First Five-Year Review Report for Building 23

W.R. Grace Curtis Bay Formerly Utilized Sites Remedial Action Program Site

Baltimore, Maryland

U.S. Army Corps of Engineers – Baltimore District
2 Hopkins Plaza
Baltimore, Maryland 21201

FINAL

Approval signature:

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Karen J. Baker
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11 May 2021
Date

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ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm^2	Square centimeter(s)
DCGL	Derived concentration guideline level
dpm	Disintegration per minute
EA	EA Engineering, Science, and Technology, Inc., PBC
EPA	U.S. Environmental Protection Agency
FS	Feasibility study
FSS	Final status survey
FUSRAP	Formerly Used Sites Remedial Action Program
FYR	Five-year review
HHRA	Human Health Risk Assessment
LUC	Land use control
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
mrem	Millirem
NCP	National Contingency Plan
NPL	National Priorities List
pCi/g	Picocuries per gram
RA	Remedial action
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual radioactive
RI	Remedial investigation
ROD	Record of Decision
^{232}Th	Thorium-232
^{238}U	Uranium-238
USACE	U.S. Army Corps of Engineers

EXECUTIVE SUMMARY

The purpose of this Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) five-year review (FYR) is to assess the protectiveness of the remedy as described in the Record of Decision (ROD) Amendment for Building 23 at the W.R. Grace Curtis Bay Formerly Used Sites Remedial Action Program (FUSRAP) site. Building 23 is typically described in plan view as consisting of four rectangular sections of approximately equal size ("quadrants"), and the remedial action for Building 23 targets the southwestern rectangular section of the building (referred to as the "southwest quadrant"); however, documents refer to this operable unit on the W.R. Grace FUSRAP site as Building 23.

The U.S. Army Corps of Engineers (USACE), Baltimore District prepared this FYR pursuant to CERCLA §121 and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), contained in title 40 of the Code of Federal Regulations (CFR) Part 300 (40 CFR 300). USACE is conducting the response actions at the site pursuant to CERCLA and the NCP and in accordance with the Memorandum of Understanding Between the U.S. Department of Energy and USACE regarding FUSRAP (1999). This is the first FYR for Building 23 at the W.R. Grace Curtis Bay FUSRAP site.

The original remedy for Building 23 was selected in a ROD signed by USACE on 17 May 2005. The remedy selected in the 2005 ROD included decontamination of building components to meet remedial goals, as well as selective removal where decontamination was determined to be impractical or undesirable. For small areas that are inaccessible for survey and/or undesirable for removal, the ROD allowed performance of a dose assessment to confirm that the remaining dose associated with residual radioactivity in these areas is acceptable. For soil, the ROD indicated that as part of the closure process for the remedial action, residual contamination in soil beneath the southwest quadrant would be evaluated to ensure the resultant dose levels meet industrial use criteria. Based on two phases of decontamination and selective removal work in 2009-2013, substantial challenges associated with achieving remedial goals through decontamination were identified. A ROD Amendment was subsequently signed by USACE on 28 July 2020. This ROD Amendment revised the selected remedy to include demolition of the southwest quadrant of Building 23, along with land use controls for soil to remain under the footprint of the southwest quadrant. Preparations for the demolition are currently underway at the site.

No issues that affect the performance or protectiveness of the amended remedy for Building 23, as presented in the 2020 ROD Amendment, were identified during this FYR process, which included document review, data review, and site inspections. The amended remedy for the southwest quadrant is expected to be protective of human health and the environment upon completion of the remedy; and, in the interim, exposure pathways that could result in unacceptable risk are being controlled.

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1. INTRODUCTION

The purpose of this Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) five-year review (FYR) is to assess the protectiveness of the remedy as described in the Record of Decision (ROD) Amendment for Building 23 at the W.R. Grace Curtis Bay Formerly Used Sites Remedial Action Program (FUSRAP) site, and to determine if the selected remedy is, or will be, protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in the FYR. In addition, the FYR identifies issues found during the review, if any, and documents recommendations to address them. Building 23 is typically described in plan view as consisting of four rectangular sections of approximately equal size ("quadrants"), and the remedial action (RA) for Building 23 targets the southwestern rectangular section of the building (referred to as the "southwest quadrant"); however, documents refer to this operable unit on the W.R. Grace FUSRAP site as Building 23.

The U.S. Army Corps of Engineers (USACE) is conducting this FYR pursuant to CERCLA Section 121 (42 U.S. Code §9621) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), contained in title 40 of the Code of Federal Regulations (CFR) Part 300 (40 CFR 300). Under CERCLA Section 121(c), a FYR is required for RAs conducted at sites where hazardous substances, pollutants, or contaminants are above levels that allow for "unlimited use and unrestricted exposure." "Unlimited use and unrestricted exposure" means that the selected remedy will place no restrictions on the potential use of land or other natural resources.

This is the first FYR for Building 23. For RAs that leave hazardous substances, pollutants, or contaminants onsite above levels that allow for unlimited use and unrestricted exposure, CERCLA and the NCP require that the FYR period begin with the initiation of RA. Remedial activities under the 2005 ROD began in 2009; however, a FYR was not initiated prior to 2020. Based on two phases of RA work in 2009-2013, substantial challenges associated with achieving remedial goals through the originally selected remedy were identified, and a ROD Amendment for Building 23 was signed in 2020.

The Radioactive Waste Disposal Area is another operable unit at the W.R. Grace FUSRAP site. The remedy for the Radioactive Waste Disposal Area has not yet been initiated and, therefore, this portion of the FUSRAP site is not yet subject to FYR.

USACE has conducted this FYR of the RA for the southwest quadrant of Building 23. The project organization for USACE consisted of Brenda Barber (Program Manager), Julie Kaiser (Project Manager), and Eric Barbour (Project Health Physicist). EA Engineering, Science, and Technology, Inc., PBC (EA) was employed as a contractor for USACE. The project organization for EA consisted of Mike O'Neill, PMP (Project Manager), Amy Sponaugle, P.E. (Deputy Project Manager), Samantha Saalfield, Ph.D. (Document Technical Lead), and Craig Bias, Ph.D. (Health Physicist, Remwerks LLC, EA subcontractor).

EA performed several components of the FYR on behalf of USACE including:

- Prepared a community notification and published it in the *Baltimore Sun* (17 February 2020)

- Conducted a site inspection (29 January 2020)
- Conducted interviews (13 March 2020)
- Performed document review and data analysis tasks
- Performed analysis in support of the technical assessment and protectiveness determination
- Prepared the FYR Report.

Work performed by EA for USACE was subjected to USACE review and acceptance prior to completion and distribution.

1.1 SITE BACKGROUND

The W.R. Grace Curtis Bay Facility is located at 5500 Chemical Road in Baltimore, Maryland. The Facility currently occupies approximately 109.7 acres on an industrialized peninsula between Curtis Creek and Curtis Bay in southern Baltimore City (Figure 1). Building 23 is located on the western edge of the facility (Figure 2). Groundwater at the site flows to the north and east into Curtis Creek and Curtis Bay, which are adjacent to the site. A site chronology for Building 23 is presented in Table 1.

Processing of monazite sand was conducted in a processing plant located within the southwest quadrant of Building 23 in 1956 and 1957. The processing was conducted by W.R. Grace under contract to the AEC. The products of the monazite sand processing were reported to be crude thorium hydroxide and rare earth sodium sulfate. Isotopic components of raw monazite sand include uranium-238 (^{238}U), thorium-232 (^{232}Th), and their decay progeny. These processing operations are the source of residual radioactivity in the building. The byproduct or waste created by the processing operation in the southwest quadrant of Building 23, as well as some of the processing equipment, was disposed of in the Radioactive Waste Disposal Area, which is located in an unpaved area of the facility, to the east of the area developed for manufacturing activities.

The southwest quadrant of Building 23 has an approximate plan area of 2,200 square meters for the first floor. The southwest quadrant is defined as the area between east-west column lines A and D, and north-south column lines 11 and 19 (Figure 3). Multiple doorways and openings exist between the southwest quadrant and the remainder of the building on each of the first three floors; however, these doorways are no longer accessible. The building consists of mainly steel I-beam construction, with walls made of corrugated steel sheeting, brick or cinder block. The first floor of the building is a slab approximately 6 inches thick and is a mixture of old and new reinforced concrete. The area outside the southwest quadrant of Building 23 is paved.

There are no current W.R. Grace production operations in the southwest quadrant of Building 23, although certain facility support operations (i.e., electrician's shop/storage areas, a transformer substation, and access routes along the northern end of the southwest quadrant for workers) remain on the ground floor. The eastern half of Building 23 includes a large warehouse, a loading dock, transformer room, and several small rooms and offices. The northwest quadrant of Building 23 contains an active manufacturing area. Locked doors and fencing are used to restrict access to

areas of RA from foot and vehicle traffic, and radiation safety rope and signage remain in place to delineate areas of residual radioactivity. Plastic sheeting is used to reduce the transfer of dust between production areas and remediation areas.

Table 1. Chronology of Events for Building 23

Event	Date
Monazite sand processing in the southwest quadrant of Building 23	1956-1957
W.R. Grace Site is added to FUSRAP	1984
U.S. Department of Energy leads site activities under FUSRAP	1984-1998
Limited radiological survey of the southwest quadrant conducted by Oak Ridge National Laboratory	1986
USACE designated as responsible agency for site cleanup at active FUSRAP sites (includes the W.R. Grace site)	1999
USACE leads investigations and RA under FUSRAP	1999 – present
Remedial Investigation (RI) conducted by USACE	2000
Feasibility Study (FS) conducted by USACE	2003
Proposed Remedial Action Plan issued	2004
ROD signed by USACE	2005
Settlement Agreement signed by USACE and W.R. Grace[1]	2008
RA Phase I in southwest quadrant of Building 23	2009
RA Phase II in southwest quadrant of Building 23	2011-2013
Supplemental characterization of building surfaces	2015-2016
Additional soil characterization	2017
Amended Proposed Remedial Action Plan issued	2019
Amended ROD signed by USACE	2020

1. On 21 April 2008, the U.S. Bankruptcy Court of Delaware approved a Site-Wide Settlement Agreement (Docket No. 18571) between W.R. Grace & Co., et al. and the U.S. Government (represented by the U.S. Department of Justice). Among other things, the agreement defined roles and responsibilities and apportioned the liability costs for remediation of FUSRAP Material across the site.

FIVE-YEAR REVIEW SUMMARY FORM

SITE IDENTIFICATION		
Site Name: W.R. Grace Curtis Bay Formerly Utilized Sites Remedial Action Program Site		
EPA ID: Not Applicable		
Region: 3	**State:** MD	**City/County:** Baltimore City

SITE STATUS	
National Priorities List (NPL) Status: Non-NPL	
Multiple OUs? Yes	**Has the site achieved construction completion?** No

REVIEW STATUS
Lead agency: Other Federal Agency ***[If "Other Federal Agency," enter Agency name]*:** U.S. Army Corps of Engineers
Author name: Julie Kaiser, Project Manager
Author affiliation: U.S. Army Corps of Engineers
Review period: 24 January 2020 – 9 October 2020
Date of site inspection(s): 29 January 2020
Type of review: Statutory
Review number: 1
Triggering action date: 6 April 2009
Due date *(five years after triggering action date)*: 6 April 2014

2. REMEDIAL ACTION

2.1 BASIS FOR TAKING ACTION

The remedial investigation (RI) of the southwest quadrant of Building 23 conducted in 2000-2002 identified residual radiological activity above background at various locations throughout the quadrant (EA, 2002). The RI identified ^{232}Th and ^{238}U and their decay progeny as constituents of potential concern. Media impacted by these radionuclides include building components and soil.

In the Baseline Human Health Risk Assessment (HHRA) contained in the RI (EA, 2002), the Industrial Worker scenario was determined to be the most appropriate for Building 23, as it closely resembles the current and expected future use of the building. Exposure pathways that were considered included external exposure from contaminants on surfaces and inhalation or ingestion of airborne dust. The highest excess cancer risks calculated, up to 2.1×10^{-3}, were for workers located in the most impacted areas for extended periods of time and were dominated by the external exposure pathway.

2.2 REMEDY SELECTION

The general remedial action objective (RAO) established for Building 23 in the 2005 ROD, designed to be protective of human health and the environment, is as follows: *To reduce the risk to current and future human receptors from building components and soil containing residual radioactivity from monazite sand processing to an acceptable level as defined in Title 10 of CFR 40, Appendix A, Criterion 6(6).*

The selected remedy for the southwest quadrant of Building 23 was stated in the ROD as "Decontamination with Removal to Industrial Use Levels."

The remedy provided in the 2005 ROD consisted of the following:

- Application of cleanup goals derived in accordance with the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (Nuclear Regulatory Commission et al., 2000) and based on the selected chemical-specific applicable or relevant and appropriate requirement (ARAR), 10 CFR 40, Appendix A, Criterion 6(6).
- Decontamination using chemical or mechanical decontamination technologies of the concrete floors and sections of the ceilings above the concrete floor areas of the fifth floor. Where decontamination is assessed to be ineffective, impractical, or not cost effective, building components will be removed and replaced, as practical.
- Decontamination of the walls and structural steel with surface activity above remedial goals on the fourth and fifth floors, using chemical or mechanical decontamination technologies. If post-decontamination surveys indicate radiological activity above criteria, structural steel and walls will be decontaminated again and resurveyed. This iterative approach would continue until surface activity levels meet the remedial goals. Where decontamination is assessed to be ineffective, impractical, or not cost-effective, building components will be removed and replaced, as practical.

- Removal of floor tiles in the laboratory, break room, and motor control room. A radiological survey would be conducted on the concrete surface below. If surface activity levels are above remedial goals, the floor surfaces would be decontaminated using chemical or mechanical decontamination technologies. Where decontamination is assessed to be ineffective, impractical, or not cost-effective, building components will be removed and replaced, as practical.
- Removal of the wooden floored platform and abandoned-in-place piping and equipment.
- Completion of a final status survey (FSS).

In small areas where residual radioactivity may potentially exceed remedial goals, but the area is inaccessible for verification that remedial goals are met and/or removal is impractical or undesirable, the ROD allowed performance of a dose assessment. The dose assessment would be conducted specific to the conditions presented by the known, or estimated, residual activity in that small area to determine whether the dose from the remaining radioactivity meets the benchmark dose established by 10 CFR 40, Appendix A, Criterion 6(6).

The remedy presented in the 2005 ROD did not include land use controls (LUCs) or other actions specifically targeting soil, based on the following rationale presented in the ROD: "The selected remedy provides for a cleanup of soils that is expected to meet industrial use standards, as this is the foreseeable future use for the land occupied by Building 23. As part of the closure process for the RA, the actual level of residual contamination in soil beneath the southwest quadrant of Building 23 shall be evaluated to ensure the resultant dose levels meet the industrial use criteria established by the ARAR."

Remedial activities were conducted at the site between 2009 and 2013, in accordance with the selected remedy identified in the 2005 ROD. These activities included decontamination of surfaces as well as removal (demolition) of contaminated portions of the building, as described in Section 2.3. However, the complexity of the building interior created access challenges that made decontamination to meet the ARAR difficult, and also made it difficult to verify achievement of the remedial goals on all building surfaces. Data collected during and after these activities also indicated that residual radioactivity exceeding remedial goals is more extensive than previously understood, both on building surfaces in the southwest quadrant and in the soil beneath Building 23 (Section 4.3).

Based on the additional data collected, USACE and W.R. Grace re-evaluated the feasibility of the selected remedy. This evaluation included a detailed estimate of the additional level of effort required to meet remedial goals for building surfaces under the selected remedy, as well as the implementability of alternative remedies. The evaluation indicated that a remedy including complete demolition of the southwest quadrant would likely be more feasible than the originally selected remedy of decontamination with removal of certain building components. Additionally, given new data indicating that soil exceeding industrial use criteria is present beneath the southwest quadrant and that removal of all impacted soil would not be feasible, it was determined that LUCs are needed to prevent contact with impacted soil following demolition of the southwest quadrant. Therefore, an Amended Proposed Remedial Action Plan was published in June 2019,

and a ROD Amendment was signed in July 2020, with Demolition of the Southwest Quadrant of Building 23 as the preferred alternative (USACE, 2019 and USACE, 2020).

The 2020 ROD Amendment changed the selected remedy, relative to that presented in the 2005 ROD, as follows:

- The amended remedy, Demolition of the Southwest Quadrant of Building 23, replaced the remedy selected in the 2005 ROD (Decontamination with Removal to Industrial Use Levels).
- LUCs for soil are included as part of the amended remedy to address radionuclide concentrations in soil exceeding remedial goals.
- Remedial goals for building surfaces were revised to incorporate site-specific data and reflect current site conditions and guidance.

The amended remedy for the southwest quadrant of Building 23 includes the following key elements:

- Demolition of structural components in the footprint of the southwest quadrant of Building 23 (i.e., partial building demolition) while ensuring protection of the remaining building and minimizing disruptions to current plant operations, followed by reconstruction of new exterior walls along the demolished edges.
- Relocation of an active electrical substation on the ground floor of the southwest quadrant of Building 23 to another quadrant of Building 23 (i.e., construction of a new substation to accept electrical load prior to demolition of the existing substation).
- Relocation of existing utility lines (air, steam, water, etc.), active electrical conductors, and raw material transfer lines that traverse the southwest quadrant of Building 23 or that would be impacted by demolition activities.
- Coordination of relocated/temporary utility services and raw material transfer lines to ensure uninterrupted service for the facility manufacturing activities.
- Removal of de minimis soil and building foundations beneath the demolished quadrant of Building 23, as necessary to allow regrading and construction of a new concrete slab-on-grade. As-left soil sampling will be conducted prior to installing the new concrete slab to document the as-left radiological conditions of site soil.
- Restoration of the ground surface of the southwest quadrant of Building 23 after demolition activities are complete (e.g., grading, concrete, etc.), construction of a new access corridor, and construction of a new electrical shop/storage building, to replace rooms that existed in the southwest quadrant prior to demolition.
- Transportation and disposal of project wastes to offsite disposal facilities licensed or permitted to accept the waste streams.
- Completion of FSS activities to verify that remedial goals were achieved.

Remedial goals have been developed for building materials that will remain following the remedial action (e.g., structural steel along the northern and eastern boundaries of the southwest quadrant). These derived concentration guideline levels (DCGLs) were developed based on the calculated benchmark dose (EA, 2003; USACE, 2005; USACE, 2020), in accordance with 10 CFR Part 40, Appendix A, Criterion 6(6) and consistent with an Industrial Worker scenario, using RESRAD-BUILD Version 3.1 computer modeling code. The 2020 ROD Amendment presented revised remedial goals for building materials, based on current building conditions and additional data collected since the signing of the 2005 ROD. Calculated remedial goals listed in the ROD Amendment for building materials are provided in Table 2.

Table 2. Remedial Goals[(a)] for Building Materials from the 2020 Record of Decision Amendment

Decay Components[(b),(c)]	$DCGL_W$ [(d)] (dpm/100 cm^2)
Total (α+β)	16,300
Alpha (α)	9,780
Beta (β)	6,520

$DCGL_W$ = Derived Concentration Guideline Level representing the average activity that can be uniformly distributed over a 100 square centimeter area.

dpm/100 cm^2 = Disintegrations per minute per 100 square centimeters.

Notes:

(a) Based on benchmark dose of 7.37 millirem per year (mrem/year) from exposure to ^{228}Ra for an industrial scenario.
(b) ^{232}Th in equilibrium with its progeny includes a total of 6 alpha and 4 beta particles emitted per disintegration.
(c) Total activity (fixed and removable)
(d) Remedial Goals for Building 23 include cleanup to the appropriate $DCGL_W$ with a maximum removable fraction of 0.1 (10 percent).

Remedial goals for soil were calculated using RESRAD Version 6, based on the industrial worker scenario (EA, 2003; USACE 2005), and are provided in Table 3. These guideline levels are used to calculate a sum of ratios, as described in the ROD, and the overall remedial goal for soil is a sum of ratios less than 1.

Table 3. Remedial Goals[(a),(b)] for Radionuclides of Concern in Soil from the 2005 Record of Decision and 2020 Record of Decision Amendment

	$DCGL_W$ (pCi/g)	
Radionuclide	**Surface Soil**	**Subsurface Soil**
Radium-226	5	15
Radium-228	5	15
Uranium-238	257	1,372
Uranium-234	1,452	7,540
Thorium-232	2.62	4.73

$DCGL_W$ = Derived Concentration Guideline Level representing the average activity that can be uniformly distributed over a 100 square meter area.

pCi/g = Picocuries per gram.

Notes:

(a) Based on benchmark dose of 7.37 millirem per year (mrem/year) from exposure to ^{228}Ra for an industrial scenario.
(b) The remedial goal for soil is identified as 1 (i.e., unity) and represents the sum of the fraction of the total dose contributions from the individual radionuclides that are identified in the table.

2.3 STATUS OF REMEDY IMPLEMENTATION

From 2009 – 2013, two phases of RA were conducted in accordance with the 2005 ROD.

In 2009, the Phase I RA was conducted in the southwest quadrant of Building 23, with the main objectives being to reduce uncertainty in the final RA scope and improve the building condition to support subsequent remedial activities. Specific activities conducted during the Phase I RA included the following:

- ***Pilot Decontamination Tests***—Testing was conducted to determine the ability of various decontamination methods to remove both fixed and removable radiological contamination from building surfaces while preserving the structural integrity of those elements. The methods used for decontamination varied from nonabrasive techniques, primarily intended for loose or removable contamination, to more aggressive methods, which were more likely to be effective for fixed contamination.

- ***Hazardous Materials Surveys/Testing***—Surveys/testing were performed to identify materials (asbestos-containing material, materials with leachable lead, and polychlorinated biphenyls) that would require removal or control during future radiation decontamination/removal activities and to support waste disposal profiling requirements.

- ***Radiological Surveys***—Surveys were conducted to gather radiological data on structural steel, corrugated panel, and concrete surfaces (up to 2 meters beyond the available walking surfaces) that were inaccessible during the RI conducted 2000 through 2002.

- ***First Floor Concrete Slab Replacement***—To ensure a reliable working surface for subsequent RA activities, a portion of the existing deteriorated concrete slab flooring of the first floor was removed and replaced. During removal, soil beneath the slab was evaluated for the presence of contaminants and removed to a depth of approximately 14 inches below the original slab elevation to facilitate placement of the new concrete slab floor.

A detailed discussion of the methodology and results of the Phase I RA are provided in the *Final Remedial Action Data Report for the Building 23 W.R. Grace Curtis Bay Facility Formerly Utilized Sites Remedial Action Program Project, Baltimore, Maryland* (URS Corporation and ES Services, Inc., 2009).

From February 2011 to September 2013, the Phase II RA was conducted to decontaminate and demolish contaminated building components in the southwest quadrant of Building 23 in accordance with the remedial goals from the 2005 ROD. Remedial activities included the following:

- General cleaning of radiologically impacted areas
- Installation/modification of fall protection/arrest systems and material transfer systems
- Removal of miscellaneous materials/equipment

- Reconfiguration of active utilities including pipes and ductwork at the third floor level
- Removal and replacement of the roof between Column Lines B and C
- Removal of concrete and steel floors at the second, third, fourth, and fifth floor elevations, as well as brick/block wall materials and non-structural beams
- Decontamination followed by painting of structural steel at the fourth and fifth floor levels (between Column Lines A and C, 11 and 17), as well as under the roof between Column Lines B and C
- Scabbling of concrete floor on the second floor landing
- Waste management, transportation, and disposal.

A detailed discussion of the methodology and results of the Phase II RA is provided in the *Remedial Action Closure Report, W.R. Grace Curtis Bay Building 23, Formerly Utilized Sites Remedial Action Program Site Remediation, Baltimore, Maryland* (Safety and Ecology Corporation, 2013).

Following completion of the Phase II RA work, interim FSS activities were conducted by an independent party under contract to W.R. Grace. A detailed discussion of the methodology and results of the interim FSS activities is provided in *Interim Final Status Survey Report for Building 23, Report No. 2003011/G-410505* (Integrated Environmental Management, Inc., 2014).

USACE, in coordination with W.R. Grace, has prepared a remedial design for demolition of the southwest quadrant and related activities described in the 2020 ROD Amendment. In preparation for demolition, utility work including construction of a new electrical substation and relocation of utilities must be conducted in close coordination with W.R. Grace facility personnel, to limit plant downtime.

3. PROGRESS SINCE THE LAST REVIEW

This is the first Five-Year Review for the W.R. Grace Curtis Bay FUSRAP Site.

4. FIVE-YEAR REVIEW PROCESS

4.1 COMMUNITY INVOLVEMENT

Public notice of the beginning of the FYR process for Building 23 was published in the *Baltimore Sun* (17 February 2020), and is included in Appendix A. Once the FYR is completed, an additional public notice will be published, and the results will be made available at the local site repository (Enoch Pratt Library – Brooklyn Branch). W.R. Grace facility staff also participate in quarterly meetings of the South Baltimore Community Advisory Panel and monthly meetings of the Curtis Bay Community Association, and share information related to the cleanup of Building 23 as appropriate.

4.2 DOCUMENT REVIEW

This FYR consisted of a review of relevant documents, including the RI, FS, ROD, Amended Proposed Remedial Action Plan, Amended ROD, and RA and interim FSS reports. The documents that were reviewed in completing this FYR are summarized in Appendix B.

4.3 DATA REVIEW

The data review task is intended to compile, summarize, and analyze the data collected since the RA was initiated, such that the activities completed to date can be assessed and the protectiveness of the remedy determined.

Building Surface Characterization Data

Following remedial activities conducted as part of the Phase II RA, the contractor performed Pre-FSS surveys consistent with the project FSS Plan. Residual radioactivity exceeding remedial goals was found to be present in a number of areas initially designated as Class II and Class III survey units, where exceedances were not anticipated. Data are included in Appendix D of the Phase II RA Report (Safety and Ecology Corporation, 2013).

