5899 U-003-304 .21

REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT 1, VOLUME 5, APPENDIX D AND APPENDIX E - FINAL AUGUST 1994

08/01/94

DOE-FN 899 REPORT

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REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT 1

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 5
APPENDICES D AND E

AUGUST 1994

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

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D.1.0 GEOCHEMICAL ANALYSIS

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D.1.1 INTRODUCTION

The geochemical analysis was performed for source term and initial concentration development for the vadose zone and groundwater models. Analytical data for the Operable Unit 1 waste areas were compiled and screened to identify those potential constituents of concern based on the requirements of the Operable Unit 1 Baseline Risk Assessment (Appendix E). The Operable Unit 1 waste areas consist of Waste Pits 1 through 6, the Burn Pit, and the Clearwell. Potential constituents of concern for Operable Unit 1 (as defined in Appendix E) are listed in Table D.1-1.

This section:

- Provides a summary of the site-specific data of interest to the geochemical analysis.
- Presents a conceptual model illustrating the formation of leachate and its migration into the groundwater.
- Outlines the geochemical assessment and modeling conducted to estimate contaminant concentrations in Leachates A and B for inorganics and radionuclides and in the organic leachate.
- Describes the EQ3/6 geochemical code used to perform mineral solubility calculations on Leachates A and B.
- Presents model results and other calculations.
- Summarizes the model uncertainty including the limitations and assumptions required for estimating leachate contaminant concentrations.

D.1.2 SITE-SPECIFIC DATA

Validated data used for deriving leachate concentrations from the waste areas were available from several sources:

- Characterization Investigation Study (CIS) Pit Material - Chemical and Radiological
- CIS Surface Water - Chemical

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- Remedial Investigation/Feasibility Study (RI/FS) Pit Leachate - Chemical and Radiological
- RI/FS Pit Material - Chemical and Radiological
- Toxicity Characteristic Leaching Procedure (TCLP) - Chemical and Radiological

These data sets are contained in Appendices A and C. The RI/FS pit leachate data sets are the most complete although pH, actinium, polonium, and protactinium are missing. TCLP extract was analyzed for 23 metals and the radionuclides cesium-237, radium-226, radium-228, thorium-228, thorium-230, strontium-90, thorium-232, uranium-234, uranium-235/236, and uranium-238. There are no general chemistry data for the TCLP data set. Limitations associated with the missing data are outlined when model results are discussed (Appendix E.2). Leachate data sets can be found in Section 4.0.

Tabulated results of waste area constituents based on direct sampling of the waste area sludges and their corresponding contaminant inventory are presented in Tables D.1-2 through D.1-9. To derive the contaminant inventory for each potential constituent of concern for each waste area, the maximum upper confidence limit concentration from the CIS or RI/FS Pit Material data sets for each potential constituent of concern was multiplied by the waste volume and dry density for that waste area (See Section D.3.0 for waste volume and dry density information).

D.1.3 DEVELOPMENT OF THE CONCEPTUAL MODEL

In the geochemical assessment of leachate formation, the events leading to the failure of the waste pits and exposure of the waste to precipitation are not considered. It is assumed that such failure does occur, and the waste is available for chemical reactions with falling precipitation followed by migration of leachate into underlying glacial deposits where further reactions take place. The conceptual scenario used to model the release of contaminants from Operable Unit 1 waste pits is illustrated in Figure D.1-1. For inorganics and radionuclides, rainwater infiltrates the waste pits and reacts with inorganic waste solids to form a waste leachate, referred to as Leachate A. Subsequently, Leachate A migrates into the underlying glacial overburden, if present, and reacts with the naturally occurring minerals to form a modified leachate, referred to as Leachate B. Leachate B is used to constrain the initial contaminant concentrations for the groundwater fate and transport model (vadose zone model

in Section D.3.6). For organic constituents, a leachate concentration is derived from reaction of rainwater with solids. This leachate concentration is assumed to be unchanged by reaction with the glacial overburden materials.

As long as Leachate A remains in contact with the solid waste phases, the solution will retain its high pH property. However, when Leachate A migrates into the underlying glacial overburden, which is dominated by carbonate minerals, the solution chemistry of Leachate A will change to reflect the physical and chemical conditions of its new surrounding. Perched groundwater in the glacial overburden contains abundant bicarbonate ion (350 to 500 mg/L; [Table 15-1 DOE 1990b]), and it is expected that pore water will have a chemical composition similar to the perched groundwater. As Leachate A migrates into the glacial overburden it will mix with pore water, resulting in a pH decrease and possible mineral precipitation (e.g., $Ca^{+2} + OH^- + HCO_3^- <-> CaCO_3 + H_2O$). In this reaction, calcium and hydroxide ions provided by Leachate A are free to react with bicarbonate ion in the pore water to form calcite and water. Such a reaction is likely because the perched groundwater, and by inference the pore water, is calculated to be saturated with respect to calcite. This type of reaction, and many others, will modify Leachate A as it migrates into the glacial overburden, and this modified leachate is referred to as Leachate B. Therefore, the conceptual model is set up to account for the distinct chemical reactions that occur in the different environments.

Minerals in the glacial overburden underlying the waste units have been characterized (Solebello 1991). The minerals were titrated into a rainwater solution at various rates to simulate the development of groundwater collected from the glacial overburden. When results for major constituents in the modeled groundwater agreed with the range of values reported for groundwater collected from the glacial overburden, the corresponding mineral titration rates that produced the simulated groundwater were fixed for subsequent model runs involving Leachate A and glacial overburden minerals.

D.1.4 ESTIMATION OF LEACHATE CONCENTRATIONS

To estimate source terms for the Operable Unit 1 Study Area, the approach for estimating leachate concentrations for the inorganics and radionuclides was separated from the organics. Geochemical data collected for the Operable Unit 1 Study Area were assessed in conjunction with mineral solubility calculations to estimate contaminant concentrations in leachate at the

base of each Operable Unit 1 waste unit (Leachate A in Figure D.1-1) and in modified leachate within the glacial overburden (Leachate B in Figure D.1-1). All contaminant concentrations used as input data in the fate and transport model are constrained by in situ leachate analyses, surface water analyses, TCLP data, mineral solubility calculations, or the EPA 70-year rule (EPA 1988). Figure D.1-2 summarizes the approach for estimating leachate compositions for radionuclides and inorganics and Figure D.1-3 summarizes the approach for estimating leachate compositions for organics. The relative ranking of these constraints and their use to estimate leachate concentrations are summarized in Figures D.1-2 and D.1-3. Results derived from the geochemical assessment and modeling (Tables D.1-10 through D.1-25) are used as initial contaminant concentrations in the vadose zone fate and transport model to predict contaminant concentrations at the top of the Great Miami Aquifer.

D.1.4.1 Methodology for Inorganics and Radionuclides

As shown in Figure D.1-2, the preferred data for estimating contaminant concentrations in Leachate A are analyses of in situ leachate. When these data are unavailable, an approach of using the best available data, the surface water or TCLP data, is followed. If in situ leachate or surface water analyses indicated that the compound was not detected and it was detected in the pit material for the subject waste area, then the concentration of the particular potential constituent of concern was conservatively estimated as the maximum detection limit value. TCLP data are screened to determine if the use of a contaminant concentration determined by the TCLP test would result in depletion of the contaminant inventory in less than 70 years. If the use of the TCLP concentration does not deplete the contaminant inventory in less than 70 years it is used to estimate Leachate A, but if its use depletes the inventory in less than 70 years it is discarded and the contaminant concentration moves to the next level of the hierarchy, mineral solubility calculations. Mineral solubility calculations are carried out for contaminants that lack in situ and TCLP data, or for contaminants which fail the TCLP screening. Inorganic and radionuclide contaminants that lack in situ and TCLP data and cannot be constrained by mineral solubility calculations are passed along to the 70-year rule calculation to estimate their Leachate A calculation. After all contaminant concentrations in Leachate A are constrained, a computer simulation reacts Leachate A with the glacial overburden minerals to produce Leachate B.

The logic behind using this decision hierarchy is to apply the best available site-specific data to the estimation of leachate compositions. Each successively lower step on this hierarchy

represents a more conservative method for estimating contaminant concentrations in leachate. For example, using TCLP when in situ or surface water data are unavailable results in estimating a leachate composition derived by leaching with acid rather than rain water. The acetic acid leaching results in greater concentrations for many metals in leachate because acetic acid degrades into the acetate ion, which is effective at complexing metals.

Contaminant concentrations in Leachate B are used as initial input concentrations in the vadose zone fate and transport model. If a lower contaminant solubility limit was not reached during the reaction of Leachate A with pore water (perched groundwater) or with glacial overburden minerals, contaminant concentrations in Leachate A and B are identical.

In modeling the conceptual scenario, Leachate A was constrained by in situ leachate or surface water analyses, TCLP data, and the 70 year rule prior to reacting Leachate A with glacial overburden or pore water. Leachate A exits at the base of Operable Unit 1 study area and migrates downward through the glacial overburden underlying the waste pits, where it is assumed to equilibrate with the minerals in the glacial overburden instantaneously. This assumption is a requirement of the mathematical model because of the lack of kinetic data on the dissolution and precipitation rates of minerals in the glacial overburden. Leachate A is free to react with minerals in the glacial overburden to form Leachate B, and the concentration of contaminants in the leachate may be lowered by precipitation of solids. Leachate B is used to estimate the initial contaminant concentrations for the vadose zone model.

In accordance with the conceptual scenario stated above, contaminant concentrations reported for Leachate B will be lower than those for Leachate A when dissolution/precipitation reactions between Leachate A and glacial overburden minerals result in a pH for Leachate B that corresponds to a solubility minimum for the mineral controlling the contaminant of concern. For example, beryllium oxide (BeO) is more soluble at pH values greater than 9 than those less than 9. Therefore, beryllium concentrations in Leachate A will be greater than those in Leachate B when pH values in Leachate A are greater than 9 and in Leachate B less than 9. Conversely, contaminants in Leachate A that are controlled by in situ leachate analyses or TCLP values cannot increase their concentration in Leachate B by reaction with glacial overburden minerals, because waste elements are assumed to be absent in the glacial

overburden. Therefore, contaminant concentrations in Leachate A are estimates of maximum values, and these values may only be lowered by reaction with glacial overburden minerals.

Leachate A is modified by dissolution of minerals in the glacial overburden or by mixing with pore water (perched groundwater) and precipitation of secondary mineral phases. Secondary minerals represent phases that are stable in the presence of Leachate A and glacial overburden, but may not be present in the glacial overburden initially. When the reactions between Leachate A and glacial overburden minerals achieve thermodynamic equilibrium, the modified leachate is referred to as Leachate B.

In Situ Leachate

In situ leachate reflects the complex interactions that take place between the waste solids and contact solution at the waste environment. Duplicating these conditions in laboratory tests is difficult and time consuming. The method describing the sampling and testing procedure can be found in the sampling and analysis plan (DOE 1992).

Toxicity Characteristic Leaching Procedure

When in situ leachate or surface water data are unavailable, available TCLP data are used to constrain the contaminant concentrations in Leachate A. TCLP data are derived by leaching the waste with acetic acid. The use of acetic acid as the leachant (rather than rainwater which acts as the leachant for in situ leachate) results in estimates of contaminant concentrations that may be too high. That is, a conservative uncertainty is likely to be introduced into the estimation of leachate compositions. This occurs because acetic acid degrades into the acetate ion, which is very effective at complexing heavy metals in solution and maintaining their concentrations above expected solubility levels.

Geochemical Modeling

For inorganics and radionuclides, mineral solubility calculations can be performed to estimate the concentration of constituents in Leachate A when in situ, surface water, or when TCLP data are unavailable or inappropriate. The concept of mineral solubility may be illustrated by placing the mineral cerussite ($PbCO_3$) into distilled water at 25 degrees C and a pressure of 1 atmosphere. Under these conditions, the equilibrium lead concentration in solution is 1.1 mg/L, which is referred to as the solubility limit for lead in distilled water contacting cerussite at 25 degrees C and 1 atmosphere.

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Mineral solubility calculations were performed to estimate leachate compositions using the EQ3/6 computer code and thermodynamic data on mineral solubilities. The calculation of contaminant concentrations from mineral solubility data was restricted to inorganic chemicals and radionuclides, as thermodynamic data for organic constituents are unavailable.

After all constituent concentrations in Leachate A have been constrained for inorganics and radionuclides, the second reaction step is modeled to estimate the constituent concentrations in Leachate B. Reactions between Leachate A and pore water and/or minerals in the glacial overburden can result in changes in solution pH and major-ion concentrations with concomitant mineral precipitation. These reactions may be favorable for lowering contaminant concentrations in Leachate A. The modeling of Leachate B accounts for this type of scenario. Therefore, if a contaminant concentration is lowered by chemical reactions in the glacial overburden, or with pore water, the lower concentration is used to estimate the composition of Leachate B. If a contaminant concentration is unaffected by chemical reactions in the glacial overburden, its Leachate B concentration is assumed to be identical to Leachate A. This last assumption results in a Leachate B concentration on the high side because dilution of Leachate A and adsorption of constituents of concern are not considered in the geochemical model (dilution and adsorption are considered in the fate and transport model).

Mineral solubility calculations can also be carried out using Leachate A and minerals present in the glacial overburden to derive Leachate B compositions. When mineral solubility calculations are performed, in situ leachate acts as the leachant and it is assumed to equilibrate with glacial till minerals or pore water instantaneously. This assumption is a requirement of the mathematical model because kinetic data on minerals are unavailable to assess the time needed for dissolution of mineral phases to occur. As the leachant approaches thermodynamic equilibrium with the till minerals or pore water, minerals dissolve to increase the solute mass (i.e., total dissolved solids [TDS] increases) and minerals that become saturated are allowed to precipitate. These reactions continue until the leachate reaches thermodynamic equilibrium with the till minerals or pore water (i.e., constituents in the leachate reach a steady-state concentration), at which point it is referred to as Leachate B.

Because the mineral solubility calculations to derive Leachate A require knowledge of the minerals present in the waste, and this knowledge is unavailable; therefore, no mineral

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solubility calculations were carried out for Leachate A. Therefore, none of the contaminant concentrations in Leachate A are constrained by mineral solubility calculations.

EPA 70-Year Rule

When in situ and TCLP data are lacking and mineral solubility calculations fail to constrain a contaminant concentration in Leachate A, the EPA 70-year rule is the suggested guidance for estimating leachate compositions (EPA 1988). The 70-year method is based on the assumption that the contaminant inventory will be depleted within this time period, which is assumed to equal the average lifetime of a human being.

D.1.4.2 Methodology for Organic Compounds

Figure D.1-3 illustrates the approach for estimating the leachate concentrations for organic compounds used in the vadose zone models. Each successively lower step in this hierarchy represents a more conservative method for estimating the contaminant concentrations in the organic leachate. In situ leachate analyses values were the preferred leachate information. As shown on the diagram, only one organic leachate concentration is derived for each organic compound. When in situ leachate analyses data were not available and CIS surface water analyses data were available, these values were used. If the analyses for either in situ leachate or CIS surface water analyses indicated the compound was not detected and it was detected in the pit material for the subject waste area, the concentration for a particular potential constituent of concern was conservatively estimated as the maximum detection limit value. When in situ leachate and CIS surface water analyses data were not available and TCLP data were available, these values were used if the contaminant inventory in the source volume is depleted in greater than 70 years. If the depleted time is less than 70 years, then the EPA 70-year rule is used to calculate the leachate concentrations.

Specific details for the use of TCLP and EPA 70-year rule as constraints in developing the organic leachate compositions are similar to those described in Section D.1.4.1 for Leachates A and B for inorganics and radionuclides and are not described in this section.

D.1.4.3 Estimation of Inorganic and Radionuclide Concentrations

Leachate A and B results are summarized in Tables D.1-10 through D.1-17. The estimation of the Leachates A and B for Operable Unit 1 waste areas is described below.

Leachate A

Leachate A was constrained by in situ or surface water analyses (or the maximum detection limit if no analysis for the particular element or constituent was above the detection limit), TCLP data, or the EPA's 70-year rule. Leachate B is the same as Leachate A for the wet pits (Waste Pits 5 and 6, and the Clearwell) because of the lack of general chemistry data and incomplete chemical analyses of solid waste materials; therefore, no geochemical modeling of leachates was performed for Waste Pits 5 and 6 and the Clearwell. For Waste Pits 1, 2, and 3, Leachate B was calculated by reaction with the glacial overburden (till) minerals according to the decision hierarchy (Figure D.1-2). For Waste Pit 4 and the Burn Pit, Leachate B was modeled by mixing (or titrating) Leachate A into a perched groundwater sample from well 1027 using mean values (bicarbonate was modeled by equilibrium with calcite) (Appendix C-4, February 1993 Operable Unit 1 Report). The minimum ratio of perched groundwater to Leachate A is 10:1. Usually a higher mixing ratio was sufficient to saturate the solution in those phases that would solubility limit Leachate B concentrations (e.g., barite, bromellite, calomel, silver metal, thorianite, etc.). The logic for using a glacial overburden pore water (perched groundwater) is that the interstitial aqueous fluids have had time to equilibrate with the glacial materials and thus there is no need to react till minerals with Leachate A. However, for Waste Pits 1, 2, and 3, the perched groundwater sand lens is not present due to excavation, and Leachate B must be determined by geochemically modeling the reaction of Leachate A with till minerals.

Leachate B

After contaminant concentrations in Leachate A are estimated, the EQ3/6 geochemical code was utilized to obtain an estimate of Leachate B by simulating reactions between Leachate A and minerals in the glacial overburden or by mixing with perched groundwater (assumed pore water in glacial overburden). During this simulation, several mineral solubility limits were reached, and many contaminants have their concentration in Leachate B constrained by mineral solubility (Tables D.1-10 through D.1-17). More soluble elements, such as antimony, arsenic, boron, cadmium, cobalt, copper, cyanide, molybdenum, nickel, selenium, tin, and vanadium were not included in any geochemical modeling. Uranium was also not included in modeling because of its complexing with tributyl phosphate, which makes it more soluble than the model that does not include this organic contaminant. Seventy-year rule calculations were carried out in the wet pits (Waste Pits 5 and 6, and the Clearwell) for molybdenum (Waste Pit 5 and the Clearwell), radium-226 (Waste Pit 5), neptunium-237

(Clearwell) and tin (Waste Pits 5 and 6, and the Clearwell) and for benzo(ghi)fluoranthene in Waste Pit 2 using inventory data presented in Appendix A.

Results for Leachates A and B are summarized in Tables D.1-10 through D.1-17, and are discussed in Section D.1.5. These tables contain results for potential constituents of concern only, although major leachate constituents (anions and cations, e.g., Ca^{2+}, SO_4^{2-}, etc.) were modeled also.

D.1.4.4 Estimation of Organic Leachate

Organic leachate results are summarized in Tables D.1-18 through D.1-25. The estimation of the organic leachate for Operable Unit 1 waste areas is described below.

The organic leachate was constrained by in situ leachate for Waste Pits 1, 2, 3, and 4 and the Burn Pit. Surface water analyses were available for Waste Pits 5 and 6, and the Clearwell, and these were used to estimate in situ leachate compositions for several contaminants. TCLP data were not used to constrain any organic leachate concentrations. The 70-year Rule calculations were carried out for several organic constituents in Waste Pits 2 and 3, and the Clearwell.

D.1.4.5 Summary

In summary, site-specific data are used to estimate Leachate A and organic leachate compositions when they are available and appropriate. Leachate compositions are generally estimated using a combination of in situ, surface water, and TCLP data. Constraining leachate compositions with in situ leachate, TCLP data, and the surface water data provides the most defensible estimates of contaminant concentrations in leachate by using available site-specific data on Operable Unit 1 waste. For inorganics and radionuclides, Leachate A is reacted with minerals in the glacial overburden or by mixing with perched groundwater (pore water) to take credit for chemical reactions that will lower some constituents of concern. The modification of Leachate A by these reactions produces Leachate B. Contaminant concentrations in Leachate B and the organic leachate are used as the initial contaminant concentrations in the groundwater fate and transport model.

D.1.5 DISCUSSION OF RESULTS AND OBSERVED DATA

Results of the geochemical assessment for the Operable Unit 1 waste pits are given in Tables D.1-10 through D.1-25. Leachates A and B for inorganics and radionuclides and the organic leachate concentrations were developed using the approach outlined in Figures D.1-2 and D.1-3.

D.1.5.1 Leachate A and B for Inorganics and Radionuclides

While the entire list of potential inorganic and radionuclide constituents of concern as defined in Table D.1-1 are shown on Tables D.1-10 through D.1-17, leachate concentrations are provided only for those constituents detected in the pit materials for the subject waste area.

For Waste Pit 1 (Table D.1-10), in situ leachate analyses are available for ammonia, antimony, arsenic, barium, beryllium, boron, cadmium, cesium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, molybdenum, nickel, radium, silver, strontium, thorium, uranium, vanadium, and zinc. Only the technetium concentration is constrained by TCLP data. After reacting Leachate A with glacial overburden minerals using EQ3/6, results for Leachate B indicate that beryllium, chromium, manganese, mercury, strontium, thorium, and zinc concentrations have been lowered by mineral solubility. The remaining contaminant concentrations in Leachate B are identical to Leachate A.

Leachate A results for Waste Pit 2 (Table D.1-11) show ammonia, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, molybdenum, nickel, nitrate, plutonium, radium, ruthenium, selenium, silver, strontium, thallium, uranium, vanadium, and zinc concentrations are constrained by in situ leachate analyses. Technetium and thorium are constrained by TCLP data. After reacting Leachate A with glacial overburden minerals using EQ3/6, results for Leachate B (Table D.1-11) indicate that barium, beryllium, chromium, manganese, mercury, plutonium, strontium, thorium, and zinc concentrations have been lowered by mineral solubility. The remaining contaminant concentrations in Leachate B are identical to Leachate A.

Results for Waste Pit 3 are given in Table D.1-12. Leachate A concentrations for ammonia, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, molybdenum, nickel, nitrate, plutonium, selenium, silver, strontium, technetium, thallium, tin, uranium, vanadium, and zinc are constrained by in situ

leachate analyses. Radium and thorium are constrained by TCLP data. After reacting Leachate A with glacial overburden minerals using EQ3/6, results for Leachate B (Table D.1-12) indicate that barium, beryllium, manganese, mercury, plutonium, silver, strontium, thorium, and zinc concentrations have been lowered by mineral solubility. The remaining contaminant concentrations in Leachate B are identical to Leachate A.

In Waste Pit 4 (Table D.1-13), Leachate A concentrations for ammonia, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, molybdenum, nickel, plutonium, radium, selenium, silver, strontium, technetium, thorium, tin, uranium, vanadium, and zinc are constrained by in situ leachate analyses. Neptunium is constrained by TCLP data. After reacting Leachate A with pore water (perched groundwater) using EQ3/6, results for Leachate B (Table D.1-12) indicate that barium, chromium, manganese, mercury, neptunium, plutonium, silver, strontium, thorium, and vanadium concentrations have been lowered by mineral solubility. The remaining contaminant concentrations in Leachate B are identical to Leachate A.

Leachate A results for Waste Pit 5 (Table D.1-14) show antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, vanadium, and zinc concentrations are constrained by TCLP data. Cesium, neptunium, plutonium, ruthenium, selenium, silver, strontium, technetium, thallium, thorium, and uranium are constrained by in situ or surface water analyses and molybdenum, radium, and tin by the 70-year rule. All contaminant concentrations in Leachate B are identical to Leachate A.

For Waste Pit 6 (Table D.1-15), analyses are available for arsenic, barium, beryllium, lead, manganese, nickel, silver, thallium, and zinc and these concentrations are constrained by TCLP; and cadmium, chromium, cobalt, copper, cesium, neptunium, plutonium, technetium, thorium, radium, strontium, uranium and vanadium, by surface water or in situ data. Only tin is constrained with the 70-year rule. All contaminant concentrations in Leachate B are identical to Leachate A.

Results for the Burn Pit (Table D.1-16) show antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, molybdenum, neptunium, nickel, plutonium, radium, selenium, silver, uranium, vanadium, and zinc concentrations are constrained by in situ leachate analyses. Technetium and thorium

concentrations are set using TCLP data. After reacting Leachate A with pore water (perched groundwater) using EQ3/6, results for Leachate B (Table D.1-16) indicate that barium, beryllium, lead, manganese, mercury, neptunium, plutonium, silver, strontium, thorium, and zinc concentrations have been lowered by mineral solubility. The remaining contaminant concentrations in Leachate B are identical to Leachate A.

In the Clearwell all Leachate A concentrations (except Mo and Sn) are constrained by surface water data (Table D.1-17), TCLP data are unavailable and molybdenum, neptunium and tin concentrations are fixed using the 70-year rule. All contaminant concentrations in Leachate B are identical to Leachate A.

Several observations on the data presented in Tables D.1-10 through D.1-17 warrant further discussion to clarify differences in reported concentrations for a given element. For any given contaminant concentration constrained by the 70-year rule, its concentration in Leachate A or B is proportional to its inventory abundance in the waste unit. Therefore, a waste unit with a higher contaminant inventory will yield a higher contaminant concentration when the 70-year rule is applied.

D.1.5.2 Organic Leachate

Results for organic leachate concentrations for Waste Pits 1 through 6, the Burn Pit, and Clearwell are presented in Tables D.1-18 through D.1-25, respectively. While the entire list of potential organic constituents of concern for Operable Unit 1 as defined in Table D.1-1 are shown on each of these tables, leachate concentrations are provided only for organic constituents detected in the pit materials for the subject waste area.

In situ leachate analyses were available for organic constituents of concern for Waste Pits 1, 2, 3, 4, and the Burn Pit (Tables D.1-18, D.1-19, D.1-20, D.1-21, and D.1-24). When the in situ leachate analyses indicated that the constituent was not detected, the organic leachate concentration was conservatively estimated as the maximum detection limit value.

CIS surface water analyses were available for Waste Pits 5 and 6 and the Clearwell (Tables D.1-22, D.1-23, and D.1-25). For all constituents except Aroclor-1248 and Aroclor-1254 in Waste Pit 5 and Aroclor-1254 and tetrachloroethene in Waste Pit 6, constituents of concern

were not detected and the organic leachate concentration was conservatively estimated as the maximum detection limit value.

TCLP data were not used to constrain any organic leachate concentrations.

The EPA 70-year rule was used to calculate organic leachate concentrations for benzo(ghi)fluoranthene in Waste Pit 2 (Table D.1-19), and pentachlorophenol in Waste Pit 3 (Table D.1-20), and the majority of the constituents of concern in the Clearwell (Table D.1-25).

D.1.6 UNCERTAINTIES IN MODEL RESULTS

D.1.6.1 EQ3/6 Code Background

Mineral solubility calculations were performed with the EQ3/6 industry-standard geochemical computer code. EQ3/6 was developed at Lawrence Livermore National Laboratory (Wolery 1983; Daveler and Wolery 1992; Wolery 1992 a, b, and c) for predicting the behavior of metals, radionuclides, and other contaminants in the natural environment. The EQ3/6 computer code performs solubility and speciation (aqueous form) calculations and reaction-path modeling. These calculations involve the simultaneous solution of equations describing the mass balance of each component, mass action expressions for solubility equilibrium, oxidation/reduction reactions, and electrical balance constraints. Activity coefficients of aqueous species are approximated with the B-dot equation of Helgeson (1969), which are valid up to the ionic strength of seawater (about 0.7). None of the leachate samples modeled for Operable Unit 1 waste units exceeded an ionic strength of 0.2.

The EQ3/6 code accesses a data base containing the thermodynamic properties of 78 elements, 862 aqueous species, 886 minerals, and 76 gases. This data base includes 57 aqueous uranium species and 160 uranium-bearing minerals, constituting the most complete data base available for modeling the behavior of uranium in natural waters. EQ3/6 has been validated using standard geochemistry problems, such as the speciation of seawater (Nordstrom 1979), basalt/seawater interactions (Bowers et al. 1985), and numerous comparisons with experimentally determined mineral solubilities (Jackson 1988). Benchmark comparisons with the results of similar codes (e.g., PHREEQE) have been performed by INTERA (1983), Nordstrom (1979), Kincaid and Morey (1984), and Kerrisk (1981).

EQ3 is the portion of the code that calculates the initial aqueous species distribution with user-provided concentration data and computes the saturation indices (SI) of pertinent minerals. The SI is defined as log (Q/K), where Q equals the ion activity product and K equals equilibrium constant. An SI of greater than zero, zero, and less than zero corresponds to a mineral that is supersaturated, saturated, and undersaturated, respectively. After computing the speciation model, EQ3 computes a mass balance for each chemical element and performs a charge balance. This information is stored in a file that is used as input to EQ6. EQ3 differs from EQ6 in that EQ3 identifies minerals that are supersaturated and undersaturated, but (unlike EQ6) EQ3 cannot precipitate and dissolve the pertinent minerals.

The EQ6 code performs reaction-path calculations. Reaction-path (chemical evolution) modeling simulates a sequence of thermodynamic equilibrium problems in reacting systems consisting of water and minerals or other solids. The reacting system may consist of water that migrates through, and equilibrates with, waste solids and natural minerals in compositionally distinct horizons. For this case, rainwater reacts with Operable Unit 1 waste to form Leachate A followed by migration and reaction with underlying glacial overburden minerals to form Leachate B. The chemical evolution of the reacting system is driven by dissolution and precipitation of minerals or solids and/or by changes in temperature and pressure. Along each step of the reaction path, the EQ6 code computes the precipitation and dissolution of minerals based on mass action expressions for solubility equilibrium with water. Thus, EQ6 differs from EQ3 by allowing supersaturated minerals (SI greater than 0) to precipitate from solution and undersaturated minerals (SI less than 0) to dissolve.

D.1.6.2 Limitations and Assumptions of Mineral Solubility Calculations

The EQ3/6 geochemical code estimates contaminant concentrations by calculating mineral solubilities in water/solid systems. These calculations have the following limitations and assumptions:

- Limited number of organic constituents can be modeled, which can lead to low estimates of leachate concentrations for some inorganic constituents if organic complexation occurs with constituents not present in the database (e.g., lead complexed with acetate ion).
- Dissolution and precipitation kinetics are instantaneous, which can lead to estimated concentrations that are too high or too low.

- Adsorption processes are not evaluated with the EQ3/6 model.
- Modeled concentrations are site-specific solubility limits, and in most cases these concentrations are the highest concentrations that can exist in solution.

Dissolution of crystalline solids is rarely instantaneous or complete in the natural environment, except for some highly soluble salts like sodium chloride, which can lead to high estimates of contaminant concentrations. Assuming instantaneous precipitation of mineral phases can lead to low estimates of element concentrations if the mineral such as dolomite is difficult to nucleate and crystallize in the natural environment (e.g., dolomite). Finally, the calculated solubility concentrations may be too high because adsorption reactions are not considered. Adsorption reactions can substantially lower some contaminant concentrations below the calculated solubility limit (e.g., Cs^+).

D.1.6.3 Uncertainty in Estimating Leachate Compositions

Uncertainty is introduced into the estimation of leachate compositions whenever in situ leachate analyses are lacking. Surface water analyses used to estimate leachate composition probably reflect diluted in situ leachate residing within the void space of the waste. Given that dilution will occur when the leachate migrates into the underlying glacial overburden, the use of actual surface water analyses probably introduces less uncertainty than other types of data or methods used to calculate the leachate composition. The use of TCLP data to estimate leachate composition will probably result in contaminant concentrations that are greater than values expected for in situ leachate. As mentioned previously, this occurs due to the breakdown of acetic acid to acetate ion followed by the complexation of metals in the leachate. Calculations carried out to estimate contaminant concentrations using the 70-year rule will introduce a large conservative uncertainty for all but the most soluble contaminants (e.g., bromide and cesium). The possibility exists to underestimate the contaminant concentration when the 70-year rule is applied to very soluble constituents. Using the EQ3/6 geochemical code to perform mineral solubility calculations requires that several assumptions be made about the mineralogy of the waste, the kinetics of the reactions, and the lack of treatment of organic constituents. The uncertainties associated with these assumptions are discussed in Section D.1.6.2.

TABLE D.1-1

LIST OF POTENTIAL CONSTITUENTS OF CONCERN FOR OPERABLE UNIT 1 RI

Potential Constituents of Concern[a]

Inorganics	2,3,4,7,8-	Indeno(1,2,3-cd)pyrene
Antimony	Pentachlorodibenzofuran	Naphthalene
Arsenic	2,4,5-Trichlorophenol	Octachlorodibenzofuran
Barium	4,4-DDT	Octachlorodibenzo-p-dioxin
Beryllium	4-Nitroaniline	Pentachlorophenol
Boron	4-Nitrophenol	Phenanthrene
Cadmium	Acenaphthene	Pyrene
Chromium	Anthracene	Tetrachlorodibenzofuran
Cobalt	Aroclor-1221	Tetrachloroethene
Copper	Aroclor-1248	Vinyl Chloride
Cyanide	Aroclor-1254	
Lead	Aroclor-1260	Radionuclides
Manganese	Benzo(a)anthracene	Cesium-137
Mercury	Benzo(a)pyrene	Neptunium-237
Molybdenum	Benzo(b)fluoranthene	Plutonium-238
Nickel	Benzo(g,h,i)perylene	Plutonium-239/240
Selenium	Benzo(k)fluoranthene	Radium-226
Silver	Chrysene	Ruthenium-106
Thallium	Dibenzo(a,h)anthracene	Strontium-90
Tin	Dichlorodifluoromethane	Technetium-99
Vanadium	Fluoranthene	Thorium-230
Zinc	Fluorene	Thorium-232
	Heptachlorodibenzofuran	Uranium-234
Organics	Heptachlorodibenzo-p-dioxin	Uranium-235
1,2,3,7,8-	Hexachlorodibenzofuran	Uranium-238
Pentachlorodibenzofuran	Hexachlorodibenzo-p-dioxin	

[a]List of potential constituents of concern represent union of constituents detected in any OU1 Waste Area.

TABLE D.1-2

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - PIT 1

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	1.26×10^{-8}	7.78×10^{-1}
Neptunium-237	NA[e]	0.00
Plutonium-238	NA	0.00
Plutonium-239/240	NA	0.00
Radium-226	8.76×10^{-5}	5.39×10^{3}
Ruthenium-106	NA	0.00
Strontium-90	3.44×10^{-8}	2.12×10^{0}
Technetium-99	8.84×10^{-4}	5.44×10^{4}
Thorium-230	2.70×10^{-1}	1.66×10^{7}
Thorium-232	1.20×10^{3}	7.37×10^{10}
Uranium-234	1.44×10^{-1}	8.89×10^{6}
Uranium-235/236[a]	8.28×10^{1}	5.10×10^{9}
Uranium-238	3.12×10^{4}	1.92×10^{12}
Inorganics		
Antimony	8.89×10^{1}	5.47×10^{9}
Arsenic	1.13×10^{1}	6.96×10^{8}
Barium	4.05×10^{2}	2.49×10^{10}
Beryllium	8.21×10^{0}	5.05×10^{8}
Boron	1.22×10^{3}	7.52×10^{10}
Cadmium	1.62×10^{1}	9.95×10^{8}
Chromium	2.26×10^{2}	1.39×10^{10}
Cobalt	3.38×10^{1}	2.08×10^{9}
Copper	8.00×10^{1}	4.93×10^{9}
Cyanide	7.3×10^{-1}	4.49×10^{7}
Lead	3.66×10^{1}	2.25×10^{9}

TABLE D.1-2
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	2.13×10^{3}	1.31×10^{11}
Mercury	3.0×10^{-1}	1.85×10^{7}
Molybdenum	2.57×10^{1}	1.58×10^{9}
Nickel	4.71×10^{1}	2.90×10^{9}
Selenium	NA	0.00
Silver	1.22×10^{2}	7.54×10^{9}
Thallium	4.6×10^{-1}	2.83×10^{7}
Tin	NA	0.00
Vanadium	9.57×10^{1}	5.89×10^{9}
Zinc	3.67×10^{1}	2.26×10^{9}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	5.42×10^{-3}	3.34×10^{5}
2,3,4,7,8-Pentachlorodibenzofuran	7.50×10^{-4}	4.62×10^{4}
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	1.60×10^{0}	9.85×10^{7}
4-Nitrophenol	NA	0.00
4-Nitroaniline	NA	0.00
Ancenaphthene	NA	0.00
Anthracene	7.4×10^{-2}	4.56×10^{10}
Aroclor-1221	4.60×10^{0}	2.83×10^{8}
Aroclor-1248	7.07×10^{0}	4.35×10^{8}
Aroclor-1254	9.98×10^{0}	6.14×10^{8}
Aroclor-1260	7.80×10^{0}	4.80×10^{8}
Benzo(a)anthracene	1.80×10^{1}	1.11×10^{7}
Benzo(a)pyrene	1.40×10^{1}	8.62×10^{6}
Benzo(b)fluoranthene	3.07×10^{1}	1.89×10^{7}
Benzo(g,h,i)perylene	NA	0.00
Benzo(k)fluoranthene	1.40×10^{1}	8.62×10^{6}

TABLE D.1-2
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Chrysene	4.51×10^{-1}	2.78×10^{7}
Dibenzo(a,h)anthracene	NA	0.00
Dichlorodifluoromethane	2.96×10^{1}	1.82×10^{9}
Fluoranthene	1.00×10^{0}	6.16×10^{7}
Fluorene	NA	0.00
Heptachlorodibenzofuran	1.75×10^{-3}	1.08×10^{5}
Heptachlorodibenzo-p-dioxin	1.45×10^{-3}	8.93×10^{4}
Hexachlorodibenzofuran	2.26×10^{-3}	1.39×10^{5}
Hexachlorodibenzo-p-dioxin	3.21×10^{-3}	1.98×10^{5}
Indeno(1,2,3-cd)pyrene	NA	0.00
Naphthalene	6.7×10^{-2}	4.12×10^{6}
Octachlorodibenzofuran	7.60×10^{-4}	4.68×10^{4}
Octachlorodibenzo-p-dioxin	5.40×10^{-4}	3.32×10^{4}
Pentachlorophenol	NA	0.00
Phenanthrene	1.88×10^{0}	1.16×10^{8}
Pyrene	4.9×10^{-1}	3.02×10^{7}
Tetrachlorodibenzofuran	2.84×10^{-2}	1.75×10^{6}
Tetrachloroethene	2.52×10^{-1}	1.55×10^{7}
Vinyl Chloride	NA	0.00

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials Data sets.

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TABLE D.1-3

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - PIT 2

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	4.14×10^{-8}	1.00×10^{0}
Neptunium-237	NA[e]	0.00
Plutonium-238	5.84×10^{-9}	1.41×10^{-1}
Plutonium-239/240	9.65×10^{-6}	2.34×10^{2}
Radium-226	8.59×10^{-4}	2.08×10^{4}
Ruthenium-106	1.40×10^{-9}	3.40×10^{-2}
Strontium-90	2.93×10^{-8}	7.10×10^{-1}
Technetium-99	3.64×10^{-2}	8.82×10^{5}
Thorium-230	9.11×10^{-1}	2.21×10^{7}
Thorium-232	2.45×10^{3}	5.93×10^{10}
Uranium-234	1.84×10^{0}	4.47×10^{7}
Uranium-235/236[a]	2.55×10^{3}	6.18×10^{10}
Uranium-238	3.56×10^{4}	8.63×10^{11}
Inorganics		
Antimony	5.88×10^{1}	1.43×10^{9}
Arsenic	3.80×10^{2}	9.22×10^{9}
Barium	1.95×10^{3}	4.74×10^{10}
Beryllium	2.68×10^{1}	6.50×10^{8}
Boron	2.48×10^{2}	6.01×10^{9}
Cadmium	1.35×10^{1}	3.27×10^{8}
Chromium	2.94×10^{2}	7.12×10^{9}
Cobalt	1.32×10^{3}	3.21×10^{10}
Copper	1.26×10^{3}	3.05×10^{10}
Cyanide	2.64×10^{0}	6.40×10^{7}
Lead	8.48×10^{2}	2.06×10^{10}
Mercury	2.81×10^{0}	6.81×10^{7}

TABLE D.1-3
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	2.66×10^{3}	6.44×10^{10}
Molybdenum	1.93×10^{2}	4.68×10^{9}
Nickel	1.58×10^{3}	3.83×10^{10}
Selenium	1.14×10^{2}	2.75×10^{9}
Silver	4.10×10^{1}	9.94×10^{8}
Thallium	2.40×10^{0}	5.82×10^{7}
Tin	NA	0.0
Vanadium	5.29×10^{2}	1.28×10^{10}
Zinc	2.07×10^{3}	5.02×10^{10}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	5.50×10^{-4}	1.33×10^{4}
2,3,4,7,8-Pentachlorodibenzofuran	NA	0.00
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	1.40×10^{0}	3.39×10^{7}
4-Nitroaniline	4.90×10^{0}	1.19×10^{8}
4-Nitrophenol	1.90×10^{-1}	4.61×10^{6}
Acenaphthene	4.30×10^{1}	1.04×10^{9}
Anthracene	7.56×10^{1}	1.83×10^{9}
Aroclor-1221	NA	0.00
Aroclor-1248	4.90×10^{0}	1.19×10^{8}
Aroclor-1254	3.23×10^{-1}	7.83×10^{6}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	1.00×10^{2}	2.42×10^{9}
Benzo(a)pyrene	7.57×10^{1}	1.83×10^{9}
Benzo(b)fluoranthene	1.30×10^{2}	3.15×10^{9}
Benzo(g,h,i)perylene	4.20×10^{1}	1.02×10^{9}
Benzo(k)fluoranthene	4.73×10^{1}	1.15×10^{9}

TABLE D.1-3
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Chrysene	8.60×10^{1}	2.08×10^{9}
Dibenzo(a,h)anthracene	2.00×10^{-2}	4.85×10^{5}
Dichlorodifluoromethane	NA	0.00
Fluoranthene	3.09×10^{2}	7.49×10^{9}
Fluorene	6.20×10^{1}	1.50×10^{9}
Heptachlorodibenzofuran	5.90×10^{3}	1.43×10^{5}
Heptachlorodibenzo-p-dioxin	8.10×10^{-3}	1.96×10^{5}
Hexachlorodibenzofuran	2.70×10^{-3}	6.54×10^{4}
Hexachlorodibenzo-p-dioxin	3.20×10^{-4}	7.76×10^{3}
Indeno(1,2,3-cd)pyrene	4.60×10^{1}	1.12×10^{9}
Naphthalene	2.30×10^{1}	5.58×10^{8}
Octachlorodibenzofuran	4.90×10^{-3}	1.19×10^{5}
Octachlorodibenzo-p-dioxin	4.59×10^{-2}	1.11×10^{6}
Pentachlorophenol	1.60×10^{0}	3.88×10^{7}
Phenanthrene	1.56×10^{2}	3.77×10^{9}
Pyrene	1.58×10^{2}	3.84×10^{9}
Tetrachlorodibenzofuran	NA	0.00
Tetrachloroethene	4.50×10^{-2}	1.09×10^{6}
Vinyl Chloride	7.24×10^{2}	1.76×10^{7}

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-4

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - PIT 3

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	NA[e]	0.00
Neptunium-237	2.97×10^{-3}	6.17×10^{5}
Plutonium-238	5.84×10^{-8}	1.21×10^{1}
Plutonium-239/240	2.25×10^{-4}	4.67×10^{4}
Radium-226	3.10×10^{-4}	6.43×10^{4}
Ruthenium-106	NA	0.00
Strontium-90	3.81×10^{-8}	7.91×10^{0}
Technetium-99	3.07×10^{-2}	6.37×10^{6}
Thorium-230	4.25×10^{-1}	8.81×10^{7}
Thorium-232	3.62×10^{3}	7.51×10^{11}
Uranium-234	1.78×10^{-1}	3.70×10^{7}
Uranium-235/236[a]	3.38×10^{1}	7.01×10^{9}
Uranium-238	3.86×10^{3}	8.02×10^{11}
Inorganics		
Antimony	5.25×10^{1}	1.09×10^{10}
Arsenic	2.13×10^{4}	4.42×10^{12}
Barium	8.08×10^{3}	1.68×10^{12}
Beryllium	1.44×10^{1}	2.99×10^{9}
Boron	1.55×10^{2}	3.22×10^{10}
Cadmium	2.59×10^{1}	5.38×10^{9}
Chromium	1.86×10^{2}	3.86×10^{10}
Cobalt	3.60×10^{1}	7.46×10^{9}
Copper	1.74×10^{3}	3.62×10^{11}
Cyanide	1.61×10^{0}	3.34×10^{8}
Lead	6.70×10^{2}	1.39×10^{11}

TABLE D.1-4
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	1.67×10^{4}	3.47×10^{12}
Mercury	3.19×10^{0}	6.62×10^{8}
Molybdenum	2.41×10^{2}	5.00×10^{10}
Nickel	2.66×10^{2}	5.52×10^{10}
Selenium	4.95×10^{1}	1.03×10^{10}
Silver	3.74×10^{1}	7.77×10^{9}
Thallium	1.20×10^{1}	2.49×10^{9}
Tin	1.91×10^{2}	3.96×10^{10}
Vanadium	5.20×10^{3}	1.08×10^{12}
Zinc	3.11×10^{2}	6.45×10^{10}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	NA	0.00
2,3,4,7,8-Pentachlorodibenzo-p-dioxin	NA	0.00
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	NA	0.00
4-Nitroaniline	NA	0.00
4-Nitrophenol	NA	0.00
Acenaphthene	9.6×10^{-2}	1.99×10^{7}
Anthracene	1.30×10^{-1}	2.70×10^{7}
Aroclor-1221	NA	0.00
Aroclor-1248	2.73×10^{0}	5.66×10^{8}
Aroclor-1254	2.08×10^{0}	4.31×10^{8}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	3.60×10^{1}	7.47×10^{7}
Benzo(a)pyrene	3.80×10^{1}	7.89×10^{7}
Benzo(b)fluoranthene	5.60×10^{-1}	1.16×10^{8}
Benzo(g,h,i)perylene	1.60×10^{-1}	3.32×10^{7}

TABLE D.1-4
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Benzo(k)fluoranthene	NA	0.00
Chrysene	3.70×10^{-1}	7.68×10^{7}
Dibenzo(a,h)anthracene	NA	0.00
Dichlorodifluoromethane	NA	0.00
Fluoranthene	7.20×10^{-1}	1.49×10^{8}
Fluorene	NA	0.00
Heptachlorodibenzofuran	6.90×10^{-4}	1.43×10^{5}
Heptachlorodibenzo-p-dioxin	2.10×10^{-3}	4.36×10^{5}
Hexachlorodibenzofuran	2.70×10^{-4}	5.60×10^{4}
Hexachlorodibenzo-p-dioxin	2.60×10^{-4}	5.40×10^{4}
Indeno(1,2,3-cd)pyrene	1.30×10^{-1}	2.70×10^{7}
Naphthalene	NA	0.00
Octachlorodibenzofuran	7.50×10^{-4}	1.56×10^{5}
Octachlorodibenzo-p-dioxin	1.27×10^{-2}	2.64×10^{6}
Pentachlorophenol	1.30×10^{0}	2.70×10^{8}
Phenanthrene	5.80×10^{-1}	1.20×10^{8}
Pyrene	6.20×10^{-1}	1.29×10^{8}
Tetrachlorodibenzofuran	2.00×10^{-4}	4.15×10^{4}
Tetrachloroethene	1.07×10^{-2}	2.21×10^{6}
Vinyl Chloride	NA	0.00

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-5

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - PIT 4

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	NA[e]	0.00
Neptunium-237	5.67×10^{-4}	4.37×10^{4}
Plutonium-238	2.92×10^{-8}	2.25×10^{0}
Plutonium-239/240	6.43×10^{-6}	4.96×10^{2}
Radium-226	3.70×10^{-5}	2.85×10^{3}
Ruthenium-106	NA	0.00
Strontium-90	7.28×10^{-7}	5.61×10^{1}
Technetium-99	1.16×10^{-2}	8.93×10^{5}
Thorium-230	7.51×10^{-2}	5.79×10^{6}
Thorium-232	6.47×10^{3}	$4.99E \times 10^{11}$
Uranium-234	6.57×10^{-1}	5.06×10^{7}
Uranium-235/236[a]	3.24×10^{2}	2.50×10^{10}
Uranium-238	1.33×10^{5}	1.02×10^{13}
Inorganics		
Antimony	2.22×10^{2}	1.71×10^{10}
Arsenic	5.16×10^{0}	3.98×10^{8}
Barium	4.58×10^{3}	3.53×10^{11}
Beryllium	5.06×10^{1}	3.90×10^{9}
Boron	6.58×10^{2}	5.07×10^{10}
Cadmium	2.45×10^{1}	1.89×10^{9}
Chromium	1.05×10^{3}	8.09×10^{10}
Cobalt	1.29×10^{2}	9.96×10^{9}
Copper	3.52×10^{2}	2.72×10^{10}
Cyanide	7.0×10^{-1}	5.40×10^{7}
Lead	5.53×10^{1}	4.26×10^{9}

TABLE D.1-5
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	4.75×10^{3}	3.66×10^{11}
Mercury	6.2×10^{-1}	4.78×10^{7}
Molybdenum	6.98×10^{1}	5.38×10^{9}
Nickel	1.67×10^{2}	1.29×10^{10}
Selenium	3.7×10^{-1}	2.85×10^{7}
Silver	5.31×10^{2}	4.10×10^{10}
Thallium	NA	0.00
Tin	1.14×10^{2}	8.76×10^{9}
Vanadium	3.94×10^{2}	3.04×10^{10}
Zinc	1.43×10^{2}	1.10×10^{10}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	1.08×10^{-2}	8.33×10^{5}
2,3,4,7,8-Pentachlorodibenzofuran	1.74×10^{-3}	1.34×10^{5}
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	NA	0.00
4-Nitroaniline	NA	0.00
4-Nitrophenol	2.30×10^{0}	1.77×10^{8}
Acenaphthene	1.90×10^{0}	1.46×10^{8}
Anthracene	2.70×10^{0}	2.08×10^{8}
Aroclor-1221	NA	0.00
Aroclor-1248	5.92×10^{0}	4.57×10^{8}
Aroclor-1254	6.80×10^{0}	5.24×10^{8}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	4.70×10^{0}	3.62×10^{8}
Benzo(a)pyrene	4.50×10^{0}	3.47×10^{8}
Benzo(b)fluoranthene	5.20×10^{0}	4.01×10^{8}
Benzo(g,h,i)perylene	9.90×10^{1}	7.63×10^{7}

TABLE D.1-5
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Benzo(k)fluoranthene	3.70×10^{0}	2.85×10^{8}
Chrysene	3.86×10^{0}	2.98×10^{8}
Dibenzo(a,h)anthracene	6.5×10^{-2}	5.01×10^{6}
Dichlorodifluoromethane	NA	0.00
Fluoranthene	1.10×10^{1}	8.48×10^{8}
Fluorene	2.20×10^{0}	1.70×10^{8}
Heptachlorodibenzofuran	3.18×10^{3}	2.45×10^{5}
Heptachlorodibenzo-p-dioxin	3.16×10^{-3}	2.44×10^{5}
Hexachlorodibenzofuran	5.39×10^{-3}	4.16×10^{5}
Hexachlorodibenzo-p-dioxin	1.85×10^{-3}	1.43×10^{5}
Indeno(1,2,3-cd)pyrene	9.90×10^{-1}	7.63×10^{7}
Naphthalene	1.10×10^{0}	8.48×10^{7}
Octachlorodibenzofuran	3.66×10^{-3}	2.82×10^{5}
Octachlorodibenzo-p-dioxin	6.52×10^{-3}	5.03×10^{5}
Pentachlorophenol	NA	0.00
Phenanthrene	1.20×10^{1}	9.25×10^{8}
Pyrene	9.00×10^{0}	6.94×10^{8}
Tetrachlorodibenzofuran	3.11×10^{-2}	2.40×10^{6}
Tetrachloroethene	3.00×10^{1}	2.31×10^{9}
Vinyl Chloride	1.40×10^{1}	1.079×10^{6}

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-6

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - PIT 5

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	8.73×10^{-7}	6.26×10^{1}
Neptunium-237	6.52×10^{-2}	4.67×10^{6}
Plutonium-238	2.10×10^{-7}	1.51×10^{1}
Plutonium-239/240	1.56×10^{-4}	1.12×10^{4}
Radium-226	1.13×10^{-4}	8.10×10^{3}
Ruthenium-106	4.77×10^{-10}	3.42×10^{-2}
Strontium-90	1.47×10^{-7}	1.06×10^{1}
Technetium-99	1.22×10^{-1}	8.74×10^{6}
Thorium-230	3.37×10^{-1}	2.42×10^{7}
Thorium-232	4.12×10^{2}	2.95×10^{10}
Uranium-234	1.49×10^{-1}	1.07×10^{7}
Uranium-235/236[a]	2.49×10^{1}	1.79×10^{9}
Uranium-238	2.69×10^{3}	1.93×10^{11}
Inorganics		
Antimony	5.17×10^{1}	3.71×10^{9}
Arsenic	2.15×10^{3}	1.54×10^{11}
Barium	3.02×10^{4}	2.17×10^{12}
Beryllium	1.48×10^{1}	1.06×10^{9}
Boron	NA[e]	0.00
Cadmium	1.16×10^{1}	8.32×10^{8}
Chromium	1.16×10^{2}	8.30×10^{9}
Cobalt	3.55×10^{1}	2.55×10^{9}
Copper	1.18×10^{4}	8.47×10^{11}
Cyanide	5.0×10^{-1}	3.59×10^{7}
Lead	1.74×10^{2}	1.25×10^{10}

TABLE D.1-6
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	3.05×10^{3}	2.19×10^{11}
Mercury	1.60×10^{0}	1.15×10^{8}
Molybdenum	6.66×10^{2}	4.78×10^{10}
Nickel	1.50×10^{2}	1.08×10^{10}
Selenium	1.38×10^{1}	9.90×10^{8}
Silver	1.41×10^{1}	1.01×10^{9}
Thallium	3.45×10^{1}	2.48×10^{9}
Tin	4.80×10^{1}	3.44×10^{9}
Vanadium	4.92×10^{3}	3.53×10^{11}
Zinc	2.06×10^{2}	1.48×10^{10}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	NA	0.00
2,3,4,7,8-Pentachlorodibenzofuran	NA	0.00
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	NA	0.00
4-Nitroaniline	NA	0.00
4-Nitrophenol	NA	0.00
Acenaphthene	NA	0.00
Anthracene	NA	0.00
Aroclor-1221	NA	0.00
Aroclor-1248	5.50×10^{-1}	3.94×10^{7}
Aroclor-1254	7.50×10^{-1}	5.38×10^{7}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	NA	0.00
Benzo(a)pyrene	NA	0.00
Benzo(b)fluoranthene	NA	0.00
Benzo(g,h,i)perylene	NA	0.00

TABLE D.1-6
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Benzo(k)fluoranthene	NA	0.00
Chrysene	NA	0.00
Dibenzo(a,h)anthracene	NA	0.00
Dichlorodifluoromethane	NA	0.00
Fluoranthene	NA	0.00
Fluorene	NA	0.00
Heptachlorodibenzofuran	NA	0.00
Heptachlorodibenzo-p-dioxin	NA	0.00
Hexachlorodibenzofuran	NA	0.00
Hexachlorodibenzo-p-dioxin	NA	0.00
Indeno(1,2,3-cd)pyrene	NA	0.00
Naphthalene	NA	0.00
Octachlorodibenzofuran	NA	0.00
Octachlorodibenzo-p-dioxin	NA	0.00
Pentachlorophenol	NA	0.00
Phenanthrene	NA	0.00
Pyrene	NA	0.00
Tetrachlorodibenzofuran	NA	0.00
Tetrachloroethene	NA	0.00
Vinyl Chloride	NA	0.00

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-7

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - PIT 6

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	3.56×10^{-7}	4.05×10^{0}
Neptunium-237	4.82×10^{-3}	5.48×10^{4}
Plutonium-238	7.59×10^{-8}	8.63×10^{-1}
Plutonium-239/240	2.30×10^{-4}	2.62×10^{3}
Radium-226	4.45×10^{-6}	5.06×10^{1}
Ruthenium-106	NA[e]	0.00
Strontium-90	4.03×10^{8}	4.58×10^{-1}
Technetium-99	9.83×10^{-3}	1.12×10^{5}
Thorium-230	2.36×10^{-3}	2.68×10^{4}
Thorium-232	1.00×10^{1}	1.14×10^{8}
Uranium-234	8.11×10^{-1}	9.23×10^{6}
Uranium-235/236[a]	8.53×10^{2}	9.71×10^{9}
Uranium-238	6.13×10^{4}	6.98×10^{11}
Inorganics		
Antimony	NA	0.00
Arsenic	5.49×10^{1}	6.25×10^{8}
Barium	9.50×10^{1}	1.08×10^{9}
Beryllium	5.70×10^{0}	6.49×10^{-7}
Boron	NA	0.00
Cadmium	5.70×10^{0}	6.49×10^{7}
Chromium	3.00×10^{1}	3.41×10^{8}
Cobalt	2.60×10^{1}	2.96×10^{8}
Copper	2.22×10^{2}	2.53×10^{9}
Cyanide	NA	0.00
Lead	7.96×10^{1}	9.05×10^{8}

TABLE D.1-7
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	2.21×10^{2}	2.51×10^{9}
Mercury	NA	0.00
Molybdenum	NA	0.00
Nickel	5.10×10^{1}	5.80×10^{8}
Selenium	NA	0.00
Silver	1.58×10^{2}	1.80×10^{9}
Thallium	7.10×10^{1}	8.08×10^{8}
Tin	1.38×10^{1}	1.57×10^{8}
Vanadium	1.00×10^{2}	1.14×10^{9}
Zinc	4.80×10^{1}	5.46×10^{8}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	NA	0.00
2,3,4,7,8-Pentachlorodibenzofuran	NA	0.00
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	NA	0.00
4-Nitroaniline	NA	0.00
4-Nitrophenol	NA	0.00
Acenaphthene	NA	0.00
Anthracene	NA	0.00
Aroclor-1221	NA	0.00
Aroclor-1248	NA	0.00
Aroclor-1254	8.10×10^{-2}	9.22×10^{5}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	NA	0.00
Benzo(a)pyrene	NA	0.00
Benzo(b)fluoranthene	NA	0.00
Benzo(g,h,i)perylene	NA	0.00
Benzo(k)fluoranthene	NA	0.00

TABLE D.1-7
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Chrysene	NA	0.00
Dibenzo(a,h)anthracene	NA	0.00
Dichlorodifluoromethane	NA	0.00
Fluoranthene	NA	0.00
Fluorene	NA	0.00
Heptachlorodibenzofuran	NA	0.00
Heptachlorodibenzo-p-dioxin	NA	0.00
Hexachlorodibenzofuran	NA	0.00
Hexachlorodibenzo-p-dioxin	NA	0.00
Indeno(1,2,3-cd)pyrene	NA	0.00
Naphthalene	NA	0.00
Octachlorodibenzofuran	NA	0.00
Octachlorodibenzo-p-dioxin	NA	0.00
Pentachlorophenol	NA	0.00
Phenanthrene	NA	0.00
Pyrene	NA	0.00
Tetrachlorodibenzofuran	NA	0.00
Tetrachloroethene	3.11×10^{1}	3.53×10^{8}
Vinyl Chloride	NA	0.00

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-8

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - BURN PIT

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	NA[e]	0.00
Neptunium-237	8.50×10^{-4}	2.22×10^{4}
Plutonium-238	2.92×10^{-8}	7.64×10^{-1}
Plutonium-239/240	6.43×10^{-6}	1.68×10^{2}
Radium-226	3.46×10^{-5}	9.05×10^{2}
Ruthenium-106	NA	0.00
Strontium-90	3.66×10^{-9}	9.59×10^{-2}
Technetium-99	3.08×10^{-3}	8.07×10^{4}
Thorium-230	1.89×10^{-1}	4.94×10^{6}
Thorium-232	1.32×10^{2}	3.44×10^{9}
Uranium-234	2.49×10^{-1}	6.53×10^{6}
Uranium-235/236[a]	4.69×10^{1}	1.23×10^{9}
Uranium-238	5.36×10^{3}	1.40×10^{11}
Inorganics		
Antimony	1.78×10^{1}	4.66×10^{8}
Arsenic	3.47×10^{1}	9.09×10^{8}
Barium	3.05×10^{3}	7.97×10^{10}
Beryllium	7.10×10^{0}	1.86×10^{8}
Boron	4.82×10^{1}	1.26×10^{9}
Cadmium	1.54×10^{1}	4.03×10^{8}
Chromium	9.25×10^{1}	2.42×10^{9}
Cobalt	9.89×10^{1}	2.59×10^{9}
Copper	2.81×10^{2}	7.36×10^{9}
Cyanide	2.10×10^{-1}	5.50×10^{6}
Lead	3.10×10^{2}	8.11×10^{9}

TABLE D.1-8
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	9.44×10^{-2}	2.47×10^{10}
Mercury	1.2×10^{0}	3.14×10^{7}
Molybdenum	2.49×10^{1}	6.52×10^{8}
Nickel	1.87×10^{2}	4.88×10^{9}
Selenium	1.91×10^{0}	5.00×10^{7}
Silver	5.06×10^{2}	1.32×10^{10}
Thallium	5.00×10^{-1}	1.31×10^{7}
Tin	NA	0.00
Vanadium	1.30×10^{2}	3.39×10^{9}
Zinc	5.23×10^{2}	1.37×10^{10}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	NA	0.00
2,3,4,7,8-Pentachlorodibenzofuran	NA	0.00
2,4,5-Trichlorophenol	NA	0.00
4,4'-DDT	NA	0.00
4-Nitroaniline	NA	0.00
4-Nitrophenol	NA	0.00
Acenaphthene	1.10×10^{0}	2.88×10^{7}
Anthracene	3.10×10^{0}	8.12×10^{7}
Aroclor-1221	NA	0.00
Aroclor-1248	NA	0.00
Aroclor-1254	7.70×10^{0}	2.02×10^{8}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	6.30×10^{0}	1.65×10^{8}
Benzo(a)pyrene	3.90×10^{0}	1.02×10^{8}
Benzo(b)fluoranthene	9.60×10^{0}	2.51×10^{8}
Benzo(g,h,i)perylene	2.90×10^{0}	7.59×10^{7}

TABLE D.1-8
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Benzo(k)fluoranthene	3.40×10^{-1}	8.90×10^{6}
Chrysene	7.00×10^{0}	1.83×10^{8}
Dibenzo(a,h)anthracene	NA	0.00
Dichlorodifluoromethane	NA	0.00
Fluoranthene	1.60×10^{1}	4.19×10^{8}
Fluorene	1.70×10^{0}	4.45×10^{7}
Heptachlorodibenzofuran	NA	0.00
Heptachlorodibenzo-p-dioxin	9.80×10^{4}	2.57×10^{4}
Hexachlorodibenzofuran	NA	0.00
Hexachlorodibenzo-p-dioxin	NA	0.00
Indeno(1,2,3-cd)pyrene	2.20×10^{0}	5.76×10^{7}
Naphthalene	2.00×10^{-1}	1.05×10^{5}
Octachlorodibenzofuran	1.30×10^{-4}	3.40×10^{3}
Octachlorodibenzo-p-dioxin	4.00×10^{-3}	1.05×10^{5}
Pentachlorophenol	2.60×10^{0}	6.81×10^{7}
Phenanthrene	1.50×10^{1}	3.93×10^{8}
Pyrene	1.40×10^{1}	3.67×10^{8}
Tetrachlorodibenzofuran	NA	0.00
Tetrachloroethene	2.60×10^{-1}	6.81×10^{6}
Vinyl Chloride	3.00×10^{0}	7.854×10^{4}

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-9

SOURCE CHARACTERIZATION FOR OPERABLE UNIT 1 - CLEARWELL

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Radionuclides		
Cesium-137	4.66×10^{-6}	3.49×10^{1}
Neptunium-237	3.12×10^{-3}	2.34×10^{4}
Plutonium-238	2.33×10^{-8}	1.75×10^{-1}
Plutonium-239/240	6.43×10^{-6}	4.82×10^{1}
Radium-226	1.19×10^{-4}	8.91×10^{2}
Ruthenium-106	NA[e]	0.00
Strontium-90	1.63×10^{-7}	1.22×10^{0}
Technetium-99	3.08×10^{-2}	2.31×10^{5}
Thorium-230	2.36×10^{-1}	1.77×10^{6}
Thorium-232	3.37×10^{2}	2.53×10^{9}
Uranium-234	1.28×10^{-1}	9.57×10^{5}
Uranium-235/236[a]	1.61×10^{2}	1.2×10^{9}
Uranium-238	4.05×10^{3}	3.03×10^{10}
Inorganics		
Antimony	3.20×10^{1}	2.40×10^{8}
Arsenic	5.40×10^{1}	4.05×10^{8}
Barium	6.14×10^{3}	4.60×10^{10}
Beryllium	7.80×10^{0}	5.85×10^{7}
Boron	NA	0.00
Cadmium	7.20×10^{0}	5.40×10^{7}
Chromium	1.53×10^{2}	1.15×10^{9}
Cobalt	2.30×10^{1}	1.72×10^{8}
Copper	2.42×10^{3}	1.81×10^{10}
Cyanide	9.20×10^{0}	6.90×10^{7}
Lead	4.33×10^{2}	3.25×10^{9}

TABLE D.1-9
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Manganese	1.32×10^{4}	9.93×10^{10}
Mercury	4.80×10^{0}	3.60×10^{7}
Molybdenum	3.65×10^{1}	2.74×10^{8}
Nickel	1.67×10^{2}	1.25×10^{9}
Selenium	3.70×10^{0}	2.77×10^{0}
Silver	9.84×10^{0}	7.38×10^{0}
Thallium	2.10×10^{0}	1.57×10^{7}
Tin	1.82×10^{1}	1.36×10^{8}
Vanadium	2.20×10^{3}	1.65×10^{10}
Zinc	2.46×10^{2}	1.85×10^{9}
Organics		
1,2,3,7,8-Pentachlorodibenzofuran	NA	0.00
2,3,4,7,8-Pentachlorodibenzofuran	NA	0.00
2,4,5-Trichlorophenol	6.20×10^{0}	4.65×10^{7}
4,4'-DDT	NA	0.00
4-Nitroaniline	NA	0.00
4-Nitrophenol	NA	0.00
Acenaphthene	NA	0.00
Anthracene	4.50×10^{-1}	3.37×10^{6}
Aroclor-1221	NA	0.00
Aroclor-1248	3.08×10^{-1}	2.31×10^{6}
Aroclor-1254	6.44×10^{-1}	4.82×10^{6}
Aroclor-1260	NA	0.00
Benzo(a)anthracene	8.90×10^{-1}	6.67×10^{6}
Benzo(a)pyrene	6.70×10^{-1}	5.02×10^{6}
Benzo(b)fluoranthene	7.10×10^{-1}	5.32×10^{6}
Benzo(g,h,i)perylene	2.30×10^{-1}	1.72×10^{6}

TABLE D.1-9
(Continued)

Potential Constituents of Concern	UCL on Mean Concentration in Pit Material[b,c]	Contaminant Inventory in the Waste[d]
Benzo(k)fluoranthene	7.50×10^{-1}	5.62×10^{6}
Chrysene	1.00×10^{0}	7.50×10^{6}
Dibenzo(a,h)anthracene	NA	0.00
Dichlorodifluoromethane	NA	0.00
Fluoranthene	3.10×10^{0}	2.32×10^{7}
Fluorene	2.80×10^{-1}	2.10×10^{6}
Heptachlorodibenzofuran	NA	0.00
Heptachlorodibenzo-p-dioxin	NA	0.00
Hexachlorodibenzofuran	NA	0.00
Hexachlorodibenzo-p-dioxin	NA	0.00
Naphthalene	NA	0.00
Indeno(1,2,3-cd)pyrene	2.70×10^{-1}	2.02×10^{6}
Octachlorodibenzofuran	NA	0.00
Octachlorodibenzo-p-dioxin	NA	0.00
Pentachlorophenol	NA	0.00
Phenanthrene	1.79×10^{0}	1.34×10^{7}
Pyrene	1.40×10^{0}	1.05×10^{7}
Tetrachlorodibenzofuran	NA	0.00
Tetrachloroethene	NA	0.00
Vinyl Chloride	NA	0.00

[a]Uranium-235 in CIS Pit Materials Data Base.
[b]UCL - Upper Confidence Limit on mean values were extracted from statistical summaries presented in Appendix D.
[c]All concentrations in milligrams per kilogram.
[d]Total mass in milligrams.
[e]NA - Not detected or not analyzed in the CIS or RI/FS Pit Materials data sets.

TABLE D.1-10

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - PIT 1

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
pH	11.8 SU	NA[c]	6.75 SU	EQ3/6
Eh	-0.190 V	NA	+0.400 V	EQ3/6
Antimony	0.3225	ISL	0.3225	ISL
Arsenic	0.0028	ISL	0.0028	ISL
Barium	1.9236	ISL	1.9236	ISL
Beryllium	0.0774	ISL	1.83×10^{-3}	BeO
Boron	1.2279	ISL	1.2279	ISL
Cadmium	0.0414	ISL	0.0414	ISL
Cesium-137[d]	1.2×10^{-10}	mdl-ISL	1.2×10^{-10}	mdl-ISL
Chromium	0.1929	ISL	3.42×10^{-4}	CrO_2
Cobalt	1.3215	ISL	1.3215	ISL
Copper	0.0832	ISL	0.0832	ISL
Cyanide	0.5437	ISL	0.5437	ISL
Lead	0.0048	ISL	0.0048	ISL
Manganese	208.3633	ISL	0.0771	carb.SS[e]
Mercury	0.0002	ISL	1.8×10^{-10}	calomel
Molybdenum	0.3605	ISL	0.3605	ISL
Neptunium-237				
Nickel	8.2943	ISL	8.2943	ISL
Nitrate	194.7	ISL	194.7	ISL
Plutonium-238				
Plutonium-239 and 240				

TABLE D.1-10
(Continued)

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Radium-226[d]	1.213×10^{-7}	ISL	1.213×10^{-7}	ISL
Ruthenium-106				
Selenium				
Silver	0.1181	ISL	0.1181	ISL
Strontium-90[d]	9.12×10^{-11}	ISL	2.84×10^{-14}	carb.SS
Technetium-99[d]	2.18×10^{-6}	TCLP	2.18×10^{-6}	TCLP
Thorium-230	2.57×10^{-8}	mdl-ISL	2.08×10^{-9}	ThO_2
Thorium-232	0.0046	mdl-ISL	2.08×10^{-9}	ThO_2
Thorium-Total[d]	0.0015	mdl-ISL	2.08×10^{-9}	ThO_2
Uranium-234[d]	5.75×10^{-4}	ISL	5.75×10^{-4}	ISL
Uranium-235[d]	1.24×10^{-1}	ISL	1.24×10^{-1}	ISL
Uranium-238[d]	11.93	ISL	11.93	ISL
Uranium-Total[d]	10.8615	ISL	10.86	ISL
Vanadium	0.1103	ISL	0.1103	ISL
Zinc	0.2115	ISL	3.54×10^{-4}	carb.SS

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by EQ3/6 Geochemical Code (EQ3/6) Toxicity Characteristic Leaching Procedure (TCLP), in situ leachate (ISL), maximum detection limit (mdl), US EPA 70-year rule (70-year), or by solubility with respect to the indicated mineral phase.

[c] NA = Not applicable.

[d] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution: $mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

[e] carb.SS is carbonate solid solution which includes calcite, magnesite, rhodochrosite, siderite, strontianite, and smithsonite components.

TABLE D.1-11

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - PIT 2

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
pH	10.3 SU	NA[c]	6.52 SU	EQ3/6
Eh	-0.108 V	NA	+0.415 V	EQ3/6
Ammonia	275.	ISL	275.	ISL
Antimony	0.571	ISL	0.571	ISL
Arsenic	0.0677	ISL	0.0677	ISL
Barium	0.449	ISL	0.1564	barite
Beryllium	0.0057	ISL	0.004	BeO
Boron	2.82	ISL	2.82	ISL
Cadmium	0.279	ISL	0.279	ISL
Cesium-137	1.2×10^{-10}	mdl-ISL	1.2×10^{-10}	mdl-ISL
Chromium	0.0889	ISL	4.59×10^{-4}	CrO_2
Cobalt	0.595	ISL	0.595	ISL
Copper	0.145	ISL	0.145	ISL
Cyanide	0.0316	ISL	0.0316	ISL
Lead	0.0183	ISL	0.0183	ISL
Manganese	4.52	ISL	3.93×10^{-3}	carb.SS[d]
Mercury	0.0046	ISL	9.8×10^{-11}	calomel
Molybdenum	1.57	ISL	1.57	ISL
Neptunium-237[e]				
Nickel	0.189	ISL	0.189	ISL
Nitrate	4,650.	ISL	4,650.	ISL
Plutonium-238	2.9×10^{-11}	mdl-ISL	6.59×10^{-11}	PuO_2
Plutonium-239 and 240	8.03×10^{-9}	mdl-ISL	6.59×10^{-11}	PuO_2
Radium-226[e]	2.82×10^{-7}	ISL	2.82×10^{-7}	ISL

TABLE D.1-11
(Continued)

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Ruthenium-106	2.24×10^{-11}	mdl-ISL	2.24×10^{-11}	mdl-ISL
Selenium	0.0583	ISL	0.0583	ISL
Silver	0.115	ISL	0.115	ISL
Strontium-90[e]	4.7×10^{-11}	ISL	3.14×10^{-14}	carb.ss
Technetium-99[e]	5.33×10^{-6}	TCLP	5.33×10^{-6}	TCLP
Thallium	0.0055	ISL	0.0055	ISL
Thorium-230	9.3×10^{-8}	TCLP	2.05×10^{-9}	ThO_2
Thorium-232	0.0046	mdl-TCLP	2.05×10^{-9}	ThO_2
Thorium-Total[e]	0.0084	TCLP	2.05×10^{-9}	thorianite
Tin				
Uranium-234[e]	1.74×10^{-4}	ISL	1.74×10^{-4}	ISL
Uranium-235[e]	3.68×10^{-2}	ISL	3.68×10^{-2}	ISL
Uranium-238[e]	3.73	ISL	3.73	ISL
Uranium-Total[e]	3.65	ISL	3.65	ISL
Vanadium	0.334	ISL	0.334	ISL
Zinc	0.063	ISL	2.44×10^{-4}	carb.SS

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by EQ3/6 Geochemical Code (EQ3/6) Toxicity Characteristic Leaching Procedure (TCLP), in situ leachate (ISL), maximum detection limit (mdl), US EPA 70-year rule, or by solubility with respect to the indicated mineral phase.

[c] NA = Not applicable.

[d] carb.SS is carbonate solid solution which includes calcite, magnesite, rhodochrosite, siderite, strontianite, and smithsonite components.

[e] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution: $mg/\ell = 2.798 \times 10^{-15} \bullet$(gram formula wt)$\bullet$(Activity in pCi/ℓ)$\bullet$(half-life in years)

[f] No concentration units have been specified for F and NO_3 in the data sets but these are assumed in ppm of mg/ℓ.

TABLE D.1-12

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - PIT 3

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
pH	7.7 SU	NA[c]	6.54 SU	EQ3/6
Eh	+0.115 V	NA	+0.118 V	EQ3/6
Ammonia	2,625.	ISL	2,625.	ISL
Antimony	0.656	ISL	0.656	ISL
Arsenic	1.49	ISL	1.49	ISL
Barium	0.526	ISL	0.061	barite
Beryllium	0.0081	ISL	0.0041	BeO
Boron	5.48	ISL	5.48	ISL
Cadmium	0.311	ISL	0.311	ISL
Cesium-137[d]				
Chromium	0.182	ISL	0.182	ISL
Cobalt	0.137	ISL	0.137	ISL
Copper	0.782	ISL	0.782	ISL
Cyanide	1.27	ISL	1.27	ISL
Lead	1.61	ISL	1.61	ISL
Manganese	132.	ISL	0.197	carb.SS[e]
Mercury	0.0988	ISL	2.16×10^{-11}	calomel
Molybdenum	2.8	ISL	2.8	ISL
Nickel	0.0473	ISL	0.0473	ISL
Nitrate	6,574.	ISL	6,574.	ISL
Plutonium-238[d]	2.9×10^{-11}	mdl-ISL	2.9×10^{-11}	mdl-ISL
Plutonium-239 and 240	8.03×10^{-9}	mdl-ISL	6.9×10^{-11}	PuO_2
Radium-226[d]	1.95×10^{-8}	TCLP	1.95×10^{-8}	TCLP

TABLE D.1-12
(Continued)

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Ruthenium-106[d]				
Selenium	0.14	ISL	0.14	ISL
Silver	0.165	ISL	0.0285	Ag
Strontium-90[d]	7.5×10^{-10}	ISL	8.3×10^{-13}	carb.SS
Technetium-99[d]	2.06×19^{-5}	ISL	2.06×10^{-5}	ISL
Thallium	0.107	ISL	0.107	ISL
Thorium-230[d]	5.5×10^{-8}	TCLP	1.95×10^{-9}	ThO_2
Thorium-232[d]	0.0046	mdl-TCLP	1.95×10^{-9}	ThO_2
Thorium-Total[d]	0.0029	mdl-TCLP	1.95×10^{-9}	ThO_2
Tin	0.2	ISL	0.2	ISL
Uranium-234[d]	2.57×10^{-4}	ISL	2.57×10^{-4}	ISL
Uranium-235[d]	0.0367	ISL	0.0367	ISL
Uranium-238[d]	7.42	ISL	7.42	ISL
Uranium-Total[d]	4.96	ISL	4.96	ISL
Vanadium	1.24	ISL	1.24	ISL
Zinc	0.158	ISL	1.16×10^{-3}	carb.SS

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by EQ3/6 Geochemical Code (EQ3/6) Toxicity Characteristic Leaching Procedure (TCLP), in situ leachate (ISL), maximum detection limit (mdl), US EPA 70-year rule, or by solubility with respect to the indicated mineral phase.

[c] NA = Not applicable.

[d] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution:
$mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

[e] carb.SS is carbonate solid solution which includes calcite, magnesite, rhodochrosite, siderite, strontianite, and smithsonite components.

TABLE D.1-13

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - PIT 4

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
pH	7.1 SU	NA[c]	6.88 SU	EQ3/6
Eh	0.2221 V	NA	+0.257 V	EQ3/6
Ammonia	81.2	ISL	81.2	ISL
Antimony	0.956	ISL	0.956	ISL
Arsenic	0.0025	ISL	0.0025	ISL
Barium	2.79	ISL	0.0441	barite
Beryllium	0.0809	ISL	7.12×10^{-4}	ISL
Boron	2.93	ISL	2.93	ISL
Cadmium	0.118	ISL	0.118	ISL
Cesium-137[d]				
Chromium	2.22	ISL	0.0406	CrO_2
Cobalt	0.338	ISL	0.338	ISL
Copper	0.643	ISL	0.643	ISL
Cyanide	0.0265	ISL	0.0265	ISL
Lead	0.002	ISL	0.002	ISL
Manganese	588.	ISL	5.98×10^{-3}	carb.SS[e]
Mercury	0.0002	ISL	8.8×10^{-9}	calomel
Molybdenum	0.629	ISL	0.629	ISL
Neptunium-237[d]	5.11×10^{-7}	TCLP	1.45×10^{-9}	NpO_2
Nickel	2.13	ISL	2.13	ISL
Nitrate	7.3	ISL	7.3	ISL
Plutonium-238[d]	2.86×10^{-11}	mdl-ISL	2.86×10^{-11}	mdl-ISL
Plutonium-239 and 240	8.03×10^{-9}	mdl-ISL	1.01×10^{-10}	PuO_2
Radium-226[d]	9.4×10^{-9}	ISL	9.4×10^{-9}	ISL

TABLE D.1-13
(Continued)

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Ruthenium-106[d]				
Selenium	0.0025	ISL	0.0025	ISL
Silver	1.16	ISL	0.056	Ag
Strontium-90[d]	1.22×10^{-10}	ISL	7.31×10^{-13}	carb.SS
Technetium-99[d]	2.07×10^{-5}	ISL	2.07×10^{-5}	ISL
Thallium				
Thorium-230[d]	2.7×10^{-7}	ISL	2.1×10^{-9}	ThO_2
Thorium-232[d]	0.0087	mdl-ISL	2.1×10^{-9}	ThO_2
Thorium-Total[d]	0.017	ISL	2.1×10^{-9}	thorianite
Tin	0.2	mdl-ISL	0.2	mdl-ISL
Uranium-234[d]	0.0238	ISL	0.0238	ISL
Uranium-235[d]	12.7	ISL	12.7	ISL
Uranium-238[d]	1,280	ISL	1,280	ISL
Uranium-Total[d]	500	ISL	500	ISL
Vanadium	0.929	ISL	0.0145	carb.SS
Zinc	0.412	ISL	0.412	ISL

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by EQ3/6 Geochemical Code (EQ3/6) Toxicity Characteristic Leaching Procedure (TCLP), in situ leachate (ISL), maximum detection limit (mdl), US EPA 70-year rule, or by solubility with respect to the indicated mineral phase.

[c] NA = Not applicable.

[d] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution:
$mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

[e] carb.SS is carbonate solid solution which includes calcite, magnesite, rhodochrosite, siderite, strontianite, and smithsonite components.

