0.00-0.30	nd	0.04	nd	0.05	nd	0.05	nd	0.26
8 deepcore 3	318	(4.5,9.5)	0.30-0.60	nd	0.05	nd	0.06	nd	0.04	nd	0.28
8 deepcore 3	306	(4.0,4.0)	0.00-0.30	0.14		nd	0.09	nd	0.05	nd	0.28
8 deepcore 3	306	(4.0,4.0)	0.30-0.60	0.06		nd	0.06	nd	0.04	nd	0.27
8 deepcore 3	306	(4.0,4.0)	0.60-0.90	1.16		nd	0.05	nd	0.04	nd	0.26
8 deepcore 3	306	(4.0,4.0)	0.90-1.20	0.55		nd	0.07	nd	0.04	nd	0.23
8 deepcore 3	306	(4.0,4.0)	1.20-1.50	0.19		nd	0.05	nd	0.03	nd	0.25
8 deepcore 3	306	(4.0,4.0)	1.50-1.80	0.06		nd	0.06	nd	0.04	nd	0.24
8 deepcore 3	306	(4.5,8.5)	0.00-0.30	0.04		nd	0.08	nd	0.05	nd	0.31
8 deepcore 3	306	(4.5,8.5)	0.30-0.60	nd	0.04	nd	0.06	nd	0.05	nd	0.27
8 deepcore 3	306	(4.5,8.5)	0.60-0.90	nd	0.05	nd	0.06	nd	0.04	nd	0.23
8 deepcore 3	306	(5.0,8.0)	0.00-0.30	nd	0.06	nd	0.06	nd	0.05	nd	0.28
8 deepcore 3	306	(5.0,8.0)	0.30-0.60	nd	0.05	nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	306	(5.0,8.0)	0.60-0.90	nd	0.05	nd	0.05	nd	0.03	nd	0.28
8 deepcore 3	268	(6.5,2.5)	0.00-0.30	nd	0.05	nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	268	(6.5,2.5)	0.30-0.60	nd	0.06	nd	0.05	nd	0.04	nd	0.26
8 deepcore 3	268	(6.5,2.5)	0.60-0.90	nd	0.04	nd	0.07	nd	0.04	nd	0.26
8 deepcore 3	268	(6.5,2.5)	0.90-1.20	nd	0.06	nd	0.06	nd	0.04	nd	0.26
8 deepcore 3	268	(6.5,2.5)	1.20-1.50	nd	0.05	nd	0.06	nd	0.04	nd	0.22
8 deepcore 3	268	(6.5,2.5)	1.50-1.80	nd	0.04	nd	0.09	nd	0.04	nd	0.24
8 deepcore 3	268	(6.5,2.5)	1.80-2.10	nd	0.04	nd	0.09	nd	0.05	nd	0.30
8 deepcore 3	268	(6.5,2.5)	2.10-2.40	nd	0.04	nd	0.06	nd	0.04	nd	0.27
8 deepcore 3	268	(5.0,2.5)	0.00-0.30	nd	0.04	nd	0.06	nd	0.03	nd	0.23
8 deepcore 3	268	(5.0,2.5)	0.30-0.60	nd	0.04	nd	0.06	nd	0.03	nd	0.25
8 deepcore 3	268	(5.0,2.5)	0.60-0.90	nd	0.05	nd	0.06	nd	0.04	nd	0.24

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] Datapoint locations are further defined in individual survey file drawings and floor plans

Survey	Grid	Coordinate [c]	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Mn-54 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
Containment											
8 deepcore 4	193	(5.8,1.5)	0.00-0.15	nd	0.05	nd	0.08	nd	0.05	nd	0.29
8 deepcore 4	193	(5.8,1.5)	0.15-0.30	nd	0.03	nd	0.06	nd	0.03	nd	0.23
8 deepcore 4	193	(5.8,1.5)	0.30-0.45	nd	0.03	nd	0.05	nd	0.03	nd	0.22
8 deepcore 4	211	(2.7,5.0)	0.00-0.15	nd	0.06	nd	0.08	nd	0.06	nd	0.37
8 deepcore 4	211	(2.7,5.0)	0.15-0.30	nd	0.05	nd	0.07	nd	0.05	nd	0.29
8 deepcore 4	213	(3.2,2.2)	0.00-0.15	nd	0.04	nd	0.08	nd	0.04	nd	0.27
8 deepcore 4	214	(2.5,1.3)	0.00-0.15	nd	0.05	nd	0.08	nd	0.04	nd	0.30
8 deepcore 4	214	(2.5,1.3)	0.15-0.30	nd	0.04	nd	0.06	nd	0.04	nd	0.24
8 deepcore 4	214	(2.5,1.3)	0.30-0.45	nd	0.05	nd	0.07	nd	0.05	nd	0.25

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] Datapoint locations are further defined in individual survey file drawings and floor plans

Survey Unit 9

Description

Survey Unit 9 is an area of approximately 2900 m^2 that occupies the northeast section of the Protected Area. This area encompasses the Screenhouse (lake water inlet), Service Water System piping, and Fire Protection System piping. Other subsurface structures and equipment include the following:

- Diesel storage tanks (2) southeast of the Screen House,
- Diesel storage tank north of the Turbine Building),
- Septic tanks along the southeast boundary of the survey unit,
- Liquid radwaste release piping,
- Transformer station and associated underground power conduit located in survey grid 234, and
- Electrical power and instrumentation conduit, Condenser Cooling Water, Service Water, Well Water and Fire Protection, Compressed Air system piping, and storm drains.

History

The HSA has identified this survey unit to potentially contain residual radioactivity in area soils. A materials transport route to the main gate traverses this survey unit from north to south. The liquid radwaste discharge line for radioactive effluent is located below grade in this area.

Radiological Status

Residual radioactivity was not identified above background values trace values (0.33 pCi/g) in any survey performed in this area. Subsurface soil contamination is not indicated by the HSA or process knowledge and was not identified by characterization analyses. The radiological status of Survey Unit 9 is Class 1 based on proximity to the following area locations:

- Contaminated material transport pathways,
- Areas of known soil contamination,
- Buildings containing contaminated equipment and materials.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.43
Standard deviation (&)	0.00

Scoping survey analyses resulted in identical concentration values for Cs-137. An estimated standard deviation value of 0.43 is conservatively assumed for relative shift calculation. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{\text{DCGL} - \text{LBGR}}{\sigma} = \frac{5.11 - 2.5}{0.43} = 6.1$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   The approximate bounding dimensions of survey unit 9 are 40 x 60 meters
   Random Numbers 0.52, 0.62
   X = (0.52)(40 m) = 20.8 m
   Y = (0.62)(60 m) = 37.2 m

   Sample Spacing $L = \sqrt{Area/N} = \sqrt{2900/14} = 14.3$ meter spacing

   As a conservative measure 22 samples were collected using 11.8 meter spacing. For data points falling outside the survey unit or where obstructions prohibited sample collection, alternate sample locations were identified by the random selection process described above.

Supporting Surveys
One deep-core survey was conducted to investigate the potential presence of subsurface contamination. The maximum sample depth was approximately 2.25 meters. Sample point locations were judgmentally selected using historical documentation, process knowledge, and location availability based on subsurface obstructions.

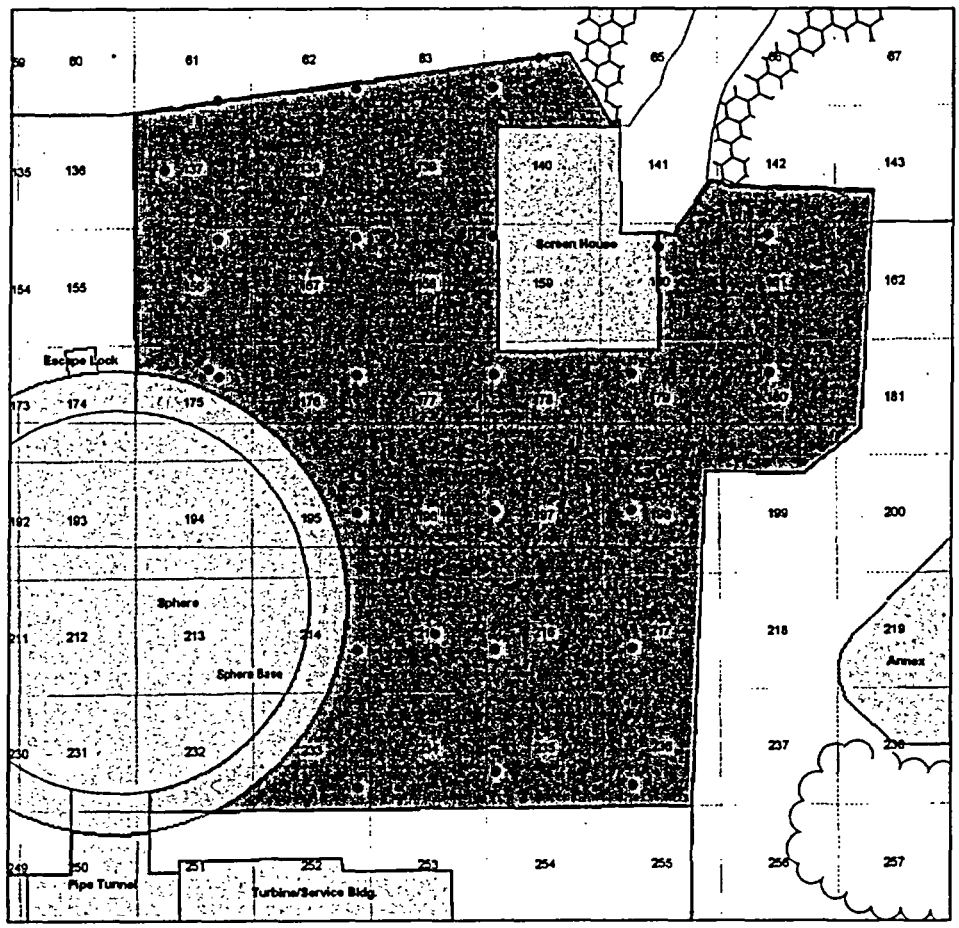
Data Summary

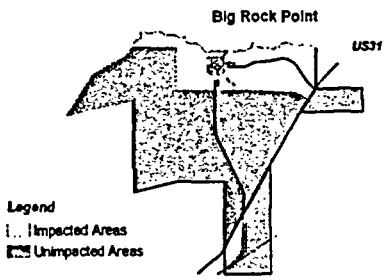
Survey Unit 9

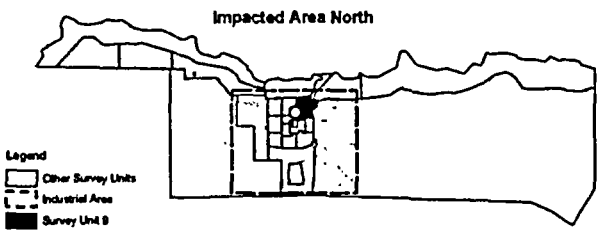
Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$9A_1$	22	Cs_{137}	0.19	0.33
		Co_{60}**	0.04	0.04
$9A_{deepcore1}$	19	Cs_{137}	0.09	0.14
		Co_{60}	nd	-

* nd indicates no activity detected
** Activity detected in one sample only

Survey Unit 9







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
$9A_1$	61	(7.2,1.8)	0.00-0.15	0.09		nd	0.10	nd	0.35
$9A_1$	62	(9.0,1.8)	0.00-0.15	0.08		nd	0.04	nd	0.22
$9A_1$	64	(0.8,1.8)	0.00-0.15	0.26		nd	0.12	nd	0.31
$9A_1$	156	(7.2,9.0)	0.00-0.15	nd	0.08	nd	0.08	nd	0.40
$9A_1$	157	(9.0,9.0)	0.00-0.15	nd	0.03	nd	0.04	nd	0.21
$9A_1$	159	(0.8,9.0)	0.00-0.15	nd	0.09	nd	0.09	nd	0.42
$9A_1$	160	(5.0,8.0)	0.00-0.15	0.20		nd	0.06	nd	0.24
$9A_1$	161	(4.4,9.0)	0.00-0.15	0.17		nd	0.05	nd	0.25
$9A_1$	175	(7.2,7.2)	0.00-0.15	0.29		nd	0.07	nd	0.25
$9A_1$	176	(9.0,7.2)	0.00-0.15	0.23		nd	0.06	nd	0.26
$9A_1$	178	(0.8,7.2)	0.00-0.15	nd	0.10	nd	0.08	nd	0.37
$9A_1$	179	(2.6,7.2)	0.00-0.15	0.07		nd	0.04	nd	0.22
$9A_1$	180	(4.4,7.2)	0.00-0.15	0.14		nd	0.04	nd	0.27
$9A_1$	195	(9.0,5.4)	0.00-0.15	0.24		nd	0.06	nd	0.26
$9A_1$	197	(0.8,5.4)	0.00-0.15	nd	0.10	nd	0.08	nd	0.42
$9A_1$	198	(2.6,5.4)	0.00-0.15	0.13		0.04		nd	0.29
$9A_1$	214	(9.0,3.6)	0.00-0.15	0.33		nd	0.06	nd	0.25
$9A_1$	216	(0.8,3.6)	0.00-0.15	0.22		nd	0.10	nd	0.40
$9A_1$	217	(2.6,3.6)	0.00-0.15	0.25		nd	0.06	nd	0.26
$9A_1$	233	(9.0,1.8)	0.00-0.15	0.25		nd	0.11	nd	0.36
$9A_1$	235	(0.8,3.0)	0.00-0.15	0.24		nd	0.07	nd	0.42
$9A_1$	236	(2.6,1.8)	0.00-0.15	0.11		nd	0.11	nd	0.43
$9A_{deepcore1}$	137	(2.6,4.9)	0.00-0.60	0.03		nd	0.05	nd	0.21
$9A_{deepcore1}$	137	(2.6,4.9)	0.60-1.20	nd	0.04	nd	0.05	nd	0.21
$9A_{deepcore1}$	137	(2.6,4.9)	1.20-1.80	nd	0.05	nd	0.09	nd	0.36
$9A_{deepcore1}$	137	(2.6,4.9)	1.80-2.40	nd	0.04	nd	0.11	nd	0.34
$9A_{deepcore1}$	137	(2.6,4.9)	2.40-3.00	nd	0.08	nd	0.11	nd	0.27
$9A_{deepcore1}$	137	(2.6,4.9)	3.00-3.60	nd	0.08	nd	0.10	nd	0.43
$9A_{deepcore1}$	175	(6.3,7.9)	0.00-0.60	0.14		nd	0.10	nd	0.41
$9A_{deepcore1}$	175	(6.3,7.9)	0.60-1.20	nd	0.09	nd	0.11	nd	0.42
$9A_{deepcore1}$	175	(6.3,7.9)	1.20-1.80	nd	0.08	nd	0.07	nd	0.26
$9A_{deepcore1}$	175	(6.3,7.9)	1.80-2.40	nd	0.07	nd	0.08	nd	0.41
$9A_{deepcore1}$	175	(6.3,7.9)	2.40-3.00	nd	0.07	nd	0.09	nd	0.29
$9A_{deepcore1}$	175	(6.3,7.9)	3.00-3.60	nd	0.04	nd	0.05	nd	0.26
$9A_{deepcore1}$	175	(6.3,7.9)	3.60-4.10	nd	0.08	nd	0.13	nd	0.42
$9A_{deepcore1}$	215	(5.7,5.0)	0.00-0.60	[c]					
$9A_{deepcore1}$	215	(5.7,5.0)	0.60-1.20	nd	0.07	nd	0.03	nd	0.34
$9A_{deepcore1}$	215	(5.7,5.0)	1.20-1.80	nd	0.08	nd	0.09	nd	0.29

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c]: Sample was not obtained for analysis (surface gravel)

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$9A_{deepcore1}$	215	(5.7,5.0)	1.80-2.40	nd	0.07	nd	0.10	nd	0.37
$9A_{deepcore1}$	215	(5.7,5.0)	2.40-3.00	nd	0.04	nd	0.06	nd	0.24
$9A_{deepcore1}$	215	(5.7,5.0)	3.00-3.60	nd	0.06	nd	0.12	nd	0.44
$9A_{deepcore1}$	215	(5.7,5.0)	3.60-11.2	nd	0.02	nd	0.04	nd	0.18

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 10

Description

Survey Unit 10 is a relatively small are of approximately 950 m^2 immediately east of the Service Building. This survey unit is primarily paved open space that provides entry into the Protected Area. Subsurface structures and equipment include the following systems, piping, and conduit:

- Liquid Radwaste discharge,
- Electrical power and instrumentation,
- Condenser Cooling Water,
- Service Water,
- Well Water,
- Fire Protection,
- Compressed Air, and
- Storm drains.

History

The HSA has identified this survey unit to potentially contain residual radioactivity in area soils. A materials transfer route to the main entry gate traverses this survey unit from north to south.

Radiological Status

Residual radioactivity was not identified above background levels in any survey performed in this area. Subsurface residual radioactivity is not indicated by the HSA or process knowledge. The radiological status of Survey Unit 10 is Class 1 based on proximity to the following area locations:

- Contaminated material transport pathways,
- Areas of known soil contamination, and
- Buildings containing contaminated equipment and materials

Primary Survey Design

1. Sample Data Points Required
   A scoping survey was not conducted in this area. Based on physical characteristics, historical documentation and the process knowledge of land usage for this area, Survey Unit 10 is identical to the adjoining survey units (7 and 9) within the Protected Area. The standard deviation for determination of relative shift was set at the highest value identified (0.43) in the surrounding area. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL} - \text{LBGR}}{\sigma} = \frac{5.11 - 2.5}{0.43} = 6.1$$

   With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

The approximate bounding dimensions of Survey Unit 10 are 20 x 40 meters
Random Numbers 0.07, 0.97
X = (0.07)(20 m) = 1.4 m
Y = (0.97)(40 m) = 38.8 m

Sample Spacing $L = \sqrt{Area/N} = \sqrt{950/14} = 8.2$ meter spacing

As a conservative measure 21 samples were collected using 7.1 meter spacing.

Supporting Surveys
No supporting surveys have been conducted to date.

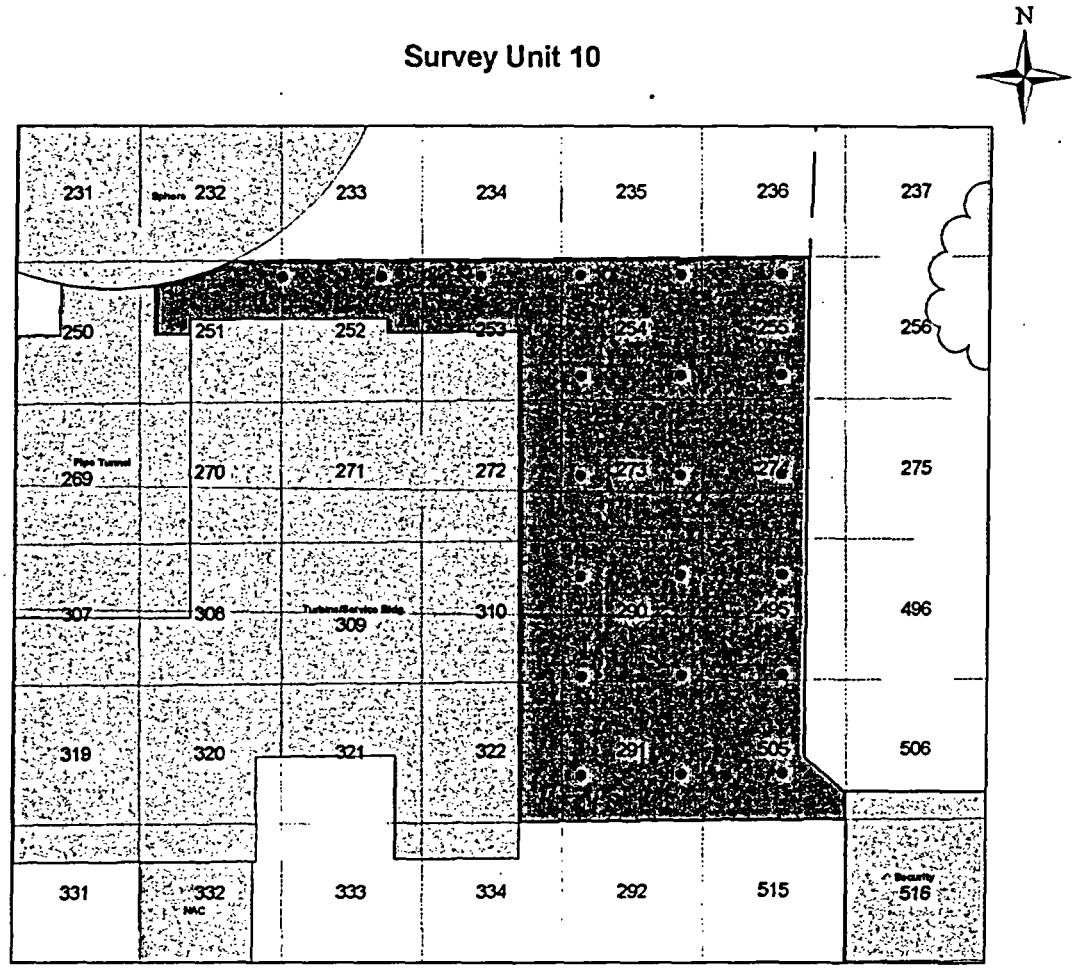
Data Summary

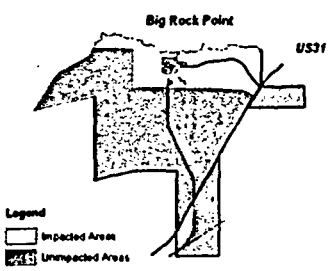
Survey Unit 10

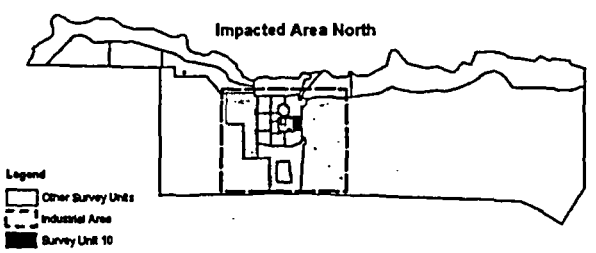
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$10A_1$	21	Cs_{137}	0.22	0.52

* nd indicates non detect

Survey Unit 10







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$10A_1$	252	(0.1,8.8)	0.00-0.15	nd	0.03	nd	0.04	nd	0.20
$10A_1$	252	(7.2,8.8)	0.00-0.15	nd	0.03	nd	0.05	nd	0.19
$10A_1$	253	(4.3,8.8)	0.00-0.15	nd	0.04	nd	0.04	nd	0.19
$10A_1$	254	(1.4,8.8)	0.00-0.15	nd	0.04	nd	0.05	nd	0.19
$10A_1$	254	(8.5,8.8)	0.00-0.15	0.03		nd	0.04	nd	0.20
$10A_1$	255	(5.6,8.8)	0.00-0.15	0.30		nd	0.07	nd	0.22
$10A_1$	254	(1.4,1.7)	0.00-0.15	0.36		nd	0.07	nd	0.26
$10A_1$	254	(8.5,1.7)	0.00-0.15	nd	0.04	nd	0.05	nd	0.24
$10A_1$	255	(5.6,1.7)	0.00-0.15	0.52		nd	0.08	nd	0.36
$10A_1$	273	(1.4,4.6)	0.00-0.15	nd	0.04	nd	0.05	nd	0.17
$10A_1$	273	(8.5,4.6)	0.00-0.15	nd	0.04	nd	0.04	nd	0.17
$10A_1$	274	(5.6,4.6)	0.00-0.15	nd	0.06	nd	0.06	nd	0.38
$10A_1$	290	(1.4,7.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.20
$10A_1$	290	(8.5,7.5)	0.00-0.15	nd	0.05	nd	0.05	nd	0.18
$10A_1$	495	(5.6,7.5)	0.00-0.15	0.06		nd	0.05	nd	0.22
$10A_1$	290	(1.4,0.4)	0.00-0.15	nd	0.03	nd	0.05	nd	0.17
$10A_1$	290	(8.5,0.4)	0.00-0.15	nd	0.04	nd	0.04	nd	0.22
$10A_1$	495	(5.6,0.4)	0.00-0.15	nd	0.04	nd	0.05	nd	0.24
$10A_1$	291	(1.4,3.3)	0.00-0.15	nd	0.05	nd	0.05	nd	0.22
$10A_1$	291	(8.5,3.3)	0.00-0.15	nd	0.05	nd	0.04	nd	0.18
$10A_1$	505	(5.6,3.3)	0.00-0.15	0.02		nd	0.05	nd	0.14

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 11

Description

Survey Unit 11 is an area of approximately 2350 m^2 located south of the Protected Area. This location encompasses the Radwaste Building and Mixed Low-Level Waste Storage Building. Subsurface structures and equipment include the following:

- Radwaste storage vaults,
- Electrical power and fiber optic conduit,
- Drain piping, and
- Remote security camera and motion sensor relay communication.

History

The HSA has identified this survey unit to potentially contain residual radioactivity in soil. This area was the temporary storage and staging location for all plant radioactive waste material prior to shipment to a licensed disposal facility. Contamination events have occurred in this area and extensive soil remediation efforts have been documented.

Radiological Status

Residual radioactivity was identified at less than 1.0 pCi/g in this survey area. The radiological status of Survey Unit 11 is Class 1 based on former building usage, proximity to material transport pathways, and the current radiological status of the solid radwaste vaults.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60
Mean value (pCi/g)	0.16	0.10
Standard deviation (&)	0.27	0.06

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{DCGL_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{DCGL_{Co}}\right)^2} = \sqrt{\left(\frac{0.27_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{0.06_{Co}}{4.99_{Co}}\right)^2}$$

$$\sigma = 0.05$$

For the Unity Rule, the DCGL for the weighted sum is 1. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1-0.5}{0.05} = 10$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample data point locations were selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 50 X 60 meters
   Random Numbers 0.186, 0.004
   X = (0.186)(,50 m) =23.6 m
   Y = (0.004)(60 m) = 49.5 m

   Sample Spacing $L = \sqrt{Area/N} = \sqrt{2350/14} = 12.9$ meters

   As a conservative measure 25 samples were collected using 11 meter spacing.

Supporting Surveys
Two deep-core surveys were conducted for the investigation of potential subsurface contamination. These surveys include samples collected through the concrete flooring in proximity the radwaste vaults and split spoon samples taken in open areas surrounding the Radwaste Building. The maximum sample depth was approximately 1.8 meters. Sample point locations were judgmentally selected based on historical documentation, process knowledge, and location availability where subsurface obstructions were not present.

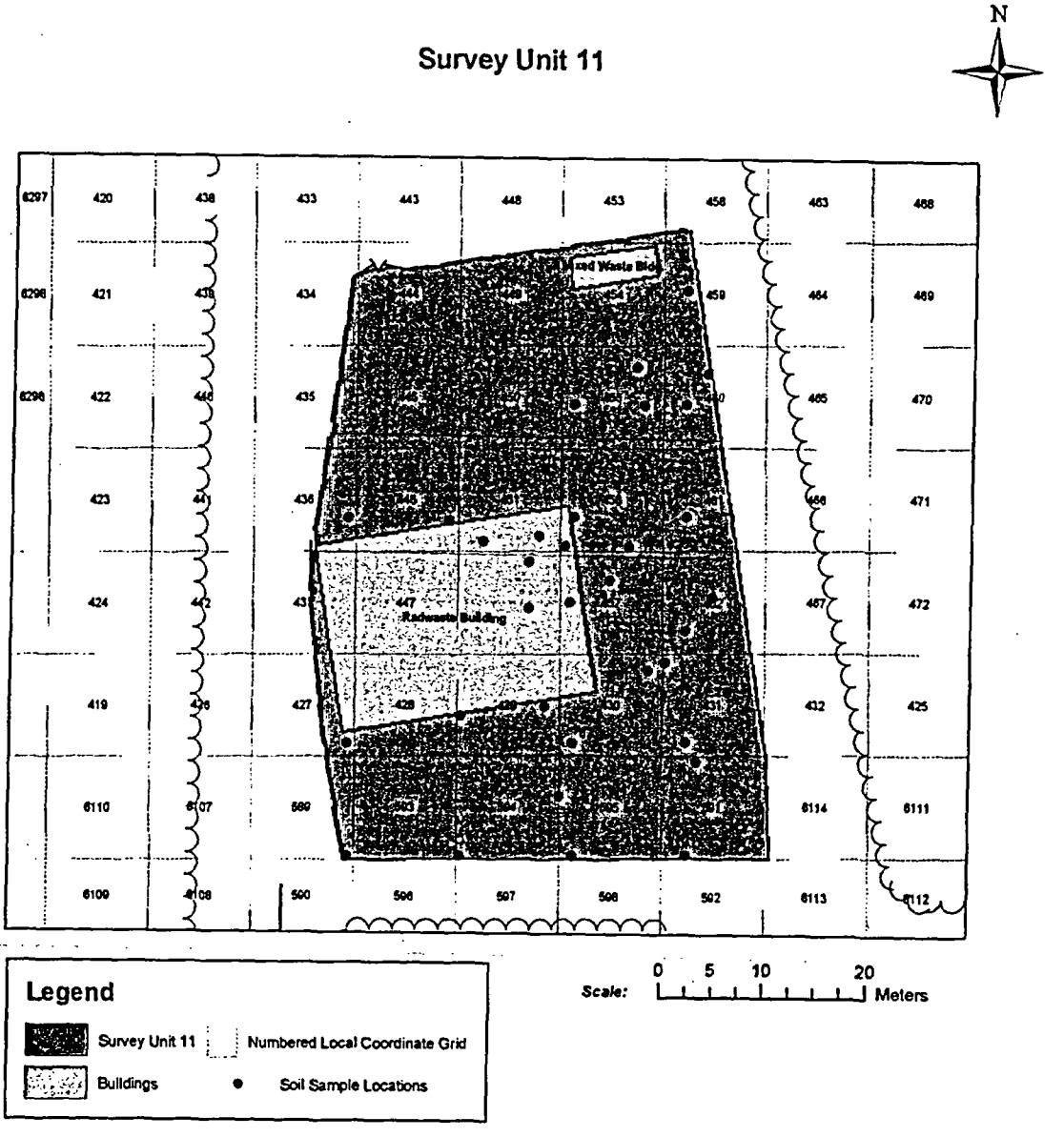
Data Summary

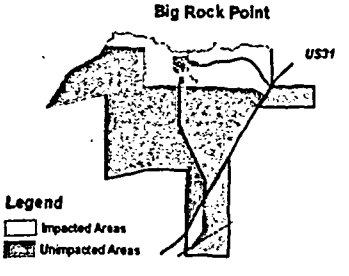
Survey Unit 11

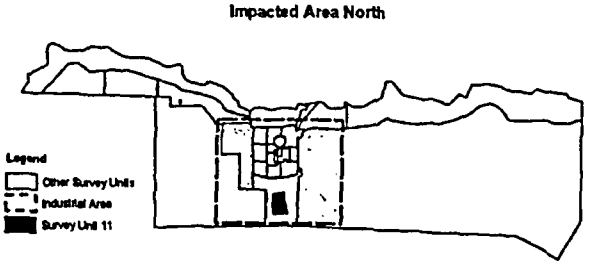
Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$11A_1$	25	Cs_{137}	0.17	0.40
		Co_{60}*	0.48	0.64
$11A_{deepcore1}$	6	Cs_{137}*	0.28	0.43
$11A_{deepcore2}$	33	Cs_{137}	0.09	0.93
		Co_{60}*	0.19	0.24

*Radioactivity identified in 2 samples only

Survey Unit 11







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$11A_1$	589	(9.3,0.3)	0.00-0.15	nd	0.04	nd	0.05	nd	0.19
$11A_1$	594	(0.3,0.3)	0.00-0.15	nd	0.04	nd	0.04	nd	0.26
$11A_1$	595	(1.3,0.3)	0.00-0.15	0.05		nd	0.06	nd	0.25
$11A_1$	591	(2.3,0.3)	0.00-0.15	0.11		nd	0.09	nd	0.28
$11A_1$	431	(2.3,1.3)	0.00-0.15	nd	0.06	nd	0.05	nd	0.23
$11A_1$	430	(1.3,1.3)	0.00-0.15	0.24		nd	0.05	nd	0.28
$11A_1$	429	(0.3,4.0)	0.00-0.15	0.17		nd	0.07	nd	0.24
$11A_1$	427	(9.3,1.3)	0.00-0.15	nd	0.04	nd	0.04	nd	0.19
$11A_1$	462	(2.3,2.3)	0.00-0.15	0.18		nd	0.06	nd	0.28
$11A_1$	461	(2.3,3.3)	0.00-0.15	0.18		nd	0.09	nd	0.28
$11A_1$	456	(1.3,3.3)	0.00-0.15	0.07		nd	0.05	nd	0.23
$11A_1$	460	(2.3,4.3)	0.00-0.15	0.16		nd	0.06	nd	0.28
$11A_1$	455	(1.3,4.3)	0.00-0.15	0.14		nd	0.06	nd	0.30
$11A_1$	459	(2.3,5.3)	0.00-0.15	0.12		nd	0.06	nd	0.28
$11A_1$	436	(9.3,3.3)	0.00-0.15	0.39		0.64		nd	0.32
$11A_1$	429	(8.6,4.9)	0.00-0.15	0.22		nd	0.08	nd	0.24
$11A_1$	430	(8.6,8.4)	0.00-0.15	0.10		nd	0.07	nd	0.27
$11A_1$	455	(7.4,7.9)	0.00-0.15	0.12		nd	0.07	nd	0.25
$11A_1$	460	(4.4,7.3)	0.00-0.15	0.10		nd	0.07	nd	0.23
$11A_1$	455	(8.1,4.2)	0.00-0.15	0.13		nd	0.06	nd	0.28
$11A_1$	446	(9.1,3.0)	0.00-0.15	0.18		0.31		nd	0.28
$11A_1$	591	(3.4,9.4)	0.00-0.15	0.15		nd	0.06	nd	0.24
$11A_1$	462	(4.9,5.5)	0.00-0.15	0.40		nd	0.09	nd	0.30
$11A_1$	457	(4.8,7.2)	0.00-0.15	0.25		nd	0.08	nd	0.28
$11A_1$	595	(0.0,6.1)	0.00-0.15	0.20		nd	0.06	nd	0.28
$11A_{deepcore1}$	456	(6.7,0.4)	0.00-0.30	nd	0.14	nd	0.13	nd	0.43
$11A_{deepcore1}$	456	(6.7,0.4)	0.60-1.20	0.43		nd	0.06	nd	0.22
$11A_{deepcore1}$	456	(6.7,0.4)	1.20-1.80	0.12		nd	0.07	nd	0.39
$11A_{deepcore1}$	431	(0.3,9.2)	0.00-0.90	nd	0.15	nd	0.13	nd	0.41
$11A_{deepcore1}$	431	(0.3,9.2)	0.90-1.20	nd	0.10	nd	0.10	nd	0.41
$11A_{deepcore1}$	431	(0.3,9.2)	1.20-1.80	nd	0.08	nd	0.11	nd	0.34
$11A_{deepcore2}$	451	(2.5,1.0)	0.00-0.30	nd	0.04	nd	0.06	nd	0.24
$11A_{deepcore2}$	451	(2.5,1.0)	0.30-0.60	nd	0.05	nd	0.06	nd	0.22
$11A_{deepcore2}$	451	(2.5,1.0)	0.60-0.90	nd	0.04	nd	0.04	nd	0.24
$11A_{deepcore2}$	451	(2.5,1.0)	0.90-1.20	0.07		nd	0.05	nd	0.24
$11A_{deepcore2}$	451	(2.5,1.0)	1.20-1.50	nd	0.04	nd	0.05	nd	0.20
$11A_{deepcore2}$	451	(2.5,1.0)	1.50-1.80	nd	0.04	nd	0.04	nd	0.23
$11A_{deepcore2}$	451	(8.0,1.5)	0.00-0.30	0.05		nd	0.07	nd	0.22
$11A_{deepcore2}$	451	(8.0,1.5)	0.30-0.60	0.06		nd	0.06	nd	0.23
$11A_{deepcore2}$	451	(8.0,1.5)	0.60-0.90	0.06		nd	0.05	nd	0.25
$11A_{deepcore2}$	451	(8.0,1.5)	0.90-1.20	0.05		nd	0.06	nd	0.25
$11A_{deepcore2}$	456	(0.5,0.5)	0.00-0.30	0.93		0.24		nd	0.35
$11A_{deepcore2}$	456	(0.5,0.5)	0.30-0.60	0.02		0.14		nd	0.22
$11A_{deepcore2}$	456	(0.5,0.5)	0.60-0.90	0.10		nd	0.05	nd	0.27
$11A_{deepcore2}$	456	(0.5,0.5)	0.90-1.20	0.05		nd	0.06	nd	0.23
$11A_{deepcore2}$	456	(0.5,0.5)	1.20-1.50	0.06		nd	0.06	nd	0.20
$11A_{deepcore2}$	457	(1.0,5.0)	0.00-0.30	0.05		nd	0.06	nd	0.25

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$11A_{deepcore2}$	457	(1.0,5.0)	0.30-0.60	0.04		nd	0.07	nd	0.24
$11A_{deepcore2}$	457	(1.0,5.0)	0.60-0.90	0.05		nd	0.07	nd	0.23
$11A_{deepcore2}$	457	(1.0,5.0)	0.90-1.20	0.05		nd	0.07	nd	0.25
$11A_{deepcore2}$	457	(1.0,5.0)	1.20-1.50	nd	0.05	nd	0.05	nd	0.25
$11A_{deepcore2}$	457	(1.0,5.0)	1.50-1.80	0.04		nd	0.05	nd	0.18
$11A_{deepcore2}$	452	(7.0,4.5)	0.00-0.30	0.04		nd	0.06	nd	0.26
$11A_{deepcore2}$	452	(7.0,4.5)	0.30-0.60	nd	0.05	nd	0.06	nd	0.25
$11A_{deepcore2}$	452	(7.0,4.5)	0.60-0.90	nd	0.04	nd	0.04	nd	0.20
$11A_{deepcore2}$	452	(7.0,4.5)	0.90-1.20	0.05		nd	0.04	nd	0.23
$11A_{deepcore2}$	452	(7.0,4.5)	1.20-1.50	0.06		nd	0.05	nd	0.21
$11A_{deepcore2}$	452	(7.0,4.5)	1.50-1.80	0.03		nd	0.05	nd	0.21
$11A_{deepcore2}$	452	(7.0,9.0)	0.00-0.30	0.07		nd	0.07	nd	0.28
$11A_{deepcore2}$	452	(7.0,9.0)	0.30-0.60	0.06		nd	0.07	nd	0.32
$11A_{deepcore2}$	452	(7.0,9.0)	0.60-0.90	nd	0.06	nd	0.08	nd	0.25
$11A_{deepcore2}$	452	(7.0,9.0)	0.90-1.20	0.07		nd	0.06	nd	0.24
$11A_{deepcore2}$	452	(7.0,9.0)	1.20-1.50	nd	0.05	nd	0.05	nd	0.20
$11A_{deepcore2}$	452	(7.0,9.0)	1.50-1.80	nd	0.04	nd	0.05	nd	0.21

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 12

Description

Survey Unit 12 is an area of approximately 9800 m^2 located immediately north of the Protected Area fence along the Lake Michigan shoreline. No buildings have been located in this area. Survey Unit 12 is bound to the east by the discharge canal and encompasses the rip-rap breakwater. Subsurface structures and equipment include storm drain lines, electrical conduit, and septic system piping.

History

The discharge canal has been dredged on several occasions in plant history to maintain water depth and flow characteristics against the sand build-up that results from current and wave action. The HSA has identified residual radioactivity in Survey Unit 12 soil that is believed to originate from the placement of dredging spoils in the beach area.

Radiological Status

Residual radioactivity was identified in a several samples within this survey unit. Although trace values of Mn-54 were identified in two of the scoping survey samples used for design of the primary survey, Mn-54 was not identified in any subsequent characterization survey conducted in Survey Unit 12. Residual radioactivity in subsurface soil was not identified by deep core sample analyses. The radiological status of this survey unit is Class 2.

Primary Survey Design

1. Sample Data Points Required

The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60	Mn-54
Mean value (pCi/g)	0.61	0.31	0.05
Standard Deviation (&)	0.51	0.64	0.05

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{4.99_{Co}}\right)^2 + \left(\frac{\sigma_{Mn}}{474_{Mn}}\right)^2} =$$

$$\sigma = \sqrt{\left(\frac{0.51}{5.11_{Cs}}\right)^2 + \left(\frac{0.64}{4.99_{Co}}\right)^2 + \left(\frac{0.05}{474_{Mn}}\right)^2}$$

σ =0.16

For the Unity Rule the DCGL for the weighted sum is 1. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1-0.5}{0.16} = 3.1$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 160 x 70 meters
   Random Numbers 0.482449, 0.413809
   X = (0.482449)(160 m) = 77.2 meters
   Y = (0.413809)(70 m) = 29.0 meters

   $$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{9800/14} = 26 \text{ meters}$$

   As a conservative measure, 25 samples were collected using 21.2 meter spacing.

Supporting Surveys

Surface soil survey $12A_1$ was conducted to further investigate the bound of potential contamination resulting from the contour grading of dredge spoils in this area. Deep-core sampling was performed in three survey efforts to investigate the extent of potential subsurface contamination. The maximum sample depth was approximately 3.6 meters. Sample point locations were judgmentally selected based on historical data, process knowledge, and location availability due to subsurface obstruction. Survey $12A_{gpr}$ was performed in association with the GPR (ground penetrating radar) investigation of possible buried legacy material in this area.

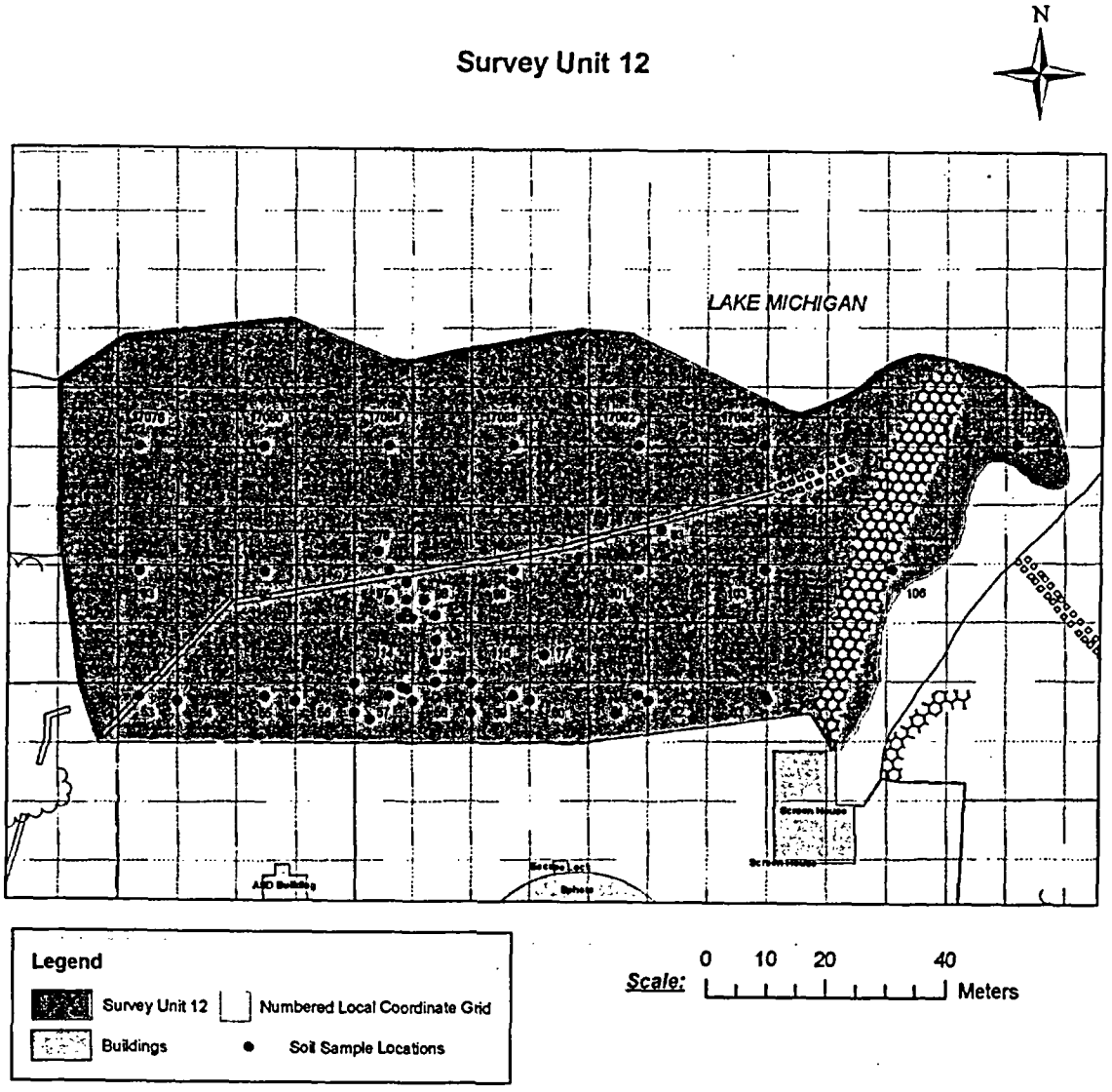
Data Summary

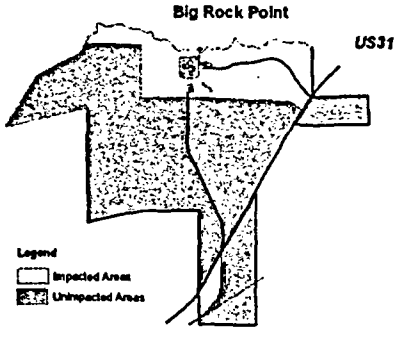
Survey Unit 12

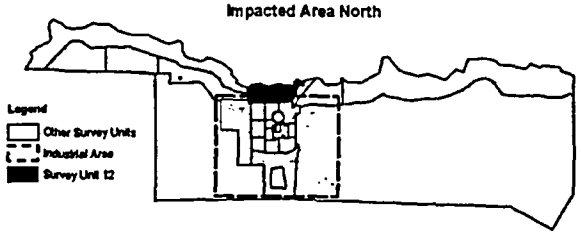
Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$12A_1$	18	Cs_{137}	0.61	1.83
$12A_2$	25	Cs_{137}	0.26	1.48
		Co_{60}*	0.16	0.18
$12A_{deepcore1}$	4	Cs_{137}**	0.08	0.08
$12A_{deepcore2}$	4	Cs_{137}	0.52	1.56
$12A_{deepcore3}$	15	Cs_{137}	0.12	0.20
$12A_{gpr}$	4	Cs_{137}	0.25	0.29

* Co-60 detected in 2 samples only
** Cs-137 detected in 1 sample only

Survey Unit 12







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	Activity [a]	MDA [b]	Activity [a]
$12A_1$	57	(0.0,5.0)	0.00-0.15	0.13		nd	0.05	nd	0.20
$12A_1$	57	(9.0,9.0)	0.00-0.15	0.21		nd	0.04	nd	0.24
$12A_1$	57	(9.0,9.0)	0.15-0.30	0.08		nd	0.05	nd	0.23
$12A_1$	59	(0.0,5.0)	0.00-0.15	0.21		nd	0.04	nd	0.24
$12A_1$	97	(6.0,4.0)	0.00-0.15	0.44		nd	0.06	nd	0.24
$12A_1$	97	(8.0,1.0)	0.00-0.15	1.83		nd	0.06	nd	0.32
$12A_1$	97	(9.0,1.0)	0.00-0.15	1.38		nd	0.09	nd	0.32
$12A_1$	97	(9.0,1.0)	0.15-0.30	1.38		nd	0.06	nd	0.30
$12A_1$	97	(9.0,1.0)	0.30-0.45	1.18		nd	0.06	nd	0.28
$12A_1$	97	(9.0,1.0)	0.45-0.60	0.43		nd	0.05	nd	0.21
$12A_1$	97	(9.0,1.0)	0.60-0.75	0.29		nd	0.05	nd	0.18
$12A_1$	97	(9.0,4.0)	0.00-0.30	0.32		nd	0.04	nd	0.17
$12A_1$	97	(9.0,7.0)	0.00-0.15	0.11		nd	0.04	nd	0.17
$12A_1$	97	(9.0,7.0)	0.15-0.30	0.15		nd	0.04	nd	0.14
$12A_1$	98	(0.0,1.0)	0.00-0.15	1.37		nd	0.07	nd	0.32
$12A_1$	98	(2.0,4.0)	0.00-0.15	0.91		nd	0.05	nd	0.19
$12A_1$	116	(0.0,0.0)	0.00-0.15	0.32		nd	0.06	nd	0.24
$12A_1$	114	(0.0,0.0)	0.00-0.15	0.17		nd	0.05	nd	0.19
$12A_2$	53	(3.6,7.8)	0.00-0.15	0.32		nd	0.06	nd	0.33
$12A_2$	93	(3.6,9.0)	0.00-0.15	0.19		nd	0.02	nd	0.16
$12A_2$	17076	(3.6,0.2)	0.00-0.15	0.08		nd	0.06	nd	0.26
$12A_2$	55	(4.8,7.8)	0.00-0.15	0.11		nd	0.06	nd	0.24
$12A_2$	95	(4.8,9.0)	0.00-0.15	0.12		nd	0.03	nd	0.20
$12A_2$	17080	(4.8,0.2)	0.00-0.15	0.15		nd	0.06	nd	0.27
$12A_2$	57	(6.0,7.8)	0.00-0.15	0.20		nd	0.06	nd	0.25
$12A_2$	97	(6.0,9.0)	0.00-0.15	0.14		nd	0.05	nd	0.21
$12A_2$	17084	(6.0,0.2)	0.00-0.15	0.04		nd	0.05	nd	0.29
$12A_2$	59	(7.2,7.8)	0.00-0.15	0.20		nd	0.05	nd	0.27
$12A_2$	99	(7.2,9.0)	0.00-0.15	0.19		nd	0.04	nd	0.20
$12A_2$	17088	(7.2,0.2)	0.00-0.15	0.18		nd	0.06	nd	0.24
$12A_2$	61	(8.4,7.8)	0.00-0.15	0.28		nd	0.07	nd	0.30
$12A_2$	101	(8.4,9.0)	0.00-0.15	0.16		nd	0.05	nd	0.20
$12A_2$	17092	(8.4,0.2)	0.00-0.15	0.07		nd	0.04	nd	0.21
$12A_2$	63	(9.6,7.8)	0.00-0.15	0.19		nd	0.06	nd	0.25
$12A_2$	103	(9.6,9.0)	0.00-0.15	0.21		nd	0.04	nd	0.22
$12A_2$	17096	(9.6,0.2)	0.00-0.15	0.19		nd	0.07	nd	0.25
$12A_2$	106	(0.8,9.0)	0.00-0.15	nd	0.07	0.14		nd	0.28
$12A_2$	17171	(2.0,0.2)	0.00-0.15	1.48		0.18		nd	0.28
$12A_2$	61	(4.6,4.8)	0.00-0.15	nd	0.06	nd	0.05	nd	0.27
$12A_2$	83	(2.3,5.9)	0.00-0.15	0.15		nd	0.04	nd	0.22
$12A_2$	117	(2.5,4.5)	0.00-0.15	0.89		nd	0.05	nd	0.31
$12A_2$	57	(2.6,3.9)	0.00-0.15	0.28		nd	0.06	nd	0.26
$12A_2$	78	(4.1,2.3)	0.00-0.15	0.16		nd	0.04	nd	0.20

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey	Grid	Coordinate	Depth (meters)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$12A_{deepcore1}$	57	(8.1,9.3)	0.00-0.60	0.08		nd	0.08	nd	0.36
$12A_{deepcore1}$	57	(8.1,9.3)	0.60-1.80	nd	0.12	nd	0.09	nd	0.40
$12A_{deepcore1}$	57	(8.1,9.3)	1.80-3.00	nd	0.04	nd	0.04	nd	0.18
$12A_{deepcore1}$	57	(8.1,9.3)	3.00-3.60	nd	0.04	nd	0.06	nd	0.21
$12A_{deepcore2}$	97	(9.0,2.0)	0.00-0.60	1.56		nd	0.06	nd	0.27
$12A_{deepcore2}$	97	(9.0,2.0)	0.60-1.50	0.20		nd	0.07	nd	0.28
$12A_{deepcore2}$	97	(9.0,2.0)	2.40-3.30	0.21		nd	0.05	nd	0.23
$12A_{deepcore2}$	97	(9.0,2.0)	3.30-4.05	0.11		nd	0.04	nd	0.18
$12A_{deepcore3}$	54	(0.0,7.0)	0.00-0.30	nd	0.05	nd	0.05	nd	0.24
$12A_{deepcore3}$	54	(0.0,7.0)	0.30-0.60	0.03		nd	0.05	nd	0.27
$12A_{deepcore3}$	56	(0.0,7.0)	0.00-0.30	0.20		nd	0.05	nd	0.26
$12A_{deepcore3}$	56	(0.0,7.0)	0.30-0.60	0.16		nd	0.06	nd	0.24
$12A_{deepcore3}$	58	(0.0,7.0)	0.00-0.30	0.12		nd	0.06	nd	0.26
$12A_{deepcore3}$	58	(0.0,7.0)	0.30-0.60	0.10		nd	0.05	nd	0.22
$12A_{deepcore3}$	60	(0.0,7.0)	0.00-0.30	0.19		nd	0.05	nd	0.27
$12A_{deepcore3}$	60	(0.0,7.0)	0.30-0.60	0.11		nd	0.05	nd	0.25
$12A_{deepcore3}$	60	(0.0,7.0)	0.60-0.90	0.12		nd	0.06	nd	0.25
$12A_{deepcore3}$	62	(0.0,7.0)	0.00-0.30	[c]					
$12A_{deepcore3}$	62	(0.0,7.0)	0.30-0.60	nd	0.06	nd	0.05	nd	0.27
$12A_{deepcore3}$	64	(0.0,7.0)	0.00-0.30	nd	0.06	nd	0.06	nd	0.29
$12A_{deepcore3}$	64	(0.0,7.0)	0.30-0.60	0.12		nd	0.06	nd	0.23
$12A_{deepcore3}$	64	(0.0,7.0)	0.60-0.90	0.08		nd	0.05	nd	0.26
$12A_{deepcore3}$	64	(0.0,7.0)	0.90-1.20	0.05		nd	0.05	nd	0.26
$12A_{gpr}$	98	(4.0,1.3)	1.20-1.50	0.29		nd	0.03	nd	0.19
$12A_{gpr}$	115	(4.0,7.1)	1.20-1.50	0.20		nd	0.06	nd	0.26
$12A_{gpr}$	115	(4.0,3.7)	1.20-1.50	nd	0.05	nd	0.06	nd	0.25
$12A_{gpr}$	115	(4.0,0.1)	1.20-1.50	nd	0.04	nd	0.05	nd	0.25

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] Large rock obstructed the first 30 cm at this location.

Survey Unit 13

Description
Survey Unit 13 is a narrow expanse of shoreline between the water's edge and the vegetation line in the northeast section of the owner controlled property. This location is approximately 49,500 m^2 in area and contains no surface or subsurface structures, components, or equipment.

History
Survey Unit 13 is a pristine section of Lake Michigan shoreline that has remained remote from normal plant operational activities. The HSA designates this area as unlikely to contain residual radioactivity in soils.

Radiological Status
Due to near-record lows in Lake Michigan water level, additional shoreline is exposed for surveys conducted in this area. Three samples collected in this survey unit identified residual radioactivity below IDCGLs. The location of this survey unit is near the plant discharge canal where licensed radioactive liquid release occurred; the levels of radionuclides identified in these surveys is consistent with contaminant migration that would result from wind, current, and wave action along the shoreline. The radiological status of this survey unit is Class 3.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.19
Standard Deviation (σ)	0.15

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.15} = 16.6$$

   With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

   As a conservative measure 20 sample data points were selected for this survey unit.

2. Sample Locations
   Sample locations were selected by random method. Random numbers were generated and applied to the bounding survey unit dimensions to determine data point coordinate locations. This process was continued until 20 sample data points fell within the survey unit boundary.

Supporting Surveys
No supporting surveys were conducted in this survey unit.

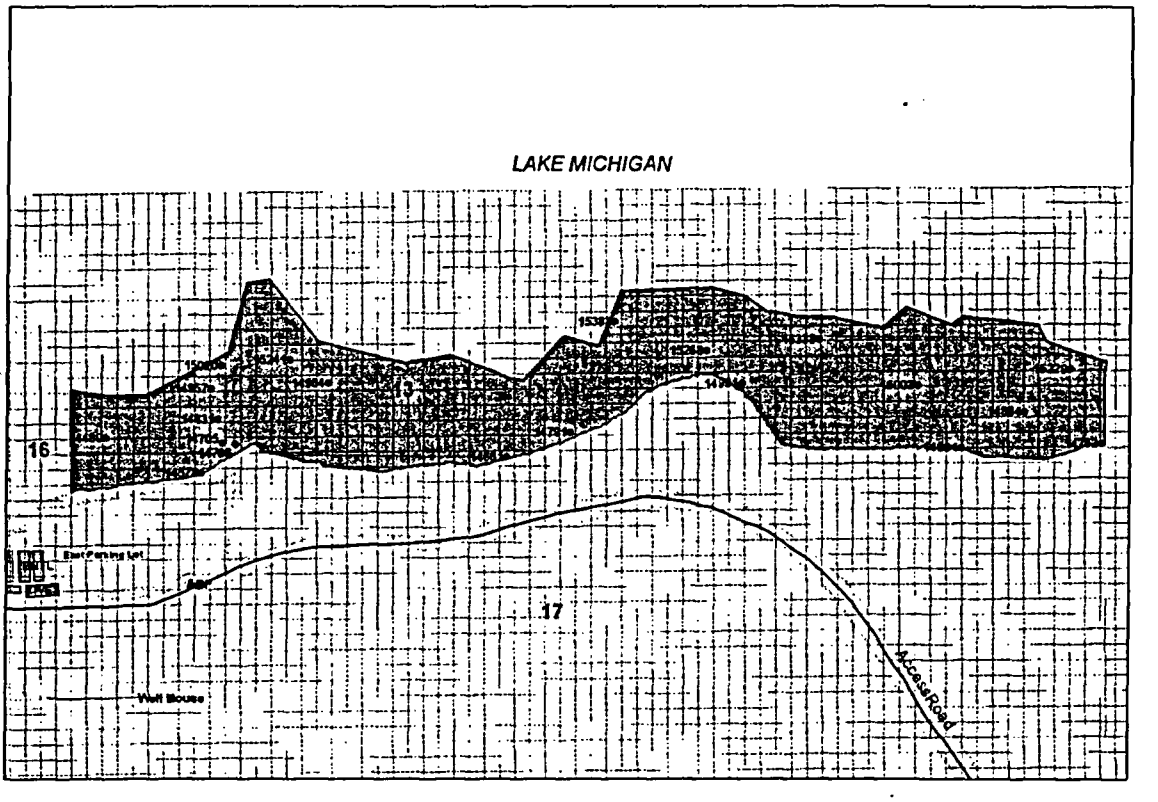
Data Summary

Survey Unit 13

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$13A_1$	20	Cs_{137}	0.36	0.97
		Co_{60}*	0.07	0.10

* Activity detected in 3 samples only.

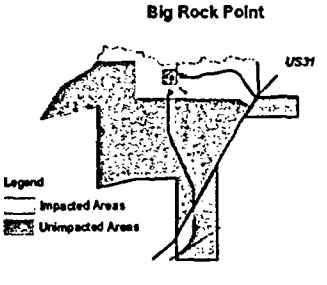
Survey Unit 13

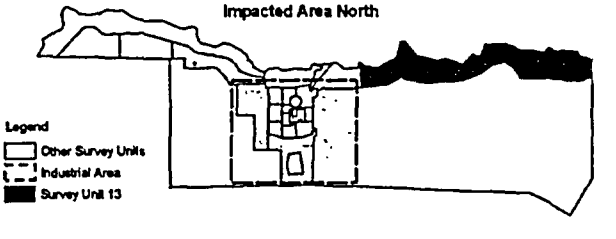


Legend

- Survey Unit 13
- Numbered Local Coordinate Grid
- Buildings
- Soil Sample Locations

Scale: 0 50 100 200 Meters





Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$13A_1$	15338	(8.5,0.7)	0.00-0.15	0.22		nd	0.05	nd	0.22
$13A_1$	14480	(2.6,0.3)	0.00-0.15	0.33		0.04		nd	0.28
$13A_1$	14691	(0.0,9.6)	0.00-0.15	0.03		nd	0.07	nd	0.25
$13A_1$	14884	(0.6,3.0)	0.00-0.15	0.07		nd	0.08	nd	0.25
$13A_1$	15229	(0.8,0.7)	0.00-0.15	0.03		nd	0.08	nd	0.33
$13A_1$	14831	(5.4,1.7)	0.00-0.15	0.54		nd	0.08	nd	0.30
$13A_1$	15388	(5.8,3.3)	0.00-0.15	0.06		nd	0.06	nd	0.25
$13A_1$	15268	(5.8,4.2)	0.00-0.15	0.12		nd	0.06	nd	0.21
$13A_1$	15241	(2.1,0.0)	0.00-0.15	0.95		nd	0.07	nd	0.28
$13A_1$	14705	(8.0,6.1)	0.00-0.15	0.71		nd	0.05	nd	0.26
$13A_1$	14706	(6.5,4.9)	0.00-0.15	0.93		nd	0.06	nd	0.25
$13A_1$	14762	(1.0,2.0)	0.00-0.15	0.33		nd	0.06	nd	0.27
$13A_1$	14964	(7.6,4.5)	0.00-0.15	0.09		nd	0.06	nd	0.26
$13A_1$	15020	(7.4,6.5)	0.00-0.15	0.20		0.07		nd	0.24
$13A_1$	14578	(4.7,6.9)	0.00-0.15	0.23		nd	0.05	nd	0.24
$13A_1$	14991	(8.6,2.3)	0.00-0.15	0.07		nd	0.06	nd	0.24
$13A_1$	14957	(0.8,1.8)	0.00-0.15	0.14		nd	0.07	nd	0.23
$13A_1$	14791	(6.9,1.7)	0.00-0.15	0.55		nd	0.05	nd	0.27
$13A_1$	15003	(2.3,0.4)	0.00-0.15	0.61		0.10		nd	0.28
$13A_1$	14661	(4.6,5.8)	0.00-0.15	0.97		nd	0.06	nd	0.27

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 14

Description

Survey Unit 14 is a narrow expanse of shoreline between the waters edge and the vegetation line in the northwest section of the owner controlled property. This location is approximately 33,000 m^2 in area and contains no surface or subsurface structures, components, or equipment.

History

Survey Unit 14 is a pristine section of Lake Michigan shoreline that has remained remote from normal plant operational activities. The HSA designates this area as unlikely to contain residual radioactivity in area soils

Radiological Status

Residual radioactivity was not identified in any soil samples collected in Survey Unit 14 above established background levels. The radiological status of this survey unit is Class 3.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.50
Standard Deviation (&)	0.40

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.15} = 6.2$$

   With ! and b error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

   As a conservative measure 20 sample data points were selected for this survey unit.

2. Sample Locations
   Sample locations were selected by random method. Random numbers were generated and applied to the bounding survey unit dimensions to determine data point coordinate locations. This process was continued until 20 sample data points fell within the survey unit boundary.

Supporting Surveys

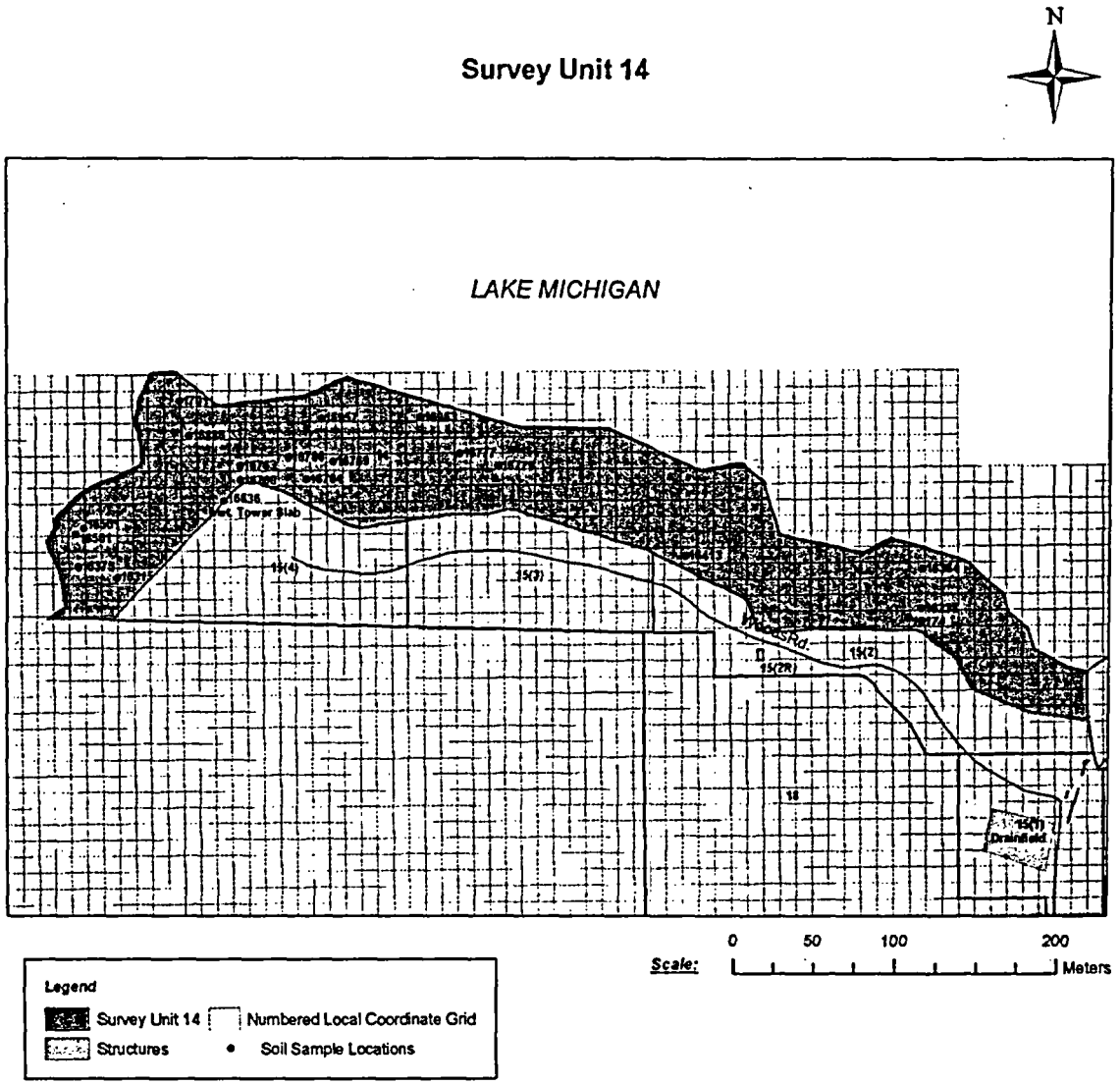
No supporting surveys were conducted in this survey unit.

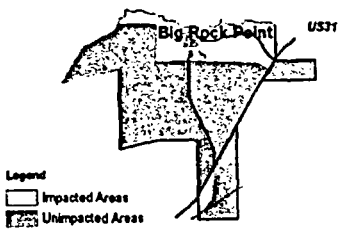
Data Summary

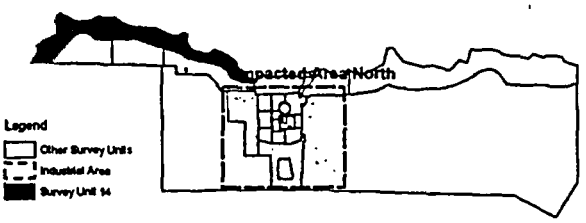
Survey Unit 14

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$14A_1$	20	Cs_{137}	0.16	0.40

Survey Unit 14







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$14A_1$	6886	(4.9,2.2)	0.00-0.15	0.10		nd	0.06	nd	0.2
$14A_1$	16501	(9.1,4.4)	0.00-0.15	0.20		nd	0.05	nd	0.2
$14A_1$	16779	(7.2,1.7)	0.00-0.15	0.04		nd	0.05	nd	0.2
$14A_1$	16769	(4.5,5.5)	0.00-0.15	0.40		nd	0.04	nd	0.2
$14A_1$	17011	(9.7,3.6)	0.00-0.15	0.20		nd	0.05	nd	0.2
$14A_1$	16501	(4.6,1.1)	0.00-0.15	0.09		nd	0.05	nd	0.2
$14A_1$	16762	(6.7,3.2)	0.00-0.15	0.20		nd	0.07	nd	0.2
$14A_1$	16963	(9.5,2.1)	0.00-0.15	0.09		nd	0.06	nd	0.2
$14A_1$	16704	(7.8,4.4)	0.00-0.15	0.20		nd	0.05	nd	0.2
$14A_1$	16413	(3.2,4.7)	0.00-0.15	nd	0.04	nd	0.05	nd	0.2
$14A_1$	16957	(7.4,2.0)	0.00-0.15	0.10		nd	0.05	nd	0.2
$14A_1$	16364	(8.3,5.6)	0.00-0.15	0.30		nd	0.06	nd	0.2
$14A_1$	16174	(9.8,5.4)	0.00-0.15	0.20		nd	0.06	nd	0.2
$14A_1$	16777	(3.4,9.8)	0.00-0.15	0.08		nd	0.04	nd	0.2
$14A_1$	16766	(6.9,8.4)	0.00-0.15	nd	0.05	nd	0.05	nd	0.3
$14A_1$	16375	(5.7,0.8)	0.00-0.15	nd	0.04	nd	0.06	nd	0.2
$14A_1$	16700	(6.7,3.9)	0.00-0.15	0.07		nd	0.06	nd	0.2
$14A_1$	16636	(6.6,1.4)	0.00-0.15	0.06		nd	0.04	nd	0.2
$14A_1$	16315	(0.0,4.0)	0.00-0.15	nd	0.06	nd	0.04	nd	0.2
$14A_1$	16238	(7.8,0.8)	0.00-0.15	nd	0.05	nd	0.05	nd	0.2

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 15(1)

Description
Survey Unit 15(1) is an area of approximately 11,500 m^2 located adjacent to the western boundary of the surface water drainage stream. This area encompasses the north/south section of the Woods Road and the plant septic drainfield. The drainfield is a mound constructed pump-back system that connects to septic effluent holding tanks located inside the Protected Area. Subsurface structures and components include electrical conduit and septic piping in vicinity of the Woods Road.

History
The Woods Road is an unimproved lane that provided access to the weather station tower formerly located in Survey Unit 15(4). Several locations in connecting survey units along this road were used as locations for the storage construction debris and refuse.

Radiological Status
Residual radioactivity was not identified in any soil samples collected in Survey Unit 15(1) above established background levels. The drainfield connection to the site septic system represents a potential contaminant migration pathway into this area. The drainfield is scheduled for further evaluation when the septic system is removed from service. The radiological status of this survey unit is Class 2.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.19
Standard Deviation (&)	0.25

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.25} = 10.4$$

   With ⫯ and ⫰ error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 85 X 190 meters
   Random Numbers 0.866922, 0.791992
   X = (0.866992)(85 m) = 73.6 m
   Y = (0.791992)(190 m) = 150.4 m

   $$\text{Sample Spacing L} = \sqrt{\text{Area}/N} = \sqrt{11534/14} = 28.7 \text{ meters}$$

As a conservative measure 25 samples were collected using 20 meter spacing.

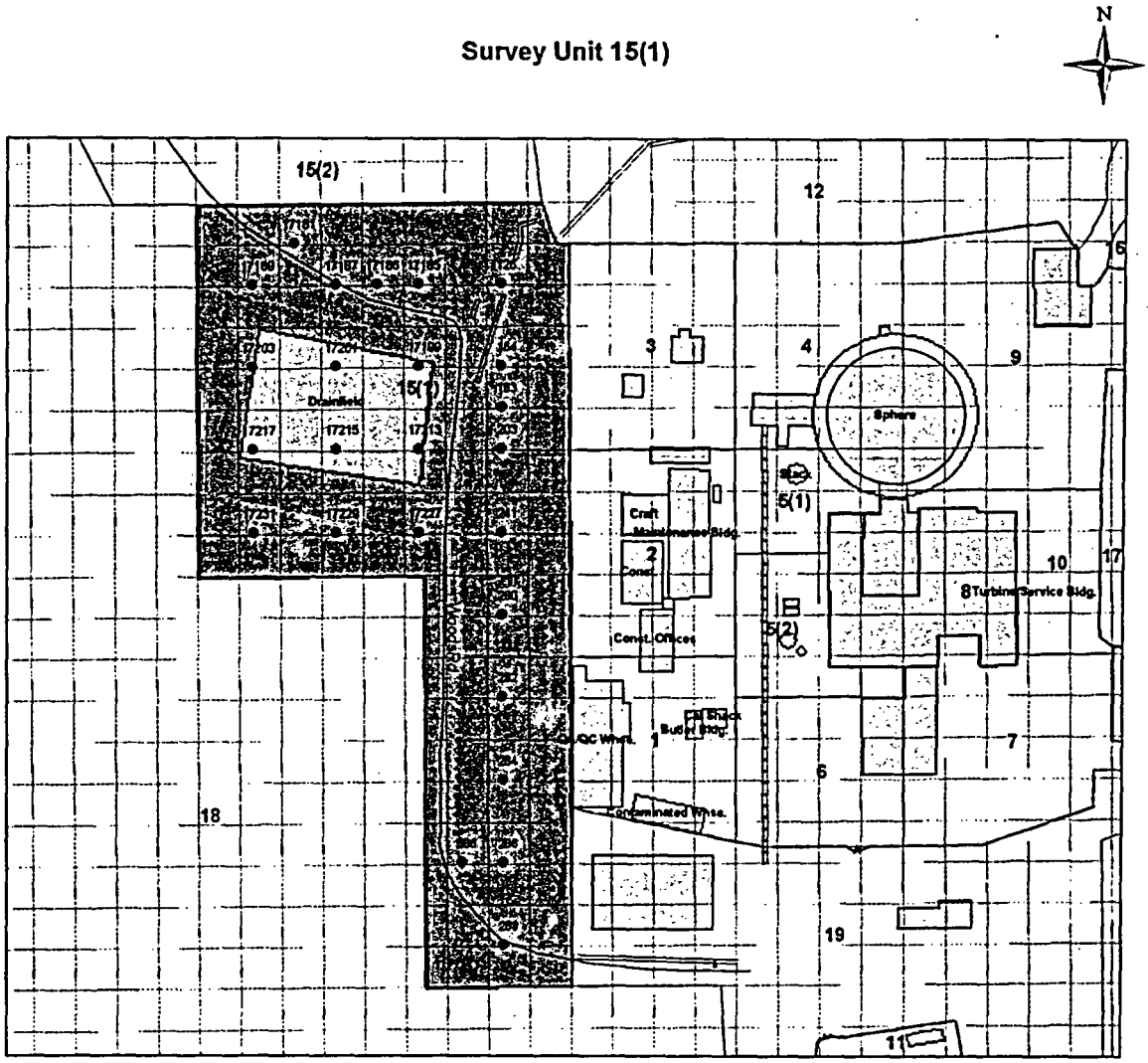
Supporting Surveys
No supporting surveys were conducted in this survey unit.

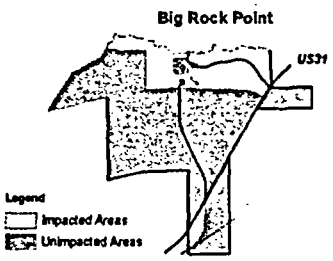
Data Summary

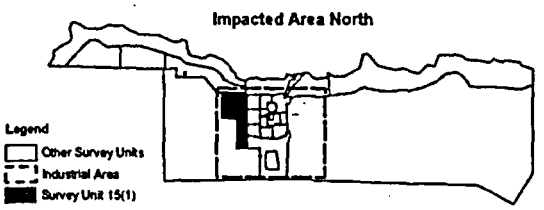
Survey Unit 15(1)

Survey	No. of Samples	Radionuclid	Mean (pCi/g)	Max. Value (pCi/g)
15(1)A_1	25	Cs_{137}	0.22	1.20

Survey Unit 15(1)







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
15(1)A1	288	(3.6,0.5)	0.00-0.15	0.06		nd	0.06	nd	0.27
15(1)A1	286	(3.6,0.5)	0.00-0.15	0.37		nd	0.07	nd	0.29
15(1)A1	284	(3.6,0.5)	0.00-0.15	0.33		nd	0.04	nd	0.22
15(1)A1	282	(3.6,0.5)	0.00-0.15	0.17		nd	0.05	nd	0.23
15(1)A1	280	(3.6,0.5)	0.00-0.15	0.21		nd	0.05	nd	0.23
15(1)A1	241	(3.6,0.5)	0.00-0.15	0.06		nd	0.05	nd	0.26
15(1)A1	203	(3.6,0.5)	0.00-0.15	0.20		nd	0.05	nd	0.28
15(1)A1	164	(3.6,0.5)	0.00-0.15	0.08		nd	0.06	nd	0.25
15(1)A1	126	(3.6,0.5)	0.00-0.15	0.12		nd	0.06	nd	0.25
15(1)A1	17185	(3.6,0.5)	0.00-0.15	0.13		nd	0.05	nd	0.22
15(1)A1	17189	(3.6,0.5)	0.00-0.15	0.18		nd	0.06	nd	0.31
15(1)A1	17213	(3.6,0.5)	0.00-0.15	0.27		nd	0.05	nd	0.28
15(1)A1	17227	(3.6,0.5)	0.00-0.15	0.14		nd	0.06	nd	0.29
15(1)A1	17229	(3.6,0.5)	0.00-0.15	0.13		nd	0.05	nd	0.19
15(1)A1	17215	(3.6,0.5)	0.00-0.15	0.15		nd	0.06	nd	0.29
15(1)A1	17201	(3.6,0.5)	0.00-0.15	0.19		nd	0.06	nd	0.27
15(1)A1	17187	(3.6,0.5)	0.00-0.15	1.20		nd	0.06	nd	0.31
15(1)A1	17189	(3.6,0.5)	0.00-0.15	0.18		nd	0.04	nd	0.22
15(1)A1	17203	(3.6,0.5)	0.00-0.15	0.18		nd	0.06	nd	0.28
15(1)A1	17217	(3.6,0.5)	0.00-0.15	0.23		nd	0.06	nd	0.29
15(1)A1	17231	(3.6,0.5)	0.00-0.15	0.06		nd	0.05	nd	0.26
15(1)A1	586	(0.1,2.2)	0.00-0.15	nd	0.05	nd	0.05	nd	0.26
15(1)A1	183	(6.1,5.8)	0.00-0.15	0.19		nd	0.05	nd	0.24
15(1)A1	17186	(4.7,3.7)	0.00-0.15	0.20		nd	0.05	nd	0.25
15(1)A1	17181	(8.5,7.3)	0.00-0.15	0.25		nd	0.05	nd	0.22

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 15(2)

Description

Survey Unit 15(2) is an area of approximately 10,300 m^2 west of the Protected Area that parallels the shoreline south of Survey Unit 14. This area encompasses an east/west section of the Woods Road connecting Survey Units 15(1) and 15(3). Survey Unit 15(2R) is contained within this area along the southwest section of the Woods Road. Subsurface structures and components do not exist in this wooded area.

History

The Woods Road is an unimproved lane that provided access to the former weather station tower located in Survey Unit 15(4). Low levels of radioactivity have been identified in construction debris (Survey Unit 15(2R)) that was once stored along this road. Cleanup efforts have resulted in the removal of all construction waste in this area.

Radiological Status

Residual radioactivity was not identified in any soil samples collected in this survey unit above established background levels. The radiological status of Survey Unit 15(2) is Class 2.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.36
Standard Deviation (σ)	0.11

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.11} = 23.7$$

   With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 270 X 130 meters
   Random Numbers 0.444554, 0.428292
   X = (0.444554)(270 m) = 120.0 m
   Y = (0.428292)(130 m) = 55.7 m

   $$\text{Sample Spacing L} = \sqrt{\text{Area}/N} = \sqrt{10255/14} = 27.0 \text{ meters}$$

As a conservative measure 25 samples were collected using 20 meter spacing.

Supporting Surveys

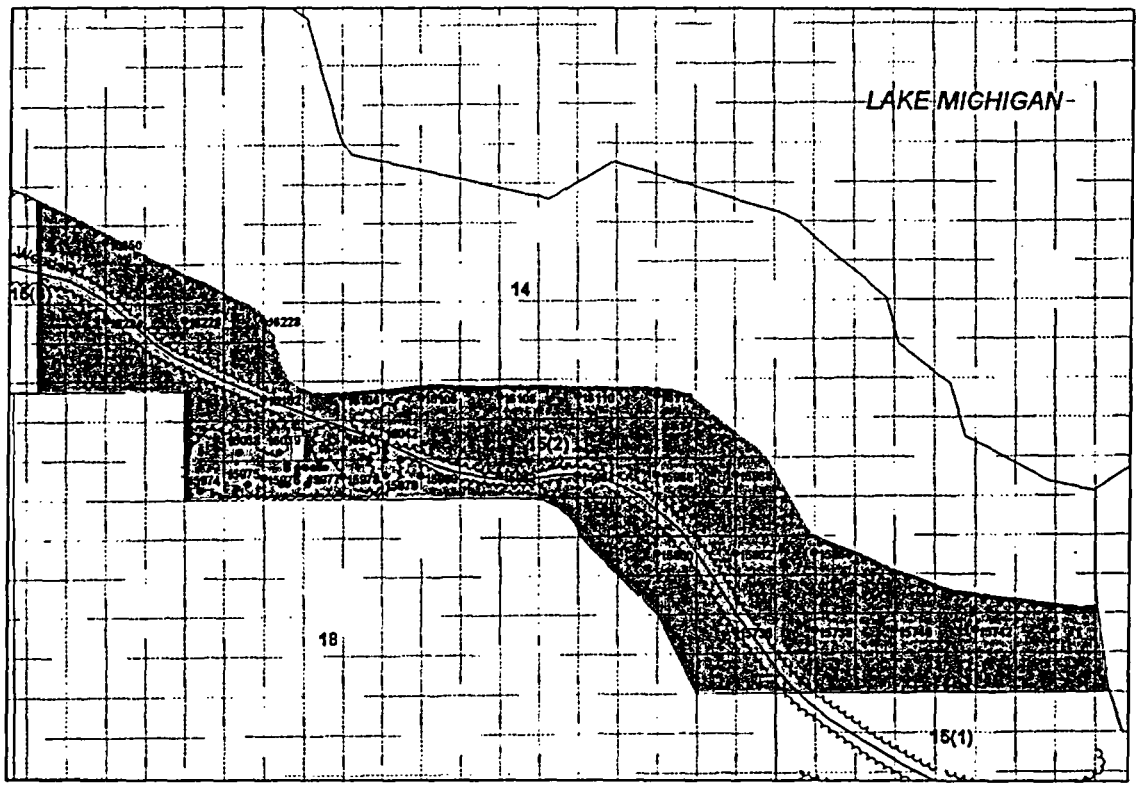
Supporting survey 15(2)A_1 was performed for the evaluation of surface and subsurface soils in the vicinity of construction debris along the Woods Road. Data point locations were judgmentally selected based on historical information and process knowledge for areas of greatest potential to contain radioactivity.

Data Summary

Survey Unit 15(2)

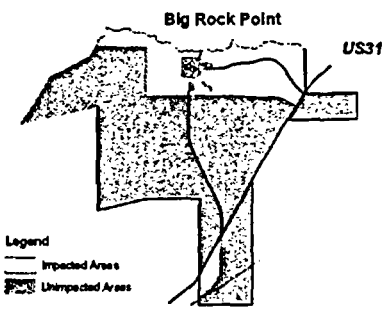
Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max.Value (pCi/g)
15(2)A_1	44	Cs_{137}	0.18	1.06
15(2)A_2	25	Cs_{137}	0.22	0.53

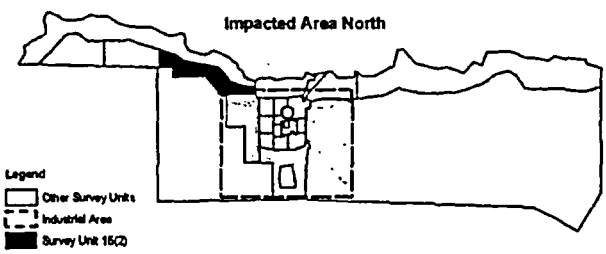
Survey Unit 15(2)



Legend
- Survey Unit 15(2)
- Survey Unit 15(2R)
- Numbered Local Coordinate Grid
- Soil Sample Locations

Scale: 0 10 20 40 Meters





Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
15(2)A_1	15979	(1.0,7.7)	0.00-0.15	0.24		nd	0.05	nd	0.24
15(2)A_1	16042	(5.0,1.7)	0.00-0.15	0.15		nd	0.06	nd	0.24
15(2)A_1	16042	(1.0,1.7)	0.00-0.15	0.29		nd	0.04	nd	0.23
15(2)A_1	16041	(7.0,0.0)	0.00-0.30	0.12		nd	0.05	nd	0.24
15(2)A_1	16042	(1.0,0.0)	0.30-0.60	nd	0.05	nd	0.04	nd	0.22
15(2)A_1	16042	(1.0,2.0)	0.00-0.30	0.44		nd	0.03	nd	0.21
15(2)A_1	16042	(1.0,4.0)	0.00-0.30	0.11		nd	0.05	nd	0.18
15(2)A_1	15976	(6.0,4.0)	0.00-0.30	0.15		nd	0.04	nd	0.25
15(2)A_1	15976	(6.0,4.0)	0.30-0.60	0.06		nd	0.06	nd	0.22
15(2)A_1	15976	(6.0,4.0)	0.60-0.90	nd	0.04	nd	0.05	nd	0.22
15(2)A_1	15976	(6.0,4.0)	0.90-1.20	nd	0.04	nd	0.05	nd	0.20
15(2)A_1	15976	(4.5,4.0)	0.00-0.30	0.07		nd	0.06	nd	0.22
15(2)A_1	15976	(4.5,4.0)	0.30-0.60	0.03		nd	0.04	nd	0.23
15(2)A_1	15976	(4.5,4.0)	0.60-0.90	nd	0.04	nd	0.04	nd	0.22
15(2)A_1	15976	(6.0,9.0)	0.00-0.30	0.12		nd	0.05	nd	0.21
15(2)A_1	15976	(6.0,9.0)	0.30-0.60	nd	0.03	nd	0.05	nd	0.21
15(2)A_1	15977	(1.0,4.0)	0.00-0.30	0.09		nd	0.06	nd	0.24
15(2)A_1	15977	(1.0,4.0)	0.30-0.60	nd	0.03	nd	0.03	nd	0.20
15(2)A_1	15977	(4.0,8.0)	0.00-0.30	0.13		nd	0.06	nd	0.21
15(2)A_1	15977	(4.0,8.0)	0.30-0.60	nd	0.04	nd	0.03	nd	0.21
15(2)A_1	15977	(4.0,8.0)	0.60-0.90	nd	0.05	nd	0.05	nd	0.19
15(2)A_1	15977	(5.5,8.0)	0.00-0.30	0.04		nd	0.05	nd	0.23
15(2)A_1	15977	(5.5,8.0)	0.30-0.60	nd	0.04	nd	0.04	nd	0.18
15(2)A_1	15977	(2.5,8.0)	0.00-0.30	0.02		nd	0.04	nd	0.20
15(2)A_1	15977	(2.5,8.0)	0.30-0.60	nd	0.05	nd	0.05	nd	0.28
15(2)A_1	15977	(4.0,5.0)	0.00-0.30	0.14		nd	0.06	nd	0.21
15(2)A_1	15977	(4.0,5.0)	0.30-0.60	nd	0.04	nd	0.05	nd	0.22
15(2)A_1	15976	(8.5,8.0)	0.00-0.30	0.80		nd	0.09	nd	0.27
15(2)A_1	15976	(8.5,8.0)	0.30-0.60	0.08		nd	0.06	nd	0.21
15(2)A_1	15976	(8.5,8.0)	0.60-0.90	0.03		nd	0.06	nd	0.21
15(2)A_1	15977	(0.5,8.0)	0.00-0.30	0.11		nd	0.05	nd	0.23
15(2)A_1	15977	(0.5,8.0)	0.30-0.60	1.06		nd	0.07	nd	0.28
15(2)A_1	15977	(0.5,8.0)	0.60-0.90	nd	0.04	nd	0.04	nd	0.19
15(2)A_1	15976	(6.0,8.0)	0.00-0.30	0.12		nd	0.06	nd	0.21
15(2)A_1	15976	(6.0,8.0)	0.30-0.60	0.03		nd	0.05	nd	0.22
15(2)A_1	15976	(6.0,8.0)	0.60-0.90	nd	0.03	nd	0.05	nd	0.19
15(2)A_1	16038	(4.0,2.0)	0.00-0.30	0.10		nd	0.05	nd	0.21
15(2)A_1	16038	(4.0,2.0)	0.30-0.60	nd	0.04	nd	0.05	nd	0.22
15(2)A_1	15975	(6.0,4.0)	0.00-0.30	0.12		nd	0.06	nd	0.21
15(2)A_1	15975	(6.0,4.0)	0.30-0.60	nd	0.05	nd	0.06	nd	0.19
15(2)A_1	15974	(4.0,2.5)	0.00-0.30	0.24		nd	0.05	nd	0.22
15(2)A_1	15976	(8.5,6.5)	0.30-0.60	0.07		nd	0.04	nd	0.18
15(2)A_1	15976	(8.5,6.5)	0.60-0.90	nd	0.05	nd	0.04	nd	0.19
15(2)A_1	15976	(8.5,8.0)	0.90-1.20	nd	0.04	nd	0.05	nd	0.19
15(2)A_2	71	(0.0,5.7)	0.00-0.15	0.34		nd	0.04	nd	0.21
15(2)A_2	15742	(0.0,5.7)	0.00-0.15	0.46		nd	0.05	nd	0.23
15(2)A_2	15740	(0.0,5.7)	0.00-0.15	0.23		nd	0.04	nd	0.23
15(2)A_2	15738	(0.0,5.7)	0.00-0.15	0.13		nd	0.05	nd	0.28
15(2)A_2	15736	(0.0,5.7)	0.00-0.15	0.53		nd	0.05	nd	0.26
15(2)A_2	15864	(0.0,5.7)	0.00-0.15	0.10		nd	0.06	nd	0.21

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
15(2)A_2	15862	(0.0,5.7)	0.00-0.15	0.13		nd	0.07	nd	0.34
15(2)A_2	15860	(0.0,5.7)	0.00-0.15	0.29		nd	0.03	nd	0.29
15(2)A_2	15988	(0.0,5.7)	0.00-0.15	0.20		nd	0.06	nd	0.24
15(2)A_2	15986	(0.0,5.7)	0.00-0.15	0.27		nd	0.05	nd	0.22
15(2)A_2	15984	(0.0,5.7)	0.00-0.15	0.26		nd	0.05	nd	0.30
15(2)A_2	15982	(0.0,5.7)	0.00-0.15	0.16		nd	0.05	nd	0.24
15(2)A_2	15980	(0.0,5.7)	0.00-0.15	0.08		nd	0.05	nd	0.21
15(2)A_2	15978	(0.0,5.7)	0.00-0.15	0.15		nd	0.05	nd	0.26
15(2)A_2	15976	(0.0,5.7)	0.00-0.15	0.23		nd	0.05	nd	0.23
15(2)A_2	16112	(0.0,5.7)	0.00-0.15	0.16		nd	0.05	nd	0.25
15(2)A_2	16110	(0.0,5.7)	0.00-0.15	0.08		nd	0.05	nd	0.23
15(2)A_2	16108	(0.0,5.7)	0.00-0.15	0.28		nd	0.05	nd	0.19
15(2)A_2	16106	(0.0,5.7)	0.00-0.15	0.23		nd	0.04	nd	0.2
15(2)A_2	16104	(0.0,5.7)	0.00-0.15	0.16		nd	0.04	nd	0.18
15(2)A_2	16102	(0.0,5.7)	0.00-0.15	0.44		nd	0.05	nd	0.29
15(2)A_2	16228	(0.0,5.7)	0.00-0.15	0.09		nd	0.05	nd	0.22
15(2)A_2	16226	(0.0,5.7)	0.00-0.15	0.24		nd	0.05	nd	0.24
15(2)A_2	16224	(0.0,5.7)	0.00-0.15	0.17		nd	0.04	nd	0.21
15(2)A_2	16350	(0.0,5.7)	0.00-0.15	0.05		nd	0.04	nd	0.17

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 15(2R)

Description
Survey Unit 15(2R) is an area of approximately 18 m^2 located along the south edge of the Woods Road within the boundaries of Survey Unit 15(2). Subsurface structures and components do not exist in this wooded area.

History
This location was a storage area for minor volumes of miscellaneous refuse and construction debris. Surveys conducted during removal of this material identified radioactivity of plant origin in a small area of approximately two crumbling red bricks. All construction debris has been removed from the area. A post-remediation survey was conducted and confirmatory measurements were performed by representatives of the Michigan Department of Environmental Quality (MDEQ) and USNRC, Region 3.

Radiological Status
The results of surveys conducted following the removal of soil and construction debris have identified this area to contain radioactivity levels similar to the established reference background value for northwestern Michigan. The radiological status of Survey Unit 15(2R) is Class 1.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60
Mean value (pCi/g)	1.84	0.06
Standard Deviation σ	1.46	0.02

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{DCGL_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{DCGL_{Co}}\right)^2} = \sigma = \sqrt{\left(\frac{1.46_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{0.02_{Co}}{4.99_{Co}}\right)^2}$$

$\sigma = 0.29$

The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{IDCGL - LBGR}{\sigma} = \frac{1 - 0.5}{0.29} = 1.7$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 17 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 3 X 6 meters
   Random Numbers 0.866667, 0.762408
   Random Start Location
   X = (0.866667)(3 m) = 2.6 m
   Y = (0.762408)(6 m) = 4.6 m

   Sample Spacing $L = \sqrt{Area/y} = \sqrt{18/17} = 1.02$ meters

   As a conservative measure, 19 sample datapoints were collected for the primary survey.

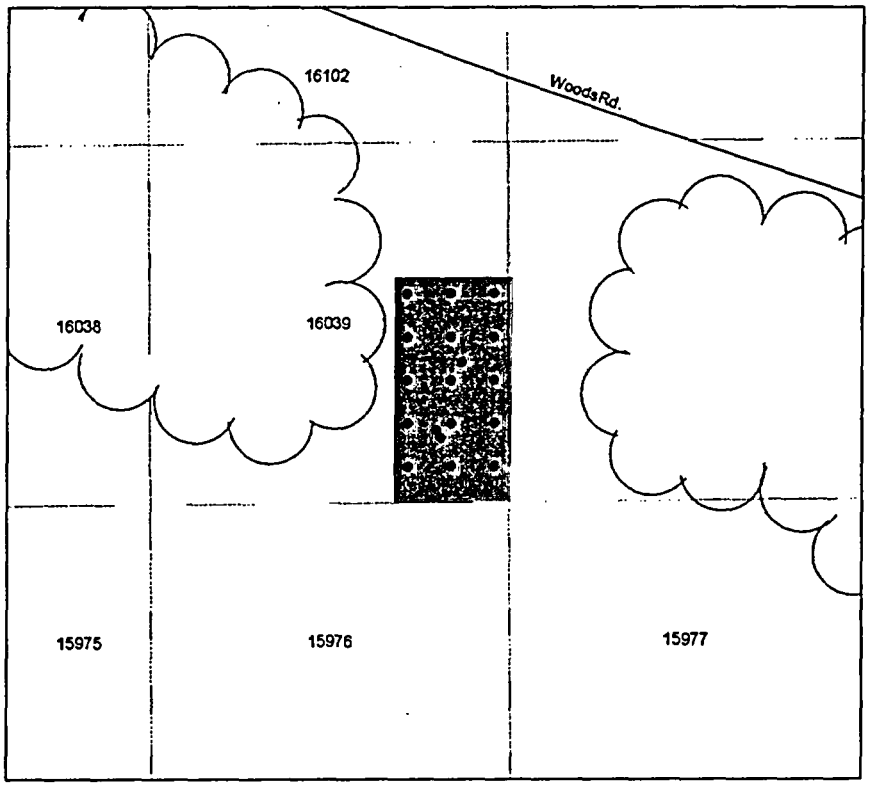
Supporting Surveys
A surface scan survey of100% coverage was conducted for the investigation of potential areas of elevated contamination. Supporting surveys $15(2R)B_{deepcore1}$ and $15(2R)B_{deepcore2}$ were performed for the evaluation of potential contaminants in subsurface soil. In addition, data point locations were selected by regulatory personnel for split sample comparison with MDEQ and USNRC.

Data Summary

Survey Unit 15(2R)

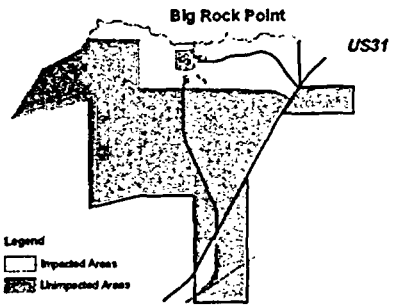
Survey	Data Points	Radionuclides	Mean Ci/g	Max.Value pCi/g
$15(2R)B_1$	19	Cs_{137}	0.75	2.03
$15(2R)B_{deepcore1}$	5	Cs_{137}	0.06	0.08

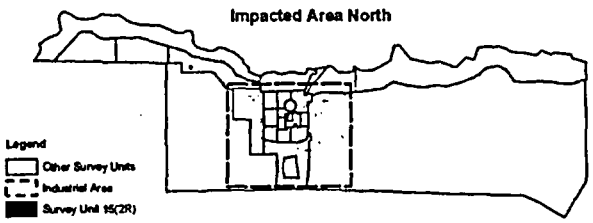
Survey Unit 15(2R)



Legend
- Survey Unit 15(2R)
- Numbered Local Coordinate Grid
- Soil Sample Locations

Scale: 0 2.5 5 10 Meters





Survey Results

Survey	Grid	Coordinate[c] (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
15(2R)B_1	16039	(7.2)(1.0)	0.00-0.15	0.29		nd	0.07	nd	0.24
15(2R)B_1	16039	(8.4)(1.0)	0.00-0.15	0.02		nd	0.05	nd	0.27
15(2R)B_1	16039	(9.6)(1.0)	0.00-0.15	0.07		nd	0.05	nd	0.22
15(2R)B_1	16039	(7.2)(2.2)	0.00-0.15	0.25		nd	0.05	nd	0.22
15(2R)B_1	16039	(8.1)(1.8) s	0.00-0.15	0.24		nd	0.06	nd	0.22
15(2R)B_1	16039	(8.4)(2.2)	0.00-0.15	0.24		nd	0.06	nd	0.26
15(2R)B_1	16039	(9.6)(2.2)	0.00-0.15	0.49		nd	0.05	nd	0.28
15(2R)B_1	16039	(7.2)(3.4)	0.00-0.15	0.51		nd	0.06	nd	0.24
15(2R)B_1	16039	(8.4)(3.4)	0.00-0.15	1.40		nd	0.05	nd	0.25
15(2R)B_1	16039	(9.6)(3.4)	0.00-0.15	2.03		nd	0.08	nd	0.34
15(2R)B_1	16039	(7.2)(4.6)	0.00-0.15	1.15		nd	0.06	nd	0.29
15(2R)B_1	16039	(8.4)(4.6)	0.00-0.15	0.42		nd	0.04	nd	0.20
15(2R)B_1	16039	(9.6)(4.6)	0.00-0.15	1.53		nd	0.04	nd	0.23
15(2R)B_1	16039	(7.2)(5.8)	0.00-0.15	0.77		nd	0.05	nd	0.20
15(2R)B_1	16039	(8.4)(5.8)	0.00-0.15	1.74		nd	0.03	nd	0.28
15(2R)B_1	16039	(9.6)(5.8)	0.00-0.15	0.53		nd	0.04	nd	0.24
15(2R)B_1	16039	(8.7)(3.9) s	0.00-0.15	1.55		nd	0.07	nd	0.27
15(2R)$B_{1deepcore}$	16039	(8.1)(1.8) s	0.15-0.30	nd	0.04	nd	0.05	nd	0.22
15(2R)$B_{1deepcore}$	16039	(8.7)(3.9) s	0.15-0.30	0.23		nd	0.04	nd	0.20
15(2R)$B_{1deepcore}$	16039	(8.7)(3.9) s	0.30-0.60	0.08		nd	0.05	nd	0.22
15(2R)$B_{2deepcore}$	16039	(8.0)(2.0)	0.00-0.15	[d]					
15(2R)$B_{2deepcore}$	16039	(8.0)(2.0)	0.15-0.30	0.04		nd	0.05	nd	0.26
15(2R)$B_{2deepcore}$	16039	(8.0)(2.0)	0.30-0.45	nd	0.04	nd	0.04	nd	0.21
15(2R)$B_{2deepcore}$	16039	(8.0)(2.0)	0.45-0.60	nd	0.04	nd	0.05	nd	0.21
15(2R)$B_{2deepcore}$	16039	(8.0)(2.0)	0.60-0.90	nd	0.03	nd	0.05	nd	0.19

[a] nd indicates non detect, MDA provided
[b] no entry in the MDA column is provided when residual radioactivity is detected
[d] stone/gravel, sample not obtainable
[c] S indicates sample splits with NRC and MDEQ

Survey Unit 15(3)

Description
Survey Unit 15(3) is an area of approximately 10,100 m^2 west of the Protected Area that parallels the shoreline south of Survey Unit 14. This area encompasses an east/west section of the Woods Road connecting Survey Units 15(2) and 15(4). Subsurface structures and components do not exist in this wooded area.

