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AUG 24 2007

Mr. James A. Saric, Remedial Project Manager
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77 West Jackson Boulevard
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EMCBC-00699-07

Mr. Thomas Schneider, Project Manager
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Southwest District Office
401 East Fifth Street
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Dear Mr. Saric and Mr. Schneider:

AUGUST 2007 CHANGE PAGES TO THE INTERIM RESIDUAL RISK ASSESSMENT REPORT, REVISION 1

Enclosed are the change pages to Revision 1 of the Interim Residual Risk Assessment (IRRA) Report for the Fernald Preserve. The pages contain updated text that reflects several minor comments received from U.S. Environmental Protection Agency on August 20, 2007. There are nine change pages, and they are designated in the last line of the header as "Change Page: August 21, 2007." Note that the pages are double sided so that they can be exchanged easily with the old pages. However, because the pages are double sided, several pages have one side that contains no changes. Attachment A to this letter summarizes the pages and text that were changed.

If you have any questions or require additional information, please contact me at (513) 648-3139.

Sincerely,

Johnny Reising

Johnny W. Reising
Director

Enclosures

cc w/enclosures:
T. Schneider, OEPA-Dayton (three copies of enclosures)
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EXECUTIVE SUMMARY

Results presented in this Interim Residual Risk Assessment (IRRA) Report show that the non-carcinogenic risk and carcinogenic risk to all evaluated site receptors are within the acceptable range discussed within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The CERCLA guidance considers acceptable risk to be less than one for the hazard index (HI) and less than 1.0E-04 for the incremental lifetime cancer risk (ILCR). This conclusion, along with the results in the soil certification reports, indicate that the remedial actions identified in the Operable Unit 5 Record of Decision were executed successfully and the soil on the Fernald Preserve has been restored to an acceptable risk level compatible with the final land use objective.

Remedial actions associated with the removal of the contaminated structures, soil, and waste materials at the former Feed Material Production Center (FMPC) are documented in the Records of Decision (RODs) for Operable Units 1, 2, 3, 4, and 5. The remedial actions were implemented under the Fernald Closure Project (FCP), and documentation of the completed remedial actions can be found in the Remedial Action Reports for Operable Units 1, 2, 3, 4, and 5.

Risk calculations in the Comprehensive Response Action Risk Evaluation (CRARE) for Operable Unit 5 were performed using *estimated* post-remediation contaminant concentrations in soil and surface-water media that reflected the preliminary remediation levels, which were based on the preliminary remediation goals developed from the Operable Unit 5 Baseline Risk Assessment. The IRRA evaluates the receptor risk due to exposure to *measured* post-remediation contaminant concentrations in the soil and surface water on the Fernald Preserve. In this context, the IRRA risk calculations reflect actual site conditions.

Target receptors in the CRARE were selected for the on-site undeveloped park and off-site farm land-use scenarios. The IRRA calculations deal only with the receptors for the on-site undeveloped park, as groundwater remediation is ongoing and the evaluation of the off-site farm scenario is dependent on the groundwater pathway for ingestion of water (humans and livestock) and irrigation of crops. Off-site receptors will be evaluated in a final risk assessment report that will be submitted after the Great Miami Aquifer has been restored to the final remediation levels listed in the Operable Unit 5 Record of Decision.

The IRRA calculations evaluated six human receptors in nine exposure zones. In line with the final land use of an undeveloped park, and the need for support staff to operate a museum, the converted waste-

water treatment (CWWT) plant and the On-site Disposal Facility (OSDF) valve houses, the receptors reflect visitors and workers who recreate and labor at the site. Receptors include the undeveloped park user (also evaluated in the CRARE), museum visitor, museum worker, groundskeeper/sampler, construction worker, and a building maintenance worker. The trespasser who wanders across the OSDF is not considered in this report, as this scenario of potential exposure is less conservative than the potential exposure received by the groundskeeper/sampler and building maintenance personnel who enter the OSDF zone to perform work. A receptor may spend as few as ten days a year at the site (museum visitor) or as many as 250 days a year (museum worker). The receptor exposure zones reflect soil footprints from historic operations at the site (e.g., production facilities, waste storage areas, etc) and a reasonably large area for the receptor to traverse when they visit and work at the site.

Reasonable maximum exposure (RME) scenarios were developed for the receptors to estimate the chemical and radionuclide intake via inhalation of particulate, vapors from volatile organic compounds (VOCs) and radon gas, incidental ingestion of soil and surface water, dermal contact with soil and surface water, and exposure to external radiation. Ninety-five contaminants were evaluated and a subset of chemicals and radionuclides was compiled for each exposure zone to derive input concentrations for the air, soil, and surface-water pathways. Cancer slope factors (CSFs) and reference doses (RfDs) for the contaminants were compiled from the Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS) and Health Effects Summary Tables (HEAST) and the Oak Ridge National Laboratory's (ORNL) Risk Assessment Information System (RAIS) web sites. The intake values, CSFs, and RfDs are used to calculate HI and ILCR.

Most of the risk to the receptors is driven by a small subset of chemicals and radionuclides. Arsenic, beryllium, uranium, aroclor-1254, aroclor-1260, uranium-238 and lead-210 are responsible for the majority of risk in the soil pathways. Benzo(a)pyrene and dibenzo(a,h)anthracene are key contaminants for the dermal surface-water pathway. Manganese and radon-222 contribute most of the risk to the inhalation pathway. After the radionuclide background is subtracted from the total risk, uranium-238 is the largest contributor to external radiation.

The highest carcinogenic risk occurs in Zone 5 (former production area) for the undeveloped park user (5.66E-05) and groundskeeper/sampler (4.70E-05), and it is driven primarily by dermal exposure to surface water containing benzo(a)pyrene and dibenzo(a,h)anthracene. However, the risk is largely an

artifact of using one-half of the analytical detection limit for these compounds, and this conservative assumption would be less conservative (i.e., lower risk values) if lower analytical detection limits had been obtained for the compounds. This statement is supported by an uncertainty analysis that concludes the greatest uncertainty in the risk calculations is knowing the true concentration of benzo(a)pyrene and dibenzo(a,h)anthracene in surface water.

One of the uncertainty scenarios used a 70-year exposure duration for the undeveloped park user and zero values for benzo(a)pyrene and dibenzo(a,h)anthracene in surface water to compare present risk results to CRARE results for the undeveloped park user. Carcinogenic risk for this uncertainty calculation was slightly higher than the CRARE result, and this is due to higher residual arsenic and beryllium concentrations in the soil, relative to the estimated concentrations used in the CRARE. This comparison between present and CRARE results indicates that remedial actions at the Fernald Preserve were successful in reducing radionuclide concentrations in soil to values below the estimates used in the CRARE, while some chemical concentrations (e.g., arsenic and beryllium) in soil are measured to be greater than those used in the CRARE. However, when all chemicals and radionuclides are summed across all pathways, the risk analysis presented here produces results of the same magnitude as the CRARE and, per CERCLA guidance, less than the upper bound of 1.0E-04.