TABLE D.1-14

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - PIT 5

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Antimony	0.1577	TCLP	0.1577	TCLP
Arsenic	0.00928	TCLP	0.00928	TCLP
Barium	0.628	TCLP	0.628	TCLP
Beryllium	0.0198	TCLP	0.0198	TCLP
Boron				
Cadmium	0.0094	TCLP	0.0094	TCLP
Cesium-137[c]	1.04×10^{-9}	SW	1.04×10^{-9}	SW
Chromium	0.0243	TCLP	0.0243	TCLP
Cobalt	0.0748	TCLP	0.0748	TCLP
Copper	0.9478	TCLP	0.9478	TCLP
Cyanide	8.70	SW	8.70	SW
Lead	0.0177	TCLP	0.0177	TCLP
Manganese	2.4135	TCLP	2.4135	TCLP
Mercury	0.0218	TCLP	0.0218	TCLP
Molybdenum	1.15×10^{-2}	70-year	1.15×10^{-2}	70-year
Neptunium-237[c]	5.0×10^{-7}	mdl-SW	5.0×10^{-7}	mdl-SW
Nickel	0.3025	TCLP	0.3025	TCLP
Plutonium-238[c]	2.8×10^{-12}	mdl-SW	2.8×10^{-12}	mdl-SW
Plutonium-239 and 240[c]	8×10^{-10}	mdl-SW	8×10^{-10}	mdl-SW
Radium-226[c]	1.95×10^{-5}	70-year	1.95×10^{-5}	70-year
Ruthenium-106[c]	1.27×10^{-11}	mdl-SW	1.27×10^{-11}	mdl-SW
Selenium	0.0021	SW	0.0021	SW

TABLE D.1-14
(Continued)

Element	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Silver	3.35×10^{-3}	mdl-SW	3.35×10^{-3}	mdl-SW
Strontium-90[c]	2.9×10^{-10}	SW	2.9×10^{-10}	SW
Technetium-99[c]	1.88×10^{-5}	SW	1.88×10^{-5}	SW
Thallium	5.5×10^{-4}	mdl-SW	5.5×10^{-4}	mdl-SW
Thorium-230[c]	5.14×10^{-9}	SW	5.14×10^{-9}	SW
Thorium-232[c]	4.6×10^{-4}	mdl-SW	4.6×10^{-4}	mdl-SW
Tin	8.29	70-year	8.29	70-year
Uranium-234[c]	6.79×10^{-5}	SW	6.79×10^{-5}	SW
Uranium-235[c]	0.0089	SW	0.0089	SW
Uranium-238[c]	1.2	SW	1.2	SW
Vanadium	1.4388	TCLP	1.4388	TCLP
Zinc	0.3338	TCLP	0.3338	TCLP

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by Toxicity Characteristic Leaching Procedure (TCLP), surface water (SW), the maximum detection limit (mdl), US EPA 70-year rule (70-year), or by solubility with respect to the indicated mineral phase.

[c] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution:
$mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

TABLE D.1-15

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - PIT 6

Constituent	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Antimony				
Arsenic	0.6316	TCLP	0.6316	TCLP
Barium	1.9559	TCLP	1.9559	TCLP
Beryllium	0.0204	TCLP	0.0204	TCLP
Boron				
Cadmium	9.5×10^{-4}	mdl-SW	9.5×10^{-4}	mdl-SW
Cesium-137[c]	8.6×10^{-11}	mdl-SW	8.6×10^{-11}	mdl-SW
Chromium	2.2×10^{-3}	mdl-SW	2.2×10^{-3}	mdl-SW
Cobalt	4.75×10^{-3}	mdl-SW	4.75×10^{-3}	mdl-SW
Copper	0.006	mdl-SW	0.006	mdl-SW
Cyanide				
Lead	0.6914	TCLP	0.6914	TCLP
Manganese	2.008	TCLP	2.008	TCLP
Mercury				
Molybdenum				
Neptunium-237[c]	1.06×10^{-5}	mdl-SW	1.06×10^{-5}	mdl-SW
Nickel	0.165	TCLP	0.165	TCLP
Plutonium-238[c]	1.1×10^{-11}	mdl-SW	1.1×10^{-11}	mdl-SW
Plutonium-239 and 240[c]	8×10^{-10}	mdl-SW	8×10^{-10}	mdl-SW
Radium-226[c]	5.0×10^{-11}	mdl-SW	5.0×10^{-11}	mdl-SW
Ruthenium-106[c]				
Selenium				

TABLE D.1-15
(Continued)

Constituent	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Silver	0.0667	TCLP	0.0667	TCLP
Strontium-90[c]	7.0×10^{-12}	mdl-SW	7.0×10^{-12}	mdl-SW
Technetium-99[c]	1.612×10^{-4}	SW	1.612×10^{-4}	SW
Thallium	0.7535	TCLP	0.7535	TCLP
Thorium-230[c]	1.5×10^{-8}	SW	1.5×10^{-8}	SW
Thorium-232[c]	4.6×10^{-4}	mdl-SW	4.6×10^{-4}	mdl-SW
Tin	1.30	70-year	1.30	70-year
Uranium-234[c]	1.377E-05	SW	1.377×10^{-5}	SW
Uranium-235[c]	4.62×10^{-3}	SW	4.62×10^{-3}	SW
Uranium-238[c]	1.496	SW	1.496	SW
Vanadium	7.0×10^{-3}	mdl-SW	7.0×10^{-3}	mdl-SW
Zinc	1.7918	TCLP	1.7918	TCLP

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is Toxicity Characteristic Leaching Procedure (TCLP), surface water (SW), maximum detection limit (mdl), or by the US EPA 70-year rule (70-year).

[c] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution:
$mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

TABLE D.1-16

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - BURN PIT

Constituent	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
pH	12.16 SU	NA[c]	6.84SU	EQ3/6
Eh	+0.1377 V	NA	+0.259 V	EQ3/6
Antimony	0.103	ISL	0.103	ISL
Arsenic	0.0494	ISL	0.0494	ISL
Barium	8.3836	ISL	0.035	barite
Beryllium	0.0082	ISL	8.22×10^{-4}	BeO
Boron	2.12	ISL	2.12	ISL
Cadmium	0.0197	ISL	0.0197	ISL
Cesium-137[d]				
Chromium	0.129	ISL	0.129	ISL
Cobalt	0.0377	ISL	0.0377	ISL
Copper	0.118	ISL	0.118	ISL
Cyanide	3.6	ISL	3.6	ISL
Lead	0.0981	ISL	0.0113	$PbCO_3$
Manganese	2.96	ISL	0.0298	carb.SS[e]
Mercury	3.0×10^{-4}	ISL	2.4×10^{-8}	calomel
Molybdenum	1.05	ISL	1.05	ISL
Neptunium-237[d]	3.9×10^{-7}	mdl-ISL	1.5×10^{-9}	NpO_2
Nickel	0.299	ISL	0.299	ISL
Nitrate	5.7	ISL	5.7	ISL
Plutonium-238[d]	2.86×10^{-11}	mdl-ISL	2.86×10^{-11}	mdl-ISL
Plutonium-239 and 240[d]	8.03×10^{-9}	mdl-ISL	9.1×10^{-11}	PuO_2
Radium-226[d]	7.34×10^{-8}	ISL	7.34×10^{-8}	ISL
Ruthenium-106[d]				

TABLE D.1-16
(Continued)

Constituent	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Selenium	0.0038	ISL	0.0038	ISL
Silver	0.107	ISL	2.06×10^{-3}	Ag
Strontium-90[d]	1.8×10^{-11}	mdl-ISL	1.67×10^{-13}	carb.SS
Technetium-99[d]	1.47×10^{-6}	TCLP	1.47×10^{-6}	TCLP
Thorium-230[d]	1.13×10^{-7}	TCLP	2.12×10^{-9}	ThO_2
Thorium-232S[d]	0.0110	TCLP	2.12×10^{-9}	ThO_2
Thorium-Total[d]	0.0106	TCLP	2.12×10^{-9}	ThO_2
Tin				
Uranium-234[d]	1.46×10^{-4}	ISL	1.46×10^{-4}	ISL
Uranium-235[d]	3.04×10^{-2}	ISL	3.04×10^{-2}	ISL
Uranium-238[d]	2.95	ISL	2.95	ISL
Uranium-Total[d]	2.87	ISL	2.87	ISL
Vanadium	0.0743	ISL	0.0743	ISL
Zinc	0.253	ISL	0.0110	carb.SS

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by EQ3/6 Geochemical Code (EQ3/6) Toxicity Characteristic Leaching Procedure (TCLP), in situ leachate (ISL), maximum detection limit (mdl), US EPA 70-year rule, or by solubility with respect to the indicated mineral phase.

[c] NA = Not applicable.

[d] Radioactive constituent. Formula for conversion of aqueous radioactivity to concentration of radionuclide in solution:
$mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

[e] carb.SS is carbonate solid solution which includes calcite, magnesite, rhodochrosite, siderite, strontianite, and smithsonite components.

TABLE D.1-17

LEACHATE A AND LEACHATE B COMPOSITIONS FOR INORGANICS AND RADIONUCLIDES IN OPERABLE UNIT 1 - THE CLEARWELL

Constituent	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Antimony	7.0×10^{-4}	mdl-SW	7.0×10^{-4}	mdl-SW
Arsenic	0.0042	SW	0.0042	SW
Barium	1.35×10^{-2}	mdl-SW	1.35×10^{-2}	mdl-SW
Beryllium	5.0×10^{-4}	mdl-SW	5.0×10^{-4}	mdl-SW
Boron				
Cadmium	9.5×10^{-4}	mdl-SW	9.5×10^{-4}	mdl-SW
Cesium-137[c]	7.0×10^{-11}	mdl-SW	7.0×10^{-11}	mdl-SW
Chromium	0.0022	mdl-SW	0.0022	mdl-SW
Cobalt	4.75×10^{-3}	mdl-SW	4.75×10^{-3}	mdl-SW
Copper	0.019	SW	0.019	SW
Cyanide	0.087	SW	0.087	SW
Lead	5.5×10^{-4}	mdl-SW	5.5×10^{-4}	mdl-SW
Manganese	0.02	SW	0.02	SW
Mercury	1.0×10^{-4}	mdl-SW	1.0×10^{-4}	mdl-SW
Molybdenum	5.28	70-year	5.28	70-year
Nickel	9.0×10^{-3}	mdl-SW	9.0×10^{-3}	mdl-SW
Neptunium-237[c]	4.51×10^{-4}	70-year	4.51×10^{-4}	70-year
Plutonium-238[c]	1.1×10^{-11}	mdl-SW	1.1×10^{-11}	mdl-SW
Plutonium-239 and 240[c]	4.8×10^{-9}	mdl-SW	4.8×10^{-9}	mdl-SW
Radium-226[c]	1.1×10^{-9}	SW	1.1×10^{-9}	SW
Ruthenium-106[c]				
Selenium	0.003	SW	0.003	SW

TABLE D.1-17
(Continued)

Constituent	Leachate A Concentration[a]	Constraint[b]	Leachate B Concentration[a]	Constraint[b]
Silver	0.014	SW	0.014	SW
Strontium-90[c]	1.06×10^{-11}	mdl-SW	1.06×10^{-11}	mdl-SW
Technetium-99[c]	2.36×10^{-4}	SW	2.36×10^{-4}	SW
Thallium	5.5E-04	mdl-SW	5.5×10^{-4}	mdl-SW
Thorium-230[c]	2.06E-08	SW	2.06×10^{-8}	SW
Thorium-232[c]	4.6E-04	mdl-SW	4.6×10^{-4}	mdl-SW
Tin	2.62	70-year	2.62	70-year
Uranium-234[c]	3.07×10^{-4}	SW	3.07×10^{-4}	SW
Uranium-235[c]	0.056	SW	0.056	SW
Uranium-238[c]	18.6	SW	18.6	SW
Vanadium	0.513	SW	0.513	SW
Zinc	0.047	SW	0.047	SW

[a] Element concentrations in milligrams per liter (ppm), pH in standard units (SU), and Eh in Volts (V). Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.

[b] Constraint on reported concentration is by the maximum detection limit (mdl), surface water (SW), or by US EPA 70-year rule (70-year).

[c] Radioactive constituent. Formula for conversion of aqueous radioactivity to aqueous concentration of radionuclide:
$mg/\ell = 2.798 \times 10^{-15} \bullet (\text{gram formula wt.}) \bullet (\text{Activity in pCi}/\ell) \bullet (\text{half-life in years})$

TABLE D.1-18

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - PIT 1

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran	6×10^{-4}	ISL
2,3,4,7,8-pentachlorodibenzofuran	9×10^{-4}	ISL
2,4,5-trichlorophenol		
4,4'-DDT	0.5	mdl-ISL
4-Nitroaniline		
4-Nitrophenol		
Acenaphthene		
Acenaphthylene		
Anthracene	40	mdl-ISL
Aroclor-1221	2.5	mdl-ISL
Aroclor-1242		
Aroclor-1248	3.1	ISL
Aroclor-1254	5	mdl-ISL
Aroclor-1260	5	mdl-ISL
Benzo(a)anthracene	40	mdl-ISL
Benzo(a)pyrene	40	mdl-ISL
Benzo(b)fluoranthene	40	mdl-ISL
Benzo(g,h,i)perylene		
Benzo(k)fluoranthene	40	mdl-ISL
Chrysene	40	mdl-ISL
Dibenzo(a,h)anthracene		
Dichlorodifluoromethane	200	mdl-ISL
Fluoranthene	40	mdl-ISL
Fluorene		

TABLE D.1-18
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran	1.7×10^{-3}	mdl-ISL
Heptachlorodibenzo-p-dioxin	3.4×10^{-3}	mdl-ISL
Hexachlorodibenzofuran	1.4×10^{-3}	mdl-ISL
Hexachlorodibenzo-p-dioxin	2.2×10^{-3}	mdl-ISL
Indeno(1,2,3-cd)pyrene		
Naphthalene	40	mdl-ISL
Octachlorodibenzofuran	6×10^{-4}	ISL
Octachlorodibenzo-p-dioxin	1.6×10^{-3}	ISL
Pentachlorophenol		
Phenanthrene	40	mdl-ISL
Pyrene	40	mdl-ISL
Tetrachlorodibenzofuran	1.24×10^{-2}	ISL
Tetrachloroethene	47	ISL
Vinyl Chloride		

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-19

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - PIT 2

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran	1×10^{-3}	mdl-ISL
2,3,4,7,8-pentachlorodibenzofuran		
2,4,5-trichlorophenol		
4,4'-DDT	1	mdl-ISL
4-Nitroaniline	50	mdl-ISL
4-Nitrophenol	50	mdl-ISL
Acenaphthene	12	ISL
Acenaphthylene	5	ISL
Anthracene	2	ISL
Aroclor-1221		
Aroclor-1242		
Aroclor-1248	0.5	mdl-ISL
Aroclor-1254	1	mdl-ISL
Aroclor-1260		
Benzo(a)anthracene	10	mdl-ISL
Benzo(a)pyrene	10	mdl-ISL
Benzo(b)fluoranthene	10	mdl-ISL
Benzo(g,h,i)perylene	10	mdl-ISL
Benzo(k)fluoranthene	10	mdl-ISL
Chrysene	10	mdl-ISL
Dibenzo(a,h)anthracene	10	mdl-ISL
Dichlorodifluoromethane		
Fluoranthene	9	ISL
Fluorene	6	ISL

TABLE D.1-19
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran	9×10^{-4}	ISL
Heptachlorodibenzo-p-dioxin	3.6×10^{-3}	mdl-ISL
Hexachlorodibenzofuran	1.7×10^{-3}	mdl-ISL
Hexachlorodibenzo-p-dioxin	3×10^{-3}	mdl-ISL
Indeno(1,2,3-cd)pyrene	10	mdl-ISL
Naphthalene	10	mdl-ISL
Octachlorodibenzofuran	7E-04	ISL
Octachlorodibenzo-p-dioxin	4.2E-03	ISL
Pentachlorophenol	50	mdl-ISL
Phenanthrene	10	mdl-ISL
Pyrene	7	ISL
Tetrachlorodibenzofuran		
Tetrachloroethene	5	mdl-ISL
Vinyl Chloride	160	ISL

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-20

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - PIT 3

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran		
2,3,4,7,8-pentachlorodibenzofuran		
2,4,5-trichlorophenol		
4,4'-DDT		
4-Nitroaniline		
4-Nitrophenol		
Acenaphthene		
Acenaphthylene	10	mdl-TCLP
Anthracene	10	mdl-ISL
Aroclor-1221		
Aroclor-1242		
Aroclor-1248	5	mdl-ISL
Aroclor-1254	10	mdl-ISL
Aroclor-1260		
Benzo(a)anthracene	10	mdl-ISL
Benzo(a)pyrene	10	mdl-ISL
Benzo(b)fluoranthene	10	mdl-ISL
Benzo(g,h,i)perylene	10	mdl-ISL
Benzo(k)fluoranthene		
Chrysene	5	mdl-ISL
Dibenzo(a,h)anthracene		
Dichlorodifluoromethane		
Fluoranthene	10	mdl-ISL
Fluorene		

TABLE D.1-20
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran	1.5×10^{-3}	ISL
Heptachlorodibenzo-p-dioxin	3.5×10^{-3}	ISL
Hexachlorodibenzofuran	1.7×10^{-3}	mdl-ISL
Hexachlorodibenzo-p-dioxin	1.2×10^{-3}	mdl-ISL
Indeno(1,2,3-cd)pyrene	10	mdl-ISL
Naphthalene		
Octachlorodibenzofuran		
Octachlorodibenzo-p-dioxin		
Pentachlorophenol	7.09×10^{2}	70-year
Phenanthrene	10	mdl-ISL
Pyrene	10	mdl-ISL
Tetrachlorodibenzofuran	5.7×10^{-4}	mdl-ISL
Tetrachloroethene	2.0	ISL
Vinyl Chloride		

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-21

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - PIT 4

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran	1×10^{-3}	mdl-ISL
2,3,4,7,8-pentachlorodibenzofuran	1.1×10^{-3}	mdl-ISL
2,4,5-trichlorophenol		
4,4'-DDT		
4-Nitroaniline		
4-Nitrophenol	10	mdl-ISL
Acenaphthene	12	ISL
Acenaphthylene		
Anthracene	17	ISL
Aroclor-1221		
Aroclor-1242	50	mdl-ISL
Aroclor-1248	50	mdl-ISL
Aroclor-1254	100	mdl-ISL
Aroclor-1260		
Benzo(a)anthracene	10	mdl-ISL
Benzo(a)pyrene	10	mdl-ISL
Benzo(b)fluoranthene	10	mdl-ISL
Benzo(g,h,i)perylene	10	mdl-ISL
Benzo(k)fluoranthene	10	mdl-ISL
Chrysene	10	mdl-ISL
Dibenzo(a,h)anthracene	10	mdl-ISL
Dichlorodifluoromethane		
Fluoranthene	2	ISL
Fluorene	9	ISL

TABLE D.1-21
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran	2.4×10^{-3}	mdl-ISL
Heptachlorodibenzo-p-dioxin	9.4×10^{-4}	mdl-ISL
Hexachlorodibenzofuran	1.2×10^{-3}	mdl-ISL
Hexachlorodibenzo-p-dioxin	7.5×10^{-4}	mdl-ISL
Indeno(1,2,3-cd)pyrene	10	mdl-ISL
Naphthalene	16	ISL
Octachlorodibenzofuran	9×10^{-4}	mdl-ISL
Octachlorodibenzo-p-dioxin	1.2×10^{-3}	mdl-ISL
Pentachlorophenol		
Phenanthrene	10	mdl-ISL
Pyrene	10	mdl-ISL
Tetrachlorodibenzofuran	1.7×10^{-3}	mdl-ISL
Tetrachloroethene	140	ISL
Vinyl Chloride	6.0	ISL

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-22

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - PIT 5

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran		
2,3,4,7,8-pentachlorodibenzofuran		
2,4,5-trichlorophenol		
4,4'-DDT		
4-Nitroaniline		
4-Nitrophenol		
Acenaphthene		
Acenaphthylene		
Anthracene		
Aroclor-1221		
Aroclor-1242		
Aroclor-1248	0.5	mdl-CISsw
Aroclor-1254	1	mdl-CISsw
Aroclor-1260		
Benzo(a)anthracene		
Benzo(a)pyrene		
Benzo(b)fluoranthene		
Benzo(g,h,i)perylene		
Benzo(k)fluoranthene		
Chrysene		
Dibenzo(a,h)anthracene		
Dichlorodifluoromethane		
Fluoranthene		
Fluorene		

TABLE D.1-22
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran		
Heptachlorodibenzo-p-dioxin		
Hexachlorodibenzofuran		
Hexachlorodibenzo-p-dioxin		
Indeno(1,2,3-cd)pyrene		
Naphthalene		
Octachlorodibenzofuran		
Octachlorodibenzo-p-dioxin		
Pentachlorophenol		
Phenanthrene		
Pyrene		
Tetrachlorodibenzofuran		
Tetrachloroethene		
Vinyl Chloride		

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-23

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - PIT 6

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran		
2,3,4,7,8-pentachlorodibenzofuran		
2,4,5-trichlorophenol		
4,4'-DDT		
4-Nitroaniline		
4-Nitrophenol		
Acenaphthene		
Acenaphthylene		
Anthracene		
Aroclor-1221		
Aroclor-1242		
Aroclor-1248		
Aroclor-1254	0.5	mdl-CISsw
Aroclor-1260		
Benzo(a)anthracene		
Benzo(a)pyrene		
Benzo(b)fluoranthene		
Benzo(g,h,i)perylene		
Benzo(k)fluoranthene		
Chrysene		
Dibenzo(a,h)anthracene		
Dichlorodifluoromethane		
Fluoranthene		
Fluorene		

TABLE D.1-23
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran		
Heptachlorodibenzo-p-dioxin		
Hexachlorodibenzofuran		
Hexachlorodibenzo-p-dioxin		
Indeno(1,2,3-cd)pyrene		
Naphthalene		
Octachlorodibenzofuran		
Octachlorodibenzo-p-dioxin		
Pentachlorophenol		
Phenanthrene		
Pyrene		
Tetrachlorodibenzofuran		
Tetrachloroethene	6	CISsw
Vinyl Chloride		

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-24

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - BURN PIT

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran		
2,3,4,7,8-pentachlorodibenzofuran		
2,4,5-trichlorophenol		
4,4'-DDT		
4-Nitroaniline		
4-Nitrophenol		
Acenaphthene	40	mdl-ISL
Acenaphthylene		
Anthracene	40	mdl-ISL
Aroclor-1221		
Aroclor-1242		
Aroclor-1248		
Aroclor-1254	20	mdl-ISL
Aroclor-1260		
Benzo(a)anthracene	40	mdl-ISL
Benzo(a)pyrene	40	mdl-ISL
Benzo(b)fluoranthene	40	mdl-ISL
Benzo(g,h,i)perylene	40	mdl-ISL
Benzo(k)fluoranthene	40	mdl-ISL
Chrysene	40	mdl-ISL
Dibenzo(a,h)anthracene		
Dichlorodifluoromethane		
Fluoranthene	40	mdl-ISL
Fluorene	40	mdl-ISL

TABLE D.1-24
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran		
Heptachlorodibenzo-p-dioxin	7.2×10^{-4}	mdl-ISL
Hexachlorodibenzofuran		
Hexachlorodibenzo-p-dioxin		
Indeno(1,2,3-cd)pyrene	40	mdl-ISL
Naphthalene	12	ISL
Octachlorodibenzofuran	1.1×10^{-3}	mdl-ISL
Octachlorodibenzo-p-dioxin	1.8×10^{-3}	mdl-ISL
Pentachlorophenol	200	mdl-ISL
Phenanthrene	40	mdl-ISL
Pyrene	40	mdl-ISL
Tetrachlorodibenzofuran		
Tetrachloroethene	2	ISL
Vinyl Chloride	1,000	mdl-ISL

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

TABLE D.1-25

ORGANIC LEACHATE CONCENTRATIONS IN OPERABLE UNIT 1 - CLEARWELL

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
1,2,3,7,8-pentachlorodibenzofuran		
2,3,4,7,8-pentachlorodibenzofuran		
2,4,5-trichlorophenol	8.96×10^2	70-year
4,4'-DDT		
4-Nitroaniline		
4-Nitrophenol		
Acenaphthene		
Acenaphthylene		
Anthracene	6.5×10^1	70-year
Aroclor-1221		
Aroclor-1242	1	mdl-CISsw
Aroclor-1248	1	mdl-CISsw
Aroclor-1254	2	mdl-CISsw
Aroclor-1260		
Benzo(a)anthracene	1.29×10^2	70-year
Benzo(a)pyrene	9.68×10^1	70-year
Benzo(b)fluoranthene	1.03×10^2	70-year
Benzo(g,h,i)perylene	3.32×10^1	70-year
Benzo(k)fluoranthene	1.08×10^2	70-year
Chrysene	1.45×10^2	70-year
Dibenzo(a,h)anthracene		
Dichlorodifluoromethane		
Fluoranthene	4.48×10^2	70-year
Fluorene	4.05×10^1	70-year

TABLE D.1-25
(Continued)

Organic Constituents	Leachate Concentrations[a,b]	Constraint[c]
Heptachlorodibenzofuran		
Heptachlorodibenzo-p-dioxin		
Hexachlorodibenzofuran		
Hexachlorodibenzo-p-dioxin		
Indeno(1,2,3-cd)pyrene	3.90×10^{1}	70-year
Naphthalene		
Octachlorodibenzofuran		
Octachlorodibenzo-p-dioxin		
Pentachlorophenol		
Phenanthrene	2.58×10^{2}	70-year
Pyrene	2.02×10^{2}	70-year
Tetrachlorodibenzofuran		
Tetrachloroethene		
Vinyl Chloride		

[a] Constituent concentrations in micrograms per liter.
[b] Blank spaces indicate that the constituent was not detected or analyzed in waste pit materials, therefore no leachate concentration was derived and the waste unit was assumed to have 0 source for that constituent.
[c] Constraint on reported concentration is by maximum detection limit (mdl), in situ leachate (ISL), CIS surface water (CISsw), or by the US EPA 70-year rule (70-year).

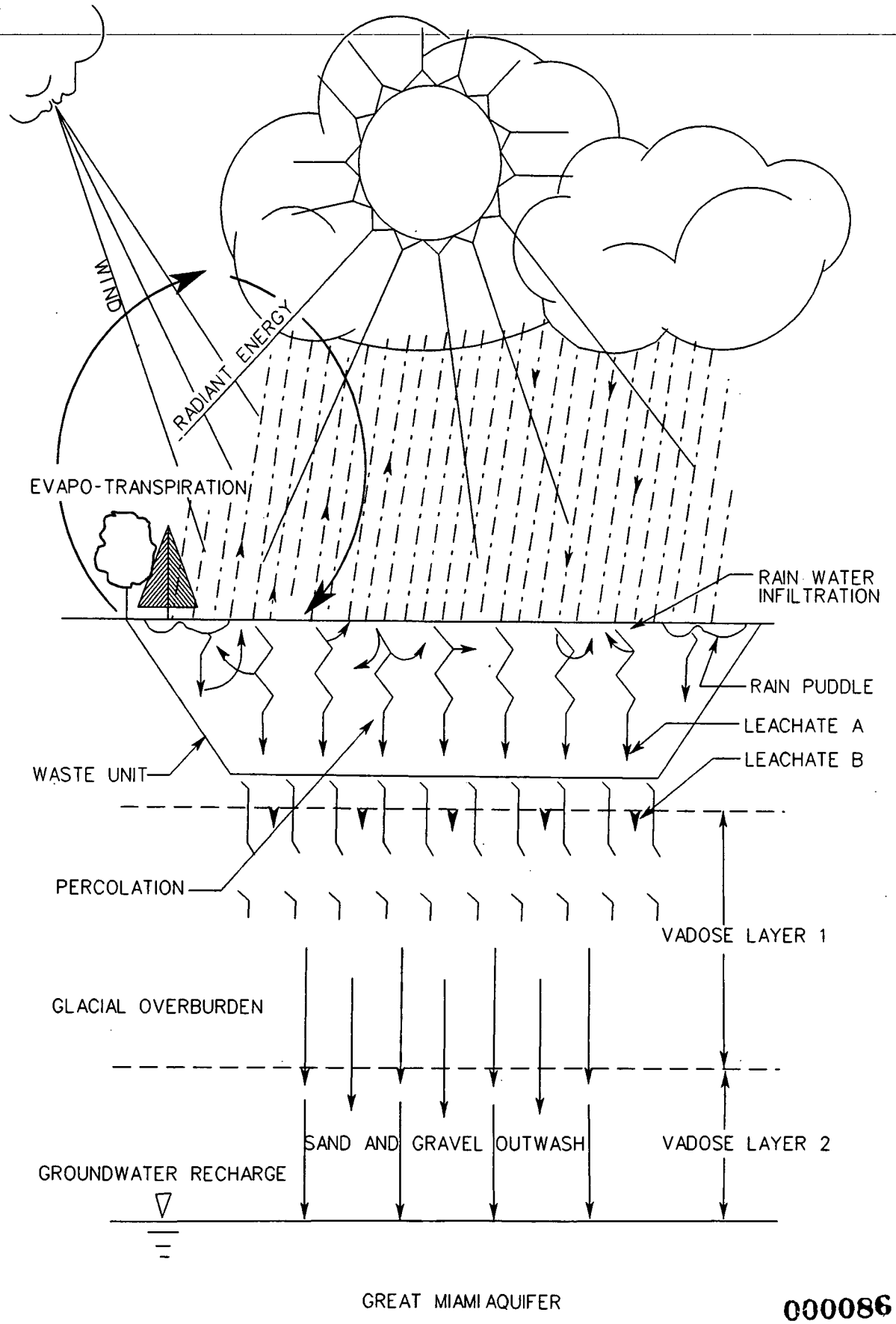

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FIGURE D.1-1. CONCEPTUAL VADOSE ZONE MODEL

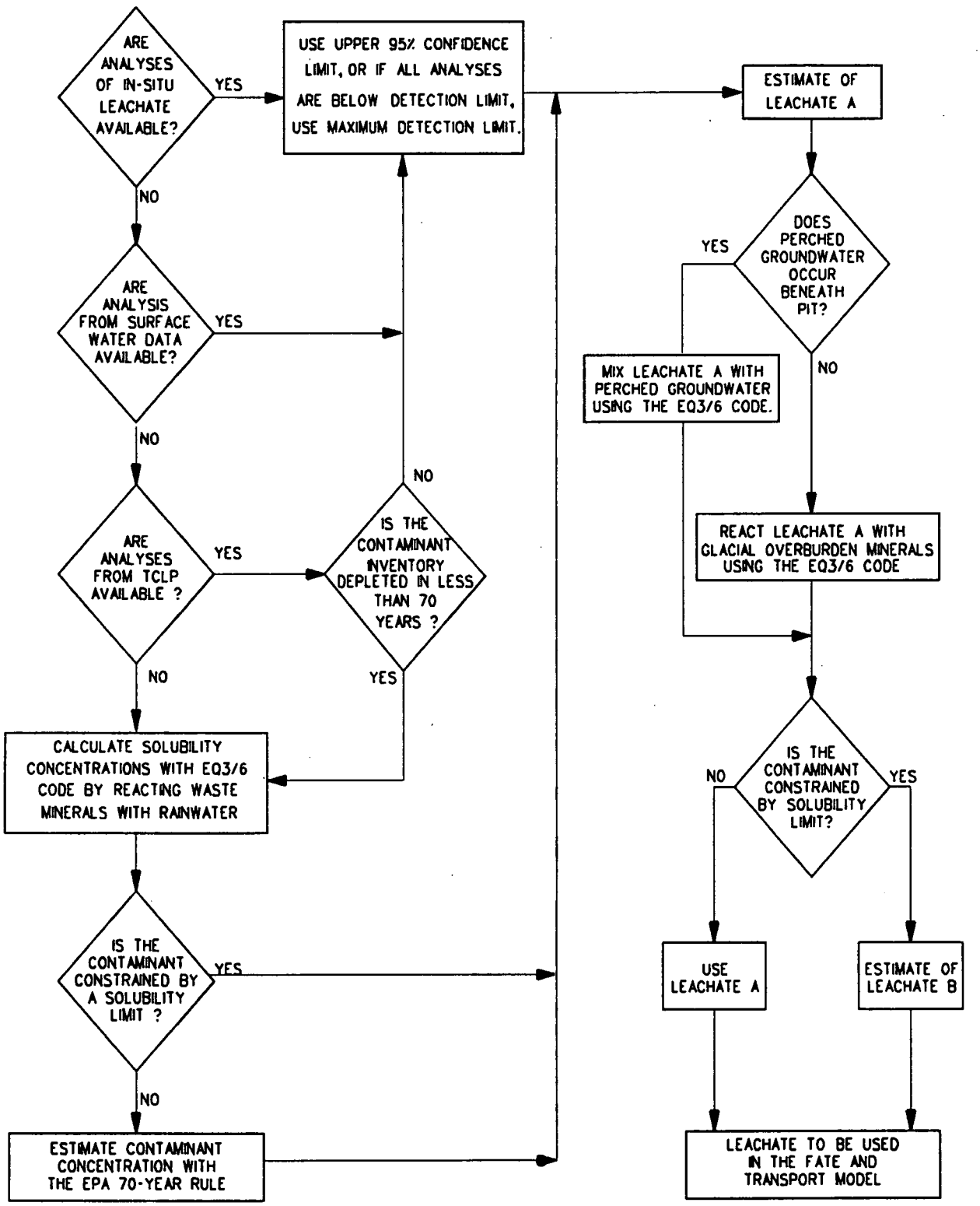

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FIGURE D.1-2. ESTIMATING LEACHATE FOR RADIONUCLIDES AND INORGANICS

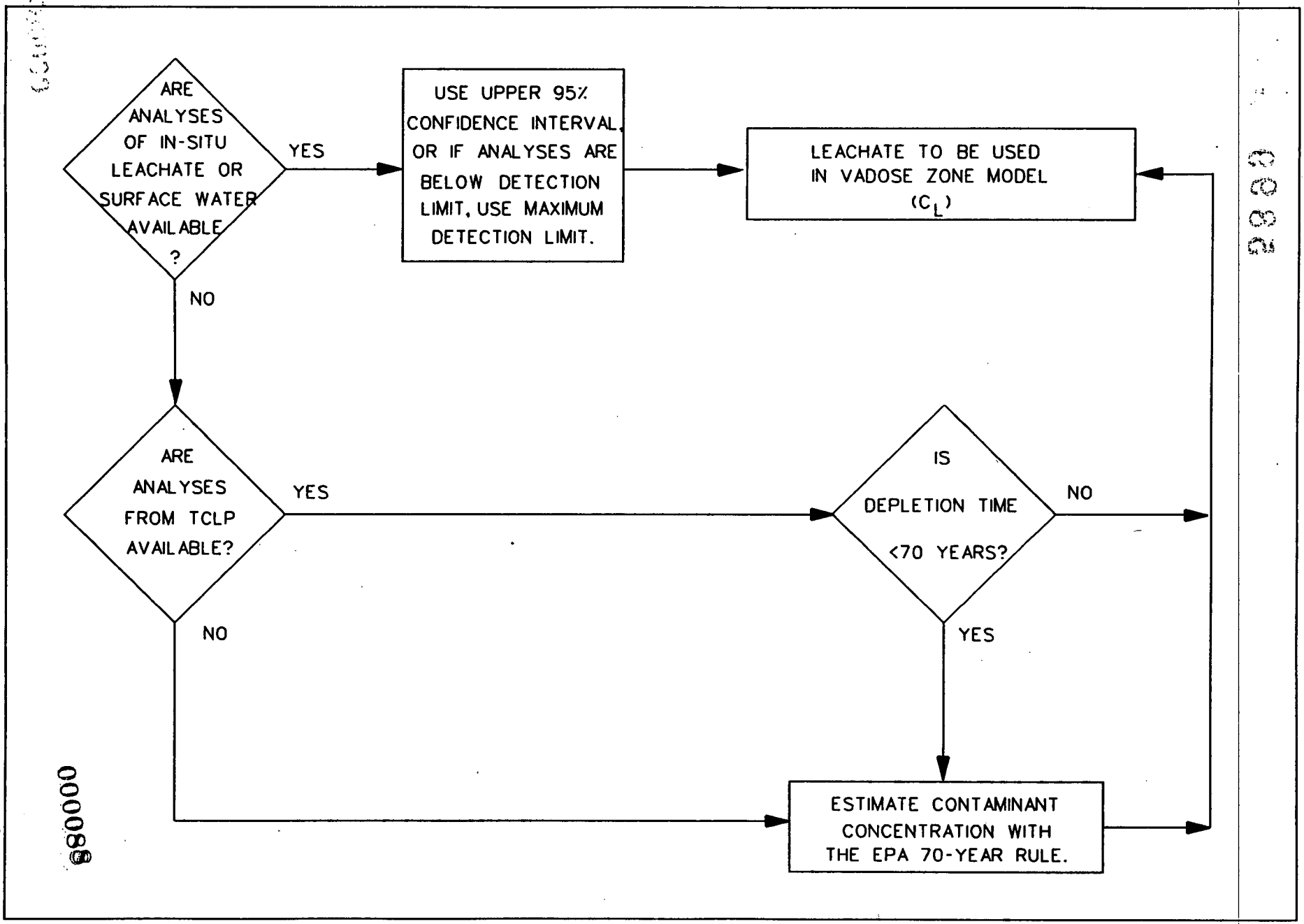

FIGURE D.1-3. ESTIMATING LEACHATE FOR ORGANICS

REFERENCES

Bowers, T. S., K. L. Von Damm, and J.M. Edmond, 1985, "Chemical Evolution of Mid-Ocean Ridge Hot Springs," Geochemica et Cosmochimica Acta, Vol. 49, pp. 2239-2252.

Daveler, S. A. and T. J. Wolery, 1992, "EQPT, A Data File Preprocessor for the EQ3/6 Software Package: User's Guide and Related Documentation (Version 7.0)", UCRL-MA-110662-PT-II (Draft 1.1), Lawrence Livermore National Laboratory, Livermore, CA.

Helgeson, 1969, "Thermodynamics of Hydrothermal Systems at Elevated Temperatures and Pressures," American Journal of Science, Vol. 267, pp. 729-804.

INTERA, 1983, "Geochemical Models Suitable for Performance Assessment of Nuclear Waste Storage: Comparison of PHREEQE and EQ3/EQ6," ONWI-473, INTERA Environmental Consultants, Houston, TX.

Jackson, K. J., 1988, "Verification and Validation Studies of the Addition of Pitzer's Equations to the EQ3/6 Brine Model," UCRL-53841, Lawrence Livermore National Laboratory, Livermore, CA.

Kerrisk, J. F., 1981, "Chemical Equilibrium Calculations for Aqueous Geothermal Brines," LA-8851-MS, Los Alamos National Laboratory, Los Alamos, NM.

Kincaid, C. T. and J.R. Morey, 1984,"Geohydrochemical Model for Solute Migration, Volume 2: Preliminary Evaluation of Selected Computer Codes," EPRI EA-3417, Electric Power Research Institute, Palo Alto, CA.

Nordstrom, D. K., 1979, "A Comparison of Computerized Chemical Models for Equilibrium Calculations on Aqueous Systems," ACS Symposium Series, American Chemical Society, Washington, D.C., Vol. 93, pp 857-892.

Solebello, L. P., 1991, "Mineralogy of Soil Core Sample, Feed Materials Production Center," Technical report issued by McCrone Associates, Inc., Fernald, OH.

U.S. Department of Energy (DOE), 1992, "Final Draft Risk Assessment Work Plan Addendum," Fernald Environmental Management Project, Remedial Investigation and Feasibility Studies, Fernald, OH.

U.S. Environmental Protection Agency (EPA), 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001, Office of Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

Wolery, T. J., 1983, "EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: User's Guide and Documentation," UCRL-53414, Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T. J, 1992a, "EQ3/6: A Software Package for Geochemical Modeling of Aqueous Systems: Package Overview and Installation Guide (Version 7.0)," UCRL-MA-110662-PT-I (Draft), Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T. J., 1992b,"EQ3NR: A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," UCRL-MA-110662-PT-III (Draft 1.1), Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T. J., 1992c, "EQ6: A Computer Program for Reaction Pathway Modeling of Aqueous Geochemical Systems: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," UCRL-MA-110662-PT-IV (Draft 1.1), Lawrence Livermore National Laboratory, Livermore, CA.

Wolery, T. J. and S. A. Daveler, 1989, "EQ6, A Computer Program for Reaction-Path Modeling of Aqueous Geochemical Systems: User's Guide and Documentation," Draft, Distribution Category UC-70, Lawrence Livermore National Laboratory, Livermore, CA.

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D.2

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D.2.0 SURFACE WATER MODELING

D.2.1 INTRODUCTION

The modeling approach used to estimate contaminant concentrations in surface water and sediment resulting from transport by surface water runoff from Operable Unit 1 is described in this section. Modeling the transport of soil by runoff requires characterization of the contaminants in the initial soil or waste source term. Based on the runoff scenarios selected, runoff and partitioning models were used to quantify the migration of contaminants from the waste source term to stream sediment and surface water from erosion by runoff effluent.

Contaminants in surface soil can be released from source areas and transported to surface water via precipitation runoff. During a rainfall event, some amount of the rainwater infiltrates the soil surface and some runs off the surface as shown in Figure D.2-1. The amount of runoff depends on soil type, vegetative cover, the amount of moisture already present in the soil, and the intensity and duration of rainfall, slope length, and slope steepness.

Contaminants in the surface soil can be transported via runoff either in the dissolved phase or adsorbed to soil particles. The less soluble a contaminant is in water, the more likely it will be adsorbed to soil particles. Because the water solubility of contaminants in Operable Unit 1 can vary widely, transport is modeled for both dissolved-phase and adsorbed-phase contaminants.

Because Paddys Run is in direct contact with the Great Miami Aquifer over a portion of its course, this section also describes the use of the surface water modeling results to define source terms for the aquifer modeling performed in Section D.3.7.

D.2.2 CONCEPTUAL MODEL

Sources that are potentially vulnerable to erosion by surface water flowing across Operable Unit 1 are the contaminated surface soils within Operable Unit 1. These soils can contribute to off-property contamination of surface water and sediment. Because Paddys Run would receive any runoff from these soils and the area of Operable Unit 1 is relatively small, these soils are treated as one large source when assessing the impact of Operable Unit 1 on water quality in Paddys Run and the Great Miami River. Surface soil contaminant concentrations

used in the surface water assessment are the upper 95 percent confidence interval on the means of the surface soil concentrations reported in each individual sample from the CIS and RI/FS surface soil data bases for Operable Unit 1 (Table D.2-1). For modeling purposes, compounds which were not detected (ND designation in Table D.2-1) in any available sample were assigned a value of zero in assigning source concentrations. For surface water modeling purposes, all of the waste areas for Operable Unit 1 were treated as a single source.

Paddys Run is an intermittent stream that begins north of the site and flows southward along the western edge of the Fernald Environmental Management Project (FEMP). Prior to the completion of Removal Action No. 2, natural drainage from Operable Unit 1 flowed to Paddys Run (Figure D.2-2). Paddys Run flows into the Great Miami River 1.5 miles south of the FEMP. Removal Action No. 2 was undertaken to minimize future runoff from reaching Paddys Run. Field work was completed for the implementation of this removal action in July 1992.

The direction of surface water flow is determined by examining the topographic map of the Operable Unit 1 Study Area presented in Figure D.2-2. Figure D.2-2 also provides information on the slope of the ground surface in the Operable Unit 1 Study Area, and the distance to the nearest receiving stream (Paddys Run).

Local meteorological data are used to obtain estimates of the amount and duration of rainfall at the site. The volume of surface water runoff flowing to Paddys Run is estimated in the surface water runoff modeling using the SCS curve method. The surface runoff modeling was based on a single storm event (6.35 cm in 24 hours; Hershfield 1961). For surface flow modeling purposes, the flow rate in Paddys Run of 410 m^3/hr generated by the storm is used.

Information on the soil types present is obtained from the soil borings in Operable Unit 1 using the U.S. Soil Conservation Service designations, which are presented in detail in Section 3.0 of this RI report. The types and areal density of vegetation in Operable Unit 1 are provided by aerial photos, site reconnaissance and interviews with personnel familiar with the Operable Unit 1 Study Area.

Many of the organic compounds found at Superfund sites are nonpolar, hydrophobic substances. Such substances tend to sorb to soils and migrate from the site more slowly than

will polar substances. Estimates of the amounts of hydrophobic substances released in site runoff were calculated using the Modified Universal Soil Loss Equation (MUSLE). Additional equations were used to describe contaminant partitioning between soil and water in the receiving water body. These partitioning models provided an estimate of the contaminant concentration in surface water runoff and in the soil that is carried with the runoff and deposited in the sediments of receiving surface water bodies (Haith 1980; Mills et al. 1982). Contaminant concentrations in Paddys Run are calculated as simple dilutions of dissolved concentrations in surface water runoff. Contaminant concentrations in the Great Miami River are calculated as simple dilutions of dissolved concentrations in Paddys Run.

D.2.3 SURFACE WATER MODEL APPLICATION

Two soil loss models obtained from the EPA "Superfund Exposure Assessment Manual" (EPA 1988), the Universal Soil Loss Equation (USLE) and MUSLE, were considered as tools to quantify soil migration. The USLE model takes the same form as MUSLE, except the USLE uses an area-dependent method to determine runoff, while MUSLE employs event-specific runoff volume and flow rate variables. The MUSLE model was chosen over the USLE model to facilitate evaluation of an event-specific worst-case conservative scenario as opposed to a yearly average contaminant transport scenario. The MUSLE model calculates the total mass of soil transported by surface water in a single rainfall event using event-specific runoff volume, storm duration, and flow rate variables.

Additional equations were used to describe contaminant partitioning between soil and water in the runoff flow. These partitioning equations provide an estimate of the contaminant concentration dissolved in water runoff and adsorbed to the soil that is carried with the runoff and deposited in the sediment of receiving surface water bodies (Haith 1980; Mills et al. 1982, Mockus 1972). The volume of runoff is also estimated to determine both the amount that stream flow may be increased by a runoff event, and to estimate dissolved contaminant loading. The depth of runoff is calculated as a function of the depth of rainfall and a soil water retention factor. In effect, the amount of water retained by the soil is subtracted from the total amount of rainfall and the remainder is available as runoff flow. A certain amount of rainfall, depending on soil conditions, is required before any runoff occurs. The dissolved contaminant concentration in the Great Miami River is estimated as a simple dilution of runoff concentration by the flow in the Great Miami River.

D.2.3.1 Model Assumptions

These models are based on the following assumptions:

- Constituents adsorbed to soils in runoff remain adsorbed in the stream sediments.
- Constituents dissolved in runoff water remain in the water column in the receiving stream.

D.2.3.2 Calculation of Soil Loss from Runoff

The soil loss model, MUSLE, obtained from the EPA "Superfund Exposure Assessment Manual," (EPA 1988), is used to model the amount of contaminated soil migrating to Paddys Run from erosion by precipitation runoff. The MUSLE model is based on the following equation.

$$Y(s)_E = (CF)[(V_r)(q_p)]^{0.56}(K)(LS)(C)(P)$$

The MUSLE employs event-specific runoff volume and flow rate variables:

$Y(s)_E$	=	Soil loss in runoff (metric tons per event)
CF	=	Conversion factor (11.8 for metric units)
V_r	=	Volume of runoff (m^3)
q_p	=	Peak runoff flow rate (m^3/s)
K	=	Soil erodibility factor (metric tons/ha/unit erosion potential
LS	=	Product of slope length factor and slope steepness factor (0.25, unitless)
C	=	Cover factor (unitless)
P	=	Erosion control practice factor (unitless)

Intermediate parameters V_r and q_p are calculated by:

$$V_r = (100)(A)(Q_r)$$

where

$$Q_r = (R_t - 0.2S_w)^2/(R_t + 0.8S_w)$$

and

$$S_w = (2.54)[(1000/CN)-10]$$

q_p is calculated by

$$q_p = [(0.028)(A)(R_t)(Q_r)]/[(T_r)(R_t - 0.2\ S_w)]$$

5899

For the calculations of V_r and q_p:

A	=	Contaminated surface area (ha)
Q_r	=	Depth of runoff (cm)
R_t	=	Depth of rainfall event (cm)
S_w	=	Soil water retention factor (cm)
CN	=	SCS runoff curve number (unitless)
T_r	=	Rainfall duration (hours)

Table D.2-2 lists the parameter values used in the Operable Unit 1 surface water runoff assessment. Based on these values, the calculated soil loss $Y(s)_E$ is 0.53 metric tons per event for the Operable Unit 1 area.

D.2.3.3 Calculation of Contaminant Partitioning and Loading

The portion of contaminant from the eroded soil that remains with the sediment or is dissolved in the water is estimated using the following equations, respectively:

$$S_s = [1/(1+\theta_c/(K_d \bullet \rho))]\ (C_i)(\rho)(A')(CF)$$

and

$$M_s = [1/(1+(K_d \bullet \rho)/\theta_c)](C_i)(\rho)(A')(CF)$$

where

S_s	=	Available quantity of contaminant absorbed to sediment (g)
M_s	=	Available quantity of contaminant dissolved in water (g)
θ_c	=	Available water capacity in top cm of soil (unitless)
K_d	=	Chemical-specific sorption partition coefficient (cm^3/g)
ρ	=	Bulk soil density (g/cm^3)
C_i	=	Concentration of contaminant in soil (mg/kg)
A'	=	Contaminated volume (ha-cm)
CF	=	Conversion factor (100 $kg/mg \bullet cm^2/ha$)

The mass of absorbed contaminant in the source area is:

$$PX_i = [Y(s)_E/100(\rho)(A')](S_s)$$

The contaminant concentration in sediment of the receiving water body is:

$$C_s = PX_i/Y(s)_E$$

where

C_s = Concentration of contaminant in sediment (mg/kg)
PX_i = Absorbed quantity of contaminant (g)

The mass of dissolved contaminant from the source area is:

$$PQ_i = M_s(Q_r/R_t)$$

where

PQ_i = Dissolved substance available per event (g)

The contaminant concentration in the runoff effluent is:

$$C_e = PQ_i/V_r$$

where

PQ_i = Dissolved substance available per event (g)
C_e = Concentration of contaminant in runoff (mg/ℓ)
V_r = Volume of runoff (m^3)

The dissolved contaminant concentration in the receiving water body (Paddys Run) downstream is:

$$C_w = (C_e)(Q_e)/(Q_t + Q_e)$$

where

C_w = Concentration of contaminant in water downstream (mg/L)
Q_e = Average runoff effluent flow rate (V_r/T_r; m^3/hr)
Q_t = Flow rate of receiving water body (m^3/hr)

The dissolved contaminant concentration in the Great Miami River is estimated by:

$$Cgmr = (C_w)(Q_t)/(Qgmr + Q_t)$$

where

Cgmr = Concentration of contaminant in the Great Miami River (mg/L)
Qgmr = Flow rate of the Great Miami River (m^3/hr)

An average flow rate of 340,000 m^3/hr was used for the Great Miami River based on previous studies (DOE 1993a). For determining the concentrations in the Great Miami River, it was conservatively assumed that flow and contaminant mass in Paddys Run empties into the Great Miami River.

D.2.4 RESULTS OF SURFACE WATER RUNOFF MODELING

Results of the surface water modeling are presented in Table D.2-3. These results show 5899 pounds per day of contaminant flowing in Paddys Run, Paddys Run sediment concentration, Paddys Run concentration, and Great Miami River concentrations. These results show ranges in Paddys Run concentrations from a minimum for cesium-137 of 2.680×10^{-14} mg/L to a maximum for uranium-238 of 2.55×10^{-1} mg/L. Since a constant dilution factor converts Paddys Run concentration to Great Miami River concentration (see discussion above), the constituents maintain the same relative concentrations in the Great Miami River although they are approximately 3 orders of magnitude lower. As shown in Table D.2-3 Paddys Run sediment is predicted to have 7.24×10^{2} mg/kg concentration of uranium-238 (the maximum constituent) and less of the remaining constituents depending on the distribution coefficient (K_d).

D.2.4.1 Comparison of Modeled Results to Measured Concentrations

Modeled concentrations in Paddys Run surface water are compared to measured concentrations for several constituents in Table D.2-4. Actual surface water concentrations are expected to vary over time, depending on the current rainfall pattern. Also, a direct comparison is limited by the scope of the surface water runoff model; only surface soil within the Operable Unit 1 Study Area are accounted for, while actual concentrations in Paddys Run result from runoff from the entire stream drainage area including upstream contributions.

Measured and modeled concentrations are consistent for the following constituents: thorium-230, thorium-232, cadmium, chromium, copper, nickel, and silver. In most of these cases, both modeled concentrations and measured concentrations in surface water samples are less than the reported detection limits for surface water samples. The modeled concentration for lead is approximately two orders of magnitude less than measured concentrations. Modeled activities for uranium-234 and uranium-238 are approximately 1 order of magnitude higher than measured activities. For lead, the modeled concentration is lower than the measured concentration which could be due to sources other than Operable Unit 1.

The fact that modeled results for several constituents are consistent with measured data suggests that the surface water runoff model is producing reasonable estimates of surface water runoff from Operable Unit 1. Comparison to measured data, however, is limited based on the discussion presented above.

D.2.5 UNCERTAINTIES IN THE SURFACE WATER MODEL

The surface water model is a mathematical tool which simplifies the actual situation. Uncertainties in the output from the model are introduced from three primary sources:

- Input Variable Uncertainty: The accuracy of the model prediction is highly dependent on the accuracy of the input variables. Input variables such as the SCS runoff curve number, rainfall and runoff factor, soil erodibility factor, slope length and steepness factor, cover factor, etc. are approximate numbers representing the physical characteristics of a given site. The chemical-specific K_d values, used to calculate the fraction of contaminants sorbed to soil particles, are another source of uncertainty.
- Modeling Uncertainty: Any mathematical model representing a physical process tends to be simplified to making approximations and assumptions. The uncertainties in model predictions will increase with increased simplification of the model. Several portions of the surface water model equations consist of empirical equations which are approximations of actual physical processes.
- Scenario Uncertainty: The assumption that the whole area of Operable Unit 1 acts as a point source of contamination, and the use of area-weighted average concentrations for the site will introduce some uncertainty in the model predictions. Another source of uncertainty and conservatism is the assumption of immediate failure of the liners for Waste Pits 1, 2, and 4.

D.2.6 PADDYS RUN LOADING TO THE GREAT MIAMI AQUIFER

Because Paddys Run lies directly in contact with the Great Miami Aquifer over a portion of its course, a contaminant migration pathway exists into the aquifer through its streambed. Migration of contaminants in surface runoff to Paddys Run from the surface soil in the Operable Unit 1 waste areas and from Paddys Run to the Great Miami Aquifer has been designated the surface water to groundwater pathway. As discussed below, a screening procedure and method of deriving the contaminant loading to the Great Miami Aquifer from Paddys Run based on the results of the surface water modeling were developed to account for this pathway in the groundwater fate and transport modeling (Section D.3.0).

D.2.6.1 Paddys Run Screening

Figure D.2-4 presents the surface water to groundwater pathway transport modeling diagram which shows the different steps that are involved in developing the source terms for CPCs and the modeling process. CPCs that follow the surface water pathway to the Great Miami Aquifer are first screened to remove constituents that pose insignificant risk. This screening is performed by taking the contaminant concentration in the runoff effluent (C_e) from

MUSLE, and applying a Great Miami Aquifer dilution factor to this concentration to determine a theoretical Great Miami Aquifer concentration. This theoretical Great Miami Aquifer concentration was then compared to 10^{-7} risk based concentrations for carcinogens or 0.1 Hazard Quotient concentrations for non-carcinogens. These screening concentrations are derived by dividing the 10^{-6} risk based concentrations or Hazard Quotient of 1 concentrations for tap water (EPA 1993) by 10. If theoretical Great Miami Aquifer concentrations are below the screening concentrations then the constituent is screened out and is not modeled in the aquifer (Table D.2-5).

The Great Miami Aquifer dilution factor is determined by a mixing equation based on the direct infiltration of 30 percent of the runoff effluent volume, prior to dilution in Paddys Run, into the Great Miami Aquifer as described below.

The predicted theoretical diluted concentration in the Great Miami Aquifer based on mixing of runoff effluent volume with the volume of water in the Great Miami Aquifer flowing in 1 Sandia Waste Isolation Flow and Transport (SWIFT) cell is:

$$C_{GMA} = (C_e)(V_{rcell})/(V_{rcell} + V_{cell})$$

where

C_{GMA}	=	Predicted theoretical diluted concentration in the Great Miami Aquifer (mg/L)
V_{cell}	=	Volume of groundwater in layer 1 of the Great Miami Aquifer in the average thickness Sandia Waste Isolation Flow and Transport (SWIFT) cell block along Paddys Run in close proximity to Operable Unit 1 (ft^3)
V_{rcell}	=	Runoff volume per SWIFT cell (ft^3/cell)

The volume of water flowing through the SWIFT cell is calculated from:

$$V_{cell} = (W_{PR})(L_{cell})(T)(\phi_{GMA})$$

where

W_{PR}	=	Average width of Paddys Run for modeling purposes (25 ft)
L_{cell}	=	Length of SWIFT cell (125 feet)
T	=	Thickness of layer 1 of the Great Miami Aquifer in SWIFT cell (34.28 ft)

ϕ_{GMA} = Porosity of the Great Miami Aquifer (25 percent)

The V_{cell} is calculated to be 2.6778×10^4 ft^3.

The runoff effluent volume per SWIFT cell along Paddys Run is estimated from:

$$V_{rcell} = (V_r)(I)/(N)$$

where

V_r	=	Runoff volume from MUSLE based on 24-hour storm event (ft^3)
I	=	Percentage of runoff effluent volume assumed to infiltrate to the Great Miami Aquifer through Paddys Run (30 percent, DOE 1993b)
N	=	Number of SWIFT cells along Paddys Run between Operable Unit 1 and the FEMP property boundary (83 cells)

The V_{rcell} is estimated as 274.01 ft^3/cell.

Table D.2-5 shows the results of the Paddys Run dilution screening of CPCs. Constituents requiring modeling with SWIFT are arsenic, technetium-99, uranium-234, and uranium-238. These contaminants represent the surface water pathway source terms for the Great Miami Aquifer modeling performed in Section D.3.7.

Table D.2-6 presents a comparison of the maximum concentration in selected wells located along Paddys Run (see Figure D.2-3) and the predicted theoretical diluted concentration in the Great Miami Aquifer. Wells 2009, 2108, 2004 and 2107 were selected based on their close proximity to Paddys Run. As shown on Table D.2-6, the predicted aquifer concentrations for the constituents of concern requiring further modeling are generally within an order of magnitude as measured concentrations in the wells with the exception of arsenic. The good correlation between measured and predicted concentrations suggests that the screening procedure produces reasonable estimates of diluted aquifer concentration from Operable Unit 1. The predicted concentration for arsenic at 5.855×10^{-6} mg/L is three orders of magnitude less than the maximum detection limit (5.000×10^{-3} mg/L), which indicates that arsenic concentrations, if present near or at the maximum detection limit, could be due to sources other than Operable Unit 1.

000101

D.2.6.2 SWIFT Loading from Paddys Run

Based on the characteristics of the infiltration from Paddys Run to the Great Miami Aquifer, a conceptual model was developed for the surface water to groundwater pathway for the Operable Unit 1 waste areas (Figure D.2-1). Surface water carrying dissolved contaminants in Paddys Run as described in Section D.2.2 can infiltrate into the Great Miami Aquifer in locations where the streambed lies in direct contact with the aquifer. Based on previous Paddys Run flow and infiltration studies (DOE 1993b), 30 percent of the runoff effluent volume is assumed to infiltrate to the Great Miami Aquifer through Paddys Run during storm events. The linear extent of the 83 grid cells along Paddys Run which were used for contaminant loading to the Great Miami Aquifer is shown on Figure D.2-3. For modeling purposes, mass loading from Paddys Run to the Great Miami Aquifer included those grid cells which were located between the uppermost reach of Paddys Run adjacent to Operable Unit 1 and the FEMP property boundary where Paddys Run exits the site.

Using the results of the surface water modeling and constituent screening process described in Subsection D.2.6.1, the loading rates of each compound were used to calculate the expected loading which would occur in the Great Miami Aquifer. The calibrated groundwater flow model for the FEMP was then used to simulate the solute transport of the compounds in the Great Miami Aquifer as further described in Section D.3.7.

TABLE D.2-1

AVAILABLE POTENTIAL CONSTITUENT OF CONCERN CONCENTRATIONS IN SURFACE SOILS AT OPERABLE UNIT 1[a]

Constituent	Upper 95% CI Concentration
Inorganics[b]	
Antimony	27.2
Arsenic	4.9
Barium	56.9
Berylium	0.8
Cadmium	5.8
Chromium	14.3
Cobalt	10.4
Copper	17.0
Cyanide	0.3
Lead	15.9
Manganese	574.1
Mercury	0.1
Molybdenum	4.3
Nickel	29.4
Selenium	0.6
Silver	8.9
Thallium	0.7
Vanadium	19.6
Zinc	46.7
Organics[c]	
4,4'-DDT	ND[d]
Aroclor-1221	ND
Aroclor-1248	ND

TABLE D.2-1
(Continued)

Constituent	Upper 95% CI Concentration
Aroclor-1254	1400
Aroclor-1260	200
Radionuclides[e]	
Cesium-137	1.0
Neptunium-237	0.5
Plutonium-238	0.4
Plutonium-239-240	0.1
Ruthenium-106	ND
Strontium-90	1.7
Technitium-99	8.7
Thorium-230	74.9
Thorium-232	4.3
Uranium-234	60.1
Uranium-235	6.8
Uranium-238	244.7
Uranium-Total	731.23[f] (mg/kg)

[a] Surface soil concentrations from the CIS surface soil data set.
[b] All concentrations in milligrams per kilogram (ppm).
[c] All concentrations in micrograms per kilogram (ppb).
[d] ND indicates constituent was not detected in any samples in the CIS surface soil data set.
[e] All concentrations in picocuries per gram (pCi/g) except Uranium-total which is in micrograms per gram (ppm).
[f] Uranium-Total concentration derived from Uranium-238 concentration from CIS surface soil data (244.7 pCi/g ÷ 0.337 [a conversion factor to micrograms per gram] ÷ 0.997 [ratio of U-238 to U-234 + U-235 + U-238]). All other radionuclide concentrations are in pCi/g.

TABLE D.2-2

VARIABLES USED IN THE SURFACE WATER RUNOFF MODEL

Variables	Units	Values
C, cover factor[a]	unitless	0.042
LS, product of slope length factor and slope steepness factor[b]	unitless	0.25
K, soil erodibility factor[a]	metric tons/ha/unit erosion potential	0.37
θ_c, available water capacity[c]	unitless	0.15
q_p, peak runoff flow rate[d]	m^3/s	0.04
Q_r, depth of runoff[e]	cm	1.25
R_t, depth of rainfall during event[e]	cm	6.35
A, contaminated area[c]	hectares	17.2
T_r, storm duration[f]	hr	24
V_r, volume of runoff[e]	m^3	2146
P, erosion control practice factor[b]	unitless	1.0
CN, SCS runoff curve number[g]	unitless	71

[a]Atlantic Environmental Services (AES), 1988, Exhibit 7-5.
[b]U.S. Environmental Protection Agency, 1988, Figure 2-6.
[c]Calculated from site-specific information.
[d]Calculated in Section D.2.3.2.
[e]AES, 1988, Exhibit 7-11; Mills et al., 1985.
[f]1-year, 24-hour storm event (Hershfield, 1961).
[g]Mills et al., 1985.

TABLE D.2-3

MODELED CONCENTRATIONS IN PADDYS RUN AND THE GREAT MIAMI RIVER

MUSLE Constituents	Paddys Run Sediment Concentration (mg/kg)	Paddys Run Loading (lb/day)	Paddys Run Concentration Cw (mg/ℓ)	Great Miami River Concentration Cgmr (mg/ℓ)
Inorganics				
Antimony	2.720×10^{1}	4.000×10^{-7}	5.540×10^{-4}	5.540×10^{-7}
Arsenic	4.900×10^{0}	9.010×10^{-8}	1.040×10^{-4}	1.250×10^{-7}
Barium	5.69×10^{0}	1.840×10^{-7}	2.110×10^{-4}	2.541×10^{-7}
Beryllium	8.000×10^{-1}	2.260×10^{-9}	2.600×10^{-6}	3.133×10^{-9}
Cadmium	5.800×10^{0}	4.270×10^{-8}	4.900×10^{-5}	5.905×10^{-8}
Chromium	1.430×10^{1}	3.510×10^{-8}	4.030×10^{-5}	4.854×10^{-8}
Cobalt	1.040×10^{1}	6.950×10^{-8}	8.000×10^{-5}	9.626×10^{-8}
Copper	1.700×10^{1}	5.000×10^{-7}	5.750×10^{-4}	6.919×10^{-7}
Cyanide	8.92×10^{-2}	7.65×10^{-6}	8.80×10^{-3}	1.059×10^{-5}
Lead	1.590×10^{1}	1.950×10^{-8}	2.240×10^{-5}	2.699×10^{-8}
Manganese	5.74×10	1.17×10^{-5}	1.350×10^{-2}	1.623×10^{-5}
Mercury	9.90×10^{-2}	3.64×10^{-8}	4.19×10^{-5}	5.041×10^{-8}
Molybdenum	4.300×10^{0}	1.760×10^{-7}	2.020×10^{-4}	2.430×10^{-7}
Nickel	2.940×10^{1}	1.660×10^{-7}	1.910×10^{-4}	2.303×10^{-7}
Selenium	6.00×10^{-1}	2.98×10^{-9}	3.43×10^{-6}	4.128×10^{-9}
Silver	8.890×10^{0}	1.820×10^{-7}	2.090×10^{-4}	2.516×10^{-7}
Thallium	7.000×10^{-1}	1.72×10^{-9}	1.97×10^{-6}	2.376×10^{-9}
Vanadium	1.960×10^{1}	7.210×10^{-8}	8.290×10^{-5}	9.979×10^{-8}
Zinc	4.670×10^{1}	7.160×10^{-8}	8.230×10^{-5}	9.907×10^{-8}
Organics				
Aroclor-1254	1.400×10^{0}	7.690×10^{-11}	8.840×10^{-8}	1.064×10^{-10}
Aroclor-1260	2.000×10^{-1}	1.19×10^{-10}	1.37×10^{-7}	1.648×10^{-10}

TABLE D.2-3
(Continued)

MUSLE Constituents	Paddys Run Sediment Concentration (mg/kg)	Paddys Run Loading (lb/day)	Paddys Run Concentration Cw (mg/ℓ)	Great Miami River Concentration Cgmr (mg/ℓ)
Radionuclides				
Cesium-137	1.150×10^{-8}	2.330×10^{-17}	2.680×10^{-14}	3.232×10^{-17}
Neptunium-237	7.070×10^{-4}	4.730×10^{-11}	5.440×10^{-8}	6.544×10^{-11}
Plutonium-238	2.333×10^{-8}	5.050×10^{-17}	5.810×10^{-14}	6.990×10^{-17}
Plutonium-239 and 240	1.610×10^{-6}	3.480×10^{-15}	4.000×10^{-12}	4.819×10^{-15}
Strontium-90	1.230×10^{-8}	4.530×10^{-15}	5.210×10^{-12}	6.276×10^{-15}
Technetium-99	2.760×10^{-4}	8.590×10^{-9}	9.880×10^{-6}	1.190×10^{-8}
Thorium-230	3.710×10^{-3}	2.350×10^{-12}	2.700×10^{-9}	3.256×10^{-12}
Thorium-232	3.930×10^{1}	2.490×10^{-8}	2.860×10^{-5}	3.448×10^{-8}
Uranium-234	9.540×10^{-3}	2.930×10^{-9}	3.360×10^{-6}	4.050×10^{-9}
Uranium-235	3.120×10^{0}	9.560×10^{-7}	1.100×10^{-3}	1.323×10^{-6}
Uranium-238	7.240×10^{2}	2.220×10^{-4}	2.550×10^{-1}	3.072×10^{-4}

TABLE D.2-4

COMPARISON OF MODELED RESULTS TO MEASURED SURFACE WATER CONCENTRATIONS IN PADDYS RUN

Constituent of Potential Concern[a]	Modeled Concentration in Paddy's Run[b]	Range of Measured Concentrations in Paddy's Run
Radionuclides (pCi/l)		
Thorium-230	5.45×10^{-2}	<1.0-2.3[c]
Thorium-232	3.13×10^{-3}	<1.0[c]
Uranium-234	2.10×10^{1}	1.2-3.6[c]
Uranium-238	8.55×10^{1}	2.0-6.8[c]
Inorganics (μg/l)		
Cadmium	0.049	<2[d]
Chromium	0.0403	<10[d]
Copper	0.575	<10[d]
Lead	0.0224	7.4-9.3[d]
Nickel	0.191	<20[d]
Silver	0.0209	<10[d]

[a] COC listed only if measured data were available for comparison.
[b] Modeled from surface soil source term.
[c] From Operable Unit 4 Remedial Investigation, U.S. Department of Energy, 1993, Table 4-SW, surface water sample locations W-10 and W-11.
[d] ASI/IT, Geochemical Program Issues 3 and 5.

TABLE D.2-5

PADDYS RUN LOADING - SCREENING FOR SWIFT

MUSLE Constituents	Runoff Effluent Concentration C_e (mg/ℓ)	Predicted Diluted Aquifer Concentration C_{GMA} (mg/ℓ)	10^{-7} Risk-Based or 0.1 Hazard Quotient Screening Level (mg/ℓ)	SWIFT Modeling Status
Inorganics				
Antimony	2.570×10^{-3}	2.603×10^{-5}	1.500×10^{-3}	No
Arsenic	5.780×10^{-4}	5.855×10^{-6}	4.60×10^{-6}	Yes
Barium	1.180×10^{-3}	1.195×10^{-5}	2.600×10^{-1}	No
Beryllium	1.450×10^{-5}	1.419×10^{-7}	1.900×10^{-6}	No
Cadmium	2.740×10^{-4}	2.775×10^{-6}	1.800×10^{-3}	No
Chromium	2.250×10^{-4}	2.279×10^{-6}	1.800×10^{-2}	No
Cobalt	4.470×10^{-4}	4.528×10^{-6}	2.0×10^{-1}	No
Copper	3.210×10^{-3}	3.251×10^{-5}	1.400×10^{-1}	No
Cyanide	4.910×10^{-2}	4.973×10^{-4}	1.800×10^{-2}	No
Lead	1.250×10^{-4}	1.266×10^{-6}	1.500×10^{-3}	No
Manganese	7.530×10^{-2}	7.627×10^{-4}	1.800×10^{-2}	No
Mercury	2.340×10^{-4}	2.370×10^{-6}	1.100×10^{-3}	No
Molybdenum	1.130×10^{-3}	1.145×10^{-5}	1.800×10^{-2}	No
Nickel	1.070×10^{-3}	1.084×10^{-5}	7.300×10^{-2}	No
Selenium	1.920×10^{-5}	1.945×10^{-7}	1.800×10^{-2}	No
Silver	1.170×10^{-3}	1.185×10^{-5}	1.800×10^{-2}	No
Thallium	1.100×10^{-5}	1.114×10^{-7}	2.900×10^{-4}	No
Vanadium	4.630×10^{-4}	4.690×10^{-6}	2.600×10^{-2}	No
Zinc	4.600×10^{-4}	4.659×10^{-6}	1.100×10^{-10}	No
Organics				
Aroclor-1254	6.460×10^{-6}	6.543×10^{-8}	1.00×10^{-5}	No
Aroclor-1260	7.640×10^{-7}	7.739×10^{-9}	1.00×10^{-5}	No

TABLE D.2-5
(Continued)

MUSLE Constituents	Runoff Effluent Concentration C_e (mg/ℓ)	Predicted Diluted Aquifer Concentration C_{GMA} (mg/ℓ)	10^{-7} Risk-Based or 0.1 Hazard Quotient Screening Level (mg/ℓ)	SWIFT Modeling Status
Radionuclides				
Cesium-137	1.500×10^{-13}	1.519×10^{-15}	2.200×10^{-12}	No
Neptunium-237	3.040×10^{-11}	3.079×10^{-9}	3.400×10^{-8}	No
Plutonium-238	3.240×10^{-11}	3.282×10^{-15}	1.400×10^{-12}	No
Plutonium-239/240	2.240×10^{-11}	2.269×10^{-13}	3.700×10^{-10}	No
Strontium-90	2.910×10^{-11}	2.948×10^{-13}	1.100×10^{-12}	No
Technetium-99	5.520×10^{-5}	5.591×10^{-7}	2.400×10^{-7}	Yes
Thorium-230	1.510×10^{-8}	1.529×10^{-10}	2.000×10^{-8}	No
Thorium-232	1.600×10^{-4}	1.621×10^{-6}	2.900×10^{-4}	No
Uranium-234	1.880×10^{-5}	1.904×10^{-7}	5.300×10^{-8}	Yes
Uranium-235	6.140×10^{-3}	6.219×10^{-5}	1.500×10^{-4}	No
Uranium-238	1.430×10^{-0}	1.448×10^{-2}	5.600×10^{-4}	Yes

TABLE D.2-6

COMPARISON OF SELECTED 2000-SERIES WELL CONCENTRATIONS TO PREDICTED MAXIMUM DILUTED AQUIFER CONCENTRATIONS

Surface Water Pathway COC	Well 2009[a] (mg/ℓ)	Well 2108[a] (mg/ℓ)	Well 2004[a] (mg/ℓ)	Well 2107[a] (mg/ℓ)	Predicted Diluted Aquifer Concentration (mg/ℓ)[d]
Arsenic	5.000×10^{-3}[b]	NA	5.000×10^{-3}[b]	5.000×10^{-3}[b]	5.855×10^{-6}
Technetium-99	NA[c]	NA	8.247×10^{-7}	NA	5.591×10^{-7}
Uranium-234	4.597×10^{-7}	1.592×10^{-6}	5.494×10^{-7}	2.467×10^{-7}	1.904×10^{-7}
Uranium-238	1.253×10^{-2}	2.959×10^{-2}	1.850×10^{-2}	6.444×10^{-3}	1.448×10^{-2}

[a] Concentration from FEMP groundwater data base. Unless otherwise indicated, the concentration represents the maximum detected concentration over 12 sampling events from 1990 through 1992.
[b] Sample concentration was below detection limit so the maximum detection limit was used.
[c] NA - data not available.
[d] The predicted aquifer concentration is based on impact from the surface water pathway only.

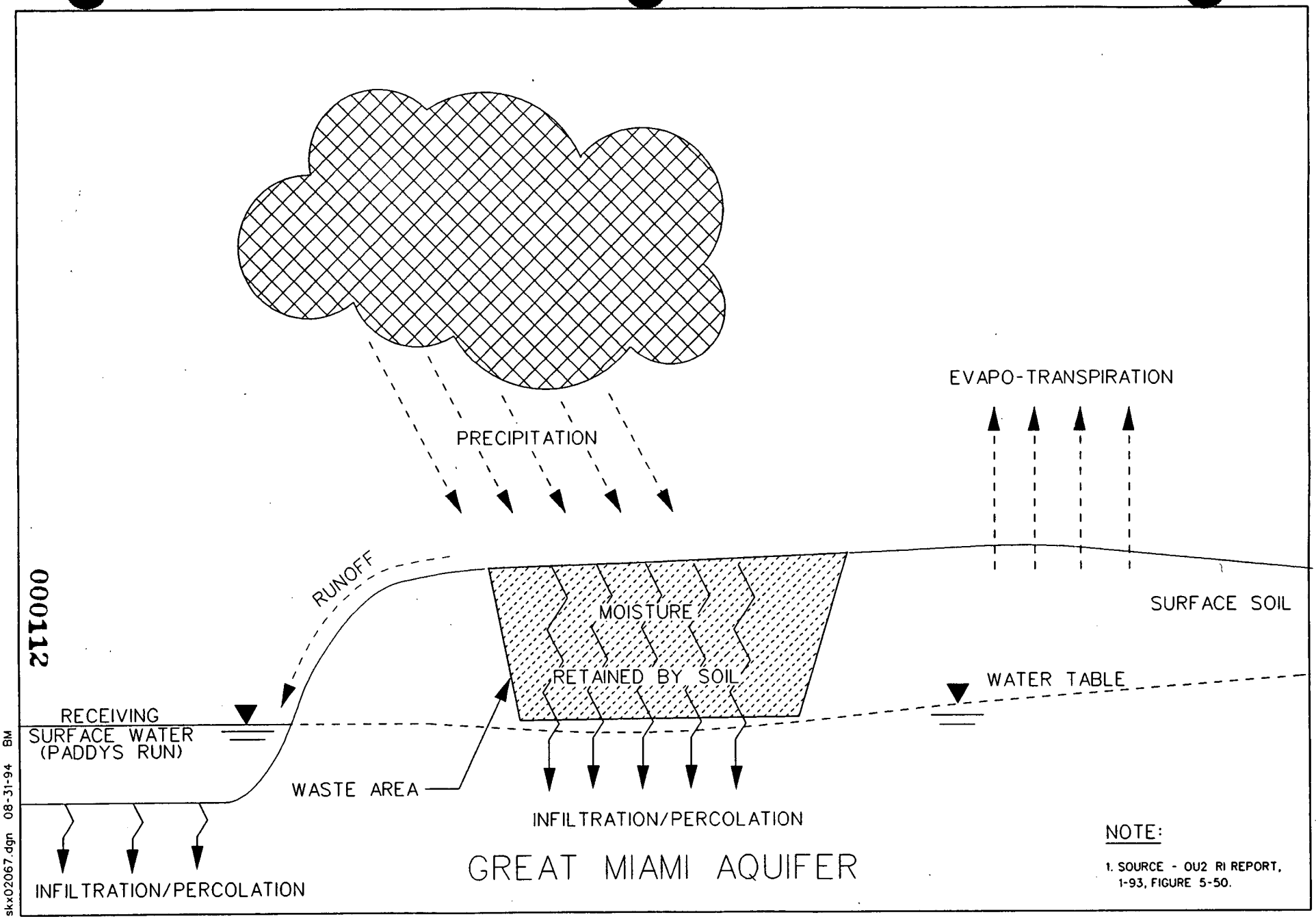
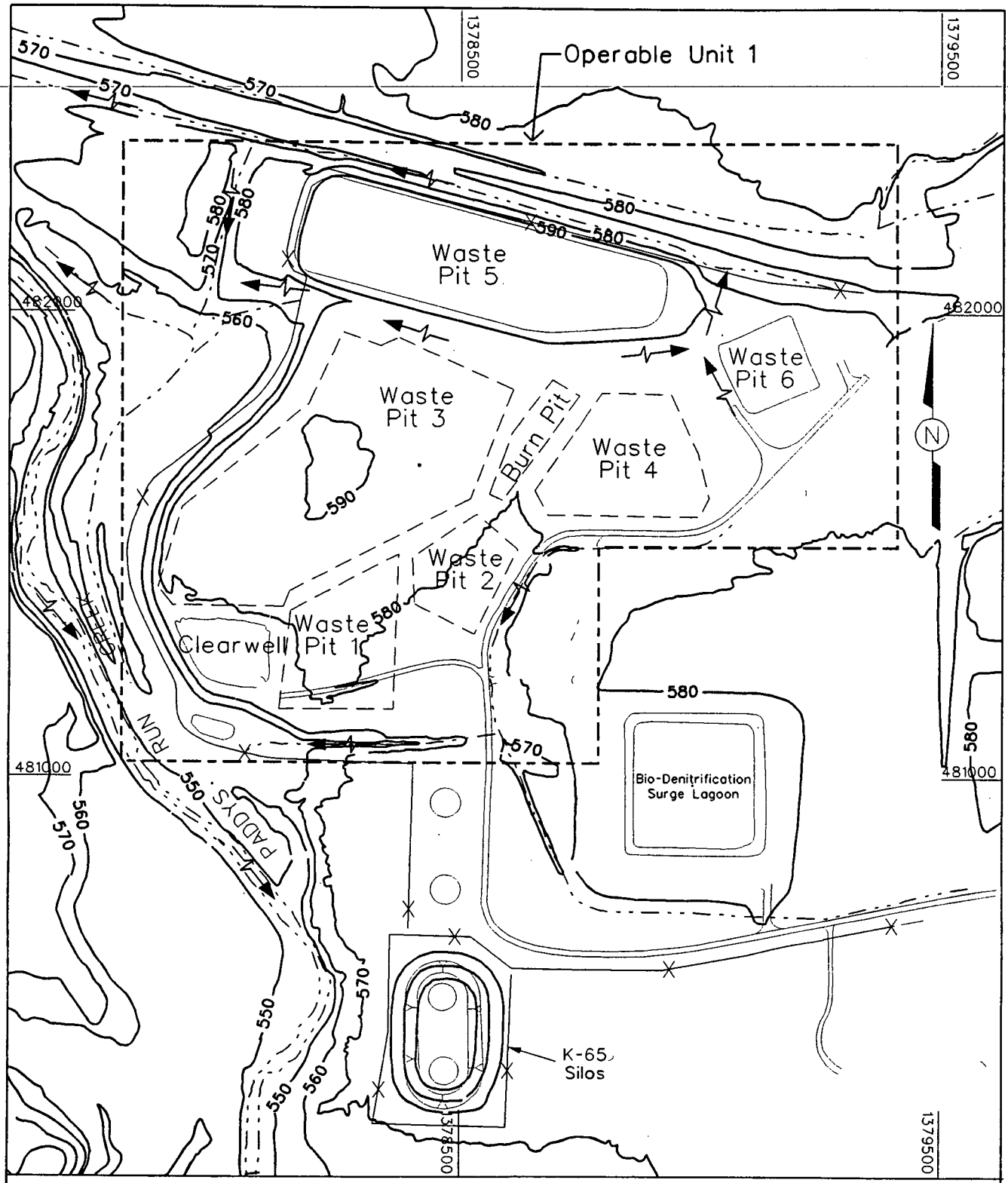


FIGURE D.2-1. CONCEPTUAL MODEL OF SURFACE WATER RUNOFF



NOTE:

1. CONTOUR INTERVAL - 10 FT.
2. SOURCE - RI OU1 REPORT, 2-93, FIGURE 5-51.
3. DRAINAGE SCENARIO BASED ON DRAINAGE PRIOR TO INSTALLATION OF STORM WATER RUNOFF CONTROL

LEGEND:

- FENCE LINE
- DRAINAGEWAYS
- ROADWAY
- OPERABLE UNIT OUTLINE
- SURFACE WATER DRAINAGE
- 580 TOPOGRAPHIC CONTOUR LINE

SCALE: 0 300 FEET

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FIGURE D.2-2. TOPOGRAPHY AND NATURAL DRAINAGE SCENARIO OF OPERABLE UNIT 1

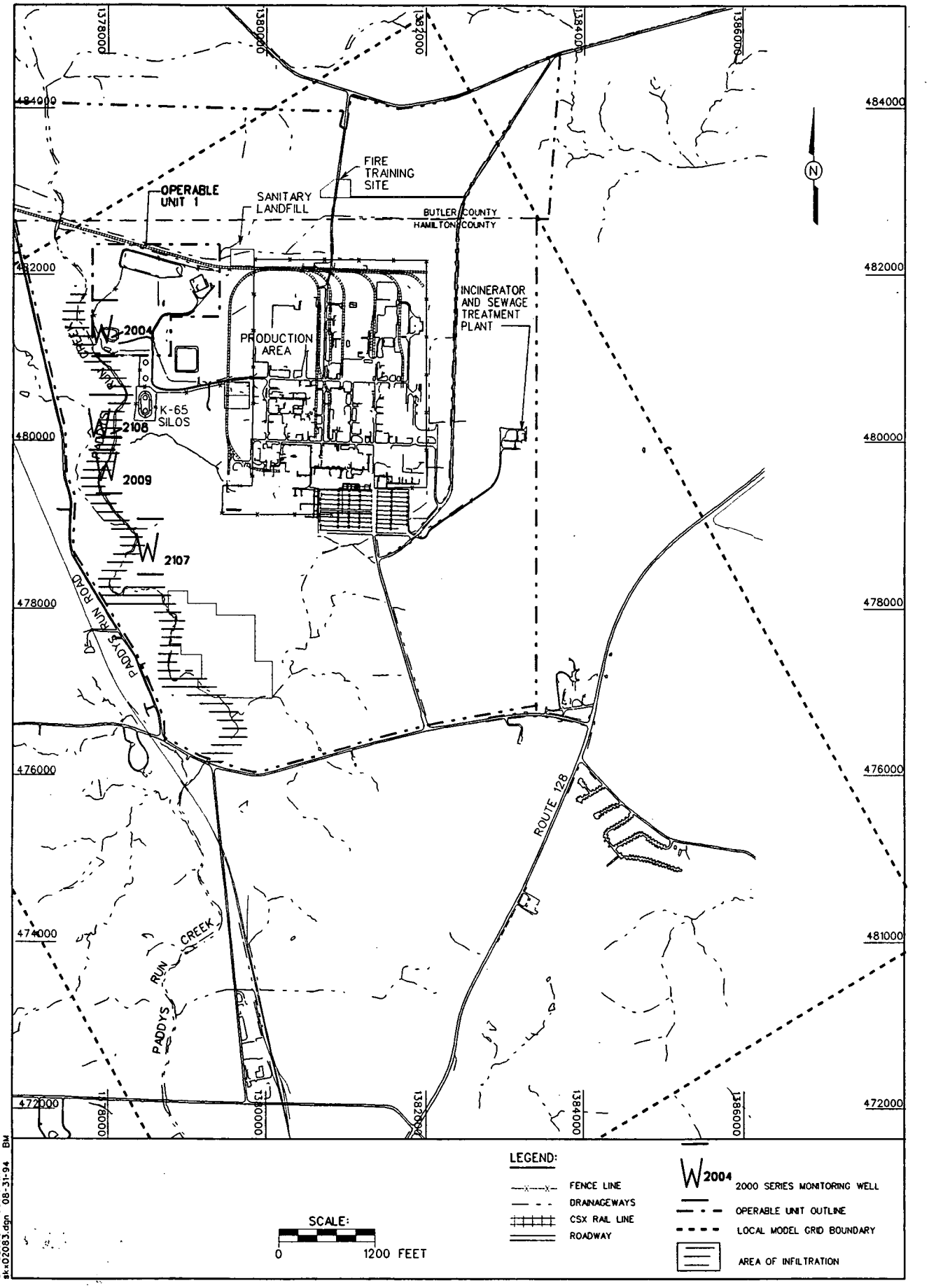

FIGURE D.2-3. LINEAR EXTENT OF PADDYS RUN INFILTRATION TO THE GREAT MIAMI AQUIFER AND LOCATION OF SELECTED 2000 SERIES WELLS

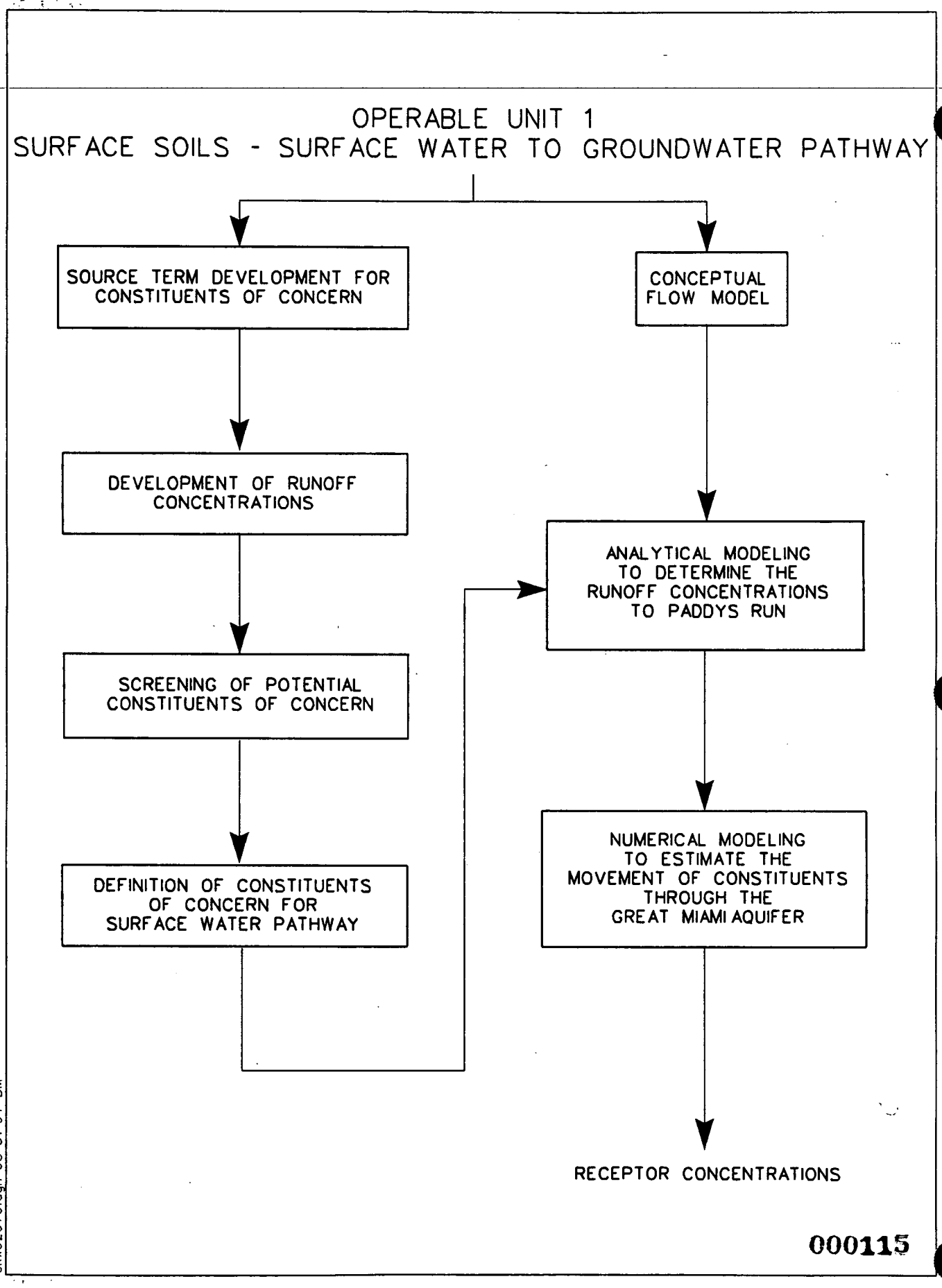

FIGURE D.2-4. SURFACE WATER TO GROUNDWATER PATHWAY TRANSPORT MODELING DIAGRAM

REFERENCES

Haith, D. A., 1980, "A Mathematical Model for Estimating Pesticide Losses in Runoff," Journal of Environmental Quality, Vol 9, No.3, pp. 428-433.