History
The Woods Road is an unimproved lane to former plant weather station located in Survey Unit 15(4). A small area along the road in this survey unit was once used for the storage of construction debris and miscellaneous refuse. All debris has been removed and the radiological investigation of this location did not identify residual radioactivity.

Radiological Status
Residual radioactivity was not identified in any sample collected in this survey unit above established background levels. The radiological status of survey Unit 15(3) is Class 3.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.22
Standard Deviation (σ)	0.08

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.08} = 32.6$$

   With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 155X 80 meters
   Random Numbers 0.216531, 0.112314
   Random start Location
   X = (0.216531)(155 m) = 33.6 m
   Y = (0.112314)(80 m) = 9.0 m

$$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{10056/14} = 26.8 \text{ meters}$$

As a conservative measure 25 samples were collected using 19.8 meter spacing.

Supporting Surveys

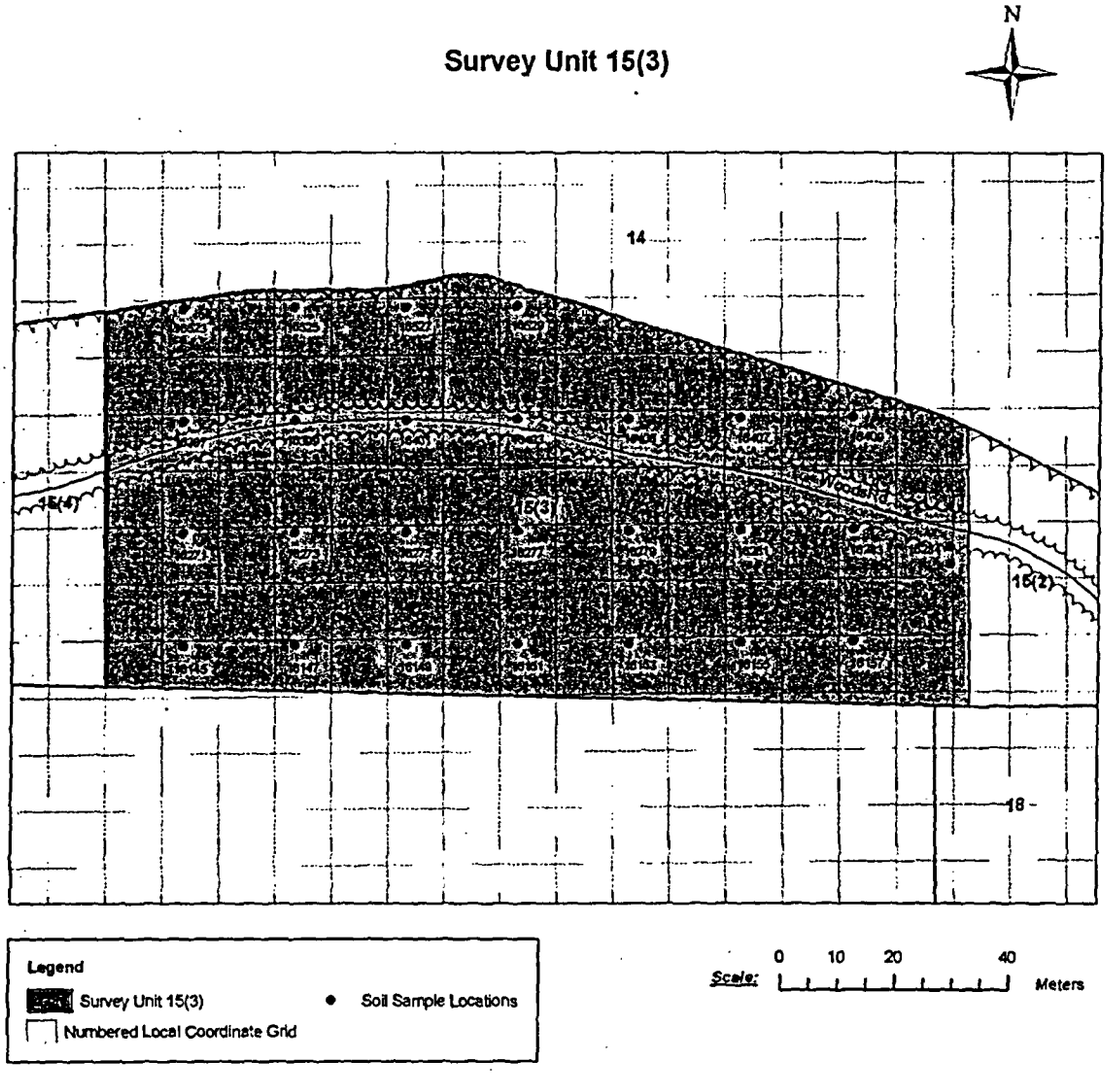
Supporting survey 15(3)A_1 was performed for the investigation of soil contamination in vicinity of the construction debris cleanup along the Woods Road. Data point locations were judgmentally selected based on historical information and process knowledge for areas of greatest potential to contain radioactivity.

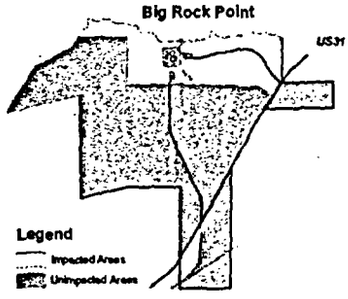
Data Summary

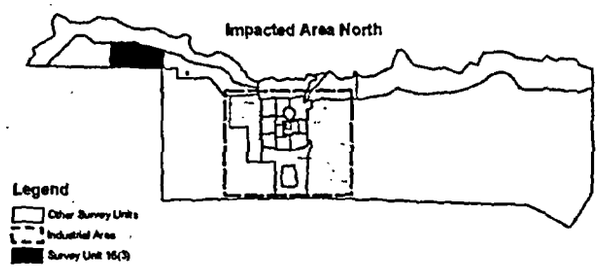
Survey Unit 15(3)

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
15(3)A_1	2	Cs_{137}	0.12	0.12
15(3)A_2	25	Cs_{137}	0.38	1.05

Survey Unit 15(3)







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
15(3)A_1	16284	(9.5,5.5)	0.00-0.30	0.11		nd	0.04	nd	0.22
15(3)A_1	16284	(9.5,2.5)	0.00-0.30	0.12		nd	0.05	nd	0.26
15(3)A_2	16145	(3.8,9.0)	0.00-0.15	0.36		nd	0.05	nd	0.25
15(3)A_2	16147	(3.6,9.0)	0.00-0.15	1.05		nd	0.08	nd	0.37
15(3)A_2	16149	(3.4,9.0)	0.00-0.15	0.30		nd	0.05	nd	0.24
15(3)A_2	16151	(3.2,9.0)	0.00-0.15	0.68		nd	0.05	nd	0.32
15(3)A_2	16153	(3.0,9.0)	0.00-0.15	0.44		nd	0.05	nd	0.25
15(3)A_2	16155	(2.8,9.0)	0.00-0.15	0.41		nd	0.05	nd	0.22
15(3)A_2	16157	(2.6,9.0)	0.00-0.15	0.66		nd	0.03	nd	0.22
15(3)A_2	16283	(2.6,8.8)	0.00-0.15	0.32		nd	0.04	nd	0.23
15(3)A_2	16281	(2.8,8.8)	0.00-0.15	0.17		nd	0.04	nd	0.27
15(3)A_2	16279	(3.0,8.8)	0.00-0.15	0.61		nd	0.06	nd	0.29
15(3)A_2	16277	(3.2,8.8)	0.00-0.15	0.48		nd	0.05	nd	0.29
15(3)A_2	16275	(3.4,8.8)	0.00-0.15	0.52		nd	0.06	nd	0.33
15(3)A_2	16273	(3.6,8.8)	0.00-0.15	0.48		nd	0.05	nd	0.25
15(3)A_2	16271	(3.8,8.8)	0.00-0.15	0.29		nd	0.06	nd	0.25
15(3)A_2	16397	(3.8,8.6)	0.00-0.15	0.54		nd	0.06	nd	0.26
15(3)A_2	16399	(3.6,8.6)	0.00-0.15	0.12		nd	0.06	nd	0.17
15(3)A_2	16401	(3.4,8.6)	0.00-0.15	0.12		Nd	0.05	nd	0.24
15(3)A_2	16403	(3.2,8.6)	0.00-0.15	0.26		Nd	0.06	nd	0.17
15(3)A_2	16405	(3.0,8.6)	0.00-0.15	0.92		Nd	0.05	nd	0.34
15(3)A_2	16407	(2.8,8.6)	0.00-0.15	0.25		Nd	0.05	nd	0.28
15(3)A_2	16409	(2.6,8.6)	0.00-0.15	0.09		Nd	0.06	nd	0.23
15(3)A_2	16529	(3.2,8.4)	0.00-0.15	0.11		Nd	0.04	nd	0.20
15(3)A_2	16527	(3.4,8.4)	0.00-0.15	0.12		Nd	0.04	nd	0.20
15(3)A_2	16525	(3.6,8.4)	0.00-0.15	0.10		Nd	0.05	nd	0.23
15(3)A_2	16523	(3.8,8.4)	0.00-0.15	0.07		Nd	0.04	nd	0.22

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 15(4)

Description
Survey Unit 15(4) is an area of approximately 11,000 m^2 west of the Protected Area that parallels the shoreline south of Survey Unit 14. The Woods Road terminates in the central portion of this survey unit. Subsurface structures and components include the footings and foundation slab of the former weather station tower.

History
The Woods Road is an unimproved lane that provided access to the former weather station tower located in this survey unit. The tower, in use until 1963, was subsequently dismantled and all that currently remains are the footings and foundation slab.

An area of the Woods Road within this survey unit was once used for the storage of construction debris and miscellaneous refuse. Cleanup efforts have resulted in the removal of all materials from this area. Radiological surveys conducted during this removal process did not identify residual radioactivity in construction debris or area soils.

Radiological Status
Residual radioactivity was not identified in any sample collected in this survey unit above established background levels. The radiological status of Survey Unit 15(4) is Class 3.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.21
Standard Deviation (σ)	0.07

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.07} = 37.2$$

   With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 190 x 100 meters
   Random Numbers 0.919787, 0.607572
   Random start Location
   X = (0.919787)(190 m) = 174.8 m
   Y = (0.607572)(100 m) = 60.8 m

Sample Spacing $L = \sqrt{Area/N} = \sqrt{10955/14} = 27.9$ meters

As a conservative measure 25 samples were collected using 20 meter spacing.

Supporting Surveys

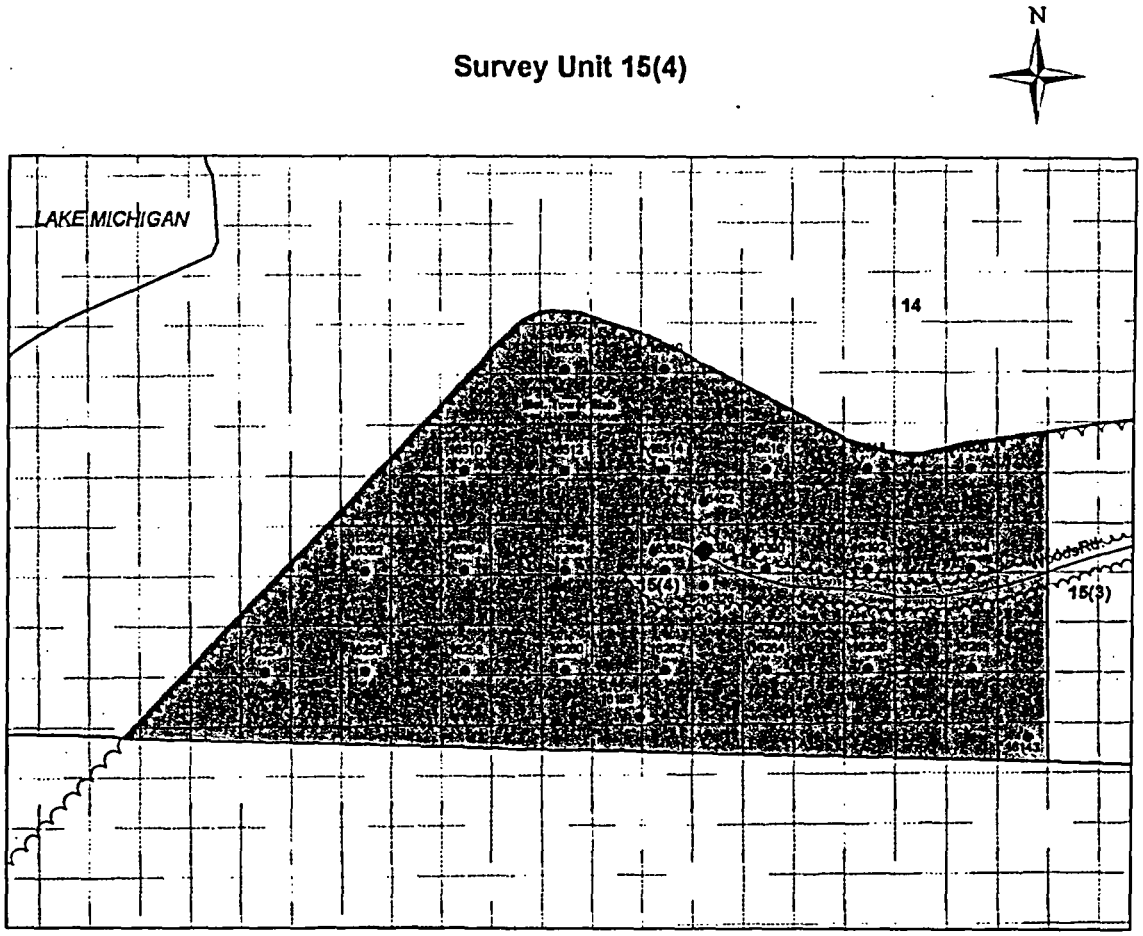
Supporting survey $15(4)A_1$ was performed for the investigation of soil contamination in vicinity of the construction debris cleanup along the Woods Road. Data point locations were judgmentally selected based on historical information and process knowledge for areas of greatest potential to contain radioactivity.

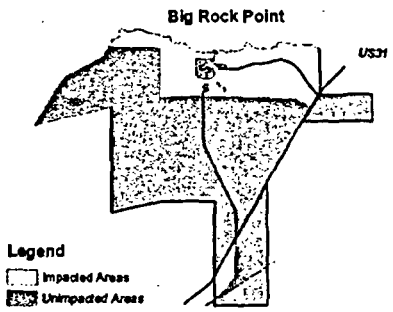
Data Summary

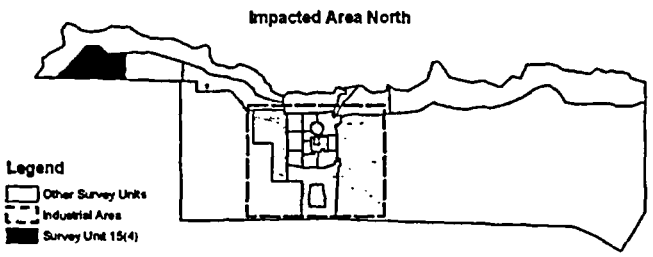
Survey Unit 15(4)

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$15(4)A_1$	9	Cs_{137}	0.16	0.64
$15(4)A_2$	25	Cs_{137}	0.23	0.43

Survey Unit 15(4)







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
15(4)A_1	16390	(2.5,4.5)	0.00-0.15	0.03		nd	0.05	nd	0.24
15(4)A_1	16326	(2.5,7.5)	0.00-0.15	0.12		nd	0.06	nd	0.23
15(4)A_1	16388	(2.5,4.5)	0.00-0.15	0.09		nd	0.05	nd	0.22
15(4)A_1	16452	(2.5,4.5)	0.00-0.15	0.64		nd	0.09	nd	0.36
15(4)A_1	16389	(2.5,3.5)	0.00-0.15	0.11		nd	0.06	nd	0.22
15(4)A_1	16389	(3.5,4.5)	0.00-0.15	0.05		nd	0.05	nd	0.22
15(4)A_1	16389	(2.5,5.5)	0.00-0.15	0.16		nd	0.06	nd	0.28
15(4)A_1	16389	(1.5,4.5)	0.00-0.15	0.08		nd	0.05	nd	0.20
15(4)A_1	16389	(2.5,4.5)	0.00-0.15	0.17		nd	0.06	nd	0.25
15(4)A_2	16520	(4.8,0.8)	0.00-0.15	0.13		nd	0.04	nd	0.21
15(4)A_2	16394	(4.8,0.8)	0.00-0.15	0.13		nd	0.03	nd	0.17
15(4)A_2	16268	(4.8,0.8)	0.00-0.15	0.29		nd	0.05	nd	0.26
15(4)A_2	16266	(4.8,0.8)	0.00-0.15	0.43		nd	0.06	nd	0.25
15(4)A_2	16392	(4.8,0.8)	0.00-0.15	0.31		nd	0.06	nd	0.25
15(4)A_2	16518	(4.8,0.8)	0.00-0.15	0.09		nd	0.05	nd	0.20
15(4)A_2	16516	(4.8,0.8)	0.00-0.15	0.32		nd	0.06	nd	0.25
15(4)A_2	16390	(4.8,0.8)	0.00-0.15	0.28		nd	0.05	nd	0.21
15(4)A_2	16264	(4.8,0.8)	0.00-0.15	0.09		nd	0.03	nd	0.20
15(4)A_2	16262	(4.8,0.8)	0.00-0.15	0.12		nd	0.04	nd	0.22
15(4)A_2	16388	(4.8,0.8)	0.00-0.15	0.10		nd	0.05	nd	0.23
15(4)A_2	16514	(4.8,0.8)	0.00-0.15	0.42		nd	0.05	nd	0.27
15(4)A_2	16640	(4.8,0.8)	0.00-0.15	0.14		nd	0.04	nd	0.23
15(4)A_2	16638	(4.8,0.8)	0.00-0.15	0.12		nd	0.05	nd	0.22
15(4)A_2	16512	(4.8,0.8)	0.00-0.15	0.29		nd	0.05	nd	0.29
15(4)A_2	16386	(4.8,0.8)	0.00-0.15	0.14		nd	0.05	nd	0.26
15(4)A_2	16260	(4.8,0.8)	0.00-0.15	0.29		nd	0.07	nd	0.25
15(4)A_2	16258	(4.8,0.8)	0.00-0.15	0.16		nd	0.05	nd	0.24
15(4)A_2	16384	(4.8,0.8)	0.00-0.15	0.18		nd	0.05	nd	0.23
15(4)A_2	16510	(4.8,0.8)	0.00-0.15	0.38		nd	0.06	nd	0.28
15(4)A_2	16382	(4.8,0.8)	0.00-0.15	0.32		nd	0.06	nd	0.30
15(4)A_2	16256	(4.8,0.8)	0.00-0.15	0.23		nd	0.04	nd	0.24
15(4)A_2	16254	(4.8,0.8)	0.00-0.15	0.10		nd	0.06	nd	0.20
15(4)A_2	16143	(6.2,7.0)	0.00-0.15	0.32		nd	0.05	nd	0.28
15(4)A_2	16198	(9.5,1.5)	0.00-0.15	0.41		nd	0.05	nd	0.27

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 16

Description

Survey Unit 16 is located immediately east of the discharge canal and encompasses approximately 8300 m^2 of Lake Michigan shore area from the waters edge to the tree line. Vehicle barricades traverse this survey unit approximately 23 meters east of the security fence. Subsurface structures and components have not been identified in this area.

History

Asphalt, concrete, and other construction rubble were once visible in a localized area along the waters edge in this survey unit. The material is believed to be early construction debris left in place as rip-rap protection against shoreline erosion. This area was investigated for the potential presence of buried man-made material. Radiological surveys were conducted and these materials were excavated and removed from the area. Residual radioactivity was not identified in any excavated soil or debris removed from the shoreline.

Radiological Status

Due to near-record lows in Lake Michigan water level, additional shoreline us exposed for surveys conducted in this area. The location of this survey unit is east of the plant discharge canal where licensed radioactive liquid release occurred; the levels of radionuclides identified in these surveys is consistent with expectations for sediment migration that would result from wind, current, and wave action along the shoreline. The radiological status of this survey unit is Class 2.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137	Co-60	Mn-54
Mean value (pCi/g)	0.32	0.11	0.04
Standard Deviation (&)	0.19	0.04	0.02

Applying the Unity Rule,

$$\sigma = \sqrt{\left(\frac{\sigma_{Cs}}{5.11_{Cs}}\right)^2 + \left(\frac{\sigma_{Co}}{4.99_{Co}}\right)^2 + \left(\frac{\sigma_{Mn}}{474_{Mn}}\right)^2}$$

$$\sigma = \sqrt{\left(\frac{0.19}{5.11_{Cs}}\right)^2 + \left(\frac{0.04}{4.99_{Co}}\right)^2 + \left(\frac{0.01}{474_{Mn}}\right)^2}$$

σ =0.04

For the Unity Rule, the DCGL for the weighted sum is 1. The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{DCGL - LBGR}{\sigma} = \frac{1 - 0.5}{0.04} = 12.5$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

2. Sample Locations
   Sample locations were systematically selected in a random start, square grid pattern with the southwest corner of the survey unit as origin.

   Bounding survey unit dimensions 140 x 60 meters
   Random Numbers 0.845432, 0.201667
   Random Start Location
   X = (0.845432)(140 m) = 118.4 meters
   Y = (0.201667)(60 m) = 12.1 meters

   $$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{8290/14} = 24.3 \text{ meters}$$

   As a conservative measure 22 samples were collected using 20.5 meter spacing.

Supporting Surveys
No supporting surveys were conducted in this area.

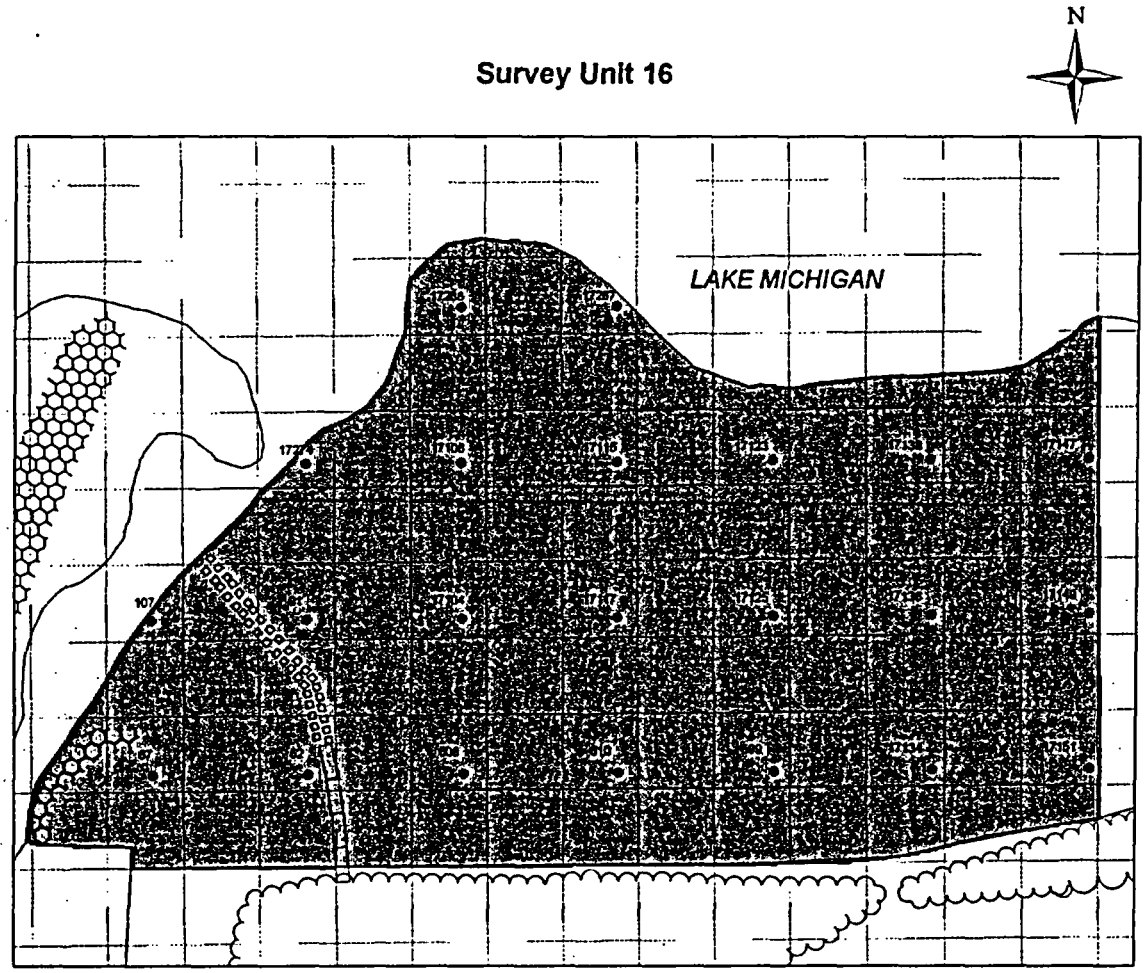
Data Summary

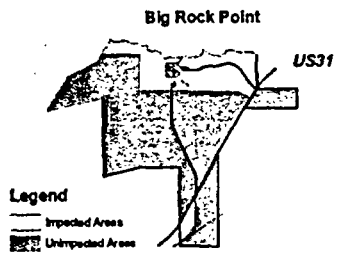
Survey Unit 16

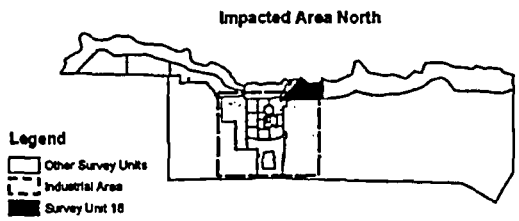
Survey	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$16A_1$	22	Cs_{137}	0.41	1.38
		**Co_{60}	0.10	0.13

* nd indicated no detected
** Activity identified in 3 samples only.

Survey Unit 16







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$16A_1$	17151	(8.9,2.1)	0.00-0.15	0.53		nd	0.06	nd	0.24
$16A_1$	17149	(8.9,2.6)	0.00-0.15	0.09		nd	0.06	nd	0.22
$16A_1$	17147	(8.9,3.1)	0.00-0.15	0.28		nd	0.07	nd	0.27
$16A_1$	17134	(8.4,2.1)	0.00-0.15	0.55		nd	0.07	nd	0.28
$16A_1$	17136	(8.4,2.6)	0.00-0.15	0.06		nd	0.08	nd	0.30
$16A_1$	17138	(8.4,3.1)	0.00-0.15	0.24		0.10		nd	0.30
$16A_1$	599	(7.9,2.1)	0.00-0.15	1.15		nd	0.07	nd	0.27
$16A_1$	17125	(7.9,2.6)	0.00-0.15	0.06		nd	0.06	nd	0.29
$16A_1$	17123	(7.9,3.1)	0.00-0.15	0.29		nd	0.07	nd	0.29
$16A_1$	610	(7.4,2.1)	0.00-0.15	1.38		nd	0.06	nd	0.27
$16A_1$	17117	(7.4,2.6)	0.00-0.15	0.09		nd	0.06	nd	0.26
$16A_1$	17115	(7.4,3.1)	0.00-0.15	0.79		0.07		nd	0.24
$16A_1$	17287	(7.4,3.6)	0.00-0.15	0.11		nd	0.07	nd	0.22
$16A_1$	608	(6.9,2.1)	0.00-0.15	0.98		nd	0.06	nd	0.29
$16A_1$	17104	(6.9,2.6)	0.00-0.15	0.09		nd	0.07	nd	0.26
$16A_1$	17106	(6.9,3.1)	0.00-0.15	0.12		nd	0.07	nd	0.29
$16A_1$	17288	(6.9,3.6)	0.00-0.15	0.75		nd	0.08	nd	0.32
$16A_1$	52	(6.4,2.1)	0.00-0.15	0.32		nd	0.06	nd	0.26
$16A_1$	91	(6.4,2.6)	0.00-0.15	0.42		0.13		nd	0.28
$16A_1$	17274	(6.4,3.1)	0.00-0.15	nd	0.05	nd	0.07	nd	0.32
$16A_1$	67	(5.9,2.1)	0.00-0.15	0.19		nd	0.05	nd	0.28
$16A_1$	107	(5.9,2.6)	0.00-0.15	0.07		nd	0.07	nd	0.25

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 17

Description

Survey Unit 17 is an area of approximately 256,500 m^2 located in the southeast quadrant of the Impacted area along the southern boundary of Survey Units 13 and 16. This area is primarily woodland; however, the following buildings and structures are located in the western quarter of the survey unit:

- Well House,
- Security Building,
- South Warehouse,
- Annex Building, and
- Portable Office Buildings.

The Big Rock Point access road and the former 138kv power easement traverse Survey Unit 17 from US Route 31 to the Industrial Area. The Big Rock Point access road provides paved access to the plant parking area located next to the Security Building. Subsurface structures and components include storm drains, conduit, Well Water System piping, and building foundations.

History

The power-line right of way was used as a storage location for large volumes of discarded concrete and asphalt rubble, structural steel, and other miscellaneous construction debris. An investigation of this area was conducted and all materials have been removed. Residual radioactivity was not identified in any construction debris or contact soil in this investigation.

The paved area adjacent to the security building was occasionally used as a transport route for the movement radioactive material from the plant main gate to the Radwaste Building.

Storm-drain piping originating from the Protected Area passes through a small section of Survey Unit 17 adjacent to the northeast section of the plant fence. Trace levels of residual radioactivity have been identified in the sediment of connecting storm drain piping within the Protected Area. The entire length of this piping system has been decontaminated and is currently monitored on a routine basis by Radiation Protection personnel .

Two areas along the former power-line easement have been established for the storage and staging of demolition debris. These materials have met the radiological criteria for staging prior to final evaluation and shipment to a Type II landfill. These areas are known as "Quality Verification Areas" (QVA).

Radiological Status

Residual radioactivity identified in this survey unit are consistent with established backgound levels. The radiological status of Survey Unit 17 is Class 3. Areas within this survey unit may be upgraded in classification due to future requirements for additional lay-down and staging locations during large scale structure demolition. Characterization surveys are scheduled to continue as buildings and components are dismantled and removed from the site.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.50
Standard Deviation (&)	0.40

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.40} = 6.5$$

   With ⬮ and ⬯ error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points. As a conservative measure 20 samples were collected for this survey.

2. Sample Locations
   Sample locations were selected by random method

   Bounding survey unit dimensions 780 x 400 meters.
   Random numbers were generated and applied to bounding survey unit dimensions to determine data point coordinate locations. This process was continued until 20 sample point locations successfully fell within the survey unit.

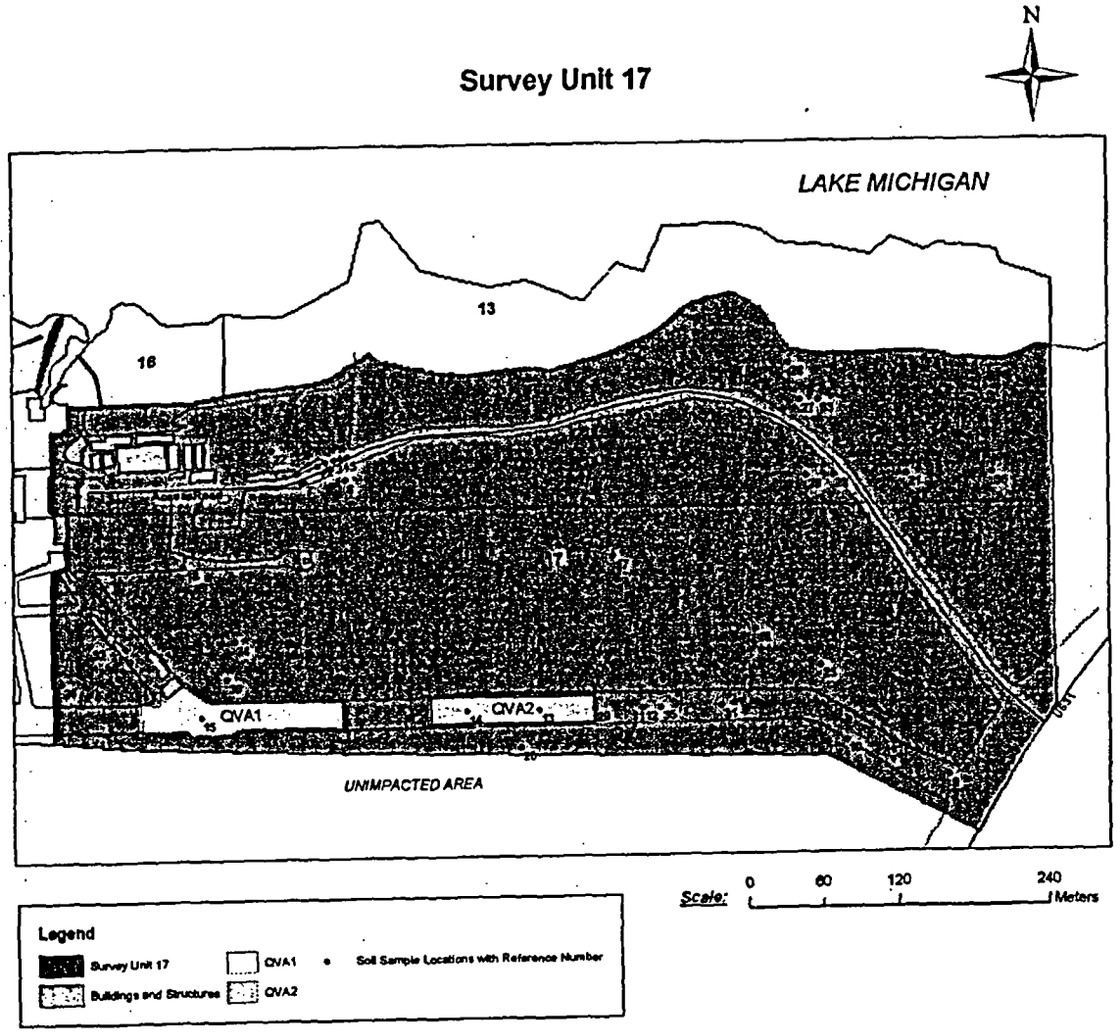
Supporting Surveys
Supporting surveys $17A_2$ and $17A_3$ were conducted for the radiological evaluation of soil prior to construction of the new Security Building located on the BRP Access Road. Survey $17A_{pl}$ was performed for the investigation of residual radioactivity in vicinity of the construction storage location on the power-line easement. Data point locations were judgmentally selected for areas of greatest potential to contain radioactivity based on historical information and process knowledge.

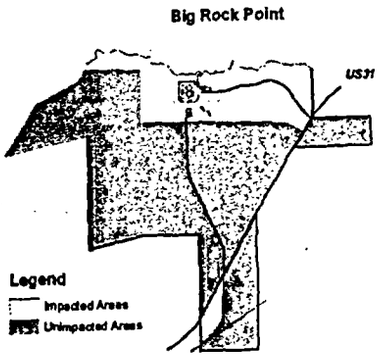
Data Summary

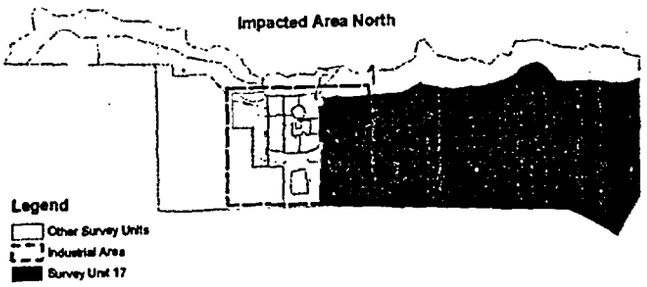
Survey Unit 17

Survey	No. of Samples	Radionuclide	Mean (pCi/g)	Max. Value (pCi/g)
$17A_1$	20	Cs_{137}	0.57	1.59
$17A_2$	5	Cs_{137}	0.38	0.48
$17A_3$	3	Cs_{137}	0.06	0.06
$17A_{pl}$	7	Cs_{137}	0.53	1.43

Survey Unit 17







Survey Results

Survey	Grid Coordinate (x,y) ($x_{Longitude}$, $y_{Latitude}$)		Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$17A_2$	17346	(5.5,5.0)	0.00-0.15	0.32		nd	0.07	nd	0.38
$17A_2$	17347	(2.0,7.5)	0.00-0.15	0.45		nd	0.07	nd	0.30
$17A_2$	17347	(9.0,9.5)	0.00-0.15	0.48		nd	0.06	nd	0.32
$17A_2$	17349	(4.5,1.0)	0.00-0.15	0.38		nd	0.07	nd	0.32
$17A_2$	17351	(0.0,1.5)	0.00-0.15	0.28		nd	0.03	nd	0.23
$17A_3$	17343	(9.0,9.0)	0.00-2.00	nd	0.06	nd	0.05	nd	0.26
$17A_3$	17344	(5.5,2.0)	0.00-2.00	nd	0.05	nd	0.06	nd	0.24
$17A_3$	17348	(8.5,3.0)	0.00-2.00	0.06		nd	0.05	nd	0.25
$17A_{pl}$	N45° 21' 25.9", W85° 11' 08.4"		0.00-0.15	0.40		nd	0.06	nd	0.30
$17A_{pl}$	N45° 21' 27.3", W85° 11' 12.2"		0.00-0.15	0.42		nd	0.06	nd	0.28
$17A_{pl}$	N45° 21' 28.0", W85° 11' 19.7"		0.00-0.15	0.35		nd	0.06	nd	0.30
$17A_{pl}$	N45° 21' 27.8", W85° 11' 19.8"		0.00-0.15	1.43		nd	0.04	nd	0.26
$17A_{pl}$	N45° 21' 27.9", W85° 11' 23.7"		0.00-0.15	0.49		nd	0.07	nd	0.30
$17A_{pl}$	N45° 21' 28.1", W85° 11' 26.4"		0.00-0.15	0.61		nd	0.05	nd	0.31
$17A_{pl}$	N45° 21' 27.9", W85° 11' 36.4"		0.00-0.15	0.14		nd	0.09	nd	0.32
$17A_1$	N45° 21' 31.5", W85° 11' 20.8"		0.00-0.15	0.49		nd	0.08	nd	0.38
$17A_1$	N45° 21' 31.9", W85° 11' 37.0"		0.00-0.15	0.08		nd	0.05	nd	0.27
$17A_1$	N45° 21' 29.5", W85° 11' 15.5"		0.00-0.15	0.30		nd	0.04	nd	0.30
$17A_1$	N45° 21' 27.2", W85° 11' 24.4"		0.00-0.15	0.45		nd	0.06	nd	0.32
$17A_1$	N45° 21' 34.1", W85° 11' 09.8"		0.00-0.15	0.66		nd	0.07	nd	0.35
$17A_1$	N45° 21' 34.6", W85° 11' 33.6"		0.00-0.15	0.10		nd	0.07	nd	0.33
$17A_1$	N45° 21' 33.9", W85° 11' 12.5"		0.00-0.15	0.48		nd	0.05	nd	0.29
$17A_1$	N45° 21' 29.2", W85° 11' 41.6"		0.00-0.15	0.76		nd	0.09	nd	0.36
$17A_1$	N45° 21' 29.2", W85° 11' 13.1"		0.00-0.15	0.51		nd	0.08	nd	0.42
$17A_1$	N45° 21' 33.5", W85° 11' 13.5"		0.00-0.15	0.54		nd	0.05	nd	0.39
$17A_1$	N45° 21' 35.7", W85° 11' 13.7"		0.00-0.15	0.49		nd	0.06	nd	0.31
$17A_1$	N45° 21' 36.7", W85° 11' 14.1"		0.00-0.15	0.92		nd	0.06	nd	0.26
$17A_1$	N45° 21' 27.5", W85° 11' 21.6"		0.00-0.15	0.54		nd	0.06	nd	0.29
$17A_1$	N45° 21' 29.1", W85° 11' 35.4"		0.00-0.15	0.61		nd	0.08	nd	0.29

Survey	Grid Coordinate (x,y) ($x_{Longitude}$, $y_{Latitude}$)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
			Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$17A_1$	N45° 21' 28.3", W85° 11' 16.8"	0.00-0.15	0.44		nd	0.07	nd	0.37
$17A_1$	N45° 21' 30.2", W85° 11' 40.5"	0.00-0.15	1.59		nd	0.10	nd	0.41
$17A_1$	N45° 21' 36.3", W85° 11' 13.0"	0.00-0.15	0.32		nd	0.05	nd	0.29
$17A_1$	N45° 21' 30.2", W85° 11' 35.1"	0.00-0.15	0.91		nd	0.08	nd	0.41
$17A_1$	N45° 21' 27.8", W85° 11' 19.1"	0.00-0.15	0.20		nd	0.05	nd	0.27
$17A_1$	N45° 21' 34.2", W85° 11' 06.6"	0.00-0.15	0.92		nd	0.07	nd	0.38

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Survey Unit 18

Description
Survey Unit 18 is an area of approximately 84,000 m^2 located west of the Protected Area. There are no structures, components, and systems in this survey unit.

History
This outlying area has remained remote from normal plant operational activities. The HSA designates this area to be unlikely to contain residual radioactivity.

Radiological Status
Residual radioactivity in soils in this survey unit are consistent with established background levels. The radiological status of Survey Unit 17 is Class 3 due to its proximity to other Class 2 Areas.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.50
Standard Deviation (σ)	0.40

   The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

   $$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.40} = 6.5$$

   With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points. As a conservative measure 20 samples were collected for this survey.

2. Sample Locations
   Sample locations were selected by random method

   Bounding survey unit dimensions 330 x 375 meters. Random numbers were generated and applied to bounding survey unit dimensions to determine data point coordinate locations. This process was continued until 20 sample point locations successfully fell within the survey unit. .

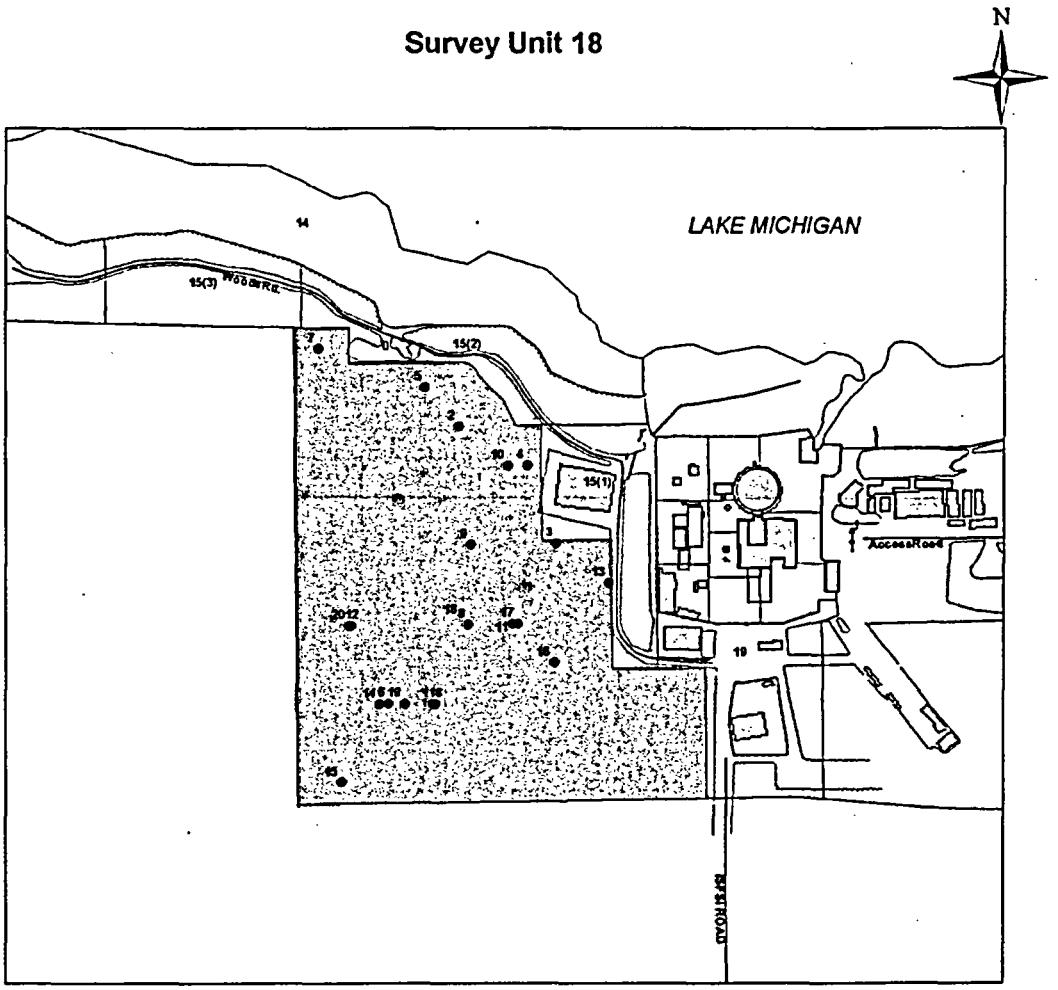
Supporting Surveys
Supporting surveys were not conducted in this area..

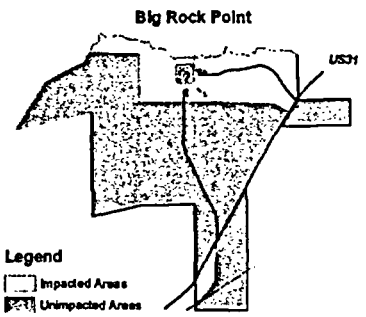
Data Summary

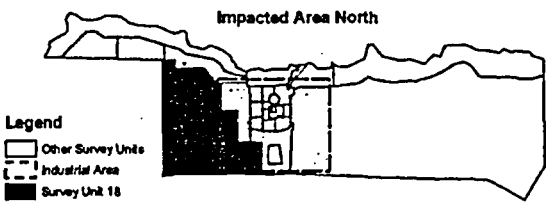
Survey Unit 18A

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$18A_1$	20	Cs_{137}	0.60	1.00

Survey Unit 18







Survey Results

Survye	Coordinate ($x_{Longitude}$, $y_{Latitude}$)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
		Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$18A_1$	N45 21'29.8", W85 11'55.9"	0.48		nd	0.06	nd	0.32
$18A_1$	N45 21'37.3", W85 11'54.9"	0.51		nd	0.06	nd	0.28
$18A_1$	N45 21'33.5", W85 11'51.4"	0.53		nd	0.06	nd	0.39
$18A_1$	N45 21'36.2", W85 11'52.4"	0.48		nd	0.07	nd	0.30
$18A_1$	N45 21'37.9", W85 11'56.1"	0.49		nd	0.06	nd	0.26
$18A_1$	N45 21'29.9", W85 11'57.5"	0.31		nd	0.06	nd	0.34
$18A_1$	N45 21'38.6", W85 11'59.9"	0.50		nd	0.07	nd	0.31
$18A_1$	N45 21'31.5", W85 11'54.6"	1.00		nd	0.09	nd	0.43
$18A_1$	N45 21'33.8", W85 11'54.5"	0.60		nd	0.05	nd	0.24
$18A_1$	N45 21'36.3", W85 11'53.1"	0.55		nd	0.06	nd	0.26
$18A_1$	N45 21'32.5", W85 11'53.0"	0.37		nd	0.05	nd	0.27
$18A_1$	N45 21'32.5", W85 11'58.8"	0.82		nd	0.07	nd	0.37
$18A_1$	N45 21'32.7", W85 11'49.5"	0.93		nd	0.08	nd	0.41
$18A_1$	N45 21'30.2", W85 11'57.8"	0.47		nd	0.06	nd	0.34
$18A_1$	N45 21'28.3", W85 11'59.2"	0.74		nd	0.08	nd	0.43
$18A_1$	N45 21'31.3", W85 11'51.5"	0.53		nd	0.06	nd	0.31
$18A_1$	N45 21'32.4", W85 11'52.8"	0.60		nd	0.06	nd	0.40
$18A_1$	N45 21'29.9", W85 11'55.8"	0.75		nd	0.08	nd	0.35
$18A_1$	N45 21'29.9", N85 11'56.9"	0.93		nd	0.09	nd	0.34
$18A_1$	N45 21'32.0", W85 11'58.9"	0.35		nd	0.07	nd	0.34

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Table format not consistent with others (grid, depth??)

Survey Unit 19

Description

Survey Unit 19 is an area of approximately 12,000 m^2 located directly south of the Protected Area. A large portion of this location has been paved to support the transport of materials to the Radwaste Storage Building located in Survey Unit 11. The Radwaste Office Building and plant substation located in the northern section of this survey unit were both constructed subsequent to final plant shut-down. Subsurface structures and components include substation footings, storm drain piping, groundwater monitoring wells, station power conduit, and electronic communication wiring.

History

This area was used as a transport and staging location for the movement of radioactive materials to the Radwaste Building. A road construction project was conducted following final plant shutdown to pave areas north of the Radwaste Building and construct a roadway to the ISFSI storage facility for spent fuel transport. Surveys conducted prior to road construction in these areas did not identify residual radioactivity in soil above established background levels.

Radiological Status

Residual radioactivity was not identified above established background levels in any survey conducted in this area. The radiological status of Survey Unit 19 is Class 2. Further characterization of this area is scheduled to continue as systems and structures are removed from the site.

Primary Survey Design

The first characterization surveys performed following cessation of power operations were conducted to investigate areas scheduled for construction (trenching, excavation, road surfacing) prior to soil disturbance. Initial surveys performed in Survey Unit 19 were conducted to support paving of the transport route north of the Radwaste Building and construction of the spent fuel roadway to the ISFSI facility. Due to sampling limitations resulting from accessibility, subsurface obstruction, and electrical hazards in northern portions of this survey unit, primary surveys were conducted by the following two methods:

1. Survey Design, Sections North And West
   In-Situ measurements were performed in 100 m^2 increments in all accessible areas. Soil samples were collected for laboratory analysis and confirmation of contaminant homogeneity. Survey results for In-Situ measurements and corresponding soil analyses are presented by survey grid location in Table 2.

2. Survey Design, Sections South And East
   Area evaluation performed by soil sampling and laboratory analysis. Sample size and data point locations were based on NUREG-1575 guidance.

a. Sample Data Points Required
The scoping survey resulted in the following data:

Nuclide identification	C-137
Mean value (pCi/g)	0.52
Standard Deviation (σ)	0.48

The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.48} = 5.45$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points.

b. Sample Locations
Sample locations were systematically selected in random start, square grid pattern with the southwest corner of the survey unit as origin.

Bounding survey unit dimensions 80 X 130 meters
Random Numbers 0.694949, 0.979969
Random Start Location
X = (0.694949)(80 m) = 55.6 m
Y = (0. 979969)(130 m) = 127.4 m

$$\text{Sample Spacing } L = \sqrt{\text{Area}/N} = \sqrt{5600/14} = 20.0 \text{ m}$$

As a conservative measure 25 samples were collected using 15 meter spacing. Soil analyses for all samples collected in the south and east sections Survey Unit 19 are summarized by survey in Table1.

Supporting Surveys

Surveys were conducted prior to construction in areas scheduled for fiber optics installation, storm drain modification, and erection of the plant substation.

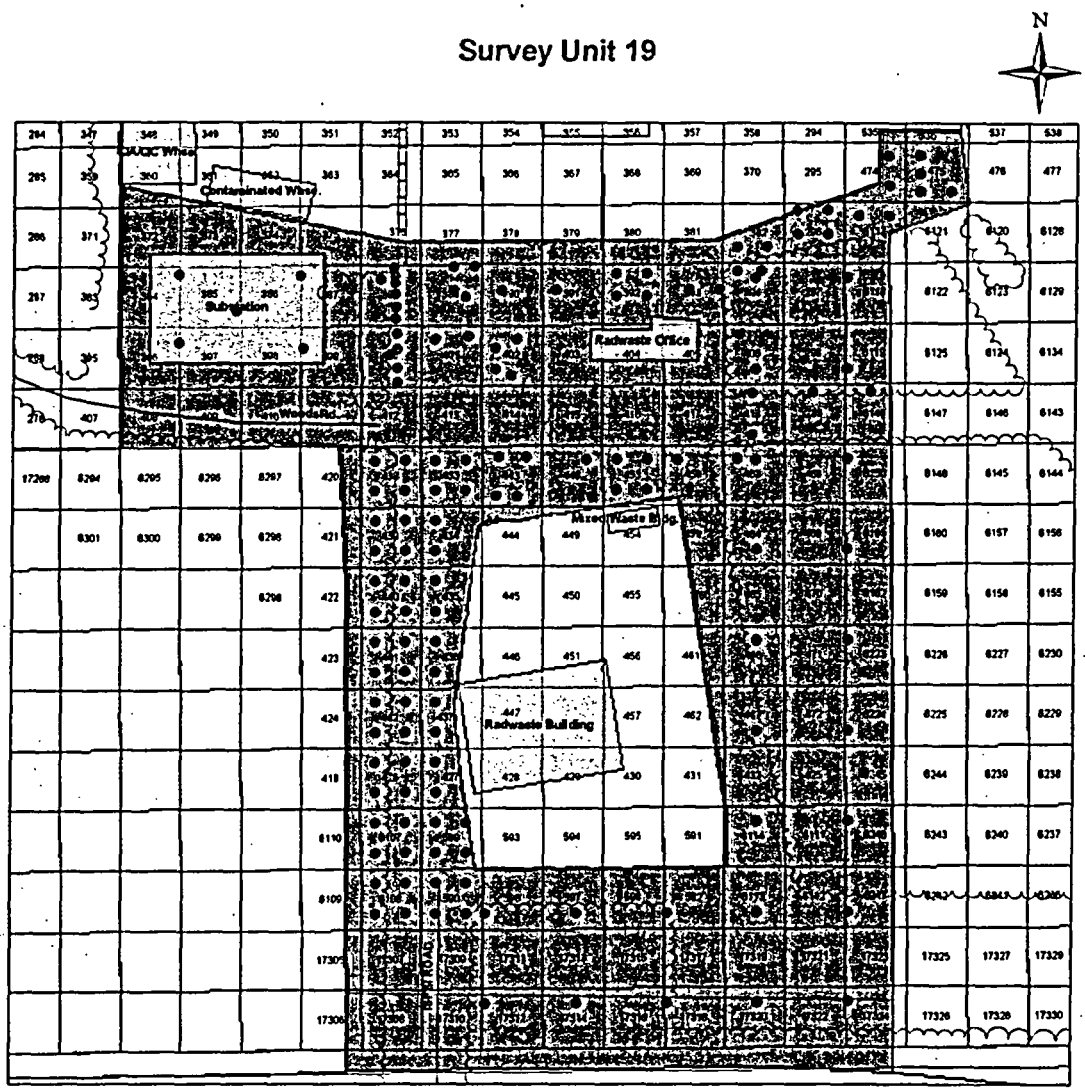
Data Summary

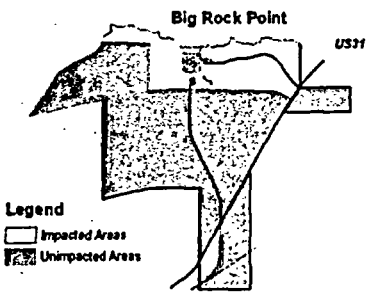
Survey Unit 19

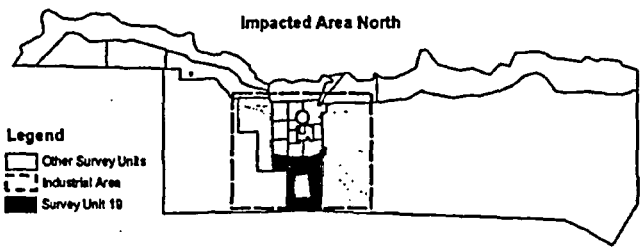
Survey **	No. of Samples	Radionuclides*	Mean (pCi/g)	Max. Value (pCi/g)
$19A_1$	79	Cs_{137}	0.18	0.45
$19A_2$	26	Cs_{137}	0.15	0.31
$19A_3$	25	Cs_{137}	0.61	1.10
		***Co_{60}	0.12	0.12
$19A_{culvert\ connection}$	4	Cs_{137}	0.22	0.35
$19A_{deepcore}$	2	nd	-	-
$19A_{td}$	15	nd	-	-

*nd - non detect
**td – trenching and digging surveys
***Co-60 identified in one sample only

Survey Unit 19







Survey Results – Table 1

Survey[c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
$19A_1$	401	(2.5,7.5)	0.00-0.15	nd	0.10	nd	0.08	nd	0.19
$19A_1$	402	(5.0,1.5)	0.00-0.15	nd	0.11	nd	0.10	nd	0.20
$19A_1$	402	(6.0,7.5)	0.00-0.15	nd	0.08	nd	0.10	nd	0.16
$19A_1$	402	(2.5,2.5)	0.00-0.15	0.31		nd	0.12	nd	0.20
$19A_1$	402	(2.5,6.0)	0.00-0.15	0.45		nd	0.16	nd	0.20
$19A_1$	418	(5.0,8.5)	0.00-0.15	0.14		nd	0.11	nd	0.22
$19A_1$	418	(5.0,1.5)	0.00-0.15	nd	0.14	nd	0.17	nd	0.25
$19A_1$	418	(5.0,1.5)	0.15-0.30	nd	0.10	nd	0.06	nd	0.21
$19A_1$	289	(5.0,8.5)	0.00-0.15	nd	0.09	nd	0.10	nd	0.24
$19A_1$	6149	(4.5,8.5)	0.00-0.15	nd	0.14	nd	0.10	nd	0.21
$19A_1$	438	(2.5,2.5)	0.00-0.15	0.27		nd	0.07	nd	0.20
$19A_1$	438	(7.5,2.5)	0.00-0.15	nd	0.09	nd	0.08	nd	0.17
$19A_1$	438	(2.5,7.5)	0.00-0.15	0.07		nd	0.08	nd	0.16
$19A_1$	438	(7.5,7.5)	0.00-0.15	nd	0.09	nd	0.08	nd	0.17
$19A_1$	433	(2.5,2.5)	0.00-0.15	nd	0.09	nd	0.06	nd	0.16
$19A_1$	433	(7.5,2.5)	0.00-0.15	nd	0.07	nd	0.07	nd	0.15
$19A_1$	433	(2.5,7.5)	0.00-0.15	0.24		nd	0.12	nd	0.16
$19A_1$	433	(2.5,7.5)	0.15-0.30	0.07		nd	0.02	nd	0.17
$19A_1$	433	(7.5,7.5)	0.00-0.15	nd	0.07	nd	0.07	nd	0.16
$19A_1$	443	(2.5,1.5)	0.00-0.15	0.17		nd	0.12	nd	0.19
$19A_1$	443	(6.0,1.5)	0.00-0.15	0.12		nd	0.11	nd	0.19
$19A_1$	443	(6.0,1.5)	0.15-0.30	0.12		nd	0.12		0.21
$19A_1$	443	(3.0,8.0)	0.00-0.15	0.24		nd	0.11	nd	0.17
$19A_1$	443	(7.5,8.0)	0.00-0.15	0.20		nd	0.13	nd	0.16
$19A_1$	448	(7.5,7.5)	0.00-0.15	nd	0.06	nd	0.07	nd	0.17
$19A_1$	453	(2.5,2.5)	0.00-0.15	nd	0.09	nd	0.1	nd	0.17
$19A_1$	453	(7.5,2.5)	0.00-0.15	nd	0.12	nd	0.16	nd	0.17
$19A_1$	453	(2.5,7.5)	0.00-0.15	0.16		nd	0.10	nd	0.18
$19A_1$	453	(7.5,7.5)	0.00-0.15	0.12		nd	0.10	nd	0.19
$19A_1$	453	(7.5,7.5)	0.15-0.30	0.17		nd	0.10	nd	0.22
$19A_1$	458	(2.5,7.5)	0.00-0.15	0.11		nd	0.11	nd	0.17
$19A_1$	439	(2.5,2.5)	0.00-0.15	0.32		nd	0.03	nd	0.23
$19A_1$	439	(7.5,2.5)	0.00-0.15	nd	0.05	nd	0.07	nd	0.18
$19A_1$	439	(2.5,7.5)	0.00-0.15	0.23		nd	0.06	nd	0.25
$19A_1$	439	(7.5,7.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.21
$19A_1$	434	(2.5,2.5)	0.00-0.15	0.09		nd	0.04	nd	0.18
$19A_1$	434	(2.5,7.5)	0.00-0.15	nd	0.07	nd	0.07	nd	0.18
$19A_1$	440	(2.5,2.5)	0.00-0.15	0.14		nd	0.03	nd	0.23
$19A_1$	440	(7.5,2.5)	0.00-0.15	0.02		nd	0.03	nd	0.21
$19A_1$	440	(2.5,7.5)	0.00-0.15	0.23		nd	0.07	nd	0.26

Survey[c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
$19A_1$	440	(7.5,7.5)	0.00-0.15	nd	0.09	nd	0.06	nd	0.18
$19A_1$	435	(2.5,2.5)	0.00-0.15	0.05		nd	0.04	nd	0.23
$19A_1$	435	(2.5,7.5)	0.00-0.15	0.14		nd	0.08	nd	0.18
$19A_1$	441	(2.5,2.5)	0.00-0.15	0.25		nd	0.05	nd	0.27
$19A_1$	441	(7.5,2.5)	0.00-0.15	nd	0.09	nd	0.07	nd	0.14
$19A_1$	441	(2.5,7.5)	0.00-0.15	0.20		nd	0.09	nd	0.21
$19A_1$	441	(7.5,7.5)	0.00-0.15	nd	0.07	nd	0.07	nd	0.14
$19A_1$	436	(2.5,2.5)	0.00-0.15	nd	0.08	nd	0.08	nd	0.15
$19A_1$	436	(2.5,7.5)	0.00-0.15	0.19		nd	0.07	nd	0.15
$19A_1$	442	(2.5,2.5)	0.00-0.15	0.36		nd	0.12	nd	0.2
$19A_1$	442	(2.5,2.5)	0.15-0.30	0.26		nd	0.14	nd	0.19
$19A_1$	442	(7.5,2.5)	0.00-0.15	nd	0.08	nd	0.11	nd	0.19
$19A_1$	442	(2.5,7.5)	0.00-0.15	0.13		nd	0.11	nd	0.22
$19A_1$	442	(7.5,7.5)	0.00-0.15	nd	0.08	nd	0.08	nd	0.17
$19A_1$	437	(2.5,2.5)	0.00-0.15	nd	0.07	nd	0.08	nd	0.18
$19A_1$	437	(2.5,7.5)	0.00-0.15	nd	0.06	nd	0.07	nd	0.18
$19A_1$	426	(2.5,2.5)	0.00-0.15	0.28		nd	0.04	nd	0.23
$19A_1$	426	(7.5,2.5)	0.00-0.15	nd	0.08	nd	0.12	nd	0.18
$19A_1$	426	(2.5,7.5)	0.00-0.15	0.32		nd	0.08	nd	0.21
$19A_1$	426	(7.5,7.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.23
$19A_1$	427	(2.5,2.5)	0.00-0.15	nd	0.06	nd	0.07	nd	0.13
$19A_1$	427	(2.5,7.5)	0.00-0.15	0.02		nd	0.03	nd	0.19
$19A_1$	6107	(2.5,2.5)	0.00-0.15	nd	0.13	nd	0.09	nd	0.20
$19A_1$	6107	(7.5,2.5)	0.00-0.15	nd	0.10	nd	0.11	nd	0.21
$19A_1$	6107	(2.5,7.5)	0.00-0.15	0.09		nd	0.13	nd	0.22
$19A_1$	6107	(7.5,7.5)	0.00-0.15	nd	0.06	nd	0.02	nd	0.15
$19A_1$	589	(2.5,2.5)	0.00-0.15	nd	0.05	nd	0.09	nd	0.17
$19A_1$	589	(7.5,2.5)	0.00-0.15	nd	0.06	nd	0.09	nd	0.19
$19A_1$	589	(2.5,7.5)	0.00-0.15	nd	0.06	nd	0.08	nd	0.20
$19A_1$	589	(7.5,7.5)	0.00-0.15	nd	0.03	nd	0.04	nd	0.20
$19A_1$	6108	(2.5,2.5)	0.00-0.15	nd	0.10	nd	0.07	nd	0.19
$19A_1$	6108	(7.5,2.5)	0.00-0.15	nd	0.09	nd	0.08	nd	0.21
$19A_1$	6108	(2.5,7.5)	0.00-0.15	nd	0.13	nd	0.11	nd	0.20
$19A_1$	6108	(7.5,7.5)	0.00-0.15	nd	0.07	nd	0.08	nd	0.19
$19A_1$	590	(2.5,2.5)	0.00-0.15	nd	0.10	nd	0.09	nd	0.21
$19A_1$	590	(7.5,2.5)	0.00-0.15	nd	0.09	nd	0.10	nd	0.14
$19A_1$	590	(2.5,7.5)	0.00-0.15	0.11		nd	0.05	nd	0.26
$19A_1$	590	(2.5,7.5)	0.15-0.30	0.19		nd	0.07	nd	0.21
$19A_1$	590	(7.5,7.5)	0.00-0.15	nd	0.06	nd	0.10	nd	0.20
$19A_2$	388	(3.5,7.5)	0.00-0.15	0.11		nd	0.06	nd	0.22
$19A_2$	389	(5.5,5.5)	0.00-0.15	0.20		nd	0.14	nd	0.15
$19A_2$	390	(3.5,5.5)	0.00-0.15	0.31		nd	0.09	nd	0.18

Survey[c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
19A2	391	(2.5,5.5)	0.00-0.15	0.07		nd	0.09	nd	0.21
19A2	392	(2.5,4.5)	0.00-0.15	nd	0.10	nd	0.13	nd	0.21
19A2	392	(7.5,4.5)	0.00-0.15	0.25		nd	0.16	nd	0.23
19A2	392	(2.5,8.2)	0.00-0.15	0.15		nd	0.09	nd	0.17
19A2	392	(7.5,8.2)	0.00-0.15	0.14		nd	0.13	nd	0.18
19A2	393	(4.5,5.5)	0.00-0.15	0.10		nd	0.13	nd	0.20
19A2	393	(9.5,5.5)	0.00-0.15	0.11		nd	0.05	nd	0.13
19A2	394	(2.5,8.5)	0.00-0.15	0.20		nd	0.14	nd	0.19
19A2	394	(6.5,8.5)	0.00-0.15	0.13		nd	0.13	nd	0.23
19A2	382	(2.5,2.5)	0.00-0.15	nd	0.10	nd	0.07	nd	0.21
19A2	382	(7.5,2.5)	0.00-0.15	0.13		nd	0.16	nd	0.18
19A2	296	(2.5,4.5)	0.00-0.15	0.16		nd	0.12	nd	0.16
19A2	296	(7.5,4.5)	0.00-0.15	nd	0.08	nd	0.12	nd	0.19
19A2	296	(2.5,8.5)	0.00-0.15	0.09		nd	0.11	nd	0.19
19A2	296	(7.5,8.5)	0.00-0.15	nd	0.07	nd	0.15	nd	0.15
19A2	6117	(2.5,7.5)	0.00-0.15	nd	0.09	nd	0.12	nd	0.19
19A2	6117	(7.5,7.5)	0.00-0.15	0.09		nd	0.14	nd	0.18
19A2	474	(2.5,2.5)	0.00-0.15	nd	0.10	nd	0.12	nd	0.18
19A2	474	(2.5,7.5)	0.00-0.15	nd	0.10	nd	0.16	nd	0.22
19A2	475	(2.5,1.5)	0.00-0.15	0.19		nd	0.13	nd	0.16
19A2	475	(2.5,4.5)	0.00-0.15	nd	0.11	nd	0.13	nd	0.18
19A2	475	(2.5,7.5)	0.00-0.15	nd	0.08	nd	0.09	nd	0.16
19A2	475	(7.5,1.5)	0.00-0.15	nd	0.14	nd	0.09	nd	0.18
19A3	394	(5.6,7.4)	0.00-0.15	0.26		nd	0.11	nd	0.42
19A3	6118	(0.6,7.4)	0.00-0.15	0.52		0.12		nd	0.28
19A3	406	(5.6,2.4)	0.00-0.15	0.60		nd	0.08	nd	0.31
19A3	6119	(0.6,2.4)	0.00-0.15	0.98		nd	0.08	nd	0.37
19A3	463	(5.6,7.4)	0.00-0.15	0.97		nd	0.09	nd	0.40
19A3	6150	(0.6,7.4)	0.00-0.15	0.55		nd	0.10	nd	0.32
19A3	464	(5.6,2.4)	0.00-0.15	0.72		nd	0.09	nd	0.36
19A3	6161	(0.6,2.4)	0.00-0.15	0.86		nd	0.06	nd	0.27
19A3	466	(5.6,7.4)	0.00-0.15	0.22		nd	0.05	nd	0.24
19A3	6223	(0.6,7.4)	0.00-0.15	0.83		nd	0.07	nd	0.42
19A3	467	(5.6,2.4)	0.00-0.15	1.10		nd	0.08	nd	0.41
19A3	6224	(0.6,2.4)	0.00-0.15	0.77		nd	0.09	nd	0.42
19A3	6114	(5.6,7.4)	0.00-0.15	0.44		nd	0.08	nd	0.40
19A3	6246	(0.6,7.4)	0.00-0.15	0.58		nd	0.07	nd	0.36
19A3	596	(0.6,2.4)	0.00-0.15	0.24		nd	0.07	nd	0.30
19A3	597	(5.6,2.4)	0.00-0.15	0.59		nd	0.09	nd	0.32
19A3	592	(0.6,2.4)	0.00-0.15	0.33		nd	0.06	nd	0.25
19A3	6113	(5.6,2.4)	0.00-0.15	0.86		nd	0.11	nd	0.37
19A3	6247	(0.6,2.4)	0.00-0.15	0.40		nd	0.09	nd	0.38

Survey[c]	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
$19A_3$	28S, 6E	(0.6,7.4)	0.00-0.15	0.69		nd	0.07	nd	0.33
$19A_3$	28S, 7E	(5.6,7.4)	0.00-0.15	0.50		nd	0.12	nd	0.36
$19A_3$	28S, 9E	(0.6,7.4)	0.00-0.15	0.50		nd	0.09	nd	0.35
$19A_3$	28S, 10E	(5.6,7.4)	0.00-0.15	0.35		nd	0.08	nd	0.36
$19A_3$	28S, 12E	(0.6,7.4)	0.00-0.15	1.08		nd	0.08	nd	0.40
$19A_3$	6245	(3.2,5.3)	0.00-0.15	0.37		nd	0.07	nd	0.35
$19A_{cc}$	401	(8.0,8.0)	0.00-0.15	0.19		nd	0.06	nd	0.23
$19A_{cc}$	389	(7.5,4.5)	0.00-0.15	nd	0.05	nd	0.06	nd	0.23
$19A_{cc}$	389	(5.5,9.5)	0.00-0.15	0.12		nd	0.06	nd	0.21
$19A_{cc}$	389	(9.0,9.5)	0.00-0.15	0.35		nd	0.06	nd	0.29
$19A_{deepcore}$	400	(5.0,5.0)	0.00-1.80	nd	0.04	nd	0.03	nd	0.17
$19A_{deepcore}$	400	(5.0,5.0)	1.80-3.00	nd	0.03	nd	0.03	nd	0.18
$19A_{td}$	385	(0.5,8.4)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	385	(9.4,2.6)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	386	(0.9,8.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	388	(5.4,0.5)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	388	(5.4,3.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	388	(5.4,5.5)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	388	(5.4,8.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	397	(0.5,7.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	399	(0.6,6.2)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	400	(5.4,0.5)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	400	(5.4,2.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	400	(5.4,3.5)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	400	(5.4,6.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	400	(5.4,7.5)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]
$19A_{td}$	400	(5.4,9.0)	0.00-0.15	nd	[d]	nd	[d]	nd	[d]

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] td – trenching and digging surveys, cc – culvert connection
[d] MDA values for samples collected during substation construction unavailable

Survey Results – Table 2

Grid	Coordinate	Soil Samples Analyses				*Insitu* Gamma Measurement			
		Cs-137 (pCi/g)		Co-60 (pCi/g)		Cs-137 (pCi/g)		Co-60 (pCi/g)	
		Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
400	[c]					Nd	0.34	nd	0.37
401	(2.5,7.5)	nd	0.10	nd	0.08	0.20		nd	0.44
402	(5.0,1.5)	nd	0.11	nd	0.10	Nd	0.35	nd	0.44
	(6.0,7.5)	nd	0.08	nd	0.10				
	(2.5,2.5)	0.31		nd	0.12				
	(2.5,6.0)	0.45		nd	0.16				
403	[c]					Nd	0.32	nd	0.43
404	[c]					[d]			
405	[c]					Nd	0.26	nd	0.36
412	[c]					Nd	0.35	nd	0.45
413	[c]					Nd	0.36	nd	0.48
414	[c]					Nd	0.38	nd	0.50
415	[c]					Nd	0.36	nd	0.51*
416	[c]					[d]			
417	[c]					nd	0.32	nd	0.46
418	(5.0,8.5)	0.14		nd	0.11	0.28		nd	0.40
	(5.0,1.5)	nd	0.14	nd	0.17				
	(5.0,1.5) 15-30 cm	nd	0.10	nd	0.06				
289	(5.0,8.5)	nd	0.09	nd	0.10	nd	0.31	nd	0.34
6149	(4.5,8.5)	nd	0.14	nd	0.10	nd	0.30	nd	0.30
438	(2.5,2.5)	0.27		nd	0.07	nd	0.44	nd	0.57**
	(7.5,2.5)	nd	0.09	nd	0.08				
	(2.5,7.5)	0.07		nd	0.08				
	(7.5,7.5)	nd	0.09	nd	0.08				
433	(2.5,2.5)	nd	0.09	nd	0.06	nd	0.42	nd	0.60**
	(7.5,2.5)	nd	0.07	nd	0.07				
	(2.5,7.5)	0.24		nd	0.12				
	(2.5,7.5) 15-30 cm	0.07		nd	0.02				
443	(7.5,7.5)	nd	0.07	nd	0.07				
	(2.5,1.5)	0.17			0.12	nd	0.51	nd	0.72**
	(6.0,1.5)	0.12			0.11				
	(6.0,1.5)	0.12		nd	0.12				
	(3.0,8.0)	0.24			0.11				
	(7.5,8.0)	0.20			0.13				
448	(7.5,7.5)	nd	0.06	nd	0.07	nd	0.45	0.51	0.66**
453	(2.5,2.5)	nd	0.09	nd	0.1	[d]			
	(7.5,2.5)	nd	0.12	nd	0.16				
	(2.5,7.5)	0.16		nd	0.1				
	(7.5,7.5)	0.12		nd	0.1				
	(7.5,7.5)	0.17		nd	0.10				
458	(2.5,7.5)	0.11		nd	0.11	[d]			
439	(2.5,2.5)	0.32		nd	0.03	0.47		nd	0.66**

Grid	Coordinate	Soil Samples Analyses				*Insitu* Gamma Measurement			
		Cs-137 (pCi/g)		Co-60 (pCi/g)		Cs-137 (pCi/g)		Co-60 (pCi/g)	
		Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
439	(7.5,2.5)	nd	0.05	nd	0.07				
	(2.5,7.5)	0.23		nd	0.06				
	(7.5,7.5)	nd	0.04	nd	0.04				
434	(2.5,2.5)	0.09		nd	0.04	nd	0.49	nd	0.70**
	(2.5,7.5)	nd	0.07	nd	0.07				
440	(2.5,2.5)	0.14		nd	0.03	nd	0.33	nd	0.48
	(7.5,2.5)	0.02		nd	0.03				
	(2.5,7.5)	0.23		nd	0.07				
	(7.5,7.5)	nd	0.09	nd	0.06				
435	(2.5,2.5)	0.05		nd	0.04	nd	0.84**	nd	0.93**
	(2.5,7.5)	0.14		nd	0.08				
441	(2.5,2.5)	0.25		nd	0.05	nd	0.51	nd	0.70**
	(7.5,2.5)	nd	0.09	nd	0.07				
	(2.5,7.5)	0.2		nd	0.09				
	(7.5,7.5)	nd	0.07	nd	0.07				
436	(2.5,2.5)	nd	0.08	nd	0.08	[d]			
	(2.5,7.5)	0.19		nd	0.07				
442	(2.5,2.5)	0.36		nd	0.12	nd	0.52**	nd	0.73**
	(2.5,2.5)	0.26		nd	0.14				
	(7.5,2.5)	nd	0.08	nd	0.11				
	(2.5,7.5)	0.13		nd	0.11				
	(7.5,7.5)	nd	0.08	nd	0.08				
437	(2.5,2.5)	nd	0.07	nd	0.08	[d]			
	(2.5,7.5)	nd	0.06	nd	0.07				
426	(2.5,2.5)	0.28		nd	0.04	nd	0.50	nd	0.66**
	(7.5,2.5)	nd	0.08	nd	0.12				
	(2.5,7.5)	0.32		nd	0.08				
	(7.5,7.5)	nd	0.04	nd	0.04				
427	(2.5,2.5)	nd	0.06	nd	0.07	[d]			
	(2.5,7.5)	0.02		nd	0.03				
6107	(2.5,2.5)	nd	0.13	nd	0.09	nd	0.50	nd	0.65**
	(7.5,2.5)	nd	0.10	nd	0.11				
	(2.5,7.5)	0.09		nd	0.13				
	(7.5,7.5)	nd	0.06	nd	0.02				
589	(2.5,2.5)	nd	0.05	nd	0.09	nd	0.51	nd	0.66**
	(7.5,2.5)	nd	0.06	nd	0.09				
	(2.5,7.5)	nd	0.06	nd	0.08				
	(7.5,7.5)	nd	0.03	nd	0.04				
6108	(2.5,2.5)	nd	0.10	nd	0.07	nd	0.51	nd	0.60
	(7.5,2.5)	nd	0.09	nd	0.08				
	(2.5,7.5)	nd	0.13	nd	0.11				
	(7.5,7.5)	nd	0.07	nd	0.08				

Grid	Coordinate	Soil Samples Analyses				*Insitu* Gamma Measurement			
		Cs-137 (pCi/g)		Co-60 (pCi/g)		Cs-137 (pCi/g)		Co-60 (pCi/g)	
		Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
590	(2.5,2.5)	nd	0.10	nd	0.09	nd	0.50	nd	0.60**
	(7.5,2.5)	nd	0.09	nd	0.10				
	(2.5,7.5)	0.11		nd	0.05				
	(2.5,7.5)	0.19		nd	0.07				
	(7.5,7.5)	nd	0.06	nd	0.10				
388	(3.5,7.5)	0.11		nd	0.06		0.29		0.38
389	(5.5,5.5)	0.20		nd	0.14		0.31		0.39
390	(3.5,5.5)	0.31		nd	0.09		0.30		0.34
391	(2.5,5.5)	0.07		nd	0.09	[d]			
392	(2.5,4.5)	nd	0.10	nd	0.13	[d]			
	(7.5,4.5)	0.25		nd	0.16				
	(2.5,8.2)	0.15		nd	0.09				
	(7.5,8.2)	0.14		nd	0.13				
393	(4.5,5.5)	0.10		nd	0.13	[d]			
	(9.5,5.5)	0.11		nd	0.05				
394	(2.5,8.5)	0.20		nd	0.14	[d]			
	(6.5,8.5)	0.13		nd	0.13				
382	(2.5,2.5)	nd	0.10	nd	0.07	[d]			
	(7.5,2.5)	0.13		nd	0.16				
296	(2.5,4.5)	0.16		nd	0.12	[d]			
	(7.5,4.5)	nd	0.08	nd	0.12				
	(2.5,8.5)	0.09		nd	0.11				
	(7.5,8.5)	nd	0.07	nd	0.15				
6117	(2.5,7.5)	nd	0.09	nd	0.12	[d]			
	(7.5,7.5)	0.09		nd	0.14				
474	(2.5,2.5)	nd	0.10	nd	0.12				
	(2.5,7.5)	nd	0.10	nd	0.16				
475	(2.5,1.5)	0.19		nd	0.13				
	(2.5,4.5)	nd	0.11	nd	0.13				
	(2.5,7.5)	nd	0.08	nd	0.09				
	(7.5,1.5)	nd	0.14	nd	0.09				
6143	[c]					nd	0.24	nd	0.27
6146	[c]					nd	0.28	nd	0.27
6147	[c]					nd	0.29	nd	0.28

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected
[c] Soil sample unobtainable due to subsurface electrical hazard
[d] Insitu measurement unobtainable due to powerline obstruction or elevated background activity.

Survey Unit 59

Description

Survey Unit 59 is an extension of the owner-controlled property that is separated from the main site by US Route 31. This location is approximately 33,589 m^2 in area and encompasses a portion of an abandoned railroad spur that once serviced the site during plant construction. The railroad grade remains; however, the rails and ties have been removed. Survey Unit 59 is an open field with forested areas located south and east of the rail grade. An unimproved lane connects the rail grade to US Route 31 provides access into this area. Subsurface structures and components do not exist in this survey unit.

History

This survey unit is an outlying area that has remained remote from plant operational activities. At the time of final plant shut down this area met the classification requirements for Non Impacted Area status. Subsequent decommissioning activities have required this area to be used for the storage of clean bulk soil. A physical inspection of the area following soil storage identified chunks of broken concrete that had inadvertently been transported with the soil. An investigation of this event identified Co-60 (< 0.1 pCi/g) in a firebrick found in this material. All construction materials have been removed from this location for offsite disposal. Extensive surveys following this event did not identify residual radioactivity above established background concentrations in soils within this area.

Radiological Status

Soil radioactivity in this survey unit is consistent with levels established as standard background for soils of this type in northwestern Michigan. Based on historical data, the radiological status of Survey Unit 59 is Class 2.

Primary Survey Design

1. Sample Data Points Required
   The scoping survey resulted in the following data:

Nuclide identification	Cs-137
Mean value (pCi/g)	0.25
Standard Deviation (σ)	0.11

The relative shift for characterization surveys is determined using LBGR values set at 50% of the IDCGL.

$$\text{Relative Shift} = \frac{\text{DCGL}-\text{LBGR}}{\sigma} = \frac{5.11-2.5}{0.11} = 23.7$$

With α and β error levels set at 0.05 and an assumed relative shift of 3, the Sign Test requirements specify a sample size of 14 data points. As a conservative measure 36 samples were collected in this survey unit.

2. Sample Locations
   Sample locations were selected by random method

   Bounding survey unit dimensions 410 x 810 meters.
   Random numbers were generated and applied to bounding survey unit dimensions to determine data point coordinate locations. This process was continued until 36 sample point locations successfully fell within the survey unit.

Supporting Surveys

Extensive soil sampling and laboratory analyses (59_{sd}) were conducted in this area early in the decommissioning process to establish area soil radioactivity baselines for development of the In-situ and surface scan measurement systems. The results of survey $59A_2$ represent randomly selected data points falling within Survey Unit 59 that were part of a larger area study conducted to define regional background radioactivity levels in soil. Supporting survey $59A_3$ was to investigate potential contamination in contact soils resulting from the movement of plant materials into this area.

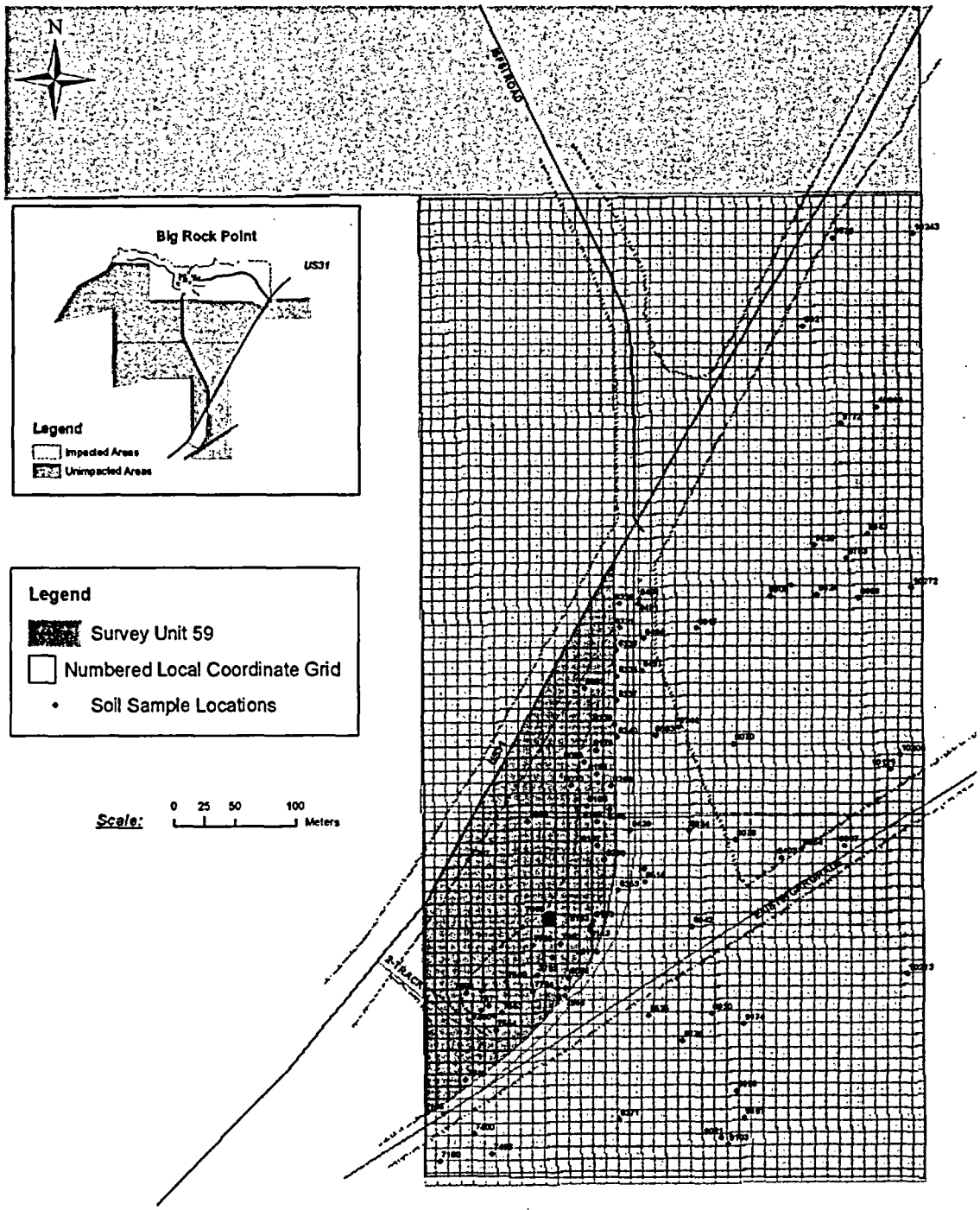
Data Summary

Survey Unit 59

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$59A_1$	36	Cs_{137}	0.31	0.72
$59A_2$	6	Cs_{137}	0.37	0.49
$59A_3$	10	Cs_{137}	0.26	0.47
$59A_{sd}$*	67	Cs_{137}	0.26	0.62

*sd indicates supplemental data

Survey Unit 59



Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$59A_{sd}$	7297	(9.5,4.5)	0.00-0.15	0.25		nd	0.12	nd	0.19
$59A_{sd}$	7308	(6.5,5.5)	0.00-0.15	0.10		nd	0.02	nd	0.20
$59A_{sd}$	7315	(5.6,4.2)	0.00-0.15	nd	0.07	nd	0.07	nd	0.23
$59A_{sd}$	7869	(1.5,1.5)	0.00-0.15	0.38		nd	0.17	nd	0.32
$59A_{sd}$	7869	(3.5,1.5)	0.00-0.15	0.36		nd	0.14	nd	0.32
$59A_{sd}$	7869	(5.5,1.5)	0.00-0.15	0.26		nd	0.14	nd	0.32
$59A_{sd}$	7869	(7.5,1.5)	0.00-0.15	0.13		nd	0.11	nd	0.24
$59A_{sd}$	7869	(9.5,1.5)	0.00-0.15	0.32		nd	0.14	nd	0.29
$59A_{sd}$	7869	(0.5,3.5)	0.00-0.15	0.29		nd	0.11	nd	0.35
$59A_{sd}$	7869	(2.5,3.5)	0.00-0.15	0.38		nd	0.14	nd	0.28
$59A_{sd}$	7869	(2.5,3.5)	0.15-0.30	0.16		nd	0.15	nd	0.31
$59A_{sd}$	7869	(4.5,3.5)	0.00-0.15	0.27		nd	0.03	nd	0.28
$59A_{sd}$	7869	(6.5,3.5)	0.00-0.15	0.26		nd	0.11	nd	0.30
$59A_{sd}$	7869	(8.5,3.5)	0.00-0.15	0.19		nd	0.14	nd	0.27
$59A_{sd}$	7869	(8.5,3.5)	0.15-0.30	nd	0.05	nd	0.06	nd	0.29
$59A_{sd}$	7869	(1.5,5.5)	0.00-0.15	0.28		nd	0.10	nd	0.26
$59A_{sd}$	7869	(3.5,5.5)	0.00-0.15	0.34		nd	0.11	nd	0.25
$59A_{sd}$	7869	(5.5,5.5)	0.00-0.15	0.31		nd	0.11	nd	0.30
$59A_{sd}$	7869	(5.5,5.5)	0.15-0.30	0.11		nd	0.16	nd	0.43
$59A_{sd}$	7869	(7.5,5.5)	0.00-0.15	0.14		nd	0.09	nd	0.27
$59A_{sd}$	7869	(9.5,5.5)	0.00-0.15	0.33		nd	0.07	nd	0.34
$59A_{sd}$	7869	(0.5,7.5)	0.00-0.15	0.46		nd	0.15	nd	0.30
$59A_{sd}$	7869	(2.5,7.5)	0.00-0.15	0.30		nd	0.04	nd	0.31
$59A_{sd}$	7869	(2.5,7.5)	0.15-0.30	nd	0.10	nd	0.15	nd	0.26
$59A_{sd}$	7869	(4.5,7.5)	0.00-0.15	0.28		nd	0.15	nd	0.32
$59A_{sd}$	7869	(6.5,7.5)	0.00-0.15	0.23		nd	0.05	nd	0.25
$59A_{sd}$	7869	(6.5,7.5)	0.15-0.30	0.14		nd	0.10	nd	0.29
$59A_{sd}$	7869	(8.5,7.5)	0.00-0.15	0.24		nd	0.12	nd	0.33
$59A_{sd}$	7869	(3.5,9.5)	0.00-0.15	0.39		nd	0.14	nd	0.33
$59A_{sd}$	7869	(5.5,9.5)	0.00-0.15	0.28		nd	0.16	nd	0.30
$59A_{sd}$	7869	(7.5,9.5)	0.00-0.15	0.38		nd	0.14	nd	0.31
$59A_{sd}$	7869	(9.5,9.5)	0.00-0.15	0.37		nd	0.14	nd	0.32
$59A_{sd}$	7956	(2.0,2.5)	0.00-0.15	nd	0.07	nd	0.09	nd	0.22
$59A_{sd}$	7956	(8.0,2.5)	0.00-0.15	nd	0.09	nd	0.11	nd	0.24
$59A_{sd}$	7956	(2.0,8.5)	0.00-0.15	nd	0.07	nd	0.07	nd	0.17
$59A_{sd}$	7956	(8.0,8.5)	0.00-0.15	nd	0.06	nd	0.06	nd	0.22
$59A_{sd}$	8020	(4.2,5.8)	0.00-0.15	0.18		nd	0.13	nd	0.43
$59A_{sd}$	8036	(1.2,7.3)	0.00-0.15	0.26		nd	0.08	nd	0.16
$59A_{sd}$	8093	(5.5,5.6)	0.00-0.15	0.19		nd	0.12	nd	0.43
$59A_{sd}$	8099	(5.2,5.2)	0.00-0.15	0.27		nd	0.15	nd	0.26
$59A_{sd}$	8113	(8.8,6.5)	0.00-0.15	0.46		nd	0.08	nd	0.26
$59A_{sd}$	8115	(0.3,7.5)	0.00-0.15	nd	0.10	nd	0.10	nd	0.21
$59A_{sd}$	8179	(5.0,5.0)	0.00-0.15	0.16		nd	0.10	nd	0.21
$59A_{sd}$	8181	(5.5,5.5)	0.00-0.15	0.38		nd	0.11	nd	0.44

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$59A_{sd}$	8185	(5.5,5.2)	0.00-0.15	0.31		nd	0.11	nd	0.43
$59A_{sd}$	8187	(5.2,5.2)	0.00-0.15	0.62		nd	0.12	nd	0.44
$59A_{sd}$	8269	(1.5,3.5)	0.00-0.15	0.44		nd	0.12	nd	0.22
$59A_{sd}$	8193	(0.0,0.0)	0.00-0.15	0.09		nd	0.10	nd	0.27
$59A_{sd}$	8193	(1.5,3.2)	0.00-0.15	0.40		nd	0.12	nd	0.22
$59A_{sd}$	8263	(7.5,5.2)	0.00-0.15	0.52		nd	0.12	nd	0.42
$59A_{sd}$	8265	(6.0,5.0)	0.00-0.15	0.24		nd	0.15	nd	0.43
$59A_{sd}$	8329	(5.0,5.0)	0.00-0.15	0.28		nd	0.10	nd	0.20
$59A_{sd}$	8331	(5.0,5.0)	0.00-0.15	0.13		nd	0.10	nd	0.18
$59A_{sd}$	8333	(2.5,6.5)	0.00-0.15	0.14		nd	0.07	nd	0.19
$59A_{sd}$	8335	(2.8,5.2)	0.00-0.15	0.21		nd	0.07	nd	0.12
$59A_{sd}$	8337	(2.5,5.5)	0.00-0.15	0.09		nd	0.09	nd	0.19
$59A_{sd}$	8339	(0.5,5.5)	0.00-0.15	0.19		nd	0.07	nd	0.20
$59A_{sd}$	8340	(2.5,5.5)	0.00-0.15	0.11		nd	0.08	nd	0.14
$59A_{sd}$	8353	(2.5,8.0)	0.00-0.15	0.38		nd	0.08	nd	0.19
$59A_{sd}$	8491	(0.2,5.2)	0.00-0.15	0.24		nd	0.05	nd	0.20
$59A_{sd}$	8494	(4.5,6.2)	0.00-0.15	0.15		nd	0.03	nd	0.22
$59A_{sd}$	8513	(4.2,5.8)	0.00-0.15	0.25		nd	0.11	nd	0.22
$59A_{sd}$	8514	(4.6,5.2)	0.00-0.15	0.14		nd	0.03	nd	0.22
$59A_{sd}$	8583	(4.4,6.5)	0.00-0.15	0.20		nd	0.10	nd	0.21
$59A_{sd}$	8842	(3.2,7.8)	0.00-0.15	nd	0.10	nd	0.09	nd	0.22
$59A_{sd}$	9807	(6.5,3.5)	0.00-0.15	nd	0.07	nd	0.16	nd	0.43
$59A_{sd}$	10125	(4.5,7.2)	0.00-0.15	0.13		nd	0.20	nd	0.44
$59A_1$	8834	(1.0,7.0)	0.00-0.15	0.28		nd	0.06	nd	0.34
$59A_1$	9078	(9.0,9.0)	0.00-0.15	0.72		nd	0.10	nd	0.42
$59A_1$	9403	(6.0,4.0)	0.00-0.15	0.62		nd	0.09	nd	0.38
$59A_1$	9564	(2.0,1.0)	0.00-0.15	0.21		nd	0.06	nd	0.28
$59A_1$	10205	(2.0,9.0)	0.00-0.15	0.25		nd	0.09	nd	0.37
$59A_1$	8103	(7.0,8.0)	0.00-0.15	0.18		nd	0.06	nd	0.32
$59A_1$	7699	(8.0,6.0)	0.00-0.15	0.36		nd	0.11	nd	0.43
$59A_1$	8744	(3.0,3.0)	0.00-0.15	0.27		nd	0.08	nd	0.36
$59A_1$	8491	(1.0,9.0)	0.00-0.15	0.04		nd	0.06	nd	0.33
$59A_1$	8817	(8.0,4.0)	0.00-0.15	0.22		nd	0.08	nd	0.34
$59A_1$	9070	(8.0,9.0)	0.00-0.15	0.19		nd	0.09	nd	0.37
$59A_1$	10272	(2.0,6.0)	0.00-0.15	0.30		nd	0.09	nd	0.43
$59A_1$	9868	(9.0,8.0)	0.00-0.15	0.18		nd	0.08	nd	0.33
$59A_1$	9462	(5.0,9.0)	0.00-0.15	0.21		nd	0.09	nd	0.39
$59A_1$	9300	(8.0,0.0)	0.00-0.15	0.62		nd	0.09	nd	0.38
$59A_1$	9943	(6.0,1.0)	0.00-0.15	0.40		nd	0.09	nd	0.42
$59A_1$	9620	(3.0,2.0)	0.00-0.15	0.19		nd	0.07	nd	0.34
$59A_1$	9676	(9.0,5.0)	0.00-0.15	0.40		nd	0.10	nd	0.41
$59A_1$	10243	(4.0,8.0)	0.00-0.15	0.29		nd	0.10	nd	0.39
$59A_1$	9521	(5.0,3.0)	0.00-0.15	0.22		nd	0.07	nd	0.43
$59A_1$	8930	(9.0,7.0)	0.00-0.15	0.52		nd	0.09	nd	0.43
$59A_1$	9174	(5.0,8.0)	0.00-0.15	0.58		nd	0.10	nd	0.42
$59A_1$	9098	(9.0,3.0)	0.00-0.15	0.34		nd	0.08	nd	0.41
$59A_1$	9181	(5.0,1.0)	0.00-0.15	0.42		nd	0.09	nd	0.42

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$59A_1$	9021	(6.0,5.0)	0.00-0.15	0.30		nd	0.10	nd	0.43
$59A_1$	7400	(2.0,0.0)	0.00-0.15	0.28		Nd	0.08	nd	0.38
$59A_1$	7160	(4.0,8.0)	0.00-0.15	0.15		nd	0.07	nd	0.36
$59A_1$	7156	(7.0,7.0)	0.00-0.15	0.28		nd	0.08	nd	0.42
$59A_1$	8371	(2.0,1.0)	0.00-0.15	0.44		nd	0.09	nd	0.42
$59A_1$	7483	(7.0,4.0)	0.00-0.15	0.39		nd	0.09	nd	0.42
$59A_1$	7472	(9.0,7.0)	0.00-0.15	0.21		nd	0.08	nd	0.30
$59A_1$	8525	(7.0,6.0)	0.00-0.15	0.26		nd	0.08	nd	0.36
$59A_1$	7872	(8.0,4.0)	0.00-0.15	0.2		nd	0.08	nd	0.31
$59A_1$	8429	(3.0,8.0)	0.00-0.15	0.05		nd	0.05	nd	0.30
$59A_1$	10014	(4.0,5.0)	0.00-0.15	0.43		nd	0.09	nd	0.43
$59A_1$	9772	(5.0,2.0)	0.00-0.15	0.33		nd	0.08	nd	0.43
$59A_2$	9624	(5.3,0.8)	0.00-0.15	0.48		nd	0.08	nd	0.39
$59A_2$	9783	(9.0,1.3)	0.00-0.15	0.39		nd	0.10	nd	0.41
$59A_2$	8497	(3.0,9.8)	0.00-0.15	0.2		nd	0.06	nd	0.33
$59A_2$	10223	(7.2,7.8)	0.00-0.15	0.49		nd	0.08	nd	0.37
$59A_2$	9103	(1.4,9.4)	0.00-0.15	0.32		nd	0.09	nd	0.43
$59A_2$	8770	(4.8,4.8)	0.00-0.15	0.34		nd	0.08	nd	0.42
$59A_3$	7554	(1.0,5.2)	0.00-0.15	0.12		nd	0.05	nd	0.27
$59A_3$	7390	(8.8,1.6)	0.00-0.15	0.24		nd	0.07	nd	0.32
$59A_3$	7389	(8.8,7.5)	0.00-0.15	0.47		nd	0.06	nd	0.33
$59A_3$	7471	(4.9,5.3)	0.00-0.15	0.31		nd	0.07	nd	0.32
$59A_3$	7553	(5.9,9.2)	0.00-0.15	0.22		nd	0.07	nd	0.34
$59A_3$	7794	(1.5,6.3)	0.00-0.15	0.22		nd	0.07	nd	0.32
$59A_3$	7550	(9.5,4.8)	0.00-0.15	0.12		nd	0.07	nd	0.31
$59A_3$	7793	(5.2,9.7)	0.00-0.15	0.37		nd	0.07	nd	0.32
$59A_3$	7952	(4.7,5.3)	0.00-0.15	0.28		nd	0.05	nd	0.29
$59A_3$	7790	(1.5,4.1)	0.00-0.15	0.21		nd	0.07	nd	0.28

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Canal Survey Unit

Description

The BRP Discharge Canal (or Canal) is an area of Lake Michigan north of the Owner Controlled Property that extends from the Screenhouse to the normal beach contour line. This location is approximately 600 m^2 in size and includes the submerged area from the Canal bottom to the waters edge. Normal water depths in the Canal range from 4 to 7 feet; however, current near record lows in Lake Michigan water levels have greatly reduced this depth. The Canal is the licensed release pathway for plant effluent waters. Circulation Water System discharge rates have historically been approximately 50,000 gal/min, resulting in a scouring effect on the Canal bottom. The Canal bottom consists of a layer of dense cobble resting on a base of hard clay. The cobble is estimated to be between 15 and 90 cm thick. Dynamics in effluent discharge have resulted in minor locations of sediment build-up in backwater eddies and areas of low flow.