1.0 INTRODUCTION

The Interim Residual Risk Assessment (IRRA) estimates the human-health risks associated with the post-remediation contaminants in the air, soil, and surface-water media at the former Fernald Feed Material Production Center (FMPC). Groundwater remediation is ongoing, and a final risk assessment will be performed when the groundwater restoration goals have been achieved for the Great Miami Aquifer. Contaminated structures, soil, and waste materials associated with the FMPC site were demolished and removed for disposal under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as documented in the Department of Energy's (DOE) Records of Decision (RODs) for Operable Units (OU) 1, 2, 3, 4, and 5 (DOE 1995a, 1995b, 1996a, 1996b, 2000, 2003) and the remedial action close-out reports (DOE 2006b, 2006c, 2006d, 2006e, 2006f). The remedial actions were implemented under the Fernald Closure Project (FCP), and the IRRA calculations document that the soil remedial actions at the Fernald site were adequate to reduce contaminant concentrations in soil and surface water to levels that are protective of human health and the environment.

CERCLA (a.k.a. superfund) requires that the actions selected to remedy hazardous waste sites be robust enough to reduce potential threats posed by the release of hazardous substance to the environment to limits that are protective of human health and the environment. Per the U.S. Environmental Protection Agency's (EPA) Risk Assessment Guidance for Superfund (RAGS, EPA 1989a), these criteria are evaluated with risk calculations to demonstrate that the risk to a receptor, defined as the "reasonable maximum exposure" (RME) individual, does not exceed an incremental lifetime cancer risk (ILCR) of 1 in 10,000 (1.0E-04) and a hazard index (HI) of greater than one.

A variety of on-property receptors were assessed using the approach and methodology in RAGS (Part A, EPA 1989a; Supplement to Part A, EPA 1991a; Part E, EPA 2004), the Exposure Factors Handbook (EFH, EPA 1997) and supplemental guidance (EPA 1991a), and site-specific data on air, soil, and surface-water concentrations. The off-property farm receptor will be evaluated for the groundwater and food pathways in the final risk assessment, which will be submitted to the regulatory agencies after the aquifer certification process has been approved by the EPA and OEPA.

For each on-site receptor, risk was calculated at three contaminant concentration levels: total risk with no background correction; radiological background subtracted from the total risk; and all background subtracted from the total risk. An uncertainty analysis was also performed to evaluate variation in risk due to different exposure zones, the exposure duration (exposure early in life versus late in life), modeled air concentrations versus measured air monitoring values, change in contaminant concentrations, and changes in cancer slope factors and reference doses. The tabulated calculations provide a useful comparison to the regulatory agencies and public on reasonable and background risk to the site visitors and workers.

1.1 OVERVIEW AND ORGANIZATION OF THE IRRA REPORT

The primary objective of the IRRA is to estimate the risk posed to on-site receptors by post-remediation (i.e., residual) contaminant concentrations in air, soil, and surface-water media within eight exposure zones that comprise the former FMPC site. Exposure pathways for the receptors include inhalation of gas (VOCs and radon) and particulate, dermal contact with soil and surface water, ingestion of soil and surface water, and external radiation. Receptors, exposure parameters, reference doses, and cancer slope factors have been updated relative to values presented in the Comprehensive Response Action Risk Evaluation (CRARE), which is Appendix H of the Operable Unit 5 Feasibility Study (OU5; DOE 1995d). Whereas this report evaluates the receptor risk due to exposure to *measured* post-remediation contaminant concentrations in air, soil, and surface water on the site, the CRARE evaluated risk using the OU5 Remedial Investigation (DOE 1995c) data set, background data (DOE 1994, 2001) and air models to *estimate* post-remediation contaminant concentrations in air, soil, and surface-water media. Target receptors in the CRARE were selected for the on-site undeveloped park and off-site farm land-use scenarios. The interim risk calculations presented in this report deal only with the receptors for the on-site undeveloped park, as groundwater remediation is ongoing and the evaluation of the off-site farm scenario is dependent on the groundwater pathway for ingestion of water by humans and livestock and irrigation of crops. Groundwater and food pathways for the off-site receptors will be covered when the final risk assessment report is submitted to the regulatory agencies.

3.0 SCENARIOS, LAND USE EXPOSURE PATHWAYS & RECEPTORS

In the OU 5 FS (DOE 1995d), DOE evaluated remedial actions, human and ecological risk, and cost to determine which of four land use objectives would be selected for the end state of the Fernald site. Collaboration with the regulatory agencies and public resulted in the selection of Land Use Objective 3 – Maximum Consolidation of Contaminated Material to Free the Majority of the Fernald Site for Restricted Land Use. Land Use Objective 3 called for off-site shipment and disposal of the highest risk waste streams (e.g., OU 1 waste pits, OU 4 silo materials, etc.), and on-site disposal of soil, waste, and building rubble, if the materials met the OSDF waste acceptance criteria. Three alternatives were evaluated for Land Use Objective 3: A) industrial park; B) developed recreational park; and C) undeveloped recreational park. Through the FS process, Alternative 3C was selected for OU 5.

The undeveloped park envisioned in the FS had no rest rooms or developed recreational facilities, with the exception of hiking trails. Since the OU 5 FS was published, the vision of the undeveloped park has changed to accommodate an on-site museum with rest rooms, a parking lot, and continued operation of the CWWT facility to support ongoing groundwater restoration activities. Therefore, the present land use scenario is the undeveloped park with some infrastructure development to support the museum and CWWT operations.

Slight changes to the undeveloped park scenario presented in the FS dictates that the IRRA must consider additional receptors to account for daily workers that support the museum and CWWT operations and the general public that visits the museum. Receptors for the IRRA will include the undeveloped park user presented in the OU 5 FS, as well as a museum visitor, museum worker, groundskeeper/sampler, building maintenance, and construction worker. Each of these receptors is discussed below with respect to exposure pathways and parameters.

Exposure pathways for receptors evaluated in the IRRA are similar to those presented in the OU 5 FS, and they consist of inhalation of radon gas, VOC vapors and soil particulate suspended by the wind, dermal contact with soil and surface water, incidental ingestion of soil and surface water, and exposure to external radiation. In contrast to the OU 5 CRARE exposure pathways, the groundwater, and food pathways will not be evaluated in the IRRA due to ongoing groundwater restoration activities. The groundwater and food pathways will be evaluated in a final risk assessment report that will be published after the groundwater has been certified as meeting the OU 5 ROD groundwater FRLs.

3.1 UNDEVELOPED PARK USER

This target receptor is the child, youth, adult, and/or senior adult that visits the park to hike, picnic, and observe birds. These individuals inhale air that contains radon, VOC vapors and soil particulate suspended by the wind, and they contact soil and surface water while hiking trails and sitting on the ground for a picnic. Contact with soil and surface water results in dermal exposure as well as incidental ingestion. The receptor is also exposed to external radiation from radioactive isotopes present in the environmental media. Exposure pathways and parameters are summarized in Table 3-1. The rationale and reference for each exposure parameter are discussed below:

- Exposure Frequency (EF): The number of days per year (d/yr) that a receptor visits the site is the EF. EF is assumed to be 20 d/yr, about every other week, for the child and adult. A higher frequency of 40 d/yr is assumed for the youth and senior adult to account for extra recreation time available to these age receptors. For example, the youth who can drive will be able to spend additional time at the park after school, relative to a working adult and young child.

- Exposure Duration (ED): The ED is the number of years over which an individual will visit the park. EPA (1989a) notes that national trends show individuals do not live in a region of the country for more than 30 years. Therefore, 30 years is used as the sum across the age groups, with the years partitioned into 3 years for child, 6 for youth, 14 for adult and 7 for senior adult. An ED of 70 years is evaluated in the uncertainty calculations presented in Section 5.0.