Hershfield, D. M., 1961, "Rainfall Frequency Atlas of the United States: For Durations from 30 Minutes to 24 Hours and Retain Periods From 1 to 100 Years," Technical Paper No. 40, U.S. Department of Commerce, Washington, D.C.

Mills, W. B., J. D. Dean, D. B. Porcella, S. A. Gherini, R. J. M. Hudson, W. E. Frick, G. L. Rupp, and G. L. Bowie, 1982, "Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants: Parts 1, 2, and 3," EPA-6001 6-82-004 a,b,c, U.S. Environmental Protection Agency, Environmental Research Laboratory, Office of Research and Development, Athens, GA.

Mockus, J., 1972, "Estimation of Direct Runoff from Storm Rainfall," In National Engineering Handbook, Sec. 4, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.

U.S. Department of Energy (DOE), 1993a, "Remedial Investigation for Operable Unit 4," Fernald Environmental Management Project, Fernald, OH.

U.S. Department of Energy (DOE), 1993b, "Paddys Run Flow and Infiltration Model Report: Description and Results," IT Corporation, prepared for the U.S. Department of Energy Fernald Field Office.

U.S. Environmental Protection Agency (EPA), 1988, "Superfund Exposure Assessment Manual," EPA/540/1-88/001, Office of Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1993, "Risk-Based Concentration Table, Second Quarter for 1993," U.S. Environmental Protection Agency, Region III Memorandum dated May 10, 1993, Philadelphia, PA.

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D.3.0 GROUNDWATER FATE AND TRANSPORT MODELING

D.3.1 INTRODUCTION

The objective of this section is to evaluate the fate and transport of constituents as they migrate from the Operable Unit 1 area through the vadose zone or Paddys Run streambed to the Great Miami Aquifer. This section provides a more detailed discussion of the modeling that is summarized in the main RI Report text (Section 5) and provides the necessary support information for Section 5. The Operable Unit 1 waste areas are Waste Pits 1 through 6, the Burn Pit, and the Clearwell.

Groundwater fate and transport models are used to predict contaminant movement from source volumes (waste areas) to receptor locations through the groundwater pathway. Used in conjunction with monitoring data, these models predict future contaminant concentrations at potential exposure locations where measured contaminant concentration data are not available. The modeling provides the best data on contaminant migration into off-property locations or for future exposure predictions by extrapolating from known field data. Conservative assumptions are used in the modeling to provide a reasonable "worst case" picture of risk. The modeled future concentrations are also based on the unremediated baseline case for the Operable Unit 1 waste areas. The results of the groundwater fate and transport modeling are used in the Operable Unit 1 Baseline Risk Assessment (Appendix E) to estimate potential risks to the environment and human health.

This section presents a description of the technical approach and the methods used to quantitatively predict contaminant concentrations for use in the Operable Unit 1 Baseline Risk Assessments.

This section:

- Presents background information on the hydrogeologic setting
- Defines the conceptual groundwater flow model based upon a reasonable and conservative depiction of the hydrogeologic setting
- Outlines the screening processes to finalize the list of constituents of potential concern (CPC)
- Presents a description and results of vadose zone modeling

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- Presents a description and results of aquifer modeling
- Compares modeling results with field data

D.3.1.1 Technical Approach

Two pathways are considered in this analysis. First, migration from the waste unit vertically through the vadose zone to the aquifer is designated the vadose zone pathway. Second, migration of contaminants from the surface soil to Paddys Run and from Paddys Run to the aquifer is designated the surface water pathway. This section considers all of the steps of the vadose zone pathway. For the surface water pathway, Section D.2.0 describes the definition of constituents, the conceptual model for the surface water pathway, the surface water modeling, the screening of constituents, and the predicted concentrations in Paddys Run and the Great Miami River. This current section, however, presents all of the Great Miami Aquifer modeling results including the concentrations in the aquifer due to mass loadings from Paddys Run.

Figure D.3-1 shows, for the vadose zone pathway, the steps in model development and the method of deriving the source and leachate concentrations. The extent to which contaminants may migrate through the groundwater system depends both on site characteristics and the nature of the contaminants. Because of the variety of the contents in the waste areas and the heterogeneity in the vadose zone beneath the waste areas, a separate conceptual model is developed for each of the waste areas in Operable Unit 1. The development of these models involves the following steps:

- Review of the available information on the specific waste area to establish the characteristics of the waste area.
- Identification of CPC by reviewing the production history and by analyzing site characterization data.
- Identification of the hydrologic processes governing the fate and transport of the constituents within each hydrostratigraphic unit.
- Development of a conceptual hydrogeologic model for each waste area, based on information about the contaminants present in that waste area and its location-specific geologic setting.

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Once the conceptual models are developed, existing computer codes that allow the creation of a proper mathematical representation of the conceptual models are selected. The mathematical representations used at the FEMP generally consider the rate at which the modeled processes occur, the interaction of different processes with each other, and the initial conditions of both the waste area and the surrounding geologic formations. Some of the major steps involved in constructing mathematical representations of the conceptual models used at the FEMP include:

- Quantification of the concentrations of constituents in the waste area and the physical parameters defining the volume and mass of each waste area.
- Use of measured data and geochemical modeling to determine the chemical speciation projected to result from the reactions of infiltrating water with the waste materials and the matrix of the glacial overburden. (Section D.1.0)
- Definition of physical parameters of the vadose zone system beneath each waste area.
- Estimation of the rate constants describing the cationic retardation of the modeled contaminants. These rate constants are based on partitioning coefficients selected during an extensive literature search.
- Estimation of the rate constants describing contaminant retardation attributable to interactions with organic carbon in the geological formation. These constants are based upon the grain-size distributions and organic carbon content of the glacial overburden matrix.
- Estimation of the rate constants describing the decay rates of the modeled contaminants. These first-order rate constants are based upon radioactive half-lives and biodegradation half-lives in groundwater for radionuclides and organic chemicals, respectively.
- Calibration of the model to field data. Selected 2000 series wells in the vicinity of the waste pits are evaluated to determine constituents that have reached the aquifer. Initial model results are compared to these data and a constant loading term is added to approximately reproduce these constituent values within the operating time frame.

The CPC from Operable Unit 1 waste areas are defined based upon sampling data and prescreening and background/nutrient screening activities (see Appendix E). Prior to fate and transport modeling, additional screening steps are undertaken to reject those that clearly would not pose a significant risk. By screening constituents, computational time is reduced.

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Screening steps consider travel time through the vadose zone, organic and radiologic decay, and comparison with toxicity levels.

After existing computer codes and site-specific input parameters are selected, the codes are used to (1) calculate constituent loading rates to the aquifer beneath the selected waste area; and (2) perform flow and solute transport modeling to determine the effects of dispersion, retardation, and contaminant degradation or decay on the projected contaminant concentrations in the Great Miami Aquifer. Estimates of future concentrations in the aquifer are the desired result of the modeling effort.

D.3.1.2 Approach to Screening and Modeling

The primary purpose of the fate and transport modeling is to provide predicted concentrations of key, risk-causing constituents so that overall risk may be determined by the risk assessors. Because the modeling is resource intensive, screening steps are undertaken to eliminate constituents that pose little or no risk using conservative assumptions. In addition, because modeling contains uncertainty by being a predictive tool based upon many assumptions, actual monitoring data is reviewed to check certain model results. For example, if a constituent is predicted to be attenuated in the vadose zone for many years, yet it is presently found in the aquifer, then the model assumptions need to be reviewed.

Figure D.3-2 shows the approach that has been followed in screening out constituents, in defining risk from the nonscreened constituents, and in incorporating monitoring results in the modeling process. This figure represents the three screening steps that remove CPCs from further consideration (see detailed discussion in Section D.3.4). In addition, this figure also shows the relationship of the monitoring data evaluation to this process. Figure D.3-3 depicts the five cases for modeling represented schematically on Figure D.3-2.

If a constituent is detected above the detection limits (i.e, Cases 2 and 3) in the Great Miami Aquifer groundwater in the vicinity of the waste areas, then further steps are undertaken. First, these detected concentrations are compared against background and a 10^{-7} risk based criteria for carcinogens or 0.1 Hazard Quotient criteria for non-carcinogens. If these concentrations are below these criteria, then the constituent is screened out since it either is caused by other factors than Operable Unit 1 or it does not pose any risk. Next, if a constituent is detected at concentrations that are higher than background and the screening

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criteria, then it is calculated whether it will reach the fence line within 1,000 years. If the calculation shows that it will not reach the fence line, then the current maximum concentration is reported at the source location and no impact is assumed at the fence line. If the calculation shows that it will reach the fence line, then the constituent is modeled with the aquifer model (SWIFT).

If constituents are detected in the Great Miami Aquifer sooner than their theoretical arrival time (as determined by the conceptual model parameters and chemical specific factors), then a direct leak loading term to the aquifer is created to represent the present concentration in the aquifer (Figure D.3-3). In theory this term may represent leakage under conditions different than the present waste area configuration or leakage through leaky well casings. In effect, five possible scenarios are created (see Figure D.3-3) that depict different combinations of direct leak source term and vadose zone breakthrough.

D.3.2 HYDROGEOLOGIC SETTING

The first step in developing the pathway analysis is to develop a conceptual understanding of the depositional history of the site and the general hydrogeologic characteristics of the deposits. This section describes the general geology and hydrogeology of the FEMP. For a detailed discussion, refer to the Groundwater Report (DOE 1990).

D.3.2.1 Geologic Setting

The geology of the area is dominated by the glacial and glaciofluvial deposits formed during the most recent continental glaciation (approximately 70,000 years before present). Prior to the advancement of the glaciers, a large valley was eroded into the shale bedrock. This valley, which is approximately 200 feet below the existing land surface, was filled with well-sorted sand and gravel glacial outwash during the retreat of early glaciers. Beneath the site, this outwash is divided by a clay layer at a depth of 120 feet below the current surface. Later glacial advances (Shelbyville) caused the displacement of the Dry Fork of the Whitewater River from its historic channel into its present channel. The Shelbyville ice deposited a moraine in the historic channel which formed a dam. The meltwater lake that formed behind the dam gave rise to the lacustrine deposits found in the area. This dam was breached at least two times, with the final breach draining the lake permanently. The lake basin is now occupied by Paddys Run.

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In the Paddys Run floodway, recent deposits of silt (loess, fluvial, and lacustrine) form a terrace above the current stream elevation. Paddys Run has cut through this recent terrace and the glacial drift. The bed of Paddys Run is located on the well-sorted outwash material which fills the buried valley, on preglacial Whitewater River deposits. Since the last retreat of the continental glaciers, the streams in the area have removed much of the till and lacustrine mantle left by the ice sheets. In the Great Miami River valley, the stream has eroded through the till and is now in direct contact with the glaciofluvial outwash deposits that contain the buried valley aquifer.

The term glacial overburden has been selected to describe the deposits located stratigraphically above the glaciofluvial material of the Great Miami Aquifer. The glacial overburden includes the following types of materials:

- Loess - Considered ubiquitous in the Fernald area, it generally forms the uppermost layer of the glacial overburden. Loess is generally a homogeneous fine-grained blanket deposit, buff to light yellow or yellowish-brown in color. The deposit originated from windblown dust of Pleistocene age carried from the unconsolidated glacial and glaciofluvial deposits uncovered by glacial recession, but prior to the invasion of a vegetative cover.

- Lacustrine - Lacustrine deposits from the glacial lake consisting of well-sorted, stratified fine sands and clays formed in the Paddys Run valley. These varved clays can be interbedded with well-sorted beach deposits along the margins of the former lake basin.

- Till - Undifferentiated glacial till makes up the majority of the glacial overburden at the FEMP site. Because of its location at the ice margin, the till is likely to have been deposited by several modes including moraine deposits, ablation till, and subglacial till sheets arising from differing ice lobes. The primary feature of tills is that they are deposited directly by a glacier without fluvial sorting. The till at the site is a heterogeneous mixture of clays, silts, and pebbles.

- Glaciofluvial - Interbedded with the till are glaciofluvial beds that originated from meltwater streams that occurred along the margins of the ice sheets. These deposits of varying extent consist of well-sorted sands and fine gavels.

D.3.2.2 Vadose Zone

The unsaturated or vadose zone exists above the groundwater table or phreatic surface of the aquifer. In this zone, the interstices are occupied partially by water and partially by air. The partially filled soil water in the unsaturated zone is known as vadose water. Overlying the Great Miami Aquifer at the FEMP are approximately 15 to 35 feet (4.6 to 11 m) of

unsaturated sand and gravel outwash deposits. These deposits are assumed to have the same hydraulic characteristics as the underlying saturated material since their depositional histories are the same.

Dense, fine-grained glacial overburden overlie the unsaturated sand and gravel outwash deposits. These types of deposits have intergranular hydraulic conductivities that are very low, with values in the range of 10^{-7} to 10^{-5} feet/day (10^{-11} to 10^{-9} cm/s) (Heath 1983). Extensive deposits of clayey till can cause isolation from zones of near-surface groundwater flow.

In the Great Plains region and in parts of the Midwest, deposits of clayey or silty clay and glaciolacustrine clay have networks of predominantly vertical joints or fractures. This jointing pattern in the Wisconsin tills has also been noted in the area surrounding the FEMP (Brockman 1988). In the FEMP area, the joints which are commonly near vertical have a polygonal expression and are typically 18 to 25 inches (0.46 to 0.63 m) across. The joints are generally oxidized approximately 2 inches on either side of the joint. Within the FEMP, fractures have been noted in the till during the RI/FS drilling program and field reconnaissance. These fractures can impart an enhanced bulk hydraulic conductivity of up to 1000 times greater than that of an unweathered till (Hendry 1988). As a result of increased lateral stresses caused by overburden loading, the hydraulic conductivity of fractured till and clay decreases with depth.

Recent investigations in similar geologic settings indicate that till deposits can be divided from a hydrogeologic standpoint into a brown weathered zone and a gray unweathered zone (Barari and Hedges 1985; Hendry 1988; Cravens and Ruedisili 1987). These studies indicate that infiltration is primarily limited to the weathered till. While precipitation enters this upper zone, it does not act as a significant source of recharge to deeper aquifer zones and the majority of the water lost from till deposits is from evapotranspiration. In addition to the losses due to evapotranspiration, some water may be discharged to small seeps or drainages.

Although the degree of fracturing within the brown tills at the FEMP has not been documented, sufficient observations have been made at the site and in the literature to indicate their presence is a characteristic physical property of these tills. Since fractures have been noted as a dominant feature in most brown tills, it is necessary to consider the effect that these fractures have on water and contaminant transport within the tills. As stated earlier,

fractures have been reported to enhance the bulk hydraulic conductivity of till as much as 1000 times with an expected increase of one to three times. It is reasonable to expect that contaminants will be transported by seepage more quickly through fractured till than unfractured till. At the FEMP, the gray till, with its appreciable silt and clay content, was regarded as providing the Great Miami Aquifer with protection from activities at the site (Dove and Norris 1951). This line of reasoning has justification because the low hydraulic conductivity produces very low velocities even if the hydraulic gradients are large. In addition, most contaminants being transported by seepage through the till matrix undergo attenuation and retardation.

If the till is fractured, these generalizations are not applicable because the velocities of water in the fractures are relatively large compared to the intergranular pore velocities in the unfractured matrix. It should be kept in mind that although the velocities are relatively large, the contaminant flux may be relatively small because the flow rate through the fractures is small.

Fractures not only control velocity but they generally impart a lower capability for attenuation and retardation by adsorption of contaminants. The adsorption processes are capable of removing more contaminant mass from solution if the water is in contact with larger surface areas in the matrix. Contaminants transported by seepage through till fractures only have an opportunity to react with the mineral constituents present in a veneer layer on the exterior of the fracture. Therefore, when flow occurs in the fractures, there is less surface area available for geochemical reactions that reduce the concentration of a contaminant or slow the movement of that contaminant. The exact nature of attenuation in fractured till is highly site specific and not well quantified. For example, if till fractures are coated with iron oxides, they may impart significant retardation on ionic solutions (Grisak et al. 1976).

Within the till deposits, there are numerous water-bearing zones that have limited interconnection. The majority of these zones are of glaciofluvial origin and consist of small beds of highly-sorted sands and gavels. These beds are probably the result of small meltwater streams that occurred along the ice margin and within the glacier itself. These intertill perched zone have the following general characteristics:

- High variability in areal extent, thickness, and volume

- Based upon hydrograph analysis, the interconnection between the intertill significantly saturated zones is limited
- Hydraulic conductivities are highly variable with an expected range of 2.8 x 10^{-5} to 280 feet/day (10^{-8} to 0.1 cm/s) (Freeze and Cherry 1979)
- Porosities range from 22.1 to 36.7, with a mean of 31 percent (Morris and Johnson 1967)

Generally these glaciofluvial interbeds are considered to be water-bearing units within the glacial overburden. However, movement of water and contaminants within these units will be limited due to limited areal and vertical extent and lack of interconnection of these units. The perched groundwater zones (saturated lenses of higher permeability sands) present beneath Operable Unit 1 waste areas are not modeled separately, but the thickness and the hydraulic properties of the sand lenses are included in the vadose zone modeling. At the FEMP, a series of slug tests on these perched groundwater zones found hydraulic conductivities ranging from 0.0071 feet/day (2.5 x 10^{-5} cm/s) (Well 1025) to 8.8 feet/day (3.1 x 10^{-3} cm/s) (Well 1196).

D.3.2.3 Great Miami Aquifer

The hydrogeology of the FEMP and the surrounding area is a textbook example of a glaciofluvial buried valley aquifer (Walton 1970; Fetter 1989; Freeze and Cherry 1979). The primary aquifer in the region is the Great Miami Aquifer, a well-sorted sand and gravel water table system consisting of sand and gravel glacial outwash deposits. Groundwater in the aquifer enters the FEMP area via buried channels on the west, north, and east. Under natural conditions, the primary flow would be across the site to the south. However, large pumping wells east of the FEMP in the Big Bend area of the Great Miami River have created a pronounced cone of depression causing flow at the FEMP to have easterly, southeasterly, and southerly components.

The aquifer is divided by a clay aquitard 1 to 20 feet (0.3 to 6 m) thick at a depth of approximately 120 feet (37 m). Flow direction and magnitude of the Great Miami Aquifer were simulated using SWIFT III, a numerical groundwater flow and solute transport model. Subsequent text describes the modeling effort in more detail.

D.3.2.4 General Contaminant Hydrogeology At The FEMP

The depositional characteristics and the hydrostratigraphic units present at the FEMP impart general contaminant transport characteristics on solutes migrating from the individual waste areas to receptor locations. These characteristics include:

- Solute migration potential: Solutes have a high migration potential through the upper weathered tills due to the fractured nature of the layer. Solute migration can also occur through the unweathered till, however, at a much slower rate. Once the solute reaches the glacial outwash, the solute migration potential is high, based on the high hydraulic conductivity and low adsorption capacity of the matrix.

- Hydraulic intercommunication: The intercommunication between perched water-bearing zones is limited in the glacial environment. Communication between the upper water-bearing zones within the till and the Great Miami Aquifer is also limited but may occur over an extended period of time.

- Adsorption/attenuation characteristics: The layers found within the glacial overburden generally have sufficient organic carbon content to cause retardation of organic constituents. The clay mineralogy would result in significant cation retardation for inorganic constituents. Given the till matrix, it is also unlikely that all of the available sites for adsorption would be used by solutes. Therefore, it is unlikely that adsorption/attenuation breakthrough would occur. Adsorption/attenuation will occur at lower rates in the regional aquifer due to the lower organic carbon and clay content in the outwash.

Based on the general hydrogeologic and contaminant transport characteristics, there is a potential pathway from the waste areas through the vadose zone to the regional aquifer. Given the high permeability of the glacial outwash, the pathway would extend from the aquifer-vadose interface to downgradient receptors.

D.3.3 CONCEPTUAL MODEL

The Operable Unit 1 waste areas exhibit considerable diversity in their contents and in the physical and chemical characteristics of the vadose zone beneath them. Because of this diversity, the modeling of the contaminant migration through the vadose zone is considered imperative for the estimation of contaminant loading rates to the regional aquifer model. To model the transport of these contaminants, it is necessary to adapt the generic conceptual model presented in the Risk Assessment Work Plan Addendum (DOE 1992) to a series of specific conceptual models for each distinct waste area. These conceptual models consider the following:

- The contents of the waste area
- The presence of standing water in the waste area
- The presence or absence of a discrete cap
- The presence/absence of perched water in the waste area
- The average concentration of contaminants in perched groundwater
- The identifiable geologic strata beneath the waste area
- The presence/absence of sand lenses in the waste area
- The thickness of each layer in the vadose zone
- The vertical permeability of the layers
- The interstitial fluid velocity through each layer based on saturation
- The dispersion coefficients of each layer
- The partition coefficients for each contaminant in each layer

Figure D.3-4 shows a generalized picture of contaminant migration at the FEMP. Two primary pathways are shown. The first pathway includes migration from the waste unit vertically through the vadose zone to the Great Miami Aquifer. The second pathway consists of loading due to surface runoff from contaminated surface soils from the Operable Unit 1 waste areas to Paddys Run and from Paddys Run to the Great Miami Aquifer (see Section D.2.0). For risk assessment purposes, maximum concentrations are considered in the Great Miami Aquifer at the waste unit boundary and at the fence line or property boundary.

Flow and contaminant transport in the vadose zone is conceptualized from the hydrogeology of the site. As discussed previously, the geology of the FEMP site is dominated by glacial sediments. Well-sorted sand and gravel glacial outwash forms the regional Great Miami Aquifer. Beneath the site, this aquifer is divided by a 1- to 20-foot-thick (0.3- to 6-m-thick) clay interbed at an approximate depth of 120 feet (37 m). The receptor pathway considered for this analysis is the upper part of the Great Miami Aquifer above the clay interbed. Contaminant transport in the vadose zone includes the bulk migration of water and dissolved materials from waste (source) areas at the FEMP to the Great Miami Aquifer. This occurs as surface water infiltrates from the surface and percolates through the source of contamination, and its surrounding soil, into the saturated zone. Downward movement of water, driven by the forces resulting from gravitational potential, capillary pressure, and other components of total fluid potential, mobilize the contaminants and carry them through the vadose zone. Vertical transport down through the vadose zone to the aquifer and the horizontal transport through the aquifer to the well of a potential human receptor is illustrated in Figure D.3-4.

Figure D.3-5 presents a generalized conceptual model of the vadose zone pathway. Once through the waste units, water filters through the vadose zone and dissolves materials,

forming an aqueous solution (leachate) (see Section D.1.0 for a detailed discussion of the derivation of leachate concentrations). This solution continues to percolate through the soil/waste matrix in the vadose zone as it moves toward the aquifer. The leachate often reacts with the soil/waste matrix through which it flows. These interactions determine what chemical species are present in the percolating water (leachate), and how fast they will move in the unsaturated zone. In this analysis the composition of the leachate and the speed at which individual constituents migrate are treated individually.

The uppermost 20 to 25 feet (6 to 8 m) of the outwash deposits is unsaturated and forms model Layer 2 of the vadose zone conceptual flow model. Overlying the outwash deposits is an unweathered till interbedded with sand and gravel glaciofluvial stringers. Within Layer 1 are sand lenses beneath some portion of Waste Pits 4, 5, 6, and the Burn Pit. The thickness of this till unit (referred to as glacial overburden) which makes up model Layer 1 ranges between 0 and 16 feet (0 and 5 m) for waste areas. A layer of weathered till overlies the gray clay. However, this layer is not included in the vadose zone modeling because of numerous fractures present within this zone. All layer thicknesses were estimated based on geologic boring logs from subsurface investigations conducted across the site.

Based on characteristics of the material underlying each Operable Unit 1 waste area, a detailed conceptual model is developed for the pathways between each waste area and receptor locations. These more detailed models are developed to account for the variable stratigraphies of the soils of the waste areas of Operable Unit 1. These detailed conceptual models are shown on Figures D.3-6 through D.3-12.

These detailed conceptual models show that perched groundwater occurs in the sand lenses within the glacial overburden beneath Waste Pits 4, 5, 6, and the Burn Pit. For the purposes of modeling, the sand lens is assumed to be a uniform 5 feet thick below the entire area of each of these four waste areas. These perched groundwater zones are modeled to represent an additional source of contaminant loading based on the concentration of constituents detected in 1000 series wells located within Operable Unit 1 from the RI/FS data base. For a particular constituent, an average concentration for each well is calculated over time. The average concentration value is compared to the concentration reported for the last sampling event, and the higher of the two concentration values is averaged for all wells. The resulting single concentration value is used for the modeling. Initial constituent concentrations,

concentration terms over time and sorbed mass are defined on these averaged liquid concentrations and the established distribution coefficient (K_d) for each constituent. The volume of groundwater present in the sand lenses is calculated based upon a volume of the sand lens and an average porosity of 39 percent. The migration pathway for contaminated perched groundwater is generally consistent with the overall conceptual model, with the exception that the glacial overburden thickness is halved for the perched groundwater pathway to account for the approximate location of the perched groundwater zones within the glacial overburden.

Based upon uranium, technetium-99 and arsenic results, loading from perched water represents an insignificant contribution (less than 2-3 orders of magnitude) when compared to the contribution from the waste pits. Since other constituents are minor contributors to total risk (see Section D.3.7), perched water concentrations from other CPCs has even less overall impact. Therefore, for the remaining constituents, perched groundwater was not included in the loading to the aquifer.

Table D.3-1 presents the waste area physical parameters including the area, volume of waste material, and dry density. These data were derived from engineering studies (Weston 1986, Parsons 1993, DOE 1993b). These parameter values are used for calculating masses of constituents and areas for the source terms. The waste areas contained in Operable Unit 1 are assumed to remain in their existing locations for the purposes of the baseline fate and transport modeling. Waste Pits 1, 2, 3, and 4 remain in their covered states and Pits 5 and 6, the Burn Pit, and the Clearwell are assumed to remain in their present states. Waste Pits 1 through 4 are assumed to remain essentially unchanged for the duration of the simulations, with a vegetative cover being established on the surface. Existing membrane liners in all waste areas are considered to be absent for purposes of the fate and transport modeling. Runoff and evapotranspiration are assumed to occur following precipitation events. Waste Pits 5 and 6, the Burn Pit, and the Clearwell are all assumed to remain uncovered and open to incoming precipitation. In addition, precipitation is assumed to pond on the surface of Waste Pits 5, 6 and the Clearwell units and either infiltrate or evaporate. No surface runoff or transpiration is allowed to occur.

D.3.3.1 Parameters

The parameters used to perform the long-term migration analysis can be divided into flow parameters and contaminant transport parameters. Flow parameters affect the velocity of groundwater movement. Contaminant transport parameters affect the rate of migration and the fate of the contaminant. Wherever possible, site-specific values are used for the analyses. Certain parameters, however, are not available for all of the waste areas, and are estimated based on pertinent scientific literature search, geochemical investigations, and are checked for consistency between model results and historical data. Conservative estimates are used when a range of values are indicated or parameter values are not available. The formulations employed for the estimation of the parameters are described in the Risk Assessment Work Plan Addendum (DOE 1992). Uncertainty in the selection of model parameter values is addressed by performing sensitivity analyses. Sensitivity analyses are performed by varying parameters within reasonable ranges. Additional information regarding the sensitivity analysis is presented in Section D.3.8.

The conceptual model depicting flow in the vadose zone considers two layers. Layer 1 soils consist of unweathered tills, present beneath six of the eight waste units in Operable Unit 1. Beneath the unweathered till is the unsaturated sand and gravel layer (Layer 2) present beneath all the waste units.

The conceptual model and media parameters for Operable Unit 1 waste areas are presented in Tables D.3-2 and D.3-3, respectively. The vertical hydraulic conductivity values for Layer 1 are obtained by dividing the horizontal hydraulic conductivities (representing the average results of slug tests conducted in 1000-series wells in the vicinity of Operable Unit 1) by 10. Sand lenses are also considered in this analysis using a separate hydraulic conductivity value derived from slug test data and calculating the harmonic mean for the overall Layer 1 hydraulic conductivity. The vertical hydraulic conductivity for Layer 2 is obtained by dividing the known horizontal hydraulic conductivity of the sand and gravel aquifer by 10. The factor of 10 represents a typical horizontal to vertical hydraulic conductivity ratio. The vertical hydraulic conductivity is estimated from 0.0114 to 0.0186 feet per day for Layer 1. The vertical hydraulic conductivity of Layer 2 is 45 feet per day for all of the Operable Unit 1 waste areas. As expected, the conductivity of the sand and gravel layer is several orders of magnitude greater than the till layer. Two of the waste units, Waste Pit 3 and the Clearwell,

are assumed to rest directly on the unsaturated sand and gravel of the Great Miami Aquifer and thus have no Layer 1 unit.

The vertical flow rates (q) are based on simulations with the Hydrologic Evaluation of Landfill Performance (HELP) model for the dry pits or with a calculation for the wet pits (see discussion below). The estimates of the vertical seepage velocities (Vx) used in the vadose zone transport model are based on the methods presented in the Risk Assessment Work Plan Addendum (DOE 1992). These methods calculate seepage velocity as a function of flow rate (q), porosity, and empirically derived soil factors. The longitudinal dispersion coefficients (D_x), a function of dispersivity, interstitial seepage, velocity and molecular diffusion coefficient are estimated by the methods presented by Biggar and Nielsen (1976), and Mills et al. (1982).

Flow and solute transport through the porous media are not only determined by the parameters considered in the conceptual model description above, they are also affected by retardation factors (R_f) and decay rates. These parameters are both chemical- and media-specific. Tables D.3-4 through D.3-6 show the retardation factors for the vadose zone Layers 1 and 2 for all the CPC for Operable Unit 1 waste areas. These tables also present the radioactive decay constants for radionuclides and the biodegradation coefficients for the organic constituents. These retardation factors and decay rates are used in the screening process, analytical modeling of the vadose zone, and numeric modeling of the aquifer.

The retardation factor is used to account for those reversible reactions that slow the arrival of a contaminant front, but do not act as a sink. The R_f can be expressed as the ratio between the rate of groundwater movement and the rate of contaminant movement. The R_f as a function of the partitioning coefficient of the constituent, the bulk density and moisture content in the vadose zone, was calculated using the formula described by Walton (1984) and Mills et al. (1982). These R_fs have been revised from the Risk Assessment Work Plan Addendum (DOE 1992) based on more conservative assumptions (for transport) of organic content and moisture content (see Table D.3-3). In the vicinity of Operable Unit 1, a distribution coefficient of 12 ml/g for Layer 1 and 1.48 for Layer 2 was based on previous studies and experimental data available (DOE 1993c) which indicates these values are conservatively low. The radioactive decay constants and biodegradation coefficients are

estimated based on the degradation rates (Howard et al. 1991) using the formulation presented in the Risk Assessment Work Plan Addendum (DOE 1992).

D.3.4 CONSTITUENT SCREENING AND REVIEW - VADOSE ZONE PATHWAY

The list of CPCs is screened in several ways to eliminate constituents that pose insignificant risk from further analysis. In addition, groundwater monitoring data is reviewed to determine constituents that are found in the aquifer so that these constituents can be evaluated in the computation of total risk. These screening steps are performed because vadose zone and aquifer modeling require long computational times and to allow the analysis to focus on the constituents that cause the high percentage of the risk. Figure D.3-13 shows the different screening steps. These steps include pre-screening and background screening (performed and presented in other sections of the RI), initial source concentration, travel time to the Great Miami Aquifer, and vadose zone output concentration screening (presented in this section), and the review of groundwater monitoring data. Table D.3-7 shows the list of CPCs, the results of different screening steps, and the list of CPCs for fate and transport modeling in the vadose zone pathway.

Each waste pit is treated separately in these screening analyses. The worst case is used to define action, i.e., if any waste pit fails a particular screening, then that constituent is maintained in subsequent analysis. These screening steps are described in sequence in the following sections.

D.3.4.1 Pre-Screening

Pre-screening is performed on the validated sampling and analysis data sets. Each constituent on the data set is evaluated based on the criteria defined in the Risk Assessment Work Plan Addendum (DOE 1992). At this stage in the process, two types of decisions are made:

- Nutrients at or below drinking water standards are screened out
- Constituents that are not detected in waste pit materials are screened out
- Constituents that are not detected in waste pit materials are screened out.

The results of this pre-screening are presented in Appendix E.2.

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D.3.4.2 Background Screening

A second preliminary screening step is conducted to remove constituents that are below background concentrations. Each constituent that passes prescreening is compared to background concentrations following the process defined in Appendix E.2. Constituents with concentrations determined to be below background concentrations are screened out. The results of this background screening are presented in Appendix E.

The constituents that "pass" the prescreening and background screening are designated "potential CPCs" (see Table D.3-7). A total of 71 potential CPCs were defined for Operable Unit 1 fate and transport modeling. These potential CPCs include 13 radionuclides, 21 inorganic constituents, and 37 organic constituents (see Table D.3-7).

D.3.4.3 Travel Time Screening

Constituents are screened based upon travel time to determine those that would not reach the Great Miami Aquifer within the time period of interest (1,000 years) in significant concentrations under conservative conditions. Travel time screening considers both physical time of travel through the vadose zone and radiological and organic decay over this time period.

Travel time screening is performed on potential CPCs based on distance, retardation factor, velocity, and dispersion. Any constituent that fails to reach the Great Miami Aquifer in 1,000 years is screened out. A second screening process involves comparing the organic or radiological decay constants for constituents to the minimum calculated travel time. If a constituent has gone through 30 half lives during this travel time, then it is screened out due to the negligible mass remaining.

Variables that are used in the screening step are:

- Retardation Factor (R_f) in the Vadose Zone
- Soil Seepage Velocity (V)
- Soil Thickness (L) between Waste Pit and Aquifer
- Axial Dispersion Coefficient (D_L)

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The mean travel time for a nondecaying CPC (t_m) is the sum of the travel time through Vadose Zone layer 1 and layer 2:

$$t_m = [R_{f1}(L_1/V_1)] + [R_{f2}(L_2/V_2)]$$

where

t_m = Travel time (day)
R_{f1} = Constituent retardation factor for vadose zone layer 1 (unitless)
L_1 = Thickness of vadose zone layer 1 (feet)
V_1 = Groundwater velocity in vadose zone layer 1 (feet/day)
R_{f2} = Constituent retardation factor for vadose zone layer 2 (unitless)
L_2 = Thickness of vadose zone layer 2 (feet)
V_2 = Groundwater velocity in vadose zone layer 2 (feet/day)

and if $t_m/30$ is less than the half life ($T_{1/2}$) then the constituent is further modeled. In other words, the minimum travel time divided by 30 is less than the half life of the constituent which indicates it reaches the aquifer in significant mass to be considered for further modeling.

A characteristic dispersion parameter is D_L/VL which will be referred to as N_d. Depending on N_d, a fraction, M (Brenner 1962), can be multiplied by t_m to give a time before which exiting concentrations will be negligible. Consequently, if Mt_m is set at 1,000 years, exiting concentrations prior to 1,000 years will be negligible. Thus, a minimum screening retardation factor, R_{min} = 1000 x V/ML can be defined, above which the mean travel time will be in excess of 1000/M years and exiting concentrations up to 1,000 years will be negligible. This analysis is conservative in that one-dimensional flow is assumed and the minimum retardation factor that occurs in any vadose layer is used. Table D.3-8 shows the input assumptions for the Operable Unit 1 waste areas.

Table D.3-9 shows the results of the travel time screening. This table breaks the travel time screening into two categories of screening due to advective transport and screening due to radiological or organic decay. The travel time screening removes the majority of the potential CPCs. The advective transport screening step removes 42 of the 71 CPCs. In addition, 8 organic constituents are removed due to decay.

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D.3.4.4 Initial Concentration Toxicity Screening

Toxicity screening is performed on the potential CPCs that passed the travel time screening by comparing the initial concentrations for the vadose zone model (Leachate B - see Appendix D.1) with 10^{-7} risk based concentrations for carcinogens or 0.1 Hazard Quotient concentrations for non-carcinogens. These screening concentrations are derived by dividing the 10^{-6} risk based or Hazard Quotient of 1 concentrations for tap water (EPA 1993) by 10. Since Leachate B cannot increase in concentration in transport through the vadose zone or aquifer, then Leachate B represents a theoretical maximum concentration in the aquifer. If the initial concentrations for all waste areas is less than the screening concentration, then the constituent is not modeled further. If any waste area includes a value greater than the screening concentration, then the constituent is still modeled for all the waste areas since modeled concentrations from the different waste areas could be additive.

Table D.3-9 presents the results of the initial concentration toxicity screening. Of the constituents that passed the travel time screening, all passed the initial toxicity screening.

D.3.4.5 Vadose Zone Model Toxicity Screening

Prior to performing aquifer modeling, the output from the vadose zone model is again toxicity screened in a manner similar to the initial concentration toxicity screening (see Section D.3.4.4). Since concentrations can only further dilute when leachate mixes with the aquifer waters, this screening step removes constituents that will clearly be below the 10^{-7} risk based or 0.1 Hazard Quotient standard in the aquifer. To perform this screening, the maximum output from the vadose zone model for a particular constituent is compared with the 10^{-7} risk based or 0.1 Hazard Quotient standard. If this maximum value is below the standard, then the constituent is screened out and is not modeled further.

Table D.3-7 shows the results of the second toxicity screening under the column heading of "Screen out ODAST Output." Antimony, barium, cadmium, copper, lead, manganese, mercury, and 4-nitroaniline are screened out because no appreciable concentration of these constituents reached the aquifer within 1,000 years.

D.3.4.6 Review of Monitoring Data

Water samples have been taken from the Great Miami Aquifer and analyzed periodically. The results for the 2000 series wells indicate the degree of contamination from the FEMP

operation in the upper Great Miami Aquifer or the first SWIFT layer to date. Four specific wells (2019, 2021, 2027, and 2648) in close proximity to Operable Unit 1 were chosen to represent the degree of existing contamination from Operable Unit 1. Table D.3-10 lists all analysis targets that were found above detection limits in the FERMCO environmental monitoring data base. Many of these targets are not of concern from a toxicity standpoint (e.g., alkalinity, aluminum, potassium, sodium, pH, etc.) and were not included in the list of potential CPCs. It should be noted that organic compounds were not detected in these wells and therefore, are not included in the list of potential CPCs on Table D.3-10. For the remaining potential CPCs that are detected, these constituents are added to the list of CPCs (Table D.3-7).

Table D.3-11 illustrates background screening and calculations of travel-time to reach the nearest property boundary (fenceline) for those potential CPCs which were detected in these wells (refer to Figure D.3-2 for the logic of the overall screening procedure). The maximum concentrations of the potential CPCs found in these wells were compared with background concentrations. For those potential CPCs whose concentrations did not exceed background, no further action is required. For those exceeding background, travel time calculations to reach the fenceline were performed. The travel time calculation were performed using Darcy's Law with an average hydraulic gradient from Operable Unit 1 to the fenceline of 0.000769, an average K_h of 450 ft/day, and an average effective porosity of 0.25. Based on a travel distance of 3,250 feet from the Operable Unit 1 boundary to the east fenceline, a water travel time of 6.43 years was calculated. Thus, the critical retardation factor (Rcrit) defining whether the fenceline is reached in 1,000 years for a particular potential CPC is 155. If the potential CPC retardation factor is less than 155, then the constituent reaches the fenceline within 1,000 years.

For those CPCs indicated in Table D.3-11 (barium, strontium-90, technetium-99, and the uranium isotopes) which reach the fence line in less than 1000 years, the groundwater model will be calibrated so that early concentrations (0-40 years) will reasonably approximate the concentrations found in the aquifer.

The combined source term from the direct leaks and natural migration scenarios are illustrated in Figure D.3-3. The figure depicts five possible cases of the direct leak and

natural migration scenario source terms using different combinations of contaminant source concentration and contaminant retardation factors. Potential CPCs are categorized into one of these five cases as presented in Table D.3-12.

The Operable Unit 1 groundwater fate and transport model contains two release scenarios: (1) natural migration of waste pit leachate through glacial overburden and (2) direct leakage of pit leachate to the Great Miami Aquifer via some form of direct channel (e.g., perched water flowing to the GMA via the casing of a leaking well). During early calibration of the fate and transport model, it was determined that the concentration of contaminants in the Great Miami Aquifer, in an area southeast of Pit 4, could not be accounted for using the natural migration scenario alone. To do so, it is required that the glacial overburden be approximated by a media approaching the permeability of sand and that chemical retardation of contaminants be assumed to approach zero. The direct leakage scenario was added to the model to account for these elevated contaminant concentrations in a localized area.

Ten cells in the vicinity of Waste Pit 4 and the Burn Pit (Figure D.3-14A) were used to model the potential contribution due to leaking wells in the vicinity of Waste Pit 4 (Table D.3-13) and the historical lack of a cover over Waste Pit 4 and the Burn Pit. The addition of this direct leakage scenario allowed the model to accurately represent current contaminant concentrations in the Great Miami Aquifer while using realistic characteristics for the glacial overburden and contaminants. The contribution from the 10 cells was assumed to end concurrent with the covering of Waste Pit 4 and the Burn Pit and the plugging of 15 leaking wells in the vicinity of Waste Pit 4. The leak is deemed to have started at year 10 and persisted for 30 years to year 40. This overall calibration scheme is illustrated in Figure D.3-3. In effect, five possible scenarios are created (see Figure D.3-3) that depict different combinations of the direct leak source term and vadose zone breakthrough. Potential CPCs are categorized into one of these five cases as presented in Table D.3-12.

Case 1 illustrates the case of a potential CPC which has a direct leak to the Great Miami Aquifer and also has a significant loading to the Great Miami Aquifer through the vadose zone (calculated by One-Dimensional Analytical Solute Transport [ODAST]) prior to 1,000 years but separated in time from the direct leak. Case 1 behavior is typical of uranium. Case 2 is similar to Case 1 except that the future releases to the aquifer are insignificant (i.e., concentrations are less than the 10^{-7} cancer risk or 0.1 Hazard Quotient criterion). Case 2

behavior is typical of barium. Case 3 illustrates the case of a CPC which has some current contamination but whose retardation factor is so high that any loading through the vadose zone would not occur until after 1,000 years. Case 3 behavior is typical of thorium-230. Technetium-99 behavior is unusual and is illustrated by Case 4. Technetium-99 is very mobile and some quantity is expected to have already migrated through the vadose zone. However, to approximate the concentrations found, it is also necessary to have an additive direct leak block. Finally, Case 5 illustrates the case of the many screened out CPCs that are determined by the procedure given in Figure D.3-2 to not pose any risk. SWIFT modeling is required only for CPCs that fall into Case 1 or Case 4, or Cases 2 and 3 when a contaminant already in the Great Miami Aquifer can reach the fenceline.

Beyond having the same source, the two release scenarios provide separate and distinct source terms within the fate and transport model. During 30 of the first 40 years of the model simulation, the model includes a contribution from the direct leakage scenario. The contribution from the natural migration scenario begins on the initial day of the model simulation and continues for all future time. Using the natural migration scenario, uranium reaches its maximum concentration beneath the waste pits, 32 ppm, in 500 years. Even if the direct leakage scenario were assumed to continue throughout the entire 500 year period, the ultimate maximum concentration would be increased by less than 1 ppm uranium. Thus, the direct leakage scenario provides a method to model current contaminant concentrations in the Great Miami Aquifer but has little impact on the maximum contaminant concentrations which will eventually occur as a result of the natural migration scenario.

D.3.4.7 Summary of CPCs

Table D.3-12 presents the summary of the modeling status of the different CPCs. This table shows the constituents that have passed the screening (Table D.3-7) and that have been found in groundwater (Table D.3-10). For constituents that have been found in groundwater, it was determined based upon groundwater travel time and constituents retardation factors whether a particular constituent would reach the fenceline (Table D.3-11). The maximum constituent concentration is reported for these constituents which will be used in the risk assessment for calculating risk. From these considerations, the list of constituents requiring aquifer (SWIFT) modeling and calibration during modeling is determined.

D.3.5 PERCHED GROUNDWATER CONCENTRATIONS

Theoretical perched groundwater concentrations are needed for the future exposure scenario to perched groundwater. These concentrations are reported on Table D.3-14 for Waste Pits 4, 5, 6 and the Burn Pit which, as discussed in Section D.3.3, have perched groundwater occurring in sand lenses beneath them. These values are the initial concentrations (Leachate B or Organic Leachate) for the entire list of CPCs determined in Section D.1.0 from the geochemical analysis. The list of CPCs represent a union of any constituent detected in any Operable Unit 1 waste area. These initial concentrations are used because they represent a conservative depiction of perched groundwater concentrations.

D.3.6 VADOSE ZONE MODELING

Vadose zone modeling is performed to estimate contaminant loading rates to the Great Miami Aquifer from a given source as a function of time. The overburden may have great capacity for immobilization and retardation of contaminants due to adsorption, precipitation, biodegradation, and radioactive decay. This capacity to prevent or slow the movement of contaminants to the aquifer is evaluated with respect to future risk.

The following criteria were used in selecting specific analytical models:

- Capability of treating adsorption, radioactive and organic decay, and longitudinal dispersion
- Capability of calculating concentrations over long time periods
- Availability of code
- Degree of code documentation
- Degree of code verification

The primary model selected is the ODAST model. To estimate time for source depletion and to calculate seepage velocity (required ODAST input parameters), leachate infiltration rates are calculated outside of ODAST. Either the HELP model (for covered pits) or an analytical solution (for pits with standing water) are utilized for calculating seepage velocities. These models are discussed below.

D.3.6.1 Models for Seepage Velocity

Description of HELP Model

To accomplish the simulation of the hydraulic system in Operable Unit 1, the HELP model is used to determine the infiltration rates through the waste units. The HELP model (EPA 1984) is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of a waste unit. The model accepts climatologic, soil, and design data and simulates a number of hydraulic processes including surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. The systems that can be modeled by HELP include various combinations of vegetation, cover soils, waste cells, special drainage layers, and relatively impermeable barrier soils.

The HELP model is designed to perform water budget calculations for a system having as many as nine layers by modeling each of the hydrologic processes that occur. Each layer must be identified as either a vertical percolation, lateral drainage, waste, or barrier soil layer. The identification of each layer used in the model is critical because the program models water flow through the various types of layers in different ways. Runoff is computed using the Soil Conservation Service runoff curve number method by considering daily precipitation totals. Percolation and vertical water routing are modeled using Darcy's Law for saturated flow with modifications for unsaturated conditions. Evapotranspiration is estimated by a modified Penman method adjusted for limiting soil moisture conditions.

The HELP model output consists of input data echo, simulation results, and a summary. The input data echo includes all the information used for input including the values chosen from the model's built-in data base and any manually input data. Following the input data echo, the program produces a table of the daily results, monthly totals, and annual totals for each year if the options for detailed output are used. Following these outputs, the summary output is given. The summary includes average monthly totals, average annual totals, and peak daily values for the simulation variables. The average monthly totals reports precipitation, runoff, evapotranspiration, percolation through the base of each layer, and lateral drainage through each layer for a particular month for all the years of a simulation. The average annual total reports the values on an annual basis. The summary of peak daily values represents the maximum values that occurred on any day during the simulation period.

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Description of Ponded Calculations

The HELP model could not perform calculations in cases where there was standing water. Since standing water is present at Waste Pits 5, 6, and the Clearwell, an alternate method was required for these ponded water cases.

A simple application of Darcy's Law in one dimension was used for these waste areas. This equation is:

$$q = K_{eff} * H/L$$

where

q	= flow rate (ft/d)
K_{eff}	= effective hydraulic conductivity (ft/d)
H	= total head = $L + H_p$ (ft)
L	= length of saturated material (ft)
H_p	= depth of pond liquid (ft)

For this analysis, it was assumed that conditions beneath a waste pit with standing water would be saturated until the bottom of the first restrictive (low hydraulic conductivity) layer and would be unsaturated beneath this restrictive layer. For the Operable Unit 1 waste areas, this occurs at the bottom of the clay liner beneath the waste pits. The gradient was calculated as the difference in head between the water surface and the bottom of this layer divided by the length of saturated material. The effective hydraulic conductivity was calculated as the harmonic mean of the hydraulic conductivity of the waste and liner layers.

Infiltration Rate Results

HELP modeling for Operable Unit 1 included separate runs for Waste Pits 1 through 4 and the Burn Pit. In each simulation, the climatologic data of precipitation and mean monthly temperature were synthetically generated for Covington, KY. Average rainfall in the period was 40.64 inches/year.

The soil physical parameters and the design data used in the simulations were varied for each waste unit to reflect the varying conditions of each unit. These values were defined based upon the Waste Pit Contents Study (Parsons 1993). In general, layers were defined for an earth cover (if present), waste pit material, clay liner (if present), glacial till, and upper Great Miami Aquifer sands. Membrane liners were ignored for these simulations. Permeabilities

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were defined based upon engineering calculations (Parsons 1993). When permeabilities were not available, assumed values were utilized.

HELP was run to "steady state," that is, until successive simulations showed no appreciable change in soil moisture content in any of the layers. HELP results presented as infiltration rates (q) are shown on Table D.3-2. Results varied from 2.8 inches/year for the Burn Pit to 10.7 inches/year for Waste Pit 4.

For the ponded water cases of Waste Pit 5, 6, and the Clearwell, results of the Darcy calculation are shown on Table D.3-2. These values ranged from 10.1 inches/year (Clearwell) to 23.5 inches/year (Waste Pit 6). Higher values for the ponded cases are consistent with the fact that the head produced by the surface water would increase the infiltration rate.

D.3.6.2 Model for Solute Transport (ODAST)

ODAST Description

The model selected to evaluate flow in the vadose zone is ODAST (Javendel et al. 1984). ODAST, a one-dimensional analytical solution, is used for determining fate and transport of the constituents not previously screened out in the unsaturated zone. This computer code is based on the solution originally developed by Ogata and Banks (1961) and calculates the normalized concentrations of a given constituent in a uniform flow field from a source having a constant or varying concentration in the initial layer. ODAST evaluates the basic one-dimensional analytical solute transport equation as a function of seepage velocity, dispersion coefficient, source decay, retardation factor, depletion time, and source rate. ODAST has been extensively verified against STRIP1B (Batu 1989).

The ODAST model implements an analytical solution to the partial differential equation

$$D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} - \lambda RC = R\frac{\partial C}{\partial t}$$

where

C = solute concentration (mass/volume)
and with the constant coefficients
D = dispersion coefficient (length^2/time)
V = seepage velocity (length/time)
R = retardation factor (dimensionless)
λ = solute decay factor (time^{-1})

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The solution must satisfy the initial and boundary conditions

$$C(x,0) = 0$$

$$-D\frac{\partial C}{\partial x} + VC\,|_{x=0} = \begin{cases} VC_o\, e^{,-\alpha t} & 0 \le t \le \tau_o \\ 0, & t > \tau_o \end{cases}$$

$$\frac{\partial C}{\partial x}\Big|_{x\to\infty} = 0$$

where the constants

C_o = initial source concentration (mass/vol)
α = source depletion factor (time^{-1})
τ_o = source depletion time (time)

The solution is obtained using a Laplace transform technique and involves products of exponential and complementary error functions (Javandel et al. 1984). The solution for C is divided by C_0 to yield normalized concentrations.

Because the coefficients in the governing equation are constant and the solution must satisfy a zero concentration gradient condition as x approaches infinity, ODAST is only strictly applicable to one-dimensional transport in homogeneous, semi-infinite media. However, the present application of ODAST is intended only to provide conservative estimates of aquifer mass loading histories.

ODAST is run only for those constituents that pass the travel time and initial concentration screening steps. Model runs can be executed for only one CPC at a time, and the solution may be applied over any arbitrary segment of a waste area that is judged to contain an unchanging subsurface. A superposition technique is used to combine calculations for the two homogeneous layers comprising the vadose zone conceptual model. The ODAST solution at the bottom of layer 1 is divided into 1000 small time steps and a layer 2 run is performed for each of these steps. Each of these layer 2 runs assumes no source decay, a recharge period 1/1000 of the total modeling time, and a source concentration equal to the averaged layer 1 solution for that time period. The solution at the bottom of layer 2 is obtained by summing the results of the 1000 layer 2 runs at specified time steps. For RI/FS modeling, concentrations are calculated up to 1,000 years, typically in steps of 20 years. Constituents

that migrate quickly, such as organics, require smaller time steps for accurate representation of loading curves.

ODAST requires a formatted ASCII file containing the input parameters for a particular problem. This is the only input required. Likewise, output is contained in a single formatted ASCII file. The unit conventions for the input file parameters are: specified calculation times and source depletion time are expressed in years, all other parameters use days, and any consistent length scale may be used.

The first parameters appearing in the input file are specifications of the values of the independent variables for which the calculations are desired. These include the number of x positions, number of times, and the actual x positions (measured positive downward from the top of the layer) and times. Because concentrations are required at the bottom of the layer, only one x position, representing layer thickness, is used. Layer thicknesses vary among and within the waste areas and are obtained from interpolated measurements at the FEMP. As previously stated, times up to 1,000 years in 20 year increments are normally used. The number of times may be greater and increments smaller if the constituent migrates rapidly.

The final line of the input file contains the waste area, solute, and medium dependent parameters. In order of appearance in the file, they are the dispersion coefficient, seepage velocity, retardation factor, source depletion time, solute decay factor, and source depletion factor.

Seepage velocity and the dispersion coefficient depend upon the characteristics of the waste area and the vadose zone medium. Seepage velocity is calculated as an empirical function of the percolation rate obtained from the HELP model, saturated hydraulic conductivity, and porosity (EPA 1988). The dispersion coefficient is obtained as an empirical function of seepage velocity (Biggar and Nielsen 1976).

The retardation factor accounts for transport delays due to reversible reactions between the chemical constituent and the vadose zone solid matrix. It is thus dependent on both solute and medium characteristics, and is calculated as a function of the constituent's partitioning coefficient and the vadose zone bulk density and moisture content (Walton 1984 and Mills et al. 1985).

The solute decay factor is constituent dependent. This parameter accounts for biodegradation in organics and radioactive decay in radionuclides, and is zero for stable inorganics (ASI/IT 1992).

Source depletion time and factor control the mass flux history of the constituent at the top of the modeled layer. As can be seen from the upstream boundary condition, source mass flux decays exponentially. To calculate depletion time and factor for the waste at the top of layer 1, the time dependent expression for mass flow from the source is integrated from zero to the source depletion time. This integral is equated to the depleted mass of the constituent to provide a single equation in two unknowns. A second equation is obtained by arbitrarily specifying a mass depletion fraction. This is the level (very close to, but less than one) at which the source is declared depleted; technically, the source is depleted only as time approaches infinity. As stated previously, depletion factor is zero and depletion time is 1/1000 of the total modeling time for the layer 2 runs.

For the 1,000-year scenario, the projected concentration of the leachate entering the Great Miami Aquifer beneath the waste area was calculated by multiplying the normalized concentration at the base of the lowest layer by the source term (initial contaminant concentration - Leachate B). The loading rates were calculated by multiplying the projected concentration beneath the waste area by the volumetric recharge rate from the source. The plots of loading rates versus time were then produced for the constituents which were projected to reach the aquifer within 1,000 years. The peak values in these plots were considered as the maximum loading rates to be observed in the aquifer for the contaminants over 1,000 years.

ODAST Modeling Results

Loading rates to the Great Miami Aquifer were estimated for each CPC for the Operable Unit 1 waste areas and for selected CPCs detected in the perched groundwater using ODAST. Technetium-99, uranium-234, uranium-235, uranium-238 and arsenic were selected from the perched groundwater CPCs they appear to present the highest risk based on the ratio of the maximum detected concentration and the 10^{-7} risk based or 0.1 Hazard Quotient concentrations. Table D.3-15 provides a summary of the loading times and rates for the CPCs which will reach the Great Miami Aquifer within 1,000 years. The loading rates were used as input data for SWIFT aquifer model to model the groundwater movement and solute

transport in the Great Miami Aquifer. This table also presents the approximate number of years for the CPCs from Operable Unit 1 to reach the Great Miami Aquifer and the maximum concentrations of compounds in the leachate that would be expected before being diluted in the aquifer.

For the waste area source, Table D.3-15 shows that uranium-238 has the highest loading rate and loading concentrations at between 530 and 540 years. Uranium-234 and 235 also contribute significant loading and concentrations at these times. Boron and vinyl chloride have the highest loading and concentration of the inorganic and organic constituents respectively. Since different constituents contribute different proportions of risk based upon unit risk factors, concentrations need to be multiplied by risk factors to determine risks associated with a particular compound i.e., concentrations are not directly comparable from the standpoint of risk. To demonstrate the effect of loading for the perched groundwater source beneath Waste Pits 4, 5, 6 and the Burn Pit based on the highest risk, technetium-99, uranium-234, uranium-235, uranium-238 and arsenic were modeled. As shown in Table D.3-15, uranium-238 has the highest loading rate and loading concentrations between 530 and 540 years. When compared to loading concentrations from the waste area source, the radionuclide loading concentrations from the perched groundwater source are several orders of magnitude lower. Arsenic in the perched groundwater does not reach the Great Miami Aquifer in 1,000 years.

Loading rates of a constituent from ODAST to the aquifer from a given source vary over time. Typically, loading rates experience a mild increase representing the dispersion front followed by a sharp increase representing the principle breakthrough of the constituent. They can then stabilize or decrease depending upon the depletion time of the source. For a long depletion time the source remains active for a longer period during the simulation. The depletion rate is low for long depletion times, this ensures a mild change in the source term with time and helps to approach a steady-state condition within the simulation time of 1,000 years. For short depletion time, the source term vanishes earlier during the simulation period. For high depletion rates, the source term decreases faster during the simulation period. These factors cause an unsteady variation along with a sharp decline in the loading rates.

D.3.7 AQUIFER MODELING

Aquifer modeling is performed on both CPCs defined for the vadose zone pathway and CPCs from the surface water pathway. The derivation of the CPCs for the surface water pathway and the surface water modeling is presented in Section D.2.0.

D.3.7.1 Description of Model, Background, and Development

Groundwater modeling for the Operable Unit 1 risk analysis was performed with the calibrated groundwater flow model for the FEMP. This model utilizes the SWIFT code and was previously calibrated using groundwater elevations obtained during the April 1986 monitoring period. A brief summary of the calibration and the results of the calibration are presented in this section.

The groundwater modeling program was initiated to define groundwater transport in and around the FEMP. The selection, verification, calibration, and results of groundwater modeling are presented in two separate reports (IT 1990b and DOE 1990), and in the Groundwater Modeling Report - Summary of Model Development (DOE 1993c). The groundwater model used in support of the risk analysis is a finite-difference computer model of groundwater flow and solute transport. The computer program used is SWIFT/386 Version 2.51. A comprehensive verification study of the SWIFT code has been completed and a report issued (IT 1990a). A detailed presentation of the model, its development, and the baseline input data was issued as a part of the overall modeling report prepared under the RI/FS (DOE 1990) and revised and issued as a separate report (DOE 1993c). Only the most pertinent information is presented here.

Steps in the development of the model for application to the FEMP have included:

- Construction and calibration of a regional, two-dimensional, steady-state groundwater flow model
- Construction and calibration of a regional, three-dimensional, steady-state groundwater flow model
- Application of a local, two-dimensional, analytical solute transport model to help strategize the numerical solute transport model
- Construction of a local, two-dimensional, transient solute transport model

- Construction and calibration of a local, three-dimensional, transient solute transport model with uranium concentration data from the monitoring wells

The regional model covers an area of 28.7 square miles (74.3 km^2), including the FEMP, the Southwestern Ohio Water Company (SOWC) collector wells, and a portion of the Great Miami River. The regional model's grid spacing varies between 250 feet and 2,000 feet (76 m and 610 m), and has the closest grid spacing in the area of the SOWC collector wells. It was calibrated against field data using a steady-state flow condition and calibration results were incorporated into the local area model.

The local model covers a smaller area than the regional model and uses a tighter grid spacing, with grid cells 125 feet (38 m) on a side. The smaller grid was established to include the area of the existing uranium plume, and extends from the northern part of the FEMP to approximately 1,500 feet (460 m) north of the Great Miami River (Figure D.3-14B). The grid size was selected based on the need to simulate a uranium dispersivity of 100 feet (30 m) longitudinally, which was the preferred value based on literature review (IT 1990c). Using this dispersivity value, the grid size was selected to accommodate dispersivity values as low as 62.5 feet (19 m), or half the distance of the local grid area of 125 feet (38 m). The relationship between the local and regional models was established by imposing the steady-state flow field predicted by the regional model onto the local solute transport model.

The regional and local models each contain five layers. These layers are conceptually shown in Figure D.3-4. The uppermost two layers represent the upper and lower parts of the upper Great Miami Aquifer that underlies the area. The middle layer represents a clay interbed that is present in the immediate vicinity of the FEMP site, and the lowermost two layers represent the upper and lower parts of the lower Great Miami Aquifer. In regions where the clay interbed is not present, the middle layer has the same characteristics as the upper two layers. The layers extend laterally into bedrock to the edges of the buried valley that contains the aquifer. The number of aquifer cells in each layer was decreased with depth in the aquifer to simulate the narrowing bedrock valley. This was done using bedrock topography maps of the region and simulated the U-shaped buried valley which contains the Great Miami Aquifer.

Pumping wells are located in the area spanned by both the regional and local models. These include a FEMP production well (there are four total, but only one pumps significant

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quantities of water) and three industrial wells located south of the FEMP site in both models. Pumping from each of these wells was assigned to the proper cell and layer in the model. In addition, the regional model also simulates the presence of two large capacity collector wells owned by the SOWC located by the Great Miami River. Although they are not directly included in the local model, they do influence its results by way of the boundary conditions brought in from the regional model.

The calibration of the groundwater flow model was performed by comparing hydraulic heads calculated by the model against heads measured in numerous monitoring wells throughout the FEMP and surrounding areas. This calibration was performed using the regional flow model. Reasonable estimates of hydraulic conductivity and recharge were initially input into the model and then varied within an acceptable range to adjust model-computed heads into agreement with observed monitoring well heads.

The model used varying hydraulic conductivity values for the five layers based on the results of the calibration. The uppermost and middle layers were assigned hydraulic conductivity values of 450 feet per day (140 m/day), and the lowermost layers used 600 feet per day (180 m/day). In addition, a portion of the middle layer which underlies the FEMP was assigned 0.0003 feet per day (9×10^{-5} m/day) as a hydraulic conductivity value to represent the clay interbed (as shown by geologic borings). This simulated the presence of a low permeability clay and created a semi-confining layer underneath part of the FEMP and its surrounding area. Vertical to horizontal hydraulic conductivity ratios were set for all layers at 0.1. Results of the recent South Plume pump test calculated aquifer values for vertical to horizontal ratios from 0.07 to 0.17 (i.e., over a range which includes this value) (Parsons 1993).

Recharge rates set as a result of the regional model calibration were assigned to several different zones. In areas where the sand and gravel aquifer is overlain by glacial overburden, a recharge of 6 inches per year (0.15 m/yr) was used. Regions where the Great Miami Aquifer is exposed at the surface use 14 inches per year (0.36 m/yr), with Paddys Run channel being assigned a value of 32 inches per year (0.81 m/yr) in the local model to simulate its increased infiltration. An additional region, the area covered by the FEMP was also included as a consequence of the sensitivity analysis. This region was assigned a value

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of 2 inches per year (0.05 m/yr) to simulate the developed nature of the site and the effects of storm water drainage into the storm sewer system.

Groundwater flow conditions simulated by the model were successful and reproduced the observed flow conditions throughout the study area. Based on water levels from 55 wells, the arithmetic mean residual (observed head minus calculated head at the monitoring well) for the calibrated flow model was 0.33 feet (0.1 m). The excellent match portrayed by this residual value is realized when compared to a total change in hydraulic head of approximately 20 feet (6.1 m) over the modeling area. The mean of the absolute values of the residuals was 1.08 feet (0.33 m), with a standard deviation of 1.36 feet (0.41 m). Water balances performed using the model showed total inflow and total outflow from the model to agree within 0.2 percent.

To maintain hydraulic similarity between the regional and local flow models, a computer program was used to check, cell by cell, the correspondence of heads in the local model with heads in the regional model. The program verified that the regional flow model calibration was preserved in the local model which was used for solute transport; thus, no new flow calibration was necessary. The local model used hydraulic parameters identical to those used in the calibrated regional model. Boundary conditions for the local model were set from corresponding cells in the regional model to maintain the hydraulic similarity.

D.3.7.2 SWIFT Modeling

The calibrated groundwater flow model for the FEMP is used to simulate the solute transport of the compounds in the Great Miami Aquifer. A constant loading period was defined for ODAST output for each constituent for the SWIFT modeling based upon source decay, retardation and constituent decay factors. Typically, a 5 year loading period was used for organics (low retardation factors) while a 20 year period was defined for radionuclides (high retardation factors). Loading rates for each period were calculated by averaging the results of the vadose zone modeling over the length of each period. In this way, total mass inflow into the aquifer was maintained. Compounds were simulated for a total of 1,000 years in the Great Miami Aquifer.

Loading rates were assigned to each of the potential source areas in the model and were adjusted to account for the varying surface area occupied by each waste area. Model source

areas were calculated by dividing the area of the actual source by the area of a model grid cell, which is 125 feet (38 m) on a side (a total of 15,625 square feet [1450 m^2]). This defined the number of cells needed for each source area in the model as shown in Table D.3-16. Cells in the model were then assigned to each source area to correspond with the physical location of the source. The loading rate for each compound was then divided by the number of model cells in each source area to derive the adjusted loading rate for each cell in the source area.

In the case of uranium-234, uranium-235, and uranium-238, all three uranium isotopes were modeled as one compound to simplify the modeling and to allow the use of the previously calibrated total-uranium solute transport model. Because the previous model utilizes total-uranium and because the uranium at the FEMP is mostly uranium-238 (approximately 99 percent by mass), this approach was used.

Initial background concentrations of each compound in the aquifer were set at zero. The model simulations for the Operable Unit 1 CPCs used dispersivity values of 100 feet (30 m) longitudinal and 10 feet (3 m) in the transverse direction. These values were determined during the solute transport calibration for uranium and are based on values taken from literature review (DOE 1990 and Walton 1984). Distribution coefficients (Kd) and decay factors for simulated compounds were also taken from literature review and are shown in Table D.3-17.

Model simulations were performed using SWIFT/386 on a Powerbox PC microcomputer. Simulation execution times varied between 18 and 37 hours and required extensive computing capacity. Output was written to a single file from which relevant data was extracted using data manipulation programs written for that purpose. Contour plots were made for selected constituents at different simulation times for CPCs from both the vadose zone and surface water pathways to represent plumes in space and plume changes over time. Contour plots are presented at 100 years, at the time of maximum concentration, and at 1,000 years.

Calibration to 2000 Series Wells Concentrations

As described above, modeled values are compared to monitored concentrations to confirm model predictions (see Section D.3.1.2). Calibration was performed to year 40 to reproduce approximate concentrations found in the aquifer. Table D.3-12 shows that calibration is

required for barium, strontium-90, technetium-99 and uranium, based on these CPCs being present above background concentrations in the Great Miami Aquifer and reaching the fenceline within 1,000 years.

For barium, a source term of 0.2×10^{-1} lbs/day was added to 10 cells within Operable Unit 1 for the 30 year block of time. With this loading rate, a concentration of 0.37 ppm was modeled at the location of well 2027 compared to an average measured value of 0.33 ppm (based on 6 quarters of data 1991 and 1992). Since these values are within the same order of magnitude, calibration was considered complete.

For strontium-90, a source term of 0.44×10^{-12} lbs/day was added to 10 cells within Operable Unit 1 for the 30 year block of time. With this loading rate, a concentration of 5.3×10^{-9} ppb was modeled at the location of well 2019 compared to an average measured value of 5.3×10^{-9} ppb (based on six quarters of data 1991 and 1992). Since these values are within the same order of magnitude, calibration was considered complete.

For technetium-99, a source term of 0.128×10^{-4} lbs/day was added to 10 cells within Operable Unit 1 for the 30-year block of time. With this loading rate, a concentration of 1.78×10^{-1} ppb was modeled at the location of well 2019 compared to an average measured value 1.71×10^{-1} ppb (based on 6 quarters of data 1991 and 1992). Since these values are within the same order of magnitude, calibration was considered complete.

For uranium, a direct leak source term of 0.2×10^{-3} lbs/day was added through the 10 cells within Operable Unit 1 for the 30-year block of time. This loading rate resulted in modeled uranium concentrations which closely approximate those measured in the Great Miami Aquifer. Figure D.3-14C shows the modeled U-238 concentration contours in the vicinity of Operable Unit 1. A comparison of the modeled versus measured values for the seven wells used to calibrate the model in the vicinity of Waste Pit 4 are shown in Table D.3-18.

Vadose Zone Pathway SWIFT Results

Table D.3-19 summarizes the SWIFT modeling results. This table shows the time and value of maximum concentration for each of the modeled constituents for both the waste area and perched groundwater sources. In addition, concentrations, based on monitoring data, are presented for constituents found in groundwater. These represent present day (model year 40) concentrations of these constituents. By comparing Tables D.3-15 and D.3-19, constituents

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are typically predicted to decrease two orders of magnitude from the vadose zone concentration to the Great Miami Aquifer. From Table D.3-19, it is seen that the uranium isotopes for the waste area source have the highest modeled concentrations in the Great Miami Aquifer. Uranium-238 is more than two orders of magnitude more than uranium-235 and almost 4 orders of magnitude greater than the next highest constituent, vinyl chloride. Even with variable unit risk factors, uranium-238 will dominate the risk.

Based on the previous discussion, the time of maximum risk on-site and off-site risk is determined by the maximum uranium-238 for the waste area source. These concentrations occur at 500 years (on-site) and 660 years (off-site). For the perched water source, the time of maximum risk on-site and off-site risk is also determined by the maximum uranium-238. These concentrations occur at 540 years (on-site) and 690 years (off-site). Because uranium isotopes have the same retardation factors, the maximums for uranium-234 and 235 also occur at these times. Tables D.3-20 and D.3-21 present the CPC concentrations at these years at the maximum on site location and maximum off site location. Again it is seen that the uranium isotopes especially uranium-238 dominate the concentrations and thus the risks at these locations and times. Appendix E will calculate the total risk based upon these concentrations.

Figures D.3-15 through 23 illustrate the concentrations in the groundwater at the three selected time intervals for uranium, cyanide and tetrachloroethene due to loading from the Operable Unit 1 source areas. Plume maps of these constituents are presented to provide spatial distributions of representative constituents as they migrate through time. From Figures D.3-15 through 23, it can be observed that the contaminant plumes are moving towards the east and southeasterly directions. This flow direction corresponds to the model flow field and is influenced by the high capacity SOWC water supply wells located east of the facility. For uranium, (Figures D.3-15, 16, and 17), minimal concentrations are predicted after 100 years. A maximum is reached in 500 years which slowly declines to 1,000 years (compare Figures D.3-16 and 17). The cyanide plots (Figures D.3-18 ,19, and 20) all show similar trends suggesting a small but constant source term. The tetrachloroethene plots (Figures D.3-21, 22, and 23) also show similar trends over time. A "steady state" equilibrium is reached for the tetrachloroethene plume based upon a continuing source and a high decay rate.

Surface Water Pathway SWIFT Results

Section D.2.0 modeled runoff and stream concentrations. Because Paddys Run lies directly in contact with the Great Miami Aquifer over a portion of its course, a contaminant migration pathway exists into the aquifer through its streambed. Migration of contaminants in surface runoff to Paddys Run from the surface soil in the Operable Unit 1 waste areas and from Paddys Run to the Great Miami Aquifer has been designated the surface water to groundwater pathway. CPCs that follow the surface water pathway to the Great Miami Aquifer are first screened to remove constituents that pose insignificant risk. This screening is performed by taking the contaminant concentration in the runoff effluent (C_e) from MUSLE, and applying a Great Miami Aquifer dilution factor to this concentration to determine a theoretical Great Miami Aquifer concentration. This theoretical Great Miami Aquifer concentration was then compared to 10^{-7} risk based concentrations for carcinogens or 0.1 Hazard Quotient concentrations for non-carcinogens. These screening concentrations are derived by dividing the 10^{-6} risk based concentrations or Hazard Quotient of 1 concentrations for tap water (EPA 1993) by 10. If theoretical Great Miami Aquifer concentrations are below the screening concentrations then the constituent is screened out and is not modeled in the aquifer (Table D.2-5). One-hundred percent of the runoff effluent volume is assumed to flow to the Great Miami River, and 30 percent of the runoff effluent volume is assumed to infiltrate to the Great Miami Aquifer through Paddys Run during storm events.

Since Paddys Run exfiltrates to the Great Miami Aquifer, the constituents that passed the surface water screening (see Section D.2.0) are modeled with SWIFT. Constituents requiring modeling include arsenic, technetium-99 and uranium-234 and 238 isotopes (see Table D.2-5).

Table D.3-22 summarizes the results of the SWIFT modeling for these surface water constituents presenting the time and maximum concentrations. The radionuclides all show maximum concentrations within 40 years. Arrival times are fast since there is a direct connection between Paddys Run and the aquifer. Maximums are reached quickly because the source term maximizes at the beginning and depletes over time. Because of their higher K_ds, arsenic and lead take a longer time to reach a maximum concentration. Mass of constituents entering the aquifer from the surface water are initially adsorbed. Like the vadose zone pathway, uranium-238 has the highest concentration of the modeled constituents by five orders of magnitude over uranium-234 and 4 orders of magnitude over arsenic.

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Figure D.3-24 shows the total uranium plume from the surface water loading at the time of maximum concentration of 10 years at coordinates N481,311, E1,377,790. This figure shows a plume centered on Paddys Run with primary transport to the east and to the south. Some western transport is also shown caused by mounding and dispersion. This figure shows the general trends of how the south plume could have been created by exfiltration from Paddys Run.

D.3.8 UNCERTAINTY IN MODELING RESULTS

The fate and transport modeling performed for Operable Unit 1 is subject to uncertainty and variability due to factors such as the lack of compound specific characterization data, the inability of the models to simulate natural systems with 100 percent accuracy, and the assumptions for future site conditions for the waste units. Of these factors, the assumptions made for the future conditions of the waste units have the most impact on the modeling results. The waste units are all assumed to release contaminants to the environment without future maintenance. This is a worst case scenario and thus yields higher contamination levels than would be considered if a vegetative cover or cap was constructed. However, this type of assumption is the primary premise in performing a baseline assessment and the most conservative for the purpose of evaluating the risk from the groundwater pathway.

The inherent assumptions built into the models and the assumptions made to develop input parameters for the models also have an impact on the final results. The major uncertainty in the analysis is the estimation of parameters related to the attenuation and retardation of constituents. Based upon the data available, a conservative approach was used which may overestimate the concentration of the leachate. The assumptions of total contact between the waste and the leaching fluid and no containment of the leachate concentrations will produce higher concentrations than would be anticipated under actual conditions.

The following sections discuss uncertainty associated with the different models used in the fate and transport modeling.

D.3.8.1 HELP Model

The HELP model is mainly sensitive to the parameters used to define evapotranspiration and runoff. The majority of water exiting the system is lost through these two mechanisms and thus the remaining water becomes the seepage passing through the waste unit. Evapotranspiration is controlled by the plant cover type used, which was assumed to be bare

ground for the Operable Unit 1 simulations. This would in fact cause a large decrease in contaminant seepage and loadings if vegetative cover were established, as the amount of water available for seepage would decrease. As this is currently not the case, the present results from the HELP model are more conservative.