Components and equipment in this area include the following:

- Liquid radioactive release pipe located next to the Screenhouse weir at the point of effluent discharge,
- Storm water discharge piping approximately tenmeters north of the Screenhouse,
- Liquid process monitor intake piping that traverses the Canal approximately eight meters from the Screenhouse, and
- The concrete floor and foundation footings of the Screenhouse.

History

Routine environmental sampling of the Canal has identified trace levels of residual radioactivity in area sediment. Minor quantities of residual radioactivity has also been identified in dredge spoils taken from maintenance excavations of the Canal.

Radiological Status

The Canal is the permitted release pathway for plant effluent water discharge into Lake Michigan. Characterization analyses have identified elevated levels of residual radioactivity in sediment in the Canal. This area is scheduled to be returned to normal lakeshore contour to achieve the Big Rock Point Greenfield condition. The radiological status of the Canal survey unit is Class 1. Characterization of the Canal is scheduled to continue and remediation efforts will be conducted as necessary to meet the requirements of unrestricted site release.

Survey Design

The survey size and data point locations were judgmentally selected. The survey objective was to collect representative samples of Canal sediment at systematic intervals from the point of effluent discharge. Sediment sampling was performed by underwater divers using hand auger tools. Sample point locations were selected to be representative of the Canal bottom; however, visible locations of sediment build-up were specifically targeted based on historical knowledge of increased potential for these areas to contain residual radioactivity.

Core profiles greater than 15 cm were unobtainable by deep-water sampling. To investigate potential depth of activity in Canal sediment a series of caissons were installed traversing the Canal in a sediment rich area of shallow water. Samples were collected to a depth of 30 cm by removing water and excavating the sediment in 15 cm intervals.

Supporting Surveys

The extent of terrain in this survey unit has increased due to the current low water levels of Lake Michigan. Some survey data points overlap adjoining survey unit boundaries due to the fluctuation in Lake Michigan water levels. Survey Canal A_1 was conducted to include shoreline areas normally under water in this survey unit.

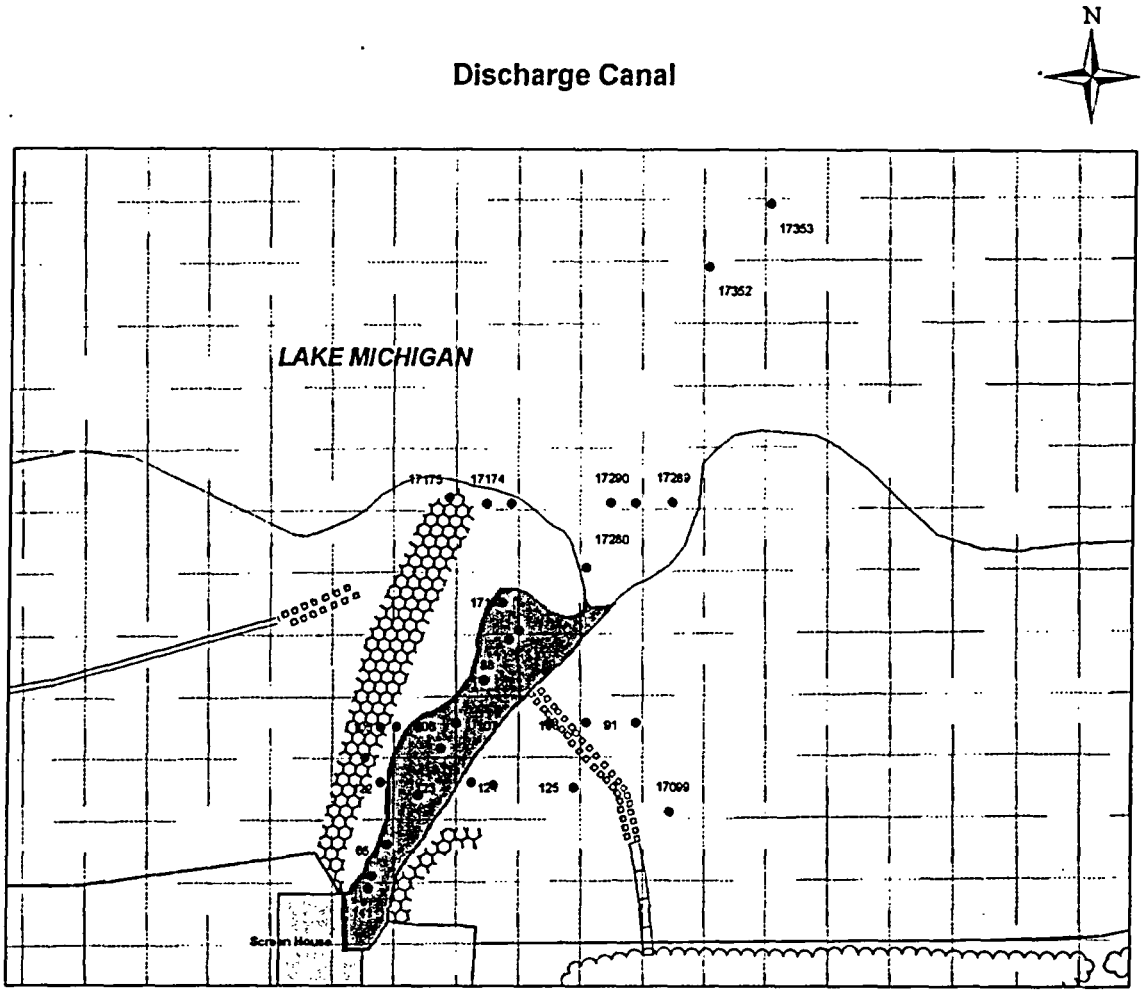
Data Summary

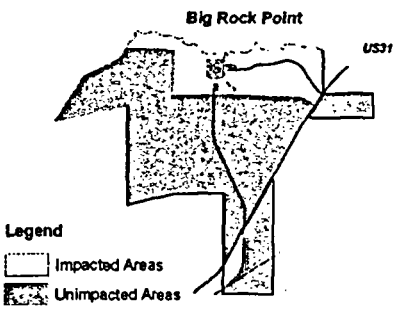
Canal Survey Unit

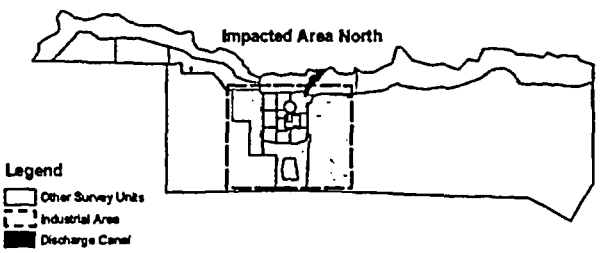
Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
CanalA_1	18	Cs_{137}	0.61	1.90
		Co_{60}	0.38	2.68
		Mn_{54}*	0.12	0.23
CanalA_2	17	Cs_{137}	1.39	3.31
		Co_{60}	2.87	17.74
		Mn_{54}	0.32	1.04

*Mn-54 detected in 3 samples.

Discharge Canal







Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Mn-54 (pCi/g)		Am-241 (pCi/g)	
				Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]	Activity[a]	MDA[b]
Canal A_1	124	(2.5,6.0)	0.00-0.15	0.85		0.17		nd	0.04	nd	0.25
Canal A_1	124	(6.0,5.5)	0.00-0.15	0.34		0.09		nd	0.04	nd	0.27
Canal A_1	125	(9.0,5.0)	0.00-0.15	0.33		0.16		nd	0.04	nd	0.29
Canal A_1	108	(5.0,5.5)	0.00-0.15	0.16		0.14		0.02		nd	0.27
Canal A_1	91	(1.0,5.5)	0.00-0.15	nd	0.06	nd	0.06	nd	0.04	nd	0.27
Canal A_1	91	(9.0,5.5)	0.00-0.15	0.23		0.06		nd	0.04	nd	0.23
Canal A_1	17290	(5.0,1.0)	0.00-0.15	0.36		0.09		nd	0.04	nd	0.24
Canal A_1	17290	(9.0,1.0)	0.00-0.15	0.33		0.16		nd	0.04	nd	0.25
Canal A_1	17289	(5.0,1.0)	0.00-0.15	0.42		0.09		nd	0.04	nd	0.25
Canal A_1	17099	(4.5,1.0)	0.00-0.15	0.20		0.09		nd	0.04	nd	0.24
Canal A_1	122	(8.0,6.0)	0.00-0.15	1.20		2.68		0.23		nd	0.39
Canal A_1	105	(5.5,0.0)	0.00-0.15	1.90		1.37		0.12		nd	0.31
Canal A_1	106	(4.0,5.0)	0.00-0.15	nd	0.04	0.13		nd	0.05	nd	0.24
Canal A_1	106	(0.5,5.0)	0.00-0.15	0.26		0.18		nd	0.05	nd	0.25
Canal A_1	105	(8.0,5.0)	0.00-0.15	0.67		0.65		nd	0.06	nd	0.31
Canal A_1	17174	(9.0,1.0)	0.00-0.15	0.96		0.11		nd	0.04	nd	0.23
Canal A_1	17174	(5.0,1.0)	0.00-0.15	1.37		0.14		nd	0.05	nd	0.28
Canal A_1	17175	(9.0,2.0)	0.00-0.15	0.21		0.09		nd	0.03	nd	0.24
Canal A_2	141	(6.0,9.0)	0.00-0.15	3.31		17.74		1.04		nd	0.43
Canal A_2	65	(6.5,1.0)	0.00-0.15	1.24		2.38		0.19		nd	0.37
Canal A_2	65	(9.0,6.0)	0.00-0.15	1.26		2.21		0.12		nd	0.35
Canal A_2	123	(4.0,4.0)	0.00-0.15	1.41		5.03		0.38		nd	0.41
Canal A_2	106	(7.5,1.5)	0.00-0.15	1.08		2.10		0.15		nd	0.36
Canal A_2	107	(0.0,5.5)	0.00-0.15	1.19		2.56		0.28		nd	0.36
Canal A_2	88	(4.5,2.5)	0.00-0.15	1.59		2.22		0.10		nd	0.38
Canal A_2	88	(8.5,9.0)	0.00-0.15	1.22		0.75		0.06		nd	0.29
Canal A_2	17280	(1.0,0.5)	0.00-0.15	1.25		0.29		nd	0.06	nd	0.26
Canal A_2	17352	(1.0,9.0)	0.00-0.15	1.74		0.16		nd	0.04	nd	0.29
Canal A_2	17353	(1.0,9.0)	0.00-0.15	0.64		0.21		nd	0.05	nd	0.32
Canal A_2	89	(4.5,4.0)	0.00-0.15	2.17		8.32		0.82		nd	0.43
Canal A_2	89	(4.5,4.0)	0.15-0.30	0.84		0.22		0 nd	0.05	nd	0.31
Canal A_2	17170	(0.0,0.5)	0.00-0.15	1.78		1.97		0.13		nd	0.37
Canal A_2	17170	(0.0,0.5)	0.15-0.30	0.42		0.15		nd	0.03	nd	0.07
Canal A_2	17169	(7.5,5.0)	0.00-0.15	1.58		2.00		0.23		nd	0.34
Canal A_2	17169	(7.5,5.0)	0.15-0.30	0.92		0.40		nd	0.04	nd	0.32

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

Drainage Ditch Survey Unit

Description

The Drainage Ditch is a seasonal stream less than one meter wide that extends approximately 370 meters from the northern boundary of the Non-Impacted Area to Lake Michigan. Surface waters from wetland elevations to the south concentrate in low areas along the railroad grade and flow north into the Industrial Area. Stormwater runoff is diverted around the Protected Area to the Drainage Ditch and discharges into Lake Michigan. The Drainage Ditch also receives water from a series of catch basins and corrugated metal piping that act to remove storm water away from buildings and parking lots in the Industrial Area. Subsurface structures and components include storm water culverts and piping. The stream is traversed in limited areas by septic piping and electrical conduit

History

Residual radioactivity has been identified in the sediment of storm water piping in the Protected Area and in Drainage Ditch soils near the west pipe discharge. Sediment accumulations have been removed from all east section storm water piping originating in the Protected Area. In addition, a sediment collection barrel was installed in the west section piping and locations of potential sediment accumulation are routinely monitored to identify the potential migration of contaminants in this system. Sample analyses have not identified residual radioactivity in the liquid effluent of the storm water system.

Radiological Status

Resisual radioactivity was identified at trace level concentrations (<0.2 pCi/g) in several sediment samples collected in the Drainage Ditch stream. The Drainage Ditch Survey Unit is designated as a Class 2 Area.

Survey Design

The size and data point locations of this survey were judgmentally selected. Samples were systematically collected at 20 meter intervals in straight sections of the stream. Additional samples were collected in stream bends, areas of low flow, and visible locations of sediment accumulation. Samples were also collected in suspect areas at every culvert outlet and discharge pipe to the Drainage Ditch.

Supporting Surveys

Supporting surveys were not conducted in this survey unit.

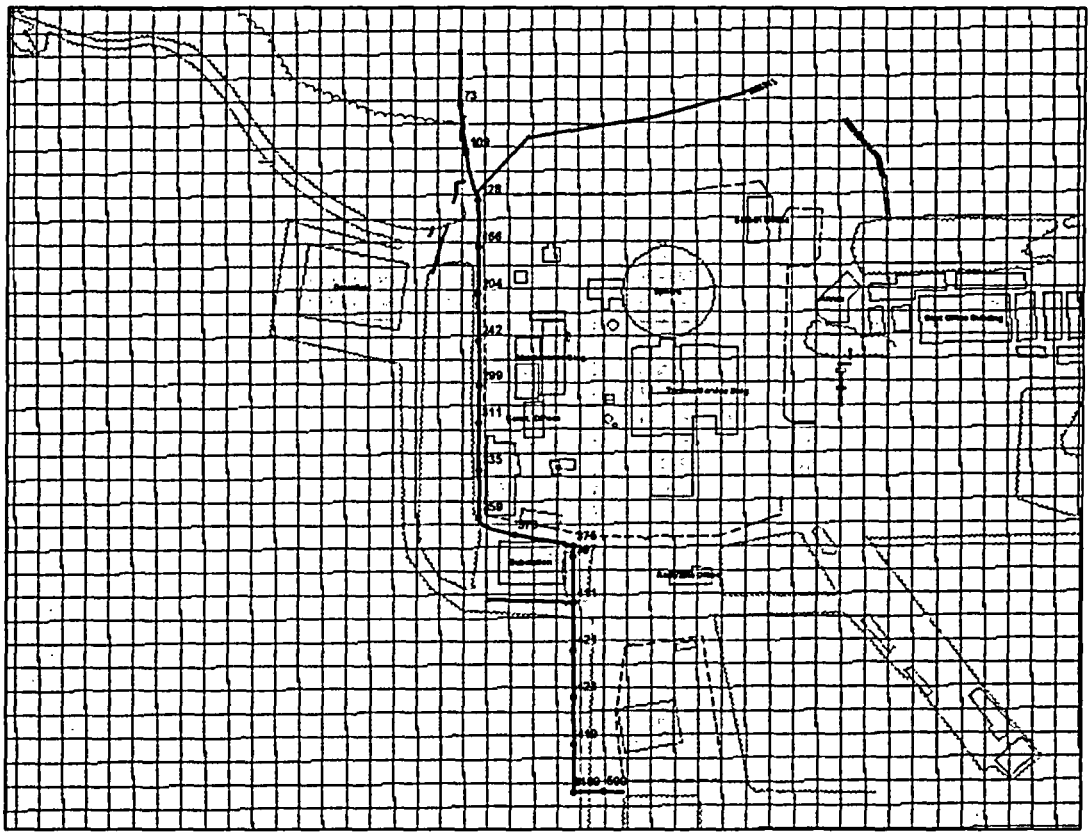
Data Summary

Drainage Ditch

Survey	No. of Samples	Radionuclides	Mean (pCi/g)	Max. Value (pCi/g)
$Stream_1$	19	Cs_{137}	0.13	0.32
		Co_{60}*	0.11	0.17

*Co-60 detected in 2 samples.

Surface Water Drainage Ditch



Legend

- Surface Water Drainage Ditch
- Buildings and Structures
- Numbered Local Coordinate Grid
- Sediment Sample Locations

Scale: 0 20 40 80 Meters

Survey Results

Survey	Grid	Coordinate (x,y)	Depth (m)	Cs-137 (pCi/g)		Co-60 (pCi/g)		Am-241 (pCi/g)	
				Activity [a]	MDA [b]	Activity [a]	MDA [b]	Activity [a]	MDA [b]
$StreamA_1$	590	(0.0,5.5)	0.00-0.15	nd	0.04	nd	0.05	nd	0.25
$StreamA_1$	6109	(7.5,5.5)	0.00-0.15	nd	0.06	nd	0.08	nd	0.30
$StreamA_1$	419	(7.5,5.5)	0.00-0.15	nd	0.04	nd	0.04	nd	0.21
$StreamA_1$	423	(7.5,5.5)	0.00-0.15	nd	0.05	nd	0.07	nd	0.30
$StreamA_1$	421	(7.5,5.5)	0.00-0.15	nd	0.07	nd	0.08	nd	0.39
$StreamA_1$	411	(7.5,5.5)	0.00-0.15	0.03		nd	0.05	nd	0.30
$StreamA_1$	387	(7.5,5.5)	0.00-0.15	0.06		nd	0.08	nd	0.26
$StreamA_1$	375	(7.5,0.0)	0.00-0.15	0.32		0.17		nd	0.30
$StreamA_1$	373	(2.5,5.0)	0.00-0.15	0.07		nd	0.05	nd	0.20
$StreamA_1$	359	(7.5,2.5)	0.00-0.15	0.14		nd	0.06	nd	0.30
$StreamA_1$	335	(7.5,2.5)	0.00-0.15	nd	0.07	nd	0.06	nd	0.32
$StreamA_1$	311	(7.5,2.5)	0.00-0.15	0.12		nd	0.06	nd	0.27
$StreamA_1$	299	(7.5,8.0)	0.00-0.15	0.18		nd	0.05	nd	0.25
$StreamA_1$	242	(7.5,7.5)	0.00-0.15	0.14		0.05		nd	0.30
$StreamA_1$	204	(7.5,7.5)	0.00-0.15	0.22		nd	0.05	nd	0.23
$StreamA_1$	166	(7.5,7.5)	0.00-0.15	0.08		nd	0.05	nd	0.24
$StreamA_1$	128	(7.5,7.5)	0.00-0.15	0.07		nd	0.04	nd	0.18
$StreamA_1$	109	(2.5,7.5)	0.00-0.15	0.07		nd	0.04	nd	0.21
$StreamA_1$	73	(0.0,7.5)	0.00-0.15	0.20		nd	0.05	nd	0.19

[a] nd indicates non detect, MDA provided
[b] No entry in the MDA column is provided when residual radioactivity is detected

REFERENCES

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2. Big Rock Point Background Radioactivity in Soil, EA-BRP-DW-O1-00, June 2000

3. Big Rock Point Background Radioactivity in Soil, EA-BRP-SC-100

4. Big Rock Point Radiation Protection and Environmental Services Policy and Program Description, Administrative Procedure D5.1

5. Big Rock Point Restoration Project, Historical Site Assessment

6. Condition Report C-BRP-00-0087, *Paint Chip Removal Uncovers Soil Contamination*, April 12, 2000

7. Condition Report C-BRP-00-0178, *Followup Survey of Building Debris Identified Trace Contamination on Site Property South of US 31*, July 12, 2000

8. Condition Report C-BRP-98-0056, *Canal and Service Water LPM Contamination Alarms, Unknown Cause*, March 14, 1998

9. Consumers Energy Big Rock Plant Core Borings Report, Radian International, August 23, 1999

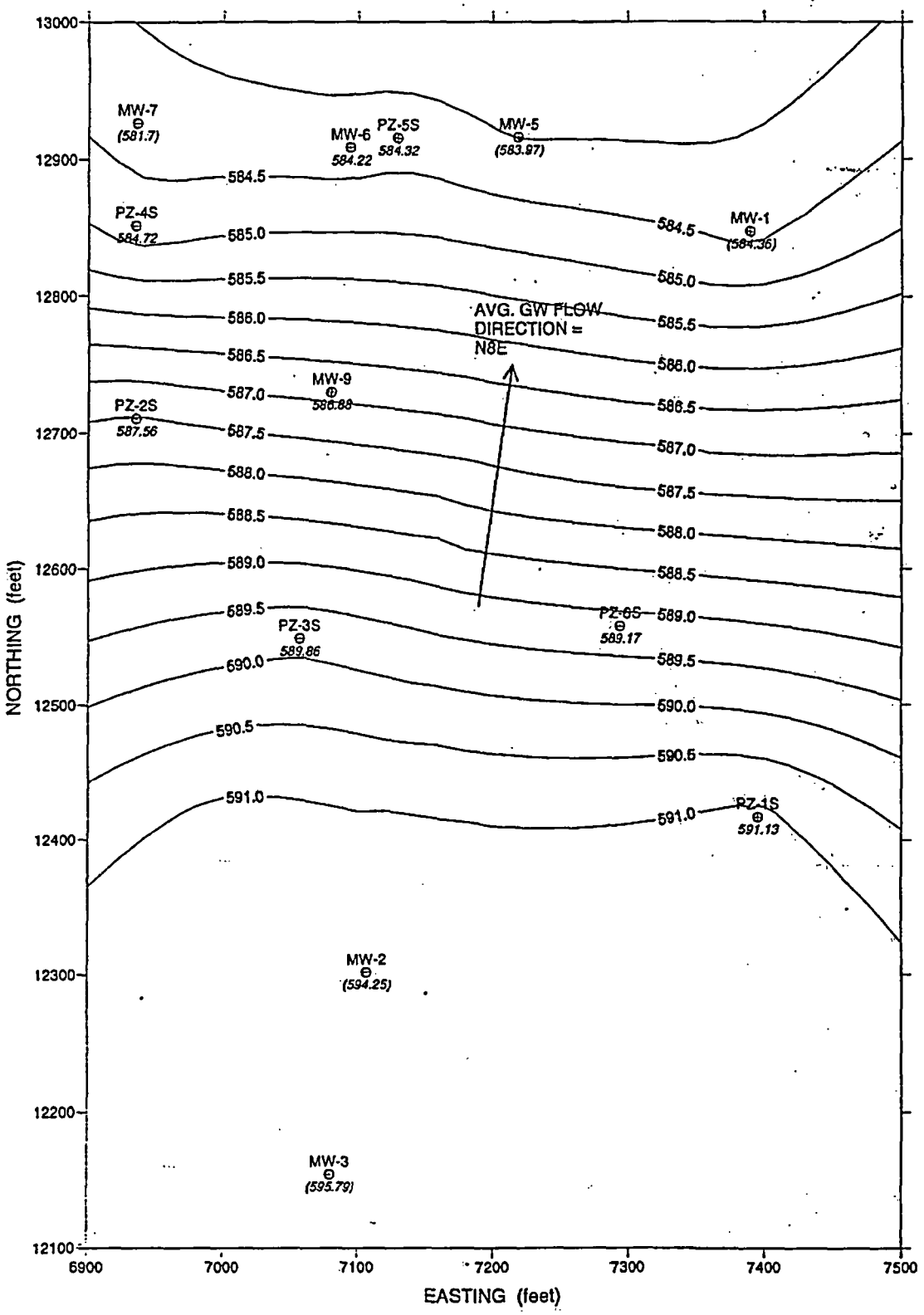
10. Consumers Energy Big Rock Plant Geoprobe Soil Sampling, Radian International, May 3, 1999

11. NUREG/CR 5849, Open Land Surveys, Affected Areas

12. RESRAD Calculation of Contamination Levels Equal to 25 mrem/yr at 5 years Post – Shutdown, RAE/HP97019

13. United States Nuclear Regulatory Commission, Environmental Assessment and Finding of No Significant Impact, Docket No 50-155

BIG ROCK, SHALLOW GROUNDWATER - HYDRAULIC HEAD CONTOURS (05/15/02 Data)



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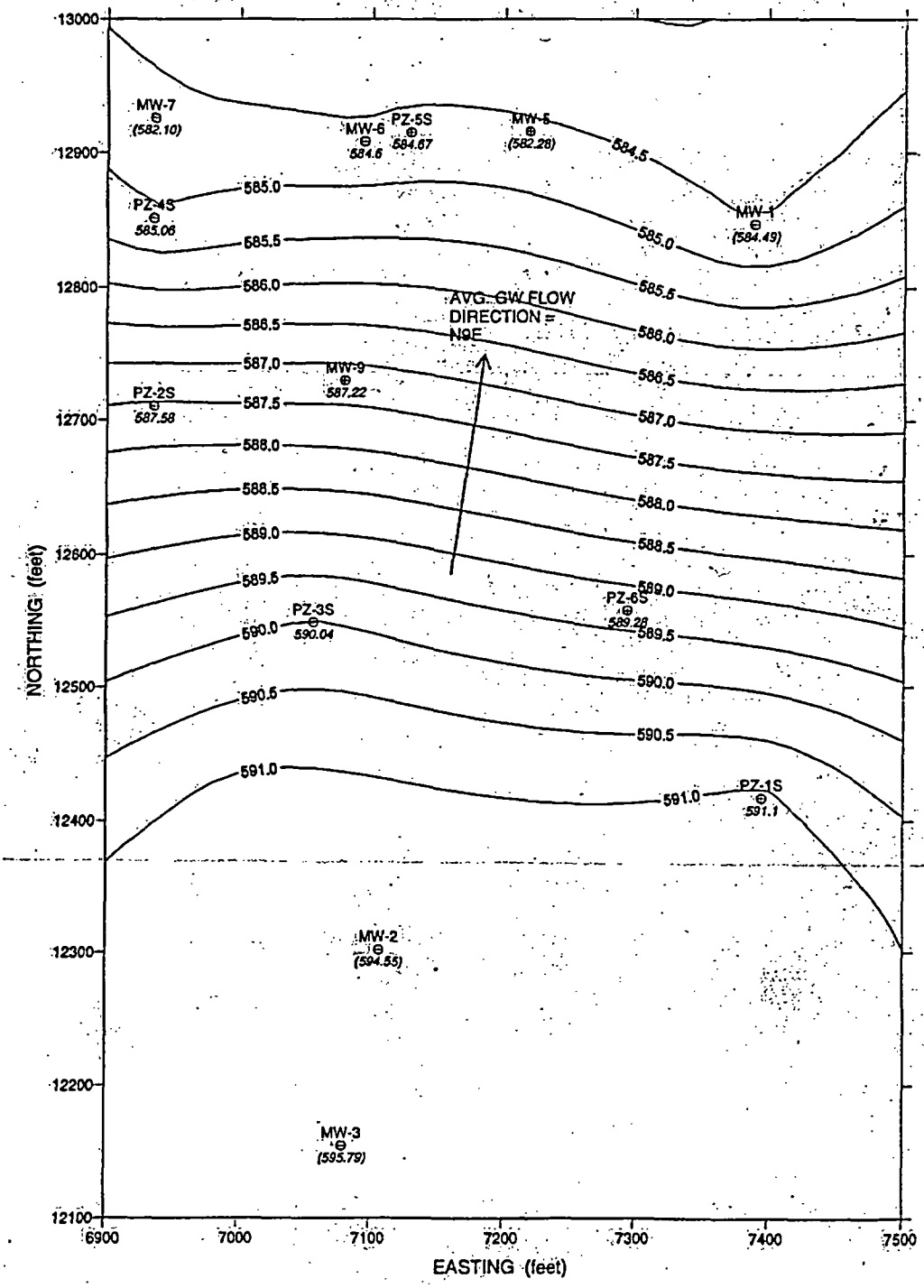

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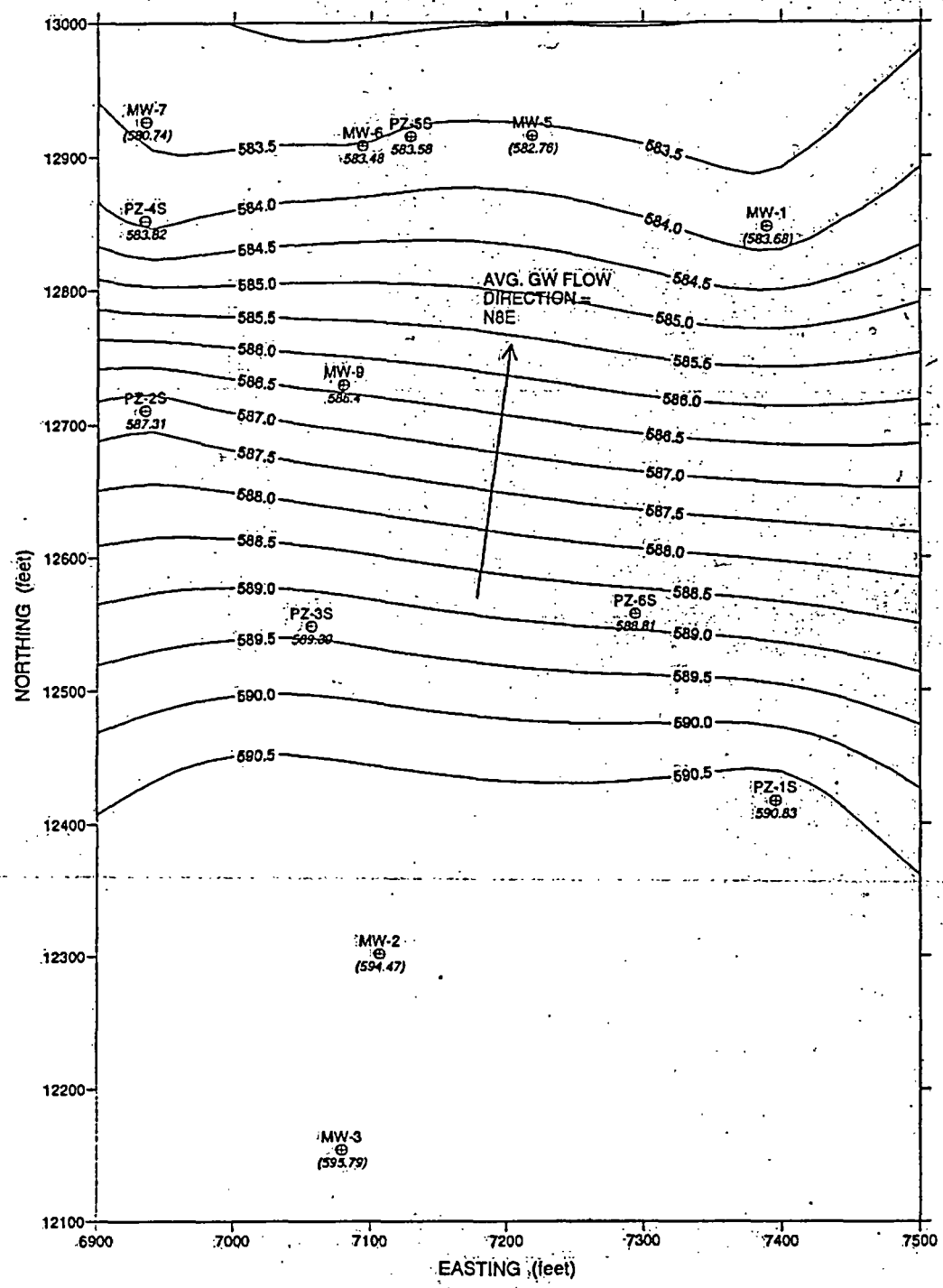

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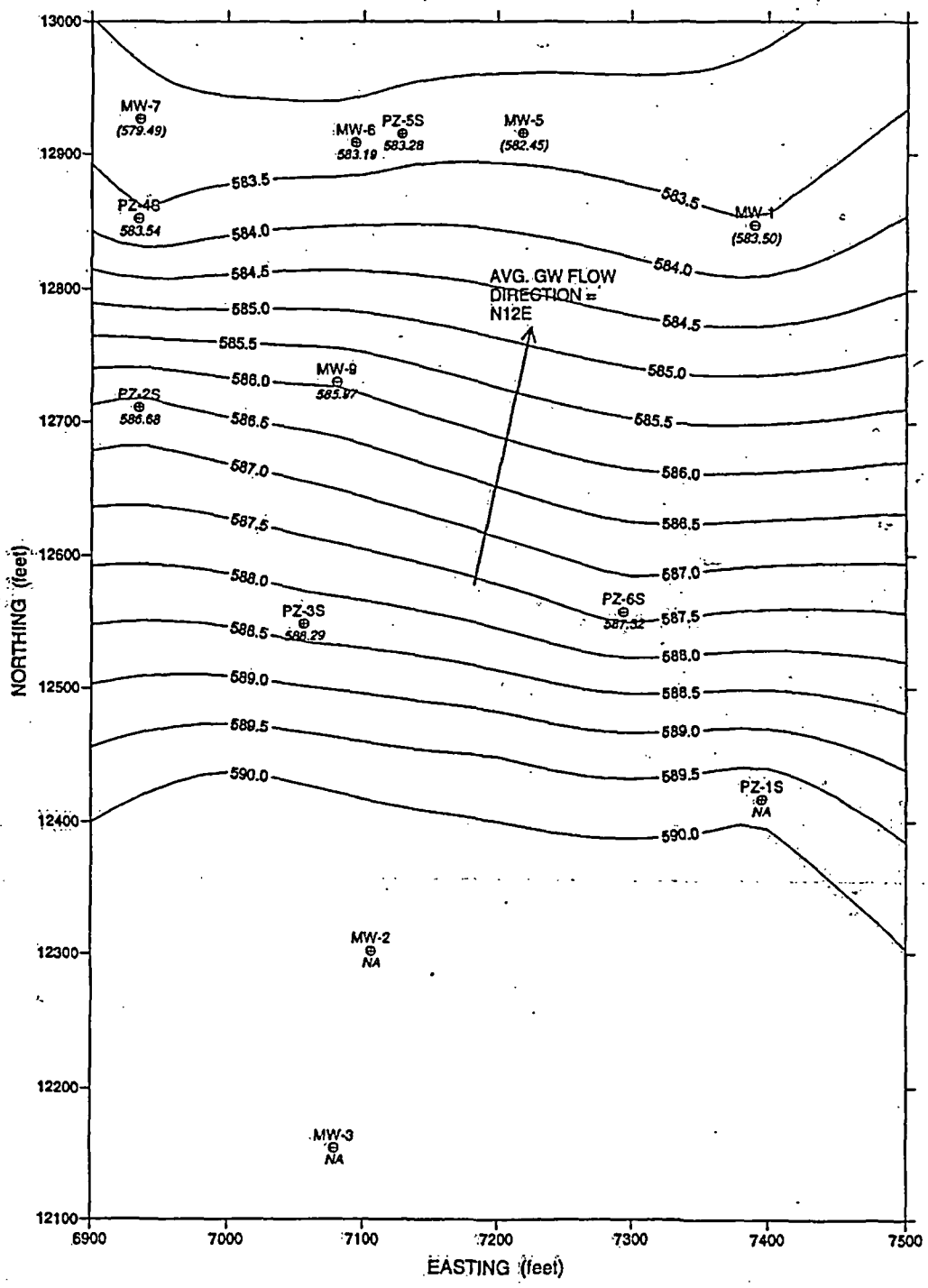

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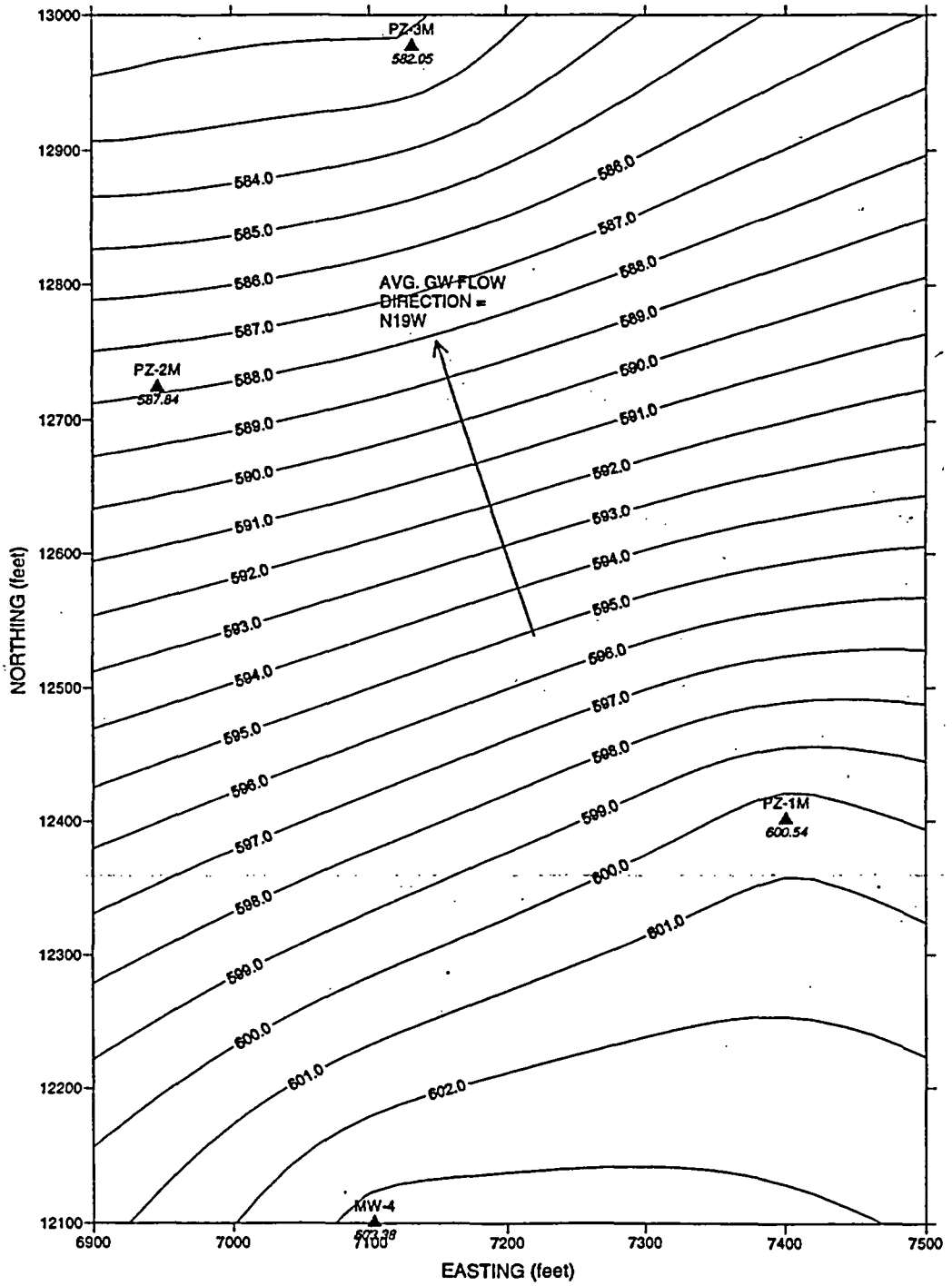

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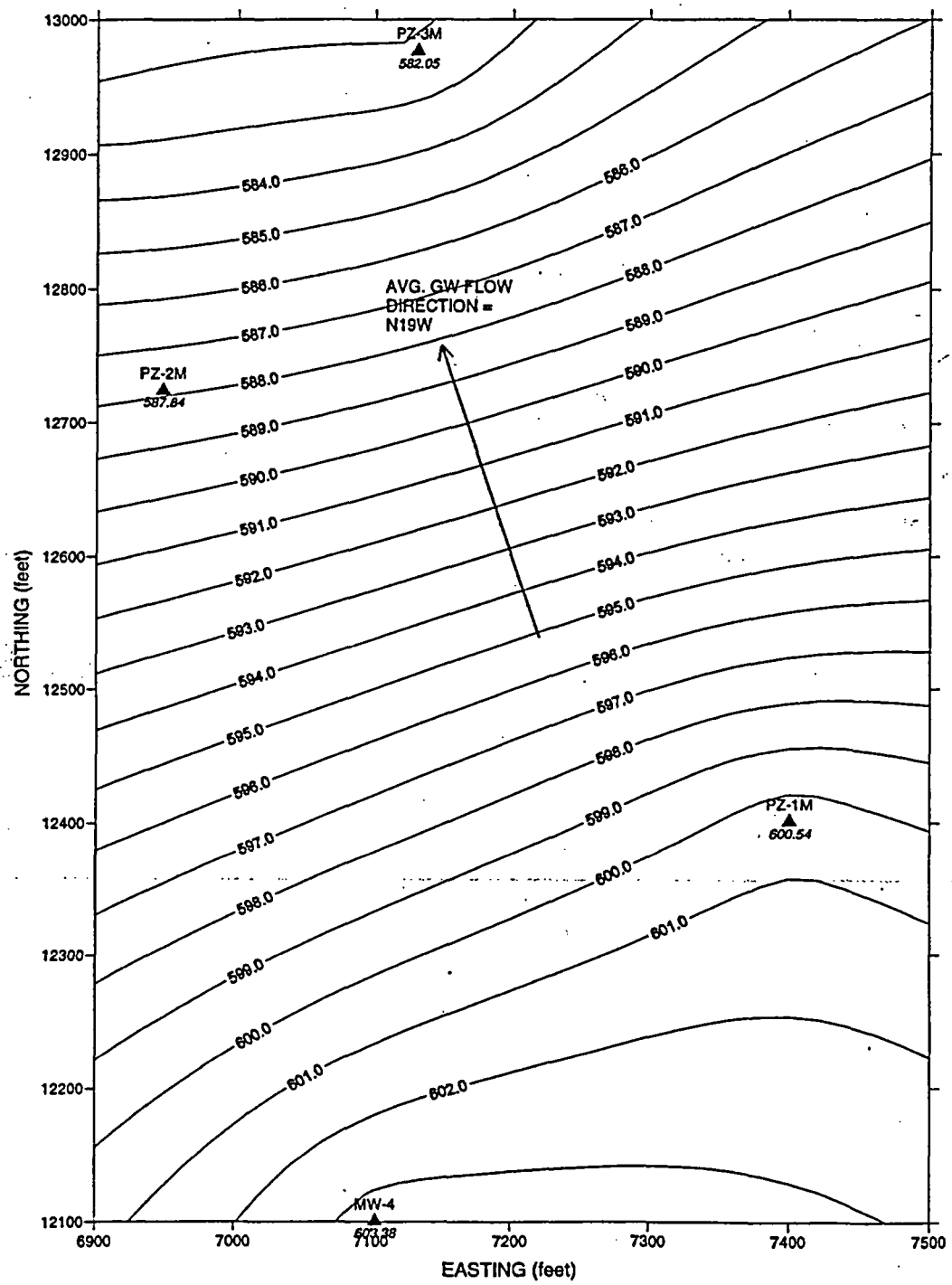

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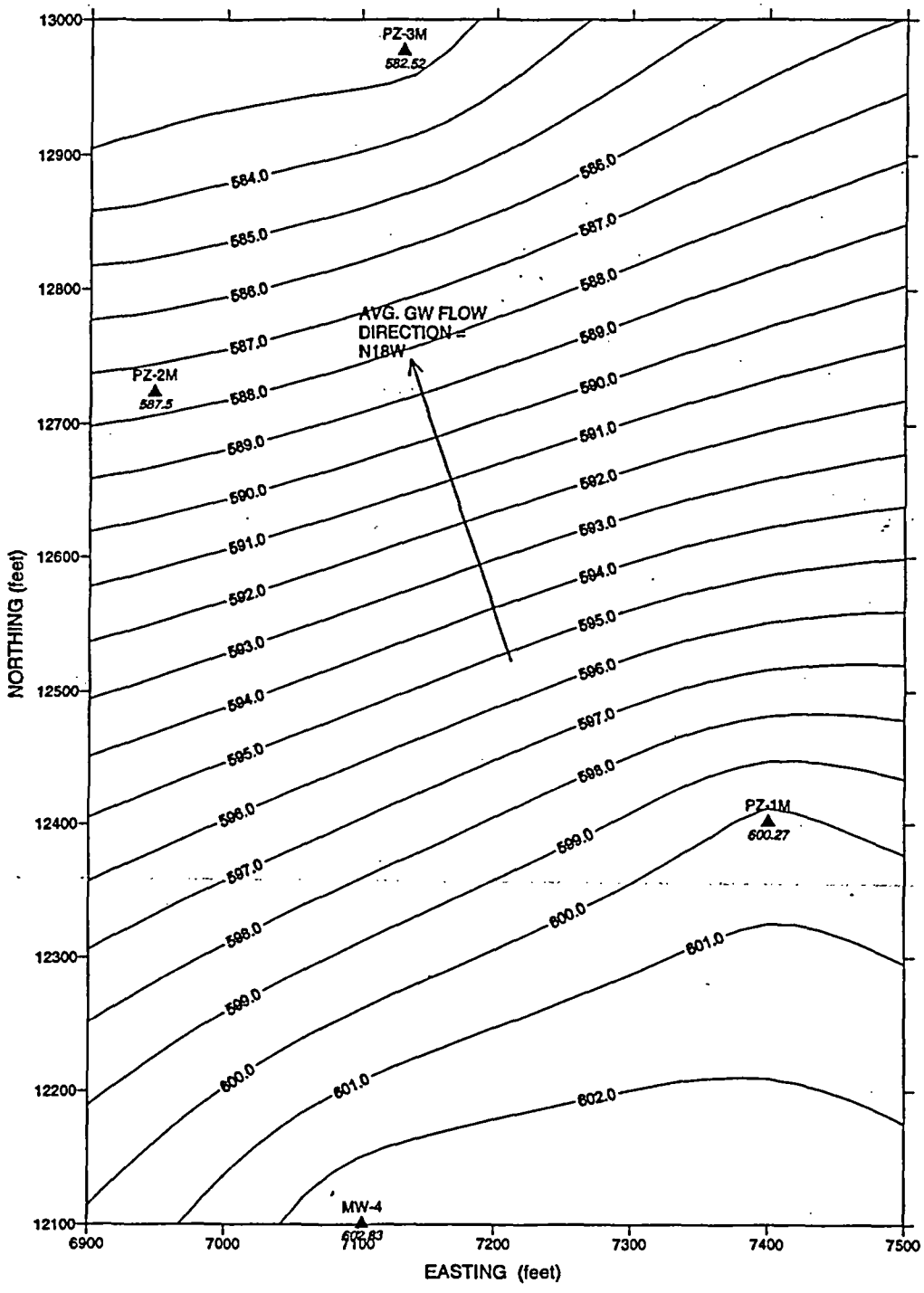

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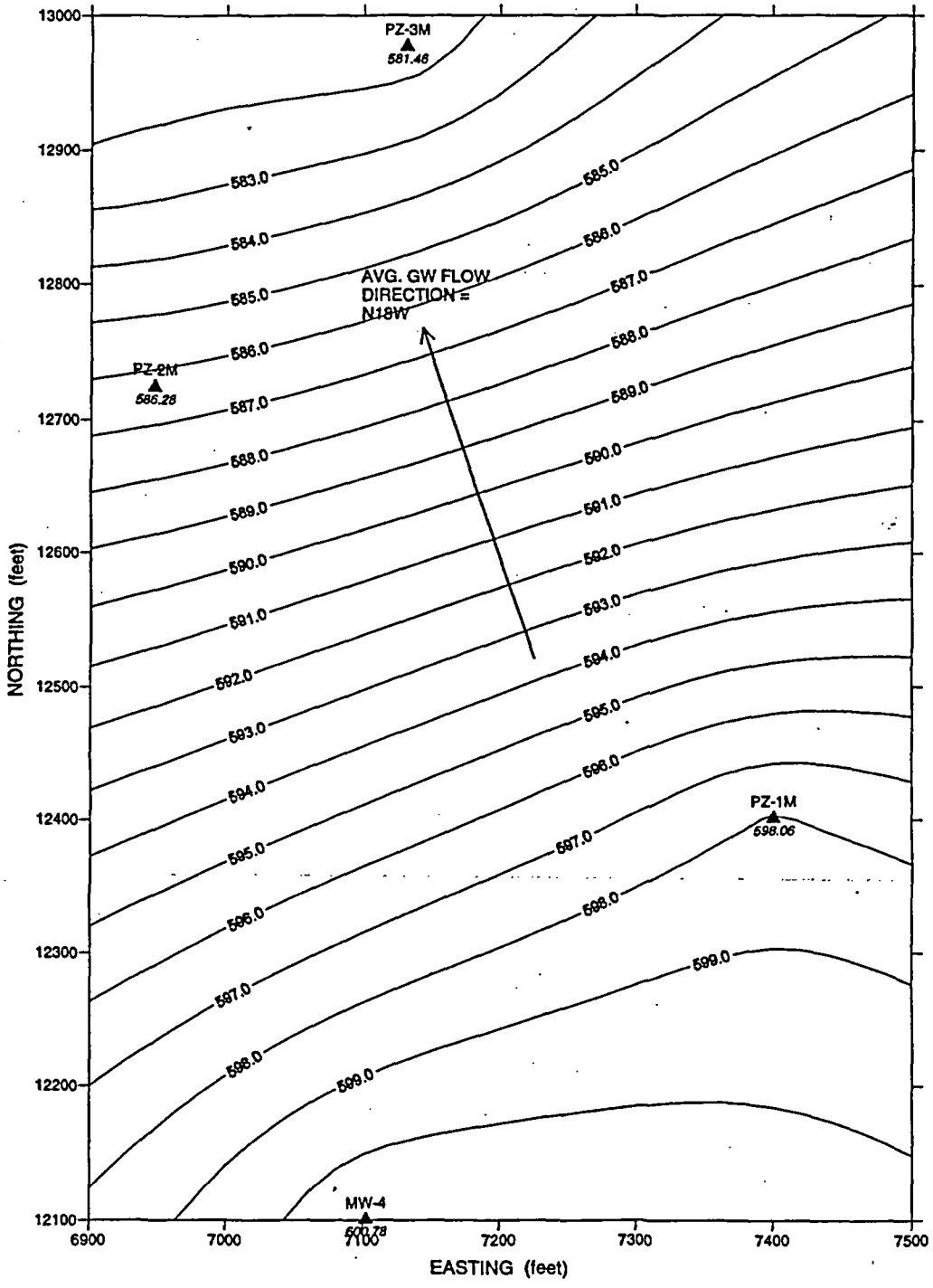
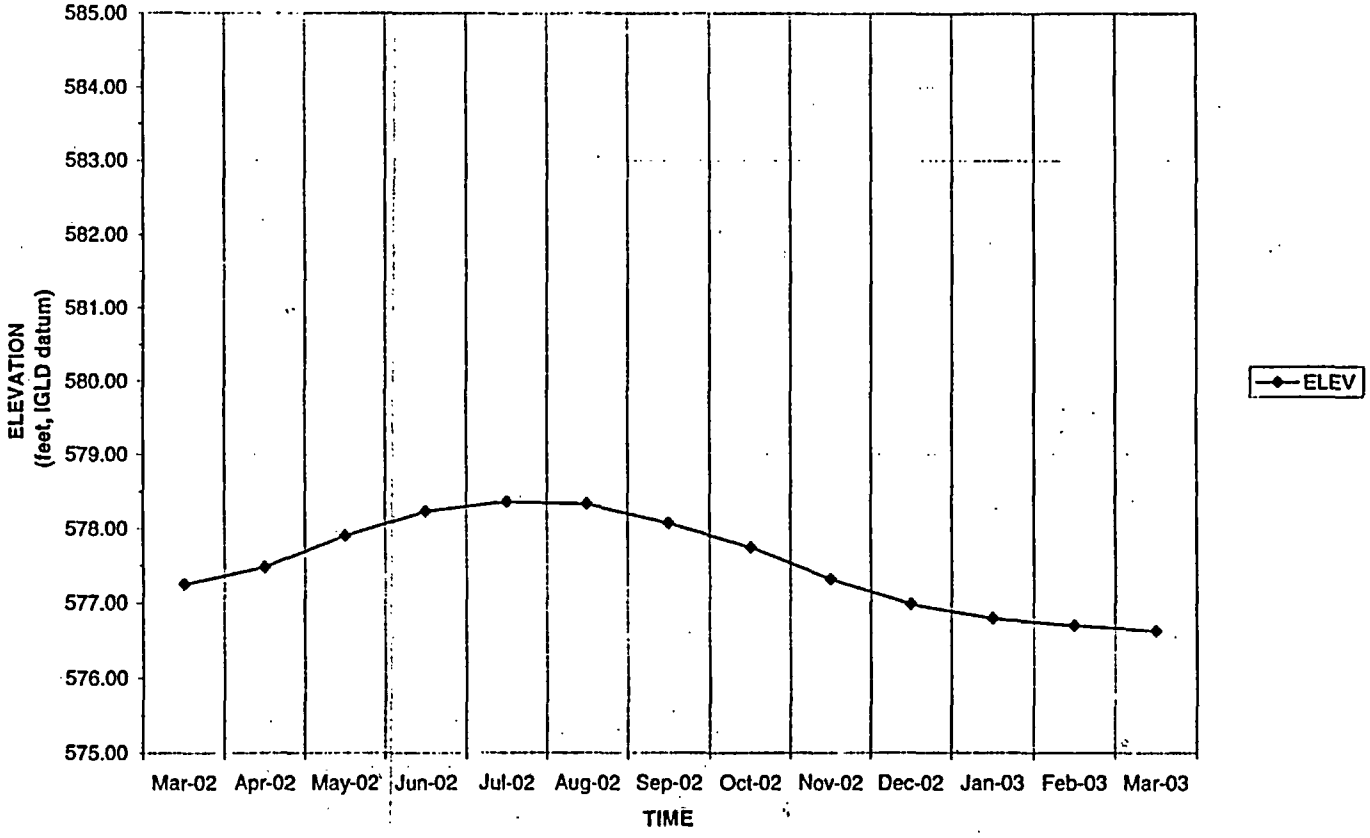


BIG ROCK SITE: Lake Michigan Elevation vs. Time (March 2002- March 2003)



OTWELL MAWBY, P.C.

TABLE OF CONTENTS

4.0 SITE REMEDIATION PLAN 1

4.1 INTRODUCTION 1
4.1.1 Purpose 1
4.1.2 Scope 1

4.2 REMEDIATION ACTIONS 2
4.2.1 Structures, Systems and Components 2
4.2.2 Soil and Water 3

4.3 REMEDIATION ACTIVITY IMPACT ON THE RADIATION PROTECTION PROGRAM 8
4.3.1 Commitment to Radiation Protection Procedures 9

4.4 ALARA EVALUATION 10
4.4.1 Dose Models 10
4.4.2 Methods for ALARA Evaluation 10
4.4.3 Remediation Methods and Cost 11
4.4.4 Remediation Cost Basis 11

4.5 UNIT COST ESTIMATES 12
4.5.1 Waste Disposal Cost 12
4.5.2 Worker Accident Costs 13
4.5.3 Worker Dose 13
4.5.4 Labor Costs 14
4.5.5 Equipment Costs 14
4.5.6 Schedule Delay Cost 14

4.6 PRESENT WORTH OF FUTURE COLLECTIVE AVERTED DOSE 14

4.7 ALARA CALCULATION RESULTS 15
4.7.1 ALARA Cost Benefit (Concentration/DCGL) for Soil Excavation 15

4.8 REFERENCES 17

APPENDICES

4-A ALARA Calculations 4A-1

4-B Soil Remediation Cost Data 4B-1

4-C-1 Screening Level Calculations 4C-1

4-C-2 Site-Specific DCGL Calculations 4C-3

4-D Average Soil Radionuclide Concentrations for Big Rock Point 4D-1

4.0 SITE REMEDIATION PLAN

4.1 INTRODUCTION

This section of the License Termination Plan (LTP) describes remediation actions proposed for use in the decommissioning of Big Rock Point (BRP). In accordance with 10 CFR 20, Appendix 4-B, remediation will assure that dose less than or equal to the annual dose limit of 25 mrem/year, reduced to as low as reasonably achievable (ALARA), is met for the critical population group. In addition, the portion of this dose attributable to drinking water sources has been subtracted from the dose available to radionuclides in soil in the calculation of site-specific Derived Concentration Guideline Level (DCGL). LTP Section 6.8.2 provides a complete discussion of site-specific DCGL derivation. Remediation will be performed under the Radiation Protection Program in a manner that will assure that both worker doses and environmental doses will be ALARA.

4.1.1 Purpose

This remediation plan describes the use of characterization data to define the requirements for remediation, projected remediation volumes, and methods to be utilized to reduce site soils to levels that will allow the Greenfield site to meet unrestricted release criteria.

4.1.2 Scope

This remediation plan addresses current and planned remediation actions for soil and water at BRP, as well as remediation that may be performed on sediments in portions of the plant discharge canal. Because the site is intended to be released after the removal of all aboveground and most belowground structures, (see LTP Section 4.2), this remediation plan addresses only briefly the activities involved with structures, systems and components (SSCs). Further description of previous and future decommissioning activities involving SSCs may be found in LTP Chapter 3, *Identification of Remaining Site Dismantlement Activities.*

Remediation of soils has occurred as a normal course of business at BRP, both during and following the plant operational phase. Early remediation has served to limit both lateral and vertical spread of residual radioactivity with time. However, residual radioactivities in areas of high dose rate, and in areas inaccessible to workers during power operations, have remained for future remediation. This plan focuses on current and future remediation actions. Past remediations are described in Appendix 2-B of LTP Chapter 2, *Site Characterization.*

This section also discusses BRP's commitment to health physics procedures and approved work practices applicable to remediation, in order that worker health and safety is assured, and releases of radioactive materials to the environment are minimized. It also addresses ALARA for dose to the public following unrestricted site release.

4.2 REMEDIATION ACTIONS

The BRP site will be decommissioned to the Greenfield definition provided in LTP Section 1.4. All equipment, buildings and structures, including subsurface foundations are expected to be removed, either as material meeting unrestricted release criteria, material meeting the requirements of the BRP 10 CFR 20.2002 license requirements for disposal of demolition debris, or material that requires disposal as radioactive waste [Reference 4-5]. Contaminated soil and groundwater, as the only materials remaining at the time of site release, are the only materials that are subject to remediation.

NUREG-1700, *Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans*, guidance for the content of LTP Chapter 4 calls for discussion of activities involving remediation of all structures with residual radioactivity levels in excess of unrestricted use limits [Reference 4-8]. Due to the Greenfield definition, no structures will be remediated for release with the site. Consequently, specific discussion is limited to remediation considerations for surface and subsurface soil, and surface and subsurface ground water at this site. However, general discussion of structures, systems and components (SSCs) dismantlement activities is provided in LTP Section 4.2.1, and in LTP Chapter 3.

Soil remediation may be initiated as residual radioactivity is identified in areas accessible for safe and effective remediation. If an area is not immediately available, remediation may be initiated when the area becomes available due to structure removal, when dose rates from surrounding activities and facilities are ALARA, and when the area can be adequately protected from recontamination. The approximate schedule for completion of soil remediation in various areas is linked to the schedule for final status surveys. This schedule is provided in LTP Section 5.8.6.2 and summarized in Table 5-11. Figure 3-2 of this LTP illustrates the relationships among demolition and remediation activities, remediation surveys and the Final Status Survey (FSS). These schedules are meant to illustrate the general order and duration of activities, and are not to be taken as licensing commitments.

4.2.1 Structures, Systems and Components

All equipment, components and structures, including subsurface foundations, but excluding an on-site septic drainfield and the plant intake water pipe, will be removed rather than undergo remediation[1]. The drainfield is being retained in place, with the concurrence from local and state health officials. The drainfield is in an impacted area, but characterization studies show that it will meet site release criteria without remediation. The plant intake water pipe will be plugged and retained in place, in order to minimize environmental impact. The intake water pipe is a non-impacted structure, and exists predominately in public waters.

[1] Facilities supporting the ISFSI will remain on site until after spent fuel has been transported to a permanent federal repository.

Following system and component removal, contaminated structures are removed in a general sequence of perimeter buildings first, followed last by the Containment Building and its critical support facilities such as liquid radwaste processing, heating, ventilating and air conditioning (HVAC), and plumbing. The Containment Building's steel sphere remains in place until all fuel is removed to dry fuel storage, and the major sources of contamination, including fuel pool structure, reactor vessel and reactor bioshield, either have been removed, or have been packaged for shipping. This sequence assures that radioactive materials are appropriately protected against uncontrolled release to the environment during the dismantlement process. Table 3-5 of this LTP provides projected dates for future decommissioning activities.

Aboveground portions of structures are decontaminated to safe levels prior to demolition. This serves to limit the possibility of environmental residual radioactivity, and also aids in maximizing the amount of material that may be disposed of by unrestricted release or as industrial demolition debris under the provisions of the NRC approved10 CFR 20.2002 alternate disposal procedure request [Reference 4-5]. Belowground portions of structures subsequently are removed, evaluated for appropriate disposal, and shipped to the appropriate disposal facility. Soils uncovered by these activities are surveyed and remediated, as necessary, prior to backfill. Soils with radionuclide concentrations higher than acceptable for retention onsite (higher than DCGL for the mixture) will be packaged and shipped for disposal as radioactive waste.

4.2.2 Soil and Water

Considering the 35-year operating history of BRP, relatively little soil contamination has occurred. Factors that have mitigated residual radioactivity external to the containment sphere are discussed in LTP Section 2.2.4.2. However, one significant event of groundwater contamination occurred due to leakage of approximately 20,000 gallons of steam condensate from the Condensate Storage Tank in 1984. Details of this event are provided in LTP Section 2.2.5.3.d.3. Other liquid spills also occurred as identified in LTP Chapter 2, but all were much less significant. Analyses of water samples from groundwater monitoring wells (1994-present), numerous samplings of groundwater obtained by core borings through the Turbine Building and Containment floors, and water samples from excavations during ongoing demolition activities, have identified only tritium to be present above environmental LLDs (lower limits of detection).

4.2.2.1 Soil

There are four areas where sampling has shown that limited residual radioactivity levels remain present in soils above site-specific DCGLs. To place the extent of residual radioactivity in perspective, as of midsummer, 2002, only seven of more than 1100 soil sample locations had indicated residual radioactivity levels higher than the site-specific DCGLs. The areas with sufficient residual radioactivity to warrant consideration as candidates for remediation are [Reference 4-2]:

1) West of and Beneath Turbine Building

This area has been affected by past leaks from the outside Condensate Storage Tank. Although some soil was removed following the incidents during the plant operational phase, the volume of soil still requiring remediation is estimated to be approximately 10 cubic meters. Ratio of Cs-137 to Co-60 from soil samples in this area is approximately 200.

2) Pipe Tunnel, South of Containment Building

Expansion joints and penetrations through the floor allowed condensed liquid from steam leaks to soak into soil beneath the pipe tunnel floor in the area adjacent to the Containment Building on its south side. There also were other recorded incidents of contamination in this area (see Appendix 2-B of Chapter 2). The volume of soil estimated to require removal is approximately 30 cubic meters. Ratio of Cs-137 to Co-60 from soil samples in this area is approximately 0.05.

3) North of Condensate Storage Tank

An area west of the Turbine Building and north of the Condensate Storage Tank location that was affected by Waste Hold Tank overflows and possible contamination from radioactive filters and resins during transfer from the Liquid Waste Vaults (the vaults are just east of the residual radioactivity area). This area has been partially remediated in the past, but is still estimated to require removal of approximately 40 cubic meters of contaminated soil. Ratio of Cs-137 to Co-60 from soil samples in this area is approximately 20.

4) Plant Discharge Canal

The area to be remediated is approximately 600 square meters. Residual radioactivity averages less than 15 cm deep into sediments that lie interspersed with and in some low flow areas, on top of, cobble. Remediation of contaminated sediment is expected to result in approximately 30 cubic meters of waste. This area has been impacted by permitted discharge into Lake Michigan, and currently is under water. However, due to the Greenfield objective of returning the lakeshore to original contours, the current deep area adjacent to the plant may be filled. The filled area would be accessible by the public at the current low water level of Lake Michigan. The purpose of remediation would be to treat the area as if it were part of the plant site. Ratio of Cs-137 to Co-60 from sediment samples in this area is approximately 0.6.

5) Other Potential Areas

An estimate for all additional potential, but yet unidentified residual radioactivities above site-specific DCGLs has been made based on a residual radioactivity depth of 15 cm for 200 square meters of subsurface foundation area (30 cubic meters). This volume includes foundation areas not yet available for characterization, including a suspect area beneath the Liquid

Radwaste Vault where high dose rates have not allowed core borings to be obtained directly through the floor to this point in time. Ratio of Cs-137 to Co-60 in these areas is assumed to be at the site-wide soil average of approximately 1.2.

Based on the known and potential residual radioactivity areas described above, the total soil volume that contains at least some residual radioactivity above site-specific DCGLs is expected to be approximately 150 cubic meters. Residual radioactivity in soil above the site-specific DCGLs will be removed from the above areas, (and any other locations which may later be found greater than site-specific DCGL concentrations), and will be disposed of as radioactive waste. Where appropriate, site excavation procedures, work permits and other appropriate site requirement documents will address dewatering, analysis and disposition of liquids accumulating within excavations, control of dust, control of contamination, safety requirements, and other constraints. As needed, additional investigations will be performed to ensure that any changing soil residual radioactivity profile during the remediation actions is adequately identified and addressed [Reference 4-6].

Soil remediation equipment will include, but not be limited to, back and track hoe excavators, front-end loaders and hand digging. As practical, when the remediation depth approaches the soil interface region for unacceptable and acceptable residual radioactivity levels, a squared edge excavator bucket design or similar technique may be used. This minimizes the mixing of contaminated soils with acceptable lower soil layers as would occur with a toothed bucket. However, due to the cobbly nature of many plant soils, toothed buckets or hand digging may be required where residual radioactivity occurs in the vicinity of imbedded cobble and rocks. In the plant discharge area, either hand digging or specialized underwater operations may be performed to remove pockets of sediment with concentrations above site-specific DCGLs for disposal as radioactive waste.

The site characterization process has established the location and extent of residual radioactivity in soil. Details may be found in Chapter 2 of this LTP. However, it should also be noted that soil volume estimates (or implied volumes of soil used in LTP Chapter 6, *Compliance with the Radiological Criteria for License Termination,* dose calculations, etc.) may vary slightly from section to section.

Depth profiles have shown that residual radioactivity in soils greater than site-specific DCGLs do not extend deeper than 0.30 meter except for one sample in vicinity of the waste hold tank leaks and two isolated samples in the pipe tunnel. In each case, nearby samples did not detect deep residual radioactivity. Thus, the extent of subsurface residual radioactivity is known to be very limited. However, local residual radioactivity not detected by core samples performed to date may be found when foundations or subsurface piping are removed. While these and other excavations are open, evaluations will be performed by use of sampling, scanning, in situ measurements, or other approved method defined by plant procedures, to assess the need for remediation. License Termination Plan Section 5.4 discusses soil sampling and survey methods.

4.2.2.2 Groundwater

Tritium exists in groundwater as described in Sections 2.4.5.3 and 6.8.2.1 of this LTP. However, at the current time, no tritium above the Environmental Protection Agency (EPA) drinking water guidelines has been detected in the aquifer suitable as a drinking water supply (maximum detected in the potential drinking water aquifer is 1560 pCi/l, well below the EPA guideline of 20,000 pCi/l). Twenty monitoring wells are utilized to monitor for tritium and other potential radionuclides in groundwater. No radionuclide other than tritium has been detected in groundwater at greater than environmental LLD levels [Reference 4-4].

In the latter part of 2002, samples were taken of soil and water beneath the Turbine Building slab during the removal of an equipment drain. The water contained tritium at levels, corrected for decay, evaluated to be consistent with those originally present in the condensate tank at the time of the leak in 1984. The water has been trapped within a sub-floor vault support foundation within the Turbine Building that was originally filled with dry sand (see Section 2.4.5.3.c). Hydrostatic pressure generated by the condensate system leak has caused tritiated water in-leakage along pipe penetrations that pass through this structure. The sub-floor vault area has held the condensate water in place and has intermittently released small amounts into the environment as a result of localized fluctuations in water table conditions.

Removal of this tritium source term beneath the Turbine Building is a phased process described below:

Phase One: Remove tritium contaminated water by conventional pumping in all areas below the Turbine Building identifying tritium concentrations above the EPA drinking water standard of 20,000 pCi/l.

Phase Two: Remove all available free water trapped inside the sub-floor vault by vacuum extraction.

Phase Three: Completely empty the sub-floor vault of all soil and residual water prior to removal of the Turbine Building foundation. This effort will remove the tritium source term and protect the environment from potential contamination during subsurface demolition and foundation removal.

Phase One and Phase Two of the source term removal process have been completed. Phase One dewatering in the Turbine Building began in April 2003 by intervals of low capacity pumping separated by periods in which water levels were allowed to recover. This effort was conducted over an approximate 6-month period and terminated when well production in the sub-floor vault area became insufficient for standard water removal methods.

A remediation vendor was contracted to perform the Phase Two removal of residual water remaining within the sub-floor vault by means of vacuum assisted recovery. Drop pipes were placed in 14 locations near the sub-floor elevation and connected by manifold to a diesel driven vacuum pump. The vacuum recovery process, conducted during December 2003, effectively removed all available free water from

the sub-floor vault area. To date, 6,300 gallons of tritiated water have been removed from 14 sample/extraction wells installed within the sub-floor vault and 18,000 gallons have been removed from 15 sample/extraction wells in other Turbine Building areas within the contaminant migration pathway. Tritium concentration in all sample locations outside the sub-floor vault have been reduced to levels below the EPA drinking standard (20,000 pCi/l).

Phase Three is scheduled to begin in early fall of 2004 when the Turbine Building floor is breached and the total volume of soil within the sub-floor vault (approximately 360 m^3) is excavated and removed.

The Turbine Building and Containment structures cover an area of approximately 2800 m^2 and have foundations that extend to a maximum depth of 11 m (35 feet). When these foundations are removed, the excavation will encompass a total volume of over 30,000 m^3 and will include temporary removal of both shallow and intermediate groundwater zones at this location. Soils that are excavated in support of foundation removal will be subject to final status survey in accordance with LTP, Section 5.4.2.4. Soil volumes exceeding the release criterion will be disposed of as radiological waste. Foundation materials will be surveyed, then handled as radiological waste or under procedures that implement the approved 10 CFR 20.2002 process, as appropriate.

A comprehensive dewatering system, located inside the Industrial Area, to maintain excavation conditions as dry as possible for worker safety. This system includes construction of a slurry wall to isolate excavated areas from shallow groundwater intrusion and placement of wells to dewater the shallow and intermediate groundwater zones. Dewatering activities will continue to reduce tritium concentrations in the shallow and intermediate groundwater zones. Groundwater collected from the dewatering process will be pumped to a retention basin for sediment collection and then released under provisions of the Big Rock Point Offsite Dose Calculation Manual (ODCM) and state and local surface water discharge regulations.

Following the FSS of the excavated area, this location will be backfilled and returned to grade elevation. The slurry wall will be breached to reestablish northerly groundwater flow conditions. Monitoring for potential contaminants will continue to be performed in all three groundwater strata until the FSS is complete to insure that radioactivity concentrations are known and fully within the bounds of the allowable dose requirements for site release.

The EPA guideline of 20,000 pCi/l does not apply to water confined in subsurface structures beneath the Turbine Building and Containment, or within the upper or intermediate groundwater zones, all of which are unsuitable by health standards as a potable water supply. However, as of May 10, 2004, no groundwater sampling points outside the Turbine Building sub-floor vault show tritium concentrations greater than 20,000 pCi/l. This assures that these water sources will not eventually reach the deeper potable supply at concentrations capable of elevating that aquifer to or above the EPA guideline value.

4.2.2.3 Surface Water

No radionuclides of plant origin have been detected in surface water at the plant site, other than those detected in samples taken at the discharge weir during permitted release of liquid batch discharges to the discharge canal. Consequently, no remediation of surface waters is required. Discharge canal sediments, the only place that radionuclides of plant origin remain from those permitted discharges may be remediated as discussed in LTP Section 4.2.2.1.

4.3 REMEDIATION ACTIVITY IMPACT ON THE RADIATION PROTECTION PROGRAM

The Radiation Protection Program approved for decommissioning is similar to the program in place during 35 years of commercial power operation. During power operations, contaminated SSCs were decontaminated in order to perform maintenance or repair actions, and contaminated soils were removed to prevent further spread of contamination into the environment. The techniques were similar to those being used for decommissioning. Many components were removed and replaced during operation. The techniques used for component removal did not differ significantly from those being used during decommissioning. However, chemical decontamination and radioactive decay both allow component removal at lower dose levels than observed during the plant operational period. Reactor system chemical decontamination at BRP was performed immediately after final shutdown. Subsequent component removal and dismantlement activities have been performed at much lower dose rates than would have been present otherwise.

The BRP Radiation Protection Program adequately controlled radiation and radioactive contamination during power operation, although plant age and design provided significant challenges to the limitation of worker dose. Since shutdown, dose rates have been lowered by chemical decontamination, and ALARA engineers have been able to plan major personnel dose evolutions such as reactor vessel and bioshield removal late in the decommissioning schedule. At these later dates, radioactive decay of activated materials (primarily Co-60) has lowered component dose rates another 50%. The combination of these factors has greatly improved the plant's ability to limit personnel exposure to radiation. Consequently, Radiation Protection Program effectiveness has improved for decommissioning in comparison to power operations.

With specific reference to soil remediation, application of the Greenfield definition for site release is seen as a major factor in reduction of worker dose. With removal of equipment and structures from an area prior to major soil remediation efforts, only the radioactive materials within the soil remain present as a source of radiation exposure to the remediation worker. Since average concentration of soil radioactivity is well below the DCGL, worker doses are minimal under such conditions.

4.3.1 Commitment to Radiation Protection Procedures

Big Rock Point intends to continue under its Part 50 license throughout the decommissioning process. Radiation Protection procedures are required under the Defueled Technical Specifications for implementation of the requirements of 10 CFR 20. The Defueled Technical Specifications, in conjunction with the requirement for maintaining an Offsite Dose Calculation Manual (containing relocated technical specifications), also specify requirements for effluent controls, environmental monitoring, reporting requirements and limitation of offsite dose within the guidelines of 10 CFR 50, Appendix I.

Radiation Protection procedures developed and utilized during plant operation continue to be utilized for the protection of plant and contract personnel, and for protection of the environment. Changes and additions to these procedures, to improve applicability to specific circumstances during the decommissioning process, are made under plant administrative controls that include appropriate reviews and approvals. Training and instructions provided to plant and contract workers follow the requirements of 10 CFR 19.12, and reports of personnel exposure are provided pursuant to the applicable sections of 10 CFR Parts 19 and 20. The requirements of these regulations are implemented by means of plant procedures.

4.3.1.1 Remediation Procedures

Procedures applicable to remediation of soils during plant operation have been found to be equally applicable to use during decommissioning, although the criteria for extent of remediation has changed. During plant operation, various ALARA and cost criteria were used to determine the extent of remediation. For decommissioning, criteria for release of an area specifically for the FSS are in accordance with criteria for survey area turnover (see LTP Section 5.1.3.2). In general, remediation will not be considered complete for decommissioning purposes until the sum of the DCGL fractions is shown to be less than 1.0 for Class 1 and Class 2 survey areas and less than 0.5 for Class 3 areas. Remediation surveys are discussed in LTP Chapter 5, *Final Status Survey Plan*.

The soil remediation process begins with a remediation area walkdown and subsequent evaluation of appropriate work processes necessary to assure worker safety, environmental protection and effective removal of residual radioactivity. Deep excavations require consideration of need for shoring or alternatively, requirements for angle of slope, dependent on soil type, to avoid cave-in. Potential need for personnel monitoring and engineering controls to limit inhalation and airborne environmental release is assessed, as is the need for controls to prohibit or limit contamination spread into or out of the excavation by other means, such as by surface water flow or transfer by equipment. Potential for the presence of subsurface installations such as piping or electrical conduit is evaluated. Based on these and other inputs, a work plan is developed, along with any radiation work permit(s) necessary for the work to be performed.

The processes of soil handling and analysis for excavated soils are described in LTP Section 5.4.2.4. LTP Section 5.4.1 provides descriptions of instruments and survey methods applicable both to remediation and FSS activities. Approved procedures are utilized for all such activities.

No unique safety or remediation issues have been identified associated with remediation of soil or groundwater at BRP. As described above, decommissioning remediation processes and procedures are similar to those utilized during plant operation, but differ in terms of endpoint of remediation. Consequently, decommissioning remediation work is coordinated closely with FSS personnel in order to ensure appropriate monitoring and control of excavated materials and the level of remediation required for the specific area (see LTP Sections 5.3.6.4 and 5.3.6.5). At the conclusion of the remediation process, FSS personnel perform a walkdown of the remediated area, and the area may be turned over for final survey, as appropriate.

4.4 ALARA EVALUATION

As described in LTP Chapter 6, dose assessment scenarios were evaluated for the residual radioactivity that could remain in soils. The ALARA analysis is conservatively based on a modified resident farmer scenario. The resident farmer critical group applies to existing open land areas and all site areas where standing buildings have been removed.

4.4.1 Dose Models

As discussed above, the critical group for BRP under the Greenfield definition is the resident farmer. Accordingly, the ALARA evaluations for remediation actions in this section use the parameters for population density, evaluation time interval, monetary discount rate and area that are applicable to the resident farmer scenario.

4.4.2 Methods for ALARA Evaluation

NUREG-1727, *Decommissioning Standard Review Plan*, Section 7.0, ALARA Analysis, states, "Licensees or responsible parties that remediate building surfaces or soil to the generic screening levels established by the NRC staff do not need to demonstrate that these levels are ALARA" [Reference 4-7]. The DCGLs for BRP soil are site-specific values. Approximately half of the site-specific DCGLs are below the generic screening levels, and half above. Appendix 4-C-1 includes screening levels, and Appendix 4-C-2 includes site-specific DCGLs for the radionuclides present in BRP soils. Chapter 6 of this LTP provides details on the BRP site-specific DCGL derivation. Because some of the site-specific DCGLs exceed screening level values, BRP is conservatively providing an ALARA evaluation of the remediation actions for soil.

The ALARA evaluations were performed in accordance with the guidance in NUREG-1727. The dose contribution of each radionuclide in the BRP mixture was evaluated, and the contributions summed. The principle equations used for the calculations are presented in Appendix 4-A. The evaluation determines if the benefit of the dose averted by the remediation is greater or less than the cost of the remediation. When the benefit is greater than the cost, additional remediation is required. Conversely, when the benefit is less than the cost, remediation is not required beyond the point that the average member of the critical population group would receive 25 mrem/year.

4.4.3 Remediation Methods and Cost

Remediation methods and costs for other than soil remediation are not applicable to BRP, due to the plant's commitment of restoration to a Greenfield condition. Additional information on the restoration process is provided in LTP Chapter 3. Groundwater remediation is discussed in LTP Section 4.2.2.2.

4.4.4 Remediation Cost Basis

Unit costs for soil excavation are established for 150 m^3 of contaminated soil excavated and shipped from the site, and also for a lower volume of 33 m^3. The larger volume of 150 m^3 represents soil at the average concentration of contaminated soils measured in the characterization analyses (average concentration for the total mixture of radionuclides is approximately 1.6 pCi/g, per Case 1 of Appendices 4-C-1 and 4-C-2). Description of component areas and volumes is provided in LTP Section 4.2.2. The lower volume of 33 m^3 is commensurate with removal of only the small volumes of residual radioactivity where the sum of the site-specific DCGL and screening level fractions of the individual nuclides equals unity for the shipped mixture, or approximately 7 pCi/g, per Case 2 of Appendices 4-C-1 and 4-C-2. The 150 m^3 and 33 m^3 soil volume cases are presented here, as Case 1 and Case 2, respectively (see Section 4.5), to illustrate the variations in costs and benefit as a function of volume. Remediation volumes from BRP are likely to be nearest 150 m^3, and are not expected to be less than 33 m^3. If volumes greater than 150 m^3 are generated, the cost/benefit ratio will remain above unity: the calculations show that the larger the volume, the greater the cost/benefit ratio.

Soil remediation unit costs (dollars per cubic meter) were determined for methods appropriate to the volumes removed. Power excavation equipment, hand shoveling, or specialized underwater sediment removal systems in the case of the discharge canal, may be employed in contaminated soils removal. Non-radioactive materials such as rocks and cobble may be separated out either during the excavation process, or later. For sediments, dewatering and/or drying may be required to meet shipping requirements. In each case, the costs are based on the net volume of soil shipped for disposal.

Certain activities which are wholly or partially attributable to other decommissioning activities, such as removal of asphalt paving, foundations and floors of buildings, and excavation of soils over subsurface pipes and drains, are not included in the cost of remediation, since these activities would be undertaken whether or not soils in the area were contaminated. Likewise, dewatering activities are excluded, since dewatering is routinely performed to assist in safe removal of subsurface structures, as well as to assist in radiological surveys and remediation, when required. Dewatering small volumes of tritium trapped by underground structures has not been found to be a significant cost factor, so this also is excluded.

Residual radioactivity reduction, based on total quantity of radioactivity removed, is assumed at 95%. The formulas associated with the cost elements are provided in Appendix 4-A, and the cost elements themselves are listed and further described in Appendix 4-B.

4.5 UNIT COST ESTIMATES

In order to perform ALARA evaluations, unit cost values are required. These values are used to perform the NUREG-1727 cost-benefit analysis. Two cases were investigated:

Case 1 Soil at the average concentration of radionuclides identified by characterization studies to date, (150 m^3), and

Case 2 Soil at the generic screening and site-specific DCGL levels for the mixture of radionuclides identified by characterization. This total nuclide concentration is approximately a factor of 4.5 times as high as the mean identified for the 150 m^3 case, and thus represents a volume of 1/4.5 = 0.22 times 150 m^3, or 33 m^3.

For Case 1, the most significant cost factors are the soil excavation cost factor, at \$1808/m^3, and the waste disposal cost factor, at \$1349/m^3. Total cost factor is \$3192/m^3. These are provided in Appendix 4-B, along with associated component costs and appropriate reference bases.

For Case 2, unit excavation cost is lower (\$887/m^3) due to lower power equipment utilization, and disposal costs are greater (\$2398/m^3) because the higher radionuclide concentrations require a greater fraction of waste to be shipped to Envirocare in the state of Utah. Total unit cost for this case is \$3340/m^3. Further description of these costs follow, and a summary of data for both cases is provided in Appendix 4-B.

4.5.1 Waste Disposal Cost

Round trip truck transportation:
Clive, Utah (Envirocare site) round trip: 5140 km.
Oak Ridge, TN round trip: 2830 km
Average distance = 3985 km

Case 1 Disposal Cost:

The BRP contract for soil disposal is $X per pound, if sent to Utah, and $Y per pound, if meeting criteria for disposal at Oak Ridge.

1.6 kg/liter of soil, or $(f_1)(1{,}600\ kg/m^3)(0.454\ lb/kg)\ (\$X/lb) = (726.4)(f_1)(\$X)/m^3$

1.6 kg/liter of soil, or $(f_2)(1{,}600\ kg/m^3)(0.454\ lb/kg)\ (\$Y/lb) = (726.4)(f_2)(\$Y)/m^3$

$1,349/m^3$

Note: X and Y are proprietary values defined by negotiated contract; f_1 and f_2 are fractions of waste sent to Utah and Tennessee, respectively.

Case 1 Accident Cost:

Volume of 13.6 m^3 of soil per truck shipment, per NUREG-1727, Table D2, with average distance of 3985 km/ round trip, total miles for 150 m^3 (11 trips) equals 43,800 km. Rail transport for soil is not anticipated due to the small volumes of soil involved. The distance and haul volume are used for determining transport accident cost in accordance with NUREG-1727, Appendix D, (Equations D6) and the fatal accident rate of 3.8E-08/km given in NUREG-1727, Table D2.

Transport accident cost totals $5,000.

Case 2 Disposal and Accident Costs

Due to the higher concentrations, more waste is assumed sent to Clive, Utah. Unit cost, calculated as for Case 1 above = $2398/$m^3$.

Three truckloads, conservatively assuming a haul distance of 5140 km = 15420 km: Transport accident cost totals $1,758.

4.5.2 Worker Accident Costs

To determine worker accident cost in accordance with NUREG-1727 Appendix D, the accident rate of 4.2E-08/hour was applied to NUREG-1727 Equation (D5). The hours used for labor cost, times number of field workers on a crew, were used for worker accident cost. Accident cost of $60 for Case 1 and $30 for Case 2 are not significant contributors to total cost.

4.5.3 Worker Dose

Costs associated with worker dose are a function of the hours worked and the workers' radiation exposure for the task. Slightly elevated background dose rates, with an average of (0.5 mrem/hour) used for all soil remediation activities. This low value is due to application of the Greenfield definition: most soil remediation follows removal of structures and equipment and, therefore, dose rates are significantly reduced. At $2000 per person-rem, this cost totals $474 for Case 1 and $236 for Case 2.

4.5.4 Labor Costs

Manpower cost assumptions are based on contracts established with the principal site contractors and for Consumers Energy site personnel. Appendix 4-B utilizes an hourly cost for the remediation crew of $180/hour in Case 1 and $160/hour for Case 2. These crew rates assume a manual labor rate of $35/hour, and technician, supervisory and specialized equipment operator rates of $50/hour. Engineering and technical support costs are included as identified in Appendix 4-B. Unit labor costs are $237/m^3 for Case 1 (high equipment utilization), and $402/m^3 for Case 2 (predominantly manual labor with lower volume productivity).

4.5.5 Equipment Costs

Hand tools, power excavation equipment and underwater sediment removal equipment are among the tools that may be utilized for soil remediation. Total cost of $210,700 is calculated for this cost category in Case 1. A cost of $1000 is included for equipment mobilization in Case 1 and $500 is included for Case 2. The bulk of Case 1 equipment cost derives from the underwater sediment removal activities at the discharge canal. Case 1 unit cost is $1405/m^3. For Case 2, there is limited powered land excavation, but no underwater work. Backhoe and loader costs are $100/hour, and dump trucks $50/hour, excluding the $50/hour operator cost that is assigned to labor costs, above. Equipment utilization cost of $16,000 is assigned for Case 2 and equipment unit cost is calculated to be $485/m^3.

4.5.6 Schedule Delay Cost

A contract clause requires payment of fees for certain delays in schedule. A total delay cost of $25,000 is assumed for Case 1. The type of delay most likely to occur is assumed to be that of major equipment (specialized underwater sediment removal equipment) availability, either due to delivery problems, or operability problems during use. No delay charges are assumed in Case 2, since hand digging and small equipment operations are less likely to have major impact on schedule.

4.6 PRESENT WORTH OF FUTURE COLLECTIVE AVERTED DOSE

The remediation cost of $3192/m^3 derived for soil in Appendix 4-B for Case 1 and $3340 for Case 2 was compared to the benefit of the dose averted through the remediation action. As noted earlier, activity concentration in the lower volume (33 m^3) Case 2 is a factor of approximately 4.5 times as high as in Case 1. The benefits of averted dose were calculated using Equations D1 and D2 in NUREG-1727 as modified to account for multiple radionuclides as presented in Equation A-2 of this LTP Section. Appendices 4-C-1 and 4-C-2 provide spreadsheet tables of these calculations for both volumes against NRC screening levels and site-specific DCGLs, respectively. The averted dose, being proportional to excavated soil concentration, also is a factor of approximately 4.5 times higher for Case 2 than for Case 1. It is conservatively assumed that the soil is spread over a 10,000 m^2 area, 15 cm thick in both cases, even though there would not be enough soil to actually meet this condition.

The parameters used in the equations were taken from NUREG-1727, Table D2, as suitable for the resident farmer scenario. The calculation of present worth of the future collective averted dose was performed in Case 1 for the observed average total concentration equaling 1.6 pCi/g, with individual nuclides included as low as 0.0093 pCi/g (Sr-90) [Reference 4-1]. Concentration inputs are shown in the spreadsheets of Appendices 4-C-1 and 4-C-2. Results of all radionuclides are summed. Based on NRC default screening levels, a value of $415 is obtained for the total benefit from the collective averted dose in Case 1 and $1888 is obtained for Case 2. Based on site-specific DCGLs, a value of $404 is obtained for the total benefit from the collective averted dose in Case 1 and $1719 is obtained for Case 2.

4.7 ALARA CALCULATION RESULTS

The total remediation cost may be compared with the benefit from the collective averted dose using Equation D8 from NUREG-1727. This equation is presented in Appendix 4-A as Equation A-2. The calculational inputs and outputs are presented in Appendix 4-C-1 for screening levels, and in Appendix 4-C-2 for site-specific DCGLs.

4.7.1 ALARA Cost Benefit (Concentration/DCGL) for Soil Excavation

Due to high removal and shipping costs, excavation of the expected quantities of soil from the site show that the residual radioactivity is ALARA at both the site-specific DCGL and generic screening level for the mix without additional actions in either Case 1 or Case 2. A farm resident population of four individuals on areas of 10,000 m^2 is assumed for each of the cost/benefit calculations. However, at a contamination depth of 0.15 m, the 150 m^3 volume (Case 1) would cover only 10% of this area, and the 33 m^3 volume (Case 2) would cover only approximately 2.2% of this area. Use of these fractions would reduce dose, and each of the cost/benefit ratios given below would be increased. Such increased values would provide increased support that concentrations need not be reduced below either the site-specific DCGLs or the generic screening levels to be ALARA.

For Case 1, a Concentration/DCGL value of $478,800/$415 = 1154 is obtained with plant soil concentrations evaluated against the surface soil screening values from NUREG-1727 Table C2.3. When evaluated against site-specific DCGLs, the value is $478,800/$404 = 1185.

For the 33 m^3 soil excavation volume (Case 2), the screening level case gives $110,223/$1888 = 58.4, and the site-specific DCGL case gives $110,223/$1719 = 64.1.

Since the Concentration/DCGL values are greater than one for all cases of soil remediation, remediation below the 25 mrem/year dose limit is not justified. It is observed that the cost/benefit ratio is lower for smaller volumes of higher activity concentration, and increases with larger volumes of lower activity concentration.

It will be noted that all calculations in this LTP chapter equate both the generic screening levels and the site-specific DCGLs to 25 mrem/year. This conforms to the guidance in NUREG-1727. However, 25 mrem/year gives slightly conservative doses for specific concentrations of radionuclides in soil at BRP since, as described in Section 6.8.2 of this LTP, site-specific DCGLs for BRP soils are based on an annual dose of 24.219 mrem/year. This lower dose basis compensates for a conservatively calculated annual dose of 0.782 mrem/year from tritium in an aquifer that could be used as a future drinking water supply [Reference 4-3]. Validity of the ALARA cost/benefit analysis result is not affected by this minor difference.

4.8 REFERENCES

4-1 Big Rock Point Engineering Analysis EA-BRP-SC-02-06, *Surrogate Measurement of Hard-to-Detect Nuclides*

4-2 Big Rock Point Engineering Analysis EA-BRP-SC-02-04, *Radionuclides Present in Onsite Soil and Water*

4-3 Big Rock Point Engineering Analysis EA-BRP-SC-02-05, *Effect of Subsurface Soil and Water Contamination and the Development of Surface Soil DCGLs*

4-4 Big Rock Point Offsite Dose Calculation Manual, Volume 25A, Section I, *Procedural and Surveillance Requirements,* (Relocated Technical Specifications)

4-5 Letter from U.S. Nuclear Regulatory Commission letter to Big Rock Point dated February 5, 2002, *Big Rock Point Plant - Proposed Disposal Procedures in Accordance with 10 CFR 20.2002*

4-6 U.S. Nuclear Regulatory Commission NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, August 2000

4-7 U.S. Nuclear Regulatory Commission NUREG-1727, *Decommissioning Standard Review Plan*

4-8 U.S. Nuclear Regulatory Commission NUREG-1700, *Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans,* April 2000

A.1 Present Worth of Future Collective Averted Dose

The present worth of future collective averted dose may be estimated by use of Equation D2 of NUREG-1727:

$$PW = (P_D)(A)(0.025)(F)\left[\frac{Conc}{DCGL}\right] * \left[\frac{1-e^{-(r+\lambda)N}}{r+\lambda}\right] \qquad \textbf{(Equation A-1)}$$

Where:

Pd = Population Density for Resident Farmer (0.0004/m^2)

A = Area of residual radioactivity (10,000 m^2) for this resident farmer calculation

0.025 = Annual dose (rem/y) to the average resident farmer from residual radioactivity at the DCGL

F = Fraction of the residual radioactivity removed by the remedial action. Assumed equal to 0.95.

Conc = Average concentration of residual radioactivity being evaluated in units of pCi/g of soil

DCGL = Derived concentration guideline level that represents dose rate of 25mrem/year in pCi/g

r = Monetary discount rate (0.030y^{-1})

λ = Radiological decay constant for a radionuclide in units of y^{-1}

N = Length of time collective dose is calculated (1,000y)

A.2 Concentration/DCGL

Concentration/DCGL is the ratio of soil concentration to the derived concentration guideline that is calculated as a cost to benefit ratio for the remediation process. If the ratio exceeds 1.0, further costs are not justified for remediation to below 25mrem/year. If the cost-benefit ratio is less than 1.0, it is cost effective to reduce levels to a level below 25 mrem/year that gives a ratio of 1.0 or greater.

Equation D8 of NUREG-1727 may be expressed for the summation of all nuclides as follows:

$$\frac{Conc}{DCGL} = \frac{Cost_T}{\sum_i^n (\$2000)(P_D)(0.025)(Df_i)(F)(A)\left[\frac{1-e^{-(r+\lambda_i)N}}{r+\lambda_i}\right]} \qquad \textbf{(Equation A-2)}$$

Where:

$$Df_i = \text{Dose Fraction} = \frac{(Di)}{\sum_i^n (Di)} = \frac{(Conc/DCGL)_i}{\sum_i^n (Conc/DCGL)_i}$$

$D_i = (25)(Conc/DCGL)_i$ = annual dose contribution (mrem) from individual residual nuclide at site release This equals $(25)(Df_i)$ when the mixture is at the site-specific DCGL or generic screening level for the mix.

$\sum_i^n (Di)$ = annual dose total from all residual nuclides in soil at time of site release (mrem).

And the remaining symbols are as defined for Equation A-1.

Df_i relates dose of a single radionuclide of a mixture to total dose from the mixture. A mixture that will provide 25 mrem/year may be termed the mixture DCGL. Setting Df_i equal to 1.0 in this equation (thus reducing it to the equivalent of Equation A-1, rearranged for expression of Conc/DCGL) will result in a value of Conc/DCGL at the nuclide's observed concentration, rather than at the mixture's DCGL.

Case 1. Soil Excavation Remediation –150m^3 at observed average concentration

Volume Evaluated For Unit Cost Determination: 150 m^3 , Total mix conc. = 1.6 pCi/g
Primary Crew Size: 3. Supervisor, 1; RP, 0.5; Laborers, 1; Equipment operator, 0.5
Support Personnel: 0.4. Resident and Schedule Engineers, 0.15; HP/ Environmental, 0.25 Hourly Cost: $180
Excavation Rate, including beneficiation: 1.9 m^3/h
Hours: 158 (150 m^3/1.9m^3/h)(2.0) [2.0 = contingency]
Labor Cost: $35,550 (Includes 25% for contingency and non-field support staff)
Equipment Costs: Land, $23,700; Underwater Equipment, $186,000 (consumables $3,100)
Mobilization Costs: $1000
Prime Contract Delay Cost: $25,000
Total Excavation Cost: $271,250 = $1808/ m^3
Waste Generation: 150 m^3 (5,300 ft^3/35.315 ft^3/m^3)
Waste Disposal Cost: $202,000 ($1349/m^3)
Worker Accident Cost @158x3 hours = 2.0E-5 fatalities: $60 Per NUREG-1727
Transportation Accident Cost @ 43,800 km (1.66E-3 fatalities by truck): $5000 Per NUREG-1727, Appendix D
Worker Dose, 158 hours for 3 in field @ 0.0005 rem/hour: 0.237 person-rem = $474
Total Costs: $478,800
Cost per m^3: $3,192

Case 2. Soil Excavation Remediation – 33 m^3 at default screening level or site-specific DCGL level for nuclide mix

Volume Evaluated For Unit Cost Determination: 33 m^3, Total mix Concentration = 6.87 pCi/g
Primary Crew Size: 3.8, Supervisor, 1; RP, 0.5; Laborers, 2; Equip Operator, 0.3
Support Personnel: 0.4, Resident and Schedule Engineers, 0.15; HP/ Environmental, 0.25 Hourly Cost: $160
Excavation Rate, with minor beneficiation: 0.8 m^3/h
Hours: 62 (33 m^3/0.8m^3/h)(1.5) [1.5 = contingency]
Labor Cost: $13,260 (Includes 25% for contingency and non-field support staff)
Equipment Costs: $15,500 (consumables $2,000)
Mobilization Costs: $500
Prime Contract Delay Cost: None
Total Excavation Cost: $29,260 = $887/ m^3
Waste Generation: 33 m^3 (1165 ft^3/35.315 ft^3/m^3)
Waste Disposal Cost: $79,134 ($2398/m^3)
Worker Accident Cost @ 62 hours x 3.8 workers = 9.9E-6 fatalities: $30 Per NUREG-1727
Transportation Accident Cost @ 15,420 km (5.86E-4 fatalities by truck): $1758 Per NUREG-1727, Appendix D
Worker Dose, 62 hours x 3.8 workers in field @ 0.0005 rem/hour: 0.118 person-rem = $236
Total Costs: $110,223
Cost per m^3: $3340

Case 1 — **PW at Actual mean Soil Concentration vs Screening Level (150 cu. m^3)**

Radionuclide	λ (1/yr)	Pd*A*F/40 (unitless)	Conc (pCi/g)	Screen (pCi/g)	N (years)	r (1/y)	PW (unitless)
Cs-137	0.0231	0.095	0.6680	1.10E+01	1000	0.03	1.09E-01
Co-60	0.1317	0.095	0.5720	3.80E+00	1000	0.03	8.84E-02
Sr-90	0.0427	0.095	0.0094	1.70E+00	1000	0.03	9.56E-03
Mn-54	0.5749	0.095	0.0370	1.50E+01	1000	0.03	3.87E-04
Fe-55	0.2665	0.095	1.7600	1.00E+04	1000	0.03	5.64E-05
H-3*	0.0563	0.095	0.0490	1.10E+02	1000	0.03	4.90E-04
Total			3.0954				0.208
Benefit of Averted	Dose =	$2000*PW					$ 415.10

Case 2 — **PW at Screening Level for Mix in 33 cubic meters**

Radionuclide	λ (1/yr)	Pd*A*F/40 (unitless)	Conc (pCi/g)	Screen (pCi/g)	N (years)	r (1/y)	PW (unitless)
Cs-137	0.0231	0.095	3.039	1.10E+01	1000	0.03	4.95E-01
Co-60	0.1317	0.095	2.602	3.80E+00	1000	0.03	4.02E-01
Sr-90	0.0247	0.095	0.043	1.70E+00	1000	0.03	4.35E-02
Mn-54	0.5749	0.095	0.168	1.50E+01	1000	0.03	1.76E-03
Fe-55	0.2665	0.095	8.006	1.00E+04	1000	0.03	2.56E-04
H-3*	0.0563	0.095	0.223	1.10E+02	1000	0.03	2.23E-03
Total			14.080				0.944
Benefit of Averted	Dose =	$2000*PW					$ 1,888.16

Calculation of Gross Activity Screening Level for Mix[1]

Radionuclide	Original Conc (pCi/g)	Screening Level (pCi/g)	Conc/ Screen	Conc @ Mix Scrn (pCi/g)	Dose Check (mrem/yr)
Cs-137	0.6680	1.10E+01	6.07E-02	3.04E+00	6.91E+00
Co-60	0.5720	3.80E+00	1.51E-01	2.60E+00	1.71E+01
Sr-90	0.0094	1.70E+00	5.50E-03	4.26E-02	6.26E-01
Mn-54	0.0370	1.50E+01	2.47E-03	1.68E-01	2.81E-01
Fe-55	1.7600	1.00E+04	1.76E-04	8.01E+00	1.92E-02
H-3	0.0490	1.10E+02	4.45E-04	2.23E-01	4.91E-02
Total	3.0954		2.20E-01	1.41E+01	2.42E+01

[1] Equation 4-4 of NUREG-1575

Case 1 PW at Actual mean Soil Concentration vs DCGL (150 cu. m^3)

Radionuclide	λ (1/yr)	Pd*A*F/40 (unitless)	Conc (pCi/g)	DCGL (pCi/g)	N (years)	r (1/y)	PW (unitless)
Cs-137	0.0231	0.095	0.6680	1.32E+01	1000	0.03	9.05E-02
Co-60	0.1317	0.095	0.5720	3.21E+00	1000	0.03	1.05E-01
Sr-90	0.0427	0.095	0.0094	2.47E+00	1000	0.03	6.58E-03
Mn-54	0.5749	0.095	0.0370	1.37E+01	1000	0.03	4.24E-04
Fe-55	0.2665	0.095	1.7600	3.58E+05	1000	0.03	1.57E-06
H-3**	0.0563	0.095	0.0490	3.25E+02	1000	0.03	1.66E-04
Total			1.6038				0.202
Benefit of Averted Dose=		$2000*PW					$ 404.74

Case 2 PW at DCGL for Mix in 33 cubic meters of Soil

Radionuclide	λ (1/yr)	Pd*A*F/40 (unitless)	Conc (pCi/g)	DCGL (pCi/g)	N (years)	r (1/y)	PW (unitless)
Cs-137	0.0231	0.095	2.837	1.32E+01	1000	0.03	3.85E-01
Co-60	0.1317	0.095	2.429	3.21E+00	1000	0.03	4.45E-01
Sr-90	0.0427	0.095	0.040	2.48E+00	1000	0.03	2.79E-02
Mn-54	0.5749	0.095	0.157	1.37E+01	1000	0.03	1.80E-03
Fe-55	0.2665	0.095	7.475	3.58E+05	1000	0.03	6.69E-06
H-3**	0.0563	0.095	0.208	3.28E+02	1000	0.03	7.05E-04
Total			13.147				0.860
Benefit of Averted Dose=		$2000*PW					$ 1,719.05

Calculation of Gross Activity DCGL for Mix*

Radionuclide	Original Conc (pCi/g)	Site-Spec. DCGL (pCi/g)	Conc/ DCGL	Conc @ Mix DCGL (pCi/g)	Dose Check (mrem/yr)
Cs-137	0.6680	1.32E+01	5.06E-02	2.84E+00	5.21E+00
Co-60	0.5720	3.21E+00	1.78E-01	2.43E+00	1.83E+01
Sr-90	0.0094	2.47E+00	3.79E-03	3.97E-02	3.89E-01
Mn-54	0.0370	1.37E+01	2.70E-03	1.57E-01	2.78E-01
Fe-55	0.2694	3.58E+05	4.91E-06	7.46E+00	5.05E-04
H-3	0.048	3.25E+02	1.51E-04	2.08E-01	1.55E-02
Total	1.6038		2.35E-01	1.31E+01	2.42E+01

*Equation 4-4 of NUREG-1575

DATA SOURCE

This analysis utilizes soil and groundwater characterization data from systematic sampling (random and judgmental) of Survey Units 5, 8 and Canal. The data set includes all 389 plant gamma analysis samples with positive results for any radionuclide of potential plant origin listed in the survey unit characterization data tables of LTP Chapter 2 for Survey Units 5(1), 5(2), 8 and Canal. These survey units represent the areas of highest onsite soil concentrations. In addition, this analysis utilizes data of LTP Tables 2-14 and 2-11a. These tables provide data for all soil surface samples analyzed for combined gamma and HTD (hard-to-detect) nuclides (13 samples obtained for representative high contamination areas), plus subsurface soil samples analyzed for combined gamma and HTD nuclides (seven samples obtained in two areas where contamination exceeded 15 cm depth), and groundwater samples analyzed for gamma and HTD nuclides (seven samples, including representative samples of each groundwater zone).