An Interim FSS was also performed following completion of the Phase II RA. The results identified only 1 of 33 survey units with residual radioactivity exceeding the remedial goals. However, it was not possible to access 100 percent of the area in 23 of the other 32 survey units. Detailed data from these surveys are presented in the Interim FSS Report (Integrated Environmental Management, Inc., 2014).

Supplemental characterization activities were conducted in 2015 and 2016 to address data gaps with respect to radiological activity on building surfaces. Results of the surveys indicated that impacts to building surfaces extended to multiple building surfaces on all levels of the building.

Overall, building characterization data collected since the Phase II RA indicated that contamination in excess of the remedial goals remained following two phases of remedial action. These data illustrated the difficulty of achieving and verifying assessment of the remedy selected

in the 2005 ROD. Therefore, a change in the remedy from decontamination and removal to demolition was selected in the 2020 ROD Amendment (see Section 2.2).

Soil Characterization Data

Additional soil characterization was required by the ROD (USACE, 2005) to verify that resultant dose levels in soil under the selected remedy meet industrial use criteria (Section 2.2).

Soil beneath the building's concrete slab was sampled for radiological analysis as part of the Phase I RA, to depths of approximately 8 feet. Detailed results are included in Appendix T of the Phase I RA Report (URS Corporation and ES Services, Inc., 2009). The maximum reported concentration of ^{232}Th was 39.3 picocuries per gram (pCi/g), and the reported maximum concentration of ^{226}Ra was 1.87 pCi/g.

Additional delineation of radiological activity in soil was conducted in February 2017. Radiological results for 257 soil samples collected from 40 borings in 2017 are provided in Table C-1 (Appendix C), and the results are summarized on Figure 4. The maximum reported concentration of ^{232}Th was 74.7 picocuries per gram (pCi/g), and the reported maximum concentration of ^{226}Ra was 2.51 pCi/g.

The results of the additional soil characterization indicated that the dose levels in soil do not meet industrial use criteria, and therefore the remedy selected in the 2005 ROD would not achieve the RAO. To address this, LUCs for soil were included in the remedy selected in the 2020 ROD Amendment.

4.4 SITE INSPECTION

A site inspection at Building 23 was conducted by W.R. Grace and EA personnel on 29 January 2020. The site inspection checklist and photograph log are included in Appendix D. During the inspection, EA and W.R. Grace personnel reviewed the current condition and use of the southwest quadrant of Building 23. The team entered through a locked door and observed the ground floor in the area adjacent to the poly corridor. A radiation safety rope and signage ("CAUTION – Radioactive Materials Area" and "NOTICE – Notify EH&S Prior to Entry") remained in place to delineate areas on the first floor where residual radioactivity exceeds the remedial goals. This same signage was also observed on the second and third floors to note additional areas where residual radioactivity exceeds the remedial goals. The team observed a fence installed at ground level to further segregate the areas of RA from foot and vehicle traffic, and plastic sheeting hung between production and remediation areas to reduce the transfer of dust was in place. The southwest quadrant of Building 23 also contains an electrical substation and parts storage/light workshop areas used to support the Facility electricians. Note: the site inspection was conducted prior to finalization of the 2020 ROD Amendment; however, no issues affecting the protectiveness of the current remedy were identified during the site inspection.

4.5 INTERVIEWS

During the FYR process, an interview was conducted in March 2020 with the W.R. Grace Project Manager, Paul Bucens, who coordinates the remedy at Building 23. The purpose of the interview

was to document the status of the remedy and any issues or concerns regarding the remedy. A detailed interview record is included in Appendix E. The interview responses indicate that administrative and engineering controls are in place to limit access to the southwest quadrant, and that challenges with implementation of the current remedy (decontamination and focused removal) led W.R. Grace and USACE to evaluate an alternative demolition remedy.

5. TECHNICAL ASSESSMENT OF THE REMEDY

5.1 QUESTION A: IS THE REMEDY FUNCTIONING AS INTENDED BY THE DECISION DOCUMENTS?

The remedy for the southwest quadrant of Building 23, as defined in the 2005 ROD, was initiated in 2009. This remedy generally functioned as intended; however, the results of the Phase I and Phase II RAs indicated that the remedy was not feasible, due to challenges of accessibility, time requirements of iterative surveys and decontamination, and more widespread contamination. Therefore, the remedy was revised in the 2020 ROD Amendment. The remedy as defined in the 2020 ROD Amendment is functioning as intended.

Remedial Action Performance

Two phases of RA, which included decontamination of interior building surfaces and selective demolition, have been conducted in accordance with the 2005 ROD (Section 2.3). Post-RA data indicated that the inaccessibility of some surfaces presents challenges for decontamination and for collecting sufficient FSS data to achieve unrestricted release. Therefore, the remedy was revised via the 2020 ROD Amendment, to include demolition of the southwest quadrant along with LUCs for soil beneath the quadrant. RA construction activities in accordance with the 2020 ROD Amendment were initiated in Fall 2020.

Early Indicators of Potential Issues and Opportunities to Optimize Path Forward

No indicators of potential issues with the amended remedy or opportunities to further optimize the path forward were identified.

Implementation of Institutional Controls and Other Measures

Building 23 remains an active manufacturing facility, although no current production operations occur in the southwest quadrant. A fence has been installed at ground level to further segregate the areas of RA from foot and vehicle traffic and plastic sheeting was hung between production and remediation areas to reduce the transfer of dust. Currently, the southwest quadrant of Building 23 contains an electrical substation and parts storage/light workshop areas used by W.R. Grace electricians in support of operations. Based on the data gathered through investigation and remediation activities, these areas do not pose a radiological risk for such activities. Facility personnel also have access to portions of the southwest quadrant that are known to have residual radioactivity exceeding remedial goals, for purposes such as gaining access to other areas and performing periodic maintenance operations. According to W.R. Grace, access for maintenance of utilities that run through the area is infrequent, of short duration, and conducted in consultation with environmental, health and safety resources. Signs and ropes are used to limit access to areas of the first, second, and third floors that have higher potential for exposure to residual radioactivity on building surfaces (a photograph log is provided in Appendix D). Air and dose monitoring results for perimeter and baseline samples that were collected during historical investigation and remediation activities in the southwest quadrant were reported to be less than regulatory limits for members of the public, indicating that inhalation and external dose are not a concern for public

receptors that currently happen to be in the vicinity of the southwest quadrant. As such, the controls are considered adequate to protect facility personnel and visitors from that potential exposure under current conditions.

Following completion of the demolition of the southwest quadrant of Building 23, LUCs will be required to address radionuclide concentrations in soil exceeding remedial goals. LUCs to limit contact with contaminated soil and groundwater are currently in place for the entirety of the Curtis Bay facility, under a Resource Conservation and Recovery Act (RCRA) Administrative Order on Consent (Docket No. RCRA-03-2015-0074). The soil-related LUCs that are in place under RCRA have been implemented via the facility's Soil Management Plan, which includes planning and health and safety protocols required for intrusive earth moving activities. As described in the ROD Amendment, additional LUCs will be enacted as part of the amended Building 23 remedy. Specific requirements associated with radionuclides remaining in soil will be added to the facility's Soil Management Plan, to provide assurance that any future activities that disturb soil within the footprint of the southwest quadrant of Building 23 will be conducted with oversight by radiologically-trained personnel and with protections for workers appropriate to maintain acceptable dose levels. In the meantime, the facility's existing Soil Management Plan and excavation permit process provide for oversight of excavation activities.

5.2 QUESTION B: ARE THE EXPOSURE ASSUMPTIONS, TOXICITY DATA, CLEANUP LEVELS, AND REMEDIAL ACTION OBJECTIVES USED AT THE TIME OF REMEDY SELECTION STILL VALID?

The exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of remedy selection via the 2020 ROD Amendment are still valid.

5.2.1 Changes in Standards and To-Be-Considered Guidance

In the 2005 ROD, USACE determined that the cleanup standards found in 10 CFR Part 40, Appendix A, Criterion 6(6), were relevant and appropriate for determining the remedial goals for remediating contaminated building surfaces and soil at the W.R. Grace Building 23 site. This ARAR (10 CFR 40 Appendix A) has not changed since the ROD was finalized, remains relevant and appropriate for use at the site, and was therefore retained in the 2020 ROD Amendment.

5.2.2 Changes in Exposure Pathways

Conditions in and near Building 23 have not changed the human health routes of exposure or receptors in a way that could affect the protectiveness of the remedy.

The exposure assumptions used in calculating remedial goals for building surfaces have not changed since the signing of the 2020 ROD Amendment. The exposure assumptions used in calculating remedial goals for soil have not changed since the signing of the 2005 ROD.

5.2.3 Changes in Toxicity and Other Contaminant Characteristics

A radiologic cancer risk coefficient of 7.6×10^{-7} lifetime cancer risk per millirem exposure (U.S. Environmental Protection Agency [EPA], 1994) was used to derive the lifetime cancer risks for

external exposure, and Federal Guidance Report No. 13 risk coefficients were used to derive the lifetime exposures via inhalation and ingestion (EPA, 1999). These coefficients remain appropriate for assessing risk at Building 23.

The site-specific benchmark dose calculation from the FS, conducted in accordance with 10 CFR Part 40, Appendix A, Criterion 6(6), was verified (Appendix F) and remains appropriate for assessing dose at the site.

5.2.4 Changes in Risk Assessment Methodologies

There have been no major changes in risk assessment methodology since the signing of the ROD that would impact the protectiveness of the Building 23 remedy. A review of methodology used in the Baseline HHRA was performed. The Baseline HHRA was included as Appendix M of the RI (EA, 2002).

The Baseline HHRA assessed the risks associated with Building 23, contaminated with residual radioactivity to the levels present at the time of the RI. The risk models used are appropriate and follow guidance outlined in the EPA Risk Assessment Guidance for Superfund Volume I and Human Health Evaluation Manual (Parts A, B, and D) (EPA, 1989), and other relevant EPA guidance including the Exposure Factors Handbook (EPA, 1991).

The methodology was reviewed relative to current guidance and is still appropriate. Newer models are available; however, they essentially use the same basic criteria for the reasonable maximum exposure scenario. The site-specific parameters used are also appropriate. The soil ingestion rates used are consistent with or more conservative than the rates recommended in the 2017 update of Chapter 5 of the Exposure Factors Handbook (EPA, 2017). The worker scenarios are properly developed for worker occupancy as yearlong within the facility.

5.3 QUESTION C: HAS ANY OTHER INFORMATION COME TO LIGHT THAT COULD CALL INTO QUESTION THE PROTECTIVENESS OF THE REMEDY?

There is no other information to call into question the protectiveness of the remedy.

5.4 TECHNICAL ASSESSMENT SUMMARY

The review of documents, ARARs, risk assumptions, and results of the site inspection indicates that the remedy at Building 23 is functioning as intended.

Although risk assessment methodologies presented in EPA guidance have evolved, the nature of the changes is such that a risk assessment using the updated methodology would not be expected to lead to identification of issues with the protectiveness of the remedy. No changes in exposure pathways were noted during the review period (2009–2020). Residual radioactivity on building surfaces and in soils beneath the building exceeding the remedial goals remained during the review period.

6. ISSUES, RECOMMENDATIONS, AND FOLLOW-UP ACTIONS

No issues or recommendations were identified.

7. PROTECTIVENESS STATEMENT

Protectiveness Statement(s)	
Operable Unit: Building 23	*Protectiveness Determination:* Will be Protective
Protectiveness Statement: The current remedy at Building 23, as presented in the 2020 ROD Amendment, will be protective of human health and the environment. The remedy for the southwest quadrant of Building 23 is expected to be protective upon completion and, in the interim, exposure pathways that could result in unacceptable risk are being controlled.	

8. NEXT REVIEW

The next FYR for Building 23 is required five years from the completion date of this review.

9. REFERENCES

EA Engineering Science and Technology, Inc. (EA). 2002. *Final Remedial Investigation (RI) Report of Building 23 at W.R. Grace Curtis Bay Facility, Baltimore, Maryland.* April.

———. 2003. *Final Feasibility Study (FS) Report of Building 23 at W.R. Grace Curtis Bay Facility, Baltimore, Maryland.* February.

———. 2020. *Technical Memorandum: Supplemental Radiological Characterization of the Southwest Quadrant of Building 23, W.R. Grace FUSRAP Site, Curtis Bay, Maryland.* April.

Integrated Environmental Management, Inc. 2014. *Interim Final Status Survey Report for Building 23, Report No. 2003011/G-410505, Rev. 0.* 11 July.

Nuclear Regulatory Commission et al. 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM),* NUREG-1575, Rev. 1 (also cited as EPA 402-R-97-016, Rev. 1 and DOE/EH-0624, Rev. 1). August.

Oak Ridge National Laboratory. 1989. *Results of the Indoor Radiological Survey*. Prepared for the U.S. Department of Energy. July.

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URS Corporation and ES Services, Inc. 2009. *Final Remedial Action Data Report for the Building 23 W.R. Grace Curtis Bay Facility Formerly Utilized Sites Remedial Action Program Project, Baltimore, Maryland*. December.

U.S. Army Corps of Engineers (USACE). 2005. *Record of Decision, Building 23 at W.R. Grace Curtis Bay Facility, Baltimore, Maryland.* April.

———. 2019. *Amended Proposed Remedial Action Plan (PRAP) for Building 23 at W.R. Grace Curtis Bay Facility, Baltimore, Maryland*. June.

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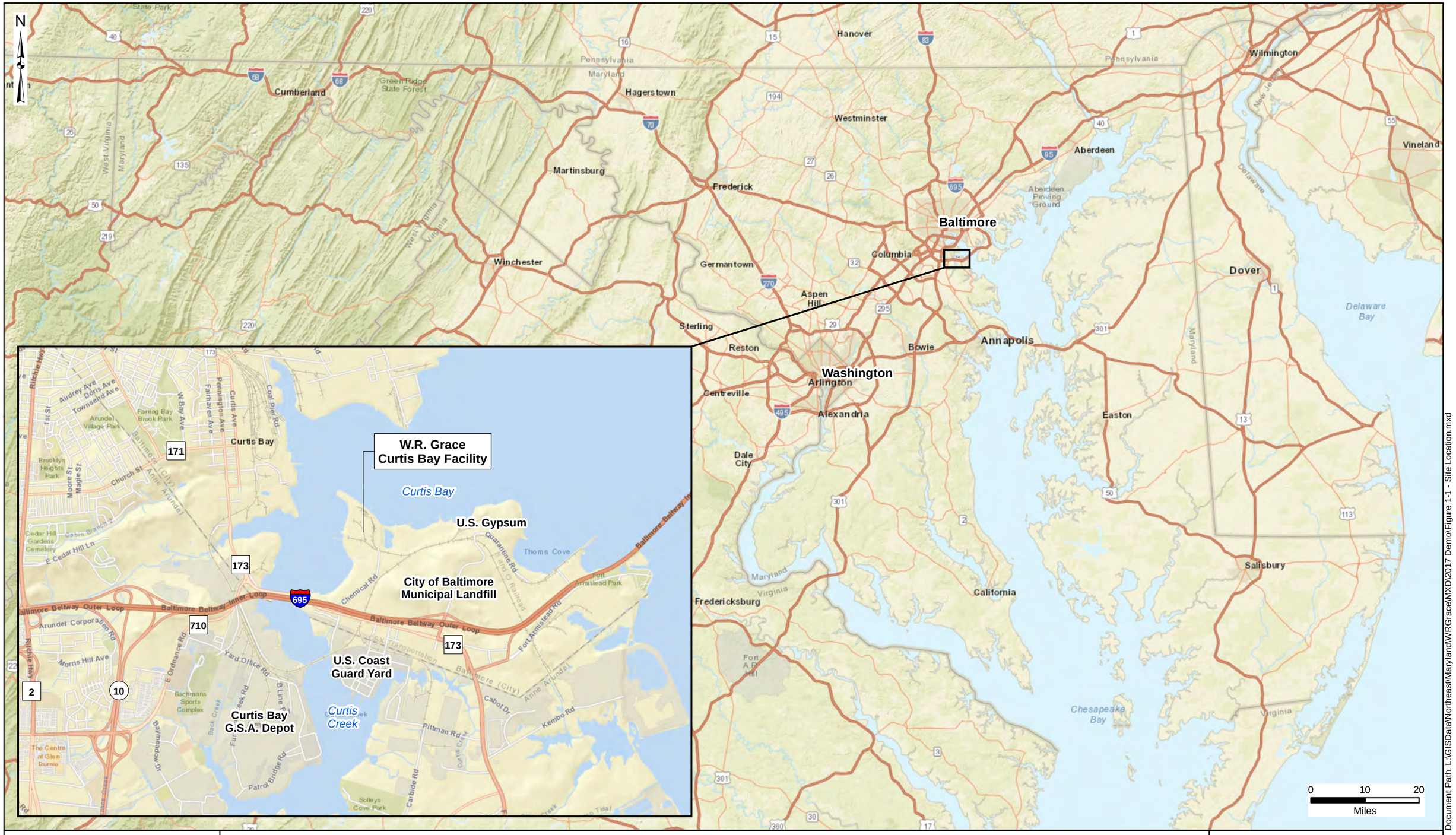


Document Path: L:\GISData\Northeast\Maryland\WRGraceMXD\2017 Demo\Figure 1-1 - Site Location.mxd

SITE LOCATION

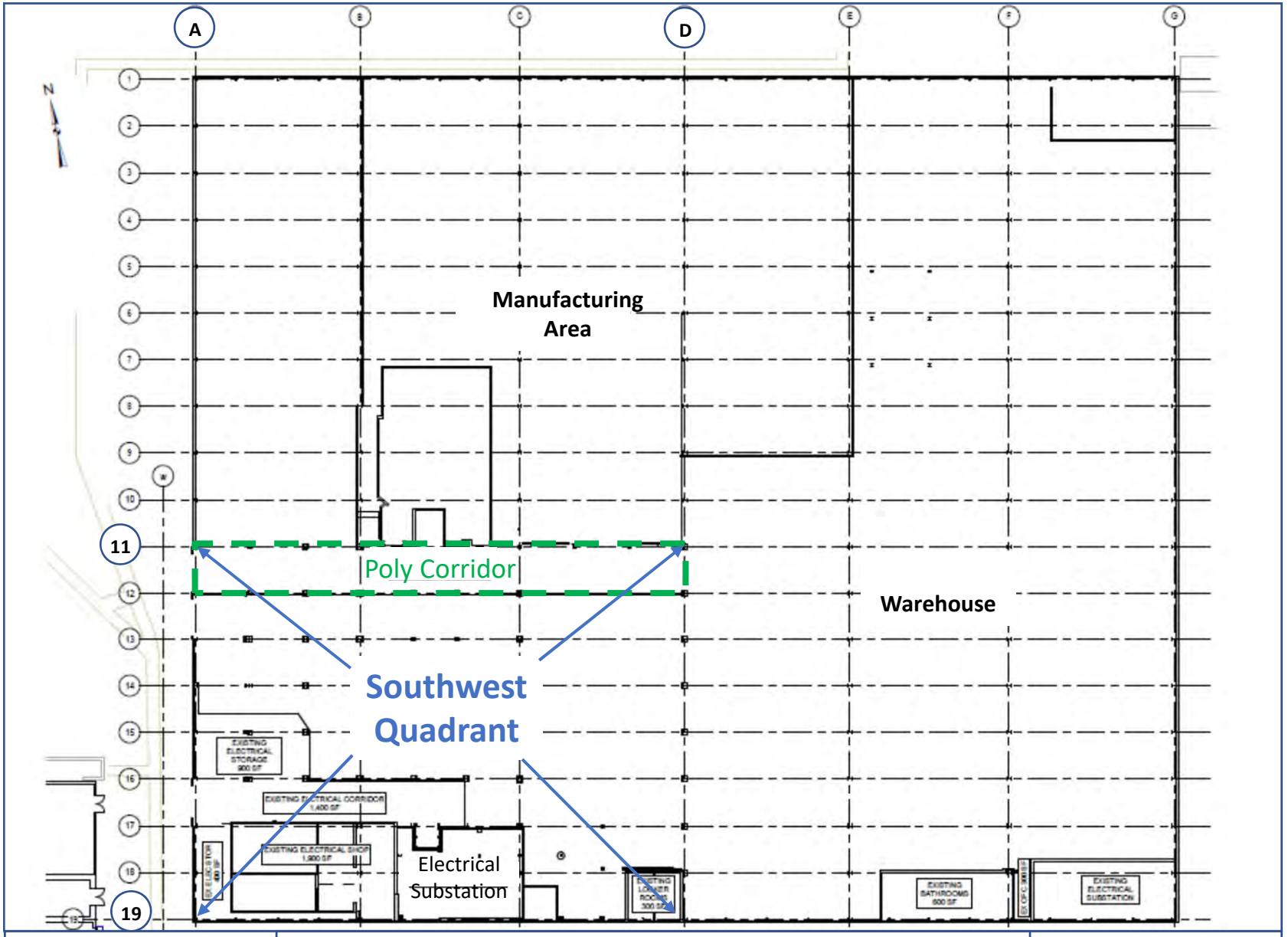
W.R. Grace Curtis Bay Facility
Baltimore, MD

Figure 1

Document Path: L:\Northeast\Maryland\WRGrace\MXD\2017 Demo\Figure 1-2 - Building 23 Site Location Map.mxd

BUILDING 23 SITE LOCATION MAP
W.R. Grace Curtis Bay Facility
Baltimore, MD

Figure 2

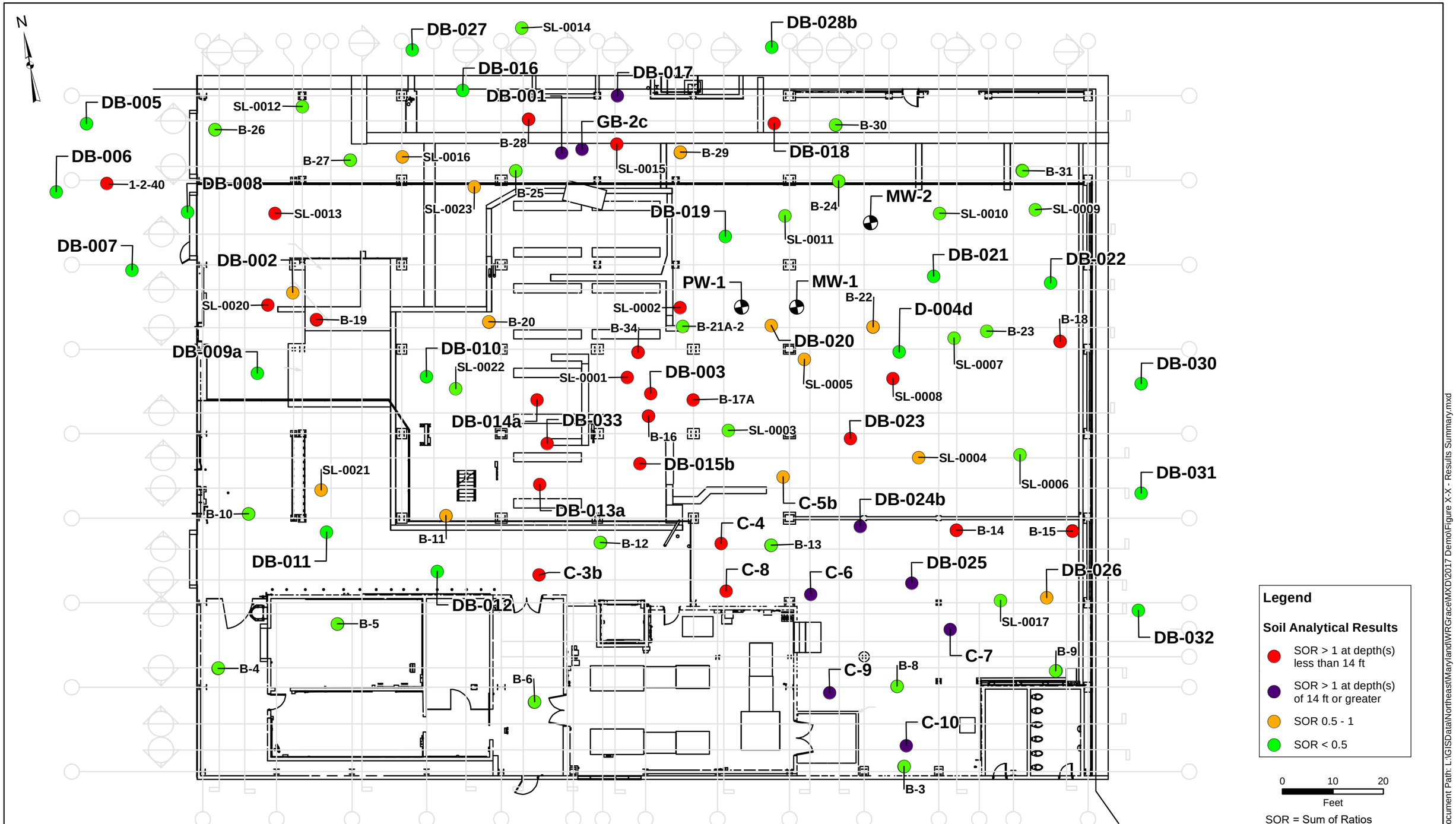


BUILDING 23 SITE DETAIL MAP - FIRST FLOOR PLAN VIEW

W.R. Grace Curtis Bay Facility

Baltimore, MD

Figure 3



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SUMMARY OF RESULTS FROM DELINEATION OF RADIOLOGICAL IMPACTS IN SOIL

W.R. Grace Curtis Bay Facility
Baltimore, MD

Figure 4

Appendix A
Public Notice (Published 17 February 2020)

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LEGAL NOTICES

Notice of Initiation of the Five-Year Review for Remedial Action at Building 23
W.R. Grace Curtis Bay Facility, Baltimore, Maryland

The U. S. Army Corps of Engineers, Baltimore District, has initiated a five-year review for the W.R. Grace Curtis Bay Formerly Utilized Sites Remedial Action Program (FUSRAP) Site, Baltimore, Maryland.