- Body Weight (BW): EPA (1997) has tabulated BW for individuals. The adult and senior adult are equated to the mean BW in EPA Table 7-11, which is rounded to 70 kg. An average of mean values reported for ages 7 to 18 (EPA Table 7-3) is rounded to 47 kg for the youth. The child mean values reported for ages 0 to 6 (EPA Table 7-3) are used to derive an average weight of 15 kg.

- Averaging Time for non-carcinogens (AT_{nc}): Averaging time refers to the number of days over which the toxin acts on the body. EPA (1989a) defines the averaging time for non-carcinogen chemicals as the exposure duration multiplied by 365 days/yr.

- Averaging Time for carcinogens (AT_c): For carcinogenic compounds and radioactive isotopes, EPA (1989a) assumes the carcinogen acts over a 70-yr lifetime for the individual. Therefore, averaging time (days) for carcinogens is 70 yrs multiplied by 365 days/yr.

- Inhalation Rate (IhR): The volume of air which an individual breathes each hour is the IhR. EPA (1997) reports the same value (1.0 m^3/hr) for the child and adult receptors for short-term exposure and light activities (EPA Table 5-23). Therefore, this value is used for all age groups. Short-term exposure and light activities are applicable to a park visitor that spends an hour or two hiking trails and watching birds.

- Exposure Time (ET) for Air: The amount of time the receptor spends at the park each visit is the ET. As the park is undeveloped, the assumption is made that the receptor will spend a fraction of a normal day (two hours) inhaling dust, VOC vapors and radon gas on each day they visit the undeveloped park.

- Ingestion Rate (IR) for Soil: The mass of soil that is ingested incidentally each day is the IR. EPA (1989b & 1997) estimates that a residential child will ingest 0.2 g/d, which is lowered to 0.1 g/d for the adult. The IR for the youth and senior adult is assumed to be similar to the adult.

- Fraction of Ingested Soil that is Contaminated (FI): In some risk exposure scenarios, a receptor may pass in and out of contaminated soil zones, and only a fraction of the ingested soil will contain contaminants. For the IRRA, the receptor is assumed to spend 100 percent of their park time in a contamination zone, and FI is set equal to 1.0.

- Surface Area (SA), Dermal Contact with Soil: The skin SA exposed to soil is assumed to be the head, hands, forearms, feet, and lower legs. All SA values for body parts are obtained from EPA (2004, Exhibit C-1), and the sum for these body parts appears in Table 3-1.

- Adherence Factor (AF): The AF for soil to skin is taken from EPA (2004). For a residential scenario, the AF value is 0.2 for child and youth, and 0.07 for adult and senior.

- Shielding Factor (SH): The SH accounts for material between the receptor and radiation source that can attenuate the external radiation received by an individual. For outdoor conditions on the site, the SH is taken as 0.25 to account for substantial surface-water coverage (water shields radiation emitted from the soil below the water) and the placement of clean mulch over the remedial footprint (the mulch is worked into the remedial footprint, which dilutes the soil concentration and provides some shielding from radiation emitted by nuclides on the soil particles).

- Ingestion Rate (IR) for Surface Water: The 1997 EPA Exposure Factors Handbook does not contain guidance on the surface-water pathway. An older version of the handbook (EPA 1989b) assigned 0.05 liter per hour (L/hr) for an adult swimmer. Although swimming in the ponds on site is not allowed, this ingestion rate will be used for the child, youth, adult and senior to cover the conservative case where splashing results in a similar ingestion rate.

- Exposure Time (ET) for Surface Water: As swimming is not allowed in the ponds on the site, contact with water will be a transient activity of short duration. It is assumed that the receptor will spend one hour wading and splashing on each summer day spent at the undeveloped park.

- Exposure Frequency (EF) for Surface Water: It is assumed that wading in the surface water, which is not permitted, will take place only during the summer months. Therefore, all receptors spend one day each weekend of the 12 summer weeks (12 d/yr) contacting the water.

- Surface Area (SA), Dermal Contact with Surface Water: The skin SA exposed to soil is assumed to be the face, hands, forearms, feet and lower legs. All SA values for body parts are obtained from EPA (2004, Exhibit C-1), and the sum for these body parts appears in Table 3-1.

- Dose Absorbed (DA) per Event, Dermal Contact with Surface Water: This is a chemical specific value that is calculated from the permeability constant and chemical concentration in the water. All constants and chemical concentrations used in this calculation are tabulated in Appendix E.

3.2 MUSEUM VISITOR

This target receptor is the child, youth, adult, and/or senior adult that visits the museum and participates in an occasional field trip run by the museum. Although these individuals spend most of their time in the museum, they will inhale air that contains radon, VOC vapors and soil particulate when they walk from the parking lot to the museum and when they participate in field trips. The receptor may contact soil and surface water when they participate in a museum field trip or if they wander through the grounds between the parking lot and museum. Contact with soil and surface water results in dermal exposure as well as incidental ingestion. The receptor is also exposed to external radiation from radioactive isotopes present in the environmental media. Exposure pathways and parameters are summarized in Table 3-2. The rationale and reference for each exposure parameter are discussed below:

- Exposure Frequency (EF): The number of days per year (d/yr) that a receptor visits the museum is the EF. EF is assumed to be 10 d/yr for the child, youth, and adult. A higher frequency of 20 d/yr is assumed for the senior adult to account for extra recreation time available to this age receptor.

- Exposure Duration (ED): The ED is the number of years over which an individual will visit the park. EPA (1989a) notes that national trends show individuals do not live in a region of the country for more than 30 years. Therefore, 30 years is used as the sum across the age groups, with the years partitioned into 3 years for child, 6 for youth, 14 for adult and 7 for senior adult.

- Body Weight (BW): EPA (1997) has tabulated BW for individuals. The adult and senior adult are equated to the mean BW in EPA Table 7-11, which is rounded to 70 kg. An average of mean values reported for ages 7 to 18 (EPA Table 7-3) is rounded to 47 kg for the youth. The child mean values reported for ages 0 to 6 (EPA Table 7-3) are used to derive an average weight of 15 kg.

- Averaging Time for non-carcinogens (AT_{nc}): Averaging time refers to the number of days over which the toxin acts on the body. EPA (1989a) defines the averaging time for non-carcinogen chemicals as the exposure duration multiplied by 365 days/yr.

- Averaging Time for carcinogens (AT_c): For carcinogenic compounds and radioactive isotopes, EPA (1989a) assumes the carcinogen acts over a 70-yr lifetime for the individual. Therefore, averaging time (days) for carcinogens is 70 yrs multiplied by 365 days/yr.

- Inhalation Rate (IhR): The volume of air which an individual breathes each hour is the IhR. EPA (1997) reports the same value (1.0 m^3/hr) for the child and adult receptors for short-term exposure and light activities (EPA Table 5-23). Therefore, this value is used for all age groups. Short-term exposure and light activities are applicable to a museum visitor that spends an hour or two in the museum.

- Exposure Time (ET) for Air: The amount of time the receptor spends outdoors on each visit to the museum is assumed to be one-half hour per each day they visit the museum. This time is allocated to walking between the parking lot and museum and participating in an occasional field trip.

- Ingestion Rate (IR) for Soil: The mass of soil that is ingested incidentally each day is the IR. EPA (1989b & 1997) estimates that a residential child will ingest 0.2 g/d, which is lowered to 0.1 g/d for the adult. However, there is very little time spent outdoors for the museum visitor, and the rate is decreased to 0.1 g/d for child, 0.075 g/d for youth and 0.05 g/d for the adult and senior adult.