Runoff in the HELP model is controlled by the Soil Conservation Study runoff curve number used, which in turn is derived from the ground type, vegetation type, and land use. If any of these factors are incorrect, available water for seepage could change and thus loading to the aquifer would change.

Uncertainty was also involved in the computation of seepage flow rates for the glacial till and the unsaturated sand and gravel layer. The unsaturated seepage flow rate is a function of the unsaturated hydraulic conductivity which depends on parameters such as porosity, residual saturation, and pore size distribution index. All of these parameters vary in a physical formation matrix and thus cannot be fully defined for use in a numerical model. However, the sensitivity of HELP to hydraulic conductivity was examined. A typical HELP run for the production area of the site had four layers: (1) earth cover, (2) fractured brown clay, (3) till or gray clay, and (4) unsaturated aquifer. Thicknesses were 0.5, 15, 17, and 35 feet respectively. The lowest hydraulic conductivity was that of the till layer. Table D.3-23 illustrates the effect of changing this conductivity on seepage rate.

It is apparent that a reduction of over 2 orders of magnitude is necessary to cause a significant reduction in the seepage velocity. Apparently the rate of 10.92 inches/year is limited by other factors (i.e., that is all the water that is available for seepage). Consequently, one would expect that the rate would not increase significantly with increases in hydraulic conductivity.

A sensitivity analysis of effect on seepage rate of change in conductivity values was also performed using a different stratigraphy; that of Waste Pit 1. Five layers were present (1) earth cover - 0.5 feet, (2) Pit 1 Waste - 18 feet, (3) clay liner - 11 feet, (4) till - 2 feet, and (5) unsaturated aquifer - 24.3 feet. Conductivities of each of these layers were changed in order of magnitude steps, both up and down. The results are illustrated in Table D.3-24.

It is apparent that for Pit 1 large changes in all conductivities will affect the seepage rate. Reduction in the conductivity would cause an almost proportional reduction in seepage rate.

An increase of 10 caused an increase by a factor of 3+ so that it is apparent that other factors (evapotranspiration, etc.) are becoming important. The seepage rate would certainly be expected to be bounded by these values.

D.3.8.2 ODAST Model

Sensitivity analyses were conducted on the vadose zone model ODAST by varying the Darcy velocity, the longitudinal dispersivity, and the layer thickness within the model to determine their impacts on the loading curves generated by the models. Data from a waste unit was used as a baseline for comparison and an unretarded, nondecaying contaminant was used. Longitudinal dispersivity, Darcy velocity, and layer thickness were all varied by a factor of two by both doubling and halving each of the parameters while all other input was held constant. ODAST was used to evaluate the impacts of each of these parameters on final modeling results. The results of these analyses are presented in Figures D.3-25, D.3-26, and D.3-27.

All three figures illustrate that for a given source loading rate, the peak concentration reached for a nondecaying solute is the same regardless of the flow system used. This is shown by the peak loadings reached by the contaminant, which is 100 ppb for all cases studied. The main influence noted in all three cases has to do with the time required for maximum loading to occur at the base of the vadose zone. Longitudinal dispersion (Figure D.3-25) has a negligible impact on the time for loading to reach the aquifer and the vadose models are not sensitive to its value. The models are sensitive to both Darcy velocity (Figure D.3-26) and layer thickness (Figure D.3-27) as these both directly control the transport time required to pass through the vadose zone. Doubled layer thicknesses or halved Darcy velocities cause a significant increase in the time required for contaminant to reach the aquifer and for maximum loading to occur. Likewise, halving the layer thicknesses and doubling the Darcy velocity causes a decrease in the times.

The impact of the Darcy velocity and layer thickness on the models is somewhat limited due to the derivation of the parameters themselves. Layer thicknesses were derived from Operable Unit 1 boring data which should not vary over a large range within the operable unit. Darcy velocity is a function of the seepage rate, calculated by the HELP model, and the formation porosity, which is fairly well defined for the media simulated by the models.

A parameter specific sensitivity analysis was conducted for uranium-234, as a part of the modeling analysis to observe the variation of the modeling results by changing the values of certain parameters. The sensitivity runs were performed by increasing and decreasing hydraulic conductivity, porosity, and retardation factor from the estimated values in a series of order-of-magnitude steps in the range of known site values. Hydraulic conductivity is a very important flow parameter. It is used as a direct input into the seepage velocity calculation, moreover, hydraulic conductivity is also a controlling factor in determining the seepage flow under both saturated and unsaturated conditions as described in the previous section.

Results indicate that the variation of hydraulic conductivity only affects the arrival time of the contaminant (uranium-234), however there is no significant change in the peak concentration. The arrival times of the contaminant in the aquifer were estimated at 100 and 540 years, respectively, due to increase and decrease in the hydraulic conductivity value by 1 order of magnitude from the estimated value. Further decreasing the hydraulic conductivity by 2 orders of magnitude, the arrival time was delayed to 2,200 years. Sensitivity runs conducted by varying porosity (increasing as well as decreasing porosity by 30 percent) had no significant effect either on the arrival time or peak concentration. Results also indicate that the variation of distribution co-efficient affects the arrival time, whereas the peak concentration remains unchanged. Arrival times, for the sensitivity runs performed by decreasing and increasing distribution co-efficient by 1 order of magnitude were 40 years and 1,200 years respectively.

From sensitivity analysis, it was seen that the variation of different parameters affects the arrival time of the contaminant, however, there is no significant change in the peak concentration. It was observed that the peak concentration for uranium was always within 1 order of magnitude when steady state or peak concentration was reached.

When decay is combined with low seepage velocities and/or retardation due to adsorption, the contaminant concentration at the Great Miami Aquifer is significantly reduced. However, the difference between the peak concentrations reaching the aquifer for low and high seepage velocities is sensitive to whether the contaminant concentration reached a steady state. For any contaminant, if the steady state condition was reached for both low and high seepage flow

velocities, the peak concentrations differ less compared to other constituents that did not reach a steady state concentrations at the aquifer within the simulation period of 1,000 years.

The movement of organic constituents to the Great Miami Aquifer is greatly impeded by high biodegradation rates. For low seepage velocities and dispersion coefficients, the transport process is delayed and more time is available for degradation of the organic chemicals. Thus for organic chemicals, the peak concentrations were several orders of magnitude lower (or zero) with low-end as compared to high-end seepage velocities and dispersion coefficients.

The range of hydraulic conductivities at a site is constrained by the geology. Nevertheless, the reasonable range of hydraulic conductivities at a site permits a high degree of variability in contaminant transport.

D.3.8.3 SWIFT Model

Like the vadose zone models, SWIFT is mostly influenced by the solute transport parameters it uses to simulate contaminant movement through the aquifer. Of these, retardation is the least well defined and has the most impact on the fate of contaminants in the groundwater. Calibration of the SWIFT model for uranium was performed as part of the RI/FS process. The SWIFT flow model was calibrated by comparing hydraulic heads calculated by the model against heads measured in numerous monitoring wells throughout the FEMP and surrounding areas. The flow calibration is described in Section 3.7-1. The SWIFT solute transport model was calibrated by simulation of uranium transport in the Great Miami Aquifer (IT 1990a) over the period of operation at the FEMP. A portion of this calibration involved testing uranium retardation values to determine which value fit historical loading data and present day groundwater concentration data most accurately. Uranium retardation factors below 4 were found to transport uranium too quickly through the system and thus did not match historical data. Retardation factors above 15 were found to not match present day uranium distributions without large aquifer dispersion values, which were felt to be unrealistic. Consequently, a retardation factor of 12 was found to give the best match for uranium during the modeling process, which also fell within the range of the geochemical studies performed for uranium at the FEMP (IT 1989). This same value was used in uranium fate and transport modeling.

Two SWIFT sensitivity runs were completed with parameters chosen to maximize dilution and dispersion (Run #1) and to minimize dilution and dispersion (Run #2). The retardation factor

of 12 (corresponding to K_d of 1.4 ml/g) is considered to be a conservatively low value since most experimental data for FEMP and other locations indicate higher values. This value was used in Run #1, SWIFT layers 1 and 2. Other parameter values layers 1 and 2 for Runs #1 and #2 were chosen to represent a reasonable range that might be expected in the aquifer sand and gravel layers. Nominal values for other layers were retained. Table D.3-25 illustrates the input parameters and results for these runs.

These results indicate that almost an order of magnitude variation in maximum concentration could be expected within the range of variation expected for site parameters. Note however that the plume spread is more significant with almost a factor of 100 variation in size for the area within the 1 ppb contour. Note that while Run #2 has higher concentrations, the 1 ppb contour is contained in a small area underneath the site. The time of occurrence for peak concentrations for Run #2 is also extended beyond 1,000 years.

As described in Section D.3.1.2, "direct leak" terms have now been incorporated into the calibration process so that a better match of early concentrations of uranium and consideration of other constituents with limited groundwater monitoring data are possible. The major parameter affecting solute transport is retardation. Higher retardation factors delay the appearance of a concentration peak at a receptor almost proportionately. Experimental determination of retardation factors for CPCs, which have relatively large source terms and are relatively toxic is an important factor in reducing uncertainty in solute transport.

TABLE D.3-1

WASTE AREA PHYSICAL PARAMETERS FOR OPERABLE UNIT 1 MODELING

Location	Area		Volume of Waste Material		Dry Density
	(m^2)	(ft^2)	(m^3)	(yd^3)	(kg/m^3)
Waste Pit 1	7,682	82,691	37,083	48,500	1,660
Waste Pit 2	4,172	44,901	18,503	24,200	1,310
Waste Pit 3	22,422	241,347	156,055	204,100	1,330
Waste Pit 4	7,785	83,799	42,130	55,100	1,830
Waste Pit 5	14,965	161,077	74,854	97,900	958
Waste Pit 6	3,011	32,410	7,340	9,600	1,550
Burn Pit	2,019	21,732	23,167	30,300	1,130
Clearwell	2,737	29,461	2,829	3,700	2,650

TABLE D.3-2

VADOSE ZONE MODEL INPUT PARAMETERS
OPERABLE UNIT 1

Waste Unit	Layer	Thickness (ft)[a]	K_v (ft/day)	q (ft/day)	V_x (ft/day)	D_x (ft^2/day)
Waste Pit 1	1	2.0	1.140×10^{-2}	7.500×10^{-4}	2.453×10^{-3}	8.231×10^{-4}
	2	24.3	4.500×10^{1}	7.500×10^{-4}	5.176×10^{-3}	1.052×10^{-3}
Waste Pit 2	1	13.0	1.140×10^{-2}	1.380×10^{-3}	4.407×10^{-3}	9.855×10^{-4}
	2	20.0	4.500×10^{1}	1.380×10^{-3}	9.016×10^{-3}	1.398×10^{-3}
Waste Pit 3	1	0.0				
	2	23.7	4.500×10^{1}	2.240×10^{-3}	1.401×10^{-2}	1.872×10^{-3}
Waste Pit 4	1	13.0	1.860×10^{-2}	2.440×10^{-3}	7.768×10^{-3}	1.283×10^{-3}
	2	21.7	4.500×10^{1}	2.440×10^{-3}	1.514×10^{-2}	1.983×10^{-3}
Waste Pit 5	1	13.3	1.830×10^{-3}	3.670×10^{-3}	1.149×10^{-2}	1.630×10^{-3}
	2	23.0	4.500×10^{1}	3.670×10^{-3}	2.196×10^{-2}	2.665×10^{-3}
Waste Pit 6	1	15.9	1.670×10^{-2}	5.360×10^{-3}	1.648×10^{-2}	2.114×10^{-3}
	2	24.3	4.500×10^{1}	5.360×10^{-3}	3.099×10^{-2}	3.607×10^{-3}
Burn Pit	1	12.9	1.410×10^{-2}	6.430×10^{-4}	2.133×10^{-3}	7.976×10^{-4}
	2	21.7	4.500×10^{1}	6.430×10^{-4}	4.500×10^{-3}	9.935×10^{-10}
Clearwell	1	0.0				
	2	23.7	4.500×10^{1}	2.290×10^{-3}	1.429×10^{-2}	1.900×10^{-3}

K_v - vertical hydraulic conductivity
q - vertical flow rate
V_x - vertical seepage velocity
D_x - longitudinal dispersion coefficient

[a] The thicknesses specified are for ODAST simulations only

TABLE D.3-3

MEDIA PARAMETERS FOR VADOSE ZONE MODEL OPERABLE UNIT 1

	Vadose Zone	
Parameter	Layer 1[a]	Layer 2[b]
Porosity (%)	34	39
Specific yield (%)	6	25
Bulk density (g/cc)	1.78	1.60
Field capacity (%)	28	14
Organic content (%)	1	0.5
Fines passing less than 200 mesh (%)	70	16
Moisture content (%)	34[c]	26[d]

[a] Layer 1 consists of a clay-rich till interbedded with glaciofluvial sand and gravel stringers.
[b] Layer 2 consists of well-sorted sand and gravel outwash deposits existing above the Great Miami Aquifer.
[c] Layer 1 is assumed saturated.
[d] Average between porosity and field capacity.

TABLE D.3-4

RETARDATION FACTORS AND DECAY CONSTANTS FOR RADIONUCLIDES AT OPERABLE UNIT 1

Constituent	Retardation Factor Vadose 1	Retardation Factor Vadose 2	Radioactive Decay Constant (Day^{-1})
Cs-137	9.49×10^{3}	8.43×10^{3}	6.294×10^{-5}
Np-237	2.89×10^{2}	3.18×10^{1}	8.874×10^{-10}
Pu-238	8.91z x 10^{3}	6.16×10^{2}	2.164×10^{-5}
Pu-239/240	8.91×10^{3}	6.16×10^{2}	7.870×10^{-8}
Ra-226	3.65×10^{3}	6.53×10^{2}	1.187×10^{-6}
Ru-106	4.19×10^{3}	3.39×10^{2}	1.890×10^{3}
Sr-90	5.34×10^{1}	1.64×10^{1}	6.640×10^{-5}
Tc-99	1.62×10^{0}	1.43×10^{0}	8.916×10^{-9}
Th-230	3.04×10^{4}	1.97×10^{4}	2.466×10^{-3}
Th-232	3.04×10^{4}	1.97×10^{4}	9.926×10^{-4}
U-234	6.38×10^{1}	1.01×10^{1}	7.767×10^{-9}
U-235	6.38×10^{1}	1.01×10^{1}	2.698×10^{-12}
U-238	6.38×10^{1}	1.01×10^{1}	4.250×10^{-13}

TABLE D.3-5

RETARDATION FACTORS FOR INORGANIC COMPOUNDS AT OPERABLE UNIT 1

Inorganics	Retardation Factor Vadose 1	Retardation Factor Vadose 2
Antimony	1.05×10^3	1.23×10^3
Arsenic	1.31×10^3	2.78×10^3
Barium	5.97×10^3	1.24×10^2
Beryllium	6.81×10^3	1.54×10^3
Boron	1.67×10^1	1.95×10^1
Cadmium	2.62×10^3	7.48×10^1
Chromium	7.86×10^3	4.32×10^2
Cobalt	2.88×10^3	3.70×10^2
Copper	6.56×10^2	2.16×10^2
Lead	1.57×10^4	2.35×10^2
Manganese	9.44×10^2	3.09×10^2
Mercury	5.34×10^1	6.25×10^1
Molybdenum	4.73×10^2	6.25×10^1
Nickel	3.41×10^3	2.46×10^3
Selenium	3.88×10^3	9.24×10^2
Silver	9.44×10^2	5.55×10^2
Thallium	7.86×10^3	9.23×10^3
Tin	3.40×10^3	4.00×10^3
Vanadium	5.24×10^3	1.23×10^3
Zinc	1.26×10^4	1.23×10^3

TABLE D.3-6

RETARDATION FACTORS AND BIODEGRADATION COEFFICIENTS FOR ORGANIC COMPOUNDS AT OPERABLE UNIT 1

Organics	Retardation Factor Vadose 1	Retardation Factor Vadose 2	Organic Decay Constant (Day^{-1})
1,2,3,7,8-Pentachlorodibenzofuran	1.66×10^4	4.20×10^3	NA[a]
2,3,4,7,8-Pentachlorodibenzofuran	$1.66 \times 10^{3-}$	4.20×10^3	NA
4-Nitroaniline	NA	NA	
4-Nitrophenol	3.04×10^0	1.52×10^0	7.07×10^{-2}
4,4'-DDT	3.89×10^4	9.85×10^3	1.20×10^{-4}
Acenaphthene	2.10×10^2	5.39×10^1	1.70×10^{-3}
Anthracene	7.03×10^2	1.79×10^2	3.80×10^{-4}
Aroclor-1248	1.41×10^4	3.57×10^3	NA
Aroclor-1254	2.68×10^4	6.80×10^3	NA
Aroclor-1260	3.24×10^4	8.20×10^3	NA
Benzo(a)anthracene	1.00×10^4	2.54×10^3	2.50×10^{-4}
Benzo(a)pyrene	2.40×10^4	6.07×10^3	2.50×10^3
Benzo(b)fluoranthene	9.33×10^4	2.36×10^4	2.80×10^{-4}
Benzo(g,h,i)perylene	4.27×10^5	1.08×10^5	2.70×10^{-4}
Benzo(k)fluoranthene	1.74×10^5	4.40×10^4	8.0×10^{-5}
Chrysene	1.00×10^4	2.54×10^3	1.70×10^{-4}
Cyanide[b]	1.22×10^0	1.11×10^0	9.50×10^{-4}
Dibenzo(a,h)anthracene	2.34×10^4	5.93×10^3	1.80×10^{-4}
Dichlorodifluoromethane	4.63×10^0	1.92×10^0	9.50×10^{-4}
Fluoranthene	5.37×10^3	1.36×10^3	3.90×10^{-4}
Fluorene	3.77×10^2	9.63×10^1	2.90×10^{-3}
Heptachlorodibenzo-p-dioxin	2.63×10^5	6.65×10^4	NA
Heptachlorodibenzofuran	1.66×10^4	4.20×10^3	6.19×10^3

TABLE D.3-6
(Continued)

Organics	Retardation Factor Vadose 1	Retardation Factor Vadose 2	Organic Decay Constant (Day^{-1})
Hexachlorodibenzo-p-dioxin	2.63×10^5	6.65×10^4	NA
Hexachlorodibenzofuran	1.66×10^4	4.20×10^3	NA
Ideno(1,2,3-cd)pyrene	1.15×10^6	2.90×10^5	2.40×10^{-4}
Naphthalene	5.87×10^1	1.56×10^1	2.69×10^3
Octachlorodibenzo-p-dioxin	2.63×10^5	6.65×10^4	NA
Octachlorodibenzofuran	1.66×10^4	4.20×10^3	6.19×10^{-3}
Pentachlorophenol	2.56×10^3	6.49×10^2	4.60×10^{-4}
Phenanthrene	7.29×10^2	1.85×10^2	8.70×10^{-4}
Pyrene	3.79×10^3	9.60×10^2	9.00×10^{-5}
Tetrachlorodibenzofuran	1.66×10^4	4.20×10^3	NA
Tetrachloroethene	9.51×10^0	3.15×10^0	4.20×10^{-4}
Vinyl chloride	1.10×10^0	1.03×10^0	2.40×10^{-4}

[a] NA denotes not available.
[b] Cyanide is an inorganic compound but it has an organic decay constant.

TABLE D.3-7

SCREENING SUMMARY OF POTENTIAL CONSTITUENTS OF CONCERN FOR OPERABLE UNIT 1

Potential Constituent of Concern	Screen Out Advective Travel Time	Screen Out Decay Travel Time	Screen Out Initial Concentration	Screen Out ODAST Output	Found in GW	Constituent of Concern
Inorganics						
Antimony				X	X	X
Arsenic	X				X	X
Barium				X	X	X
Beryllium	X					
Boron						X
Cadmium						X
Chromium	X					
Cobalt	X					
Copper						X
Cyanide						X
Lead					X	X
Manganese				X	X	X
Mercury						X
Molybdenum						X
Nickel	X					
Selenium	X					
Silver	X					
Thallium	X					

TABLE D.3-7
(Continued)

Potential Constituent of Concern	Screen Out Advective Travel Time	Screen Out Decay Travel Time	Screen Out Initial Concentration	Screen Out ODAST Output	Found in GW	Constituent of Concern
Tin	X					
Vanadium	X					
Zinc	X					
Organics						
1,2,3,7,8-Pentachlorodibenzofuran	X					
2,3,4,7,8-Pentachlorodibenzofuran	X					
2,4,5-Trichlorophenol		X				
4,4-DDT	X					
4-Nitrophenol		X				
4-Nitroaniline				X		
Acenaphthene		X				
Anthracene		X				
Aroclor-1221						X
Aroclor-1248	X					
Aroclor-1254	X					
Aroclor-1260	X					
Benzo(a)anthracene	X					
Benzo(a)pyrene	X					
Benzo(b)fluoranthene	X					

TABLE D.3-7
(Continued)

Potential Constituent of Concern	Screen Out Advective Travel Time	Screen Out Decay Travel Time	Screen Out Initial Concentration	Screen Out ODAST Output	Found in GW	Constituent of Concern
Benzo(ghi)perylene	X					
Benzo(ghi)fluoranthene	X					
Benzo(k)fluoranthene	X					
Chrysene	X					
Dibenzo(a,h)anthracene	X					
Dichlorodifluoromethane						X
Fluoranthene	X					
Fluorene		X				
Heptachlorodibenzofuran	X					
Heptachlorodibenzo-p-dioxin	X					
Hexachlorodibenzofuran	X					
Hexachlorodibenzo-p-dioxin	X					
Indeno(1,2,3-cd)pyrene	X					
Naphthalene		X				
Octachlorodibenzofuran	X					
Octachlorodibenzo-p-dioxin	X					
Pentachlorophenol	X					
Phenanthrene		X				
Pyrene	X					

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TABLE D.3-7
(Continued)

Potential Constituent of Concern	Screen Out Advective Travel Time	Screen Out Decay Travel Time	Screen Out Initial Concentration	Screen Out ODAST Output	Found in GW	Constituent of Concern
Tetrachlorodibenzofuran	X					
Tetrachloroethene						X
Vinyl Chloride						X
Radionuclides						
Cesium-137	X					
Neptunium-237						X
Plutonium-238	X					
Plutonium-239/240	X					
Radium-226	X					
Ruthenium-106		X				
Strontium-90					X	X
Technetium-99					X	X
Thorium-230	X					
Thorium-232	X					
Uranium-234					X	X
Uranium-235						X
Uranium-238					X	X

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TABLE D.3-8

INPUT PARAMETERS AND FORMULAS FOR TRAVEL TIME SCREENING

Parameter	Units	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Waste Pit 6	Burn Pit	Clearwell
Thickness Vadose 1	(ft)	2.00	13.00	0.00	13.00	13.30	15.90	12.90	0.00
Thickness Vadose 2	(ft)	24.30	20.00	23.70	21.70	23.00	24.30	21.70	23.70
Total Thickness L	(ft)	26.30	33.00	23.70	34.70	36.30	40.20	34.60	23.70
Infiltration Rate q	(in/yr)	3.281	6.023	9.828	10.708	16.091	23.466	2.818	10.051
Infiltration Rate q	(ft/day)	7.491×10^{-4}	1.375×10^{-3}	2.244×10^{-3}	2.445×10^{-3}	3.674×10^{-3}	5.358×10^{-3}	6.434×10^{-3}	2.295×10^{-3}
V Vadose 1	(ft/day)	2.531×10^{-3}	4.538×10^{-3}	7.265×10^{-3}	7.889×10^{-3}	1.167×10^{-2}	1.677×10^{-2}	2.187×10^{-3}	7.423×10^{-3}
V Vadose 2	(ft/day)	5.171×10^{-3}	8.987×10^{-3}	1.403×10^{-3}	1.517×10^{-3}	2.198×10^{-2}	3.098×10^{-2}	4.502×10^{-3}	1.432×10^{-2}
Nd Vadose 1		1.638×10^{-1}	1.690×10^{-2}		1.262×10^{-2}	1.061×10^{-2}	8.038×10^{-3}	2.84×10^{-2}	
Nd Vadose 2		8.368×10^{-3}	7.762×10^{-3}	5.636×10^{-3}	6.032×10^{-3}	5.277×10^{-3}	4.789×10^{-3}	1.017×10^{-2}	5.606×10^{-3}
Brenner Multiplier M Vadose 1		0.1	0.4		0.5	0.5	0.5	0.3	
Brenner Multiplier M Vadose 2		0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.6

Formulas:

$Nd = D/(V)(L)$

$D = 6.458 \times 10^{-4} + (0.14)(V)^{1.11}$

TABLE D.3-9

TOXICITY SCREENING FOR CONSTITUENTS THAT PASSED TRAVEL TIME SCREENING

Constituent	Leachate B Concentrations										
	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Waste Pit 6	Burn Pit	Clearwell	Maximum Concentration	Screening Level	Screen Out
Radionuclides[a]											
Neptunium-237		3.00×10^{-6}	1.1×10^{-10}	1.45×10^{-9}	5.00×10^{-7}	1.06×10^{-5}	1.50×10^{-9}	4.51×10^{-4}	4.51×10^{-4}	3.40×10^{-8}	No
Strontium-90	2.84×10^{-14}	3.14×10^{-14}	8.30×10^{-13}	7.31×10^{-13}	2.90×10^{-10}	7.00×10^{-12}	1.67×10^{-13}	1.06×10^{-11}	2.90×10^{-10}	1.10×10^{-12}	No
Technetium-99	2.18×10^{-6}	5.33×10^{-6}	2.06×10^{-5}	2.07×10^{-5}	1.88×10^{-5}	1.61×10^{-4}	1.47×10^{-6}	2.36×10^{-4}	2.36×10^{-4}	2.40×10^{-7}	No
Uranium-234	5.75×10^{-4}	1.74×10^{-4}	2.57×10^{-4}	2.38×10^{-2}	6.79×10^{-5}	1.38×10^{-5}	1.46×10^{-4}	3.07×10^{-4}	2.38×10^{-2}	5.3×10^{-8}	No
Uranium-235	1.24×10^{-1}	3.68×10^{-2}	3.67×10^{-2}	12.7	8.9×10^{-3}	4.62×10^{-3}	3.04×10^{-2}	5.6×10^{-2}	12.58	$1.5E \times 10^{-4}$	No
Uranium-238	11.93	3.73	7.42	1.28×10^{3}	1.2	1.5	2.95	18.6	18.6	5.6×10^{-4}	No
Inorganics[a]											
Antimony	3.23×10^{-1}	5.71×10^{-1}	6.56×10^{-1}	9.56×10^{-1}	1.58×10^{-1}		1.03×10^{-1}	7.00×10^{-4}	9.56×10^{-1}	1.5×10^{-3}	No
Barium	1.92×10^{0}	1.56×10^{-1}	2.61×10^{-2}	4.41×10^{-2}	6.28×10^{-1}	1.96×10^{0}	3.50×10^{-2}	1.35×10^{-2}	1.96×10^{0}	2.60×10^{-1}	No
Boron	1.23×10^{0}	2.82×10^{0}	5.48×10^{0}	2.93×10^{0}			2.12×10^{0}		5.48×10^{0}	3.30×10^{0}	No
Cadmium	4.14×10^{-2}	2.79×10^{-1}	3.11×10^{-1}	1.18×10^{-1}	9.40×10^{-3}	9.50×10^{-4}	1.97×10^{-2}	9.50×10^{-4}	3.11×10^{-1}	1.80×10^{-3}	No
Copper	8.32×10^{-2}	1.45×10^{-1}	7.82×10^{-1}	6.43×10^{-1}	9.48×10^{-1}	6.00×10^{-3}	1.18×10^{-1}	1.90×10^{-2}	9.48×10^{-1}	1.4×10^{-1}	No
Cyanide	5.44×10^{-1}	3.16×10^{-2}	1.27×10^{0}	2.65×10^{-2}	8.64×10^{-2}	2.90×10^{-2}	3.60×10^{0}	8.70×10^{-2}	3.60×10^{0}	1.80×10^{-2}	No
Lead	4.80×10^{-3}	1.83×10^{-2}	1.61×10^{0}	2.00×10^{-3}	1.77×10^{-2}	6.91×10^{-1}	1.13×10^{-2}	5.50×10^{-4}	1.61×10^{0}	1.50×10^{-3}	No
Manganese	7.71×10^{-2}	3.93×10^{-3}	1.97×10^{-1}	5.98×10^{-3}	2.41×10^{0}	2.01×10^{0}	2.98×10^{-2}	2.00×10^{-2}	2.41×10^{0}	1.80×10^{-2}	No
Mercury	1.80×10^{-10}	9.80×10^{-11}	2.16×10^{-11}	8.80×10^{-9}	2.18×10^{-2}	5.00×10^{-5}	2.40×10^{-8}	1.00×10^{-4}	2.18×10^{-2}	1.10×10^{-3}	No
Molybdenum	3.61×10^{-1}	1.57×10^{0}	1.57×10^{0}	6.29×10^{-1}	1.50×10^{2}		1.05×10^{0}	5.28×10^{0}	1.50×10^{2}	1.80×10^{-2}	No
Organics[b]											
4-nitroaniline		5.00×10^{1}							5.00×10^{1}	1.10×10^{1}	No
Aroclor-1221	2.50×10^{0}								2.50×10^{0}	1.00×10^{3}	No
Dichlorofluoromethane	2.00×10^{2}								2.00×10^{2}	3.90×10^{1}	No
Tetrachloroethene	4.70×10^{1}			1.40×10^{2}		6.00×10^{0}	2.00×10^{0}		1.40×10^{2}	1.30×10^{-1}	No

[a]Initial concentration in parts per million (ppm).
[b]Initial concentration in parts per billion (ppb).

TABLE D.3-10

CONSTITUENTS DETECTED IN WELLS 2019, 2021, 2027, AND 2648

Constituent	Constituent	Constituent
1,1-Dichloroethane	Magnesium, (Dissd.)	TH-230
Alkalinity at CaCO3	Manganese	TOC
Aluminum	Manganese, (Dissd.)	Total dissolved solids
Antimony	Molybdenum	U-234
Ammonia, as nitrogen	NP-237	U-235/236
Arsenic	Nickel	U-238
Barium	Nickei, (Dissd.) Nitrogen, Nitrate	U-TOTAL
Barium, (Dissd.)	Nitrogen, Nitrate+Nitrite	Vanadium
Calcium	PU-238	Zinc
Calcium, (Dissd.)	pH	Zinc, (Dissd.)
Chloride	Phosphorus, Total Potassium	
Chromium, Total	Potassium, (Dissd.)	
Copper	RA-226	
Copper, (Dissd.)	RA-228	
Fluoride	Selenium	
GROSS ALPHA	Sodium	
GROSS BETA	Sodium, (Dissd.)	
Iron	Specific conductance	
Iron, (Dissd.)	Sulfate	
Lead	TC-99	
Magnesium	TH-228	

TABLE D.3-11

BACKGROUND SCREENING FOR CONSTITUENTS FOUND IN THE GREAT MIAMI AQUIFER AND POTENTIAL TRAVEL TO FENCELINE

Constituent	Maximum Concentration (mg/l or pCi/l)	Background Concentration (mg/l or pCi/l)	Background Concentration Basis[a]	Above Background?	Retardation Factor (R)	Reach Fenceline? (Rcrit > R)[b]	Groundwater Model Calibration Required?
Inorganics	mg/ℓ	mg/ℓ					
Antimony	0.175	0.006	MCL	Yes	1230	No	No
Arsenic	0.582	0.05	MCL	Yes	278	No	No
Barium	0.651	0.18	UCL	Yes	124	Yes	Yes
Chromium	0.066	0.1	MCL	No			No
Copper	0.176	0.27	UTL	No			No
Lead	0.058	0.015	MCL	Yes	235	No	No
Manganese	2.072	0.736	UCL	Yes	309	No	No
Molybdenum	0.031	0.04	UTL	No			No
Nickel	0.064	0.1	MCL	No			No
Selenium	0.005	0.006	UTL	No			No
Silver	0.0015	0.1	MCL	No			No
Zinc	0.319	0.735	UCL	No			No
Radionuclides	pCi/ℓ	pCi/ℓ					
Plutonium-238	0.133	1.0	UTL[c]	No	616	No	No
Radium-226	1.78	8.5	UTL[c]	No	653	No	No
Strontium-90	0.731	5	UTL[c]	No	16.4	Yes	Yes
Technetium-99	6860	36	UTL[c]	Yes	1.43	Yes	Yes

TABLE D.3-11
(Continued)

Constituent	Maximum Concentration (mg/l or pCi/l)	Background Concentration (mg/l or pCi/l)	Background Concentration Basis[a]	Above Background?	Retardation Factor (R)	Reach Fenceline? (Rcrit > R)[b]	Groundwater Model Calibration Required?
Radionuclides	pCi/ℓ	pCi/ℓ					
Thorium-230	1.04	3.44	UTL[c]	No	19,700	No	No
Uranium-234	7.99	4.2	UTL[c]	Yes	12	Yes	Yes
Uranium-235	0.5955	1.0	UTL[c]	No	12	Yes	Yes
Uranium-238	6.34	4.4	UTL[c]	Yes	12	Yes	Yes

[a] MCL - Maximum Contaminant Level; UTL - Upper Tolerance Level based on background sampling; UCL - Upper Confidence Limit based on background sampling.
[b] Rcrit = 155
[c] Background concentrations for radionuclides from Table 9 of the *Characterization of Background Water Quality for Streams and Groundwater* (Draft) (DOE May 1993c). Due to the draft nature of the values, the are not used to screen out constituents. UTL was set equal to the maximum detected value or maximum sample quantitation limit, whichever is larger.

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TABLE D.3-12

CONSTITUENTS OF POTENTIAL CONCERN SUMMARY LIST

Potential Constituent of Concern	Loading Case[a]	Passed Natural Migration Screening[b]	Found in Groundwater Above Background Concentration[b]	Reaches Fenceline[c]	Reported Maximum Aquifer Concentration[c,d]	Requires SWIFT Modeling	Requires SWIFT Model Calibration
Radionuclides							
Neptunium-237	Case 2	X				X	
Strontium-90	Case 1	X		Yes	0.731 pCi/ℓ	X	X
Technetium-99	Case 4	X	X	Yes	6,860 pCi/ℓ	X	X
Uranium-234	Case 1	X	X	Yes	7.99 pCi/ℓ	X	X
Uranium-235	Case 1	X		Yes	0.5955 pCi/ℓ	X	X
Uranium-238	Case 1	X	X	Yes	6.34 pCi/ℓ	X	X
Inorganics							
Antimony	Case 2		X	No	0.175mg/ℓ		
Arsenic	Case 3		X	No	0.582mg/ℓ		
Barium	Case 2		X	Yes	0.651mg/ℓ	X	X
Boron	Case 1	X				X	
Cyanide	Case 2	X				X	
Lead	Case 2		X	No	0.058 mg/ℓ		
Manganese	Case 2		X	No	2.072 mg/ℓ		
Molybdenum	Case 1	X				X	
Organics							
Aroclor-1221	Case 2	X				X	

TABLE D.3-12
(Continued)

Potential Constituent of Concern	Loading Case[a]	Passed Natural Migration Screening[b]	Found in Groundwater Above Background Concentration[b]	Reaches Fenceline[c]	Reported Maximum Aquifer Concentration[c,d]	Requires SWIFT Modeling	Requires SWIFT Model Calibration
Dichlorodifluoro-methane	Case 4	X				X	
Tetrachloroethene	Case 4	X				X	
Vinyl Chloride	Case 4	X				X	

[a] See Figure D.3-3 for loading case designation.
[b] See Figure D.3-13 for overall screening approach.
[c] See Figure D.3-2 for screening approach.
[d] If reported maximum aquifer concentration doesn't reach fenceline, then it represents the maximum on-site concentration used in the baseline risk assessment.

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TABLE D.3-13

PLUGGED WASTE PIT MONITORING WELLS

Well Number	Depth (ft)	Riser Material	Installation Date	Plugged Date	Reason for Plugging
1019	10	PVC	02/**/85	07/23/92	Failed casing joints (camera surveyed).
1021	10	PVC	02/**/85	08/31/92	Failed casing joints (camera surveyed).
1022	11.35	PVC	02/**/85	08/18/92	Failed casing joints (camera surveyed).
2019	72	PVC	02/**/85	07/30/92	Failed casing joints (camera surveyed).
2021	72	PVC	02/13/85	09/10/92	Failed casing joints (camera surveyed).
2022	83	PVC	02/14/85	08/26/92	Failed casing joints (camera surveyed).
3019	123	PVC	02/06/85	08/06/92	Failed casing joints (camera surveyed).
3084	116	Stainless	11/14/87	09/30/93	Failed casing joints and bore-hole seal (camera surveyed).

**Exact installation date not available.

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TABLE D.3-14

PROJECTED MAXIMUM PERCHED WATER CONCENTRATIONS

	Leachate B or Organic Leachate Concentration				
Constituent	Pit 4	Pit 5	Pit 6	Burn Pit	Maximum
Inorganics (ppm)					
Antimony	0.956	0.1577	NA	0.103	0.956
Arsenic	0.0025	0.00928	0.6316	0.0494	0.6316
Barium	0.041	0.628	1.9559	0.035	1.9559
Beryllium	7.12×10^{-4}	0.0198	0.0204	8.22×10^{-4}	0.0204
Boron	2.93	NA	NA	2.12	2.93
Cadmium	0.118	0.0094	9.5×10^{-4}	0.0197	0.118
Chromium	0.0406	0.0243	2.2×10^{-3}	0.129	0.129
Cobalt	0.338	0.0748	4.75×10^{-3}	0.0377	0.338
Copper	0.643	0.9478	0.006	0.118	0.9478
Cyanide	0.0265	8.64×10^{-2}	NA	3.6	3.6
Lead	0.002	0.0177	0.6914	0.0113	0.6914
Manganese	5.98×10^{-3}	2.4135	2.008	0.0298	
Mercury	8.8×10^{-9}	0.0218	NA	2.4×10^{-8}	0.0218
Molybdenum	0.629	1.15×10^{2}	NA	1.05	1.15×10^{2}
Nickel	2.13	0.3025	0.165	0.299	2.13
Selenium	0.0025	0.0021	NA	0.0038	0.0038
Silver	0.0041	3.35×10^{-3}	0.0667	2.06×10^{-3}	0.0667
Thallium	0.01	5.5×10^{-4}	0.7535	0.0002	0.7535
Tin	0.2	8.29	1.3	NA	8.29
Vanadium	0.929	1.4388	0.007	0.0743	1.4388
Zinc	0.0145	0.3338	1.7918	0.011	1.7918
Radionuclides (ppm)					
Cesium-137	NA	1.04×10^{-9}	8.6×10^{-11}	NA	1.04×10^{-9}

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TABLE D.3-14
(Continued)

Constituent	Leachate B or Organic Leachate Concentration				
	Pit 4	Pit 5	Pit 6	Burn Pit	Maximum
Neptunium-237	1.45×10^{-9}	5.0×10^{-7}	1.06×10^{-5}	2.1×10^{-9}	1.06×10^{-5}
Plutonium-238	2.86×10^{-11}	2.8×10^{-12}	1.1×10^{-11}	2.86×10^{-11}	2.86×10^{-11}
Plutonium-239/240	1.01×10^{-10}	8×10^{-10}	8×10^{-10}	9.1×10^{-11}	8×10^{-10}
Radium-226	9.4×10^{-9}	NA	5.0×10^{-11}	7.33×10^{-8}	7.33×10^{-8}
Ruthenium-106	NA	1.27×10^{-11}	NA	NA	1.27×10^{-11}
Strontium-90	7.31×10^{-13}	2.9×10^{-10}	7.0×10^{-12}	1.77×10^{-11}	2.9×10^{-10}
Technetium-99	2.07×10^{-5}	1.88×10^{-5}	1.612×10^{-4}	1.47×10^{-6}	1.612×10^{-4}
Thorium-230	2.1×10^{-9}	5.14×10^{-9}	1.5×10^{-8}	NA	1.5×10^{-8}
Thorium-232	2.1×10^{-9}	4.6×10^{-4}	4.6×10^{-4}	NA	4.6×10^{-4}
Thorium - Total	2.1×10^{-9}	NA	NA	2.12×10^{-9}	2.12×10^{-9}
Uranium-234	0.0238	6.79×10^{-5}	1.377×10^{-5}	1.45×10^{-4}	0.0238
Uranium-235	12.78	0.0089	4.62×10^{-3}	0.0301	12.78
Uranium-238	1,280	1.2	1.496	2.95	1,280
Uranium-Total	500	NA	NA	2.87	500
Organics (ppb)					
1,2,3,7,8-Pentachlorodibenzofuran	1×10^{-3}	NA	NA	NA	1×10^{-3}
2,3,4,7,8-Pentachlorodibenzofuran	1.1×10^{-3}	NA	NA	NA	1×10^{-3}
2,4,5-Trichlorophenol	NA	NA	NA	NA	NA
4,4-DDT	NA	NA	NA	NA	NA
4-Nitroaniline	NA	NA	NA	NA	NA
4-Nitrophenol	10	NA	NA	NA	10
Ancenaphthene	12	NA	NA	40	40
Anthracene	17	NA	NA	40	40
Aroclor-1221	NA	NA	NA	NA	NA
Aroclor-1248	50	0.5	NA	NA	50

TABLE D.3-14
(Continued)

	Leachate B or Organic Leachate Concentration				
Constituent	Pit 4	Pit 5	Pit 6	Burn Pit	Maximum
Aroclor-1254	100	1	0.5	10	100
Aroclor-1260	NA	NA	NA	NA	NA
Benzo(a)anthracene	10	NA	NA	40	40
Benzo(a)pyrene	10	NA	NA	40	40
Benzo(b)fluoranthene	10	NA	NA	40	40
Benzo(ghi)perylene	10	NA	NA	40	40
Benzo(ghi)fluoranthene	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	10	NA	NA	40	40
Chrysene	10	NA	NA	40	40
Dibenzo(a,h)anthracene	10	NA	NA	NA	10
Dichlorodifluoromethane	NA	NA	NA	NA	NA
Fluoranthene	2	NA	NA	40	40
Fluorene	9	NA	NA	40	40
Heptachlorodibenzofuran	2.4×10^{-3}	NA	NA	NA	2×10^{-3}
Heptachlorodibenzo-p-dioxin	9.4×10^{-4}	NA	NA	7.2×10^{-4}	9.4×10^{-4}
Hexachlorodibenzofuran	1.2×10^{-3}	NA	NA	NA	1.2×10^{-3}
Hexachlorodibenzo-p-dioxin	7.5×10^{-4}	NA	NA	NA	7.5×10^{-4}
Indeno(1,2,3-cd)pyrene	10	NA	NA	40	40
Naphthalene	16	NA	NA	12	16
Octachlorodibenzofuran	9×10^{-4}	NA	NA	1.1×10^{-3}	1.1×10^{-3}
Octachlorodibenzo-p-dioxin	1.2×10^{-3}	NA	NA	1.8×10^{-3}	1.8×10^{-3}
Pentachlorophenol	NA	NA	NA	200	200
Phenanthrene	10	NA	NA	40	40
Pyrene	10	NA	NA	40	40

TABLE D.3-14
(Continued)

	Leachate B or Organic Leachate Concentration				
Constituent	Pit 4	Pit 5	Pit 6	Burn Pit	Maximum
Tetrachlorodibenzofuran	5.3×10^{-3}	NA	NA	NA	5.3×10^{-3}
Tetrachloroethene	140	NA	6	2	140
Vinyl Chloride	6	NA	NA	1,000	1,000

NP = Not Present
NA = Not detected in pit materials or analysis results not available

TABLE D.3-15

SUMMARY OF LOADING TIMES AND CONCENTRATIONS FOR CONSTITUENTS OF POTENTIAL CONCERN

Constituents of Concern	Minimum Time of Arrival to the Aquifer (years)[a]	Time of Maximum Loading Concentration (years)	Maximum Loading Rates to the Aquifer (mg/day)	Maximum Loading Concentration (mg/ℓ)
Vadose Zone Pathway Waste Area Source				
Radionuclides				
Np-237	440	980-1,000	1.135×10^{-2}	1.231×10^{-5}
Sr-90	100	180-200	8.2×10^{-8}	8.971×10^{-11}
Tc-99	5	10-15	3.786×10^{-1}	4.110×10^{-4}
U-234	10	620-630	5.8684×10^{2}	1.381×19^{-2}
U-235	10	620-630	3.88549×10^{2}	9.205×10^{2}
U-238	10	620-630	5.18150×10^{5}	1.228×10^{3}
Inorganics				
Boron	90	350-360	3.1×10^{3}	7.330×10^{0}
Cyanide	5	10-15	7.94×10^{0}	1.870×10^{-2}
Molybdenum	620	980-1,000	3.60×10^{-1}	2.710×10^{-3}
Organics				
Aroclor-1221	680	980-1,000	1.26×10^{0}	9.821×10^{-3}
Dichlorodifluorourethane	15	35-40	2.20×10^{-1}	1.731×10^{-3}
Tetrachloroethene	40	80-85	9.81×10^{-4}	1.051×10^{-6}
Vinyl Chloride	5	20-25	2.442×10^{1}	1.03×10^{-2}
Perched Groundwater Source				
Radionuclides				
Tc-99	10	20-30	24×10^{-4}	5.67×10^{-6}
U-234	400	530-540	1.65×10^{-4}	3.91×10^{-7}
U-235	400	530-540	0.11	2.59×10^{-4}
U-238	400	530-540	14.62	3.45×10^{-2}
Inorganics				
Arsenic	>1,000			

[a]Model simulation time = 0 is 1953 for the waste area source and time = 0 is 1993 for perched groundwater source.

TABLE D.3-16

SOURCE AREAS FOR OPERABLE UNIT 1 AQUIFER MODEL

Location	Area		Number of Cells for Modeled Area
	(m^2)	(ft^2)	
Waste Pit 1	7,682	82,691	5
Waste Pit 2	4,172	44,901	3
Waste Pit 3	22,422	241,347	15
Waste Pit 4	7,785	83,799	5
Waste Pit 5	14,965	161,077	10
Waste Pit 6	3,011	32,410	2
Burn Pit	2,019	21,732	1
Clearwell	2,737	29,461	2

TABLE D.3-17

DISTRIBUTION COEFFICIENTS AND DECAY FACTORS FOR COMPOUNDS MODELED BY SWIFT

Parameters	Distribution Coeffecient (Kd) (ml/g)	Decay Factors λ (1/day)
Radionuclides		
Np-237	5.00	8.874×10^{-10}
Sr-90	2.50	6.640×10^{-5}
Tc-99	0.07	8.916×10^{-9}
U-234	1.48	7.767×10^{-9}
U-235	1.48	2.698×10^{-12}
U-238	1.48	4.250×10^{-13}
Inorganics		
Arsenic	45	NA
Barium	20	NA
Boron	3	NA
Cyanide	0.019	NA
Lead	38	NA
Molybdenum	10	NA
Organics		
Aroclor-1221	12.7	NA
Dichlorodifluoromethane	0.15	9.50×10^{-4}
Tetrachloroethene	0.35	4.20×10^{-4}
Vinyl Chloride	0.0041	2.40×10^{-4}

TABLE D.3-18

SUMMARY TABLE OF COMPARISON BETWEEN MEASURED AND MODELED U-238 CONCENTRATIONS IN THE GREAT MIAMI AQUIFER

Well	Measured (μg/l)* Maximum	Measured (μg/l)* Average	Modeled (μg/l)
2004	13.90	7.74	0.032
2019	15.70	4.28	26.11
2021	15.80	7.68	22.44
2027	16.00	8.48	8.12
2643	15.40	7.00	14.19
2648	27.00	9.72	20.31
2649	9.30	4.86	0.164

* Average of 1992 and 1993 snapshots data.

TABLE D.3-19

SUMMARY OF CONSTITUENTS OF CONCERN PREDICTED MAXIMUM CONCENTRATIONS IN GROUNDWATER

Constituents of Concern	Time (yrs)[b]	Maximum Concentration in the Aquifer[a]
SWIFT Modeled Constituents		
Waste Area Source		
Radionuclides		
Np-237	1000	1.634×10^{-9}
Sr-90	200	1.368×10^{-12}
Tc-99	20	1.935×10^{-4}
U-234	500	3.628×10^{-4}
U-235	500	2.429×10^{-1}
U-238	500	$3.202 \times 10^{+1}$
Inorganics		
Barium	1000	8.975×10^{-1}
Boron	170	2.565×10^{-1}
Cadmium	880	1.281×10^{-2}
Copper	1000	5.774×10^{-3}
Cyanide	15	3.762×10^{-4}
Lead	1000	8.552×10^{-4}
Mercury	480	1.146×10^{-3}
Molybdenum	560	1.296×10^{-1}
Organics		
Aroclor-1221	1000	2.690×10^{-5}
Dichlorodifluoromethane	40	5.400×10^{-6}
Tetrachloroethene	80	6.276×10^{-9}
Vinyl Chloride	25	1.459×10^{-3}
Perched Groundwater Source		
Radionuclides		
Tc-99	20	9.35×10^{-8}
U-234	540	1.71×10^{-7}
U-235	540	1.148×10^{-4}
U-238	540	1.514×10^{-2}

TABLE D.3-19
(Continued)

Constituents of Concern	Time (yrs)[b]	Maximum Concentration in the Aquifer[a]
Inorganics		
Arsenic	>1,000	
Non-Modeled Constituents		
Waste Area Source		
Inorganics		
Antimony	40	0.175
Arsenic	40	0.582
Lead	40	0.058
Manganese	40	2.072

[a] All concentrations in milligrams per liter (ppm)
[b] Model simulation time = 0 is 1953 for waste area source and time = 0 is 1993 for perched groundwater source.

TABLE D.3-20

MAXIMUM CONCENTRATIONS OF COCs IN GROUNDWATER

Constituents of Concern	Concentration (mg/ℓ)
Waste Area Source at 500 Years[a,b]	
Radionuclides	
Np-237[a]	1.65×10^{-10}
Sr-90[a]	3.342×10^{-14}
Tc-99[a]	9.856×10^{-7}
U-234	3.628×10^{-4}
U-235	2.429×10^{-1}
U-238	3.202×10^{1}
Inorganics	
Barium	7.451×10^{-1}
Boron	1.148×10^{-1}
Cadmium	6.304×10^{-4}
Copper	0.00
Cyanide	4.219×10^{-6}
Lead	0.00
Mercury	4.568×10^{-4}
Molybdenum	1.697×10^{-2}
Organics	
Aroclor-1221	0.00
Dichlorodifluoromethane	7.375×10^{-12}
Tetrachloroethene	6.305×10^{-10}
Vinyl Chloride	0.00
Perched Groundwater Source at 540 Years[d,e]	
Radionuclides	
Tc-99	4.98×10^{-11}
U-234	1.71×10^{-7}
U-235	1.148×10^{-4}
U-238	1.514×10^{-2}
Inorganics	
Arsenic	0.00

TABLE D.3-20
(Continued)

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[a]Maximum on-site risk within OU1 occurs at coordinates N 481,883, E 1,379,047.
[b]Model simulation time = 0 is 1953.
[c]Non-modeled constituents on Table D.3-17 are also assumed to be present at 500 years.
[d]Maximum on-site risk within OU1 occurs at coordinates N 481,976, E 1,378,706.
[e]Model simulation time = 0 is 1993.

TABLE D.3-21

MAXIMUM CONCENTRATIONS OF COCs AT THE FENCELINE

Constituents of Concern	Concentration (mg/ℓ)
Waste Area Source at 660 Years[a,b]	
Radionuclides	
Np-237	1.957×10^{-17}
Sr-90	4.014×10^{-17}
Tc-99	1.865×10^{-7}
U-234	2.771×10^{-5}
U-235	1.856×10^{-2}
U-238	2.446×10^{0}
Inorganics	
Barium	2.633×10^{-6}
Boron	2.634×10^{-2}
Cadmium	8.975×10^{-12}
Copper	0.00
Cyanide	1.243×10^{-8}
Lead	0.00
Mercury	3.799×10^{-10}
Molybdenum	1.844×10^{-7}
Organics	
Aroclor-1221	0.00
Dichlorodifluoromethane	1.104×10^{-14}
Tetrachloroethene	0.00
Vinyl Chloride	0.00
Perched Groundwater Source at 690 Years[c,d]	
Radionuclides	
U-234	1.60×10^{-8}
U-235	1.098×10^{-5}
U-238	1.448×10^{-3}
Tc-99	3.81×10^{-21}
Inorganics	
Arsenic	0.00

TABLE D.3-21
(Continued)

---

[a]Maximum off-site risk occurs at coordinates N 480,244, E 1,383,458.
[b]Model simulation time = 0 is 1953.
[c]Maximum off-site risk occurs at coordinates N 480,524, E 1,383,441.
[d]Model simulation time = 0 is 1993.

TABLE D.3-22

SUMMARY OF CONSTITUENTS OF POTENTIAL CONCERN PREDICTED MAXIMUM CONCENTRATIONS IN GROUNDWATER SURFACE WATER PATHWAY

Constituents of Concern	Time (yrs)[a]	Maximum Concentration in the Aquifer[b]
Radionuclides[c]		
U-234	10	3.0137×10^{-9}
U-238	10	2.660×10^{-4}
Inorganics		
Arsenic	210	7.196×10^{-8}

[a] Model simulation time = 0 is 1993.
[b] All concentrations in milligrams per liter (ppm).
[c] Maximum risk occurs at coordinates N 481,311, E 1,377,790

TABLE D.3-23

EFFECT OF CHANGES IN HYDRAULIC CONDUCTIVITY OF THE TILL LAYER ON SEEPAGE RATE

Run No.	Hydraulic Conductivity of Till (cm/sec)	Seepage Velocity (in/yr)
1	9.3×10^{-5} (Nominal)	10.92
2	9.3×10^{-6}	10.92
3	9.3×10^{-7}	10.37
4	9.3×10^{-8}	2.19
5	9.3×10^{-9}	0.22

TABLE D.3-24

EFFECT OF VARYING HYDRAULIC CONDUCTIVITIES ON SEEPAGE VELOCITY

Run No.	Hydraulic Conductivity of Layers	Seepage Velocity (in/yr)
1	Nominal values	3.28
2	10 x Nominal values	11.01
3	Nominal values/10	0.331

TABLE D.3-25

SWIFT CONTAMINANT TRANSPORT SENSITIVITY RUNS USING WASTE PIT 1 SOURCE

Input or Result	Run No. 1	Run No. 2
K_d, ml/g	1.4	32
K_H, ft/day	700	200
K_V, ft/day	70	20
α_L, ft	200	50
α_T, ft	20	5
Maximum Conc.,ppb	57.6	555
Time of occurrence of maximum, year	620	1000*
Approximate area of 1 ppb contour, acre	1500	25

*The run was terminated at 1,000 years at which time the concentrations were still increasing. Consequently, the actual time of occurrence of the maximum would be after 1,000 years.

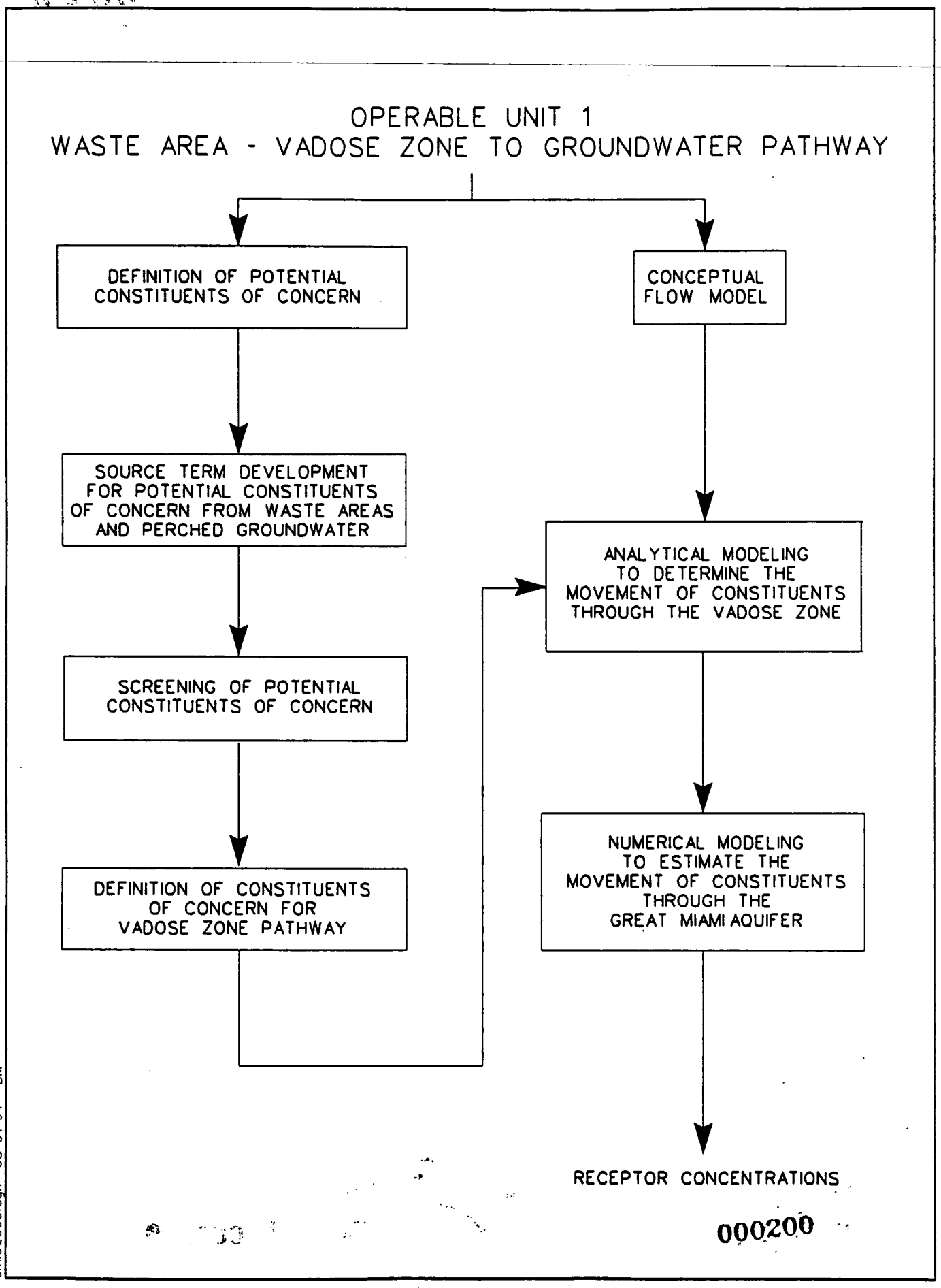

FIGURE D.3-1. VADOSE ZONE PATHWAY TRANSPORT MODELING DIAGRAM

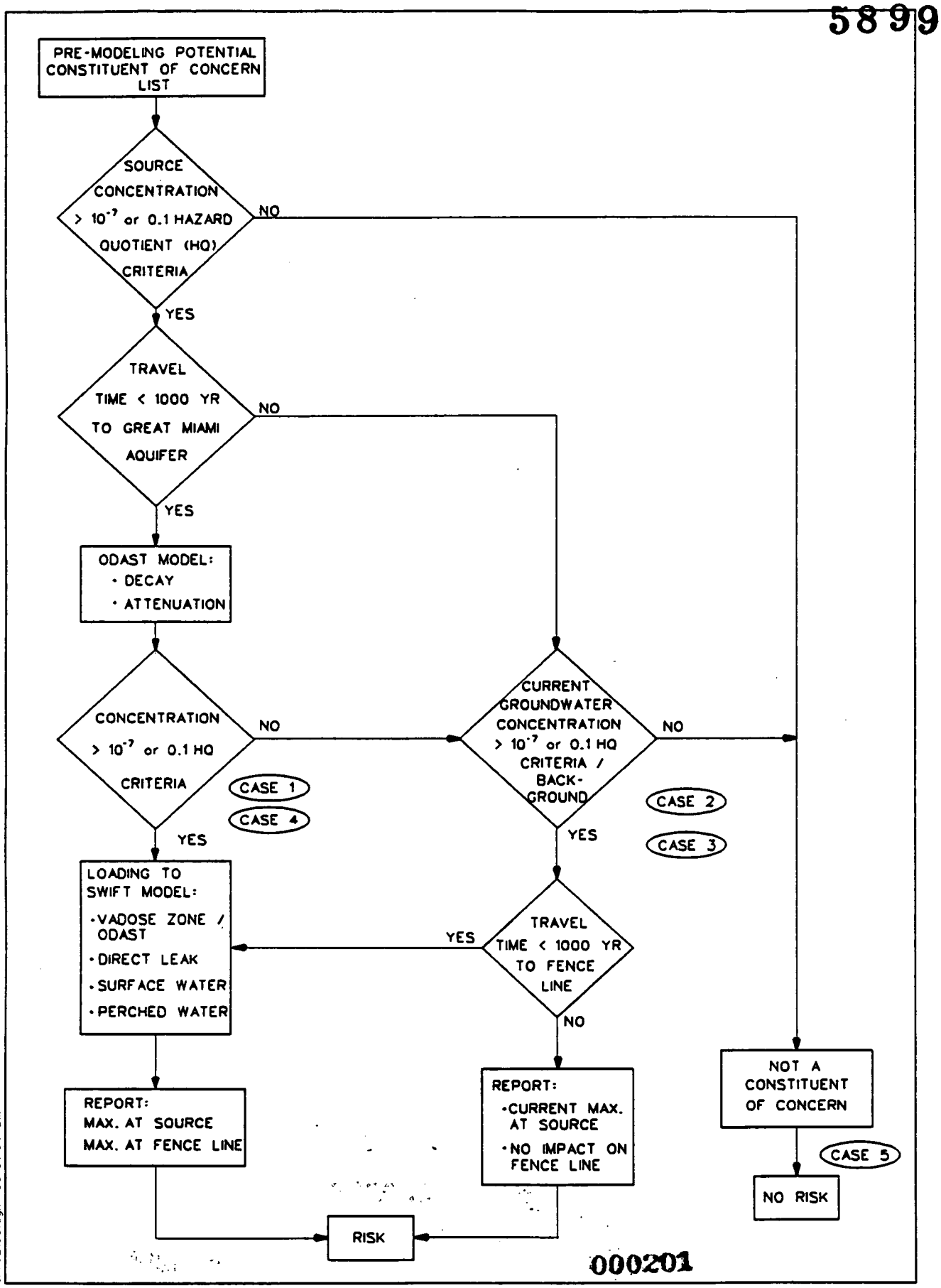

FIGURE D.3-2. APPROACH FOR SCREENING AND INCORPORATION OF MONITORING DATA INTO THE MODELING PROCESS

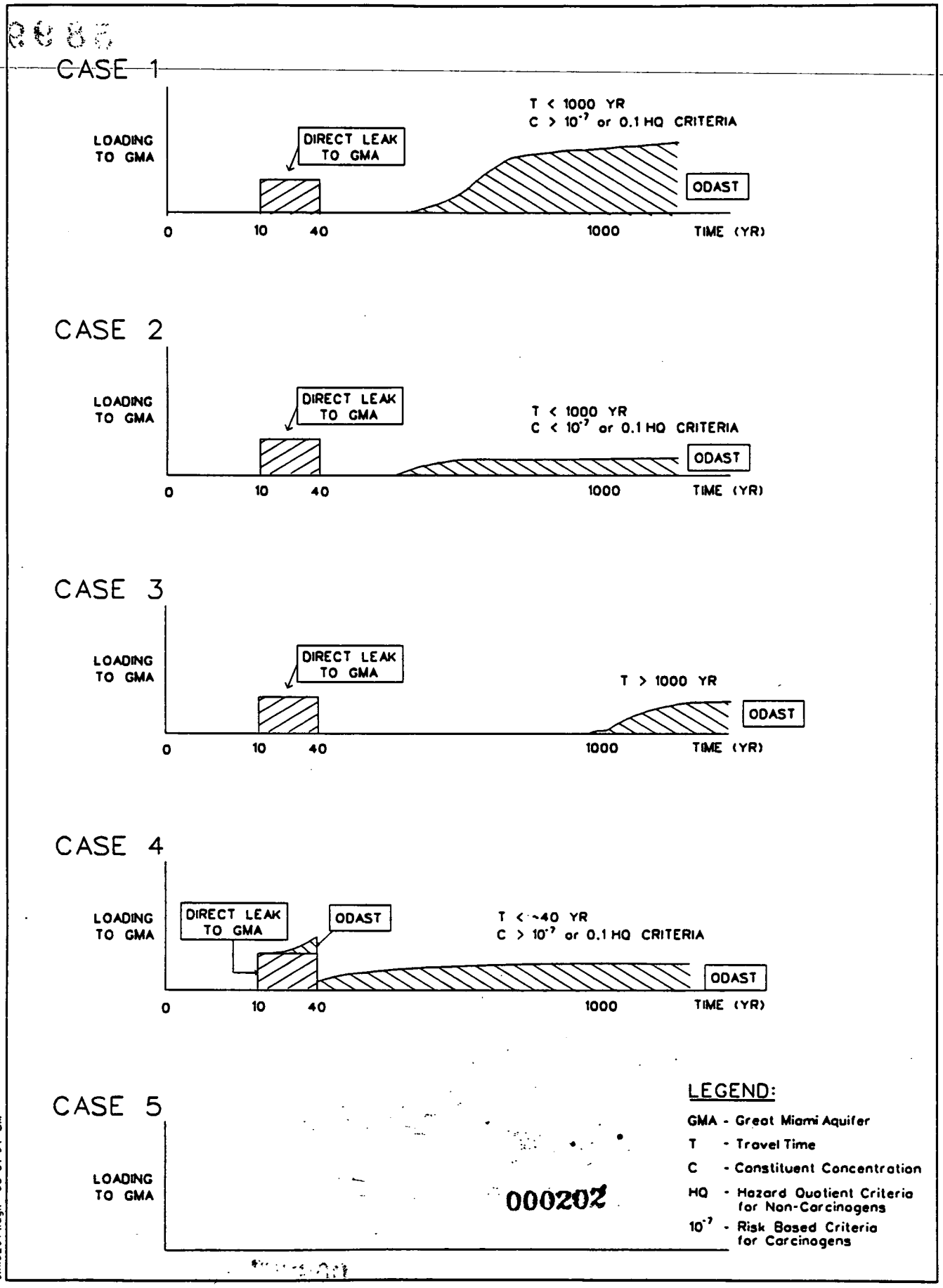

FIGURE D.3-3. CASES FOR LOADING CONSTITUENTS TO THE GREAT MIAMI AQUIFER

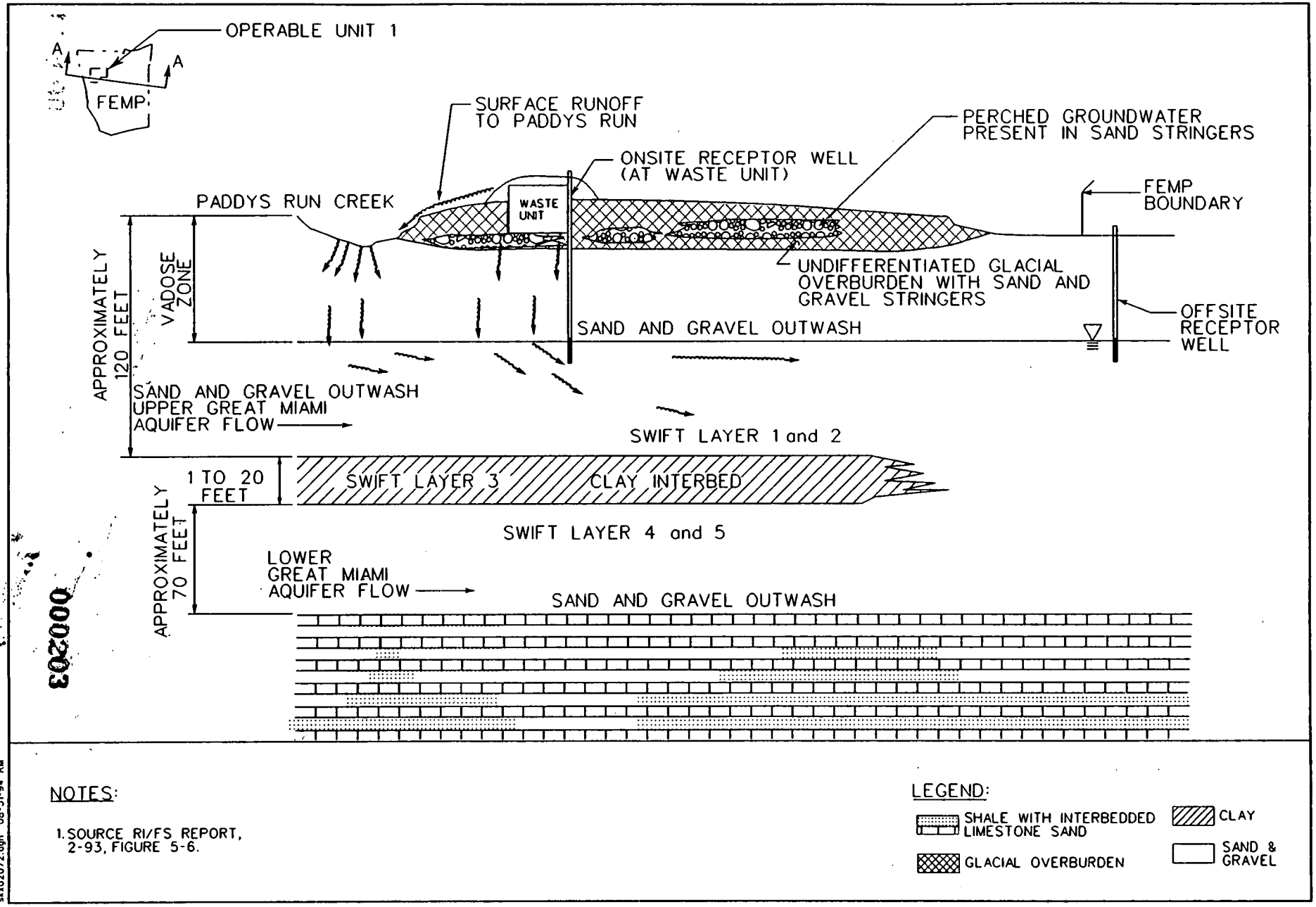

FIGURE D.3-4. CONCEPTUAL MODEL OF CONTAMINANT TRANSPORT BY GROUNDWATER AT THE FEMP

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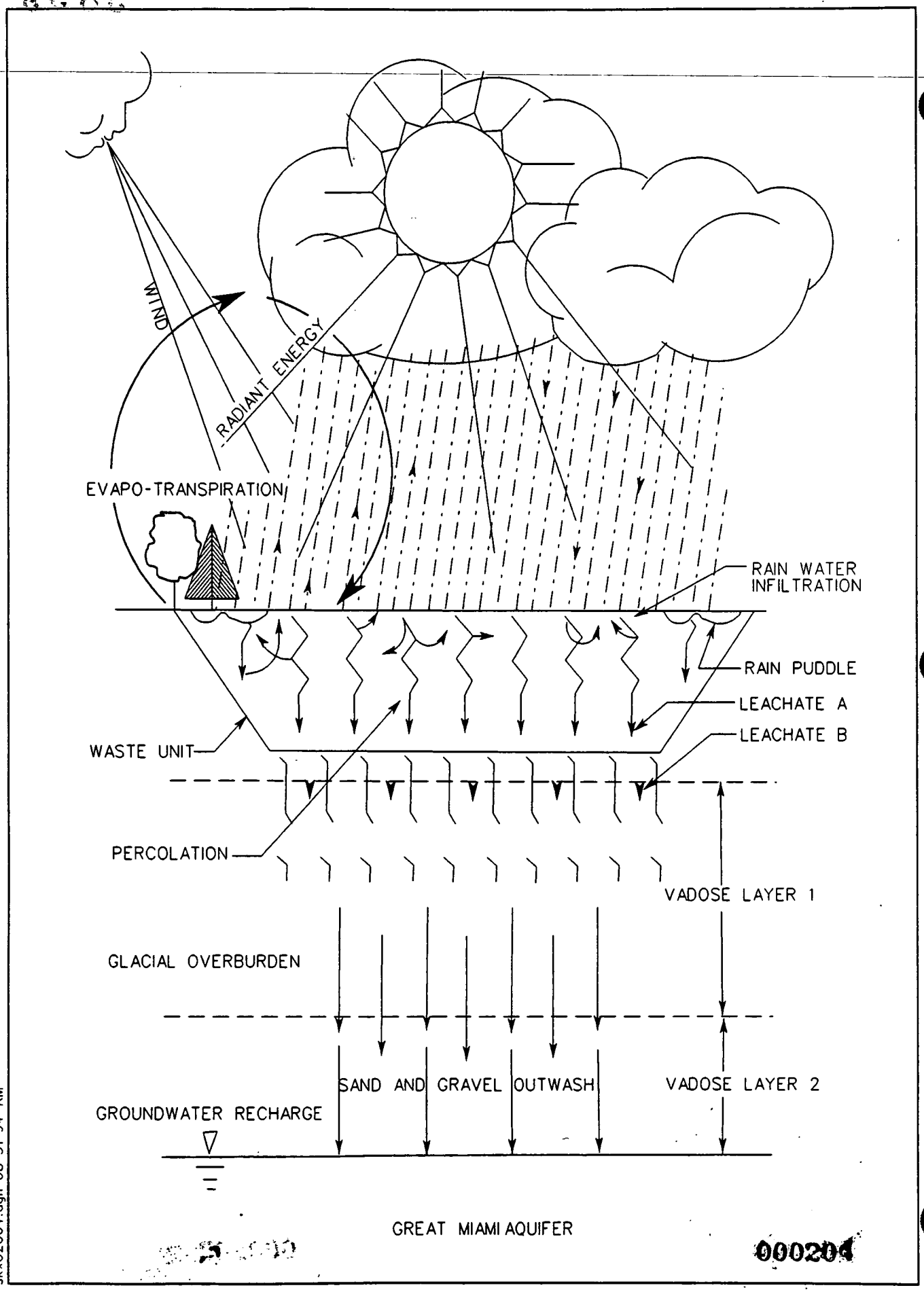
000203

5899



SKX02064-A/OU1/FAIR
skx02064.dgn 08-31-94 RM

FIGURE D.3-5. CONCEPTUAL VADOSE ZONE MODEL

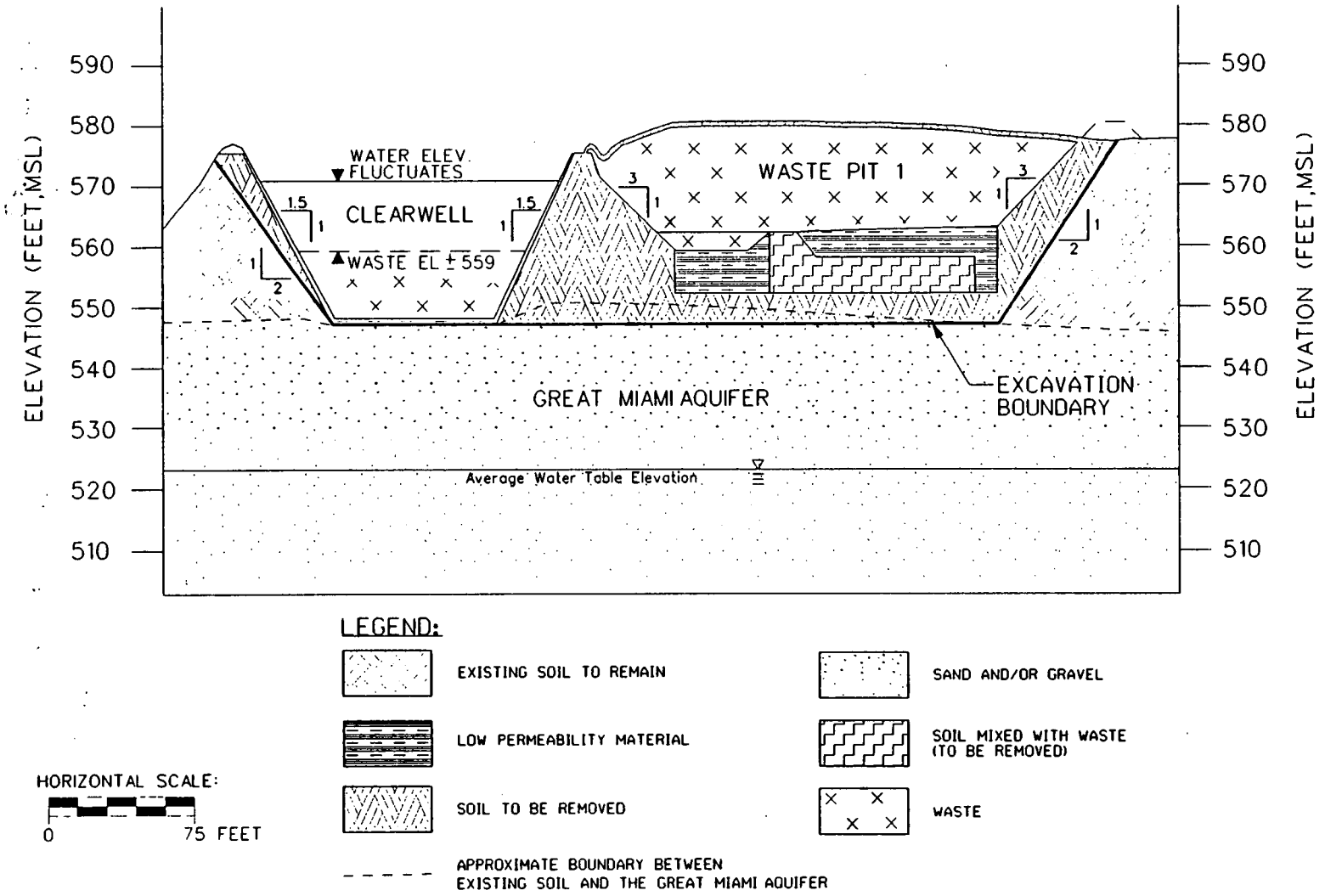


FIGURE D.3-6. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1-WASTE PIT 1 AND THE CLEARWELL

000205

5899

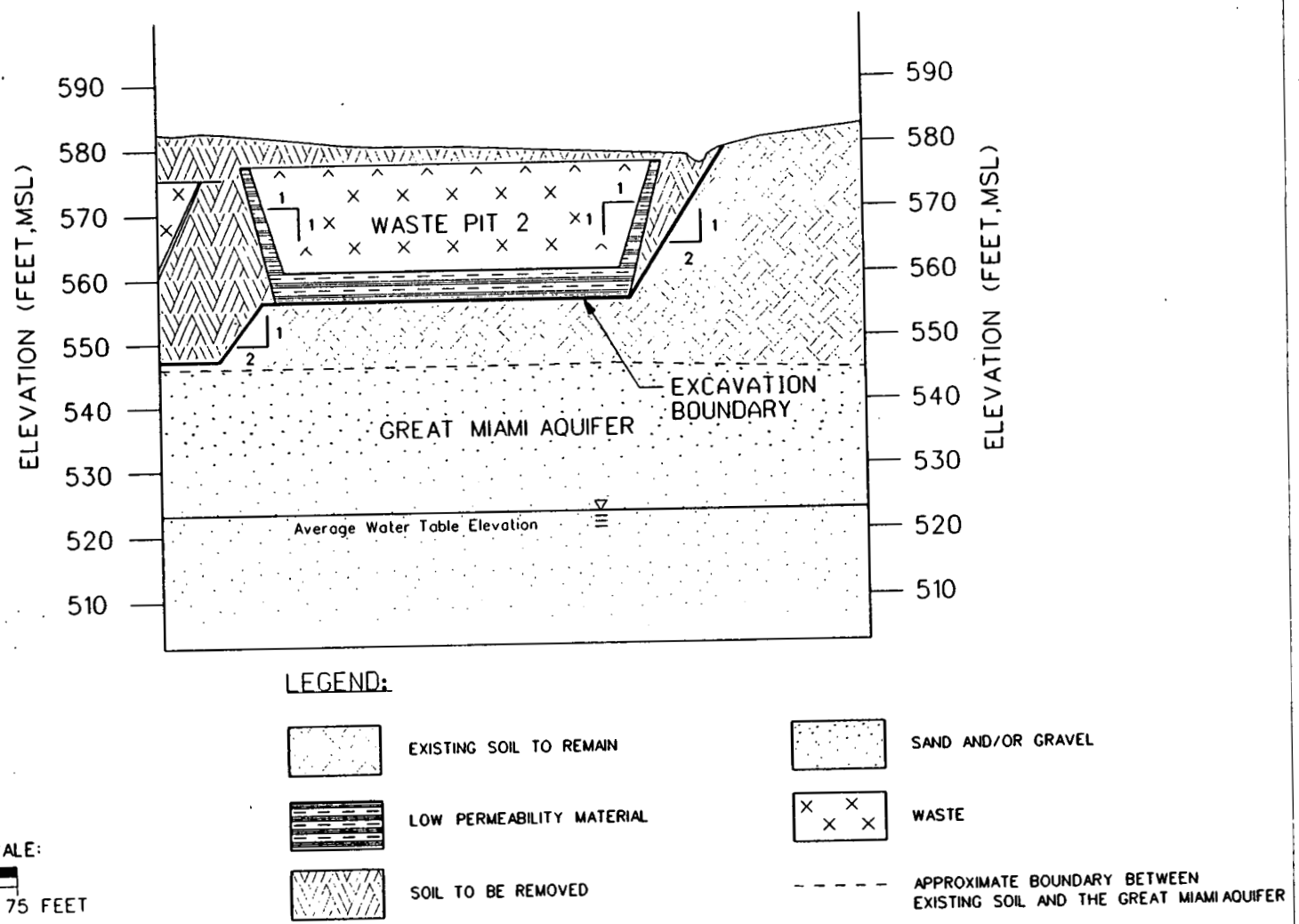


FIGURE D.3-7. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1-WASTE PIT 2

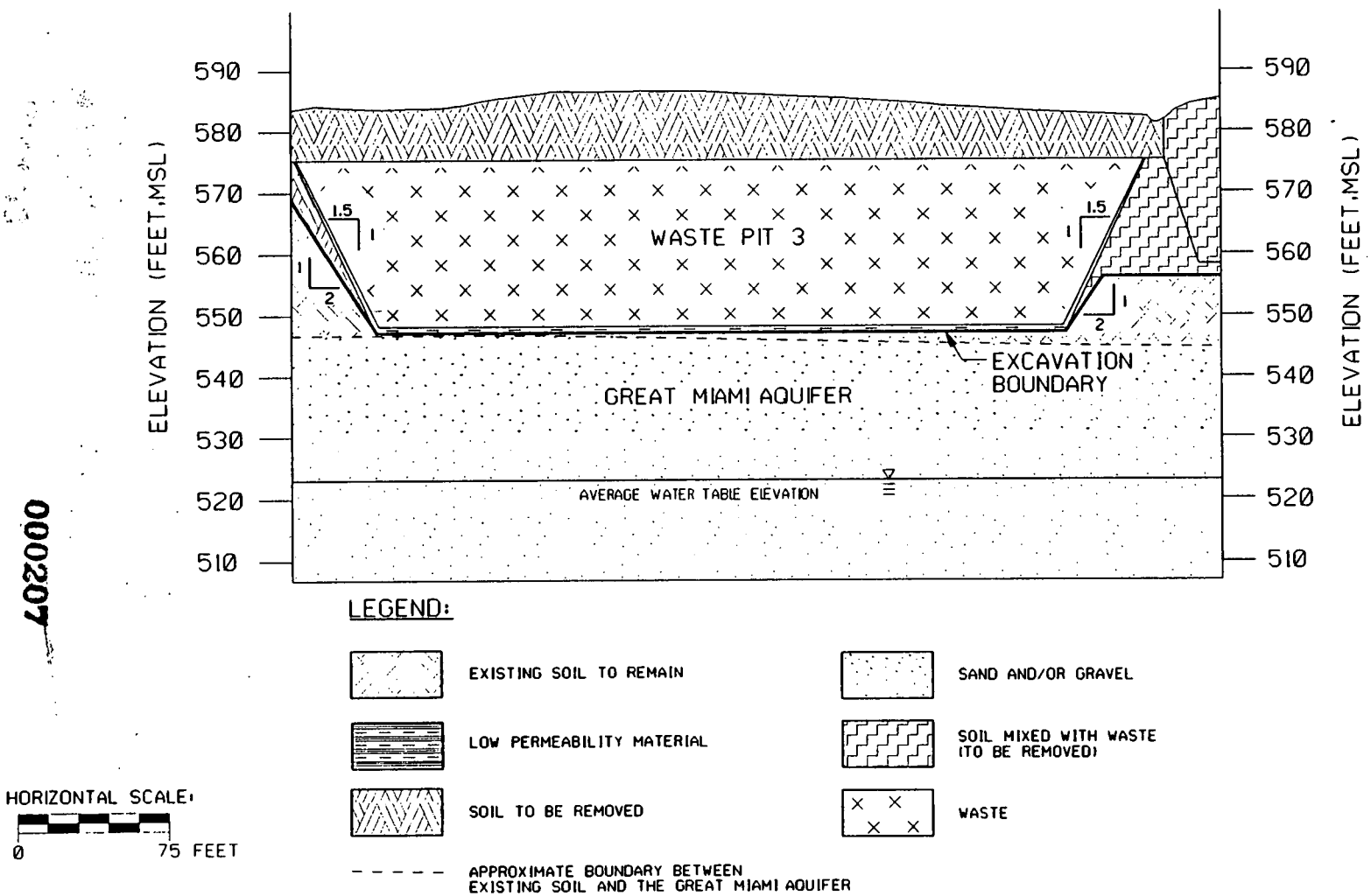


FIGURE D.3-8. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1 - WASTE PIT 3