The review process involves an evaluation of the risk posed by residual radioactivity remaining at Building 23, which is associated with monazite sand processing by the property owner to extract the radioactive element thorium under a contract with the Atomic Energy Commission in the 1950s. As a result of the processing operations, low levels of radioactive contamination remain in Building 23. The selected remedy to address residual radioactivity at Building 23 provides for either decontamination or removal of areas within the southwest quadrant of Building 23 that had been impacted with FUSRAP radionuclides. The remedy is documented in a Record of Decision dated 2005. An amendment to the 2005 Record of Decision is currently being coordinated with stakeholders to propose the complete demolition of the southwest quadrant of Building 23.

The methods, findings, and conclusions of the review will be documented in a Five-Year Review Report. The report will also identify issues found during the review, if any, and propose recommendations to address them. The final Five-Year Review report is anticipated by September 2020 and will be made available to the public.

Recent environmental documents from the site are available for review in the project's Administrative Record File, which is located at:

Enoch Pratt Library – Brooklyn Branch
300 East Patapsco Avenue
Baltimore, Maryland 21201
410-396-1120

This full public notice is also available on the internet at the following link: www.nab.usace.army.mil/EnvironmentalNotices

If you have any questions please contact Chris Gardner via email at Christopher.P.Gardner@usace.army.mil.
2/17/2020 6602673

NOTICE

EQ Northeast, Inc. (EQNE), a full-service environmental company with offices in Halethorpe MD, is seeking a permit to operate a controlled hazardous substances (CHS) facility as de-

AUCTIONS

Law Offices of
Adam J. Roa, P.C.
401 Washington Ave., Ste. 803
Towson, MD 21204

ESTATE AUCTION
$10,000 Suggested Opening Bid
BEREA
Two Story Inside-Group
BRICK TOWNHOME
- Renovation Needed -
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Home contains a living room, dining room, kitchen, 3 bedrooms, 2 baths and basement; lot size 18' x 106' m/l; annual $120 ground rent. *Please see our website or call for complete details, photos and terms.*
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A $5,000 cashier's check deposit is required to bid. *Please see our web site or call for complete details, photos & terms.*
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3 Bedrooms ♦ Bath ♦ Garage
Sale On Premises
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Off Rogers Avenue
Baltimore, MD 21207
THURS., FEB. 27 AT 11:00 A.M.
Renovation needed. A $5,000 deposit by cashier's check is required of the winning bidder at the auction. *Please see our website or call for complete details, photos & terms.*
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.57 Acre Level Lot Zoned BM
Auction to be held on the premises on Thursday, March 5, 2020 at 1:00pm
$75,000 - Opening bid | $5,000 deposit required
J-L JHL AUCTIONEERS
Jeff Baughman • 443.956.2628
jeff@jhlauctioneers.com
www.jhlauctioneers.com • 410.424.5456

THE AUCTION COMPANIES
CHECK OUR WEBSITES FOR ALL UPCOMING FORECLOSURE

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Appendix B
List of Documents Reviewed

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LIST OF DOCUMENTS REVIEWED

Amec Foster Wheeler Environment & Infrastructure, Inc. (AMEC). 2015. *Assessment Report, Building 23, W.R. Grace Curtis Bay Facility, Baltimore, Maryland.* September 16.

EA Engineering Science and Technology, Inc. (EA). 2002. *Final Remedial Investigation (RI) Report of Building 23 at W.R. Grace Curtis Bay Facility, Baltimore, Maryland.* April.

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USACE. 2020. *Record of Decision Amendment for Building 23 at the W.R. Grace Formerly Utilized Sites Remedial Action Program (FUSRAP) Site, 5500 Chemical Road, Baltimore, Maryland*. July.

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Appendix C
2017 Soil Characterization Data

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TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	B-2	B-2	B-2	B-2	B-2	DB-001	DB-001	DB-001	DB-001	DB-002	DB-002
	Sample Name	B-2-14-16	B-2-16-18	B-2-18-20	B-2-22-24	B-2-24-26	DB-001-8-10	DB-001-10-12	DB-001-12-14	DB-001-14-16	DB-002-8-10	DB-002-10-12
	Sample Date	2/21/2017	2/21/2017	2/21/2017	2/21/2017	2/21/2017	2/13/2017	2/13/2017	2/13/2017	2/13/2017	2/13/2017	2/13/2017
	Sample Depth	14-16 ft	16-18 ft	18-20 ft	22-24 ft	24-26 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	8-10 ft	10-12 ft
	Parent Sample											
Analyte	Unit											
Isotopic Uranium (Isotopic Uranium)												
Uranium-234	pCi/g	0.498	0.832	0.425	1.2	1.01	1.6	0.909	0.704	0.889	0.821	0.967
Uranium-235	pCi/g	< 0.0282 U	0.0598	< 0.0556 U	0.0831	< 0.0507 U	< 0.0881 U	0.0648	< 0.0482 U	0.0309	0.043	< 0.0524 U
Uranium-238	pCi/g	0.412	0.837	0.478	1	0.95	1.45	0.9	0.555	0.776	0.716	1.11
Isotopic Thorium (A-01-R MOD)												
Thorium-228	pCi/g	8.47	0.374	0.592	1.67	1.19	0.602	10.3	7.84	5.5	2.37	1.42
Thorium-230	pCi/g	1.65	0.481	0.507	1.12	1.28	0.537	1.9	1.47	1.08	1.09	1.13
Thorium-232	pCi/g	8.19	0.333	0.607	1.32	1.29	0.547	9.66	7.55	5.41	2.09	1.53
General Chemistry (E160.3)												
Moisture Content[1]	%	--	--	--	--	--	--	--	--	13.3	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	86.7	--	--
Other Detected Radionuclides (GA-01-R MOD)												
Actinium-228	pCi/g	7.93	0.502	0.789	1.48	1.55	0.495	7.68	6.46	--	2.24	1.85
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	8.15	--	--	--	--	1.55	8.96	6.63	--	3.31	2.19
Bismuth-214	pCi/g	0.567	0.543	0.987	1.52	1.57	0.579	0.834	0.61	--	0.874	1.35
Lead-212	pCi/g	8.16	0.573	0.622	1.16	1.6	0.614	7.99	6.47	--	2.06	1.82
Lead-214	pCi/g	0.554	0.491	0.962	1.44	1.66	0.637	--	0.568	--	1.13	1.55
Potassium-40	pCi/g	2.87	2.19	4.2	13.9	15.9	3.09	6.56	3.24	--	13	13.1
Radium-226	pCi/g	0.567	0.543	0.987	1.52	1.57	0.579	0.834	0.61	0.582	0.874	1.35
Thallium-208	pCi/g	2.86	0.218	0.431	0.531	0.679	0.207	2.44	2.31	--	0.753	0.664
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

Location ID		DB-002	DB-002	DB-003	DB-003	DB-003	DB-003	DB-004	DB-004	DB-004	DB-004	DB-004
Sample Name		DB-002-12-14	DB-002-14-16	DB-003-8-10	DB-003-10-12	DB-03-12-14	DB-003-14-16	DB-004-0-2	DB-004-2-4	DB-004-4-6	DB-004-6-8	DB-004-8-10
Sample Date		2/13/2017	2/13/2017	2/13/2017	2/13/2017	2/13/2017	2/13/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017
Sample Depth		12-14 ft	14-16 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft
Parent Sample												
Analyte	Unit											
Isotopic Uranium (Isotopic Uranium)												
Uranium-234	pCi/g	1.32	1.11	0.441	1.3	0.652	0.719	0.191	0.198	0.312	0.184	0.145
Uranium-235	pCi/g	0.0737	0.0617	< 0.0656 U	0.0996	0.0324	0.0517	< 0.0301 U	< 0.0418 U	< 0.064 U	< 0.0272 U	< 0.0453 U
Uranium-238	pCi/g	1.29	1.09	0.266	1.43	0.623	0.531	0.0844	0.164	0.321	0.203	0.105
Isotopic Thorium (A-01-R MOD)												
Thorium-228	pCi/g	2.45	1.24	8.05	0.983	2.45	0.777	0.277	0.628	2.5	2.64	1.78
Thorium-230	pCi/g	1.38	1.09	1.21	0.654	0.531	0.388	0.308	0.147	0.416	0.655	0.303
Thorium-232	pCi/g	2.48	1.08	8.01	0.789	2.45	0.674	0.263	0.456	2.2	2.53	1.69
General Chemistry (E160.3)												
Moisture Content[1]	%	--	13.3	--	--	--	14.8	--	--	--	--	--
Percent Solids	%	--	86.7	--	--	--	85.2	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MO												
Actinium-228	pCi/g	2.09	1.74	6.69	0.882	1.93	0.915	--	0.527	2.15	1.55	0.441
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	2.64	--	7.17	--	--	--	--	1.09	--	--	--
Bismuth-214	pCi/g	1.25	1.5	--	0.75	0.35	0.286	0.423	0.381	0.589	0.291	--
Lead-212	pCi/g	1.49	1.73	6.36	0.743	1.97	--	0.304	0.491	2.47	1.23	0.599
Lead-214	pCi/g	1.27	1.34	--	0.812	0.385	0.331	0.292	0.314	0.504	0.317	0.2
Potassium-40	pCi/g	12.2	10.1	5.3	9.08	4.68	--	3.19	3.69	5.58	3.13	2.1
Radium-226	pCi/g	1.25	1.5	0.278	0.75	0.35	0.286	0.423	0.381	0.589	0.291	< 0.199 U
Thallium-208	pCi/g	0.718	0.572	2.22	0.31	0.692	0.294	0.0957	0.218	0.706	0.45	0.207
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.
ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-004	DB-004	DB-005	DB-005	DB-005	DB-005	DB-005	DB-005	DB-005	DB-005
	Sample Name	DB-004-10-12	DB-004-12-14	DB-005-0-4	DB-005-4-6	DB-005-6-8	DB-005-8-10	DB-005-10-12	DUP-3	DB-005-12-14	DUP-4
	Sample Date	2/27/2017	2/27/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017
	Sample Depth	10-12 ft	12-14 ft	0-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	10-12 ft	12-14 ft	12-14 ft
	Parent Sample								DB-005-10-12		DB-005-12-14
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.219	0.317	0.756	0.162	0.194	0.121	0.0786	0.22	0.0897	< 0.0711 U
Uranium-235	pCi/g	0.0282	< 0.0451 U	0.042	< 0.0327 U	< 0.0563 U	< 0.0564 U	< 0.0309 U	< 0.0405 U	< 0.0319 U	< 0.081 U
Uranium-238	pCi/g	0.209	0.415	0.634	0.107	0.157	0.161	0.114	0.111	0.0938	0.147
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	1.43	1.39	0.941	0.348	0.343	0.221	0.285	0.351	0.306	0.196
Thorium-230	pCi/g	0.301	0.579	0.844	0.227	0.223	0.174	0.211	0.244	0.345	0.227
Thorium-232	pCi/g	0.907	1.33	0.817	0.237	0.226	0.29	0.183	0.236	0.28	0.15
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	0.534	2.24	0.568	0.447	--	--	--	--	--	--
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	1.05	--	--	--	--	--	--	--
Bismuth-214	pCi/g	0.37	1.2	0.371	0.317	0.627	0.443	0.531	0.529	0.448	0.223
Lead-212	pCi/g	0.552	1.64	0.417	0.289	0.372	0.34	0.279	0.289	0.292	--
Lead-214	pCi/g	0.285	1.28	0.515	0.36	0.725	0.538	0.446	0.593	0.574	0.31
Potassium-40	pCi/g	1.91	10.1	7.1	1.18	1.48	2	1.39	--	2.85	2.48
Radium-226	pCi/g	0.37	1.2	0.371	0.317	0.627	0.443	0.531	0.529	0.448	0.223
Thallium-208	pCi/g	0.188	0.558	0.221	--	0.137	0.126	--	0.113	0.117	--
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-005	DB-006	DB-006	DB-006	DB-006	DB-006	DB-006	DB-006	DB-007	DB-007
	Sample Name	DB-005-14-16	DB-006-0-4	DB-006-4-6	DB-006-6-8	DB-006-8-10	DB-006-10-12	DB-006-12-14	DB-006-14-16	DB-007-0-2	DB-007-2-4
	Sample Date	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017
	Sample Depth	14-16 ft	0-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.126	0.388	0.144	0.0803	0.132	0.105	0.0791	0.109	0.646	0.228
Uranium-235	pCi/g	< 0.0294 U	< 0.05 U	< 0.0483 U	< 0.0589 U	< 0.0556 U	< 0.0453 U	< 0.0295 U	< 0.0467 U	0.0354	< 0.0461 U
Uranium-238	pCi/g	0.0472	0.296	0.0621	0.0496	0.147	0.0488	0.142	0.0967	0.558	0.218
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.264	0.477	0.269	0.183	0.203	0.165	0.263	0.276	0.385	0.251
Thorium-230	pCi/g	0.246	0.393	0.236	0.201	0.234	0.115	0.237	0.152	0.712	0.349
Thorium-232	pCi/g	0.203	0.466	0.197	0.136	0.213	0.125	0.248	0.227	0.428	0.222
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	0.66	0.44	--	--	0.332	--	--	--	--	--
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-214	pCi/g	--	0.403	0.204	0.255	--	0.483	0.573	0.433	0.442	0.42
Lead-212	pCi/g	0.433	0.389	0.227	0.285	--	--	0.223	0.346	0.287	--
Lead-214	pCi/g	0.439	0.341	0.303	0.429	0.364	0.451	0.438	0.485	0.383	0.501
Potassium-40	pCi/g	1.83	7.5	1.33	2.25	2.08	1.61	2.27	1.78	6.11	--
Radium-226	pCi/g	< 0.279 U	0.403	0.204	0.255	< 0.363 U	0.483	0.573	0.433	0.442	0.42
Thallium-208	pCi/g	0.186	0.145	--	0.134	--	0.107	0.133	--	--	0.155
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-007	DB-007	DB-007	DB-007	DB-007	DB-007	DB-007	DB-008	DB-008	DB-008
	Sample Name	DB-007-4-8	DB-007-8-10	DB-007-10-12	DB-007-12-14	DUP-5	DB-007-14-16	DUP-6	DB-008-0-2	DB-008-2-4	DB-008-4-8
	Sample Date	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017
	Sample Depth	4-8 ft	8-10 ft	10-12 ft	12-14 ft	12-14 ft	14-16 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft
	Parent Sample					DB-007-12-14		DB-007-14-16			
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.203	0.184	0.147	0.137	0.0936	0.191	0.138	0.517	0.813	0.395
Uranium-235	pCi/g	< 0.0286 U	0.0312	< 0.0285 U	< 0.0285 U	< 0.0341 U	< 0.0452 U	< 0.0448 U	< 0.0487 U	0.0525	0.0432
Uranium-238	pCi/g	0.179	0.209	0.145	0.194	0.114	0.163	0.15	0.537	0.725	0.329
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.184	0.35	0.475	0.253	0.338	0.33	0.485	0.567	1.2	1.54
Thorium-230	pCi/g	0.307	0.47	0.592	0.304	0.321	0.592	0.658	0.925	0.962	0.977
Thorium-232	pCi/g	0.329	0.222	0.402	0.154	0.252	0.348	0.413	0.47	1.29	1.35
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	--	--	0.597	--	--	--	--	--	0.839	1.4
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	--	--	--	1.75	2.08
Bismuth-214	pCi/g	0.718	0.476	0.489	0.648	0.444	--	0.981	0.404	0.966	0.996
Lead-212	pCi/g	0.347	0.253	0.479	0.262	--	--	0.651	0.324	1.13	1.37
Lead-214	pCi/g	0.584	0.64	0.661	0.681	0.626	0.811	0.841	0.452	0.96	0.83
Potassium-40	pCi/g	--	1.73	--	--	--	2.94	3.63	5.6	4.41	1.79
Radium-226	pCi/g	0.718	0.476	0.489	0.648	0.444	< 0.335 U	0.981	0.404	0.966	0.996
Thallium-208	pCi/g	--	0.108	0.243	--	--	0.186	0.23	0.114	0.39	--
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-008	DB-008	DB-008	DB-008	DB-009	DB-010	DB-010	DB-010	DB-010	DB-010
	Sample Name	DB-008-8-10	DB-008-10-12	DB-008-12-14	DB-008-14-16	DB-009-1-2	DB-010-0-2	DB-010-2-4	DB-010-4-6	DB-010-6-8	DB-010-8-10
	Sample Date	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/24/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017
	Sample Depth	8-10 ft	10-12 ft	12-14 ft	14-16 ft	1-2 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.234	0.291	0.297	0.322	0.832	0.208	0.184	0.181	0.26	0.269
Uranium-235	pCi/g	< 0.0518 U	< 0.0555 U	< 0.0303 U	< 0.05 U	< 0.0466 U	0.0417	< 0.0315 U	< 0.0566 U	< 0.0297 U	0.0409
Uranium-238	pCi/g	0.18	0.256	0.162	0.296	0.741	0.262	0.166	0.166	0.256	0.205
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.689	0.771	0.623	0.644	3.04	0.365	0.3	0.537	1.21	0.92
Thorium-230	pCi/g	0.894	0.667	0.58	0.325	0.799	0.53	0.253	0.2	0.171	0.276
Thorium-232	pCi/g	0.902	0.899	0.588	0.493	2.83	0.218	0.204	0.315	1.17	0.647
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOD											
Actinium-228	pCi/g	--	1.32	--	0.892	1.74	0.321	--	0.395	1.14	1.05
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	3.66	--	--	--	2.26	--
Bismuth-214	pCi/g	0.7	1.17	0.755	0.647	0.377	0.307	--	0.293	0.234	--
Lead-212	pCi/g	0.949	1.4	0.704	0.652	2	0.27	0.239	0.423	1.05	--
Lead-214	pCi/g	0.898	1.2	0.731	0.672	0.374	0.365	0.307	0.251	0.417	0.347
Potassium-40	pCi/g	2.96	6.3	3.31	2.63	1.9	2.74	--	1.11	3.16	1.83
Radium-226	pCi/g	0.7	1.17	0.755	0.647	0.377	0.307	< 0.282 U	0.293	0.234	< 0.264 U
Thallium-208	pCi/g	0.453	0.34	0.263	0.279	0.672	0.137	--	0.231	0.357	0.348
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-010	DB-010	DB-010	DB-010	DB-011	DB-011	DB-011	DB-011	DB-011	DB-011
	Sample Name	DB-010-8-10-DUP	DB-010-10-12	DB-010-12-14	DB-010-14-16	DB-011-0-2	DB-011-2-4	DB-011-4-6	DB-011-6-8	DB-011-8-10	DB-011-10-12
	Sample Date	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017
	Sample Depth	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft
	Parent Sample	DB-010-8-10									
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.339	0.524	0.308	0.563	0.559	0.219	0.135	0.259	0.727	0.591
Uranium-235	pCi/g	< 0.0316 U	< 0.0302 U	< 0.0484 U	< 0.0614 U	0.0586	< 0.0549 U	< 0.0264 U	< 0.0276 U	0.0634	< 0.0638 U
Uranium-238	pCi/g	0.26	0.376	0.367	0.685	0.448	0.287	0.131	0.336	0.683	0.642
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.78	0.464	1.27	0.909	0.492	0.208	0.556	1.2	0.998	1
Thorium-230	pCi/g	0.244	0.45	0.522	0.741	0.593	0.458	0.184	0.462	0.969	0.986
Thorium-232	pCi/g	0.743	0.423	1.34	0.775	0.426	0.234	0.456	1.4	1.11	0.793
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOD											
Actinium-228	pCi/g	0.637	1.27	0.8	1.06	--	0.313	0.443	1.9	1.79	1.17
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	2.48	--	--	--	--	--	2.93	--	--
Bismuth-214	pCi/g	0.332	0.516	0.647	0.867	0.434	0.67	0.302	0.989	1.16	1.23
Lead-212	pCi/g	0.841	1.12	0.586	1.05	0.406	0.318	0.472	1.74	1.45	1.33
Lead-214	pCi/g	--	0.667	0.47	1.24	0.398	0.73	0.286	1.03	1.49	1.27
Potassium-40	pCi/g	2.67	4.45	3.29	5.01	2.61	1.64	--	8.16	9.03	7.18
Radium-226	pCi/g	0.332	0.516	0.647	0.867	0.434	0.67	0.302	0.989	1.16	1.23
Thallium-208	pCi/g	0.338	0.414	0.258	0.414	0.15	0.0991	0.178	0.592	0.523	0.423
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-011	DB-011	DB-012	DB-012	DB-012	DB-012	DB-012	DB-012	DB-012	DB-012
	Sample Name	DB-011-12-14	DB-011-14-16	DB-012-0-2	DB-012-2-4	DB-012-4-6	DB-012-6-8	DUP-7	DB-012-8-10	DB-012-10-12	DUP-8
	Sample Date	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017	2/17/2017
	Sample Depth	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	6-8 ft	8-10 ft	10-12 ft	10-12 ft
	Parent Sample							DB-012-6-8			DB-012-10-12
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	1.04	0.615	0.208	0.128	0.198	0.349	0.304	0.737	0.854	0.82
Uranium-235	pCi/g	< 0.048 U	0.029	< 0.0302 U	< 0.0483 U	< 0.0653 U	0.0282	< 0.0509 U	< 0.0467 U	0.0393	< 0.0459 U
Uranium-238	pCi/g	1.1	0.581	0.198	0.154	0.208	0.331	0.257	0.625	0.762	0.833
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.563	0.924	0.125	0.132	0.414	1.81	3.18	1.45	1.34	1.25
Thorium-230	pCi/g	0.572	0.603	0.28	0.21	0.205	0.413	0.561	0.877	0.927	0.852
Thorium-232	pCi/g	0.46	0.688	0.143	0.123	0.463	1.69	2.72	1.06	1.36	1.21
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	0.874	1.15	--	--	0.658	1.96	2.94	2.03	1.76	1.24
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	2.68	3.91	--	--	--
Bismuth-214	pCi/g	0.843	0.81	0.265	0.306	0.389	0.571	0.411	1.54	1.25	1.32
Lead-212	pCi/g	0.67	0.729	0.183	--	0.383	1.93	3.17	1.59	1.77	1.72
Lead-214	pCi/g	1.03	0.91	0.274	0.317	0.292	--	--	1.32	1.44	1.36
Potassium-40	pCi/g	3.21	3.02	--	1.71	2.65	3.78	3.39	13.5	9.6	8.6
Radium-226	pCi/g	0.843	0.81	0.265	0.306	0.389	0.571	0.411	1.54	1.25	1.32
Thallium-208	pCi/g	0.303	0.208	--	--	0.17	0.644	1.13	0.488	0.514	0.546
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-012	DB-012	DB-013	DB-013	DB-014	DB-014	DB-015	DB-015	DB-016	DB-016
	Sample Name	DB-012-12-14	DB-012-14-16	DB-013-0-2	DB-013-2-3	DB-014-0-2	DB-014-2-3	DB-015-0-4	DB-015-4-6	DB-016-0-2	DB-016-2-4
	Sample Date	2/17/2017	2/17/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/20/2017	2/20/2017
	Sample Depth	12-14 ft	14-16 ft	0-2 ft	2-3 ft	0-2 ft	2-3 ft	0-4 ft	4-6 ft	0-2 ft	2-4 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.193	0.535	11.4	1.51	9.53	0.535	1	0.984	0.407	0.238
Uranium-235	pCi/g	< 0.0289 U	< 0.0619 U	0.659	< 0.0327 U	0.398	0.0587	0.0531	0.0401	< 0.0279 U	< 0.028 U
Uranium-238	pCi/g	0.235	0.301	11.5	1.44	9.34	0.596	1.01	0.804	0.416	0.103
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.277	0.664	74.5	2.53	42.7	0.328	5.62	9.52	0.377	0.415
Thorium-230	pCi/g	0.199	0.533	9.84	0.685	8.31	0.255	1.35	1.81	0.629	0.355
Thorium-232	pCi/g	0.239	0.672	74.7	2.51	38.5	0.274	5.39	8.8	0.408	0.296
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	0.599	1.09	55.6	1.82	30.8	0.436	3.32	6.02	0.193	0.328
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	57.8	--	29.7	--	3.76	6.99	--	--
Bismuth-214	pCi/g	0.543	0.811	0.716	--	1.51	0.391	1.26	1.13	0.441	0.345
Lead-212	pCi/g	0.323	0.948	56.4	1.94	33.1	0.264	3.23	6.64	0.324	0.308
Lead-214	pCi/g	0.48	1.06	--	0.52	1.55	0.32	0.913	1.03	0.456	0.362
Potassium-40	pCi/g	--	3.62	--	2.48	7.32	5.02	3.04	2.84	1.86	3.19
Radium-226	pCi/g	0.543	0.811	0.716	< 0.587 U	1.51	0.391	1.26	1.13	0.441	0.345
Thallium-208	pCi/g	0.153	0.283	19.4	0.694	11	0.0948	1.1	2.09	0.0897	0.105
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	12.5	--	--	1.37	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-016	DB-016	DB-016	DB-016	DB-016	DB-016	DB-017	DB-017	DB-017
	Sample Name	DB-016-4-6	DB-016-6-8	DB-016-8-10	DB-016-10-12	DB-016-12-14	DB-016-14-16	DB-017-0-2	DB-017-2-4	DB-017-4-6
	Sample Date	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017
	Sample Depth	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft
	Parent Sample									
Analyte	Unit									
Isotopic Uranium (Isotopic Uranium)										
Uranium-234	pCi/g	0.126	0.178	0.422	0.325	0.32	0.87	0.389	0.133	0.144
Uranium-235	pCi/g	< 0.0574 U	< 0.0456 U	0.0362	< 0.045 U	< 0.0594 U	0.04	< 0.0504 U	< 0.0824 U	< 0.0278 U
Uranium-238	pCi/g	0.111	0.176	0.428	0.44	0.392	0.872	0.386	0.223	0.156
Isotopic Thorium (A-01-R MOD)										
Thorium-228	pCi/g	0.482	0.815	0.838	0.722	0.668	0.648	0.525	0.718	1.42
Thorium-230	pCi/g	0.396	0.467	0.913	0.435	0.505	0.903	0.612	0.255	0.557
Thorium-232	pCi/g	0.348	0.876	0.734	0.589	0.539	0.648	0.272	0.476	1.61
General Chemistry (E160.3)										
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI										
Actinium-228	pCi/g	0.522	0.881	1.23	0.802	0.666	0.581	--	0.554	1.36
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	--	--	--	1.86
Bismuth-214	pCi/g	0.443	0.447	0.871	0.917	0.789	0.698	0.498	--	0.295
Lead-212	pCi/g	0.413	0.939	1.08	0.806	0.734	0.685	--	0.429	1.24
Lead-214	pCi/g	0.454	0.486	1.15	0.953	0.8	0.622	0.488	0.371	0.384
Potassium-40	pCi/g	2.51	3.41	8.75	3.85	4.2	3.91	3.32	2.13	2.14
Radium-226	pCi/g	0.443	0.447	0.871	0.917	0.789	0.698	0.498	< 0.279 U	0.295
Thallium-208	pCi/g	0.188	0.342	0.416	0.462	0.26	0.283	0.134	0.281	0.429
Thorium-228	pCi/g	--	--	--	--	--	--	--	0.429	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-017	DB-017	DB-017	DB-017	DB-017	DB-018	DB-018	DB-018	DB-018	DB-018
	Sample Name	DB-017-6-8	DB-017-8-10	DB-017-10-12	DB-017-12-14	DB-017-14-16	DB-018-0-2	DB-018-2-4	DB-018-4-6	DB-018-6-8	DB-018-8-10
	Sample Date	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017
	Sample Depth	6-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.29	1.72	1.28	0.65	0.379	0.271	0.211	0.189	0.336	0.309
Uranium-235	pCi/g	< 0.053 U	0.142	0.0838	0.0294	< 0.0481 U	< 0.0423 U	< 0.0534 U	< 0.058 U	< 0.0569 U	< 0.0503 U
Uranium-238	pCi/g	0.404	1.73	1.09	0.55	0.358	0.258 U	0.128	0.198	0.183	0.246
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	4.09	3.7	1.62	1.69	9.24	3.71	1.86	5.12	2.57	0.817
Thorium-230	pCi/g	0.837	1.17	1.44	0.696	1.27	0.591	0.485	0.996	0.612	0.311
Thorium-232	pCi/g	4.08	3.6	1.47	1.85	8.72	3.44	1.89	4.65	2.48	0.78
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	3.72	3.15	1.72	2.12	8.14	2.73	1.96	3.92	2.42	--
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	4.44	3.78	--	2.12	8.05	4.15	--	4.57	3.66	0.779
Bismuth-214	pCi/g	0.62	--	1.47	0.68	0.913	0.35	0.291	0.396	0.601	--
Lead-212	pCi/g	4.08	3.81	1.79	1.77	8.62	3.3	1.8	3.86	2.28	0.692
Lead-214	pCi/g	0.676	0.986	1.69	0.745	0.784	0.52	0.624	0.419	0.719	0.52
Potassium-40	pCi/g	5.58	7.76	14.4	3.05	4.36	2.22	3.01	--	4.73	1.81
Radium-226	pCi/g	0.62	< 0.652 U	1.47	0.68	0.913	0.35	0.291	0.396	0.601	< 0.402 U
Thallium-208	pCi/g	1.41	1.14	0.544	0.629	2.8	1.18	0.52	1.26	0.815	0.292
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-019	DB-019	DB-019	DB-019	DB-020	DB-020	DB-020	DB-020	DB-020	DB-020
	Sample Name	DB-019-0-2	DB-019-2-4	DB-019-4-8	DB-019-8-10	DB-020-0-2	DB-020-2-4	DB-020-4-6	DB-020-6-8	DB-020-8-10	DB-020-10-12
	Sample Date	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017
	Sample Depth	0-2 ft	2-4 ft	4-8 ft	8-10 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.482	0.201	0.526	0.242	0.376	0.336	0.156	0.115	0.34	0.608
Uranium-235	pCi/g	< 0.0338 U	< 0.0562 U	< 0.0367 U	< 0.0354 U	0.0655	0.0312	< 0.0677 U	< 0.0488 U	< 0.0571 U	0.0463
Uranium-238	pCi/g	0.641	0.316	0.439	0.26	0.33	0.146	0.143	0.129	0.447	0.598
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.525	0.867	1.52	0.857	1.62	0.925	3.2	1.98	2.47	1.5
Thorium-230	pCi/g	0.659	0.557	0.455	0.468	0.717	0.428	0.462	0.498	0.63	0.624
Thorium-232	pCi/g	0.415	0.609	1.71	0.944	1.3	0.708	3.1	1.69	2.35	1.61
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	< 0.355 U	0.388	1.24	0.899	0.915	--	3	1.43	2.57	0.791
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	1.82	--	--	--	2.98	--
Bismuth-214	pCi/g	0.399	0.418	0.558	--	0.429	0.321	0.306	0.211	0.47	0.335
Lead-212	pCi/g	0.314	0.582	1.17	0.959	0.861	0.79	3.51	1.42	2.27	0.723
Lead-214	pCi/g	0.372	0.464	0.682	0.506	0.452	0.523	0.344	0.39	0.481	0.284
Potassium-40	pCi/g	8.85	3.2	4.86	13.3	7.79	2.78	2.52	3.52	6.86	1.64
Radium-226	pCi/g	0.399	0.418	0.558	< 0.831 U	0.429	0.321	0.306	0.211	0.47	0.335
Thallium-208	pCi/g	0.12	0.2	0.441	0.261	0.3	0.32	1.11	0.624	0.776	0.295
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-020	DB-020	DB-021	DB-021	DB-021	DB-021	DB-021	DB-021	DB-021	DB-022
	Sample Name	DB-020-12-14	DB-020-14-16	DB-021-0-2	DB-021-2-4	DB-021-4-8	DB-021-8-10	DB-021-10-12	DB-021-12-14	DB-021-14-16	DB-022-0-2
	Sample Date	2/15/2017	2/15/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017
	Sample Depth	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.187	0.501	0.279	0.134	0.123	0.236	0.344	0.354	0.21	0.337
Uranium-235	pCi/g	< 0.0921 U	< 0.0311 U	< 0.0339 U	< 0.0636 U	< 0.0496 U	< 0.0304 U	< 0.0531 U	0.032	< 0.0491 U	< 0.0747 U
Uranium-238	pCi/g	0.217	0.187	0.356	0.091	0.0965	0.195	0.319	0.312	0.21	0.322
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.928	1.75	0.217	0.255	0.191	0.349	0.479	0.68	0.593	0.326
Thorium-230	pCi/g	0.392	0.518	0.515	0.326	0.225	0.136	0.391	0.194	0.352	0.361
Thorium-232	pCi/g	1	1.49	0.314	0.243	0.149	0.194	0.398	0.608	0.628	0.249
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	17.5	--
Percent Solids	%	--	--	--	--	--	--	--	--	82.5	--
Other Detected Radionuclides (GA-01-R MO											
Actinium-228	pCi/g	0.765	1.28	--	--	--	--	0.702	0.607	0.687	--
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-214	pCi/g	0.266	0.388	0.447	0.221	--	--	0.811	0.389	0.348	0.261
Lead-212	pCi/g	0.89	1.3	0.188	0.212	0.0887	--	0.623	0.507	0.516	0.257
Lead-214	pCi/g	0.332	0.445	0.483	0.236	0.168	0.236	0.694	0.433	0.288	0.364
Potassium-40	pCi/g	3.15	3.69	6.91	0.726	1.25	3.13	6.03	2.42	3.28	5.74
Radium-226	pCi/g	0.266	0.388	0.447	0.221	< 0.161 U	< 0.278 U	0.811	0.389	0.348	0.261
Thallium-208	pCi/g	0.353	0.478	--	0.0527	0.0625	--	0.242	0.169	0.185	--
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