This analysis also utilizes soil tritium data obtained from analyses in August 2002, from Survey Unit 12 (cores from the PZ-3MA location) where the upper and intermediate groundwater tritium plumes are present. This analysis is documented in the revised LTP Section 6.8.2.4.

ANALYSIS

Data obtained from analyses performed by offsite vendors for HTD radionuclides (LTP Table 2-14) have been utilized to determine surrogate relationships specific to soils and contamination types at the BRP site. Samples with positive identification of HTD nuclides (two samples with Sr-90 and one with Fe-55) are shown in Table 4D-1. Ratios (scaling factors) of the HTD radionuclides to the surrogate nuclides Cs-137 and Co-60 based on activity of positively identified Sr-90 and Fe-55, are presented in Table 4D-2.

Additional analysis was performed to identify scaling factors from a larger data population that included identified activity of HTD nuclides as well as minimum detectable activity (MDA) values when the surrogate is greater than 2.5 pCi/g. The cutoff of 2.5 pCi/g was utilized because all positive identifications occurred with surrogates above this level. Results of this analysis are provided in Table 4D-3. Use of MDA values gives a higher, therefore more conservative, ratio of 3.07 for Fe-55 than obtained by use of the single value greater than MDA (0.47). Thus, the more conservative value of 3.07 is chosen for use. In the case of Sr-90, use of the MDA data provides a lower ratio (0.012) than use of only the two values above MDA (0.020). Thus, the more conservative value of 0.020 is chosen for use.

In order to identify the actual radionuclides present, all the site and vendor data described here has been reviewed for nuclides reported as present in the analyzed samples. The radionuclides Cs-134 and Zn-65 (one identification of each among the 389 samples) have been excluded on the basis of low concentration (Cs-134 at 0.01 pCi/g) and short halflife (Zn-65 at 0.33 pCi/g).

The data set provided in the tabulations of characterization data for Survey Units 5(1), 5(2), 8 and Canal (Appendix 2-E) have been evaluated by extraction of the sample means, ranges, medians and number of positive samples from the database. The scaling rations discussed above, were then applied to the mean soil concentrations of Cs-137 and Co-60 to provide scaled means for Sr-90 and Fe-55. This data is provided in Table 4D-4.

RESULTS

Radionuclides of plant origin present in BRP soils and water are as follows:

Dry Soils:	Cs-137	Sr-90	Mn-54	Co-60	Fe-55
Water:	H-3				

Table 4D-1. Levels of Hard-to-Detect Nuclides and Surrogates in Soil

Soil Sample	$t_{1/2}$ Years	Grid 250 pCi/g 3/02	Grid 228 pCi/g 3/02
Co-60	5.27	80.7	0.51
Cs-137	30.17	3.8	8.14
Fe-55	2.7	38	
Sr-90	29	0.13	0.04

Table 4D-2. Hard-to-Detect Nuclides Scaled to Surrogates, Positive Results Only

Nuclide	Activity Sum (pCi/g)	Scale Factor	Scaled to Surrogate
Co-60	80.70	--	--
Cs-137	11.94	--	--
Fe-55	38.00	0.47	Co-60
Sr-90	0.17	0.02	Cs-137

Table 4D-3. Scaling by Inclusion of Minimum Detectable Activity Levels (MDAs) Surrogate by actual and MDA (from LTP Table 2-14)

Sr-90				Actual						Actual		
Grid	318	318	318	250	266	248	248	247	247	228		
Cs-137	3.56	4.01	4.18	3.8	21.7	14	10.2	25.7	13.36	8.14		
Sr-90 MDA	<0.02	<0.04	<0.04	0.13	<0.06	<0.6	<0.06	<0.04	<0.1	0.04		
Ratio Sr-90/ Cs-137	0.0056	0.010	0.0095	0.034	0.0027	0.042	0.0058	0.0015	0.0074	0.0049	Mean	S.D.
											0.012	0.014

Fe-55		Actual					
Grid	269	250	250	266	Canal		
Co-60	6.43	80.7.	15.6	5.17	8.27		
Fe-55 MDA	<48	38	<3.66	<36	<1.7		
Ratio Fe-55/Co-60	7.46	0.470	0.234	6.96	0.205	Mean	S.D.
						3.07	3.79

The most conservative (highest) scaling factors of Tables 4D-2 and 4D-3 have been applied in Table 4D-4 to the gamma surrogate soil and sediment concentration means provided by ArcView:

Table 4D-4. Characterization Survey Data, 389 Samples Analyzed (ArcView Output Except for Surrogate Scaling)

Nuclide	Positive Samples	Mean pCi/g	Range pCi/g	Median pCi/g[1]
Cs-137	193	0.668	0 – 30.7	0.39
Co-60	125	0.572	0 – 105.9	0.25
Mn-54	20	0.037	0 – 8.68	0.17
HTD Nuclide				
Sr-90[2]	(193)	0.013		
Fe-55[3]	(125)	1.76		

[1] – Median excludes samples with zero activity for nuclide of interest
[2] – Scaled at 0.020xCs-137 (using data from Table 4D-2)
[3] – Scaled at 3.07xCo-60 (using data from Table 4D-3)

Only three soil tritium analyses have been performed to date. The highest soil tritium identified (a sample taken from the upper groundwater zone near the center of the tritium plume just beyond the north industrial area fence line) is 0.049 pCi/g (see LTP Section 6.8.2.4).

CONCLUSION

The mean concentrations for onsite soils, as determined for the survey areas with highest contamination levels, are appropriate for use in LTP Chapter 4 ALARA analysis. These values are documented in Table 4D-4. Hard-to-detect radionuclides Sr-90 and Fe-55 should be utilized as shown in Table 4D-4. These values are obtained by use of the conservative scaling factors of 0.020 for Sr-90 : Cs-137 and 3.07 for Fe-55 : Co-60.

Due to the small number of soil tritium analyses to date, the highest observed tritium concentration (0.049 pCi/g) should be utilized.

TABLE OF CONTENTS

5.0 FINAL STATUS SURVEY PLAN 1

5.1 INTRODUCTION 1
5.1.1 Purpose 1
5.1.2 Scope 1
5.1.3 Final Status Survey Preparation and Implementation Overview 1
5.1.4 Regulatory Requirements and Industry Guidance 6

5.2 DEVELOPMENT OF SURVEY PLAN 7
5.2.1 Radiological Status 7
5.2.2 Classification of Areas 9
5.2.3 Establishing Survey Units 13
5.2.4 Access Control Measures 14

5.3 SURVEY DESIGN AND DATA QUALITY OBJECTIVES 15
5.3.1 Data Quality Objectives (DQOs) 15
5.3.2 Scan Survey Coverage 16
5.3.3 Sample Size Determination 16
5.3.4 Background Reference Area 18
5.3.5 Sample Locations and Reference Grid 18
5.3.6 Investigation Levels and Elevated Areas Test 19

5.4 SURVEY METHODS AND INSTRUMENTATION 23
5.4.1 Survey Measurement Methods 23
5.4.2 Specific Survey Area Considerations 24
5.4.3 Instrumentation 26

5.5 DATA COLLECTION AND PROCESSING 30
5.5.1 Sample Handling and Record Keeping 31
5.5.2 Data Management 31
5.5.3 Data Verification and Validation 31
5.5.4 Graphical Data Review 32

5.6 DATA ASSESSMENT AND COMPLIANCE 33
5.6.1 Data Assessment Including Statistical Analysis 33
5.6.2 Data Conclusions 34
5.6.3 Compliance 35

5.7 REPORTING FORMAT 35
5.7.1 History File 35
5.7.2 Survey Unit Release Record 35
5.7.3 Final Status Survey Report 36
5.7.4 Other Reports 36

5.8 FINAL STATUS SURVEY QUALITY PROGRAM 36
5.8.1 Big Rock Point Quality Assurance Program 37
5.8.2 FSS Quality Assurance Project Plan (QAPP) 37

5.9 REFERENCES 48

TABLES

Table 5-1 BRP Site-Specific Radionuclides and Soil DCGL Values 8
Table 5-2 Big Rock Point Initial Land Area Survey Units 11
Table 5-3 Survey Unit Sizes 13
Table 5-4 Scan Measurement Coverage 16
Table 5-5 Investigation Levels 20
Table 5-6 Area Factors for Open Land Areas 21
Table 5-7 Investigation Actions for Individual Survey Unit Measurements 22
Table 5-8 Typical FSS Instrumentation Characteristics 30
Table 5-9 Interpretation of Sample Measurements for Sign Test 33
Table 5-10 BRP Procedures Applicable to FSSs 39
Table 5-11 Target Schedule for FSS of Various Areas 43

FIGURES

Figure 5-1 Overall FSS Process 44
Figure 5-2 Big Rock Point Owner Controlled Area 45
Figure 5-3 Initial Land Area Survey Units 46
Figure 5-4 Example of Survey Unit Local Coordinate Grid 47

APPENDICES

Appendix 5-A Calculation of Tritium in Soils 5A-1

5.0 FINAL STATUS SURVEY PLAN

5.1 INTRODUCTION

The Big Rock Point (BRP) Final Status Survey (FSS) Plan has been prepared using the applicable regulatory and industry guidance. This plan will be used to develop site procedures and work instruction to perform the FSS of the BRP site.

5.1.1 Purpose

The FSS Plan describes the final survey process used to demonstrate that the BRP site complies with radiological criteria for unrestricted use specified in 10 CFR 20.1402, i.e., annual dose limit of 25 mrem plus ALARA for all dose pathways. Nuclear Regulatory Commission (NRC) regulations applicable to radiation surveys are found in 10 CFR 50.82(a)(9)(ii)(D) and 10 CFR 20.1501(a) and (b).

5.1.2 Scope

Big Rock Point intends to release site land using a phased approach. The first phase includes the majority of the site land (approximately 560 acres) scheduled for release after all demolition, remediation and FSS activities associated with plant operation are complete. The second and final phase of site release includes the Independent Spent Fuel Storage Installation (ISFSI) following spent fuel removal, facility dismantlement and any required remediation. Once both these phases are complete the BRP site license under 10 CFR Part 50 will be terminated. It is possible that release of non-impacted portions of the site could occur prior to completing demolition activities, should Consumers Energy management decide accordingly.

This FSS Plan addresses requirements applicable to the first phase of site release. This Plan address only land areas that are identified as contaminated or potentially contaminated (impacted) resulting from activities associated with commercial nuclear plant operation. All site buildings and subsurface structures and equipment, with the exception of the facilities supporting ISFSI, will be demolished and removed from the site prior to the FSS on surface spills. Surveys on excavated areas will be performed prior to backfilling (see Sections 5.2.2.3, 5.2.4.1, and 5.4.2.1 for detailed discussion on FSSs).

To the extent practical, excavation area surveys will be designed and conducted in accordance with NUREG-1575 guidance for surface surveys [Reference 5-10].

5.1.3 Final Status Survey Preparation and Implementation Overview

The FSS Plan contained in this chapter will be used as the basis for developing FSS procedures and applying existing procedures to the FSS process. Section 5.1.4 contains a list of regulatory documents used as guidance in preparing the FSS Plan. Figure 5-1 provides an overview of the FSS process. Quality Assurance requirements are outlined in Section 5.8 and apply to activities associated with decommissioning and FSS activities.

An FSS Package will be produced for each survey area; this survey package is a collection of documentation detailing survey design, survey implementation and data evaluation for a final status survey of an area. The sections below describe specific elements of the FSS organization, preparation and implementation. All processes associated with final status surveys will be conducted in accordance with approved site procedures.

5.1.3.1 FSS Organization

The general FSS organization will consist of supervision, technical specialists, work planning coordinators, field coordinators, data analysts, and technicians. Since the FSS organization has not been implemented at the time of LTP development, it is expected that specific job titles may vary over the period of project execution. These titles are used within this document to describe various functional areas of responsibility and do not necessarily refer to specific job titles. Refer to Section 5.8.2.1 for additional detail on the FSS organization.

5.1.3.2 Survey Preparation

Survey preparation is the first step in the final status survey process and occurs after any necessary remediation is completed. In areas where remediation is required, a remediation survey or equivalent evaluation will be performed to confirm that remediation was successful prior to initiating final status survey activities. Remediation surveys, turnover surveys, or equivalent evaluation, for areas not requiring remediation, will be performed using the same process and controls as a final status survey so that data from these surveys may be used as part of the final status survey data. In order for survey data to be used for final status survey, it must have been designed and collected in compliance with Sections 5.3 through 5.5 and the area controlled in accordance with Section 5.2.4. Following turnover/remediation surveys or post-remediation evaluation, the FSS is performed. Areas to be surveyed are isolated and/or controlled to ensure that radioactive material is not reintroduced into the area from ongoing demolition or remediation activities nearby and to maintain control of the area. Section 5.2 address specific survey preparation requirements and considerations.

- *Survey Package Initiation*
  Each survey unit and package is assigned a unique identification number. To allow continuity of area identification, the protocol used for identifying survey areas during the characterization survey is used, as appropriate. Survey unit identification numbers differing from those used for characterization survey may be necessary if survey boundaries are modified. Survey unit nomenclature is defined in Section 2.4.1.

- *Review of Historical Site Assessment and Characterization Survey*
  Historical data applicable to the survey area are reviewed; this information is used for survey design and is filed in the survey package. Sources of historical data include:

- Historical Site Assessment,
- Characterization Survey,
- Remediation Files,
- Background Study,
- Survey Records,
- Personnel Accounts, and
- 10 CFR 50.75(g) File

- *Survey Area Walkdown*
  A walkdown is performed to gather information about the physical characteristics of the survey area. The walkdown provides an opportunity to determine if any physical or safety related interferences are present that may affect survey design or survey implementation, and to determine any support activities necessary to implement surveys. Typical walkdown observation items include observation that demolition work is complete and all debris has been removed, grade is suitable for surveys, and the work area is safe for survey activities. The walkdown is documented and filed in the survey package. In conjunction with or following the walkdown, representative maps of the survey area are prepared.

- *Survey Area Readiness*
  Prior to performing final status surveys all decommissioning, remediation and housekeeping activities identified as having the potential to affect the area are completed. Radiation Protection personnel may perform surveys to verify that the area meets specific radiological criteria for performance of the FSS. These surveys include readiness surveys that are conducted to 1) support remediation activities, 2) determine when a site or survey unit is ready for the final status survey, and 3) provide updated estimates of site-specific parameters to use for planning the FSS (see NUREG-1575, Section 5.4.1). In order to differentiate among these three applications, the following terminologies are utilized:

  a. Remedial Action Support Survey

     An in-process survey performed to expedite the remediation process. This survey provides information to assist in cost effective remediation, but is not normally expected to provide information sufficient to demonstrate compliance with final release criteria. However, data from these surveys may provide valid information for use in evaluation of readiness for turnover in preparation for the FSS.

  b. Turnover Survey (a.k.a. Post-Remediation Survey)

     A survey, or data compilation from Remedial Action Support Surveys, that may be used to evaluate the completion status of remediation activities. If this is a formal survey designed to meet the objectives of a final status survey as described by NUREG-1575, it may serve as the FSS for the remediated area.

c. Characterization Survey (Remediation Area or Other)

This survey, if found necessary by virtue of the turnover survey or the evaluation of other applicable data, is performed in accordance with NUREG-1575, Section 5.3. As with the Turnover Survey, if the Characterization Survey is designed to meet the objectives of a final status survey as described by NUREG-1575, it may serve as the FSS.

The survey unit can then be posted to indicate that the area is controlled for the performance of final status surveys. Controls are implemented to prevent contamination of areas during and following final status surveys, as appropriate.

5.1.3.3 Survey Design

The impacted area is organized into survey units and classified by potential for residual radioactivity as Class 1, Class 2, or Class 3. The size of the survey unit is based on survey unit classification requirements in accordance with the guidance provided in NUREG-1575 (MARSSIM). The survey design process establishes the methods and performance criteria used to conduct the FSS and defines the sample point locations and type of measurements to be performed for each survey unit. Section 5.2 contains a detailed discussion of survey design requirements.

A survey map is prepared for each survey unit and a reference grid is superimposed on the map to allow use of an (x,y) coordinate system. Random numbers between 0 and 1 are generated, which are then multiplied by the maximum x and y axis values of the sample grid. This provides coordinates for each random sample location, or a random start location for systematic grid, as appropriate. The measurement/sample locations are plotted on the map. Each measurement/sample location is assigned a unique identification code, which identifies the measurement/sample by survey unit, and sequential number. The appropriate instruments and detectors, instrument operating modes and survey methods to be used to collect and analyze data are specified.

Written survey instructions that incorporate the requirements set forth in the survey design are completed. Direction is provided, as applicable to survey design, for selection of instruments, count times, instrument modes, survey methods, required documentation, alarm/investigation setpoints, alarm actions, background requirements and other appropriate instructions. In conjunction with the survey instructions, survey data forms may be prepared to assist in survey documentation. Alternatively, electronic data recording systems may be utilized. The survey design is reviewed and quality verification steps applied to ensure that appropriate instruments, survey methods and sample locations have been properly identified.

5.1.3.4 Survey Data Collection

After preparation of a survey package, the final survey data are collected. Trained and qualified personnel will perform the necessary measurements using calibrated instruments in accordance with approved procedures and instructions contained in the survey package. Section 5.5 addresses FSS data collection requirements.

Survey areas and/or locations are identified by gridding, markings, or flags as appropriate. An FSS field coordinator performs a pre-survey briefing with the survey technicians during which the survey instructions are reviewed and additional survey unit considerations are discussed (e.g., safety). The technicians gather instruments and equipment as indicated and perform surveys in accordance with the appropriate procedures and survey package specifications. Technicians are responsible for documenting survey results and maintaining custody of samples and instrumentation. At the completion of surveys, technicians return instruments and prepare samples for analysis. Survey instruments provided to the technicians are prepared in accordance with appropriate procedures and the survey instructions. Instrument calibration and performance checks are performed in accordance with applicable procedures. Data are reviewed to flag any measurements that exceed investigation criteria so that appropriate investigation surveys and remediation can be performed as necessary.

Following completion of a FSS, the need for Quality Control (QC) surveys (replicate surveys, sample recounts, etc.) is determined. If necessary, a QC survey package is developed. QC measurement results are compared to the original measurement results. If QC results do not agree with the original survey, an investigation is performed. Section 5.8 provides additional detail regarding QC survey requirements. Following investigation, the survey data validity is assessed (see below).

5.1.3.5 Data Evaluation

Survey data assessment is performed to verify that the data are sufficient to demonstrate that the survey unit meets the unrestricted use criterion. Statistical analyses are performed on the data and compared to pre-determined investigation levels (see Section 5.3.6.2). Depending on the results of the data assessment and any required investigation, the survey unit may either be released or require further remediation, reclassification, and/or resurvey. Assumptions and requirements in the survey package are reviewed for applicability and completeness; additional data needs are identified during this review. Specific data assessment requirements are contained in Section 5.6.

A review is performed of survey data and sample counting reports to verify completeness, legibility and compliance with survey design and associated instructions. As directed by FSS supervision, the following types of activities may be performed:

a. Convert data to reporting units,
b. Calculate mean, median and range of the data set,
c. Review the data for outliers,
d. Calculate the standard deviation of the data set,
e. Calculate minimum detectable concentration (MDC) for each survey type performed, and
f. Create posting, frequency or quantile plots for visual interpretation of data.

Computer programs may be utilized for these activities. FSS personnel include data quality verifications in their evaluations of statistical calculations; integrity and usefulness of the data set and the need for further data or investigation is also included. The data evaluation process is documented and filed in the survey package.

5.1.3.6 Final Status Survey Package Completion

Survey results are documented by survey unit in corresponding survey packages. Each FSS Package may contain the data from the several survey units that are contained in a given survey area. The data are reviewed, analyzed, and processed and the results documented in the FSS Package. This documentation file provides a record of the information necessary to support the decision to release the survey units for unrestricted use. An FSS Report will be prepared to provide the necessary data and analyses from survey packages for submittal to the NRC. Section 5.7 addresses reporting of survey results and conclusions.

5.1.4 Regulatory Requirements and Industry Guidance

This FSS Plan has been developed using the guidance contained in the following documents:

a. NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, (August 2000) [Reference 5-10].

b. NUREG-1505, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys*, Revision 1 (June 1998 draft) [Reference 5-12].

c. NUREG-1507, *Minimum Detectable Concentrations With Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* (June 1998) [Reference 5-12].

d. NUREG-1700, *Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans*, (December 1998, draft) [Reference 5-13].

e. NUREG-1727, *NMSS Decommissioning Standard Review Plan*, (September 2000) [Reference 5-14]

f. Regulatory Guide 1.179, *Standard Format and Content of License Termination Plans for Nuclear Power Reactors*, (January 1999) [Reference 5-15].

Other documents used in the preparation of this plan are listed in the References section (see Section 5.9).

Big Rock Point anticipates both the NRC and the Michigan Department of Environmental Quality (MDEQ) – Radiological Protection Measurement and Standards Unit may choose to conduct confirmatory measurements during BRP FSS activities. The NRC may take confirmatory measurements to make a determination in accordance with 10 CFR 50.82(a)(11) that the FSS and associated documentation demonstrate that the site is suitable for release in accordance with the criteria established in 10 CFR Part 20, subpart E.

5.2 DEVELOPMENT OF SURVEY PLAN

5.2.1 Radiological Status

The following sections provide a summary of site characterization and dose modeling results applicable to development of the BRP FSS Plan.

5.2.1.1 Identification of Radiological Contaminants

Big Rock Point plant conducted extensive radiological characterization of the site property between 1997 and 2000 to identify and document residual contamination resulting from nuclear plant operation. The effort included reviews of historical information as well as physical measurements of onsite soils and groundwater. LTP Chapter 2, *Site Characterization,* contains a detailed discussion of this effort [References 5-4 and 5-6].

5.2.1.2 Dose Modeling Summary

Dose models based on NUREG/CR-5512, Volume 1 and RESRAD Version 6.2 were used to calculate Derived Concentration Guideline Levels (DCGLs) for the BRP site. These dose models translate residual radioactivity levels into potential radiation doses to the public and are defined by three factors: (1) exposure scenario, (2) exposure pathways, and (3) exposed critical group. The scenarios presented in NUREG/CR-5512 address the major exposure pathways of direct exposure to penetrating radiation and inhalation and ingestion of radioactive materials. These scenarios also identify the critical group. The "critical group" is the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity within the assumption of the particular land use scenario.

Since all buildings, above- and below-grade structures, and equipment within the industrial area will be demolished and removed from the site, a modified resident farmer scenario was selected to develop site-specific soil DCGLs for BRP. Due to site-specific environmental parameters, the modified residential farmer scenario is considered a very conservative dose model for the BRP site. Chapter 6, *Compliance with the Radiological Criteria for License Termination,* contains the basis and results of dose modeling performed for BRP and describes modifications of the standard resident farmer scenario to exclude meat and milk pathways. Table 5-1 provides a list of all potential radionuclides that may be present in onsite soils and the corresponding DCGLs.

Table 5-1. BRP Site-Specific Radionuclides and Soil DCGL Values

Radionuclide	25 mrem/yr Limit Open Land Areas (Surface and Subsurface Soils) (pCi/g)
H-3	3.27 E+02
Mn-54	1.37 E+01
Fe-55	3.58 E+05
Co-60	3.21 E+00
Sr-90	2.48 E+00
Cs-137	1.32 E+01
Eu-152*	7.35 E+00
Eu-154*	6.78 E+00
Eu-155*	2.87 E+02

* Europium is included due to the potential to contaminate soil from concrete demolition activities.

5.2.1.3 Tritium Evaluation for Soils

The final site survey will address tritium in soils by tritium analyses on 10% of the final status survey samples for all survey areas impacted by the tritium plume (see Figures 2-13, 2-14 and 2-15). A significant portion of the tritium plume area is to be excavated for removal of Turbine Building, Radwaste Vault and Containment foundations. Tritium analysis for 10% of samples taken from excavated soils from the defined plume area, as described in LTP Section 5.4.2.4, will be performed.

Investigation will be initiated if any sample of that survey area exceeds 10% of the tritium DCGL (32.7 pCi/g), and complete resampling, with analysis of 100% of samples for tritium will be required if investigation shows that 50% of the tritium DCGL (164 pCi/g) is exceeded. An accredited laboratory will perform these analyses on samples that have been protected from moisture loss in the interval between sampling and analysis.

Soil moisture capacity of Alpena sandy gravelly loam, making up a major portion of the native soil present at the site, is 8.75% [Reference 5-17]. A calculation that utilizes a bounding tritium water concentration of 20,000 pCi/l in contact with soil is presented in Appendix 5-A. At the 20,000 pCi/l concentration for water, soil concentration for tritium is 1.03 pCi/g. This represents an annual dose contribution of 0.076 mrem/year and is less than 1% of the soil DCGL.

In addition to soil tritium analysis, monitoring for tritium in groundwater, surface waters and effluents, under the current environmental monitoring program, will continue to be performed until the final status survey is complete.

5.2.1.4 DCGLs for Surrogate Measurements

DCGLs for CS-137 and Co-60 presented above will be modified to account for the presence of hard-to-detect (HTD) nuclides, Sr-90 and Fe-55, respectively, using surrogate ratios developed from characterization data and in accordance with NUREG-1575, Section 4.3.2 [Reference 5-8]. The equation below will be used to adjust DCGL values for Cs-137 and Co-60 to demonstrate compliance with DCGLs for Sr-90 and Fe-55, respectively.

$$DCGL_{ADJ} = DCGL_M \times \frac{DCGL_{HTD}}{[(C_{HTD} / C_M) x DCGL_M] + DCGL_{HTD}}$$

where:

$DCGL_{ADJ}$ - DCGL adjusted for surrogate measurements

$DCGL_M$ - DCGL for measured nuclide (e.g., Cs-137)

$DCGL_{HTD}$ - DCGL for HTD nuclide (e.g., Sr-90)

C_{HTD} / C_M - Concentration ratio for HTD nuclide to measured nuclide

5.2.2 Classification of Areas

Prior to the FSS, a thorough characterization of the radiological status and history of the site will be completed. Although more than 90% complete at this time, characterization of a few inaccessible areas await further dismantlement. The methods and results from site characterization are described in Chapter 2. Initial classification of site areas is based on historical information and site characterization data and was performed following the guidance in Section 4.4 of NUREG-1575 and Appendix E of NUREG-1727. Since all buildings and structures will be demolished and removed from the site for disposal prior to the FSS, classification of building areas was not performed. Area classification ensures that the number of samples and the scan coverage are commensurate with the potential for residual contamination to exceed the unrestricted use criteria. Reclassification of a survey unit will only occur to a more restrictive classification, e.g., from Class 2 to a Class 1 area; and would occur if future data indicate that the initial classification was incorrect. Any survey unit reclassification will include an evaluation of the basis for the initial classification and also the potential for survey unit classification programmatic deficiency. The basis for any reclassification will be documented, a redesign of the survey package completed, and the redesigned survey initiated. If during the conduct of a FSS, sufficient evidence is accumulated to warrant an investigation and reclassification of the survey unit, the survey may be terminated without completing the survey unit package.

5.2.2.1 Non-Impacted Areas

Non-Impacted areas are defined as areas that have no reasonable potential for residual contamination resulting from nuclear plant operations. Non-impacted areas are shown on Figure 5-2.

5.2.2.2 Impacted Areas

Impacted areas may contain residual radioactivity from licensed activities. Based on the levels of residual radioactivity present, impacted areas are further divided into Class 1, Class 2 or Class 3 designations. The definitions provided below are from NUREG-1727, Pages E1 and E2.

a. Class 1 areas are impacted areas that, prior to remediation, are expected to contain residual contamination in excess of the $DCGL_w$[1].

b. Class 2 areas are impacted areas that are not likely to contain residual radioactivity in excess of the $DCGL_w$.

c. Class 3 areas are impacted areas that have a low probability of containing residual radioactivity.

5.2.2.3 Initial Classification

Based on more than 1100 measurements made during the site characterization process and from information gathered during the Historical Site Assessment (HSA), all land areas were assigned an initial classification in preparation for the FSS. In areas where data were limited, the initial classification is considered to be conservative to minimize future reclassification and additional sampling. The scope of the FSS includes all BRP impacted land areas. Table 5-2 provides a summary of initial survey unit classifications (see Chapter 2, Appendix E for a more detailed discussion of survey units). Figure 5-3 depicts these area classifications in a site map. The scope and boundaries of the FSS will be increased if survey data show significant levels of radioactivity above background in peripheral areas.

Characterization was performed and reported by initial survey unit. The area designations developed for the characterization process were used, for the most part, to delineate and classify areas for final status survey. This allows characterization data to be efficiently used for final survey area classification and for estimating the sigma value for sample size determination. For operational efficiency, each of the final survey areas listed in Table 5-2 may be subdivided into multiple areas. Smaller survey areas may be necessary to enhance the efficiency of data collection, processing, and review and serve to better support the decommissioning schedule. The classification of all subdivided survey areas will be the same as indicated in Table 5-2, unless reclassified in accordance with this LTP.

[1] The "w" in $DCGL_w$ refers to the Wilcoxon Rank Sum test per MARSSIM (NUREG-1575, page 2-3) and generally represents the uniform level of residual contamination that results in the dose limit, regardless of the statistical test used. Big Rock Point intends to use the Sign Test and will still use the term $DCGL_w$ to denote soil contamination limits, see Section 5.4.2.

Areas beneath removed foundations will undergo final status survey prior to backfill. Survey units encompassing future excavations have been classified based on characterization data and the potential for subsurface soils to contain residual radioactivity from site operations. Excavated footprints of several structures may be combined into a single survey unit for final status survey. Following the satisfactory performance of FSS on the excavated foundation footprint surface, the excavation area will be backfilled. After backfill, all soil footprints, regardless of location will be combined with the surrounding land survey area and a surface survey performed commensurate with the area classification.

5.2.2.4 Classification Changes

Initial classification of site areas is based on historical information and site characterization data. Data from operational surveys performed in support of decommissioning, routine surveillance and any other applicable survey data may be used to change the initial classification of an area up to the time of commencement of the FSS as long as the classification reflects the levels of residual radioactivity that existed prior to remediation. Areas within initial survey units may be upgraded in classification due to future requirements for laydown and storage areas during demolition activities or incorrect initial classification.

Table 5-2. Big Rock Point Initial Land Area Survey Units

Survey Unit Designation*	Description**	Initial MARSSIM Classification	Physical Size+ (m^2)
1	Southwest corner of Protected Area (PA) contains various storage and warehouse buildings and subsurface piping/utilities.	1	1624
2	West–central section of PA contains Maintenance/ Construction Complex (MCC) and subsurface piping/utilities.	1	2002
3	Northwestern section of PA contains subsurface structures and piping/utilities.	1	2000
4	North-central section of PA contains subsurface foundations of Equipment Lock and Containment Sphere and various piping/utilities	1	1613
5(1)	Southwest of Containment encompasses northern section underground Radwaste Vaults/Liquid Radwaste Processing System and portions of Equipment Lock, Containment Sphere and northwest Turbine Building foundations	1	687
5(2)	West of Turbine Building encompasses the Liquid radwaste storage tanks; Stack, southwest Turbine Building and storage tanks foundations and various buried piping/utilities	1	837
6	South-central section of PA contains various subsurface piping/equipment including liquid radwaste discharge line	1	1512

Survey Unit Designation*	Description**	Initial MARSSIM Classification	Physical Size+ (m^2)
7	South-east section of PA contains subsurface piping/equipment include liquid radwaste discharge line	1	2160
8PT#	Area beneath Pipe Tunnel, between Containment and Turbine Buildings, contains some subsurface piping	1	313
8Sphere	Area beneath Containment contains significant subsurface foundations.	1	851
8TB##	Area beneath Turbine/Service Building contains extensive subsurface structures/foundations and significant system piping and electrical conduit.	1	1347
9	Northeast corner of PA includes below-grade structures including Screenhouse foundation, portions of Containment foundation and underground storage tanks	1	2884
10	East-central section of PA includes portions of Turbine/Service and Security Buildings	1	943
11	Radwaste compound due south of PA	1	2350
12	Lake Michigan beach north of PA	2	9778
13	Lake Michigan beach east of discharge canal to east property line	3	49,370
14	Lake Michigan beach west of industrial area	3	43,334
15(1)	Wooded property due west of PA bounded by drainage ditch to the east, includes septic drainfield	2	11,611
15(2)	Wooded property west of industrial area, south of beach property	2	10,285
15(2R)	Remediated section of survey unit 15(2)	1	18
15(3)	Wooded property west of industrial area, south of beach property	3	10,056
15(4)	Wooded property west of industrial area, south of beach property	3	10,955
16	Lake Michigan beach due east of discharge canal	2	8347
17	Wooded property east of industrial area	3	263,220
18	Wooded property west of industrial area	3	84,677
19	Wooded, wetland property south of PA surrounding Radwaste Compound (Survey Unit 11)	2	11,891
59	Site property located south of US Hwy 131 (plant railroad spur)	3	34

Survey Unit Designation*	Description**	Initial MARSSIM Classification	Physical Size+ (m^2)
Canal	Plant discharge canal sediment, currently below water surface	1	610
Drainage Ditch	Seasonal stream and surface water conveyance located west of the Industrial Area flowing into Lake Michigan	2	370

*Figure 5-3 depicts locations of survey units listed on this table.
**Chapter 2, Appendix 2-E provides a detailed description of BRP survey units and associated operating history.
#PT – Pipe Tunnel
##TB –Turbine Building
+ - Survey unit areas are preliminary based on site characterization and HSA information as of 12/31/03. Survey area sizes may be revised prior to FSS.

5.2.3 Establishing Survey Units

Survey units are areas that have similar physical characteristics and contamination levels. Survey units are assigned only one classification. The site land areas will be surveyed, evaluated, and released on a survey unit basis.

5.2.3.1 Survey Unit Size

Survey unit sizes will be selected based on area classification, survey execution logistics, building demolition sequence and applicable regulatory guidance documents.

Typical survey unit sizes for soil are listed below in Table 5-3; these are consistent with NUREG-1575 guidance. Class 1 and 2 areas provided in Table 5-2 may be further subdivided into smaller areas to meet the guidelines present in Table 5-3. If larger survey unit areas are used, a technical evaluation will be presented in the FSS Package for the specific survey unit justifying the survey unit size.

Table 5-3. Survey Unit Sizes

Impacted Area Classification	Suggested Survey Unit Land Area
1	2000 m^2
2	>2000 to 10,000 m^2
3	No Limit

5.2.3.2 Site Reference Coordinate System (Reference Grid)

A reference coordinate system is used for impacted areas to facilitate the identification of survey units within the survey area. The reference coordinate system is an X-Y plot of the site area referenced to the North American Datum (NAD) – Michigan Georeference Coordinate System. Once the reference point is established, grids may be overlaid parallel to lines of latitude and longitude.

5.2.4 Access Control Measures

5.2.4.1 Turnover

Due to the large scope of demolition activities, it is anticipated that some surveys will be performed in parallel with dismantlement activities. This will require a systematic approach to turnover of areas be established. Prior to acceptance of a survey unit for final status survey, the following conditions must be satisfied in accordance with applicable procedures. These include:

a. Decommissioning activities having the potential to contaminate a survey unit shall be complete or measures taken to eliminate such potential.

b. Tools and equipment not required for the survey must be removed, and housekeeping and cleanup shall be complete.

c. Decontamination activities in the area shall be complete.

d. Access control or other measures to prevent recontamination must be implemented.

e. Turnover or remediation surveys may be performed and documented to the same standards as final status surveys so that data can be used for the FSS.

5.2.4.2 Walkdown

The principal objective of the walkdown is to assess the physical scope of the survey unit. Walkdowns of open land areas will be completed when the final configuration of the area is known, usually near or after completion of decommissioning activities for the area. The walkdown ensures that the area has been left in the necessary configuration for FSS or that any further work has been identified. The walkdown provides detailed physical information for survey design. Details such as structural interferences or sources needing special survey techniques can be determined. Specific requirements will be identified for accessing the survey area and obtaining support functions necessary to conduct final status surveys, such as excavation shoring, interference removal, dewatering, etc. Industrial safety and environmental concerns will also be identified during this walkdown.

5.2.4.3 Transfer of Control

Once a walkdown has been performed and the turnover requirements have been met, control of access to the area is transferred from the Radiation Protection - Operations group to the FSS group. Access control and isolation methods are described in the subsection below.

5.2.4.4 Isolation and Control Measures

Since all decommissioning activities will not be completed prior to the start of the FSS, measures will be implemented to protect survey areas from contamination during and subsequent to the FSS. Decommissioning activities creating a potential for the spread of contamination will be completed within each survey unit prior to the FSS. Additionally, decommissioning activities that create a potential for the spread

of contamination to adjacent areas will be evaluated and controlled. Upon commencement of the FSS for survey areas where there is a potential for re-contamination, implementation of one or more of the following control measures will be required:

- Personnel training,
- Installation of barriers to control access to surveyed areas,
- Installation of barriers to prevent the migration of contamination from adjacent or overhead areas from water runoff, etc.,
- Installation of postings requiring contamination monitoring prior to surveyed area access,
- Locking entrances to surveyed areas of the facility,
- Installation of tamper-evident devices at entrance points, or
- Routine surveys to monitor and verify adequacy of isolation and control measures. Where adjacent activities have the potential to impact previously surveyed surfaces, monitoring surveys consisting of soil samples and/or scans will be conducted monthly, as a minimum.

Routine surveys will not be required for open land areas that are not normally occupied and are unlikely to be impacted by decommissioning activities. Post-FSS survey locations will be judgmentally selected for survey, based on technical or site-specific knowledge and current conditions present in or near the survey area. These surveys are primarily designed to detect the potential migration of contaminants from decommissioning activities taking place in adjacent areas.

5.3 SURVEY DESIGN AND DATA QUALITY OBJECTIVES

This section describes the methods and data required to determine the number and location of measurements or samples in each survey unit and the coverage fraction for scan surveys. The design activities described in this section will be documented in a survey package for each survey unit. Survey design includes the following:

- Data Quality Objectives (DQOs)
- Scan Survey Coverage
- Sample Size Determination
- Reference Grid and Sample Location

5.3.1 Data Quality Objectives (DQOs)

The appropriate design for a given survey area is developed during the DQO process as outlined in NUREG-1575 (MARSSIM, Appendix D). These seven steps are:

- State the problem
- Identify the decision
- Identify inputs to the decision
- Define the study boundaries
- Develop a decision rule
- Specify limits on decision errors
- Optimize the design for obtaining data

The DQO process will be used for designing and conducting all final status surveys at BRP. Each survey package will contain the appropriate information, hypothesis, statistical parameters and contingencies to support the DQO process.

5.3.2 Scan Survey Coverage

The area covered by scan measurement is based on the survey unit classification as described in NUREG-1575 (MARSSIM) and as shown in Table 5-4 below. A 100% scan coverage of Class 1 survey units will be required. The emphasis will be placed on scanning the higher risk areas of Class 2 survey units. Scanning percentage of Class 3 survey units will be performed on potential areas of contamination based on the judgment of FSS technical personnel.

Table 5-4. Scan Measurement Coverage

Class	Coverage Percent
1	100%
2	10 – 100%*
3	Judgmental (<10%)

* For Class 2 Survey Units, the amount of scan coverage will be proportional to the potential for finding areas of elevated activity or areas close to the release criterion in accordance with NUREG-1575 (MARSSIM, Section 5.5.3). Accordingly, BRP personnel will use the results of individual measurements collected during characterization to correlate this activity potential to scan coverage levels.

5.3.3 Sample Size Determination

NUREG-1575 (MARSSIM) describes the process for determining the number of survey measurements necessary to ensure a data set sufficient for statistical analysis. Sample size is based on the relative shift, Type I and II errors, sigma, and the specific statistical test used to evaluate the data. Data point measurements or samples are used in the statistical analysis assume a random distribution. Alternate measurement processes or new technologies may be utilized provided they meet the applicable requirements of this plan for calibration, detection limit, area coverage, operator qualification, etc.

5.3.3.1 Statistical Tests

Appropriate tests will be used for the statistical evaluation of survey data as described in NUREG-1575 (MARSSIM). For BRP final status surveys, it has been determined that contaminants (i.e., Cs-137) present in background constitute only a small fraction of the DCGL; therefore, the Sign Test will be used for the majority of the survey unit data evaluations (see Section 2.3.3). Alternate statistical tests may be employed as appropriate or as specific situations are encountered.

5.3.3.2 Decision Errors

The probability of making decision errors is controlled by hypothesis testing. The survey results will be used to select between one condition of the environment (the null hypothesis) and an alternate condition (the alternative hypothesis). These hypotheses, chosen from NUREG-1575, are defined as follows:

- Null Hypothesis (H_0): The survey unit does not meet the release criteria
- Alternate Hypothesis (H_a): The survey unit does meet the release criteria

A Type I decision error would result in the release of a survey unit containing residual radioactivity above the release criteria. This occurs when the null hypothesis is rejected when it is actually true. The probability of making a Type I error is designated as "α". A Type II decision error would result in the failure to release a survey unit when the residual radioactivity is below the release criteria. This occurs when the Null Hypothesis is accepted when it is not true. The probability of making a Type II error is designated as "β". Type I and Type II decision error probabilities are initially set at 0.05. These values may be modified to optimize survey designs following the guidance of NUREG-1575, Appendix D. Type I decision errors will only be increased in accordance with the requirements of Section I.

5.3.3.3 Relative Shift

The relative shift (δ / σ) is an expression of the resolution of the measurements in units of uncertainty. The relative shift is calculated as follows:

$$\delta/\sigma = (DCGL - LBGR)/\sigma$$

where:

δ – Shift or width of Gray Region equivalent to (DCGL-LBGR)
DCGL – Derived Concentration Guideline Level
LBGR – Lower Bound of the Gray Region
σ – Sigma, estimate of the standard deviation of the concentration of radioactivity in the survey unit

- *Lower Bound of the Gray Region*
  The Lower Bound of the Gray Region (LBGR) is the point of acceptable Type II (β) error. The LBGR is initially set at 0.5 times the $DCGL_w$; however, this value may be adjusted to optimize the relative shift for the determination of sample size as described in NUREG-1575, Appendix D. Generally, Table 5-5 of NUREG-1575 will be used to determine the number of sample data points.

- *Sigma*
  The sigma value is the estimate of the standard deviation of the concentration of radioactivity in the survey unit. Sigma values for survey design are developed from survey data that have utilized identical measurement techniques as those to be performed in the FSS. Sigma values may also be determined by estimation based on site-specific knowledge.

5.3.3.4 Sign Test Sample Size

The number of data points is determined from NUREG-1575 (MARSSIM), Table 5.5, for application of the Sign Test. This table includes the recommended 20% adjustment to ensure an adequate sample size and will be used to determine the appropriate sample size using the applicable parameters for Type I (α) and Type II (β) decision errors and relative shift (δ / σ) discussed previously.

5.3.3.5 Elevated Measurement Comparison (EMC) Sample Size Adjustment

If the actual scan MDC is greater than the required scan MDC (see Section 5.3.6.3), the sample size for the area of elevated activity will be determined using the equation provided below.

$N_{EMC} = A / A_{EMC}$

where:

N_{EMC} - Elevated Measurement Comparison sample size
A - Survey unit area
A_{EMC} - Area corresponding to the area factor calculated using the scan MDC Concentration (see Section 5.3.6.3)

5.3.4 Background Reference Area

Since it has been determined Cs-137 is present at less than 5% of the DCGL, background reference area measurements are not necessary (see Section 2.3.3). In the event that it is determined that background measurements are needed, they will be collected as described in Chapter 12 of NUREG-1505. If this occurs, the appropriate statistical test will be utilized in accordance with NUREG-1575 (MARSSIM).

5.3.5 Sample Locations and Reference Grid

Sample location is a function of the number of measurements required, the survey unit classification, and the contaminant variability.

5.3.5.1 Sample Locations

Measurement locations within the survey unit are clearly identified and documented for purposes of reproducibility. Actual measurement locations are identified by tags, labels, flags, stakes, paint marks, geopositioning units or photographic records. An identification code matches a survey location to a particular survey unit. Sample points for Class 1 and Class 2 survey units are positioned in a systematic pattern or grid throughout the survey unit by first randomly selecting a start point coordinate. A random number generator is used to determine the start point of the square grid pattern. The grid spacing, L, is a function of the area of the survey unit as shown below:

for a square grid A $$L = \sqrt{\frac{A}{n}}$$

where:

L = grid spacing length
A = the area of the survey unit,
n = the number of sample points in the survey unit (determined from NUREG-1575 Table 5.5)

Sample points are located, L, distance from the random start point in both the X and Y directions. Random sample point locations are used for Class 3 survey units. Sample location coordinates are specified using a random number generator. Measurement locations selected using a random selection process or a randomly-started systematic pattern that do not fall within the survey unit or that cannot be surveyed due to site conditions are replaced with additional random point locations as appropriate.

5.3.5.2 Reference Grid

The sample reference grid is illustrated on sample location maps. Grid reference points may also be physically marked in the field. An example reference grid and sample location map is shown in Figure 5-4. Global Positioning System (GPS) instruments may be used in open land areas to determine reference or sample grid locations within the survey area.

5.3.6 Investigation Levels and Elevated Areas Test

During survey unit measurements, levels of radioactivity may be identified that warrant investigation. Depending on the results of the investigation, the survey unit may require no action, remediation, and/or reclassification and resurvey. Investigation process and investigation levels are described below.

5.3.6.1 Investigation Process

During the survey process, locations with residual activity exceeding investigation levels are marked for further investigation. The elevated survey measurement is verified by resurvey. For Class 1 areas, size and average activity level in the elevated area is acceptable if it complies with the area factors and other criteria that may apply to evaluation of the DCGL for elevated measurements $DCGL_{EMC}$. As discussed in Section 5.3.6.3 below, the $DCGL_{EMC}$ is applicable only for Class 1 areas. If any location in a Class 2 area exceeds the $DCGL_{w}$, scanning coverage in the vicinity is increased in order to determine the extent and level of the elevated reading(s) and the area evaluated for reclassification. If the elevated reading occurs in a Class 3 area, the scanning coverage is increased and the area evaluated for reclassification and resurvey under the criteria of the new classification. All survey unit investigations will be conducted in accordance with the applicable FSS data quality objectives (DQOs).

Investigations should address: (1) the assumptions made in the survey unit classification; (2) the most likely or known cause of the contamination; and (3) the effects of summing multiple land areas with elevated activity within the survey unit. Depending on the results of the investigation, a portion of the survey unit may be reclassified or combined with an adjacent area with similar characteristics if there is sufficient justification. Either action would result in resurvey of the (new) area(s). The results of the investigation process are documented in the Survey Package.

5.3.6.2 Investigation Levels

NUREG-1575 (Table 5.8) and NUREG-1727 (Table E.2) provide investigation levels for scan surveys. In addition to investigation levels for scan surveys, direct measurement survey investigation levels have also been developed. These additional investigation levels include a very conservative value for Class 3 survey units as shown in Table 5-5.

Table 5-5. Investigation Levels

Classification	Scan Measurement	Soil Sample Analyses
Class 1	> $DCGL_{EMC}$	> $DCGL_{EMC}$ or > $DCGL_w$ + (statistical based parameter value)
Class 2	> $DCGL_w$ or >MDC_{scan}*	> $DCGL_w$
Class 3	> $DCGL_w$ or >MDC_{scan}*	> 0.5$DCGL_w$

* The larger of MDC_{scan} or $DCGL_w$ will be used.

Soil samples collected for tritium analysis (Section 5.2.1.3) are subject to the following additional investigation requirements:

Soil tritium concentrations greater than 10% DCGL

- Verify sample location and analysis, and
- Investigate potential trending in tritium concentration within the survey unit

Soil tritium concentrations greater than 50% DCGL

- Determine the lateral and vertical extent of tritium contamination within the survey unit, and
- Repeat the final status survey process for the survey unit to include tritium analysis and evaluation for all samples collected

5.3.6.3 Elevated Measurement Comparison (EMC)

The elevated measurement comparison is used for Class 1 survey units when one or more scan or static measurement exceeds the investigation level. The EMC provides assurance unusually large measurements receive the proper attention and that any area having the potential for significant dose contribution is identified. As stated in NUREG-1575, the EMC is intended to flag potential failures in the remediation process and should not be considered the primary means to identify whether or not a survey unit meets the release criterion. Locations identified by scan methodology with levels of residual radioactivity which exceed the $DCGL_{EMC}$ or soil sample analyses measurements with levels of residual radioactivity which exceed the $DCGL_{EMC}$ or $DCGL_w$ + (mean + 3σ) (of survey unit) are subject to additional surveys to determine compliance with the elevated measurement criteria. The size of the area containing the elevated residual radioactivity and the average level of residual activity within the area are determined. The average level of activity is compared to the $DCGL_W$ based on the actual area of elevated activity. The initial $DCGL_{EMC}$ is established during the survey design and is calculated as follows:

$DCGL_{EMC}$ = Area Factor x $DCGL_w$

The area factor is the multiple of the $DCGL_w$ that is permitted in the area of elevated residual radioactivity without remediation. The area factor is related to the size of the area over which the elevated activity is distributed. That area is generally bordered by levels of residual radioactivity below the $DCGL_w$ and is determined by the investigation process. Area factors calculations are described in Section 6.10 and summarized in Table 5-6 [Reference 5-5]. Alternatively, Figures 6-2 and 6-3 provide a graphical method for selecting applicable area factors. The actual area of elevated activity is determined by investigation surveys and the area factor is adjusted for the actual area of elevated activity. The product of the adjusted area factor and the $DCGL_w$ determines the $DCGL_{EMC}$. If the $DCGL_{EMC}$ is exceeded, the area is remediated and resurveyed. The results of the elevated area investigations in a given survey unit that are below the $DCGL_{EMC}$ limit are evaluated using the equation below. If more than one elevated area is identified in a given survey unit, the unity rule can be used to determine compliance. If the formula value is less than unity, no further elevated area testing is required and the EMC test is satisfied.

Table 5-6. Area Factors for Open Land Areas*

Contaminated Area (m^2)	Calculated Area Factors at Time of Peak Dose								
	H-3	Mn-54	Fe-55	Co-60	Sr-90	Cs-137	Eu-152	Eu-154	Eu-155
8094	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4047	1.00	1.01	1.00	1.01	1.00	1.02	1.02	1.01	1.02
2024	1.00	1.03	1.00	1.03	1.00	1.03	1.03	1.03	1.03
1012	1.35	1.04	1.00	1.04	1.00	1.04	1.05	1.04	1.04
506	2.91	1.09	1.98	1.08	1.98	1.13	1.07	1.07	1.06
253	6.05	1.14	3.95	1.13	3.94	1.20	1.11	1.11	1.09
126	12.4	1.20	7.93	1.20	7.87	1.29	1.17	1.16	1.14
63	24.9	1.30	15.8	1.30	15.6	1.41	1.27	1.26	1.23
32	49.2	1.49	31.2	1.49	30.5	1.62	1.44	1.45	1.39
16	98.9	1.78	62.0	1.78	59.9	1.93	1.72	1.73	1.63
8	198	2.38	123	2.38	117	2.58	2.30	2.31	2.14
4	397	3.61	243	3.62	230	3.91	3.49	3.52	3.19
2	794	5.68	473	5.75	452	6.14	5.48	5.55	4.90
1	1590	9.57	905	9.73	887	10.3	9.24	9.39	7.88

* Table 5-6 is identical to Appendix 6-L of Chapter 6.

The following formula applies to a single radionuclide contaminant. When multiple radionuclides are present, the calculation is made for each radionuclide and the sum for all radionuclides must total less than one.

$$\frac{\delta}{DCGL_W} + \frac{(Conc_{AVG} - \delta)}{(AreaFactor)(DCGL_W)} < 1$$

where:

$Conc_{AVG}$ - average concentration in elevated area

δ - Estimate of average concentration of residual radioactivity

If more than one elevated area exists in the survey unit, a separate term check will be included for each.

In practice, the ratio of Co-60 to Cs-137 in BRP soils is variable. Although this does not affect the ability to determine actual DCGL for the mixture from laboratory analyses or in-situ gamma spectrum analyses, it does affect ability to pre-define investigation levels and scan MDCs where ratios vary within a survey area. To access this issue, BRP will employ one of the following approaches:

1) Subdivide the survey unit into areas having low variability so that actual pre-determined nuclide ratios may be taken into account in the mixture DCGL and MDC calculations, or

2) Utilize conservative calculational techniques for variable ratio survey areas, which assume that the most limiting gamma-emitting radionuclide (lowest DCGL of the gamma-emitting nuclides detected at Big Rock Point) dominates the mixture (Co-60).

5.3.6.4 Remediation and Reclassification

As shown in Table 5-7, Class 1 or Class 2 areas of elevated residual activity above the $DCGL_{EMC}$ are remediated to reduce the residual radioactivity to acceptable levels. Based on survey data, it may be necessary to remediate an entire survey unit or only a portion of it. If an individual survey measurement (scan or direct) in a Class 2 survey unit exceeds the $DCGL_w$, the survey unit or a portion of it may be reclassified to a Class 1 survey unit and the survey redesigned and re-performed accordingly. If an individual survey measurement in a Class 3 survey unit exceeds 0.5 $DCGL_w$, the survey unit, or portion of a survey unit, will be evaluated, and if necessary, reclassified to a Class 2 and the survey redesigned and re-performed accordingly.

Table 5-7. Investigation Actions for Individual Survey Unit Measurements

Area Classification	Action if Investigation Results Exceed:		
	$DCGL_{EMC}$	$DCGL_w$	.5 $DCGL_w$
Class 1	Remediate or perform EMC evaluation	Acceptable*	N/A
Class 2	Reclassify and investigate**	Reclassify and investigate**	N/A
Class 3	Classify and investigate**	Reclassify and investigate**	Reclassify and resurvey, increase scan coverage

*For individual measurements above $DCGL_w$ plus the designated statistical-based parameter, the Sign Test will be conducted on the survey unit and an EMC evaluation performed.

**Requires an investigation of the initial classification process and a survey unit evaluation of sufficient intensity to satisfy the requirements of new classification status.

5.3.6.5 Resurvey

Following an investigation, if a survey unit is reclassified to a more restrictive classification or if remediation activities were performed, a resurvey is performed in accordance with approved procedures. If a Class 2 area had contamination greater than the $DCGL_W$ it should be reclassified to a Class 1 area. If the average value of Class 2 direct survey measurements was less than the $DCGL_W$, the scan MDC was sensitive enough to detect the $DCGL_{EMC}$ and there were no areas greater than the $DCGL_{EMC}$, the survey redesign may be limited to obtaining a 100% scan without having to re-perform the soil sample analyses. This condition assumes that the sample density meets the requirements for a Class 1 area.

5.4 SURVEY METHODS AND INSTRUMENTATION

5.4.1 Survey Measurement Methods

Survey measurements and sample collection are performed by personnel who have received training and are qualified to perform these activities. The techniques for performing survey measurements or collecting samples are specified in approved procedures. Final status survey measurements include surface scans and gamma spectroscopy of soil samples. In-situ gamma spectroscopy or other methods may be utilized provided that approved procedures are utilized and instrument sensitivity is sufficient to meet or exceed minimum required detection levels. Volumetric soils samples may be analyzed using on-site laboratory gamma spectroscopy, in-situ gamma spectroscopy, and sodium-iodide gamma detection for scanning in accordance with applicable procedures. Off-site laboratory facilities may also be used for QC as specified in applicable procedures. Analytical methods for both onsite and offsite laboratory facilities will be established to ensure minimum detection levels of 10% to 50% of the DCGL value. Other methods not specifically described may also be used for final status surveys provided that approved procedures for these methods are utilized.

Soil will receive scan surveys at the coverage level described in Table 5-4 and volumetric samples will be taken at designated locations. Surface soil samples will normally be taken at a depth of 0 to15 cm. Areas of sub-surface soil contamination will require sampling at a depth greater than 15 cm. The potential for sub-surface contamination will be addressed during the survey design process, and the associated survey package will contain requirements for sampling or in-situ measurements of soil below 15 cm. All activities will be performed in accordance with approved procedures.

5.4.1.1 Scans

Open land areas are scanned for gamma emitting nuclides. The gamma emitters are used as surrogates for the Hard-to-Detect (HTD) radionuclides. Sodium iodide detectors will be used for scanning open land areas at the BRP site.

5.4.1.2 Volumetric Samples

Laboratory gamma spectroscopy is used to analyze collected soil samples. Soil samples size is approximately 1600 grams. Surface samples are collected from the top 15 cm of soil and subsurface soil samples are collected at depths below 15 cm. Sample preparation includes removing extraneous material, homogenizing, and drying the soil for gamma isotopic analysis. Separate containers are used for each sample and each container is tracked through the analysis process using a chain-of-custody record. Samples are split when required by the applicable quality control procedures.

If contamination below 15 cm is suspected or known, samples will be collected using an auger or equivalent method. If a survey area has already been excavated and remediated to the soil DCGL, this area will be treated as a surface soil, and the FSS will be performed on the excavated area. Since all buildings and structures used during nuclear plant operations are scheduled for removal, it is expected that the majority of the survey units within the Industrial Area will include excavated areas. Soil samples will be collected to depths at which there is high confidence that deeper samples will not result in higher concentrations. Alternatively, a sodium-iodide detector or intrinsic germanium detector of sufficient sensitivity to detect DCGL concentrations may be utilized in a "down hole" configuration to identify the presence or absence of subsurface contamination, and the extent of such contamination. If the detector identifies the presence of contamination at a significant fraction of the DCGL, confirmatory laboratory analyses of soil samples of the suspect areas will be performed. Areas where subsurface samples may be collected include the Turbine Building, Containment Building, liquid and solid radioactive waste vaults, and effluent stack foundation areas. All subsurface sampling will be performed in accordance with the guidance in Section 11.1 of NUREG-1727. The sample size for subsurface samples will be determined using the same methods described for surface soil. Per NUREG-1727, scanning is not applicable to subsurface areas; however, BRP FSSs will employ scanning techniques commensurate with the survey unit classification. Scanning on subsurface soils, where accessible as an excavated surface, will demonstrate compliance with site release criteria.

5.4.2 Specific Survey Area Considerations

5.4.2.1 Septic Field

The only onsite subsurface equipment to remain in place after site release is the septic system drainfield located just west of the former plant protected area. The septic drainfield is a ceramic tile system, approximately 3000 m^2. All piping leading to this drainfield and associated tanks will be removed. The drainfield is considered a Class 2 area and will be surveyed as a single survey unit. The FSS for this survey unit will include both an evaluation of surface and subsurface soils. Mechanical coring equipment may be utilized to provide access for down-hole measurements and to obtain necessary subsurface samples. The FSS of the septic drainfield will also include collection of shallow groundwater samples for radioactivity analysis.

5.4.2.2 Pavement-Covered Areas

Survey of paved areas will be required along the roadways providing ingress and egress to the site. Evaluation has determined that paved roadways are Class 3 areas. All other pavement, including that in parking lots and asphalt within the protected area, will be removed for disposal prior to the FSS. The survey design of paved areas will be based on soil survey unit sizes since they are outdoor areas where the exposure scenario is most similar to direct radiation to surface soil. Scan and static gamma and beta-gamma surveys are made as determined by the survey unit design. If the potential exists for sub-surface contamination under pavement, either the pavement/asphalt will be removed prior to the FSS or samples obtained through the pavement. Pavement will remain only in Class 3 areas; scanning of paved areas will generally not be conducted, as Class 3 areas only require judgmental scanning of a small portion of the survey unit (see Section 5.3.2). Paved areas may be separate survey units or they may be incorporated into surveys of other adjacent open land areas of like classification. Surveys of paved areas may include road right-of-ways to check for radioactivity relocated from water runoff. Right-of-ways may also be separate survey units.

5.4.2.3 Discharge Canal Sediment

The discharge canal area will be evaluated as a separate survey unit. A coffer dam or equivalent method will be used to control lake water during survey activities in this area. The FSS will be performed prior to returning the shoreline to its original contour. The FSS of the discharge canal may be performed in conjunction with surveys of adjacent beach areas.

5.4.2.4 Stored Excavated Soil

It is expected that soil will be stored around the site resulting from various decommissioning activities. Soil volumes resulting from excavations to remove building foundations or buried piping may be relocated to support work activities. The locations from which stored soil originated will be tracked and storage areas controlled so that no contamination of soils will occur as a result of decommissioning activities. It is anticipated that much of this stored soil can be used for backfilling soil excavation areas after the FSS is completed. The following paragraphs provide the survey methodology for verifying that this soil is acceptable for backfill purposes.

The primary method for evaluation of excavated soils originating from Class 1 and Class 2 areas will follow the guidance provided in NUREG-1575 for Final Status Survey of Class 1 areas. Excavated soil will be evaluated in accordance with BRP procedures to determine suitability for transport and final status evaluation. Prior to performing a final status survey, excavated soil will be characterized to determine suitability for transport to an area dedicated for excavated soils. Soils that do not identify residual radioactivity greater than DCGL values will be relocated to an area dedicated for soil evaluation and graded to a maximum depth of one meter. A Class 1 final status survey will then be conducted with samples for laboratory analysis homogenized over the total depth of soil. Surface scanning and laboratory analyses will be directly compared with DCGL values. Any measurement location identifying residual radioactivity above the DCGL will be investigated and

remediated. Controls will be instituted to prevent mixing of soils from different survey areas prior to evaluation. Soils satisfying the criterion for unrestricted release will be stockpiled for use as onsite backfill material.

The radiological evaluation of soils resulting from minor trenching and digging efforts in Class 3 defined areas (no reasonable potential for subsurface contamination) will be performed by characterization survey in accordance with site procedures. Excavated soils that demonstrate residual radioactivity consistent with Class 3 status will be released for use as onsite excavation backfill.

An alternate method that may be used for evaluation of excavated soil is large-container assay performed by gamma spectroscopy.[2] If alternate methods other than those described above are to be utilized for the evaluation of excavated soils, the NRC will be given the opportunity to review technical basis evaluation(s) justifying the alternate techniques.

5.4.2.5 Groundwater Surveys

Groundwater sampling and monitoring will be performed during excavation of building foundations and subsurface structures and during FSS of corresponding survey areas, as necessary. Groundwater sampling will consist of gamma spectrum analysis and tritium analysis since this is the only radionuclide identified in site groundwater. Additionally, groundwater and surface water flow control measures will be in place during demolition activities to minimize or eliminate the impact of water movement. Dewatering activities may require placement of temporary barriers to inhibit groundwater flow; groundwater flow is not expected to be influenced beyond the demolition interval.

Monitoring wells within the tritium plume (wells MW-5 and MW-6 and piezometric wells PZ-3MA, PZ-3MB, PZ-3D and PZ-5S) will remain operable through the end of the final status survey and be sampled and analyzed quarterly, as available, for both gamma-emitting radioisotopes and tritium. To ensure that adequate data from groundwater strata are obtained, BRP will replace or repair any of these wells that become unusable. Any replacement well will allow sampling of the same groundwater zone as the well it replaces, and will be placed as close to the original location as possible in order to allow data continuity.

5.4.3 Instrumentation

Radiation detection and measurement instrumentation for the FSS is selected to provide both reliable operation and adequate sensitivity to detect the radionuclides identified at the site at levels sufficiently below the DCGL. Site history and characterization efforts have identified Cs-137 and Co-60 as the predominant radionuclides present in BRP site soils. Other radionuclides of plant origin, including hard-to-detect nuclides are present at levels much lower that those of Cs-137 and

[2] This survey method is the same as that used for the 10 CFR 20.2002 process approved for disposal of BRP demolition debris.

Co-60. Table 5-1 provides a list of potential radionuclides for evaluation in BRP site soils. Soil sampling and analysis have demonstrated that direct measurements of Cs-137 and Co-60 can be used as surrogates for estimating levels of other contaminants that may be present in BRP soils.

Detector selection is based on detection sensitivity, operating characteristics and expected performance in the field. Portable instruments, laboratory instruments and bulk assay equipment may be used to perform these basic survey measurements:

- surface scanning,
- laboratory gamma spectroscopy of soil samples, and
- gamma spectroscopy using the bulk assay monitor equipment
- direct surface contamination measurements (static or in-situ),

Radiation protection instrumentation procedures control the issuance, use, and calibration of instrumentation. Records supporting the instrumentation program are maintained in accordance with site document control procedures.

5.4.3.1 Selection

Radiation detection and measurement instrumentation is selected to meet the requirements of survey design. Gamma spectroscopy instruments used for soil sample analyses are capable of residual radioactivity detection at values less than 10% of the $DCGL_w$. Instruments used for surface scanning are capable of detecting radioactive material at levels below the $DCGL_{EMC}$ in Class 1 areas [Reference 5-3]. MDC values for scanning instruments used in Class 1 and 2 areas have the capability of detecting residual radioactivity below the $DCGL_w$. Instrumentation currently proposed for use in the FSS is listed in Table 5-8 found in Section 5.4.3.5. Instrument MDCs are discussed in Section 5.4.3.4 and nominal MDC values are also listed in Table 5-8.

Other measurement instruments or techniques other than gamma spectroscopy or NaI scanning may be utilized if evaluation determines that alternate instrumentation is equally or more efficient than the survey instruments currently proposed in this plan. The acceptability of alternate instruments or technologies for use in the FSS Program would be justified in a technical basis evaluation document to ensure equivalent or better instrument sensitivity. Technical basis evaluations for alternate final status survey instruments or techniques will be provided for NRC review prior to use. An instrument technical analysis document will include the following:

a. Description of the conditions under which the method would be used;

b. Description of the measurement method, instrumentation and criteria;

c. Justification that the technique would provide the required sensitivity for the given survey unit classification in accordance with Table 5-5; and

d. Demonstration that the instrument provides sufficient sensitivity for measurement below the release criteria with Type 1 error equivalent to 5% or less.

5.4.3.2 Calibration And Maintenance

Instruments and detectors are calibrated for the radiation types and energies of interest at the site. Gamma scintillation detectors are calibrated using Cs-137, but the energy response and MDC for Co-60 has also been determined since discrete areas of Co-60 contamination have been found by soil surface scans. Instrumentation for detecting alpha contamination is not expected to be required for BRP FSSs based on HSA information and site characterization data (see Sections 2.2.4 and 2.3.2).

Instrumentation used for the FSS will be calibrated and maintained in accordance with the BRP Radiation Protection & Environmental Services Department procedures. Radioactive sources used for calibration are traceable to the National Institute of Standards and Technology (NIST) and have been obtained in standard geometries to match the type of samples being counted. If vendor services are used, these will be obtained in accordance with purchasing requirements for quality related services, to ensure the same level of quality.

5.4.3.3 Response Checks

Instrumentation response checks are conducted to assure proper instrument response and operation. An acceptable response for field and laboratory instrumentation is an instrument reading within +/- 3 sigma as documented on a control chart. As a minimum, response checks are performed daily prior to instrument use. Source checks use source energies consistent with the nuclides encountered at the BRP site. If an instrument fails a response check, it is appropriately identified and withheld from use until the problem is corrected in accordance with applicable procedures. Measurements made from the time of the last acceptable check and the failed checks are evaluated to determine if they should remain in the data set.

5.4.3.4 Minimum Detectable Concentration (MDC)

An MDC is determined for each of the instruments used for final status surveys. The MDC is the concentration of radioactivity that an instrument can be expected to detect 95 percent of the time.

- *Laboratory Spectrometer Analysis*
  The onsite chemistry laboratory maintains two gamma isotopic spectrometers that are calibrated to various sample geometries, including a one-liter marinelli geometry for soil analysis. These systems are calibrated using a NIST mixed gamma source. Both detectors are manufactured by PGT and operate using the VMS Genie platform from Canberra Industries. Laboratory counting systems have software controlled count times which are set to meet a maximum MDC of 0.15 pCi/g for Cs-137 in soil; this is calculated as follows:

$$MDC = {L_d}/{K * V * T}$$

where:

L_d – limit of detection = $3 + 4.65 * \sqrt{bkg}$

K - proportionality constant relating detector response to activity level

V - mass of sample

T - count time

- *Land Area Scans*
  Evaluation of open land areas for unrestricted release must include a detection methodology of sufficient sensitivity to allow identification of small areas of potentially elevated activity within a survey unit. Surface scanning measurements for BRP land areas are performed by continuously passing a 2-inch x 2-inch sodium iodide (NaI) gamma scintillation detector over the subject land surface at a specified rate of speed. The scan technique uses an audible response to monitor for increase in count rate (see Chapter 2, Appendix D). An audible increase in instrument count rate requires further investigation to verify findings and define the level and extent of contamination.

  Alternatively, in-situ gamma spectroscopy of variable size areas may be utilized for areas with special considerations. In-situ measurements will cover up to one survey grid (10m x 10m) of the survey area and may also provide measurements of the same small areas (one square meter) of potentially elevated activity. The value of in-situ spectroscopy is its ability to distinguish between residual radioactive material contamination and natural radioactive materials in stone or rock. Such natural materials have been found in onsite characterization surveys and are difficult to analyze by laboratory means when large stones or rocks are responsible for the elevated activity.

- *Land Area Scan Instrument Sensitivity*
  A determination of scanning sensitivity is performed to ensure that the measurement system is able to detect concentrations of radioactivity at levels below the release limit. Expressed in terms of the scan MDC, this sensitivity is the lowest concentration of radioactivity for a given background that the measurements system is able to detect at a specified performance level. Survey planning for soil survey units will be based on a scan MDC associated with a one-meter wide strip for scanning. Rate of scan transverse will be such that the resulting scan MDC is sufficient to detect areas of elevated activity with a measurement accuracy confidence limit of 95%. This two-stage scanning technique is described in NUREG-1507 and has been evaluated for use on BRP open land areas (see Chapter 2, Appendix 2-D).

- *In-Situ Measurement Sensitivity*
  A Canberra ISOCS in-situ system, utilizing a 40% intrinsic germanium detector, has been used in site characterization [Reference 5-2]. Sensitivity for Cs-137 and Co-60 of less than 10% of initial DCGLs has been demonstrated. In-situ gamma spectroscopy for FSS will be conducted in association with the laboratory analysis of soil grab samples and/or other approved measurement techniques. The resulting analyses are then compared for the identification of potential non-homogeneous radioactivity concentrations within the survey unit. Survey units failing acceptance criteria will require further investigation.

5.4.3.5 Detection Sensitivity

The nominal detection sensitivity of detectors that may be used for final status surveys has been determined. Count times are instrument-specific and are selected to ensure that the measurements are sufficiently sensitive for the DCGL. For example, the count times associated with gamma spectroscopy of volumetric materials are administratively established to achieve MDCs less than the DCGL. The MDC scan values may not always be less than the $DCGL_W$, but will be less than $DCGL_{EMC}$ (see Section 5.3.6.3). Table 5-8 provides a summary of FSS instruments for BRP.

Table 5-8. Typical FSS Instrumentation Characteristics

Instrument and Detector	Measurement Type	Instrument Efficiency	MDA/MDC
2" x 2" NaI	Gamma*	1200 cpm/mR/hr (Cs-137)	Class I < $DCGL_{EMC}$** Class 2&3 < $DCGL_W$
Canberra Genie	Laboratory Gamma	9.7% & 44.1% (2 detectors)	< 10% of < $DCGL_W$
Canberra ISOCS	In-Situ Gamma	40%	< $DCGL_W$

* Scan for gamma emitting nuclides using the Ludlum 2350-1 rate meter or equivalent.
** MDC values for varying background values are provided in Chapter 2, Appendix 2-D.

Site-specific DCGLs have not been established for transuranic radionuclides, since they have been discounted on the basis of dose in LTP Section 6.7.2.2. However, since transuranic radionuclides are of potential concern, laboratory and In-Situ gamma analyses will continue to utilize the Am-241 MDC of 0.44 pCi/g of soil that has been applied in characterization studies to identify the presence or absence of residual transuranic radioactivity. This MDC provides for data continuity from characterization through final site surveys. Since there is no Am-241 DCGL, NRC will be notified prior to performing any dose evaluation to allow soils to remain onsite when the presence of Am-241 is detected.

5.5 DATA COLLECTION AND PROCESSING

This section describes data collection, review, validation and record keeping requirements for final status surveys.

5.5.1 Sample Handling and Record Keeping

A chain-of-custody record accompanies each sample from the point of collection through obtaining the final results to ensure the validity of the sample data. Sample tracking records are controlled and maintained in accordance with applicable procedures. Each survey unit has a document package associated with it, that covers the design and field implementation of the survey requirements. Survey unit records are considered quality records.

5.5.2 Data Management

Survey data are collected from several sources during the data life cycle and are evaluated for validity throughout the survey process. QC replicate measurements are not used as final status survey data. (See Section 5.8.4.2 for design and use of QC measurements.) Measurements performed during turnover and investigation surveys can be used as final status survey data if they were performed according to the same requirements as the final status survey data. These requirements are:

a. Survey data shall reflect the as-left survey unit condition, i.e., no further remediation required;

b. The application of isolation measures to the survey unit to prevent re-contamination and to maintain final configuration are in effect; and

c. The data collection and design were in accordance with FSS methods and procedures, e.g., scan MDC, investigation levels, survey data point number and location, statistical tests, and EMC tests.

Measurement results stored as final status survey data constitute the final survey of record and are included in the data set for each survey unit used for determining compliance with the site release criteria. Measurements are recorded in units appropriate for comparison to the applicable DCGL. Numerical values, even negative numbers, are recorded. Measurement records include, at a minimum, the surveyor's name, the location of the measurement, the instrument used, measurement results, the date and time of the measurement, any surveyor comments, and records of applicable reviews.

5.5.3 Data Verification and Validation

The final status survey data are reviewed before data assessment to ensure that they are complete, fully documented and technically acceptable. The review criteria for data acceptability will include at a minimum, the following items:

a. The instrumentation MDC for fixed or volumetric measurements was below the $DCGL_{EMC}$ for Class 1, below the $DCGL_w$ for Class 2 and below 0.5 $DCGL_w$ for Class 3 survey units;

b. The instrument calibration was current and traceable to NIST standards;

c. The field instruments were source checked with satisfactory results each day data was collected or data was evaluated if instruments did not pass a response check in accordance with Section 5.4.3.3;

d. The MDCs and assumptions used to develop them were appropriate for the instruments and techniques used to perform the survey;

e. The survey methods used to collect data were proper for the types of radiation involved and for the media being surveyed;

f. "Special methods" for data collection were properly applied for the survey unit under review;

g. The chain-of-custody was tracked from the point of sample collection to the point of obtaining results;

h. The data set is comprised of qualified measurement results collected in accordance with the survey design which accurately reflect the radiological status of the facility; and

i. The data have been properly recorded.

If the data review criteria are not met, the discrepancy will be evaluated and the decision to accept or reject the data will be documented in accordance with approved procedures. The BRP Corrective Action Program will be used to document and resolve discrepancies as applicable.

5.5.4 Graphical Data Review

Survey data may be graphed to identify patterns, relationships or possible anomalies that might not be evident using other methods of review. A posting plot or a frequency plot may be made. Other special graphical representations of the data will be made as the need dictates.

5.5.4.1 Posting Plots

Posting plots may be used to identify spatial patterns in the data. The posting plot consists of the survey unit map with the numerical data shown at the location from which it was obtained. Posting plots can reveal patches of elevated radioactivity or local areas in which the DCGL is exceeded. Incongruities in the background data may be the result of residual, undetected activity.

5.5.4.2 Frequency Plots

Frequency plots may be used to examine the general shape of the data distribution. Frequency plots are basically bar charts showing data points within a given range of values. Frequency plots reveal such things as skewness and bimodality (having two peaks). Skewness may be the result of a few areas of elevated activity. Multiple peaks in the data may indicate the presence of isolated areas of residual radioactivity due to variation of soil types. Variability may also indicate the need to subdivide the survey unit by soil type or by different nuclide distributions.

5.6 DATA ASSESSMENT AND COMPLIANCE

An assessment is performed on final status survey data to ensure that they are adequate to support the determination to release the survey unit. Simple assessment methods such as comparing the survey data to the DCGL or comparing the mean value to the DCGL are first performed. The statistical tests are then applied to the final data set, where required, and conclusions are made as to whether the survey unit meets the site release criterion.

5.6.1 Data Assessment Including Statistical Analysis

The results of the survey measurements are evaluated to determine whether the survey unit meets the release criterion. In some cases, the determination can be made without performing complex, statistical analyses.

5.6.1.1 Interpretation of Sample Measurement Results

An assessment of the measurement results is used to quickly determine whether the survey unit passes or fails the release criterion. Final status surveys for BRP land will utilize the Sign Test on the basis that contaminants originating from plant operation that may reside in soil (or groundwater) do not exist in general background in appreciable quantities. Evaluation criteria for the Sign Test is provided in Table 5-9.

Table 5-9. Interpretation of Sample Measurements for Sign Test

Measurement Results	Conclusion
All concentrations less than $DCGL_w$	Survey unit meets release criterion
Average concentration greater than $DCGL_w$	Survey unit fails
Any concentration greater than $DCGL_w$ and average concentration less than $DCGL_w$	Conduct Sign Test and elevated measurements test.

In addition, survey data are evaluated against the elevated measurement comparison criteria as previously described in Section 5.3.6.3. The statistical test is based on the null hypothesis (H_o) that the residual radioactivity in the survey unit exceeds the $DCGL_w$. There must be sufficient survey data at or below the $DCGL_w$ to reject the null hypothesis and conclude the survey unit meets the site release criterion for dose. Statistical analyses are performed using specially designed computer-based calculations or, if necessary, using hand calculations.

5.6.1.2 Sign Test

The Sign Test and Sign Test Unity Rule are one-sample statistical tests used for situations in which the radionuclide of concern is not present in background, or is present at acceptable low fractions compared to the $DCGL_W$. If contaminant is present in background, the gross measurement is assumed to be entirely from plant activities. This option is used when it can be reasonably expected that including the background concentration will not affect the outcome of the Sign Test. The advantage of using the Sign Test is a background reference area is not needed.[3]

The Sign Test is conducted as follows:

a. The survey unit measurements, X_i, i = 1, 2, 3, ...n; where n = the number of measurements, are listed.

b. X_i is subtracted from the $DCGL_W$ to obtain the difference ($DCGL_W - X_i$, i = 1, 2, 3,...,n).

c. Differences where the value is exactly zero are discarded and n is reduced by the number of such zero measurements.

d. The number of positive differences are counted. The result is the test statistic S+. Note that a positive difference corresponds to a measurement below the $DCGL_W$ and contributes evidence that the survey unit meets the site release criterion.

e. The value of S+ is compared to the critical value given in Table I.3 of NUREG-1575. The table contains critical values for given values of N and Alpha (α). The value of α is set at 0.05 during survey design. If S+ is greater than the critical value given in the table, the survey unit meets the site release criterion. If S+ is less than or equal to the critical value, the survey unit fails to meet the release criterion.

5.6.2 Data Conclusions

The results of the statistical tests, including application of the EMC, allow one of two conclusions to be made. The first conclusion is that the survey unit meets the site release criterion. The data provide statistical evidence that the level of residual radioactivity in the survey unit does not exceed the release criterion. The decision to release the survey unit is made with sufficient confidence and without further analysis. The second conclusion that can be made is that the survey unit fails to meet the release criterion. The data are not conclusive in showing that the residual radioactivity is less than the release criterion. The data are analyzed further to determine the reason for the failure. Possible reasons are that:

a. The average residual radioactivity exceeds the $DCGL_W$,

b. The average residual radioactivity is less than the $DCGL_w$, however; the survey unit fails statistical testing or elevated measurement comparison.

[3] The Sign Test may be used with background reference areas in accordance with Chapter 12 of NUREG-1505.

c. The survey design or implementation was insufficient to demonstrate compliance for unrestricted release.

If failure was due to the presence of residual radioactivity in excess of the release criterion, the survey unit shall be remediated. Survey unit failure due to inadequate design or implementation shall require investigation and reinitiation of the Final Status Survey process.

5.6.3 Compliance

The FSS is designed to demonstrate licensed radioactive materials have been removed from BRP property to the extent remaining residual radioactivity is below the radiological criteria for unrestricted release. The site-specific radiological criteria presented in this plan demonstrate compliance with the criteria of 10 CFR 20.1402. If the measurement results pass the requirements of Table 5-5 and the elevated areas evaluated per Section 5.3.6.3 pass the elevated measurement comparison, the survey unit is suitable for unrestricted release. If survey measurements do not meet the criteria specified in Table 5-5, an investigation will be performed. Investigations will include an evaluation of survey design, instrumentation use and calculations, as necessary. All investigations of this nature will be documented using the corrective action process as discussed in Section 5.8.2 and 5.8.5.

5.7 REPORTING FORMAT

Survey results are documented in history files, survey unit release records, and in the FSS Report. Other reports may be generated as requested by the NRC.

5.7.1 History File

A history file of relevant operational and decommissioning data is compiled. The purpose of the history file is to provide a substantive basis for the survey unit classification, and hence, the level of intensity of the FSS. The history file contains the following items:

- Operating history which could affect radiological status,
- Summarized scoping and site characterization data, and
- Other relevant information, as deemed necessary.

5.7.2 Survey Unit Release Record

A separate release record is prepared for each final status survey unit. The survey unit release record is a stand-alone document containing the information necessary to demonstrate compliance with the site release criteria. This record includes:

- Description of the survey unit,
- Survey unit design information,
- Survey unit measurement locations and corresponding data,
- Survey unit investigations performed and their results, and
- Survey unit data assessment results.

When a survey unit release record is given final approval, it becomes a quality record.

5.7.3 Final Status Survey Report

Survey results will be described in a written report to the NRC. The FSS Report provides a summary of the survey results and the overall conclusions to demonstrate the BRP site meets the radiological criteria for unrestricted use. Information such as the number and type of measurements, basic statistical quantities, and statistical analysis results will be included in the report. The level of detail is sufficient to clearly describe the FSS Program and to certify the results. The FSS Report will contain the following topics:

- Overview of the Results
- Discussion of Changes to FSS
- Final Status Survey Methodology
  - Survey unit sample size
  - Justification for sample size
- Final Status Survey Results
  - Number of measurements taken
  - Survey maps
  - Sample concentrations
  - Statistical evaluations, including power curves
  - Judgmental and miscellaneous data sets
- Anomalous Data
- Conclusion for Survey Units
- Summary of Changes from Initial Assumptions on Residual Radioactivity.

5.7.4 Other Reports

Other reports relating to final status survey activities may be prepared and submitted as necessary.

5.8 FINAL STATUS SURVEY QUALITY PROGRAM

Quality is built in to each phase of the FSS Program and measures must be taken during the execution of the plan to determine whether the expected level of quality is being achieved. The FSS Program will ensure that the site will be surveyed, evaluated and determined to be acceptable for unrestricted release if the residual activity results in an annual Total Effective Dose Equivalent (TEDE) to the average member of the critical group of 25 mrem/year or less for all pathways. The following sections provide a description of applicable BRP quality programs and specific quality elements of the FSS Program.

5.8.1 Big Rock Point Quality Assurance Program

The BRP quality assurance program is applied to systems, structures, components and activities important to the safe storage, control and maintenance of spent nuclear fuel and to the monitoring and control of radiological hazards. The Consumers Energy Quality Program Description (QPD) for Nuclear Power Plants defines the responsibilities and requirements to ensure decommissioning and construction/operation of the ISFSI comply with licenses and applicable regulations (10 CFR 50 and 10 CFR 72). This QPD addresses organizational responsibilities, staff qualifications, procedure review and approval, design and modification controls, procurement, measurement and test equipment (M&TE) calibration and control, testing of installed equipment, document control, and other information pertinent to quality [Reference 5-9].

5.8.2 FSS Quality Assurance Project Plan (QAPP)

The objective of the FSS QAPP is to ensure the survey data collected are of the type and quality needed to demonstrate with sufficient confidence the site is suitable for unrestricted release. The objective is met through use of the DQO process for FSS design, analysis and evaluation. The plan ensures the following items are accomplished:

a. The elements of the FSS Plan are implemented in accordance with the approved procedures;

b. Surveys are conducted by trained personnel using calibrated instrumentation;

c. The quality of the data collected is adequate; and

d. Corrective actions, when identified, are implemented in a timely manner and are determined to be effective.

The following sections describe the basic elements of the FSS QAPP.

5.8.2.1 Project Management and Organization

An FSS organization will be established for the BRP site. This organization will be responsible for planning and implementation of final status surveys. Since the FSS organization has not been fully implemented at the time of LTP development, specific job titles may vary over the period of project execution. However, the following descriptions refer to various functional areas of responsibility and do not necessarily correspond to specific job titles. It is also important to note qualified individuals may assume the responsibilities of more than one of the functional positions described below. The FSS organization consists of the following functional areas:

- *Final Status Survey Supervisor*
  The FSS Supervisor has overall responsibility for program direction, technical content, and ensuring the program complies with applicable NRC regulations and guidance. This supervisor is responsible for preparation and implementation of the FSS procedures. Additional responsibility areas may include resolution of issues or concerns raised by the NRC, the Michigan Department of Environmental Quality (MDEQ) or other Stakeholders, as well as programmatic issues raised by BRP site management. The FSS Supervisor provides overall FSS project coordination, which may include, but is not limited to, interfaces with site personnel in areas of nuclear licensing, demolition and waste disposal.

- *Final Status Survey Technical Specialists*
  Responsibilities of FSS Technical Specialists may include technical support and development of FSS procedures, design of final status surveys, preparation of survey execution instructions, development of specific technical analysis documents supporting FSS activities, and review of survey packages and data collected in support of the FSS.

- *Work Planning Coordinators*
  Work Planning Coordinators develop detailed, job-specific work instructions using the site work order process. These individuals are tasked with ensuring the appropriate interface between various site functional groups is specified in work order documents. These individuals possess specific knowledge regarding Radiation Protection, FSS, and Industrial Safety requirements.

- *Final Status Survey Field Coordinators*
  Final Status Survey Field Coordinators are responsible for control and implementation of survey packages during field activities. Specific responsibilities are likely to include:

  - Coordination of turnover surveys,
  - Survey area preparation (e.g., gridding),
  - Ensuring final status survey sampling is conducted in accordance with applicable procedures and work instructions,
  - Maintaining access controls over completed FSS survey areas,
  - Determining survey area accessibility requirements,
  - Coordination and scheduling of FSS Technicians to support the decommissioning schedule, and
  - Ensuring all necessary instrumentation and other equipment is available to support survey activities.

- *Final Status Survey Data Specialist*
  The FSS Data Specialist is responsible for maintaining the FSS data records in both electronic formats and hardcopy files, as applicable. This includes maintaining survey measurement data and supporting data files and generating reports of survey results. Responsibilities also include maintaining the integrity of the FSS database and implementing FSS Database QA requirements.

- *Final Status Survey Technician*
  Final Status Survey Technicians are responsible for performance of final status survey measurements and collection of final status survey samples in accordance with applicable site procedures and survey package instructions. An FSS Technician will be responsible for maintaining the pedigree of instrumentation used in the survey by implementing the procedural requirements for calibration, maintenance and daily checks. Final Status Survey Technicians will be trained and task-qualified for the performance of the final status activities assigned to them. Final Status Survey Technicians may also participate in survey area preparations.

5.8.2.2 Written Procedures

Sampling and survey tasks must be performed properly and consistently in order to assure the quality of final status survey results. The measurements will be performed in accordance with approved, written procedures. Approved procedures describe the methods and techniques used for final status survey measurements. Table 5-10 provides a list of BRP site procedures applicable to final status surveys and their current status.

Table 5-10. BRP Procedures Applicable to FSSs

Procedure	Title	Status
D5.1	Radiation Protection and Environmental Services Policy and Program Description	Active
D5.3	Big Rock Point Radiological Environmental Program	Active
D5.24	ALARA Program	Active
D5.19	Radiation Detection Instrumentation Calibration Facility and Source Control	Active
D5.26	Final Status Survey Program	Active
RM-76	Final Status Survey Design	Active
RM-77	Final Status Survey Implementation	Active
RM-78	Final Status Survey Assessment	Active
RM-79	Final Status Survey Quality Control	Active
RIP-59	Scan Measurements	Active
RIP-60	Calibration and Operation of the Canberra Genie 2000 (In-Situ Gamma Spectroscopy)	Active
RM-72	Sample Chain of Custody	Active
CIP-46	Operation of Canberra "Genie"	Active
CIP-50	Calibration, Functional Check and Use of Acculab V-4kg Balance	Active
RM-59	Sampling and Analysis of Bulk Material for Site Characterization or Free Release	Active

Procedure	Title	Status
RP-29	Radiological Surveys	Active
RM-70	Packaging Radioactive Waste for Burial	Active
34A-04	Corrective Action	Active
34A-02	Plant Documents	Active
D1.5	Personnel Safety	Active
D1.7	Master Training Plan	Active
D1.10	Computer Software Control	Active
34A-05	Safety Review and Independent Safety Review Committee Review	Active
D3.3	Work Management Process	Active
34A-03	Records Management	Active
34A-08	Material Control	Active
Volume 28, Section 1	Spill Prevention	Active
Volume 28, Section 2	Stormwater Plan	Active
Volume 25	BRP Offsite Dose Calculation Manual	Active
Volume 34	Quality Program Description for Nuclear Power Plants (Part 1) – Big Rock Point	Active

5.8.2.3 Training and Qualification

Personnel performing final status survey measurements will be trained and qualified. Training will include the following topics:

- Procedures governing the conduct of the FSS,
- Operation of field and laboratory instrumentation used in the FSS, and
- Collection of final status survey measurements and samples.

Qualification is obtained upon satisfactory demonstration of proficiency in implementation of procedural requirements. The extent of training and qualification will be commensurate with the education, experience and proficiency of the individual and the scope, complexity and nature of the activity required to be performed by that individual. Records of training and qualification will be maintained in accordance with approved training procedures [References 5-1 and 5-7].

5.8.2.4 Measurement and Data Acquisitions

The FSS records have been designated as quality documents and will be governed by site quality programs and procedures. Generation, handling and storage of the original final status survey design and data packages will be controlled by site procedures. Each final status survey measurement will be identified by individual, date, instrument, location, type of measurement, and mode of operation.

a. Quality Control Surveys

The FSS Procedure has built-in quality control (QC) checks for the survey process, instrumentation, field and laboratory measurements. A minimum of 5% of final survey soil, water, and sediment samples will be evaluated through the QC program. Quality Control will consist of one or more of the following: in-house recounts, split samples, third party analysis, and/or statistical comparisons. Acceptance criterion will be based on NRC Inspection Procedure 84750 or a standard statistical test. Unacceptable QC comparisons will require a documented investigation and may result in reanalysis, resurvey, or resampling.

b. Instrumentation Selection, Calibration and Operation

Proper selection and use of instrumentation will ensure sensitivities are sufficient to detect radionuclides at the minimum detection capabilities as specified in Section 5.4.3 as well as assure the validity of the survey data. Instrument calibration will be performed with NIST traceable sources using approved procedures. Issuance, control and operation of the survey instruments will be conducted in accordance with the instrumentation procedures.

5.8.2.5 Assessment and Oversight

Assessments and project oversight will include the following:

a. Self-assessments will be conducted in accordance with approved procedures and programs. As applicable, actions will be tracked in accordance with these documents.

b. Independent review of randomly selected survey packages (approximately 5%) from selected survey units will be performed by onsite quality assurance programs to ensure the survey measurements have been taken and documented in accordance with approved procedures.

c. The BRP Corrective Action Program will be applied to the FSS Program in accordance with site procedures. Applicable procedures describe the methods used to initiate condition reports (CRs) and resolve associated corrective actions.

d. Assessment and oversight by independent organizations will be conducted on a periodic basis, as deemed appropriate by site management.

5.8.2.6 Data Validation and Verification

Survey data will be reviewed prior to evaluation or analysis for completeness and for the presence of outliers. Comparisons to investigation levels will be made and measurements exceeding the investigation levels will be evaluated. Procedurally verified data will be subjected to the Sign Test as discussed in Section 5.8.1.2. Technical evaluations or calculations used to support the development of DCGLs will be independently verified to ensure correctness of the method and the quality of data.

a. Confirmatory Measurements

Consumers Energy Co. anticipates that both the NRC and the MDEQ – Radioactive Material & Standards Unit may choose to conduct confirmatory measurements. The NRC may take confirmatory measurements to make a determination in accordance with 10 CFR 50.82(a)(11) that the FSS and associated documentation demonstrate the site is suitable for release in accordance with the criteria for decommissioning in 10 CFR Part 20, subpart E. Confirmatory measurements may include collecting radiological measurements for the purpose of verifying compliance with applicable state laws and confirming and verifying compliance with NRC standards for unrestricted license termination. Timely and frequent communications with these agencies will ensure they are afforded sufficient opportunity for these confirmatory measurements prior to implementing any irreversible decommissioning actions.

b. Project Schedule

Portions of the FSS may be performed following demolition activities as areas become available for survey. Table 5-11 provides an estimate of FSS schedule based on dismantlement and demolition of specific structures and buildings. Table 5-11 is presented at a target schedule summary only; specific timeframes may be adjusted by site management or due to weather conditions, as necessary, during the demolition phase of decommissioning.