000207

5899

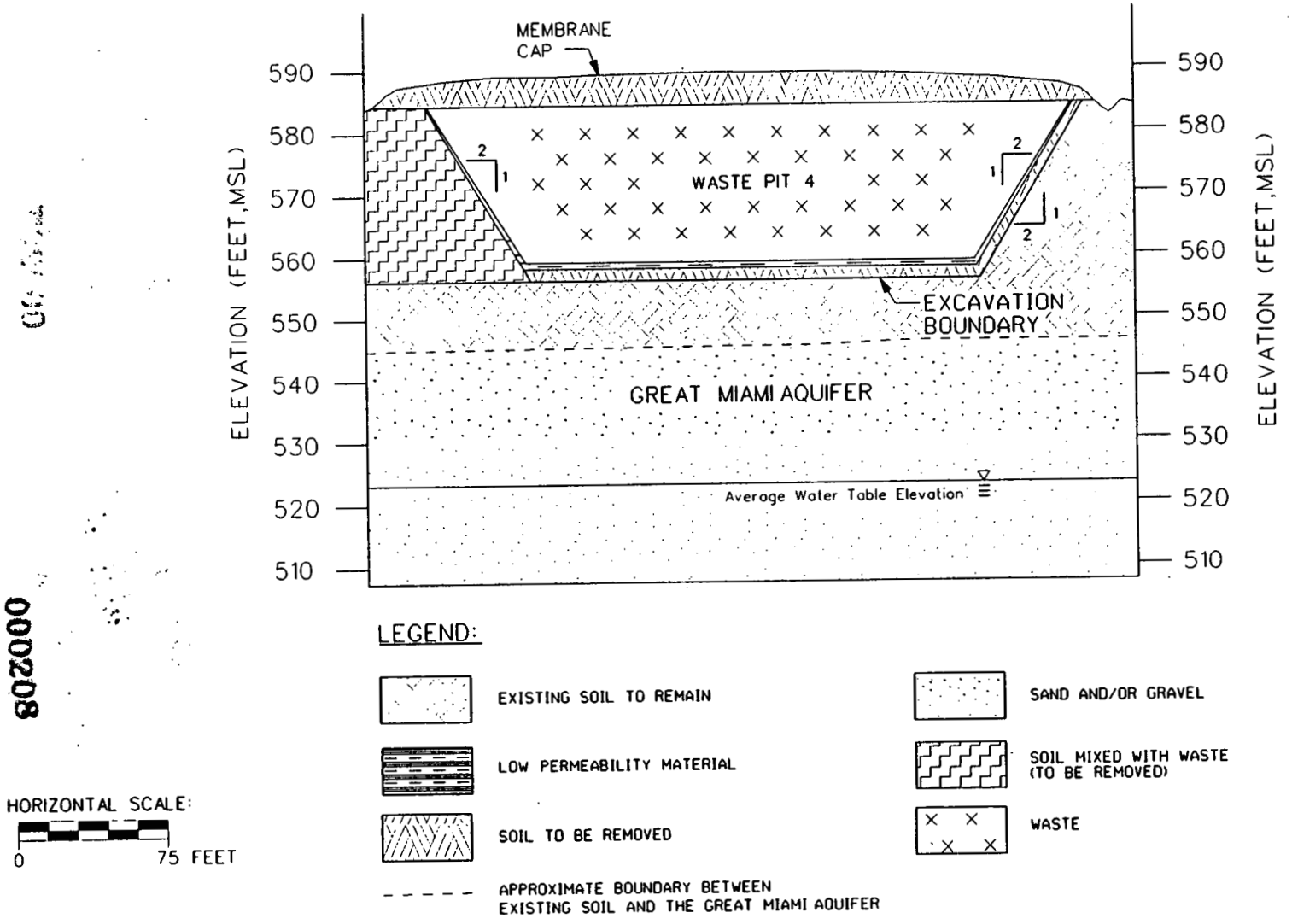


FIGURE D.3-9. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1 - WASTE PIT 4

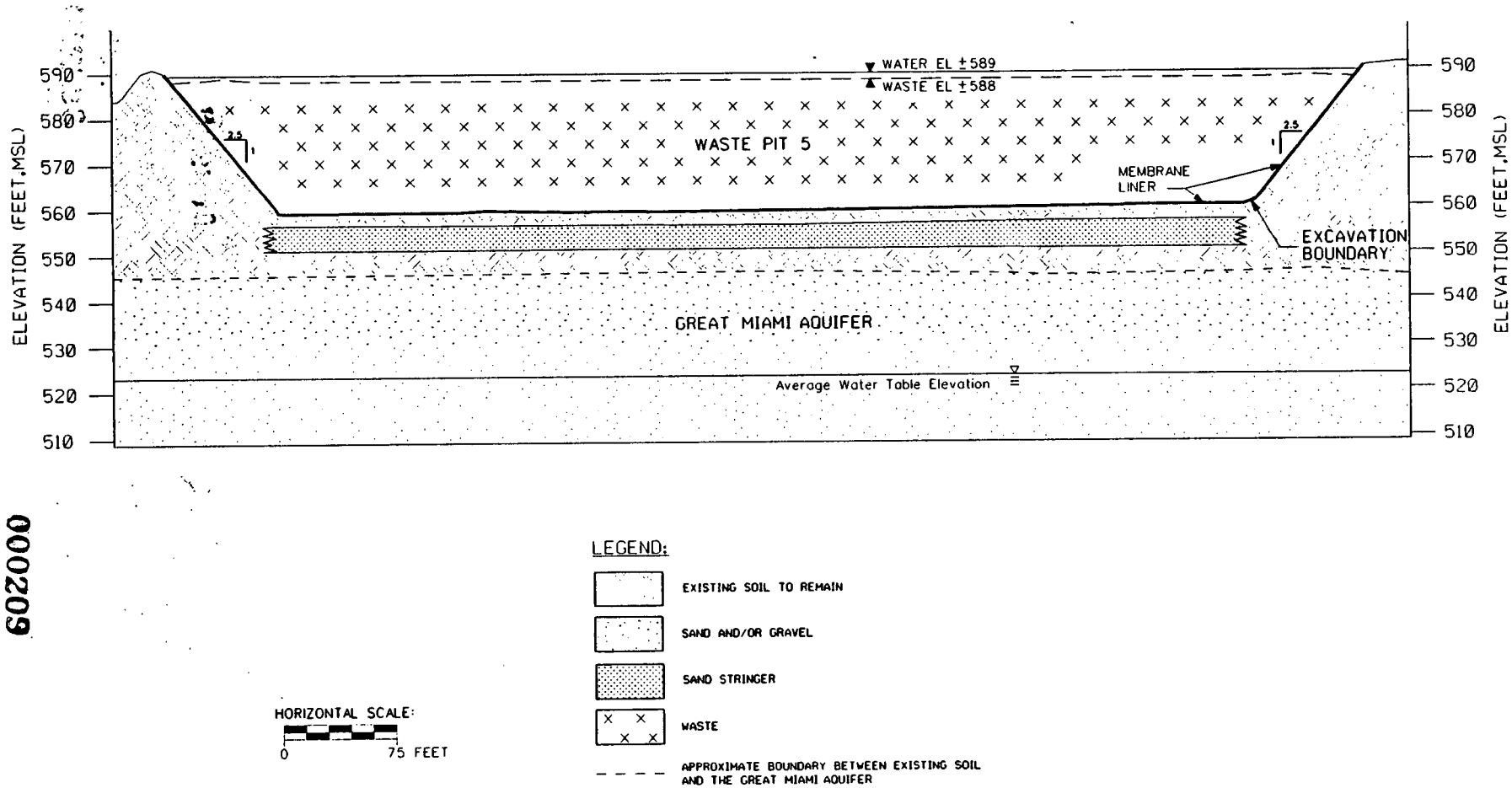
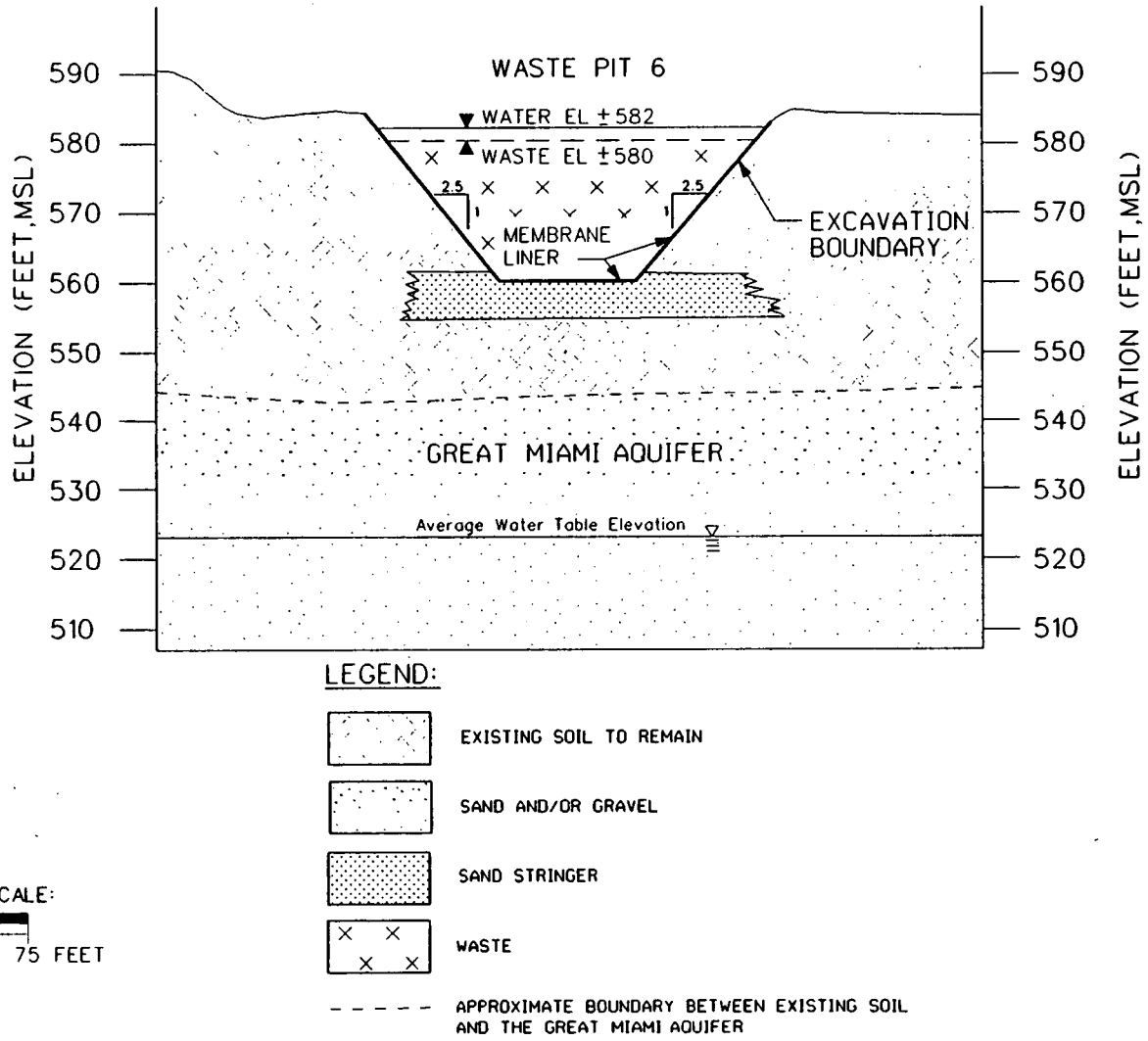


FIGURE D.3-10. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1 - WASTE PIT 5

000209

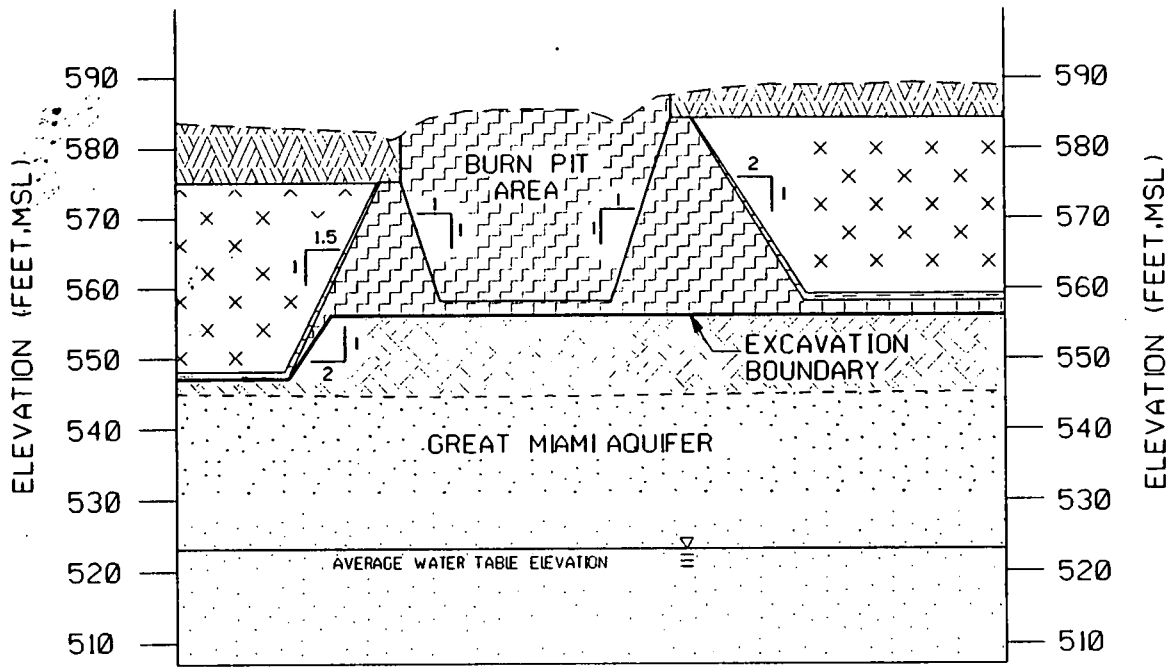
5899



HORIZONTAL SCALE:
0 75 FEET

FIGURE D.3-11. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1 - WASTE PIT 6

000210



LEGEND:

- EXISTING SOIL TO REMAIN
- LOW PERMEABILITY MATERIAL
- SOIL TO BE REMOVED
- SAND AND/OR GRAVEL
- SOIL MIXED WITH WASTE (TO BE REMOVED)
- WASTE

HORIZONTAL SCALE: 0 — 75 FEET

FIGURE D.3-12. CONCEPTUAL DIAGRAM OF OPERABLE UNIT 1 - BURN PIT

000211
5899

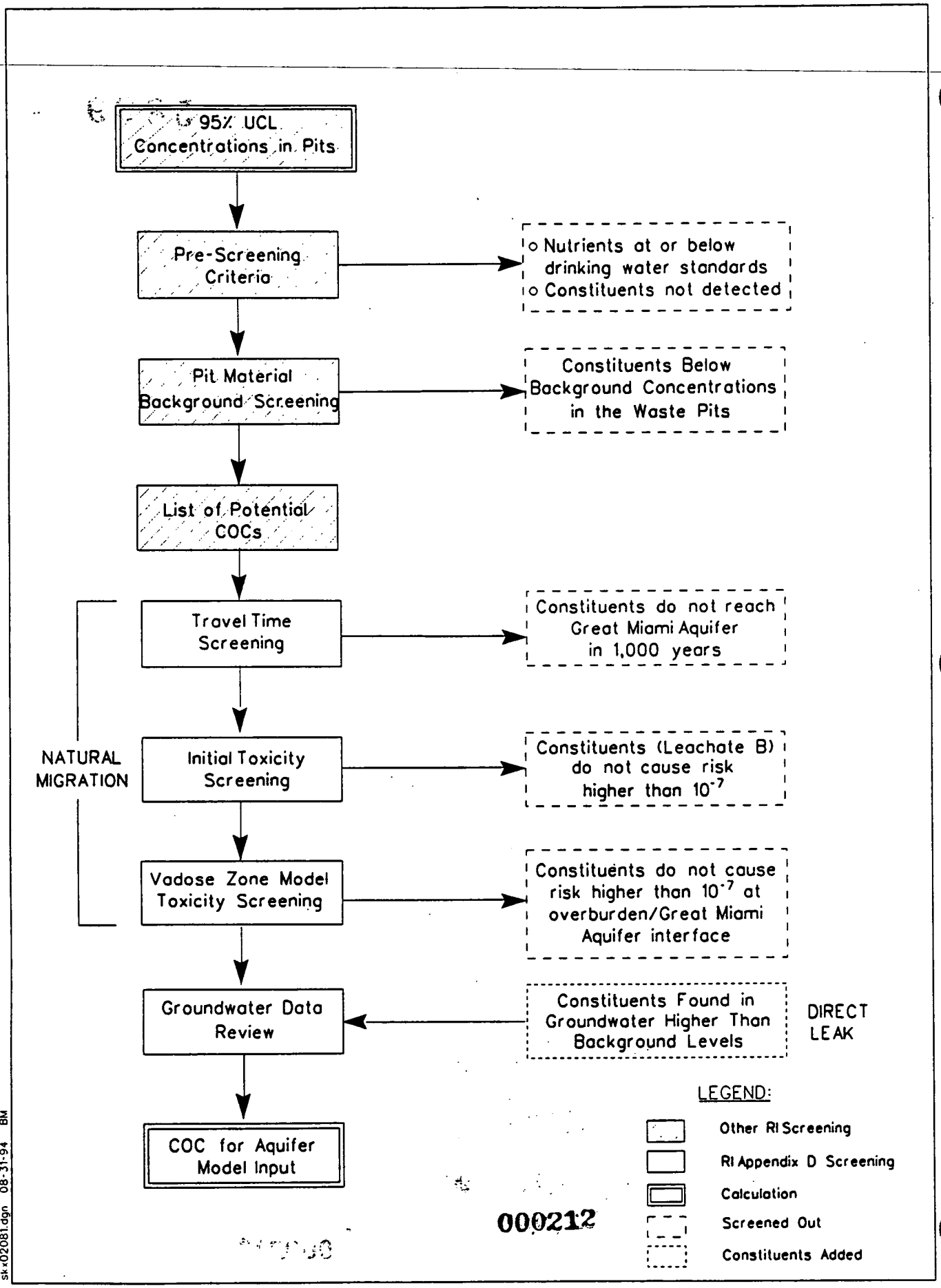


FIGURE D. 3-13. POTENTIAL CONSTITUENT OF CONCERN SCREENING DIAGRAM

000212

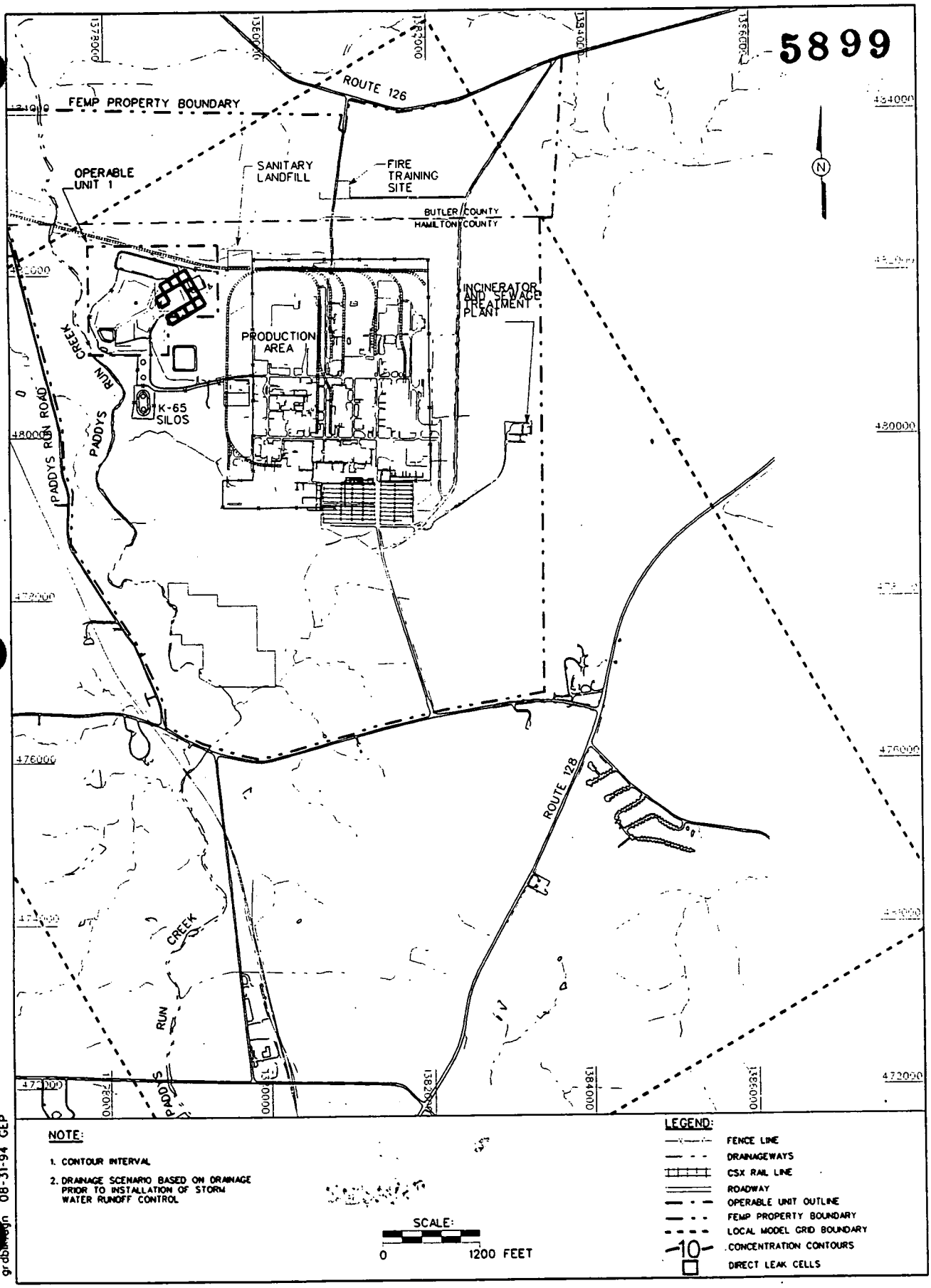
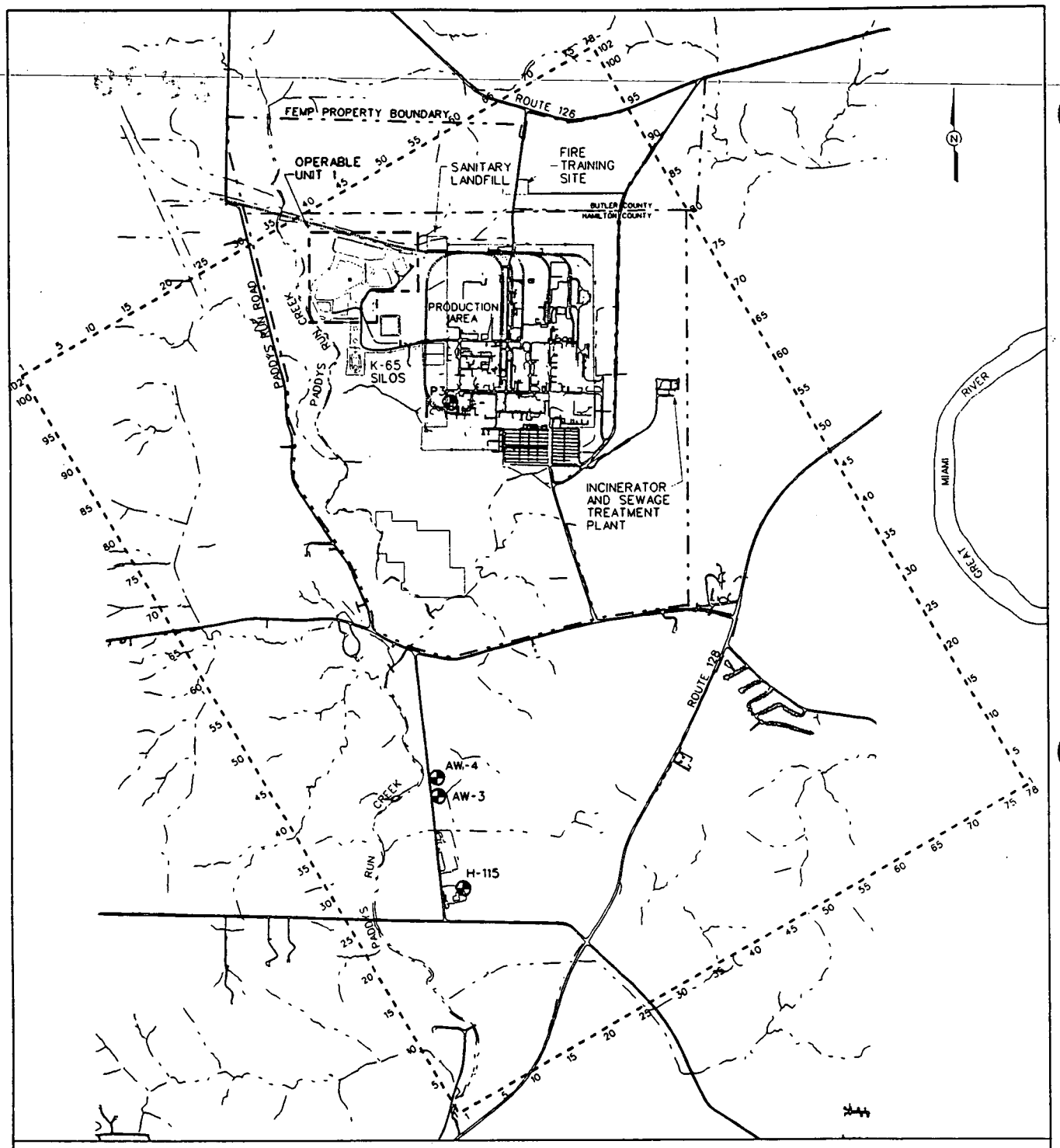


FIGURE D.3-14A. LOCATIONS OF DIRECT LEAK CELLS

000213



LEGEND:

- FENCE LINE
- DRAINAGEWAYS
- CSX RAIL LINE
- ROADWAY
- OPERABLE UNIT OUTLINE
- LOCAL AREA MODEL GRID (Cells 125 x 125 feet)
- H-115 PUMPING WELL

SCALE: 0 — 1800 FEET

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FIGURE D.3-14B. SWIFT III LOCAL AREA MODEL GRID

000214

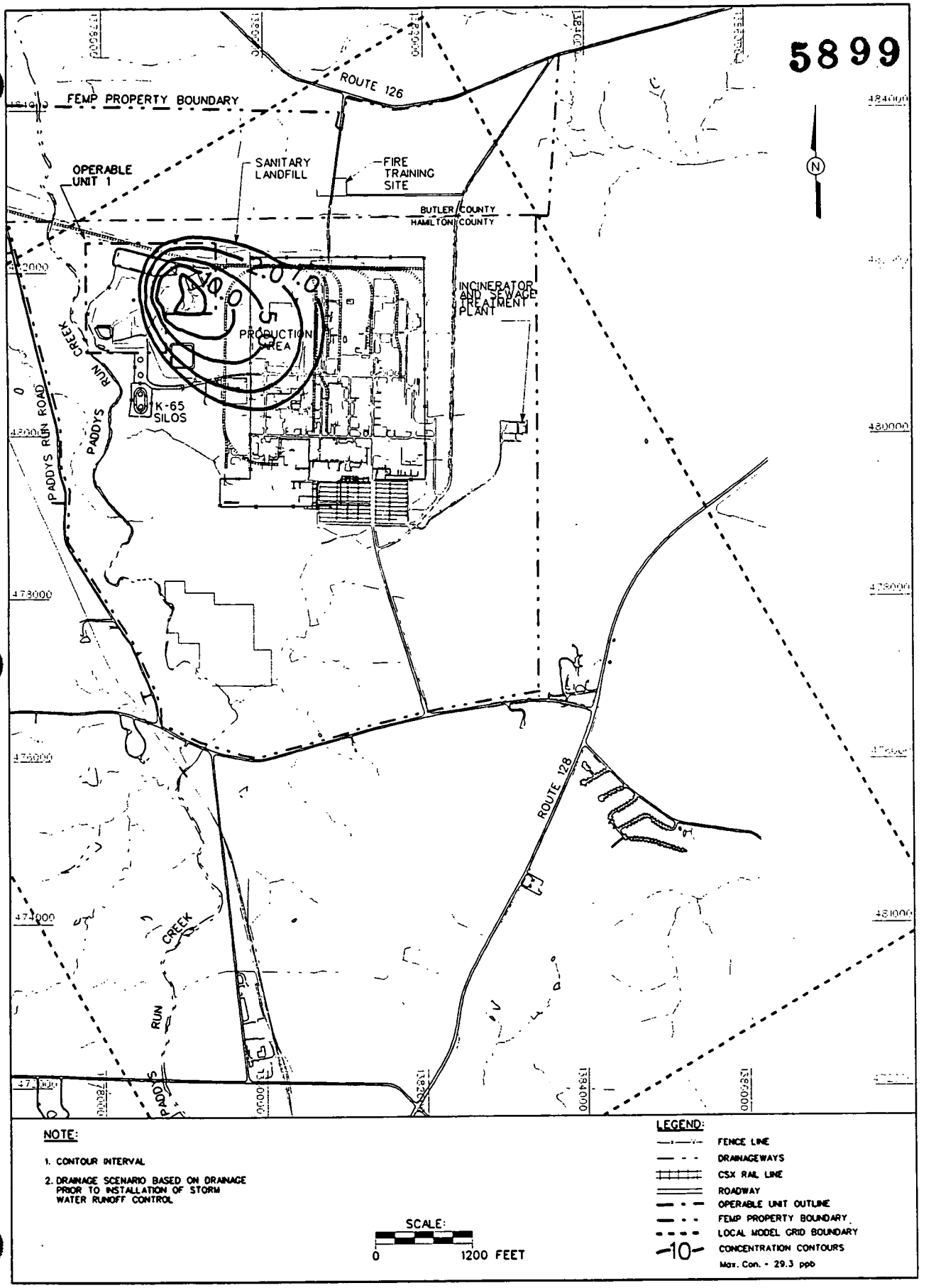

FIGURE D.3-14C. SIMULATED U-238 CONCENTRATION CONTOURS
LAYER 1 AT 40 YEARS

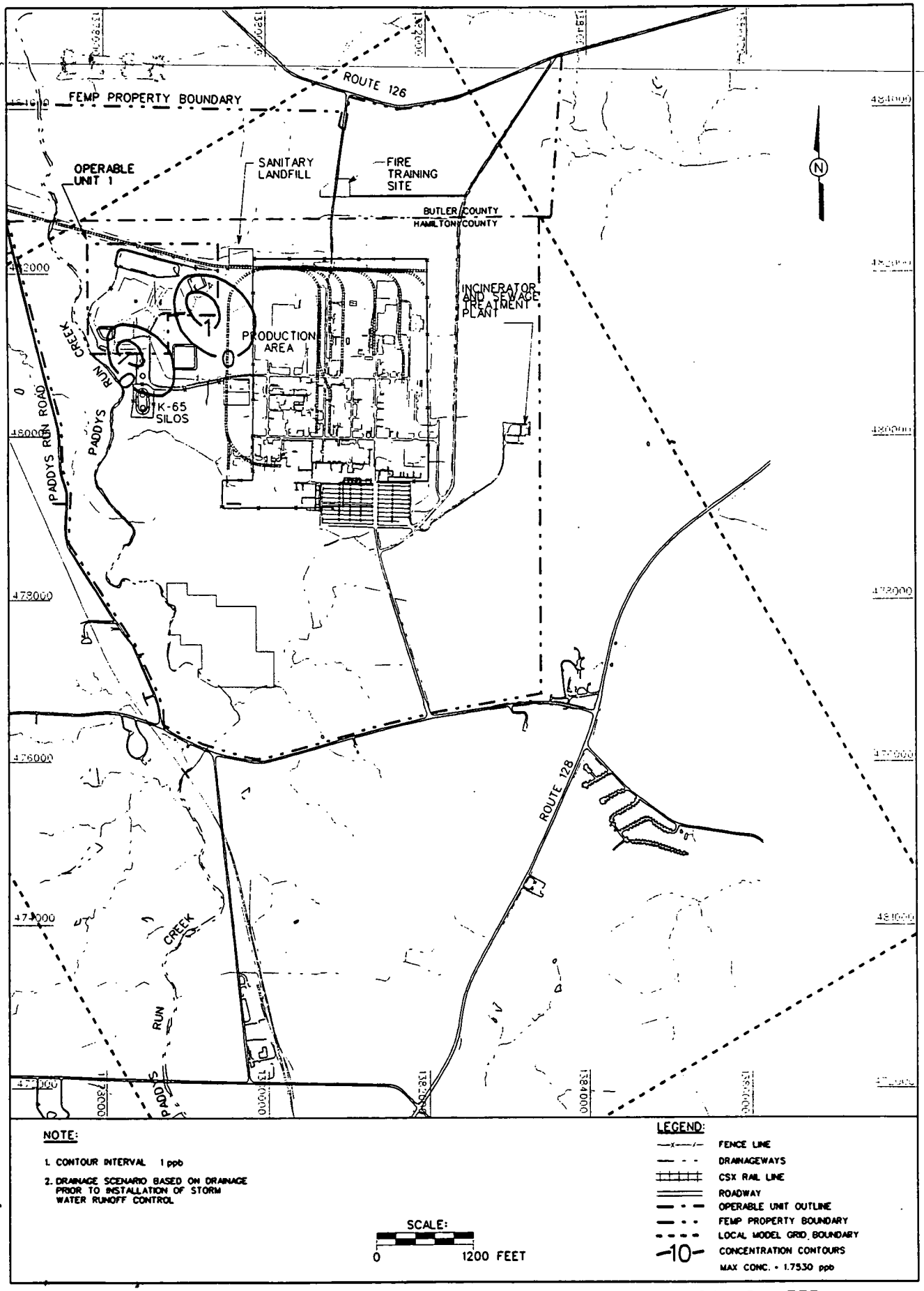

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FIGURE D.3-15. PROJECTED CONCENTRATION OF TOTAL URANIUM IN GROUNDWATER BENEATH FEMP AFTER 100 YEARS DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS

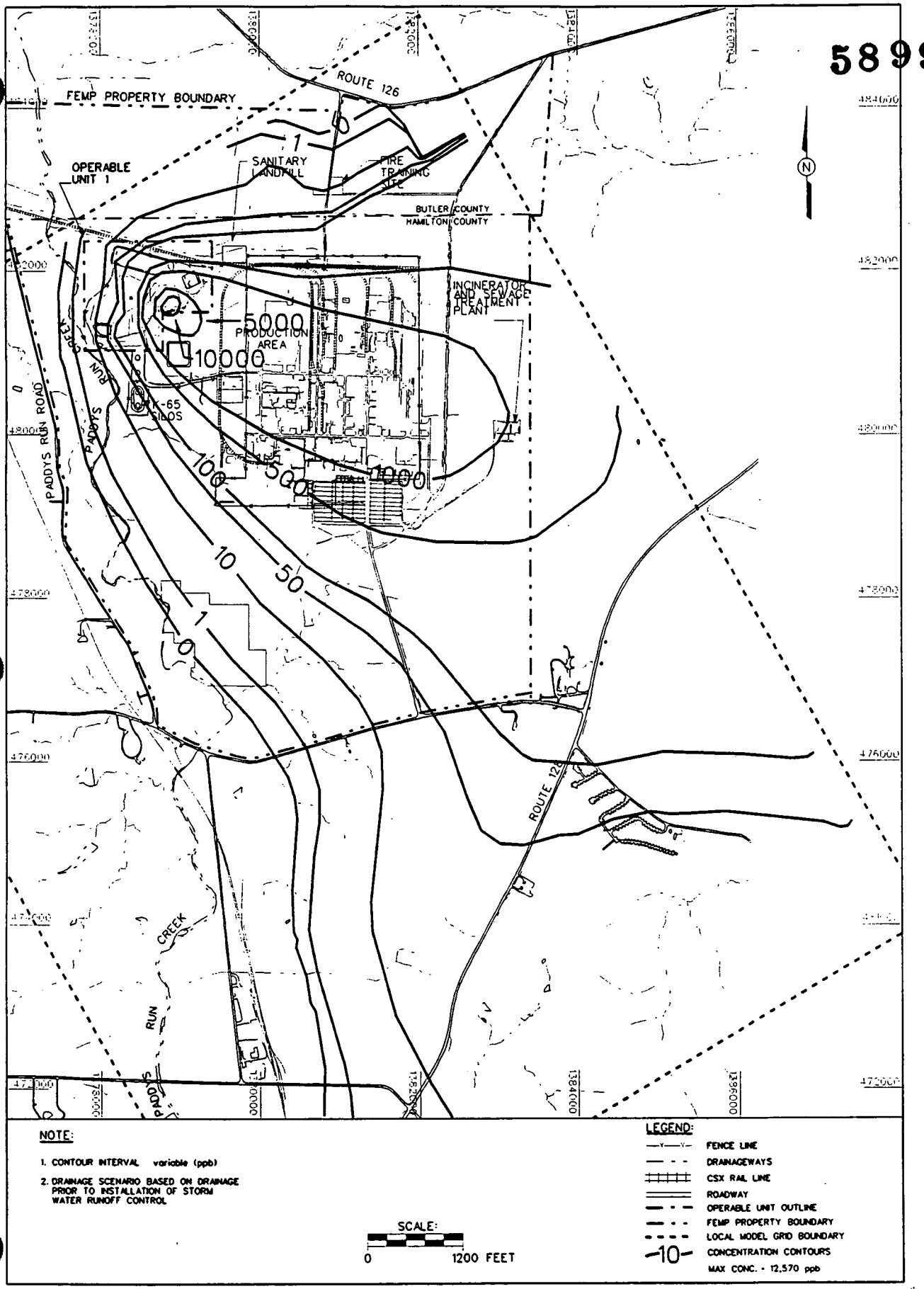
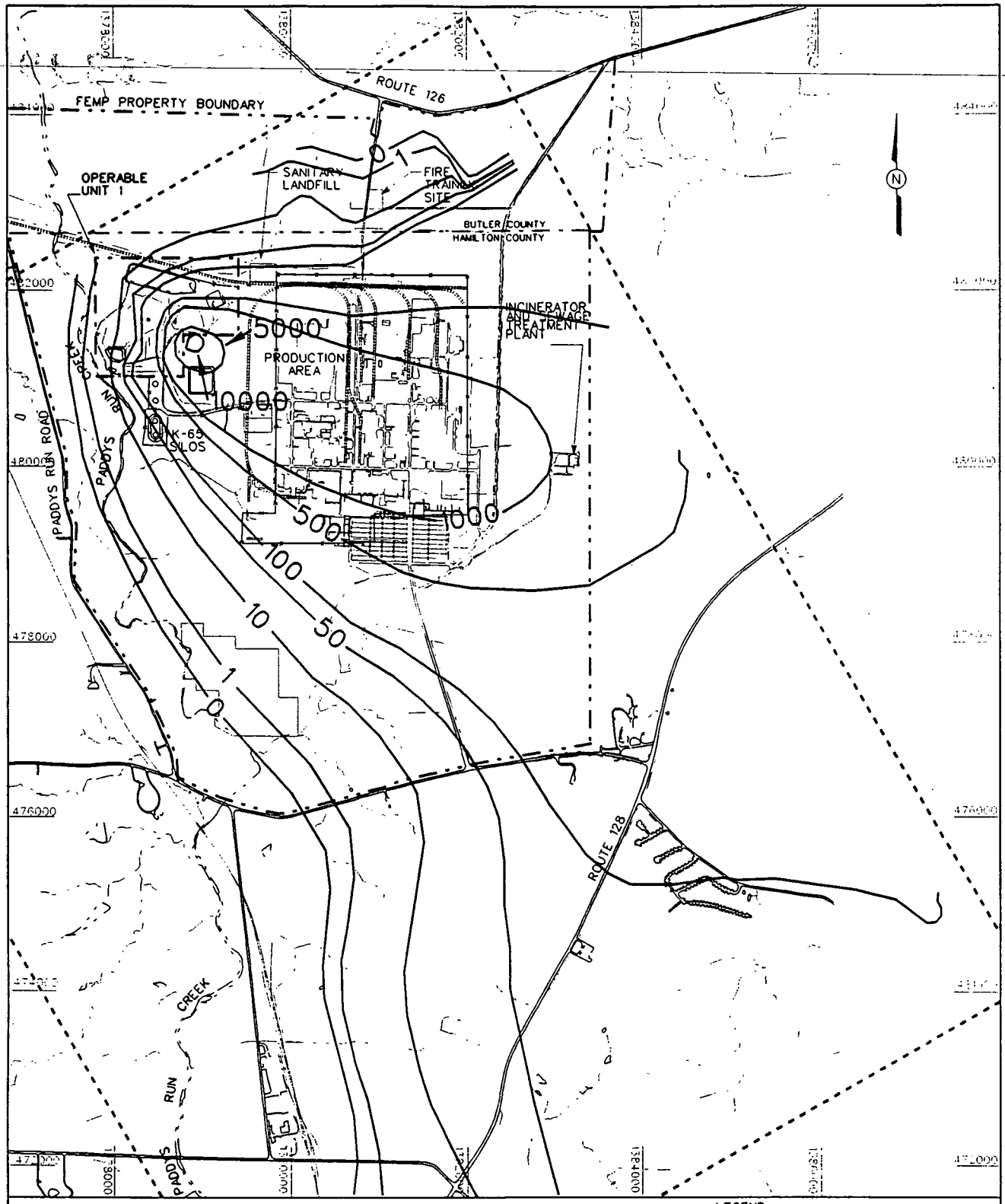


FIGURE D.3-16. PROJECTED MAXIMUM CONCENTRATION OF TOTAL URANIUM IN GROUNDWATER BENEATH FEMP DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS AFTER 500 YEARS



NOTE:

1. CONTOUR INTERVAL (variable (ppb))
2. DRAINAGE SCENARIO BASED ON DRAINAGE PRIOR TO INSTALLATION OF STORM WATER RUNOFF CONTROL

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FIGURE D.3-17. PROJECTED CONCENTRATION OF TOTAL URANIUM IN GROUNDWATER BENEATH FEMP AFTER 1000 YEARS DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS

000218

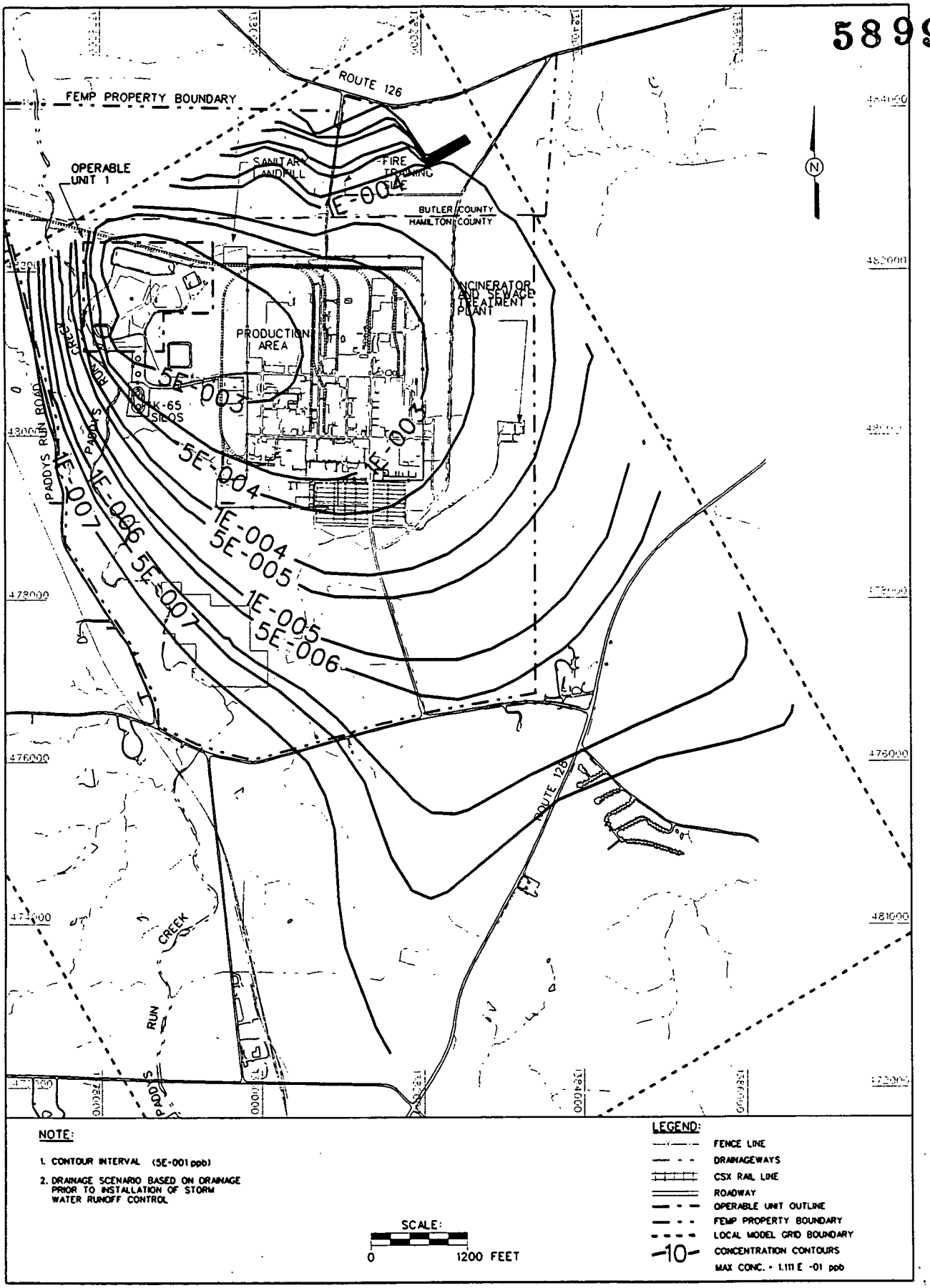


FIGURE D.3-18. PROJECTED CONCENTRATION OF CYANIDE IN GROUNDWATER BENEATH FEMP AFTER 100 YEARS DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS

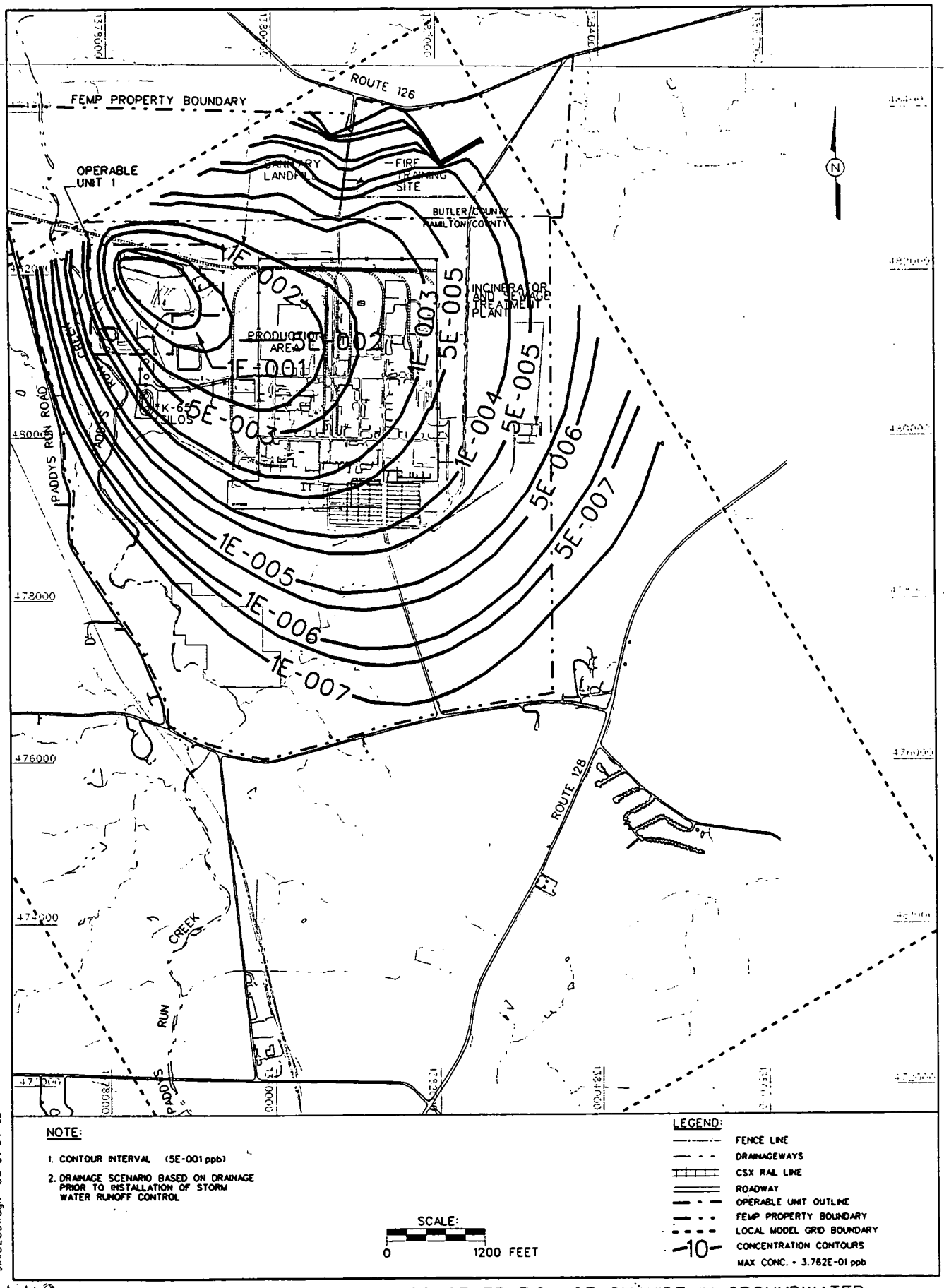


FIGURE D.3-19. PROJECTED MAXIMUM CONCENTRATION OF CYANIDE IN GROUNDWATER BENEATH FEMP DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS AFTER 15 YEARS

000220

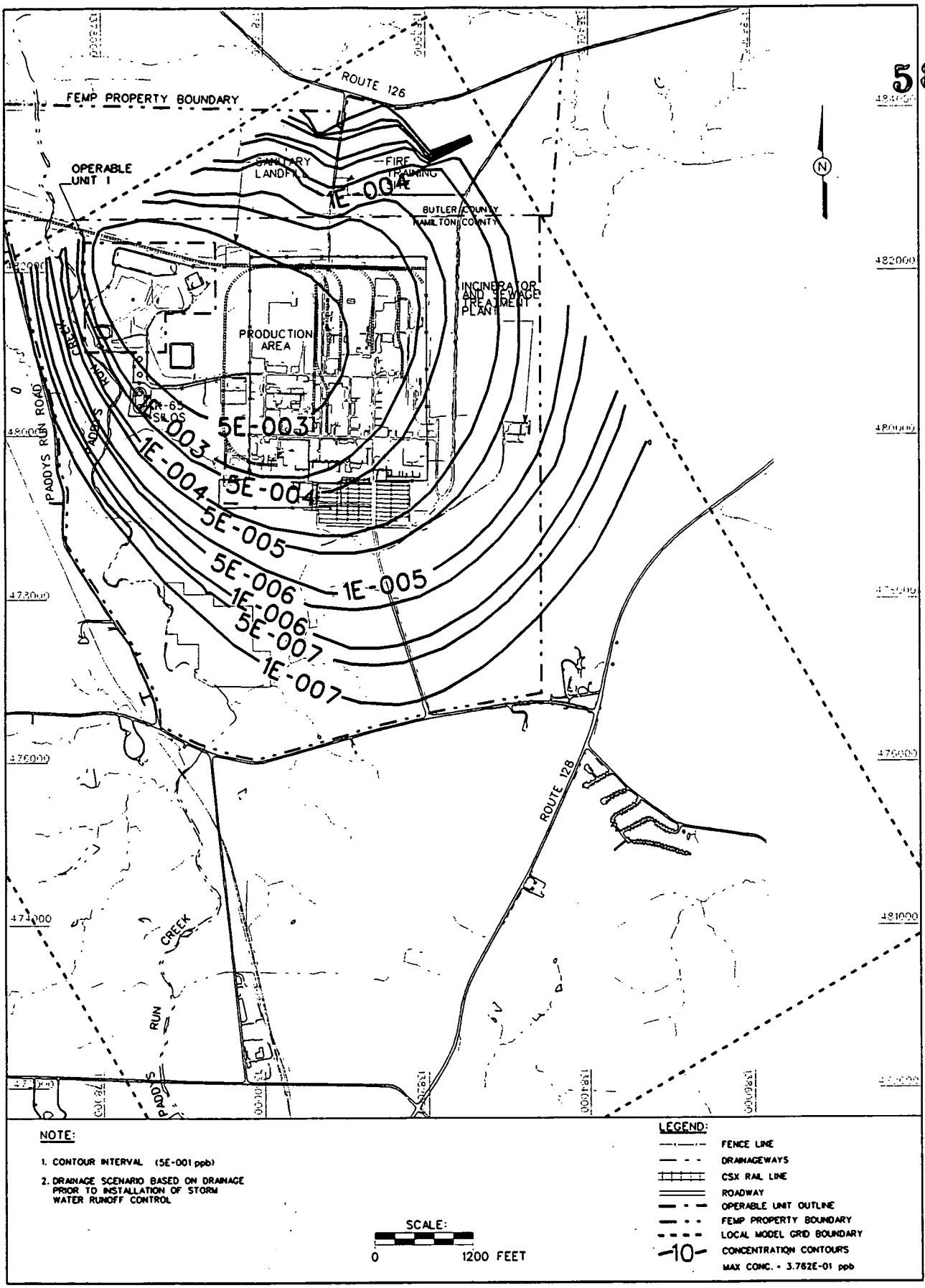


FIGURE D.3-20. PROJECTED CONCENTRATION OF CYANIDE IN GROUNDWATER BENEATH FEMP AFTER 1000 YEARS DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS

000221

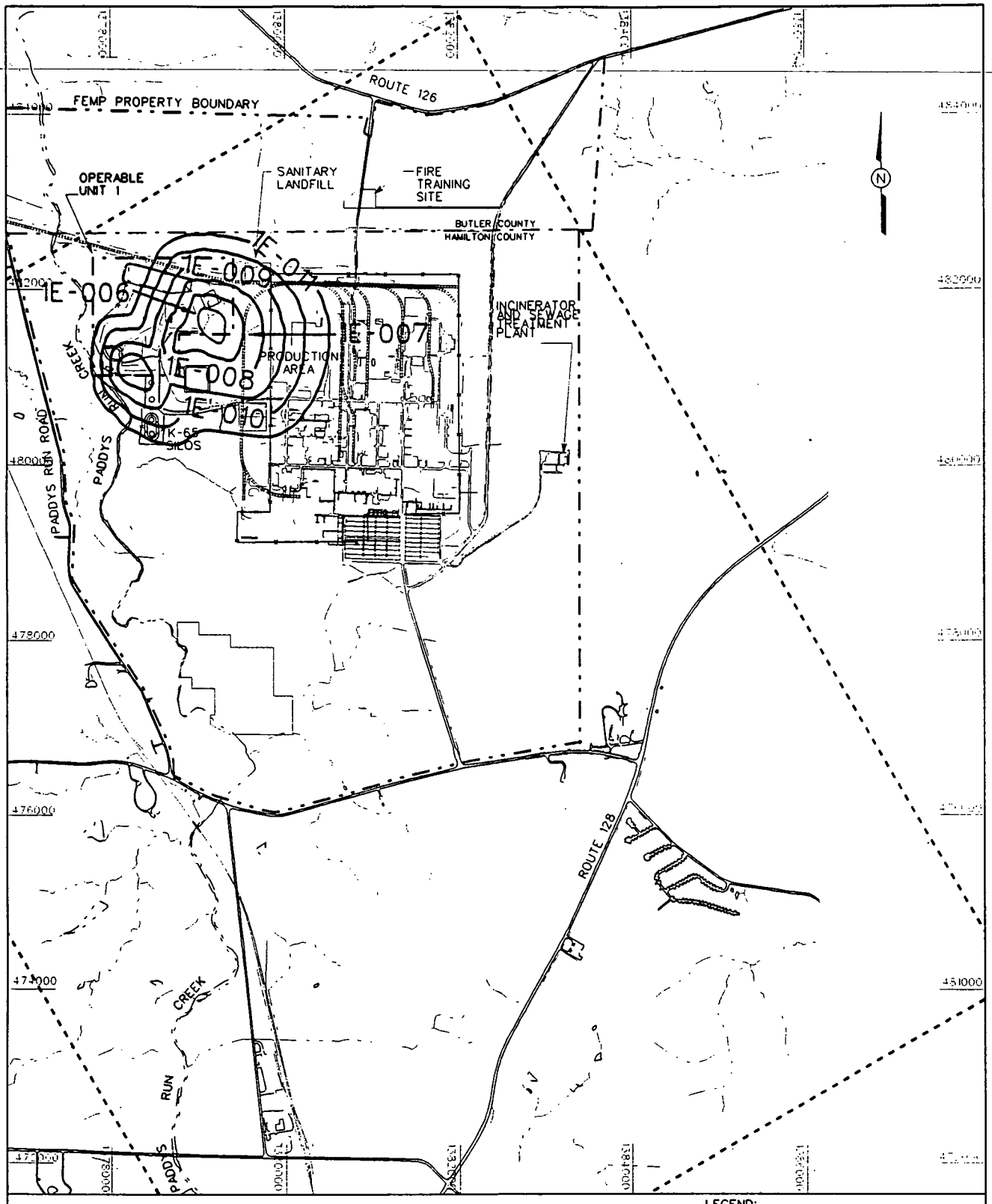
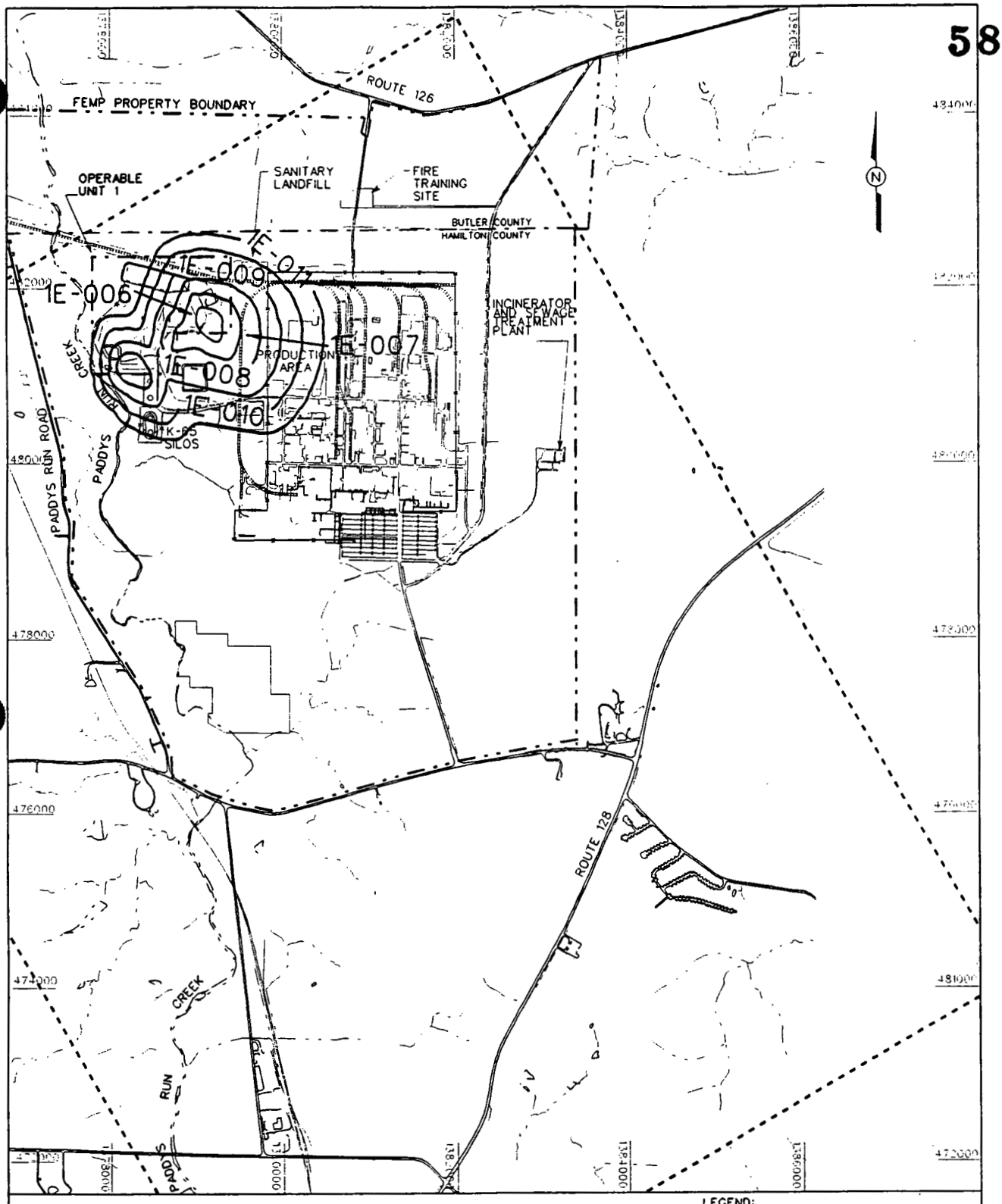


FIGURE D.3-21. PROJECTED CONCENTRATION OF TETRACHLOROETHENE IN GROUNDWATER BENEATH FEMP AFTER 100 YEARS DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS

000222



NOTE:

1. CONTOUR INTERVAL (1E-001 ppb)
2. DRAINAGE SCENARIO BASED ON DRAINAGE PRIOR TO INSTALLATION OF STORM WATER RUNOFF CONTROL

SCALE: 0 — 1200 FEET

LEGEND:

- FENCE LINE
- DRAINAGEWAYS
- CSX RAIL LINE
- ROADWAY
- OPERABLE UNIT OUTLINE
- FEMP PROPERTY BOUNDARY
- LOCAL MODEL GRID BOUNDARY
- 10 CONCENTRATION CONTOURS

MAX CONC. = 6.276E-06 ppb

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94.dgn 08-31-94 JE

FIGURE D.3-22. PROJECTED MAXIMUM CONCENTRATION OF TETRACHLOROETHENE IN GROUNDWATER BENEATH FEMP DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS AFTER 80 YEARS

000223

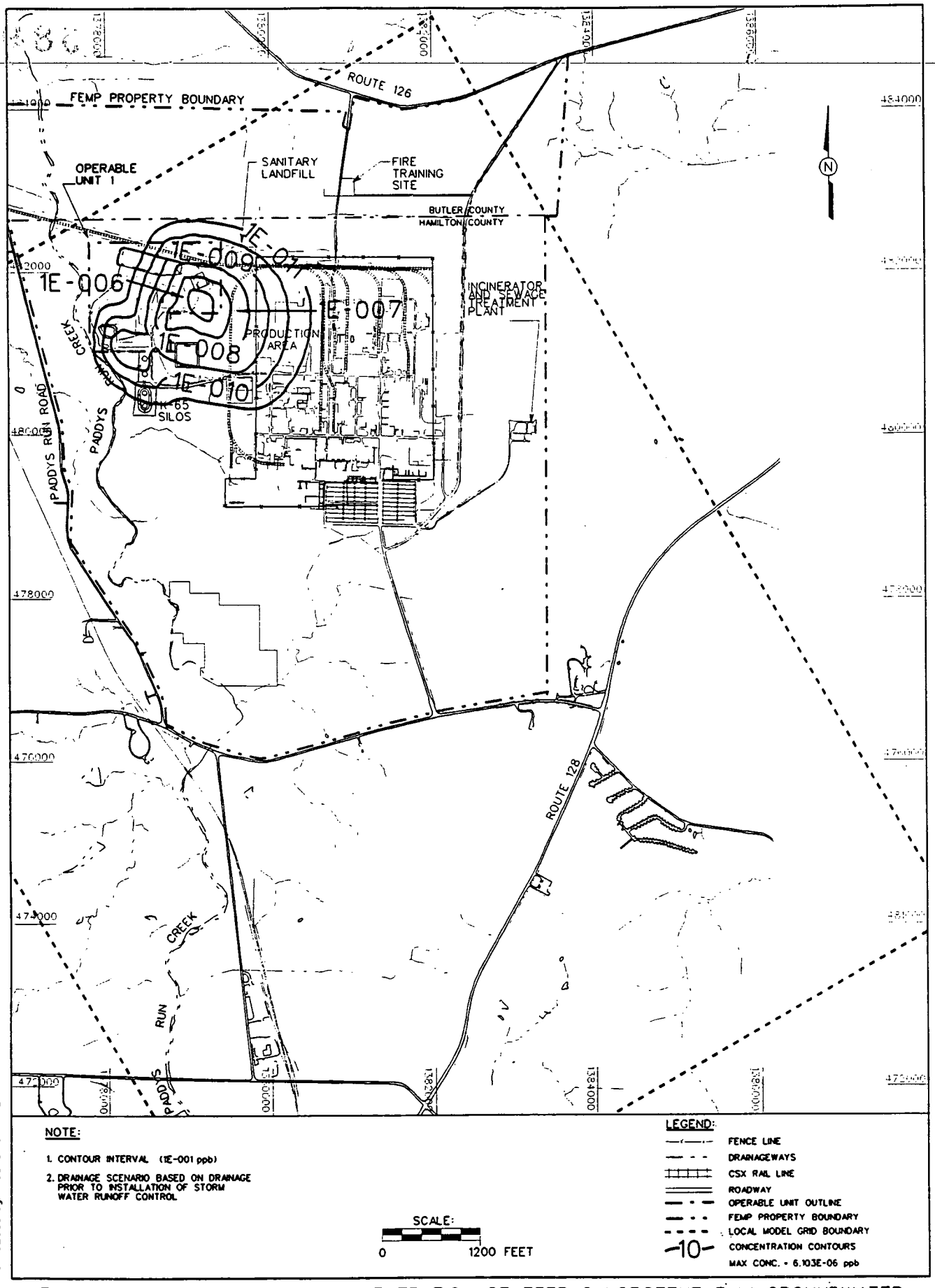


FIGURE D.3-23. PROJECTED CONCENTRATION OF TETRACHLOROETHENE IN GROUNDWATER BENEATH FEMP AFTER 1000 YEARS DUE TO LOADING FROM OPERABLE UNIT 1 WASTE STORAGE AREAS

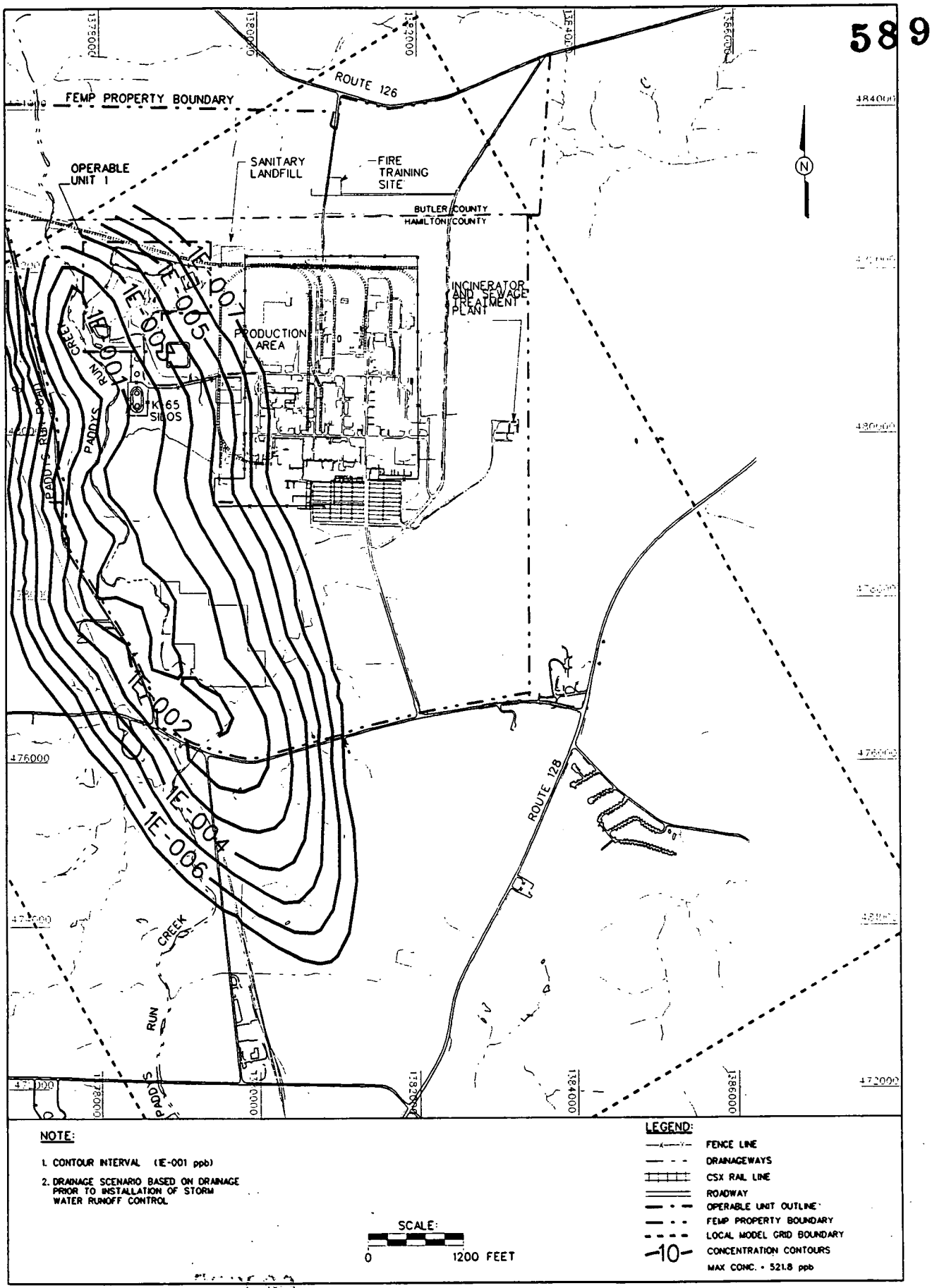
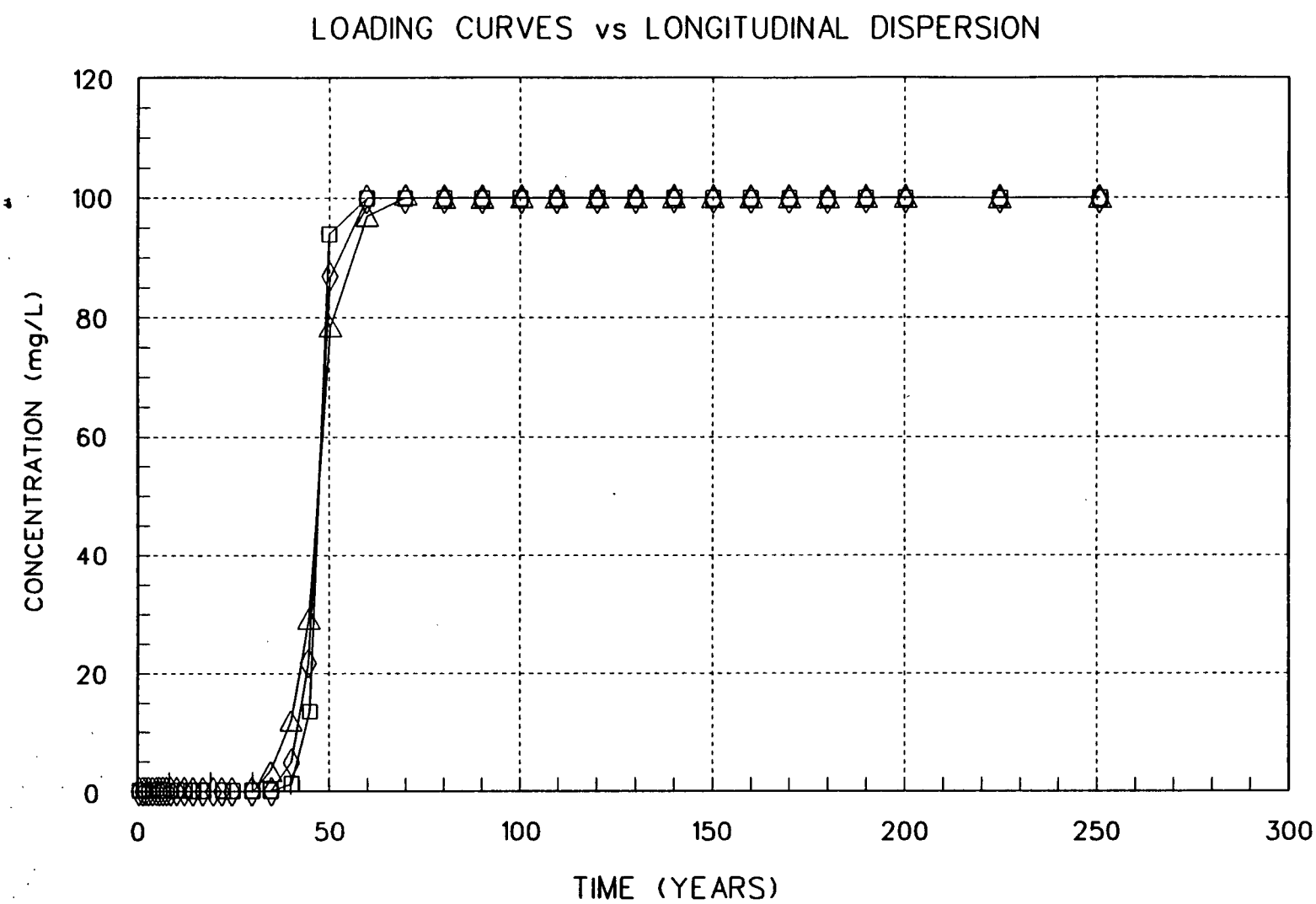


FIGURE D.3-24. PROJECTED MAXIMUM CONCENTRATION OF TOTAL URANIUM IN GROUNDWATER BENEATH FEMP DUE TO LOADING FROM PADDYS RUN CREEK AFTER 10 YEARS



NOTE:

RI OU4 REPORT, 3-93, FIGURE E2-22.

LEGEND:

- ½X DISPERSION
- 1 X DISPERSION
- 2 X DISPERSION

FIGURE D.3-25. ODAST MODEL SENSITIVITY ANALYSIS: LONGITUDINAL DISPERSION

000226

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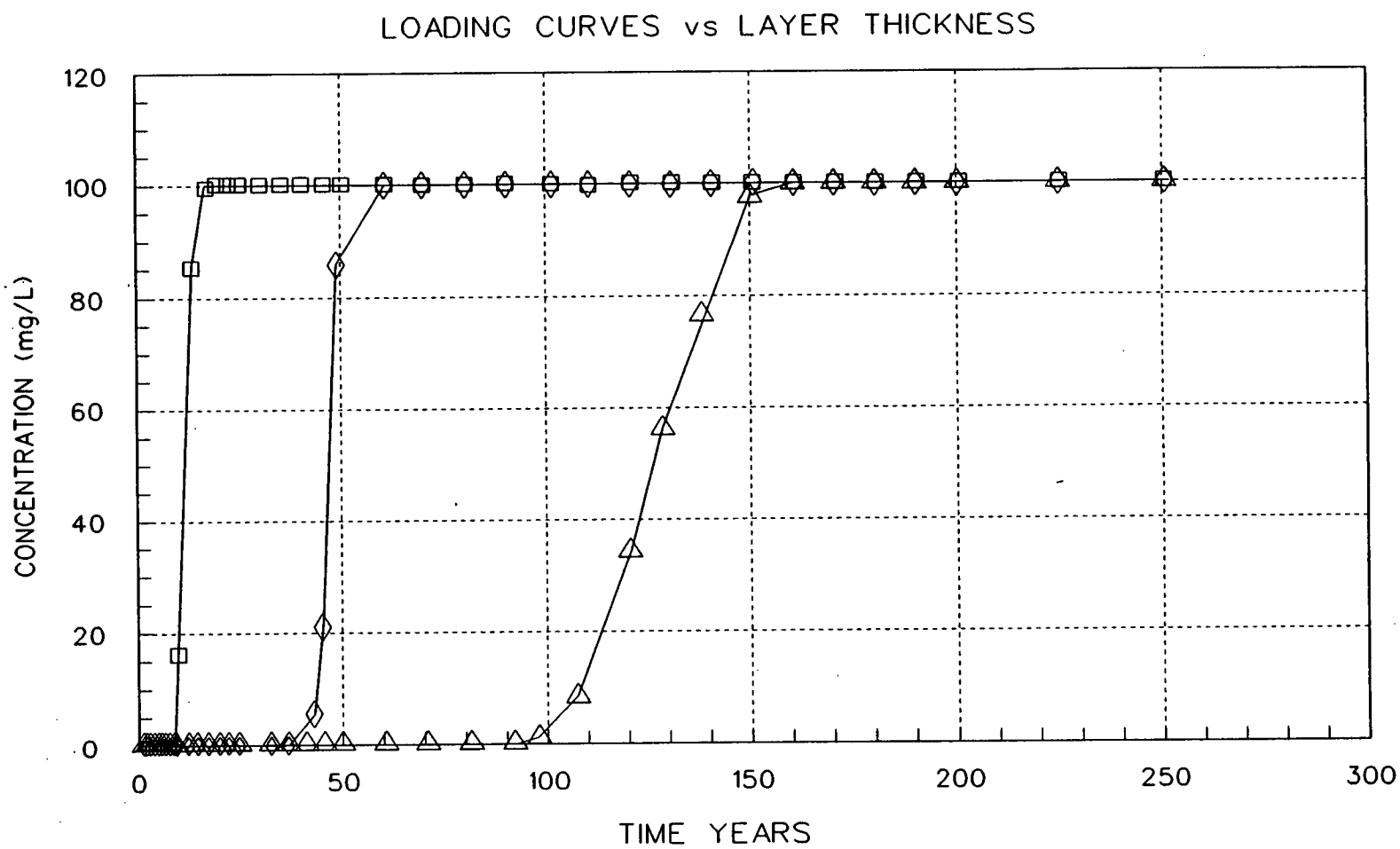


NOTE:

RI OU4 REPORT, 3-93, FIGURE E2-23.