Location ID		DB-022	DB-022	DB-022	DB-022	DB-022	DB-022	DB-023	DB-023	DB-023	DB-023
Sample Name		DB-022-2-4	DB-022-4-8	DB-022-8-10	DB-022-10-12	DB-022-12-14	DB-022-14-16	DB-023-0-2	DB-023-2-4	DB-023-4-6	DB-023-6-8
Sample Date		2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017
Sample Depth		2-4 ft	4-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft
Parent Sample											
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.241	0.382	0.224	< 0.082 U	0.123	0.21	0.574	0.609	0.48	0.284
Uranium-235	pCi/g	< 0.0533 U	< 0.0599 U	< 0.0301 U	< 0.0991 U	< 0.0346 U	< 0.0314 U	0.0307	< 0.0498 U	< 0.0309 U	< 0.0295 U
Uranium-238	pCi/g	0.212	0.418	0.141	0.0764	0.144	0.33	0.357	0.639	0.582	0.359
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.474	3.28	1.04	0.245	0.346	0.413	7.52	37	8.99	1.33
Thorium-230	pCi/g	0.222	0.67	0.273	0.179	0.26	0.386	1.45	5.27	1.27	0.353
Thorium-232	pCi/g	0.268	2.88	0.913	0.263	0.365	0.456	7.65	37	9.51	1.19
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOD											
Actinium-228	pCi/g	--	1.37	0.619	--	0.2	0.405	3.6	32.1	6.76	1.44
Beryllium-7	pCi/g	0.383	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	1.39	1.24	--	--	--	4.25	32.4	7.86	--
Bismuth-214	pCi/g	--	0.322	--	0.156	0.221	0.455	0.523	--	--	--
Lead-212	pCi/g	0.161	1.27	0.676	0.0947	0.23	0.563	3.95	34.9	6.92	1.13
Lead-214	pCi/g	0.212	0.253	0.26	0.183	0.207	--	0.424	--	--	--
Potassium-40	pCi/g	1.55	1.42	1.29	0.898	0.966	5.95	8.49	7.18	5.35	4.54
Radium-226	pCi/g	< 0.169 U	0.322	< 0.275 U	0.156	0.221	0.455	0.523	0.803	< 0.557 U	< 0.386 U
Thallium-208	pCi/g	0.101	0.457	0.207	--	--	0.233	1.29	11.6	2.46	0.388
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-023	DB-023	DB-023	DB-023	DB-024	DB-024	DB-024	DB-024	DB-024	DB-024
	Sample Name	DB-023-8-10	DB-023-10-12	DB-023-12-14	DB-023-14-16	DB-024b-0-2	DB-024b-2-4	DB-024b-4-6	DB-024b-6-8	DB-024b-8-10	DB-024b-10-12
	Sample Date	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017
	Sample Depth	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.308	0.309	0.234	0.251	0.215	0.245	0.223	0.223	0.305	0.742
Uranium-235	pCi/g	< 0.0557 U	< 0.0586 U	< 0.0695 U	< 0.0575 U	< 0.0484 U	0.0316	0.0295	< 0.0308 U	< 0.0532 U	< 0.034 U
Uranium-238	pCi/g	0.201	0.313	0.215	0.317	0.269	0.152	0.221	0.128	0.238	0.733
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	1.42	2.9	3.82	3.77	0.429	0.339	0.497	7.49	12.2	26.1
Thorium-230	pCi/g	0.336	0.549	0.772	0.766	0.517	0.305	0.241	1.12	1.65	2.92
Thorium-232	pCi/g	1.14	2.46	4.14	3.75	0.333	0.22	0.401	7.41	13.6	23.4
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	--	1.65	2.94	2.44	0.46	0.298	--	5.81	9.42	17.9
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	2.37	3.85	2.35	--	--	--	6.93	10.2	18.7
Bismuth-214	pCi/g	--	0.252	0.324	0.419	0.299	--	0.408	0.372	0.749	0.514
Lead-212	pCi/g	0.953	1.74	3.2	2.74	0.305	0.207	0.389	5.71	10.2	21.2
Lead-214	pCi/g	--	0.35	0.325	--	0.375	0.406	0.285	0.378	0.635	0.642
Potassium-40	pCi/g	4.88	3.01	2.63	3.92	3.43	3.91	1.66	2.33	6.47	13.1
Radium-226	pCi/g	< 0.368 U	0.252	0.324	0.419	0.299	< 0.296 U	0.408	0.372	0.749	0.514
Thallium-208	pCi/g	0.269	0.592	1.19	0.797	0.131	0.12	0.128	1.87	3.4	6.28
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-024	DB-024	DB-025	DB-025	DB-025	DB-025	DB-025	DB-025	DB-025	DB-025
	Sample Name	DB-024b-12-14	DB-024b-14-16	DB-025-0-2	DB-025-2-4	DB-025-4-6	DB-025-6-8	DB-025-8-10	DB-025-10-12	DB-025-12-14	DB-025-14-16
	Sample Date	2/15/2017	2/15/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017
	Sample Depth	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.568	0.923	0.342	0.407	2.15	0.308	0.357	0.349	0.405	0.272
Uranium-235	pCi/g	0.0305	< 0.0656 U	0.0416	< 0.0582 U	0.0965	< 0.0317 U	< 0.069 U	< 0.0326 U	< 0.0315 U	< 0.0303 U
Uranium-238	pCi/g	0.681	0.559	0.302	0.509	2.29	0.341	0.432	0.37	0.417	0.383
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	10.1	6.88	7.61	30.2	10.4	24	4.96	3.57	5.78	6.75
Thorium-230	pCi/g	1.34	0.976	1.18	3.07	1.68	2.96	0.845	0.414	0.812	1.22
Thorium-232	pCi/g	10.9	6.16	7.08	27.4	9.89	22.6	5.25	2.95	5.2	6.66
General Chemistry (E160.3)											
Moisture Content[1]	%	--	5.6	--	--	--	--	--	--	--	18.3
Percent Solids	%	--	94.4	--	--	--	--	--	--	--	81.7
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	6	3.35	6.52	20.4	10.5	17.2	4.72	1.97	1.98	6.78
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	5.33	3.71	6.61	21.3	10.9	17.2	5.52	2.92	2.65	6.75
Bismuth-214	pCi/g	--	0.283	0.694	0.827	0.965	--	--	0.206	--	0.764
Lead-212	pCi/g	5.84	3.93	7.23	22.2	11.4	18.7	5.19	2.04	2.1	6.79
Lead-214	pCi/g	--	0.246	0.572	0.675	1.08	0.609	0.47	0.225	0.302	--
Potassium-40	pCi/g	3.66	1.71	3.89	8.46	7.3	4.87	3.3	1.8	1.08	5.78
Radium-226	pCi/g	< 0.226 U	0.283	0.694	0.827	0.965	< 0.8 U	0.485	0.206	< 0.258 U	0.764
Thallium-208	pCi/g	1.96	1.26	2.34	7.04	3.42	5.96	1.76	0.675	0.622	2.61
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-026	DB-026	DB-026	DB-026	DB-026	DB-026	DB-026	DB-026	DB-027	DB-027
	Sample Name	DB-026-0-2	DB-026-2-4	DB-026-4-6	DB-026-6-8	DB-026-8-10	DB-026-10-12	DB-026-12-14	DB-026-14-16	DB-027-0-2	DB-027-6-8
	Sample Date	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/14/2017	2/20/2017	2/20/2017
	Sample Depth	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	6-8 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.217	0.256	0.452	0.343	0.394	0.336	0.19	0.463	0.139	0.0979
Uranium-235	pCi/g	< 0.0518 U	< 0.0581 U	< 0.0647 U	< 0.0501 U	< 0.0489 U	< 0.0319 U	< 0.0275 U	< 0.0317 U	< 0.0667 U	< 0.0454 U
Uranium-238	pCi/g	0.178	0.193	0.527	0.21	0.322	0.316	0.114	0.417	0.224	0.124
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.337	0.371	3.4	0.412	1.5	5.03	1.04	3.86	0.194	0.276
Thorium-230	pCi/g	0.295	0.405	0.745	0.396	0.52	0.948	0.196	0.897	0.409	0.287
Thorium-232	pCi/g	0.272	0.208	3.05	0.285	1.37	4.52	0.829	3.77	0.165	0.425
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	19.3	--	--
Percent Solids	%	--	--	--	--	--	--	--	80.7	--	--
Other Detected Radionuclides (GA-01-R MO											
Actinium-228	pCi/g	--	--	1.83	--	1.01	2.55	0.302	2.59	--	--
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	2.05	--	--	2.39	--	4.73	--	--
Bismuth-214	pCi/g	--	0.276	--	0.173	--	0.225	--	0.872	0.589	0.335
Lead-212	pCi/g	--	0.168	1.67	0.201	0.81	2.66	0.333	3.24	0.277	0.294
Lead-214	pCi/g	0.3	0.261	0.296	0.226	0.251	--	--	1.05	0.79	0.309
Potassium-40	pCi/g	1.54	1.66	1.81	--	1.26	1.13	0.973	8.95	3.7	1.47
Radium-226	pCi/g	< 0.23 U	0.276	< 0.481 U	0.173	< 0.436 U	0.225	< 0.272 U	0.872	0.589	0.335
Thallium-208	pCi/g	--	0.0836	0.636	0.134	0.301	0.877	0.188	1.05	0.129	0.102
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-027	DB-028	DB-028	DB-028	DB-028	DB-028	DB-028	DB-028	DB-028	DB-028
	Sample Name	DB-027-14-16	DB-028-0-2	DB-028-2-4	DB-028-4-8	DB-028-8-10	DB-028-10-12	DB-028-12-14	DB-028-14-16	DB-028-16-18	DB-028-18-20
	Sample Date	2/20/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017
	Sample Depth	14-16 ft	0-2 ft	2-4 ft	4-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	16-18 ft	18-20 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.478	0.299	0.16	0.204	0.275	0.221	0.133	0.243	0.271	0.162
Uranium-235	pCi/g	0.039	< 0.0288 U	0.0268	< 0.0274 U	< 0.0539 U	< 0.0536 U	< 0.0538 U	< 0.0286 U	< 0.0282 U	< 0.0276 U
Uranium-238	pCi/g	0.361	0.214	0.151	0.154	0.199	0.149	0.0785	0.13	0.317	0.116
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.594	0.391	0.276	0.359	0.437	0.419	0.301	0.379	0.633	1.46
Thorium-230	pCi/g	0.665	0.433	0.301	0.327	0.442	0.438	0.245	0.303	0.551	0.322
Thorium-232	pCi/g	0.639	0.327	0.247	0.225	0.428	0.248	0.247	0.162	0.46	1.29
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	0.76	0.421	--	0.406	0.479	--	0.406	0.395	0.82	1.34
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	--	--	--	1.48	--
Bismuth-214	pCi/g	0.978	0.444	0.476	0.631	0.67	0.517	0.3	0.505	0.913	0.309
Lead-212	pCi/g	0.807	0.301	0.331	0.359	0.629	0.348	0.284	0.375	0.702	--
Lead-214	pCi/g	0.859	0.395	0.528	--	0.728	0.307	0.377	0.659	1.1	0.288
Potassium-40	pCi/g	4.16	2.73	4.05	4.21	4.84	2.61	1.82	1.93	6.9	2.51
Radium-226	pCi/g	0.978	0.444	0.476	0.631	0.67	0.517	0.3	0.505	0.913	0.309
Thallium-208	pCi/g	0.308	0.131	0.101	0.141	0.237	--	0.126	--	0.212	0.542
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-030	DB-030	DB-030	DB-030	DB-030	DB-031	DB-031	DB-031	DB-031	DB-032
	Sample Name	DB-030-4.5-6	DB-030-12-14	DUP-13	DB-030-18-20	DUP-14	DB-031-5-6	DB-031-6-8	DB-031-12-14	DB-031-18-20	DB-032-5-8
	Sample Date	2/28/2017	2/28/2017	2/24/2017	2/28/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017	2/24/2017
	Sample Depth	4.5-6 ft	12-14 ft	12-14 ft	18-20 ft	18-20 ft	5-6 ft	6-8 ft	12-14 ft	18-20 ft	5-8 ft
	Parent Sample			DB-032-12-14		DB-031-18-20					
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.314	0.313	0.124	0.606	0.802	0.118	0.28	0.199	0.768	0.224
Uranium-235	pCi/g	< 0.0508 U	< 0.0554 U	< 0.028 U	0.0459	< 0.0441 U	< 0.0262 U	< 0.0475 U	< 0.0313 U	< 0.0296 U	< 0.0297 U
Uranium-238	pCi/g	0.371	0.309	0.131	0.653	0.673	0.131	0.136	0.246	0.602	0.252
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.317	0.503	0.364	0.847	0.664	0.648	1.26	0.49	0.601	0.342
Thorium-230	pCi/g	0.381	0.382	0.209	0.749	0.87	0.31	0.42	0.413	0.698	0.367
Thorium-232	pCi/g	0.204	0.481	0.266	0.907	0.803	0.529	1.14	0.521	0.777	0.349
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI											
Actinium-228	pCi/g	--	0.723	--	1.44	1.08	0.712	0.697	--	1.22	< 0.237 U
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	1.79	--	--	--	--
Bismuth-214	pCi/g	0.405	0.599	0.186	2.05	0.927	--	0.193	--	1.07	0.268
Lead-212	pCi/g	--	0.748	0.234	1.26	1.07	0.454	0.724	0.4	1.07	0.288
Lead-214	pCi/g	0.297	0.854	0.149	1.17	1.04	0.225	0.234	0.332	1.01	0.219
Potassium-40	pCi/g	1.64	5.52	--	11.2	6.91	3.12	1.06	3.52	6.02	3.66
Radium-226	pCi/g	0.405	0.599	0.186	2.05	0.927	< 0.362 U	0.193	< 0.346 U	1.07	0.268
Thallium-208	pCi/g	--	0.25	0.0935	--	0.441	0.175	0.217	0.144	0.265	0.11
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-032	DB-032	DB-033	DB-033	DB-033	DB-033	DB-033	DB-033	DB-033
	Sample Name	DB-032-12-14	DB-032-18-20	DB-033-0-2	DB-033-2-4	DB-033-4-6	DB-033-6-8	DB-033-8-10	DB-033-10-12	DB-033-12-14
	Sample Date	2/24/2017	2/24/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017
	Sample Depth	12-14 ft	18-20 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft
	Parent Sample									
Analyte	Unit									
Isotopic Uranium (Isotopic Uranium)										
Uranium-234	pCi/g	0.125	0.919	0.988	1.38	2.03	0.273	0.617	0.552	0.662
Uranium-235	pCi/g	< 0.0456 U	< 0.0461 U	< 0.0568 U	0.123	0.0818	< 0.0313 U	0.0407	0.0593	0.0409
Uranium-238	pCi/g	0.121	0.709	0.857	1.36	1.74	0.207	0.683	0.357	0.581
Isotopic Thorium (A-01-R MOD)										
Thorium-228	pCi/g	0.262	0.737	36.7	37.6	38.3	17	16.2	2.7	1.03
Thorium-230	pCi/g	0.224	0.881	5.24	5.18	5.68	1.84	2.33	0.823	0.532
Thorium-232	pCi/g	0.344	0.586	34.6	36.1	35.9	16.2	14.4	2.69	1.01
General Chemistry (E160.3)										
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI										
Actinium-228	pCi/g	0.402	0.999	21.4	26.3	30.5	11.8	10.9	2.43	1.06
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	2.79	21.5	28.5	33.4	13.1	13.7	2.65	--
Bismuth-214	pCi/g	--	0.859	--	--	--	--	0.86	0.762	0.652
Lead-212	pCi/g	--	0.95	21.2	28.5	33.4	12.6	12	2	1.25
Lead-214	pCi/g	--	0.817	--	--	--	0.41	0.766	0.758	0.549
Potassium-40	pCi/g	--	3.9	5.5	5.1	4.76	1.83	9.31	5.83	3.55
Radium-226	pCi/g	< 0.201 U	0.859	< 0.894 U	0.477	< 0.897 U	< 0.762 U	0.86	0.762	0.652
Thallium-208	pCi/g	0.125	0.259	7.41	9.21	10.4	4.09	3.92	0.758	0.328
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	DB-033	C-3	C-3	C-3	C-3	C-3	C-3
	Sample Name	DB-033-14-16	C-3-0-2 (DB-035-0-2)	C-3-2-4 (DB-035-2-4)	C-3-4-6 (DB-035-4-6)	DUP-9	C-3-6-8 (DB-035-6-8)	C-3-8-10 (DB-035-8-10)
	Sample Date	2/16/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017	2/20/2017
	Sample Depth	14-16 ft	0-2 ft	2-4 ft	4-6 ft	4-6 ft	6-8 ft	8-10 ft
	Parent Sample					C-3-4-6 (DB-035-4-6)		
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	0.873	0.218	0.0819	0.189	0.206	0.275	0.659
Uranium-235	pCi/g	0.0304	< 0.0485 U	< 0.0272 U	< 0.0587 U	< 0.0308 U	< 0.102 U	< 0.0483 U
Uranium-238	pCi/g	0.788	0.189	0.133	0.184	0.214	0.329	0.566
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	0.895	0.187	0.208	0.287	0.489	6.73	1.75
Thorium-230	pCi/g	0.988	0.528	0.211	0.204	0.176	1.23	1.13
Thorium-232	pCi/g	0.736	0.139	0.153	0.29	0.279	6.06	1.27
General Chemistry (E160.3)								
Moisture Content[1]	%	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOD								
Actinium-228	pCi/g	1.14	--	--	0.595	0.443	5.66	1.56
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	--	6.34	--
Bismuth-214	pCi/g	1.17	0.791	0.289	--	0.235	0.345	1.53
Lead-212	pCi/g	1.06	0.182	0.182	0.432	0.383	6.34	1.46
Lead-214	pCi/g	1.09	0.565	0.362	0.263	0.25	0.693	1.28
Potassium-40	pCi/g	4.86	2.01	1.02	1.58	< 0.932 U	4	11
Radium-226	pCi/g	1.17	0.791	0.289	< 0.244 U	0.235	0.345	1.53
Thallium-208	pCi/g	0.384	--	0.111	0.134	0.223	1.86	0.624
Thorium-228	pCi/g	--	--	--	--	--	--	--
Thorium-234	pCi/g	4.87	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-3	C-3	C-3	C-4	C-4	C-4	C-4
	Sample Name	C-3-10-12 (DB-035-10-12)	C-3-12-14 (DB-035-12-14)	C-3-14-16 (DB-035-14-16)	C-4-0-2 (DB-036-0-2)	C-4-2-4 (DB-036-2-4)	C-4-4-6 (DB-036-4-6)	C-4-6-8 (DB-036-6-8)
	Sample Date	2/20/2017	2/20/2017	2/20/2017	2/15/2017	2/15/2017	2/15/2017	2/15/2017
	Sample Depth	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft
	Parent Sample							
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	0.68	0.442	0.292	0.282	0.0851	0.379	0.178
Uranium-235	pCi/g	0.0294	< 0.0573 U	< 0.0258 U	< 0.0293 U	< 0.0289 U	< 0.0542 U	< 0.0268 U
Uranium-238	pCi/g	0.58	0.548	0.252	0.291	0.0483	0.264	0.172
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	1.85	2.31	0.721	9.82	19.4	5.49	3.28
Thorium-230	pCi/g	0.937	0.858	0.449	1.6	2.66	0.721	0.569
Thorium-232	pCi/g	1.45	2.03	0.471	9.33	19	4.63	3.19
General Chemistry (E160.3)								
Moisture Content[1]	%	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI								
Actinium-228	pCi/g	2.1	1.89	0.506	6.2	18.4	4.06	3.7
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	19.5	5.27	4.21
Bismuth-214	pCi/g	1.01	0.838	0.419	0.719	--	--	--
Lead-212	pCi/g	1.89	1.8	0.418	6.96	17.7	4.87	3.75
Lead-214	pCi/g	1.1	0.533	0.364	0.681	0.581	0.444	--
Potassium-40	pCi/g	7.28	5.14	1.72	4.64	3.86	3.24	2.34
Radium-226	pCi/g	1.01	0.838	0.419	0.719	< 0.81 U	< 0.59 U	0.431
Thallium-208	pCi/g	0.633	0.734	0.157	2.23	6.36	1.5	1.28
Thorium-228	pCi/g	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