- Fraction of Ingested Soil that is Contaminated (FI): In some risk exposure scenarios, a receptor may pass in and out of contaminated soil zones, and only a fraction of the ingested soil will contain contaminants. For the IRRA, the receptor is assumed to spend 100 percent of their outdoor time in a contamination zone, and FI is set equal to 1.0.

- Surface Area (SA), Dermal Contact with Soil: The skin SA exposed to soil is assumed to be the head, hands, forearms and lower legs. Feet are not included because museum visitors will be wearing foot gear. All SA values for body parts are obtained from EPA (2004, Exhibit C-1), and the sum for these body parts appears in Table 3-2.

dibenzo(a,h)anthracene, is too conservative when long exposure durations are considered, and only true detections should be used in risk calculations. Therefore, benzo(a)pyrene and dibenzo(a,h)anthracene should be retained as contaminants of concern for future sampling of the surface water in Zones 5 and 6, and the lowest achievable detection limits should be requested when the samples are sent to the analytical laboratory.

The maximum uranium concentration in surface water was entered into the risk calculation for GS 1 (double the exposure duration and undetected organic concentrations are set at one-half the detection limit value). Results for GS 2 show the HI increased by 0.6E-01 and the T-RB ILCR increased by a factor of 0.06E-05, relative to the GS 1 case, but the HI and T-RB ILCR values remain below the acceptable levels of less than one and less than 1.0E-04, respectively. Therefore, the present maximum uranium surface-water concentration of 1.88 mg/L does not present a significant increase in risk to the groundskeeper/sampler. However, the source for this elevated uranium concentration (ponds west of former Waste Pit 3) should be sampled during future monitoring activities to ensure that the uranium concentrations does not rise to a level that would create an unacceptable risk for a site receptor.

As noted above using one-half the detection limit value for benzo(a)pyrene and dibenzo(a,h)anthracene results in a high uncertainty to the calculated risk to the receptors, whereas increasing the uranium surface-water concentration to the maximum observed value presents no significant increase in the overall risk to the adult receptors. However, in Appendix E.10 the detailed calculations for UPU 1 and UPU 3 show that the child sub-receptor for the undeveloped park user does experience a significant increase in the HQ from exposure to the maximum uranium concentration in surface water (uranium HQ of 3.90E-03 for UPU 1 increases to 3.43E-01 for UPU 3). Although there is a significant increase in the exposure to chemical toxins for the child sub-receptor, the overall HI for all chemicals remains below the acceptable limit of one.

Variation in Air Concentrations

As noted in Section 4.3, the baseline case for the inhalation of particulate and gases uses the average particulate value for the background monitoring location to estimate the air concentrations for all constituents, except radon. Radon-222 is estimated using the average radon-222 value at the background monitor and the 95th percentile background concentration for radium-226 in soil. As discussed in Section 5.9, using the monitoring data to estimate the radon-222 air concentration is 40 times more conservative

than the RAECOM-dose model used in the OU5 CRARE. Therefore, uncertainty in the estimation of radon-222 air concentrations has already been established by the present use of monitoring data, relative to the radon-flux model used in the CRARE.

In the Soil Screening Guidance: Technical Background Document (EPA, 1996), EPA presents a method to estimate the air concentration for many organic constituents using a volatilization factor (VF). Part 2 of the referenced guidance presents the appropriate equations and default values, while Part 5 tabulates the chemical specific parameters (at 25°C) used in the equations. The VF has units of m^3/kg, and the soil concentration of the organic constituent is divided by the VF to yield the air concentration [e.g., $(mg/kg)/(m^3/kg) = mg/m^3$]. Table 5.9 summarizes the VF for all organic constituents that could be calculated using the data tabulated in the guidance, and the corresponding air concentrations are three to five orders of magnitude greater than the concentrations calculated using particulate mass (baseline case). Organic compounds that are not present in Part 5 of the guidance, but are contaminants of concern for the risk calculation, include arolclor-1254, aroclor-1260, methyl-2-pentanone, and phenanthrene. These four compounds are assessed using the method discussed below for inorganic constituents.

The air concentration for inorganic elements was estimated in the same manner as the baseline approach (Section 4.3), except the particulate concentration was increased to the 2005 maximum value (110 $\mu g/m^3$) observed at the fenceline, which is approximately 4 times greater than the background particulate value (26 $\mu g/m^3$) used in the baseline cases. Therefore, the use of the maximum detected particulate concentration accounts for the generation of particulates during soil remediation activities. Use of the maximum particulate concentration resulted in an increase in the air concentration for inorganic elements and the four organic constituents noted above.

Air concentrations derived using the VF and the higher particulate concentration were entered into the inhalation pathway for the groundskeeper/sampler in Zone 5 (GS 3), which represents the maximally exposed individual in the highest risk zone of the site. Results in Table 5-8 show the HI and T-RB ILCR increase for the GS 3 case, due to the increase in contaminant air concentrations. Relative to the base case (GS Zone 5), the total HI increases from 1.06E-01 to 1.21E-01, and T-RB ILCR increases from 4.70E-05 to 5.17E-05. Although this scenario has significantly higher air concentrations, there is no significant increase in the risk for the inhalation pathway.

TABLE 5-9
Calculation of Volatilization Factor and Air Concentration for Organic Constituents

Compound	Soil Conc. (mg/kg)	Volatilization Factor[1] (m^3/kg)	Air Conc. (mg/m^3)
1,1,2-Trichloroethane	3.22E-04	7.59E+03	4.25E-08
1,1-Dichloroethylene	5.58E-04	1.47E+03	3.80E-07
1,2-dichloroethane	2.76E-04	4.93E+03	5.61E-08
Acetone	5.04E-03	1.26E+04	4.02E-07
Benzene	1.38E-04	2.78E+03	4.95E-08
Benzo(a)anthracene	8.60E-02	8.94E+06	9.62E-09
Benzo(a)pyrene	8.70E-02	2.37E+07	3.66E-09
Benzo(b)fluoranthene	1.37E-01	4.64E+06	2.95E-08
Benzo(k)fluoranthene	3.05E-02	3.90E+07	7.81E-10
Bromodichloromethane	1.15E-04	8.26E+03	1.40E-08
Carbon tetrachloride	1.36E-04	1.96E+03	6.91E-08
Chrysene	8.53E-02	2.73E+06	3.13E-08
Dibenzo(a,h)anthracene	1.52E-02	7.01E+07	2.18E-10
Dieldrin	5.46E-04	2.36E+06	2.32E-10
Ethylbenzene	1.38E-04	4.15E+03	3.31E-08
Indeno(1,2,3-cd)pyrene	5.65E-02	5.67E+07	9.97E-10
Methylene chloride	1.35E-03	2.43E+03	5.58E-07
Tetrachloroethylene	9.30E-04	3.19E+03	2.92E-07
Toluene	6.05E-04	3.55E+03	1.70E-07
Trichloroethylene	3.71E-04	2.60E+03	1.43E-07
Xylenes	1.32E-03	5.08E+03	2.60E-07

[1]Calculated using equations and default values in Section 2.4.2 and values presented in Tables 36, 37, 38 & 39 of Section 5, Soil Screening Guidance: Technical Background Document (EPA, 1996)

ATTACHMENT A

Summary of Page Changes for the
Interim Residual Risk Assessment Report
Revision 1, July 2007