LEGEND:

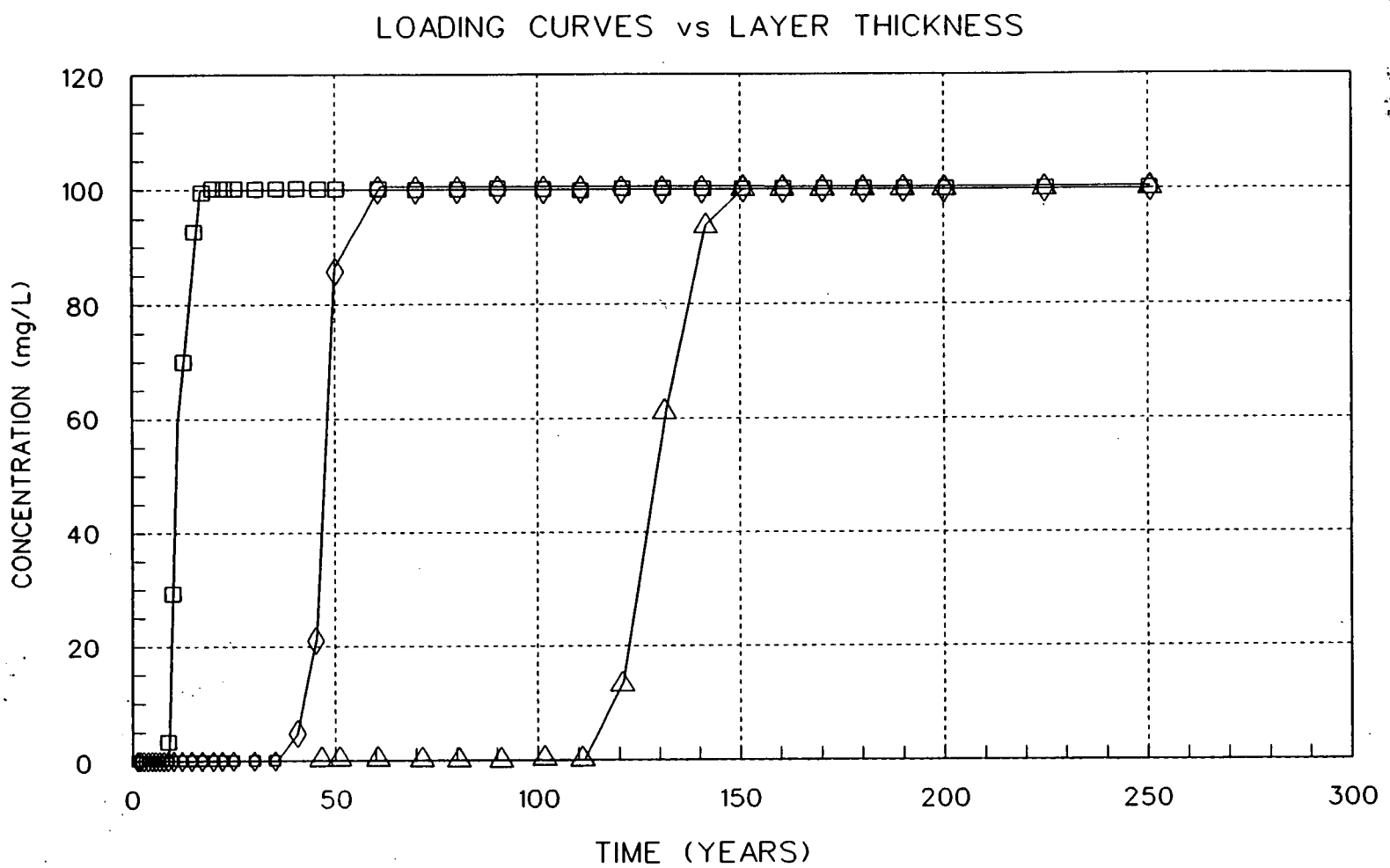
- ½X THICKNESS
- 1 X THICKNESS
- 2 X THICKNESS

000227

5899

SK02098-A OU1 FAIR
figD.3-26.dgn 08-31-94 DEG

FIGURE D.3-26. ODAST MODEL SENSITIVITY ANALYSIS: DARCY VELOCITY



NOTE:

RI OU4 REPORT, 3-93, FIGURE E2-24.

LEGEND:

- ½X THICKNESS
- 1 X THICKNESS
- 2 X THICKNESS

FIGURE D.3-27. ODAST MODEL SENSITIVITY ANALYSIS: 1SP LAYER THICKNESS

SK02098-A OU1 FAIR
skx2098.dgn 08-31-94 RM

REFERENCES

Advanced Sciences, Inc./International Technologies Corporation (ASI/IT), Oct. 1992, "Work Plan Addendum," U.S. Department of Energy, Fernald Field Office, Fernald, OH.

Batu, V., 1989, "A Generalized Two-Dimensional Analytical Solution for Hydrodynamic Dispersion in Bounded Media with the First-Type Boundary Condition at the Source," Water Resources Research, Vol. 25, No. 6, pp. 1125-1132.

Barari, A. and L. S. Hedges, 1985, "Movement of Water in Glacial Till," International Association of Hydrogeologists, Memoirs, Proceedings, Hydrogeology of Rocks of Low Permeability, International Association of Hydrogeologists, Tucson, AZ.

Biggar, J. W. and D. R. Nielsen, 1976, "Spatial Variability of the Leaching Characteristics of a Field Soil," Water Resources Research, Vol 12, No. 1.

Brenner, H., 1962, "The Diffusion Model of Longitudinal Mixing in Beds of Finite Length Numerical Values," Chemical Engineering Science, Vol. 17, pp. 229-243.

Brockman, S. C., 1988, "Glacial Geologic Mapping in Hamilton County, Ohio, Report of Progress on the Final Phase," Ohio Dept. of Natural Resources, Division of Geological Survey.

Cravens, S. J. and L. C. Ruedisili, 1987, "Water Movement in Till of East-Central South Dakota." Groundwater, Vol. 25, No. 5.

Dove, G. D. and S. E. Norris, 1951, "Conditions Governing the Occurrence of Groundwater in the Fernald Area, Ohio, with Reference to the Possibilities of Contamination by Disposal of Chemical Wastes," U.S. Geological Survey, Groundwater Branch, Columbus, OH.

Fetter, C. W., 1989, Applied Hydrogeology, 2nd ed., Charles E. Merrill Publishing Company, Columbus, OH.

Freeze, R. A. and J. A. Cherry, 1979, Groundwater, Prentice-Hall, New York, NY.

Grisak, G. E., J. A. Cherry, J. A. Vonhof, and J. P. Blumele, 1976, "Hydrogeologic and Hydrochemical Properties of Fractured Till in the Interior Plains Region: in Glacial Till, An Interdisciplinary Study." The Royal Society of Canada, Special Publications, No. 12, Robert F. Leggett, ed., Ottawa, Ontario.

Heath, R. C., 1983, "Basic Groundwater Hydrology," Water Supply Paper 2220, U.S. Geological Survey, Reston, VA.

Hendry, M. J., 1988, "Hydrogeology of Clay Till in a Prairie Region of Canada," Groundwater, Vol. 26, No. 5.

Howard, P. H., R. S. Boethling, W. F. Jarvis, W. M. Meylan and E. M. Michalenko, 1991, Environmental Degradation Rates, Lewis Publishers, Inc., Chelsea, MI.

International Technologies Corp. (IT), 1989, "Geochemical Program: Issues 3 and 5," prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

International Technologies Corp. (IT), 1990a, "Flow and Solute Transport Computer Code Verification," prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

International Technologies Corp. (IT), 1990b, "FMPC Groundwater Report," prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

International Technologies Corp. (IT), November 7, 1990c. Memorandum from Sirous H. Djafari of IT for distribution, Subject - "Determination of Hydraulic Conductivity of Till and Unsaturated Great Miami Aquifer Units."

Javandel, I., C. Doughty, and C. F. Tsang, 1984, "Groundwater Transport: Handbook of Mathematical Models," American Geophysical Union Water Resources Monograph Series 10, Washington, DC.

Mills, W. B., J. D. Dean, D. B. Porcella, S. A. Gherini, R. J. M. Hudson, W. E. Frick, G. L. Rupp, and G. L. Bowie, 1982, "Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants: Parts 1, 2, and 3," EPA-6001 6-82-004 a, b, c, U.S. Environmental Protection Agency, Environmental Research Laboratory, Office of Research and Development, Athens, GA, .

Morris, D. A. and A. I. Johnson, 1967, "Summary of Hydrologic and Physical Properties of Rock and Soil Materials, as Analyzed by the Hydrologic Laboratory of the U.S. Geological Survey," Water-Supply Paper 1839-D, U.S. Geological Survey.

Ogata, A. and R. B. Banks, 1961, "A Solution of the Differential Equation of Longitudinal Dispersion in Porous Media," Professional Paper 411-A, U.S. Geological Survey, Reston, VA.

Parsons, 1993, "South Plume Removal Action Pumping Test Report, Operable Unit 5, Project Order 37," Fernald Environmental Management Project, Fairfield, OH.

U.S. Department of Energy (DOE), 1990, "Groundwater Report," Draft, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Department of Energy (DOE), 1992, "Risk Assessment Work Plan Addendum," Final Draft, Fernald Environmental Management Project, Remedial Investigation and Feasibility Studies, Fernald, OH.

U.S. Department of Energy (DOE), May 1993a, "Characterization of Background Water Quality for Streams and Groundwater," Fernald Environmental Management Project, Fernald, OH.

U.S. Dept. of Energy (DOE), 1993b, "Engineering Evaluation Report for On-Site Disposal," Technical Report 5.1A, prepared for DOE by IT Corporation, DOE, Fernald Field Office, Fernald, OH.

U.S. Department of Energy (DOE), 1993c, "Groundwater Modeling Report - Summary of Model Development," Draft, DOE, Fernald Environmental Management Project, Fernald Field Office, Fernald, OH.

U.S. Department of Energy (DOE), Mar. 1993d, "Sitewide Characterization Report," SWCR-6 (Final), DOE, Fernald Environmental Management Project, Fernald Field Office, Fernald, OH.

U.S. Environmental Protection Agency, 1984, "The Hydrologic Evaluation of Landfill Performance (HELP) Model," EPA/530-SW-84-009, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.

U.S. Environmental Protection Agency, 1988, "The Hydrologic Evaluation of Landfill Performance (HELP) Model," EPA/530-SW-84-009, EPA, OFfice of Solid Waste and Emergency Response and EPA
Municipal Research Laboratory, Office of Research and Development, Cincinnati, OH.

U.S. Environmental Protection Agency, 1993, "Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening," Region III Technical Guidance Manual.

Walton, W. C., 1970, Groundwater Resource Evaluation, McGraw-Hill.

Walton, W. C., 1984, Practical Aspects of Groundwater Modeling, 2nd ed., National Water Well Association, Worthington, OH.

Weston, Inc., 1986, "Dept. of Energy Feed Materials Production Center, Fernald, Ohio - Site Characterization of the Waste Storage Areas, Part 1: Evaluation of Current Situation," Weston, Inc., West Chester, PA, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

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D.4.0 AIR

D.4.1 ESTIMATION OF RADON EMISSION FLUX - RAECOM MODEL

The emission flux of radon gas (radon-222) was modeled using the computer model RAECOM (NRC 1984). RAECOM is a radon generation and transport code that was originally designed to analyze radon generation and emanation through uranium mill tailings waste and earthen cover materials.

RAECOM is used in RI and FS risk assessments to analyze radon generation and emanation through media including waste materials at the FEMP and cover materials such as soil, clay, and concrete. Media-specific parameter values are used. It is acknowledged that the use of a model for scenarios that are different from those for which it was originally designed introduces uncertainty in the results. Thus, the results will be used in operable unit RI and FS risk assessments with an appropriate level of caution.

RAECOM requires input of the thickness of each source material and cover material layer, the source strength expressed either as radium-226 concentration in the waste material or as radon flux exiting the surface of the waste material layer, and the porosity, moisture content, and radon gas diffusion coefficient for each source and cover material layer. The radon flux results are useful for comparison to radon flux criteria or for use in an air dispersion model.

RAECOM calculates the radon flux exiting the surface of the upper layer of cover material. The code is based on a one-dimensional, multilayer solution of Fick's law using the boundary conditions set forth in NUREG/CR-3533 (NRC 1984). For a bare source, this solution becomes:

$$J_t = 10^4 R \rho_t E [(\lambda)(DC_l)]^{1/2} \tanh[(\lambda/DC_l)^{1/2} x_t] \qquad \text{(D-1)}$$

where

J_t	=	radon flux (pCi/m^2-sec)
R	=	radium 226 activity for Waste Pit 3 = 451 pCi/g Waste Pit 5 = 160 pCi/g Waste Pit 6 = 4.3 pCi/g
ρ_t	=	dry bulk density = 1.6 g/cm^3
E	=	radon emanation coefficient = 0.22 (unitless)
λ	=	radiological decay constant for radon

	=	2.1×10^{-6} sec^{-1}
DC_t	=	radon diffusion coefficient (cm^2/sec)
x_t	=	thickness of the tailings = 100 cm for each pit

In this air transport analysis, emission flux data was required for waste pit areas having no soil cover in the future scenario. This included Waste Pits 3, 5, and 6. As a result, equation (1) was used to calculate the emission flux for each waste pit. The specific activity of radium-226 for each waste pit was obtained from the soils contaminant database. The remainder of this section presents the derivation of emission flux for each of the waste pits.

RAECOM calculates the radon flux exiting the surface of the upper layer or cover material. For a bare source with no cover material, the radon flux equation becomes:

$$J_t = 10^4 R \rho_t E [(\lambda)(DC_t)]^{1/2} \tanh[(\lambda/DC_t)^{1/2} x_t] \qquad \text{(D-2)}$$

where

J_t	=	radon flux (pCi/m^2-sec)
R	=	radium 226 activity for Waste Pit 3 = 451 pCi/g Waste Pit 5 = 160 pCi/g Waste Pit 6 = 4.3 pCi/g
ρ_t	=	dry bulk density = 1.6 g/cm^3
E	=	radon emanation coefficient = 0.22 (unitless)
λ	=	radiological decay constant for radon
	=	2.1×10^{-6} sec^{-1}
DC_t	=	radon diffusion coefficient (cm^2/sec)
x_t	=	thickness of the tailings = 100 cm for each pit

The average dry bulk density (P_t) of radium-bearing materials in Waste Pits 3, 5, and 6 is 1.3 g/cm^3. A value of 1.6 g/cm^3 was used for conservatism.

DC_t must be calculated from the following empirical equation:

$$DC_t = 0.07 \exp[-4(m-mp^2+m^5)] \qquad \text{(D-3)}$$

where

m	=	fraction of saturation (unitless)
p	=	soil porosity assumed at 0.41 from Figure ES-1 in the document entitled "Radon Attenuation Handbook for Uranium Mill Tailings Cover Design"

The value for m can be determined from the following simple engineering correlation:

000234

$$m = [0.124(p)^{1/2} - 0.0012E_l - 0.04 + 0.156f_{cm}] \quad \text{(D-4)}$$

where

p	=	annual precipitation = 40 inches
E_l	=	annual lake evaporation = 34 inches
f_{cm}	=	fraction of soil passing a 200 mesh sieve assumed to be 60%

$m = 0.797$

then $DC_t = 1.4 \times 10^{-3}$ cm²/sec

The source terms for Waste Pits 3, 5, and 6 in pCi/m²-sec are:

Waste Pit 3 = 85.66 pCi/m²-sec
Waste Pit 5 = 30.39 pCi/m²-sec
Waste Pit 6 = 0.83 pCi/m²-sec

D.4.2 AIR TRANSPORT AND DISPERSION MODELING PROTOCOL AND RESULTS

D.4.2.1 Site Description of Operable Unit 1

Operable Unit 1, commonly referred to as the waste pit area, is located in the northwest corner of the Fernald Environmental Management Project (FEMP) facility. Surrounding Operable Unit 1 is the Production Area to the east, the K-65 silos to the south and Paddys Run to the west. There are 8 individual pits in Operable Unit 1 which are identified as Waste Pits 1 through 6, the Burn Pit and Clear Well. The location of each pit is shown in Figure 5-15. Aerial photographs of Operable Unit 1 taken in December 1988 and March 1992 show that Waste Pits 1 through 3 and the Burn Pit have been backfilled and are covered with sparse vegetation. Contents of Waste Pit 4 are protected by a temporary RCRA cover. The remaining pits are either uncovered or partially filled with water.

From U.S. Geological Survey topography maps (Southeast Ohio, Shandon Quadrangle, revised 1981) topographic characteristics surrounding the waste pits is generally flat. A major topographic feature is the Great Miami River which is located approximately one mile, at its closest point, east of the FEMP facility.

Recent aerial photographs from 1992 show vegetation, in the form of needle and broadleaf trees, growing to the north and west of Operable Unit 1. Isolated dairy and agricultural farms also surround the FEMP facility.

D.4.2.2 Climatology

The climate is defined as "continental" with a wide range of temperatures from winter to summer. Normal precipitation occurs all twelve months, with a maximum during the winter and early spring months and a minimum in late summer and fall. Summers are warm and humid with maximum temperatures in the nineties. Winters are moderately cold with frequent periods of extensive cloudiness. (National Climatic Data Center, Local Climatological Data Annual Summaries for the Greater Cincinnati Airport, 1987)

D.4.2.3 Conceptual Air Model Source Scenarios

Three scenarios were examined in the air transport analysis, one current scenario and two future scenarios (Future Agricultural and Future Government Reserve). The following are the land-use conditions of each pit under conceptual air model scenarios:

Current Scenario

- Waste Pit 1 - No land-use, assume 85 percent vegetative cover
- Waste Pit 2 - Same as Waste Pit 1
- Waste Pit 3 - Same as Waste Pit 1
- Waste Pit 4 - Not applicable, RCRA cover installed
- Waste Pit 5 - Not applicable, covered with water
- Waste Pit 6 - Same as Waste Pit 5
- Burn Pit - Same as Pit 1

Future Agricultural Scenario

- Waste Pit 1 - Used for growing crops six months of the year. Assume 100 percent vegetative cover for six months and no vegetative cover the remaining six months. Apply emission control factor for precipitation to the six month period when the soil is bare.
- Waste Pit 2 - Same as Waste Pit 1
- Waste Pit 3 - Assume that 30 percent of the soil cover has failed exposing underlying pit material. Assume no vegetative cover on exposed pit material. Remaining 70 percent of the pit maintains the soil cover and has 85 percent vegetative cover. Apply emission control factor for precipitation to exposed portion of pit material.
- Waste Pit 4 - Not applicable - RCRA cover
- Waste Pit 5 - Assume half of pit is covered with water and has no emissions. The remaining half of the pit has exposed pit material with no vegetative cover. Apply emission control factor for precipitation to bare pit material.
- Waste Pit 6 - Same as Waste Pit 5

- Burn Pit - Assume soil cover with 85 percent vegetative coverage over the entire pit.

Future Government Reserve

- Waste Pit 1 - No land use or farming activities. Assume 85 percent vegetative coverage year round.
- Waste Pit 2 - Same as Waste Pit 1.
- Waste Pit 3 - Assume that 30 percent of soil cover has failed exposing underlying pit material. Assume no vegetative cover on exposed pit material. Remaining 70 percent of soil cover has 85 percent vegetative cover. Apply emission control factor for precipitation to the exposed portion of pit material.
- Waste Pit 4 - Not applicable - RCRA cover.
- Waste Pit 5 - Assume half of pit is covered with water and has no emissions. The remaining half of the pit has exposed pit material with no vegetative cover. Apply emission control factor for precipitation to bare pit material.
- Waste Pit 6 - Same as Waste Pit 5
- Burn Pit - Assume soil cover with 85 percent vegetative coverage over the entire pit.

D.4.2.4 Air Dispersion Model

Annual average concentrations and deposition rates were determined by the EPA's air dispersion model, Industrial Source Complex Long-Term 2 Version 92273 (ISCLT2). This model was recommended for use by the Department of Energy, in the "Risk Assessment Work Plan Addendum", Section 6.0, dated June 1992.

The ISCLT2 model was designed by the EPA for assessing the air quality impact of emissions at user-selected receptors from a variety of sources. It incorporates a steady-state Gaussian plume equation that is applicable for flat or gently rolling terrain. The ISCLT2 model calculates annual average concentrations and deposition rates due to airborne emissions at user-selected receptors, based on sector averaged statistical wind summaries known as STatistical ARrays (STAR). The user is required to select from single or multiple point sources, area, or volume sources as input to the model. Input data also includes emission rates from the sources, location and configuration of sources, statistical summaries of wind speed, wind direction and atmospheric stability (STAR) and locations of receptors of interest. Other input options used in the modeling are addressed in Table D.4-1.

All ISCLT2 model calculations were conducted using the corresponding wind erosion emission rate for each waste pit given in Attachment II. These wind erosion unit emission rate concentrations for each waste pit were then multiplied by the appropriate waste pit contaminant concentrations or activity levels and summed to get a total contaminant impact at each receptor point.

D.4.2.5 ISCLT Model Input Parameters

Meteorological Data

Five meteorological parameters are required as input to the ISCLT2 model. These parameters include wind speed, wind direction, ambient air temperature, atmospheric stability and vertical mixing heights. All parameters, with the exception of vertical mixing heights, are measured directly from FEMP's on-site meteorological tower. Vertical mixing heights were calculated from atmospheric sounding data compiled twice daily, from the National Weather Service (NWS) reporting station in Dayton, Ohio (See Table D.4-2). The NWS office in Dayton was selected because it was the closest source of atmospheric sounding data to the FEMP facility. It was assumed that atmospheric conditions recorded at the NWS Dayton office would best represent the conditions at the FEMP facility.

Wind speed, wind direction and ambient air temperature data are measured at the FEMP meteorological tower at a height of 10 meters. The atmospheric stability category is derived from direct measurements of the standard deviation of the horizontal wind direction (sigma-theta) during the daytime and the low-level temperature difference (delta-T) at night. These procedures are in accordance with U.S. EPA methodology for estimating Pasquill stability categories in terms of the standard deviation of the horizontal wind direction and low level temperature differences, as described in U.S. EPA Publication 450/4-87-013 entitled "Onsite Meteorological Program Guidance for Regulatory Modeling Applications" (Section 6.0). The temperature difference is calculated from air temperature recorded at the 60 meter and 10 meter levels.

The ambient air temperatures measured at the FEMP meteorological tower and the temperatures used in the ISCLT2 model, as a function of atmospheric stability categories A through F, are given in Table D.4-3. Assignments of temperatures to stability categories were consistent with guidelines contained in the U.S. EPA publication 450/4-92-008a, entitled "Users Guide for the Industrial Source Complex (ISC2) Dispersion Models," Volume 1

(Section 3.5.11). These guidelines suggest that the annual average maximum daily temperatures be assigned to the A, B, and C stability categories, while annual average temperature be assigned to the D stability category, and annual average minimum daily temperature be assigned to the E and F categories.

The format of the meteorological data required by the ISCLT2 model is in the form of the STability ARray (STAR) program output. The STAR program output is a statistical summary of meteorological data which gives the joint frequency distribution of six wind speed classes by sixteen wind sectors (i.e. north, north-northeast, northeast etc.) by six atmospheric stability categories (A through F). STAR data for the five years, 1987 through 1989, 1991 and 1992 were used to determine the maximum on-site and off-site concentration for each emission scenario. These STAR summaries are listed in Attachment D-I.

The six wind speed classes are defined as 1 to 3 miles per hour (mph); 4 to 7 mph; 8 to 12 mph; 13 to 18 mph; 19 to 24 mph; and greater than 24 mph. Calm winds are wind speeds less than 1 mph with a variable wind direction. To account for the calm winds measured at the FEMP meteorological tower, the frequency of occurrence of calm winds were equally divided among the sixteen wind direction sectors and added to the 1 to 3 mph wind speed class.

According to the meteorological wind data measured at the FEMP monitoring station, the prevailing wind direction blows from the west-southwest to the east-northeast.

Source Data

The ISCLT2 model defines sources as any point, area or volume that has the potential to have emissions. Due to the ground level configuration of the waste pits and the large area of potential emissions, the "area source" designation was selected to best represent OU1 source type. In the current scenarios, there were 4 individual area sources. These sources were Waste Pits 1 through 3 and the Burn Pit. A total of six individual sources were considered in both future scenarios. These sources include Waste Pits 1, 2, 3, 5, 6 and the Burn Pit.

One limitation of the ISCLT2 model is its inability to calculate ground level concentrations from irregularly shaped area sources. Therefore, the user is required to breakdown each irregularly shaped source into a series of squares that would best approximate the area of the

source. This source configuration is consistent with guidelines found in the U.S. EPA publication 450/4-92-008a entitled "Users Guide for the Industrial Source Complex (ISC2) Dispersion Models", Volume 1 (Section 3.3.1). Figures D.4-1 and D.4-2 illustrate the breakdown of individual squares sources used to represent the waste pit sources for the current and future scenarios, respectively.

The ISCLT2 model requires the user to input the coordinates of the southwest corner of individual squares along with the length of one side, assuming a box with four equal sides. The individual square source coordinates and side lengths are given in Table D.4-4.

Current Scenario Sources

In the current scenario, Waste Pits 1 through 3 and the Burn Pit are assumed to be 85 percent covered with vegetation. Recent site survey and aerial photos confirm that most of the waste pit area has vegetation growing on it. Waste Pit 4 is protected by a temporary RCRA cover and has no emissions. Waste Pits 5, 6 and the Clear Well are filled with water and are not considered to be sources of emissions.

Future Scenario Sources

In the Agricultural Scenario, Waste Pits 1 and 2 are designated as areas to be used for farming. Crops are assumed to grow on these pits six months of the year. The remaining six months the soil is devoid of vegetation. During the six months that the soil is bare, the annual frequency of snow and rain events were considered as a wind erosion control factors.

It was assumed that 30 percent of surface soil covering Waste Pit 3 has eroded, which exposes the underlying pit material. The remaining 70 percent of Waste Pit 3 was assumed to have 85 vegetative cover growing on the surface soil cover. Waste Pits 5 and 6 are half filled with water, exposing the remaining half of pit material. Similar to Waste Pit 3, wind erosion control factors due to precipitation events were applied to emission rates for Waste Pits 5 and 6. The Burn Pit was assumed to be covered with 85 percent vegetation.

The Government Reserve Scenario is similar to the Agricultural scenario, except Waste Pits 1 and 2 are no longer used for growing crops. Instead, Waste Pits 1 and 2 are 85 percent covered with vegetation.

Waste Pit 4 in both future scenarios is protected by a temporary RCRA cover. The Clearwell is filled with water and is not considered an emission source.

Emission Rates

Wind erosion emission rates were calculated according to the methodology described in the U.S. EPA publication 600/8-85/002, which is entitled "Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites". The annual frequency of rain and snow were considered as control factors in calculating wind erosion emission rates. Emission rate calculations were based on the erosion potential of the surface or pit material particles of each waste pit. The wind erosion emission rate for a source is defined as either having "unlimited" or "limited" potential. Essentially, sources that have continuous vegetative growth or have surface soil that is crusted are classified as having limited erosion potential. Conversely, surface soil that is loose, fine or sandy has a high potential for erodibility and is generally classified as having an unlimited erosion potential. Example calculations for unlimited and limited erosion potential of surface soils and pit material, as well as, calculations for settling velocity and reflection coefficient that were used in the deposition modeling are listed in Attachment D-II.

In cases where bare soil or pit material were assumed to prevail, the annual occurrence or precipitation was considered as a wind erosion control mechanism. Wind erosion control factors were calculated based on annual frequencies of rain and snow. The wind erosion of particulates is greatly inhibited by when precipitation causes particles to coalesce, forming larger, non-erodible particles.

The average number of days where 0.01 inches or greater of rain fell were factored into the calculation for all unlimited wind erosion source areas. The calculation procedure used to calculate a control efficiency for precipitation is given in Attachment D-II. In addition to the rainfall frequency, the annual average number of days with an inch of snow or greater was factored into the calculations for unlimited wind erosion.

Receptor Data

A receptor grid covering approximately 12.6 square kilometers was used to determine the maximum on-site and off-site concentrations for the current and both future emission

scenarios. The location of on-site and off-site receptors for this analysis were determined by the property line surrounding the FEMP facility.

The receptor grid used an 86 x 61 receptor grid (i.e. number of receptors along the north-south axis and the number of receptors along the east-west axis), with a 50 meter spacing between each receptor. The origin of the receptor grid was located at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East). The area of the receptor grid, including individual receptors, is shown in Figure D.4-3.

Discrete receptors were also used in the air transport analysis. The discrete receptors included the following locations: Crosby Elementary School; Morgan Elementary School; Elda Elementary School; Ross Middle and High School; St. John's Elementary; and the Ross County Day Nursery. Discrete receptors and corresponding Cartesian coordinate locations from the origin are listed in Table D.4-5.

Calculation of Mean Particle Diameter and Mass Fraction

Previous geotechnical analyses of surface soil samples taken from various locations within the FEMP boundary reveal that a majority of the surface soil particles have an average aerodynamic diameter of 20 μm. This diameter is based on surface soil samples extracted from the Solid Waste Landfill, South Field, Inactive Flyash Pile and the North and South Lime Sludge Ponds within Operable Unit 2. Due to the lack of geotechnical data for surface soils within Operable Unit 1, this analysis assumed the same aerodynamic diameter for Operable Unit 1 sources as determined for the subunits within Operable Unit 2. Geotechnical data available for Waste Pit 3 indicated an average aerodynamic diameter of 17 μm for pit material. Sieve and hydrometer analysis data for surface soils and pit material are given in Attachment D-II.

It was assumed that no variability in particle diameter occurred in surface soils across the FEMP facility from the mean aerodynamic diameter listed above. Therefore, all surface soil particles had a diameter of 20 μm despite their location and all pit material particles had a diameter of 17 μm.

Calculation of Settling Velocity

The ISCLT2 User's Guide (U.S. EPA publication 450/4-92-008b, page 1-35) indicates that for particles with diameters less than 75 μm, the settling velocity is given by the following equation:

$$V_{sn} = 2\rho g r^2/9u$$

where

V_{sn} = settling velocities (cm/sec)
ρ = particle density (grams/cm^3)

g = acceleration of gravity (980 cm/s^2)
r = particle radius (cm)
u = absolute viscosity of air (1.83E-04 grams/cm/s)

An average particle density, analogous to a specific gravity of 2.67 grams/cm^3, was selected based on geotechnical analysis from surface soil samples extracted from various location within the FEMP facility (see Attachment D-II). Settling velocities calculations, based on this specific particle radius, are also given in Attachment D-II.

Calculation of Reflection Coefficient

The value chosen to represent the reflection coefficient in the deposition modeling was obtained from the ISCLT2 User's Guide. Within this guidance on Page 1-51, a figure is provided that shows the relationship between settling velocity and reflection coefficient. After the settling velocity was calculated, this figure was used to select a reflection coefficient for all sources.

D.4.2.6 Results of Air Dispersion Modeling

This section summarizes the results of the ISCLT2 modeling for current and future emission scenarios using the model input parameters and methodology described above. It is important to note that the maximum ambient air concentrations were calculated at a flagpole receptor height of 1.5 meters, which corresponds to the normal breathing height. For the deposition modeling, the deposition rates were calculated for receptor locations at ground level.

Each emission scenario in the conceptual model was modeled for all 5 years of on-site meteorological data. The modeling results for the worst case meteorological period were used to report individual contaminant concentrations for use in the risk assessment. The maximum

annual concentrations for each individual contaminant are reported in Section 5.3.3. All modeling results presented below are for the wind erosion of particulate matter.

Current Scenario - Concentration Results

Table D.4-6 summarizes maximum ambient air concentrations at the on-site receptors. Results show maximum concentrations from all pits, relevant to current scenario conditions, to be 7.0 $\mu g/m^3$ at a receptor located approximately 652 meters southeast of the origin. Table D.4-7 shows a maximum ambient air concentrations at an off-site receptor to be 0.5379 $\mu g/m^3$ and was estimated at a location approximately 474 meters south-southeast from the origin. Table D.4-8 show ISCLT2 model results for maximum ambient air concentrations at the discrete receptors from all waste pits in the current scenario.

Current Scenario - Deposition Rate Results

Table D.4-9 provides a summary of maximum annual deposition rates at on-site receptors. The highest of the annual average deposition rates was 0.4755 g/m^2 for the receptor point located 716 meters southeast of the origin. Table D.4-10 shows a maximum deposition rate of 0.0642 g/m^2 at an off-site receptor located 474 meters from the origin. Table D.4-11 shows the annual deposition rates from all pits at the discrete receptors.

Future Agricultural Scenario - Concentration Results

Table D.4-12 summarizes maximum ambient air concentrations at on-site receptors for the Future Agricultural scenario. The highest concentration of 54.6 $\mu g/m^3$ was calculated at an on-site receptor located 610 meters southeast from the origin. Table D.4-13 shows the maximum air concentration at off-site receptors to be 5.10 $\mu g/m^3$. This occurred at a receptor located approximately 474 meters south-southeast of the origin. Table D.4-14 summarizes the ambient air concentrations at discrete receptor locations.

Future Agricultural Scenario - Deposition Rate Results

Tables D.4-15 and D.4-16 show the maximum annual deposition rates from all pits to on-site and off-site receptors, respectively, for the Future Agricultural scenario. The ICSLT2 model calculated a maximum annual deposition rate of 1.98 g/m^2 at an on-site receptor located 652 meters southeast of the origin. A maximum deposition rate of 0.3626 g/m^2 was calculated for an off-site receptor located 474 meters south-southeast of the origin. Table D.4-17 shows the maximum annual deposition rates calculated from all pits at the discrete receptors.

Future Government Reserve Scenario - Concentration Results

Table D.4-18 shows the maximum on-site annual concentrations from all pits. The ISCLT2 model calculated a maximum concentration of 47.9 $\mu g/m^3$ at a receptor located 610 meters southeast of the origin. Table D.4-19 shows the maximum off-site annual concentration was calculated to be 4.06 $\mu g/m^3$ at an off-site receptor located 474 meters south-southeast from the origin. Table D.4-20 shows the maximum annual concentration calculated from all pits at the discrete receptors.

Future Government Reserve Scenario - Deposition Rate Results

Table D.4-21 shows the maximum annual deposition rates from all pits to on-site receptors. The ISCLT2 model calculated a maximum deposition rate of 1.50 $\mu g/m^3$ at a receptor located 610 meters southeast from the origin. Table D.4-22 shows the maximum off-site deposition rate from all pits to be 0.2790 g/m^2 at a receptor located 474 meters south-southeast from the origin. Table D.4-23 shows the maximum annual deposition rates calculated from all pits at the discrete receptors.

TABLE D.4-1

DISPERSION OPTIONS USED IN ISCLT MODELING OF OPERABLE UNIT 1

Source Type	Area
Dispersion Mode	Rural
Calculation Mode	Concentration
Building Downwash	None
Flagpole Receptors	None
Discrete Receptors	Yes
Gravitational Settling	None
Variable Emissions	None
Receptor Grid	Cartesian
Discrete Receptor Grid	Cartesian
Meteorology Input	Annual STAR Summaries[a]

[a] Individual annual FEMP on-site STAR data for 1987 through 1992. See Attachment D.I.

TABLE D.4-2

MIXING HEIGHTS* IN METERS USED IN ISCLT MODELING

		Wind Speed Class					
Year	Stability Class	1	2	3	4	5	6
1987	A	2105	1961	1803	1802	1526	2349
	B	1403	1307	1202	1201	1017	1566
	C	1403	1307	1202	1201	1017	1566
	D	1403	1307	1202	1201	1017	1566
	E	5000	5000	5000	5000	5000	5000
	F	5000	5000	5000	5000	5000	5000
1988	A	2133	2351	2030	1812	1665	3255
	B	1422	1567	1353	1208	1110	2170
	C	1422	1567	1353	1208	1110	2170
	D	1422	1567	1353	1208	1110	2170
	E	5000	5000	5000	5000	5000	5000
	F	5000	5000	5000	5000	5000	5000
1989	A	1854	1995	1698	1524	1730	2313
	B	1236	1330	1132	1016	1153	1542
	C	1236	1330	1132	1016	1153	1542
	D	1236	1330	1132	1016	1153	1542
	E	5000	5000	5000	5000	5000	5000
	F	5000	5000	5000	5000	5000	5000
1990	A	1823	1991	1791	1695	1629	2313
	B	1215	1327	1194	1130	1086	1542
	C	1215	1327	1194	1130	1086	1542
	D	1215	1327	1194	1130	1086	1542
	E	1215	1327	1194	1130	1086	1542
	F	5000	5000	5000	5000	5000	5000

TABLE D.4-2
(Continued)

		Wind Speed Class					
Year	Stability Class	1	2	3	4	5	6
1991	A	1823	1991	1791	1695	1629	2313
	B	1215	1327	1194	1130	1086	1542
	C	1215	1327	1194	1130	1086	1542
	D	1215	1327	1194	1130	1086	1542
	E	5000	5000	5000	5000	5000	5000
	F	5000	5000	5000	5000	5000	5000
1992	A	1823	1991	1791	1695	1629	2313
	B	1215	1327	1194	1130	1086	1542
	C	1215	1327	1194	1130	1086	1542
	D	1215	1327	1194	1130	1086	1542
	E	5000	5000	5000	5000	5000	5000
	F	5000	5000	5000	5000	5000	5000

* Calculated from National Weather Service, Dayton, Ohio sounding data.

TABLE D.4-3

AMBIENT AIR TEMPERATURES* USED IN ISCLT MODELING

	Ambient Air Temperature (°K)					
	Stability Class					
Year	A	B	C	D	E	F
1987	290	290	290	284	278	278
1988	291	291	291	284	279	279
1989	290	290	290	284	280	280
1990	290	290	290	285	279	279
1991	292	292	292	286	281	281
1992	290	290	290	284	279	279

* Ambient air temperatures measured at the FEMP on-site monitoring station.

TABLE D.4-4

SOURCE IDENTIFICATION AND COORDINATES FOR OPERABLE UNIT 1 SOURCES

SOURCE	X*(m)	Y*(m)	L(m)
P1SQ1	470	-480	70
P1SQ2	510	-410	30
P2SQ2	550	-425	55
P3SQ1	400	-400	50
P3SQ2	450	-400	50
P3SQ3	450	-350	50
P3SQ4	500	-350	50
P3SQ5	500	-300	50
P3SQ6	550	-325	50
P3SQ7	500	-375	25
P3SQ8	550	-350	25
P3SQ9	425	-350	25
P3SQ10	475	-300	25
P3SQ11	475	-275	25
P5SQ1	625	-250	75
P5SQ2	600	-225	25
P5SQ3	600	-200	25
P6SQ1	750	-275	30
BPSQ1	594	-350	12
BPSQ2	600	-338	12
BPSQ3	600	-326	24
BPSQ4	612	-302	24
BPSQ5	624	-278	15

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

000250

TABLE D.4-5

DISCRETE RECEPTORS AND COORDINATES

DISCRETE RECEPTORS	X-COORDINATE* (meters)	Y-COORDINATE* (meters)
CROSBY ELEMENTARY	-1180	-3140
MORGAN ELEMENTARY	-3200	3150
ELDA ELEMENTARY	5360	1780
ST. JOHNS ELEMENTARY	7130	-4650
ROSS MIDDLE/HIGH SCHOOL	6145	3300
ROSS COUNTY DAY NURSERY	5575	2225

* Origin located at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East)

TABLE D.4-6

MAXIMUM ANNUAL ON-SITE CONCENTRATIONS ($\mu g/m^3$) AND RECEPTOR COORDINATES* (meters) FOR THE CURRENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	2.2 (500, -400)	2.51 (550, -400)	2.5 (550, -400)	2.2 (500, -400)	2.2 (500, -400)
Pit 2	1.0 (600, -350)	1.12 (600, -350)	1.1 (650, -400)	1.0 (600, -350)	1.0 (600, -350)
Pit 3	4.6 (550, -350)	4.93 (550, -350)	5.1 (550, -350)	4.4 (550, -350)	4.6 (550, -350)
Burn Pit	1.4 (650, -300)	1.56 (650, -300)	1.6 (650, -300)	1.4 (650, -300)	1.4 (650, -300)
All Pits	6.6 (550, -350)	6.97 (550, -350)	7.0 (550, -350)	6.3 (550, -350)	6.6 (550, -350)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-7

MAXIMUM ANNUAL OFF-SITE CONCENTRATIONS ($\mu g/m^3$) AND RECEPTOR COORDINATES* (meters) FOR THE CURRENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.0835 (150, -450)	.0778 (150, -450)	.0730 (200, -600)	.0722 (150, -450)	.0867 (200, -600)
Pit 2	.0434 (150, -550)	.0293 (150, -550)	.0271 (150, -550)	.0266 (150, -450)	.0333 (150, -550)
Pit 3	.3676 (150, -450)	.2494 (150, -450)	.2302 (150, -450)	.2268 (150, -450)	.2834 (150, -450)
Burn Pit	0.2184 (150, -450)	.0146 (150, -450)	.0133 (150, -450)	.0132 (150, -450)	.0167 (150, -450)
All Pits	0.5379 (150, -450)	.3708 (150, -450)	.3363 (150, -450)	.3388 (150, -450)	.4154 (150, -450)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-8

MAXIMUM ANNUAL CONCENTRATIONS ($\mu g/m^3$) AT DISCRETE RECEPTOR LOCATIONS* FOR THE CURRENT SCENARIO

	1987	1988	1989	1991	1992
Crosby Elementary	.0071	.0059	.0064	.0052	.0065
Morgan Elementary	.0030	.0027	.0024	.0023	.0030
Elda Elementary	.0094	.0127	.0132	.0096	.0093
St. John Elementary	.0037	.0049	.0053	.0046	.0047
Ross Middle High School	.0064	.0087	.0089	.0067	.0067
Ross County Day Nursery	.0084	.0114	.0118	.0086	.0085

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-9

MAXIMUM ANNUAL ON-SITE DEPOSITION RATES (g/m^2) AND RECEPTOR COORDINATES* (meters) FOR THE CURRENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.0893 (550, -400)	.1256 (550, -400)	.1295 (550, -400)	.1019 (550, -400)	.1043 (550, -400)
Pit 2	.0458 (650, -400)	.0636 (650, -400)	.0674 (650, -400)	.0504 (650, -400)	.0520 (650, -400)
Pit 3	.2692 (550, -350)	.3213 (550, -350)	.3325 (550, -350)	.2746 (550, -350)	.2875 (550, -350)
Burn Pit	.1065 (650, -300)	.1399 (650, -300)	.1449 (650, -300)	.1174 (650, -300)	.1190 (650, -300)
All Pits	.3874 (550, -350)	.4595 (650, -350)	.4755 (650, -300)	.3903 (550, -350)	.4145 (550, -350)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-10

MAXIMUM ANNUAL OFF-SITE DEPOSITION RATES (g/m^2) AND RECEPTOR COORDINATES* (meters) FOR THE CURRENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.0125 (200, -600)	.0081 (200, -600)	.0080 (200, -600)	.0068 (150, -450)	.0088 (200, -600)
Pit 2	.0052 (150, -550)	.0032 (200, -600)	.0032 (150, -550)	.0026 (150, -450)	.0036 (150, -550)
Pit 3	.0449 (150, -450)	.0292 (150, -450)	.0275 (150, -450)	.0233 (150, -450)	.0314 (150, -450)
Burn Pit	.0031 (150, -500)	.0019 (150, -450)	.0018 (150, -500)	.0015 (150, -450)	.0021 (150, -450)
All Pits	.0642 (150, -450)	.0424 (150, -450)	.0039 (150, -450)	.0342 (150, -450)	.0453 (150, -450)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-11

MAXIMUM ANNUAL DEPOSITION RATES (g/m^2) AT DISCRETE RECEPTOR LOCATIONS* FOR THE CURRENT SCENARIO

	1987	1988	1989	1991	1992
Crosby Elementary	.0012	.0028	.0013	.0041	.0028
Morgan Elementary	.0002	.0002	.0001	.0008	.0004
Elda Elementary	.0015	.0018	.0018	.0051	.0028
St. John Elementary	.0003	.0004	.0003	.0008	.0006
Ross Middle High School	.0009	.0011	.0010	.0028	.0017
Ross Country Day Nursery	.0013	.0016	.0015	.0044	.0025

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-12

MAXIMUM ANNUAL ON-SITE CONCENTRATIONS $\mu g/m^3$) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE AGRICULTURAL SCENARIO

	1987	1988	1989	1991	1992
Pit 1	14.5 (550, -400)	20.1 (550, -400)	20.2 (550, -400)	17.3 (550, -400)	17.4 (550, -400)
Pit 2	6.4 (650, -400)	8.9 (650, -350)	9.1 (650, -400)	8.0 (600, -350)	8.1 (600, -350)
Pit 3[a]	29.5 (500, -350)	40.9 (500, -350)	41.3 (500, -350)	34.8 (500, -350)	35.0 (500, -350)
Pit 3[b]	3.30 (550, -350)	3.8 (550, -300)	3.90 (550, -300)	3.40 (550, -300)	3.50 (550, -300)
Pit 3	32.1 (500, -350)	43.1 (500, -350)	43.6 (500, -350)	37.0 (500, -350)	37.1 (500, -350)
Pit 5	23.6 (600, -200)	28.5 (750, -200)	29.5 (750, -200)	23.8 (750, -200)	24.0 (740, -200)
Pit 6	12.0 (800, -250)	16.4 (800, 250)	16.6 (800, -250)	14.1 (800, -250)	14.1 (800, -250)
Burn Pit	1.22 (650, -300)	1.56 (650, -300)	1.60 (650, -300)	1.40 (650, -300)	1.40 (650, -300)
All Pits	43.9 (500, -350)	54.6 (500, -350)	54.5 (500, -350)	47.8 (500, -350)	49.5 (500, -350)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-13

MAXIMUM ANNUAL OFF-SITE CONCENTRATIONS $\mu g/m^3$) AND RECEPTOR COORDINATES* (meters) AND THE FUTURE AGRICULTURAL SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.8947 (200, -600)	.6221 (150, -450)	.5840 (200, -600)	.5777 (150 -450)	.6935 (200, -600)
Pit 2	.3474 (150, -550)	.2344 (150, -550)	.2167 (150, -550)	.2129 (150, -450)	.2666 (150, -550)
Pit 3[a]	2.42 (150, -450)	1.66 (150, -450)	1.53 (150, -500)	1.53 (150, -450)	1.88 150, -450)
Pit 3[b]	.2250 (150, -450)	.1515 (150, -450)	.1414 (150, -450)	.1370 (150, -450)	.1730 (150, -450)
Pit 3	2.65 (150, -450)	1.81 (150, -450)	1.64 (150, -450)	1.64 (150, -450)	2.05 (150, -450)
Pit 5	1.12 (150, -450)	1.08 (950, 350)	1.02 (950, 350)	1.08 (950, 300)	.9899 (950, 350)
Pit 6	.1256 (150, -500)	.1254 (1150, 350)	.1193 1(1150, 350)	.1150 (1050, 350)	.1179 (1050, 350)
Burn Pit	.0218 (150, -450)	.0146 (150, -450)	.0133 (150, -450)	.0135 (150, -450)	.0167 (150, -450)
All Pits	5.10 (150, -450)	3.52 (150, -450)	3.19 (150, -450)	3.20 (150, -450)	3.94 (150, -450)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-14

MAXIMUM ANNUAL CONCENTRATIONS ($\mu g/m^3$) AT DISCRETE RECEPTOR LOCATIONS* FOR THE FUTURE AGRICULTURAL SCENARIO

	1987	1988	1989	1991	1992
Crosby Elementary	.0757	.0629	.0996	.0778	.0976
Morgan Elementary	.0336	.0303	.0365	.0354	.0454
Elda Elementary	.1043	.1421	.2035	.1474	.1440
St. John Elementary	.0407	.0537	.0811	.0702	.0710
Ross Middle High School	.0714	.0967	.1373	.1027	.1028
Ross Country Day Nursery	.0929	.1263	.1805	.1323	.1303

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-15

MAXIMUM ANNUAL ON-SITE DEPOSITION RATES (g/m^2) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE AGRICULTURAL SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.5488 (550, -400)	.7715 (550, -400)	.7955 (550, -400)	.6259 (550 -400)	.6410 (550, -400)
Pit 2	.2814 (650, -400)	.3909 (650, -400)	.4138 (650, -400)	.3095 (650, -400)	.3191 (650, -400)
Pit 3[a]	.8031 (500, -350)	1.14 (500, -350)	1.17 (500, -350)	.8983 (500, -350)	.9160 500, -350)
Pit 3[b]	.1927 (550, -350)	.2315 (600, -250)	.2329 (600, -350)	.1942 (550, -300)	.2027 (550, -350)
Pit 3	.9486 (550, -350)	1.26 (500, -350)	1.29 (550, -350)	1.01 (550, -350)	1.04 (550, -350)
Pit 5	.5756 (750, -200)	.8131 (750, -200)	.8564 (750, -200)	.6409 (650, -200)	.6531 (750, -200)
Pit 6	.3688 (800, -250)	.5197 (800, -250)	.5404 1(800, -250)	.4125 (800, -250)	.4191 (800, -250)
Burn Pit	.1065 (650, -300)	.1399 (650, -300)	.1449 (650, -300)	.1174 (650, -300)	.1189 (650, -300)
All Pits	1.58 (550, -350)	1.97 (550, -350)	1.98 (550, -350)	1.61 (550, -350)	1.72 (550, -350)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-16

MAXIMUM ANNUAL OFF-SITE DEPOSITION RATES (g/m²) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE AGRICULTURAL SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.0765 (200, -600)	.0499 (200, -600)	.0489 (200, -600)	.0417 (150 -450)	.0538 (200, -600)
Pit 2	.0321 (150, -550)	.0196 (200, -600)	.0196 (200, -600)	.0161 (150, -450)	.0212 (200, -600)
Pit 3[a]	.1506 (150, -450)	.1021 (150, -450)	.0911 (150, -450)	.0847 (150, -450)	.1108 150, -450)
Pit 3[b]	.0280 (150, -450)	.0180 (150, -450)	.0173 (150, -450)	.0142 (150, -450)	.0194 (150, -450)
Pit 3	.1786 (150, -450)	.1202 (150, -450)	.1084 (150, -450)	.0989 (150, -450)	.1302 (150, -450)
Pit 5	.0721 (150, -450)	.0712 (950, 350)	.0708 (1200, 350)	.0627 (900, 350)	.0627 (900, 350)
Pit 6	.0090 (150, -450)	.0096 (1150, 350)	.0092 1(1150, 350)	.0082 (1050, 350)	.0088 (1050, 350)
Burn Pit	.0031 (150, -500)	.0019 (150, -450)	.0018 (150, -450)	.0015 (150, -450)	.0021 (150, -350)
All Pits	.3626 (150, -450)	.2444 (150, -450)	.2219 (150, -450)	.2001 (150, -450)	.2627 (150, -450)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-17

MAXIMUM ANNUAL DEPOSITION RATES (g/m^2) AT DISCRETE RECEPTOR LOCATIONS* FOR THE FUTURE AGRICULTURAL SCENARIO

	1987	1988	1989	1991	1992
Crosby Elementary	.0089	.0221	.0097	.0333	.0224
Morgan Elementary	.0018	.0016	.0014	.0073	.0039
Elda Elementary	.0137	.0168	.0172	.0472	.0260
St. John Elementary	.0026	.0037	.0026	.0078	.0051
Ross Middle High School	.0083	.0102	.0099	.0268	.0161
Ross Country Day Nursery	.0119	.0146	.0147	.0404	.0229

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-18

MAXIMUM ANNUAL ON-SITE CONCENTRATIONS (g/m³) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE GOVERNMENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	1.80 (550, -400)	2.51 (550, -400)	.0489 (550, -400)	2.20 (550 -400)	2.20 (550, -400)
Pit 2	.8023 (650, -400)	1.11 (600, -350)	1.14 (650, -400)	1.00 (600, -350)	1.00 (600, -350)
Pit 3[a]	29.5 (500, -350)	40.9 (500, -350)	41.3 (500, -350)	34.8 (500, -350)	34.7 500, -350)
Pit 3[b]	3.30 (550, -350)	3.8 (550, -300)	3.90 (550, -300)	3.40 (550, -300)	3.50 (550, -300)
Pit 3	32.1 (500, -350)	43.1 (500, -350)	43.6 (500, -350)	37.0 (500, -350)	37.1 (500, -350)
Pit 5	23.6 (600, -200)	28.5 (750, -200)	29.5 (750, -200)	23.8 (750,-200)	24.0 (750, -200)
Pit 6	12.0 (800, -250)	16.4 (800, -250)	16.6 1(800, -250)	14.1 (800, -250)	14.1 (800, -250)
Burn Pit	1.22 (650, -300)	1.57 (650, -300)	1.60 (650, -300)	1.40 (650, -300)	1.40 (650, -300)
All Pits	37.6 (500, -350)	47.4 (500, -350)	47.9 (500, -350)	41.0 (500, -350)	41.9 (500, -350)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

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TABLE D.4-19

MAXIMUM ANNUAL OFF-SITE CONCENTRATIONS (g/m³) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE GOVERNMENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.1118 (200, -600)	.0778 (150, -450)	.0729 (200, -600)	.0722 (150 -450)	.0234 (200, -600)
Pit 2	.0434 (150, -550)	.0293 (150, -550)	.0269 (200, -600)	.0266 (150, -450)	.0333 (150, -550)
Pit 3[a]	2.42 (150, -450)	1.66 (150, -450)	1.53 (150, -500)	1.53 (150, -450)	1.88 150, -450)
Pit 3[b]	.2250 (150, -450)	.1515 (150, -450)	.1414 (150, -450)	.1370 (150, -450)	.1730 (150, -450)
Pit 3	2.65 (150, -450)	1.81 (150, -450)	1.64 (150, -450)	1.64 (150, -450)	2.05 (150, -450)
Pit 5	1.12 (150, -450)	1.08 (950, 350)	1.02 (950, 350)	1.08 (950, 300)	.9899 (950, 350)
Pit 6	.1256 (150, -500)	.1254 (1050, 350)	.1193 1(1150, 350)	.1150 (1050, 350)	.1179 (1050, 350)
Burn Pit	.0218 (150, -450)	.0146 (150, -450)	.0133 (150, -450)	.0135 (150, -450)	.0167 (150, -450)
All Pits	4.06 (150, -450)	2.77 (150, -450)	2.50 (150, -450)	2.50 (150, -450)	3013 (150, -450)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-20

MAXIMUM ANNUAL CONCENTRATIONS (μ/m^3) AT DISCRETE RECEPTOR LOCATIONS* FOR THE FUTURE GOVERNMENT SCENARIO

	1987	1988	1989	1991	1992
Crosby Elementary	.0599	.0498	.0541	.0674	.0846
Morgan Elementary	.0272	.0244	.0211	.0309	.0397
Elda Elementary	.0842	.1148	.1192	.1287	.1257
St. John Elementary	.0326	.0428	.0463	.0611	.0618
Ross Middle High School	.0576	.0779	.0799	.0896	.0897
Ross Country Day Nursery	.0750	.1019	.1054	.1154	.1137

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE D.4-21

MAXIMUM ANNUAL ON-SITE DEPOSITION RATES (g/m^2) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE GOVERNMENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.0893 (550, -400)	.1256 (550, -400)	.1295 (550, -400)	.1019 (550 -400)	.1043 (550, -400)
Pit 2	.0458 (650, -400)	.0636 (650, -400)	.0674 (650, -400)	.0504 (650, -400)	.0520 (650, -400)
Pit 3[a]	.8031 (500, -350)	1.14 (500, -350)	1.17 (500, -350)	.8983 (500, -350)	.9160 500, -350)
Pit 3[b]	.1927 (550, -350)	.2315 (600, -250)	.2329 (600, -350)	.1942 (550, -300)	.2027 (550, -350)
Pit 3	.9486 (550, -350)	1.26 (500, -350)	1.29 (550, -350)	1.01 (550, -350)	1.04 (550, -350)
Pit 5	.5756 (750, -200)	.8131 (750, -200)	.8564 (750, -200)	.6409 (650, -200)	.6531 (750, -200)
Pit 6	.3688 (800, -250)	.5197 (800, -250)	.5404 1(800,,-250)	.4125 (800, -250)	.4191 (800, -250)
Burn Pit	.1065 (650, -300)	.1399 (650, -300)	.1449 (650, -300)	.1174 (650, -300)	.1189 (650, -300)
All Pits	1.23 (500, -350)	1.48 (500, -350)	1.50 (500, -350)	1.21 (500, -350)	1.29 (500, -350)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-22

MAXIMUM ANNUAL OFF-SITE DEPOSITION RATES (g/m^2) AND RECEPTOR COORDINATES* (meters) FOR THE FUTURE GOVERNMENT SCENARIO

	1987	1988	1989	1991	1992
Pit 1	.0125 (200, -600)	.0081 (200, -600)	.0080 (200, -600)	.0068 (150 -450)	.0087 (200, -600)
Pit 2	.0052 (150, -550)	.0032 (200, -600)	.0032 (150, -550)	.0026 (150, -450)	.0036 (150, -550)
Pit 3[a]	.1506 (150, -450)	.1021 (150, -450)	.0911 (150, -450)	.0847 (150, -450)	.1108 150, -450)
Pit 3[b]	.0280 (150, -450)	.0180 (150, -450)	.0173 (150, -450)	.0142 (150, -450)	.0194 (150, -450)
Pit 3	.1786 (150, -450)	.1201 (150, -450)	.1084 (150, -450)	.0989 (150, -450)	.1302 (150, -450)
Pit 5	.0721 (150, -450)	.0712 (950, 350)	.0708 (1200, 350)	.0627 (900, 350)	.0675 (900, 350)
Pit 6	.0090 (150, -450)	.0096 (1150, 350)	.0092 1(1150, 350)	.0082 (1050, 350)	.0088 (1050, 350)
Burn Pit	.0031 (150, -500)	.0019 (150, -450)	.0018 (150, -450)	.0015 (150, -450)	.0021 (150, -450)
All Pits	.2790 (150, -450)	.1865 (150, -450)	.1703 (150, -450)	.1518 (150, -450)	.2021 (150, -450)

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).
[1] Portion of Pit 3 (30%) that has exposed pit material.
[2] Portion of Pit 3 (70%) that has 85% vegetative cover.

TABLE D.4-23

MAXIMUM ANNUAL DEPOSITION RATES (g/m^3) AT DISCRETE RECEPTOR LOCATIONS* FOR THE FUTURE GOVERNMENT SCENARIO

	1987	1988	1989	1991	1992
Crosby Elementary	.0069	.0177	.0076	.0266	.0179
Morgan Elementary	.0015	.0014	.0012	.0061	.0033
Elda Elementary	.0113	.0140	.0144	.0391	.0216
St. John Elementary	.0021	.0031	.0022	.0064	.0043
Ross Middle High School	.0069	.0085	.0083	.0223	.0134
Ross Country Day Nursery	.0098	.0121	.0123	.0335	.0190

* Based on origin at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

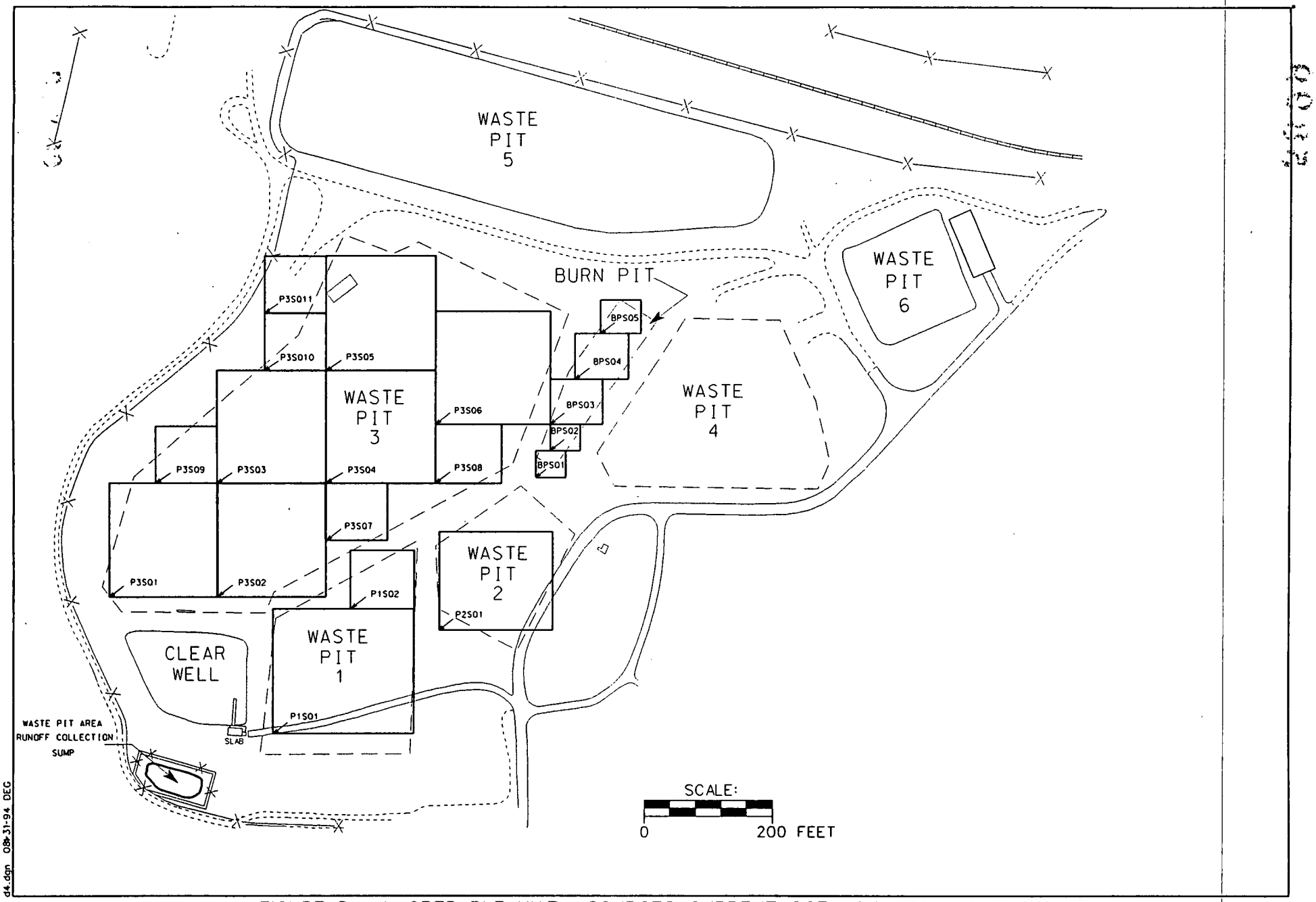
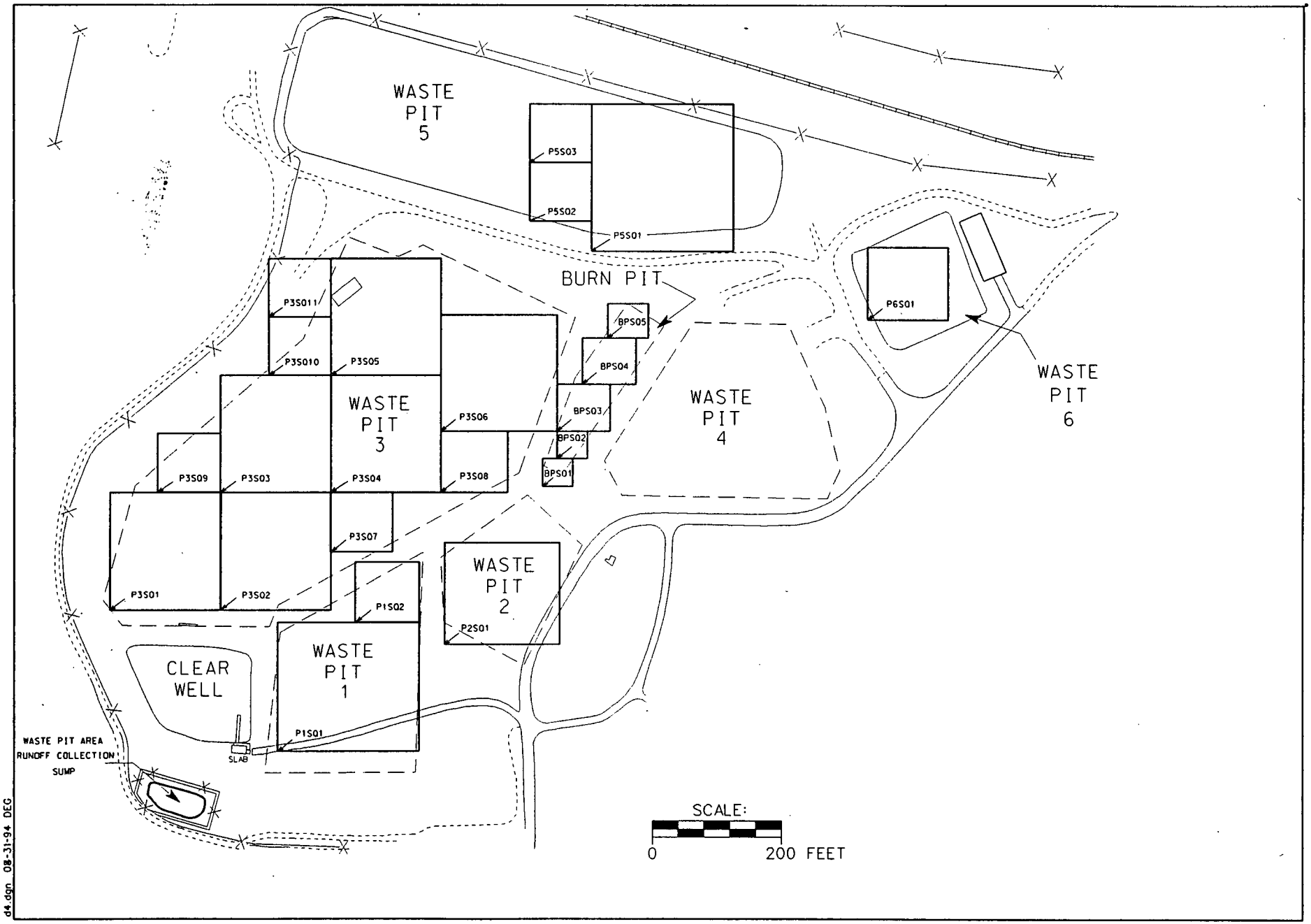
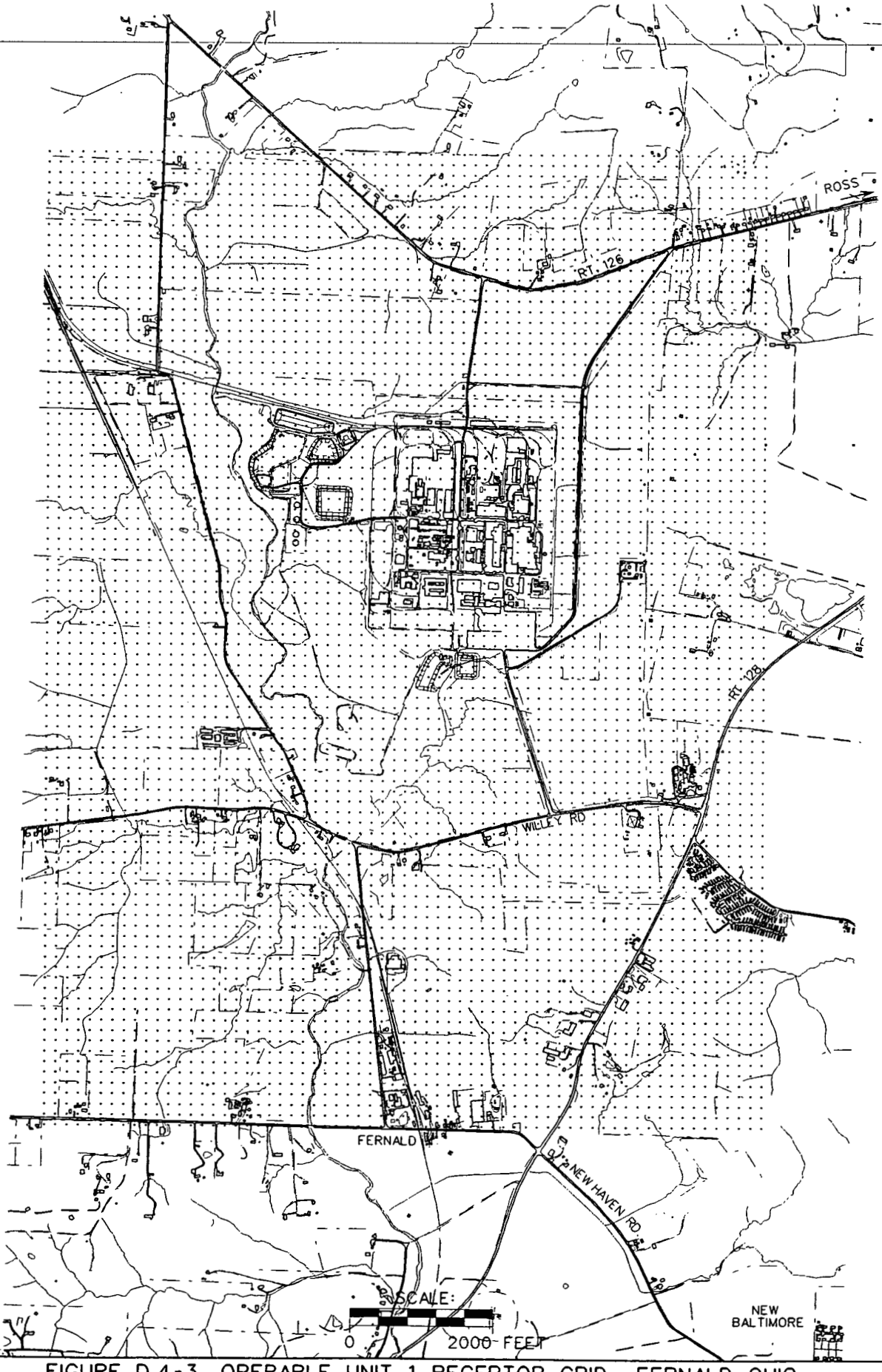


FIGURE D.4-1. OPERABLE UNIT 1 SOURCES CURRENT SCENARIO-FERNALD, OHIO



d4.dgn 08-31-94 DEG

FIGURE D.4-2. OPERABLE UNIT 1 SOURCES FUTURE SCENARIO-FERNALD, OHIO



figd4-3.out 08-31-94 DEG

FIGURE D.4-3. OPERABLE UNIT 1 RECEPTOR GRID FERNALD, OHIO

ATTACHMENT D.I

1987-1989, and 1992 Meteorological Statistical Array Data

used in the Air transport Analysis

for Operable Unit 1

Fernald Environmental Management Project

Fernald, Ohio

7 Meteorological Statistical Array Data for FEMP

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8 Meteorological Statistical Array Data from FEMP

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9 Meteorological Statistical Array Data for FEMP

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1 Meteorological Statistical Array Data for FEMP

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ATTACHMENT D.II

Sample Calculations for determining Emission Rates based on

Unlimited Erosion Potential,

Settling Velocity and Reflection Coefficient Calculations

Geotechnical Analysis of Surface Soils and Pit Material

used in the Air Transport Analysis for

Operable Unit 1

Fernald Environmental Management Project

Fernald, Ohio

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT FEMP OU-1	JOB NUMBER NGALIARN1
SUBJECT Emission rate calculations for OU-1 soil (SURFACE) cover Current Future scena	
BASED ON OU-2 Geotechnical Data	DRAWING NUMBER
BY Wagner / CHECKED BY Legu	APPROVED BY / DATE

Calculate emission rates based on current scenario. Since no surface soil geotechnical data exists relevant to the Waste Pits, assume similar soil characteristics to OU-2. Baseline Risk Assessment showed most surface soils within OU-2 subunits were between 12 μm diameters and 30 μm. This yields an average diameter of ≈20 μm. Furthermore, the TFV (Theshold Friction Velocity), which is dependent on soil diameter, remains relatively the same until soil diameters exceed 60 μm.

e.g.	Soil diameters (μm)		Threshold Friction Velocity (m/s)
when	12	yields	.10
	15		.11
	20		.12
	25		.14
	30		.15
	60		.18
	100		.25

From fig 3-4, EPA Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites

Use limited erosion potential equations to calculate emission rates assuming

(a) 85% vegetative cover
(b) 95% vegetative cover

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT FEMP OU-1		JOB NUMBER N6961ARN1	
SUBJECT Emission rate calculations			Current
BASED ON ~~85 Vegetative Cover~~		DRAWING NUMBER	
BY Wagner	CHECKED BY	APPROVED BY	DATE

$$E_{10} = 0.83 \frac{f\left(P(u^+)(1-V)\right)}{(PE/50)^2}$$

where

E_{10} = PM_{10} emission factor (mg/m²-hr)

V = Vegetative Cover

PE = Thornwaite's Precipitation Evaporation Index. From Fig 4-2

$P(u^+) = 6.7(u^+ - u_t)$ erosion potential

$P(u^+) = 6.7(u^+ - u_t)$ where u^+ = 24.0 m/s from Table 4-1

$= 6.7(24.0 - 0.12)$

$= 160\ g/m^2$

u_t = 0.12 m/s from Figure 3-4 using diameter of 20 μm.

f = # of disturbances per month.

when

V = 85% (0.85)
f = 1
$P(u^+)$ = 160 g/m²
PE = 103

then

$$E_{10} = 0.83 \frac{(1)(160)(1-.85)}{(103/50)^2}$$

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT		JOB NUMBER	
FEMP CU-1		NEGL 1ARN1	
SUBJECT Emission Rate Calculations			Current
BASED ON 85% Vegetative Cover		DRAWING NUMBER	
BY Wagner	CHECKED BY	APPROVED BY	DATE

$$E_{10} = 4.69 \text{ mg}_{PM_{10}}/m^2\text{-hr}$$

$$\left(4.69 \cancel{\text{mg}}_{PM_{10}}/m^2\text{-}\cancel{\text{hr}}\right)\left(\frac{1 \cancel{\text{hr}}}{3600 \text{ sec}}\right)\left(10^{-3} \text{g}/\cancel{\text{mg}}\right)$$

$$E_{10} = 1.3 \times 10^{-6} \text{ g}_{PM_{10}}/m^2\text{-s}$$

wind erosion emission rate based on PM_{10} fraction of soil

From previous CU-2 calculations Ratio of TSP particles to PM_{10} particles are Landfill 4.26 ; Inactive Flyash Pile 3.39 ; Southfield 2.42 ; Lime Sludge Ponds 11.49

These yield an average ratio of 5.39

multiply PM_{10} emission rate by 5.39 to calculate wind erosion emission rate based on TSP fraction of soil.

$$\left(5.39 \frac{\text{g}_{TSP}}{\text{g}_{PM_{10}}}\right)\left(1.3 \times 10^{-6} \text{ g}_{PM_{10}}/m^2\text{-s}\right)$$

$$E_{TSP} = 7.0 \times 10^{-6} \text{ g}_{TSP}/m^2\text{-s}$$

CLIENT	JOB NUMBER		
FEMP			
SUBJECT: Calculate emission rates from bare soil from Pits 1 & 2.			
BASED ON: Unlimited erosion potential		DRAWING NUMBER	
BY: Wagner	CHECKED BY:	APPROVED BY	DATE: 12/8/93

Future Agricultural Scenario

Use E_{10} that was calculated for Pit 3 material since modal diameters are the same (17 μm) for Pit material and surface soils.

$$E_{10} = 2.79 \times 10^{-5} \ g/m^2\text{-}s$$

Estimate #days where snowfall, rainfall and vegetative cover will effect emissions.

Assume months of Nov - April non-growing season

Half the year Pits 1 & 2 are covered with 100% vegetation, other six months soil is bare. Therefore 183 (365/2) days the soil has the potential for erodibility.

Subtract from 183 days, number of days when it snows greater than 1 inch. From HCD data this is 7 days.

$$183 - 7 = 176 \text{ days}$$

Subtract from 176 days, number of day with rainfall greater than 0.01 inches. This number is 72 days

$$176 - 72 = 104 \text{ days}$$

Divide 104 days by 183 to obtain percentage of days throughout the six month when the soil is void of vegetation, snowfall and not moist from rainfall

$$\frac{104}{183} = .57$$

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT		JOB NUMBER	
SUBJECT			
BASED ON		DRAWING NUMBER	
BY Wagner	CHECKED BY Leger	APPROVED BY	DATE 12/8/93

$$(2.79\times10^{-5}\ g/m^2\text{-}s)\ .57 = 1.59\times10^{-5}\ g/m^2\text{-}s$$

emission rate for Pits 1 & 2 for 6 months of the year when Pits are void of vegeta snowfall and rainfall.

The remaining 6 months the emission rate is zero. Therefore the total emission rate for the entire year is

$$(1.59\times10^{-5}\ g/m^2s)_{6\ months} + (0\ g/m^2\text{-}s)_{6\ months} =$$

$$= 1.59\times10^{-5}\ g/m^2\text{-}s$$

However, the average emission rate for the entire year is

$$\frac{1.59\times10^{-5}\ g/m^2\text{-}s}{2}$$

$$E_{10(CD)} = \underline{\underline{7.9\times10^{-6}\ g/m^2\text{-}s}}$$

This is the emission rate that the ISCLT model is going to assume will occur throughout the year, NOT 1.59×10^{-5} and 0 for six months.

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT		JOB NUMBER	
SUBJECT			
BASED ON		DRAWING NUMBER	
BY Wagner	CHECKED BY Lepu	APPROVED BY	DATE 12/8/93

Another way is assume that 104 days out of the year the soil is susceptible for emissions, Therefore

$$\frac{104 \text{ days}}{365 \text{ days}} = 0.28$$

$$= (0.28)\left(2.79 \times 10^{-5} \text{ g/m}^2\text{-s}\right)$$

$$E_{10_{(CD)}} = \underline{\underline{7.9 \times 10^{-6} \text{ g/m}^2\text{-s}}}$$

Assume a ratio of 5.39 to 1 of % PM_{10} to % TSP. See Emission Rate calculations using 85% Vegetative Cover for details

$$\left(5.39 \frac{\%\ TSP}{\%\ PM_{10}}\right)\left(7.9 \times 10^{-6} \text{ g/m}^2\text{-s}\right)_{PM_{10}}$$

$$E_{TSP_{(CD)}} \quad \underline{\underline{4.26 \times 10^{-5} \text{ g/m}^2\text{-s}}}$$

Jenny Vance
IT Corporation
February 4, 1992
Client Project ID: FERNALD OU1 ETDC Project No.: 484285

5899

IT ANALYTICAL SERVICES
304 DIRECTORS DRIVE
KNOXVILLE, TN

Pit 3 material

SAMPLE ANALYSIS RESULTS

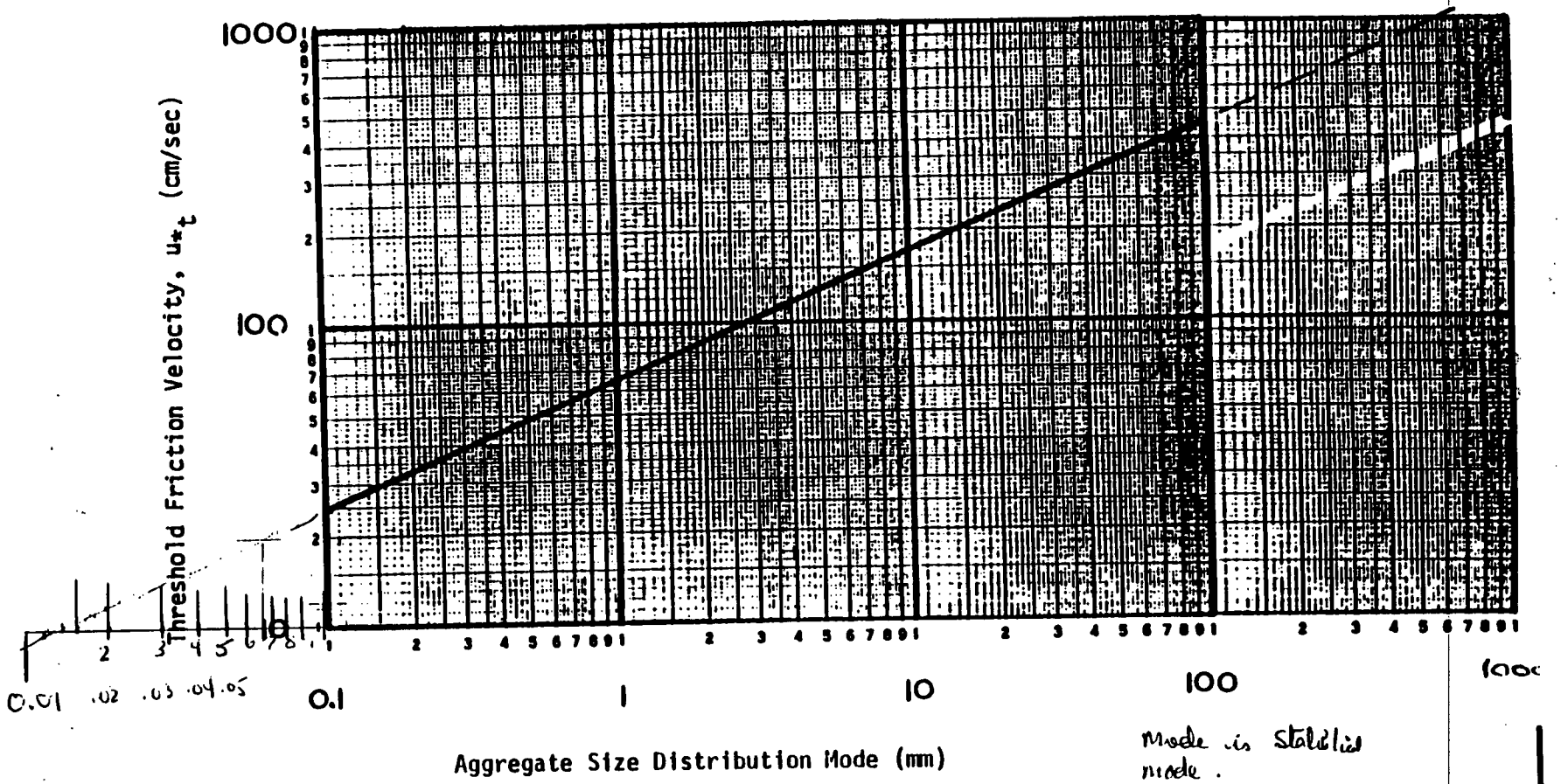
PROJECT NAME:	FERNALD OU1	USCS SYMBOL:	NONPLASTIC
PROJECT NO.:	484285	WATER CONTENT, %:	63.7
CUST. SAMPLE NO.:	63328	LIQUID LIMIT:	NONPLASTIC
ETDC SAMPLE NO.:	ETDC-1312	PLASTICITY INDEX:	NONPLASTIC
SPECIFIC GRAVITY:	2.1956 (MEASURED)	UNIT WEIGHT:	81.3 pcf

SIEVE ANALYSIS

SIEVE NO.	DIAMETER (mm)	PERCENT FINER (%)	
3.0 in	75.000	100.0	
1.5 in	37.500	100.0	
0.75 in	19.000	100.0	
0.375 in	9.500	100.0	.5
NO. 4	4.750	99.5	3.4
NO. 10	2.000	96.1	14.4
NO. 20	0.850	81.7	11.4
NO. 40	0.425	70.3	7.6
NO. 60	0.250	62.7	
NO. 140	0.106	48.1	
NO. 200	0.075	43.5	

HYDROMETER ANALYSIS

DIAMETER (mm)	PERCENT FINER (%)	
		4.1
0.0678	58.6	9.6
0.0501	49.0	5.4
0.0364	43.6	6.8
0.0237	36.8	10.9
0.0143	25.9	6.8
0.0104	19.1	5.5
0.0075	13.6	4.1
0.0053	9.5	
0.0038	9.5	
0.0015	6.8	



Mode is stabilized mode.