Location ID		C-4	C-4	C-4	C-4	C-5	C-5	C-5
Sample Name		C-4-8-10 (DB-036-8-10)	C-4-10-12 (DB-036-10-12)	C-4-12-14 (DB-036-12-14)	C-4-14-16 (DB-036-14-16)	C-5-0-2 (DB-037-0-2)	C-5-2-4 (DB-037-2-4)	C-5-4-6 (DB-037-4-6)
Sample Date		2/15/2017	2/15/2017	2/15/2017	2/15/2017	2/16/2017	2/16/2017	2/16/2017
Sample Depth		8-10 ft	10-12 ft	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft
Parent Sample								
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	0.315	0.774	0.295	0.597	0.178	1.54	0.433
Uranium-235	pCi/g	< 0.0787 U	< 0.0601 U	0.0329	< 0.0423 U	< 0.057 U	0.13	< 0.0601 U
Uranium-238	pCi/g	0.481	0.675	0.365	0.498	0.167	1.62	0.301
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	17.3	6.3	10	2.34	0.715	3.12	3.3
Thorium-230	pCi/g	2.66	0.876	1.3	0.601	0.294	0.524	0.497
Thorium-232	pCi/g	18.2	5.8	8.12	1.86	0.79	2.92	3.2
General Chemistry (E160.3)								
Moisture Content[1]	%	17.6	--	--	--	--	--	--
Percent Solids	%	82.4	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI								
Actinium-228	pCi/g	18.9	4.86	7.58	1.14	0.962	2.3	3.07
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	20.1	5.53	7.83	--	1.61	3.38	4.14
Bismuth-214	pCi/g	0.906	0.442	0.62	0.296	0.325	2.51	--
Lead-212	pCi/g	20.6	4.78	8.85	1.26	0.794	2.25	2.86
Lead-214	pCi/g	0.557	0.531	0.556	0.306	0.261	2.68	0.357
Potassium-40	pCi/g	3.41	6.36	6.67	4.21	1.93	4.34	3.79
Radium-226	pCi/g	0.906	0.442	0.62	0.296	0.325	2.51	< 0.456 U
Thallium-208	pCi/g	6.69	1.59	2.76	0.395	0.218	0.805	1.12
Thorium-228	pCi/g	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-5	C-5	C-5	C-5	C-5	C-5
	Sample Name	C-5-6-8 (DB-037-6-8)	C-5-8-10 (DB-037-8-10)	C-5-10-12 (DB-037-10-12)	C-5-12-14 (DB-037-12-14)	C-5-12-14 (DB-037-12-14)-DUP	C-5-14-16 (DB-037-14-16)
	Sample Date	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017
	Sample Depth	6-8 ft	8-10 ft	10-12 ft	12-14 ft	12-14 ft	14-16 ft
	Parent Sample					C-5-12-14 (DB-037-12-14)	
Analyte	Unit						
Isotopic Uranium (Isotopic Uranium)							
Uranium-234	pCi/g	0.213	0.302	0.378	0.343	0.428	0.458
Uranium-235	pCi/g	< 0.0503 U	< 0.0615 U	< 0.0302 U	< 0.0683 U	< 0.0678 U	< 0.0338 U
Uranium-238	pCi/g	0.273	0.244	0.216	0.271	0.551	0.493
Isotopic Thorium (A-01-R MOD)							
Thorium-228	pCi/g	1.65	2.33	5.2	2.94	3.79	1.42
Thorium-230	pCi/g	0.287	0.449	0.824	0.678	0.659	0.75
Thorium-232	pCi/g	1.58	2.04	4.5	3.23	3.17	1.39
General Chemistry (E160.3)							
Moisture Content[1]	%	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI							
Actinium-228	pCi/g	1.25	1.92	4.8	2.36	3.06	1.56
Beryllium-7	pCi/g	--	--	--	--	--	--
Bismuth-212	pCi/g	1.94	--	3.99	3.79	2.54	1.34
Bismuth-214	pCi/g	0.273	0.503	--	0.502	0.308	--
Lead-212	pCi/g	1.26	1.71	4.79	2.02	2.82	1.92
Lead-214	pCi/g	0.356	0.334	0.376	0.372	0.423	0.972
Potassium-40	pCi/g	4.68	7.93	11.6	7.99	11.6	18.8
Radium-226	pCi/g	0.273	0.503	< 0.642 U	0.502	0.308	< 0.589 U
Thallium-208	pCi/g	0.37	0.616	1.71	0.853	1.13	0.566
Thorium-228	pCi/g	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-6	C-6	C-6	C-6	C-6	C-6	C-6
	Sample Name	C-6-0-2 (DB-038-0-2)	C-6-2-4 (DB-038-2-4)	C-6-4-6 (DB-038-4-6)	C-6-6-8 (DB-038-6-8)	C-6-8-10 (DB-038-8-10)	C-6-10-12 (DB-038-10-12)	C-6-12-14 (DB-038-12-14)
	Sample Date	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017
	Sample Depth	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft
	Parent Sample							
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	0.157	0.104	0.272	0.236	0.242	0.919	0.44
Uranium-235	pCi/g	0.0286	< 0.0499 U	< 0.0315 U	< 0.0458 U	< 0.0772 U	0.0962	< 0.0564 U
Uranium-238	pCi/g	0.189	0.0999	0.259	0.188	0.235	0.728	0.535
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	0.291	0.11	1.41	31	12.9	1.89	12.1
Thorium-230	pCi/g	0.208	0.192	0.216	4.16	1.47	0.848	1.56
Thorium-232	pCi/g	0.0954	0.104	1.22	33.5	12.8	1.46	12.8
General Chemistry (E160.3)								
Moisture Content[1]	%	--	--	--	18.3	--	--	--
Percent Solids	%	--	--	--	81.7	--	--	--
Other Detected Radionuclides (GA-01-R MOI								
Actinium-228	pCi/g	0.383	--	1.12	14.4	10	1.6	9.52
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	15	9.57	2.91	9.29
Bismuth-214	pCi/g	0.219	0.39	--	--	0.359	0.983	0.643
Lead-212	pCi/g	0.205	--	1.05	16	10.1	1.87	10.1
Lead-214	pCi/g	0.346	0.236	0.421	--	0.468	0.846	0.343
Potassium-40	pCi/g	1.57	1.27	1.85	4.1	4.08	10.4	4.55
Radium-226	pCi/g	0.219	0.39	< 0.303 U	0.477	0.359	0.983	0.643
Thallium-208	pCi/g	0.0901	--	0.22	4.92	3.47	0.584	3.4
Thorium-228	pCi/g	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-6	C-7	C-7	C-7	C-7	C-7	C-7
	Sample Name	C-6-14-16 (DB-038-14-16)	C-7-0-2 (DB-039-0-2)	C-7-2-4 (DB-039-2-4)	C-7-4-6 (DB-039-4-6)	C-7-6-8 (DB-039-6-8)	C-7-8-10 (DB-039-8-10)	C-7-10-12 (DB-039-10-12)
	Sample Date	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017	2/16/2017
	Sample Depth	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft
	Parent Sample							
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	1.06	0.261	0.0932	0.318	0.569	1.44	0.496
Uranium-235	pCi/g	0.0981	< 0.0564 U	< 0.0499 U	< 0.0537 U	0.0318	0.0817	0.0335
Uranium-238	pCi/g	1.14	0.186	< 0.0678 U	0.285	0.532	1.71	0.559
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	5.17	0.375	0.152	0.374	0.214	1.59	8.39
Thorium-230	pCi/g	0.971	0.468	0.17	0.477	0.347	0.427	0.92
Thorium-232	pCi/g	5.47	0.267	0.128	0.287	0.253	1.38	7.99
General Chemistry (E160.3)								
Moisture Content[1]	%	--	--	--	10.6	--	--	--
Percent Solids	%	--	--	--	89.4	--	--	--
Other Detected Radionuclides (GA-01-R MOI								
Actinium-228	pCi/g	2.51	--	--	--	--	0.887	3.79
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	3.56	--	--	--	--	--	4.75
Bismuth-214	pCi/g	0.309	0.311	0.22	0.657	0.202	0.344	0.238
Lead-212	pCi/g	2.54	0.271	0.188	0.488	0.164	0.864	3.83
Lead-214	pCi/g	0.258	0.545	--	0.719	0.243	0.28	0.233
Potassium-40	pCi/g	2.32	2.51	1.09	3.88	1.23	--	--
Radium-226	pCi/g	0.309	0.311	0.22	0.657	0.202	0.344	0.238
Thallium-208	pCi/g	0.783	0.143	--	0.193	--	0.35	1.27
Thorium-228	pCi/g	--	--	--	--	--	--	3.83
Thorium-234	pCi/g	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-7	C-7	C-8	C-8	C-8	C-8	C-8
	Sample Name	C-7-12-14 (DB-039-12-14)	C-7-14-16 (DB-039-14-16)	C-8-0-2 (DB-040-0-2)	C-8-2-4 (DB-040-2-4)	C-8-4-6 (DB-040-4-6)	C-8-6-8 (DB-040-6-8)	C-8-8-10 (DB-040-8-10)
	Sample Date	2/16/2017	2/16/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017
	Sample Depth	12-14 ft	14-16 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft
	Parent Sample							
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	0.38	0.276	0.158	0.204	0.207	0.139	0.462
Uranium-235	pCi/g	0.0316	0.0294	< 0.0518 U	< 0.0456 U	0.0359	< 0.0284 U	0.0454
Uranium-238	pCi/g	0.264	0.34	0.204	0.132	0.169	0.127	0.437
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	4.5	8.33	0.326	0.411	1.63	4.29	12.3
Thorium-230	pCi/g	0.606	1.15	0.29	0.33	0.352	0.659	1.76
Thorium-232	pCi/g	4.17	8.23	0.207	0.299	1.31	4.24	11.4
General Chemistry (E160.3)								
Moisture Content[1]	%	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI								
Actinium-228	pCi/g	2.02	6.28	--	0.592	1.41	3.97	9.59
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	2.5	6.62	--	--	2.11	5.74	9.7
Bismuth-214	pCi/g	0.253	0.838	--	0.449	0.44	0.239	0.398
Lead-212	pCi/g	1.99	6.24	0.207	0.435	1.17	4.5	7.2
Lead-214	pCi/g	--	0.782	--	0.324	0.392	0.2	--
Potassium-40	pCi/g	--	--	2.15	3.16	3.62	--	7.95
Radium-226	pCi/g	0.253	0.838	< 0.249 U	0.449	0.44	0.239	0.398
Thallium-208	pCi/g	0.643	2.24	0.077	0.122	0.478	1.3	3.43
Thorium-228	pCi/g	1.99	6.24	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-8	C-9	C-9	C-9	C-9	C-9	C-9
	Sample Name	DUP-12	C-9-0-2 (DB-041-0-2)	C-9-2-4 (DB-041-2-4)	C-9-4-6 (DB-041-4-6)	C-9-6-8 (DB-041-6-8)	C-9-8-10 (DB-041-8-10)	C-9-10-12 (DB-041-10-12)
	Sample Date	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017
	Sample Depth	8-10 ft	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft
	Parent Sample	C-8-8-10 (DB-040-8-10)						
Analyte	Unit							
Isotopic Uranium (Isotopic Uranium)								
Uranium-234	pCi/g	0.624	0.31	0.183	0.209	0.089	0.54	0.751
Uranium-235	pCi/g	< 0.0461 U	< 0.0293 U	< 0.0432 U	< 0.0743 U	< 0.0447 U	< 0.0433 U	0.0553
Uranium-238	pCi/g	0.579	0.403	0.236	0.195	0.131	0.646	1.01
Isotopic Thorium (A-01-R MOD)								
Thorium-228	pCi/g	11.3	0.52	0.299	0.423	6.48	14	1.27
Thorium-230	pCi/g	1.39	0.383	0.25	0.241	0.826	1.68	1.14
Thorium-232	pCi/g	10.6	0.355	0.193	0.349	6.56	12.8	1.14
General Chemistry (E160.3)								
Moisture Content[1]	%	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOD								
Actinium-228	pCi/g	9.17	0.844	0.266	0.442	5.72	11.9	1.3
Beryllium-7	pCi/g	--	--	--	--	--	--	--
Bismuth-212	pCi/g	11	1.42	--	--	5.95	13.8	1.33
Bismuth-214	pCi/g	0.579	0.697	0.33	0.417	0.419	0.645	0.993
Lead-212	pCi/g	10.8	0.692	0.307	0.384	6.29	12.8	1.19
Lead-214	pCi/g	0.435	0.767	0.378	0.401	--	0.683	0.897
Potassium-40	pCi/g	9.42	3.66	--	1.66	1.79	9.17	12.3
Radium-226	pCi/g	0.579	0.697	0.33	0.417	0.419	0.645	0.993
Thallium-208	pCi/g	3.82	0.278	0.09	0.115	2.11	4.34	0.42
Thorium-228	pCi/g	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-9	C-9	C-9	C-9	C-9	C-9
	Sample Name	C-9-12-14 (DB-041-12-14)	C-9-14-16 (DB-041-14-16)	DUP-10	C-9-16-18 (DB-041-16-18)	C-9-18-20 (DB-041-18-20)	DUP-11
	Sample Date	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017	2/22/2017
	Sample Depth	12-14 ft	14-16 ft	14-16 ft	16-18 ft	18-20 ft	18-20 ft
	Parent Sample			C-9-14-16 (DB-041-14-16)			C-9-18-20 (DB-041-18-20)
Analyte	Unit						
Isotopic Uranium (Isotopic Uranium)							
Uranium-234	pCi/g	0.203	0.166	0.205	0.219	0.459	0.492
Uranium-235	pCi/g	< 0.0407 U	< 0.0515 U	< 0.0297 U	< 0.0704 U	0.0361	0.05
Uranium-238	pCi/g	0.223	0.207	0.258	0.264	0.527	0.425
Isotopic Thorium (A-01-R MOD)							
Thorium-228	pCi/g	9.32	5.16	8.31	0.515	0.869	0.683
Thorium-230	pCi/g	1.36	0.832	1.09	0.393	0.312	0.533
Thorium-232	pCi/g	8.75	5.03	8.27	0.341	0.686	0.595
General Chemistry (E160.3)							
Moisture Content[1]	%	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MOI							
Actinium-228	pCi/g	7.98	3.62	5.96	0.272	1.21	0.938
Beryllium-7	pCi/g	--	--	--	--	--	--
Bismuth-212	pCi/g	9.87	3.98	7.31	--	--	1.72
Bismuth-214	pCi/g	0.507	--	0.312	0.302	0.614	0.782
Lead-212	pCi/g	9.06	3.82	6.89	0.401	1.05	0.828
Lead-214	pCi/g	--	0.411	0.328	0.273	0.749	0.86
Potassium-40	pCi/g	3.4	2.4	3.2	1.64	4.52	5.41
Radium-226	pCi/g	0.507	< 0.654 U	0.312	0.302	0.614	0.782
Thallium-208	pCi/g	2.71	1.33	2.07	0.163	0.286	0.287
Thorium-228	pCi/g	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

TABLE C-1. PRE-DESIGN INVESTIGATION SOIL RESULTS
PRE-DESIGN INVESTIGATION AT BUILDING 23, W.R. GRACE CURTIS BAY FACILITY

	Location ID	C-10	C-10	C-10	C-10	C-10	C-10	C-10	C-10	C-10	C-10
	Sample Name	C-10-0-2	C-10-2-4	C-10-4-6	C-10-6-8	C-10-8-10	C-10-10-12	C-10-12-14	C-10-14-16	C-10-16-18	C-10-18-20
	Sample Date	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017	2/27/2017
	Sample Depth	0-2 ft	2-4 ft	4-6 ft	6-8 ft	8-10 ft	10-12 ft	12-14 ft	14-16 ft	16-18 ft	18-20 ft
	Parent Sample										
Analyte	Unit										
Isotopic Uranium (Isotopic Uranium)											
Uranium-234	pCi/g	0.323	0.196	0.58	0.826	0.811	0.573	0.142	0.274	0.192	0.321
Uranium-235	pCi/g	< 0.0251 U	< 0.0672 U	< 0.0638 U	< 0.0289 U	0.048	< 0.0517 U	< 0.063 U	< 0.044 U	< 0.0468 U	< 0.0454 U
Uranium-238	pCi/g	0.228	0.231	0.565	0.73	0.859	0.525	0.144	0.341	0.169	0.254
Isotopic Thorium (A-01-R MOD)											
Thorium-228	pCi/g	0.419	0.356	2.28	2.59	3.26	13.4	2.02	7.32	2.88	0.694
Thorium-230	pCi/g	0.347	0.399	0.584	0.723	0.793	1.96	0.43	1.47	0.507	0.342
Thorium-232	pCi/g	0.27	0.322	2.22	2.64	3.3	12.7	1.89	7.32	2.78	0.783
General Chemistry (E160.3)											
Moisture Content[1]	%	--	--	--	--	--	--	--	--	--	--
Percent Solids	%	--	--	--	--	--	--	--	--	--	--
Other Detected Radionuclides (GA-01-R MO											
Actinium-228	pCi/g	--	0.305	1.86	1.41	1.77	3.36	0.531	3.36	2.02	1.09
Beryllium-7	pCi/g	--	--	--	--	--	--	--	--	--	--
Bismuth-212	pCi/g	--	--	--	--	1.91	3.88	--	5.58	2.44	1.53
Bismuth-214	pCi/g	0.541	0.242	--	0.266	0.27	0.338	0.256	0.615	--	0.432
Lead-212	pCi/g	0.512	0.332	2.14	1.55	1.73	3.52	0.719	3.6	1.82	0.858
Lead-214	pCi/g	0.714	0.339	0.575	0.282	0.347	--	0.202	0.447	0.475	0.477
Potassium-40	pCi/g	1.84	2.2	5.87	2.21	--	--	--	4.41	2.67	3.17
Radium-226	pCi/g	0.541	0.242	< 0.333 U	0.266	0.27	0.338	0.256	0.615	< 0.3 U	0.432
Thallium-208	pCi/g	0.118	0.157	0.708	0.468	--	1.07	0.241	1.17	0.641	0.387
Thorium-228	pCi/g	--	--	--	--	--	--	--	--	--	--
Thorium-234	pCi/g	--	--	--	--	--	--	--	--	--	--

Notes:
(1) Samples for quick-turnaround isotopic thorium analysis were analyzed for percent moisture to allow correction of the results, because these samples were not dried and ground due to time constraints.

ft = foot (feet)
pCi/g = picocuries per gram
U = Not detected

Appendix D
Site Inspection Checklists and Photograph Log

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Five-Year Review Site Inspection Checklist

I. SITE INFORMATION	
Site name: W.R. Grace Curtis Bay FUSRAP Site	**Date of inspection:** January 29, 2020
Location and Region: Baltimore, Maryland	**EPA ID:**
Agency, office, or company leading the five-year review: U.S. Army Corps of Engineers	**Weather/temperature:** Sunny, breezy, near 40°F
Five-Year Review Participants: Mike O'Neill, Samantha Saalfield, and Beth Wolinski (EA Engineering) Brandon Welbourn (W.R. Grace)	

Remedy Includes: (Check all that apply)

- ☐ Landfill cover/containment
- ☐ Access controls
- ☐ Institutional controls
- ☐ Groundwater pump and treatment
- ☐ Surface water collection and treatment
- ☐ Monitored natural attenuation
- ☐ Groundwater containment
- ☐ Vertical barrier walls
- ☒ Other Decontamination of building surfaces and removal of components for which decontamination is impractical or undesirable

II. BUILDING CONDITIONS

A. Building Components

1. Floor Slab Condition **□ Good ☒ Fair □ Poor □ N/A**

Remarks The concrete floor in the southwest quadrant of the building is a mix of old and newer concrete. The concrete is degraded in areas (see photograph log).

2. Wall Panel Condition **□ Good ☒ Fair □ Poor □ N/A**

Remarks The wall panels on the south and west sides of the quadrant consist of approximately 6 feet of brick at the base, with metal panels for the remainder of the vertical extent, and partially transparent plastic panels beneath the roof. The walls are generally in good condition, but holes in the panels are visible in areas (see photograph log).

3. Roof Condition **□ Good ☒ Fair □ Poor □ N/A**

Remarks The high roof, extending from Column Line B to Column Line C, was replaced as part of the remedial action, is metal, and is in good condition. The low roof, on either side of the high roof, is older, is composed of concrete, and appears to be in fair condition.

B. Other Building Conditions

Remarks Current use of the southwest quadrant includes maintenance activities within the substation and electrical storage and work rooms. Access to high bay area east of Column Line C on the first floor, where areas of relatively high radiological activity was identified, is restricted by rope and signs indicating "Radioactive Materials Area" and "Notify EH&S Prior to Entry."

Following the remedial activities conducted in 2009-2013, floor surfaces remaining above the ground floor include concrete and metal flooring at the third floor level. A staircase provides access to this level. Three rooms remain at this level. Two of these rooms are no longer used. Maintenance personnel access an electrical panel located in one of the rooms (see photograph log). No flooring remains above the third floor level.

V. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

The objective of the selected remedy is to decontaminate building components to industrial use levels. Implementation of the remedy to-date has included decontamination and removal of building components with relatively elevated residual radiological activity levels. This work is evident in current building features including the metal grating that replaced impacted concrete at the third floor level, and the lack of flooring and decontaminated and painted beams at the fourth and fifth floor levels.

B. Early Indicators of Potential Remedy Problems

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

Data collection during and after the remedial actions indicated that the radiological impacts to building surfaces within the southwest quadrant are more extensive than previously understood. Review of site data indicates that radiological activity remains on building components, including concrete remaining on the first and third floor levels, as well as upper portions of walls and the ceiling under the low roof. Although it would likely be possible to decontaminate building surfaces to levels appropriate for industrial use, the additional effort required would be extensive and costly.

C. Opportunities for Optimization

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

The efficiency of the selected remedy was re-evaluated, considering the new data indicating a larger extent of radiological impacts. Based on detailed analysis performed by USACE in conjunction with W.R. Grace, a determination was made that the remedy will be revised to a demolition-focused alternative. A Record of Decision Amendment is in progress.