Table 5-11. Target Schedule for FSS of Various Areas

Survey Unit Description	FSS Target Start Date	Estimated FSS Duration
Radwaste Building Vault Area	March 2003	1 month
Liquid Radwaste Vault Area	September 2004	1 month
Screenhouse/Discharge Canal Area	November 2004	1 months
Administrative/Service Building Area	December 2004	2 months
Turbine Building Area	January 2005	3 months
Stack Area	March 2005	1 month
Containment Building Area	September 2005	2 months
Yard Area – remaining foundations	October 2005	2 months
All Remaining soil surfaces	January 2006	3 months

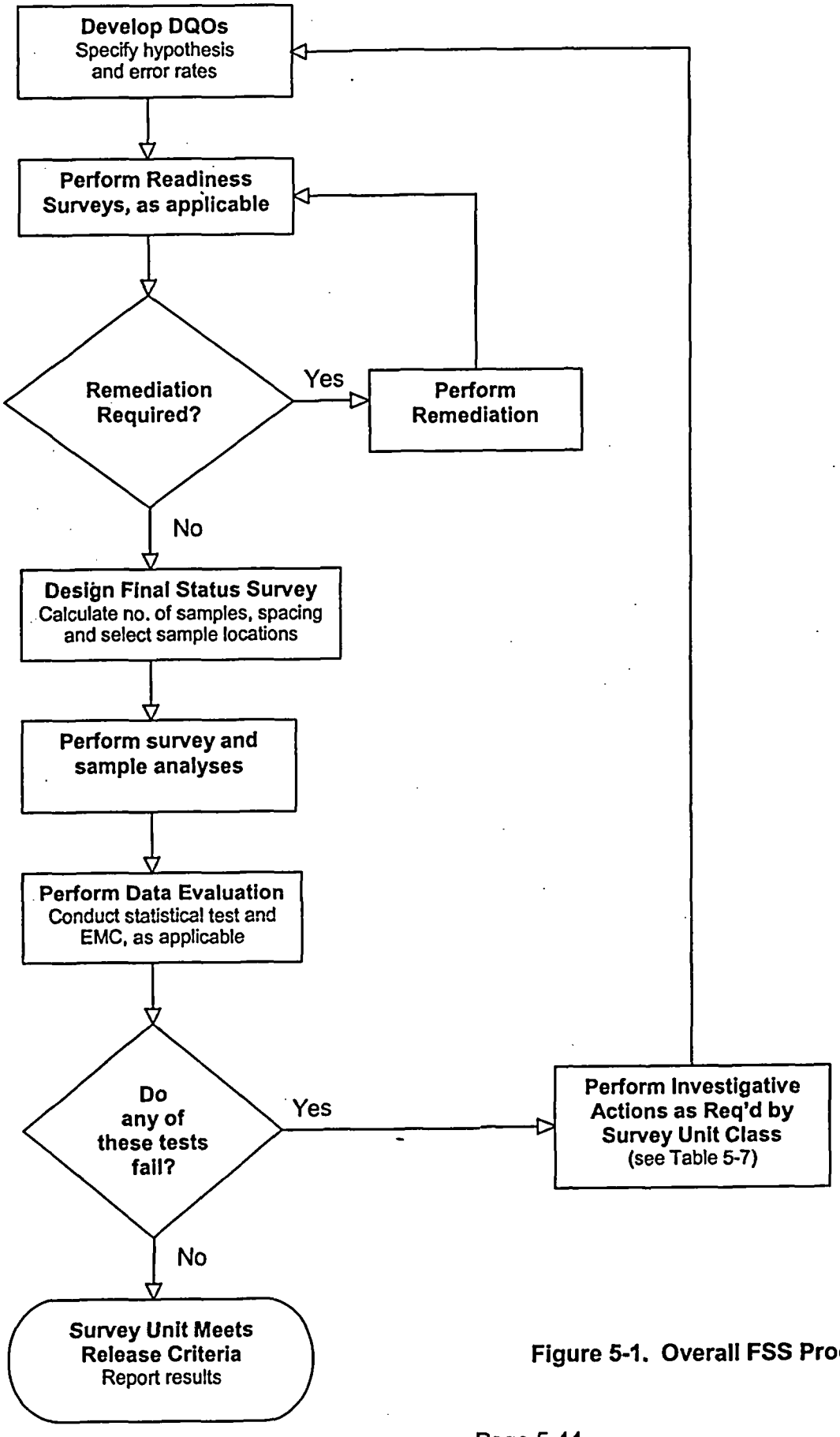


Figure 5-1. Overall FSS Process

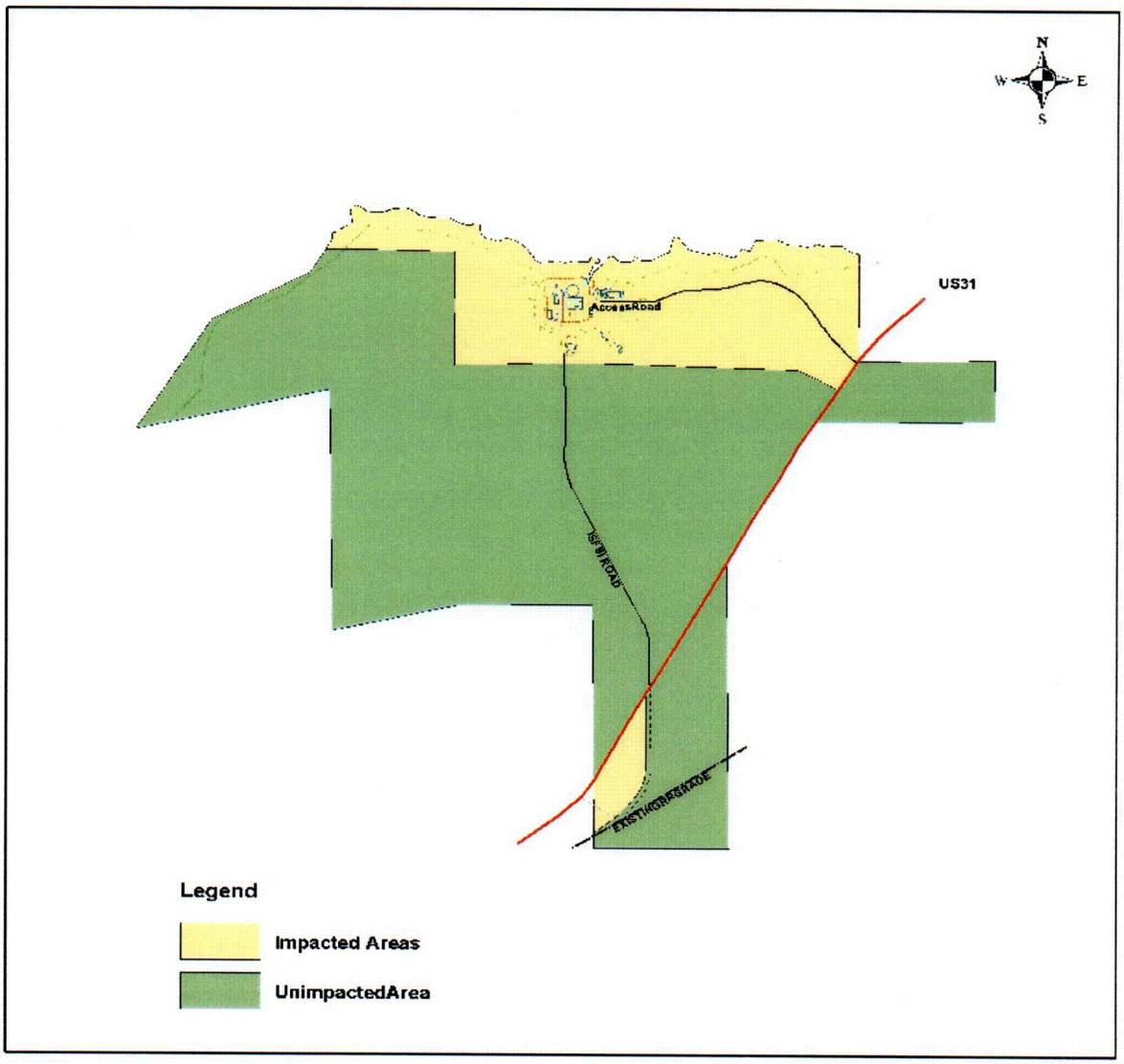


Figure 5-2: Big Rock Point Owner Controlled Area

C-15

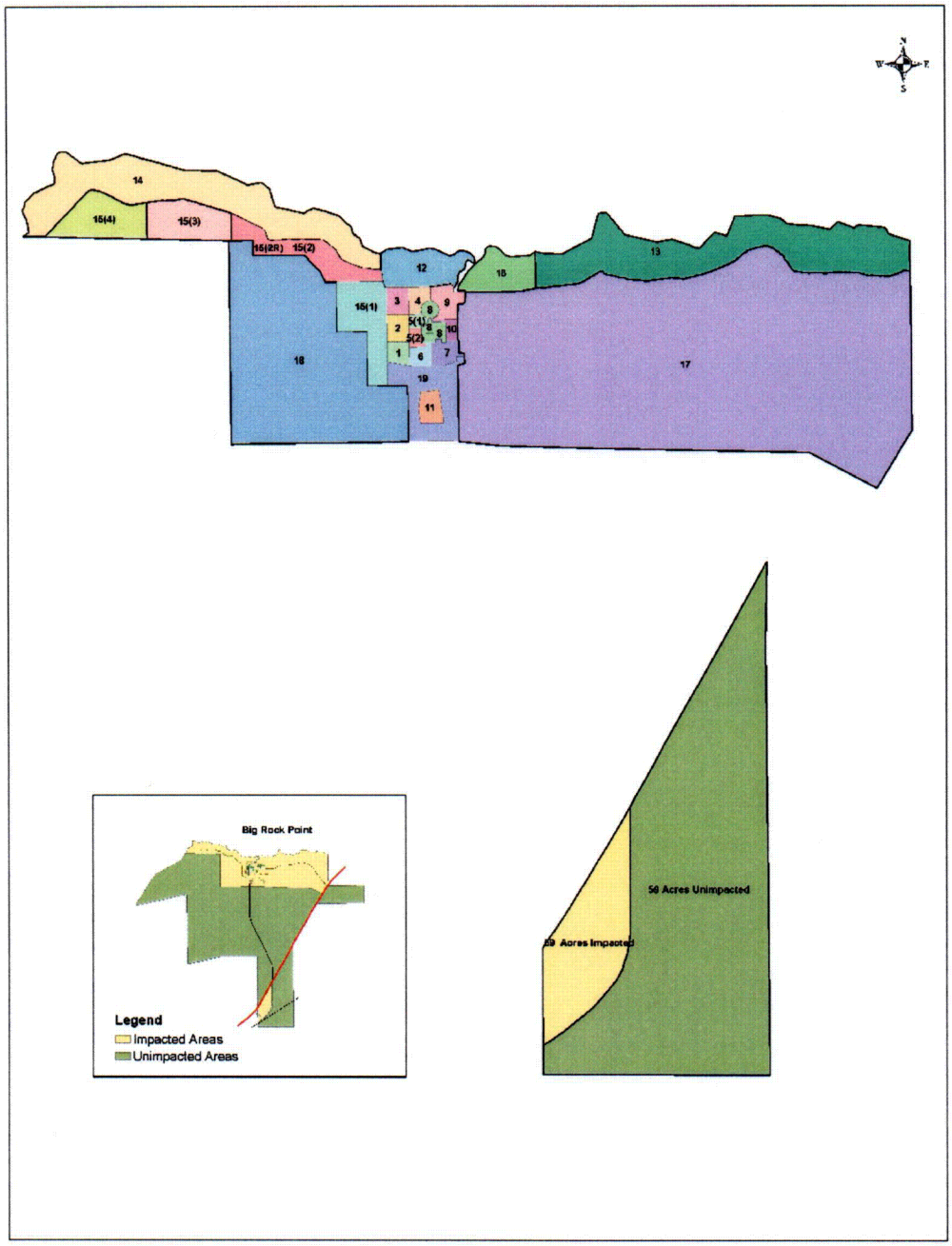


Figure 5-3. Initial Land Area Survey Units

C16

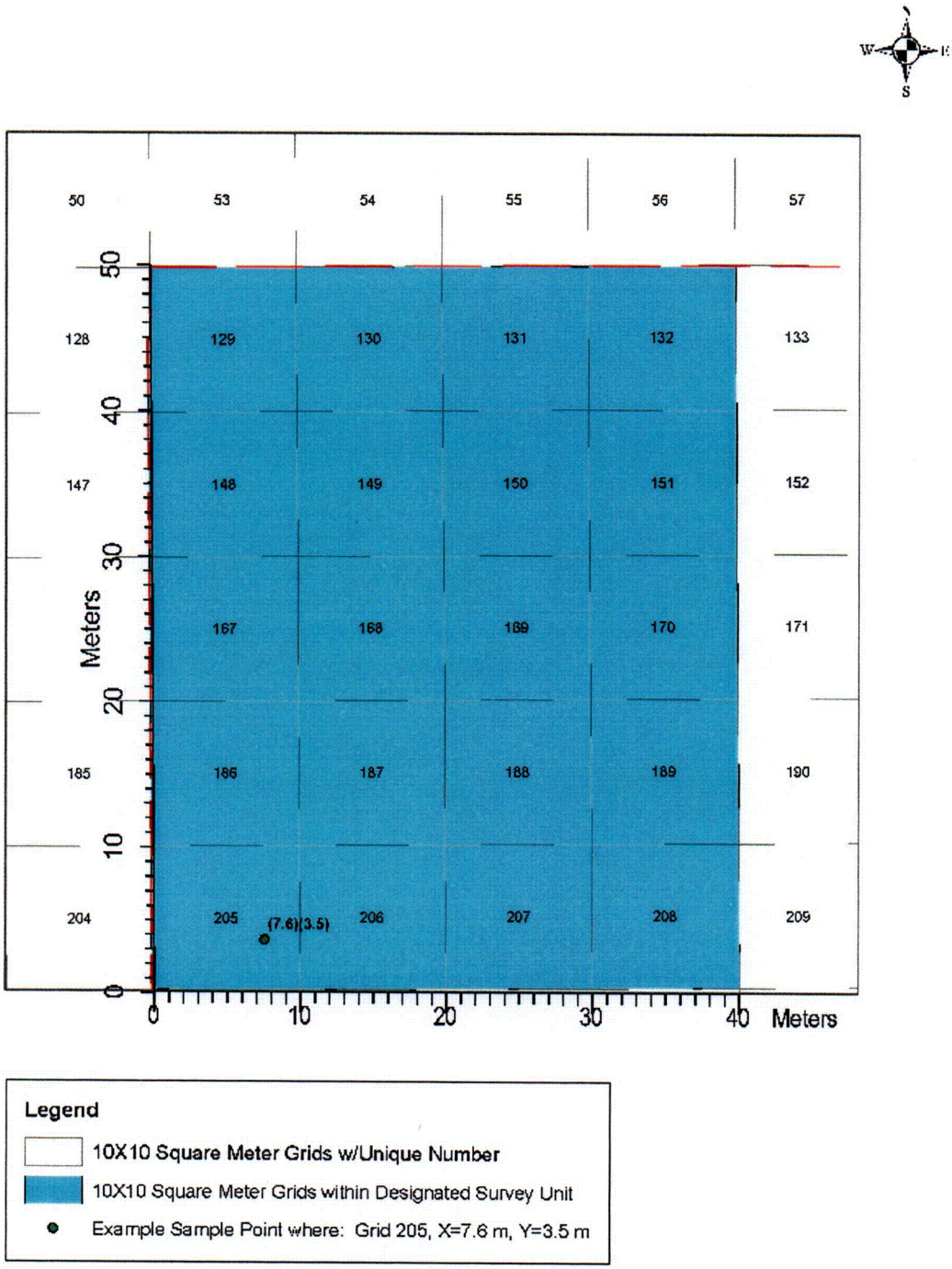


Figure 5-4. Example of Survey Unit Local Coordinate Grid

C17

5.9 REFERENCES

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5-3 Big Rock Point Engineering Analysis EA-BRP-SC-01-01, *Deriviation of Scaling Factors for Hard-to-Detect Nuclides in Soil*

5-4 Big Rock Point Engineering Analysis EA-BRP-SC-02-01, *NaI Scanning Sensitivity for Open Land Survey*

5-5 Big Rock Point Engineering Analysis EA-BRP-SC-02-04, *Radionuclides Present in Onsite Soil and Water*

5-6 Big Rock Point Engineering Analysis EA-BRP-SC-03-03, *Area Factors for Use in BRP Final Status Surveys*

5-7 Big Rock Point Historical Site Assessment, 1962-1997, May 2001

5-8 Big Rock Point Initial and Continuing Training for Decommissioning Course Descriptions

5-9 Consumers Energy Quality Program Description for Nuclear Power Plants, (CPC-2A) (Part 1) – Big Rock Point

5-10 U.S. Nuclear Regulatory Commission NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, August 2000

5-11 U.S. Nuclear Regulatory Commission Draft NUREG-1505, *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys,* Revision 1, June 1998

5-12 U.S. Nuclear Regulatory Commission Draft NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Field Conditions*, June 1998

5-13 U.S. Nuclear Regulatory Commission Draft NUREG-1700, *Standard Review Plan for Evaluating Nuclear Power Reactor License Termination Plans*, April 2000

5-14 U.S. Nuclear Regulatory Commission NUREG-1727, *NMSS Decommissioning Standard Review Plan*, September 15, 2000

5-15 U.S. Nuclear Regulatory Commission Regulatory Guide 1.179, *Standard Format and Content of License Termination Plans for Power Reactors*, January 1999

5-16 U.S. Nuclear Regulatory Commission Inspection Manual Procedure 84750, March 1994

5-17 USDA (vs. Department of Agriculture) Soil Survey, Charlevoix County, 1978

Calculation of Tritium in Soils

Concentration of tritium in soil is calculated from the maximum value of tritium in onsite monitoring wells accordance with Equation 5x.1. A bounding case is presented for tritium in water at a concentration of 20,000 pCi/l.

$$S_t = [(W_t)(0.0875)/(\rho_s)]$$

Where:

S_t = Soil concentration of tritium (pCi/g)

W_t = Maximum monitoring well water concentration of tritium (20,000 pCi/l for bounding case)

0.0875 = Maximum water saturation (by weight) for Algoma sandy loam soil in contaminated area [Reference 5-16]

ρ_s = Soil density (1,600 g/l) [Reference 5-2]

And

$$D_t = (S_t)(24.218 \text{ mrem})/(DCGL_t)$$

Where:

D_t = Annual dose from tritium in soil (mrem/year)

$DCGL_t$ = Tritium DCGL (328 pCi/g)

24.218 mrem = Annual dose associated with soil tritium DCGL (adjusted from 25 mrem for contribution from tritium in the three groundwater zones)

Thus,

$$S_t = (0.0825)(20{,}000)/1{,}600 = 1.03 \text{ pCi/g}$$

$$D_t = (S_t)(24.218)/(328) = (1.03)(0.0738) = 0.076 \text{ mrem/year}$$

TABLE OF CONTENTS

6.0 COMPLIANCE WITH THE RADIOLOGICAL DOSE CRITERIA 1

6.1 INTRODUCTION 1

6.2 SITE RELEASE CRITERIA 2
6.2.1 Radiological Criteria for Unrestricted Use 2

6.3 SITE CONDITIONS 2
6.3.1 General Description 2

6.4 SOURCE TERM ASSUMPTIONS 2
6.4.1 Potential Radionuclides of Concern 2
6.4.2 Observed Radionuclides in the Big Rock Point Environs 4

6.5 EXPOSURE SCENARIOS CONSIDERING THE SITE ENVIRONMENT 5
6.5.1 Identification of the Critical Group 5
6.5.2 Exposure Pathways for Scenario Consideration 5

6.6 MATHEMATICAL MODEL/COMPUTATIONAL METHOD USED 7
6.6.1 Mathematical Model for Dose Calculations 7
6.6.2 Computational Method Used for Dose Calculations 10
6.6.3 Identification of the Critical Group 10

6.7 PARAMETER VALUES AND A MEASURE OF THEIR UNCERTAINTY 11
6.7.1 Selection of Parameters for Use with RESRAD 11
6.7.2 Potential Dose From Discounted Radionuclides 18

6.8 DERIVED CONCENTRATION GUIDELINE LEVELS (DCGLS) 20
6.8.1 Screening DCGLs 20
6.8.2 Site-Specific Industrial Area DCGLs 21

6.9 SENSITIVITY ANALYSIS OF THE BIG ROCK POINT DOSE MODEL 28
6.9.1 Sensitivity Analysis with Uncorrelated Parameters 28
6.9.2 Sensitivity Analysis with Correlated Parameters 28
6.9.3 Results of Sensitivity Analysis 29

6.10 DERIVATION OF AREA FACTORS 30

6.11 REFERENCES 36

TABLES

6-1 BRP Site-Specific Suite of Radionuclides 4

6-2 Radionuclides for Dose Modeling 5

6-3 K_d Parameter Distribution Values 14

6-4 Southern Industrial Area K_d Results 15
6-5 Northern Industrial Area K_d Results 15
6-6 Discounted Radionuclides 18
6-7 MDA Values for Calculation of Potential Discounted Dose 19
6-8 Screening Values for Use Outside the Industrial Area 21
6-9 Parameters Required to Calculate the Concentration of Tritium in Contaminated Soil 23
6-10 Site-Specific Surface Soil DCGL Values 25
6-11 100 Square-Meter Contaminated Zone - 1.5 Meters Thick, Except Surface 27
6-12 Potential Parameter Correlations 29

FIGURES

6-1 RESRAD Mathematical Dose Models 32
6-2 Area Factors for Gamma Emitting Radionuclides 33
6-3 Area Factors for Hard-to-Detect Radionuclides 34
6-4 Parameter Selection Process 35

APPENDICES

6-A RESRAD Version 6.1 Input Parameters, Classification and Description 6A-1
6-B Southern Industrial Area Site-Specific RESRAD v6.21 Input Parameters 6B-1
6-C Northern Industrial Area Site-Specific RESRAD v6.21 Input Parameters 6C-1
6-D RESRAD v6.21 Input Parameters for Probabilistic Sensitivity Analysis 6D-1
6-E RESRAD v6.21 Sensitivity Analysis Distribution Parameters and Results 6E-1
6-F Selected RESRAD v6.21 Parameters for BRP Dose Modeling 6F-1
6-G RESRAD v6.21 Sensitivity Analysis Distribution Parameters and Results for Discounted Radionuclides 6G-1
6-H RESRAD Summary Report for Calculation of Potential Discounted Dose 6H-1
6-I RESRAD Summary Report for Generation of Site-Specific DCGL Values 6I-1
6-J RESRAD v6.21 Sensitivity Analysis Distribution Parameters 6J-1
6-K BRP Dose Model Sensitivity Analysis Results 6K-1
6-L Calculated Area Factors 6L-1

6.0 COMPLIANCE WITH THE RADIOLOGICAL DOSE CRITERIA

6.1 INTRODUCTION

The goal of the Big Rock Point (BRP) Restoration Project is to release the site, after removal of all structures, for unrestricted use in compliance with the Nuclear Regulatory Commission's (NRC) annual dose limit of 25 mrem/year plus ALARA (as low as reasonably achievable). The NRC dose limit applies to residual radioactivity that is distinguishable from background. This chapter of the License Termination Plan provides the methods for calculating the annual dose from residual radioactivity that may remain when the site is released for unrestricted use and the methods used to demonstrate compliance with the unrestricted use criteria.

Structures, foundations, paved surfaces and buried piping and utilities will have been removed prior to performance of the Final Status Survey (FSS) for each specified survey area.[1] Therefore, the scope of this chapter is limited to calculating annual dose resulting from surface and subsurface soil and groundwater contamination. This chapter will also provide a description of and the justification for:

- Source term assumptions,
- Exposure scenarios considering the site environment,
- The mathematical model/computational method used, and
- The parameter values and a measure of their uncertainty.

The Historical Site Assessment (HSA) and the Site Characterization have shown that the majority of the site area contains no residual radioactivity that is distinguishable from background radiation. Therefore, compliance with the unrestricted use criteria for these areas will be demonstrated by comparison of the FSS results with published unrestricted release screening criteria in accordance with the acceptance criteria contained in Section 5.0 of NUREG-1727, NMSS Decommissioning Standard Review Plan [Reference 6-19]. However, residual radioactivity has been identified in surface and subsurface soil and groundwater within the Industrial Area of the site. Therefore, since these areas do not meet the criteria for the use of unrestricted release screening criteria, site-specific Derived Concentration Guideline Levels (DCGLs) have been established in accordance with the description and the justification provided in this chapter for use in these areas.

[1] In accordance with the Greenfield description in Chapter 1, the septic drainfield and the intake structure and pipe will remain in place after all other restoration activities have been completed.

6.2 SITE RELEASE CRITERIA

6.2.1 Radiological Criteria for Unrestricted Use

The site release criteria for the BRP site will correspond to the radiological criteria for unrestricted use given in 10 CFR 20.1402, or:

- Dose Criterion: The residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem/year, including that from groundwater sources; and

- ALARA Criterion: The residual radioactivity has been reduced to levels that are ALARA.

6.3 SITE CONDITIONS

6.3.1 General Description

A detailed description of applicable BRP environmental conditions and parameters is provided in Chapter 8 *Supplement to the Environmental Report*. These parameters include site and surrounding area physical descriptions including population, topography, vegetation, soil types, surface water quality, climate and meteorology, hydrology, and geology. Additionally Chapter 2, *Site Characterization,* (Section 2.4.3) contains a detailed description of the BRP site Hydrogeological Assessment results completed in 2002. The information contained in Chapters 2 and 8 form the basis for determining many of the site-specific dose modeling inputs (see Section 6.7.1). Site-specific environmental conditions and parameters were also compared to the basis for development of generic screening DCGL values discussed in Section 6.8.1.

6.4 SOURCE TERM ASSUMPTIONS

6.4.1 Potential Radionuclides of Concern

As part of the source-term abstraction process, an analysis was performed to identify a suite of radionuclides that could potentially be present in site soils and groundwater following completion of decommissioning activities and structure demolition [Reference 6-1]. This analysis considered radionuclides identified in two different companion NUREGs; NUREG/CR-3474, Long-Lived Activation Products in Reactor Materials, and NUREG/CR-4289, Residual Radionuclide Contamination Within and Around Commercial Nuclear Power Plants [References 6-21 and 6-22].

NUREG/CR-3474 identified radionuclides and an activity inventory that would be present in BWR internals at the time of reactor shutdown. This inventory included trace elements that would not likely be found in site area soils due to their low abundance. An evaluation of radionuclides that may be discounted as being of potential importance for BRP was performed. Based on this evaluation, it was determined that individual radionuclides which contributed less than 0.1 percent of

the total activity and with half-lives less than 244 days could be discounted from the list of identified radionuclides providing that dose contributed by the sum of the radionuclides discounted does not exceed one percent of the total calculated dose. The total percentage of activity attributed to radionuclides that meet these criteria amounts to 0.065 percent. The radionuclides that were discounted on this basis included Cl-36, Ar-39, Ca-41, Sc-46, Cr-51, Mn-53, Co-58, Fe-59, Se-79, Kr-81, Kr-85, Nb-92m, Zr-93, Mo-93, Ag-108m, Sn-121m, Sb-124, Ba-133, Cs-135, Ce-141, Pm-145, Sm-146, Sm-151, Tb-158, Ho-166m, Hf-178m, Pb-205, and U-233.

The dose contribution from discounted radionuclides was evaluated using the RESRAD computer code (version 6.0) in the deterministic mode using the resident farmer scenario to represent post demolition Greenfield conditions. An activity concentration was input for each radionuclide based on percent of total activity attributed to it. One hundred percent corresponded to 100 pCi/g. All RESRAD parameters were allowed to remain at their default values except for the thickness of the contaminated zone, which was set to 15 cm to correspond with the NRC's definition of thickness of contaminated surface soil. This evaluation indicated that the radionuclides discounted under the above criteria contributed less than one percent of the calculated dose at the year of maximum dose following site release.

NUREG/CR-4289 investigated residual radionuclide concentrations, distributions and inventories at seven nuclear power plants (four shutdown and three operating) to provide a database for use in formulating policies, strategies and guidelines for the eventual decommissioning of retired nuclear power plants. This study addressed radionuclides (both activation and fission products) transported from the reactor pressure vessel and deposited in all other contaminated systems of each nuclear plant. Emphasis was placed on measuring the long-lived radionuclides that are of special concern from a low-level waste management standpoint. The additional radionuclides identified in NUREG/CR-4289 were evaluated under the same criteria for discounting used for the radionuclides identified by NUREG/CR-3474.

Radionuclides identified by NUREG/CR-3474 and NUREG/CR-4289 were combined to form a single list of radionuclides. However, not all of these radionuclides were applicable for a site-specific suite of radionuclides for BRP because historical, site-specific radionuclide data exists from 10 CFR Part 61 waste stream characterization analyses. Review of this historical data shows that Nb-94, Ru-106, Sb-125, Ce-144 and Np-237 have not been observed in BRP waste stream analyses at concentrations above their reported minimum detectable activity (MDA) concentrations. Therefore, these radionuclides contained in NRC regulatory guidance may be discounted for purposes of the site-specific suite of radionuclides. In addition to identifying the absence of the radionuclides identified above, review of the historical data also indicated that Cm-243 has been observed in waste stream characterization analyses. Therefore, Cm-243 was added to the BRP site-specific suite of radionuclides.

An evaluation was performed to evaluate the validity of discounting Nb-94, Ru-106, Sb-125, Ce-144 and Np-237. This consisted of performing a RESRAD calculation for all of the radionuclides included in the site-specific suite of radionuclides. This calculation was again performed using the resident farmer scenario to represent post

demolition Greenfield conditions. Reported MDA concentration values were used as input concentration values for Nb-94, Ru-106, Sb-125, Ce-144 and Np-237 as well as other radionuclides reported to have concentrations at less than MDA. This evaluation indicated that the discounted radionuclides contributed less than one percent of the calculated dose per year at the year of maximum dose following site release. This validates the assumption that Nb-94, Ru-106, Sb-125, Ce-144 and Np-237 may be discounted from the site-specific suite of radionuclides for use at BRP.

The above analysis resulted in a BRP site-specific suite of radionuclides that includes the 24 radionuclides listed in Table 6-1.

Table 6-1. BRP Site-Specific Suite of Radionuclides

H-3	Ni-63	Cs-134	Pu-239
C-14	Zn-65	Cs-137	Pu-240
Mn-54	Sr-90	*Eu-152	Pu-241
Fe-55	Tc-99	*Eu-154	Am-241
Ni-59	Ag-110m	*Eu-155	Cm-243
Co-60	I-129	Pu-238	Cm-244

* The europium isotopes are applicable specifically to the analysis of activated concrete and other materials, including soils, only after performance of activated concrete demolition work that could lead to contamination by these radionuclides.

6.4.2 Observed Radionuclides in the Big Rock Point Environs

During the site characterization process, soil and groundwater characterization data were judgmentally selected to be representative of the highest radioactivity levels at BRP. Additionally, soil samples were analyzed for combined gamma emitting and hard-to-detect (HTD) radionuclides (13 samples obtained for representative high contamination areas), subsurface soil samples analyzed for combined gamma emitting and HTD radionuclides (seven samples obtained in two areas where contamination exceeded 15 cm depth), and from groundwater samples analyzed for gamma and HTD nuclides (seven samples, including representative samples from each groundwater zone).

The samples analyzed for HTD radionuclides were sent to offsite contract laboratories for radiochemical analysis to determine the presence of 23 out of the 24 radionuclides identified in Table 6-1. The soil samples were not analyzed for tritium because the samples had been dried; however, tritium is known to be present in groundwater onsite and is, therefore, potentially present in soil. These soil samples represented the highest specific activity samples identified by onsite gamma spectroscopy during site characterization studies and are considered to be representative of site soils potentially contaminated with radionuclides. Water samples were selected from both the highest tritium areas (four samples) and from each representative subsurface groundwater aquifer (three samples). This sampling and analysis has been evaluated in an Engineering Analysis, EA-BRP-SC-0204, Radionuclides Present in Onsite Soil and Water [Reference 6-4].

The radionuclides Mn-54, Co-60 and Cs-137 have been identified in soil samples by onsite gamma spectroscopy. These same gamma-emitting radionuclides plus the HTD radionuclides Fe-55 and Sr-90 were identified in soil samples sent to the contract laboratories. Tritium has been identified in samples in the three subsurface groundwater aquifers. No gamma emitting or HTD radionuclides other than tritium have been identified in the eight water samples analyzed for HTD nuclides. It is concluded that this nuclide list includes all radionuclides present at measurable levels in onsite soils and groundwater.

Based on the above, the radionuclides listed in Table 6-2 are known to be potentially present in BRP surface and subsurface soils. Dose modeling was based on these radionuclides. The three europium isotopes were also included in the dose modeling because of the potential for soil contamination from activated concrete demolition debris.

Table 6-2. Radionuclides for Dose Modeling

H-3	Fe-55	Sr-90	Eu-152
Mn-54	Co-60	Cs-137	Eu-154
			Eu-155

6.5 EXPOSURE SCENARIOS CONSIDERING THE SITE ENVIRONMENT

6.5.1 Identification of the Critical Group

In the case of using screening DCGLs, the decisions involved in identifying the appropriate critical group have already been made. Critical group descriptions acceptable to the NRC for use in generic screening are developed and contained in NUREG/CR-5512, Volume 1 [Reference 6-23]. NUREG/CR-5512 and NUREG-1549 provide the rationale for applicability of the critical group [Reference 6-18]. The critical group described is a resident farmer, which is the most conservative critical group for generic screening. A farmer moves onto the site and grows some of his or her diet and uses water tapped from the onsite bedrock aquifer.

The critical group for site-specific analysis of the Industrial Area is considered to be a modified resident farmer; this individual lives on the site and grows some of his or her diet in an adjacent garden and uses water tapped from the onsite bedrock aquifer. However, as discussed in Sections 6.5.2 and 6.6.3, this resident would not consume animal products grown onsite.

6.5.2 Exposure Pathways for Scenario Consideration

6.5.2.1 Screening DCGL Exposure Pathways

The generic screening scenario accounts for exposure involving residual radioactivity that is initially in the surficial soil. The twelve pathways for exposure include:

- External exposure to penetrating radiation from volume soil sources while outdoors,
- External exposure to penetrating radiation from volume sources while indoors,
- Inhalation exposure to resuspended soil while outdoors,
- Inhalation exposure to resuspended soil while indoors,
- Inhalation exposure to resuspended surface sources of soil tracked indoors,
- Direct ingestion of soil,
- Inadvertent ingestion of soil tracked indoors,
- Ingestion of drinking water from a contaminated groundwater source,
- Ingestion of plant products grown in contaminated soil,
- Ingestion of plant products irrigated with contaminated groundwater,
- Ingestion of animal products (meat and milk) grown on the site, and
- Ingestion of fish from a contaminated surface water source.

6.5.2.2 Site-Specific Industrial Area Exposure Pathways

The modified resident farmer scenario for the Industrial Area also accounts for exposure involving residual radioactivity that is initially in the surficial soil. However, the scenario must also account for exposure involving subsurface contaminated soil and exposure from the three groundwater zones that contain low concentrations of tritium.

The exposure pathways for the site-specific Industrial Area dose modeling are the same as those involved with the generic screening scenario; however, the pathways involving exposure from the ingestion of animal products (meat and milk) grown on the site are suppressed. Because of the Industrial Area's Lake Michigan shoreline location, it is highly unlikely that the site would ever be used for subsistence farming (see Section 6.6.3 for additional discussion of site soil and demographic considerations).

6.6 MATHEMATICAL MODEL/COMPUTATIONAL METHOD USED

6.6.1 Mathematical Model for Dose Calculations

6.6.1.1 Screening DCGL Mathematical Model

As discussed in Section 6.8.1, screening DCGLs published by the NRC may be used to demonstrate compliance with the site release criteria presented in Section 6.2 for Impacted Areas of the site that do not have the potential for subsurface or groundwater contamination. Areas of the site classified as non-impacted, by definition, do not require demonstration of compliance with the site release criteria.

The screening DCGLs were derived from a mathematical model related to surface soils and a scenario analysis that combined exposure pathways for inhalation, external exposure, ingestion of contaminated drinking water, and ingestion of soil and agricultural food products, including fish from a pond. The residential scenario was intentionally developed in a conservative manner to account for potential residential and light agricultural activities.

The purpose of the generic modeling was to derive a groundwater concentration from residual radioactive materials in soil in a conservative manner to permit screening and to indicate when additional site data or modeling sophistication is warranted.

6.6.1.2 Site-Specific DCGL Mathematical Model

The hydrogeology of the site Industrial Area leads to modeling the Industrial Area as two distinct regions, the Southern Industrial Area and the Northern Industrial Area. The Southern Industrial Area is upgradient of all the site's significantly contaminated areas. It consists of six distinct unconsolidated geological units and spans approximately 80 feet from the surface to fractured bedrock. The Northern Industrial Area also consists of six distinct unconsolidated geological units, but spans only approximately 60 feet from the surface to fractured bedrock [Reference 6-12]. The RESRAD mathematical dose models for both the Southern Industrial Area and the Northern Industrial Area are depicted in Figure 6-1.

a. Southern Industrial Area Subsurface Description

Unit 6a, the uppermost unit consists of 0.91 to 1.8 meters (3.0 to 6.0 feet) of loosely compacted and well-rounded gravel or sand. Fine-grained clay or silt materials are noticeably absent within this unit. For purposes of the RESRAD mathematical model, a mean thickness of 1.37 meters (4.5 feet) is used. Physical parameters for Unit 6a are included in Appendix 6-B. Both the RESRAD dose model contaminated zone and the first unsaturated zone below it consist of Unit 6a soil.

The layer below Unit 6a in the Southern Industrial Area is Unit 5 which consists of approximately 7.3 meters (24 feet) of a very dense, unsorted mixture of roughly equal parts sand, fine grained clay and silt, and fine to coarse gravel (up

to 7.6 centimeter (3.0 inch) diameter). For purposes of the RESRAD mathematical model, a thickness of 7.32 meters (24 feet) is used. Physical parameters for Unit 5 are included in Appendix 6-B. Unit 5 defines the second unsaturated zone in the RESRAD dose model.

Unit 4 is below Unit 5 in the Southern Industrial Area. Unit 4 consists of a moderately well sorted medium to coarse sand with some fine gravel. The thickness of Unit 4 in the Southern Industrial Area is approximately 1.5 meters (five feet). For purposes of the RESRAD mathematical model, a thickness of 1.52 meters (five feet) is used. Physical parameters for Unit 4 are included in Appendix 6-B.

Unit 4 defines the third unsaturated zone in the RESRAD dose model. Unit 4 is a groundwater zone under artesian conditions and is depicted in the RESRAD dose model as an unsaturated zone with physical parameters measured from the groundwater zone.

Unit 3 is below Unit 4 in the Southern Industrial Area. Unit 3 is a very dense deposit containing abundant fine-grained clay and silt, but also including significant sand and fine gravel fractions. This unit is similar to Unit 5, in that the clay rich portions appear to be unsorted, but it also contains frequent thin sand seams 0.30 to 1.5 centimeters (0.01 to 0.05 feet) thick. The sand seam frequency varies, but the average is estimated to be three to four seams per 30 centimeters (foot). The thickness of Unit 3 in the Southern Industrial Area is approximately 9.1 meters (30 feet). For purposes of the RESRAD mathematical model, a thickness of 9.14 meters (30 feet) is used. Physical parameters for Unit 3 are included in Appendix 6-B. Unit 3 defines the fourth unsaturated zone in the RESRAD dose model.

The layer below Unit 3 in the Southern Industrial Area is Unit 2, which consists of approximately 6.1 meters (20 feet) of a very dense to hard dry deposit, composed of significant fractions of both clay and silt with only minor sand. This layer is absent in the Northern Industrial Area. Physical parameters for Unit 2 are included in Appendix 6-B. Unit 2 defines the fifth unsaturated zone in the RESRAD dose model.

Unit 1 comprises the bottom zone in the RESRAD dose model for the Southern Industrial Area. It consists of gray-brown, fine to medium grained limestone with occasional fossil rich zones. The bedrock exhibited frequent natural fractures in both high-angle and bedding parallel orientations. Other features present included numerous thin, irregular zones containing dark colored, carbonaceous material. Physical parameters for Unit 1 are included in Appendix 6-B. Unit 1 defines the saturated zone in the RESRAD dose model and is the source of potable water supply for an onsite aquifer.

b. Northern Industrial Area Subsurface Description

Unit 6a, the uppermost unit consists of 0.91 to 1.8 meters (3.0 to 6.0 feet) of loosely compacted and well-rounded gravel or sand. Fine grained clay or silt materials are noticeably absent within this unit. For purposes of the RESRAD mathematical model, a mean thickness of 1.37 meters (4.5 feet) is used. Physical parameters for Unit 6a are included in Appendix 6-C. Both the RESRAD dose model contaminated zone and the first unsaturated zone below it consist of Unit 6a soil.

The layer below Unit 6a in the Northern Industrial Area is Unit 6b, which consists of 0.91 to 1.8 meters (three to six feet) of a slightly more compact sand and gravel unit with intermixed clay-rich layers. The gravel in this zone is generally finer grained (less than 1.3 centimeter (0.5 inch) diameter), and all of the granular particles tended to be subrounded to slightly angular; the individual clay-rich layers (clay, clayey sand, clayey gravel) ranged in thickness from 3.0 to 15 centimeters (0.1 to 0.5 feet). For purposes of the RESRAD mathematical model, a mean thickness of 1.37 meters (4.5 feet) is used. Physical parameters for Unit 6b are included in Appendix 6-C. Unit 6b defines the second unsaturated zone in the RESRAD dose model. Unit 6b is an unconfined groundwater zone and it is depicted in the RESRAD dose model as an unsaturated zone with physical parameters measured from the groundwater zone.

The layer below Unit 6b in the Northern Industrial Area is Unit 5 which consists of approximately 2.1 to 6.1 meters (seven to 20 feet) of a very dense, unsorted mixture of roughly equal parts sand, fine grained clay and silt, and fine to coarse gravel (up to 7.6 centimeter [3.0 inch] diameter). For purposes of the RESRAD mathematical model, a thickness of 4.11 meters (13.5 feet) is used. Physical parameters for Unit 5 are included in Appendix 6-C. Unit 5 defines the third unsaturated zone in the RESRAD dose model.

Unit 4 is below Unit 5 in the Northern Industrial Area. Unit 4 consists of a moderately well sorted medium to coarse sand with some fine gravel. The thickness of Unit 4 in the Northern Industrial Area is approximately 0.61 meters (two feet). For purposes of the RESRAD mathematical model, a thickness of 0.61 meters (two feet) is used. Physical parameters for Unit 4 are included in Appendix 6-C. Unit 4 defines the fourth unsaturated zone in the RESRAD dose model. Unit 4 is a groundwater zone under artesian conditions and is depicted in the RESRAD dose model as an unsaturated zone with physical parameters measured from the groundwater zone.

Unit 3 is below Unit 4 in the Northern Industrial Area. Unit 3 is a very dense deposit containing abundant fine-grained clay and silt, but also including significant sand and fine gravel fractions. This unit is similar to Unit 5, in that the clay rich portions appear to be unsorted, but it also contains frequent thin sand seams (0.30 to 1.5 centimeters [0.01 to 0.05 feet] thick). The sand seam frequency varies, but the average is estimated to be three to four seams per 0.30 meter (foot). The thickness of Unit 3 in the Northern Industrial Area is

approximately 7.3 meters (24 feet). For purposes of the RESRAD mathematical model, a thickness of 7.32 meters (24 feet) is used. Physical parameters for Unit 3 are included in Appendix 6-C. Unit 3 defines the fifth unsaturated zone in the RESRAD dose model.

Unit 1 comprises the bottom zone in the RESRAD dose model for the Northern Industrial Area. It consists of gray-brown, fine to medium grained limestone with occasional fossil rich zones. The bedrock exhibited frequent natural fractures in both high-angle and bedding parallel orientations. Other features present included numerous thin, irregular zones containing dark colored, carbonaceous material. Physical parameters for Unit 1 are included in Appendix 6-C. Unit 1 defines the saturated zone in the RESRAD dose model and is the source of potable water supply for an onsite aquifer.

6.6.2 Computational Method Used for Dose Calculations

RESRAD v6.21 was selected as the computer code to perform site-specific dose modeling within the site Industrial Areas because of the ability to model subsurface soil contamination and groundwater contamination contained within the code. Argonne National Laboratory (ANL) developed the RESRAD computer code under the sponsorship of the U.S. Department of Energy (DOE). The code has been used widely by DOE and its contractors, the U.S. NRC, U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers, industrial firms, universities, and foreign government agencies and institutions. This code is a pathway analysis model designed to evaluate potential radiological doses to an average member of the specific critical group.

The NRC adopted a risk-informed approach in assessing impacts on the health and safety of the public from radioactive contamination. Therefore, the NRC tasked ANL to develop parameter distribution functions and parametric analysis for RESRAD for conducting probabilistic dose analysis. As part of this effort, external modules equipped with probabilistic sampling and analytical capabilities were developed for the RESRAD code. The modules are also equipped with user-friendly input/output interface features to accommodate numerous parameter distribution functions and to fulfill results display requirements.

The RESRAD database includes inhalation and ingestion dose conversion factors from the EPA's Federal Guidance Report (FGR) No. 11, direct external exposure dose conversion factors from FGR-12 and radionuclide half-lives from International Commission on Radiological Protection Publication 38 [References 6-15, 6-16 and 6-10].

6.6.3 Identification of the Critical Group

The critical group for site-specific analysis of the Industrial Area is considered to be a modified resident farmer who moves onto the site and grows some of his or her diet in a garden and uses water tapped from the bedrock aquifer beneath the site. However, this resident farmer would not consume animal products grown onsite. Since the Industrial Area is located on the Lake Michigan shoreline, it is highly

unlikely the site would ever be used for subsistence farming. The lakeshore of Little Traverse Bay in Lake Michigan is highly developed for summer residence and recreational uses. In addition, there currently are no Lake Michigan shoreline farms within 20 miles of Charlevoix. Only 10.1 percent of Charlevoix County land is used for agricultural purposes and the county has an established declining trend in land use for agricultural purposes. Also, lakeshore soils in the area are poorly suited for subsistence farming in that the soil is a gravelly-sandy loam containing low natural fertility and having a moderately low organic content. Finally, lakeshore property values would effectively prohibit use of the site for subsistence farming and it is likely that the future use of the site would be resort or recreational use. For these reasons, it is justifiable to suppress the meat and milk pathways in the RESRAD dose model.

Suppression of the meat and milk pathways has minimal impact on dose modeling. Turning the meat and milk pathways on would result in less than a one percent increase in potential discounted dose discussed in Section 6.7.2. The impact on DCGL values discussed in Section 6.8.2 would range from no impact on DCGL values for the europium isotopes to a 16.5 percent reduction in the DCGL value for Sr-90. The DCGL value for Fe-55 would have a 77.5 percent reduction, but still have a large value of 8.07 E+04 pCi/g.

6.7 PARAMETER VALUES AND A MEASURE OF THEIR UNCERTAINTY

6.7.1 Selection of Parameters for Use with RESRAD

6.7.1.1 Parameter Classification

Dose assessment input parameters may be generally classified as physical, behavioral, or metabolic as defined below.

Physical Parameter: Any parameter whose value would not change if a different group of receptors were considered is classified as a physical parameter. Physical parameters would be determined by the source, its location, and geological characteristics of the site (i.e., these parameters are source- and site-specific). These include the hydrogeological, geochemical, and meteorological characteristics of the site. The characteristics of atmospheric and biospheric transport up to, but not including, uptake by, or exposure of, the dose receptor, would also be considered physical input parameters.

Behavioral Parameter: Any parameter whose value would depend on the receptor's behavior and the scenario definition is classified as a behavioral parameter. For the same group of receptors, a parameter value could change if the scenario changed (e.g., parameters for recreational use could be different from those for residential use).

Metabolic Parameter: If a parameter represents the metabolic characteristics of the potential receptor and is independent of scenario, it is classified as a metabolic parameter. The parameter values may vary in different population age groups. According to the recommendations of the International Commission on Radiological Protection, Report 43 (ICRP 1985), parameters representing metabolic

characteristics are defined by average values for the general population [Reference 6-11]. These values are not expected to be modified for a site-specific analysis because the parameter values would not depend on site conditions.

NUREG-1727, *NMSS Decommissioning Standard Review Plan*, states the licensee may use default values for the behavioral and metabolic parameters, with limited justification, if the values are consistent with the generic definition of the average member of the critical group, and the screening group is reflective of the scenario. Therefore, RESRAD v6.21 default values will be used for the behavioral and metabolic parameters. RESRAD v6.2 input parameters that impact dose, along with their classification and description are provided in Appendix 6-A. These parameters and their classification and description are based on Table 2.1 of Attachment A to NUREG/CR-6697, *Development of Probabilistic RESRAD 6.0* and RESRAD-BUILD 3.0 Computer Codes [Reference 6-26].

6.7.1.2 Default Parameters

As discussed in Section 6.5, BRP dose calculations and derivation of site-specific DCGLs was based on a modified resident farmer scenario. The modified resident farmer scenario accounts for exposure involving residual radioactivity that is initially in the surficial soil, contained in subsurface soils at known maximum concentration levels and contained in the three Industrial Area groundwater zones at known maximum concentration levels. A resident moves onto the site and grows default amounts of his or her diet in a garden and uses water tapped from the bedrock aquifer under the site. This scenario is based on the following assumptions:

- Radioactive contamination occurs in a surface soil layer, subsurface soil and the three Industrial Area groundwater zones.
- The property will not be used for livestock and dairy animal production.
- Residency can occur immediately after release of the property.
- Radioactive dose results from exposure via external exposure, inhalation, and ingestion.

The model includes eleven exposure pathways created by the activities considered in the scenario as follows:

- External exposure to penetrating radiation from volume soil sources while outdoors,
- External exposure to penetrating radiation from volume sources while indoors,
- Inhalation exposure to resuspended soil while outdoors,
- Inhalation exposure to resuspended soil while indoors,
- Inhalation exposure to resuspended surface sources of soil tracked indoors,

- Direct ingestion of soil,
- Inadvertent ingestion of soil tracked indoors,
- Ingestion of drinking water from a contaminated groundwater source,
- Ingestion of plant products grown in contaminated soil,
- Ingestion of plant products irrigated with contaminated groundwater, and
- Ingestion of fish from a contaminated surface water source.

In accordance with NUREG-1727, default values for the behavioral and metabolic parameters were used in the model.

6.7.1.3 Big Rock Point Site-Specific Measured Physical Parameters

To the extent possible, site-specific values were used for physical parameters and mixed physical (parameters classed as physical and behavioral or metabolic parameters). The site-specific values were derived from information contained in BRP Plant Manual, Volume 32, *Environmental Report for Decommissioning*, to the extent possible and the November 8, 2002 Hydrogeological Assessment Report [Reference 6-9]. The input parameter values and their source justification are provided in Appendices 6-B and 6-C.

6.7.1.4 Big Rock Point Site-Specific Calculated Physical Parameters

a. Derivation of Site-Specific Distribution Coefficients (K_ds)

Big Rock Point chose to use one of the methods discussed in Appendix O to Draft NUREG-1757, Volume 2, *Consolidated NMSS Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria*, for the development of input K_d values for soil [Reference 6-20]. According to the answer to Question 6, K_d values for input into site-specific dose modeling codes may be determined by using sensitivity analyses, which include an appropriate range of K_d values, to identify the importance of the K_d to the dose assessment and how the change in K_d impacts the dose (i.e., how dose changes as K_d increases or decreases).

Using the results of the sensitivity analysis, a conservative K_d value is chosen, depending on how it affects the dose (e.g., if higher K_d values result in the larger dose, an input K_d value should be selected from the upper quartile of the distribution, or if lower K_d values result in the larger dose, an input K_d value should be selected from the lower quartile of the distribution).

K_d values were derived for both the site Southern and Northern Industrial Areas using the parameters contained in Appendices 6-B and 6-C.

Following preparation of the dose models, a probabilistic RESRAD calculation was performed for each of the radionuclides individually and for individual radionuclides in each location of the Industrial Area under evaluation [Reference 6-2]. An uncertainty analysis was performed for the radionuclide's (element's) K_d value in each of the seven RESRAD zones (contaminated zone, unsaturated zones 1-5, and the saturated zone). K_d parameter distribution values for each element were obtained from Attachment C to NUREG/CR-6697. The statistical distribution type for K_d is truncated lognormal-n. The K_d parameter distribution values for each element are provided in Table 6-3.

Table 6-3. K_d Parameter Distribution Values

Element	Log Mean (μ)	Standard Deviation (σ)	Lower Quartile	Upper Quartile
H	-2.81	0.5	0.001	0.999
Mn	5.06	2.29	0.001	0.999
Fe	5.34	2.67	0.001	0.999
Co	5.46	2.53	0.001	0.999
Sr	3.45	2.12	0.001	0.999
Cs	6.10	2.33	0.001	0.999
Eu	6.72	3.22	0.001	0.999
Gd	6.72	3.22	0.001	0.999

Following completion of each RESRAD calculation, the most conservative K_d value for each of the seven RESRAD zones was determined. In accordance with the guidance contained in Appendix O to Draft NUREG-1757, the K_d value at the upper or lower quartile of the distribution resulting in the highest derived dose is an acceptable value to input into the dose code without further justification. For those radionuclides where the K_d does not have a significant impact on the dose assessment (i.e., K_d is not a sensitive parameter), the median value within the range is an acceptable input parameter. If the absolute value of the partial ranked correlation coefficient (PRCC) was greater than 0.25, then the parameter value at either the 75% quartile or the 25% quartile was selected based on TEDE correlation with the parameter. If the PRCC value of the peak all-pathway dose was negative, the K_d to dose correlation is negative and the K_d value at the 25% quartile was selected. If the PRCC value was positive, the K_d to dose correlation is positive and the K_d value at the 75% quartile was selected. If the absolute value of the PRCC was equal to or less than 0.25, the dose correlation is not sensitive and the K_d value at the 50% quartile was selected. Partial ranked correlation coefficient was chosen because NUREG/CR-6692 recommends that it be used when nonlinear relationships, widely disparate scales or long tails are present in the inputs and outputs [Reference 6-25].

The results of the K_d derivation are summarized in Table 6-4 for the Southern Industrial Area and in Table 6-5 for the Northern Industrial Area.

Table 6-4. Southern Industrial Area K_d Results (cm^3/g) (and PRCC* Value)

Element	Contaminated Zone	Unsaturated Zone 1	Unsaturated Zone 2	Unsaturated Zone 3	Unsaturated Zone 4	Unsaturated Zone 5	Saturated Zone
H	0.043(-0.47)	0.060(0.04)	0.043(-0.35)	0.060(-0.01)	0.043(-0.46)	0.043(-0.31)	0.060(-0.08)
Mn	733(1.00)	156(-0.05)	155(0.02)	157(-0.05)	155(0.02)	155(-0.05)	165(-0.03)
Fe	1251(1.00)	206(-0.02)	204(-0.09)	207(-0.02)	215(-0.04)	204(0.05)	205(0.01)
Co	1284(1.00)	232(-0.09)	231(-0.04)	234(0.02)	231(0.03)	230(-0.11)	232(0.05)
Sr	131(0.98)	31.2(-0.03)	31.0(-0.06)	31.4(-0.07)	31.0(-0.03)	31.0(-0.08)	31.1(-0.02)
Cs	2130(0.99)	441(-0.04)	438(-0.05)	444(-0.05)	438(0.02)	438(0.06)	440(0.03)
Eu	7194(1.00)	817(0.03)	809(-0.06)	824(-0.03)	809(0.03)	808(-0.02)	814(-0.02)
Gd	7194(0.98)	817(0.00)	809(-0.02)	824(0.00)	809(-0.02)	808(0.02)	814(-0.06)

*PRCC = Partial ranked correlation coefficient for peak all-pathways dose

Table 6-5. Northern Industrial Area K_d Results (cm^3/g) (and PRCC* Value)

Element	Contaminated Zone	Unsaturated Zone 1	Unsaturated Zone 2	Unsaturated Zone 3	Unsaturated Zone 4	Unsaturated Zone 5	Saturated Zone
H	0.043(-0.57)	0.060(-0.05)	0.060(-0.07)	0.060(-0.04)	0.060(-0.07)	0.043(-0.35)	0.060(0.04)
Mn	733(1.00)	156(-0.05)	155(0.02)	157(-0.05)	155(0.02)	155(-0.05)	156(-0.03)
Fe	1251(1.00)	206(-0.02)	204(-0.09)	207(-0.02)	204(-0.04)	204(0.05)	205(0.01)
Co	1284(1.00)	232(-0.09)	231(-0.04)	234(0.02)	231(0.03)	230(-0.11)	232(0.05)
Sr	131(0.95)	31.2(-0.14)	31.0(-0.05)	31.4(-0.12)	31.0(-0.03)	31.0(-0.14)	31.1(0.00)
Cs	2130(0.99)	441(-0.04)	438(-0.05)	444(-0.05)	438(0.02)	438(0.06)	440(0.03)
Eu	7194(1.00)	817(0.03)	809(-0.06)	824(-0.03)	809(0.03)	808(-0.02)	814(-0.02)
Gd	7194(0.98)	817(0.00)	809(-0.02)	824(0.00)	809(-0.02)	808(0.02)	814(-0.06)

*PRCC = Partial ranked correlation coefficient for peak all-pathways dose

The derived K_d values are nearly identical for both the Southern and Northern Industrial Areas. Furthermore, the calculated dose with an input concentration of 1 pCi/g for each of the nine radionuclides in the Southern and Northern Industrial Area models with the calculated K_d values yields an identical calculated dose of 19.8 mrem/year at the initial time. This occurs because we have shown that the dominant exposure pathways are, with the exception of tritium, water independent for the six radionuclides identified to be present in BRP soils. Water independent parameters (contamination depth, contaminated zone soil constants, root depths and other parameters which affect dose from the water independent pathways) are the same for the both the Northern and Southern Industrial Areas.

b. Derivation of Site-Specific Physical Parameters

Whenever possible, site-specific physical parameter values were determined by direct measurement. If a physical parameter value could not be determined by direct measurement, a site-specific value was derived by a probabilistic sensitivity analysis using RESRAD v6.21 [Reference 6-3]. The process followed for this probabilistic sensitivity analysis is outlined in Figure 6-2.

The mathematical model used for the parameter selection process was the RESRAD model for the Northern Industrial Area. This model was selected because there are no known significant areas of surface soil, subsurface soil or groundwater contamination within the Southern Industrial Area. Also, the Northern Industrial Area RESRAD model is considered to be the most conservative because the bedrock aquifer is closer to the surface in the Northern Industrial Area than it is in the Southern Industrial Area and the silty clay layer directly above the bedrock aquifer in the Southern Industrial Area does not exist in the Northern Industrial Area. As noted in Section 6.7.2.4.a, no difference is found for doses calculated in the Northern or Southern Industrial Areas for the radionuclides found in soils at BRP. This is because doses from these radionuclides are driven by water independent pathways. Some doses from discounted radionuclides, calculated at laboratory analytical minimum detectable concentration levels (see LTP Section 6.7.2), are more dependent upon water pathways. Thus, the Northern Industrial Area parameters are more conservative for these radionuclides.

The upper two groundwater zones are not considered to be viable sources of potable water due to low yield and distance from the surface, i.e., State of Michigan statutes prohibit drilling wells this shallow. Also, it is not considered likely that a resident would decide to drop a well into the sand lens to get some water for irrigation in violation of State of Michigan statutes because, due to the shoreline location, it would be easier to run a hose to Lake Michigan to obtain irrigation water.

As shown schematically in Figure 6-2, the parameter selection process starts with the selection of the RESRAD parameter to be evaluated. For purposes of BRP dose modeling, the RESRAD pathways for radon, meat consumption and milk consumption are suppressed and their associated parameters are not used. The selected parameter must then be classified as behavioral, metabolic or physical. Some parameters may belong to more than one of these types.

If the parameters were classified as behavioral or metabolic, the default values used in RESRAD v6.21 were used for performing sensitivity analyses. These parameter values are provided in Appendix 6-D. If the parameters were classified as physical, then they were reviewed to determine if measured, site-specific values for the parameters were available. Measured, site-specific values for physical parameters are also provided in Appendix 6-D.

If measured, site-specific values for physical parameters were not available; the parameters were then ranked by priority as 1, 2, or 3 where 1 represents high priority, 2 represents medium priority and 3 represents low priority. This ranking was the second step in the procedure used by Argonne National Laboratory to develop the probabilistic RESRAD code. The parameter ranking has been documented in Attachment B to NUREG/CR-6697. The assigned priority ranking for each physical parameter for which measured, site-specific values are not available is provided in Appendix 6-D.

If the physical parameters were ranked as priority 3, the default values used in RESRAD v6.21 were used for performing sensitivity analyses. These parameter values are also provided in Appendix 6-D. Three exceptions to this assignment exist. These are for the parameters of humidity in air, indoor time fraction and inhalation rate for which statistical parameter distributions were developed.

Argonne National Laboratory developed statistical parameter distributions for the physical parameters ranked as priority 1 or 2. These parameter distributions have been documented in Attachment C to NUREG/CR-6697. The parameter distributions for BRP priority 1 and 2 physical parameters are listed in Appendix 6-E.

Once the parameter values listed in Appendix 6-D and the statistical parameter distributions listed in Appendix 6-E were loaded into RESRAD v6.21, the code was run in the probabilistic mode. The absolute value of the calculated PRCC of the peak all-pathways dose was then used to classify the parameters with statistical distributions as sensitive or non-sensitive. PRCC was chosen because Reference 6-25 recommends it be used when nonlinear relationships, widely disparate scales or long tails are present in the inputs and outputs. The calculated PRCC values are listed in Appendix 6-E. If the absolute value of the PRCC was greater than 0.25, then the parameter was classified as sensitive. If the absolute value of the PRCC was equal to or less than 0.25, then the parameter was classified as non-sensitive.

Finally, values for use in dose modeling for the physical parameters with statistical distributions were selected based on sensitivity of the calculated PRCC.

If the absolute value of the PRCC was greater than 0.25, then the parameter value at either the 75% quartile or the 25% quartile was selected based on TEDE correlation with the parameter. If the PRCC value of the peak all-pathways dose was negative, the K_d parameter to dose correlation is negative and the K_d parameter value at the 25% quartile was selected. If the PRCC value was positive, the K_d parameter to dose correlation is positive and the K_d value at the 75% quartile was selected.

If the absolute value of the PRCC was equal to or less than 0.25, then the parameter value at the 50% quartile was selected.

The appropriate behavioral, metabolic, physical and probabilistically determined parameter values listed in Appendices 6-D and 6-E were compiled and listed in Appendix 6-F. The RESRAD v6.21 parameters listed in Appendix 6-F are appropriate for dose modeling of surface soil, subsurface soil and groundwater zone contamination at BRP.

6.7.2 Potential Dose From Discounted Radionuclides

As discussed in Section 6.4, a site-specific suite of 24 radionuclides was identified as potentially present in BRP soils. However, only six of these radionuclides were observed in soils during site characterization. Therefore, only these six radionuclides plus the three isotopes of europium were considered in dose modeling. Because of this, an evaluation was performed to ensure the potential dose contribution from these 15 discounted radionuclides does not exceed ten percent of the 10 CFR 20.1402 TEDE dose limit of 25 mrem/year for unrestricted license termination [Reference 6-6]. The radionuclides of concern include the following 15 radionuclides listed in Table 6-6.

Table 6-6. Discounted Radionuclides

C-14	Tc-99	Pu-238	Am-241
Ni-59	Ag-110m	Pu-239	Cm-243
Ni-63	I-129	Pu-240	Cm-244
Zn-65	Cs-134	Pu-241	

6.7.2.1 Derivation of Site-Specific Parameters for Discounted Radionuclides

The RESRAD dose model was prepared in the same manner as that used by EA-BRP-SC-0202 to derive K_d values, using the parameters contained in Appendix 6-F. A probabilistic RESRAD v6.21 calculation was performed for each of the 15 discounted radionuclides. An uncertainty analysis was performed for the radionuclide (element) and progeny K_d value in each of the seven RESRAD dose model zones (contaminated zone, unsaturated zones 1 - 5, and the saturated zone). K_d parameter distribution values for each element were obtained from Attachment C to NUREG/CR-6697. The statistical distribution type for K_d is truncated lognormal-n. The K_d parameter distribution values for each element are provided in Appendix 6-G.

Following completion of each RESRAD calculation, the appropriate K_d value for each of the seven RESRAD zones was determined. The K_d value at the upper, middle or lower quartile of the distribution was selected as the appropriate K_d value. If the absolute value of the PRCC was greater than 0.25, then the parameter value at either the 75% quartile or the 25% quartile was selected based on TEDE correlation with the parameter. If the PRCC value of the peak all-pathway dose was negative, the K_d value at the 25% quartile was selected. If the PRCC value was positive, the K_d value at the 75% quartile was selected. If the absolute value of the PRCC was

equal to or less than 0.25 the dose correlation is not sensitive and the K_d value at the 50% quartile was selected. The results of the K_d derivation from the RESRAD v6.21 calculations are summarized in Appendix 6-G. K_d value results were rounded to three significant figures.

EA-BRP-SC-0203 derived appropriate physical parameter values for use in BRP dose modeling using probabilistic sensitivity analyses. These physical parameters included those for which site-specific measurements were not obtained; however, radionuclide specific physical parameters were derived only for radionuclides that have been observed in BRP soils (and the three isotopes of europium). Therefore, in order to calculate potential dose from the discounted radionuclides, it was necessary to derive radionuclide specific physical parameters using the same methodology as that used to perform EA-BRP-SC-0203. This parameter selection process is outlined in Figure 6-2. For purposes of BRP dose modeling, the RESRAD pathways for radon, meat consumption and milk consumption are suppressed and their associated parameters are not used. The parameter classification and priority ranking from EA-BRP-SC-0203 were retained. The assigned parameter classification and priority ranking are listed in Appendix 6-G. The parameter distribution types from Attachment C to NUREG/CR-6697 are also listed in Appendix 6-G. Once the parameter values listed in Appendix 6-F, the K_d values derived above and the statistical parameter distributions referred to in Appendix 6-G were loaded into RESRAD v6.21, the code was run in the probabilistic mode. The absolute value of the calculated PRCC was then used to classify the parameters with statistical distributions as sensitive or non-sensitive. If the absolute value of the PRCC was greater than 0.25, then the parameter was classified as sensitive. If the absolute value of the PRCC was equal to or less than 0.25, then the parameter was classified as non-sensitive. The parameter value was selected on the basis of TEDE correlation as described above for K_d value selection. The selected parameter values are listed in Appendix 6-G.

6.7.2.2 Calculation of Potential Discarded Dose from Discounted Radionuclides

The potential discounted dose was calculated based on the median minimum detectable activity (MDA) for each radionuclide from the laboratory analyses performed to analyze for each radionuclide in the entire suite of 24 radionuclides. The median MDA for each radionuclide and the associated analytical uncertainty is provided in Table 6-7 below.

Table 6-7. MDA Values for Calculation of Potential Discounted Dose

Radionuclide	MDA (pCi/g)	Radionuclide	MDA (pCi/g)
C-14	0.470 ± 0.821	Pu-238	0.0450 ± 2.09
Ni-59	2.35 ± 2.70	Pu-239	0.040 ± 0.114
Ni-63	0.400 ± 1.02	Pu-240	0.040 ± 0.114
Zn-65	0.0687 ± 0.077	Pu-241	7.25 ± 1.62
Tc-99	0.310 ± 1.09	Am-241	0.0665 ± 0.078
Ag-110m	0.0300 ± 0.016	Cm-243	0.0601 ± 0.131
I-129	0.260 ± 0.037	Cm-244	0.0601 ± 0.131
Cs-134	0.0222 ± 0.015		

The dose model used for this calculation included the parameter values provided in Appendix 6-G. Soil contamination has only been observed to occur in small areas of no more than 150 square meters (1600 square feet). Also, no contaminated soil has been observed above the characterization DCGL values at depths greater than 30 centimeters (12 inches). Therefore, the dose calculation was performed with a contamination zone thickness of 0.3 meters (12 inches) and a contamination zone area of 150 square meters (1600 square feet). The calculation was performed using RESRAD v6.21 in the deterministic mode. The discounted radionuclides were entered with concentrations equal to their MDAs, and known radionuclides were entered at the mean concentrations shown in LTP Section 4, Appendix 4D, Table 4D-4, as derived from characterization data. The RESRAD Summary Report is provided as Appendix 6-H.

Minimum detectable activities are from soil analyses provided in Table 2-11. Analyses were performed on site soils in 2001 and 2002. The analyses provide an upper limit for maximum soil concentrations of the discarded radionuclides that could have been present without detection at that time. Since site release will not occur prior to 2006 and it is conservatively assumed the analyzed soils will remain until then, RESRAD values for t=4 years are utilized for discarded nuclide dose. The calculated peak dose from all radionuclides discounted from the site-specific suite of 24 potential radionuclides is 0.054 mrem/year.

The annual dose of 0.054 mrem/year has been subtracted, along with 0.766 mrem/year due to tritium (see Section 6.8.2) from the allowable annual limit of 25 mrem/year, to provide a conservative limit of 24.18 mrem/year from which other DCGLs are derived.

6.8 DERIVED CONCENTRATION GUIDELINE LEVELS (DCGLs)

6.8.1 Screening DCGLs

The historical site assessment and site characterization have shown that the majority of the site does not contain radioactivity distinguishable from background levels in surface soils, subsurface soils or in subsurface water. This includes survey areas that are classified as Non-Impacted or Impacted Class 2 or 3. Only approximately six acres of the site are classified as Impacted Class 1 and are known or highly suspected to contain localized contamination areas.

The Impacted Class 2 or 3 areas of the site consist of a wide variety of soil types. Both surface and subsurface waters on the site flow northward into Lake Michigan. No Non-Impacted areas exist between the Impacted Class 1 areas with known contamination and Lake Michigan.

For the reasons presented above, screening DCGLs published by the NRC may be used to demonstrate compliance with the site release criteria presented in Section 6.2 for Impacted Class 2 or 3 areas [Reference 6-17]. Areas of the site classified as non-impacted, by definition, do not require demonstration of compliance with the site release criteria. These screening DCGL values are presented in Table 6-8 below.

Table 6-8.

Screening Values for Use Outside the Industrial Area

Radionuclide	DCGL (pCi/g)	Radionuclide	DCGL (pCi/g)
H-3	110	Cs-134	5.7
C-14	12	Cs-137	11
Mn-54	15	Eu-152	8.7
Fe-55	10000	Eu-154	8.0
Ni-59	5500	Eu-155	280*
Co-60	3.8	Pu-238	2.5
Ni-63	2100	Pu-239	2.3
Zn-65	11*	Pu-240	2.3*
Sr-90	1.7	Pu-241	72
Tc-99	19	Am-241	2.1
Ag-110m	4.9*	Cm-243	3.2
I-129	0.50	Cm-244	4.2*

*These values were obtained from NUREG/CR-5512, Vol. 3, Table 6.91 for P_{crit} = 0.1.

6.8.2 Site-Specific Industrial Area DCGLs

6.8.2.1 Dose Limit Reduction Due to Tritium in Groundwater Aquifers

Site-specific DCGLs have been developed to account for tritium that may be present in groundwater by subtracting this tritium dose from the dose guideline of 25 mrem/year. The resultant dose (24.18 mrem/year, taking into account both tritium and discounted nuclides, as described in LTP Section 6.7.2), serves as a limit at which the DCGLs are calculated for each of the other radionuclides. This methodology lowers the DCGL values to assure that when groundwater tritium is present (such as beneath Survey Unit 12), it is accounted for so that total dose at DCGL concentration (or a DCGL fraction of 1.0), plus groundwater tritium dose, will not exceed 25 mrem/year.

Hydrogeological assessment has identified that groundwater occurs in three distinct zones beneath the Industrial Area of the BRP site. These zones include the base of the near surface native sand and gravel layer, the intermediate depth sand layer, and the uppermost fractured portion of the underlying bedrock. Tritium (but no other radionuclides) has been identified in each of these groundwater zones in the Northern Industrial Area. The highest levels attributable to the intermediate groundwater zone have been found at sample points SC-3 and SC-5 of LTP Table 2-12c that were obtained by boring through the base of the Containment Building. The mean tritium concentration of all samples obtained through April, 2004 from SC-3 and SC-5 equals 22,266 pCi/l. The highest samples within the upper groundwater zone are found in monitoring well PZ-5S, with a mean of all samples equal to 1,103 pCi/l. These means are used in the dose calculations that follow. The highest concentration sample point for the deep aquifer is PZ-3D. For PZ-3D, the maximum value of 1,560 pCi/l is used for dose calculation. The highest value is chosen in this case due to the significance of dose from this pathway; it is the only aquifer containing tritium that is potentially useful as a drinking water supply.

The near-surface location of the two upper groundwater-bearing zones are prevented by county health laws from use as sources of drinking water. The limited thickness and pumping capacity (less than a gallon per minute) of these same two units also prevents their use as sources of non-potable water for irrigation or other purposes. The fractured bedrock zone is considered to be the main potable water aquifer that could be utilized in any future development at the site, as well as a potential source of non-potable water. For these reasons, the upper two groundwater-bearing zones are modeled for the RESRAD calculations as contaminated zones bearing tritium contamination. Although there are also much deeper aquifers in the area, use of the most shallow fractured bedrock aquifer (45-foot depth) is most conservative for use in this evaluation.

The tritium concentrations provided above are the concentrations of tritium contained in the groundwater itself. Therefore, for use in RESRAD, these concentrations must be converted into concentrations of tritium in soil. Following the guidance of "Tritium and Carbon-14 Pathway Models" which appears as Appendix L to ANL/EAD-4, User's Manual for RESRAD Version 6, the concentration of tritium in soil water is expressed as [Reference 6-27]:

$$W_{H-3}{}^{(cz)} = \frac{\rho_b{}^{(cz)} \times S_{H-3}}{\theta^{(cz)} \times R_d{}^{(cz)}}$$

where:

$W_{H-3}{}^{(cz)}$ = concentration of H-3 in soil water in the contaminated zone, pCi/cm^3,
$\rho_b{}^{(cz)}$ = bulk density of the contaminated zone, g/cm^3
S_{H-3} = concentration of H-3 in contaminated soil, pCi/g
$\theta^{(cz)}$ = volumetric water constant = $p_t{}^{(cz)} \times R_s{}^{(cz)}$,
$k_d{}^{(cz)}$ = distribution coefficient for tritium from Table 6-5,
$R_d{}^{(cz)}$ = retardation factor = $1 + \rho_b{}^{(cz)} \times k_d{}^{(cz)}/\theta^{(cz)}$,
$p_t{}^{(cz)}$ = total soil porosity, and
$R_s{}^{(cz)}$ = saturation ratio

Solving the above equation for the concentration of tritium in the contaminated soil gives:

$$S_{H-3} = \frac{W_{H-3}{}^{(cz)} \times \theta^{(cz)} \times [1 + \rho_b{}^{(cz)} x\, k_d{}^{(cz)}/\theta^{(cz)}]}{\rho_b{}^{(cz)}}$$

Based on the groundwater tritium concentrations and the parameters listed in Appendix 6-F, the parameters required to calculate the concentration of tritium in the contaminated soil of the upper and intermediate groundwater-bearing zones are provided in Table 6-9 below.

Table 6-9. Parameters Required to Calculate the Concentration of Tritium in Contaminated Soil

Parameter	Groundwater Zone	
	Upper	Intermediate
$W_{H\text{-}3}^{(cz)}$	1.10 pCi/cm^3	22.3 pCi/cm^3
$\theta^{(cz)}$	0.274	0.317
$p_t^{(cz)}$	0.274	0.317
$k_d^{(cz)}$	0.060	0.060
$\rho_b^{(cz)}$	1.95 g/cm^3	1.83 g/cm^3

Based on these parameters, the contaminated soil tritium concentrations resulting from solving the above equation are 0.221 pCi/g in the upper groundwater zone and 5.19 pCi/g in the intermediate groundwater zone.

RESRAD v6.21 was then used with the parameters listed in Appendix 6-F and the above soil tritium concentrations to calculate the peak dose resulting from the contaminated groundwater zones [Reference 6-5]. For the upper groundwater zone, the 1.37 meter thick soil layer above the upper groundwater zone was modeled as a cover layer with the physical properties of the unsaturated zone 1 listed in Appendix 6-F. This mathematical model resulted in a deterministic mode calculated peak dose of 0.024 mrem/year that occurs at 2.70 years.

Cover for the intermediate groundwater zone is defined by the three zones that reside above it. These zones were modeled as a cover above the intermediate zone with physical properties based on Appendix 6-F. The densities of the zones were weight averaged based on zone thickness to derive an average value for the cover. This mathematical model resulted in a deterministic mode calculated peak dose of 0.395 mrem/year that occurs at 1.81 years.

Calculation of peak dose from tritium contamination of the bedrock aquifer is not as straightforward as the calculation for the upper two groundwater zones because RESRAD v6.21 does not have the ability to model contamination in the saturated zone. However, RESRAD v6.21 will internally calculate radionuclide concentrations in the saturated zone and use these concentrations to calculate dose from the water dependent pathways. Because of this feature, RESRAD v6.21 was used in the deterministic mode with the parameters listed in Appendix 6-F as the site-specific dose model. An arbitrary tritium soil concentration of 100 pCi/g was used for the contaminated zone as a source for tritium to enter the water dependent pathways. This calculation showed that, at the time of peak dose (3.05 years), 89.9 percent of the dose was from the water pathway and 10.1 percent from the plant pathway through irrigation.

Since the bedrock aquifer is a potential source of potable water, the dose was calculated by comparison with the EPA's 40 CFR 141.16 drinking water standard. This standard is for a peak concentration of 20,000 pCi/l, which will ensure that the annual dose equivalent to the total body or to any organ will not exceed four mrem/year. Thus, the dose from groundwater may be calculated as follows:

$$Dose_{DW} = C_{DW} \times \frac{4\ mrem/y}{20{,}000\ pCi/l}$$

Solving the above equation for the tritium concentration of 1560 pCi/l in the bedrock aquifer yields a calculated annual dose from drinking water of 0.312 mrem/year. Addition of the dose from the plant pathway through irrigation (0.0046 mrem/year) results in a total dose from tritium in this aquifer of 0.317 mrem/year. However, a more conservative approach is to divide 0.312 mrem/year by the RESRAD calculated factor of 89.9 percent of total dose. This yields a total dose of 0.347 mrem/year from all water dependent pathways in the bedrock aquifer.

Assuming that the calculated peak dose from each groundwater zone occurs at the same time, the calculated peak dose from each groundwater zone may be conservatively summed to yield a total dose contribution of 0.766 mrem/year from tritium contamination in each groundwater zone. The sum of peak dose, as opposed to using peak of mean doses, results in conservatively lower DCGLs of the remaining radionuclides when the tritium dose is subtracted from the dose guideline of 25 mrem/year to yield a dose of 24.23 mrem/year. When discarded nuclide dose of 0.054 mrem/year is subtracted, the resultant dose limit is 24.18 mrem/year.

6.8.2.2 *Derivation of Site-Specific DCGLs*

Six radionuclides have been observed in site soils or groundwater. These include H-3, Mn-54, Co-60, Cs-137 and the HTD radionuclides Fe-55 and Sr-90. Therefore, it is appropriate to derive surface soil DCGL values for these radionuclides and demonstrate it is conservative to apply these DCGL values to subsurface soils down to depths of 10.7 meters. In addition to deriving DCGL values for the observed radionuclides, DCGL values were also derived for the three isotopes of europium, Eu-152, Eu-154, and Eu-155 that could contaminate site soils during demolition of neutron activated concrete.

To derive surface soil DCGL values, RESRAD v6.21 was used in the deterministic mode with the parameters listed in Appendix 6-F to calculate DCGL values for the above six radionuclides. A contaminated zone thickness of 1.5 meters was used for the DCGL derivation. This thickness represents the maximum depth of soil contamination observed to date. DCGL values were also derived for contaminated zone thicknesses of 0.15 and 1.0 meters. Comparison of these values with the values obtained for the 1.5 meter thickness indicates the use of a 1.5 meter thickness provides the most conservative (lowest) DCGL values. The level of conservatism is highlighted by the fact soil characterization has not detected concentrations above site-specific DCGLs at soil depths greater than 1.5 meters.

As discussed in Section 6.8.2.1, subtraction of dose due to tritium in the groundwater plumes and dose from discarded radionuclides that may be present in other limited areas (see Section 6.7.2), results in a net allowable limit for identified radionuclides of 24.18 mrem/year. The RESRAD Summary Report for the 1.5-meter contaminated zone thickness calculation of DCGLs at this limit is included as Appendix 6-I.

The above calculation resulted in the surface soil DCGL values listed in Table 6-10 (calculated results were conservatively rounded to three significant figures):

Table 6-10. Site-Specific Surface Soil DCGL Values

Radionuclide	DCGL Value (pCi/g)	Radionuclide	DCGL Value (pCi/g)
H-3	327	Cs-137	13.2
Mn-54	13.7	Eu-152	7.36
Fe-55	3.58E+05	Eu-154	6.79
Co-60	3.21	Eu-155	287
Sr-90	2.48		

6.8.2.3 Subsurface Soil Contamination

The site characterization process identified several discrete locations of small area and volume pockets of subsurface soil contamination. For purposes of this LTP, subsurface soil contamination is defined as any soil contamination found at depths of greater than 0.15 meters (six inches). The site characterization process did not identify subsurface soil contamination at depths greater than 1.5 meters (five feet); however, a potential exists for subsurface soil contamination down to a level of approximately 10.7 meters (35 feet) at the base of the Containment structure. It should be noted corings through the concrete in the basement of the Containment structure did not identify any contaminates in soil under the Containment structure other than groundwater tritium.

Because subsurface soil contamination has been found only in discrete pockets of small area and volume, it is not appropriate to assume subsurface soil contamination exists over the entire area of assumed surface soil contamination. Therefore, it is not appropriate to apply the same dose limit correction process for subsurface soil that was applied for subsurface water contamination in the three groundwater plumes. Instead, it has been demonstrated it is conservative to apply surface soil DCGL values to subsurface soils down to depths of 10.7 meters (35 feet).

The surface soil DCGL values were used as input soil concentration values for RESRAD v6.21 peak total dose calculations for each radionuclide. Calculations were performed for the contaminated zone located at five different depths. These depths included the surface 15 cm (six inches) to represent the definition of surface soil contamination, then 1.5 meter thick zones below that surface layer to represent subsurface contamination layers:

- 0.15 to 1.65 meters (6 inches to 5.4 feet) below the surface,
- 1.5 to 3.0 meters (5.1 to 10.2 feet) below the surface,
- 2.74 to 4.24 meters (9.0 to 13.9 feet) below the surface, and
- 10.7 to 12.2 meters (35.1 to 40.0 feet) below the surface.

The 0.15 to 1.65 meters (to 5.4 feet) below the surface location represented the lowest depth at which soil contamination was observed during the site characterization process. The 2.74 to 4.24 meters (beginning at 9.0 feet) sub-surface location represents potential contamination within the third soil classification layer in the site mathematical dose model and is the approximate depth of the liquid radwaste vault. The 10.7 to 12.2 meters (35 to 40 feet) sub-surface location represents the base of the Containment structure.

In each calculation, the integrity of the site mathematical dose model was maintained, except that the area of contamination was fixed at 100 square meters, and thickness and number of the unsaturated zones were varied to account for the depth of the contaminated zone. Physical parameters of the contaminated zone were varied to match those of the appropriate unsaturated zone in the site dose model and the cover density used was a weighted average based on zone thickness to derive an average density for the cover.

These calculations demonstrated the peak total dose for tritium, Fe-55 and Sr-90 increases[2] with depth from the surface and peak total dose for the remaining radionuclides decreases with depth from the surface, mainly due to added gamma shielding at subsurface depths. For the radionuclides whose dose increases with depth of contamination, the annual dose limit of 24.18 mrem (plus the assigned 0.766 mrem for tritium in drinking water and 0.054 mrem/year from discounted radionuclides) is not exceeded by application of the surface soil DCGL value to subsurface soil contamination .

Based on the results of these calculations provided in Table 6-11, the application of surface soil DCGLs to discrete pockets of subsurface contamination down to 10.7 meters (35 feet) below the surface is acceptable and conservative. In Table 6-11 below, the surface layer used for comparison represents a contamination zone of only 15 cm thickness, not the 1.5 m thickness utilized in the derivation of site-specific DCGLs. The 15 cm depth of Table 6-11 is provided only for comparison of site-specific values to what would be obtained at the standard surface default value of 15 cm.

[2] Fe-55 and Sr-90 increase only for the first interval due primarily to the change from a 15 cm contamination thickness to a 1.5 meter thickness.

Table 6-11. 100 Square Meter Contaminated Zone – 1.5 Meters Thick, Except Surface*

Radionuclide	Individual Radionuclide Dose Contribution at Time of Radionuclide Peak Total Dose with Contamination at DCGL Concentrations (mrem/year)				
	To 0.15m Surface*	0.15 m to 1.65 m Subsurface	1.5 m to 3.0 m Subsurface	2.7 m to 4.2 m Subsurface	10.7 m to 12.2 m Subsurface
H-3	0.32	1.75	2.26	2.24	2.42
Mn-54	18.1	2.35	0.00	0.00	0.00
Fe-55	0.47	1.96	0.00	0.00	0.00
Co-60	17.5	3.05	0.00	0.00	0.00
Sr-90	0.32	2.12	0.00	0.00	0.00
Cs-137	16.9	2.02	0.00	0.00	0.00
Eu-152	18.6	2.62	0.00	0.00	0.00
Eu-154	18.3	2.70	0.00	0.00	0.00
Eu-155	20.8	0.15	0.00	0.00	0.00

*The calculation for surface soil contamination was performed with a contamination zone thickness of 0.15 meters to provide comparison with default surface contamination.

Application of site-specific surface soil DCGL values to subsurface contamination will assure that if future excavation and spreading of subsurface contamination on the surface occurs, site-specific DCGL values will not be exceeded.

6.8.2.4 Subsurface Tritium

The effects of calculated subsurface tritium concentrations in soil have been accounted for in the determination of the other DCGLs by the method of calculation utilized in Section 6.8.2.1; groundwater tritium concentrations for tritium in contact with soil were converted to soil concentrations, conservatively assuming 100% saturation of the soil with tritiated water. For the sake of conservatism, the surface soil DCGL for tritium also will be utilized for subsurface tritium, even though the dose from the observed subsurface tritium activity in all three groundwater zones has been subtracted from the allowable dose used for DCGL calculation.

The tritium soil analyses that have been performed to date on site soils show that the calculational assumptions described here provide conservative results. Shelby tube samples of soil were obtained during installation of piezometric well PZ-3MA near the centerline of the tritium plume area. Analyses indicated no detectable soil tritium at approximately 9.5 meters (30 to 32 foot) depth, 0.049 pCi/g soil tritium at approximately 4.5 meters (14 to 15 foot) depth, and no detectable soil tritium at 2.5 to 3.0 meters (8 to 10 foot) depth. This well was screened at 8.8 to 9.8 meters (29 to 32 feet), and groundwater concentration at this location was 2105 pCi/l at the time the soil sample was taken. Groundwater concentration in a nearby well (PZ-5S), screened at 2.5 to 4.0 meters (8 to 13 feet), was 957 pCi/l. The maximum concentration of 0.049 pCi/g for soil tritium is significantly lower than the calculated soil value obtained in the conservative calculations of LTP Section 6.8.2.1.

6.9 SENSITIVITY ANALYSIS OF THE BIG ROCK POINT DOSE MODEL

An evaluation was performed to determine sensitivity of the parameters used in the BRP RESRAD v6.21 dose model and to rank sensitive parameters in the order of their sensitivity to the calculated peak mean dose [Reference 6-7]. In contrast to the sensitivity analyses described earlier in this chapter that were used to select conservative non-site specific parameter values, this analysis included evaluation of measured site-specific parameters as well as those judged to be appropriate based on literature and probabilistic analyses described earlier (see listing in Appendix 6-F). The objective of this analysis was to identify parameters significantly linked to dose so that a final evaluation could be performed of parameter suitability for use at the Big Rock Point site.

6.9.1 Sensitivity Analysis with Uncorrelated Parameters

The site-specific RESRAD v6.21 dose model used for the sensitivity analysis was based on the parameters listed in Appendix 6-F. The dose model was loaded with the statistical parameter distributions provided in Appendix 6-J and run in the probabilistic mode. The uncertainty analysis input settings for this calculation were:

- Latin Hypercube sampling
- Random seed – 1000
- Number of observations – 300
- Number of repetitions – 1
- Grouping of observations – correlated or uncorrelated

Calculations were performed for the entire site-specific suite of nine radionuclides (including the three isotopes of europium) with an input concentration of 1 pCi/g for each radionuclide and individually for each of the six radionuclides that have been observed in site soils. Results of these calculations are presented in Appendix 6-K (the ten most sensitive parameters for the suite of radionuclides and the five most sensitive parameters for individual radionuclides).

6.9.2 Sensitivity Analysis with Correlated Parameters

A few input parameters are clearly related, such as effective porosity and total porosity. NUREG/CR-6697, Attachment C identified potential correlations among RESRAD parameters assigned statistical distributions. These correlations for which RESRAD v6.21 allows correlation are provided in Table 6-12 below.

Table 6-12. Potential Parameter Correlations

Parameter	Correlated With	Positive/Negative Correlation
Distribution coefficients	Soil/plant transfer factors	Negative
Effective porosity	Total porosity	Strong positive
Erosion rate	Wind speed	Positive
Erosion rate	Runoff coefficient	Positive
Runoff coefficient	Erosion rate	Positive
Soil density	Total porosity	Negative
Soil/plant transfer factors	Distribution coefficients	Negative
Total porosity	Soil density	Negative
Total porosity	Effective porosity	Strong positive
Wind speed	Erosion rate	Positive

The calculations with uncorrelated parameters were repeated with the addition of the potential parameter correlations contained in Table 6-12 as additional parameter inputs for the uncertainty analysis. In the correlated/uncorrelated grouping, the RESRAD v6.21 user must specify the degree of correlation between each correlated parameter by inputting the correlation coefficient between the ranks of the parameters. If the correlation identified in Table 6-12 was indicated to be positive, a rank correlation coefficient of 0.5 was used. If the correlation is indicated to be negative, a rank correlation coefficient of -0.5 was used. If the correlation is indicated to be strong positive, a rank correlation coefficient of 0.9 was used.

6.9.3 Results of Sensitivity Analysis

Results of these calculations are presented in Appendix 6-K (the ten most sensitive parameters for the suite of radionuclides and the five most sensitive parameters for individual radionuclides). Comparison of most sensitive parameters in Appendix 6-K with those of Appendix 6-E and Table 6-5 for the full suite of radionuclides indicate agreement among parameters of dose significance, but also show that density of the contaminated zone, assigned as a constant based on site-specific data, is highly linked to dose. Evaluation identified the reason to be the increase in total quantity of radioactivity that would be present at a given concentration as density increases. Also, among the single-nuclide runs, high positive correlations are noted for tritium with respect to runoff coefficient and fruit, vegetable and grain consumption.

Site soils data for contaminated zone density (1.75 g/cm^2) was reviewed and found to accurately represent the onsite soil. Soil with this density was utilized to backfill and level the entire Industrial Area. The value of 1.75 g/cm^2 is higher (more conservative) than either the default deterministic value of 1.50 g/cm^2 or the probabilistic mean value of 1.52 presented in NUREG/CR-6697. Consequently, it was determined that use of the density of 1.75 g/cm^2 is appropriately conservative.

Runoff coefficient was investigated and the value utilized (0.448) was found to be adequately conservative for the soils type and slope of the site (values for intermediate combinations of clay and loam and slopes of 4.6 to 6.1 m/mi as present

at the site both are referenced as 0.2 in NUREG/CR-6697, Table 4.2-1). The value used for fruit, vegetable and grain consumption (205 kg/y) was found to be significantly higher and, therefore, adequately conservative, as compared to both the default RESRAD value (160 kg/y) and the sum of values used by D&D (52.8+44.6+14.4 = 111.8 kg/y). Thus, the evaluation showed that the chosen values were appropriate for use without further adjustment.

Results of the sensitivity calculations also show that the chosen parameters provide dose stability. Dose stability may be defined as acceptable variability of dose within the range of parameters chosen to represent site conditions.

RESRAD probabilistic analyses show that the deterministic dose is at approximately the 90 percentile of the probabilistic range when the probabilistic input includes the largest possible number of probability distributions (147 parameter distributions in this RESRAD run). The deterministic result is on the high side as a reflection of the choice of conservative parameter values in accordance with Reference 6-26, Attachment C, as well as the tendency of the probabilistic calculations to spread dose over longer periods and, thereby, report lower peak dose. The deterministic peak dose for the sum of radionuclides is 17.6 mrem/year at T=0 and the probabilistic peak of mean dose is 11.5 mrem/year at T=0. Dose stability is indicated by residence of the deterministic value within the probabilistic range of expected values.

6.10 DERIVATION OF AREA FACTORS

NUREG-1727, Appendix C, Section 4.3.3.5 states that the extent of residual radioactivity can be taken into account when modifying the default (baseline) scenarios. The baseline scenarios assume large areas of homogeneous surface contamination. If the area of residual radioactivity is smaller than the baseline, the licensee may propose modifying the exposure pathways to account for the effect on the critical group's activities. Two methods can be followed: (1) the licensee can reduce the calculated dose by the fraction of the default area or modify usage parameters accordingly; or (2) modify the exposure scenario and pathways to account for the size of the residual radioactivity. When the extent of residual radioactivity becomes smaller, some of the activities are no longer viable as reasonable assumptions for exposure.

The meat and milk pathways have been suppressed in the BRP site-specific dose model because it is highly unlikely that a farm of any size would ever be established on the shoreline of Lake Michigan at the site location. Therefore, area factors have been determined based on variation in the size of the residual radioactivity.

Within RESRAD v6.21, the internal area factor[3] (FA3) used to calculate dose from the plant ingestion pathway is automatically calculated to adjust for size of the contaminated zone when the contaminated fraction is set to the default entry of -1 in accordance with the equation below:

[3] Not to be confused with the area factors calculated for final status surveys.

$$FA_3 = A/2{,}000 \text{ when } 0 \leq A \leq 1{,}000\ m^2$$
$$= 0.5 \text{ when } A > 1{,}000\ m^2$$

An area factor for use in elevated measurement comparison during final status surveys is defined by the equation:

$$Area\ Factor = \frac{DCGL_{EMC}}{DCGL_W}$$

where: $DCGL_W$ = Baseline DCGL value and
$DCGL_{EMC}$ = Elevated measurement comparison DCGL value

NUREG-1505 provides the methodology for calculating area factors in Chapter 8. Chapter 8 states that the area factors should be calculated using dose pathway models and assumptions that are consistent with those used to calculate the $DCGL_W$. Area factors are computed by taking the ratio of the dose per unit concentration calculated by RESRAD for the baseline area to that calculated for various smaller areas.

RESRAD v6.21 was used in the deterministic mode to calculate dose per unit concentration values using the site-specific input parameters contained in Appendix 6-F. A contaminated zone thickness of 1.5 meters was used for the calculations to match the contaminated zone thickness used to derive DCGL values. The contaminated zone area was varied from the baseline area of 8,094 m^2 down to 1 m^2. Each time a new contaminated zone area was used, a corresponding value for length of contaminated zone parallel to the aquifer flow was calculated.

The dose per unit concentration value is termed the dose to source ratio (DSR) by RESRAD (units of mrem/year per pCi/g). The DSRs calculated by RESRAD were used to calculate area factors in accordance with the following equation:

$$AF_i = \frac{DSR_{Baseline}}{DSR_i}$$

where:

Af_i = Area Factor at EMC area i
$DSR_{Baseline}$ = *DSR at the baseline area of 8,094 m^2*
DSR_i = *DSR for EMC area i*

The results of the area factor calculations (rounded to three significant figures) are provided as Appendix 6-L. Area factors for the gamma emitting radionuclides are shown as a graphical plot in Figure 6-2 and the area factors for HTD radionuclides are shown as a graphical plot in Figure 6-3.

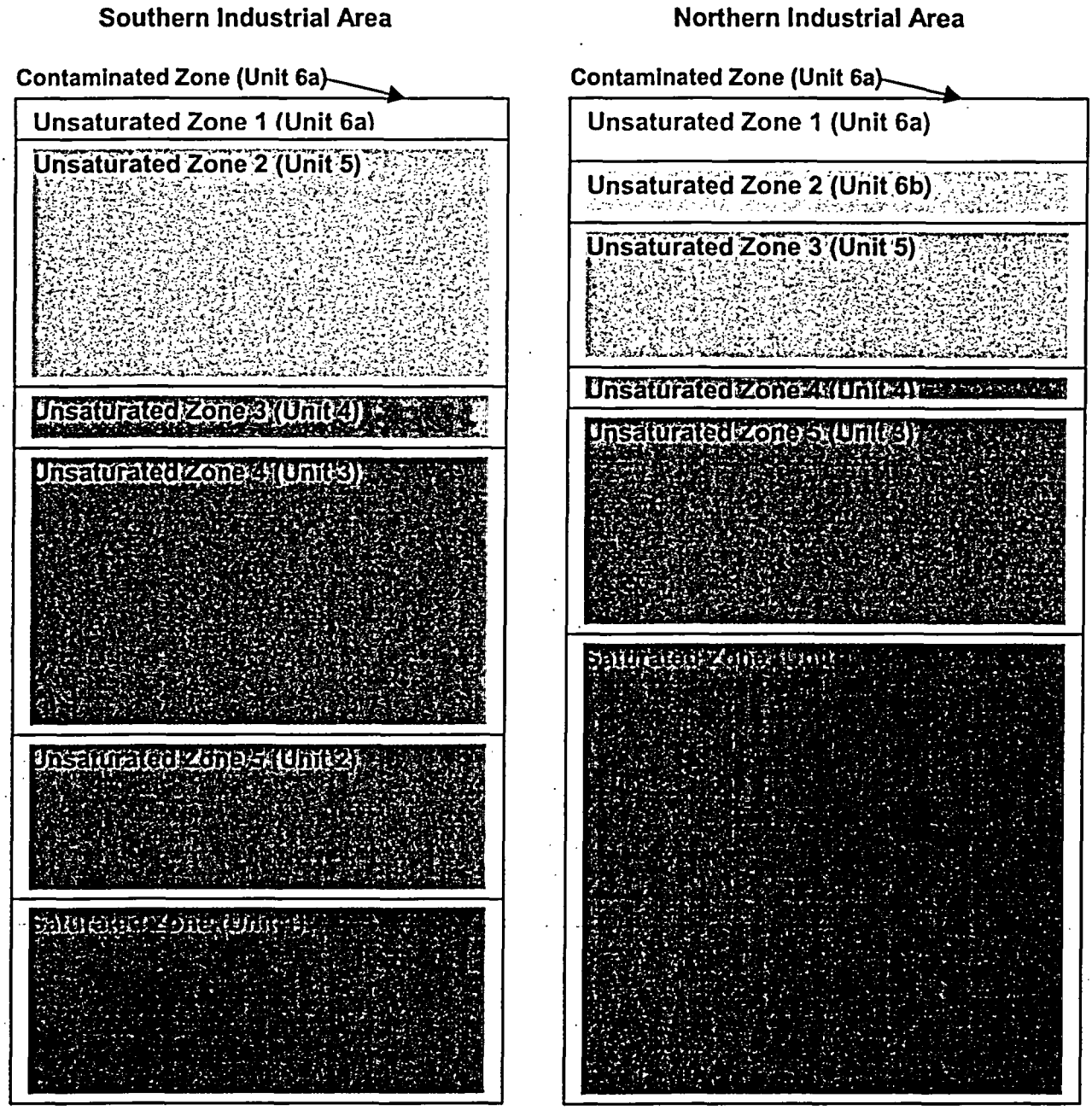

Figure 6-1. RESRAD Mathematical Dose Models

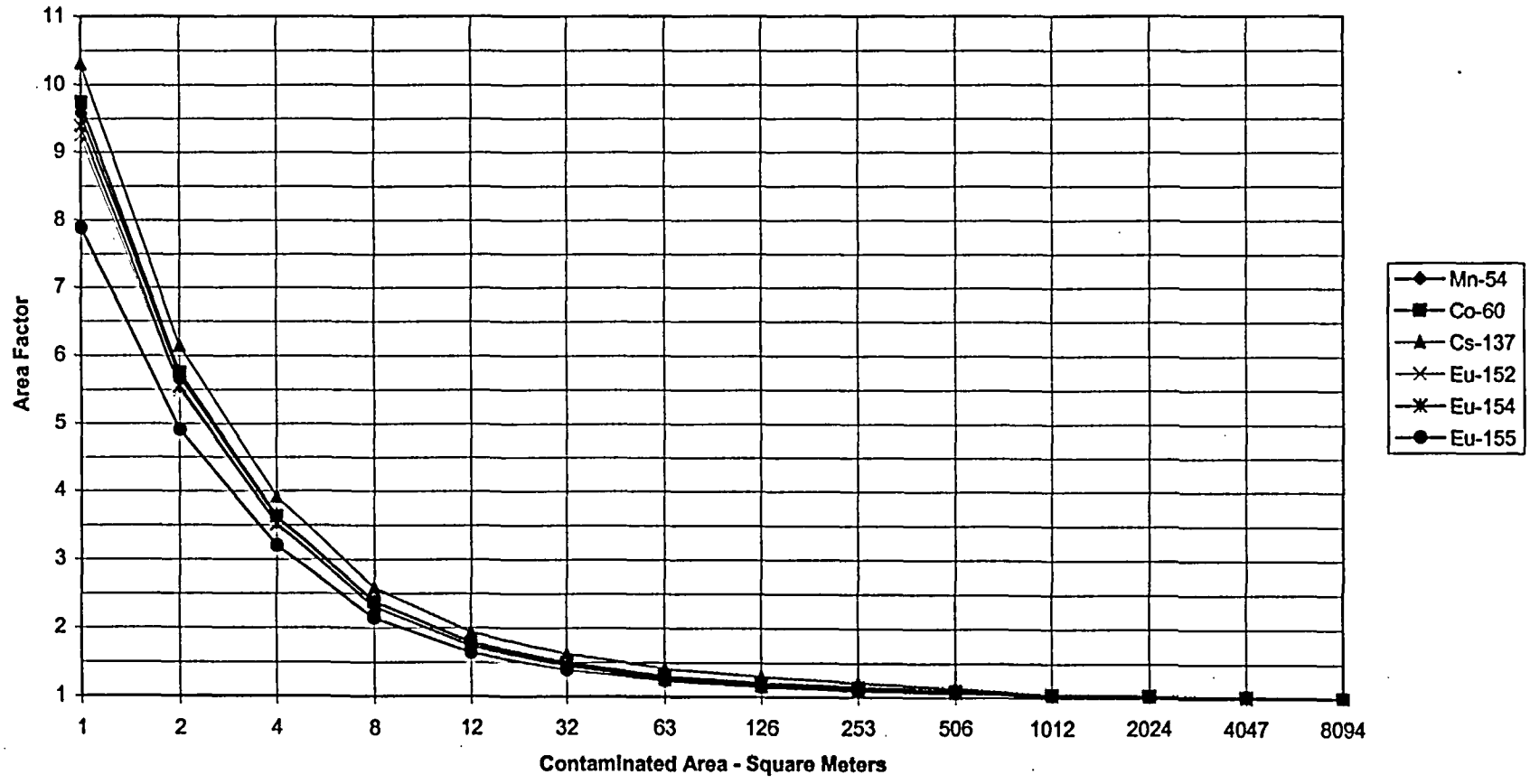

Figure 6-2. Area Factors for Gamma Emitting Radionuclides

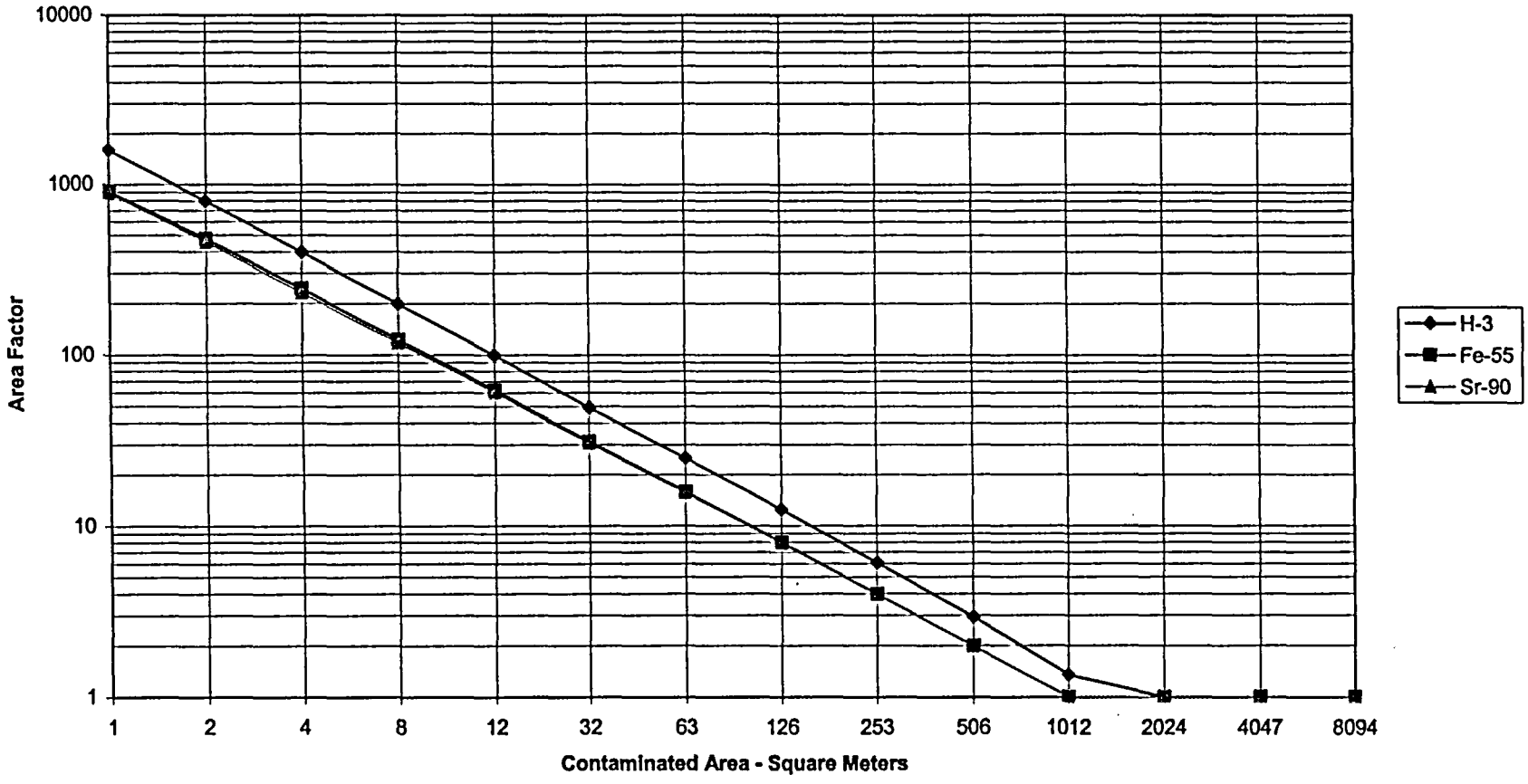

Figure 6-3. Area Factors for Hard-to-Detect Radionuclides

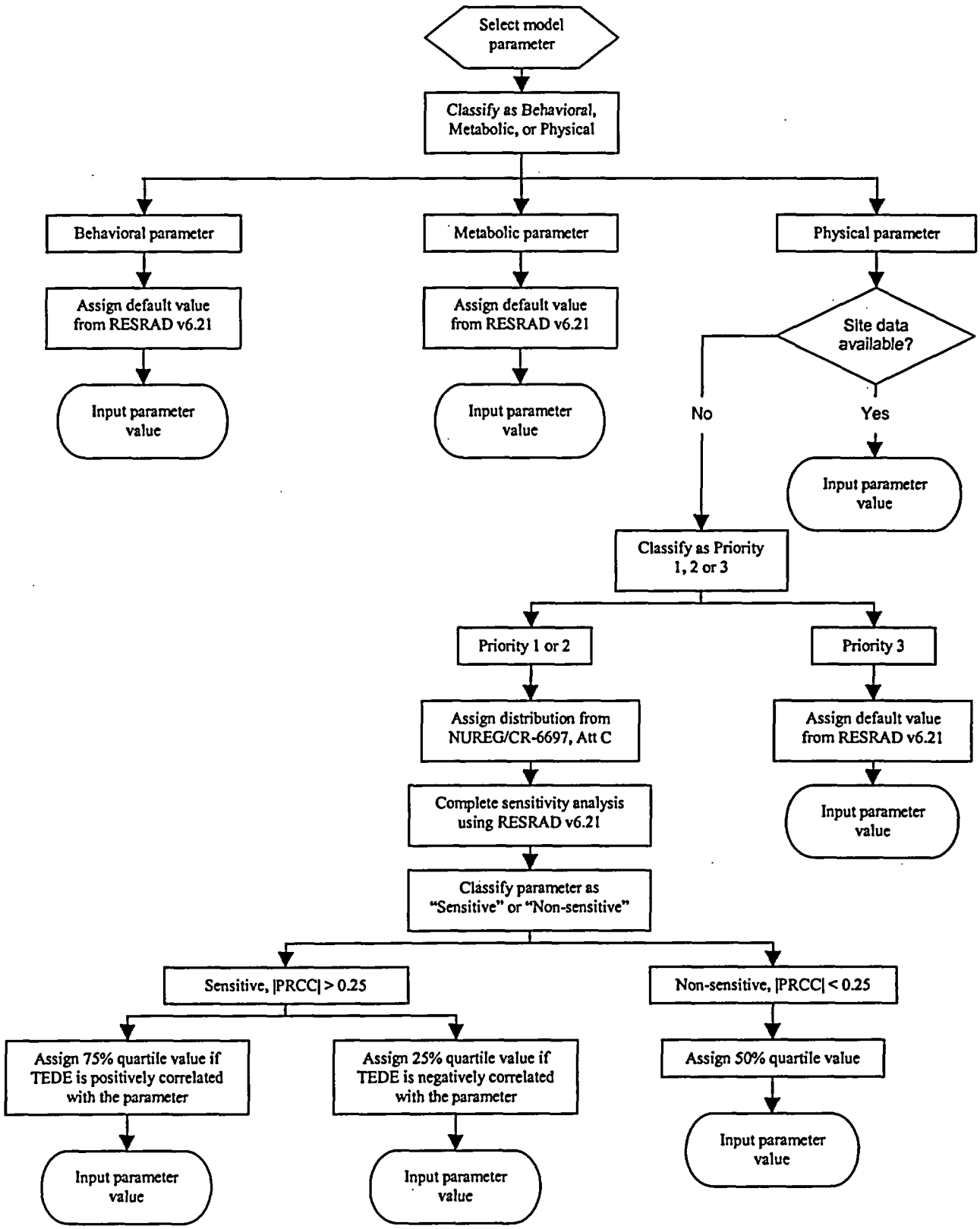

Figure 6-4. Parameter Selection Process

6.11 REFERENCES

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6-2 Big Rock Point Engineering Analysis EA-BRP-SC-02-02, Derivation of K_d Values for use at Big Rock Point

6-3 Big Rock Point Engineering Analysis EA-BRP-SC-02-03, RESRAD Parameter Selection for use in Big Rock Point Dose Modeling

6-4 Big Rock Point Engineering Analysis EA-BRP-SC-02-04, Radionuclides Present in Onsite Soil and Water

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6-6 Big Rock Point Engineering Analysis EA-BRP-SC-03-01, Evaluation of Potential Dose from Discounted Radionuclides

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6-24 U.S. Nuclear Regulatory Commission NUREG/CR-5512, Volume 3, Residual Radioactive Contamination from Decommissioning Parameter Analysis, October 1999

6-25 U.S. Nuclear Regulatory Commission NUREG/CR-6692, Probabilistic Modules for the RESRAD and RESRAD-BUILD Computer Codes, November 2000

6-26 U.S. Nuclear Regulatory Commission NUREG/CR-6697, Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes, November 2002

6-27 Yu, C., et al., ANL/EAD-4, User's Manual for RESRAD Version 6, July 2001

Parameter	Classification	Description
Contamination		
Thickness of contaminated zone	Physical	The distance (m) between the uppermost and lowermost soil samples that has radionuclide concentration clearly above background.
Area of contaminated zone	Physical	Area (m^2) that contains location of soil exceeding background radionuclide concentrations.
Shape of the contaminated zone	Physical	The code has the capability to handle any shape of contaminated zone. If the shape factor flag has been set, the 12 annular area fields comprising shape factor data are input. The shape factor data are calculated by RESRAD by drawing 2 to 12 concentric circles emanating from the receptor location inside (or possibly outside) the contaminated area. The outermost circle circumscribes the entire contaminated zone. For each annular ring, the outer radius and fraction of the ring within the contaminated zone should be entered. For simple shapes (square, rectangle, triangle, doughnut), two circles are sufficient. For complicated shapes, all 12 concentric circles can be used.
Initial concentration of principal radionuclides in soil	Physical	Average radionuclide concentration (pCi/g) in the contaminated zone. The contaminated zone is treated as a uniformly contaminated volume with the same radionuclide concentration.
Initial concentration of radionuclides present in groundwater	Physical	The measured groundwater concentration (pCi/l) of principal radionuclides. The groundwater concentration should be measured at the same time the soil concentrations are measured. Groundwater concentration can be input only if time since placement of material is > 0.