Section	Change Page	Changes Inserted
Executive Summary	ES-2	Added text in 2nd paragraph to note that vapors from VOCs are part of the inhalation pathway.
Executive Summary	ES-3	No changes, but text from ES-2 was pushed to ES-3
Section 1.1	1-2	Noted that gas consists of VOCs and radon.
Section 3.0	3-1	Added text in 4th paragraph to note that vapors from VOCs are part of the inhalation pathway.
Section 3-1	3-2	Added text in 1st paragraph to note that vapors from VOCs are part of the inhalation pathway.
Section 3-1	3-3	Added text in 3rd paragraph to note that vapors from VOCs are part of the inhalation pathway.
Section 3-2	3-5	Added text in 1st paragraph to note that vapors from VOCs are part of the inhalation pathway.
Section 5-8	5-14	Added text in 2nd paragraph to note that the volatilization factor is calculated with chemical specific data tabulated at 25°C.
Section 5-8	5-14	Added text in 3rd paragraph to note that the maximum particulate concentration represents inhalation conditions during soil remediation activities.
Table 5-9	5-21	Added text to footnote to reference equations and default values in Section 2.4.2 and chemical specific values in Tables 36, 37, 38 & 39 of Section 5.0 of the Soil Screening Guidance: Technical Background Document (EPA 1996)

NOTE: Change pages are double sided.

EXECUTIVE SUMMARY

Results presented in this Interim Residual Risk Assessment (IRRA) Report show that the non-carcinogenic risk and carcinogenic risk to all evaluated site receptors are within the acceptable range discussed within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The CERCLA guidance considers acceptable risk to be less than one for the hazard index (HI) and less than 1.0E-04 for the incremental lifetime cancer risk (ILCR). This conclusion, along with the results in the soil certification reports, indicate that the remedial actions identified in the Operable Unit 5 Record of Decision were executed successfully and the soil on the Fernald Preserve has been restored to an acceptable risk level compatible with the final land use objective.

Remedial actions associated with the removal of the contaminated structures, soil, and waste materials at the former Feed Material Production Center (FMPC) are documented in the Records of Decision (RODs) for Operable Units 1, 2, 3, 4, and 5. The remedial actions were implemented under the Fernald Closure Project (FCP), and documentation of the completed remedial actions can be found in the Remedial Action Reports for Operable Units 1, 2, 3, 4, and 5.

Risk calculations in the Comprehensive Response Action Risk Evaluation (CRARE) for Operable Unit 5 were performed using *estimated* post-remediation contaminant concentrations in soil and surface-water media that reflected the preliminary remediation levels, which were based on the preliminary remediation goals developed from the Operable Unit 5 Baseline Risk Assessment. The IRRA evaluates the receptor risk due to exposure to *measured* post-remediation contaminant concentrations in the soil and surface water on the Fernald Preserve. In this context, the IRRA risk calculations reflect actual site conditions.

Target receptors in the CRARE were selected for the on-site undeveloped park and off-site farm land-use scenarios. The IRRA calculations deal only with the receptors for the on-site undeveloped park, as groundwater remediation is ongoing and the evaluation of the off-site farm scenario is dependent on the groundwater pathway for ingestion of water (humans and livestock) and irrigation of crops. Off-site receptors will be evaluated in a final risk assessment report that will be submitted after the Great Miami Aquifer has been restored to the final remediation levels listed in the Operable Unit 5 Record of Decision.

The IRRA calculations evaluated six human receptors in nine exposure zones. In line with the final land use of an undeveloped park, and the need for support staff to operate a museum, the converted waste-

water treatment (CWWT) plant and the On-site Disposal Facility (OSDF) valve houses, the receptors reflect visitors and workers who recreate and labor at the site. Receptors include the undeveloped park user (also evaluated in the CRARE), museum visitor, museum worker, groundskeeper/sampler, construction worker, and a building maintenance worker. The trespasser who wanders across the OSDF is not considered in this report, as this scenario of potential exposure is less conservative than the potential exposure received by the groundskeeper/sampler and building maintenance personnel who enter the OSDF zone to perform work. A receptor may spend as few as ten days a year at the site (museum visitor) or as many as 250 days a year (museum worker). The receptor exposure zones reflect soil footprints from historic operations at the site (e.g., production facilities, waste storage areas, etc) and a reasonably large area for the receptor to traverse when they visit and work at the site.

Reasonable maximum exposure (RME) scenarios were developed for the receptors to estimate the chemical and radionuclide intake via inhalation of particulate, vapors from volatile organic compounds (VOCs) and radon gas, incidental ingestion of soil and surface water, dermal contact with soil and surface water, and exposure to external radiation. Ninety-five contaminants were evaluated and a subset of chemicals and radionuclides was compiled for each exposure zone to derive input concentrations for the air, soil, and surface-water pathways. Cancer slope factors (CSFs) and reference doses (RfDs) for the contaminants were compiled from the Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS) and Health Effects Summary Tables (HEAST) and the Oak Ridge National Laboratory's (ORNL) Risk Assessment Information System (RAIS) web sites. The intake values, CSFs, and RfDs are used to calculate HI and ILCR.

Most of the risk to the receptors is driven by a small subset of chemicals and radionuclides. Arsenic, beryllium, uranium, aroclor-1254, aroclor-1260, uranium-238 and lead-210 are responsible for the majority of risk in the soil pathways. Benzo(a)pyrene and dibenzo(a,h)anthracene are key contaminants for the dermal surface-water pathway. Manganese and radon-222 contribute most of the risk to the inhalation pathway. After the radionuclide background is subtracted from the total risk, uranium-238 is the largest contributor to external radiation.

The highest carcinogenic risk occurs in Zone 5 (former production area) for the undeveloped park user (5.66E-05) and groundskeeper/sampler (4.70E-05), and it is driven primarily by dermal exposure to surface water containing benzo(a)pyrene and dibenzo(a,h)anthracene. However, the risk is largely an

artifact of using one-half of the analytical detection limit for these compounds, and this conservative assumption would be less conservative (i.e., lower risk values) if lower analytical detection limits had been obtained for the compounds. This statement is supported by an uncertainty analysis that concludes the greatest uncertainty in the risk calculations is knowing the true concentration of benzo(a)pyrene and dibenzo(a,h)anthracene in surface water.

One of the uncertainty scenarios used a 70-year exposure duration for the undeveloped park user and zero values for benzo(a)pyrene and dibenzo(a,h)anthracene in surface water to compare present risk results to CRARE results for the undeveloped park user. Carcinogenic risk for this uncertainty calculation was slightly higher than the CRARE result, and this is due to higher residual arsenic and beryllium concentrations in the soil, relative to the estimated concentrations used in the CRARE. This comparison between present and CRARE results indicates that remedial actions at the Fernald Preserve were successful in reducing radionuclide concentrations in soil to values below the estimates used in the CRARE, while some chemical concentrations (e.g., arsenic and beryllium) in soil are measured to be greater than those used in the CRARE. However, when all chemicals and radionuclides are summed across all pathways, the risk analysis presented here produces results of the same magnitude as the CRARE and, per CERCLA guidance, less than the upper bound of 1.0E-04.