Photograph Log
W.R. Grace Curtis Bay—Building 23
Baltimore, Maryland
January 29, 2020

Photo 1. Western exterior wall of the Southwest Quadrant of Building 23

Photo 2: 1st floor view of Southwest Quadrant, looking southeast

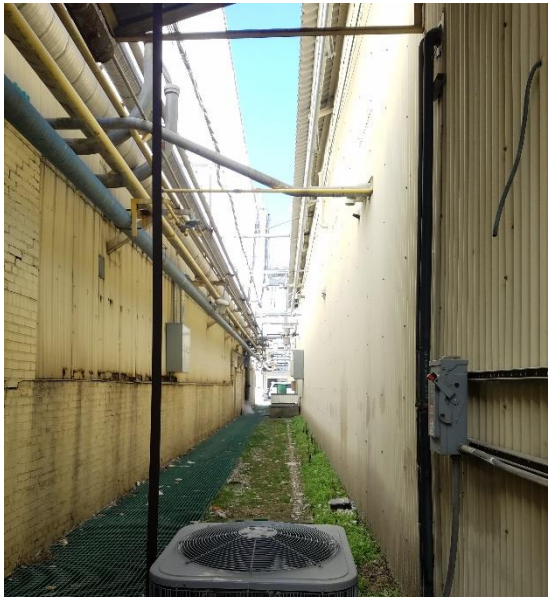

Photo 3. Southern exterior wall of Building 23 (left) viewed from alleyway

Photo 4: Rad Materials Area Sign and rope across 1st Floor

Photo 5: 1st Floor restricted area with rope and Rad Materials Area signage, looking east

Photo 6: View from 2nd Floor Level (signage marking restricted areas), looking southeast

Photo 7: View from 3rd Floor of exterior walls in the southwest corner, with Low Roof (concrete), looking southwest

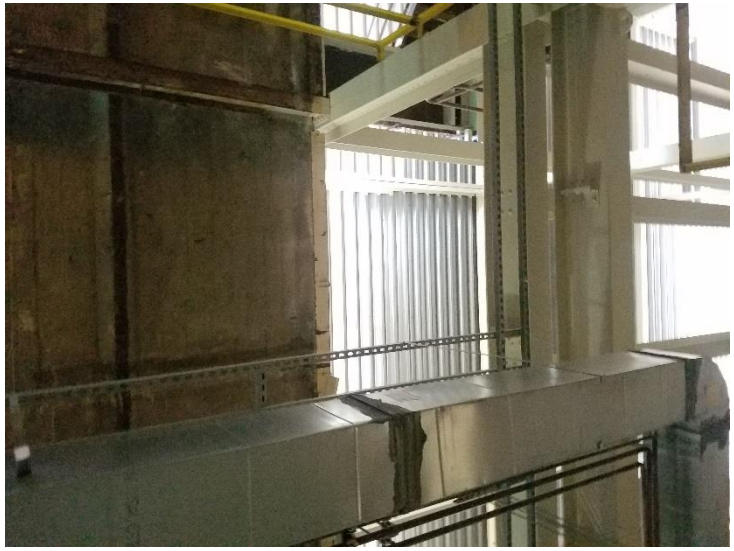

Photo 8: High Roof (metal, illuminated by sunlight) and Low Roof (concrete) ceilings viewed from the 3rd Floor (looking up)

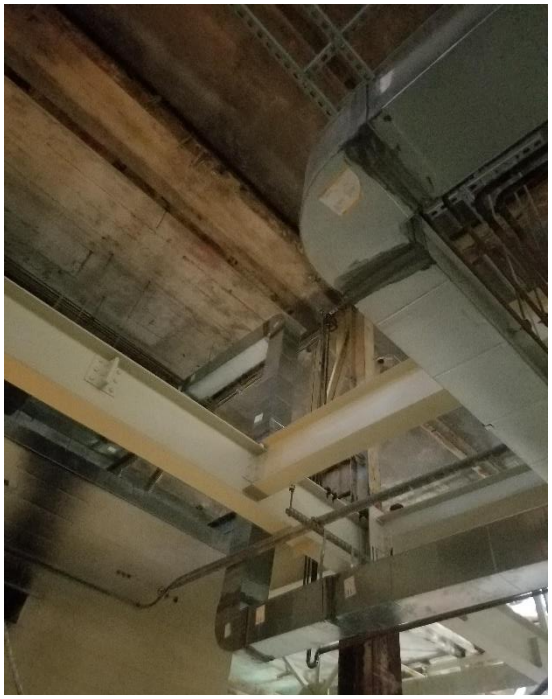

Photo 9: Low Roof Ceiling in western portion of 3rd Floor

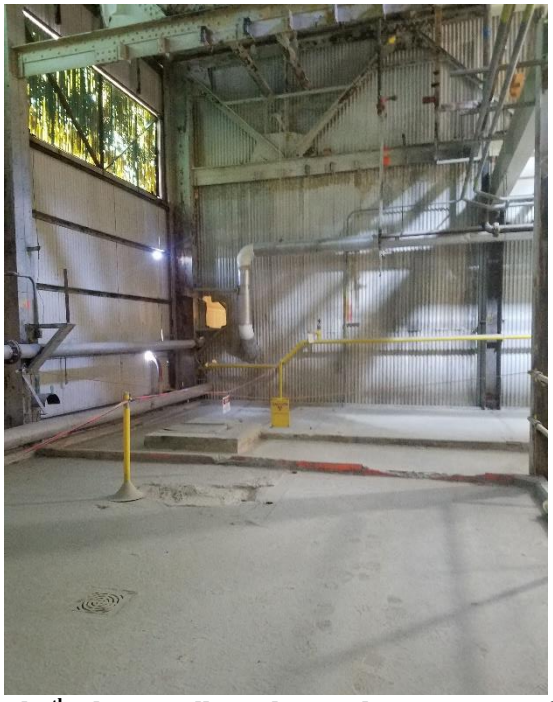

Photo 10: 3rd and 4th Floor Walls in the northwest corner of the Southwest Quadrant with rope and signage to restrict access, looking north

Photo 11: Metal grating floors, 3rd Floor between Column Lines B&C, looking east

Photo 12: Unused Control Room viewed from 3rd Floor, looking northeast

Photo 13: Electrical equipment located in 3rd floor utility room

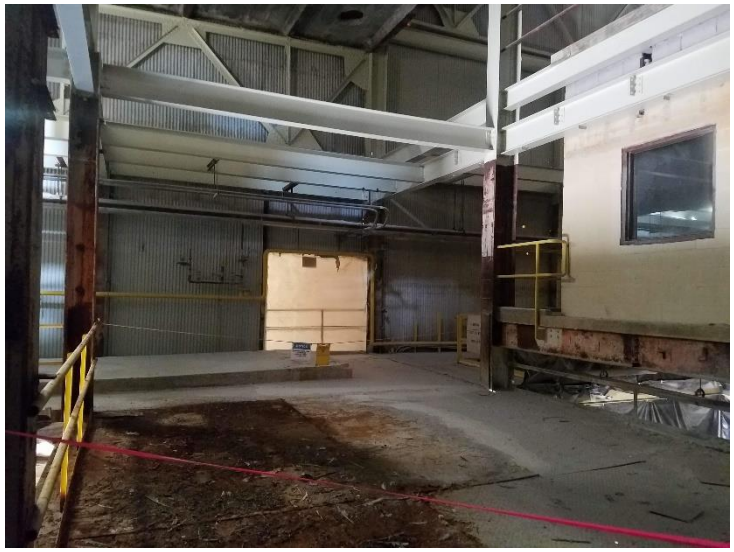

Photo 14: 3rd Floor west of Control Room, looking north, with rope and signage to restrict access

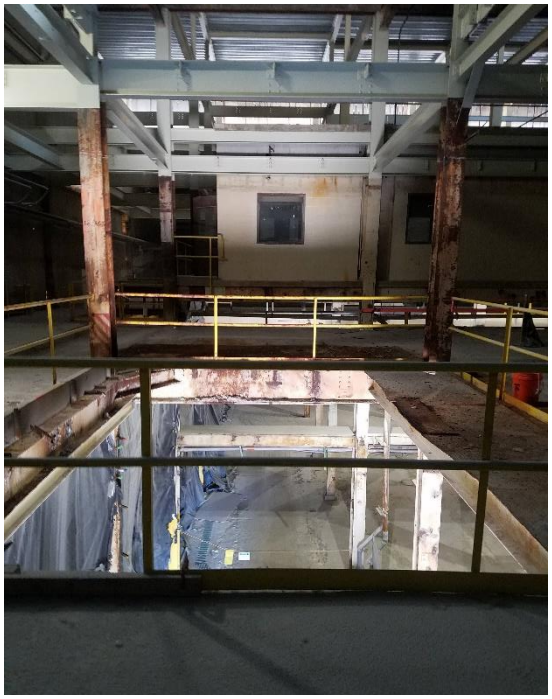

Photo 15: View from northwest corner of 3rd Floor, looking east

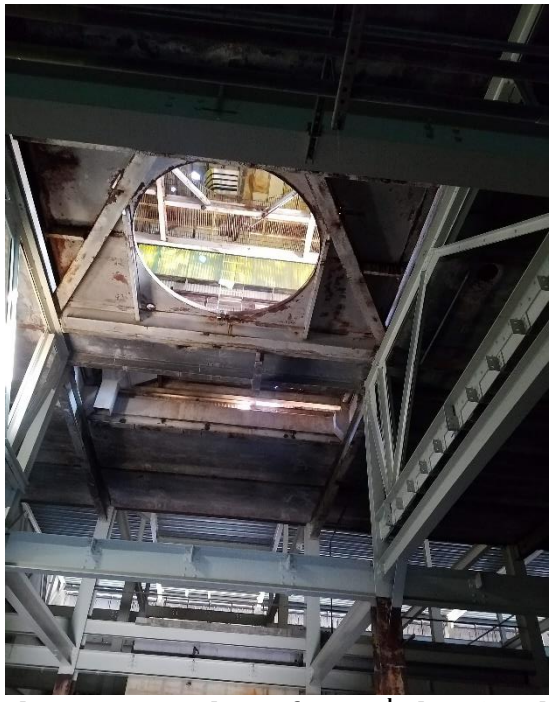

Photo 16: Looking up at Penthouse from 3rd Floor (northwest corner)

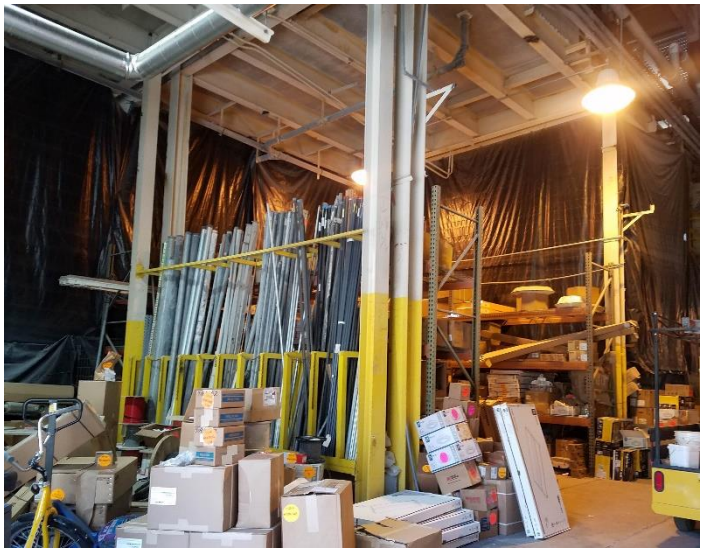

Photo 17: Storage outside of electrical rooms in southwest corner

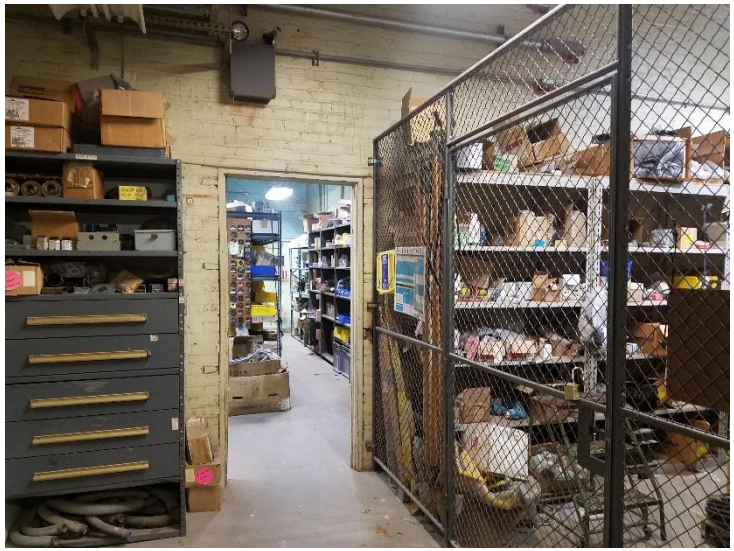

Photo 18: Electrical storage rooms

Photo 19: Poly Sheeting in walkway outside electrical rooms

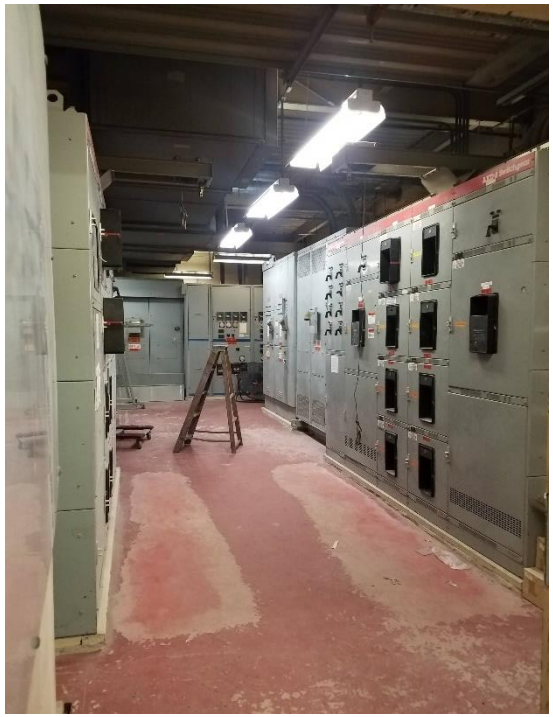

Photo 20: Substation #4

Photo 21: Electrical Shop

Photo 22: Low Roof and east side of wall along Column Line D, looking up and west from within the Southeast Quadrant

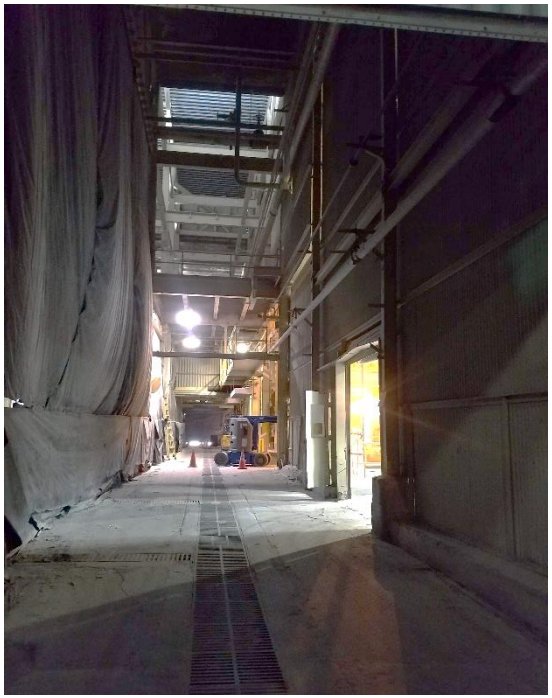

Photo 23: View of Poly Corridor (facing west)

Appendix E
Interview Records

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INTERVIEW RECORD

Site Name: W. R. Grace Curtis Bay FUSRAP Site	**EPA ID No.:** N/A
Subject: Five Year Review	**Date:** 13 March 2020
Type: ☐ Telephone ☐ Visit ☒ Other (e-mail) **Location of Visit:** N/A	☒ Incoming ☐ Outgoing

Contact Made By:

Name: Samantha Saalfield	**Title:** Geologist	**Organization:** EA Engineering, Science, and Technology, Inc., PBC

Individual Contacted:

Name: Paul Bucens	**Title:** Project Manager Corporate EHS	**Organization:** W.R. Grace & Co.
Telephone No: 617-899-0354 **Fax No:** **E-Mail Address:** paul.g.bucens@grace.com	**Street Address:** 7500 Grace Drive Columbia, MD 21044	

1. What is your overall opinion of the progress to date in implementation of the selected remedy for Building 23?

Building 23 remains in a safe condition. Progress towards completion of the remedy continues. Remediation has been undertaken with a substantial proportion of the residual contamination addressed through two remedial actions (ca. 2009 and 2010 through 2013) since the Record of Decision was issued in 2005. Decontamination and focused removal has been challenging to implement in some areas of the building. A path to completion, through demolition and off-site disposal, over the next couple of years has been defined in consensus with USACE.

2. Have any unexpected issues arisen during implementation of the remedy?

Overall no, however, decontamination and focused removal has been challenging to implement in some areas of the building.

3. How is the southwest quadrant currently used by W.R. Grace facility personnel? How have activities in and access to the southwest quadrant changed since the ROD was signed in 2005?

Currently the southwest quadrant of Building 23 contains an electrical substation and parts storage/light workshop areas in support of the Facility electricians. Based on the data gathered through investigation and remediation activities, these areas do not pose a radiological risk for such activities. The remainder of the southwest quadrant is secured by fence and a locked door. Access for maintenance of utilities that run through the area is infrequent, of short duration, and conducted in consultation with environment, health and safety resources.

Access to the southwest quadrant before and after execution of the ROD in 2005 has been limited. By the completion of the 2009 actions, a fence had been installed at ground level to further segregate the areas of remedial action from foot and vehicle traffic and plastic sheeting was hung between production and remediation areas to reduce transfer of dust. Administrative controls remained in place.

4. Are there any documents related to the remedial action that are maintained onsite (e.g., manuals, health and safety documents, or standard operating procedures)? If so, please list

All documents related to the FUSRAP remedial action are maintained by W.R. Grace's Corporate Environment, Health and Safety department. Regular communication is maintained with Facility management and information is provided as required.

5. Has site ownership or zoning changed since the ROD was signed in 2005?

No.

6. Are you aware of any concerns among W.R. Grace personnel or leadership regarding the remedy?

No. W.R. Grace leadership and facility personnel are briefed periodically by Corporate or Facility Environment, Health and Safety personnel.

7. Are you aware of any W.R. Grace concerns regarding potential exposures given the current building use and interim control measures currently in place?

No. W.R. Grace leadership and facility personnel are briefed periodically by Corporate or Facility Environment, Health and Safety personnel.

8. Are you aware of any concerns expressed by community members or regulatory representatives regarding the remedy? Please summarize W.R. Grace's community and regulatory outreach activities with respect to the remedy for Building 23.?

No concerns have been expressed. W.R. Grace Facility staff participate in quarterly meetings of the South Baltimore Community Advisory Panel (SBCAP) and monthly meetings of the Curtis Bay Community Association (CCBA). As appropriate, information related to Building 23 is shared. Periodically W.R. Grace Corporate EHS and USACE representatives meet with Maryland Department of the Environment to discuss the status of activity related to Building 23 remediation (most recently mid-2018).

9. Do you have any other comments, suggestions, or recommendations regarding the remedy?

No. W.R. Grace and USACE continue to work cooperatively towards completion of the remedy under the process defined in a 2008 Settlement Agreement. W.R. Grace understands that, with W.R. Grace concurrence, the remedy is currently being revised by USACE to demolition of the southwest quadrant of Building 23.

Appendix F
Benchmark Dose Review for Building 23

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RESRAD Modeling Review for Benchmark Dose for Building 23
W.R. Grace FUSRAP Site
Baltimore, Maryland
Rev. 2

Contract No: *W912DR-13-D-0018, Task Order No. 0003*

Prepared for:

U.S. Army Corps of Engineers – Baltimore District
City Crescent Building, Room 10200
10 South Howard Street
Baltimore, Maryland 21201

Prepared by:

EA Engineering, Science, and Technology, Inc., PBC
225 Schilling Circle, Suite 400
Hunt Valley, Maryland 21031
(410) 584-7000

NOVEMBER 2018

EA Project No.: 6273203

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LIST OF ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
ARAR	Applicable or relevant and appropriate requirements
CFR	Code of Federal Regulations
cm	centimeter
COMAR	Code of Maryland Regulations
d	day
DCF	dose conversion factor
DCGL	derived concentration guideline level
EPA	Environmental Protection Agency
FGR	Federal Guidance Report
FS	Feasibility Study
FUSRAP	Formerly Utilized Sites Remedial Action Program
g	gram
h	hour
ICRP	International Commission on Radiation Protection
m^2	square meter(s)
m^3	cubic meter(s)
mrem	millirem
NRC	U.S. Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission Guidance
pCi/g	picocurie per gram
Ra-226	radium-226
Ra-228	radium-228
RESRAD	Residual Radioactivity (computer code)
ROD	Record of Decision
TEDE	total effective dose equivalent
Th-232	thorium-232
U-238	uranium-238
USACE	U.S. Army Corps of Engineers
yr	year

1. INTRODUCTION

This report documents and reviews the calculation of benchmark doses for radionuclides in soil under Building 23 at the W.R. Grace Formerly Utilized Sites Remedial Action Program (FUSRAP) site, located in Curtis Bay, Maryland. W.R. Grace conducted thorium-processing operations of monazite sands at the facility in the late 1950s under contract with the U.S. Atomic Energy Commission. The thorium-processing operations were conducted in the southwest quadrant of Building 23. Isotopic components of the raw monazite sand included uranium-238 (U-238) and thorium-232 (Th-232) and their decay progeny. As a consequence of the processing, radiological activity is present in soils beneath the southwest quadrant of Building 23.

The benchmark dose for Building 23 was calculated using the Residual Radioactivity (RESRAD) computer code methodology, (Yu et al. 2001), and was documented in the Feasibility Study (FS) (EA 2003). As discussed in the FS, the benchmark dose was the basis for development of cleanup levels (i.e., derived concentration guideline levels [DCGLs]) for use during subsequent remedial action activities at the site.

2. OBJECTIVES

The primary objectives of this document are the following:

A. Review the previous technical basis and assumptions for the benchmark dose that was used to develop DCGLs for Building 23, which are documented in the *Final Record of Decision for Building 23 at the W.R. Grace Curtis Bay Facility, Baltimore, Maryland,* (USACE 2005).
B. Consider possible updates to select parameters used to calculate the benchmark doses for Building 23.

3. RELEVANT AND APPROPRIATE REQUIREMENT

The Remedial Investigation and FS for Building 23 identified potential applicable or relevant and appropriate requirements (ARARs) for the site, and determined which were applicable, relevant and appropriate, or to be considered. No applicable requirements were identified for the W.R. Grace FUSRAP site, although potentially relevant and appropriate requirements were identified.

Per the Record of Decision (ROD) for Building 23, the most relevant and appropriate chemical-specific ARAR for the site is 10 Code of Federal Regulations (CFR) 40 Appendix A, Criterion 6(6), which provides requirements for the maximum concentration of radium in soil, and states:

> *The design requirements in this criterion for longevity and control of radon releases apply to any portion of a licensed and/or disposal site unless such portion contains a concentration of radium in land, averaged over areas of 100 square meters, which, as a result of byproduct*

> *material, does not exceed the background level by more than: (i) 5 picocuries per gram (pCi/g) of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over the first 15 centimeters (cm) below the surface, and (ii) 15 pCi/g of radium-226, or, in the case of thorium byproduct material, radium-228, averaged over 15-cm thick layers more than 15 cm below the surface. Byproduct material containing concentrations of radionuclides other than radium in soil, and surface activity on remaining structures, must not result in a total effective dose equivalent (TEDE) exceeding the dose from cleanup of radium contaminated soil to the above standard (benchmark dose), and must be at levels which are as low as is reasonably achievable. If more than one residual radionuclide is present in the same 100-square-meter area, the sum of the ratios for each radionuclide of concentration present to the concentration limit will not exceed "1" (unity). A calculation of the potential peak annual TEDE within 1000 years to the average member of the critical group that would result from applying the radium standard (not including radon) on the site must be submitted for approval. The use of decommissioning plans with benchmark doses which exceed 100 mrem/yr, before application of ALARA, requires the approval of the Commission after consideration of the recommendation of the NRC staff. This requirement for dose criteria does not apply to sites that have decommissioning plans for soil and structures approved before June 11, 1999.*

The text of Criterion 6(6) creates a specific methodology for deriving the dose values for thorium byproduct material, which is distinct from the methodology for material that is predominantly composed of uranium byproduct material. The uranium decay chain yields radium-226 (Ra-226), and the thorium decay chain yields radium-228 (Ra-228).

4. RADIONUCLIDES OF CONCERN

The material at issue at the W.R. Grace FUSRAP site is thorium byproduct material resulting from the processing of monazite sands to extract thorium in the late 1950s under contract with the U.S. Atomic Energy Commission. Radiological components of monazite sands include U-238, Th-232, and their decay progeny.

5. EXPOSURE SCENARIOS, PATHWAYS, AND MODELING METHODOLOGY

A visual representation of the available pathway models in RESRAD is provided in Figure 1. Pathways include direct exposure, inhalation (dust and radon), and ingestion (multiple pathways). Exposure pathways used in RESRAD analysis presented in the FS for Building 23 are shown in Figure 2. The analysis did not include several pathways (specifically, ingestion of plants, meat, milk, fish, and water) since they were determined to be not applicable conditions for future use. In addition, radon was not included as a pathway since the selected ARAR, 10 CFR 40 Appendix A, Criterion 6(6), specifically excludes this pathway from consideration during calculation of the potential peak annual TEDE. In Figure 2, incomplete pathways are noted with an "**X**".