Parameter	Classification	Description
Leach rate	Physical	The fraction of the available radionuclide leached from the contaminated zone per unit of time (1/yr). Radionuclide leach rates should be used if known. The nonzero leach rate is used to calculate the leaching of the radionuclide from the contaminated zone and to derive the water/soil concentration ratio and distribution coefficient. If the derived distribution coefficient is greater than zero, the input distribution coefficient would be replaced by these values.
Solubility limit	Physical	The solubility limit (mol/L) provides an additional option for calculating the distribution coefficient in the code. The solubility limit serves as an upper bound on the amount of a radionuclide released from the soil particles.
Time since placement of material	Physical	The duration (yr) between the placement of radioactive material on-site and the performance of a radiological survey. A non-zero value for this parameter is necessary to activate the groundwater concentration input box. The non-zero value of this parameter is used along with groundwater concentration to calculate the water/soil concentration ratio and effective distribution coefficient.
Times for calculation	Physical	The times in years following the radiological survey for which tabular values for single-radionuclide soil guidelines and mixture sums will be obtained. The code calculates dose at time zero and up to nine user specified times.
Contaminated zone density	Physical	Bulk density of the contaminated zone (g/cm^3).
Contaminated zone distribution coefficient	Physical	Site-specific values should be used everywhere for each radionuclide. Default values are provided by the code for most radionuclides. However, these values should be used with care because distribution coefficients can vary over many orders of magnitude.
Use plant/soil ratio	Not Applicable	The code allows distribution coefficients to be calculated from the plant root uptake factors (plant/soil concentration ratio). This option becomes active if the plant/soil ratio box is checked.

Parameter	Classification	Description
Contaminated zone field capacity	Physical	Volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is one of several hydrogeological parameters used to calculate water transport through the unsaturated part of the soil. The user can use this input to specify a minimum moisture content for each partially saturated region. It is also called specific retention, irreducible water content, or residual water content.
Contaminated zone erosion rate	Physical, Behavioral	Average volume of soil material removed from one place to another by water, wind, or moving ice per unit of ground surface area per unit time.
Contaminated zone total porosity	Physical	Ratio of the pore volume to the total volume of the contaminated zone.
Contaminated zone hydraulic conductivity	Physical	The measure of the soil's ability to transmit water (m/year) when submitted to a hydraulic gradient. The hydraulic conductivity depends on the soil grain size, the structure of the soil matrix, the type of soil fluid, and the relative amount of soil fluid (saturation) present in the soil matrix.
Contaminated zone b parameter	Physical	An empirical and dimensionless parameter that is used to evaluate the saturation ratio (or the volumetric water saturation) of the soil according to a soil characteristic function called the conductivity function.
Carbon-Model Parameters		
Thickness of evasion layer of C-14 in soil	Physical	The maximum soil thickness layer through which C-14 can escape to the air by conversion to CO_2. C-14 below this depth is assumed to be trapped.
C-14 evasion flux rate from soil	Physical	The fraction of the soil inventory of C-14 that is lost to the atmosphere per unit time.
C-12 concentration in local water	Physical	The stable carbon concentration in g/cm^3 of C-12 in water.
C-12 concentration in contaminated soil	Physical	The stable carbon concentration in g/cm^3 of C-12 in the contaminated soil
Fraction of vegetation carbon absorbed from soil	Physical	The fraction of total vegetation carbon obtained by direct root uptake from the soil.

Parameter	Classification	Description
Fraction of vegetation carbon absorbed from air	Physical	The fraction of total vegetation carbon assimilated from the atmosphere through photosynthesis.
C-12 evasion flux rate from soil	Physical	The fraction of C-12 in soil that escapes to the atmosphere per unit time.
Grain fraction in beef cattle feed	Behavioral	The fraction of grain (non-leafy) vegetation in the livestock diet (0.8). The balance is assumed to be leafy vegetation: hay or fodder.
Grain fraction in milk cow feed	Behavioral	The fraction of grain (non-leafy) vegetation in the livestock diet (0.2). The balance is assumed to be leafy vegetation: hay or fodder.
Soil		
Cover depth	Physical	Distance (m) from the ground surface to the contaminated zone.
Density of cover material	Physical	Bulk density of the cover material (g/cm^3).
Cover total porosity	Physical	The ratio of the void space volume to the total volume of the porous medium.
Cover volumetric water content	Physical	The fraction of the total volume of the porous medium that is occupied by water.
Cover radon diffusion coefficient	Physical	The effective (or interstitial) radon diffusion coefficient is the ratio of the diffusive flux density of radon activity across the pore area to the gradient of the radon activity concentration in the pore space (m^2/s). Entering –1 for any diffusion coefficient will cause the code to calculate the diffusion coefficient based on the porosity and water content of the medium.
Cover erosion rate	Physical, Behavioral	The average volume of cover material that is removed per unit of ground surface area and per unit of time. Erosion rates can be estimated by means of the universal soil loss equation.
Number of unsaturated zones	Physical	Number of unsaturated zones. An unsaturated zone is defined as a horizontal uncontaminated layer located between the contaminated zone and the aquifer. The code allows a maximum of five unsaturated zones.

Parameter	Classification	Description
Unsaturated zone thickness	Physical	The thickness of the uncontaminated unsaturated zone that lies below the bottom of the contaminated zone and above the groundwater table. The code has provisions for up to five different horizontal strata within this zone. Each stratum is characterized by six radionuclide independent parameters: thickness, density, total porosity, effective porosity, b parameter, and hydraulic conductivity.
Unsaturated zone density	Physical	Bulk density of the unsaturated zone soil (g/cm^3).
Unsaturated zone distribution coefficient	Physical	Site-specific values should be used everywhere for each radionuclide. Default values are provided by the code for most radionuclides. However, these values should be used with care because distribution coefficients can vary over many orders of magnitude.
Unsaturated zone total porosity	Physical	Ratio of the pore volume to the total volume of the unsaturated zone.
Unsaturated zone effective porosity	Physical	The effective porosity is the ratio of the pore volume where water can circulate to the total volume. It is used along with other hydrological parameters to calculate the water transport breakthrough times.
Unsaturated zone field capacity	Physical	Volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is one of several hydrogeological parameters used to calculate water transport through the unsaturated part of the soil. The user can use this input to specify a minimum moisture content for each partially saturated region. It is also called specific retention, irreducible water content, or residual water content.
Unsaturated zone hydraulic conductivity	Physical	The measure of the soil's ability to transmit water when submitted to a hydraulic gradient. The hydraulic conductivity depends on the soil grain size, the structure of the soil matrix, the type of soil fluid, and the relative amount of soil fluid (saturation) present in the soil matrix.

Parameter	Classification	Description
Unsaturated zone soil-specific b parameter	Physical	An empirical and dimensionless parameter that is used to evaluate the saturation ratio (or the volumetric water saturation) of the soil according to a soil characteristic function called the conductivity function.
Water		
Density of saturated zone	Physical	Bulk density of the saturated zone (g/cm^3).
Saturated zone distribution coefficient	Physical	Site-specific values should be used everywhere for each radionuclide. Default values are provided by the code for most radionuclides. However, these values should be used with care because distribution coefficients can vary over many orders of magnitude.
Saturated zone total porosity	Physical	Ratio of the pore volume to the total volume of the saturated zone.
Saturated zone effective porosity	Physical	The effective porosity is the ratio of the pore volume where water can circulate to the total volume. It is used along with other hydrological parameters to calculate the water transport breakthrough times.
Saturated zone field capacity	Physical	Volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. The field capacity is one of several hydrogeological parameters used to calculate water transport through the saturated part of the soil. It is also called specific retention, irreducible water content, or residual water content. (The field capacity and b parameter of the saturated zone are used only if the water table drop rate is positive.)
Saturated zone hydraulic conductivity	Physical	The measure of the soil's ability to transmit water when submitted to a hydraulic gradient. The hydraulic conductivity depends on the soil grain size, the structure of the soil matrix, the type of soil fluid, and the relative amount of soil fluid (saturation) present in the soil matrix.

Parameter	Classification	Description
Saturated zone hydraulic gradient	Physical	The change in hydraulic head per unit of distance in the groundwater flow direction. In an unconfined (water table) aquifer, the horizontal hydraulic gradient of groundwater flow is approximately the slope of the water table. In a confined aquifer, it represents the difference in potentiometric surfaces over a unit distance.
Saturated zone b parameter	Physical	An empirical and dimensionless parameter that is used to evaluate the saturation ratio (or the volumetric water saturation) of the soil according to a soil characteristic function called the conductivity function.
Length of contaminated zone parallel to the aquifer flow	Physical	The distance (m) between two parallel lines perpendicular to the direction of aquifer flow, one at the upgradient edge of the contaminated zone and the other at the downgradient edge.
Water table drop rate	Physical	The rate at which the depth of the water table is lowered. If the water table drop rate is greater than zero, the unsaturated zone thickness will be created or increased. The saturation of this newly created unsaturated zone is estimated by the hydrological parameters of the saturated zone. The code does not allow a negative water table drop rate.
Well-pump intake depth (below water table)	Physical	The screened depth of a well within the aquifer (the saturated zone).
Well pumping rate	Behavioral, Physical	The volume of water removed from the groundwater aquifer annually for all domestic purposes in m^3/y.

Parameter	Classification	Description
Model: non-dispersion or mass balance	Not Applicable	Two models are used in the code for calculating the water/soil concentration ratio for the groundwater pathway: a mass-balance (MB) model and a nondispersion (ND) model. The MB model assumes that a well is located at the center of the contaminated zone, and the ND model assumes that the well is located at the downgradient edge of the contaminated zone. In the MB model, it is assumed that all of the radionuclides released from the contaminated zone are withdrawn through the well. In the ND model, it is assumed that the saturated zone is a single homogenous stratum, and the water withdrawn introduces only a minor perturbation in the water flow.
Evapotranspiration coefficient	Physical	The ratio of the total volume of water leaving the ground via evapotranspiration to the total volume of water available within the root zone of the soil during a fixed period of time.
Humidity in air	Physical	Average absolute humidity in air. It is used in the tritium model to calculate tritium concentration in air.
Average annual wind speed	Physical	The overall average of the wind speed, measured near the ground.
Precipitation rate	Physical	Average volume of water in the form of rain, snow, hail or sleet that falls per unit area and per unit time at the site (m/yr)
Irrigation mode	Behavioral	Method of irrigation (overhead or ditch).
Irrigation rate	Behavioral	The average volume of water that is added to the soil at the site, per unit of surface area and per unit of time. Irrigation is the practice of supplying water artificially to the soil in order to permit agricultural use of the land in an arid region or to compensate for occasional droughts in semidry or semi humid regions. It is the average annual irrigation rate.
Runoff coefficient	Physical	Fraction of annual precipitation that does not infiltrate into the soil and is not transferred back to the atmosphere through evapotranspiration.
Watershed area for nearby stream or pond	Physical	The site-specific area that drains into the nearby pond.

Parameter	Classification	Description
Accuracy for water soil computation	Not Applicable	The fractional accuracy desired (convergence criterion) in the Romberg integration used to obtain water/soil concentration ratios.
Ingestion		
Fruit, vegetable, and grain consumption rate	Metabolic, Behavioral	The dietary factor for fruit, vegetable, and grain consumption by humans. The default is based on national averages.
Leafy vegetable consumption	Metabolic, Behavioral	The dietary factor for leafy vegetable consumption by humans. The default is based on national averages.
Milk consumption	Metabolic, Behavioral	The dietary factor for milk consumption by humans. The default is based on national averages.
Meat and poultry consumption	Metabolic, Behavioral	The dietary factor for meat and poultry consumption by humans. The default is based on national averages.
Fish consumption rate	Metabolic, Behavioral	The dietary factor for fish consumption by humans. The default is based on national averages.
Other seafood consumption rate	Metabolic, Behavioral	The dietary factor for other seafood consumption by humans. The default is based on national averages.
Aquatic food contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake for the fish pathway. The remaining balance is from off-site sources, which are assumed to be uncontaminated. The default value of 0.5 indicates that 50% of aquatic food is being obtained from on-site sources. Setting the value to 0 will turn off the fish pathway entirely.
Soil ingestion rate	Metabolic, Behavioral	The average annual quantity of soil ingested for the soil ingestion pathway.
Drinking water intake	Metabolic, Behavioral	The drinking water ingestion rate.
Storage time for fruits, non-leafy vegetables, and grain	Behavioral	The storage times are used to calculate radioactive ingrowth and decay adjustment factors for food and feed due to storage. The code has values for fruits, non-leafy vegetables, and grain (one category), leafy vegetables, milk, well and surface water, livestock fodder, meat, fish and crustacea; and mollusks.
Storage time for leafy vegetables	Behavioral	See above.
Storage time for milk	Behavioral	See above.
Storage time for meat	Behavioral	See above.
Storage time for fish	Behavioral	See above.

Parameter	Classification	Description
Storage time for crustacea and mollusks	Behavioral	See above.
Storage time for well water	Behavioral	See above.
Storage time for surface water	Behavioral	See above.
Storage time for livestock fodder	Behavioral	For livestock fodder the storage time is an annual average. The default value is obtained by assuming 6 months of outside gazing and 6 months of silage fodder with an average silo time of 3 months.
Drinking water contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake for the drinking water pathway. The remaining balance (if value <1) of the drinking water is from off-site sources, which are assumed to be uncontaminated. Setting the value to zero will turn off the drinking water pathway entirely.
Household water contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated household water for use in calculating radon exposure. The remaining balance (if value <1) of the household water is from off-site sources, which are assumed to be uncontaminated. The default value of 1 indicates that all household water is from an on-site source.
Livestock water contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake of livestock water for the meat and milk pathway. The remaining balance (if value <1) of the livestock water is from off-site sources, which are assumed to be uncontaminated. The default value of 1 indicates that all livestock water is from an on-site source.
Irrigation water contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake of irrigation water for the plant, meat and milk pathways. The remaining balance (if value <1) of the irrigation water is from off-site sources, which are assumed to be uncontaminated. The default value of 1 indicates that all irrigation water is from an on-site source.

Parameter	Classification	Description
Plant food contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake for the plant pathway. The appropriate values range from 0 to 1, although a negative value can be input. The remaining balance is from off-site sources, which are assumed to be uncontaminated. The default value of -1 specifies that the contaminated fraction of plant food will be calculated from the appropriate area factor in the code. Setting the value to 0 will turn off the plant pathway entirely.
Meat contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake for the meat pathway. The appropriate values range from 0 to 1, although a negative value can be input. The remaining balance is from off-site sources, which are assumed to be uncontaminated. The default value of -1 specifies that the contaminated fraction of meat will be calculated from the appropriate area factor in the code. Setting the value to 0 will turn off the meat pathway entirely.
Milk contaminated fraction	Behavioral, Physical	Allows specification of the fraction of contaminated intake for the milk pathway. The appropriate values range from 0 to 1, although a negative value can be input. The remaining balance is from off-site sources, which are assumed to be uncontaminated. The default value of -1 specifies that the contaminated fraction of milk will be calculated from the appropriate area factor in the code. Setting the value to 0 will turn off the milk pathway entirely.
Livestock fodder intake rate for meat	Metabolic	The daily intake of fodder by livestock kept for meat consumption. The code uses the area factor to calculate the contaminated intake.
Livestock fodder intake rate for milk	Metabolic	The daily intake of fodder by livestock kept for milk consumption. The code uses the area factor to calculate the contaminated intake.
Livestock water intake rate for meat	Metabolic	The daily intake of water by livestock kept for meat consumption. The code uses the area factor to calculate the contaminated intake.

Parameter	Classification	Description
Livestock water intake rate for milk	Metabolic	The daily intake of water by livestock kept for milk consumption. The code uses the area factor to calculate the contaminated intake.
Livestock intake of soil	Metabolic	Daily intake of soil by livestock kept for meat or milk consumption.
Mass loading for foliar deposition	Physical	The average mass loading of airborne contaminated soil particles in a garden during the growing season.
Depth of soil mixing layer	Physical	Used in calculating the depth factor for dust inhalation and soil ingestion pathways and for foliar deposition for the plant, meat, and milk ingestion pathways. The depth factor is the fraction of the resuspendable soil particles at the ground surface that are contaminated. It is calculated by assuming that mixing of soil will occur in the soil mixing layer.
Depth of roots	Physical	The maximum root depth below the ground surface.
Groundwater fractional usage for drinking water	Behavioral, Physical	The four groundwater fractional usage parameters (drinking water, household water, livestock water, and irrigation water) are included primarily for all groundwater (well or spring) and surface water (pond or river) scenarios. Hence, the fractions will usually be set at 1 or 0. A value of 1 specifies 100% groundwater usage and 0 selects 100% surface water usage.
Groundwater fractional usage for household water	Behavioral, Physical	See above.
Groundwater fractional usage for livestock water	Behavioral, Physical	See above.
Groundwater fractional usage for irrigation water	Behavioral, Physical	See above.
Wet weight crop yield for non-leafy plants	Physical	The weight of the edible portion of plant food produced per unit land area for different food classes. The code has wet weight crop yield for non-leafy, leafy, and fodder. Non-leafy and leafy vegetables are for human consumption; fodder is for animal consumption.
Wet weight crop yield for leafy plants	Physical	See above.
Wet weight crop yield for fodder	Physical	See above.

Parameter	Classification	Description
Length of growing season for non-leafy vegetables	Physical	The exposure time to contamination for the plant food during the growing season. The contamination can reach the edible portion of the plant food through foliar deposition, root uptake, and water irrigation. The code has length of growing season for non-leafy vegetables, leafy vegetables, and fodder.
Length of growing season for leafy vegetables	Physical	See above.
Length of growing season for fodder	Physical	See above.
Translocation factor for non-leafy vegetables	Physical	The fraction of the contamination that is retained on the foliage that is transferred to the edible portion of the plant. The code has three food categories, non-leafy (includes non-leafy vegetables, fruit, and grain) and leafy vegetables for human and fodder for animal consumption (in all three values).
Translocation factor for leafy vegetables	Physical	See above.
Translocation factor for fodder	Physical	See above.
Weathering removal constant	Physical	The weathering process would remove contaminants from foliage of the plant food. The process is characterized by a removal constant and reduces the amount of contaminants on foliage exponentially during the exposure period.
Dry foliar interception fraction for non-leafy vegetables	Physical	The fraction of deposited radionuclides that is retained on the foliage of the plant food. Both the dry deposition (from airborne particulates) and the wet deposition processes (from irrigation) are considered. The code has wet as well as dry foliar interception fraction for non-leafy, leafy (for human consumption), and fodder (for animal consumption).
Dry foliar interception fraction for leafy vegetables	Physical	See above.
Dry foliar interception fraction for fodder	Physical	See above.
Wet foliar interception fraction for non-leafy vegetables	Physical	See above.
Wet foliar interception fraction for leafy vegetables	Physical	See above.

Parameter	Classification	Description
Wet foliar interception fraction for fodder	Physical	See above.
Slope factor - external	Metabolic	The ratio of cancer risk per year to the radionuclide concentration in the soil. The slope factors are based on the EPA methodology of calculating cancer risk.
Slope factor - inhalation	Metabolic	The ratio of cancer risk to the radionuclide activity inhaled.
Slope factor - ingestion	Metabolic	The ratio of cancer risk to the radionuclide activity ingested.
Plant transfer factor	Physical	The ratio of radionuclide concentration in edible portions of the plant at harvest time to the dry soil radionuclide concentration. It is assumed that the same root uptake transfer factors can be used for leafy and non-leafy vegetables. The code has element-specific values.
Meat transfer factor	Physical	The ratio of radionuclide concentration in beef to the daily intake of the same radionuclide in livestock feed or water (pCi/kg)/(pCi/d). The code has element-specific values for meat.
Milk transfer factor	Physical	The ratio of radionuclide concentration in milk to the daily intake of the same radionuclide in livestock feed or water (pCi/kg)/(pCi/d). The code has element-specific values for milk.
Bioaccumulation factor for fish	Physical	The ratio of radionuclide concentration in the aquatic food to the concentration of the same radionuclide in water (pCi/kg)/(pCi/L). The code has the element-specific aquatic bioaccumulation factors for fish and crustacea and mollusks.
Bioaccumulation factor for crustacea and mollusks	Physical	The ratio of radionuclide concentration in the aquatic food to the concentration of the same radionuclide in water (pCi/kg)/(pCi/L). The code has the element-specific aquatic bioaccumulation factors for fish and crustacea and mollusks.
Occupancy (Inhalation & External Parameters)		
Inhalation rate	Metabolic, Behavioral	The annual air intake in m^3/yr. The default value of 8,400 m^3/yr is recommended by the International Commission on Radiological Protection (1975).

Parameter	Classification	Description
Inhalation dose conversion factors	Metabolic	Radionuclide-specific values from FGR-11. Usually values for more than one inhalation class are listed per radionuclide. The three classes D, W, and Y correspond to retention half-times of less than 10 days, 10 to 100 days, and greater than 100 days; respectively. For some gaseous radionuclides (e.g., H-3, C-14, Ni-59, and Ni-63), inhalation classes other than D, W, and Y are also listed. The most conservative dose conversion factor is chosen as the default. The values can be changed if chemical forms are known or more appropriate data are available.
Ingestion dose conversion factors	Metabolic	Radionuclide-specific values from FGR-11. Ingestion dose conversion factors depend on the chemical form, which determines the fraction of a radionuclide entering the gastrointestinal tract that reaches body fluids. The code lists these fractions along with the dose conversion factor. The most conservative values are chosen as the default for the dose conversion factor. The values can be changed if chemical forms are known or more appropriate data are available.
Mass loading for inhalation	Physical, Behavioral	The air/soil concentration ratio or average mass loading of airborne contaminated soil particles. The code uses this parameter along with the area factor for inhalation pathway dose estimation. This average mass-loading factor includes short periods of high mass loading and sustained periods of normal activity on a typical farm.
Indoor dust filtration factor	Physical, Behavioral	Describes the effect of the building structure on the level of contaminated dust existing indoors. This is the fraction of the outdoor contaminated dust that will be available indoors.
External gamma shielding factor	Physical	Describes the effect of building structure on the level of gamma radiation existing indoors. It is the fraction of the outdoor gamma radiation that will be available indoors. The shielding factor value is used in calculating the occupancy factor.
Building foundation thickness	Physical	Average thickness of the building shell structure in the subsurface of the soil.

Parameter	Classification	Description
Building foundation density	Physical	The solid phase of mass to the total volume.
Building foundation total porosity	Physical	The ratio of the void space volume to the total volume of the porous medium.
Building foundation volumetric water content	Physical	The fraction of the total volume of the porous medium that is occupied by water.
Building foundation radon diffusion coefficient	Physical	The effective (or interstitial) radon diffusion coefficient is the ratio of the diffusive flux density of radon activity across the pore area to the gradient of the radon activity concentration in the pore space. Entering –1 for any diffusion coefficient will cause the code to calculate the diffusion coefficient based on the porosity and water content of the medium.
Contamination radon diffusion coefficient	Physical	See building foundation radon diffusion coefficient above.
Radon vertical dimension of mixing	Physical	The height into which the plume of radon is uniformly mixed in the outdoor air (above).
Building air exchange rate	Physical, Behavioral	The building exchange rate (or ventilation) is defined as the number of the total volumes of air contained in the building being exchanged with outside air per unit of time.
Building height	Physical	The average height of rooms in the building.
Building indoor area factor	Physical	The fraction of the area built on the contaminated soil. Values greater than 1 indicate contribution from adjacent walls. A default value of zero is assumed, which forces the code to calculate this time dependent area factor by assuming a floor area of 100 m^2 and walls extending into the contaminated area. This factor is time dependent because of erosion.
Foundation depth below ground surface	Physical	The vertical distance in the soil immediately from the bottom of the basement floor slab to the ground surface. A default value of –1 is used in the code; in this case the code adjusts the depths so that the foundation depth will not extend into the contaminated zone at each of the times at which dose is computed.

Parameter	Classification	Description
Radon-222 emanation coefficient	Physical	The fraction of the total radon generated by radium decay that escapes soil. (Depends on such parameters as porosity, particle size distribution, mineralogy, and moisture content.)
Radon-220 emanation coefficient	Physical	See radon-222 emanation coefficient (above).
Indoor time fraction	Behavioral	The average fraction of time during which an individual stays inside the house.
Outdoor time fraction	Behavioral	The average fraction of time during which an individual stays outdoors on the site.
Exposure duration	Behavioral	The exposure duration is the span of time, in years, during which an individual is expected to spend time on the site. This value is used in calculating lifetime cancer risk from exposure to radionuclide contamination. It is also used to calculate time-integrated dose if exposure duration is less than a year.

Parameter	Class	Units	Parameter Value	Source Justification
Contamination				
Thickness of contaminated zone	P	m	0.15	Assumed depth of contaminated surface soil.
Area of contaminated zone	P	m^2	8,094	Surface area of the Southern Industrial Area.
Shape of the contaminated zone	P	-	Circular	Default Physical value.
Initial concentration of principal radionuclides in soil	P	pCi/g	10	Assumed value used for DCGL generation.
Initial concentration of radionuclides present in groundwater	P	pCi/L	Not Used	Groundwater tritium concentration was not used as an input in the K_d determination.
Leach rate	P	1/yr	0	Default Physical value to invoke the calculation of this parameter via a first-order leaching model that uses the value of the soil/water distribution coefficient in the contaminated zone.
Solubility limit	P	mol/L	0	Default Physical value – not used by RESRAD with leach rate flag set to 0.
Time since placement of material	P	yr	0	Default Physical value assumed acceptable for purposes of DCGL generation.
Times for calculation	P	yr	1, 3, 10, 30, 100, 300, 1000	Default values applicable to the BRP site.
Contaminated zone (Unit 6a) density	P	g/cm^3	1.75	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone (Unit 6a) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value..
Use plant/soil ratio	NA	Check box	No	For purposes of DCGL calculation, the code should not be allowed to calculate the distribution coefficient from the plant root uptake factors.
Contaminated zone (Unit 6a) field capacity	P	-	0.263	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone erosion rate	P,B	m/yr	0.001	Default Physical/Behavioral value.
Contaminated zone (Unit 6a) total porosity	P	-	0.351	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone (Unit 6a) hydraulic conductivity	P	m/yr	536	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone (Unit 6a) b parameter	P	-	4.05	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Carbon-Model Parameters				
Thickness of evasion layer of C-14 in soil	P	m	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-14 evasion flux rate from soil	P	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in local water	P	g/cm^3	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in contaminated soil	P	g/g	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Fraction of vegetation carbon absorbed from soil	P	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Fraction of vegetation carbon absorbed from air	P	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 evasion flux rate from soil	P	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in beef cattle feed	B	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in milk cow feed	B	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
DCF correction factor for gaseous forms of C-14	P	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Soil				
Cover depth	P	m	0	The contamination is assumed to be on surface soil.
Density of cover material	P	g/cm^3	Not Used	A cover is not used in the site-specific dose model.
Cover total porosity	P	-	Not Used	A cover is not used in the site-specific dose model.
Cover volumetric water content	P	-	Not Used	A cover is not used in the site-specific dose model.
Cover radon diffusion coefficient	P	m^2/s	Not Used	A cover is not used in the site-specific dose model.
Cover erosion rate	P,B	m/yr	Not Used	A cover is not used in the site-specific dose model.
Number of unsaturated zones	P	-	5	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) thickness	P	m	1.22	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 2 (Unit 5) thickness	P	m	7.32	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Unsaturated Zone 3 (Unit 4) thickness	P	m	1.52	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 4 (Unit 3) thickness	P	m	9.14	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 5 (Unit 2) thickness	P	m	6.10	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) density	P	g/cm^3	1.75	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 2 (Unit 5) density	P	g/cm^3	1.92	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 3 (Unit 4) density	P	g/cm^3	1.83	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 4 (Unit 3) density	P	g/cm^3	1.85	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 5 (Unit 2) density	P	g/cm^3	2.17	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated Zone 2 (Unit 5) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated Zone 3 (Unit 4) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated Zone 4 (Unit 3) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated Zone 5 (Unit 2) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated Zone 1 (Unit 6a) total porosity	P	-	0.351	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 2 (Unit 5) total porosity	P	-	0.287	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 3 (Unit 4) total porosity	P	-	0.317	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 4 (Unit 3) total porosity	P	-	0.313	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Unsaturated Zone 5 (Unit 2) total porosity	P	-	0.194	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) effective porosity	P	-	0.088	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 2 (Unit 5) effective porosity	P	-	0.037	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 3 (Unit 4) effective porosity	P	-	0.029	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 4 (Unit 3) effective porosity	P	-	0.054	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 5 (Unit 2) effective porosity	P	-	0.033	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) field capacity	P	-	0.263	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 2 (Unit 5) field capacity	P	-	0.250	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 3 (Unit 4) field capacity	P	-	0.287	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 4 (Unit 3) field capacity	P	-	0.258	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 5 (Unit 2) field capacity	P	-	0.161	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) hydraulic conductivity	P	m/yr	536	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.
Unsaturated Zone 2 (Unit 5) hydraulic conductivity	P	m/yr	5.17	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.
Unsaturated Zone 3 (Unit 4) hydraulic conductivity	P	m/yr	1050	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.
Unsaturated Zone 4 (Unit 3) hydraulic conductivity	P	m/yr	15.6	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.
Unsaturated Zone 5 (Unit 2) hydraulic conductivity	P	m/yr	8.20E-03	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 1 (Unit 6a) soil-specific b parameter	P	-	4.05	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Unsaturated Zone 2 (Unit 5) soil-specific b parameter	P	-	4.90	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 3 (Unit 4) soil-specific b parameter	P	-	4.05	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 4 (Unit 3) soil-specific b parameter	P	-	4.90	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated Zone 5 (Unit 2) soil-specific b parameter	P	-	7.12	November 2002 Version 0.0 Hydrogeological Assessment Report.
Water				
Density of saturated zone (Unit 1)	P	g/cm^3	1.52	Environmental Report for Decommissioning (ERD) identifies the saturated zone as highly fractured Traverse limestone; Table 2.1 of the RESRAD Data Collection Handbook provides a value for sand that was used as an approximation for fractured limestone.
Saturated zone (Unit 1) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Saturated zone (Unit 1) total porosity	P	-	0.30	RESRAD Data Collection Handbook Table 3.2 value for limestone.
Saturated zone (Unit 1) effective porosity	P	-	0.14	RESRAD Data Collection Handbook Table 3.2 value for limestone.
Saturated zone (Unit 1) field capacity	P	-	0.16	In accordance with the RESRAD Data Collection Handbook, field capacity equals the total porosity minus the effective porosity.
Saturated zone (Unit 1) hydraulic conductivity	P	m/yr	1520	November 2002 Version 0.0 Hydrogeological Assessment Report.
Saturated zone (Unit 1) hydraulic gradient	P	-	0.02	Default value for generic use of RESRAD. It was not possible to measure the hydraulic gradient for the Southern Industrial Area.
Saturated zone (Unit 1) soil-specific b parameter	P	-	4.05	RESRAD Data Collection Handbook Table 13.1 value for sand as an approximation for fractured limestone.
Length of contaminated zone parallel to the aquifer flow	P	m	102	Diameter of an 8,094 m^2 contaminated zone.
Water table drop rate	P	m/yr	0.001	Default Physical value.

Parameter	Class	Units	Parameter Value	Source Justification
Well-pump intake depth (below water table)	P	m	10	Default value applicable to the BRP site.
Well pumping rate	B, P	m^3/yr	250	Default Behavioral/Physical value.
Model: non-dispersion or mass balance	NA	-	MB	The mass-balance model was chosen as the most conservative since it assumes that all of the radionuclides released from the contaminated zone are withdrawn through the well.
Evapotranspiration coefficient	P	-	0.24	Northern Michigan value taken from Figure 12.1 of the RESRAD Data Collection Handbook.
Humidity in air	P	g/m^3	8	Default Physical value.
Average annual wind speed	P	m/s	5	Environmental Report for Decommissioning.
Precipitation rate	P	m/yr	0.8	Environmental Report for Decommissioning.
Irrigation mode	B	-	Overhead	Behavioral value - ditch irrigation is not used in the Midwest.
Irrigation rate	B	m/yr	0.2	Behavioral default value.
Runoff coefficient	P	-	0.2	Default Physical value.
Watershed area for nearby stream or pond	P	m^2	2306717	ERD - the entire BRP site drains into Lake Michigan.
Accuracy for water soil computation	NA	-	0.001	Default value applicable to the BRP site.
Ingestion				
Fruit, vegetable, and grain consumption rate	M, B	kg/yr	160	Metabolic/Behavioral default value.
Leafy vegetable consumption	M, B	kg/yr	14	Metabolic/Behavioral default value.
Milk consumption	M, B	L/yr	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Meat and poultry consumption	M, B	kg/yr	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Fish consumption rate	M, B	kg/yr	5.4	Metabolic/Behavioral default value.
Other seafood consumption rate	M, B	kg/yr	0.9	Metabolic/Behavioral default value.
Aquatic food contaminated fraction	B, P	-	0.5	Default Behavioral/Physical value applicable to the BRP site.
Soil ingestion rate	M, B	g/yr	36.5	Metabolic/Behavioral default value.
Drinking water intake	M, B	L/yr	510	Metabolic/Behavioral default value.

Parameter	Class	Units	Parameter Value	Source Justification
Storage time for fruits, non-leafy vegetables, and grain	B	d	14	Behavioral default value.
Storage time for leafy vegetables	B	d	1	Behavioral default value.
Storage time for milk	B	d	1	Behavioral default value.
Storage time for meat	B	d	20	Behavioral default value.
Storage time for fish	B	d	7	Behavioral default value.
Storage time for crustacea and mollusks	B	d	7	Behavioral default value.
Storage time for well water	B	d	1	Behavioral default value.
Storage time for surface water	B	d	1	Behavioral default value.
Storage time for livestock fodder	B	d	45	Behavioral default value.
Drinking water contaminated fraction	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Household water contaminated fraction	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Livestock water contaminated fraction	B, P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Irrigation water contaminated fraction	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Plant food contaminated fraction	B, P	-	-1	Default Behavioral/Physical value applicable to the BRP site.
Meat contaminated fraction	B, P	-	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Milk contaminated fraction	B, P	-	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for meat	M	kg/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for milk	M	kg/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for meat	M	L/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for milk	M	L/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock intake of soil	M	kg/d	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.

Parameter	Class	Units	Parameter Value	Source Justification
Mass loading for foliar deposition	P	g/m^3	1E-4	Default Physical value applicable to the BRP site.
Depth of soil mixing layer	P	m	0.15	Default Physical value applicable to the BRP site.
Depth of roots	P	m	0.9	Default Physical value applicable to the BRP site.
Groundwater fractional usage for drinking water	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Groundwater fractional usage for household water	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Groundwater fractional usage for livestock water	B, P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Groundwater fractional usage for irrigation water	B, P	-	1	Behavioral/Physical default value applicable to the BRP site.
Wet weight crop yield for non-leafy plants	P	kg/m^2	0.7	Default Physical value applicable to the BRP site.
Wet weight crop yield for leafy plants	P	kg/m^2	1.5	Default Physical value applicable to the BRP site.
Wet weight crop yield for fodder	P	kg/m^2	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Length of growing season for non-leafy vegetables	P	yr	0.17	Default value.
Length of growing season for leafy vegetables	P	yr	0.25	Default value.
Length of growing season for fodder	P	yr	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Translocation factor for non-leafy vegetables	P	-	0.1	Default Physical value applicable to the BRP site.
Translocation factor for leafy vegetables	P	-	1	Default Physical value applicable to the BRP site.
Translocation factor for fodder	P	-	1	Default Physical value applicable to the BRP site.
Weathering removal constant	P	1/yr	20	Default Physical value applicable to the BRP site.
Dry foliar interception fraction for non-leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Dry foliar interception fraction for leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Dry foliar interception fraction for fodder	P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.

Parameter	Class	Units	Parameter Value	Source Justification
Wet foliar interception fraction for non-leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Wet foliar interception fraction for leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Wet foliar interception fraction for fodder	P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Slope factor - external	M	(risk/yr)/ (pCi/g)	Nuclide specific	Metabolic default value.
Slope factor - inhalation	M	risk/pCi	Nuclide specific	Metabolic default value.
Slope factor - ingestion	M	risk/pCi	Nuclide specific	Metabolic default value.
Plant transfer factor	P	-	Element specific	Default Physical value applicable to the BRP site.
Meat transfer factor	P	(pCi/kg)/ (pCi/d)	Element specific	Default Physical value applicable to the BRP site.
Milk transfer factor	P	(pCi/L)/ (pCi/d)	Element specific	Default Physical value applicable to the BRP site.
Bioaccumulation factor for fish	P	(pCi/kg)/ (pCi/L)	Element specific	Default Physical value applicable to the BRP site.
Bioaccumulation factor for crustacea and mollusks	P	(pCi/kg)/ (pCi/L)	Element specific	Default Physical value applicable to the BRP site.
Occupancy (Inhalation & External Parameters)				
Inhalation rate	M, B	m^3/yr	8,400	Metabolic/Behavioral default value.
Inhalation dose conversion factors	M	mrem/pCi	Nuclide Specific	Metabolic default value.
Ingestion dose conversion factors	M	mrem/pCi	Nuclide Specific	Metabolic default value.
Mass loading for inhalation	P, B	g/m^3	1E-4	Default Physical/Behavioral value applicable to the BRP site.
Indoor dust filtration factor	P, B	-	0.4	Default Physical/Behavioral value applicable to the BRP site.
External gamma shielding factor	P	-	0.7	Default Physical value applicable to the BRP site.
Building foundation thickness	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building foundation bulk density	P	g/m^3	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building foundation total porosity	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.

Parameter	Class	Units	Parameter Value	Source Justification
Building foundation volumetric water content	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building foundation radon diffusion coefficient	P	m^2/s	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Contaminated soil zone radon diffusion coefficient	P	m^2/s	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Radon vertical dimension of mixing	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building air exchange rate	P, B	1/hr	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building (room) height	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building indoor area factor	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Foundation depth below ground surface	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Radon-222 emanation coefficient	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Radon-220 emanation coefficient	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Indoor time fraction	B	-	0.5	Behavioral default value.
Outdoor time fraction	B	-	0.25	Behavioral default value.
Exposure duration	B	yr	30	Behavioral default value.

Parameter	Class	Units	Parameter Value	Source Justification
Contamination				
Thickness of contaminated zone (Unit 6a)	P	m	0.15	Assumed depth of contaminated surface soil.
Area of contaminated zone (Unit 6a)	P	m^2	8,094	Surface area of the Northern Industrial Area.
Shape of the contaminated zone (Unit 6a)	P	-	Circular	Default Physical value.
Initial concentration of principal radionuclides in soil	P	pCi/g	10	Assumed value used for DCGL generation.
Initial concentration of radionuclides present in groundwater	P	pCi/L	Not Used	Groundwater tritium concentration was not used as an input in the K_d determination.
Leach rate	P	1/yr	0	Default Physical value to invoke the calculation of this parameter via a first-order leaching model that uses the value of the soil/water distribution coefficient in the contaminated zone.
Solubility limit	P	mol/L	0	Default Physical value – not used by RESRAD with leach rate flag set to 0.
Time since placement of material	P	yr	0	Default Physical value assumed acceptable for purposes of DCGL generation.
Times for calculation	P	yr	1, 3, 10, 30, 100, 300, 1000	Default values applicable to the BRP site.
Contaminated zone (Unit 6a) density	P	g/cm^3	1.75	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone (Unit 6a) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Use plant/soil ratio	NA	Check box	No	For purposes of the sensitivity analysis, the code should not be allowed to calculate the distribution coefficient from the plant root uptake factors.
Contaminated zone (Unit 6a) field capacity	P	-	0.263	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone (Unit 6a) erosion rate	P,B	m/yr	0.001	Default Physical/Behavioral value.
Contaminated zone (Unit 6a) total porosity	P	-	0.351	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Contaminated zone (Unit 6a) hydraulic conductivity	P	m/yr	536	November 2002 Version 0.0 Hydrogeological Assessment Report.
Contaminated zone (Unit 6a) b parameter	P	-	4.05	November 2002 Version 0.0 Hydrogeological Assessment Report.
Carbon-Model Parameters				
Thickness of evasion layer of C-14 in soil	P	m	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-14 evasion flux rate from soil	P	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in local water	P	g/cm^3	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in contaminated soil	P	g/g	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Fraction of vegetation carbon absorbed from soil	P	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Fraction of vegetation carbon absorbed from air	P	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 evasion flux rate from soil	P	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in beef cattle feed	B	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in milk cow feed	B	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
DCF correction factor for gaseous forms of C-14	P	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Soil				
Cover depth	P	m	0	The contamination is assumed to be on surface soil.
Density of cover material	P	g/cm^3	Not Used	A cover is not used in the site-specific dose model.
Cover total porosity	P	-	Not Used	A cover is not used in the site-specific dose model.
Cover volumetric water content	P	-	Not Used	A cover is not used in the site-specific dose model.
Cover radon diffusion coefficient	P	m^2/s	Not Used	A cover is not used in the site-specific dose model.
Cover erosion rate	P,B	m/yr	Not Used	A cover is not used in the site-specific dose model.
Number of unsaturated zones	P	-	5	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Unsaturated zone 1 (Unit 6a) thickness	P	m	1.37	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 2 (Unit 6b) thickness	P	m	1.37	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 3 (Unit 5) thickness	P	m	4.11	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 4 (Unit 4) thickness	P	m	0.61	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 5 (Unit 3) thickness	P	m	7.32	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 1 (Unit 6a) density	P	g/cm^3	1.75	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 2 (Unit 6b) density	P	g/cm^3	1.95	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 3 (Unit 5) density	P	g/cm^3	1.92	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 4 (Unit 4) density	P	g/cm^3	1.83	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 5 (Unit 3) density	P	g/cm^3	1.85	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 1 (Unit 6a) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated zone 2 (Unit 6b) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated zone 3 (Unit 5) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated zone 4 (Unit 4) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated zone 5 (Unit 3) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Unsaturated zone 1 (Unit 6a) total porosity	P	-	0.351	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 2 (Unit 6b) total porosity	P	-	0.274	November 2002 Version 0.0 Hydrogeological Assessment Report.

Parameter	Class	Units	Parameter Value	Source Justification
Unsaturated zone 3 (Unit 5) total porosity	P	-	0.287	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 4 (Unit 4) total porosity	P	-	0.317	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 5 (Unit 3) total porosity	P	-	0.313	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 1 (Unit 6a) effective porosity	P	-	0.088	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 2 (Unit 6b) effective porosity	P	-	0.026	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 3 (Unit 5) effective porosity	P	-	0.037	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 4 (Unit 4) effective porosity	P	-	0.029	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 5 (Unit 3) effective porosity	P	-	0.054	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 1 (Unit 6a) field capacity	P	-	0.263	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 2 (Unit 6b) field capacity	P	-	0.248	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 3 (Unit 5) field capacity	P	-	0.250	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 4 (Unit 4) field capacity	P	-	0.287	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 5 (Unit 3) field capacity	P	-	0.258	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 1 (Unit 6a) hydraulic conductivity	P	m/yr	536	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.
Unsaturated zone 2 (Unit 6b) hydraulic conductivity	P	m/yr	554	November 2002 Version 0.0 Hydrogeological Assessment Report laboratory test.
Unsaturated zone 3 (Unit 5) hydraulic conductivity	P	m/yr	5.17	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.
Unsaturated zone 4 (Unit 4) hydraulic conductivity	P	m/yr	1046	November 2002 Version 0.0 Hydrogeological Assessment Report field (slug) test.

Parameter	Class	Units	Parameter Value	Source Justification
Unsaturated zone 5 (Unit 3) hydraulic conductivity	P	m/yr	15.6	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 1 (Unit 6a) soil-specific b parameter	P	-	4.05	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 2 (Unit 6b) soil-specific b parameter	P	-	4.38	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 3 (Unit 5) soil-specific b parameter	P	-	4.90	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 4 (Unit 4) soil-specific b parameter	P	-	4.05	November 2002 Version 0.0 Hydrogeological Assessment Report.
Unsaturated zone 5 (Unit 3) soil-specific b parameter	P	-	4.90	November 2002 Version 0.0 Hydrogeological Assessment Report.
Water				
Density of saturated zone (Unit 1)	P	g/cm^3	1.52	Environmental Report for Decommissioning (ERD) identifies the saturated zone as highly fractured Traverse limestone; Table 2.1 of the RESRAD Data Collection Handbook provides a value for sand, which was used as an approximation for fractured limestone.
Saturated zone (Unit 1) distribution coefficient	P	cm^3/g	Nuclide specific	Default Physical value.
Saturated zone (Unit 1) total porosity	P	-	0.30	RESRAD Data Collection Handbook Table 3.2 value for limestone.
Saturated zone (Unit 1) effective porosity	P	-	0.14	RESRAD Data Collection Handbook Table 3.2 value for limestone.
Saturated zone (Unit 1) field capacity	P	-	0.16	In accordance with the RESRAD Data Collection Handbook, field capacity equals the total porosity minus the effective porosity.
Saturated zone (Unit 1) hydraulic conductivity	P	m/yr	1.52E+03	November 2002 Version 0.0 Hydrogeological Assessment Report.
Saturated zone (Unit 1) hydraulic gradient	P	-	0.0007	November 2002 Version 0.0 Hydrogeological Assessment Report.
Saturated zone (Unit 1) soil-specific b parameter	P	-	4.05	RESRAD Data Collection Handbook Table 13.1 value for sand as an approximation for fractured limestone.

Parameter	Class	Units	Parameter Value	Source Justification
Length of contaminated zone parallel to the aquifer flow	P	m	102	Diameter of an 8,094 m^2 circular contaminated zone.
Water table drop rate	P	m/yr	0.001	Default Physical value.
Well-pump intake depth (below water table)	P	m	10	Default value applicable to the BRP site.
Well pumping rate	B, P	m^3/yr	250	Default Behavioral/Physical value.
Model: non-dispersion or mass balance	NA	-	MB	The mass-balance model was chosen as the most conservative since it assumes that all of the radionuclides released from the contaminated zone are withdrawn through the well.
Evapotranspiration coefficient	P	-	0.24	Northern Michigan value taken from Figure 12.1 of the RESRAD Data Collection Handbook.
Humidity in air	P	g/m^3	8	Default Physical value.
Average annual wind speed	P	m/s	5	Environmental Report for Decommissioning.
Precipitation rate	P	m/yr	0.8	Environmental Report for Decommissioning.
Irrigation mode	B	-	Overhead	Behavioral value - ditch irrigation is not used in the Midwest.
Irrigation rate	B	m/yr	0.2	Behavioral default value.
Runoff coefficient	P	-	0.2	Default Physical value.
Watershed area for nearby stream or pond	P	m^2	2306717	ERD - the entire BRP site drains into Lake Michigan.
Accuracy for water soil computation	NA	-	0.001	Default value applicable to the BRP site.
Ingestion				
Fruit, vegetable, and grain consumption rate	M, B	kg/yr	160	Metabolic/Behavioral default value.
Leafy vegetable consumption	M, B	kg/yr	14	Metabolic/Behavioral default value.
Milk consumption	M, B	L/yr	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Meat and poultry consumption	M, B	kg/yr	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Fish consumption rate	M, B	kg/yr	5.4	Metabolic/Behavioral default value.
Other seafood consumption rate	M, B	kg/yr	0.9	Metabolic/Behavioral default value.
Aquatic food contaminated fraction	B, P	-	0.5	Default Behavioral/Physical value applicable to the BRP site.

Parameter	Class	Units	Parameter Value	Source Justification
Soil ingestion rate	M, B	g/yr	36.5	Metabolic/Behavioral default value.
Drinking water intake	M, B	L/yr	510	Metabolic/Behavioral default value.
Storage time for fruits, non-leafy vegetables, and grain	B	d	14	Behavioral default value.
Storage time for leafy vegetables	B	d	1	Behavioral default value.
Storage time for milk	B	d	1	Behavioral default value.
Storage time for meat	B	d	20	Behavioral default value.
Storage time for fish	B	d	7	Behavioral default value.
Storage time for crustacea and mollusks	B	d	7	Behavioral default value.
Storage time for well water	B	d	1	Behavioral default value.
Storage time for surface water	B	d	1	Behavioral default value.
Storage time for livestock fodder	B	d	45	Behavioral default value.
Drinking water contaminated fraction	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Household water contaminated fraction	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Livestock water contaminated fraction	B, P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Irrigation water contaminated fraction	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Plant food contaminated fraction	B, P	-	-1	Default Behavioral/Physical value applicable to the BRP site.
Meat contaminated fraction	B, P	-	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Milk contaminated fraction	B, P	-	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for meat	M	kg/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for milk	M	kg/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for meat	M	L/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for milk	M	L/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.

Parameter	Class	Units	Parameter Value	Source Justification
Livestock intake of soil	M	kg/d	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Mass loading for foliar deposition	P	g/m^3	1E-4	Default Physical value applicable to the BRP site.
Depth of soil mixing layer	P	m	0.15	Default Physical value applicable to the BRP site.
Depth of roots	P	m	0.9	Default Physical value applicable to the BRP site.
Groundwater fractional usage for drinking water	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Groundwater fractional usage for household water	B, P	-	1	Default Behavioral/Physical value applicable to the BRP site.
Groundwater fractional usage for livestock water	B, P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Groundwater fractional usage for irrigation water	B, P	-	1	Behavioral/Physical default value applicable to the BRP site.
Wet weight crop yield for non-leafy plants	P	kg/m^2	0.7	Default Physical value applicable to the BRP site.
Wet weight crop yield for leafy plants	P	kg/m^2	1.5	Default Physical value applicable to the BRP site.
Wet weight crop yield for fodder	P	kg/m^2	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Length of growing season for non-leafy vegetables	P	yr	0.17	Default value.
Length of growing season for leafy vegetables	P	yr	0.25	Default value.
Length of growing season for fodder	P	yr	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Translocation factor for non-leafy vegetables	P	-	0.1	Default Physical value applicable to the BRP site.
Translocation factor for leafy vegetables	P	-	1	Default Physical value applicable to the BRP site.
Translocation factor for fodder	P	-	1	Default Physical value applicable to the BRP site.
Weathering removal constant	P	1/yr	20	Default Physical value applicable to the BRP site.
Dry foliar interception fraction for non-leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Dry foliar interception fraction for leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.

Parameter	Class	Units	Parameter Value	Source Justification
Dry foliar interception fraction for fodder	P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Wet foliar interception fraction for non-leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Wet foliar interception fraction for leafy vegetables	P	-	0.25	Default Physical value applicable to the BRP site.
Wet foliar interception fraction for fodder	P	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Slope factor - external	M	(risk/yr)/ (pCi/g)	Nuclide specific	Metabolic default value.
Slope factor - inhalation	M	risk/pCi	Nuclide specific	Metabolic default value.
Slope factor - ingestion	M	risk/pCi	Nuclide specific	Metabolic default value.
Plant transfer factor	P	-	Element specific	Default Physical value applicable to the BRP site.
Meat transfer factor	P	(pCi/kg)/ (pCi/d)	Element specific	Default Physical value applicable to the BRP site.
Milk transfer factor	P	(pCi/L)/ (pCi/d)	Element specific	Default Physical value applicable to the BRP site.
Bioaccumulation factor for fish	P	(pCi/kg)/ (pCi/L)	Element specific	Default Physical value applicable to the BRP site.
Bioaccumulation factor for crustacea and mollusks	P	(pCi/kg)/ (pCi/L)	Element specific	Default Physical value applicable to the BRP site.
Occupancy (Inhalation & External Parameters)				
Inhalation rate	M, B	m^3/yr	8,400	Metabolic/Behavioral default value.
Inhalation dose conversion factors	M	mrem/pCi	Nuclide Specific	Metabolic default value.
Ingestion dose conversion factors	M	mrem/pCi	Nuclide Specific	Metabolic default value.
Mass loading for inhalation	P, B	g/m^3	1E-4	Default Physical/Behavioral value applicable to the BRP site.
Indoor dust filtration factor	P, B	-	0.4	Default Physical/Behavioral value applicable to the BRP site.
External gamma shielding factor	P	-	0.7	Default Physical value applicable to the BRP site.
Building foundation thickness	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building foundation bulk density	P	g/m^3	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.

Parameter	Class	Units	Parameter Value	Source Justification
Building foundation total porosity	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building foundation volumetric water content	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building foundation radon diffusion coefficient	P	m^2/s	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Contaminated soil zone radon diffusion coefficient	P	m^2/s	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Radon vertical dimension of mixing	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building air exchange rate	P, B	1/hr	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building (room) height	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Building indoor area factor	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Foundation depth below ground surface	P	m	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Radon-222 emanation coefficient	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Radon-220 emanation coefficient	P	-	Not Used	The Radon Exposure Pathway is not used because the NRC does not regulate exposure to radon.
Indoor time fraction	B	-	0.5	Behavioral default value.
Outdoor time fraction	B	-	0.25	Behavioral default value.
Exposure duration	B	yr	30	Behavioral default value.

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Contamination					
Thickness of contaminated zone	P	2	m	0.15	Assigned value
Area of contaminated zone	P	2	m^2	8,094	Assigned value
Shape of the contaminated zone	P	3	-	Circular	Default Physical value
Initial concentration of principal radionuclides in soil	P	2	pCi/g	1	Assigned value
Initial concentration of radionuclides present in groundwater	P	3	pCi/L	0	Not Used
Leach rate	P	3	1/yr	0	Default Physical value to invoke the calculation of this parameter via a first-order leaching model that uses the value of the soil/water distribution coefficient in the contaminated zone.
Solubility limit	P	3	mol/L	0	Default Physical value – not used by RESRAD with leach rate flag set to 0
Time since placement of material	P	3	yr	0	Default Physical value assumed acceptable for purposes of DCGL generation
Times for calculation	P	3	yr	1, 3, 10, 30, 100, 300, 1000	Default values applicable to the BRP site
Contaminated zone density	P	1	g/cm^3	1.75	Site-specific measured physical parameter
Contaminated zone distribution coefficient for H-3	P	1	cm^3/g	0.043	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Mn	P	1	cm^3/g	733	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Fe	P	1	cm^3/g	1251	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Co	P	1	cm^3/g	1284	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Sr	P	1	cm^3/g	131	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Cs	P	1	cm^3/g	2130	EA-BRP-SC-0202

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Contaminated zone distribution coefficient for Eu	P	1	cm^3/g	7194	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Gd	P	1	cm^3/g	7194	EA-BRP-SC-0202
Use plant/soil ratio	NA	3	Check box	No	For purposes of the sensitivity analysis, the code should not be allowed to calculate the distribution coefficient from the plant root uptake factors.
Contaminated zone field capacity	P	3	-	0.263	Site-specific measured physical parameter
Contaminated zone erosion rate	P,B	2	m/yr	Continuous logarithmic	NUREG/CR-6697, Attachment C
Contaminated zone total porosity	P	2	-	0.351	Site-specific measured physical parameter
Contaminated zone hydraulic conductivity	P	2	m/yr	536	Site-specific measured physical parameter
Contaminated zone b parameter	P	2	-	4.05	Site-specific measured physical parameter
Carbon-Model Parameters					
Thickness of evasion layer of C-14 in soil	P	2	m	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-14 evasion flux rate from soil	P	3	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in local water	P	3	g/cm^3	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in contaminated soil	P	3	g/g	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Fraction of vegetation carbon absorbed from soil	P	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Fraction of vegetation carbon absorbed from air	P	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 evasion flux rate from soil	P	3	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in beef cattle feed	B	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in milk cow feed	B	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
DCF correction factor for gaseous forms of C-14	P	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Soil					
Cover depth	P	2	m	0	The contamination is assumed to be on surface soil.
Density of cover material	P	1	g/cm^3	Not Used	A cover is not used in the site-specific dose model.
Cover total porosity	P	3	-	Not Used	A cover is not used in the site-specific dose model.
Cover volumetric water content	P	3	-	Not Used	A cover is not used in the site-specific dose model.
Cover radon diffusion coefficient	P	3	m^2/s	Not Used	A cover is not used in the site-specific dose model.
Cover erosion rate	P,B	2	m/yr	Not Used	A cover is not used in the site-specific dose model.
Number of unsaturated zones	P	3	-	5	Site-specific measured physical parameter
Unsaturated zone 1 thickness	P	1	m	1.37	Site-specific measured physical parameter
Unsaturated zone 2 thickness	P	1	m	1.37	Site-specific measured physical parameter
Unsaturated zone 3 thickness	P	1	m	4.11	Site-specific measured physical parameter
Unsaturated zone 4 thickness	P	1	m	0.61	Site-specific measured physical parameter
Unsaturated zone 5 thickness	P	1	m	7.32	Site-specific measured physical parameter
Unsaturated zone 1 density	P	2	g/cm^3	1.75	Site-specific measured physical parameter

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Unsaturated zone 2 density	P	2	g/cm^3	1.95	Site-specific measured physical parameter
Unsaturated zone 3 density	P	2	g/cm^3	1.92	Site-specific measured physical parameter
Unsaturated zone 4 density	P	2	g/cm^3	1.83	Site-specific measured physical parameter
Unsaturated zone 5 density	P	2	g/cm^3	1.85	Site-specific measured physical parameter
Unsaturated zone 1 distribution coefficient for H-3	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Mn	P	1	cm^3/g	156	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Fe	P	1	cm^3/g	206	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Co	P	1	cm^3/g	232	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Sr	P	1	cm^3/g	31.2	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Cs	P	1	cm^3/g	441	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Eu	P	1	cm^3/g	817	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Gd	P	1	cm^3/g	817	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for H-3	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Mn	P	1	cm^3/g	158	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Fe	P	1	cm^3/g	204	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Co	P	1	cm^3/g	231	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Sr	P	1	cm^3/g	31.0	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Cs	P	1	cm^3/g	438	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Eu	P	1	cm^3/g	809	EA-BRP-SC-0202

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Unsaturated zone 2 distribution coefficient for Gd	P	1	cm^3/g	809	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for H-3	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Mn	P	1	cm^3/g	157	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Fe	P	1	cm^3/g	207	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Co	P	1	cm^3/g	234	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Sr	P	1	cm^3/g	31.4	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Cs	P	1	cm^3/g	444	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Eu	P	1	cm^3/g	824	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Gd	P	1	cm^3/g	824	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for H-3	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Mn	P	1	cm^3/g	155	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Fe	P	1	cm^3/g	204	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Co	P	1	cm^3/g	231	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Sr	P	1	cm^3/g	31.0	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Cs	P	1	cm^3/g	438	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Eu	P	1	cm^3/g	809	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Gd	P	1	cm^3/g	809	EA-BRP-SC-0202

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Unsaturated zone 5 distribution coefficient for H-3	P	1	cm^3/g	0.043	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Mn	P	1	cm^3/g	155	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Fe	P	1	cm^3/g	204	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Co	P	1	cm^3/g	230	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Sr	P	1	cm^3/g	31.0	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Cs	P	1	cm^3/g	438	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Eu	P	1	cm^3/g	808	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Gd	P	1	cm^3/g	808	EA-BRP-SC-0202
Unsaturated zone 1 total porosity	P	2	-	0.351	Site-specific measured physical parameter
Unsaturated zone 2 total porosity	P	2	-	0.274	Site-specific measured physical parameter
Unsaturated zone 3 total porosity	P	2	-	0.287	Site-specific measured physical parameter
Unsaturated zone 4 total porosity	P	2	-	0.317	Site-specific measured physical parameter
Unsaturated zone 5 total porosity	P	2	-	0.313	Site-specific measured physical parameter
Unsaturated zone 1 effective porosity	P	2	-	0.088	Site-specific measured physical parameter
Unsaturated zone 2 effective porosity	P	2	-	0.026	Site-specific measured physical parameter
Unsaturated zone 3 effective porosity	P	2	-	0.037	Site-specific measured physical parameter
Unsaturated zone 4 effective porosity	P	2	-	0.029	Site-specific measured physical parameter

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Unsaturated zone 5 effective porosity	P	2	-	0.054	Site-specific measured physical parameter
Unsaturated zone 1 field capacity	P	3	-	0.263	Site-specific measured physical parameter
Unsaturated zone 2 field capacity	P	3	-	0.248	Site-specific measured physical parameter
Unsaturated zone 3 field capacity	P	3	-	0.250	Site-specific measured physical parameter
Unsaturated zone 4 field capacity	P	3	-	0.287	Site-specific measured physical parameter
Unsaturated zone 5 field capacity	P	3	-	0.258	Site-specific measured physical parameter
Unsaturated zone 1 hydraulic conductivity	P	2	m/yr	536	Site-specific measured physical parameter
Unsaturated zone 2 hydraulic conductivity	P	2	m/yr	554	Site-specific measured physical parameter
Unsaturated zone 3 hydraulic conductivity	P	2	m/yr	5.17	Site-specific measured physical parameter
Unsaturated zone 4 hydraulic conductivity	P	2	m/yr	1046	Site-specific measured physical parameter
Unsaturated zone 5 hydraulic conductivity	P	2	m/yr	15.6	Site-specific measured physical parameter
Unsaturated zone 1 soil-specific b parameter	P	2	-	4.05	Site-specific measured physical parameter
Unsaturated zone 2 soil-specific b parameter	P	2	-	4.38	Site-specific measured physical parameter
Unsaturated zone 3 soil-specific b parameter	P	2	-	4.90	Site-specific measured physical parameter
Unsaturated zone 4 soil-specific b parameter	P	2	-	4.05	Site-specific measured physical parameter
Unsaturated zone 5 soil-specific b parameter	P	2	-	4.90	Site-specific measured physical parameter
Water					
Density of saturated zone	P	1	g/cm^3	Truncated normal	NUREG/CR-6697, Attachment C

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Saturated zone distribution coefficient for H-3	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Saturated zone distribution coefficient for Mn	P	1	cm^3/g	156	EA-BRP-SC-0202
Saturated zone distribution coefficient for Fe	P	1	cm^3/g	205	EA-BRP-SC-0202
Saturated zone distribution coefficient for Co	P	1	cm^3/g	232	EA-BRP-SC-0202
Saturated zone distribution coefficient for Sr	P	1	cm^3/g	31.1	EA-BRP-SC-0202
Saturated zone distribution coefficient for Cs	P	1	cm^3/g	440	EA-BRP-SC-0202
Saturated zone distribution coefficient for Eu	P	1	cm^3/g	814	EA-BRP-SC-0202
Saturated zone distribution coefficient for Gd	P	1	cm^3/g	814	EA-BRP-SC-0202
Saturated zone total porosity	P	1	-	Truncated normal	NUREG/CR-6697, Attachment C
Saturated zone effective porosity	P	1	-	Truncated normal	NUREG/CR-6697, Attachment C
Saturated zone field capacity	P	3	-	0.16	RESRAD Data Collection Handbook total porosity for limestone minus the effective porosity for limestone
Saturated zone hydraulic conductivity	P	1	m/yr	1.52E+03	Site-specific measured physical parameter
Saturated zone hydraulic gradient	P	2	-	0.0007	Site-specific measured physical parameter
Saturated zone soil-specific b parameter	P	2	-	Bounded lognormal-n	NUREG/CR-6697, Attachment C
Length of contaminated zone parallel to the aquifer flow	P	2	m	102	Diameter of an 8,094 m^2 contaminated zone
Water table drop rate	P	3	m/yr	0.001	Default Physical value
Well-pump intake depth (below water table)	P	2	m	Triangular	NUREG/CR-6697, Attachment C
Well pumping rate	B, P	2	m^3/yr	330.34	NUREG/CR-6697, Attachment C, Table 3.10-

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Model: non-dispersion or mass balance	NA	3	-	MB	The mass-balance model was chosen as the most conservative since it assumes that all of the radionuclides released from the contaminated zone are withdrawn through the well.
Evapotranspiration coefficient	P	2	-	Uniform	NUREG/CR-6697, Attachment C
Humidity in air	P	3	g/m^3	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Average annual wind speed	P	2	m/s	5	Site-specific measured physical parameter
Precipitation rate	P	2	m/yr	0.8	Site-specific measured physical parameter
Irrigation mode	B	3	-	Overhead	Behavioral value - ditch irrigation is not used in the Midwest.
Irrigation rate	B	3	m/yr	0.2	Behavioral default value
Runoff coefficient	P	2	-	Uniform	NUREG/CR-6697, Attachment C
Watershed area for nearby stream or pond	P	3	m^2	2306717	The entire BRP site drains into Lake Michigan.
Accuracy for water soil computation	NA	3	-	0.001	Default value applicable to the BRP site
Ingestion					
Fruit, vegetable, and grain consumption rate	M, B	2	kg/yr	Triangular	NUREG/CR-6697, Attachment C
Leafy vegetable consumption	M, B	3	kg/yr	14	Metabolic/Behavioral default value
Milk consumption	M, B	2	L/yr	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Meat and poultry consumption	M, B	3	kg/yr	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Fish consumption rate	M, B	3	kg/yr	5.4	Metabolic/Behavioral default value
Other seafood consumption rate	M, B	3	kg/yr	0.9	Metabolic/Behavioral default value
Aquatic food contaminated fraction	B, P	2	-	Triangular	NUREG/CR-6697, Attachment C
Soil ingestion rate	M, B	2	g/yr	Triangular	NUREG/CR-6697, Attachment C
Drinking water intake	M, B	2	L/yr	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Storage time for fruits, non-leafy vegetables, and grain	B	3	d	14	Behavioral default value

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Storage time for leafy vegetables	B	3	d	1	Behavioral default value
Storage time for milk	B	3	d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Storage time for meat	B	3	d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Storage time for fish	B	3	d	7	Behavioral default value
Storage time for crustacea and mollusks	B	3	d	7	Behavioral default value
Storage time for well water	B	3	d	1	Behavioral default value
Storage time for surface water	B	3	d	1	Behavioral default value
Storage time for livestock fodder	B	3	d	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Drinking water contaminated fraction	B, P	3	-	1	Default Behavioral/Physical value applicable to the BRP site
Household water contaminated fraction	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Livestock water contaminated fraction	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Irrigation water contaminated fraction	B, P	3	-	1	Default Behavioral/Physical value applicable to the BRP site
Plant food contaminated fraction	B, P	3	-	-1	Default Behavioral/Physical value applicable to the BRP site
Meat contaminated fraction	B, P	3	-	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Milk contaminated fraction	B, P	3	-	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for meat	M	3	kg/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for milk	M	3	kg/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for meat	M	3	L/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for milk	M	3	L/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Livestock intake of soil	M	3	kg/d	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Mass loading for foliar deposition	P	3	g/m^3	1E-4	Default Physical value applicable to the BRP site
Depth of soil mixing layer	P	2	m	Triangular	NUREG/CR-6697, Attachment C
Depth of roots	P	1	m	Uniform	NUREG/CR-6697, Attachment C
Groundwater fractional usage for drinking water	B, P	3	-	1	Default Behavioral/Physical value applicable to the BRP site
Groundwater fractional usage for household water	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Groundwater fractional usage for livestock water	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Groundwater fractional usage for irrigation water	B, P	3	-	1	Behavioral/Physical default value applicable to the BRP site
Wet weight crop yield for non-leafy plants	P	2	kg/m^2	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Wet weight crop yield for leafy plants	P	3	kg/m^2	1.5	Default Physical value applicable to the BRP site
Wet weight crop yield for fodder	P	3	kg/m^2	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Length of growing season for non-leafy vegetables	P	3	yr	0.17	Default Physical value applicable to the BRP site
Length of growing season for leafy vegetables	P	3	yr	0.25	Default Physical value applicable to the BRP site
Length of growing season for fodder	P	3	yr	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Translocation factor for non-leafy vegetables	P	3	-	0.1	Default Physical value applicable to the BRP site
Translocation factor for leafy vegetables	P	3	-	1	Default Physical value applicable to the BRP site
Translocation factor for fodder	P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Weathering removal constant	P	2	1/yr	Triangular	NUREG/CR-6697, Attachment C
Dry foliar interception fraction for non-leafy vegetables	P	3	-	0.25	Default Physical value applicable to the BRP site

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Dry foliar interception fraction for leafy vegetables	P	3	-	0.25	Default Physical value applicable to the BRP site
Dry foliar interception fraction for fodder	P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Wet foliar interception fraction for non-leafy vegetables	P	3	-	0.25	Default Physical value applicable to the BRP site
Wet foliar interception fraction for leafy vegetables	P	2	-	Triangular	NUREG/CR-6697, Attachment C
Wet foliar interception fraction for fodder	P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Slope factor - external	M	3	(risk/yr)/ (pCi/g)	Nuclide specific	Metabolic default value
Slope factor - inhalation	M	3	risk/pCi	Nuclide specific	Metabolic default value
Slope factor - ingestion	M	3	risk/pCi	Nuclide specific	Metabolic default value
Plant transfer factor for H-3	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Mn	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Fe	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Co	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Sr	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Cs	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Eu	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Plant transfer factor for Gd	P	1	-	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for H-3	P	2	(pCi/kg)/ (pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for Mn	P	2	(pCi/kg)/ (pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for Fe	P	2	(pCi/kg)/ (pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for Co	P	2	(pCi/kg)/ (pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for Sr	P	2	(pCi/kg)/ (pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for Cs	P	2	(pCi/kg)/ (pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Meat transfer factor for Eu	P	2	(pCi/kg)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Meat transfer factor for Gd	P	2	(pCi/kg)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for H-3	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Mn	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Fe	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Co	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Sr	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Cs	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Eu	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
Milk transfer factor for Gd	P	2	(pCi/L)/(pCi/d)	Truncated lognormal-n	NUREG/CR-6697, Attachment C
H-3 bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C
Mn bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C]
Fe bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C
Co bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C
Sr bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C
Cs bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C
Eu bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Gd bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	Lognormal-n	NUREG/CR-6697, Attachment C
Bioaccumulation factor for crustacea and mollusks	P	3	(pCi/kg)/(pCi/L)	Element specific	Default Physical value applicable to the BRP site
Occupancy (Inhalation & External Parameters)					
Inhalation rate	M, B	3	m^3/yr	Triangular	NUREG/CR-6697, Attachment C
Inhalation dose conversion factors	M	3	mrem/pCi	Nuclide Specific	Metabolic default value
Ingestion dose conversion factors	M	3	mrem/pCi	Nuclide Specific	Metabolic default value
Mass loading for inhalation	P, B	2	g/m^3	Continuous linear	NUREG/CR-6697, Attachment C
Indoor dust filtration factor	P, B	2	-	Uniform	NUREG/CR-6697, Attachment C
External gamma shielding factor	P	2	-	Bounded lognormal-n	NUREG/CR-6697, Attachment C
Building foundation thickness	P	3	m	Not Used	The Radon Exposure Pathway is not used
Building foundation bulk density	P	3	g/m^3	Not Used	The Radon Exposure Pathway is not used
Building foundation total porosity	P	3	-	Not Used	The Radon Exposure Pathway is not used
Building foundation volumetric water content	P	3	-	Not Used	The Radon Exposure Pathway is not used
Building foundation radon diffusion coefficient	P	3	m^2/s	Not Used	The Radon Exposure Pathway is not used
Contaminated soil zone radon diffusion coefficient	P	3	m^2/s	Not Used	The Radon Exposure Pathway is not used
Radon vertical dimension of mixing	P	3	m	Not Used	The Radon Exposure Pathway is not used
Building air exchange rate	P, B	3	1/hr	Not Used	The Radon Exposure Pathway is not used
Building (room) height	P	3	m	Not Used	The Radon Exposure Pathway is not used
Building indoor area factor	P	3	-	Not Used	The Radon Exposure Pathway is not used
Foundation depth below ground surface	P	3	m	Not Used	The Radon Exposure Pathway is not used
Radon-222 emanation coefficient	P	3	-	Not Used	The Radon Exposure Pathway is not used
Radon-220 emanation coefficient	P	3	-	Not Used	The Radon Exposure Pathway is not used

Parameter	Class[1]	Priority[2]	Units	Value/Distribution	Basis
Indoor time fraction	B	3	-	Continuous linear	NUREG/CR-6697, Attachment C
Outdoor time fraction	B	3	-	0.25	Behavioral default value.
Exposure duration	B	3	yr	30	Behavioral default value.

Notes:

[1]P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4)
[2]1 = high priority parameter, 2 = medium priority parameter, 3 = low priority parameter

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Density of saturated zone	1	Truncated normal	1.52	0.230	0.001	0.999	0.03	1.52	-	1.52
Saturated zone total porosity	1	Truncated normal	0.425	0.0867	0.001	0.999	-0.07	0.424	-	0.424
Saturated zone effective porosity	1	Truncated normal	0.355	0.0906	0.001	0.999	-0.09	0.355	-	0.355
Depth of roots	1	Uniform	0.3	4.0	-	-	-0.48	-	1.22	1.22
Plant transfer factor for H	1	Truncated lognormal-n	1.57	1.1	0.001	0.999	-0.11	4.80	-	4.80
Plant transfer factor for Mn	1	Truncated lognormal-n	-1.20	0.9	0.001	0.999	-0.01	0.299	-	0.299
Plant transfer factor for Fe	1	Truncated lognormal-n	-6.91	0.9	0.001	0.999	-0.03	0.001	-	0.001
Plant transfer factor for Co	1	Truncated lognormal-n	-2.53	0.9	0.001	0.999	-0.04	0.079	-	0.079
Plant transfer factor for Sr	1	Truncated lognormal-n	-1.20	1.0	0.001	0.999	0.54	-	0.589	0.589
Plant transfer factor for Cs	1	Truncated lognormal-n	-3.22	1.0	0.001	0.999	0.07	0.040	-	0.040
Plant transfer factor for Eu	1	Truncated lognormal-n	-6.21	1.1	0.001	0.999	-0.09	0.002	-	0.002
Plant transfer factor for Gd	1	Truncated lognormal-n	-6.21	1.1	0.001	0.999	0.11	0.002	-	0.002
Contaminated zone erosion rate	2	Continuous logarithmic	Default[4]				-0.09	0.001	-	0.001
Saturated zone soil-specific b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30	0.06	2.88	-	2.88
Well-pump intake depth (below water table)	2	Triangular	6	30	10	-	0.03	14.5	-	14.5
Evapotranspiration coefficient	2	Uniform	0.5	0.75	-	-	0.05	0.624	-	0.624
Runoff coefficient	2	Uniform	0.1	0.8	-	-	0.00	0.449	-	0.449
Fruit, vegetable, and grain consumption rate	2	Triangular	135	318	178	-	-0.05	205	-	205
Aquatic food contaminated fraction	2	Triangular	0	1	0.39	-	-0.09	0.448	-	0.448
Soil ingestion rate	2	Triangular	0	36.5	18.3	-	0.06	18.2	-	18.2
Drinking water intake	2	Truncated lognormal-n	6.015	0.489	0.001	0.999	0.06	409	-	409
Depth of soil mixing layer	2	Triangular	0.0	0.6	0.15	-	-0.06	0.232	-	0.232
Wet weight crop yield for non-leafy plants	2	Truncated lognormal-n	0.56	0.48	0.001	0.999	0.00	1.75	-	1.75
Weathering removal constant	2	Triangular	5.1	84	18	-	-0.05	32.8	-	32.8
Wet foliar interception fraction for leafy vegetables	2	Triangular	0.06	0.95	0.67	-	-0.07	0.581	-	0.581
Meat transfer factor for H	2	Truncated lognormal-n	-4.42	1.0	0.001	0.999	0.13	0.012	-	0.012
Meat transfer factor for Mn	2	Truncated lognormal-n	-6.91	0.7	0.001	0.999	0.03	0.001	-	0.001
Meat transfer factor for Fe	2	Truncated lognormal-n	-3.51	0.4	0.001	0.999	0.04	0.030	-	0.030
Meat transfer factor for Co	2	Truncated lognormal-n	-3.51	1.0	0.001	0.999	-0.12	0.030	-	0.030
Meat transfer factor for Sr	2	Truncated lognormal-n	-4.61	0.4	0.001	0.999	0.03	0.010	-	0.010
Meat transfer factor for Cs	2	Truncated lognormal-n	-3.00	0.4	0.001	0.999	0.01	0.050	-	0.050
Meat transfer factor for Eu	2	Truncated lognormal-n	-6.21	1.0	0.001	0.999	-0.13	0.002	-	0.002
Meat transfer factor for Gd	2	Truncated lognormal-n	-6.21	1.0	0.001	0.999	0.05	0.002	-	0.002
Milk transfer factor for H	2	Truncated lognormal-n	-4.6	0.9	0.001	0.999	0.04	0.010	-	0.010
Milk transfer factor for Mn	2	Truncated lognormal-n	-8.11	0.7	0.001	0.999	0.09	0.010	-	0.010

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Milk transfer factor for Fe	2	Truncated lognormal-n	-8.11	0.7	0.001	0.999	0.02	0.000	-	0.000
Milk transfer factor for Co	2	Truncated lognormal-n	-6.21	0.7	0.001	0.999	0.13	0.002	-	0.002
Milk transfer factor for Sr	2	Truncated lognormal-n	-6.21	0.5	0.001	0.999	-0.04	0.002	-	0.002
Milk transfer factor for Cs	2	Truncated lognormal-n	-4.61	0.5	0.001	0.999	-0.01	0.010	-	0.010
Milk transfer factor for Eu	2	Truncated lognormal-n	-9.72	0.9	0.001	0.999	-0.10	5.99E-05	-	5.99E-05
Milk transfer factor for Gd	2	Truncated lognormal-n	-9.72	0.9	0.001	0.999	0.03	6.01E-05	-	6.01E-05
H bioaccumulation factor for fish	2	Lognormal-n	0	0.1	-	-	-0.05	1.00	-	1.00
Mn bioaccumulation factor for fish	2	Lognormal-n	6	1.1	-	-	0.12	400	-	400
Fe bioaccumulation factor for fish	2	Lognormal-n	5.3	1.1	-	-	0.02	199	-	199
Co bioaccumulation factor for fish	2	Lognormal-n	5.7	1.1	-	-	0.04	297	-	297
Sr bioaccumulation factor for fish	2	Lognormal-n	4.1	1.1	-	-	0.02	60.0	-	60.0
Cs bioaccumulation factor for fish	2	Lognormal-n	7.6	0.7	-	-	-0.06	1990	-	1990
Eu bioaccumulation factor for fish	2	Lognormal-n	3.9	1.1	-	-	0.02	49.2	-	49.2
Gd bioaccumulation factor for fish	2	Lognormal-n	3.2	1.1	-	-	0.01	24.4	-	24.4
Mass loading for inhalation	2	Continuous linear	Default[4]				0.03	2.35E-05	-	2.35E-05
Indoor dust filtration factor	2	Uniform	0.15	0.95	-	-	-0.06	0.550	-	0.550
External gamma shielding factor	2	Bounded lognormal-n	-1.3	0.59	0.044	1	0.72	-	0.397	0.397
Humidity in air	3	Truncated lognormal-n	1.98	0.334	0.001	0.999	0.03	7.22	-	7.22
Indoor time fraction	3	Continuous linear	Default[4]				0.93	-	0.667	0.667
Inhalation rate	3	Triangular	4,380	13,100	8,400	-	0.00	8570	-	8570

Notes:

[1]1 = high priority parameter, 2 = medium priority parameter

[2]Distribution's Statistical Parameter
Lognormal-n: 1 = mean, 2 = standard deviation
Bounded lognormal-n: 1 = underlying mean value, 2 = underlying standard deviation, 3 = lower limit, 4 = upper limit
Truncated lognormal-n: 1 = underlying mean value, 2 = underlying standard deviation, 3 = lower quantile, 4 = upper quantile
Truncated normal: 1 = mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Triangular: 1 = minimum, 2 = maximum, 3 = most likely
Uniform: 1 = minimum, 2 = maximum

[3]PRCC = Partial ranked correlation coefficient for peak all-pathways dose

[4]Default RESRAD v6.21 distribution parameters were used

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Contamination					
Thickness of contaminated zone	P	2	m	0.15	Assigned value
Area of contaminated zone	P	2	m^2	8,094	Assigned value
Shape of the contaminated zone	P	3	-	Circular	Default RESRAD v6.21 Physical value applicable to the BRP site
Initial concentration of principal radionuclides in soil	P	2	pCi/g	1	Assigned value
Initial concentration of radionuclides present in groundwater	P	3	pCi/L	0	Not Used
Leach rate	P	3	1/yr	0	Default Physical value to invoke the calculation of this parameter via a first-order leaching model that uses the value of the soil/water distribution coefficient in the contaminated zone.
Solubility limit	P	3	mol/L	0	Default Physical value – not used by RESRAD with leach rate flag set to 0
Time since placement of material	P	3	yr	0	Default RESRAD v6.21 Physical value assumed acceptable for purposes of DCGL generation
Times for calculation	P	3	yr	1, 3, 10, 30, 100, 300, 1000	Default RESRAD v6.21 Physical value applicable to the BRP site
Contaminated zone density	P	1	g/cm^3	1.75	Site-specific measured physical parameter
Contaminated zone distribution coefficient for H-3	P	1	cm^3/g	0.043	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Mn	P	1	cm^3/g	733	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Fe	P	1	cm^3/g	1251	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Co	P	1	cm^3/g	1284	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Sr	P	1	cm^3/g	131	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Cs	P	1	cm^3/g	2130	EA-BRP-SC-0202

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Contaminated zone distribution coefficient for Eu	P	1	cm^3/g	7194	EA-BRP-SC-0202
Contaminated zone distribution coefficient for Gd	P	1	cm^3/g	7194	EA-BRP-SC-0202
Use plant/soil ratio	NA	3	Check box	No	For purposes of the sensitivity analysis, the code should not be allowed to calculate the distribution coefficient from the plant root uptake factors.
Contaminated zone field capacity	P	3	-	0.263	Site-specific measured physical parameter
Contaminated zone erosion rate	P,B	2	m/yr	0.001	Sensitivity analysis
Contaminated zone total porosity	P	2	-	0.351	Site-specific measured physical parameter
Contaminated zone hydraulic conductivity	P	2	m/yr	536	Site-specific measured physical parameter
Contaminated zone b parameter	P	2	-	4.05	Site-specific measured physical parameter
Carbon-Model Parameters					
Thickness of evasion layer of C-14 in soil	P	2	m	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-14 evasion flux rate from soil	P	3	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in local water	P	3	g/cm^3	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 concentration in contaminated soil	P	3	g/g	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Fraction of vegetation carbon absorbed from soil	P	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Fraction of vegetation carbon absorbed from air	P	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
C-12 evasion flux rate from soil	P	3	1/s	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in beef cattle feed	B	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Grain fraction in milk cow feed	B	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
DCF correction factor for gaseous forms of C-14	P	3	-	Not Used	Carbon-14 has not been identified in any contaminated surface, subsurface or aquifer samples.
Soil					
Cover depth	P	2	m	0	The contamination is assumed to be on surface soil.
Density of cover material	P	1	g/cm^3	Not Used	A cover is not used in the site-specific dose model.
Cover total porosity	P	3	-	Not Used	A cover is not used in the site-specific dose model.
Cover volumetric water content	P	3	-	Not Used	A cover is not used in the site-specific dose model.
Cover radon diffusion coefficient	P	3	m^2/s	Not Used	A cover is not used in the site-specific dose model.
Cover erosion rate	P,B	2	m/yr	Not Used	A cover is not used in the site-specific dose model.
Number of unsaturated zones	P	3	-	5	Site-specific measured physical parameter
Unsaturated zone 1 thickness	P	1	m	1.37	Site-specific measured physical parameter
Unsaturated zone 2 thickness	P	1	m	1.37	Site-specific measured physical parameter
Unsaturated zone 3 thickness	P	1	m	4.11	Site-specific measured physical parameter
Unsaturated zone 4 thickness	P	1	m	0.61	Site-specific measured physical parameter
Unsaturated zone 5 thickness	P	1	m	7.32	Site-specific measured physical parameter
Unsaturated zone 1 density	P	2	g/cm^3	1.75	Site-specific measured physical parameter

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Unsaturated zone 2 density	P	2	g/cm^3	1.95	Site-specific measured physical parameter
Unsaturated zone 3 density	P	2	g/cm^3	1.92	Site-specific measured physical parameter
Unsaturated zone 4 density	P	2	g/cm^3	1.83	Site-specific measured physical parameter
Unsaturated zone 5 density	P	2	g/cm^3	1.85	Site-specific measured physical parameter
Unsaturated zone 1 distribution coefficient for H	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Mn	P	1	cm^3/g	156	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Fe	P	1	cm^3/g	206	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Co	P	1	cm^3/g	232	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Sr	P	1	cm^3/g	31.2	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Cs	P	1	cm^3/g	441	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Eu	P	1	cm^3/g	817	EA-BRP-SC-0202
Unsaturated zone 1 distribution coefficient for Gd	P	1	cm^3/g	817	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for H	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Mn	P	1	cm^3/g	155	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Fe	P	1	cm^3/g	204	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Co	P	1	cm^3/g	231	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Sr	P	1	cm^3/g	31.0	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Cs	P	1	cm^3/g	438	EA-BRP-SC-0202
Unsaturated zone 2 distribution coefficient for Eu	P	1	cm^3/g	809	EA-BRP-SC-0202

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Unsaturated zone 2 distribution coefficient for Gd	P	1	cm^3/g	809	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for H	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Mn	P	1	cm^3/g	157	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Fe	P	1	cm^3/g	207	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Co	P	1	cm^3/g	234	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Sr	P	1	cm^3/g	31.4	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Cs	P	1	cm^3/g	444	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Eu	P	1	cm^3/g	824	EA-BRP-SC-0202
Unsaturated zone 3 distribution coefficient for Gd	P	1	cm^3/g	824	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for H	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Mn	P	1	cm^3/g	155	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Fe	P	1	cm^3/g	204	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Co	P	1	cm^3/g	231	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Sr	P	1	cm^3/g	31.0	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Cs	P	1	cm^3/g	438	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Eu	P	1	cm^3/g	809	EA-BRP-SC-0202
Unsaturated zone 4 distribution coefficient for Gd	P	1	cm^3/g	809	EA-BRP-SC-0202

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Unsaturated zone 5 distribution coefficient for H	P	1	cm^3/g	0.043	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Mn	P	1	cm^3/g	155	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Fe	P	1	cm^3/g	204	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Co	P	1	cm^3/g	230	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Sr	P	1	cm^3/g	31.0	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Cs	P	1	cm^3/g	438	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Eu	P	1	cm^3/g	808	EA-BRP-SC-0202
Unsaturated zone 5 distribution coefficient for Gd	P	1	cm^3/g	808	EA-BRP-SC-0202
Unsaturated zone 1 total porosity	P	2	-	0.351	Site-specific measured physical parameter
Unsaturated zone 2 total porosity	P	2	-	0.274	Site-specific measured physical parameter
Unsaturated zone 3 total porosity	P	2	-	0.287	Site-specific measured physical parameter
Unsaturated zone 4 total porosity	P	2	-	0.317	Site-specific measured physical parameter
Unsaturated zone 5 total porosity	P	2	-	0.313	Site-specific measured physical parameter
Unsaturated zone 1 effective porosity	P	2	-	0.088	Site-specific measured physical parameter
Unsaturated zone 2 effective porosity	P	2	-	0.026	Site-specific measured physical parameter
Unsaturated zone 3 effective porosity	P	2	-	0.037	Site-specific measured physical parameter
Unsaturated zone 4 effective porosity	P	2	-	0.029	Site-specific measured physical parameter

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Unsaturated zone 5 effective porosity	P	2	-	0.054	Site-specific measured physical parameter
Unsaturated zone 1 field capacity	P	3	-	0.263	Site-specific measured physical parameter
Unsaturated zone 2 field capacity	P	3	-	0.248	Site-specific measured physical parameter
Unsaturated zone 3 field capacity	P	3	-	0.250	Site-specific measured physical parameter
Unsaturated zone 4 field capacity	P	3	-	0.287	Site-specific measured physical parameter
Unsaturated zone 5 field capacity	P	3	-	0.258	Site-specific measured physical parameter
Unsaturated zone 1 hydraulic conductivity	P	2	m/yr	536	Site-specific measured physical parameter
Unsaturated zone 2 hydraulic conductivity	P	2	m/yr	554	Site-specific measured physical parameter
Unsaturated zone 3 hydraulic conductivity	P	2	m/yr	5.17	Site-specific measured physical parameter
Unsaturated zone 4 hydraulic conductivity	P	2	m/yr	1046	Site-specific measured physical parameter
Unsaturated zone 5 hydraulic conductivity	P	2	m/yr	15.6	Site-specific measured physical parameter
Unsaturated zone 1 soil-specific b parameter	P	2	-	4.05	Site-specific measured physical parameter
Unsaturated zone 2 soil-specific b parameter	P	2	-	4.38	Site-specific measured physical parameter
Unsaturated zone 3 soil-specific b parameter	P	2	-	4.90	Site-specific measured physical parameter
Unsaturated zone 4 soil-specific b parameter	P	2	-	4.05	Site-specific measured physical parameter
Unsaturated zone 5 soil-specific b parameter	P	2	-	4.90	Site-specific measured physical parameter
Water					
Density of saturated zone	P	1	g/cm^3	1.52	Sensitivity analysis

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Saturated zone distribution coefficient for H-3	P	1	cm^3/g	0.060	EA-BRP-SC-0202
Saturated zone distribution coefficient for Mn	P	1	cm^3/g	156	EA-BRP-SC-0202
Saturated zone distribution coefficient for Fe	P	1	cm^3/g	205	EA-BRP-SC-0202
Saturated zone distribution coefficient for Co	P	1	cm^3/g	232	EA-BRP-SC-0202
Saturated zone distribution coefficient for Sr	P	1	cm^3/g	31.1	EA-BRP-SC-0202
Saturated zone distribution coefficient for Cs	P	1	cm^3/g	440	EA-BRP-SC-0202
Saturated zone distribution coefficient for Eu	P	1	cm^3/g	814	EA-BRP-SC-0202
Saturated zone distribution coefficient for Gd	P	1	cm^3/g	814	EA-BRP-SC-0202
Saturated zone total porosity	P	1	-	0.424	Sensitivity analysis
Saturated zone effective porosity	P	1	-	0.355	Sensitivity analysis
Saturated zone field capacity	P	3	-	0.16	RESRAD Data Collection Handbook total porosity for limestone minus the effective porosity for limestone
Saturated zone hydraulic conductivity	P	1	m/yr	1.52E+03	Site-specific measured physical parameter
Saturated zone hydraulic gradient	P	2	-	0.0007	Site-specific measured physical parameter
Saturated zone soil-specific b parameter	P	2	-	2.88	Sensitivity analysis
Length of contaminated zone parallel to the aquifer flow	P	2	m	102	Diameter of an 8,094 m^2 contaminated zone
Water table drop rate	P	3	m/yr	0.001	Default RESRAD v6.21 Physical value applicable to the BRP site
Well-pump intake depth (below water table)	P	2	m	14.5	Sensitivity analysis
Well pumping rate	B, P	2	m^3/yr	330.34	NUREG/CR-6697, Attachment C, Table 3.10-1

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Model: non-dispersion or mass balance	NA	3	-	MB	The mass-balance model was chosen as the most conservative since it assumes that all of the radionuclides released from the contaminated zone are withdrawn through the well.
Evapotranspiration coefficient	P	2	-	0.624	Sensitivity analysis
Humidity in air	P	3	g/m^3	7.22	Sensitivity analysis
Average annual wind speed	P	2	m/s	5	Site-specific measured physical parameter
Precipitation rate	P	2	m/yr	0.8	Site-specific measured physical parameter
Irrigation mode	B	3	-	Overhead	Behavioral value - ditch irrigation is not used in the Midwest.
Irrigation rate	B	3	m/yr	0.2	Behavioral RESRAD v6.21 default value
Runoff coefficient	P	2	-	0.449	Sensitivity analysis
Watershed area for nearby stream or pond	P	3	m^2	2306717	The entire BRP site drains into Lake Michigan.
Accuracy for water soil computation	NA	3	-	0.001	Default RESRAD v6.21 value applicable to the BRP site
Ingestion					
Fruit, vegetable, and grain consumption rate	M, B	2	kg/yr	205	Sensitivity analysis
Leafy vegetable consumption	M, B	3	kg/yr	14	Metabolic/Behavioral RESRAD v6.21 default value
Milk consumption	M, B	2	L/yr	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Meat and poultry consumption	M, B	3	kg/yr	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Fish consumption rate	M, B	3	kg/yr	5.4	Metabolic/Behavioral RESRAD v6.21 default value
Other seafood consumption rate	M, B	3	kg/yr	0.9	Metabolic/Behavioral RESRAD v6.21 default value
Aquatic food contaminated fraction	B, P	2	-	0.448	Sensitivity analysis
Soil ingestion rate	M, B	2	g/yr	18.2	Sensitivity analysis
Drinking water intake	M, B	2	L/yr	409	Sensitivity analysis

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Storage time for fruits, non-leafy vegetables, and grain	B	3	d	14	Behavioral RESRAD v6.21 default value
Storage time for leafy vegetables	B	3	d	1	Behavioral RESRAD v6.21 default value
Storage time for milk	B	3	d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Storage time for meat	B	3	d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Storage time for fish	B	3	d	7	Behavioral RESRAD v6.21 default value
Storage time for crustacea and mollusks	B	3	d	7	Behavioral RESRAD v6.21 default value
Storage time for well water	B	3	d	1	Behavioral default value
Storage time for surface water	B	3	d	1	Behavioral default value
Storage time for livestock fodder	B	3	d	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Drinking water contaminated fraction	B, P	3	-	1	Default RESRAD v6.21 Behavioral/Physical value applicable to the BRP site
Household water contaminated fraction	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Livestock water contaminated fraction	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Irrigation water contaminated fraction	B, P	3	-	1	Default RESRAD v6.21 Behavioral/Physical value applicable to the BRP site
Plant food contaminated fraction	B, P	3	-	-1	Default RESRAD v6.21 Behavioral/Physical value applicable to the BRP site
Meat contaminated fraction	B, P	3	-	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Milk contaminated fraction	B, P	3	-	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for meat	M	3	kg/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock fodder intake rate for milk	M	3	kg/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Livestock water intake rate for meat	M	3	L/d	Not Used	The meat ingestion pathway is suppressed in the site-specific dose model.
Livestock water intake rate for milk	M	3	L/d	Not Used	The milk ingestion pathway is suppressed in the site-specific dose model.
Livestock intake of soil	M	3	kg/d	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Mass loading for foliar deposition	P	3	g/m^3	1E-4	Default RESRAD v6.21 Physical value applicable to the BRP site
Depth of soil mixing layer	P	2	m	0.232	Sensitivity analysis
Depth of roots	P	1	m	1.22	Sensitivity analysis
Groundwater fractional usage for drinking water	B, P	3	-	1	Default RESRAD v6.21 Behavioral/Physical value applicable to the BRP site
Groundwater fractional usage for household water	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Groundwater fractional usage for livestock water	B, P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Groundwater fractional usage for irrigation water	B, P	3	-	1	Behavioral/Physical default value applicable to the BRP site
Wet weight crop yield for non-leafy plants	P	2	kg/m^2	1.75	Sensitivity analysis
Wet weight crop yield for leafy plants	P	3	kg/m^2	1.5	Default RESRAD v6.21 Physical value applicable to the BRP site
Wet weight crop yield for fodder	P	3	kg/m^2	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Length of growing season for non-leafy vegetables	P	3	yr	0.17	Default RESRAD v6.21 Physical value applicable to the BRP site
Length of growing season for leafy vegetables	P	3	yr	0.25	Default RESRAD v6.21 Physical value applicable to the BRP site
Length of growing season for fodder	P	3	yr	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Translocation factor for non-leafy vegetables	P	3	-	0.1	Default RESRAD v6.21 Physical value applicable to the BRP site
Translocation factor for leafy vegetables	P	3	-	1	Default RESRAD v6.21 Physical value applicable to the BRP site

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Translocation factor for fodder	P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Weathering removal constant	P	2	1/yr	32.8	Sensitivity analysis
Dry foliar interception fraction for non-leafy vegetables	P	3	-	0.25	Default RESRAD v6.21 Physical value applicable to the BRP site
Dry foliar interception fraction for leafy vegetables	P	3	-	0.25	Default RESRAD v6.21 Physical value applicable to the BRP site
Dry foliar interception fraction for fodder	P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Wet foliar interception fraction for non-leafy vegetables	P	3	-	0.25	Default RESRAD v6.21 Physical value applicable to the BRP site
Wet foliar interception fraction for leafy vegetables	P	2	-	0.581	Sensitivity analysis
Wet foliar interception fraction for fodder	P	3	-	Not Used	The meat and milk ingestion pathways are suppressed in the site-specific dose model.
Slope factor - external	M	3	(risk/yr)/(pCi/g)	Nuclide specific	Metabolic RESRAD v6.21 default value
Slope factor - inhalation	M	3	risk/pCi	Nuclide specific	Metabolic RESRAD v6.21 default value
Slope factor - ingestion	M	3	risk/pCi	Nuclide specific	Metabolic RESRAD v6.21 default value
Plant transfer factor for H	P	1	-	4.80	Sensitivity analysis
Plant transfer factor for Mn	P	1	-	0.299	Sensitivity analysis
Plant transfer factor for Fe	P	1	-	0.001	Sensitivity analysis
Plant transfer factor for Co	P	1	-	0.079	Sensitivity analysis
Plant transfer factor for Sr	P	1	-	0.589	Sensitivity analysis
Plant transfer factor for Cs	P	1	-	0.040	Sensitivity analysis
Plant transfer factor for Eu	P	1	-	0.002	Sensitivity analysis
Plant transfer factor for Gd	P	1	-	0.002	Sensitivity analysis
Meat transfer factor for H	P	2	(pCi/kg)/(pCi/d)	0.012	Sensitivity analysis
Meat transfer factor for Mn	P	2	(pCi/kg)/(pCi/d)	0.001	Sensitivity analysis
Meat transfer factor for Fe	P	2	(pCi/kg)/(pCi/d)	0.030	Sensitivity analysis
Meat transfer factor for Co	P	2	(pCi/kg)/(pCi/d)	0.030	Sensitivity analysis

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Meat transfer factor for Sr	P	2	(pCi/kg)/(pCi/d)	0.010	Sensitivity analysis
Meat transfer factor for Cs	P	2	(pCi/kg)/(pCi/d)	0.050	Sensitivity analysis
Meat transfer factor for Eu	P	2	(pCi/kg)/(pCi/d)	0.002	Sensitivity analysis
Meat transfer factor for Gd	P	2	(pCi/kg)/(pCi/d)	0.002	Sensitivity analysis
Milk transfer factor for H	P	2	(pCi/L)/(pCi/d)	0.010	Sensitivity analysis
Milk transfer factor for Mn	P	2	(pCi/L)/(pCi/d)	0.010	Sensitivity analysis
Milk transfer factor for Fe	P	2	(pCi/L)/(pCi/d)	0.000	Sensitivity analysis
Milk transfer factor for Co	P	2	(pCi/L)/(pCi/d)	0.002	Sensitivity analysis
Milk transfer factor for Sr	P	2	(pCi/L)/(pCi/d)	0.002	Sensitivity analysis
Milk transfer factor for Cs	P	2	(pCi/L)/(pCi/d)	0.010	Sensitivity analysis
Milk transfer factor for Eu	P	2	(pCi/L)/(pCi/d)	5.99E-05	Sensitivity analysis
Milk transfer factor for Gd	P	2	(pCi/L)/(pCi/d)	6.01E-05	Sensitivity analysis
H bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	1.00	Sensitivity analysis
Mn bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	400	Sensitivity analysis
Fe bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	199	Sensitivity analysis
Co bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	297	Sensitivity analysis
Sr bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	60.0	Sensitivity analysis

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Cs bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	1990	Sensitivity analysis
Eu bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	49.2	Sensitivity analysis
Gd bioaccumulation factor for fish	P	2	(pCi/kg)/(pCi/L)	24.4	Sensitivity analysis
Bioaccumulation factor for crustacea and mollusks	P	3	(pCi/kg)/(pCi/L)	Element specific	Default RESRAD v6.21 Physical value applicable to the BRP site
Occupancy (Inhalation & External Parameters)					
Inhalation rate	M, B	3	m^3/yr	8570	Sensitivity analysis
Inhalation dose conversion factors	M	3	mrem/pCi	Nuclide Specific	Metabolic default value
Ingestion dose conversion factors	M	3	mrem/pCi	Nuclide Specific	Metabolic RESRAD v6.21 default value
Mass loading for inhalation	P, B	2	g/m^3	2.35E-05	Sensitivity analysis
Indoor dust filtration factor	P, B	2	-	0.550	Sensitivity analysis
External gamma shielding factor	P	2	-	0.397	Sensitivity analysis
Building foundation thickness	P	3	m	Not Used	The Radon Exposure Pathway is not used
Building foundation bulk density	P	3	g/m^3	Not Used	The Radon Exposure Pathway is not used
Building foundation total porosity	P	3	-	Not Used	The Radon Exposure Pathway is not used
Building foundation volumetric water content	P	3	-	Not Used	The Radon Exposure Pathway is not used
Building foundation radon diffusion coefficient	P	3	m^2/s	Not Used	The Radon Exposure Pathway is not used
Contaminated soil zone radon diffusion coefficient	P	3	m^2/s	Not Used	The Radon Exposure Pathway is not used
Radon vertical dimension of mixing	P	3	m	Not Used	The Radon Exposure Pathway is not used
Building air exchange rate	P, B	3	1/hr	Not Used	The Radon Exposure Pathway is not used
Building (room) height	P	3	m	Not Used	The Radon Exposure Pathway is not used
Building indoor area factor	P	3	-	Not Used	The Radon Exposure Pathway is not used
Foundation depth below ground surface	P	3	m	Not Used	The Radon Exposure Pathway is not used

Parameter	Class[1]	Priority[2]	Units	Parameter Value	Basis for Parameter Selection
Radon-222 emanation coefficient	P	3	-	Not Used	The Radon Exposure Pathway is not used
Radon-220 emanation coefficient	P	3	-	Not Used	The Radon Exposure Pathway is not used
Indoor time fraction	B	3	-	0.667	Sensitivity analysis
Outdoor time fraction	B	3	-	0.25	Behavioral RESRAD v6.21 default value.
Exposure duration	B	3	yr	30	Behavioral RESRAD v6.21 default value.