1.0 INTRODUCTION

The Interim Residual Risk Assessment (IRRA) estimates the human-health risks associated with the post-remediation contaminants in the air, soil, and surface-water media at the former Fernald Feed Material Production Center (FMPC). Groundwater remediation is ongoing, and a final risk assessment will be performed when the groundwater restoration goals have been achieved for the Great Miami Aquifer. Contaminated structures, soil, and waste materials associated with the FMPC site were demolished and removed for disposal under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as documented in the Department of Energy's (DOE) Records of Decision (RODs) for Operable Units (OU) 1, 2, 3, 4, and 5 (DOE 1995a, 1995b, 1996a, 1996b, 2000, 2003) and the remedial action close-out reports (DOE 2006b, 2006c, 2006d, 2006e, 2006f). The remedial actions were implemented under the Fernald Closure Project (FCP), and the IRRA calculations document that the soil remedial actions at the Fernald site were adequate to reduce contaminant concentrations in soil and surface water to levels that are protective of human health and the environment.

CERCLA (a.k.a. superfund) requires that the actions selected to remedy hazardous waste sites be robust enough to reduce potential threats posed by the release of hazardous substance to the environment to limits that are protective of human health and the environment. Per the U.S. Environmental Protection Agency's (EPA) Risk Assessment Guidance for Superfund (RAGS, EPA 1989a), these criteria are evaluated with risk calculations to demonstrate that the risk to a receptor, defined as the "reasonable maximum exposure" (RME) individual, does not exceed an incremental lifetime cancer risk (ILCR) of 1 in 10,000 (1.0E-04) and a hazard index (HI) of greater than one.

A variety of on-property receptors were assessed using the approach and methodology in RAGS (Part A, EPA 1989a; Supplement to Part A, EPA 1991a; Part E, EPA 2004), the Exposure Factors Handbook (EFH, EPA 1997) and supplemental guidance (EPA 1991a), and site-specific data on air, soil, and surface-water concentrations. The off-property farm receptor will be evaluated for the groundwater and food pathways in the final risk assessment, which will be submitted to the regulatory agencies after the aquifer certification process has been approved by the EPA and OEPA.

For each on-site receptor, risk was calculated at three contaminant concentration levels: total risk with no background correction; radiological background subtracted from the total risk; and all background subtracted from the total risk. An uncertainty analysis was also performed to evaluate variation in risk due to different exposure zones, the exposure duration (exposure early in life versus late in life), modeled air concentrations versus measured air monitoring values, change in contaminant concentrations, and changes in cancer slope factors and reference doses. The tabulated calculations provide a useful comparison to the regulatory agencies and public on reasonable and background risk to the site visitors and workers.

1.1 OVERVIEW AND ORGANIZATION OF THE IRRA REPORT

The primary objective of the IRRA is to estimate the risk posed to on-site receptors by post-remediation (i.e., residual) contaminant concentrations in air, soil, and surface-water media within eight exposure zones that comprise the former FMPC site. Exposure pathways for the receptors include inhalation of gas (VOCs and radon) and particulate, dermal contact with soil and surface water, ingestion of soil and surface water, and external radiation. Receptors, exposure parameters, reference doses, and cancer slope factors have been updated relative to values presented in the Comprehensive Response Action Risk Evaluation (CRARE), which is Appendix H of the Operable Unit 5 Feasibility Study (OU5; DOE 1995d). Whereas this report evaluates the receptor risk due to exposure to *measured* post-remediation contaminant concentrations in air, soil, and surface water on the site, the CRARE evaluated risk using the OU5 Remedial Investigation (DOE 1995c) data set, background data (DOE 1994, 2001) and air models to *estimate* post-remediation contaminant concentrations in air, soil, and surface-water media. Target receptors in the CRARE were selected for the on-site undeveloped park and off-site farm land-use scenarios. The interim risk calculations presented in this report deal only with the receptors for the on-site undeveloped park, as groundwater remediation is ongoing and the evaluation of the off-site farm scenario is dependent on the groundwater pathway for ingestion of water by humans and livestock and irrigation of crops. Groundwater and food pathways for the off-site receptors will be covered when the final risk assessment report is submitted to the regulatory agencies.

3.0 SCENARIOS, LAND USE EXPOSURE PATHWAYS & RECEPTORS

In the OU 5 FS (DOE 1995d), DOE evaluated remedial actions, human and ecological risk, and cost to determine which of four land use objectives would be selected for the end state of the Fernald site. Collaboration with the regulatory agencies and public resulted in the selection of Land Use Objective 3 – Maximum Consolidation of Contaminated Material to Free the Majority of the Fernald Site for Restricted Land Use. Land Use Objective 3 called for off-site shipment and disposal of the highest risk waste streams (e.g., OU 1 waste pits, OU 4 silo materials, etc.), and on-site disposal of soil, waste, and building rubble, if the materials met the OSDF waste acceptance criteria. Three alternatives were evaluated for Land Use Objective 3: A) industrial park; B) developed recreational park; and C) undeveloped recreational park. Through the FS process, Alternative 3C was selected for OU 5.

The undeveloped park envisioned in the FS had no rest rooms or developed recreational facilities, with the exception of hiking trails. Since the OU 5 FS was published, the vision of the undeveloped park has changed to accommodate an on-site museum with rest rooms, a parking lot, and continued operation of the CWWT facility to support ongoing groundwater restoration activities. Therefore, the present land use scenario is the undeveloped park with some infrastructure development to support the museum and CWWT operations.

Slight changes to the undeveloped park scenario presented in the FS dictates that the IRRA must consider additional receptors to account for daily workers that support the museum and CWWT operations and the general public that visits the museum. Receptors for the IRRA will include the undeveloped park user presented in the OU 5 FS, as well as a museum visitor, museum worker, groundskeeper/sampler, building maintenance, and construction worker. Each of these receptors is discussed below with respect to exposure pathways and parameters.

Exposure pathways for receptors evaluated in the IRRA are similar to those presented in the OU 5 FS, and they consist of inhalation of radon gas, VOC vapors and soil particulate suspended by the wind, dermal contact with soil and surface water, incidental ingestion of soil and surface water, and exposure to external radiation. In contrast to the OU 5 CRARE exposure pathways, the groundwater, and food pathways will not be evaluated in the IRRA due to ongoing groundwater restoration activities. The groundwater and food pathways will be evaluated in a final risk assessment report that will be published after the groundwater has been certified as meeting the OU 5 ROD groundwater FRLs.

3.1 UNDEVELOPED PARK USER

This target receptor is the child, youth, adult, and/or senior adult that visits the park to hike, picnic, and observe birds. These individuals inhale air that contains radon, VOC vapors and soil particulate suspended by the wind, and they contact soil and surface water while hiking trails and sitting on the ground for a picnic. Contact with soil and surface water results in dermal exposure as well as incidental ingestion. The receptor is also exposed to external radiation from radioactive isotopes present in the environmental media. Exposure pathways and parameters are summarized in Table 3-1. The rationale and reference for each exposure parameter are discussed below:

- Exposure Frequency (EF): The number of days per year (d/yr) that a receptor visits the site is the EF. EF is assumed to be 20 d/yr, about every other week, for the child and adult. A higher frequency of 40 d/yr is assumed for the youth and senior adult to account for extra recreation time available to these age receptors. For example, the youth who can drive will be able to spend additional time at the park after school, relative to a working adult and young child.

- Exposure Duration (ED): The ED is the number of years over which an individual will visit the park. EPA (1989a) notes that national trends show individuals do not live in a region of the country for more than 30 years. Therefore, 30 years is used as the sum across the age groups, with the years partitioned into 3 years for child, 6 for youth, 14 for adult and 7 for senior adult. An ED of 70 years is evaluated in the uncertainty calculations presented in Section 5.0.