Figure 1. Exposure Pathways Considered in RESRAD

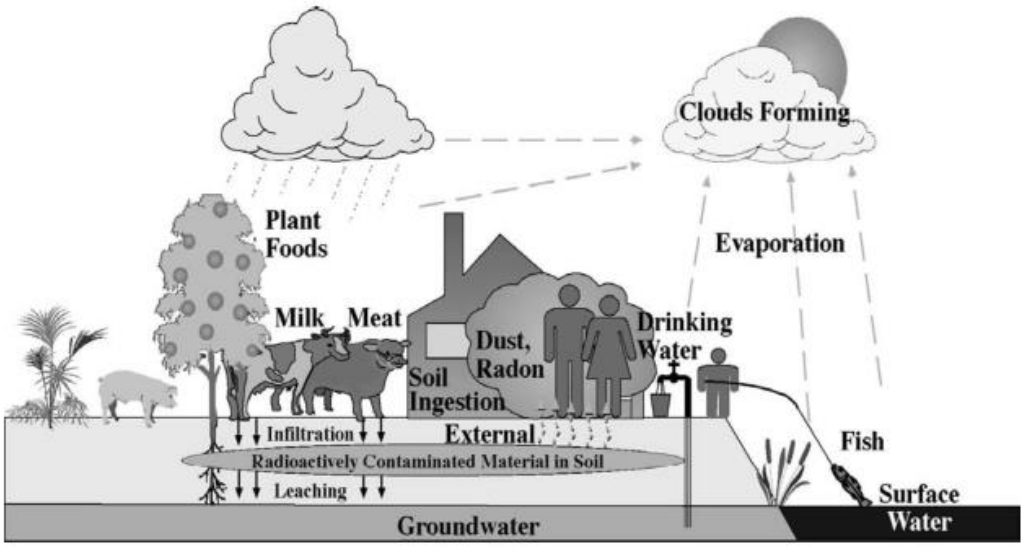
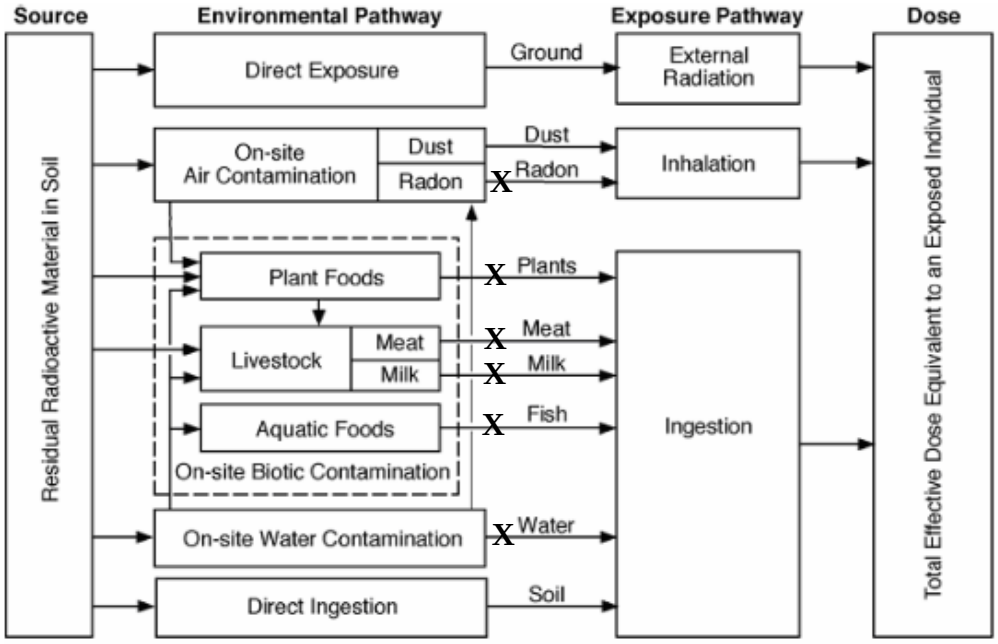


Figure 2. Representation of RESRAD Pathways Used for the W.R. Grace FUSRAP Site



5.1 Evaluation of Exposure Scenarios

Based on the current and reasonably foreseeable future land use for the W.R. Grace site, three exposure scenarios were considered realistic for consideration during modeling: urban resident, industrial worker, and maintenance/construction worker. The industrial worker scenario typically is a limited-timeframe scenario and is most appropriate for areas subject to industrial use and for locations where commercial businesses may exist or where such development could be foreseen. The maintenance/construction worker scenario is a limited-timeframe scenario that addresses the unique exposure conditions that may exist during construction with land disturbance activities.

Scenarios considered in the FS for Building 23 included the industrial worker and the maintenance/construction worker scenarios (EA 2003). The residential scenario is not likely appropriate for Building 23, since the building is located in the manufacturing portion of the facility, which is secured, and there is no indication that the use of that area (heavy manufacturing) will change in the foreseeable future. The industrial worker is considered working in a building which may be an industrial plant setting or a commercial or office type of building with an engineered foundation. The contaminated zone was modeled as a 1-meter layer across the entirety of the southwest quadrant (2,200 square meters [m^2]). The worker is assumed to be onsite for 7 hours per day indoors and 1 hour per day outdoors. The worker is at the site for 250 days per year for 25 years.

5.2 Evaluation of Pathways

As shown in Figure 2, ingestion, inhalation, and external pathways were utilized as pathways in the Building 23 FS. The only ingestion pathway was from soil. This is considered appropriate for the scenarios that were considered. The groundwater pathway was not used since groundwater use at the entire W.R. Grace facility is highly restricted (long-term restriction by the U.S. Environmental Protection Agency [EPA]) and Maryland regulations (Code of Maryland Regulations [COMAR] 26.03.01.05) prohibit the installation of individual water supply systems in this area since public water is available. The external exposure pathway is the pathway that delivers the most dose. As noted previously, radon was not used in the model since the ARAR specifically excludes it from dose calculations.

5.3 Modeling Methodology for Calculation of Benchmark Doses

The RESRAD computer code developed by Argonne National Laboratory for the Department of Energy was used in the Building 23 FS to calculate the benchmark dose from radium. Where site-specific values for input parameters were not available, conservative literature or default values provided in RESRAD were used. RESRAD modeling presented in the FS for Building 23 was performed using RESRAD Version 6.1. The RESRAD code has been continually revised and improved since it was issued in 1989; the current version is RESRAD-ONSITE, Version 7.2.

RESRAD code and associated documentation are available online at the following website: https://web.evs.anl.gov/resrad/home2/index.cfm. A description of the quality assurance program for verification, benchmarking, and validation of RESRAD is also described in Yu et al. (2001).

The radiation dose that is the basis of the soil guidelines calculated using RESRAD is the TEDE, which is defined as the sum of the effective dose equivalent for external irradiation and the committed effective dose equivalent for internal irradiation. The effective dose is the weighted sum of the equivalent doses to specified organs and tissues. For the FS benchmark dose analysis, the weighting factors were based on EPA's Health Effects Assessment Summary Tables (HEAST 2001). The committed effective dose for internal irradiation is the weighted sum of the equivalent doses deposited in the body in a 50-yr period (for an adult) following the intake of a radionuclide (ICRP 1996).

Benchmark doses for this site were calculated using the scenario-specific exposure routes shown in Table 1 and by applying the requirements of 10 CFR 40 Appendix A, Criterion 6(6) for thorium byproduct material, using only the Ra-228 content.

Table 1. Scenario-Specific Exposure Routes

Exposure Routes	Industrial Worker (Adult)	Maintenance/Construction Worker (Adult)
Direct Exposure (from soil)	X	X
Inhalation of dust (soil particulates)	X	X
Inhalation of radon	Specifically excluded by the ARAR	
Ingestion of plant foods	Not considered applicable conditions for future use	
Ingestion of livestock (meat/milk)	Not considered applicable conditions for future use	
Ingestion of aquatic foods	Not considered applicable conditions for future use	
Ingestion of groundwater	Not considered applicable conditions for future use	
Ingestion of soil (incidental)	X	X

6. VERIFICATION OF THE BENCHMARK DOSE PRESENTED IN THE FEASIBILITY STUDY

The benchmark dose for Building 23, as presented in the FS, was modeled using RESRAD Version 6.1 and was determined to be 7.37 millirem per year (mrem/yr). The RESRAD modeling was performed for surface soil with a Ra-228 concentration of 5 pCi/g (demonstrated to be more conservative than subsurface soil with a Ra-228 concentration of 15 pCi/g) using an industrial worker scenario, which was selected as the most realistic simulation of the current and expected future use of Building 23.

To verify the FS results, the benchmark dose was recalculated, using the original parameters, in RESRAD-ONSITE Version 7.2. The modeling output (Appendix A) indicates that the benchmark dose (7.37 mrem/year) in the FS can be replicated. Further discussion regarding parameter inputs and differences between the RESRAD versions is provided in Section 7.

7. RESRAD INPUT VALUES, ASSUMPTIONS, AND RECOMMENDATIONS

The verification of the benchmark dose (Section 6) indicates that modeling with RESRAD-ONSITE Version 7.2 gives good agreement with the parameters and modeling approach utilized in the FS for Building 23. RESRAD is an integrated site-assessment model that incorporates many links between those components of the model describing human exposure and those governing the physical transport of radionuclides over time. A summary of RESRAD parameters utilized in calculating the benchmark dose for Building 23 is provided in Appendix B. The RESRAD input parameters that are most important to the dose contribution are inhalation rate, ambient-air dust concentration (mass loading), outdoor-time and indoor-time fraction at the site, and soil-ingestion rate.

Potential updates to some parameters in RESRAD, relative to the modeling presented in the FS, were evaluated to confirm the continued efficacy of the FS modeling results. Key parameters are reviewed below. A summary of parameters that were varied during re-calculation of the benchmark dose is provided in Appendix B.

7.1 Guidance for Dose Assessments

The following guidance was identified as potentially relevant to the Building 23 benchmark analysis:

- EPA Directive 9200.4-35P, *Remediation Goals for Radioactively Contaminated CERCLA Sites Using the Benchmark Dose Cleanup Criteria in 10 CFR Part 40 Appendix A, Criterion 6(6)* (EPA 2000);
- EPA Directive 9200.4-25, *Use of Soil Cleanup Criteria in 40 CFR Part 192 as Remediation Goals for CERCLA Sites* (EPA 1998); and
- U.S. Nuclear Regulatory Commission (NRC) guidance NUREG-1620, *Standard Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978* (NRC 2003).

Based on a review of the guidance documents, the benchmark dose should be developed using site-specific parameters and RESRAD/EPA default values (if no site-specific parameters are available) and applicable EPA risk/dose assessment exposure assumptions. In addition, the guidance indicates that the analyses should incorporate the Ra-228 concentration standards for thorium processing (i.e., Ra-228).

The guidance documents also provided guidance concerning development of appropriate cleanup concentration levels based on the benchmark dose. Specifically, EPA Directive 9200.4-35P (EPA 2000) indicates that final cleanup concentration levels (i.e., DCGLs) should be developed for each radionuclide of concern at the site (U-238, Th-232, and decay progeny) to meet the benchmark dose and that sum of fractions calculations (unity rule) should be used to show compliance for all radionuclide concentrations (not just Ra-228).

The protocol described above for benchmark dose development appears to have been used for the Building 23 FS, although the guidance documents were not directly referenced in the FS. In addition, the ROD for Building 23 documents that DCGLs were developed for all radionuclides of concern at the site (U-238, Th-232, and decay progeny), and sum of fractions analysis was used to show compliance with the ARAR. Since characterization data indicate that radionuclides other than Ra-228 are present, it is likely that a final remediation level of less than 5 pCi/g for Ra-228 in soil will be achieved at Building 23, as the dose from the other radionuclides will be taken into account during the sum of fraction analysis.

7.2 Contaminated Zone Dimensions

The dimensions of the contaminated zone are set to values that reasonably capture the maximum size of an individual site. The size of the contaminated area may affect exposure by incidental soil ingestion, inhalation of particulates, and external gamma irradiation. The RESRAD default contaminated zone area of 10,000 m^2 results in an effectively infinite area for the incidental soil ingestion and external gamma irradiation exposure routes. For the FS dose assessment, the size of the southwest quadrant was identified as 2,200 m^2 (the size of the southwest quadrant footprint), which was a conservative site-specific input based upon existing characterization data. Supplemental characterization data collected as part of pre-design activities conducted in 2017 further refined the nature and extent of radiological contamination at the site. The 2017 characterization data provides additional support that the FS site-specific input for the contaminated zone area (2,200 m^2) is a reasonable, yet conservative, estimation for that modeling parameter. As such, this parameter appears appropriate and additional RESRAD analysis using an adjusted value for this parameter is not required.

7.3 Initial Principal Radionuclides

The RESRAD modeling for surface soil presented in the FS used Ra-228 (5 pCi/g) as the initial source concentration for the Initial Principal Radionuclide parameter. This meets the requirements in the ARAR and is consistent with EPA Directive 9200.4-35P guidance (EPA 2000).

For modeling purposes for subsurface evaluations, it is sometimes appropriate to input Ra-228 with the parent Th-232 at equal activity concentration to prevent the Ra-228 activity from complete decay

in the time necessary for any cover to erode. This possible approach for subsurface soil at the W.R. Grace site has been documented by the U.S. Army Corps of Engineers (USACE) (Peterson and Hearty 2001). For the FS modeling, Th-232 was not included as a principle radionuclide in the RESRAD model for surface soil, which was the selected conservative scenario for the Building 23 benchmark dose analysis, since there is no cover included in that scenario. As such, no source term revisions are necessary for Building 23 benchmark dose analysis, and additional RESRAD analysis was not required.

7.4 Evaluation of Select Parameters

Default parameters were used in calculating the FS benchmark dose, in addition to select site-specific parameters based on site conditions. As part of the re-evaluation of this benchmark dose, the default parameters used from RESRAD Version 6.1 were compared to the defaults in RESRAD-ONSITE Version 7.2 and found to be consistent. Therefore, no additional RESRAD analysis is required to assess updated default parameters.

There are several modeling parameters in RESRAD for exposure assessment, as noted in Table 2 below, that were utilized in the FS benchmark dose model. The values used in the FS for inhalation rate, mass loading, and soil ingestion rate were the RESRAD default parameters from RESRAD Version 6.1 (consistent with Version 7.2, as indicated above). Recent guidance regarding the parameters listed in Table 2 is provided in the following documents:

- *Exposure Factors Handbook* (EPA 2011);
- *Update for Chapter 5 Exposure Factors Handbook, Soil and Dust Ingestion*, EPA/600/R-17/384F (EPA 2017); and
- *Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil and Building Surfaces*, ANL/EVS/TM-14-4 (Yu et al, 2015).

To assess the impact of these parameters on the FS modeling results, additional RESRAD analysis was conducted to incorporate the updated parameter values for exposure assessment shown in Table 2.

Table 2. Industrial Worker Scenario: Critical Parameters

Parameter	Building 23 FS	Updated Value
Inhalation rate (m^3/yr)	8400	7780 [(a)]
Mass loading (g/m^3)	1×10^{-4}	7×10^{-4} [(b)]
Outdoor time fraction (1 h/d)	0.0285	0.0285 [(c)]
Indoor time fraction (7 h/d)	0.1998	0.1996 [(d)]
Soil ingestion (g/yr)	36.5	25 [(e)]

d/y = days per year
g/m^3 = grams per cubic meter
g/yr = grams per hear
h/d = hours per day
m^3/yr = cubic meters per year
Notes:
(a) Calculated as [21.3 m^3/d × 365.25 d/yr], where 21.3 m^3/d is the upper percentile daily inhalation rate of an adult from 21 to less than 61 years old (EPA 2011, Table 6-1).
(b) Yu et al. 2015.
(c) Calculated as (1 h/d × 250 d/yr) / 8766 h/yr, where an 8 h/d work day includes 7 h/d indoors, and 250 d/yr is the exposure frequency.
(d) Calculated as (7 h/d × 250 d/yr) / 8766 h/yr,
(e) The soil-ingestion rate compensates for the time-based occupancy factor applied by RESRAD in calculating exposure from the soil ingestion pathway. Calculated as [0.1 g/d × 250 d/yr], where 0.1 g/d is the site- related upper percentile daily soil ingestion rate for the industrial worker (EPA 2017, Table 5.1).

The modeling output (Appendix C) indicates that the benchmark dose (7.412 mrem/yr) using the updated critical parameters values is slightly higher than the benchmark dose in the FS (7.37 mrem/yr), which used RESRAD default values as noted above. Given the de minimis difference between the doses, the more conservative FS benchmark dose is considered to be a realistic and appropriate dose for the scenario evaluated, and revisions to these parameters are not required.

7.5 Dose Conversion Factors

Prior to 2012, dose conversion factors (DCFs) employed dose coefficients published in Federal Guidance Report (FGR) 11 (EPA 1988), which are based on older uptake, metabolism, and internal dosimetry models from the late 1970s. The FGR 11 dose coefficients also pertain only to adults. Since 2012, the DCFs available in RESRAD have changed as described below.

With the release of RESRAD-ONSITE Version 7.2 in July 2016, the latest nuclear decay data from International Commission on Radiological Protection (ICRP) Publication 107 (ICRP 2008) have been included in RESRAD. These decay data are used in conjunction with the internal dosimetry methodology described in ICRP Publication 60 and the resulting DCFs are referred to as "DCFPAK 3.02" in RESRAD's internal dose library.

The ICRP 72 DCFs are based on the internal dosimetry methodology described in ICRP Publication 60 (ICRP 1991). RESRAD-ONSITE Version 7.2 also includes a new set of DCFs that pertain to a Reference Person. The Reference Person uses ICRP 72 age-specific DCFs and reflects the age and gender structure and air and water intake rates of the U.S. population. In this regard, the Reference Person reflects the same population-level approach to radiation protection applied by EPA in developing radionuclide cancer risk coefficients (EPA 1999). However, the Reference Person DCFs available in RESRAD-ONSITE Version 7.2 were not used in the FS modeling calculations, as stated in Section 6, and thus were not used for the verification modeling.

The external DCFs now included in RESRAD-ONSITE Version 7.2 also employ the latest nuclear decay data from ICRP Publication 107. These external DCFs are based on the same dosimetry as those used in previous modeling, as described in FGR 12 (EPA 1993). As noted previously, the verification of the benchmark dose (Section 6) indicates that modeling with RESRAD-ONSITE Version 7.2, including DCF values that are included in this version of RESRAD, gives good agreement with the modeling results obtained during the FS.

8. CONCLUSIONS

Based on a review of the benchmark dose analysis presented in the Building 23 FS and guidance documents that are potentially relevant to this analysis (Section 7.1), and after conducting verification modeling using the most current version of RESRAD (RESRAD-ONSITE Version 7.2), the following observations are made regarding the benchmark dose analysis:

- The development of the benchmark dose for surface soil in the Building 23 FS appears to meet ARAR requirements and is consistent with available guidance documents identified in Section 7.1, although these documents were not directly referenced in the FS.
- Verification modeling of the benchmark dose for surface soil, using the most current version of RESRAD (RESRAD-ONSITE Version 7.2) and the site-specific and default input parameters identified in the Building 23 FS, gives good agreement with the parameters and modeling approach utilized in the Building 23 FS. The results for both the Building 23 FS and verification modeling are 7.37 mrem/yr.
- Additional modeling of the benchmark dose for surface soil was conducted to assess the sensitivity of several exposure parameters (inhalation rate, mass loading, and soil ingestion rate) within the verification model. Modeling results indicate a de minimis difference between the initial verification model (7.37 mrem/yr) and the verification model using updated exposure parameters (7.412 mrem/yr).

In summary, the benchmark dose analysis in the Building 23 FS meets requirements of the ARAR and appears consistent with available guidance documents. In addition, the RESRAD modeling results in the Building 23 FS are reproducible, and the modeling results appear to have low sensitivity to variations of the default values for several exposure parameters. These observations lead to the conclusion that the benchmark dose analysis in the Building 23 FS is appropriate, and the benchmark dose results are suitable for developing DCGLs for the radionuclides of concern at the site.

9. REFERENCES

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APPENDIX A

BUILDING 23 BENCHMARK DOSE RESRAD OUTPUT FILE – VERIFICATION ANALYSIS USING FS PARAMETERS

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Summary : RESRAD WR Grace Reproduction
File : C:\USERS\CLAUDE WIBLIN\DOCUMENTS\0- GRACE\RESRAD RUNS\SITE1.RAD

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : RESRAD WR Grace Reproduction
File : C:\USERS\CLAUDE WIBLIN\DOCUMENTS\0- GRACE\RESRAD RUNS\SITE1.RAD

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ac-228 (Source: FGR 12)	5.978E+00	5.978E+00	DCF1(1)
A-1	Bi-212 (Source: FGR 12)	1.171E+00	1.171E+00	DCF1(2)
A-1	Pb-212 (Source: FGR 12)	7.043E-01	7.043E-01	DCF1(3)
A-1	Po-212 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(4)
A-1	Po-216 (Source: FGR 12)	1.042E-04	1.042E-04	DCF1(5)
A-1	Ra-224 (Source: FGR 12)	5.119E-02	5.119E-02	DCF1(6)
A-1	Ra-228 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(7)
A-1	Rn-220 (Source: FGR 12)	2.298E-03	2.298E-03	DCF1(8)
A-1	Th-228 (Source: FGR 12)	7.940E-03	7.940E-03	DCF1(9)
A-1	Tl-208 (Source: FGR 12)	2.298E+01	2.298E+01	DCF1(10)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.078E-03	4.770E-03	DCF2(1)
B-1	Th-228+D	3.454E-01	3.420E-01	DCF2(2)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ra-228+D	1.442E-03	1.440E-03	DCF3(1)
D-1	Th-228+D	8.086E-04	3.960E-04	DCF3(2)
D-34	Food transfer factors:			
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(2,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(1,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(1,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(2,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(2,2)

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Summary : RESRAD WR Grace Reproduction
File : C:\USERS\CLAUDE WIBLIN\DOCUMENTS\0- GRACE\RESRAD RUNS\SITE1.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)	2.200E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.000E+02	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-228	5.000E+00	0.000E+00	---	S1(1)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(1)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.956E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.118E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.202E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.080E-06	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.998E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.850E-02	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+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	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	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	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Summary : RESRAD WR Grace Reproduction
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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	2200.00 square meters	Ra-228	5.000E+00
Thickness:	1.00 meters		
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.000E+02 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	5.569E+00	6.790E+00	7.345E+00	4.191E+00	3.606E-01	5.424E-05	6.481E-16	0.000E+00
M(t):	5.569E-02	6.790E-02	7.345E-02	4.191E-02	3.606E-03	5.424E-07	6.481E-18	0.000E+00

Maximum TDOSE(t): 7.368E+00 mrem/yr at t = 2.620 ± 0.005 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.620E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	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.
Ra-228	7.297E+00	0.9903	1.248E-02	0.0017	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.874E-02	0.0080
Total	7.297E+00	0.9903	1.248E-02	0.0017	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.874E-02	0.0080

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.620E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.368E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.368E+00	1.0000

*Sum of all water independent and dependent pathways.

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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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	5.503E+00	0.9882	3.830E-03	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.166E-02	0.0111
Total	5.503E+00	0.9882	3.830E-03	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.166E-02	0.0111

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.569E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.569E+00	1.0000

*Sum of all water independent and dependent pathways.

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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.
Ra-228	6.719E+00	0.9895	8.812E-03	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.242E-02	0.0092
Total	6.719E+00	0.9895	8.812E-03	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.242E-02	0.0092

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.790E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.790E+00	1.0000

*Sum of all water independent and dependent pathways.

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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.
Ra-228	7.275E+00	0.9904	1.282E-02	0.0017	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.737E-02	0.0078
Total	7.275E+00	0.9904	1.282E-02	0.0017	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.737E-02	0.0078

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.345E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.345E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : RESRAD WR Grace Reproduction
File : C:\USERS\CLAUDE WIBLIN\DOCUMENTS\0- GRACE\RESRAD RUNS\SITE1.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.
Ra-228	4.154E+00	0.9911	8.627E-03	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.869E-02	0.0068
Total	4.154E+00	0.9911	8.627E-03	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.869E-02	0.0068

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.191E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.191E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : RESRAD WR Grace Reproduction
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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)

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.
Ra-228	3.574E-01	0.9912	7.602E-04	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.412E-03	0.0067
Total	3.574E-01	0.9912	7.602E-04	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.412E-03	0.0067

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.606E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.606E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : RESRAD WR Grace Reproduction
File : C:\USERS\CLAUDE WIBLIN\DOCUMENTS\0- GRACE\RESRAD RUNS\SITE1.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.
Ra-228	5.376E-05	0.9912	1.144E-07	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.629E-07	0.0067
Total	5.376E-05	0.9912	1.144E-07	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.629E-07	0.0067

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.424E-05	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.424E-05	1.0000

*Sum of all water independent and dependent pathways.

Summary : RESRAD WR Grace Reproduction
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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.
Ra-228	6.424E-16	0.9912	1.368E-18	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.339E-18	0.0067
Total	6.424E-16	0.9912	1.368E-18	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.339E-18	0.0067

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.481E-16	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.481E-16	1.0000

*Sum of all water independent and dependent pathways.