Notes:

[1]P = physical, B = behavioral, M = metabolic; (see NUREG/CR-6697, Attachment B, Table 4)
[2]1 = high priority parameter, 2 = medium priority parameter, 3 = low priority parameter

Appendix 6-G, RESRAD v6.21 Sensitivity Analysis Distribution Parameters and Results for Discounted Radionuclides

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Contaminated Zone distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	0.40		95.7	95.7[4]
Contaminated Zone distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	1.00		1130	1130[4]
Contaminated Zone distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	0.97		21200	21200[4]
Contaminated Zone distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	-0.73		0.061	0.061[4]
Contaminated Zone distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	1.00		888	888[4]
Contaminated Zone distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.84		1.05	1.05[4]
Contaminated Zone distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	1.00		2130	2130[4]
Contaminated Zone distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	0.99		3360	3360[4]
Contaminated Zone distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.96		11700	11700[4]
Contaminated Zone distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	0.97		23000	23000[4]
Contaminated Zone distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	0.06	824		824[4]
Contaminated Zone distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	-0.01	17.1		17.1[4]
Contaminated Zone distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	0.00	379		379[4]
Contaminated Zone distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	0.06	5720		5720[4]
Contaminated Zone distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	-0.01	126		126[4]
Unsaturated Zone 1 distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	-0.26		1.25	1.25[4]
Unsaturated Zone 1 distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	0.09	421		421[4]
Unsaturated Zone 1 distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	0.04	1054		1054[4]
Unsaturated Zone 1 distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	-0.18	0.505		0.505[4]
Unsaturated Zone 1 distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	0.08	215		215[4]
Unsaturated Zone 1 distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.08	4.53		4.53[4]

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Unsaturated Zone 1 distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	-0.05	441		441[4]
Unsaturated Zone 1 distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	-0.05	947		947[4]
Unsaturated Zone 1 distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.03	1440		1440[4]
Unsaturated Zone 1 distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	-0.04	6710		6710[4]
Unsaturated Zone 1 distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	-0.01	823		823[4]
Unsaturated Zone 1 distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	-0.03	16.9		16.9[4]
Unsaturated Zone 1 distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	-0.02	375		375[4]
Unsaturated Zone 1 distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	0.02	5810		5810[4]
Unsaturated Zone 1 distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	0.05	126		126[4]
Unsaturated Zone 2 distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	-0.18	10.8		10.8[4]
Unsaturated Zone 2 distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	-0.02	420		420[4]
Unsaturated Zone 2 distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	-0.03	1040		1040[4]
Unsaturated Zone 2 distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	-0.14	0.500		0.500[4]
Unsaturated Zone 2 distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	0.07	214		214[4]
Unsaturated Zone 2 distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.09	4.49		4.49[4]
Unsaturated Zone 2 distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	0.06	438		438[4]
Unsaturated Zone 2 distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	0.03	947		947[4]
Unsaturated Zone 2 distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.01	1420		1420[4]
Unsaturated Zone 2 distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	0.00	6680		6680[4]
Unsaturated Zone 2 distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	0.06	812		812[4]
Unsaturated Zone 2 distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	0.03	16.8		16.8[4]

Appendix 6-G, RESRAD v6.21 Sensitivity Analysis Distribution Parameters and Results for Discounted Radionuclides

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Unsaturated Zone 2 distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	0.04	371		371[4]
Unsaturated Zone 2 distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	0.04	5810		5810[4]
Unsaturated Zone 2 distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	0.07	124		124[4]
Unsaturated Zone 3 distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	-0.25		1.26	1.26[4]
Unsaturated Zone 3 distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	0.03	423		423[4]
Unsaturated Zone 3 distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	-0.07	1066		1066[4]
Unsaturated Zone 3 distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	-0.17	0.509		0.509[4]
Unsaturated Zone 3 distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	0.04	216		216[4]
Unsaturated Zone 3 distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.12	4.55		4.55[4]
Unsaturated Zone 3 distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	-0.13	444		444[4]
Unsaturated Zone 3 distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	0.01	953		953[4]
Unsaturated Zone 3 distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.05	1430		1430[4]
Unsaturated Zone 3 distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	0.03	6740		6740[4]
Unsaturated Zone 3 distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	-0.03	828		828[4]
Unsaturated Zone 3 distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	-0.03	828		828[4]
Unsaturated Zone 3 distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	0.08	378		378[4]
Unsaturated Zone 3 distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	0.01	5880		5880[4]
Unsaturated Zone 3 distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	0.14	126		126[4]
Unsaturated Zone 4 distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	0.01	10.8		10.8[4]
Unsaturated Zone 4 distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	0.07	419		419[4]
Unsaturated Zone 4 distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	-0.05	1039		1039[4]

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Unsaturated Zone 4 distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	0.01	0.499		0.499[4]
Unsaturated Zone 4 distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	-0.03	214		214[4]
Unsaturated Zone 4 distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.05	4.50		4.50[4]
Unsaturated Zone 4 distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	0.05	438		430[4]
Unsaturated Zone 4 distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	0.06	943		943[4]
Unsaturated Zone 4 distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.13	1430		1430[4]
Unsaturated Zone 4 distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	-0.05	6670		6670[4]
Unsaturated Zone 4 distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	0.04	825		825[4]
Unsaturated Zone 4 distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	0.04	16.8		16.8[4]
Unsaturated Zone 4 distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	0.02	371		371[4]
Unsaturated Zone 4 distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	0.02	371		371[4]
Unsaturated Zone 4 distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	0.03	126		126[4]
Unsaturated Zone 5 distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	-0.25		1.25	1.25[4]
Unsaturated Zone 5 distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	-0.01	421		421[4]
Unsaturated Zone 5 distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	0.11	1037		1037[4]
Unsaturated Zone 5 distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	-0.23	0.499		0.499[4]
Unsaturated Zone 5 distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	0.11	213		213[4]
Unsaturated Zone 5 distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.20	4.49		4.49[4]
Unsaturated Zone 5 distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	0.07	438		438[4]
Unsaturated Zone 5 distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	-0.03	944		944[4]
Unsaturated Zone 5 distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.01	1410		1410[4]

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Unsaturated Zone 5 distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	0.02	6670		6670[4]
Unsaturated Zone 5 distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	0.06	812		812[4]
Unsaturated Zone 5 distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	0.05	16.8		16.8[4]
Unsaturated Zone 5 distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	-0.01	370		370[4]
Unsaturated Zone 5 distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	0.10	5780		5780[4]
Unsaturated Zone 5 distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	0.04	124		124[4]
Saturated Zone distribution coefficient for C	1	Truncated lognormal-n	2.4	3.22	0.001	0.999	-0.15	10.8		10.8
Saturated Zone distribution coefficient for Ni	1	Truncated lognormal-n	6.05	1.46	0.001	0.999	0.06	419		419
Saturated Zone distribution coefficient for Zn	1	Truncated lognormal-n	6.98	4.44	0.001	0.999	-0.07	1049		1049
Saturated Zone distribution coefficient for Tc	1	Truncated lognormal-n	-0.67	3.16	0.001	0.999	0.01	0.503		0.503
Saturated Zone distribution coefficient for Ag	1	Truncated lognormal-n	5.38	2.10	0.001	0.999	0.05	215		215
Saturated Zone distribution coefficient for I	1	Truncated lognormal-n	1.52	2.19	0.001	0.999	-0.06	4.52		4.52
Saturated Zone distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999	0.00	440		440
Saturated Zone distribution coefficient for Pu	1	Truncated lognormal-n	6.86	1.89	0.001	0.999	-0.06	943		943
Saturated Zone distribution coefficient for Am	1	Truncated lognormal-n	7.28	3.15	0.001	0.999	0.02	1430		1430
Saturated Zone distribution coefficient for Cm	1	Truncated lognormal-n	8.82	1.82	0.001	0.999	0.00	6700		6700
Saturated Zone distribution coefficient for Ac	1	Truncated lognormal-n	6.72	3.22	0.001	0.999	-0.04	817		817
Saturated Zone distribution coefficient for Np	1	Truncated lognormal-n	2.84	2.25	0.001	0.999	-0.08	16.9		16.9
Saturated Zone distribution coefficient for Pa	1	Truncated lognormal-n	5.94	3.22	0.001	0.999	0.18	373		373
Saturated Zone distribution coefficient for Th	1	Truncated lognormal-n	8.68	3.62	0.001	0.999	-0.01	5770		5770
Saturated Zone distribution coefficient for U	1	Truncated lognormal-n	4.84	3.13	0.001	0.999	-0.07	125		125

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Plant transfer factor for C	1	Truncated lognormal-n	-0.36	0.9	0.001	0.999	0.06	1.59E-01		1.59E-01[5]
Plant transfer factor for Zn	1	Truncated lognormal-n	-0.92	0.9	0.001	0.999	-0.13	3.97E-01		3.97E-01[5]
Plant transfer factor for Tc	1	Truncated lognormal-n	1.61	0.9	0.001	0.999	0.00	4.97E+00		4.97E+00[5]
Plant transfer factor for Ag	1	Truncated lognormal-n	-5.52	0.9	0.001	0.999	0.03	4.00E-03		4.00E-03[5]
Plant transfer factor for I	1	Truncated lognormal-n	-3.91	0.9	0.001	0.999	0.73		3.67E-02	3.67E-02[5]
Plant transfer factor for Pu	1	Truncated lognormal-n	-6.91	0.9	0.001	0.999	0.59		1.82E-03	1.82E-03[5]
Plant transfer factor for Am	1	Truncated lognormal-n	-6.91	0.9	0.001	0.999	0.48		1.82E-03	1.82E-03[5]
Plant transfer factor for Cm	1	Truncated lognormal-n	-6.91	0.9	0.001	0.999	-0.02	9.91E-04		9.91E-04[5]
Plant transfer factor for Ac	1	Truncated lognormal-n	-6.91	1.1	0.001	0.999	0.04	9.94E-04		9.94E-04[5]
Plant transfer factor for Np	1	Truncated lognormal-n	-3.91	0.9	0.001	0.999	0.08	2.00E-02		2.00E-02[5]
Plant transfer factor for Pa	1	Truncated lognormal-n	-4.61	1.1	0.001	0.999	-0.03	9.95E-03		9.95E-03[5]
Plant transfer factor for Th	1	Truncated lognormal-n	-6.91	0.9	0.001	0.999	0.04	9.93E-04		9.93E-04[5]
Plant transfer factor for U	1	Truncated lognormal-n	-6.21	0.9	0.001	0.999	0.01	2.00E-03		2.00E-03[5]
Meat transfer factor for C	2	Truncated lognormal-n	-3.47	1.0	0.001	0.999	0.01	3.09E-02		3.09E-02[6]
Meat transfer factor for Zn	2	Truncated lognormal-n	-2.30	0.3	0.001	0.999	0.06	1.00E-01		1.00E-01[6]
Meat transfer factor for Tc	2	Truncated lognormal-n	-9.21	0.7	0.001	0.999	-0.09	9.99E-05		9.99E-05[6]
Meat transfer factor for Ag	2	Truncated lognormal-n	-6.21	0.7	0.001	0.999	0.06	2.00E-03		2.00E-03[6]
Meat transfer factor for I	2	Truncated lognormal-n	-3.22	0.4	0.001	0.999	0.05	3.99E-02		3.99E-02[6]
Meat transfer factor for Pu	2	Truncated lognormal-n	-9.21	0.2	0.001	0.999	0.03	1.00E-04		1.00E-04[6]
Meat transfer factor for Am	2	Truncated lognormal-n	-9.90	0.2	0.001	0.999	-0.05	5.01E-05		5.01E-05[6]
Meat transfer factor for Cm	2	Truncated lognormal-n	-10.82	1.0	0.001	0.999	-0.05	1.99E-05		1.99E-05[6]
Meat transfer factor for Ac	2	Truncated lognormal-n	-10.82	1.0	0.001	0.999	-0.12	1.99E-05		1.99E-05[6]
Meat transfer factor for Np	2	Truncated lognormal-n	-6.91	0.7	0.001	0.999	0.02	9.96E-04		9.96E-04[6]
Meat transfer factor for Pa	2	Truncated lognormal-n	-12.21	1.0	0.001	0.999	0.08	4.95E-06		4.95E-06[6]
Meat transfer factor for Th	2	Truncated lognormal-n	-9.21	1.0	0.001	0.999	0.09	9.97E-05		9.97E-05[6]
Meat transfer factor for U	2	Truncated lognormal-n	-7.13	0.7	0.001	0.999	0.06	9.98E-04		9.98E-04[6]
Milk transfer factor for C	2	Truncated lognormal-n	-4.4	0.9	0.001	0.999	-0.02	1.22E-02		1.22E-02[7]
Milk transfer factor for Zn	2	Truncated lognormal-n	-4.61	0.9	0.001	0.999	0.08	9.91E-03		9.91E-03[7]
Milk transfer factor for Tc	2	Truncated lognormal-n	-6.91	0.7	0.001	0.999	-0.02	9.95E-04		9.95E-04[7]
Milk transfer factor for Ag	2	Truncated lognormal-n	-5.12	0.7	0.001	0.999	0.04	5.95E-03		5.95E-03[7]
Milk transfer factor for I	2	Truncated lognormal-n	-4.61	0.5	0.001	0.999	0.04	9.93E-03		9.93E-03[7]
Milk transfer factor for Pu	2	Truncated lognormal-n	-13.82	0.5	0.001	0.999	-0.12	9.92E-07		9.92E-07[7]
Milk transfer factor for Am	2	Truncated lognormal-n	-13.12	0.7	0.001	0.999	0.04	1.99E-06		1.99E-06[7]
Milk transfer factor for Cm	2	Truncated lognormal-n	-13.12	0.9	0.001	0.999	-0.03	1.99E-06		1.99E-06[7]
Milk transfer factor for Ac	2	Truncated lognormal-n	-13.12	0.9	0.001	0.999	0.05	1.99E-06		1.99E-06[7]

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]				PRCC[3]	50% Quartile	25% or 75% Quartile	Assigned Parameter Value
			1	2	3	4				
Milk transfer factor for Np	2	Truncated lognormal-n	-11.51	0.7	0.001	0.999	0.08	1.00E-05		1.00E-05[7]
Milk transfer factor for Pa	2	Truncated lognormal-n	-12.21	0.9	0.001	0.999	0.13	4.95E-06		4.95E-06[7]
Milk transfer factor for Th	2	Truncated lognormal-n	-12.21	0.9	0.001	0.999	-0.05	4.96E-06		4.96E-06[7]
Milk transfer factor for U	2	Truncated lognormal-n	-7.82	0.6	0.001	0.999	0.00	4.00E-04		4.00E-04[7]
C bioaccumulation factor for fish	2	Lognormal-n	12	1.1			0.09	1.62E+04		1.62E+04[8]
Zn bioaccumulation factor for fish	2	Lognormal-n	6.9	1.1			-0.10	9.88E+02		9.88E+02[8]
Tc bioaccumulation factor for fish	2	Lognormal-n	3.0	1.1			0.03	2.01E+01		2.01E+01[8]
Ag bioaccumulation factor for fish	2	Lognormal-n	1.6	1.1			0.04	4.95E+00		4.95E+00[8]
I bioaccumulation factor for fish	2	Lognormal-n	3.7	1.1			0.88		8.45E+01	8.45E+01[8]
Pu bioaccumulation factor for fish	2	Lognormal-n	3.4	1.1			0.06	2.98E+01		2.98E+01[8]
Am bioaccumulation factor for fish	2	Lognormal-n	3.4	1.1			0.03	2.97E+01		2.97E+01[8]
Cm bioaccumulation factor for fish	2	Lognormal-n	3.4	1.1			-0.21	2.98E+01		2.98E+01[8]
Ac bioaccumulation factor for fish	2	Lognormal-n	2.7	1.1			-0.01	1.48E+01		1.48E+01[8]
Np bioaccumulation factor for fish	2	Lognormal-n	3.4	1.1			0.05	2.98E+01		2.98E+01[8]
Pa bioaccumulation factor for fish	2	Lognormal-n	2.3	1.1			-0.08	9.93E+00		9.93E+00[8]
Th bioaccumulation factor for fish	2	Lognormal-n	4.6	1.1			0.10	9.94E+01		9.94E+01[8]
U bioaccumulation factor for fish	2	Lognormal-n	2.3	1.1			0.09	9.94E+00		9.94E+00[8]

Notes:

[1]1 = high priority parameter, 2 = medium priority parameter

[2]Distribution's Statistical Parameter
Lognormal-n: 1 = mean, 2 = standard deviation
Truncated lognormal-n: 1 = underlying mean value, 2 = underlying standard deviation, 3 = lower quantile, 4 = upper quantile

[3]PRCC = Partial ranked correlation coefficient

[4]cm^3/g

[5]Unit less

[6](pCi/kg)/(pCi/d)

[7](pCi/L)/(pCi/d)

[8](pCi/kg)/(pCi/L)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 1
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary ... 2
Site-Specific Parameter Summary 9
Summary of Pathway Selections 23
Contaminated Zone and Total Dose Summary 24
Total Dose Components
Time = 0.000E+00 25
Time = 4.000E+00 27
Time = 3.000E+01 29
Time = 3.000E+02 31
Time = 1.000E+03 33
Dose/Source Ratios Summed Over All Pathways 35
Single Radionuclide Soil Guidelines 37
Dose Per Nuclide Summed Over All Pathways 39
Soil Concentration Per Nuclide 42

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Dose Conversion Factor (and Related) Parameter Summary

Menu	Parameter	Current Value	Default	Name
	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D			
B-1	Ag-110m+D	6.72E+00	6.72E+00	DCF2(1)
B-1	Am-241	8.03E-05	8.03E-05	DCF2(2)
B-1	Am-243+D	4.44E-01	4.44E-01	DCF2(3)
B-1	C-14	4.40E-01	4.40E-01	DCF2(4)
B-1	Cm-243	2.09E-06	2.09E-06	DCF2(5)
B-1	Cm-244	3.07E-01	3.07E-01	DCF2(6)
B-1	Co-60	2.48E-01	2.48E-01	DCF2(8)
B-1	Cs-134	2.19E-04	2.19E-04	DCF2(9)
B-1	Cs-137+D	4.63E-05	4.63E-05	DCF2(10)
B-1	Fe-55	3.19E-05	3.19E-05	DCF2(11)
B-1	H-3	2.69E-06	2.69E-06	DCF2(12)
B-1	I-129	6.40E-08	6.40E-08	DCF2(13)
B-1	Mn-54	1.74E-04	1.74E-04	DCF2(14)
B-1	Ni-59	6.70E-06	6.70E-06	DCF2(15)
B-1	Ni-63	2.70E-06	2.70E-06	DCF2(16)
B-1	Np-237+D	6.29E-06	6.29E-06	DCF2(17)
B-1	Pa-231	5.40E-01	5.40E-01	DCF2(18)
B-1	Pb-210+D	1.28E+00	1.28E+00	DCF2(19)
B-1	Pu-238	2.32E-02	2.32E-02	DCF2(20)
B-1	Pu-239	3.92E-01	3.92E-01	DCF2(21)
B-1	Pu-240	4.29E-01	4.29E-01	DCF2(22)
B-1	Pu-241+D	4.29E-01	4.29E-01	DCF2(23)
B-1	Ra-226+D	8.25E-03	8.25E-03	DCF2(24)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 2 (Continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Dose Conversion Factor (and Related) Parameter Summary

Menu	Parameter	Current Value	Default	Parameter Name
	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.08E-03	5.08E-03	DCF2(27)
B-1	Sr-90+D	1.31E-03	1.31E-03	DCF2(28)
B-1	Tc-99	8.33E-06	8.33E-06	DCF2(29)
B-1	Th-228+D	3.45E-01	3.45E-01	DCF2(30)
B-1	Th-229+D	2.16E+00	2.16E+00	DCF2(31)
B-1	Th-230	3.26E-01	3.26E-01	DCF2(32)
B-1	Th-232	1.64E+00	1.64E+00	DCF2(33)
B-1	U-233	1.35E-01	1.35E-01	DCF2(34)
B-1	U-234	1.32E-01	1.32E-01	DCF2(35)
B-1	U-235+D	1.23E-01	1.23E-01	DCF2(36)
B-1	U-236	1.25E-01	1.25E-01	DCF2(37)
B-1	Zn-65	2.04E-05	2.04E-05	DCF2(38)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.48E-02	1.48E-02	DCF3(1)
D-1	Ag-110m+D	1.08E-05	1.08E-05	DCF3(2)
D-1	Am-241	3.64E-03	3.64E-03	DCF3(3)
D-1	Am-243+D	3.63E-03	3.63E-03	DCF3(4)
D-1	C-14	2.09E-06	2.09E-06	DCF3(5)
D-1	Cm-243	2.51E-03	2.51E-03	DCF3(6)
D-1	Cm-244	2.02E-03	2.02E-03	DCF3(8)
D-1	Co-60	2.69E-05	2.69E-05	DCF3(9)
D-1	Cs-134	7.33E-05	7.33E-05	DCF3(10)
D-1	Cs-137+D	5.00E-05	5.00E-05	DCF3(11)
D-1	Fe-55	6.07E-07	6.07E-07	DCF3(12)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 3
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD File: BRP Dose Modeling

Dose Conversion Factor (and Related) Parameter Summary

Menu	Parameter	Current Value	Default	Name
D-1	H-3	6.40E-08	6.40E-08	DCF3(13)
D-1	I-129	2.76E-04	2.76E-04	DCF3(14)
D-1	Mn-54	2.77E-06	2.77E-06	DCF3(15)
D-1	Ni-59	2.10E-07	2.10E-07	DCF3(16)
D-1	Ni-63	5.77E-07	5.77E-07	DCF3(17)
D-1	Np-237+D	4.44E-03	4.44E-03	DCF3(18)
D-1	Pa-231	1.06E-02	1.06E-02	DCF3(19)
D-1	Pb-210+D	7.27E-03	7.27E-03	DCF3(20)
D-1	Pu-238	3.20E-03	3.20E-03	DCF3(21)
D-1	Pu-239	3.54E-03	3.54E-03	DCF3(22)
D-1	Pu-240	3.54E-03	3.54E-03	DCF3(23)
D-1	Pu-241+D	6.85E-05	6.85E-05	DCF3(24)
D-1	Ra-226+D	1.33E-03	1.33E-03	DCF3(26)
D-1	Ra-228+D	1.44E-03	1.44E-03	DCF3(27)
D-1	Sr-90+D	1.53E-04	1.53E-04	DCF3(28)
D-1	Tc-99	1.46E-06	1.46E-06	DCF3(29)
D-1	Th-228+D	8.08E-04	8.08E-04	DCF3(30)
D-1	Th-229+D	4.03E-03	4.03E-03	DCF3(31)
D-1	Th-230	5.48E-04	5.48E-04	DCF3(32)
D-1	Th-232	2.73E-03	2.73E-03	DCF3(33)
D-1	U-233	2.89E-04	2.89E-04	DCF3(34)
D-1	U-234	2.83E-04	2.83E-04	DCF3(35)
D-1	U-235+D	2.67E-04	2.67E-04	DCF3(36)
D-1	U-236	2.69E-04	2.69E-04	DCF3(37)
D-1	Zn-65	1.44E-05	1.44E-05	DCF3(38)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 3 (continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Menu	Parameter	Current Value	Default	Name
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	9.94E-04	2.50E-03	RTF(1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.99E-05	2.00E-05	RTF(1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.99E-06	2.00E-05	RTF(1,3)
D-34				
D-34	Ag-110m+D, plant/soil concentration ratio, dimensionless	4.00E-03	1.50E-01	RTF(2,1)
D-34	Ag-110m+D, beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.00E-03	3.00E-03	RTF(2,2)
D-34	Ag-110m+D, milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.95E-03	2.50E-02	RTF(2,3)
D-34				
D-34	Am-241 , plant/soil concentration ratio, dimensionless	1.82E-03	1.00E-03	RTF(3,1)
D-34	Am-241 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.01E-05	5.00E-05	RTF(3,2)
D-34	Am-241 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.99E-06	2.00E-06	RTF(3,3)
D-34				
D-34	Am-243+D , plant/soil concentration ratio, dimensionless	1.82E-03	1.00E-03	RTF(4,1)
D-34	Am-243+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.01E-05	5.00E-05	RTF(4,2)
D-34	Am-243+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.99E-06	2.00E-06	RTF(4,3)
D-34				
D-34	C-14 , plant/soil concentration ratio, dimensionless	1.59E-01	5.50E+00	RTF(5,1)
D-34	C-14 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.09E-02	3.10E-02	RTF(5,2)
D-34	C-14 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.22E-02	1.20E-02	RTF(5,3)
D-34				
D-34	Cm-243 , plant/soil concentration ratio, dimensionless	9.91E-04	1.00E-03	RTF(6,1)
D-34	Cm-243 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.99E-05	2.00E-05	RTF(6,2)
D-34	Cm-243 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.99E-06	2.00E-06	RTF(6,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 4
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD File: BRP Dose Modeling

Dose Conversion Factor (and Related) Parameter Summary (continued)

Menu	Parameter	Current Value	Default	Name
D-34	Cm-244 , plant/soil concentration ratio, dimensionless	9.91E-04	1.00E-03	RTF(8,1)
D-34	Cm-244 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.99E-05	2.00E-05	RTF(8,2)
D-34	Cm-244 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.99E-06	2.00E-06	RTF(8,3)
D-34				
D-34	Co-60 , plant/soil concentration ratio, dimensionless	7.90E-02	8.00E-02	RTF(9,1)
D-34	Co-60 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.00E-02	2.00E-02	RTF(9,2)
D-34	Co-60 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.00E-03	2.00E-03	RTF(9,3)
D-34				
D-34	Cs-134 , plant/soil concentration ratio, dimensionless	4.00E-02	4.00E-02	RTF(10,1)
D-34	Cs-134 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.00E-02	3.00E-02	RTF(10,2)
D-34	Cs-134 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	8.00E-03	RTF(10,3)
D-34				
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.00E-02	4.00E-02	RTF(11,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.00E-02	3.00E-02	RTF(11,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	8.00E-03	RTF(11,3)
D-34				
D-34	Fe-55 , plant/soil concentration ratio, dimensionless	1.00E-03	1.00E-03	RTF(12,1)
D-34	Fe-55 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.00E-02	2.00E-02	RTF(12,2)
D-34	Fe-55 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	0.00E+00	3.00E-04	RTF(12,3)
D-34				
D-34	H-3 , plant/soil concentration ratio, dimensionless	4.80E+00	4.80E+00	RTF(13,1)
D-34	H-3 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.20E-02	1.20E-02	RTF(13,2)
D-34	H-3 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	1.00E-02	RTF(13,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 4 (continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Menu	Parameter	Current Value	Default	Name
D-34	I-129 , plant/soil concentration ratio, dimensionless	3.67E-02	2.00E-02	RTF(14,1)
D-34	I-129 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.99E-02	7.00E-03	RTF(14,2)
D-34	I-129 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.93E-03	1.00E-02	RTF(14,3)
D-34	Mn-54 , plant/soil concentration ratio, dimensionless	2.99E-01	3.00E-01	RTF(15,1)
D-34	Mn-54 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-03	5.00E-04	RTF(15,2)
D-34	Mn-54 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	3.00E-04	RTF(15,3)
D-34				
D-34	Ni-59 , plant/soil concentration ratio, dimensionless	5.00E-02	5.00E-02	RTF(16,1)
D-34	Ni-59 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.00E-03	5.00E-03	RTF(16,2)
D-34	Ni-59 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.00E-02	2.00E-02	RTF(16,3)
D-34				
D-34	Ni-63 , plant/soil concentration ratio, dimensionless	5.00E-02	5.00E-02	RTF(17,1)
D-34	Ni-63 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.00E-03	5.00E-03	RTF(17,2)
D-34	Ni-63 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.00E-02	2.00E-02	RTF(17,3)
D-34				
D-34	Np-237+D , plant/soil concentration ratio, dimensionless	2.00E-02	2.00E-02	RTF(18,1)
D-34	Np-237+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.96E-04	1.00E-03	RTF(18,2)
D-34	Np-237+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-06	5.00E-06	RTF(18,3)
D-34				
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	9.95E-03	1.00E-02	RTF(19,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	4.95E-06	5.00E-03	RTF(19,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.95E-06	5.00E-06	RTF(19,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 5
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD File: BRP Dose Modeling

Dose Conversion Factor (and Related) Parameter Summary (continued)

Menu	Parameter	Current Value	Default	Name
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.00E-02	1.00E-02	RTF(20,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.00E-04	8.00E-04	RTF(20,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.00E-04	3.00E-04	RTF(20,3)
D-34				
D-34	Pu-238 , plant/soil concentration ratio, dimensionless	1.82E-03	1.00E-03	RTF(21,1)
D-34	Pu-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-04	1.00E-04	RTF(21,2)
D-34	Pu-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.92E-07	1.00E-06	RTF(21,3)
D-34				
D-34	Pu-239 , plant/soil concentration ratio, dimensionless	1.82E-03	1.00E-03	RTF(22,1)
D-34	Pu-239 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-04	1.00E-04	RTF(22,2)
D-34	Pu-239 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.92E-07	1.00E-06	RTF(22,3)
D-34				
D-34	Pu-240 , plant/soil concentration ratio, dimensionless	1.82E-03	1.00E-03	RTF(23,1)
D-34	Pu-240 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-04	1.00E-04	RTF(23,2)
D-34	Pu-240 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.92E-07	1.00E-06	RTF(23,3)
D-34				
D-34	Pu-241+D , plant/soil concentration ratio, dimensionless	1.82E-03	1.00E-03	RTF(24,1)
D-34	Pu-241+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-04	1.00E-04	RTF(24,2)
D-34	Pu-241+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.92E-07	1.00E-06	RTF(24,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.00E-02	4.00E-02	RTF(26,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-03	1.00E-03	RTF(26,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-03	1.00E-03	RTF(26,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 5 (continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Menu	Parameter	Current Value	Default	Name
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.00E-02	4.00E-02	RTF(27,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-03	1.00E-03	RTF(27,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-03	1.00E-03	RTF(27,3)
D-34				
D-34	Sr-90+D , plant/soil concentration ratio, dimensionless	5.89E-01	3.00E-01	RTF(28,1)
D-34	Sr-90+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-02	8.00E-03	RTF(28,2)
D-34	Sr-90+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.00E-03	2.00E-03	RTF(28,3)
D-34				
D-34	Tc-99 , plant/soil concentration ratio, dimensionless	4.97E+00	5.00E+00	RTF(29,1)
D-34	Tc-99 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.99E-05	1.00E-04	RTF(29,2)
D-34	Tc-99 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.95E-04	1.00E-03	RTF(29,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	9.93E-04	1.00E-03	RTF(30,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.97E-05	1.00E-04	RTF(30,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.96E-06	5.00E-06	RTF(30,3)
D-34				
D-34	Th-229+D , plant/soil concentration ratio, dimensionless	9.93E-04	1.00E-03	RTF(31,1)
D-34	Th-229+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.97E-05	1.00E-04	RTF(31,2)
D-34	Th-229+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.96E-06	5.00E-06	RTF(31,3)
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	9.93E-04	1.00E-03	RTF(32,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.97E-05	1.00E-04	RTF(32,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.96E-06	5.00E-06	RTF(32,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 6
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Dose Conversion Factor (and Related) Parameter S ummary (continued)
File: BRP Dose Modeling

Menu	Parameter	Current Value	Default	Name
D-34	Th-232 , plant/soil concentration ratio, dimensionless	9.93E-04	1.00E-03	RTF(33,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.97E-05	1.00E-04	RTF(33,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.96E-06	5.00E-06	RTF(33,3)
D-34				
D-34	U-233 , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(34,1)
D-34	U-233 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.98E-04	3.40E-04	RTF(34,2)
D-34	U-233 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.00E-04	6.00E-04	RTF(34,3)
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(35,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.98E-04	3.40E-04	RTF(35,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.00E-04	6.00E-04	RTF(35,3)
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(36,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.98E-04	3.40E-04	RTF(36,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.00E-04	6.00E-04	RTF(36,3)
D-34				
D-34	U-236 , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(37,1)
D-34	U-236 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	9.98E-04	3.40E-04	RTF(37,2)
D-34	U-236 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	4.00E-04	6.00E-04	RTF(37,3)
D-34				
D-34	Zn-65 , plant/soil concentration ratio, dimensionless	3.97E-01	4.00E-01	RTF(38,1)
D-34	Zn-65 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-01	1.00E-01	RTF(38,2)
D-34	Zn-65 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	9.91E-03	1.00E-02	RTF(38,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 6 (continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Menu	Parameter	Current Value	Default	Name
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.48E+01	1.50E+01	BIOFAC(1,1)
D-5	Ac-227+D , crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(1,2)
D-5				
D-5	Ag-110m+D, fish	4.95E+00	5.00E+00	BIOFAC(2,1)
D-5	Ag-110m+D, crustacea and mollusks	7.70E+02	7.70E+02	BIOFAC(2,2)
D-5				
D-5	Am-241 , fish	2.97E+01	3.00E+01	BIOFAC(3,1)
D-5	Am-241 , crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(3,2)
D-5				
D-5	Am-243+D , fish	2.97E+01	3.00E+01	BIOFAC(4,1)
D-5	Am-243+D , crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(4,2)
D-5				
D-5	C-14 , fish	1.62E+04	5.00E+04	BIOFAC(5,1)
D-5	C-14 , crustacea and mollusks	9.10E+03	9.10E+03	BIOFAC(5,2)
D-5				
D-5	Cm-243 , fish	2.98E+01	3.00E+01	BIOFAC(6,1)
D-5	Cm-243 , crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(6,2)
D-5				
D-5	Cm-244 , fish	2.98E+01	3.00E+01	BIOFAC(8,1)
D-5	Cm-244 , crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(8,2)
D-5				
D-5	Co-60 , fish	2.97E+02	3.00E+02	BIOFAC(9,1)
D-5	Co-60 , crustacea and mollusks	2.00E+02	2.00E+02	BIOFAC(9,2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 7
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD File: BRP Dose Modeling

Dose Conversion Factor (and Related) Parameter Summary (continued)

Menu	Parameter	Current Value	Default	Name
D-5	Cs-134 , fish	1.99E+03	2.00E+03	BIOFAC(10,1)
D-5	Cs-134 , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(10,2)
D-5				
D-5	Cs-137+D , fish	1.99E+03	2.00E+03	BIOFAC(11,1)
D-5	Cs-137+D , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(11,2)
D-5				
D-5	Fe-55 , fish	1.99E+02	2.00E+02	BIOFAC(12,1)
D-5	Fe-55 , crustacea and mollusks	3.20E+03	3.20E+03	BIOFAC(12,2)
D-5				
D-5	H-3 , fish	1.00E+00	1.00E+00	BIOFAC(13,1)
D-5	H-3 , crustacea and mollusks	1.00E+00	1.00E+00	BIOFAC(13,2)
D-5				
D-5	I-129 , fish	8.45E+01	4.00E+01	BIOFAC(14,1)
D-5	I-129 , crustacea and mollusks	5.00E+00	5.00E+00	BIOFAC(14,2)
D-5				
D-5	Mn-54 , fish	4.00E+02	4.00E+02	BIOFAC(15,1)
D-5	Mn-54 , crustacea and mollusks	9.00E+04	9.00E+04	BIOFAC(15,2)
D-5				
D-5	Ni-59 , fish	9.90E+01	1.00E+02	BIOFAC(16,1)
D-5	Ni-59 , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(16,2)
D-5				
D-5	Ni-63 , fish	9.90E+01	1.00E+02	BIOFAC(17,1)
D-5	Ni-63 , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(17,2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 7 (continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)

Menu	Parameter	Current Value	Default	
D-5	Np-237+D , fish	2.98E+01	3.00E+01	BIOFAC(18,1)
D-5	Np-237+D , crustacea and mollusks	4.00E+02	4.00E+02	BIOFAC(18,2)
D-5				
D-5	Pa-231 , fish	9.93E+00	1.00E+01	BIOFAC(19,1)
D-5	Pa-231 , crustacea and mollusks	1.10E+02	1.10E+02	BIOFAC(19,2)
D-5				
D-5	Pb-210+D , fish	3.00E+02	3.00E+02	BIOFAC(20,1)
D-5	Pb-210+D , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(20,2)
D-5				
D-5	Pu-238 , fish D-5	2.98E+01	3.00E+01	BIOFAC(21,1)
D-5	Pu-238 , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(21,2)
D-5				
D-5	Pu-239 , fish	2.98E+01	3.00E+01	BIOFAC(22,1)
D-5	Pu-239 , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(22,2)
D-5				
D-5	Pu-240 , fish	2.98E+01	3.00E+01	BIOFAC(23,1)
D-5	Pu-240 , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(23,2)
D-5				
D-5	Pu-241+D , fish	2.98E+01	3.00E+01	BIOFAC(24,1)
D-5	Pu-241+D , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(24,2)
D-5				
D-5	Ra-226+D , fish	5.00E+01	5.00E+01	BIOFAC(26,1)
D-5	Ra-226+D , crustacea and mollusks	2.50E+02	2.50E+02	BIOFAC(26,2)
D-5				
D-5	Ra-228+D , fish	5.00E+01	5.00E+01	BIOFAC(27,1)
	Ra-228+D , crustacea and mollusks	2.50E+02	2.50E+02	BIOFAC(27,2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 8
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD File: BRP Dose Modeling

Dose Conversion Factor (and Related) Parameter Summary (continued)

Menu	Parameter	Current Value	Default	Name
D-5	Sr-90+D , fish	6.00E+01	6.00E+01	BIOFAC(28,1)
D-5	Sr-90+D , crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(28,2)
D-5				
D-5	Tc-99 , fish	2.01E+01	2.00E+01	BIOFAC(29,1)
D-5	Tc-99 , crustacea and mollusks	5.00E+00	5.00E+00	BIOFAC(29,2)
D-5				
D-5	Th-228+D , fish	9.94E+01	1.00E+02	BIOFAC(30,1)
D-5	Th-228+D , crustacea and mollusks	5.00E+02	5.00E+02	BIOFAC(30,2)
D-5				
D-5	Th-229+D , fish	9.94E+01	1.00E+02	BIOFAC(31,1)
D-5	Th-229+D , crustacea and mollusks	5.00E+02	5.00E+02	BIOFAC(31,2)
D-5				
D-5	Th-230 , fish	9.94E+01	1.00E+02	BIOFAC(32,1)
D-5	Th-230 , crustacea and mollusks	5.00E+02	5.00E+02	BIOFAC(32,2)
D-5				
D-5	Th-232 , fish	9.94E+01	1.00E+02	BIOFAC(33,1)
D-5	Th-232 , crustacea and mollusks	5.00E+02	5.00E+02	BIOFAC(33,2)
D-5				
D-5	U-233 , fish	9.94E+00	1.00E+01	BIOFAC(34,1)
D-5	U-233 , crustacea and mollusks	6.00E+01	6.00E+01	BIOFAC(34,2)
D-5				
D-5	U-234 , fish	9.94E+00	1.00E+01	BIOFAC(35,1)
D-5	U-234 , crustacea and mollusks	6.00E+01	6.00E+01	BIOFAC(35,2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 8 (continued)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Menu	Parameter	Current Value	Default	Name
D-5	U-235+D , fish	9.94E+00	1.00E+01	BIOFAC(36,1)
D-5	U-235+D , crustacea and mollusks	6.00E+01	6.00E+01	BIOFAC(36,2)
D-5	U-236 , fish	9.94E+00	1.00E+01	BIOFAC(37,1)
D-5	U-236 , crustacea and mollusks	6.00E+01	6.00E+01	BIOFAC(37,2)
D-5				
D-5	Zn-65 , fish	9.88E+02	1.00E+03	BIOFAC(38,1)
D-5	Zn-65 , crustacea and mollusks	1.00E+04	1.00E+04	BIOFAC(38,2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 9
File : DiscDose-All.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.50E+02	1.00E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.00E-01	2.00E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.38E+01	1.00E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.42E+01	2.50E+01	---	BRDL
R011	Time since placement of material (yr)	0.00E+00	0.00E+00	---	TI
R011	Times for calculations (yr)	4.00E+00	1.00E+00	---	T(2)
R011	Times for calculations (yr)	3.00E+01	3.00E+00	---	T(3)
R011	Times for calculations (yr)	3.00E+02	1.00E+01	---	T(4)
R011	Times for calculations (yr)	1.00E+03	3.00E+01	---	T(5)
R011	Times for calculations (yr)	not used	1.00E+02	---	T(6)
R011	Times for calculations (yr)	not used	3.00E+02	---	T(7)
R011	Times for calculations (yr)	not used	1.00E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ag-110m	3.00E-02	0.00E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Am-241	6.65E-02	0.00E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): C-14	4.70E-01	0.00E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Cm-243	6.01E-02	0.00E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Cm-244	6.01E-02	0.00E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): Co-60	5.72E-01	0.00E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): Cs-134	2.22E-02	0.00E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): Cs-137	6.68E-01	0.00E+00	---	S1(11)
R012	Initial principal radionuclide (pCi/g): Fe-55	1.76E+00	0.00E+00	---	S1(12)
R012	Initial principal radionuclide (pCi/g): H-3	4.90E-02	0.00E+00	---	S1(13)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 9 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R012	Initial principal radionuclide (pCi/g): I-129	2.60E-01	0.00E+00	---	S1(14)
R012	Initial principal radionuclide (pCi/g): Mn-54	3.70E-02	0.00E+00	---	S1(15)
R012	Initial principal radionuclide (pCi/g): Ni-59	2.35E+00	0.00E+00	---	S1(16)
R012	Initial principal radionuclide (pCi/g): Ni-63	4.00E-01	0.00E+00	---	S1(17)
R012	Initial principal radionuclide (pCi/g): Pu-238	4.50E-02	0.00E+00	---	S1(21)
R012	Initial principal radionuclide (pCi/g): Pu-239	4.00E-02	0.00E+00	---	S1(22)
R012	Initial principal radionuclide (pCi/g): Pu-240	4.00E-02	0.00E+00	---	S1(23)
R012	Initial principal radionuclide (pCi/g): Pu-241	7.25E+00	0.00E+00	---	S1(24)
R012	Initial principal radionuclide (pCi/g): Sr-90	1.30E-02	0.00E+00	---	S1(28)
R012	Initial principal radionuclide (pCi/g): Tc-99	3.10E-01	0.00E+00	---	S1(29)
R012	Initial principal radionuclide (pCi/g): Zn-65	6.87E-02	0.00E+00	---	S1(38)
R012	Concentration in groundwater (pCi/L): Ag-110m	not used	0.00E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Am-241	not used	0.00E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): C-14	not used	0.00E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Cm-243	not used	0.00E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Cm-244	not used	0.00E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): Co-60	not used	0.00E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): Cs-134	not used	0.00E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.00E+00	---	W1(11)
R012	Concentration in groundwater (pCi/L): Fe-55	not used	0.00E+00	---	W1(12)
R012	Concentration in groundwater (pCi/L): H-3	not used	0.00E+00	---	W1(13)
R012	Concentration in groundwater (pCi/L): I-129	not used	0.00E+00	---	W1(14)
R012	Concentration in groundwater (pCi/L): Mn-54	not used	0.00E+00	---	W1(15)
R012	Concentration in groundwater (pCi/L): Ni-59	not used	0.00E+00	---	W1(16)
R012	Concentration in groundwater (pCi/L): Ni-63	not used	0.00E+00	---	W1(17)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 10
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R012	Concentration in groundwater (pCi/L): Pu-238	not used	0.00E+00	---	W1(21)
R012	Concentration in groundwater (pCi/L): Pu-239	not used	0.00E+00	---	W1(22)
R012	Concentration in groundwater (pCi/L): Pu-240	not used	0.00E+00	---	W1(23)
R012	Concentration in groundwater (pCi/L): Pu-241	not used	0.00E+00	---	W1(24)
R012	Concentration in groundwater (pCi/L): Sr-90	not used	0.00E+00	---	W1(28)
R012	Concentration in groundwater (pCi/L): Tc-99	not used	0.00E+00	---	W1(29)
R012	Concentration in groundwater (pCi/L): Zn-65	not used	0.00E+00	---	W1(38)
R013	Cover depth (m)	0.00E+00	0.00E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.50E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.00E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.75E+00	1.50E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.00E-03	1.00E-03	---	VCZ
R013	Contaminated zone total porosity	3.51E-01	4.00E-01	---	TPCZ
R013	Contaminated zone field capacity	2.63E-01	2.00E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.36E+02	1.00E+01	---	HCCZ
R013	Contaminated zone b parameter	4.05E+00	5.30E+00	---	BCZ
R013	Average annual wind speed (m/sec)	5.00E+00	2.00E+00	---	WIND
R013	Humidity in air (g/m**3)	8.00E+00	8.00E+00	---	HUMID
R013	Evapotranspiration coefficient	6.24E-01	5.00E-01	---	EVAPTR
R013	Precipitation (m/yr)	8.00E-01	1.00E+00	---	PRECIP

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 10 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R013	Irrigation (m/yr)	2.00E-01	2.00E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	4.49E-01	2.00E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	2.31E+06	1.00E+06	---	WAREA
R013	Accuracy for water/soil computations	1.00E-03	1.00E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.52E+00	1.50E+00	---	DENSAQ
R014	Saturated zone total porosity	4.24E-01	4.00E-01	---	TPSZ
R014	Saturated zone effective porosity	3.55E-01	2.00E-01	---	EPSZ
R014	Saturated zone field capacity	1.60E-01	2.00E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	1.52E+03	1.00E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	7.00E-04	2.00E-02	---	HGWT
R014	Saturated zone b parameter	2.88E+00	5.30E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.00E-03	1.00E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.45E+01	1.00E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	MB	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	3.30E+02	2.50E+02	---	UW
R015	Number of unsaturated zone strata	5	1	---	NS
R015	Unsat. zone 1, thickness (m)	1.22E+00	4.00E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.75E+00	1.50E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.51E-01	4.00E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	8.80E-02	2.00E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.63E-01	2.00E-01	---	FCUZ(1)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 11
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, soil-specific b parameter	4.05E+00	5.30E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	5.36E+02	1.00E+01	---	HCUZ(1)
R015	Unsat. zone 2, thickness (m)	1.37E+00	0.00E+00	---	H(2)
R015	Unsat. zone 2, soil density (g/cm**3)	1.95E+00	1.50E+00	---	DENSUZ(2)
R015	Unsat. zone 2, total porosity	2.74E-01	4.00E-01	---	TPUZ(2)
R015	Unsat. zone 2, effective porosity	2.60E-02	2.00E-01	---	EPUZ(2)
R015	Unsat. zone 2, field capacity	2.48E-01	2.00E-01	---	FCUZ(2)
R015	Unsat. zone 2, soil-specific b parameter	4.38E+00	5.30E+00	---	BUZ(2)
R015	Unsat. zone 2, hydraulic conductivity (m/yr)	5.54E+02	1.00E+01	---	HCUZ(2)
R015	Unsat. zone 3, thickness (m)	4.11E+00	0.00E+00	---	H(3)
R015	Unsat. zone 3, soil density (g/cm**3)	1.92E+00	1.50E+00	---	DENSUZ(3)
R015	Unsat. zone 3, total porosity	2.87E-01	4.00E-01	---	TPUZ(3)
R015	Unsat. zone 3, effective porosity	3.70E-02	2.00E-01	---	EPUZ(3)
R015	Unsat. zone 3, field capacity	2.50E-01	2.00E-01	---	FCUZ(3)
R015	Unsat. zone 3, soil-specific b parameter	4.90E+00	5.30E+00	---	BUZ(3)
R015	Unsat. zone 3, hydraulic conductivity (m/yr)	5.17E+00	1.00E+01	---	HCUZ(3)
R015	Unsat. zone 4, thickness (m)	6.10E-01	0.00E+00	---	H(4)
R015	Unsat. zone 4, soil density (g/cm**3)	1.83E+00	1.50E+00	---	DENSUZ(4)
R015	Unsat. zone 4, total porosity	3.17E-01	4.00E-01	---	TPUZ(4)
R015	Unsat. zone 4, effective porosity	2.90E-02	2.00E-01	---	EPUZ(4)
R015	Unsat. zone 4, field capacity	2.87E-01	2.00E-01	---	FCUZ(4)
R015	Unsat. zone 4, soil-specific b parameter	4.05E+00	5.30E+00	---	BUZ(4)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 11 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 4, hydraulic conductivity (m/yr)	1.05E+03	1.00E+01	---	HCUZ(4)
R015	Unsat. zone 5, thickness (m)	7.32E+00	0.00E+00	---	H(5)
R015	Unsat. zone 5, soil density (g/cm**3)	1.85E+00	1.50E+00	---	DENSUZ(5)
R015	Unsat. zone 5, total porosity	3.13E-01	4.00E-01	---	TPUZ(5)
R015	Unsat. zone 5, effective porosity	5.40E-02	2.00E-01	---	EPUZ(5)
R015	Unsat. zone 5, field capacity	2.58E-01	2.00E-01	---	FCUZ(5)
R015	Unsat. zone 5, soil-specific b parameter	4.90E+00	5.30E+00	---	BUZ(5)
R015	Unsat. zone 5, hydraulic conductivity (m/yr)	1.56E+01	1.00E+01	---	HCUZ(5)
R016	Distribution coefficients for Ag-110m				
R016	Contaminated zone (cm**3/g)	8.88E+02	0.00E+00	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	2.15E+02	0.00E+00	---	DCNUCU(2,1)
R016	Unsaturated zone 2 (cm**3/g)	2.14E+02	0.00E+00	---	DCNUCU(2,2)
R016	Unsaturated zone 3 (cm**3/g)	2.16E+02	0.00E+00	---	DCNUCU(2,3)
R016	Unsaturated zone 4 (cm**3/g)	2.14E+02	0.00E+00	---	DCNUCU(2,4)
R016	Unsaturated zone 5 (cm**3/g)	2.13E+02	0.00E+00	---	DCNUCU(2,5)
R016	Saturated zone (cm**3/g)	2.15E+02	0.00E+00	---	DCNUCS(2)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	5.17E-04	ALEACH(2)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 12
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Am-241				
R016	Contaminated zone (cm**3/g)	1.17E+04	2.00E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	1.44E+03	2.00E+01	---	DCNUCU(3,1)
R016	Unsaturated zone 2 (cm**3/g)	1.42E+03	2.00E+01	---	DCNUCU(3,2)
R016	Unsaturated zone 3 (cm**3/g)	1.43E+03	2.00E+01	---	DCNUCU(3,3)
R016	Unsaturated zone 4 (cm**3/g)	1.43E+03	2.00E+01	---	DCNUCU(3,4)
R016	Unsaturated zone 5 (cm**3/g)	1.41E+03	2.00E+01	---	DCNUCU(3,5)
R016	Saturated zone (cm**3/g)	1.43E+03	2.00E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.92E-05	ALEACH(3)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(3)
R016	Distribution coefficients for C-14				
R016	Contaminated zone (cm**3/g)	9.57E+01	0.00E+00	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	1.25E+00	0.00E+00	---	DCNUCU(5,1)
R016	Unsaturated zone 2 (cm**3/g)	1.08E+01	0.00E+00	---	DCNUCU(5,2)
R016	Unsaturated zone 3 (cm**3/g)	1.26E+00	0.00E+00	---	DCNUCU(5,3)
R016	Unsaturated zone 4 (cm**3/g)	1.08E+01	0.00E+00	---	DCNUCU(5,4)
R016	Unsaturated zone 5 (cm**3/g)	1.25E+00	0.00E+00	---	DCNUCU(5,5)
R016	Saturated zone (cm**3/g)	1.08E+01	0.00E+00	---	DCNUCS(5)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.79E-03	ALEACH(5)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(5)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 Page 12 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Cm-243				
R016	Contaminated zone (cm**3/g)	2.30E+04	-1.00E+00	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	6.71E+03	-1.00E+00	---	DCNUCU(6,1)
R016	Unsaturated zone 2 (cm**3/g)	6.68E+03	-1.00E+00	---	DCNUCU(6,2)
R016	Unsaturated zone 3 (cm**3/g)	6.74E+03	-1.00E+00	---	DCNUCU(6,3)
R016	Unsaturated zone 4 (cm**3/g)	6.67E+03	-1.00E+00	---	DCNUCU(6,4)
R016	Unsaturated zone 5 (cm**3/g)	6.67E+03	-1.00E+00	---	DCNUCU(6,5)
R016	Saturated zone (cm**3/g)	6.70E+03	-1.00E+00	---	DCNUCS(6)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.00E-05	ALEACH(6)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(6)
R016	Distribution coefficients for Cm-244				
R016	Contaminated zone (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCU(8,1)
R016	Unsaturated zone 2 (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCU(8,2)
R016	Unsaturated zone 3 (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCU(8,3)
R016	Unsaturated zone 4 (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCU(8,4)
R016	Unsaturated zone 5 (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCU(8,5)
R016	Saturated zone (cm**3/g)	-1.00E+00	-1.00E+00	1.39E+03	DCNUCS(8)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.31E-04	ALEACH(8)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(8)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 13
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Co-60				
R016	Contaminated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(9,1)
R016	Unsaturated zone 2 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(9,2)
R016	Unsaturated zone 3 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(9,3)
R016	Unsaturated zone 4 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(9,4)
R016	Unsaturated zone 5 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(9,5)
R016	Saturated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCS(9)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.59E-04	ALEACH(9)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(9)
R016	Distribution coefficients for Cs-134				
R016	Contaminated zone (cm**3/g)	2.13E+03	1.00E+03	---	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	4.41E+02	1.00E+03	---	DCNUCU(10,1)
R016	Unsaturated zone 2 (cm**3/g)	4.38E+02	1.00E+03	---	DCNUCU(10,2)
R016	Unsaturated zone 3 (cm**3/g)	4.44E+02	1.00E+03	---	DCNUCU(10,3)
R016	Unsaturated zone 4 (cm**3/g)	4.38E+02	1.00E+03	---	DCNUCU(10,4)
R016	Unsaturated zone 5 (cm**3/g)	4.38E+02	1.00E+03	---	DCNUCU(10,5)
R016	Saturated zone (cm**3/g)	4.40E+02	1.00E+03	---	DCNUCS(10)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.15E-04	ALEACH(10)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(10)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 13 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(11,1)
R016	Unsaturated zone 2 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(11,2)
R016	Unsaturated zone 3 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(11,3)
R016	Unsaturated zone 4 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(11,4)
R016	Unsaturated zone 5 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(11,5)
R016	Saturated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCS(11)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.59E-04	ALEACH(11)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(11)
R016	Distribution coefficients for Fe-55				
R016	Contaminated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCC(12)
R016	Unsaturated zone 1 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(12,1)
R016	Unsaturated zone 2 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(12,2)
R016	Unsaturated zone 3 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(12,3)
R016	Unsaturated zone 4 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(12,4)
R016	Unsaturated zone 5 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(12,5)
R016	Saturated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCS(12)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.59E-04	ALEACH(12)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(12)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 14
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for H-3				
R016	Contaminated zone (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCC(13)
R016	Unsaturated zone 1 (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCU(13,1)
R016	Unsaturated zone 2 (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCU(13,2)
R016	Unsaturated zone 3 (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCU(13,3)
R016	Unsaturated zone 4 (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCU(13,4)
R016	Unsaturated zone 5 (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCU(13,5)
R016	Saturated zone (cm**3/g)	0.00E+00	0.00E+00	---	DCNUCS(13)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.05E+00	ALEACH(13)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(13)
R016	Distribution coefficients for I-129				
R016	Contaminated zone (cm**3/g)	1.05E+00	1.00E-01	---	DCNUCC(14)
R016	Unsaturated zone 1 (cm**3/g)	4.53E+00	1.00E-01	---	DCNUCU(14,1)
R016	Unsaturated zone 2 (cm**3/g)	4.49E+00	1.00E-01	---	DCNUCU(14,2)
R016	Unsaturated zone 3 (cm**3/g)	4.55E+00	1.00E-01	---	DCNUCU(14,3)
R016	Unsaturated zone 4 (cm**3/g)	4.50E+00	1.00E-01	---	DCNUCU(14,4)
R016	Unsaturated zone 5 (cm**3/g)	4.49E+00	1.00E-01	---	DCNUCU(14,5)
R016	Saturated zone (cm**3/g)	4.52E+00	1.00E-01	---	DCNUCS(14)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.82E-01	ALEACH(14)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(14)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 14 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Mn-54				
R016	Contaminated zone (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCC(15)
R016	Unsaturated zone 1 (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCU(15,1)
R016	Unsaturated zone 2 (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCU(15,2)
R016	Unsaturated zone 3 (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCU(15,3)
R016	Unsaturated zone 4 (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCU(15,4)
R016	Unsaturated zone 5 (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCU(15,5)
R016	Saturated zone (cm**3/g)	2.00E+02	2.00E+02	---	DCNUCS(15)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.29E-03	ALEACH(15)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(15)
R016	Distribution coefficients for Ni-59				
R016	Contaminated zone (cm**3/g)	1.13E+03	1.00E+03	---	DCNUCC(16)
R016	Unsaturated zone 1 (cm**3/g)	4.21E+02	1.00E+03	---	DCNUCU(16,1)
R016	Unsaturated zone 2 (cm**3/g)	4.20E+02	1.00E+03	---	DCNUCU(16,2)
R016	Unsaturated zone 3 (cm**3/g)	4.23E+02	1.00E+03	---	DCNUCU(16,3)
R016	Unsaturated zone 4 (cm**3/g)	4.19E+02	1.00E+03	---	DCNUCU(16,4)
R016	Unsaturated zone 5 (cm**3/g)	4.21E+02	1.00E+03	---	DCNUCU(16,5)
R016	Saturated zone (cm**3/g)	4.19E+02	1.00E+03	---	DCNUCS(16)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.06E-04	ALEACH(16)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(16)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 15
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Ni-63				
R016	Contaminated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCC(17)
R016	Unsaturated zone 1 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(17,1)
R016	Unsaturated zone 2 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(17,2)
R016	Unsaturated zone 3 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(17,3)
R016	Unsaturated zone 4 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(17,4)
R016	Unsaturated zone 5 (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCU(17,5)
R016	Saturated zone (cm**3/g)	1.00E+03	1.00E+03	---	DCNUCS(17)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.59E-04	ALEACH(17)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(17)
R016	Distribution coefficients for Pu-238				
R016	Contaminated zone (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCC(21)
R016	Unsaturated zone 1 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(21,1)
R016	Unsaturated zone 2 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(21,2)
R016	Unsaturated zone 3 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(21,3)
R016	Unsaturated zone 4 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(21,4)
R016	Unsaturated zone 5 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(21,5)
R016	Saturated zone (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCS(21)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.30E-04	ALEACH(21)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(21)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 15 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Pu-239				
R016	Contaminated zone (cm**3/g)	3.36E+03	2.00E+03	---	DCNUCC(22)
R016	Unsaturated zone 1 (cm**3/g)	9.47E+02	2.00E+03	---	DCNUCU(22,1)
R016	Unsaturated zone 2 (cm**3/g)	9.47E+02	2.00E+03	---	DCNUCU(22,2)
R016	Unsaturated zone 3 (cm**3/g)	9.53E+02	2.00E+03	---	DCNUCU(22,3)
R016	Unsaturated zone 4 (cm**3/g)	9.43E+02	2.00E+03	---	DCNUCU(22,4)
R016	Unsaturated zone 5 (cm**3/g)	9.44E+02	2.00E+03	---	DCNUCU(22,5)
R016	Saturated zone (cm**3/g)	9.43E+02	2.00E+03	---	DCNUCS(22)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.37E-04	ALEACH(22)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(22)
R016	Distribution coefficients for Pu-240				
R016	Contaminated zone (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCC(23)
R016	Unsaturated zone 1 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(23,1)
R016	Unsaturated zone 2 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(23,2)
R016	Unsaturated zone 3 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(23,3)
R016	Unsaturated zone 4 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(23,4)
R016	Unsaturated zone 5 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(23,5)
R016	Saturated zone (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCS(23)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.30E-04	ALEACH(23)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(23)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 16
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Pu-241				
R016	Contaminated zone (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCC(24)
R016	Unsaturated zone 1 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(24,1)
R016	Unsaturated zone 2 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(24,2)
R016	Unsaturated zone 3 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(24,3)
R016	Unsaturated zone 4 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(24,4)
R016	Unsaturated zone 5 (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCU(24,5)
R016	Saturated zone (cm**3/g)	2.00E+03	2.00E+03	---	DCNUCS(24)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.30E-04	ALEACH(24)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(24)
R016	Distribution coefficients for Sr-90				
R016	Contaminated zone (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCC(28)
R016	Unsaturated zone 1 (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCU(28,1)
R016	Unsaturated zone 2 (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCU(28,2)
R016	Unsaturated zone 3 (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCU(28,3)
R016	Unsaturated zone 4 (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCU(28,4)
R016	Unsaturated zone 5 (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCU(28,5)
R016	Saturated zone (cm**3/g)	3.00E+01	3.00E+01	---	DCNUCS(28)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.52E-02	ALEACH(28)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(28)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 16 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Tc-99				
R016	Contaminated zone (cm**3/g)	6.10E-02	0.00E+00	---	DCNUCC(29)
R016	Unsaturated zone 1 (cm**3/g)	5.05E-01	0.00E+00	---	DCNUCU(29,1)
R016	Unsaturated zone 2 (cm**3/g)	5.00E-01	0.00E+00	---	DCNUCU(29,2)
R016	Unsaturated zone 3 (cm**3/g)	5.09E-01	0.00E+00	---	DCNUCU(29,3)
R016	Unsaturated zone 4 (cm**3/g)	4.99E-01	0.00E+00	---	DCNUCU(29,4)
R016	Unsaturated zone 5 (cm**3/g)	4.99E-01	0.00E+00	---	DCNUCU(29,5)
R016	Saturated zone (cm**3/g)	5.03E-01	0.00E+00	---	DCNUCS(29)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.17E+00	ALEACH(29)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(29)
R016	Distribution coefficients for Zn-65				
R016	Contaminated zone (cm**3/g)	2.12E+04	0.00E+00	---	DCNUCC(38)
R016	Unsaturated zone 1 (cm**3/g)	1.05E+03	0.00E+00	---	DCNUCU(38,1)
R016	Unsaturated zone 2 (cm**3/g)	1.04E+03	0.00E+00	---	DCNUCU(38,2)
R016	Unsaturated zone 3 (cm**3/g)	1.07E+03	0.00E+00	---	DCNUCU(38,3)
R016	Unsaturated zone 4 (cm**3/g)	1.04E+03	0.00E+00	---	DCNUCU(38,4)
R016	Unsaturated zone 5 (cm**3/g)	1.04E+03	0.00E+00	---	DCNUCU(38,5)
R016	Saturated zone (cm**3/g)	1.05E+03	0.00E+00	---	DCNUCS(38)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.17E-05	ALEACH(38)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(38)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 17
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Ac-227				
R016	Contaminated zone (cm**3/g)	8.24E+02	2.00E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	8.23E+02	2.00E+01	---	DCNUCU(1,1)
R016	Unsaturated zone 2 (cm**3/g)	8.12E+02	2.00E+01	---	DCNUCU(1,2)
R016	Unsaturated zone 3 (cm**3/g)	8.28E+02	2.00E+01	---	DCNUCU(1,3)
R016	Unsaturated zone 4 (cm**3/g)	8.25E+02	2.00E+01	---	DCNUCU(1,4)
R016	Unsaturated zone 5 (cm**3/g)	8.12E+02	2.00E+01	---	DCNUCU(1,5)
R016	Saturated zone (cm**3/g)	8.17E+02	2.00E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	5.57E-04	ALEACH(1)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Am-243				
R016	Contaminated zone (cm**3/g)	1.17E+04	2.00E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	1.44E+03	2.00E+01	---	DCNUCU(4,1)
R016	Unsaturated zone 2 (cm**3/g)	1.42E+03	2.00E+01	---	DCNUCU(4,2)
R016	Unsaturated zone 3 (cm**3/g)	1.43E+03	2.00E+01	---	DCNUCU(4,3)
R016	Unsaturated zone 4 (cm**3/g)	1.43E+03	2.00E+01	---	DCNUCU(4,4)
R016	Unsaturated zone 5 (cm**3/g)	1.41E+03	2.00E+01	---	DCNUCU(4,5)
R016	Saturated zone (cm**3/g)	1.43E+03	2.00E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.92E-05	ALEACH(4)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(4)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 17 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Np-237				
R016	Contaminated zone (cm**3/g)	1.71E+01	-1.00E+00	---	DCNUCC(18)
R016	Unsaturated zone 1 (cm**3/g)	1.69E+01	-1.00E+00	---	DCNUCU(18,1)
R016	Unsaturated zone 2 (cm**3/g)	1.68E+01	-1.00E+00	---	DCNUCU(18,2)
R016	Unsaturated zone 3 (cm**3/g)	1.70E+01	-1.00E+00	---	DCNUCU(18,3)
R016	Unsaturated zone 4 (cm**3/g)	1.68E+01	-1.00E+00	---	DCNUCU(18,4)
R016	Unsaturated zone 5 (cm**3/g)	1.68E+01	-1.00E+00	---	DCNUCU(18,5)
R016	Saturated zone (cm**3/g)	1.69E+01	-1.00E+00	---	DCNUCS(18)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.66E-02	ALEACH(18)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(18)
R016	Distribution coefficients for daughter Pa-231				
R016	Contaminated zone (cm**3/g)	3.79E+02	5.00E+01	---	DCNUCC(19)
R016	Unsaturated zone 1 (cm**3/g)	3.75E+02	5.00E+01	---	DCNUCU(19,1)
R016	Unsaturated zone 2 (cm**3/g)	3.71E+02	5.00E+01	---	DCNUCU(19,2)
R016	Unsaturated zone 3 (cm**3/g)	3.78E+02	5.00E+01	---	DCNUCU(19,3)
R016	Unsaturated zone 4 (cm**3/g)	3.71E+02	5.00E+01	---	DCNUCU(19,4)
R016	Unsaturated zone 5 (cm**3/g)	3.70E+02	5.00E+01	---	DCNUCU(19,5)
R016	Saturated zone (cm**3/g)	3.73E+02	5.00E+01	---	DCNUCS(19)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.21E-03	ALEACH(19)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(19)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 18
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCC(20)
R016	Unsaturated zone 1 (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCU(20,1)
R016	Unsaturated zone 2 (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCU(20,2)
R016	Unsaturated zone 3 (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCU(20,3)
R016	Unsaturated zone 4 (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCU(20,4)
R016	Unsaturated zone 5 (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCU(20,5)
R016	Saturated zone (cm**3/g)	1.00E+02	1.00E+02	---	DCNUCS(20)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.58E-03	ALEACH(20)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(20)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCC(26)
R016	Unsaturated zone 1 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(26,1)
R016	Unsaturated zone 2 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(26,2)
R016	Unsaturated zone 3 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(26,3)
R016	Unsaturated zone 4 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(26,4)
R016	Unsaturated zone 5 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(26,5)
R016	Saturated zone (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCS(26)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	6.54E-03	ALEACH(26)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(26)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 18 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCC(27)
R016	Unsaturated zone 1 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(27,1)
R016	Unsaturated zone 2 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(27,2)
R016	Unsaturated zone 3 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(27,3)
R016	Unsaturated zone 4 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(27,4)
R016	Unsaturated zone 5 (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCU(27,5)
R016	Saturated zone (cm**3/g)	7.00E+01	7.00E+01	---	DCNUCS(27)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	6.54E-03	ALEACH(27)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(27)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCC(30)
R016	Unsaturated zone 1 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(30,1)
R016	Unsaturated zone 2 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(30,2)
R016	Unsaturated zone 3 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(30,3)
R016	Unsaturated zone 4 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(30,4)
R016	Unsaturated zone 5 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(30,5)
R016	Saturated zone (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCS(30)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	7.65E-06	ALEACH(30)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(30)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 19
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Th-229				
R016	Contaminated zone (cm**3/g)	5.72E+03	6.00E+04	---	DCNUCC(31)
R016	Unsaturated zone 1 (cm**3/g)	5.81E+03	6.00E+04	---	DCNUCU(31,1)
R016	Unsaturated zone 2 (cm**3/g)	5.81E+03	6.00E+04	---	DCNUCU(31,2)
R016	Unsaturated zone 3 (cm**3/g)	5.88E+03	6.00E+04	---	DCNUCU(31,3)
R016	Unsaturated zone 4 (cm**3/g)	5.77E+03	6.00E+04	---	DCNUCU(31,4)
R016	Unsaturated zone 5 (cm**3/g)	5.78E+03	6.00E+04	---	DCNUCU(31,5)
R016	Saturated zone (cm**3/g)	5.77E+03	6.00E+04	---	DCNUCS(31)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	8.02E-05	ALEACH(31)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(31)
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCC(32)
R016	Unsaturated zone 1 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(32,1)
R016	Unsaturated zone 2 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(32,2)
R016	Unsaturated zone 3 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(32,3)
R016	Unsaturated zone 4 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(32,4)
R016	Unsaturated zone 5 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(32,5)
R016	Saturated zone (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCS(32)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	7.65E-06	ALEACH(32)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(32)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 19 (cont)

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

R016	Distribution coefficients for daughter Th-232				
R016	Contaminated zone (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCC(33)
R016	Unsaturated zone 1 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(33,1)
R016	Unsaturated zone 2 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(33,2)
R016	Unsaturated zone 3 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(33,3)
R016	Unsaturated zone 4 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(33,4)
R016	Unsaturated zone 5 (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCU(33,5)
R016	Saturated zone (cm**3/g)	6.00E+04	6.00E+04	---	DCNUCS(33)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	7.65E-06	ALEACH(33)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(33)
R016	Distribution coefficients for daughter U-233				
R016	Contaminated zone (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCC(34)
R016	Unsaturated zone 1 (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCU(34,1)
R016	Unsaturated zone 2 (cm**3/g)	1.24E+02	5.00E+01	---	DCNUCU(34,2)
R016	Unsaturated zone 3 (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCU(34,3)
R016	Unsaturated zone 4 (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCU(34,4)
R016	Unsaturated zone 5 (cm**3/g)	1.24E+02	5.00E+01	---	DCNUCU(34,5)
R016	Saturated zone (cm**3/g)	1.25E+02	5.00E+01	---	DCNUCS(34)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.64E-03	ALEACH(34)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(34)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 20
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter U-234				
R016	Contaminated zone (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCC(35)
R016	Unsaturated zone 1 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(35,1)
R016	Unsaturated zone 2 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(35,2)
R016	Unsaturated zone 3 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(35,3)
R016	Unsaturated zone 4 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(35,4)
R016	Unsaturated zone 5 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(35,5)
R016	Saturated zone (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCS(35)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	9.15E-03	ALEACH(35)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(35)
R016	Distribution coefficients for daughter U-235				
R016	Contaminated zone (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCC(36)
R016	Unsaturated zone 1 (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCU(36,1)
R016	Unsaturated zone 2 (cm**3/g)	1.24E+02	5.00E+01	---	DCNUCU(36,2)
R016	Unsaturated zone 3 (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCU(36,3)
R016	Unsaturated zone 4 (cm**3/g)	1.26E+02	5.00E+01	---	DCNUCU(36,4)
R016	Unsaturated zone 5 (cm**3/g)	1.24E+02	5.00E+01	---	DCNUCU(36,5)
R016	Saturated zone (cm**3/g)	1.25E+02	5.00E+01	---	DCNUCS(36)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.64E-03	ALEACH(36)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(36)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 20 (cont)

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter U-236				
R016	Contaminated zone (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCC(37)
R016	Unsaturated zone 1 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(37,1)
R016	Unsaturated zone 2 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(37,2)
R016	Unsaturated zone 3 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(37,3)
R016	Unsaturated zone 4 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(37,4)
R016	Unsaturated zone 5 (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCU(37,5)
R016	Saturated zone (cm**3/g)	5.00E+01	5.00E+01	---	DCNUCS(37)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	9.15E-03	ALEACH(37)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(37)
R017	Inhalation rate (m**3/yr)	8.57E+03	8.40E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.35E-05	1.00E-04	---	MLINH
R017	Exposure duration	3.00E+01	3.00E+01	---	ED
R017	Shielding factor, inhalation	5.50E-01	4.00E-01	---	SHF3
R017	Shielding factor, external gamma	3.97E-01	7.00E-01	---	SHF1
R017	Fraction of time spent indoors	6.67E-01	5.00E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.50E-01	2.50E-01	---	FOTD
R017	Shape factor flag, external gamma	1.00E+00	1.00E+00	>0 shows circular AREA.	FS

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 21
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.00E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.07E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.00E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.00E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.00E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.00E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.00E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.00E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.00E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.00E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.00E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.00E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.00E+00	---	FRACA(1)
R017	Ring 2	not used	2.73E-01	---	FRACA(2)
R017	Ring 3	not used	0.00E+00	---	FRACA(3)
R017	Ring 4	not used	0.00E+00	---	FRACA(4)
R017	Ring 5	not used	0.00E+00	---	FRACA(5)
R017	Ring 6	not used	0.00E+00	---	FRACA(6)
R017	Ring 7	not used	0.00E+00	---	FRACA(7)
R017	Ring 8	not used	0.00E+00	---	FRACA(8)
R017	Ring 9	not used	0.00E+00	---	FRACA(9)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 21 (cont)

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Ring 12	not used	0.00E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	2.05E+02	1.60E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.40E+01	1.40E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.20E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.30E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.40E+00	5.40E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.00E-01	9.00E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.82E+01	3.65E+01	---	SOIL
R018	Drinking water intake (L/yr)	4.09E+02	5.10E+02	---	DWI
R018	Contamination fraction of drinking water	1.00E+00	1.00E+00	---	FDW
R018	Contamination fraction of household water	not used	1.00E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.00E+00	---	FLW
R018	Contamination fraction of irrigation water	1.00E+00	1.00E+00	---	FIRW
R018	Contamination fraction of aquatic food	4.48E-01	5.00E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	7.50E-02	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.80E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.50E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.00E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.60E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.00E-01	---	LSI

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 22
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Mass loading for foliar deposition (g/m**3)	1.00E-04	1.00E-04	---	MLFD
R019	Depth of soil mixing layer (m)	2.32E-01	1.50E-01	---	DM
R019	Depth of roots (m)	1.22E+00	9.00E-01	---	DROOT
R019	Drinking water fraction from ground water	1.00E+00	1.00E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.00E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.00E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.00E+00	1.00E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	1.75E+00	7.00E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.50E+00	1.50E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.10E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.70E-01	1.70E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.50E-01	2.50E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.00E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.00E-01	1.00E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.00E+00	1.00E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.00E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.50E-01	2.50E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.50E-01	2.50E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.50E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.50E-01	2.50E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	5.81E-01	2.50E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.50E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	3.28E+01	2.00E+01	---	WLAM

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 22 (cont)

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
C14	Fraction of vegetation carbon from soil	2.00E-02	2.00E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	9.80E-01	9.80E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	3.00E-01	3.00E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	7.00E-07	7.00E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	1.00E-10	1.00E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	8.00E-01	8.00E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	2.00E-01	2.00E-01	---	AVFG5
C14	DCF correction factor for gaseous forms of C14	8.89E+01	8.89E+01	---	CO2F
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.40E+01	1.40E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.00E+00	1.00E+00	---	STOR_T(2)
STOR	Milk	1.00E+00	1.00E+00	---	STOR_T(3)
STOR	Meat and poultry	2.00E+01	2.00E+01	---	STOR_T(4)
STOR	Fish	7.00E+00	7.00E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.00E+00	7.00E+00	---	STOR_T(6)
STOR	Well water	1.00E+00	1.00E+00	---	STOR_T(7)
STOR	Surface water	1.00E+00	1.00E+00	---	STOR_T(8)
STOR	Livestock fodder	4.50E+01	4.50E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.50E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.40E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.00E-01	---	TPCV

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 23
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Total porosity of the building foundation	not used	1.00E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.00E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.00E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.00E-06	---	DIFCV
R021	in foundation material	not used	3.00E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.00E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.00E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.00E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.50E+00	---	HRM
R021	Building interior area factor	not used	0.00E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.00E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.50E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.50E-01	---	EMANA(2)
TITL	Number of graphical time points	1024	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 23 (cont)

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Site-Specific Parameter Summary (continued)

Summary of Pathway Selections

Pathway	I I	User Selection
1 -- external gamma	I	active
2 -- inhalation (w/o radon)	I	active
3 -- plant ingestion	I	active
4 -- meat ingestion	I	suppressed
5 -- milk ingestion	I	suppressed
6 -- aquatic foods	I	active
7 -- drinking water	I	active
8 -- soil ingestion	I	active
9 -- radon	I	suppressed
Find peak pathway doses	I	active

RESRAD, Version6.21 T «Limit=0.5year 6/15/2004 6:06 Page 24
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File: DiscDose-All.RAD

Contaminated Zone Dimensions	
Area:	150 square meters
Thickness:	0.30 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Ag-110m	3.00E-02
Am-241	6.65E-02
C-14	4.70E-01
Cm-243	6.01E-02
Cm-244	6.01E-02
Co-60	5.72E-01
Cs-134	2.22E-02
Cs-137	6.68E-01
Fe-55	1.76E+00
H-3	4.90E-02
I-129	2.60E-01
Mn-54	3.70E-02
Ni-59	2.35E+00
Ni-63	4.00E-01
Pu-238	4.50E-02
Pu-239	4.00E-02
Pu-240	4.00E-02
Pu-241	7.25E+00
Sr-90	1.30E-02
Tc-99	3.10E-01
Zn-65	6.87E-02

Page 24 (cont)

Toal Dose TDOSE(t), mrem/y

Basic Radiation Dose Limit = 2.42E+01 mrem/yr

Total Mixture Sum	M(t) = Fraction of Basic Dose		Limit	Received	at Time (t)
t (y):	0.00E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
TDOSE(t):	4.95E+00	3.06E+00	5.64E-01	1.04E-08	1.49E-07
M(t):	2.04E-01	1.26E-01	2.33E-02	4.31E-10	6.14E-09

Maximum TDOSE(t): 4.95E+00

mrem/y at t=0.00E+00 years

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 25
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p) Asmrem/yr and Fraction of Total Dose At =0.00E+00 years

	Water Independent Pathways (Inhalation excludes radon)													
	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Radio-Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ag-110m	1.36E-01	0.0275	7.98E-09	0	0.00E+00	0	3.29E-06	0	0.00E+00	0	0.00E+00	0	5.10E-07	0
Am-241	1.28E-03	0.0003	1.56E-04	0	0.00E+00	0	1.78E-03	0.0004	0.00E+00	0	0.00E+00	0	6.06E-04	0.0001
C-14	1.27E-07	0	8.98E-07	0	0.00E+00	0	2.29E-04	0	0.00E+00	0	0.00E+00	0	1.13E-07	0
Cm-243	1.52E-02	0.0031	9.61E-05	0	0.00E+00	0	5.96E-04	0.0001	0.00E+00	0	0.00E+00	0	3.73E-04	0.0001
Cm-244	3.69E-06	0	7.71E-05	0	0.00E+00	0	4.76E-04	0.0001	0.00E+00	0	0.00E+00	0	2.98E-04	0.0001
Co-60	3.61E+00	0.7293	6.19E-07	0	0.00E+00	0	4.59E-03	0.0009	0.00E+00	0	0.00E+00	0	3.61E-05	0
Cs-134	7.50E-02	0.0152	4.60E-09	0	0.00E+00	0	2.23E-04	0	0.00E+00	0	0.00E+00	0	3.46E-06	0
Cs-137	9.46E-01	0.1912	1.11E-07	0	0.00E+00	0	5.33E-03	0.0011	0.00E+00	0	0.00E+00	0	8.26E-05	0
Fe-55	0.00E+00	0	2.20E-08	0	0.00E+00	0	3.80E-06	0	0.00E+00	0	0.00E+00	0	2.36E-06	0
H-3	0.00E+00	0	2.33E-07	0	0.00E+00	0	9.09E-06	0	0.00E+00	0	0.00E+00	0	9.59E-10	0
I-129	1.24E-03	0.0003	1.98E-07	0	0.00E+00	0	8.93E-03	0.0018	0.00E+00	0	0.00E+00	0	1.49E-04	0
Mn-54	5.49E-02	0.0111	8.95E-10	0	0.00E+00	0	8.46E-05	0	0.00E+00	0	0.00E+00	0	1.76E-07	0
Ni-59	0.00E+00	0	3.35E-08	0	0.00E+00	0	9.95E-05	0	0.00E+00	0	0.00E+00	0	1.24E-06	0
Ni-63	0.00E+00	0	1.32E-08	0	0.00E+00	0	4.64E-05	0	0.00E+00	0	0.00E+00	0	5.76E-07	0
Pu-238	3.24E-06	0	9.26E-05	0	0.00E+00	0	1.05E-03	0.0002	0.00E+00	0	0.00E+00	0	3.59E-04	0.0001
Pu-239	5.29E-06	0	9.05E-05	0	0.00E+00	0	1.04E-03	0.0002	0.00E+00	0	0.00E+00	0	3.55E-04	0.0001

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 25 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p) Asmrem/yr and Fractionof Total Dose At =0.00E+00 years

Water Independent Pathways (Inhalation excludes radon)

	Water		Fish		Radon		Plant		Meat		Milk		All Pathways	
	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pu-240	2.80E-06	0	9.05E-05	0	0.00E+00	0	1.04E-03	0.0002	0.00E+00	0	0.00E+00	0	3.54E-04	0.0001
Pu-241	1.69E-04	0	3.21E-04	0.0001	0.00E+00	0	3.71E-03	0.0007	0.00E+00	0	0.00E+00	0	1.27E-03	0.0003
Sr-90	1.33E-04	0	8.81E-08	0	0.00E+00	0	4.64E-03	0.0009	0.00E+00	0	0.00E+00	0	4.88E-06	0
Tc-99	7.05E-06	0	5.56E-09	0	0.00E+00	0	3.91E-03	0.0008	0.00E+00	0	0.00E+00	0	4.62E-07	0
Zn-65	6.60E-02	0.0133	4.60E-09	0	0.00E+00	0	9.86E-04	0.0002	0.00E+00	0	0.00E+00	0	1.54E-06	0
Total	4.91E+00	0.9912	9.26E-04	0.0002	0.00E+00	0	3.88E-02	0.0078	0.00E+00	0	0.00E+00	0	3.89E-03	0.0008

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 26
Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p) Asmrem/yr and Fractionof Total Dose At t=0.000 E+00 years
Water Dependent Pathways

	Water		Fish		Radon		Plant		Meat		Milk		All Pathways	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.36E-01	0.0275
Am-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0,00E+00	0	3.82E-03	0.0008
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.30E-04	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.63E-02	0.0033
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	8.55E-04	0.0002
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.61E+00	0.7302
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.52E-02	0.0152
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.52E-01	0.1923
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.18E-06	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.33E-06	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.03E-02	0.0021
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.49E-02	0.0111
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.01E-04	0
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.70E-05	0
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.51E-03	0.0003
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.49E-03	0.0003
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.49E-03	0.0003
Pu-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.47E-03	0.0011
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.77E-03	0.001
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.92E-03	0.0008
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.70E-02	0.0135
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.95E+00	

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 27
Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p) as mrem/yr and Fraction of Total Dose at t =4.00 E+00 years
Water Independent Pathways (Inhalation excludes radon)

	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ag-110m	2.36E-03	0.0008	1.39E-10	0	0.00E+00	0	5.63E-08	0	0.00E+00	0	0.00E+00	0	8.84E-09	0
Am-241	1.27E-03	0.0004	1.55E-04	0.0001	0.00E+00	0	1.74E-03	0.0006	0.00E+00	0	0.00E+00	0	6.02E-04	0.0002
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	1.38E-02	0.0045	8.72E-05	0	0.00E+00	0	5.34E-04	0.0002	0.00E+00	0	0.00E+00	0	3.39E-04	0.0001
Cm-244	3.17E-06	0	6.61E-05	0	0.00E+00	0	4.03E-04	0.0001	0.00E+00	0	0.00E+00	0	2.56E-04	0.0001
Co-60	2.13E+00	0.6957	3.65E-07	0	0.00E+00	0	2.67E-03	0.0009	0.00E+00	0	0.00E+00	0	2.13E-05	0
Cs-134	1.95E-02	0.0064	1.20E-09	0	0.00E+00	0	5.73E-05	0	0.00E+00	0	0.00E+00	0	9.01E-07	0
Cs-137	8.61E-01	0.2815	1.01E-07	0	0.00E+00	0	4.78E-03	0.0016	0.00E+00	0	0.00E+00	0	7.52E-05	0
Fe-55	0.00E+00	0	7.87E-09	0	0.00E+00	0	1.34E-06	0	0.00E+00	0	0.00E+00	0	8.43E-07	0
H-3	0.00E+00	0	1.38E-21	0	0.00E+00	0	6.60E-20	0	0.00E+00	0	0.00E+00	0	5.76E-24	0
I-129	2.69E-04	0.0001	4.30E-08	0	0.00E+00	0	1.91E-03	0.0006	0.00E+00	0	0.00E+00	0	3.24E-05	0
Mn-54	2.13E-03	0.0007	3.47E-11	0	0.00E+00	0	3.24E-06	0	0.00E+00	0	0.00E+00	0	6.81E-09	0
Ni-59	0.00E+00	0	3.34E-08	0	0.00E+00	0	9.80E-05	0	0.00E+00	0	0.00E+00	0	1.23E-06	0
Ni-63	0.00E+00	0	1.28E-08	0	0.00E+00	0	4.44E-05	0	0.00E+00	0	0.00E+00	0	5.58E-07	0
Pu-238	3.14E-06	0	8.97E-05	0	0.00E+00	0	1.01E-03	0.0003	0.00E+00	0	0.00E+00	0	3.48E-04	0.0001
Pu-239	5.28E-06	0	9.04E-05	0	0.00E+00	0	1.03E-03	0.0003	0.00E+00	0	0.00E+00	0	3.54E-04	0.0001
Pu-240	2.79E-06	0	9.04E-05	0	0.00E+00	0	1.02E-03	0.0003	0.00E+00	0	0.00E+00	0	3.54E-04	0.0001
Pu-241	9.50E-04	0.0003	3.63E-04	0.0001	0.00E+00	0	4.13E-03	0.0013	0.00E+00	0	0.00E+00	0	1.43E-03	0.0005
Sr-90	1.14E-04	0	7.53E-08	0	0.00E+00	0	3.91E-03	0.0013	0.00E+00	0	0.00E+00	0	4.18E-06	0
Tc-99	1.19E-09	0	9.36E-13	0	0.00E+00	0	6.66E-07	0	0.00E+00	0	0.00E+00	0	7.79E-11	0
Zn-65	1.04E-03	0.0003	7.24E-11	0	0.00E+00	0	1.53E-05	0	0.00E+00	0	0.00E+00	0	2.43E-08	0
Total	3.03E+00	0.9908	9.42E-04	0.0003	0.00E+00	0	2.34E-02	0.0076	0.00E+00	0	0.00E+00	0	3.82E-03	0.0012

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 28
Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p) as mrem/yr and Fraction of Total Dose at t = 4.000E+00 years

	Water Dependent Pathways													
	Water		Fish		Radon		Plant		Meat		Milk		All Pathways	
Radio-Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.36E-03	0.0008
Am-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.77E-03	0.0012
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.47E-02	0.0048
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.28E-04	0.0002
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.13E+00	0.6966
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.96E-02	0.0064
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	8.66E-01	0.2831
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.19E-06	0
H-3	4.40E-10	0	2.08E-15	0	0.00E+00	0	1.52E-11	0	0.00E+00	0	0.00E+00	0	4.55E-10	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.22E-03	0.0007
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.13E-03	0.0007
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.93E-05	0
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.49E-05	0
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.45E-03	0.0005
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.48E-03	0.0005
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.47E-03	0.0005
Pu-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.87E-03	0.0022
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.03E-03	0.0013
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.68E-07	0
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.05E-03	0.0003
Total	4.40E-10	0	2.08E-15	0	0.00E+00	0	1.52E-11	0	0.00E+00	0	0.00E+00	0	3.06E+00	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 29
Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD
Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.
Ag-110m	8.43E-15	0	4.97E-22	0	0.00E+00	0	1.84E-19	0	0.00E+00	0	0.00E+00	0	3.17E-20	0
Am-241	1.22E-03	0.0022	1.48E-04	0.0003	0.00E+00	0	1.52E-03	0.0027	0.00E+00	0	0.00E+00	0	5.76E-04	0.001
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	7.31E-03	0.013	4.64E-05	0.0001	0.00E+00	0	2.59E-04	0.0005	0.00E+00	0	0.00E+00	0	1.80E-04	0.0003
Cm-244	1.17E-06	0	2.45E-05	0	0.00E+00	0	1.37E-04	0.0002	0.00E+00	0	0.00E+00	0	9.46E-05	0.0002
Co-60	6.84E-02	0.1213	1.18E-08	0	0.00E+00	0	7.89E-05	0.0001	0.00E+00	0	0.00E+00	0	6.89E-07	0
Cs-134	3.10E-06	0	1.91E-13	0	0.00E+00	0	8.32E-09	0	0.00E+00	0	0.00E+00	0	1.43E-10	0
Cs-137	4.66E-01	0.8251	5.48E-08	0	0.00E+00	0	2.36E-03	0.0042	0.00E+00	0	0.00E+00	0	4.08E-05	0.0001
Fe-55	0.00E+00	0	9.82E-12	0	0.00E+00	0	1.53E-09	0	0.00E+00	0	0.00E+00	0	1.05E-09	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
I-129	1.30E-08	0	2.07E-12	0	0.00E+00	0	8.40E-08	0	0.00E+00	0	0.00E+00	0	1.56E-09	0
Mn-54	1.42E-12	0	2.33E-20	0	0.00E+00	0	1.98E-15	0	0.00E+00	0	0.00E+00	0	4.57E-18	0
Ni-59	0.00E+00	0	3.30E-08	0	0.00E+00	0	8.84E-05	0.0002	0.00E+00	0	0.00E+00	0	1.22E-06	0
Ni-63	0.00E+00	0	1.05E-08	0	0.00E+00	0	3.31E-05	0.0001	0.00E+00	0	0.00E+00	0	4.57E-07	0
Pu-238	2.54E-06	0	7.26E-05	0.0001	0.00E+00	0	7.42E-04	0.0013	0.00E+00	0	0.00E+00	0	2.81E-04	0.0005
Pu-239	5.26E-06	0	9.00E-05	0.0002	0.00E+00	0	9.31E-04	0.0016	0.00E+00	0	0.00E+00	0	3.53E-04	0.0006
Pu-240	2.77E-06	0	8.96E-05	0.0002	0.00E+00	0	9.26E-04	0.0016	0.00E+00	0	0.00E+00	0	3.51E-04	0.0006
Pu-241	3.47E-03	0.0062	4.93E-04	0.0009	0.00E+00	0	5.07E-03	0.009	0.00E+00	0	0.00E+00	0	1.92E-03	0.0034
Sr-90	4.12E-05	0.0001	2.73E-08	0	0.00E+00	0	1.29E-03	0.0023	0.00E+00	0	0.00E+00	0	1.52E-06	0
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Zn-65	1.97E-15	0	1.38E-22	0	0.00E+00	0	2.66E-17	0	0.00E+00	0	0.00E+00	0	4.62E-20	0
Total	5.46E-01	0.9677	9.64E-04	0.0017	0.00E+00	0	1.35E-02	0.0238	0.00E+00	0	0.00E+00	0	3.80E-03	0.0067

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 30

Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD
Total Dose Contributions TDOSE(I,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+01 years

	Water Dependant Pathways													
	Water		Fish		Radon		Plant		Meat		Milk		All Pathways	
Nuclide	mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	8.43E-15	0
Am-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.46E-03	0.0061
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.80E-03	0.0138
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.58E-04	0.0005
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.85E-02	0.1214
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.11E-06	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.68E-01	0.8293
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.59E-09	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.86E-08	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.42E-12	0
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	8.97E-05	0.0002
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.36E-05	0.0001
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.10E-03	0.0019
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.38E-03	0.0024
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.37E-03	0.0024
Pu-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.10E-02	0.0194
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.34E-03	0.0024
Tc-99	1.12E-19	0	8.58E-24	0	0.00E+00	0	3.35E-21	0	0.00E+00	0	0.00E+00	0	1.16E-19	0
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.99E-15	0
Total	1.12E-19	0	8.58E-24	0	0.00E+00	0	3.35E-21	0	0.00E+00	0	0.00E+00	0	5.64E-01	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 31
Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD

Total Dose Contributions TDOSE(I,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	Mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Am-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.56E-09	0.1493	0.00E+00	0	0.00E+00	0	0.00E+00	0
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.14E-12	0.0003	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.62E-12	0.0005	0.00E+00	0	0.00E+00	0	0.00E+00	0
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.53E-26	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.58E-12	0.0006	0.00E+00	0	0.00E+00	0	0.00E+00	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.26E-10	0.0121	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.67E-12	0.0006	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.32E-10	0.0127	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.42E-09	0.136	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.35E-09	0.1292	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.83E-09	0.5586	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.59E-14	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.04E-08	1	0.00E+00	0	0.00E+00	0	0.00E+00	0