- Body Weight (BW): EPA (1997) has tabulated BW for individuals. The adult and senior adult are equated to the mean BW in EPA Table 7-11, which is rounded to 70 kg. An average of mean values reported for ages 7 to 18 (EPA Table 7-3) is rounded to 47 kg for the youth. The child mean values reported for ages 0 to 6 (EPA Table 7-3) are used to derive an average weight of 15 kg.

- Averaging Time for non-carcinogens (AT_{nc}): Averaging time refers to the number of days over which the toxin acts on the body. EPA (1989a) defines the averaging time for non-carcinogen chemicals as the exposure duration multiplied by 365 days/yr.

- Averaging Time for carcinogens (AT_c): For carcinogenic compounds and radioactive isotopes, EPA (1989a) assumes the carcinogen acts over a 70-yr lifetime for the individual. Therefore, averaging time (days) for carcinogens is 70 yrs multiplied by 365 days/yr.

- Inhalation Rate (IhR): The volume of air which an individual breathes each hour is the IhR. EPA (1997) reports the same value (1.0 m^3/hr) for the child and adult receptors for short-term exposure and light activities (EPA Table 5-23). Therefore, this value is used for all age groups. Short-term exposure and light activities are applicable to a park visitor that spends an hour or two hiking trails and watching birds.

- Exposure Time (ET) for Air: The amount of time the receptor spends at the park each visit is the ET. As the park is undeveloped, the assumption is made that the receptor will spend a fraction of a normal day (two hours) inhaling dust, VOC vapors and radon gas on each day they visit the undeveloped park.

- Ingestion Rate (IR) for Soil: The mass of soil that is ingested incidentally each day is the IR. EPA (1989b & 1997) estimates that a residential child will ingest 0.2 g/d, which is lowered to 0.1 g/d for the adult. The IR for the youth and senior adult is assumed to be similar to the adult.

- Fraction of Ingested Soil that is Contaminated (FI): In some risk exposure scenarios, a receptor may pass in and out of contaminated soil zones, and only a fraction of the ingested soil will contain contaminants. For the IRRA, the receptor is assumed to spend 100 percent of their park time in a contamination zone, and FI is set equal to 1.0.

- Surface Area (SA), Dermal Contact with Soil: The skin SA exposed to soil is assumed to be the head, hands, forearms, feet, and lower legs. All SA values for body parts are obtained from EPA (2004, Exhibit C-1), and the sum for these body parts appears in Table 3-1.

- Adherence Factor (AF): The AF for soil to skin is taken from EPA (2004). For a residential scenario, the AF value is 0.2 for child and youth, and 0.07 for adult and senior.

- Shielding Factor (SH): The SH accounts for material between the receptor and radiation source that can attenuate the external radiation received by an individual. For outdoor conditions on the site, the SH is taken as 0.25 to account for substantial surface-water coverage (water shields radiation emitted from the soil below the water) and the placement of clean mulch over the remedial footprint (the mulch is worked into the remedial footprint, which dilutes the soil concentration and provides some shielding from radiation emitted by nuclides on the soil particles).

- Ingestion Rate (IR) for Surface Water: The 1997 EPA Exposure Factors Handbook does not contain guidance on the surface-water pathway. An older version of the handbook (EPA 1989b) assigned 0.05 liter per hour (L/hr) for an adult swimmer. Although swimming in the ponds on site is not allowed, this ingestion rate will be used for the child, youth, adult and senior to cover the conservative case where splashing results in a similar ingestion rate.

- Exposure Time (ET) for Surface Water: As swimming is not allowed in the ponds on the site, contact with water will be a transient activity of short duration. It is assumed that the receptor will spend one hour wading and splashing on each summer day spent at the undeveloped park.

- Exposure Frequency (EF) for Surface Water: It is assumed that wading in the surface water, which is not permitted, will take place only during the summer months. Therefore, all receptors spend one day each weekend of the 12 summer weeks (12 d/yr) contacting the water.

- Surface Area (SA), Dermal Contact with Surface Water: The skin SA exposed to soil is assumed to be the face, hands, forearms, feet and lower legs. All SA values for body parts are obtained from EPA (2004, Exhibit C-1), and the sum for these body parts appears in Table 3-1.

- Dose Absorbed (DA) per Event, Dermal Contact with Surface Water: This is a chemical specific value that is calculated from the permeability constant and chemical concentration in the water. All constants and chemical concentrations used in this calculation are tabulated in Appendix E.

3.2 MUSEUM VISITOR

This target receptor is the child, youth, adult, and/or senior adult that visits the museum and participates in an occasional field trip run by the museum. Although these individuals spend most of their time in the museum, they will inhale air that contains radon, VOC vapors and soil particulate when they walk from the parking lot to the museum and when they participate in field trips. The receptor may contact soil and surface water when they participate in a museum field trip or if they wander through the grounds between the parking lot and museum. Contact with soil and surface water results in dermal exposure as well as incidental ingestion. The receptor is also exposed to external radiation from radioactive isotopes present in the environmental media. Exposure pathways and parameters are summarized in Table 3-2. The rationale and reference for each exposure parameter are discussed below:

- Exposure Frequency (EF): The number of days per year (d/yr) that a receptor visits the museum is the EF. EF is assumed to be 10 d/yr for the child, youth, and adult. A higher frequency of 20 d/yr is assumed for the senior adult to account for extra recreation time available to this age receptor.

- Exposure Duration (ED): The ED is the number of years over which an individual will visit the park. EPA (1989a) notes that national trends show individuals do not live in a region of the country for more than 30 years. Therefore, 30 years is used as the sum across the age groups, with the years partitioned into 3 years for child, 6 for youth, 14 for adult and 7 for senior adult.

- Body Weight (BW): EPA (1997) has tabulated BW for individuals. The adult and senior adult are equated to the mean BW in EPA Table 7-11, which is rounded to 70 kg. An average of mean values reported for ages 7 to 18 (EPA Table 7-3) is rounded to 47 kg for the youth. The child mean values reported for ages 0 to 6 (EPA Table 7-3) are used to derive an average weight of 15 kg.

- Averaging Time for non-carcinogens (AT_{nc}): Averaging time refers to the number of days over which the toxin acts on the body. EPA (1989a) defines the averaging time for non-carcinogen chemicals as the exposure duration multiplied by 365 days/yr.

- Averaging Time for carcinogens (AT_c): For carcinogenic compounds and radioactive isotopes, EPA (1989a) assumes the carcinogen acts over a 70-yr lifetime for the individual. Therefore, averaging time (days) for carcinogens is 70 yrs multiplied by 365 days/yr.

- Inhalation Rate (IhR): The volume of air which an individual breathes each hour is the IhR. EPA (1997) reports the same value (1.0 m^3/hr) for the child and adult receptors for short-term exposure and light activities (EPA Table 5-23). Therefore, this value is used for all age groups. Short-term exposure and light activities are applicable to a museum visitor that spends an hour or two in the museum.

- Exposure Time (ET) for Air: The amount of time the receptor spends outdoors on each visit to the museum is assumed to be one-half hour per each day they visit the museum. This time is allocated to walking between the parking lot and museum and participating in an occasional field trip.