See pag 23 Table 3-3

Figure 3-4. Relationship of Threshold Friction Veloc
to Size Distribution Mode

002092

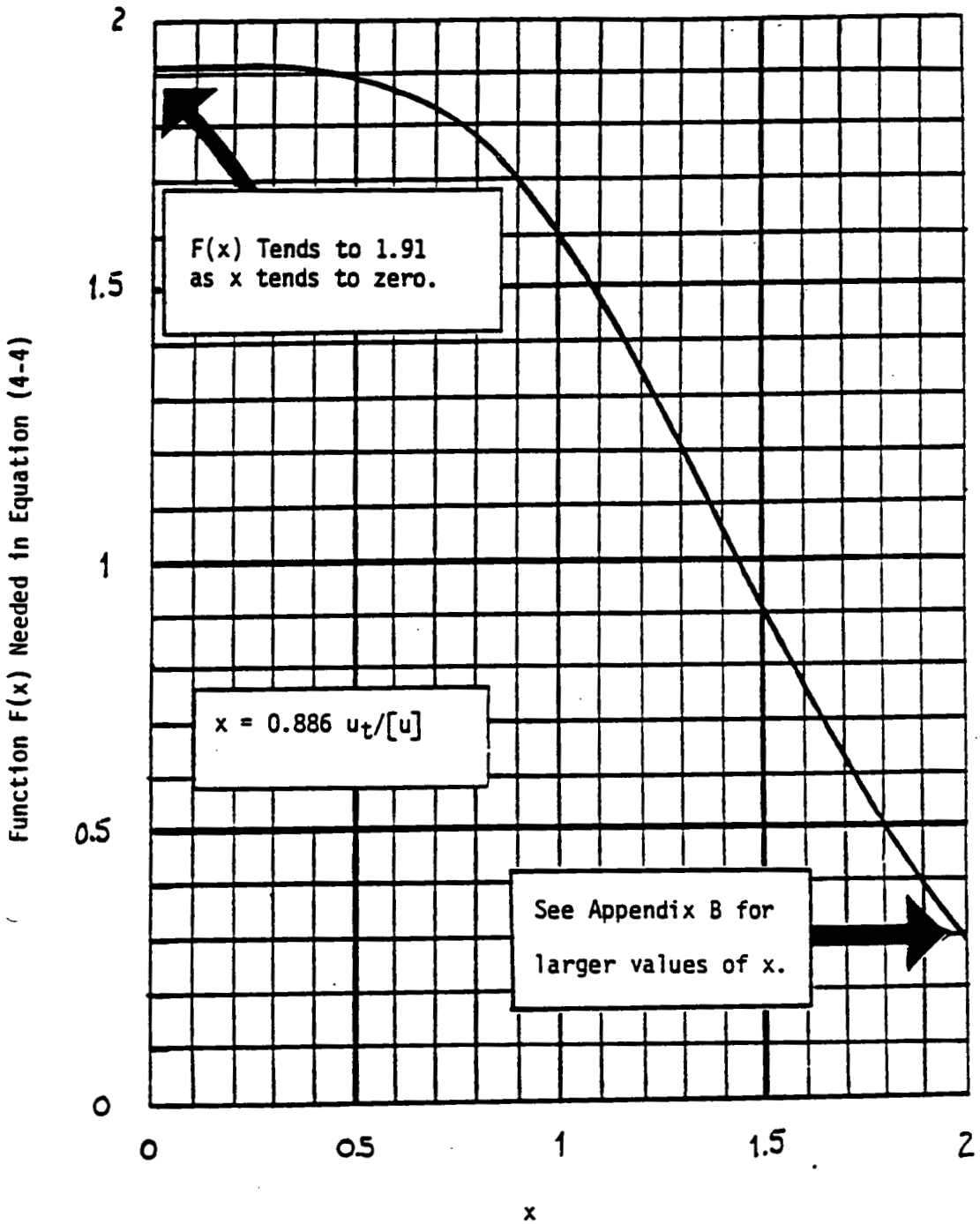


Figure 4-3. Graph of Function F(X) Needed to Estimate Unlimited Erosion

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT FEMP OU-1		JOB NUMBER NG96 1ARN1	
SUBJECT Emission Rates from Pit Material			
BASED ON Future Scenario		DRAWING NUMBER	
BY Wagner	CHECKED BY	APPROVED BY	DATE

Determine Emission Rate from Pit 3 material based on Pit 3 material soil data and "Unlimited Erosion Potential"

① Calculate Modal diameter of PM_{10} fraction of soil.

From Hydrometer Analysis of Pit 3 material majority of particles, less than 75 μm in diameter, have diameters between 10.4 μm and 23.7 μm. (See Attachment 1) Therefore, an average diameter within this range is 17.1 μm.

② Using Equation 4-4, Unlimited erosion potential from *EPA Publication 600/8-85/002, Calculate Emission rate based on PM_{10} fraction of soil.

$$E_{10} = 0.036\,(1-V)\left(\frac{[u]}{u_t}\right)^3 F(x)$$

where V = Vegetative cover = 0%
[u] = Mean annual wind speed = 2.28 m/s from 6 years of on-site data
u_t = TFV @ 7 meter height
F(x) = See Figure 4-3*
E_{10} = ($g_{PM_{10}}$ / m^2-hr) PM_{10} Emission rate

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT FEMP OU-1		JOB NUMBER NG96 1ARN1	
SUBJECT Emission Rate Calculations			
BASED ON Pit Material Geotechnical data		DRAWING NUMBER	
BY Wagner	CHECKED BY	APPROVED BY	DATE

Assume the future scenario all of Pit 3 material is exposed (i.e. no vegetative cover).

Because Figure 3-4 estimates TFV at ground level, this TFV must be adjusted to 7 meter height taking into account surface roughness.

$$u(7m) = \frac{u_*}{0.4} \ln\left(\frac{z}{z_0}\right)$$

where u_* = TFV (m/s) @ ground level from fig 3-4.
z = height above surface (cm)
z_0 = roughness height (cm)

u_* =	12 cm/s	.12 m/s
z =	7 meters	700 cm
z_0 =	1.0 cm	0.01 m

$$= \frac{.12\ m/s}{0.4} \ln\left(\frac{700\ cm}{1\ cm}\right)$$

$$= \underline{1.97\ m/s}$$

$$E_{10} = 0.036(1-0)\left(\frac{2.28\ m/s}{1.97\ m/s}\right)^3 1.8$$

$$= 0.10\ g/m^2\text{-}hr\left(\frac{1\ hr}{3600\ sec}\right)$$

$$E_{10} = \underline{2.79 \times 10^{-5}\ g/m^2\text{-}s}$$

wind erosion emissi rate based on PM fraction of soil.

000295

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT	JOB NUMBER
FEMP	

SUBJECT: Calculate emission rate for portion (30%) of Pit 3 that has fail

BASED ON: Non-Vegetative emission rate and precipitation control factors

BY	CHECKED BY	APPROVED BY	DATE
Wagner			12/8/93

Pit 3 - Future Agricultural Scenario

Assume 30 percent of Pit 3 has no vegetative cover for the entire year.

Emission Rate for non-vegetative pit material is:

$$E_{10} = 2.79 \times 10^{-5}\ g/m^2\text{-}s$$

From LCD data for CUG, shows 129 days out of 365 have precipitation $\geq$ 0.01 inches

$$365 - 129 = 236 \text{ days}$$

Out of 236 days, 7 have snowfall greater than 1 inch.

$$236 - 7 = 229 \text{ days}$$

$$\frac{229}{365} = 63\% \text{ of the year soil has the potential for erodibility.}$$

$$E_{10_{(CO)}} = \left(2.79 \times 10^{-5}\ g/m^2\text{-}s\right)(0.63)$$

$$= \underline{\underline{1.75 \times 10^{-5}\ g/m^2\text{-}s}}$$

000296

$$E_{TSP_{(CO)}} = 5.39\ \frac{\%\ TSP}{\%\ PM_{10}}\left(1.75 \times 10^{-5}\ g/m^2\text{-}s\right) = \underline{\underline{9.43 \times 10^{-5}\ g/m^2\text{-}s}}$$

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT FEMP OU-1		JOB NUMBER N696 1ARN1	
SUBJECT Settling Velocity, Reflection Coefficent Calculations			
BASED ON Surface Soil data OU-2		DRAWING NUMBER	
BY Wagner	CHECKED BY Leger	APPROVED BY	DATE

Specific Gravity calculated from OU-2 surface samples from specific subunits.

Solid Waste Landfill	2.65	average = 2.67
South Field	2.71	
Inactive Flyash Pile	2.65	
Lime Sludge Ponds	2.65	

Assume that specific gravity for OU-2 are the same for OU-1 surface soils.

Using equation 1-55 pg 1-35 USEPA Publication 450/4-92-008b "ISC User Guide Vol.2, calculate settling velocity

$$V_{sn} = \frac{2 \rho g r^2}{9 \mu}$$

where

ρ = particle density (specific gravity)

g = acceleration due to gravity

μ = absolute viscosity of air

r = particle radius

V_{sn} = Settling Velocity

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT FEMP OU-1	JOB NUMBER NGG61ARN1
SUBJECT Vsn, γ calculations	
BASED ON Sfc Soil OU-2	DRAWING NUMBER
BY Wagner / CHECKED BY Leger	APPROVED BY / DATE

$\rho = 2.67\ g/cm^3$

$g = 980\ cm/s^2$

$\mu = 1.83 \times 10^{-4}\ g/cm\text{-}s$

$r = 20\mu m/2 = 10\mu m$

$= 1.0 \times 10^{-3} cm$

$$(10\,\mu m)(10^{-6}\,m/\mu m)\left(\frac{cm}{10^{-2}\,m}\right) = 10.0 \times 10^{-4} cm$$

$$= 1.0 \times 10^{-3} cm$$

$$V_{sn} = \frac{2(2.67\ g/cm^3)(980\ cm/s^2)(1.0 \times 10^{-3} cm)^2}{9\,(1.83 \times 10^{-4}\ g/cm\text{-}s)}$$

[redacted] or 0.0323 m/s Vsn for OU-1 surface soils

From Figure 1-7 ISC User Guide Vol. 2, calculate Reflection Coefficent (γ) for OU-1 surface soils.

[redacted]

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT		JOB NUMBER	
SUBJECT Settling Velocity, Reflection Coefficent for Pit Material			
BASED ON		DRAWING NUMBER	
BY Woegner	CHECKED BY Leger	APPROVED BY	DATE

Calculate V_{sn} & γ for Pit material using modal diameter of 17 μm and particle density of 2.195 g/cm³. $r = 9.0 \times 10^{-4}$ cm

$$V_{sn} = \frac{2(2.20\ g/cm^3)(980\ cm/s^2)(9.0 \times 10^{-4}\ cm)^2}{9(1.83 \times 10^{-4}\ g/cm\text{-}s)}$$

$$= 2.12\ cm/s \text{ or } 0.0212\ m/s$$

Determine γ,

$\gamma = 0.71$, From Fig 1-7 ISC uses Guide Vol. 2

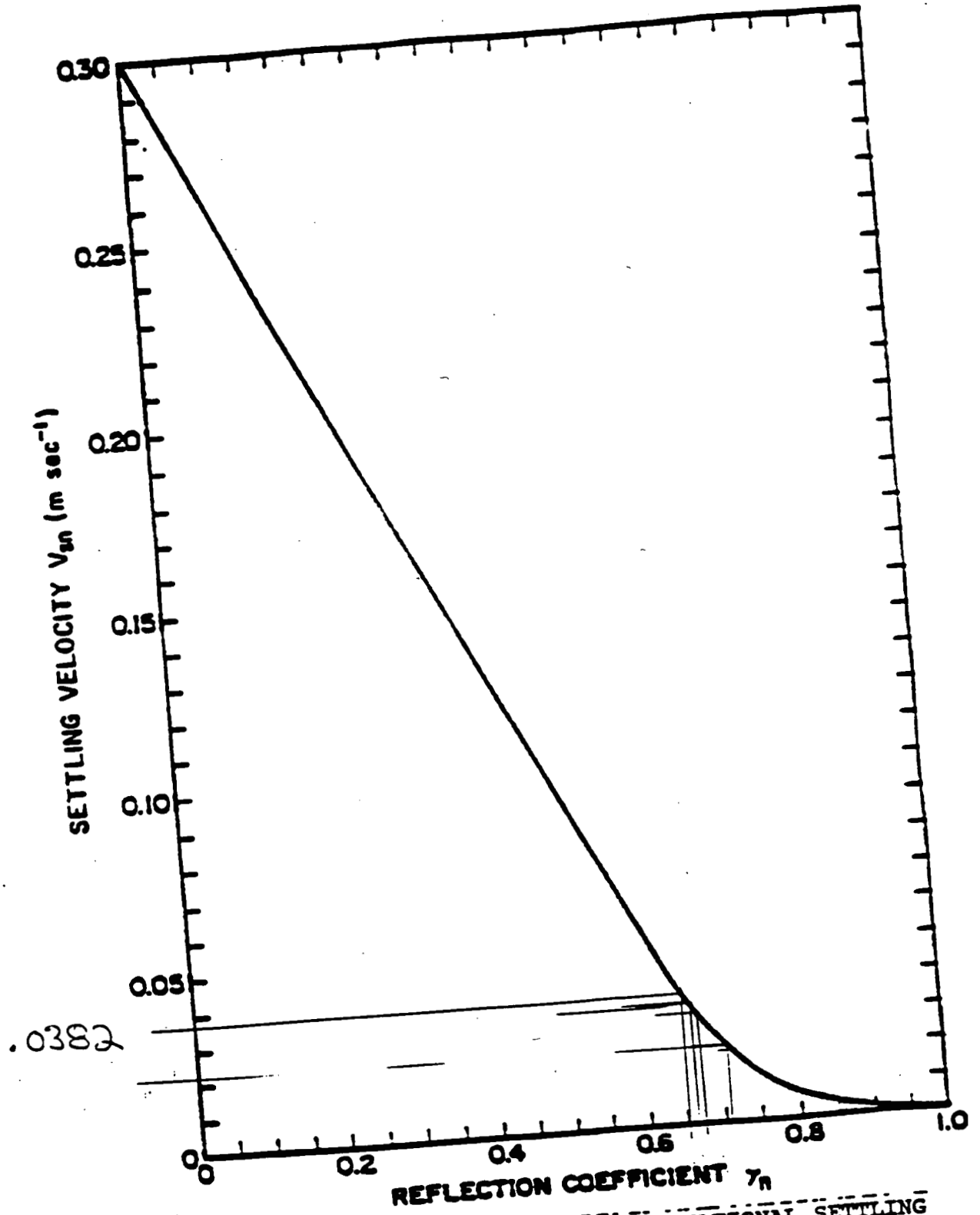


FIGURE 1-7. RELATIONSHIP BETWEEN THE GRAVITATIONAL SETTLING VELOCITY, V_{sn} AND THE REFLECTION COEFFICIENT, γ_N, SUGGESTED BY DUMBAULD, et al. (1976)

Vicki Graves
IT Corporation
May 19, 1993
Client Project ID: Fernald OU2
ETDC Project No.: 483500.075.01

IT ANALYTICAL SERVICES
KINGSTON, TN
(615) 482-6497

5899

PARTICLE SIZE ANALYSIS
ASTM D 422

[redacted]

Project Name: FERNALD OU2

Client Number: 111499

Project Number: 483500.075.01

ETDC Number: ETDC- 3473

Specific Gravity = 2.6500 Assumed

Moisture Content = 23.1%

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer	
	3"	75.000	100.0%	
	1.5"	37.500	100.0%	1.2
	0.75"	19.000	98.8%	1.5
	0.375"	9.500	97.3%	0.8
	#4	4.750	96.5%	2.7
	#10	2.000	93.8%	

FINE	Sieve No.	Diameter mm	Percent Finer	
	#20	0.850	88.9%	4.9
	#40	0.425	84.7%	4.2
	#60	0.250	80.9%	3.8
	#100	0.149	77.3%	3.6
	#140	0.106	75.5%	1.8
	#200	0.075	74.2%	1.3

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer	
	0.06782	73.4%	0.8
	0.04188	67.6%	5.8
	0.03014	64.7%	2.9
	0.02106	38.6%	26.1
	0.01288	21.2%	17.4
	0.00921	17.4%	3.8
	0.00650	13.5%	3.9
	0.00463	11.6%	1.9
	0.00328	10.6%	1.0
	0.00140	7.7%	2.9

Majority of particles <75, fall between 30μ-12μ. Mean Particle Diameter 21μm.

000301

%TSP ≤75μm = 74.2%

%PM10 ≤ 10μm = 17.4%

Vicki Graves
IT Corporation
June 28, 1993
Client Project ID: Fernald OU2
ETDC Project No.: 483500.075.02

IT ANALYTICAL SERVICES
KINGSTON, TN
(615) 482-6497

PARTICLE SIZE ANALYSIS
ASTM D 422

Phase II

[redacted]

Project Name:	FERNALD OU2	Client Number:	114493
Project Number:	483500.075.02	ETDC Number:	ETDC- 3559

Specific Gravity =	2.6500 Assumed

Moisture Content =	84.2%

SIEVE ANALYSIS

COARSE	Sieve No.	Diameter mm	Percent Finer
	3"	75.000	100.0%
	1.5"	37.500	100.0%
	0.75"	19.000	100.0%
	0.375"	9.500	100.0%
	#4	4.750	100.0%
	#10	2.000	100.0%

FINE	Sieve No.	Diameter mm	Percent Finer	
	#20	0.850	100.0%	.2
	#40	0.425	99.8%	.3
	#60	0.250	99.5%	.5
	#100	0.149	99.0%	.2
	#140	0.106	98.8%	.2
	#200	0.075	98.6%	

HYDROMETER ANALYSIS

HYDROMETER	Diameter mm	Percent Finer	
	0.05460	95.2%	3.4
	0.03956	89.8%	5.4
	0.02928	79.1%	10.7
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	5.4
	0.00956	3.2%	2.1
	0.00880	1.1%	
	0.00481	0.0%	
	0.00333	0.0%	
	0.00137	0.0%	

% TSP ≤ 75μ = .986
% ~ < 10μ = .032

000502

Vicki Graves
IT Corporation
May 19, 1993
Client Project ID: Fernald OU2
ETDC Project No.: 483500.075.01

5899

IT ANALYTICAL SERVICES
KINGSTON, TN
(615) 482-6497

PARTICLE SIZE ANALYSIS
ASTM D 422

~~Sample 3.1 0-2ft~~
SF boring 1965

Project Name:	FERNALD OU2	Client Number:	112735
Project Number:	483500.075.01	ETDC Number:	ETDC- 3481

Specific Gravity =	2.7064 Measured

Moisture Content =	11.3%

SIEVE ANALYSIS

	Sieve No.	Diameter mm	Percent Finer	
COARSE	3"	75.000	100.0%	
	1.5"	37.500	100.0%	
	0.75"	19.000	100.0%	
	0.375"	9.500	97.6%	2.4
	#4	4.750	93.2%	4.4
	#10	2.000	89.8%	3.4

	Sieve No.	Diameter mm	Percent Finer	
FINE	#20	0.850	86.0%	3.8
	#40	0.425	82.6%	3.4
	#60	0.250	79.8%	2.8
	#100	0.149	76.6%	3.2
	#140	0.106	73.9%	2.7
	#200	0.075	71.3%	2.6

HYDROMETER ANALYSIS

	Diameter mm	Percent Finer		Normalized Airborne	% of fraction of sample
HYDROMETER	0.05540	68.4%	2.9	95.8	4.8
	0.04017	63.5%	4.9	88.9	6.9
	0.02894	60.2%	3.3	84.3	4.6
	0.01924	50.3%	9.9	70.4	13.9
	[illegible]	30.5%	[illegible]	42.7	27.7
	0.00883	22.2%	8.3	31.1	11.6
	0.00627	18.1%	4.1	25.3	5.8
	0.00447	15.7%	2.4	22.0	3.3
	0.00316	13.2%	2.5	18.5	3.5
	0.00137	9.9%	3.3	13.9	4.6

000303

≤10μm 30.5 (PM_{10})
≤75μm 71.3 (TSP)

Vicki Graves
IT Corporation
May 19, 1993
Client Project ID: Fernald OU2
ETDC Project No.: 483500.075.01

IT ANALYTICAL SERVICES
KINGSTON, TN
(615) 482-6497

PARTICLE SIZE ANALYSIS
ASTM D 422

Surface Soil
TP-SS-05
0-6

Project Name:	FERNALD OU2	Client Number:	111826
Project Number:	483500.075.01	ETDC Number:	ETDC- 3476

Specific Gravity =	2.6500 Assumed	Moisture Content =	29.8%

SIEVE ANALYSIS

	Sieve No.	Diameter mm	Percent Finer	
COARSE	3"	75.000	100.0%	
	1.5"	37.500	100.0%	
	0.75"	19.000	100.0%	
	0.375"	9.500	94.8%	5.2
	#4	4.750	90.4%	4.4
	#10	2.000	83.8%	6.6

	Sieve No.	Diameter mm	Percent Finer	
FINE	#20	0.850	75.1%	8.5
	#40	0.425	67.0%	8.1
	#60	0.250	59.7%	7.3
	#100	0.149	53.2%	6.5
	#140	0.106	49.8%	3.4
	#200	0.075	47.2%	2.6

HYDROMETER ANALYSIS

	Diameter mm	Percent Finer	
HYDROMETER	0.06493	39.4%	8.8
	0.04631	38.8%	1.6
	0.03302	34.3%	2.5
	0.02169	25.3%	9.0
	0.01284	18.8%	6.5
	0.00921	14.7%	4.1 ← <10μ
	0.00648	12.3%	2.4
	0.00463	8.8%	3.5
	0.00327	7.4%	1.4
	0.00140	6.5%	0.9

% particles < 10μ = 14.7%
" < 75μ = ~~47.2%~~ 49.8

IT ANALYTICAL SERVICES
304 DIRECTORS DRIVE
KNOXVILLE, TN

Jenny Vance
IT Corporation
February 4, 1992
Client Project ID: FERNALD OU1 ETDC Project No.: 484285

OU-1 Pit 3 material

SAMPLE ANALYSIS RESULTS

PROJECT NAME:	FERNALD OU1	USCS SYMBOL:	NONPLASTIC
PROJECT NO.:	484285	WATER CONTENT, %:	63.7
CUST. SAMPLE NO.:	[redacted]	LIQUID LIMIT:	NONPLASTIC
ETDC SAMPLE NO.:	ETDC-1312	PLASTICITY INDEX:	NONPLASTIC
SPECIFIC GRAVITY:	2.1956 (MEASURED)	UNIT WEIGHT:	81.3 pcf

SIEVE ANALYSIS

SIEVE NO.	DIAMETER (mm)	PERCENT FINER (%)
3.0 in	75.000	100.0
1.5 in	37.500	100.0
0.75 in	19.000	100.0
0.375 in	9.500	100.0
NO. 4	4.750	99.5
NO. 10	2.000	96.1
NO. 20	0.850	81.7
NO. 40	0.425	70.3
NO. 60	0.250	62.7
NO. 140	0.106	48.1
NO. 200	0.075	43.5

HYDROMETER ANALYSIS

	DIAMETER (mm)	PERCENT FINER (%)	
			10%
73.04	0.0678	41.4 58.6	
	0.0501	51.0 49.0	19%
	0.0364	56.4 43.6	43.6%
	0.0237	36.8	
10.30	0.0143	25.9	1.7
	0.0104	19.1	9.1%
	0.0075	13.6	
1.10	0.0053	9.5	
	0.0038	9.5	19.5%
	0.0015	6.8	

000305 932

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E.1

E.1.0 INTRODUCTION

This appendix contains the Operable Unit 1 Baseline Risk Assessment, which was prepared to support the Operable Unit 1 Remedial Investigation (RI) report. Operable Unit 1 is defined as the waste pit area and includes Waste Pits 1 through 6, the Clearwell, Burn Pit, berms, liners, and soil within the operable unit boundary. The primary objective of this Baseline Risk Assessment is to evaluate and document the potential threats to human health and the environment that may be posed by current and predicted future exposures to contaminants within Operable Unit 1 if no remedial actions are taken beyond those already complete.

The specific objectives of this Baseline Risk Assessment are:

- Estimate the magnitude of potential health risks, as calculated using Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) methodology, associated with Operable Unit 1 if no remedial actions are taken.
- Identify the areas, environmental media, and contaminants that pose the primary health concerns.
- Identify the areas, environmental media, and contaminants that pose little or no threat to human health.
- Identify whether there are data gaps so additional information can be collected in subsequent phases of the Remedial Investigation/Feasibility Study (RI/FS) process to support cleanup decisions.
- Provide a basis for determining whether remediation is necessary at the site.
- Identify specific areas and environmental media for which cleanup is appropriate.
- Present a "baseline" of potential human health risks for the no-action alternative in the FS.
- Provide a basis for determining cleanup levels and criteria.

This Baseline Risk Assessment provides the framework for determining human health risks associated with Operable Unit 1, if no further remedial actions or institutional controls are applied. If risks are deemed unacceptable, the baseline risk assessment is used to develop information necessary to assist in evaluating remedial alternatives.

The following activities/analyses are performed in the Baseline Risk Assessment to develop this information:

- Identification of constituents of potential concern
- Identification of significant exposure pathways
- Quantification of significant exposures attributable to Operable Unit 1
- Estimation of health risks to potential on- and off-site receptors
- Characterization of sources and degrees of uncertainty in the risk analysis

The Operable Unit 1 RI addresses only the potential risks associated with the contaminant sources, or waste storage areas within the boundaries of Operable Unit 1. Baseline risks associated with contaminants currently found in the surrounding groundwater, surface water, and sediments will be addressed in the Operable Unit 5 RI/FS. Operable Units 2, 3, and 4 will also address the potential for constituent migration from these operable units and the potential impact on environmental media. Thus, while the Operable Unit 1 RI provides information on surrounding media, the baseline risk assessment addresses only the risks posed by contaminants in Operable Unit 1 in order to determine if remediation is required. With the use of fate and transport modeling, the risk assessment will address the potential for Operable Unit 1 to contribute to future contamination in the surrounding media.

The Site-Wide Characterization Report (DOE 1993c) contains detailed information concerning site ecological receptors and any potential impacts the site may have had on these resources. Therefore, risks to ecological resources and any associated impacts will not be addressed in this document. These concerns are within the scope of Operable Unit 5, as specified in the Risk Assessment Work Plan Addendum (DOE 1992a), and agreed to by EPA Region V BTAG in February 1993.

The organization of this Baseline Risk Assessment for Operable Unit 1 is consistent with the four primary steps of the risk assessment process, as described in U.S. Environmental Protection Agency (EPA) guidance. These steps include data compilation and analysis, exposure assessment, toxicity assessment, and risk characterization. The report is organized as follows:

- Section E.1.0 (Introduction) presents general information on the site background and the overall approach used in the Operable Unit 1 Baseline Risk Assessment.

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- Section E.2.0 (Identification of Constituents of Potential Concern) reviews the data collection effort and evaluates available data to identify contaminants of potential concern for the human health evaluation.

- Section E.3.0 (Human Exposure Assessment) describes the exposure setting, potential receptor populations, and relevant exposure pathways; estimates exposure point concentrations (based on the fate and transport assessment presented in Section 5.0 of the RI Report); and quantifies exposure for each receptor population.

- Section E.4.0 (Toxicity Assessment) provides human toxicity information for the contaminants detected at Operable Unit 1.

- Section E.5.0 (Health Risk Characterization) presents the methodology and results of the health risk assessment.

- Section E.6.0 (Uncertainties) summarizes the uncertainties associated with selection of constituents of potential concern, exposure and toxicity assessments, and risk characterization for the human health assessment.

- Section E.7.0 (Summary and Comparison to Background) provides a risk summary and a comparison of site risks to background risks due to the presence of inorganic and radiological constituents in native soils.

This appendix contains four attachments. Attachment E.I presents a summary of background concentrations of chemicals in various environmental media. Attachment E.II presents summary statistics for the different data sets used in preparing the Baseline Risk Assessment. Attachment E.III contains receptor-specific intakes for the constituents of potential concern. Attachment E.IV presents calculated chemical-specific risks for all receptor and exposure routes.

E.1.1 OVERVIEW

The Fernald Environmental Management Project (FEMP) is located on 425 hectares (1,050 acres) in Hamilton and Butler counties in southwestern Ohio. The Fernald site is approximately 29 kilometers (17 miles) northwest of downtown Cincinnati, Ohio, between the villages of Ross and Fernald (Figure E.1-1). The site became contaminated with radioactive and nonradioactive materials as a result of processing and disposal activities that took place during production at the facility. The U.S. Department of Energy (DOE) is responsible for cleanup under the Environmental Restoration and Waste Management Program. The major goals of this program are to eliminate potential hazards to human health and the environment.

The Fernald site is operated by the Fernald Environmental Restoration Management Corporation (FERMCO).

For completion of the RI/FS and implementation of the remedial actions, the site is divided into five study areas, or operable units, as shown in Figure E.1-2:

- **Operable Unit 1** - Waste Pit Area
- **Operable Unit 2** - Other Waste Units
- **Operable Unit 3** - Former production area
- **Operable Unit 4** - Silos 1 through 4
- **Operable Unit 5** - Environmental Media

Each operable unit is undergoing a separate RI/FS, which characterizes the nature and extent of contamination, evaluates potential risks to human health and the environment, and evaluates potential remedial alternatives for each unit. This Baseline Risk Assessment for Operable Unit 1 addresses potential human health impacts associated with the waste pit area under current and hypothetical future conditions in the absence of cleanup. The health risk assessment provides a technical basis for determining whether remedial action is warranted and provides a basis for evaluation for remedial alternatives in the event that site remediation is deemed necessary. Potential ecological impacts associated with Operable Unit 1 are addressed in the Site-Wide Characterization Report (DOE 1993c) and will be addressed in the Operable Unit 1 FS and the Operable Unit 5 RI.

E.1.1.1 Environmental Compliance Process

The assessment of baseline health risks and environmental impacts for a contaminated site is an important element of the RI/FS process. This process addresses the cleanup of hazardous waste sites under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Four primary evaluation documents constitute the RI/FS for Operable Unit 1:

- The RI, which presents site characterization results and addresses the nature and extent of contamination.
- This Baseline Risk Assessment, which uses information from the RI to estimate human health impacts that could occur if no cleanup actions are taken.

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- The FS, which develops and evaluates cleanup alternatives based on the results of the Baseline Risk Assessment and the various response actions that might be appropriate for the contaminated locations and media at the site.

- The proposed plan (PP), which summarizes the analysis of final alternatives from the FS and identifies the preferred remedial action alternative.

The decision-making process for the cleanup of Operable Unit 1 integrates the requirements of two major environmental laws. The first major law is CERCLA, which establishes the need for this baseline risk assessment and addresses the cleanup of contaminated sites. The second major law, the National Environmental Policy Act (NEPA), requires evaluating the impacts of major federal actions that may significantly affect the quality of human health and the environment. The results of a NEPA evaluation are presented as an Environmental Impact Statement (EIS) or an Environmental Assessment (EA). The documents developed for site cleanup under the RI/FS process of CERCLA are supplemented by an evaluation of NEPA values and therefore also meet the procedural and documentational requirements of NEPA.

The activities and environmental compliance documents for Operable Unit 1 are developed in coordination with EPA Region V and the State of Ohio. The documents are also made available to the public, and public involvement is an important factor in the decision-making process for site remediation. The primary evaluation documents of the RI/FS-NEPA document (i.e., the RI, Baseline Risk Assessment, FS, and PP) will be used to develop the record of decision (ROD) for cleanup of Operable Unit 1. Responses to public comments will be addressed in a responsiveness summary and incorporated into the ROD, which will be included in the Administrative Record with the final RI/FS-NEPA document package for this action. Following the ROD, remedial design and remedial action activities will be implemented at Operable Unit 1. Public involvement in the proposed action will continue during the post-ROD period.

Environmental compliance activities at the Fernald site are governed by several legal agreements in addition to regulatory requirements. The Ohio Environmental Protection Agency (OEPA) regulates most Resource Conservation and Recovery Act (RCRA) activities while EPA oversees CERCLA activities. Although many CERCLA and RCRA activities

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overlap in certain situations, there is no tri-party agreement between EPA, OEPA, and DOE that addresses overlapping issues.

E.1.1.2 General FEMP Description

The site is located on 425 hectares (1,050 acres) in Hamilton and Butler counties, approximately 17 miles northwest of downtown Cincinnati, Ohio (Figure E.1-1). The main physiographic features in the area are gently rolling uplands, steep hillsides along major streams, and the Great Miami River Valley. The site is generally open grassland, with wooded areas on the southern, western, and northern portions.

Located on relatively flat terrain, the site slopes gently from the northeast to the southwest. Drainage on the site is generally from east to west into Paddys Run Creek (Paddys Run), the primary surface drainage feature of the site. An intermittent tributary of the Great Miami River, Paddys Run flows from north to south near the western boundary of the site (Figure E.1-2). Paddys Run has historically received direct runoff from the western sections of the site, including the waste storage areas. A small tributary of Paddys Run, known as the storm sewer outfall ditch, is located to the south and east of the former production area.

Bounded on the west and south sides by roads, the perimeter of the irregularly-shaped site property is fenced, with the exception of two road entrance portals. A second inner fence line surrounds the former production area and waste disposal area (Figure E.1-2). The facility contains several large buildings and several waste ponds and storage silos. The structures contain stored materials and inactive process equipment. A railroad spur runs along the north side of the former production and waste disposal areas.

There are no residences within the Fernald site. Land use in the vicinity of the site is mainly agricultural, with dairy, beef, corn, and soy bean production. Several industries are located south of the facility. The Miami Whitewater Forest, a Hamilton County park, is located within five miles of the Fernald site. Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon are located near the site. There is an estimated population of more than 24,000 people within five miles of the site. The nearest residence is within three quarters of a mile (1,200 meters) of the center of the facility. The nearest residences to the western boundary are located along the western side of Paddys Run Road (Figure E.1-2). A dairy operation, Knollman Farm is located on Willey Road just

outside the southeast corner of the site's property boundary. Several businesses are located along Paddys Run Road, approximately one-half mile south of the property boundary. The nearest residence is located approximately one-quarter mile southwest along Willey Road. There are no schools, daycare centers, hospitals, or nursing homes within a one mile radius of the site. The Site-Wide Characterization Report (DOE 1993c) provides more detailed information on local populations, physical features of the area, and land uses surrounding the site.

From 1952 to 1989, the site operated with the primary mission of producing uranium metal products for use as feed materials in DOE and Department of Defense (DOD) programs. Production at the Fernald site peaked in 1960 at approximately 12,000 metric tons of uranium (mtu) per year. A product decline began in 1964, and reached a low in 1975 of about 1230 mtu. During the 1970s, DOE considered closing the Fernald site. However, production levels subsequently increased in the 1980s, and there was a rapid employment increase for several years. Implementation of a major facilities restoration program followed. Production ceased in July 1989; shutdown became permanent in June 1991 when the site mission changed from production to environmental restoration and waste management. The on-property worker population includes employees of DOE, FERMCO, and other contractors.

During its operating life, the site was called the Feed Materials Production Center (FMPC). When the site mission changed, the FMPC changed its name to the Fernald Environmental Management Project (FEMP). The site is referred to throughout this report as the FEMP even though most of the activities described herein took place during the site's production years.

The Fernald facility converted uranium ore concentrates and "recycle materials" into high-purity uranium metal with varying isotopic ratios. Some of this metal was cast into ingots and shipped to the DOE facility located at Reactive Metals, Incorporated (RMI), in Ashtabula, Ohio, for extrusion into bars. These extrusions were returned to Fernald for heat treating and fabrication into target element cores for DOE reactors. Section 1.0 of the RI report includes a more detailed description of the uranium production process at the FEMP facility.

A variety of chemical and metallurgical processes were utilized at the FEMP to manufacture uranium products. Eight separate operation plants associated with the production facility

generated a variety of radioactive and nonradioactive wastes. Large quantities of liquid and solid wastes were generated by the various operations. Before Spring 1984, solid and slurried wastes from these processes were disposed in the waste storage area. Between 1984 and 1987, liquids from the general sump were discharged to Waste Pit 5. This area includes six low-level radioactive waste storage pits, the Biodenitrification Surge Lagoon (BSL), the Clearwell, the Burn Pit, two earthen-berm concrete silos containing K-65 silo residues, one concrete silo containing waste residue, one empty silo, two lime sludge ponds, and a sanitary landfill. Portions of the waste storage area are included in Operable Unit 1, Operable Unit 2, and Operable Unit 4.

The major types of waste streams generated at the site include depleted magnesium fluoride slag, slag leach filter cake, neutralized raffinate, depleted sump cake, general sump sludge, and dust collector residues. Several radionuclides are known to have been present in feed materials processed, stored, or disposed at the FEMP. Uranium, composed of the isotopes U-238, U-234, and U-235, is the most abundant radioactive material within the stored waste. Small quantities of transuranics and fission products — including strontium-90 (Sr-90), cesium-137 (Cs-137), ruthenium-106 (Ru-106), and technetium-99 (Tc-99) — also may be contained in plant effluents and wastes as a consequence of handling some reprocessed metals. Other types of wastes sent to the waste pits include 1,1,1-trichloroethane, spent barium chloride salt, methylene chloride/perchloroethylene degreaser, polychlorinated biphenyl (PCB) waste, contaminated waste oil, caustic bases and acids, contaminated and uncontaminated scrap metal, construction debris, and rubble.

In addition to uranium foundry operations, the FEMP processed small amounts of thorium from 1954 to 1975. Since 1975, Fernald has received, assayed, and stored quantities of thorium-bearing materials for potential use in future DOE programs. The site maintains long-term storage facilities for a variety of thorium materials as part of its role as the thorium repository for DOE. Thorium is also found in the waste pits.

E.1.2 OPERABLE UNIT 1 BACKGROUND

The background information presented in the following sections provides a general overview of Operable Unit 1 and its existing contamination. More detailed information describing each of these topics is presented in the RI report.

E.1.2.1 Description of the Waste Pit Area

As shown in Figure E.1-2, the waste pit area is located in the northwest corner of the facility. The specific features of Operable Unit 1 are shown in Figure E.1-4. Waste Pits 1 through 6, located west of the former production area, contain a variety of liquid and solid wastes that were generated by eight separate operations plants at the site. Waste Pits 1 through 4 and the Burn Pit are covered with earth and Waste Pits 5 and 6 are covered with water. The Clearwell was a settling pond, and the Burn Pit contains residue from burned refuse. The following is a brief summary, based on process knowledge, describing each unit located within Operable Unit 1 and types of wastes received. Table E.1-1 provides a detailed listing of wastes disposed in Operable Unit 1. A more detailed description of each of the units in Operable Unit 1 is included in Sections 1.0 and 3.0 of the RI Report.

Waste Pit 1

This waste pit is a Solid Waste Management Unit (SWMU) used primarily for dry, solid wastes between 1952 and 1959. From 1958 to 1959 the waste pit was also used as a settling basin for effluent from Waste Pit 2. Waste material placed in this waste pit consisted primarily of neutralized slag leach filter cakes, depleted sump cakes, depleted MgF_2 slag, scrap graphite, contaminated brick, and sump liquor. The waste in Waste Pit 1 is approximately 18 feet deep.

Waste Pit 2

This unit is a SWMU that operated between 1957 and 1964, and was used primarily for disposing dry, solid wastes. This waste pit was constructed near a small pond east of Waste Pit 1 and was lined with a compacted clay layer. The waste pit received primarily dry, low-level radioactive wastes consisting of neutralized waste filter cakes, sump cakes, depleted MgF_2 slag, contaminated brick, sump liquor, and concentrated raffinate residues. Raffinate residues were placed in Waste Pit 2 between 1958 and 1959, during which time the waste pit functioned as a settling basin. Waste Pit 2 is 23.5 feet deep and contains approximately 24,200 cubic yards (yd^3) of waste. Waste Pit 2 was covered with fill and graded to direct surface drainage to the Clearwell for subsequent discharge to the Great Miami River.

Waste Pit 3

This waste pit also is a SWMU and was built for settling solids from wet waste streams. The waste pit, which operated between 1959 and 1977, was a large settling basin with a concrete

spillway that overflowed into the clay-lined Clearwell. This was the first "wet" waste pit built for settling solids from wet waste streams. The waste pit was used to dispose of slag leach residue, filter cakes, flyash, and lime sludges. The principal waste contained in Waste Pit 3 is lime-neutralized radioactive raffinate concentrate. Waste Pit 3 is approximately 42 feet deep and contains an estimated 204,000 yd^3 of waste.

Waste Pit 4

The unit served as a landfill from 1960 until 1986. Waste Pit 4 received process residues, filter cakes, slurries, raffinates, graphite, noncombustible trash, and asbestos. Waste Pit 4 is approximately 32 feet deep and contains an estimated 55,100 yd^3 of waste. The waste contained in Waste Pit 4 is classified as "mixed waste," containing both RCRA hazardous waste and radioactive waste. Waste Pit 4 has undergone an interim RCRA closure, certified by the OEPA. The final closure of Waste Pit 4 is deferred to the CERCLA program. Interim closure activities included covering the waste pit with fill material (soil and rocks), installing a 6-foot compacted clay cap and covering the waste pit with a polyethylene liner.

Waste Pit 5

Waste Pit 5 operated from 1968 to 1983, and is considered as a Hazardous Waste Management Unit (HWMU) under RCRA. The total waste volume of Waste Pit 5 is approximately 97,900 yd^3 and is approximately 29 feet deep. Until 1983, liquid waste slurries, including neutralized raffinate, neutralized slag leach residue, lime sludge, and sump sludge were pumped to Waste Pit 5 for solids to settle. Between 1983 and February 1987, Waste Pit 5 received only clear decant from the general sump, filtrate from Plant 8, or nonradioactive slurries that flowed across Waste Pit 5 to the Clearwell. Waste Pit 5 is water covered.

Waste Pit 6

Waste Pit 6 was constructed in 1979 and operated until 1985. The unit covers approximately 0.3 hectare (0.75 acre), with a maximum depth of 24 feet. The estimated total volume of waste in Waste Pit 6 is 9,600 yd^3. The surface of Waste Pit 6 is presently covered with up to two feet of water to reduce the release of fugitive emissions. Fine-grained solid waste — including green salt, filter cakes, and process residues containing elevated levels of uranium — have been placed in Waste Pit 6.

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Clearwell

The Clearwell, which was opened in 1959, was originally used as the final settling basin for the wet chemical waste pits (Waste Pits 3 and 5). The Clearwell now receives only storm water runoff from most of the surfaces of Waste Pits 1, 2, and 3 and from the entire surface of Waste Pit 5. The Clearwell is lined with clay and has a surface area of approximately 2,737 square meters (29,461 square feet) and contains approximately 3,700 yd^3 of waste. Storm water from the waste pit area is now collected and pumped to the BSL as discussed in Section 1.5.4.2 of the RI Report.

Burn Pit

This is another SWMU that was used to dispose of combustible items. The Burn Pit was constructed when clay was excavated from it to line Waste Pits 1 and 2. Beginning in 1957, the Burn Pit was used to dispose of laboratory chemicals and to burn materials, such as uranium metal scraps, pyrophoric and reactive chemicals, oils, and other low-level contaminated materials. Other wastes burned in the waste pit include boxes and wooden pallets, noncombustible items such as laboratory glassware, miscellaneous metal containers (other than drums), and graphite crucibles. The Burn Pit was taken out of service in 1969 and covered with clay. The Burn Pit had an approximate surface area of 2,019 square meters (21,732 square feet) and contains approximately 30,300 yd^3 of waste. Although the Burn Pit is located between Waste Pits 3 and 4, the boundaries are no longer discernible.

E.1.2.2 Operable Unit 1 Response Actions

A Baseline Risk Assessment is prepared to address a contaminated site as it exists and should reflect conditions resulting from completed interim actions. The Baseline Risk Assessment does not, however, reflect conditions expected to result from planned actions or actions that have not been fully implemented. Potential health risks associated with future remedial actions at the FEMP will be addressed as part of the remedial alternatives evaluation in the FS of each operable unit. Therefore, the Baseline Risk Assessment for Operable Unit 1 reflects conditions resulting from interim actions that have been completed as of June 1993, but not conditions that will result from planned or ongoing removal or interim actions.

Removal actions are intended to control or eliminate a release or threat of release of hazardous constituents before a final remedial action if there is a threat to public health and

welfare or the environment. At the time this risk assessment was conducted, five removal actions had been completed within Operable Unit 1:

Removal Action No. 2, Operable Unit 1 Study Area Runoff Control

This removal action, completed in July 1992, involved control of radioactively contaminated storm water runoff from Operable Unit 1 as discussed in Section 1.5.4.2 of the RI. Waste storage units within Operable Unit 1 that were included in this removal action were Waste Pits 1 through 6, the Burn Pit, and the Clearwell.

Removal Action No. 6, Control of Exposed Material in Waste Pit 6

This removal action, completed in December 1990, involved redistributing the exposed material so all solids were below the water cover level in Waste Pit 6. This removal action reduced particulate emissions to the environment.

Removal Action No. 11, Waste Pit 5 Experimental Treatment Facility

This removal action involved the dismantling of the Experimental Treatment Facility, removing surrounding soils to prevent any potential spread of contamination beyond the immediate area, and packaging the waste materials generated during this removal action for storage pending final disposition. This action was completed in March 1992.

Removal Action No. 18, Control of Exposed Material in Waste Pit 5

This removal action, completed in December 1992, involved dredging the exposed material below the waterline. The completion of this removal action reduces the threat of airborne particulate radioactive emissions from the exposed material in Waste Pit 5.

Removal Action No. 22, Study Area Contaminant Improvement

This removal action was performed to minimize the potential for wind and water erosion of contaminated materials from access roads and exposed surfaces in Operable Unit 1. This removal action was completed June 30, 1993.

In addition to these removal actions, Waste Pit 4 has undergone interim RCRA closure, certified by the OEPA. Final closure has been deferred to the CERCLA program. Closure conditions are reflected in the Baseline Risk Assessment for Operable Unit 1.

E.1.2.3 Data Sets used in the Operable Unit 1 Baseline Risk Assessment

Contamination within Operable Unit 1 was evaluated using the results from three sampling and analytical efforts. Each effort was conducted by a different sampling group, but many of the sampling and analysis techniques employed were similar. A detailed discussion of sampling events is provided in Section 2.0 of the RI.

E.1.2.3.1 Weston Characterization Investigation Study (CIS)

Roy F. Weston performed a CIS of the FEMP waste storage areas in 1986 and 1987. The waste storage areas include what is now identified as the Operable Unit 1 Study Area. The findings of the CIS were published in three volumes. A geophysical survey, as documented in "Volume 1: Geophysical Survey", was conducted to provide information on waste concentrations and shallow stratigraphy as well as to locate buried steel drums and tanks. Magnetic and electromagnetic terrain conductivity and ground penetrating radar surveys were performed in the waste storage areas including Waste Pits 1, 2, 3, and 4, and the Burn Pit. "Volume 2: Chemical and Radiological Analyses of the Waste Storage Pits" reports the findings of analyses performed on waste pit media, as well as liquid and sediment from those waste pits with standing liquid caps. Chemical analyses performed included RCRA characteristics, EPA HSL inorganics, HSL organics with a library search for non-HSL constituents, indicators, and ions. The scope of radiological testing provided for on-site gamma spectroscopy analysis. Selected samples were then sent off site for radiochemical analysis for uranium, thorium, and several other radionuclides. "Volume 3: Radiological Survey of Surface Soils" describes the radiological characterization of the surface soils throughout the waste storage area and associated drainage routes. Initially, a grid based on 50-foot spacing was set up throughout the study area. Surface soils were systematically surveyed with a Field Instrument for Detecting Low-Energy Radiation (FIDLER) and verified with a Geiger Mueller (GM) detector. A finer grid based on 6.5-foot spacing was used over areas with elevated readings. Soil samples collected down to 18 inches below ground, detected with U-238 activity concentrations greater than 35 pCi/g, were analyzed on site by gamma spectroscopy for various radionuclides. Of the samples analyzed on site, those with the highest activity concentrations were then analyzed off site for uranium, thorium, and other radionuclides. An extensive description of this study is presented in Section 2.0 of the RI.

E.1.2.3.2 RI/FS

Extensive sampling was performed in support of Operable Unit 1 RI/FS efforts. The objectives of the sampling program included: (1) characterize the nature and extent of contamination; (2) determine the associated risk to human health and the environment; and (3) evaluate potential remedial options. During sampling activities from 1987 to 1993, the following media were sampled: waste pit materials and associated leachates from the clay capped waste pits — Waste Pits 1, 2, 3, and 4, and the Burn Pit; surface soils; subsurface soils; surface water and sediment; perched groundwater; and groundwater from the upper, middle, and lower Great Miami Aquifer. All media except the ecological media samples had at least three samples analyzed for full HSL parameters and various radiological parameters. Testing of ecological samples of benthic microinvertebrates, vegetation, and fauna included HSL inorganics and organics but not pesticides and PCBs. Waste pit media and leachate were also tested for dioxins and furans, 40 CFR 264 Appendix IX parameters, and general chemistry parameters. Additionally, water quality parameter analyses were applied to liquid samples from waste pit media leachate, surface water, and groundwater. Geotechnical testing was performed on waste pit media and sediment. This sampling effort is fully described in Section 2.0 of the Operable Unit 1 RI report.

E.1.2.3.3 RI/FS 1992 Sampling Investigation of Waste Pits 5 and 6, and the Clearwell

In a separate sampling event under the RI/FS program, leachate and sediment from the three water-covered pits — Waste Pits 5 and 6, and the Clearwell — were sampled (see Section 2.3.2 of this remedial investigation for a detailed description of RI/FS sampling). These data were originally intended for use for treatability purposes but were also needed to supplement CIS characterization data to establish the source term for each of the waste pits for fate and transport modeling. Samples were obtained with a crane equipped with a clamshell bucket. After excess liquid was decanted from the sediment, the leachate and sediment samples were shipped for analytical testing for those parameters listed in 40 CFR 261 Appendix VIII and 40 CFR 264 Appendix IX.

E.1.2.4 Nature and Extent of Operable Unit 1 Contamination

Environmental media — including waste material, leachate, waste pit water, surface soil, surface water and sediment, subsurface soil, perched groundwater, and biological resources — at the FEMP have been sampled to determine the nature and extent of contamination at

Operable Unit 1. This section is a summary of the results of these analyses. A more detailed summary can be found in Section 4.0 of the RI.

E.1.2.4.1 Waste Pits

Both radiological and chemical testing were performed on material taken from the Operable Unit 1 waste pits. The principle radiological contaminants in waste pit materials were determined to be uranium, thorium, and radium isotopes. Other radionuclides, such as Tc-99, Sr-90, plutonium isotopes, and neptunium (Np-237), were found in trace amounts. Waste pit materials consistently exceeded background levels by one to six orders of magnitude although the variations do not follow any discernable patterns. Results were not only heterogenous from waste pit to waste pit and from boring to boring within each waste pit, but also between samples taken from different depths of the same boring. In general, Waste Pits 2 and 4 had noticeably higher levels of radiological contamination than the other waste pits, while the Burn Pit contained the least amount of radiological contaminants.

With respect to chemical constituents within waste pit materials, all borehole samples fell within established limits for RCRA characteristics of corrosivity, reactivity, ignitability, and EP Toxicity. Several Hazardous Substances List (HSL) inorganic analytes existing in the waste materials exceeded background levels by more than one order of magnitude. The principal constituents include arsenic, barium, beryllium, boron, cadmium, chromium, copper, cyanide, lead, manganese, mercury, molybdenum, nickel, selenium, sodium, and vanadium. Again, distribution trends of these constituents are not discernible.

Leachate samples collected from Waste Pits 4, 5, and 6 and the Clearwell contained uranium and technetium as the principal radionuclides. HSL inorganic results generally reported the presence of the same constituents as reported in the surrounding waste material in each waste pit.

Surface liquids from Waste Pits 4, 5, and 6 and the Clearwell, with standing liquid covers, were also analyzed. Note that Waste Pit 4 was capped after the Characterization Investigation Study (CIS) sampling, but prior to RI/FS sampling efforts. As with the leachates, the principal radionuclides in surface liquids were found to be uranium and technetium. Cyanide, vanadium, and zinc were principle inorganics detected in surface liquids. A few organic compounds were detected in minor concentrations.

E.1.2.4.2 Surface Soils

The results of surface soil radiological analyses indicate that uranium was the predominant radionuclide contaminant in the surface soils of Operable Unit 1. Although U-238 occurred above background concentrations at all sampled locations, no discernable trend was present. Radium-226 and Thorium-232 were also detected above background concentrations in a comparatively limited number of samples, principally in samples taken east of Waste Pits 1, 2, 4, and 5.

Predominant inorganic compounds detected in surface soil chemical analyses were analytes antimony, barium, chromium, lead, manganese, nickel, silver, vanadium, and zinc. Although volatile and semivolatile organic analyses were not performed on surface soils, analyses for pesticides and PCBs did occur. While no pesticides were detected, a limited number of samples contained Aroclor-1254.

E.1.2.4.3 Subsurface Soils

The subsurface soils surrounding each waste pit were assessed for radiological constituents. Subsurface soils were collected from the glacial overburden, the upper saturated sand and gravel, the lower saturated sand and gravel, and the deep sand and gravel aquifers. The principal radiological constituents in the subsurface soils were identified as isotopic radium, thorium, and uranium. Peak isotopic levels ranged from one to three orders of magnitude greater than background levels with the highest concentrations found in the shallow glacial overburden from zero to three feet in depth. The highest shallow soil concentrations of U-238 were detected in the following areas: between the southern portions of the Burn Pit and Waste Pit 4; north of the Burn Pit, south of Waste Pit 5; east of Waste Pit 4, south of Waste Pit 6, and in the western portions of Waste Pit 5. Two areas with notable concentrations greater than three feet in depth are the area between the Burn Pit and Waste Pit 5 at approximately 35 feet below grade and between the southern portions of the Clearwell and Waste Pit 1 at a depth of 15 feet.

E.1.2.4.4 Groundwater

All of the 1000-series wells, which are relatively shallow and monitor perched groundwater in the glacial overburden, had detectable levels of uranium isotopes exceeding background activity levels. Notable observations occurred in Well 1021 on the south margin of Waste Pit 4 and in those wells on the northern margin of Waste Pit 4 and northwestern margin of Waste

Pit 6. A pattern of elevated detections of U-238 in Operable Unit 1 perched groundwater 899 appears to be centered in the vicinity of the Burn Pit and surrounding most of Waste Pit 4. Thorium and radium isotope activity levels displayed a similar distribution to that of uranium, but were found in lower concentrations. Organic contamination in the 1000-series wells was limited. Well 1031, located east of the Clearwell, showed significant contamination with organic constituents including trichloroethane at 540 μg/L and tetrachloroethane at 290 μg/L.

The 2000-series wells monitor the upper portion of the Great Greater Miami Aquifer. The majority of the radiological contamination, primarily uranium isotopes, present in the 2000-series wells appears to be localized in the east and northeast portion of Operable Unit 1 in the vicinity of Waste Pits 4, 5, and 6, and the Burn Pit. Groundwater at this depth flows west to east, and the wells located west of the four source areas previously mentioned contained significantly lower levels of radionuclides.

Thirteen inorganic constituents were detected in 2000-series well samples. These analytes include aluminum, arsenic, cadmium, chromium, copper, magnesium, manganese, molybdenum, nickel, silver, vanadium, and zinc. Wells 2019, 2027 and 2084, located in the northeast section of Operable Unit 1, consistently showed elevated levels of these constituents. A limited number of organic constituents was detected in the 2000-series wells.

The 3000-series wells monitor a deeper region of the Great Miami Aquifer. Elevated uranium concentrations were detected in every 3000-series well except one, which is located up-gradient to the waste pits. These wells also had 11 inorganic constituents detected above background concentrations and limited detection of organic compounds.

E.1.2.4.5 Surface Water and Sediment

Surface water sampling at 12 locations along drainage pathways indicates that radionuclides are present in the storm water runoff from the Operable Unit 1 Study Area. Likewise, sediment samples revealed widespread uranium contamination in most of the drainage pathways within Operable Unit 1.

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E.1.3 RISK ASSESSMENT GUIDANCE

E.1.3.1 Applicable Guidance

To the extent possible, this assessment follows guidance available from EPA as of July 1993. In accordance with the Amended Consent Agreement between EPA and DOE (1991), a methodology was prepared for performing risk assessments at Fernald. This methodology, presented in the Risk Assessment Work Plan Addendum (DOE 1992a), was prepared to establish specific risk assessment methodology to be followed in all RI/FS risk assessments for the FEMP. The Risk Assessment Work Plan Addendum is based primarily on the following EPA guidance and databases:

- Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Volume I, Part A, Interim Final (EPA 1989a)
- Exposure Factors Handbook (EPA 1990d)
- Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Volume I, Supplemental Guidance, Standard Default Exposure Factors, Interim Final (EPA 1991a)
- Integrated Risk Information System (IRIS) (EPA 1993a), an on-line database of toxicological information
- Health Effects Assessment Summary Tables (HEAST) (EPA 1993g)

Additional EPA guidance, including supplements to the previously mentioned documents, was used and cited where appropriate.

E.1.3.2 Modifications and Enhancements To Risk Assessment Work Plan

The Baseline Risk Assessment is performed in accordance with the Risk Assessment Work Plan Addendum (DOE 1992a) with the following exceptions:

- Constituent concentrations based on measurement data from small sample populations (less than seven samples) are calculated from the arithmetic mean for the log transformed data.

  Justification: The type of distribution cannot be confidently determined for data sets with small sample sizes. Normality is assumed for small sample sizes as default because EPA Region V has specifically requested this treatment (EPA 1992c).

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- Target organ effects were not determined when evaluating exposure to systemic toxicants.

  Justification: Target organ effects and mode of action were not considered separately for systemic toxicants because in the current source term, hazard indices (HI) were low (typically less than 1) with the exception of the off-property user of meat and milk (HI=11). However, for this receptor, the hazard index was composed of 3 toxicants (silver, zinc, and antimony) all of which had a hazard quotient exceeding 1. For the future source term, all receptor had a hazard index exceeding 1 with the exception of the Great Miami River user. The hazard indices for these receptors were also primarily the result of a few toxicants all with individual hazard quotients exceeding 1. Therefore, the concern for consideration of target organ effects and mode of action are not of concern for evaluation of potential systemic toxicity.

- Risk from household use of perched water was evaluated for the on-property RME adult farmer, but perched water was not considered as a possible source for irrigation or livestock consumption. Risks from ingestion of perched groundwater were calculated; however, they were not summed in the totals for the on-property RME resident adult farmer and child.

  Justification: Cancer risks and hazard indices were calculated for ingestion of perched groundwater for consideration even though this aquifer would not provide sufficient yield for a potable water source. Therefore, totals for cancer risks and hazard indices for these receptors were based on the Great Miami Aquifer as the probable potable water source.

- Slope factors for radionuclides are taken from HEAST, Annual Fiscal Year 1993 (EPA 1993g).

  Justification: Radionuclides are not included in the IRIS database (EPA 1993a), so the Operable Unit 1 Baseline Risk Assessment uses the most up-to-date HEAST available (EPA 1993g) at the time that the quantitative assessment was performed.

- Risks to off-property receptors for future exposure scenarios also are presented.

  Justification: Off-property residents may be exposed to the site-related contaminants via air and water transport from the site. The Baseline Risk Assessment for this exposure scenario was specifically requested by EPA in the comment resolution for the Site-Wide Characterization Report.

- In response to EPA guidance on Baseline Risk Assessments issued in February 1992 by Deputy Administrator F. H. Habicht (EPA 1992d), an attempt was made to calculate descriptions of individual risk to include the "central tendency" of the risk distribution for a future resident. This

average exposure scenario is known as the central tendency (CT) scenario throughout this report.

Justification: Specific guidance on the implementation and use of the CT scenario is not yet available from EPA's Office of Emergency and Remedial Response, so interim guidance from EPA Region V has been used in constructing this scenario and in presenting the risks to a hypothetical receptor resulting from the calculated average exposures.

- The methods used to calculate exposures from direct exposures to radiation, dermal contact, and inhalation while showering have been changed to reflect EPA guidance that became available after the Risk Assessment Work Plan Addendum was published. These are presented in more detail in the section on the exposure assessment (Section E.3.0).

  Justification: DOE and EPA have agreed that the Baseline Risk Assessment will use the most recently recommended and approved methods, models, and parameters.

- The removal processes considered to predict concentrations in food include the effects of leaching in addition to the radioactive and chemical decay presented in the Risk Assessment Work Plan Addendum. This is presented in more detail in the section on the exposure assessment (Section E.3.0 of this appendix).

  Justification: During irrigation and aerial deposition, contaminants are added to the soil. Simultaneously, radioactive decay, chemical degradation, and soil leaching deplete these contaminants. The methodology set forth in the Risk Assessment Work Plan Addendum effectively calculates radioactive decay and chemical degradation, but approximates the effect of leaching by calculating plant concentrations after 70 years of deposition/irrigation. This approach is appropriate for most chemical and radionuclides at the site. However, this approach overestimates the concentrations of very mobile contaminants such as Tc-99. An updated methodology, based on work published in National Council on Radiation Protection (NCRP) Report No. 76 (NCRP 1984b) and Commentary No. 3 (NCRP 1989) has been adopted to more accurately represent the physical processes at the site.

- Risks and hazard quotients (HQs) are not quantified for chemicals for which toxicity data are not available in IRIS, HEAST, or from ECAO. Some contaminant exposures (childhood exposures to lead, dermal exposure to PAHs, etc.) might be better addressed using a qualitative approach.

  Justification: It is not possible to perform a quantitative risk assessment for chemicals for which toxicity data are not available. The large number of chemicals that are quantitatively assessed is adequate to provide estimates of risk for this operable unit.

Since publication of the Risk Assessment Work Plan Addendum, EPA has provided additional technical guidance concerning methods, models, and parameters that has been incorporated into this Baseline Risk Assessment to the fullest extent possible. Additional guidance documents are referenced where applicable.

E.1.3.3 Recent Agency Guidance

On February 24, 1994 a meeting was held between USEPA Region V and DOE personnel. In this meeting, agreements were reached regarding use of a new receptor (the expanded trespasser), dermal exposure to polycyclic aromatic hydrocarbons (PAHs), child inhalation rates, and skin surface area used for dermal exposure. The approach used in this baseline risk assessment was modified for consistency with these agreements.

Expanded Trespasser

For the purpose of establishing preliminary remediation goals (PRGs) for the Future Land Use With Continued Federal Ownership, an on-property trespassing receptor was established. Under this exposure scenario, access to the site would be restricted and discouraged through the construction and maintenance of signs, fences, and locked gates around the perimeter of the restricted area. Despite these controls, it was assumed that trespassing would occur. The expanded trespassing scenario assumes a youth (age 6 to 18) trepasses 110 days per year for two hours each day and the same person trepasses as an adult (ages 18 to 50) 40 days per year for one hour each day. This receptor and the associated exposure factors apply only to Operable Units 1, 2, 3, and 4. The risk assessment for the Operable Unit 5 Feasibility Study will include additional trespassing as well as recreational exposure scenarios, which are to be fully developed on a site-wide basis within the Operable Unit 5 RI/FS. A full array of trespassing and recreational exposure scenarios from no trespassing through full recreational use of the site will be developed.

Dermal Exposures to PAHs

Reliable cancer slope factors for dermal exposure to (PAHs) are currently unavailable. Current policy indicates it is inappropriate to extrapolate dermal slope factors from oral slope factors for PAHs. Also, extrapolation from other routes of exposure is inappropriate due to varied absorption, metabolic transformations and target organ end point responses. However, PAHs are potent skin carcinogens. Current information on the contribution to cancer risk from dermal exposure to PAHs indicates the toxicity from the dermal pathway may be as

toxic as from the oral route of exposure. In order to provide an estimate of the risk contribution from PAHs via dermal exposure for all direct contact pathways, the risk posed for dermal exposure was assumed equal to the risk from oral exposure.

Child Inhalation Rates

DOE calculated a value of 0.5 m^3/hr. for use as the appropriate value for the child's inhalation rate to be used for residential exposure scenarios. This value was developed utilizing currently used physiological parameters by pediatric medical practitioners from the Children's Hospital at the University of Cincinnati Medical Center. The ventilation volumes and rates used approximate the normal active child, in a conservative manner. The value developed for risk assessments is an upward adjustment of the normal child, to the moderately active child whose ventilation rate and volume are on the high side of the normal range. Accordingly, the value of 0.5m^3/hour is used as the inhalation rate for children, 0-6 years of age, and accounts for an increased activity above the normal resting level of activity. This value, developed in consultation with the physicians, is based upon current medical parameters used to treat patients. A value of 0.83m^3/hour was used for trespassing scenarios to account for even higher ventilation volumes.

Body Surface Area for Dermal Exposure

The 95th percentile body surface area value of 2.3m^2, recommended by EPA was the physiological parameter used for the human body surface area during calculation of dermal exposures for all risk assessments.

E.1.4 OVERVIEW OF OPERABLE UNIT 1 CONCEPTUAL MODEL

Conceptual site models facilitate consistent and comprehensive evaluation of the risks to human health by creating a framework for identifying the paths by which human health may be impacted by contaminants found at Operable Unit 1. The conceptual models depict the relationships between five elements necessary to construct a complete exposure pathway:

- Sources of potential constituents of concern
- Release mechanisms
- Transport pathways
- Exposure mechanisms and exposure routes
- Receptors

Two conceptual site models were developed for Operable Unit 1 to provide the basis for identifying the potential risks to human health. One conceptual site model considers the potential risks to human health from the current configuration of Operable Unit 1 source terms and receptors (current conditions) and the second model considers potential risks from a hypothetical future configuration of Operable Unit 1 source terms and receptors (future conditions). Three land use configurations are also considered: (1) current land use with access controls; (2) current land use without access controls, and (3) future land use without access controls. The conceptual site models do not consider existing contamination in groundwater or any off-site media, which will be addressed in the Operable Unit 5 risk assessment. Only soil, surface water, and waste pit material from within the boundaries of Operable Unit 1 are considered, as are future groundwater, surface water, and sediment contamination that has as its source the media within the Operable Unit 1 boundaries.

The current source term configuration used in this assessment reflects the physical state of the operable unit as it exists today. The current conceptual site model is based on the following assumptions:

- Waste Pits 1, 2, and 3 and the Burn Pit are covered with soil
- Waste Pit 4 is covered with a RCRA cap (polyethylene over 4 feet of compacted clay)
- Waste Pits 5 and 6 and the Clearwell are completely covered with water
- Infiltration through the site is unaltered
- Surface water runoff is collected by the existing drainage system, so neither contaminated water nor sediment leaves the Operable Unit 1 boundaries
- Vegetative covers remain unchanged
- The effects of radiological and chemical decay of the source are assumed to be minimal

The future source term configuration is hypothetical. It is developed from the assumption that the operable unit may be used for residential and agricultural purposes. This land use development considers both the site's current configuration and the processes that would act

on it if all maintenance activities were discontinued. The future conceptual site model is based on the following assumptions:

- Waste Pits 1 and 2 and the Burn Pit are covered with soil (existing caps)
- The polyethylene cap on Waste Pit 4 breaks down and the clay cap is exposed
- Waste Pits 5 and 6 are half covered with water after infiltration or evaporation and pit material is exposed
- The sediment in the Clearwell remains covered with water because of its depth and steep side
- The cover material over Waste Pit 3 settles into the underlying raffinate and the buried wastes in the pit are exposed
- Waste Pits 1 and 2 are irrigated and used to grow crops and animal feed
- Infiltration through the site is altered by changes in the water levels of the waste pits, the degraded cover of Waste Pit 3, and the use of irrigation on Waste Pits 1 and 2
- Excess surface water runoff flows to Paddys Run
- Vegetative cover is consistent with local agricultural practices and ecological succession
- A house is placed on the most stable pit (Waste Pit 4) and a well is drilled at the location producing the maximum risk

The future conceptual site model is discussed in greater detail in Section E.3.0.

E.1.4.1 Temporal Considerations/Source Term Scenarios

The Operable Unit 1 Baseline Risk Assessment addresses the effects of time when determining the nature and magnitude of potential human exposures to site contaminants. Over time, dynamic processes in the environment affect chemical mobility and behavior, as well as the bioavailability of contaminants to human receptors. To account for potential changes in exposure concentrations with time, the Operable Unit 1 Baseline Risk Assessment estimates exposure concentrations under both current and future source-term configurations. Over time, contaminant levels in environmental media on- and off-property will change as a result of chemical transport within and between various environmental media, and processes such as chemical partitioning, dilution, attenuation, and degradation. Physical conditions of the

property are also assumed to degrade, leaving exposed waste. This hypothetical future source term configuration provides the basis for the analysis of future conditions. The assessment of current conditions addresses only existing levels of constituents of concern in the environmental media of Operable Unit 1, considering the current configuration of the source term. Current concentrations of contaminants are assumed to result from environmental processes operating on the property as it is today.

The various exposure scenarios evaluated for the current and future source terms are described in detail in Section E.3.0 of this Baseline Risk Assessment.

E.1.4.2 Populations of Concern

The exposure assessment presented in Section E.3.0 describes the potential receptors and locations that are selected to assess current and potential future impacts on human receptors on and off site. The potential receptors and receptor locations are determined from a reasonable area of impact considering site-specific environmental conditions; the results of site characterization, environmental monitoring, and contaminant fate and transport modeling, and the nature of potential exposure pathways. Potentially exposed human populations are identified for each distinct land use condition including current and future land use and site access considerations. Subpopulations, such as young children, that could be exposed to increased risk as a result of behavior or increased sensitivity also are identified to address all significant potential relevant human exposure scenarios.

Potential receptors are further characterized according to the degree of potential exposures. In accordance with EPA guidance, risk estimates for receptor populations are developed on the basis of reasonable maximum exposure (RME) conditions. RME conditions can reasonably be expected to occur under current and future land use scenarios, and are defined by conservative exposure parameters. The RME is intended to represent a conservative exposure case that is above the average estimated exposure level. The Operable Unit 1 Baseline Risk Assessment is based on RME assumptions for each potential receptor exposure scenario evaluated.

The Baseline Risk Assessment also evaluates more typical exposure conditions by utilizing a central tendency analysis for a selected receptor. Both central tendency and RME exposure

assumptions were used to estimate risks for the on-property resident adult under future land use conditions, thereby providing a range of estimated risks for this important receptor.

E.1.4.3 Land Use Scenarios

The Operable Unit 1 Baseline Risk Assessment addresses a wide range of potential exposure scenarios under a variety of assumptions regarding land use and site access. Currently, land use adjacent to the site is primarily agricultural, with dairy, beef, corn, and soy bean production. In addition, more than 400 acres of open land at the site are being leased to a local dairy farm for livestock grazing. Consistent with these uses, the Operable Unit 1 Baseline Risk Assessment for the current land use scenario addresses receptors both on and off site, including visitors, trespassers, off-property farmers, and on-property cattle grazing.

Long-term risks to the public may be associated with the presence of hazardous substances remaining on the property in the future. These long-term risks are evaluated under the baseline (no-action) assessment, assuming that future land uses will not differ substantially from current uses of the surrounding area and that site access and use will be unrestricted. Receptors evaluated under future land uses for Operable Unit 1 include the off-property farmer, user of meat and milk, on-property resident, home builder, and a user of Great Miami River.

In addition to land use, the presence of site access controls is also a critical factor in defining potential exposures to on-site contamination. At present, a security fence surrounds the entire site property, and a second line of fences surrounds several internal areas, including the former production area and the waste disposal area. Access in and out of the facility is controlled at security checkpoints, and the fenceline is regularly patrolled. These active (security patrols) and passive (fences) access restrictions have proven to be effective for restricting unauthorized site access and are expected to continue for the foreseeable future. The Baseline Risk Assessment under the current land use assumption includes exposure scenarios that assume that these access controls will remain in effect. However, the Amended Consent Agreement also requires that the Baseline Risk Assessment for each operable unit estimate risks under scenarios that discount the effects of access controls. Therefore, the Baseline Risk Assessment under current land use conditions for Operable Unit 1 also includes risk estimates for a hypothetical scenario assuming that environmental restoration of the property has ceased and present access restrictions are discontinued. This evaluation

considers only the current, unimproved condition of Operable Unit 1. The assessment of potential risks under future land use scenarios assumes unrestricted access to the site.

E.1.4.4 Exposure Pathways

An exposure pathway is a route by which a contaminant can move from a source to a receptor. The exposure assessment presented in Section E.3.0 lists the exposure pathways considered during the course of this Baseline Risk Assessment. Exposure pathways were considered if there were (1) a source or chemical release from a source; (2) an exposure point where contact can occur; and (3) an exposure route by which contaminants are taken into the body.

TABLE E.1-1

OPERABLE UNIT 1 UNIT DESCRIPTION

Unit	Period of Operation	Physical Inventory	Physical Description
Waste Pit 1 Waste Capacity: 48,500 cubic yards	1952-1959	Brick, magnesium fluoride slag, neutralized waste filter cake, scrap graphite, sump cakes from the production facility, sump liquor, and uranium.	Clay liner; silts and clays with varying grain size; solid, semisolid and grease-like materials; 0.5-foot cover soil; 70 percent vegetative cover.
Waste Pit 2 Waste Capacity: 24,200 cubic yards	1957-1964	Brick, magnesium fluoride slag, neutralized waste filter cake, scrap graphite, sump cakes from production plants, sump liquor, raffinates, thorium, and uranium.	Clay liner; coarse sand; clay and silt-material of semisolid consistency; fragments of concrete up to 1-inch size; 1-to 4-foot soil cover; 70 percent vegetative cover.
Waste Pit 3 Waste Capacity: 204,000 cubic yards	1959-1977	Liquid effluent and slurries, lime neutralized raffinates, slag leach residues, uranium, and thorium.	Clay liner; coarse-grained material underlain by very soft, moist to wet, semisolid material; wood fragments; soil/flyash cover up to 14 ft. deep; 70 percent vegetative cover.
Waste Pit 4 Waste Capacity: 55,100 cubic yards	1960-1986	Asbestos and paint, dust collector residues, process residues, trailer cake, uranium, thorium, neutralized raffinate, uranium tetrafluoride, uranium trioxide, black oxide, graphite, concrete, flyash, and pallets.	Clay liner; silt and sand with layers of clay below 10 feet; material was saturated below 9 feet; 6-foot layer of compacted clay with a PE. cover.
Waste Pit 5 Waste Capacity: 97,900 cubic yards	1968-1987	Neutralized raffinate, neutralized slag leach residue, sump sludge, wastewater from production area (through GS), steel and concrete rubble, uranium, and thorium.	Synthetic liner; standing water; 4 feet of watery material with sand-sized grains underlain by 25 feet of a 1,1,1-trichloroethane wet semisolid material with very little cohesion; covered with water.

TABLE E.1-1
(Continued)

Unit	Period of Operation	Physical Inventory	Physical Description
Waste Pit 6 Waste Capacity: 9,600 cubic yards	1979-1985	Asbestos, filter cake, process residues containing elevated levels of uranium, UF_4, and MgF_2	Synthetic liner; saturated, soft, coarse to fine sand and clay materials; covered with water.
Clearwell Waste Capacity: 3,700 cubic yards	1959-present	Arsenic, barium, mercury, aluminum, magnesium, calcium, cobalt, cyanide, calcium fluoride, iron, vanadium, PCBs, and trichloroethane	Clay liner; silt-sized, semi-solid material and sand; covered with water.
Burn Pit Waste Capacity: 30,300 cubic yards	1957-1969	Arsenic, mercury, aluminum, magnesium, calcium, iron, lead, silver, PCBs, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, pentachlorophenol(2), phenanthrene, 2-methylnaphthalene, tetrachlorethane, ethylbenzene, fluoranthene, phenol, xylenes, and pyrene	Silt-sized, semi-solid material; sand-sized material; and fill with glass, wood, and aluminum; not covered.

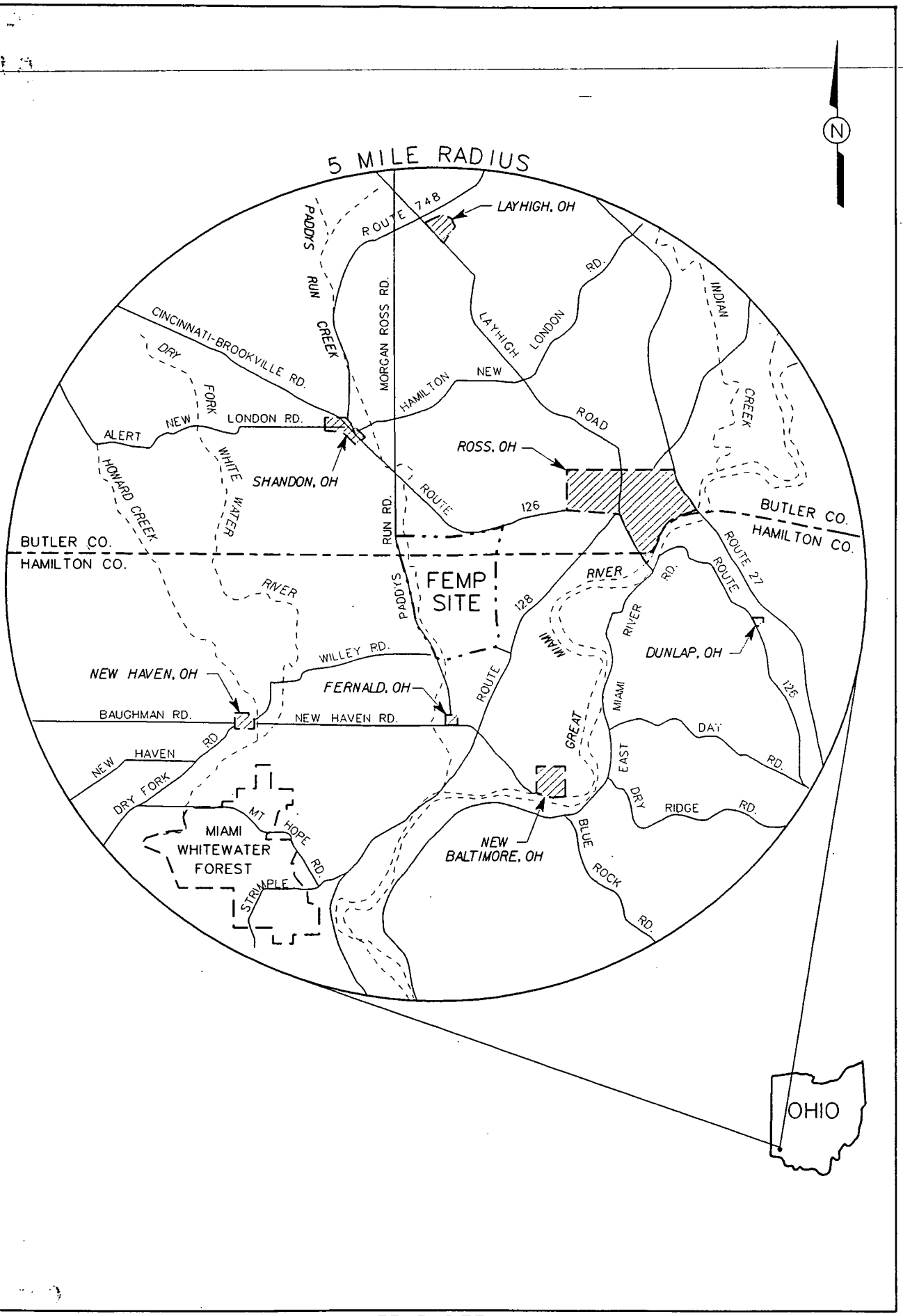

FIGURE E.1-1. FEMP SITE LOCATION MAP

409191-A-344 /OU1 /KNOX /DS
40919344.ou1 08-31-94 GP

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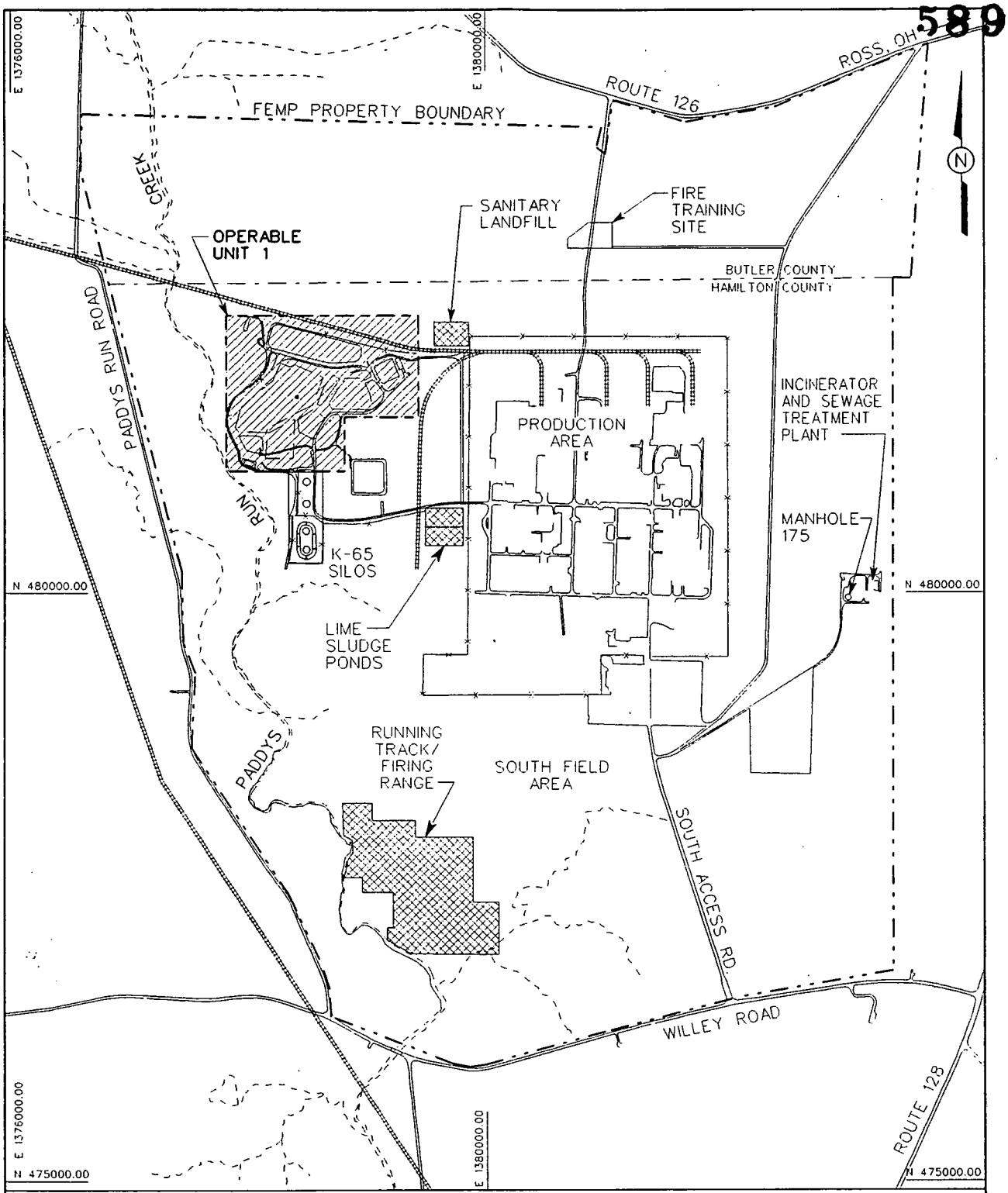


NOTE:

1. OPERABLE UNIT 3 INCLUDES ALL BUILDINGS, PIPELINES, AND ABOVEGROUND STRUCTURES IN THE PRODUCTION AREA. OPERABLE UNIT 5 INCLUDES GROUNDWATER, SURFACE WATER, SOILS, FLORA AND FAUNA, IN THE REGIONAL AREA AS WELL AS THE PRODUCTION AREA.