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 32

Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD
Total Dose Contributions TDOSE(I,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+02 years Water Dependent Pathways

	Water		Fish		Radon		Plant		Meat		Milk		All Pathways	
Nuclide	mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.	Mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Am-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.56E-09	0.1493
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.14E-12	0.0003
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.62E-12	0.0005
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.53E-26	0
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.58E-12	0.0006
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.26E-10	0.0121
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.67E-12	0.0006
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.32E-10	0.0127
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.42E-09	0.136
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.35E-09	0.1292
Pu-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.83E-09	0.5586
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.59E-14	0
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.04E-08	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 33

Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD
Total Dose Contributions TDOSE(I,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Am-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-241	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 34

Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD Total Dose Contributions TDOSE(I,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+02 years

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ag-110m	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Am-241	2.06E-08	0.1384	6.97E-12	0	0.00E+00	0	1.94E-10	0.0013	0.00E+00	0	0.00E+00	0	2.08E-08	0.1397
C-14	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-243	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cm-244	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-134	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
I-129	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-59	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Ni-63	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-238	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-239	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-240	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Pu-241	1.27E-07	0.852	4.30E-11	0.0003	0.00E+00	0	1.19E-09	0.008	0.00E+00	0	0.00E+00	0	1.28E-07	0.8603
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Tc-99	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Zn-65	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Total	1.47E-07	0.9903	4.99E-11	0.0003	0.00E+00	0	1.39E-09	0.0093	0.00E+00	0	0.00E+00	0	1.49E-07	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5year 6/15/2004 6:06 AM Page 35
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.42E+01 mrem/y

Parent (i)	Product (j)	Branch Fraction*	t=	DSR(j,t) (mrem/yr)/(pCi/g) 0.00E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Ag-110m	Ag-110m	t=1.00E+00		4.54E+00	7.86E-02	2.81E-13	0.00E+00	0.00E+00
Am-241	Am-241	1.00E+00		5.74E-02	5.66E-02	5.21E-02	2.34E-08	0.00E+00
Am-241	Np-237	1.00E+00		1.33E-07	1.15E-06	5.35E-06	4.07E-12	3.12E-07
Am-241	U-233	1.00E+00		1.51E-15	6.42E-14	2.03E-12	2.34E-17	6.65E-10
Am-241	Th-229	1.00E+00		4.06E-18	1.44E-15	3.63E-13	2.55E-18	1.31E-11
Am-241	□DSR(j)	5.74E-02		5.66E-02	5.21E-02	2.34E-08	3.13E-07	
C-14	C-14	1.00E+00		4.89E-04	1.56E-42	0.00E+00	0.00E+00	0.00E+00
Cm-243	Cm-243	9.98E-01		2.70E-01	2.45E-01	1.29E-01	9.69E-12	0.00E+00
Cm-243	Pu-239	9.98E-01		5.20E-07	4.51E-06	2.14E-05	4.22E-11	0.00E+00
Cm-243	U-235	9.98E-01		1.57E-15	9.26E-14	3.36E-12	5.83E-19	0.00E+00
Cm-243	Pa-231	9.98E-01		1.23E-20	4.71E-18	1.14E-15	3.35E-19	0.00E+00
Cm-243	Ac-227	9.98E-01		1.71E-22	3.21E-19	4.78E-16	3.84E-20	0.00E+00
Cm-243	□DSR(j)	2.70E-01		2.45E-01	1.30E-01	5.18E-11	0.00E+00	
Cm-243	Cm-243	2.40E-03		6.49E-04	5.88E-04	3.11E-04	2.33E-14	0.00E+00
Cm-243	Am-243	2.40E-03		4.84E-08	4.16E-07	2.09E-06	3.42E-13	0.00E+00
Cm-243	Pu-239	2.40E-03		4.00E-14	2.35E-12	8.26E-11	2.48E-15	0.00E+00
Cm-243	U-235	2.40E-03		8.89E-23	3.20E-20	8.25E-18	2.01E-23	0.00E+00
Cm-243	Pa-231	2.40E-03		5.45E-28	1.21E-24	2.04E-21	7.48E-24	0.00E+00
Cm-243	Ac-227	2.40E-03		6.52E-30	6.72E-26	6.99E-22	7.76E-25	0.00E+00
Cm-243	□DSR(j)	6.49E-04		5.89E-04	3.14E-04	3.68E-13	0.00E+00	

RESRAD, Version 6.21 T« Limit = 0.5year 6/15/2004 6:06 AM Page 35 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.42E+01 mrem/y

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) 0.00E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Cm-244	U-236	1.00E+00	1.85E-15	1.06E-13	3.12E-12	2.38E-17	0.00E+00
Cm-244	Th-232	1.00E+00	1.80E-25	6.03E-23	1.33E-20	1.15E-24	0.00E+00
Cm-244	Ra-228	1.00E+00	4.09E-25	7.65E-22	7.30E-19	2.22E-23	0.00E+00
Cm-244	Th-228	1.00E+00	3.69E-26	3.10E-22	8.54E-19	4.74E-25	0.00E+00
Cm-244	□DSR(j)	1.42E-02	1.21E-02	4.28E-03	9.36E-11	0.00E+00	
Co-60	Co-60	1.00E+00	6.32E+00	3.72E+00	1.20E-01	7.91E-26	0.00E+00
Cs-134	Cs-134	1.00E+00	3.39E+00	8.82E-01	1.40E-04	0.00E+00	0.00E+00
Cs-137	Cs-137	1.00E+00	1.43E+00	1.30E+00	7.01E-01	9.86E-12	0.00E+00
Fe-55	Fe-55	1.00E+00	3.51E-06	1.25E-06	1.47E-09	1.40E-45	0.00E+00
H-3	H-3	1.00E+00	1.90E-04	9.29E-09	0.00E+00	0.00E+00	0.00E+00
I-129	I-129	1.00E+00	3.97E-02	8.52E-03	3.79E-07	2.60E-35	0.00E+00
Mn-54	Mn-54	1.00E+00	1.49E+00	5.76E-02	3.85E-11	0.00E+00	0.00E+00

RESRAD, Version 6.21 T« Limit = 0.5year 6/15/2004 6:06 AM Page 36
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD
Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.42E+01 mrem/y

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.00E+00	4.00E+00	3.00E+01		1.00E+03
Ni-59	Ni-59	1.00E+00	4.29E-05	4.22E-05	3.82E-05	5.37E-11	0.00E+00
Ni-63	Ni-63	1.00E+00	1.17E-04	1.12E-04	8.40E-05	1.67E-11	0.00E+00
Pu-238	Pu-238	1.00E+00	3.35E-02	3.21E-02	2.44E-02	2.94E-09	0.00E+00
Pu-238	U-234	1.00E+00	5.43E-09	4.71E-08	2.42E-07	2.09E-13	0.00E+00
Pu-238	Th-230	1.00E+00	2.56E-14	1.47E-12	5.59E-11	7.86E-16	0.00E+00
Pu-238	Ra-226	1.00E+00	2.24E-15	8.10E-13	2.11E-10	2.82E-15	0.00E+00
Pu-238	Pb-210	1.00E+00	1.27E-18	1.92E-15	2.52E-12	2.91E-15	0.00E+00
Pu-238	□DSR(j)	3.35E-02	3.21E-02	2.44E-02	2.94E-09	0.00E+00	
Pu-239	Pu-239	1.00E+00	3.72E-02	3.69E-02	3.45E-02	3.55E-08	0.00E+00
Pu-239	U-235	1.00E+00	1.65E-10	1.48E-09	9.51E-09	5.40E-16	0.00E+00
Pu-239	Pa-231	1.00E+00	1.76E-15	1.12E-13	4.59E-12	3.54E-16	0.00E+00
Pu-239	Ac-227	1.00E+00	2.94E-17	9.92E-15	2.39E-12	4.17E-17	0.00E+00
Pu-239	□DSR(j)	3.72E-02	3.69E-02	3.45E-02	3.55E-08	0.00E+00	
Pu-240	Pu-240	1.00E+00	3.72E-02	3.68E-02	3.42E-02	3.37E-08	0.00E+00
Pu-240	U-236	1.00E+00	5.29E-11	4.66E-10	2.65E-09	8.79E-15	0.00E+00
Pu-240	Th-232	1.00E+00	6.74E-21	3.90E-19	1.58E-17	4.76E-22	0.00E+00
Pu-240	Ra-228	1.00E+00	1.94E-20	6.38E-18	9.90E-16	9.20E-21	0.00E+00
Pu-240	Th-228	1.00E+00	2.07E-21	3.08E-18	1.24E-15	1.97E-22	0.00E+00
Pu-240	□DSR(j)	3.72E-02	3.68E-02	3.42E-02	3.37E-08	0.00E+00	

RESRAD, Version 6.21 T« Limit = 0.5year 6/15/2004 6:06 AM Page 36 (cont)
Summary: Evaluation of Potential Dose from Discarded Radionuclides
File: DiscDose-All.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.42E+01 mrem/y

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.00E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Pu-241	Pu-241	1.00E+00	7.09E-04	5.79E-04	1.55E-04	3.61E-16	0.00E+00
Pu-241	Am-241	1.00E+00	4.53E-05	3.69E-04	1.36E-03	8.04E-10	0.00E+00
Pu-241	Np-237	1.00E+00	6.93E-11	3.95E-09	9.40E-08	1.40E-13	1.76E-08
Pu-241	U-233	1.00E+00	6.58E-19	1.54E-16	2.53E-14	7.52E-19	1.95E-11
Pu-241	Th-229	1.00E+00	1.30E-21	2.54E-18	3.53E-15	7.46E-20	3.77E-13
Pu-241	□DSR(j)	7.54E-04	9.47E-04	1.51E-03	8.04E-10	1.77E-08	
Pu-241	Pu-241	2.45E-05	1.74E-08	1.42E-08	3.79E-09	8.84E-21	0.00E+00
Pu-241	Np-237	2.45E-05	3.21E-12	2.54E-11	6.39E-11	6.41E-20	1.60E-23
Pu-241	U-233	2.45E-05	3.66E-20	1.46E-18	3.15E-17	3.78E-23	2.64E-15
Pu-241	Th-229	2.45E-05	9.84E-23	3.36E-20	6.38E-18	9.17E-24	5.64E-17
Pu-241	□DSR(j)	1.74E-08	1.42E-08	3.85E-09	7.30E-20	2.70E-15	
Sr-90	Sr-90	1.00E+00	3.67E-01	3.10E-01	1.03E-01	4.30E-12	0.00E+00
Tc-99	Tc-99	1.00E+00	1.27E-02	2.15E-06	3.74E-19	0.00E+00	0.00E+00
Zn-65	Zn-65	1.00E+00	9.75E-01	1.53E-02	2.90E-14	0.00E+00	0.00E+00

RESRAD, Version 6.21 T« Limit = 0.5year 6/15/2004 6:06 AM Page 37
Summary: Evaluation of Potential Dose from Discarded Radionuclides
File: DiscDose-All.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.42E+01 mrem/y

Nuclide t=	0.00E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Ag-110m	5.34E+00	3.08E+02	8.62E+13	*4.752E+15	*4.752E+15
Am-241	4.22E+02	4.28E+02	4.65E+02	1.03E+09	7.75E+07
C-14	4.96E+04	*4.454E+12	*4.454E+12	*4.454E+12	*4.454E+12
Cm-243	8.96E+01	9.88E+01	1.87E+02	4.64E+11	*5.159E+13
Cm-244	1.70E+03	2.00E+03	5.66E+03	2.59E+11	*8.086E+13
Co-60	3.84E+00	6.51E+00	2.02E+02	*1.131E+15	*1.131E+15
Cs-134	7.15E+00	2.75E+01	1.73E+05	*1.294E+15	*1.294E+15
Cs-137	1.70E+01	1.87E+01	3.46E+01	2.46E+12	*8.701E+13
Fe-55	6.90E+06	1.95E+07	1.65E+10	*2.409E+15	*2.409E+15
H-3	1.27E+05	2.61E+09	*9.594E+15	*9.594E+15	*9.594E+15
I-129	6.10E+02	2.84E+03	6.39E+07	*1.766E+08	*1.766E+08
Mn-54	1.63E+01	4.21E+02	6.30E+11	*7.744E+15	*7.744E+15
Ni-59	5.65E+05	5.74E+05	6.35E+05	*8.085E+10	*8.085E+10
Ni-63	2.06E+05	2.16E+05	2.88E+05	1.45E+12	*5.916E+13
Pu-238	7.23E+02	7.54E+02	9.92E+02	8.23E+09	*1.711E+13
Pu-239	6.51E+02	6.57E+02	7.03E+02	6.83E+08	*6.212E+10
Pu-240	6.52E+02	6.59E+02	7.08E+02	7.19E+08	*2.277E+11
Pu-241	3.21E+04	2.56E+04	1.60E+04	3.01E+10	1.37E+09
Sr-90	6.60E+01	7.81E+01	2.36E+02	5.63E+12	*1.365E+14
Tc-99	1.92E+03	1.13E+07	*1.696E+10	*1.696E+10	*1.696E+10
Zn-65	2.48E+01	1.58E+03	8.35E+14	*8.241E+15	*8.241E+15

*At specific activity limit

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 38
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ag-110m	3.00E-02	0.00E+00	4.54E+00	5.34E+00	4.54E+00	5.34E+00
Am-241	6.65E-02	0.00E+00	5.74E-02	4.22E+02	5.74E-02	4.22E+02
C-14	4.70E-01	0.00E+00	4.89E-04	4.96E+04	4.89E-04	4.96E+04
Cm-243	6.01E-02	0.00E+00	2.70E-01	8.96E+01	2.70E-01	8.96E+01
Cm-244	6.01E-02	0.00E+00	1.42E-02	1.70E+03	1.42E-02	1.70E+03
Co-60	5.72E-01	0.00E+00	6.32E+00	3.84E+00	6.32E+00	3.84E+00
Cs-134	2.22E-02	0.00E+00	3.39E+00	7.15E+00	3.39E+00	7.15E+00
Cs-137	6.68E-01	0.00E+00	1.43E+00	1.70E+01	1.43E+00	1.70E+01
Fe-55	1.76E+00	0.00E+00	3.51E-06	6.90E+06	3.51E-06	6.90E+06
H-3	4.90E-02	0.00E+00	1.90E-04	1.27E+05	1.90E-04	1.27E+05
I-129	2.60E-01	84.0 ± 0.2	8.52E+00	2.84E+00	3.97E-02	6.10E+02
Mn-54	3.70E-02	0.00E+00	1.49E+00	1.63E+01	1.49E+00	1.63E+01
Ni-59	2.35E+00	0.00E+00	4.29E-05	5.65E+05	4.29E-05	5.65E+05
Ni-63	4.00E-01	0.00E+00	1.17E-04	2.06E+05	1.17E-04	2.06E+05
Pu-238	4.50E-02	0.00E+00	3.35E-02	7.23E+02	3.35E-02	7.23E+02
Pu-239	4.00E-02	0.00E+00	3.72E-02	6.51E+02	3.72E-02	6.51E+02
Pu-240	4.00E-02	0.00E+00	3.72E-02	6.52E+02	3.72E-02	6.52E+02
Pu-241	7.25E+00	48.00±0.10	1.57E-03	1.54E+04	7.54E-04	3.21E+04
Sr-90	1.30E-02	0.00E+00	3.67E-01	6.60E+01	3.67E-01	6.60E+01
Tc-99	3.10E-01	11.36± 0.02	1.29E-01	1.88E+02	1.27E-02	1.92E+03
Zn-65	6.87E-02	0.00E+00	9.75E-01	2.48E+01	9.75E-01	2.48E+01

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 39
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Ag-110m	Ag-110m	1.00E+00	1.36E-01	2.36E-03	8.43E-15	0.00E+00	0.00E+00
Am-241	Am-241	1.00E+00	3.82E-03	3.77E-03	3.46E-03	1.56E-09	0.00E+00
Am-241	Pu-241	1.00E+00	3.28E-04	2.67E-03	9.84E-03	5.83E-09	0.00E+00
Am-241	ΣDOSE(j)		4.14E-03	6.44E-03	1.33E-02	7.39E-09	0.00E+00
Np-237	Am-241	1.00E+00	8.84E-09	7.66E-08	3.56E-07	2.71E-13	2.08E-08
Np-237	Pu-241	1.00E+00	5.02E-10	2.87E-08	6.82E-07	1.01E-12	1.28E-07
Np-237	Pu-241	2.45E-05	2.33E-11	1.84E-10	4.63E-10	4.65E-19	1.16E-22
Np-237	ΣDOSE(j)		9.37E-09	1.05E-07	1.04E-06	1.28E-12	1.49E-07
U-233	Am-241	1.00E+00	1.01E-16	4.27E-15	1.35E-13	1.56E-18	4.42E-11
U-233	Pu-241	1.00E+00	4.77E-18	1.12E-15	1.84E-13	5.45E-18	1.41E-10
U-233	Pu-241	2.45E-05	2.65E-19	1.06E-17	2.29E-16	2.74E-22	1.91E-14
U-233	ΣDOSE(j)		1.06E-16	5.39E-15	3.19E-13	7.01E-18	1.85E-10
Th-229	Am-241	1.00E+00	2.70E-19	9.60E-17	2.42E-14	1.69E-19	8.72E-13
Th-229	Pu-241	1.00E+00	9.39E-21	1.84E-17	2.56E-14	5.41E-19	2.73E-12
Th-229	Pu-241	2.45E-05	7.14E-22	2.43E-19	4.63E-17	6.65E-23	4.09E-16
Th-229	ΣDOSE(j)		2.80E-19	1.15E-16	4.98E-14	7.10E-19	3.60E-12

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 39 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides File : DiscDose-All.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides(i) and Pathways(p)
as mrem/yr and Fraction of Total Dose at t =3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

C-14	C-14	1.00E+00	2.30E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cm-243	Cm-243	9.98E-01	1.62E-02	1.47E-02	7.78E-03	5.82E-13	0.00E+00
Cm-243	Cm-243	2.40E-03	3.90E-05	3.54E-05	1.87E-05	1.40E-15	0.00E+00
Cm-243	ΣDOSE(j)		1.63E-02	1.47E-02	7.80E-03	5.84E-13	0.00E+00
Pu-239	Cm-243	9.98E-01	3.13E-08	2.71E-07	1.28E-06	2.53E-12	0.00E+00
Pu-239	Cm-243	2.40E-03	2.40E-15	1.41E-13	4.97E-12	1.49E-16	0.00E+00
Pu-239	Pu-239	1.00E+00	1.49E-03	1.48E-03	1.38E-03	1.42E-09	0.00E+00
Pu-239	ΣDOSE(j)		1.49E-03	1.48E-03	1.38E-03	1.42E-09	0.00E+00
U-235	Cm-243	9.98E-01	9.45E-17	5.56E-15	2.02E-13	3.51E-20	0.00E+00
U-235	Cm-243	2.40E-03	5.34E-24	1.92E-21	4.96E-19	1.21E-24	0.00E+00
U-235	Pu-239	1.00E+00	6.60E-12	5.90E-11	3.80E-10	2.16E-17	0.00E+00
U-235	ΣDOSE(j)		6.60E-12	5.90E-11	3.81E-10	2.16E-17	0.00E+00
Pa-231	Cm-243	9.98E-01	7.39E-22	2.83E-19	6.84E-17	2.01E-20	0.00E+00
Pa-231	Cm-243	2.40E-03	3.28E-29	7.29E-26	1.23E-22	4.49E-25	0.00E+00
Pa-231	Pu-239	1.00E+00	7.04E-17	4.47E-15	1.84E-13	1.42E-17	0.00E+00
Pa-231	ΣDOSE(j)		7.04E-17	4.47E-15	1.84E-13	1.42E-17	0.00E+00
Ac-227	Cm-243	9.98E-01	1.03E-23	1.93E-20	2.87E-17	2.31E-21	0.00E+00
Ac-227	Cm-243	2.40E-03	3.10E-31	4.04E-27	4.20E-23	4.66E-26	0.00E+00
Ac-227	Pu-239	1.00E+00	1.18E-18	3.97E-16	9.57E-14	1.67E-18	0.00E+00
Ac-227	ΣDOSE(j)		1.18E-18	3.97E-16	9.57E-14	1.67E-18	0.00E+00
Am-243	Cm-243	2.40E-03	2.91E-09	2.50E-08	1.26E-07	2.06E-14	0.00E+00

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 40
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Cm-244	Cm-244	1.00E+00	8.55E-04	7.27E-04	2.54E-04	6.51E-15	0.00E+00
Pu-240	Cm-244	1.00E+00	1.15E-07	9.66E-07	3.93E-06	5.62E-12	0.00E+00
Pu-240	Pu-240	1.00E+00	1.49E-03	1.47E-03	1.37E-03	1.35E-09	0.00E+00
Pu-240	ΣDOSE(j)		1.49E-03	1.47E-03	1.37E-03	1.36E-09	0.00E+00
U-236	Cm-244	1.00E+00	1.11E-16	6.37E-15	1.88E-13	1.43E-18	0.00E+00
U-236	Pu-240	1.00E+00	2.12E-12	1.86E-11	1.06E-10	3.52E-16	0.00E+00
U-236	ΣDOSE(j)		2.12E-12	1.86E-11	1.06E-10	3.53E-16	0.00E+00
Th-232	Cm-244	1.00E+00	1.08E-26	3.63E-24	7.98E-22	6.93E-26	0.00E+00
Th-232	Pu-240	1.00E+00	2.70E-22	1.56E-20	6.32E-19	1.90E-23	0.00E+00
Th-232	ΣDOSE(j)		2.70E-22	1.56E-20	6.33E-19	1.91E-23	0.00E+00
Ra-228	Cm-244	1.00E+00	2.46E-26	4.60E-23	4.39E-20	1.34E-24	0.00E+00
Ra-228	Pu-240	1.00E+00	7.75E-22	2.55E-19	3.96E-17	3.68E-22	0.00E+00
Ra-228	ΣDOSE(j)		7.75E-22	2.55E-19	3.97E-17	3.69E-22	0.00E+00
Th-228	Cm-244	1.00E+00	2.22E-27	1.86E-23	5.14E-20	2.85E-26	0.00E+00
Th-228	Pu-240	1.00E+00	8.30E-23	1.23E-19	4.95E-17	7.86E-24	0.00E+00
Th-228	ΣDOSE(j)		8.30E-23	1.23E-19	4.96E-17	7.89E-24	0.00E+00
Co-60	Co-60	1.00E+00	3.61E+00	2.13E+00	6.85E-02	4.53E-26	0.00E+00

Page 40 (cont)

Nuclide (j)	Parent (i)	BRF(i)	Dose(j,t) (mrem/yr) t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Cs-134	Cs-134	1.00E+00	7.52E-02	1.96E-02	3.11E-06	0.00E+00	0.00E+00
Cs-137	Cs-137	1.00E+00	9.52E-01	8.66E-01	4.68E-01	6.58E-12	0.00E+00
Fe-55	Fe-55	1.00E+00	6.18E-06	2.19E-06	2.59E-09	0.00E+00	0.00E+00
H-3	H-3	1.00E+00	9.33E-06	4.55E-10	0.00E+00	0.00E+00	0.00E+00
I-129	I-129	1.00E+00	1.03E-02	2.22E-03	9.86E-08	0.00E+00	0.00E+00
Mn-54	Mn-54	1.00E+00	5.49E-02	2.13E-03	1.42E-12	0.00E+00	0.00E+00
Ni-59	Ni-59	1.00E+00	1.01E-04	9.93E-05	8.97E-05	1.26E-10	0.00E+00
Ni-63	Ni-63	1.00E+00	4.70E-05	4.49E-05	3.36E-05	6.67E-12	0.00E+00
Pu-238	Pu-238	1.00E+00	1.51E-03	1.45E-03	1.10E-03	1.32E-10	0.00E+00
U-234	Pu-238	1.00E+00	2.44E-10	2.12E-09	1.09E-08	9.43E-15	0.00E+00
Th-230	Pu-238	1.00E+00	1.15E-15	6.63E-14	2.52E-12	3.54E-17	0.00E+00
Ra-226	Pu-238	1.00E+00	1.01E-16	3.64E-14	9.51E-12	1.27E-16	0.00E+00
Pb-210	Pu-238	1.00E+00	5.71E-20	8.66E-17	1.13E-13	1.31E-16	0.00E+00

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 41
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Pu-241	Pu-241	1.00E+00	5.14E-03	4.20E-03	1.12E-03	2.62E-15	0.00E+00
Pu-241	Pu-241	2.45E-05	1.26E-07	1.03E-07	2.75E-08	6.41E-20	0.00E+00
Pu-241	ΣDOSE(j)		5.14E-03	4.20E-03	1.12E-03	2.62E-15	0.00E+00
Sr-90	Sr-90	1.00E+00	4.77E-03	4.03E-03	1.34E-03	5.59E-14	0.00E+00
Tc-99	Tc-99	1.00E+00	3.92E-03	6.68E-07	1.16E-19	0.00E+00	0.00E+00
Zn-65	Zn-65	1.00E+00	6.70E-02	1.05E-03	1.99E-15	0.00E+00	0.00E+00

BRF(i) is the branch fraction of the parent nuclide

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 42
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Ag-110m	Ag-110m	1.00E+00	3.00E-02	5.20E-04	1.87E-15	0.00E+00	0.00E+00
Am-241	Am-241	1.00E+00	6.65E-02	6.61E-02	6.33E-02	4.06E-02	1.29E-02
Am-241	Pu-241	1.00E+00	0.00E+00	4.21E-02	1.79E-01	1.52E-01	4.81E-02
Am-241	ΣS(j):		6.65E-02	1.08E-01	2.42E-01	1.93E-01	6.10E-02
Np-237	Am-241	1.00E+00	0.00E+00	8.15E-08	4.33E-07	5.27E-07	1.67E-07
Np-237	Pu-241	1.00E+00	0.00E+00	2.72E-08	8.21E-07	1.97E-06	6.25E-07
Np-237	Pu-241	2.45E-05	0.00E+00	1.98E-10	5.71E-10	9.02E-13	7.38E-21
Np-237	ΣS(j):		0.00E+00	1.09E-07	1.25E-06	2.50E-06	7.91E-07
U-233	Am-241	1.00E+00	0.00E+00	7.22E-13	3.13E-11	4.65E-10	3.11E-10
U-233	Pu-241	1.00E+00	0.00E+00	1.62E-13	4.19E-11	1.63E-09	1.16E-09
U-233	Pu-241	2.45E-05	0.00E+00	1.81E-15	5.36E-14	8.20E-14	6.42E-15
U-233	ΣS(j):		0.00E+00	8.86E-13	7.32E-11	2.09E-09	1.47E-09
Th-229	Am-241	1.00E+00	0.00E+00	9.19E-17	3.18E-14	7.31E-12	3.35E-11
Th-229	Pu-241	1.00E+00	0.00E+00	1.56E-17	3.32E-14	2.33E-11	1.19E-10
Th-229	Pu-241	2.45E-05	0.00E+00	2.34E-19	6.12E-17	2.87E-15	4.34E-15
Th-229	ΣS(j):		0.00E+00	1.08E-16	6.51E-14	3.07E-11	1.53E-10
C-14	C-14	1.00E+00	4.70E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 42 (cont)
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Cm-243	Cm-243	9.98E-01	6.00E-02	5.44E-02	2.89E-02	4.04E-05	1.61E-12
Cm-243	Cm-243	2.40E-03	1.44E-04	1.31E-04	6.95E-05	9.72E-08	3.87E-15
Cm-243	ΣS(j):		6.01E-02	5.45E-02	2.90E-02	4.05E-05	1.61E-12
Pu-239	Cm-243	9.98E-01	0.00E+00	6.58E-06	3.67E-05	6.79E-05	6.05E-05
Pu-239	Cm-243	2.40E-03	0.00E+00	3.02E-12	1.39E-10	3.99E-09	1.33E-08
Pu-239	Pu-239	1.00E+00	4.00E-02	4.00E-02	3.98E-02	3.81E-02	3.39E-02
Pu-239	ΣS(j):		4.00E-02	4.00E-02	3.98E-02	3.81E-02	3.40E-02
U-235	Cm-243	9.98E-01	0.00E+00	1.31E-14	5.85E-13	1.13E-11	1.66E-11
U-235	Cm-243	2.40E-03	0.00E+00	3.99E-21	1.41E-18	3.90E-16	2.68E-15
U-235	Pu-239	1.00E+00	0.00E+00	1.56E-10	1.12E-09	6.99E-09	9.32E-09
U-235	ΣS(j):		0.00E+00	1.56E-10	1.12E-09	7.00E-09	9.33E-09
Pa-231	Cm-243	9.98E-01	0.00E+00	3.73E-19	1.31E-16	3.30E-14	1.69E-13
Pa-231	Cm-243	2.40E-03	0.00E+00	8.47E-26	2.31E-22	7.36E-19	1.68E-17
Pa-231	Pu-239	1.00E+00	0.00E+00	6.62E-15	3.57E-13	2.32E-11	9.86E-11
Pa-231	ΣS(j):		0.00E+00	6.62E-15	3.57E-13	2.32E-11	9.88E-11
Ac-227	Cm-243	9.98E-01	0.00E+00	1.16E-20	2.70E-17	2.67E-14	1.62E-13
Ac-227	Cm-243	2.40E-03	0.00E+00	2.12E-27	3.89E-23	5.40E-19	1.54E-17
Ac-227	Pu-239	1.00E+00	0.00E+00	2.73E-16	9.16E-14	1.93E-11	9.45E-11
Ac-227	ΣS(j):		0.00E+00	2.73E-16	9.16E-14	1.94E-11	9.47E-11
Am-243	Cm-243	2.40E-03	0.00E+00	5.16E-08	2.88E-07	5.37E-07	4.90E-07

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 43
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/ g t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Cm-244	Cm-244	1.00E+00	6.01E-02	5.15E-02	1.89E-02	5.61E-07	1.03E-18
Pu-240	Cm-244	1.00E+00	0.00E+00	2.36E-05	1.13E-04	1.51E-04	1.19E-04
Pu-240	Pu-240	1.00E+00	4.00E-02	4.00E-02	3.96E-02	3.62E-02	2.86E-02
Pu-240	ΣS(j):		4.00E-02	4.00E-02	3.97E-02	3.63E-02	2.87E-02
U-236	Cm-244	1.00E+00	0.00E+00	1.42E-12	5.40E-11	4.59E-10	4.00E-10
U-236	Pu-240	1.00E+00	0.00E+00	4.65E-09	3.09E-08	1.13E-07	9.60E-08
U-236	ΣS(j):		0.00E+00	4.65E-09	3.10E-08	1.13E-07	9.64E-08
Th-232	Cm-244	1.00E+00	0.00E+00	9.47E-23	2.98E-20	4.42E-18	1.97E-17
Th-232	Pu-240	1.00E+00	0.00E+00	4.62E-19	2.40E-17	1.21E-15	4.89E-15
Th-232	ΣS(j):		0.00E+00	4.62E-19	2.40E-17	1.22E-15	4.91E-15
Ra-228	Cm-244	1.00E+00	0.00E+00	1.04E-23	1.53E-20	4.02E-18	1.85E-17
Ra-228	Pu-240	1.00E+00	0.00E+00	6.58E-20	1.41E-17	1.11E-15	4.60E-15
Ra-228	ΣS(j):		0.00E+00	6.58E-20	1.41E-17	1.11E-15	4.62E-15
Th-228	Cm-244	1.00E+00	0.00E+00	2.47E-24	1.16E-20	3.96E-18	1.85E-17
Th-228	Pu-240	1.00E+00	0.00E+00	1.87E-20	1.13E-17	1.09E-15	4.59E-15
Th-228	ΣS(j):		0.00E+00	1.87E-20	1.14E-17	1.10E-15	4.61E-15
Co-60	Co-60	1.00E+00	5.72E-01	3.37E-01	1.09E-02	3.67E-18	0.00E+00

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 43
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/ g t= 0.000E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Cs-134	Cs-134	1.00E+00	2.22E-02	5.78E-03	9.20E-07	0.00E+00	0.00E+00
Cs-137	Cs-137	1.00E+00	6.68E-01	6.08E-01	3.29E-01	5.68E-04	3.90E-11
Fe-55	Fe-55	1.00E+00	1.76E+00	6.29E-01	7.85E-04	5.47E-34	0.00E+00
H-3	H-3	1.00E+00	4.90E-02	2.94E-16	0.00E+00	0.00E+00	0.00E+00
I-129	I-129	1.00E+00	2.60E-01	5.63E-02	2.71E-06	0.00E+00	0.00E+00
Mn-54	Mn-54	1.00E+00	3.70E-02	1.44E-03	9.62E-13	0.00E+00	0.00E+00
Ni-59	Ni-59	1.00E+00	2.35E+00	2.35E+00	2.32E+00	2.08E+00	1.55E+00
Ni-63	Ni-63	1.00E+00	4.00E-01	3.88E-01	3.18E-01	4.00E-02	1.85E-04
Pu-238	Pu-238	1.00E+00	4.50E-02	4.36E-02	3.53E-02	3.93E-03	1.33E-05
U-234	Pu-238	1.00E+00	0.00E+00	4.93E-07	2.95E-06	2.88E-06	2.35E-08
Th-230	Pu-238	1.00E+00	0.00E+00	8.98E-12	4.36E-10	1.12E-08	1.52E-08
Ra-226	Pu-238	1.00E+00	0.00E+00	5.18E-15	1.87E-12	4.12E-10	9.35E-10
Pb-210	Pu-238	1.00E+00	0.00E+00	1.57E-16	3.68E-13	3.10E-10	8.13E-10

RESRAD, Version 6.21 T« Limit = 0.5 year 06/15/2004 06:06 Page 44
Summary : Evaluation of Potential Dose from Discarded Radionuclides
File : DiscDose-All.RAD

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.00E+00	4.00E+00	3.00E+01	3.00E+02	1.00E+03
Pu-241	Pu-241	1.00E+00	7.25E+00	5.98E+00	1.70E+00	3.62E-06	7.18E-21
Pu-241	Pu-241	2.45E-05	1.78E-04	1.46E-04	4.16E-05	8.88E-11	1.76E-25
Pu-241	ΣS(j):		7.25E+00	5.98E+00	1.70E+00	3.62E-06	7.18E-21
Sr-90	Sr-90	1.00E+00	1.30E-02	1.11E-02	4.03E-03	1.07E-07	1.47E-19
Tc-99	Tc-99	1.00E+00	3.10E-01	5.22E-05	1.55E-29	0.00E+00	0.00E+00
Zn-65	Zn-65	1.00E+00	6.87E-02	1.08E-03	2.06E-15	0.00E+00	0.00E+00

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 76.21 seconds

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 1
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary ... 2
Site-Specific Parameter Summary 4
Summary of Pathway Selections 10
Contaminated Zone and Total Dose Summary 11
Total Dose Components
Time = 0.000E+00 12
Time = 1.000E+00 13
Time = 3.000E+00 14
Time = 1.000E+01 15
Time = 3.000E+01 16
Time = 1.000E+02 17
Time = 3.000E+02 18
Time = 1.000E+03 19
Dose/Source Ratios Summed Over All Pathways 20
Single Radionuclide Soil Guidelines 20
Dose Per Nuclide Summed Over All Pathways 22
Soil Concentration Per Nuclide 23

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 2
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Dose Conversion Factor (and Related) Parameter Summary
File: BRP Dose Modeling

Menu	Parameter	Current Value	Default	Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Co-60	2.19E-04	2.19E-04	DCF2(1)
B-1	Cs-137+D	3.19E-05	3.19E-05	DCF2(2)
B-1	Eu-152	2.21E-04	2.21E-04	DCF2(3)
B-1	Eu-154	2.86E-04	2.86E-04	DCF2(5)
B-1	Eu-155	4.14E-05	4.14E-05	DCF2(6)
B-1	Fe-55	2.69E-06	2.69E-06	DCF2(7)
B-1	Gd-152	2.43E-01	2.43E-01	DCF2(8)
B-1	H-3	6.40E-08	6.40E-08	DCF2(9)
B-1	Mn-54	6.70E-06	6.70E-06	DCF2(10)
B-1	Sr-90+D	1.31E-03	1.31E-03	DCF2(11)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Co-60	2.69E-05	2.69E-05	DCF3(1)
D-1	Cs-137+D	5.00E-05	5.00E-05	DCF3(2)
D-1	Eu-152	6.48E-06	6.48E-06	DCF3(3)
D-1	Eu-154	9.55E-06	9.55E-06	DCF3(5)
D-1	Eu-155	1.53E-06	1.53E-06	DCF3(6)
D-1	Fe-55	6.07E-07	6.07E-07	DCF3(7)
D-1	Gd-152	1.61E-04	1.61E-04	DCF3(8)
D-1	H-3	6.40E-08	6.40E-08	DCF3(9)

Page 2 (cont)

D-1	Mn-54	2.77E-06	2.77E-06	DCF3(10)
D-1	Sr-90+D	1.53E-04	1.53E-04	DCF3(11)
D-34	Food transfer factors:			
D-34	Co-60 , plant/soil concentration ratio, dimensionless	7.90E-02	8.00E-02	RTF(1,1)
D-34	Co-60 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.00E-02	2.00E-02	RTF(1,2)
D-34	Co-60 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.00E-03	2.00E-03	RTF(1,3)
D-34				
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.00E-02	4.00E-02	RTF(2,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.00E-02	3.00E-02	RTF(2,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	8.00E-03	RTF(2,3)
D-34				
D-34	Eu-152 , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(3,1)
D-34	Eu-152 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.00E-03	2.00E-03	RTF(3,2)
D-34	Eu-152 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.99E-05	2.00E-05	RTF(3,3)
D-34				
D-34	Eu-154 , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(5,1)
D-34	Eu-154 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.00E-03	2.00E-03	RTF(5,2)
D-34	Eu-154 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.99E-05	2.00E-05	RTF(5,3)
D-34				
D-34	Eu-155 , plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(6,1)
D-34	Eu-155 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.00E-03	2.00E-03	RTF(6,2)
D-34	Eu-155 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.99E-05	2.00E-05	RTF(6,3)
D-34				
D-34	Fe-55 , plant/soil concentration ratio, dimensionless	1.00E-03	1.00E-03	RTF(7,1)
D-34	Fe-55 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.00E-02	2.00E-02	RTF(7,2)
D-34	Fe-55 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	0.00E+00	3.00E-04	RTF(7,3)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 3
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: BRP Dose Modeling

Menu		Parameter	Current Value	Parameter Default	Name
D-34	Gd-152	plant/soil concentration ratio, dimensionless	2.00E-03	2.50E-03	RTF(8,1)
D-34	Gd-152	beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.00E-03	2.00E-03	RTF(8,2)
D-34	Gd-152	milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.01E-05	2.00E-05	RTF(8,3)
D-34					
D-34	H-3	plant/soil concentration ratio, dimensionless	4.80E+00	4.80E+00	RTF(9,1)
D-34	H-3	beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.20E-02	1.20E-02	RTF(9,2)
D-34	H-3	milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	1.00E-02	RTF(9,3)
D-34					
D-34	Mn-54	plant/soil concentration ratio, dimensionless	2.99E-01	3.00E-01	RTF(10,1)
D-34	Mn-54	beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-03	5.00E-04	RTF(10,2)
D-34	Mn-54	milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.00E-02	3.00E-04	RTF(10,3)
D-34					
D-34	Sr-90+D	plant/soil concentration ratio, dimensionless	5.89E-01	3.00E-01	RTF(11,1)
D-34	Sr-90+D	beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.00E-02	8.00E-03	RTF(11,2)
D-34	Sr-90+D	milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.00E-03	2.00E-03	RTF(11,3)
D-5	Bioaccumuation factors,	fresh water, L/kg:			
D-5	Co-60	fish	2.97E+02	3.00E+02	BIOFAC(1,1)
D-5	Co-60	crustacea and mollusks	2.00E+02	2.00E+02	BIOFAC(1,2)
D-5					
D-5	Cs-137+D	fish	1.99E+03	2.00E+03	BIOFAC(2,1)
					Page 3 (cont)
D-5	Cs-137+D	crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(2,2)

Page 3 (cont)

Menu		Parameter	Current Value	Parameter Default	Name
D-5	Eu-152	fish	4.92E+01	5.00E+01	BIOFAC(3,1)
D-5	Eu-152	crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(3,2)
D-5					
D-5	Eu-154	fish	4.92E+01	5.00E+01	BIOFAC(5,1)
D-5	Eu-154	crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(5,2)
D-5					
D-5	Eu-155	fish	4.92E+01	5.00E+01	BIOFAC(6,1)
D-5	Eu-155	crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(6,2)
D-5					
D-5	Fe-55	fish	1.99E+02	2.00E+02	BIOFAC(7,1)
D-5	Fe-55	crustacea and mollusks	3.20E+03	3.20E+03	BIOFAC(7,2)
D-5					
D-5	Gd-152	fish	2.44E+01	2.50E+01	BIOFAC(8,1)
D-5	Gd-152	crustacea and mollusks	1.00E+03	1.00E+03	BIOFAC(8,2)
D-5					
D-5	H-3	fish	1.00E+00	1.00E+00	BIOFAC(9,1)
D-5	H-3	crustacea and mollusks	1.00E+00	1.00E+00	BIOFAC(9,2)
D-5					
D-5	Mn-54	fish	4.00E+02	4.00E+02	BIOFAC(10,1)
D-5	Mn-54	crustacea and mollusks	9.00E+04	9.00E+04	BIOFAC(10,2)
D-5					
D-5	Sr-90+D	fish	6.00E+01	6.00E+01	BIOFAC(11,1)
D-5	Sr-90+D	crustacea and mollusks	1.00E+02	1.00E+02	BIOFAC(11,2)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 4
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
R011	Area of contaminated zone (m**2)	8.09E+03	1.00E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.50E+00	2.00E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.02E+02	1.00E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.42E+01	2.50E+01	---	BRDL
R011	Time since placement of material (yr)	0.00E+00	0.00E+00	---	TI
R011	Times for calculations (yr)	1.00E+00	1.00E+00	---	T(2)
R011	Times for calculations (yr)	3.00E+00	3.00E+00	---	T(3)
R011	Times for calculations (yr)	1.00E+01	1.00E+01	---	T(4)
R011	Times for calculations (yr)	3.00E+01	3.00E+01	---	T(5)
R011	Times for calculations (yr)	1.00E+02	1.00E+02	---	T(6)
R011	Times for calculations (yr)	3.00E+02	3.00E+02	---	T(7)
R011	Times for calculations (yr)	1.00E+03	1.00E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Co-60	1.00E+00	0.00E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Cs-137	1.00E+00	0.00E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Eu-152	1.00E+00	0.00E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Eu-154	1.00E+00	0.00E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Eu-155	1.00E+00	0.00E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Fe-55	1.00E+00	0.00E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): H-3	1.00E+00	0.00E+00	---	S1(9)

Page 4 (cont)

R012	Initial principal radionuclide (pCi/g): Mn-54	1.00E+00	0.00E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): Sr-90	1.00E+00	0.00E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Co-60	not used	0.00E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.00E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Eu-152	not used	0.00E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Eu-154	not used	0.00E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Eu-155	not used	0.00E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Fe-55	not used	0.00E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): H-3	not used	0.00E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): Mn-54	not used	0.00E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): Sr-90	not used	0.00E+00	---	W1(11)
R013	Cover depth (m)	0.00E+00	0.00E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.50E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.00E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.75E+00	1.50E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.00E-03	1.00E-03	---	VCZ
R013	Contaminated zone total porosity	3.51E-01	4.00E-01	---	TPCZ
R013	Contaminated zone field capacity	2.63E-01	2.00E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.36E+02	1.00E+01	---	HCCZ
R013	Contaminated zone b parameter	4.05E+00	5.30E+00	---	BCZ
R013	Average annual wind speed (m/sec)	5.00E+00	2.00E+00	---	WIND
R013	Humidity in air (g/m**3)	7.22E+00	8.00E+00	---	HUMID
R013	Evapotranspiration coefficient	6.24E-01	5.00E-01	---	EVAPTR
R013	Precipitation (m/yr)	8.00E-01	1.00E+00	---	PRECIP
R013	Irrigation (m/yr)	2.00E-01	2.00E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	4.49E-01	2.00E-01	---	RUNOFF

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 5
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
R011	Area of contaminated zone (m**2)	8.09E+03	1.00E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.50E+00	2.00E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.02E+02	1.00E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.42E+01	2.50E+01	---	BRDL
R011	Time since placement of material (yr)	0.00E+00	0.00E+00	---	TI
R011	Times for calculations (yr)	1.00E+00	1.00E+00	---	T(2)
R011	Times for calculations (yr)	3.00E+00	3.00E+00	---	T(3)
R011	Times for calculations (yr)	1.00E+01	1.00E+01	---	T(4)
R011	Times for calculations (yr)	3.00E+01	3.00E+01	---	T(5)
R011	Times for calculations (yr)	1.00E+02	1.00E+02	---	T(6)
R011	Times for calculations (yr)	3.00E+02	3.00E+02	---	T(7)
R011	Times for calculations (yr)	1.00E+03	1.00E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Co-60	1.00E+00	0.00E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Cs-137	1.00E+00	0.00E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Eu-152	1.00E+00	0.00E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Eu-154	1.00E+00	0.00E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Eu-155	1.00E+00	0.00E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Fe-55	1.00E+00	0.00E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): H-3	1.00E+00	0.00E+00	---	S1(9)
					Page 5 (cont)
R012	Initial principal radionuclide (pCi/g): Mn-54	1.00E+00	0.00E+00	---	S1(10)

Page 5 (cont)

R012	Initial principal radionuclide (pCi/g): Sr-90	1.00E+00	0.00E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Co-60	not used	0.00E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.00E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Eu-152	not used	0.00E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Eu-154	not used	0.00E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Eu-155	not used	0.00E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Fe-55	not used	0.00E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): H-3	not used	0.00E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): Mn-54	not used	0.00E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): Sr-90	not used	0.00E+00	---	W1(11)
R013	Cover depth (m)	0.00E+00	0.00E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.50E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.00E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.75E+00	1.50E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.00E-03	1.00E-03	---	VCZ
R013	Contaminated zone total porosity	3.51E-01	4.00E-01	---	TPCZ
R013	Contaminated zone field capacity	2.63E-01	2.00E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.36E+02	1.00E+01	---	HCCZ
R013	Contaminated zone b parameter	4.05E+00	5.30E+00	---	BCZ
R013	Average annual wind speed (m/sec)	5.00E+00	2.00E+00	---	WIND
R013	Humidity in air (g/m**3)	7.22E+00	8.00E+00	---	HUMID
R013	Evapotranspiration coefficient	6.24E-01	5.00E-01	---	EVAPTR
R013	Precipitation (m/yr)	8.00E-01	1.00E+00	---	PRECIP
R013	Irrigation (m/yr)	2.00E-01	2.00E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	4.49E-01	2.00E-01	---	RUNOFF

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 6
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
R016	Distribution coefficients for Co-60				
R016	Contaminated zone (cm**3/g)	1.28E+03	1.00E+03	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.31E+02	1.00E+03	---	DCNUCU(1,1)
R016	Unsaturated zone 2 (cm**3/g)	2.34E+02	1.00E+03	---	DCNUCU(1,2)
R016	Unsaturated zone 3 (cm**3/g)	2.31E+02	1.00E+03	---	DCNUCU(1,3)
R016	Unsaturated zone 4 (cm**3/g)	2.30E+02	1.00E+03	---	DCNUCU(1,4)
R016	Saturated zone (cm**3/g)	2.32E+02	1.00E+03	---	DCNUCS(1)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	7.15E-05	ALEACH(1)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	2.13E+03	1.00E+03	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	4.38E+02	1.00E+03	---	DCNUCU(2,1)
R016	Unsaturated zone 2 (cm**3/g)	4.44E+02	1.00E+03	---	DCNUCU(2,2)
R016	Unsaturated zone 3 (cm**3/g)	4.38E+02	1.00E+03	---	DCNUCU(2,3)
R016	Unsaturated zone 4 (cm**3/g)	4.38E+02	1.00E+03	---	DCNUCU(2,4)
R016	Saturated zone (cm**3/g)	4.40E+02	1.00E+03	---	DCNUCS(2)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.31E-05	ALEACH(2)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Eu-152				
R016	Contaminated zone (cm**3/g)	7.19E+03	-1	---	DCNUCC(3)
					Page 6 (cont)
R016	Unsaturated zone 1 (cm**3/g)	8.09E+02	-1	---	DCNUCU(3,1)

Page 6 (cont)

R016	Unsaturated zone 2 (cm**3/g)	8.24E+02	-1	---	DCNUCU(3,2)
R016	Unsaturated zone 3 (cm**3/g)	8.09E+02	-1	---	DCNUCU(3,3)
R016	Unsaturated zone 4 (cm**3/g)	8.08E+02	-1	---	DCNUCU(3,4)
R016	Saturated zone (cm**3/g)	8.14E+02	-1	---	DCNUCS(3)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.28E-05	ALEACH(3)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(3)
R016	Distribution coefficients for Eu-154				
R016	Contaminated zone (cm**3/g)	7.19E+03	-1	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	8.09E+02	-1	---	DCNUCU(5,1)
R016	Unsaturated zone 2 (cm**3/g)	8.24E+02	-1	---	DCNUCU(5,2)
R016	Unsaturated zone 3 (cm**3/g)	8.09E+02	-1	---	DCNUCU(5,3)
R016	Unsaturated zone 4 (cm**3/g)	8.08E+02	-1	---	DCNUCU(5,4)
R016	Saturated zone (cm**3/g)	8.14E+02	-1	---	DCNUCS(5)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.28E-05	ALEACH(5)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(5)
R016	Distribution coefficients for Eu-155				
R016	Contaminated zone (cm**3/g)	7.19E+03	-1	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	8.09E+02	-1	---	DCNUCU(6,1)
R016	Unsaturated zone 2 (cm**3/g)	8.24E+02	-1	---	DCNUCU(6,2)
R016	Unsaturated zone 3 (cm**3/g)	8.09E+02	-1	---	DCNUCU(6,3)
R016	Unsaturated zone 4 (cm**3/g)	8.08E+02	-1	---	DCNUCU(6,4)
R016	Saturated zone (cm**3/g)	8.14E+02	-1	---	DCNUCS(6)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.28E-05	ALEACH(6)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(6)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 7
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
R016	Distribution coefficients for Fe-55				
R016	Contaminated zone (cm**3/g)	1.25E+03	1.00E+03	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	2.04E+02	1.00E+03	---	DCNUCU(7,1)
R016	Unsaturated zone 2 (cm**3/g)	2.07E+02	1.00E+03	---	DCNUCU(7,2)
R016	Unsaturated zone 3 (cm**3/g)	2.04E+02	1.00E+03	---	DCNUCU(7,3)
R016	Unsaturated zone 4 (cm**3/g)	2.04E+02	1.00E+03	---	DCNUCU(7,4)
R016	Saturated zone (cm**3/g)	2.05E+02	1.00E+03	---	DCNUCS(7)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	7.34E-05	ALEACH(7)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(7)
R016	Distribution coefficients for H-3				
R016	Contaminated zone (cm**3/g)	4.30E-02	0.00E+00	---	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	6.00E-02	0.00E+00	---	DCNUCU(9,1)
R016	Unsaturated zone 2 (cm**3/g)	6.00E-02	0.00E+00	---	DCNUCU(9,2)
R016	Unsaturated zone 3 (cm**3/g)	6.00E-02	0.00E+00	---	DCNUCU(9,3)
R016	Unsaturated zone 4 (cm**3/g)	4.30E-02	0.00E+00	---	DCNUCU(9,4)
R016	Saturated zone (cm**3/g)	6.00E-02	0.00E+00	---	DCNUCS(9)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.75E-01	ALEACH(9)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(9)

Page 7 (cont)

R016	Distribution coefficients for Mn-54				
R016	Contaminated zone (cm**3/g)	7.33E+02	2.00E+02	---	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	1.55E+02	2.00E+02	---	DCNUCU(10,1)
R016	Unsaturated zone 2 (cm**3/g)	1.57E+02	2.00E+02	---	DCNUCU(10,2)
R016	Unsaturated zone 3 (cm**3/g)	1.55E+02	2.00E+02	---	DCNUCU(10,3)
R016	Unsaturated zone 4 (cm**3/g)	1.55E+02	2.00E+02	---	DCNUCU(10,4)
R016	Saturated zone (cm**3/g)	1.56E+02	2.00E+02	---	DCNUCS(10)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.25E-04	ALEACH(10)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(10)
R016	Distribution coefficients for Sr-90				
R016	Contaminated zone (cm**3/g)	1.31E+02	3.00E+01	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	3.10E+01	3.00E+01	---	DCNUCU(11,1)
R016	Unsaturated zone 2 (cm**3/g)	3.14E+01	3.00E+01	---	DCNUCU(11,2)
R016	Unsaturated zone 3 (cm**3/g)	3.10E+01	3.00E+01	---	DCNUCU(11,3)
R016	Unsaturated zone 4 (cm**3/g)	3.10E+01	3.00E+01	---	DCNUCU(11,4)
R016	Saturated zone (cm**3/g)	3.11E+01	3.00E+01	---	DCNUCS(11)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	7.00E-04	ALEACH(11)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(11)
R016	Distribution coefficients for daughter Gd-152				
R016	Contaminated zone (cm**3/g)	7.19E+03	-1	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	8.09E+02	-1	---	DCNUCU(8,1)
R016	Unsaturated zone 2 (cm**3/g)	8.24E+02	-1	---	DCNUCU(8,2)
R016	Unsaturated zone 3 (cm**3/g)	8.09E+02	-1	---	DCNUCU(8,3)
R016	Unsaturated zone 4 (cm**3/g)	8.08E+02	-1	---	DCNUCU(8,4)
R016	Saturated zone (cm**3/g)	8.14E+02	-1	---	DCNUCS(8)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.28E-05	ALEACH(8)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(8)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 8
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
R017	Inhalation rate (m**3/yr)	8.57E+03	8.40E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.35E-05	1.00E-04	---	MLINH
R017	Exposure duration	3.00E+01	3.00E+01	---	ED
R017	Shielding factor, inhalation	5.50E-01	4.00E-01	---	SHF3
R017	Shielding factor, external gamma	3.97E-01	7.00E-01	---	SHF1
R017	Fraction of time spent indoors	6.67E-01	5.00E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.50E-01	2.50E-01	---	FOTD
R017	Shape factor flag, external gamma	1.00E+00	1.00E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.00E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.07E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.00E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.00E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.00E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.00E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.00E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.00E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.00E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.00E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.00E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.00E+00	---	RAD_SHAPE(12)

Page 8 (cont)

R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.00E+00	---	FRACA(1)
R017	Ring 2	not used	2.73E-01	---	FRACA(2)
R017	Ring 3	not used	0.00E+00	---	FRACA(3)
R017	Ring 4	not used	0.00E+00	---	FRACA(4)
R017	Ring 5	not used	0.00E+00	---	FRACA(5)
R017	Ring 6	not used	0.00E+00	---	FRACA(6)
R017	Ring 7	not used	0.00E+00	---	FRACA(7)
R017	Ring 8	not used	0.00E+00	---	FRACA(8)
R017	Ring 9	not used	0.00E+00	---	FRACA(9)
R017	Ring 10	not used	0.00E+00	---	FRACA(10)
R017	Ring 11	not used	0.00E+00	---	FRACA(11)
R017	Ring 12	not used	0.00E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	2.05E+02	1.60E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.40E+01	1.40E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.20E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.30E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.40E+00	5.40E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.00E-01	9.00E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.82E+01	3.65E+01	---	SOIL
R018	Drinking water intake (L/yr)	4.09E+02	5.10E+02	---	DWI
R018	Contamination fraction of drinking water	1.00E+00	1.00E+00	---	FDW
R018	Contamination fraction of household water	not used	1.00E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.00E+00	---	FLW
R018	Contamination fraction of irrigation water	1.00E+00	1.00E+00	---	FIRW
R018	Contamination fraction of aquatic food	4.48E-01	5.00E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	5.00E-01	FPLANT

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 9
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.80E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.50E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.00E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.60E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.00E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.00E-04	1.00E-04	---	MLFD
R019	Depth of soil mixing layer (m)	2.32E-01	1.50E-01	---	DM
R019	Depth of roots (m)	1.22E+00	9.00E-01	---	DROOT
R019	Drinking water fraction from ground water	1.00E+00	1.00E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.00E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.00E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.00E+00	1.00E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	1.75E+00	7.00E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.50E+00	1.50E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.10E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.70E-01	1.70E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.50E-01	2.50E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.00E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.00E-01	1.00E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.00E+00	1.00E+00	---	TIV(2)

Page 9 (cont)

R19B	Translocation Factor for Fodder	not used	1.00E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.50E-01	2.50E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.50E-01	2.50E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.50E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.50E-01	2.50E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	5.81E-01	2.50E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.50E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	3.28E+01	2.00E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.00E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.00E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.00E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.80E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.00E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.00E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.00E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.00E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.00E-01	---	AVFG5
C14	DCF correction factor for gaseous forms of C14	not used	8.89E+01	---	CO2F
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.40E+01	1.40E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.00E+00	1.00E+00	---	STOR_T(2)
STOR	Milk	1.00E+00	1.00E+00	---	STOR_T(3)
STOR	Meat and poultry	2.00E+01	2.00E+01	---	STOR_T(4)
STOR	Fish	7.00E+00	7.00E+00	---	STOR_T(5)

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 10
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	Current Value	Parameter Default	RESRAD (if differs)	Name
STOR	Crustacea and mollusks	7.00E+00	7.00E+00	---	STOR_T(6)
STOR	Well water	1.00E+00	1.00E+00	---	STOR_T(7)
STOR	Surface water	1.00E+00	1.00E+00	---	STOR_T(8)
STOR	Livestock fodder	4.50E+01	4.50E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.50E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.40E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.00E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.00E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.00E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.00E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.00E-06	---	DIFCV
R021	in foundation material	not used	3.00E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.00E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.00E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.00E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.50E+00	---	HRM
R021	Building interior area factor	not used	0.00E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.50E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.50E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	1	---	---	KYMAX

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 10 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 11
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Contaminated Zone Dimensions	
Area:	8094.00 square meters
Thickness:	1.50 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
Co-60	1.00E+00
Cs-137	1.00E+00
Eu-152	1.00E+00
Eu-154	1.00E+00
Eu-155	1.00E+00
Fe-55	1.00E+00
H-3	1.00E+00
Mn-54	1.00E+00
Sr-90	1.00E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.418E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.00E+00	1.00E00+	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
TDOSE(t):	2.79E+01	2.52E+01	2.18E+01	1.47E+01	6.77E+00	1.04E+00	7.93E-03	2.56E-10
M(t):	1.15E+00	1.04E+00	9.00E-01	6.09E-01	2.80E-01	4.31E-02	3.28E-04	1.06E-11

Maximum TDOSE(t): 2.785E+01 mrem/yr at t = 0.000E+00 years

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 12
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	7.32E+00	0.2627	1.68E-06	0	0.00E+00	0	2.18E-01	0.0078	0.00E+00	0	0.00E+00	0	4.21E-04	0
Cs-137	1.62E+00	0.058	2.58E-07	0	0.00E+00	0	2.17E-01	0.0078	0.00E+00	0	0.00E+00	0	8.25E-04	0
Eu-152	3.29E+00	0.1181	1.76E-06	0	0.00E+00	0	1.38E-03	0	0.00E+00	0	0.00E+00	0	1.05E-04	0
Eu-154	3.56E+00	0.1279	2.25E-06	0	0.00E+00	0	2.01E-03	0.0001	0.00E+00	0	0.00E+00	0	1.53E-04	0
Eu-155	8.40E-02	0.003	3.16E-07	0	0.00E+00	0	3.13E-04	0	0.00E+00	0	0.00E+00	0	2.38E-05	0
Fe-55	0.00E+00	0	1.94E-08	0	0.00E+00	0	5.86E-05	0	0.00E+00	0	0.00E+00	0	8.93E-06	0
H-3	0.00E+00	0	1.24E-04	0	0.00E+00	0	1.67E-02	0.0006	0.00E+00	0	0.00E+00	0	5.93E-07	0
Mn-54	1.70E+00	0.0611	3.75E-08	0	0.00E+00	0	6.22E-02	0.0022	0.00E+00	0	0.00E+00	0	3.17E-05	0
Sr-90	1.17E-02	0.0004	1.06E-05	0	0.00E+00	0	9.75E+00	0.3501	0.00E+00	0	0.00E+00	0	2.52E-03	0.0001
Total	1.76E+01	0.6312	1.40E-04	0	0.00E+00	0	1.03E+01	0.3686	0.00E+00	0	0.00E+00	0	4.09E-03	0.0001

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 12 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.53E+00	0.2706
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.83E+00	0.0658
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.29E+00	0.1181
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.56E+00	0.128
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	8.43E-02	0.003
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.76E-05	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.69E-02	0.0006
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.76E+00	0.0633
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.76E+00	0.3506
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.79E+01	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 13
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	6.41E+00	0.2545	1.47E-06	0	0.00E+00	0	1.91E-01	0.0076	0.00E+00	0	0.00E+00	0	3.69E-04	0
Cs-137	1.58E+00	0.0626	2.52E-07	0	0.00E+00	0	2.12E-01	0.0084	0.00E+00	0	0.00E+00	0	8.06E-04	0
Eu-152	3.12E+00	0.1238	1.67E-06	0	0.00E+00	0	1.31E-03	0.0001	0.00E+00	0	0.00E+00	0	1.00E-04	0
Eu-154	3.29E+00	0.1306	2.08E-06	0	0.00E+00	0	1.86E-03	0.0001	0.00E+00	0	0.00E+00	0	1.42E-04	0
Eu-155	7.30E-02	0.0029	2.75E-07	0	0.00E+00	0	2.72E-04	0	0.00E+00	0	0.00E+00	0	2.07E-05	0
Fe-55	0.00E+00	0	1.50E-08	0	0.00E+00	0	4.54E-05	0	0.00E+00	0	0.00E+00	0	6.91E-06	0
H-3	0.00E+00	0	3.30E-05	0	0.00E+00	0	4.49E-03	0.0002	0.00E+00	0	0.00E+00	0	1.58E-07	0
Mn-54	7.57E-01	0.03	1.67E-08	0	0.00E+00	0	2.76E-02	0.0011	0.00E+00	0	0.00E+00	0	1.41E-05	0
Sr-90	1.14E-02	0.0005	1.03E-05	0	0.00E+00	0	9.51E+00	0.3775	0.00E+00	0	0.00E+00	0	2.46E-03	0.0001
Total	1.53E+01	0.605	4.91E-05	0	0.00E+00	0	9.95E+00	0.3948	0.00E+00	0	0.00E+00	0	3.92E-03	0.0002

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 13 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.61E+00	0.2621
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.79E+00	0.0711
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.12E+00	0.1239
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.29E+00	0.1307
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.33E-02	0.0029
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.23E-05	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.53E-03	0.0002
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.84E-01	0.0311
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.53E+00	0.378
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.52E+01	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 14
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	4.93E+00	0.2265	1.13E-06	0	0.00E+00	0	1.47E-01	0.0068	0.00E+00	0	0.00E+00	0	2.84E-04	0
Cs-137	1.51E+00	0.0692	2.40E-07	0	0.00E+00	0	2.02E-01	0.0093	0.00E+00	0	0.00E+00	0	7.70E-04	0
Eu-152	2.81E+00	0.1292	1.51E-06	0	0.00E+00	0	1.18E-03	0.0001	0.00E+00	0	0.00E+00	0	9.02E-05	0
Eu-154	2.81E+00	0.1292	1.78E-06	0	0.00E+00	0	1.59E-03	0.0001	0.00E+00	0	0.00E+00	0	1.21E-04	0
Eu-155	5.52E-02	0.0025	2.08E-07	0	0.00E+00	0	2.06E-04	0	0.00E+00	0	0.00E+00	0	1.57E-05	0
Fe-55	0.00E+00	0	8.97E-09	0	0.00E+00	0	2.71E-05	0	0.00E+00	0	0.00E+00	0	4.14E-06	0
H-3	0.00E+00	0	2.34E-06	0	0.00E+00	0	3.19E-04	0	0.00E+00	0	0.00E+00	0	1.12E-08	0
Mn-54	1.50E-01	0.0069	3.30E-09	0	0.00E+00	0	5.47E-03	0.0003	0.00E+00	0	0.00E+00	0	2.79E-06	0
Sr-90	1.09E-02	0.0005	9.83E-06	0	0.00E+00	0	9.06E+00	0.4162	0.00E+00	0	0.00E+00	0	2.34E-03	0.0001
Total	1.23E+01	0.5642	1.70E-05	0	0.00E+00	0	9.42E+00	0.4326	0.00E+00	0	0.00E+00	0	3.63E-03	0.0002

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 14 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.08E+00	0.2333
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.71E+00	0.0786
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.81E+00	0.1293
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.81E+00	0.1293
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.54E-02	0.0025
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.13E-05	0
H-3	5.59E-02	0.0026	1.39E-06	0	0.00E+00	0	9.71E-03	0.0004	0.00E+00	0	0.00E+00	0	6.60E-02	0.003
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.55E-01	0.0071
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.07E+00	0.4168
Total	5.59E-02	0.0026	1.39E-06	0	0.00E+00	0	9.71E-03	0.0004	0.00E+00	0	0.00E+00	0	2.18E+01	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 15
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	1.96E+00	0.1334	4.50E-07	0	0.00E+00	0	5.85E-02	0.004	0.00E+00	0	0.00E+00	0	1.13E-04	0
Cs-137	1.28E+00	0.0871	2.05E-07	0	0.00E+00	0	1.72E-01	0.0117	0.00E+00	0	0.00E+00	0	6.54E-04	0
Eu-152	1.95E+00	0.1328	1.05E-06	0	0.00E+00	0	8.22E-04	0.0001	0.00E+00	0	0.00E+00	0	6.26E-05	0
Eu-154	1.62E+00	0.1101	1.02E-06	0	0.00E+00	0	9.15E-04	0.0001	0.00E+00	0	0.00E+00	0	6.97E-05	0
Eu-155	2.08E-02	0.0014	7.81E-08	0	0.00E+00	0	7.73E-05	0	0.00E+00	0	0.00E+00	0	5.89E-06	0
Fe-55	0.00E+00	0	1.49E-09	0	0.00E+00	0	4.50E-06	0	0.00E+00	0	0.00E+00	0	6.85E-07	0
H-3	0.00E+00	0	2.15E-10	0	0.00E+00	0	2.93E-08	0	0.00E+00	0	0.00E+00	0	1.03E-12	0
Mn-54	5.15E-04	0	1.14E-11	0	0.00E+00	0	1.88E-05	0	0.00E+00	0	0.00E+00	0	9.59E-09	0
Sr-90	9.16E-03	0.0006	8.28E-06	0	0.00E+00	0	7.63E+00	0.5185	0.00E+00	0	0.00E+00	0	1.97E-03	0.0001
Total	6.85E+00	0.4655	1.11E-05	0	0.00E+00	0	7.86E+00	0.5343	0.00E+00	0	0.00E+00	0	2.88E-03	0.0002

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 15 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.02E+00	0.1374
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.45E+00	0.0988
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.96E+00	0.1329
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.62E+00	0.1102
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	2.08E-02	0.0014
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.18E-06	0
H-3	5.27E-06	0	1.30E-10	0	0.00E+00	0	9.11E-07	0	0.00E+00	0	0.00E+00	0	6.21E-06	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.34E-04	0
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.64E+00	0.5193
Total	5.27E-06	0	1.30E-10	0	0.00E+00	0	9.11E-07	0	0.00E+00	0	0.00E+00	0	1.47E+01	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 16
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	1.41E-01	0.0209	3.24E-08	0	0.00E+00	0	4.21E-03	0.0006	0.00E+00	0	0.00E+00	0	8.12E-06	0
Cs-137	8.07E-01	0.1192	1.29E-07	0	0.00E+00	0	1.08E-01	0.016	0.00E+00	0	0.00E+00	0	4.12E-04	0.0001
Eu-152	6.91E-01	0.102	3.70E-07	0	0.00E+00	0	2.91E-04	0	0.00E+00	0	0.00E+00	0	2.21E-05	0
Eu-154	3.35E-01	0.0495	2.12E-07	0	0.00E+00	0	1.89E-04	0	0.00E+00	0	0.00E+00	0	1.44E-05	0
Eu-155	1.27E-03	0.0002	4.77E-09	0	0.00E+00	0	4.72E-06	0	0.00E+00	0	0.00E+00	0	3.60E-07	0
Fe-55	0.00E+00	0	8.75E-12	0	0.00E+00	0	2.65E-08	0	0.00E+00	0	0.00E+00	0	4.03E-09	0
H-3	0.00E+00	0	4.70E-22	0	0.00E+00	0	6.42E-20	0	0.00E+00	0	0.00E+00	0	2.26E-24	0
Mn-54	4.72E-11	0	1.04E-18	0	0.00E+00	0	1.73E-12	0	0.00E+00	0	0.00E+00	0	8.79E-16	0
Sr-90	5.61E-03	0.0008	5.07E-06	0	0.00E+00	0	4.67E+00	0.6905	0.00E+00	0	0.00E+00	0	1.21E-03	0.0002
Total	1.98E+00	0.2926	5.82E-06	0	0.00E+00	0	4.79E+00	0.7072	0.00E+00	0	0.00E+00	0	1.67E-03	0.0002

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 16 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.46E-01	0.0215
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	9.15E-01	0.1352
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.91E-01	0.1021
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.35E-01	0.0495
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.27E-03	0.0002
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	3.05E-08	0
H-3	1.24E-17	0	3.08E-22	0	0.00E+00	0	2.15E-18	0	0.00E+00	0	0.00E+00	0	1.47E-17	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.89E-11	0
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.68E+00	0.6915
Total	1.24E-17	0	3.08E-22	0	0.00E+00	0	2.15E-18	0	0.00E+00	0	0.00E+00	0	6.77E+00	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 17
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	1.41E-05	0	3.24E-12	0	0.00E+00	0	4.21E-07	0	0.00E+00	0	0.00E+00	0	8.12E-10	0
Cs-137	1.60E-01	0.153	2.55E-08	0	0.00E+00	0	2.14E-02	0.0205	0.00E+00	0	0.00E+00	0	8.15E-05	0.0001
Eu-152	1.81E-02	0.0174	9.70E-09	0	0.00E+00	0	7.62E-06	0	0.00E+00	0	0.00E+00	0	5.81E-07	0
Eu-154	1.35E-03	0.0013	8.52E-10	0	0.00E+00	0	7.62E-07	0	0.00E+00	0	0.00E+00	0	5.81E-08	0
Eu-155	7.15E-08	0	2.69E-13	0	0.00E+00	0	2.66E-10	0	0.00E+00	0	0.00E+00	0	2.03E-11	0
Fe-55	0.00E+00	0	1.37E-19	0	0.00E+00	0	4.13E-16	0	0.00E+00	0	0.00E+00	0	6.29E-17	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	1.01E-03	0.001	9.12E-07	0	0.00E+00	0	8.41E-01	0.8065	0.00E+00	0	0.00E+00	0	2.18E-04	0.0002
Total	1.80E-01	0.1727	9.48E-07	0	0.00E+00	0	8.62E-01	0.827	0.00E+00	0	0.00E+00	0	3.00E-04	0.0003

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 17 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.46E-05	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.81E-01	0.1736
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.81E-02	0.0174
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.35E-03	0.0013
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.18E-08	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	4.76E-16	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	8.42E-01	0.8077
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.04E+00	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 18
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	5.27E-17	0	1.21E-23	0	0.00E+00	0	1.54E-18	0	0.00E+00	0	0.00E+00	0	3.03E-21	0
Cs-137	1.56E-03	0.1965	2.48E-10	0	0.00E+00	0	2.05E-04	0.0259	0.00E+00	0	0.00E+00	0	7.95E-07	0.0001
Eu-152	5.50E-07	0.0001	2.95E-13	0	0.00E+00	0	2.28E-10	0	0.00E+00	0	0.00E+00	0	1.76E-11	0
Eu-154	1.94E-10	0	1.22E-16	0	0.00E+00	0	1.08E-13	0	0.00E+00	0	0.00E+00	0	8.35E-15	0
Eu-155	5.19E-20	0	1.95E-25	0	0.00E+00	0	1.90E-22	0	0.00E+00	0	0.00E+00	0	1.47E-23	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	7.51E-06	0.0009	6.79E-09	0	0.00E+00	0	6.15E-03	0.7763	0.00E+00	0	0.00E+00	0	1.62E-06	0.0002
Total	1.57E-03	0.1975	7.04E-09	0	0.00E+00	0	6.36E-03	0.8022	0.00E+00	0	0.00E+00	0	2.42E-06	0.0003

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 18 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.42E-17	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.76E-03	0.2224
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.50E-07	0.0001
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.94E-10	0
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	5.21E-20	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.16E-03	0.7775
Total	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	7.93E-03	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 19
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-137	1.43E-10	0.5579	2.28E-17	0	0.00E+00	0	7.85E-12	0.0306	0.00E+00	0	0.00E+00	0	7.30E-14	0.0003
Eu-152	8.48E-23	0	6.76E-17	0	0.00E+00	0	4.91E-16	0	0.00E+00	0	0.00E+00	0	9.14E-17	0
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	2.67E-13	0.001	2.41E-16	0	0.00E+00	0	9.11E-11	0.3557	0.00E+00	0	0.00E+00	0	5.76E-14	0.0002
Total	1.43E-10	0.559	3.32E-16	0	0.00E+00	0	9.90E-11	0.3863	0.00E+00	0	0.00E+00	0	1.31E-13	0.0005

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 19 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Co-60	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Cs-137	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	1.51E-10	0.5888
Eu-152	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	6.50E-16	0
Eu-154	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Eu-155	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Fe-55	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
H-3	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Mn-54	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Sr-90	1.29E-11	0.0501	2.04E-14	0.0001	0.00E+00	0	1.03E-12	0.004	0.00E+00	0	0.00E+00	0	1.05E-10	0.4112
Total	1.29E-11	0.0501	2.04E-14	0.0001	0.00E+00	0	1.03E-12	0.004	0.00E+00	0	0.00E+00	0	2.56E-10	1

*Sum of all water independent and dependent pathways.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 20
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD
Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction* t=	DSR(j,t) (mrem/yr)/(pCi/g) 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Co-60	Co-60	1.00E+00	7.53E+00	6.61E+00	5.08E+00	2.02E+00	1.46E-01	1.46E-05	5.42E-17	0.00E+00
Cs-137	Cs-137	1.00E+00	1.83E+00	1.79E+00	1.71E+00	1.45E+00	9.15E-01	1.81E-01	1.76E-03	1.51E-10
Eu-152	Eu-152	7.21E-01	2.37E+00	2.25E+00	2.03E+00	1.41E+00	4.98E-01	1.31E-02	3.97E-07	6.11E-23
Eu-152	Eu-152	2.79E-01	9.18E-01	8.72E-01	7.86E-01	5.46E-01	1.93E-01	5.06E-03	1.54E-07	2.37E-23
Eu-152	Gd-152	2.79E-01	3.52E-17	1.03E-16	2.29E-16	5.79E-16	1.09E-15	1.37E-15	1.35E-15	6.50E-16
Eu-152	äDSR(j)	9.18E-01	8.72E-01	7.86E-01	5.46E-01	1.93E-01	5.06E-03	1.54E-07	6.50E-16	
Eu-154	Eu-154	1.00E+00	3.56E+00	3.29E+00	2.81E+00	1.62E+00	3.35E-01	1.35E-03	1.94E-10	2.18E-34
Eu-155	Eu-155	1.00E+00	8.43E-02	7.33E-02	5.54E-02	2.08E-02	1.27E-03	7.18E-08	5.21E-20	0.00E+00
Fe-55	Fe-55	1.00E+00	6.76E-05	5.23E-05	3.13E-05	5.18E-06	3.05E-08	4.76E-16	2.32E-38	0.00E+00
H-3	H-3	1.00E+00	1.69E-02	4.53E-03	6.60E-02	6.21E-06	1.47E-17	0.00E+00	0.00E+00	0.00E+00
Mn-54	Mn-54	1.00E+00	1.76E+00	7.84E-01	1.55E-01	5.34E-04	4.89E-11	1.14E-35	0.00E+00	0.00E+00
Sr-90	Sr-90	1.00E+00	9.76E+00	9.53E+00	9.07E+00	7.64E+00	4.68E+00	8.42E-01	6.16E-03	1.05E-10

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)*...BRF(j).
The DSR includes contribution from associated (half-life < 0.5 year) daughters.

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 20 (cont)
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.42E+01 mrem/y

Nuclide (I)	t=	0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
Co-60		3.21E+00	3.66E+00	4.76E+00	1.20E+01	1.66E+02	1.66E+06	*1.131E+15	*1.131E+15
Cs-137		1.32E+01	1.35E+01	1.41E+01	1.66E+01	2.64E+01	1.34E+02	1.37E+04	1.60E+11
Eu-152		7.35E+00	7.74E+00	8.59E+00	1.24E+01	3.50E+01	1.33E+03	4.39E+07	*1.765E+14
Eu-154		6.78E+00	7.34E+00	8.59E+00	1.49E+01	7.21E+01	1.79E+04	1.25E+11	*2.639E+14
Eu-155		2.87E+02	3.30E+02	4.36E+02	1.16E+03	1.90E+04	3.37E+08	*4.651E+14	*4.651E+14
Fe-55		3.58E+05	4.63E+05	7.73E+05	4.66E+06	7.93E+08	*2.409E+15	*2.409E+15	*2.409E+15
H-3		1.44E+03	5.34E+03	3.67E+02	3.89E+06	*9.594E+15	*9.594E+15	*9.594E+15	*9.594E+15
Mn-54		1.37E+01	3.08E+01	1.56E+02	4.53E+04	4.94E+11	*7.744E+15	*7.744E+15	*7.744E+15
Sr-90		2.48E+00	2.54E+00	2.67E+00	3.16E+00	5.17E+00	2.87E+01	3.92E+03	2.30E+11

*At specific activity limit

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 21
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Co-60	1.00E+00	0.00E+00	7.53E+00	3.21E+00	7.53E+00	3.21E+00
Cs-137	1.00E+00	0.00E+00	1.83E+00	1.32E+01	1.83E+00	1.32E+01
Eu-152	1.00E+00	0.00E+00	3.29E+00	7.35E+00	3.29E+00	7.35E+00
Eu-154	1.00E+00	0.00E+00	3.56E+00	6.78E+00	3.56E+00	6.78E+00
Eu-155	1.00E+00	0.00E+00	8.43E-02	2.87E+02	8.43E-02	2.87E+02
Fe-55	1.00E+00	0.00E+00	6.76E-05	3.58E+05	6.76E-05	3.58E+05
H-3	1.00E+00	2.88 ± 0.006	7.40E-02	3.27E+02	1.69E-02	1.44E+03
Mn-54	1.00E+00	0.00E+00	1.76E+00	1.37E+01	1.76E+00	1.37E+01
Sr-90	1.00E+00	0.00E+00	9.76E+00	2.48E+00	9.76E+00	2.48E+00

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23 Page 22
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
			DOSE(j,t), mrem/yr							
Co-60	Co-60	1.00E+00	7.53E+00	6.61E+00	5.08E+00	2.02E+00	1.46E-01	1.46E-05	5.42E-17	0.00E+00
Cs-137	Cs-137	1.00E+00	1.83E+00	1.79E+00	1.71E+00	1.45E+00	9.15E-01	1.81E-01	1.76E-03	1.51E-10
Eu-152	Eu-152	7.21E-01	2.37E+00	2.25E+00	2.03E+00	1.41E+00	4.98E-01	1.31E-02	3.97E-07	6.11E-23
Eu-152	Eu-152	2.79E-01	9.18E-01	8.72E-01	7.86E-01	5.46E-01	1.93E-01	5.06E-03	1.54E-07	2.37E-23
Eu-152	ΣDOSE(j)		3.29E+00	3.12E+00	2.81E+00	1.96E+00	6.91E-01	1.81E-02	5.50E-07	8.48E-23
Gd-152	Eu-152	2.79E-01	3.52E-17	1.03E-16	2.29E-16	5.79E-16	1.09E-15	1.37E-15	1.35E-15	6.50E-16
Eu-154	Eu-154	1.00E+00	3.56E+00	3.29E+00	2.81E+00	1.62E+00	3.35E-01	1.35E-03	1.94E-10	0.00E+00
Eu-155	Eu-155	1.00E+00	8.43E-02	7.33E-02	5.54E-02	2.08E-02	1.27E-03	7.18E-08	5.21E-20	0.00E+00
Fe-55	Fe-55	1.00E+00	6.76E-05	5.23E-05	3.13E-05	5.18E-06	3.05E-08	4.76E-16	0.00E+00	0.00E+00
H-3	H-3	1.00E+00	1.69E-02	4.53E-03	6.60E-02	6.21E-06	1.47E-17	0.00E+00	0.00E+00	0.00E+00
Mn-54	Mn-54	1.00E+00	1.76E+00	7.84E-01	1.55E-01	5.34E-04	4.89E-11	0.00E+00	0.00E+00	0.00E+00
Sr-90	Sr-90	1.00E+00	9.76E+00	9.53E+00	9.07E+00	7.64E+00	4.68E+00	8.42E-01	6.16E-03	1.05E-10

BRF(i) is the branch fraction of the parent nuclide.

Page 23

RESRAD, Version 6.21 T« Limit = 0.5 year 06/22/2004 06:23
Summary : Derivation of Surface Soil DCGL Values Using a 1.5m CZ Thickness
File : DCGL10c.RAD

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	t= 0.00E+00	1.00E+00	3.00E+00	1.00E+01	3.00E+01	1.00E+02	3.00E+02	1.00E+03
			S(j,t),pCi/g							
Co-60	Co-60	1.00E+00	1.00E+00	8.77E-01	6.74E-01	2.68E-01	1.93E-02	1.93E-06	7.20E-18	0.00E+00
Cs-137	Cs-137	1.00E+00	1.00E+00	9.77E-01	9.33E-01	7.93E-01	4.99E-01	9.88E-02	9.64E-04	8.85E-11
Eu-152	Eu-152	7.21E-01	7.21E-01	6.84E-01	6.17E-01	4.29E-01	1.51E-01	3.97E-03	1.21E-07	1.86E-23
Eu-152	Eu-152	2.79E-01	2.79E-01	2.65E-01	2.39E-01	1.66E-01	5.87E-02	1.54E-03	4.67E-08	7.20E-24
Eu-152	ΣS(j):		1.00E+00	9.49E-01	8.56E-01	5.95E-01	2.10E-01	5.51E-03	1.67E-07	2.58E-23
Gd-152	Eu-152	2.79E-01	0.00E+00	1.75E-15	4.98E-15	1.40E-14	2.72E-14	3.42E-14	3.43E-14	3.40E-14
Eu-154	Eu-154	1.00E+00	1.00E+00	9.24E-01	7.90E-01	4.55E-01	9.41E-02	3.79E-04	5.44E-11	6.12E-35
Eu-155	Eu-155	1.00E+00	1.00E+00	8.70E-01	6.58E-01	2.47E-01	1.51E-02	8.52E-07	6.18E-19	0.00E+00
Fe-55	Fe-55	1.00E+00	1.00E+00	7.74E-01	4.63E-01	7.67E-02	4.51E-04	7.04E-12	3.49E-34	0.00E+00
H-3	H-3	1.00E+00	1.00E+00	2.67E-01	1.90E-02	1.75E-06	3.86E-18	0.00E+00	0.00E+00	0.00E+00
Mn-54	Mn-54	1.00E+00	1.00E+00	4.45E-01	8.80E-02	3.03E-04	2.78E-11	6.47E-36	0.00E+00	0.00E+00
Sr-90	Sr-90	1.00E+00	1.00E+00	9.76E-01	9.29E-01	7.83E-01	4.80E-01	8.63E-02	6.42E-04	2.28E-11

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time = 1.43 seconds

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]			
			1	2	3	4
Distribution coefficient for H	1	Truncated lognormal-n	-2.81	0.5	0.001	0.999
Distribution coefficient for Mn	1	Truncated lognormal-n	5.06	2.29	0.001	0.999
Distribution coefficient for Fe	1	Truncated lognormal-n	5.34	2.67	0.001	0.999
Distribution coefficient for Co	1	Truncated lognormal-n	5.46	2.53	0.001	0.999
Distribution coefficient for Sr	1	Truncated lognormal-n	3.45	2.12	0.001	0.999
Distribution coefficient for Cs	1	Truncated lognormal-n	6.10	2.33	0.001	0.999
Distribution coefficient for Eu	1	Truncated lognormal-n	6.72	3.22	0.001	0.999
Distribution coefficient for Gd	1	Truncated lognormal-n	6.72	3.22	0.001	0.999
Density of contaminated zone	1	Truncated normal	1.52	0.230	0.001	0.999
Density of saturated zone	1	Truncated normal	1.52	0.230	0.001	0.999
Saturated zone total porosity	1	Truncated normal	0.425	0.0867	0.001	0.999
Saturated zone effective porosity	1	Truncated normal	0.355	0.0906	0.001	0.999
Saturated zone hydraulic conductivity	1	Bounded lognormal-n	2.3	2.11	0.004	9250
Unsaturated zone 1 thickness	1	Bounded lognormal-n	2.296	1.276	0.18	320
Unsaturated zone 2 thickness	1	Bounded lognormal-n	2.296	1.276	0.18	320
Unsaturated zone 3 thickness	1	Bounded lognormal-n	2.296	1.276	0.18	320
Unsaturated zone 4 thickness	1	Bounded lognormal-n	2.296	1.276	0.18	320
Unsaturated zone 5 thickness	1	Bounded lognormal-n	2.296	1.276	0.18	320
Depth of roots	1	Uniform	0.3	4.0	-	-
Plant transfer factor for H	1	Truncated lognormal-n	1.57	1.1	0.001	0.999
Plant transfer factor for Mn	1	Truncated lognormal-n	-1.20	0.9	0.001	0.999
Plant transfer factor for Fe	1	Truncated lognormal-n	-6.91	0.9	0.001	0.999
Plant transfer factor for Co	1	Truncated lognormal-n	-2.53	0.9	0.001	0.999
Plant transfer factor for Sr	1	Truncated lognormal-n	-1.20	1.0	0.001	0.999
Plant transfer factor for Cs	1	Truncated lognormal-n	-3.22	1.0	0.001	0.999
Plant transfer factor for Eu	1	Truncated lognormal-n	-6.21	1.1	0.001	0.999
Plant transfer factor for Gd	1	Truncated lognormal-n	-6.21	1.1	0.001	0.999
Concentration of H-3	2	NR	-	-	-	-
Concentration of Mn-54	2	NR	-	-	-	-
Concentration of Fe-55	2	NR	-	-	-	-
Concentration of Co-60	2	NR	-	-	-	-
Concentration of Sr-90	2	NR	-	-	-	-
Concentration of Cs-137	2	NR	-	-	-	-
Concentration of Eu-152	2	NR	-	-	-	-
Concentration of Eu-154	2	NR	-	-	-	-
Concentration of Eu-155	2	NR	-	-	-	-
Area of contaminated zone	2	NR	-	-	-	-
Thickness of contaminated zone	2	NR	-	-	-	-
Length parallel to aquifer flow	2	NR	-	-	-	-
Contaminated zone total porosity	2	Truncated normal	0.425	0.0867	0.001	0.999
Contaminated zone erosion rate	2	Continuous logarithmic	Default[3]			
Contaminated zone hydraulic conductivity	2	Bounded lognormal-n	2.3	2.11	0.004	9250
Contaminated zone b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Evapotranspiration coefficient	2	Uniform	0.5	0.75	-	-
Wind speed	2	Bounded lognormal-n	1.445	0.2419	1.4	13
Precipitation rare	2	None recommended	-	-	-	-
Runoff coefficient	2	Uniform	0.1	0.8	-	-
Saturated zone hydraulic gradient	2	Bounded lognormal-n	-5.11	1.77	7E-05	0.5
Saturated zone soil-specific b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Well-pump intake depth (below water table)	2	Triangular	6	30	10	-
Well pumping rare	2	None recommended	-	-	-	-
Unsaturated zone 1 density	2	Truncated normal	1.52	0.230	0.001	0.999
Unsaturated zone 2 density	2	Truncated normal	1.52	0.230	0.001	0.999
Unsaturated zone 3 density	2	Truncated normal	1.52	0.230	0.001	0.999
Unsaturated zone 4 density	2	Truncated normal	1.52	0.230	0.001	0.999
Unsaturated zone 5 density	2	Truncated normal	1.52	0.230	0.001	0.999

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]			
			1	2	3	4
Unsaturated zone 1 total porosity	2	Truncated normal	0.425	0.0867	0.001	0.999
Unsaturated zone 2 total porosity	2	Truncated normal	0.425	0.0867	0.001	0.999
Unsaturated zone 3 total porosity	2	Truncated normal	0.425	0.0867	0.001	0.999
Unsaturated zone 4 total porosity	2	Truncated normal	0.425	0.0867	0.001	0.999
Unsaturated zone 5 total porosity	2	Truncated normal	0.425	0.0867	0.001	0.999
Unsaturated zone 1 effective porosity	2	Truncated normal	0.355	0.0906	0.001	0.999
Unsaturated zone 2 effective porosity	2	Truncated normal	0.355	0.0906	0.001	0.999
Unsaturated zone 3 effective porosity	2	Truncated normal	0.355	0.0906	0.001	0.999
Unsaturated zone 4 effective porosity	2	Truncated normal	0.355	0.0906	0.001	0.999
Unsaturated zone 5 effective porosity	2	Truncated normal	0.355	0.0906	0.001	0.999
Unsaturated zone 1 soil-b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Unsaturated zone 2 soil-b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Unsaturated zone 3 soil-b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Unsaturated zone 4 soil-b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Unsaturated zone 5 soil-b parameter	2	Bounded lognormal-n	1.06	0.66	0.5	30
Unsaturated zone 1 hydraulic conductivity	2	Bounded lognormal-n	2.3	2.11	0.004	9250
Unsaturated zone 2 hydraulic conductivity	2	Bounded lognormal-n	2.3	2.11	0.004	9250
Unsaturated zone 3 hydraulic conductivity	2	Bounded lognormal-n	2.3	2.11	0.004	9250
Unsaturated zone 4 hydraulic conductivity	2	Bounded lognormal-n	2.3	2.11	0.004	9250
Unsaturated zone 5 hydraulic conductivity	2	Bounded lognormal-n	2.3	2.11	0.004	9250
Fruit, vegetable, and grain consumption rate	2	Triangular	135	318	178	-
Mass loading for inhalation	2	Continuous linear	Default[3]			
Indoor dust filtration factor	2	Uniform	0.15	0.95	-	-
External gamma shielding factor	2	Bounded lognormal-n	-1.3	0.59	0.044	1
Soil ingestion rate	2	Triangular	0	36.5	18.3	-
Drinking water ingestion rate	2	Truncated lognormal-n	6.015	0.489	0.001	0.999
Aquatic food contaminated fraction	2	Triangular	0	1	0.39	-
Depth of soil mixing layer	2	Triangular	0.0	0.6	0.15	-
Wet weight crop yield for non-leafy vegetables	2	Truncated lognormal-n	0.56	0.48	0.001	0.999
Weathering removal constant	2	Triangular	5.1	84	18	-
Wet foliar interception fraction for leafy vegetables	2	Triangular	0.06	0.95	0.67	-
Meat transfer factor for H	2	Truncated lognormal-n	-4.42	1.0	0.001	0.999
Meat transfer factor for Mn	2	Truncated lognormal-n	-6.91	0.7	0.001	0.999
Meat transfer factor for Fe	2	Truncated lognormal-n	-3.51	0.4	0.001	0.999
Meat transfer factor for Co	2	Truncated lognormal-n	-3.51	1.0	0.001	0.999
Meat transfer factor for Sr	2	Truncated lognormal-n	-4.61	0.4	0.001	0.999
Meat transfer factor for Cs	2	Truncated lognormal-n	-3.00	0.4	0.001	0.999
Meat transfer factor for Eu	2	Truncated lognormal-n	-6.21	1.0	0.001	0.999
Meat transfer factor for Gd	2	Truncated lognormal-n	-6.21	1.0	0.001	0.999
Milk transfer factor for H	2	Truncated lognormal-n	-4.6	0.9	0.001	0.999
Milk transfer factor for Mn	2	Truncated lognormal-n	-8.11	0.7	0.001	0.999
Milk transfer factor for Fe	2	Truncated lognormal-n	-8.11	0.7	0.001	0.999
Milk transfer factor for Co	2	Truncated lognormal-n	-6.21	0.7	0.001	0.999
Milk transfer factor for Sr	2	Truncated lognormal-n	-6.21	0.5	0.001	0.999
Milk transfer factor for Cs	2	Truncated lognormal-n	-4.61	0.5	0.001	0.999
Milk transfer factor for Eu	2	Truncated lognormal-n	-9.72	0.9	0.001	0.999
Milk transfer factor for Gd	2	Truncated lognormal-n	-9.72	0.9	0.001	0.999

Parameter	Priority[1]	Distribution	Distribution's Statistical Parameters[2]			
			1	2	3	4
H bioaccumulation factor for fish	2	Lognormal-n	0	0.1	-	-
Mn bioaccumulation factor for fish	2	Lognormal-n	6	1.1	-	-
Fe bioaccumulation factor for fish	2	Lognormal-n	5.3	1.1	-	-
Co bioaccumulation factor for fish	2	Lognormal-n	5.7	1.1	-	-
Sr bioaccumulation factor for fish	2	Lognormal-n	4.1	1.1	-	-
Cs bioaccumulation factor for fish	2	Lognormal-n	7.6	0.7	-	-
Eu bioaccumulation factor for fish	2	Lognormal-n	3.9	1.1	-	-
Gd bioaccumulation factor for fish	2	Lognormal-n	3.2	1.1	-	-
Humidity in air	3	Truncated lognormal-n	1.98	0.334	0.001	0.999
Indoor time fraction	3	Continuous linear	Default[3]			
Inhalation rate	3	Triangular	4,380	13,100	8,400	-

Notes:

[1]1 = high priority parameter, 2 = medium priority parameter, 3 = low priority parameter

[2]Distribution's Statistical Parameter
Lognormal-n: 1 = mean, 2 = standard deviation
Bounded lognormal-n: 1 = underlying mean value, 2 = underlying standard deviation, 3 = lower limit, 4 = upper limit
Truncated lognormal-n: 1 = underlying mean value, 2 = underlying standard deviation, 3 = lower quantile, 4 = upper quantile
Truncated normal: 1 = mean, 2 = standard deviation, 3 = lower quantile, 4 = upper quantile
Triangular: 1 = minimum, 2 = maximum, 3 = most likely
Uniform: 1 = minimum, 2 = maximum

[3]Default RESRAD v6.21 distribution parameters were used

NR – Not ranked, NUREG/CR-6697 did not provide statistical distributions for these parameters nor do default distributions exist in RESRAD v6.21

Rank	Uncorrelated Parameters			Correlated Parameters		
	Parameter Class[1]	Parameter	PRCC[2] Coefficient	Parameter Class[1]	Parameter	PRCC[2] Coefficient
Site-Specific Suite of Nine Radionuclides in One Calculation						
1	B	Indoor time fraction	0.94	P	Density of Contaminated Zone	0.94
2	P	External gamma shielding factor	0.71	P	K_d of Co-60 in Contaminated Zone	0.52
3	P	Plant transfer factor for Sr	0.61	P	K_d of Eu-152 in Contaminated Zone	0.36
4	P	Depth of roots	-0.55	P	K_d of Sr-90 in Contaminated Zone	0.21
5	P	Density of Contaminated Zone	0.54	P	K_d of Mn-54 in Contaminated Zone	0.14
6	P, B	Indoor dust filtration factor	-0.27	P	K_d of Cs-137 in Unsaturated Zone 3	-0.13
7	P	K_d of Sr-90 in Unsaturated Zone 4	0.27	P	K_d of Eu-152 in Unsaturated Zone 2	0.13
8	P	K_d of Co-60 in Unsaturated Zone 5	0.24	P	K_d of H-3 in Unsaturated Zone 2	0.11
9	P	K_d of Mn-54 in Unsaturated Zone 3	-0.21	P	K_d of Cs-137 in Unsaturated Zone 2	0.11
10	P	Plant transfer factor for Cs	0.21	P	K_d of Fe-55 in Contaminated Zone	0.10
Tritium Only Calculation						
1	P	Depth of roots	-0.97	P	Depth of roots	-0.97
2	P	Runoff coefficient	0.86	P	Runoff coefficient	0.80
3	M, B	Fruit, vegetable and grain consumption	0.73	M, B	Fruit, vegetable and grain consumption	0.74
4	P	Density of Contaminated Zone	0.72	P	Density of Contaminated Zone	0.66
5	P	Evapotranspiration coefficient	0.37	P	Evapotranspiration coefficient	0.40
Mn-54 Only Calculation						
1	B	Indoor time fraction	0.93	B	Indoor time fraction	0.93
2	P	External gamma shielding factor	0.69	P	External gamma shielding factor	0.68
3	P	Density of Contaminated Zone	0.52	P	Density of Contaminated Zone	0.44
4	P	K_d of Mn-54 in Contaminated Zone	0.42	P	K_d of Mn-54 in Contaminated Zone	0.36
5	P	Saturated zone hydraulic conductivity	-0.21	P	Saturated zone hydraulic conductivity	-0.23
Fe-55 Only Calculation						
1	P	Plant transfer factor for Fe	0.86	P	Depth of roots	-0.79
2	P	Depth of roots	-0.76	B	Indoor time fraction	0.64
3	B	Indoor time fraction	0.62	P	Plant transfer factor for Fe	0.63
4	P	Depth of soil mixing layer	-0.52	M, B	Soil ingestion	0.52
5	M, B	Soil ingestion	0.50	P	Depth of soil mixing layer	-0.51

Rank	Uncorrelated Parameters			Correlated Parameters		
	Parameter Class[1]	Parameter	PRCC[2] Coefficient	Parameter Class[1]	Parameter	PRCC[2] Coefficient
Co-60 Only Calculation						
1	B	Indoor time fraction	0.92	B	Indoor time fraction	0.92
2	P	External gamma shielding factor	0.65	P	External gamma shielding factor	0.65
3	P	Density of Contaminated Zone	0.53	P	Density of Contaminated Zone	0.44
4	P	K_d of Co-60 in Contaminated Zone	0.42	P	K_d of Co-60 in Contaminated Zone	0.35
5	P	Saturated zone hydraulic conductivity	-0.21	P	Saturated zone hydraulic conductivity	-0.23
Sr-90 Only Calculation						
1	P	Plant transfer factor for Sr	0.96	P	Depth of roots	-0.90
2	P	Depth of roots	-0.91	P	Plant transfer factor for Sr	0.86
3	M, B	Fruit, vegetable and grain consumption	0.52	M, B	Fruit, vegetable and grain consumption	0.41
4	P	K_d of Sr-90 in Contaminated Zone	0.35	P	Density of Unsaturated Zone 5	0.17
5	P	Well pump intake depth	-0.15	P	K_d of Sr-90 in Contaminated Zone	-0.17
Cs-137 Only Calculation						
1	B	Indoor time fraction	0.94	B	Indoor time fraction	0.93
2	P	External gamma shielding factor	0.71	P	External gamma shielding factor	0.71
3	P	Density of Contaminated Zone	0.46	P	Density of Contaminated Zone	0.37
4	P	Plant transfer factor for Cs	0.43	P	Plant transfer factor for Cs	0.30
5	P	K_d of Cs-137 in Contaminated Zone	0.30	P	Saturated zone hydraulic conductivity	-0.29

[1]Parameter Classification: P = Physical; B = Behavioral; M = Metabolic
[2]PRCC = Partial Rank Correlation Coefficient

Contaminated Area (m^2)	Calculated Area Factors at Time of Peak Dose								
	H-3	Mn-54	Fe-55	Co-60	Sr-90	Cs-137	Eu-152	Eu-154	Eu-155
8094	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4047	1.00	1.01	1.00	1.01	1.00	1.02	1.02	1.01	1.02
2024	1.00	1.03	1.00	1.03	1.00	1.03	1.03	1.03	1.03
1012	1.35	1.04	1.00	1.04	1.00	1.04	1.05	1.04	1.04
506	2.91	1.09	1.98	1.08	1.98	1.13	1.07	1.07	1.06
253	6.05	1.14	3.95	1.13	3.94	1.20	1.11	1.11	1.09
126	12.4	1.20	7.93	1.20	7.87	1.29	1.17	1.16	1.14
63	24.9	1.30	15.8	1.30	15.6	1.41	1.27	1.26	1.23
32	49.2	1.49	31.2	1.49	30.5	1.62	1.44	1.45	1.39
16	98.9	1.78	62.0	1.78	59.9	1.93	1.72	1.73	1.63
8	198	2.38	123	2.38	117	2.58	2.30	2.31	2.14
4	397	3.61	243	3.62	230	3.91	3.49	3.52	3.19
2	794	5.68	473	5.75	452	6.14	5.48	5.55	4.90
1	1590	9.57	905	9.73	887	10.3	9.24	9.39	7.88