Summary : RESRAD WR Grace Reproduction
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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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228+D	Ra-228+D	1.000E+00	8.705E-01	7.676E-01	5.969E-01	2.475E-01	2.002E-02	3.010E-06	3.598E-17	0.000E+00
Ra-228+D	Th-228+D	1.000E+00	2.432E-01	5.905E-01	8.721E-01	5.907E-01	5.209E-02	7.838E-06	9.364E-17	0.000E+00
Ra-228+D	∑DSR(j)		1.114E+00	1.358E+00	1.469E+00	8.382E-01	7.211E-02	1.085E-05	1.296E-16	0.000E+00

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.000E+02 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	8.979E+01	7.363E+01	6.807E+01	1.193E+02	1.387E+03	9.218E+06	*2.726E+14	*2.726E+14

*At specific activity limit

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 = 2.620 ± 0.005 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ra-228	5.000E+00	2.620 ± 0.005	1.474E+00	6.786E+01	1.474E+00	6.786E+01

Summary : RESRAD WR Grace Reproduction
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr							
		t=	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	Ra-228	1.000E+00	4.352E+00	3.838E+00	2.985E+00	1.238E+00	1.001E-01	1.505E-05	1.799E-16	0.000E+00
Th-228	Ra-228	1.000E+00	1.216E+00	2.952E+00	4.361E+00	2.953E+00	2.605E-01	3.919E-05	4.682E-16	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g							
		t=	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	Ra-228	1.000E+00	5.000E+00	4.409E+00	3.429E+00	1.422E+00	1.150E-01	1.729E-05	2.067E-16	0.000E+00
Th-228	Ra-228	1.000E+00	0.000E+00	1.423E+00	2.669E+00	1.973E+00	1.759E-01	2.648E-05	3.166E-16	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 0.32 seconds

APPENDIX B

RESRAD PARAMETER SUMMARY TABLE

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Appendix B

Summary Table of RESRAD Parameters for Benchmark Dose Assessment - 2003 Feasibility Study for Building 23 and 2018 Verification Modeling

FS Exposure Scenario: Industrial and maintenance workers
FS Exposure Pathways: External gamma, inhalation, soil ingestion
FS RESRAD Version: Version 6.1
FS Calculated Benchmark Max Dose (mrem/yr): Surface Industrial: 7.37; Surface Maintenance: 4.183; Subsurface Industrial: 14.05; Subsurface Maintenance: 9.158 [for Ra-228]
FS Tmax (years): Not stated; likely 148 years for subsurface with erosion.
FS Soil DCGLs (pCi/g): Radium-226: 5 pCi/g (Surface), 15 pCi/g (Subsurface); Thorium-232: 2.62 pCi/g (Surface), 4.73 pCi/g (Subsurface)

		2003 Feasibility Study for Building 23 (Verification modeling output included in Appendix A)					2018 Verification Modeling
Menu	**Parameter**	**User Input (Surface/ Subsurface)**	**Default**	**Used by RESRAD (if different from user input)**	**Parameter Name**	**Notes**	**Updated Parameters (Modeling output included in Appendix C)**
NA	Exposure Frequency (d/yr)	2.500E+02	--			250 d/yr for industrial - FS Table A-5 (130 day/yr for maintenance).	
NA	Indoor Exposure Frequency (hr/d)	7.000E+00	--			7 hr/d for industrial - FS Table A-5 (2 hr/d for maintenance).	
NA	Outdoor Exposure Frequency (hr/d)	1.000E+00	--			1 hr/d for industrial - FS Table A-5 (6 hr/d for maintenance).	
R011	Area of contaminated zone (m^2)	2.200E+03	1.000E+04		AREA	2,200 m2 used in RESRAD; however, FS Table A-5 lists 26,100 m2 (surface) and 18,400 m2 (subsurface)	
R011	Thickness of contaminated zone (m)	1.000E+00	2.000E+00		THICK0	1 meter - FS Table A-5	
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00		SUBMFRACT		
R011	Length parallel to aquifer flow (m)	not used	1.000E+02		LCZPAQ		
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	2.500E+01		BRDL		
R011	Time since placement of material (yr)	0.000E+00	0.000E+00		TI		
R011	Times for calculations (yr)	1.000E+00	1.000E+00		T (2)		
R011	Times for calculations (yr)	3.000E+00	3.000E+00		T (3)		
R011	Times for calculations (yr)	1.000E+01	1.000E+01		T (4)		
R011	Times for calculations (yr)	3.000E+01	3.000E+01		T (5)		
R011	Times for calculations (yr)	1.000E+02	1.000E+02		T (6)		
R011	Times for calculations (yr)	3.000E+02	3.000E+02		T (7)		
R011	Times for calculations (yr)	1.000E+03	1.000E+03		T (8)		
R011	Times for calculations (yr)	not used	0.000E+00		T (9)		
R011	Times for calculations (yr)	not used	0.000E+00		T(10)		
R012	Initial principal radionuclide (pCi/g): Ra-228	5.000E+00	0.000E+00		S1 (1)		
R012	Concentration in groundwater (pCi/ L)	not used	0.000E+00		W1 (1)		
R013	Cover depth (m)	0.000E+00 / 1.500E-01	0.000E+00		COVERO	0 meter for surface, 0.15 meter for subsurface - FS Table A-5	
R013	Density of cover material (g/cm^3)	not used	1.500E+00		DENSCV		
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03		VCV		
R013	Density of contaminated zone (g/cm^3)	1.500E+00	1.500E+00		DENSCZ		
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03		VCZ		
R013	Contaminated zone total porosity	3.000E-01	4.000E-01		TPCZ	Effective porosity 0.3 - FS Table A-5	
R013	Contaminated zone field capacity	2.000E-01	2.000E-01		FCCZ		

		2003 Feasibility Study for Building 23 (Verification modeling output included in Appendix A)					2018 Verification Modeling
Menu	Parameter	User Input (Surface/ Subsurface)	Default	Used by RESRAD (if different from user input)	Parameter Name	Notes	Updated Parameters (Modeling output included in Appendix C)
R013	Contaminated zone hydraulic conductivity (m/yr)	1.956E+03	1.000E+01		HCCZ	1956 m/yr - FS Table A-5 (average as described in Section A.6.1)	
R013	Contaminated zone b parameter	5.300E+00	5.300E+00		BCZ	Selected based on soil type - FS Section A.6.1	
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00		WIND		
R013	Humidity in air (g/m^3)	not used	8.000E+00		HUMID		
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01		EVAPTR		
R013	Precipitation (m/yr)	1.118E+00	1.000E+00		PRECIP	1.118 m/yr - FS Table A-5	
R013	Irrigation (m/yr)	2.000E-01	2.000E-01		RI		
R013	Irrigation mode	overhead	overhead		IDITCH		
R013	Runoff coefficient	2.000E-01	2.000E-01		RUNOFF		
R013	Watershed area for nearby stream or pond (m^2)	not used	1.000E+06		WAREA		
R013	Accuracy for water/soil computations	not used	1.000E-03		EPS		
R014	Density of saturated zone (g/cm^3)	not used	1.500E+00		DENSAQ		
R014	Saturated zone total porosity	not used	4.000E-01		TPSZ		
R014	Saturated zone effective porosity	not used	2.000E-01		EPSZ	Effective porosity 0.3 - FS Table A-5	
R014	Saturated zone field capacity	not used	2.000E-01		FCSZ		
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02		HCSZ	1956 m/yr - FS Table A-5 (average as described in Section A.6.1)	
R014	Saturated zone hydraulic gradient	not used	2.000E-02		HGWT	Hydraulic gradient 0.004 - FS Table A-5 (average as described in Section A.6.1)	
R014	Saturated zone b parameter	not used	5.300E+00		BSZ		
R014	Water table drop rate (m/yr)	not used	1.000E-03		VWT		
R014	Well pump intake depth (m below water table)	not used	1.000E+01		DWIBWT		
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND		MODEL		
R014	Well pumping rate (m^3/yr)	not used	2.500E+02		UW		
R015	Number of unsaturated zone strata	not used	1		NS		
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00		H(l)		
R015	Unsat . zone 1, soil density (g/cm^3)	not used	1.500E+00		DENSUZ(l)		
R015	Unsat . zone 1, total porosity	not used	4.000E-01		TPUZ(l)		
R015	Unsat. zone 1, effective porosity	not used	2.000E-01		EPUZ(l)		
R015	Unsat . zone 1, field capacity	not used	2.000E-01		FCUZ (1)		
R015	Unsat . zone 1, soil -specific b parameter	not used	5.300E+00		BUZ(l)		
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01		HCUZ (1)		
R016	Distribution coefficients for Ra-228						
R016	Contaminated zone (cm^3/g)	7.000E+01	7.000E+01		DCNUCC (1)		
R016	Unsaturated zone 1 (cm^3/g)	not used	7.000E+01		DCNUCU(1, 1)		
R016	Saturated zone (cm^3/g)	not used	7.000E+01		DCNUCS (1)		
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.20E-03	ALEACH(1)		
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)		
R016	Distribution coefficients for Ra-228						

		2003 Feasibility Study for Building 23 (Verification modeling output included in Appendix A)					2018 Verification Modeling
Menu	Parameter	User Input (Surface/ Subsurface)	Default	Used by RESRAD (if different from user input)	Parameter Name	Notes	Updated Parameters (Modeling output included in Appendix C)
R016	Contaminated zone (cm^3/g)	6.000E+04	6.000E+04		DCNUCC (2)		
R016	Unsaturated zone 1 (cm^3/g)	not used	6.000E+04		DCNUCU(2 , 1)		
R016	Saturated zone (cm^3/g)	not used	6.000E+04		DCNUCS (2)		
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.08E-06	ALEACH(2)		
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)		
R017	Inhalation rate (m^3/yr)	8.400E+03	8.400E+03		INHALR		7.780E+03 (EPA 2011)
R017	Mass loading for inhalation (g/m^3)	1.000E-04	1.000E-04		MLINH		7.000E-04 (Yu et al 2015)
R017	Exposure duration	2.500E+01	3.000E+01		ED	Exposure duration of 25 years - FS Table A-5 (maintenance & industrial).	
R017	Shielding factor, inhalation	4.000E-01	4.000E-01		SHF3		
R017	Shielding factor, external gamma	7.000E-01	7.000E-01		SHFl		
R017	Fraction of time spent indoors	1.998E-01	5.000E-01		FIND	Fraction of 0.1998 for industrial - FS Table A-5 (0.030 for maintenance).	0.1996
R017	Fraction of time spent outdoors (on site)	2.850E-02	2.500E-01		FOTD	Fraction of 0.0285 for industrial - FS Table A-5 (0.0890 for maintenance).	0.0285
R017	Shape factor flag , external gamma	1.000E+00	1.000E+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	5.000E+01		RAD SHAPE (1)		
R017	Outer annular radius (m), ring 2 :	not used	7.071E+01		RAD SHAPE (2)		
R017	Outer annular radius (m), ring 3 :	not used	0.000E+00		RAD SHAPE (3)		
R017	Outer annular radius (m), ring 4 :	not used	0.000E+00		RAD_SHAPE(4)		
R017	Outer annular radius (m), ring 5 :	not used	0.000E+00		RAD_SHAPE(5)		
R017	Outer annular radius (m), ring 6 :	not used	0.000E+00		RAD_ SHAPE(6)		
R017	Outer annular radius (m), ring 7 :	not used	0.000E+00		RAD_SHAPE(7)		
R017	Outer annular radius (m), ring 8 :	not used	0.000E+00		RAD_ SHAPE(8)		
R017	Outer annular radius (m), ring 9 :	not used	0.000E+00		RAD_SHAPE(9)		
R017	Outer annular radius (m), ring 10:	not used	0.000E+00		RAD_SHAPE(lO)		
R017	Outer annular radius (m) , ring 11 :	not used	0.000E+00		RAD SHAPE (11)		
R017	Outer annular radius (m), ring 1 2 :	not used	0.000E+00		RAD_ SHAPE(l2)		
R017	Fractions of annular areas within AREA:						
R017	Ring 1	not used	0.000E+00		FRACA (1)		
R017	Ring 2	not used	2.732E-01		FRACA (2)		
R017	Ring 3	not used	0.000E+00		FRACA (3)		
R017	Ring 4	not used	0.000E+00		FRACA (4)		
R017	Ring 5	not used	0.000E+00		FRACA (5)		
R017	Ring 6	not used	0.000E+00		FRACA (6)		
R017	Ring 7	not used	0.000E+00		FRACA (7)		
R017	Ring 8	not used	0.000E+00		FRACA (8)		
R017	Ring 9	not used	0.000E+00		FRACA (9)		
R017	Ring 10	not used	0.000E+00		FRACA (10)		

		2003 Feasibility Study for Building 23 (Verification modeling output included in Appendix A)					2018 Verification Modeling
Menu	Parameter	User Input (Surface/ Subsurface)	Default	Used by RESRAD (if different from user input)	Parameter Name	Notes	Updated Parameters (Modeling output included in Appendix C)
R017	Ring 11	not used	0.000E+00		FRACA (11)		
R017	Ring 12	not used	0.000E+00		FRACA (12)		
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02		DIET (1)	FS Table A-4 and Section A.5.3.3 indicate no plant ingestion (consistent)	
R018	Leafy vegetable consumption (kg/ yr)	not used	1.400E+01		DIET (2)	FS Table A-4 and Section A.5.3.3 indicate no plant ingestion (consistent)	
R018	Milk consumption (L/yr)	not used	9.200E+01		DIET (3)	FS Table A-4 and Section A.5.3.5 indicate no milk ingestion (consistent)	
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01		DIET (4)	FS Table A-4 and Section A.5.3.4 indicate no meat ingestion (consistent)	
R018	Fish consumption (kg/yr)	not used	5.400E+00		DIET (5)	FS Table A-4 indicates aquatic foods pathway included, but Section A.5.3.6 and RESRAD do not.	
R018	Other seafood consumption (kg/ yr)	not used	9.000E-01		DIET (6)	FS Table A-4 indicates aquatic foods pathway included, but Section A.5.3.6 and RESRAD do not.	
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01		SOIL		25 (EPA 2017)
R018	Drinking water intake (L/yr)	not used	5.100E+02		DWI	FS Table A-4 and Section A.5.3.7 indicate no drinking water intake (consistent)	
R018	Contamination fraction of drinking water	not used	1.000E+00		FDW		
R018	Contamination fraction of household water	not used	1.000E+00		FHHW		
R018	Contamination fraction of livestock water	not used	1.000E+00		FLW		
R018	Contamination fraction of irrigation water	not used	1.000E+00		FI RW		
R018	Contamination fraction of aquatic food	not used	5.000E-01		FR9		
R018	Contamination fraction of plant food	not used	-1		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	6.800E+01		LFI5		
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01		LFI6		
R019	Livestock water intake for meat (L/ day)	not used	5.000E+01		LWI5		
R019	Livestock water intake for milk (L/ day)	not used	1.600E+02		LWI6		
R019	Livestock soil intake (kg/day)	not used	5.000E-01		LSI		
R019	Mass loading for foliar deposition (g/m^3)	not used	1.000E-04		MLFD		
R019	Depth of soil mixing layer (m)	1.50E-01	1.500E-01		DM		
R019	Depth of roots (m)	not used	9.000E-01		DROOT		
R019	Drinking water fraction from ground water	not used	1.000E+00		FGWDW		
R019	Household water fraction from ground water	not used	1.000E+00		FGWHH		
R019	Livestock water fraction from ground water	not used	1.000E+00		FGWLW		
R019	Irrigation fraction from ground water	not used	1.000E+00		FGWIR		
R19B	Wet weight crop yield for Non- Leafy (kg/ m^2)	not used	7.000E-01		YV (1)		
R19B	Wet weight crop yield for Leafy (kg/m^2)	not used	1.500E+00		YV (2)		
R19B	Wet weight crop yield for Fodder (kg/m^2)	not used	1.100E+00		YV (3)		

		2003 Feasibility Study for Building 23 (Verification modeling output included in Appendix A)					2018 Verification Modeling
Menu	Parameter	User Input (Surface/ Subsurface)	Default	Used by RESRAD (if different from user input)	Parameter Name	Notes	Updated Parameters (Modeling output included in Appendix C)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01		TE (1)		
R19B	Growing Season for Leafy (years)	not used	2.500E-01		TE (2)		
R19B	Growing Season for Fodder (years)	not used	8.000E-02		TE (3)		
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01		TIV (1)		
R19B	Translocation Factor for Leafy	not used	1.000E+00		TIV (2)		
R19B	Translocation Factor for Fodder	not used	1.000E+00		TIV (3)		
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01		RDRY (1)		
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01		RDRY (2)		
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01		RDRY (3)		
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01		RWET (1)		
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01		RWET (2)		
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01		RWET (3)		
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01		WLAM		
C14	C-12 concentration in water (g/cm^3)	not used	2.000E-05		C12WTR		
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02		C12CZ		
C14	Fraction of vegetation carbon from soil	not used	2.000E-02		CSOIL		
C14	Fraction of vegetation carbon from air	not used	9.800E-01		CAIR		
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01		DMC		
C14	C- 14 evasion flux rate from soil (1/sec)	not used	7.000E-07		EVSN		
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10		REVSN		
C14	Fraction of grain in beef cattle feed	not used	8.000E-01		AVFG4		
C14	Fraction o f grain in milk cow feed	not used	2.000E-01		AVFG5		
STOR	Storage times of contaminated foodstuffs (days):						
STOR	Fruits, non-leafy vegetables, and grain	1.40E+01	1.400E+01		STOR_T(1)		
STOR	Leafy vegetables	1.00E+00	1.000E+00		STOR_T(2)		
STOR	Milk	1.00E+00	1.000E+00		STOR_T(3)		
STOR	Meat and poultry	2.00E+01	2.000E+01		STOR_T(4)		
STOR	Fish	7.00E+00	7.000E+00		STOR_T(5)		
STOR	Crustacea and mollusks	7.00E+00	7.000E+00		STOR_T(6)		
STOR	Well water	1.00E+00	1.000E+00		STOR_T(7)		
STOR	Surface water	1.00E+00	1.000E+00		STOR_T(8)		
STOR	Livestock fodder	4.50E+01	4.500E+01		STOR_T(9)		
R021	Thickness of building foundation (m)	not used	1.500E-01		FLOOR1		
R021	Bulk density of building foundation (g/cm^3)	not used	2.400E+00		DENSFL		
R021	Total porosity of the cover material	not used	4.000E-01		TPCV		
R021	Total porosity of the building foundation	not used	1.000E-01		TPFL		
R021	Volumetric water content of the cover material	not used	5.000E-02		PH20CV		
R021	Volumetric water content of the foundation	not used	3.000E-02		PH20FL		
R021	Diffusion coefficient for radon gas (m/sec) :						

		2003 Feasibility Study for Building 23 (Verification modeling output included in Appendix A)					2018 Verification Modeling
Menu	Parameter	User Input (Surface/ Subsurface)	Default	Used by RESRAD (if different from user input)	Parameter Name	Notes	Updated Parameters (Modeling output included in Appendix C)
R021	in cover material	not used	2.000E-06		DIFCV		
R021	in foundation material	not used	3.000E-07		DIFFL		
R021	in contaminated zone soil	not used	2.000E-06		DIFCZ		
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00		HMIX		
R021	Average building air exchange rate (1/hr)	not used	5.000E-01		REXG		
R021	Height of the building (room) (m)	not used	2.500E+00		HRM		
R021	Building interior area factor	not used	0.000E+00		FAI		
R021	Building depth below ground surface (m)	not used	-1.000E+00		DMFL		
R021	Emanating power of Rn-222 gas	not used	2.500E-01		EMANA (1)		
R021	Emanating power of Rn-220 gas	not used	1.500E-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	257	--		KYMAX		

APPENDIX C

BUILDING 23 BENCHMARK DOSE RESRAD OUTPUT FILE – VERIFICATION ANALYSIS WITH UPDATED PARAMETERS BASED ON GUIDANCE

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Summary : Updated parameters Ra-228 only 2200 m^2
File : C:\USERS\WGAUL\DOCUMENTS\TIDEH2O\WR GRACE\DCGL\UPDATED PARMS 10-15 RA-228 ONLY.RAD

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : Updated parameters Ra-228 only 2200 m^2
File : C:\USERS\WGAUL\DOCUMENTS\TIDEH2O\WR GRACE\DCGL\UPDATED PARMS 10-15 RA-228 ONLY.RAD

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ac-228 (Source: FGR 12)	5.978E+00	5.978E+00	DCF1(1)
A-1	Bi-212 (Source: FGR 12)	1.171E+00	1.171E+00	DCF1(2)
A-1	Pb-212 (Source: FGR 12)	7.043E-01	7.043E-01	DCF1(3)
A-1	Po-212 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(4)
A-1	Po-216 (Source: FGR 12)	1.042E-04	1.042E-04	DCF1(5)
A-1	Ra-224 (Source: FGR 12)	5.119E-02	5.119E-02	DCF1(6)
A-1	Ra-228 (Source: FGR 12)	0.000E+00	0.000E+00	DCF1(7)
A-1	Rn-220 (Source: FGR 12)	2.298E-03	2.298E-03	DCF1(8)
A-1	Th-228 (Source: FGR 12)	7.940E-03	7.940E-03	DCF1(9)
A-1	Tl-208 (Source: FGR 12)	2.298E+01	2.298E+01	DCF1(10)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ra-228+D	5.078E-03	4.770E-03	DCF2(1)
B-1	Th-228+D	3.454E-01	3.420E-01	DCF2(2)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ra-228+D	1.442E-03	1.440E-03	DCF3(1)
D-1	Th-228+D	8.086E-04	3.960E-04	DCF3(2)
D-34	Food transfer factors:			
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(1,3)
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(2,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(1,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(1,2)
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(2,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(2,2)

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Summary : Updated parameters Ra-228 only 2200 m^2

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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)	2.200E+03	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-228	5.000E+00	0.000E+00	---	S1(1)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(1)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.956E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.118E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	not used	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	not used	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	not used	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	not used	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	not used	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	not used	2.000E-02	---	HGWT
R014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	not used	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	not used	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	not used	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW

Summary : Updated parameters Ra-228 only 2200 m^2
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Number of unsaturated zone strata	not used	1	---	NS
R015	Unsat. zone 1, thickness (m)	not used	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	not used	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	not used	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	not used	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	not used	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	not used	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	not used	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	not used	7.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.202E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	not used	6.000E+04	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.080E-06	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	7.780E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	7.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	2.500E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.996E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.850E-02	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+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	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Summary : Updated parameters Ra-228 only 2200 m^2
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	2.500E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	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	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)

Summary : Updated parameters Ra-228 only 2200 m^2
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

Summary : Updated parameters Ra-228 only 2200 m^2
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Summary : Updated parameters Ra-228 only 2200 m^2
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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	2200.00 square meters	Ra-228	5.000E+00
Thickness:	1.00 meters		
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 2.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	5.565E+00	6.813E+00	7.391E+00	4.226E+00	3.637E-01	5.471E-05	6.537E-16	0.000E+00
M(t):	2.226E-01	2.725E-01	2.957E-01	1.690E-01	1.455E-02	2.188E-06	2.615E-17	0.000E+00

Maximum TDOSE(t): 7.412E+00 mrem/yr at t = 2.644 ± 0.005 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.644E+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.
Ra-228	7.291E+00	0.9837	8.099E-02	0.0109	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.014E-02	0.0054
Total	7.291E+00	0.9837	8.099E-02	0.0109	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.014E-02	0.0054

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.644E+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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.412E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.412E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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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	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-228	5.498E+00	0.9880	2.481E-02	0.0045	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.220E-02	0.0076
Total	5.498E+00	0.9880	2.481E-02	0.0045	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.220E-02	0.0076

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.565E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.565E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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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.
Ra-228	6.714E+00	0.9854	5.709E-02	0.0084	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.271E-02	0.0063
Total	6.714E+00	0.9854	5.709E-02	0.0084	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.271E-02	0.0063

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.813E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.813E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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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.
Ra-228	7.269E+00	0.9835	8.306E-02	0.0112	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.926E-02	0.0053
Total	7.269E+00	0.9835	8.306E-02	0.0112	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.926E-02	0.0053

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.391E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.391E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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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.
Ra-228	4.150E+00	0.9821	5.589E-02	0.0132	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.963E-02	0.0046
Total	4.150E+00	0.9821	5.589E-02	0.0132	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.963E-02	0.0046

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.226E+00	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.226E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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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)

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.
Ra-228	3.571E-01	0.9819	4.925E-03	0.0135	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.651E-03	0.0045
Total	3.571E-01	0.9819	4.925E-03	0.0135	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.651E-03	0.0045

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.637E-01	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.637E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
File : C:\USERS\WGAUL\DOCUMENTS\TIDEH2O\WR GRACE\DCGL\UPDATED PARMS 10-15 RA-228 ONLY.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.
Ra-228	5.372E-05	0.9819	7.411E-07	0.0135	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.483E-07	0.0045
Total	5.372E-05	0.9819	7.411E-07	0.0135	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.483E-07	0.0045

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.471E-05	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.471E-05	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
File : C:\USERS\WGAUL\DOCUMENTS\TIDEH2O\WR GRACE\DCGL\UPDATED PARMS 10-15 RA-228 ONLY.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.
Ra-228	6.419E-16	0.9819	8.861E-18	0.0136	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.969E-18	0.0045
Total	6.419E-16	0.9819	8.861E-18	0.0136	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.969E-18	0.0045

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.537E-16	1.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.537E-16	1.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

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.
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

*Sum of all water independent and dependent pathways.

Summary : Updated parameters Ra-228 only 2200 m^2
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Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228+D	Ra-228+D	1.000E+00	8.666E-01	7.642E-01	5.942E-01	2.464E-01	1.993E-02	2.996E-06	3.582E-17	0.000E+00
Ra-228+D	Th-228+D	1.000E+00	2.465E-01	5.985E-01	8.840E-01	5.987E-01	5.281E-02	7.946E-06	9.492E-17	0.000E+00
Ra-228+D	∑DSR(j)		1.113E+00	1.363E+00	1.478E+00	8.451E-01	7.273E-02	1.094E-05	1.307E-16	0.000E+00

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 2.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	2.246E+01	1.835E+01	1.691E+01	2.958E+01	3.437E+02	2.285E+06	*2.726E+14	*2.726E+14

*At specific activity limit

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 = 2.644 ± 0.005 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Ra-228	5.000E+00	2.641 ± 0.005	1.482E+00	1.686E+01	1.482E+00	1.686E+01

Summary : Updated parameters Ra-228 only 2200 m^2
File : C:\USERS\WGAUL\DOCUMENTS\TIDEH2O\WR GRACE\DCGL\UPDATED PARMS 10-15 RA-228 ONLY.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr							
		t=	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	Ra-228	1.000E+00	4.333E+00	3.821E+00	2.971E+00	1.232E+00	9.963E-02	1.498E-05	1.791E-16	0.000E+00
Th-228	Ra-228	1.000E+00	1.233E+00	2.993E+00	4.420E+00	2.994E+00	2.640E-01	3.973E-05	4.746E-16	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g							
		t=	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-228	Ra-228	1.000E+00	5.000E+00	4.409E+00	3.429E+00	1.422E+00	1.150E-01	1.729E-05	2.067E-16	0.000E+00
Th-228	Ra-228	1.000E+00	0.000E+00	1.423E+00	2.669E+00	1.973E+00	1.759E-01	2.648E-05	3.166E-16	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 0.74 seconds