- Ingestion Rate (IR) for Soil: The mass of soil that is ingested incidentally each day is the IR. EPA (1989b & 1997) estimates that a residential child will ingest 0.2 g/d, which is lowered to 0.1 g/d for the adult. However, there is very little time spent outdoors for the museum visitor, and the rate is decreased to 0.1 g/d for child, 0.075 g/d for youth and 0.05 g/d for the adult and senior adult.

- Fraction of Ingested Soil that is Contaminated (FI): In some risk exposure scenarios, a receptor may pass in and out of contaminated soil zones, and only a fraction of the ingested soil will contain contaminants. For the IRRA, the receptor is assumed to spend 100 percent of their outdoor time in a contamination zone, and FI is set equal to 1.0.

- Surface Area (SA), Dermal Contact with Soil: The skin SA exposed to soil is assumed to be the head, hands, forearms and lower legs. Feet are not included because museum visitors will be wearing foot gear. All SA values for body parts are obtained from EPA (2004, Exhibit C-1), and the sum for these body parts appears in Table 3-2.

dibenzo(a,h)anthracene, is too conservative when long exposure durations are considered, and only true detections should be used in risk calculations. Therefore, benzo(a)pyrene and dibenzo(a,h)anthracene should be retained as contaminants of concern for future sampling of the surface water in Zones 5 and 6, and the lowest achievable detection limits should be requested when the samples are sent to the analytical laboratory.

The maximum uranium concentration in surface water was entered into the risk calculation for GS 1 (double the exposure duration and undetected organic concentrations are set at one-half the detection limit value). Results for GS 2 show the HI increased by 0.6E-01 and the T-RB ILCR increased by a factor of 0.06E-05, relative to the GS 1 case, but the HI and T-RB ILCR values remain below the acceptable levels of less than one and less than 1.0E-04, respectively. Therefore, the present maximum uranium surface-water concentration of 1.88 mg/L does not present a significant increase in risk to the groundskeeper/sampler. However, the source for this elevated uranium concentration (ponds west of former Waste Pit 3) should be sampled during future monitoring activities to ensure that the uranium concentrations does not rise to a level that would create an unacceptable risk for a site receptor.

As noted above using one-half the detection limit value for benzo(a)pyrene and dibenzo(a,h)anthracene results in a high uncertainty to the calculated risk to the receptors, whereas increasing the uranium surface-water concentration to the maximum observed value presents no significant increase in the overall risk to the adult receptors. However, in Appendix E.10 the detailed calculations for UPU 1 and UPU 3 show that the child sub-receptor for the undeveloped park user does experience a significant increase in the HQ from exposure to the maximum uranium concentration in surface water (uranium HQ of 3.90E-03 for UPU 1 increases to 3.43E-01 for UPU 3). Although there is a significant increase in the exposure to chemical toxins for the child sub-receptor, the overall HI for all chemicals remains below the acceptable limit of one.

Variation in Air Concentrations

As noted in Section 4.3, the baseline case for the inhalation of particulate and gases uses the average particulate value for the background monitoring location to estimate the air concentrations for all constituents, except radon. Radon-222 is estimated using the average radon-222 value at the background monitor and the 95th percentile background concentration for radium-226 in soil. As discussed in Section 5.9, using the monitoring data to estimate the radon-222 air concentration is 40 times more conservative

than the RAECOM-dose model used in the OU5 CRARE. Therefore, uncertainty in the estimation of radon-222 air concentrations has already been established by the present use of monitoring data, relative to the radon-flux model used in the CRARE.

In the Soil Screening Guidance: Technical Background Document (EPA, 1996), EPA presents a method to estimate the air concentration for many organic constituents using a volatilization factor (VF). Part 2 of the referenced guidance presents the appropriate equations and default values, while Part 5 tabulates the chemical specific parameters (at 25°C) used in the equations. The VF has units of m^3/kg, and the soil concentration of the organic constituent is divided by the VF to yield the air concentration [e.g., $(mg/kg)/(m^3/kg) = mg/m^3$]: Table 5.9 summarizes the VF for all organic constituents that could be calculated using the data tabulated in the guidance, and the corresponding air concentrations are three to five orders of magnitude greater than the concentrations calculated using particulate mass (baseline case). Organic compounds that are not present in Part 5 of the guidance, but are contaminants of concern for the risk calculation, include arolclor-1254, aroclor-1260, methyl-2-pentanone, and phenanthrene. These four compounds are assessed using the method discussed below for inorganic constituents.

The air concentration for inorganic elements was estimated in the same manner as the baseline approach (Section 4.3), except the particulate concentration was increased to the 2005 maximum value (110 $\mu g/m^3$) observed at the fenceline, which is approximately 4 times greater than the background particulate value (26 $\mu g/m^3$) used in the baseline cases. Therefore, the use of the maximum detected particulate concentration accounts for the generation of particulates during soil remediation activities. Use of the maximum particulate concentration resulted in an increase in the air concentration for inorganic elements and the four organic constituents noted above.

Air concentrations derived using the VF and the higher particulate concentration were entered into the inhalation pathway for the groundskeeper/sampler in Zone 5 (GS 3), which represents the maximally exposed individual in the highest risk zone of the site. Results in Table 5-8 show the HI and T-RB ILCR increase for the GS 3 case, due to the increase in contaminant air concentrations. Relative to the base case (GS Zone 5), the total HI increases from 1.06E-01 to 1.21E-01, and T-RB ILCR increases from 4.70E-05 to 5.17E-05. Although this scenario has significantly higher air concentrations, there is no significant increase in the risk for the inhalation pathway.

TABLE 5-9
Calculation of Volatilization Factor and Air Concentration for Organic Constituents

Compound	Soil Conc. (mg/kg)	Volatilization Factor[1] (m^3/kg)	Air Conc. (mg/m^3)
1,1,2-Trichloroethane	3.22E-04	7.59E+03	4.25E-08
1,1-Dichloroethylene	5.58E-04	1.47E+03	3.80E-07
1,2-dichloroethane	2.76E-04	4.93E+03	5.61E-08
Acetone	5.04E-03	1.26E+04	4.02E-07
Benzene	1.38E-04	2.78E+03	4.95E-08
Benzo(a)anthracene	8.60E-02	8.94E+06	9.62E-09
Benzo(a)pyrene	8.70E-02	2.37E+07	3.66E-09
Benzo(b)fluoranthene	1.37E-01	4.64E+06	2.95E-08
Benzo(k)fluoranthene	3.05E-02	3.90E+07	7.81E-10
Bromodichloromethane	1.15E-04	8.26E+03	1.40E-08
Carbon tetrachloride	1.36E-04	1.96E+03	6.91E-08
Chrysene	8.53E-02	2.73E+06	3.13E-08
Dibenzo(a,h)anthracene	1.52E-02	7.01E+07	2.18E-10
Dieldrin	5.46E-04	2.36E+06	2.32E-10
Ethylbenzene	1.38E-04	4.15E+03	3.31E-08
Indeno(1,2,3-cd)pyrene	5.65E-02	5.67E+07	9.97E-10
Methylene chloride	1.35E-03	2.43E+03	5.58E-07
Tetrachloroethylene	9.30E-04	3.19E+03	2.92E-07
Toluene	6.05E-04	3.55E+03	1.70E-07
Trichloroethylene	3.71E-04	2.60E+03	1.43E-07
Xylenes	1.32E-03	5.08E+03	2.60E-07

[1]Calculated using equations and default values in Section 2.4.2 and values presented in Tables 36, 37, 38 & 39 of Section 5, Soil Screening Guidance: Technical Background Document (EPA, 1996)