LEGEND:

—X—X— FENCE LINE
DRAINAGE WAY
CSX RAIL LINE
OPERABLE UNIT 1 OUTLINE
FEMP PROPERTY BOUNDARY

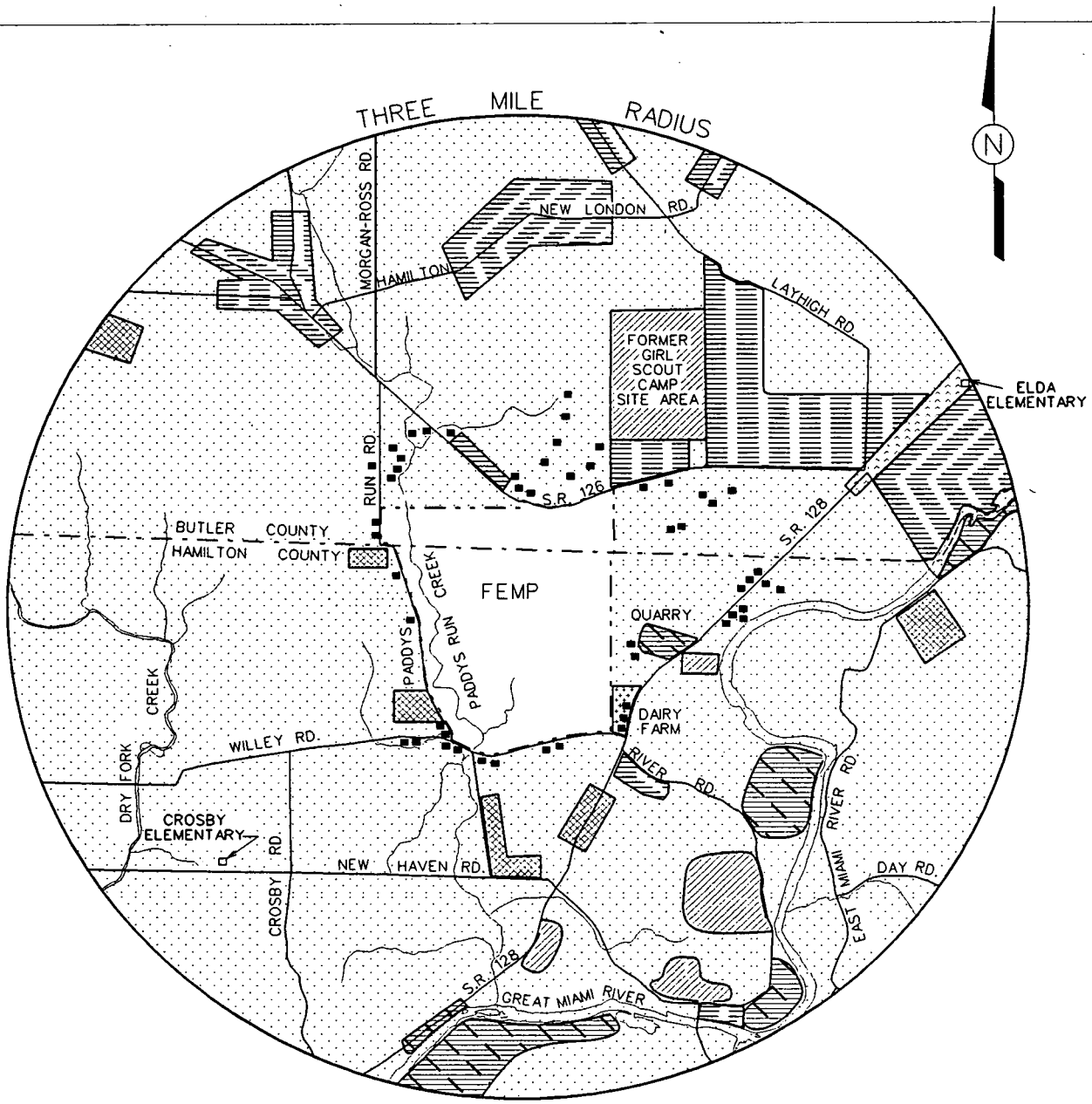
OPERABLE UNIT 1
OPERABLE UNIT 2
OPERABLE UNIT 4

SCALE:
0 1200 FEET

409191-A-66 /OU1 /KNOX /DS
40919166.ou1 08-31-94 GP

FIGURE E.1-2. LOCATION OF OPERABLE UNIT 1 WITHIN THE FEMP

000366



LEGEND:

- COUNTY LINE
- FEMP PROPERTY BOUNDARY
- HOUSE AND BARN(S)
- SCHOOL
- RESIDENTIAL
- MINING
- INDUSTRIAL
- RECREATION
- MIXED USE
- AGRICULTURE/OPEN LAND
- AGRI-BUSINESS

SCALE
0 — 1 MILE

FIGURE E.1-3. LAND USE ADJACENT TO THE FEMP

409191-A-345 /OU1/KNOX /DS
40919345.ou1 08-31-94 DEG

000367

E.2

E.2.0 IDENTIFICATION OF CONSTITUENTS OF POTENTIAL CONCERN

5899

The previously described analytical sampling procedures yielded a large amount of information about the chemicals and radionuclides present in Operable Unit 1. The risk assessment process would be unmanageable without methods to summarize data and determine which constituents pose a potential health threat. This section describes the data used for risk assessment, how the data were evaluated, and how constituents of potential concern (CPCs) were determined. Section E.2.1, Data Sources, describes the database used for risk assessment. Section E.2.2, Data Analysis, describes the data validation procedure. Section E.2.3, Identification of CPCs, describes the methods used to determine which chemicals were important for risk assessment and the results of the CPC determination process for Operable Unit 1.

E.2.1 DATA SOURCES

Investigations producing data acceptable for risk assessment are summarized in Table E.2-1. It is important to note that there are two investigative efforts for each source: the CIS and the RI/FS. A summary of these studies is presented in Section E.1.2.4 of this Appendix. A detailed description of these investigations and figures showing sample locations are presented in Section 2.0 of the RI.

In order to determine the relative magnitude that each waste source contributed to the total health risk, and because of heterogeneity between the different sources, Operable Unit 1 data were separated into discrete analytical units. These analytical units are:

- Waste Pit 1
- Waste Pit 2
- Waste Pit 3
- Waste Pit 4
- Waste Pit 5
- Waste Pit 6
- Burn Pit
- Clearwell
- Surface soil between the pits

Data on background concentrations are also compared to on-site results for inorganic and radiological constituents. Data sources for each analytical unit within Operable Unit 1 and the background data are described in the following sections.

E.2.1.1 Waste Pit 1 Contents Data Sources

Material in Waste Pit 1 was sampled during two investigations and sent to an off-site laboratory for analysis. The RI/FS program collected 6 samples for radiological analysis, 6 samples for analysis of HSL inorganic chemicals, and 11 samples for HSL organic chemical analysis. These samples were generally taken from the bottom two-thirds of the waste pit.

The CIS program collected 5 samples for radiological analysis and 10 samples for analysis of inorganic and organic HSL chemicals. These samples were generally taken from the upper two-thirds of the waste pit.

E.2.1.2 Waste Pit 2 Contents Data Sources

The RI/FS program for Waste Pit 2 collected 4 samples and sent them to an off-site laboratory for radiological analysis. In addition, 4 samples were collected for analysis of HSL inorganic chemicals and 9 samples were collected for analysis of HSL organic chemicals. These samples were generally taken from the bottom two-thirds of the waste pits.

The CIS program collected 5 samples and sent them off site for radiological analysis, and 5 samples for analysis of inorganic and organic HSL chemicals. These samples were generally taken from the upper two-thirds of the waste pit.

E.2.1.3 Waste Pit 3 Contents Data Sources

The RI/FS program for Waste Pit 3 collected 6 samples for radiological analysis. Six samples were also collected for analysis of inorganic HSL chemicals and 12 samples were collected for analysis of organic HSL chemicals. These samples were generally taken from the bottom two-thirds of the waste pit.

Seven samples were collected during the CIS for radiological analyses by an off-site laboratory. Six samples were also analyzed for inorganic and organic HSL chemicals. These samples were generally taken from the upper two-thirds of the waste pit.

E.2.1.4 Waste Pit 4 Contents Data Sources

Two investigations were conducted on the material in Waste Pit 4. The RI/FS program collected 5 samples and sent them to an off site laboratory for radiological analysis. Five samples were collected for analysis of inorganic HSL chemicals, while 12 samples were

collected for analysis of organic HSL chemicals. The RI/FS samples were generally taken from the bottom two-thirds of the waste pit.

Four samples were collected during the CIS program and were sent off site for radiological analysis. Four samples were also collected for analysis of inorganic and organic chemicals on the HSL. These samples were generally taken from the upper two-thirds of the waste pit.

E.2.1.5 Waste Pit 5 Contents Data Sources

Two investigations sampled material in Waste Pit 5. Analyses were performed by off-site laboratories. The RI/FS waste pit sampling program conducted in 1992 collected 10 samples for radiological analysis, 10 samples for analysis of inorganic HSL chemicals, and 12 samples for analysis of organic chemicals on the HSL. These samples were grab samples from the upper layers of submerged sludge at the bottom of the waste pit.

The CIS program collected 7 samples for radiological analysis, and 6 samples for analysis of inorganic and organic HSL chemicals. Some of these samples were taken from the upper portions of the exposed waste in the waste pit and other samples were grab samples from the upper layers of the submerged sludge at the bottom of the waste pit.

Two surface water samples were also collected during the CIS. These samples were analyzed for radiological constituents, as well as HSL organics and inorganics.

E.2.1.6 Waste Pit 6 Contents Data Sources

Two investigations sampled material in Waste Pit 6. All analyses were performed by an off-site laboratory. The RI/FS waste pit sampling program conducted in 1992 collected 8 samples for radiological analysis. Twelve samples were collected for analysis of inorganic and organic HSL chemicals. These samples were grab samples from the upper layers of submerged sludge at the bottom of the waste pit.

The CIS program collected 4 samples for radiological analysis, and 6 samples for analysis of inorganic and organic chemicals on the HSL. Some of these samples were taken from the upper portions of the exposed waste in the waste pit. Other samples were grab samples from the upper layers of the submerged sludge at the bottom of the waste pit.

Five surface water samples were also collected during the CIS and analyzed for radiological and HSL (organic and inorganic) constituents.

E.2.1.7 Burn Pit Contents Data Sources

The RI/FS program at the Burn Pit collected 3 samples and sent them to an off-site laboratory for radiological analysis. Three samples were collected for analyses of inorganic chemicals on the HSL, while 5 were collected for analysis of organic chemicals on the HSL. These samples were generally taken from the bottom two-thirds of the waste pit.

The CIS program collected 6 samples and sent them off site for radiological analyses. Six samples were also collected for analysis of inorganic and organic chemicals on the HSL. These samples were generally taken from the upper two-thirds of the waste pit.

E.2.1.8 Clearwell Contents Data Sources

Two investigations sampled material in the Clearwell. The RI/FS waste pit sampling program conducted in 1992 collected 6 samples and sent them to an off-site lab for radiological analyses. Six samples were also collected for analysis of inorganic and organic chemicals on the HSL. These samples were grab samples from the upper layers of submerged sludge at the bottom of the waste pit.

The CIS program collected 4 samples and sent them off site for radiological analyses. Three samples were also collected for analysis of inorganic and chemicals on the HSL. Some of these samples were taken from the upper portions of the exposed waste in the waste pit. Other samples were grab samples from the upper layers of the submerged sludge at the bottom of the waste pit.

During the CIS, 2 surface water samples were collected from the Clearwell. These samples were analyzed for both radiological constituents as well as HSL organics and inorganics.

E.2.1.9 Surface Soil Data Sources

During the RI/FS sampling program, 9 surface soil samples were collected and analyzed for radionuclides. Seventeen surface soil samples were collected and analyzed for inorganic and organic chemicals on the HSL during the Waste Pit Area Storm Water Runoff Removal

Action portion of the RI/FS sampling program. The location of these samples are depicted on figures provided in Section 2.0.

The CIS sampling program collected 60 surface soil samples within the Operable Unit 1 boundaries and sent them to an on-site laboratory for radiological analysis by gamma spectroscopy. The list of analytes included U-238, Ra-226, Th-232, Ru-106, Cs-137, and Sr-90.

E.2.1.10 Background Sources

Attachment E.I of this Appendix presents a summary of background data for various environmental media. These data were extracted from two sources.

In the spring of 1992, 89 background soil samples were collected at 30 locations in accordance with the "RCRA/CERCLA Background Soil Characterization Study" (DOE 1993b). These samples were analyzed for 17 radionuclides and 27 nonradioactive metals, and the results were evaluated and validated. This report was the primary source on background conditions in the soil.

During the past five years, the environmental monitoring programs at the FEMP have collected data on the background concentrations of a variety of constituents in groundwater and surface water. The data from these programs has been assembled and presented in "Characterization of Background Water Quality for Streams and Groundwater" (DOE 1993a). This report was the primary source on background conditions in groundwater and surface water near the FEMP.

E.2.2 DATA ANALYSIS

This section describes how data were analyzed prior to determination of CPCs for each analytical unit. First, the data validation process is discussed. Then the method yielding the final concentration term for each constituent in each of the waste sources is described. These final concentration terms will be used for risk assessment, CPC determination, and fate and transport modeling described in Section 5.0 of the RI.

E.2.2.1 Data Validation

Specific parameters associated with the data were reviewed to determine whether they met the stipulated data quality objectives. The quality objectives addressed five principal parameters: precision, accuracy, completeness, comparability, and representativeness. To verify that these objectives were met, field measurements, sampling and handling procedures, laboratory analysis and reporting, and nonconformances and discrepancies in the data were examined to determine compliance with appropriate and applicable procedures. The procedures and criteria for validation are defined in the RI/FS Data Validation Program Guidelines, which are based on the EPA National Functional Guidelines for Data Review (EPA 1988a, EPA 1988b, EPA 1991f, EPA 1991g, and EPA 1991h).

The validation process for the FEMP RI/FS was divided into two phases. The first phase evaluated field data to verify the completeness and accuracy and representativeness of field sampling. The key field data reviewed in the validation process were:

- Field Activity Daily Logs
- Sample Collection Logs
- Specific field forms for sample collection and handling
- Chain of Custody, Request for Analysis
- Field instrument calibrations
- Field personnel training
- Variances and surveillances of field activities

The second phase dealt with analytical chemical and radiological validation. The key analytical data reviewed in the validation process were:

Organic chemicals

- Holding times
- Gas Chromatography/Mass Spectroscopy (GC/MS) tune
- Initial and continuing GC/MS calibration
- Surrogate recoveries
- Matrix spike, matrix spike duplicates
- Blank evaluation using the 5X/10X rule
- Internal standards

Inorganic chemicals

- Holding times

- Inductively Coupled Plasma/Graphite Furnace Atomic Analysis instrument performance checks
- Initial and continuing calibrations
- Blank evaluations

Radionuclides

- Shipping reports
- Holding times
- Duplicate precision
- Laboratory control samples
- Blanks
- Detection limits
- Matrix spikes
- Uranium isotopic ratios

The culmination of the validation process was the assignment of the qualifier flag for each analytical result, reflecting the level of confidence assigned to that datum. All of the measured contaminant concentration data obtained in the RI/FS sampling program for Operable Unit 1 have been validated and have been through a peer review process. Data which did not adequately meet the criteria addressed during data validation were flagged with an "R" qualifier. These data were not used in the quantitative baseline risk assessment process according to EPA guidance (EPA 1989a). Section 2.13 of the Operable Unit 1 RI report provides additional information on data qualifiers.

E.2.2.2 Concentration Term

The statistical method used to determine a representative concentration for each constituent is discussed in this section. The rationale used to develop this methodology and the statistical techniques are based on the following sources:

- "Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Volume I, Part A, Interim Final" (EPA 1989a)
- "Statistical Methods for Evaluating the Attainment of Cleanup Standards, Volume 1 and Volume 3 (Draft)" (EPA 1989c, 1990a)
- "Statistical Methods for Environmental Pollution Monitoring" (Gilbert 1987)
- "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance" (EPA 1989d)

- EPA comments (December 1991 and March 1992) on the statistical methods used in the October 1991 Draft "Risk Assessment Work Plan Addendum" (Saric 1991 and 1992).
- Supplemental Guidance to Risk Assessment Guidance for Superfund: Calculating the Concentration Term, Interim Bulletin Volume 1, Number 1 (EPA 1992c).

As mentioned previously, two of the generations of characterization studies were fully validated for risk assessment purposes: the RI/FS and the CIS data sets. The RI/FS database consisted of results from both the 1991 RI/FS Treatability Study conducted by ASI and the 1992 RI/FS Supplemental Study, consisting of inorganic and radiological analysis of Waste Pits 5, 6, and the Clearwell as performed by WEMCO. This merged data set will be referred to as the RI/FS data set for the purposes of this discussion. The merged RI/FS data set and the CIS data set are analyzed separately, and both were considered when determining the final representative concentration for a constituent.

Determination of Distribution

Each background data set will be evaluated to determine the probability distribution (normal, lognormal, or other) that best describes the data set. Two methods will be used to determine the distribution type.

In the first method, one of the following quantitative techniques were employed to determine the appropriate distribution. The acceptable test procedures include either the Kolmogorov-Smirnov test with Lilliefors adjustment (Lilliefors 1967a) or the Shapiro-Wilke test (Shapiro and Wilk 1965). The Shapiro-Frances test (Shapiro and Francia 1972) was used in place of the Shapiro-Wilk when there are 50 or more samples. The chosen test was performed on the untransformed data to test the normality assumption and on the log-transformed data to test the assumption of lognormality. If the test failed to provide sufficient evidence of either normality or lognormality then a second method was employed.

The second method consists of the construction of a probability plot of the data set. If the plotted points fit a straight line reasonably well, a normal distribution was assumed. If the data do not follow a straight line on the probability plot, the data was log-transformed and a new plot generated. If the log-transformed data reasonably fit a straight line then a lognormal distribution was assumed. If a straight line does not fit the transformed probability plot, then

it was assumed that the data set is neither normally distributed nor lognormally distributed. Visual inspection of the probability plot is often sufficient to determine whether the plotted points follow a normal or lognormal distribution though some professional judgement may be necessary when there are minor deviations. The statistical methods employed to determine the concentration terms are robust to minor deviations from normality or lognormality and visual inspection of probability plots is often a sufficient tool.

Treatment of Non-Detected Results

Analytical results are presented as "non-detects" whenever chemical concentrations in samples do not exceed the detection or quantitation levels for the analytical procedures for those samples. There are numerous terms used to describe the detection or quantitation levels (EPA 1989a). SQLs are the most relevant quantitiaon limits for evaluation non-detected chemicals. SQLs take into account sample characteristics, sample preparation, and analytical adjustments. Generally, the detection limit (DL), the lowest amount of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method, is multiplied by a factor of three or five to obtain the SQL.

For radionuclides, the minimum detectable activity (MDA) corresponds most directly to the SQL for chemical. The MDA is the estimate of the activity level that can be practically achieved under a specified set of typical measurement parameters. These parameters include the sample size, counting time, counting efficiency, self-absorption and decay corrections, chemical yield, and other factors involved in determining activity concentrations. For the purposes of evaluation data in this RI/FS, the term "SQL" will be used for both chemicals and radionuclides.

Non-detected results, if present in the data set, must be considered with positively detected results for determining the descriptive statistics for data sets. Although EPA guidance (EPA 1989a) allows for best professional judgement in determining the most appropriate assignment of values for non-detected results, EPA Region V requested that a value of one-half the SQL be assigned for each non-detected result. Statistical treatment of background data for risk assessments will conform with the methodology requested by EPA Region V. If SQLs cannot be obtained for chemical analytical results, the CRQL will be used as the value of the SQL.

E.2.2.2.1 Determination of UCL/Max for Each Data Set

The concentration term is assumed to be the 95 percent Upper Confidence Limit (UCL) of the mean. If the distribution for an analyte was determined to be either normal or lognormal, the appropriate equation was used to calculate the 95 percent UCL. In cases where the calculated 95 percent UCL exceeded the maximum detected value, then the concentration term was assigned to the maximum detected value. If a distribution could not be determined a non-parametric approach was adopted. For cases where there were less than seven samples, the maximum detected value was used.

Concentration Term from a Normal Distribution

When the distribution of concentration data was determined to be normal the concentration term was calculated as the UCL of the mean. The following formula was used to estimate the UCL (Gilbert 1987)

$$UCL_{(.95)} = \bar{x} + t_{(.95,n-1)} \times \frac{s}{\sqrt{n-1}} \qquad \text{(E.2-1)}$$

where

n = *number of samples*
$\bar{x}$ = *sample mean concentration*
$t_{(.95,n-1)}$ = *percentage point from the t distribution*
s = *sample standard deviation*

$$= \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2}$$

Concentration Term from a Lognormal Distribution

When the distribution of concentration data was determined to be lognormal the concentration term was calculated as the UCL of the mean. The following formula was used to estimate the UCL:

$$UCL_{(.95)} = e^{\bar{y} + \frac{s_y^2}{2} + \frac{S_y \times H_{.95}}{\sqrt{n-1}}} \qquad \text{(E.2-2)}$$

where

n = *number of samples*
$\bar{y}$ = *sample mean of the* log-*transformed data*
$H_{(.95)}$ = *quantities obtained from tables provided by Land*(1975)
S_y = *sample standard deviation of the* log-*transformed data*

$$= \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(y_i-\bar{y})^2}$$

Concentration Term from an Undetermined Distribution

If the distribution of the background data could not be adequately determined a non-parametric method was used to estimate the concentration term. In this case the non-parametric 95th percentile concentration is used as the concentration term. The initial step in determining the 95th percentile concentration is to order the data such that

$$x_1 \le x_2 \le \ldots \le x_i$$

where

$x_{j,\,(j=1\ to\ i)}$ = *sample concentrations*
i = *the number of background samples*

The 95th percentile concentration is then determined to be

$$C_{(.95)} = x_k \qquad \text{(E.2-3)}$$

such that

$$k \ge i \times 0.95 \ (i = \textit{number of samples})$$

where

$C_{(.95)}$ = *95th Percentile Concentration*

k = *The Identification Number of the Sample Selected*

E.2.2.2.2 Determination of Final Concentration Term

The final concentration term is determined by selecting the larger of the UCL/Max values from the two data sets. The final concentration term was used for modeling, risk assessment, and CPC screening.

E.2.3 IDENTIFICATION OF CONSTITUENTS OF POTENTIAL CONCERN (CPCs)

CPCs are selected based on the likelihood that they are anthropogenic, site-related, and their ability to produce carcinogenic or toxic effects. This section presents the systematic selection process used to compare constituent concentrations to background levels, and to assess the effectiveness of the constituent in inducing adverse health effects. A flow diagram describing the CPC selection procedure is presented in Figure E.2-1.

E.2.3.1 Methodology

CPCs are determined using a two step procedure. The first is comparison to background levels (applicable to inorganic and radionuclide constituents only). Then, toxicological screening is performed. These steps are described separately below.

E.2.3.1.1 Comparison to Background

The first step in selecting CPCs is to compare the site related data to background concentration levels. To conduct the comparison between the site-related measurements and the background data for a constituent, two tests were used in sequence: (1) a "location" test (Student's t-test or Wilcoxon Rank Sum test) and (2) followed by the "95th Percentile Test" (see below for details). If either of the test results rejects the null hypothesis (i.e., the distribution of measurements at the site appears to be shifted to the right (to higher measurements) of the background distribution), the constituent is considered to be a possible CPC and is submitted to toxicological screening. The constituent is not included as a possible CPC only if both test results indicate that there was not a "significant difference" between the two distributions. For cases where the location tests could not be performed due to small sample sizes or large portion of nondetects and the 95th Percentile Test suggests that the site-related data are not different from the background data, professional judgement by risk assessors was used to make the final determination.

The "location" test can be either the t-test, a parametric statistical method (assuming a normal distribution), or the Wilcoxon Rank Sum (WRS) test (or the Mann-Whitney U-test, a direct [illegible]lary to the WRS) which is the counterpart of the t-test in a nonparametric approach. The

t-test was used to compare the mean of the site-related data with the mean of the background data. The WRS test compares two distributions of rank ordered data (equivalent distribution of ranks would indicate the data came from similar data sets). For instances in which the t-test cannot be applied to the data, the WRS test was conducted. Details of these procedures can be obtained from Gilbert, 1987.

The 95th Percentile Test determines if any sample measurements for a given constituent exceed the upper 95th percentile for the background distribution. If so, the test indicates that the data contains at least one relatively high concentration and the constituent should be considered as a CPC. The 95th percentile for the background distribution can be computed as follows:

For background data with a normal distribution:

$$P_{95} = \bar{x} + z_{0.95} * s \qquad \text{(E.2-4)}$$

where:

$\bar{x}$ = sample arithmetic mean
s = sample standard deviation
$z_{0.95}$ = 1.645

For background data with a lognormal distribution:

$$P_{95} = \exp(\bar{y} + z_{0.95} * s_y) \qquad \text{(E.2-5)}$$

where:

$\bar{y}$ = sample arithmetic mean of the log-transformed data ($y = \ln x$; $\bar{y} = \Sigma y/n$)
s_y = sample standard deviation of the log-transferred data
$z_{0.95}$ = 1.645

For background data with an undefined distribution:

If the distribution of the background data could not be adequately determined a non-parametric method was used to estimate the 95th percentile (Maritz 1981). The initial step in determining the 95th percentile concentration is to order the data such that

$$x_1 \le x_2 \le \ldots \le x_i$$

where

$x_{j,\ (j=1\ to\ i)}$ = *sample concentrations*
i = *the number of background samples*

The 95th percentile concentration is then determined to be

$$C_{(.95)} = x_k \tag{E.2-6}$$

such that

$$k \geq i \times 0.95 \ (i = \textit{number of samples})$$

where

$C_{(.95)}$ = *95th Percentile Concentration*

k = *The Identification Number of the Sample Selected*

Because organic chemicals, some fission product radionuclides, and activation product radionuclides are not naturally occurring at measurable levels, background concentrations are assumed to be zero. Consequently, if these organic chemicals, fission products, or activation products are selected as CPCs, they are not based on comparison to background.

Inorganic and radiological constituents not significantly above background levels were excluded from the CPC list and assigned symbol "A" in Attachment E.II.

The 95th percentile test is used as the second step in the statistical CPC screening. If a potential contaminant was not identified by the first step (location test) then the 95th percentile test was applied. The 95th percentile test is used to identify potential contaminants with maximum concentration significantly greater than background. Those constituents that would be eliminated based on the location test, but fail the 95th percentile test, remain as CPCs.

E.2.3.1.2 Toxicological Screening

After statistical comparisons to background were made, detected compounds which were shown to exceed background were subjected to toxicological screening to exclude constituents

that are unlikely to have a human health risk at the levels detected. The following process was used:

- Essential macronutrients for which there are no known toxic effects at the concentrations defined were deleted. Examples of chemicals in this class include magnesium, calcium, potassium, and sodium. The deletion symbol "B" was assigned to chemicals deleted from the CPC list for this reason in Attachment E.II.
- Essential micronutrients for which there are no toxic effects at the concentrations found were deleted. Examples of chemicals in this class include iron and nitrate. Chemicals deleted for this reason were assigned the deletion symbol "C" in Attachment E.II.
- Ubiquitous elements in soil, not toxic except at high levels were deleted from the CPC list. Examples of chemicals in this class include Silicon, Aluminum, Chloride, Sulfide and Sulfate. Chemicals deleted for this reason were assigned the deletion symbol "D" in Attachment E.II.
- Nonspecific chemical classes that are either too general to be useful for risk assessment (e.g., Total Organic Carbon) or for which chemical-specific results are presented in the same analysis (e.g., polynuclear aromatic hydrocarbons and chlorinated hydrocarbons) were excluded from the CPC list and assigned the deletion symbol "E" in Attachment E.II.
- Chemicals with representative concentrations lower than screening values calculated from USEPA RAGs Part B, based on a HQ of 0.1 and a risk level of 10^{-7}, were removed from the CPC list and assigned the deletion symbol "F" in Attachment E.II.
- Chemicals retained as CPCs but not quantitatively evaluated in the risk assessment were assigned the symbol "G" in Attachment E.II. Lead is an example of this type of chemical. These chemicals were discussed qualitatively or semi-qualitatively.
- The list of chemicals removed was reviewed to identify those whose toxic effects were exerted upon a common target organ, or have synergistic or additive effects. Toxicity, concentration, and any additive/synergistic effects due to concomitant exposure were examined, as well as structure-activity relationships or other chemical similarities. The possible contribution to site risk was assessed to determine whether a compound should be returned to the CPC list.
- Methodology has established the 95th percentile background value as a decision making point; radionuclides exceeding this value are considered CPCs while radionuclides at less than that value are deleted.

E.2.3.2 Results of Selecting CPCs

E.2.3.2.1 Surface Soil

Table E.2-2 lists the CPCs for surface soil. This table contains only those constituents which have been selected for quantitative evaluation in this assessment. A complete list of analytes and the rationale for their exclusion is presented in Attachment E.II of this Appendix.

E.2.3.2.2 Waste Pit 1

Table E.2-3 lists the CPCs and representative concentrations for waste pit material in Waste Pit 1. Only those constituents that have been selected for quantitative evaluation in this assessment are included. A complete list of analytes and the rationale for their exclusion is presented in Attachment E.II of this Appendix.

E.2.3.2.3 Waste Pit 2

Table E.2-4 lists the CPCs and representative concentrations for waste pit material in Waste Pit 2. These tables contain only those constituents that are evaluated quantitatively in the risk assessment. Attachment E.II of this Appendix contains a complete list of analytes and the rationale for their exclusion.

E.2.3.2.4 Waste Pit 3

Table E.2-5 lists the CPCs and representative concentrations for waste pit materials in Waste Pit 3. These tables contain only those constituents which have been selected for quantitative evaluation in this assessment. The complete list of analytes and the rationale for their exclusion is presented in Attachment E.II of this Appendix.

E.2.3.2.5 Waste Pit 4

Table E.2-5 lists the CPCs and representative concentrations for waste pit materials in Waste Pit 4. Only those constituents selected for quantitative evaluation are included. Attachment E.II of this Appendix contains a complete list of analytes and the rationale for their exclusion.

E.2.3.2.6 Waste Pit 5

Table E.2-6 presents the CPCs and representative concentrations in Waste Pit 5 for radionuclides and chemicals. The CPCs in Waste Pit 5 standing water are contained in Tables E.2-14 (radionuclides) and E.2-15 (chemicals). These tables contain only those constituents that are quantitatively evaluated in this assessment. A complete list of analytes and the rationale for their exclusion is presented in Attachment E.II of this Appendix.

E.2.3.2.7 Waste Pit 6

Table E.2-7 contains the CPCs and representative concentrations for Waste Pit 6 sludge. These tables contain only those constituents which have been selected for quantitative evaluation in this assessment. A complete list of analytes and the rationale for their exclusion is contained in Attachment E.II of this Appendix.

E.2.3.2.8 Burn Pit

Tables E.2-8 lists the CPCs and representative concentrations for the Burn Pit. These tables contain only those constituents which have been selected for quantitative evaluation in this assessment. A complete list of analytes and the rationale for their exclusion is presented in Attachment E.II of this Appendix.

E.2.3.2.9 Clearwell

Table E.2-9 contains the CPCs and representative concentrations for the Clearwell sludge and standing water. Only those constituents that are quantitatively evaluated in this assessment are included. Attachment E.II of this Appendix contains a complete list of analytes and the rationale for their exclusion.

TABLE E.2-1

DATA USED FOR THE OPERABLE UNIT 1 RISK ASSESSMENT

		Data		
Source	Medium	Radiological	Chemical	Justification
Pit 1	Waste	Weston CIS Borings	Weston CIS Borings	Validated Data Available
		ASI/IT RI/FS Borings	ASI/IT RI/FS Borings	Validated Data Available
Pit 2	Waste	Weston CIS Borings	Weston CIS Borings	Validated Data Available
		ASI/IT RI/FS Borings	ASI/IT RI/FS Borings	Validated Data Available
Pit 3	Waste	Weston CIS Borings	Weston CIS Borings	Validated Data Available
		ASI/IT RI/FS Borings	ASI/IT RI/FS Borings	Validated Data Available
Pit 4	Waste	Weston CIS Borings	Weston CIS Borings	Validated Data Available
		ASI/IT RI/FS Borings	ASI/IT RI/FS Borings	Validated Data Available
Pit 5	Waste	Weston CIS Grab Samples	Weston CIS Grab Samples	Validated Data Available
		WEMCO RI/FS Grab Samples	WEMCO RI/FS Grab Samples	Validated Data Available
	Standing Water	Weston CIS Grab Samples	Weston CIS Grab Samples	Validated Data Available
Pit 6	Waste	Weston CIS Grab Samples	Weston CIS Grab Samples	Validated Data Available
		WEMCO RI/FS Grab Samples	WEMCO RI/FS Grab Samples	Validated Data Available
	Standing Water	Weston CIS Grab Samples	Weston CIS Grab Samples	Validated Data Available
Burn Pit	Waste	Weston CIS Borings	Weston CIS Borings	Validated Data Available
		ASI/IT RI/FS Borings	ASI/IT RI/FS Borings	Validated Data Available
Clearwell	Waste	Weston CIS Grab Samples	Weston CIS Grab Samples	Validated Data Available
		WEMCO RI/FS Grab Samples	WEMCO RI/FS Grab Samples	Validated Data Available
	Standing Water	Weston CIS Grab Samples	Weston CIS Grab Samples	Validated Data Available
Surface Soil	Soil	Weston CIS Grab Samples	RI/FS Grab Samples	Validated Data Available
		RI/FS Grab Samples	RI/FS Grab Samples	Validated Data Available

TABLE E.2-2

CPC IN SURFACE SOIL (0-24 INCHES DEEP)

Parameters	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Dist.[1]	CIS Data: Representative Concentration[2]	RIFS Data: Frequency of Detection	RIFS Data: Maximum Value	RIFS Data: Dist.[1]	RIFS Data: Representative Concentration[2]	Representative Concentration[3]
Antimony	mg/Kg					17 / 17	32.8	L	27.9	27.9
Beryllium	mg/Kg					17 / 17	1.0	L	0.8	0.8
Cadmium	mg/Kg					17 / 17	7.7	L	5.9	5.9
Aroclor-1254	ug/Kg					3 / 17	1400.0	U	1400.0	1400.0
Cesium-137	pCi/g	11 / 24	6	L	0.8					0.8
Neptunium-237	pCi/g	1 / 24	0.5	U	0.5					0.5
Plutonium-238	pCi/g	4 / 24	0.7	U	0.1					0.1
Plutonium-239/240	pCi/g	4 / 24	0.6	U	0.2					0.2
Radium-226	pCi/g					10 / 13	2.2	N	1.4	1.4
Radium-228	pCi/g					10 / 13	4.7	L	2.2	2.2
Strontium-90	pCi/g	1 / 24	1.5	U	1.5	3 / 11	0.9	U	0.9	1.5
Technetium-99	pCi/g	10 / 24	58	U	5.6	1 / 12	0.9	U	0.9	5.6
Thorium-228	pCi/g	20 / 24	48.0	U	7.8	11 / 11	4.1	L	2.2	7.8
Thorium-230	pCi/g	22 / 24	972.0	U	146.0	11 / 11	6.1	L	3.5	146.0
Thorium-232	pCi/g	19 / 24	31.0	U	5.5	11 / 11	1.6	L	1.2	5.5
Thorium-Total	mg/Kg					1 / 1	5.8	U	5.8	5.8
Uranium-234	pCi/g	24 / 24	241.0	L	117.5	13 / 13	28.5	L	17.5	117.5
Uranium-235/236	pCi/g	24 / 24	51.0	U	18.6	5 / 13	3.9	U	3.9	18.6
Uranium-238	pCi/g	24 / 24	1500.0	U	788.0	13 / 13	103.7	L	103.7	788.0
Uranium-Total	mg/Kg					9 / 9	413.5	U	413.5	413.5
Benzo(A)Anthracene	ug/Kg					1 / 16	98.0	U	98.0	98.0
Benzo(A)Pyrene	ug/Kg					1 / 16	42.0	U	42.0	42.0
Benzo(B)Fluoranthene	ug/Kg					1 / 16	59.0	U	59.0	59.0
Benzo(K)Fluoranthene	ug/Kg					1 / 16	46.0	U	46.0	46.0
Chrysene	ug/Kg					1 / 16	88.0	U	88.0	88.0

Notes:

1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).

2 – The representative concentration for the CIS or RIFS data sets is the either the maximum value or 95% UCL value. If the distribution could not be determined, but there were more than 7 detects, the non-parametric 95th percentile was used as the representative concentration.

3 – The representative concentration for surface soils is the maximum of the representative concentration from either the CIS or RIFS data.

TABLE E.2-3
CPCs IN PIT 1

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Antimony	mg/Kg	1 / 5	0.4	U	NA	6 / 6	125.0	U	NA	125.0
Arsenic	mg/Kg	5 / 5	15.0	U	NA	5 / 6	1.7	U	NA	15.0
Beryllium	mg/Kg	4 / 5	2.2	U	NA	6 / 6	12.5	U	NA	12.5
Cadmium	mg/Kg	4 / 5	5.0	U	NA	6 / 6	18.5	U	NA	18.5
Chromium	mg/Kg	5 / 5	46.0	U	NA	6 / 6	347.0	U	NA	347.0
Lead	mg/Kg	1 / 5	17.0	U	NA	5 / 5	53.4	U	NA	53.4
Silver	mg/Kg	4 / 5	33.0	U	NA	6 / 6	189.0	U	NA	189.0
4,4-DDT	ug/Kg	1 / 6	1600.0	U	NA		0.0			1600.0
Aroclor-1221	ug/Kg		0.0			1 / 6	4600.0	U	NA	4600.0
Aroclor 1248	ug/Kg	1 / 6	3500.0	U	NA	5 / 6	10000.0	U	NA	10000.0
Aroclor 1254	ug/Kg	6 / 6	11500.0	U	NA	5 / 5	13000.0	U	NA	13000.0
Aroclor 1260	ug/Kg	2 / 6	7800.0	U	NA		0.0			7800.0
Cesium-137	pCi/g	1 / 5	1.1	U	NA	1 / 6	0.3	U	NA	1.1
Plutonium-238	pCi/g					1 / 5	1.0	U	NA	1.0
Plutonium-239/240	pCi/g					1 / 6	1.0	U	NA	1.0
Radium-226	pCi/g					5 / 6	99.6	U	NA	99.6
Radium-228	pCi/g					5 / 6	41.0	U	NA	41.0
Ruthenium-106						1 / 6	2.4	U	NA	2.4
Strontium-90						5 / 6	7.7	U	NA	7.7
Technetium-99	pCi/g	1 / 5	15.0	U	NA	1 / 6	1.1	U	NA	15.0
Thorium-228	pCi/g	5 / 5	52.0	U	NA	2 / 4	790.0	U	NA	790.0
Thorium-230	pCi/g	5 / 5	3600.0	U	NA	4 / 4	5460.0	U	NA	5460.0
Thorium-232	pCi/g	5 / 5	55.0	U	NA	2 / 4	490.0	U	NA	490.0
Thorium-Total	mg/Kg					2 / 4	4400.0	U	NA	4400.0
Uranium-234	pCi/g	5 / 5	1180.0	U	NA	4 / 4	830.0	U	NA	1180.0
Uranium-235/236	pCi/g	5.0 / 5	151.0	U	NA	5 / 5	259.0	U	NA	259.0
Uranium-238	pCi/g	5 / 5	6980.0	U	NA	5 / 5	16160.0	U	NA	16160.0
Uranium-Total	mg/Kg					6 / 6	48480.0	U	NA	48480.0
2-Methylnaphthalene	ug/Kg	2 / 6	240.0	U	NA		0.0			240.0
Benzo(A)Anthracene	ug/Kg	2 / 6	100.0	U	NA		0.0			100.0
Benzo(A)Pyrene	ug/Kg	1 / 6	140.0	U	NA		0.0			140.0
Benzo(B)Fluoranthene	ug/Kg	5 / 6	330.0	U	NA		0.0			330.0
Benzo(K)Fluoranthene	ug/Kg	1 / 6	140.0	U	NA		0.0			140.0
Chrysene	ug/Kg	5 / 6	540.0	U	NA		0.0			540.0
Phenanthrene	ug/Kg	6 / 6	2400.0	U	NA		0.0			2400.0

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TABLE E.2-3
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
1,2,3,4,6,7,8-HpCDD[4]	ug/Kg					5 / 6	1.2	U	NA	1.2
1,2,3,4,6,7,8-HpCDF[4]	ug/Kg					5 / 6	1.2	U	NA	1.2
1,2,3,4,7,8-HxCDF[4]	ug/Kg					3 / 6	0.8	U	NA	0.8
1,2,3,6,7,8-HxCDD[4]	ug/Kg					4 / 6	0.8	U	NA	0.8
1,2,3,6,7,8-HxCDF[4]	ug/Kg					3 / 6	0.3	U	NA	0.3
1,2,3,7,8,9-HxCDD[4]	ug/Kg					3 / 6	0.5	U	NA	0.5
1,2,3,7,8-PeCDF[4]	ug/Kg					5 / 6	1.2	U	NA	1.2
2,3,4,6,7,8-HxCDF[4]	ug/Kg					3 / 6	0.4	U	NA	0.4
2,3,4,7,8-PeCDF[4]	ug/Kg					4 / 6	1.2	U	NA	1.2
2,3,7,8-TCDF[4]	ug/Kg					5 / 6	14.0	U	NA	14.0
Heptachlorodibenzo-p-dioxin	ug/Kg					5 / 6	2.3	U	NA	2.3
Heptachlorodibenzofuran	ug/Kg					5 / 6	2.7	U	NA	2.7
Hexachlorodibenzo-p-dioxin	ug/Kg					5 / 6	4.9	U	NA	4.9
Hexachlorodibenzofuran	ug/Kg					4 / 6	2.9	U	NA	2.9
Octachlorodibenzo-p-dioxin	ug/Kg					5 / 6	0.7	U	NA	0.7
Octachlorodibenzofuran	ug/Kg					3 / 6	0.8	U	NA	0.8
Pentachlorodibenzofuran	ug/Kg					5 / 6	7.9	U	NA	7.9
Tetrachlorodibenzofuran	ug/Kg					6 / 6	35.0	U	NA	35.0

Notes:

1 – Distribution, N=Normal, L=Lognormal, U=Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).

2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.

3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.

4 – TCDD = Tetrachlorodibenzo-p-dioxin
PeCDD = Pentachlorodibenzo-p-dioxin
HxCDD = Hexachlorodibenzo-p-dioxin
HpCCD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenz-p-dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

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TABLE E.2-4
CPCs IN PIT 2

Parameter	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Dist.[1]	CIS Data: 95% UCL[2]	RIFS Data: Frequency of Detection	RIFS Data: Maximum Value	RIFS Data: Dist.[1]	RIFS Data: 95% UCL[2]	Representative Concentration[3]
Antimony	mg/Kg	2 / 5	1.2	U	NA	4 / 4	55.4	U	NA	55.4
Arsenic	mg/Kg	5 / 5	10.0	U	NA	4 / 4	423.0	U	NA	423.0
Barium	mg/Kg	5 / 5	208.0	U	NA	4 / 4	1920.0	U	NA	1920.0
Beryllium	mg/Kg	5 / 5	8.9	U	NA	4 / 4	26.9	U	NA	26.9
Cadmium	mg/Kg	5 / 5	9.6	U	NA	4 / 4	12.8	U	NA	12.8
Chromium	mg/Kg	5 / 5	91.0	U	NA	4 / 4	282.0	U	NA	282.0
Copper	mg/Kg	5 / 5	329.0	U	NA	4 / 4	1340.0	U	NA	1340.0
Lead	mg/Kg	5 / 5	190.0	U	NA	4 / 4	758.0	U	NA	758.0
Molybdenum	mg/Kg					4 / 4	215.0	U	NA	215.0
Nickel	mg/Kg	5 / 5	609.0	U	NA	4 / 4	1740.0	U	NA	1740.0
Thallium	mg/Kg					1 / 4	2.4	U	NA	2.4
Vanadium	mg/Kg	5 / 5	106.0	U	NA	4 / 4	594.0	U	NA	594.0
4,4-DDT	ug/Kg	2 / 5	1400.0	U	NA					1400.0
Aroclor 1248	ug/Kg	1 / 5	321.0	U	NA	2 / 4	4900.0	U	NA	4900.0
Aroclor 1254	ug/Kg	1 / 5	323.0	U	NA					323.0
Cesium-137	pCi/g	2 / 5	3.6	U	NA	1 / 4	0.5	U	NA	3.6
Plutonium-238	pCi/g	2 / 5	0.1	U	NA					0.1
Plutonium-239/240	pCi/g	2 / 5	0.6	U	NA					0.6
Radium-226	pCi/g					4 / 4	951.0	U	NA	951.0
Radium-228	pCi/g					4 / 4	437.0	U	NA	437.0
Ruthenium-106	pCi/g					1 / 4	4.0	U	NA	4.0
Strontium-90	pCi/g					3 / 4	4.0	U	NA	4.0
Technetium-99	pCi/g	3 / 5	618.0	U	NA	1 / 4	1.6	U	NA	618.0
Thorium-228	pCi/g	5 / 5	164.0	U	NA	2 / 2	697.0	U	NA	697.0
Thorium-230	pCi/g	5 / 5	3980.0	U	NA	2 / 2	18400.0	U	NA	18400.0
Thorium-232	pCi/g	5 / 5	88.0	U	NA	2 / 2	340.0	U	NA	340.0
Thorium-Total	mg/kg					2 / 2	2780.0	U	NA	2780.0
Uranium-234	pCi/g	5 / 5	18200.0	U	NA	2 / 2	1651.0	U	NA	18200.0
Uranium-235/236	pCi/g	5 / 5	8780.0	U	NA	2 / 2	130.0	U	NA	130.0
Uranium-238	pCi/g	5 / 5	17900.0	U	NA	2 / 2	1861.0	U	NA	17900.0
Uranium-Total	mg/kg					4 / 4	5803.0	U	NA	5803.0
2-Methylnaphthalene	ug/Kg	2 / 5	7000.0	U	NA	3 / 7	7800.0	U	NA	7800.0
4-Chloro-3-Methylphenol	ug/Kg					1 / 7	230.0	U	NA	230.0
Acenaphthylene	ug/Kg					1 / 7	110.0	U	NA	110.0
Benzo(A)Anthracene	ug/Kg	5 / 5	130000.0	U	NA	3 / 7	100000.0	U	NA	130000.0
Benzo(A)Pyrene	ug/Kg	4 / 5	120000.0	U	NA	3 / 7	68000.0	U	NA	120000.0
Benzo(B)Fluoranthene	ug/Kg	5 / 5	110000.0	U	NA	3 / 7	130000.0	U	NA	130000.0
Benzo(G,H,I)Perylene	ug/Kg	3 / 5	42000.0	U	NA	3 / 7	42000.0	U	NA	42000.0
Benzo(K)Fluoranthene	ug/Kg	4 / 5	75000.0	U	NA	3 / 7	44000.0	U	NA	75000.0
Chrysene	ug/Kg	4 / 5	4200.0	U	NA	2 / 7	86000.0	U	NA	86000.0
Dibenzo(A,H)Anthracene	ug/Kg	2 / 5	16000.0	U	NA	3 / 7	20000.0	U	NA	20000.0
Dibenzofuran	ug/Kg	3 / 5	36000.0	U	NA	3 / 7	21000.0	U	NA	36000.0
Fluoranthene	ug/Kg	5 / 5	490000.0	U	NA	5 / 7	280000.0	U	NA	490000.0

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TABLE E.2-4
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Indeno(1,2,3-Cd)Pyrene	ug/Kg	3 / 5	46000.0	U	NA	3 / 7	37000.0	U	NA	46000.0
Pentachlorophenol	ug/Kg					2 / 7	1600.0	U	NA	1600.0
Phenanthrene	ug/Kg	5 / 5	370000.0	U	NA	5 / 7	280000.0	U	NA	370000.0
Pyrene	ug/Kg	5 / 5	250000.0	U	NA	5 / 7	230000.0	U	NA	250000.0
Tributyl Phosphate	ug/Kg					4 / 4	39000.0	U	NA	39000.0
1,1-Dichloroethene	ug/Kg					6 / 10	120.0	U	NA	120.0
Benzene	ug/Kg					1 / 10	4.0	U	NA	4.0
Vinyl Chloride	ug/Kg	1 / 4	670.0	U	NA	6 / 10	1900.0	U	NA	1900.0
1,2,3,4,6,7,8-HpCDD[4]	ug/Kg					2 / 4	3.8	U	NA	3.8
1,2,3,4,6,7,8-HpCDF[4]	ug/Kg					1 / 4	1.0	U	NA	1.0
1,2,3,4,7,8-HxCDF[4]	ug/Kg					1 / 4	0.3	U	NA	0.3
HpCDD[4]	ug/Kg					3 / 4	8.1	U	NA	8.1
HpCDF[4]	ug/Kg					3 / 4	5.9	U	NA	5.9
HxCDD[4]	ug/Kg					1 / 4	0.3	U	NA	0.3
HxCDF[4]	ug/Kg					2 / 4	2.7	U	NA	2.7
OCDD[4]	ug/Kg					4 / 4	45.9	U	NA	45.9
OCDF[4]	ug/Kg					3 / 4	4.9	U	NA	4.9
PeCDF[4]	ug/Kg					1 / 4	0.6	U	NA	0.6

Notes:
1 - Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 - NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 - The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 - TCDD = Tetrachlorodibenzo-p-dioxin
PeCDD = Pentachlorodibenzo-p-dioxin
HxCDD = Hexachlorodibenzo-p-dioxin
HpCCD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenz-p-dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

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TABLE E.2–5

CPCs IN PIT 3

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Antimony	mg/Kg	2 / 7	18	U	NA	4 / 6	63.5	U	NA	63.5
Arsenic	mg/Kg	7 / 7	3050	N	1970.1	6 / 6	37200.0	U	NA	37200.0
Barium	mg/Kg	7 / 7	14400	U	NA	6 / 6	3570.0	U	NA	14400.0
Beryllium	mg/Kg	7 / 7	24	L	42.8	6 / 6	10.7	U	NA	24.0
Cadmium	mg/Kg	7 / 7	13	L	13.4	6 / 6	38.6	U	NA	38.6
Chromium	mg/Kg	7 / 7		U	NA	6 / 6	2010.0	U	NA	2330.0
Lead	mg/Kg	5 / 7	613	U	NA	6 / 6	837.0	U	NA	837.0
Manganese	mg/Kg	7 / 7	10600	L	18063.6	6 / 6	20200.0	U	NA	20200.0
Molybdenum	mg/Kg		0		0.0	6 / 6	284.0	U	NA	284.0
Nickel	mg/Kg	7 / 7	504	L	1120.6	6 / 6	292.0	U	NA	504.0
Thallium	mg/Kg	3 / 7	12	U	NA	4 / 6	4.1	U	NA	12.0
Vanadium	mg/Kg	7 / 7	9700	N	5756.7	6 / 6	2200.0	U	NA	5756.7
Aroclor–1248	ug/Kg					4 / 6	4800.0	U	NA	4800.0
Aroclor–1254	ug/Kg	2 / 7	550.0	U	NA	5 / 6	3400.0	U	NA	3400.0
Cesium–137	pCi/g					1 / 6	0.5	U	NA	0.5
Neptunium–237	pCi/g	3 / 7	2.1	U	NA					2.1
Plutonium–238	pCi/g	3 / 7	1.0	U	NA	1 / 5	1.0	U	NA	1.0
Plutonium–239/240	pCi/g	3 / 7	14.0	U	NA	2 / 5	1.6	U	NA	14.0
Radium–226	pCi/g					6 / 6	451.0	U	NA	451.0
Radium–228	pCi/g					6 / 6	241.0	U	NA	241.0
Ruthenium–106	pCi/g					2 / 6	4.2	U	NA	4.2
Strontium–90	pCi/g	1 / 7	5.2	U	NA	3 / 6	4.9	U	NA	5.2
Technetium–99	pCi/g	6 / 7	1110.0	U	NA	6 / 6	33.0	U	NA	1110.0
Thorium–228	pCi/g	7 / 7	40.0	L	174.5	4 / 5	554.0	U	NA	554.0
Thorium–230	pCi/g	7 / 7	11680.0	N	9115.9	6 / 6	11370.0	U	NA	11370.0
Thorium–232	pCi/g	7 / 7	59.0	U	NA	4 / 5	396.0	U	NA	396.0
Thorium–Total	mg/Kg					4 / 5	3570.0	U	NA	3570.0
Uranium–234	pCi/g	7 / 7	475.0	L	986.8	4 / 4	991.0	U	NA	991.0
Uranium–235/236	pCi/g	7 / 7	21.0	N	17.6	5 / 5	89.2	U	NA	89.2
Uranium–238	pCi/g	7 / 7	1380.0	L	1260.7	6 / 6	1740.0	U	NA	1740.0
Uranium–Total	mg/Kg					6 / 6	5938.0	U	NA	5938.0
Acenaphthylene	ug/Kg					1 / 4	96.0	U	NA	96.0
Benzo(A)Anthracene	ug/Kg	1 / 7	60.0	U	NA	1 / 7	360.0	U	NA	360.0
Benzo(A)Pyrene	ug/Kg					1 / 7	280.0	U	NA	280.0
Benzo(B)Fluoranthene	ug/Kg	1 / 7	110.0	U	NA	1 / 7	560.0	U	NA	560.0
Benzo(G,H,I)Perylene	ug/Kg					1 / 7	160.0	U	NA	160.0
Chrysene	ug/Kg	1 / 7	75.0	U	NA	1 / 7	370.0	U	NA	370.0

TABLE E.2-5
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Max Hit	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Indeno(1,2,3-Cd)Pyrene	ug/Kg					1 / 7	130.0	U	NA	130.0
N-Nitroso-Di-N-Propylamine	ug/Kg					2 / 4	460.0	U	NA	460.0
Pentachlorophenol	ug/Kg	2 / 6	1300.0	U	NA	5 / 5	1000.0	U	NA	1300.0
Phenanthrene	ug/Kg	1 / 7	120.0	U	NA	2 / 7	580.0	U	NA	580.0
2-Hexanone	ug/Kg					4 / 10	17.0	U	NA	17.0
1,2,3,4,6,7,8-HpCDD[4]	ug/Kg					5 / 6	1.7	U	NA	1.7
1,2,3,4,6,7,8-HpCDF[4]	ug/Kg					3 / 6	0.2	U	NA	0.2
1,2,3,6,7,8-HxCDD[4]	ug/Kg					1 / 6	0.0	U	NA	0.0
HpCDD[4]	ug/Kg					5 / 6	3.2	U	NA	3.2
HpCDF[4]	ug/Kg					5 / 6	1.0	U	NA	1.0
HxCDD[4]	ug/Kg					1 / 6	0.3	U	NA	0.3
HxCDF[4]	ug/Kg					4 / 6	0.4	U	NA	0.4
OCDD[4]	ug/Kg					6 / 6	19.4	U	NA	19.4
OCDF[4]	ug/Kg					5 / 6	1.1	U	NA	1.1
Tetrachlorodibenzofuran	ug/Kg					1 / 6	0.2	U	NA	0.2
Fluoride	ug/Kg					2 / 5	2350000.0	U	NA	2350000.0

Notes:
1 - Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 - NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 - The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 - TCDD = Tetrachlorodibenzo-p-dioxin
PeCDD = Pentachlorodibenzo-p-dioxin
HxCDD = Hexachlorodibenzo-p-dioxin
HpCCD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenz-p-dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

TABLE E.2–6
CPCs IN PIT 4

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Antimony	mg/Kg	1 / 4	0.5	U	NA	4 / 5	317.0	U	NA	317.0
Beryllium	mg/Kg	4 / 4	13.0	U	NA	3 / 5	50.6	U	NA	50.6
Cadmium	mg/Kg	3 / 4	29.0	U	NA	5 / 5	34.8	U	NA	34.8
Chromium	mg/Kg	4 / 4	94.0	U	NA	5 / 5	1500.0	U	NA	1500.0
Lead	mg/Kg	4 / 4	63.0	U	NA	5 / 5	63.2	U	NA	63.2
Manganese	mg/Kg	4 / 4	3600.0	U	NA	5 / 5	5620.0	U	NA	5620.0
Nickel	mg/Kg	4 / 4	50.0	U	NA	5 / 5	223.0	U	NA	223.0
Silver	mg/Kg	3 / 4	444.0	U	NA	5 / 5	755.0	U	NA	755.0
Vanadium	mg/Kg	4 / 4	235.0	U	NA	5 / 5	558.0	U	NA	558.0
Aroclor 1242	ug/Kg	2 / 5	1034.0	U	NA					1034.0
Aroclor 1248	ug/Kg	3 / 5	854.0	U	NA	4 / 6	7500.0	U	NA	7500.0
Aroclor 1254	ug/Kg	5 / 5	1008.0	U	NA	3 / 6	6800.0	U	NA	6800.0
Neptunium–237	pCi/g	1 / 4	0.4	U	NA					0.4
Plutonium–238	pCi/g	2 / 4	0.5	U	NA					0.5
Plutonium–239/240	pCi/g	1 / 4	0.4	U	NA					0.4
Radium–226	pCi/g					5 / 6	50.1	U	NA	50.1
Radium–228	pCi/g					6 / 6	141.0	U	NA	141.0
Ruthenium–106	pCi/g					1 / 6	1.1	U	NA	1.1
Strontium–90	pCi/g					5 / 6	144.0	U	NA	144.0
Technetium–99	pCi/g	4 / 4	225.0	U	NA	5 / 6	9.4	U	NA	225.0
Thorium–228	pCi/g	4 / 4	395.0	U	NA	4 / 4	2469.0	U	NA	2469.0
Thorium–230	pCi/g	4 / 4	566.0	U	NA	6 / 6	1815.0	U	NA	1815.0
Thorium–232	pCi/g	4 / 4	92.0	U	NA	4 / 4	838.0	U	NA	838.0
Thorium–Total	mg/Kg					4 / 4	7565.0	U	NA	7565.0
Uranium–234	pCi/g	4 / 4	2320.0	U	NA	3 /3	4100.0	U	NA	4100.0
Uranium–235/236	pCi/g	4 / 4	426.0	U	NA	4 / 4	934.0	U	NA	934.0
Uranium–238	pCi/g	4 / 4	15800.0	U	NA	4 / 4	41900.0	U	NA	41900.0
Uranium–Total	mg/Kg					6 / 6	0.1	U	NA	0.1
2–Methylnaphthalene	ug/Kg	2 / 5	1100.0	U	NA	2 / 9	480.0	U	NA	1100.0
4–Chloro–3–Methylphenol	ug/Kg					2 / 9	77.0	U	NA	77.0
Benzo(A)Anthracene	ug/Kg	5 / 5	4100.0	U	NA	2 / 9	4700.0	U	NA	4700.0
Benzo(A)Pyrene	ug/Kg	4 / 5	4800.0	U	NA	2 / 9	2900.0	U	NA	4800.0
Benzo(B)Fluoranthene	ug/Kg	4 / 5	5800.0	U	NA	2 / 9	5200.0	U	NA	5800.0
Benzo(G,H,I)Perylene	ug/Kg	3 / 5	1300.0	U	NA	1 / 9	990.0	U	NA	1300.0
Benzo(K)Fluoranthene	ug/Kg	4 / 5	3700.0	U	NA					3700.0
Chrysene	ug/Kg	5 / 5	4500.0	U	NA	2 / 9	3300.0	U	NA	4500.0
Dibenzo(A,H)Anthracene	ug/Kg	2 / 5	560.0	U	NA					560.0
Dibenzofuran	ug/Kg	4 / 5	1700.0	U	NA	2 / 9	1200.0	U	NA	1700.0
Indeno(1,2,3–Cd)Pyrene	ug/Kg	4 / 5	1400.0	U	NA	1 / 9	990.0	U	NA	1400.0

TABLE E.2–6
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Phenanthrene	ug/Kg	5 / 5	16000.0	U	NA	2 / 9	12000.0	U	NA	16000.0
Tributyl Phosphate	ug/Kg					2 / 2	72000.0	U	NA	72000.0
2–Hexanone	ug/Kg					4 / 9	29.0	U	NA	29.0
3–Chloropropene	ug/Kg					1 / 2	3.0	U	NA	3.0
Benzene	ug/Kg					1 / 9	14.0	U	NA	14.0
Vinyl Chloride	ug/Kg					2 / 9	14.0	U	NA	14.0
1,2,3,4,6,7,8–HpCDD[4]	ug/Kg					4 / 6	2.6	U	NA	2.6
1,2,3,4,6,7,8–HpCDF[4]	ug/Kg					5 / 6	3.2	U	NA	3.2
1,2,3,4,7,8,9–HpCDD[4]	ug/Kg					3 / 6	2.4	U	NA	2.4
1,2,3,4,7,8–HxCDD[4]	ug/Kg					1 / 6	0.1	U	NA	0.1
1,2,3,4,7,8–HxCDF[4]	ug/Kg					5 / 6	2.9	U	NA	2.9
1,2,3,6,7,8–HxCDD[4]	ug/Kg					2 / 6	0.2	U	NA	0.2
1,2,3,6,7,8–HxCDF[4]	ug/Kg					5 / 6	1.1	U	NA	1.1
1,2,3,7,8,9–HxCDD[4]	ug/Kg					2 / 6	0.2	U	NA	0.2
1,2,3,7,8,9–HxCDF[4]	ug/Kg					3 / 6	0.8	U	NA	0.8
1,2,3,7,8–PeCDF[4]	ug/Kg					5 / 6	2.1	U	NA	2.1
2,3,4,6,7,8–HxCDF[4]	ug/Kg					4 / 6	1.2	U	NA	1.2
2,3,4,7,8–PeCDF[4]	ug/Kg					5 / 6	2.7	U	NA	2.7
2,3,7,8–TCDF[4]	ug/Kg					5 / 6	9.9	U	NA	9.9
HpCDD[4]	ug/Kg					5 / 6	4.0	U	NA	4.0
HpCDF[4]	ug/Kg					5 / 6	4.4	U	NA	4.4
HxCDD[4]	ug/Kg					4 / 6	2.7	U	NA	2.7
HxCDF[4]	ug/Kg					5 / 6	8.5	U	NA	8.5
OCDD[4]	ug/Kg					5 / 6	9.0	U	NA	9.0
OCDF[4]	ug/Kg					4 / 6	4.9	U	NA	4.9
PeCDF[4]	ug/Kg					5 / 6	15.3	U	NA	15.3
TCDD[4]	ug/Kg					2 / 6	0.5	U	NA	0.5
TCDF[4]	ug/Kg					6 / 6	34.1	U	NA	34.1
Fluoride	ug/Kg					1 / 2	3793000.0	U	NA	3793000.0

Notes:
1 – Distribution, N = Normal, L = Lognormal, U=Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – TCDD = Tetrachlorodibenzo–p–dioxin
PeCDD = Pentachlorodibenzo–p–dioxin
HxCDD = Hexachlorodibenzo–p–dioxin
HpCCD = Heptachlorodibenzo–p–dioxin
OCDD = Octachlorodibenz–p–dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

TABLE E.2–7
CPCs IN PIT 5

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Antimony	mg/Kg	5 / 6	64.0	U	NA	10 / 10	88.1	L	96.2	88.1
Arsenic	mg/Kg	6 / 6	2800.0	U	NA	8 / 10	715.0	N	561.3	2800.0
Barium	mg/Kg	6 / 6	36900.0	U	NA	10 / 10	18100.0	L	12941.7	36900.0
Beryllium	mg/Kg	6 / 6	18.0	U	NA	10 / 10	22.4	N	14.4	18.0
Cadmium	mg/Kg	4 / 6	17.0	U	NA	10 / 10	4.7	L	3.5	17.0
Chromium	mg/Kg	6 / 6	223.0	U	NA	10 / 10	108.0	L	92.5	223.0
Cobalt	mg/Kg	4 / 6	44.0	U	NA	10 / 10	17.1	L	12.0	44.0
Copper	mg/Kg	5 / 6	18200.0	U	NA	10 / 10	8680.0	N	5300.9	18200.0
Lead	mg/Kg	5 / 6	236.0	U	NA	10 / 10	134.0	L	109.8	236.0
Manganese	mg/Kg	6 / 6	4740.0	U	NA	10 / 10	599.0	N	501.6	4740.0
Molybdenum	mg/Kg					10 / 10	1350.0	L	1931.9	1350.0
Nickel	mg/Kg	6 / 6	247.0	U	NA	10 / 10	189.0	N	138.6	247.0
Thallium	mg/Kg	4 / 6	11.0	U	NA	4 / 10	52.0	U	NA	52.0
Vanadium	mg/Kg	6 / 6	5380.0	U	NA	10 / 10	4530.0	N	2794.5	5380.0
Aroclor 1248	ug/Kg	2 / 6	550.0	U	NA					550.0
Aroclor 1254	ug/Kg	2 / 6	750.0	U	NA					750.0
Cesium–137	pCi/g	2 / 6	76.0	U	NA	10 / 10	106.0	L	223.5	106.0
Neptunium–237	pCi/g	5 / 6	19.0	U	NA	3 / 3	83.0	U	NA	83.0
Plutonium–238	pCi/g	5 / 6	4.4	U	NA	3 / 10	0.3	U	NA	4.4
Plutonium–239/240	pCi/g	5 / 6	13.0	U	NA	5 / 10	3.7	U	NA	13.0
Radium–226	pCi/g					10 / 10	180.0	L	159.9	159.9
Radium–228	pCi/g					9 / 10	49.0	N	32.6	32.6
Ruthenium–106	pCi/g					2 / 10	1.6	U	NA	1.6
Strontium–90	pCi/g	6 / 6	31.0	U	NA	9 / 10	18.0	N	9.7	31.0
Technetium–99	pCi/g	6 / 6	2990.0	U	NA	10 / 10	3020.0	L	2247.5	2990.0
Thorium–228	pCi/g	6 / 6	44.0	U	NA	10 / 10	38.0	U	NA	44.0
Thorium–230	pCi/g	6 / 6	8480.0	U	NA	10 / 10	2600.0	U	NA	8480.0
Thorium–232	pCi/g	6 / 6	55.0	U	NA	7 / 10	10.0	U	NA	55.0
Thorium–Total	mg/Kg					8 / 10	92.0	U	92.0	92.0
Uranium–234	pCi/g	6 / 6	1250.0	U	NA	10 / 10	1400.0	N	892.9	1250.0
Uranium–235/236	pCi/g	6 / 6	79.0	U	NA	5 / 10	58.0	U	NA	58.0
Uranium–238	pCi/g	6 / 6	1230.0	U	NA	10 / 10	2800.0	L	1473.4	1473.4
Uranium–Total	mg/Kg					10 / 10	3700.0	N	2770.0	2770.0

Notes:
1 – Distribution, N=Normal, L=Lognormal, U=Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or WMC data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.

TABLE E.2-8

CPCs IN SURFACE WATER OF PIT 5

Parameter	Units	CIS Data: Frequency Detection	CIS Data: Maximum Value	CIS Data: Filtered/ Unfiltered	Representative Concentration[1]
Cyanide	ug/L	2 / 2	87.0	Unfiltered	87.0
Antimony	ug/L	2 / 2	4.5	Unfiltered	4.5
Arsenic	ug/L	2 / 2	2.1	Unfiltered	2.1
Barium	ug/L	2 / 2	108.0	Unfiltered	108.0
Copper	ug/L	2 / 2	21.0	Unfiltered	21.0
Lead	ug/L	2 / 2	2.9	Unfiltered	2.9
Nickel	ug/L	2 / 2	21.0	Unfiltered	21.0
Selenium	ug/L	2 / 2	2.1	Unfiltered	2.1
Vanadium	ug/L	2 / 2	47.0	Unfiltered	47.0
Cesium-137	pCi/L	2 / 2	90.0	Unfiltered	90.0
Strontium-90	pCi/L	2 / 2	41.0	Unfiltered	41.0
Technetium-99	pCi/L	2 / 2	320.0	Unfiltered	320.0
Thorium-230	pCi/L	2 / 2	0.1	Unfiltered	0.1
Uranium-234	pCi/L	2 / 2	420.0	Unfiltered	420.0
Uranium-235	pCi/L	2 / 2	19.0	Unfiltered	19.0
Uranium-238	pCi/L	2 / 2	400.0	Unfiltered	400.0
Benzene	ug/L	2 / 2	11.0	Unfiltered	11.0
Methylene Chloride	ug/L	2 / 2	2.0	Unfiltered	2.0
Toluene	ug/L	2 / 2	1.0	Unfiltered	1.0

Notes:
1 – Representative concentration is assumed to equal the maximum concentration detected.

TABLE E.2–9

CPCs IN PIT 6

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Arsenic	mg/kg	1 / 1	7.6	U	NA	9 / 9	76.7	L	65.3	65.3
Beryllium	mg/kg	1 / 1	5.7	U	NA	9 / 9	2.1	N	1.5	5.7
Cadmium	mg/kg	1 / 1	5.7	U	NA	1 / 9	1.3	U	NA	5.7
Lead	mg/kg	1 / 1	60.0	U	NA	9 / 9	113.0	L	90.4	90.4
Silver	mg/kg	1 / 1	158.0	U	NA	7 / 9	9.2	L	12.7	158.0
Aroclor 1254	ug/Kg	1 / 4	81.0	U	NA					81.0
Cesium–137	pCi/g	3 / 4	31.0	U	NA	9 / 9	14.0	N	10.6	31.0
Neptunium–237	pCi/g	4 / 4	3.6	U	NA					3.6
Plutonium–238	pCi/g	4 / 4	1.4	U	NA	6 / 9	1.0	U	NA	1.4
Plutonium–239/240	pCi/g	4 / 4	15.0	U	NA	9 / 9	14.0	N	11.1	15.0
Radium–226	pCi/g					9 / 9	4.9	L	4.3	4.3
Radium–228	pCi/g					9 / 9	191.0	L	257.5	191.0
Strontium–90	pCi/g	4 / 4	5.1	U	NA	6 / 9	4.8	U	NA	5.1
Technetium–99	pCi/g	4 / 4	164.0	U	NA	5 / 9	45.0	U	NA	164.0
Thorium–228	pCi/g	4 / 4	1.2	U	NA	9 / 9	1.7	N	1.5	1.5
Thorium–230	pCi/g	4 / 4	44.0	U	NA	9 / 9	62.0	N	45.2	45.2
Thorium–232	pCi/g	4 / 4	1.2	U	NA	9 / 9	1.0	N	0.7	1.2
Uranium–234	pCi/g	4 / 4	5330.0	U	NA	9 / 9	4064.0	L	3455.2	5330.0
Uranium–235/236	pCi/g	4 / 4	1750.0	U	NA	9 / 9	337.0	L	286.4	1750.0
Uranium–238	pCi/g	4 / 4	18700.0	U	NA	9 / 9	28746.0	L	22721.3	22721.3
Uranium–Total	mg/kg					9 / 9	27733.0	L	45960.0	27733.0
Tetrachloroethene	ug/Kg	4 / 4	29000.0	U	NA					29000.0

Notes:

1 – Distribution, N=Normal, L=Lognormal, U=Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).

2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.

3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RI/FS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.

4 – Laboratory contaminant, not considered a CPC.

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TABLE E.2-10

CPCs IN SURFACE WATER OF PIT 6

Parameter	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Filtered/ Unfiltered	Representative Concentration[1]
Antimony	ug/L	1 / 5	1.7	Unfiltered	1.7
Lead	ug/L	1 / 5	2.9	Unfiltered	2.9
Radium-228	pCi/L	5 / 5	31.3	Unfiltered	31.3
Technetium-99	pCi/L	5 / 5	3500.0	Unfiltered	3500.0
Thorium-230	pCi/L	2 / 5	0.3	Unfiltered	0.3
Uranium-234	pCi/L	5 / 5	77.0	Unfiltered	77.0
Uranium-235	pCi/L	5 / 5	9.3	Unfiltered	9.3
Uranium-238	pCi/L	5 / 5	460.0	Unfiltered	460.0
Chloroform	ug/L	4 / 5	3.0	Unfiltered	3.0
Tetrachloroethene	ug/L	5 / 5	2.0	Unfiltered	2.0
Toluene	ug/L	4 / 5	6.0	Unfiltered	6.0

Notes:
1 – Representative concentration is assumed to equal the maximum concentration detected.

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TABLE E.2–11

CPCs IN BURN PIT – SOLID CONTENTS

		CIS Data				RIFS Data				
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]
Antimony	mg/Kg	1 / 7	0.6	U	NA	2 / 4	17.8	U	NA	17.8
Arsenic	mg/Kg	5 / 7	21.0	U	NA	4 / 4	39.2	U	NA	39.2
Beryllium	mg/Kg	5 / 7	16.0	U	NA	4 / 4	1.9	U	NA	1.9
Cadmium	mg/Kg	7 / 7	35.0	U	NA	4 / 4	5.4	U	NA	5.4
Chromium	mg/Kg	7 / 7	88.0	U	NA	4 / 4	91.2	U	NA	91.2
Lead	mg/Kg	5 / 7	53.0	U	NA	4 / 4	279.0	U	NA	279.0
Silver	mg/Kg	2 / 6	506.0	U	NA	4 / 4	21.6	U	NA	21.6
Vanadium	mg/Kg	3 / 6	290.0	U	NA	4 / 4	43.3	U	NA	43.3
Aroclor 1242	ug/Kg	1 / 7	290.0	U	NA					290.0
Aroclor 1248	ug/Kg	1 / 7	200.0	U	NA					200.0
Aroclor 1254	ug/Kg	5 / 7	2700.0	U	NA	3 / 4	7700.0	U	NA	7700.0
Neptunium–237	pCi/g	2 / 6	0.6	U	NA					0.6
Plutonium–238	pCi/g	1 / 6	0.5	U	NA					0.5
Plutonium–239/240	pCi/g	1 / 6	0.4	U	NA					0.4
Radium–226	pCi/g				0.0	4 / 4	39.2	U	NA	39.2
Radium–228	pCi/g				0.0	4 / 4	10.4	U	NA	10.4
Ruthenium–106	pCi/g				0.0	2 / 4	1.5	U	NA	1.5
Technetium–99	pCi/g	4 / 6	64.0	U	NA	4 / 4	3.3	U	NA	64.0
Thorium–228	pCi/g	6 / 6	19.0	U	NA	4 / 4	900.0	U	NA	900.0
Thorium–230	pCi/g	6 / 6	218.0	U	NA	4 / 4	4530.0	U	NA	4530.0
Thorium–232	pCi/g	6 / 6	21.0	U	NA	4 / 4	410.0	U	NA	410.0
Thorium–Total	mg/Kg				0.0	4 / 4	3700.0	U	NA	3.7
Uranium–234	pCi/g	6 / 6	415.0	U	NA	4 / 4	1711.0	U	NA	1711.0
Uranium–235/236	pCi/g	6 / 6	27.0	U	0.0	4 / 4	102.0	U	NA	102.0
Uranium–238	pCi/g	6 / 6	454.0	U	NA	4 / 4	1996.0	U	NA	1996.0
Uranium–Total	mg/Kg				0.0	4 / 4	4458.0	U	NA	4.5

TABLE E.2–11
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
2–Methylnaphthalene	ug/Kg	1 / 7	50.0	U	NA	2 / 5	820.0	U	NA	820.0
Benzo(A)Anthracene	ug/Kg	4 / 7	170.0	U	NA	2 / 5	6300.0	U	NA	6300.0
Benzo(A)Pyrene	ug/Kg	1 / 7	160.0	U	NA	2 / 5	3900.0	U	NA	3900.0
Benzo(B)Fluoranthene	ug/Kg	4 / 7	170.0	U	NA	1 / 5	9600.0	U	NA	9600.0
Benzo(G,H,I)Perylene	ug/Kg	1 / 7	85.0	U	NA	2 / 5	2900.0	U	NA	2900.0
Benzo(K)Fluoranthene	ug/Kg	1 / 7	200.0	U	NA	1 / 5	340.0	U	NA	340.0
Bis(2–Ethylhexyl) Phthalate	ug/Kg	5 / 7	2000.0	U	NA	3 / 5	9700.0	U	NA	9700.0
Chrysene	ug/Kg	3 / 7	83.0	U	NA	2 / 5	7000.0	U	NA	7000.0
Dibenzofuran	ug/Kg				0.0	1 / 5	900.0	U	NA	900.0
Indeno(1,2,3–Cd)Pyrene	ug/Kg	1 / 7	78.0	U	NA	2 / 5	2200.0	U	NA	2200.0
Pentachlorophenol	ug/Kg	2 / 7	2600.0	U	NA					2600.0
Phenanthrene	ug/Kg	4 / 7	190.0	U	NA	3 / 5	15000.0	U	NA	15000.0
2–Hexanone	ug/Kg				0.0	1 / 4	2.0	U	NA	2.0
Vinyl Chloride	ug/Kg				0.0	1 / 4	3.0	U	NA	3.0
1,2,3,4,6,7,8–HpCDD[4]	ug/Kg				0.0	2 / 4	0.5	U	NA	0.5
1,2,3,4,6,7,8–HpCDF[4]	ug/Kg				0.0	2 / 4	0.3	U	NA	0.3
1,2,3,4,7,8,9–HpCDD[4]	ug/Kg				0.0	1 / 4	0.3	U	NA	0.3
HpCDD[4]	ug/Kg				0.0	2 / 4	1.0	U	NA	1.0
HpCDF[4]	ug/Kg				0.0	1 / 4	0.3	U	NA	0.3
OCDD[4]	ug/Kg				0.0	2 / 4	4.0	U	NA	4.0
OCDF[4]	ug/Kg				0.0	2 / 4	0.3	U	NA	0.3

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – TCDD = Tetrachlorodibenzo–p–dioxin
PeCDD = Pentachlorodibenzo–p–dioxin
HxCDD = Hexachlorodibenzo–p–dioxin
HpCCD = Heptachlorodibenzo–p–dioxin
OCDD = Octachlorodibenzo–p–dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

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TABLE E.2-12

CPCs IN THE CLEARWELL – SOLID CONTENTS

		CIS Data				RIFS Data				
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration
Antimony	mg/Kg	2 / 4	32.0	U	NA	5 / 7	10.9	U	NA	32.0
Arsenic	mg/Kg	4 / 4	18.0	U	NA	6 / 7	59.1	U	NA	59.1
Barium	mg/Kg	4 / 4	6910.0	U	NA	7 / 7	1790.0	N	1569.9	6910.0
Beryllium	mg/Kg	4 / 4	9.1	U	NA	7 / 7	2.9	L	3.2	9.1
Cadmium	mg/Kg	2 / 4	7.2	U	NA	7 / 7	2.9	L	7.0	7.2
Chromium	mg/Kg	4 / 4	76.0	U	NA	7 / 7	196.0	N	148.4	148.4
Copper	mg/Kg	4 / 4	1120.0	U	NA	7 / 7	3320.0	L	18483.3	3320.0
Lead	mg/Kg	4 / 4	83.0	U	NA	7 / 7	588.0	N	417.1	417.1
Manganese	mg/Kg	4 / 4	1660.0	U	NA	7 / 7	19800.0	N	12661.4	12661.4
Thallium	mg/Kg	1 / 4	2.1	U	NA	4 / 7	1.6	U	NA	2.1
Vanadium	mg/Kg	4 / 4	2600.0	U	NA	7 / 7	285.0	L	351.5	2600.0
Aroclor 1242	ug/Kg	1 / 4	121.0	U	NA					121.0
Aroclor 1248	ug/Kg	1 / 4	308.0	U	NA					308.0
Aroclor 1254	ug/Kg	4 / 4	737.0	U	NA					737.0
Cesium-137	pCi/g	4 / 4	450.0	U	NA	6 / 6	71.4	U	NA	450.0
Neptunium-237	pCi/g	3 / 4	2.2	U	NA	4 / 6	1.8	U	NA	2.2
Plutonium-238	pCi/g					5 / 6	0.5	U	NA	0.5
Plutonium-239/240	pCi/g					5 / 6	0.5	U	NA	0.5
Radium-226	pCi/g					6 / 6	170.0	U	NA	170.0
Radium-228	pCi/g					6 / 6	26.4	U	NA	26.4
Strontium-90	pCi/g	4 / 4	26.0	U	NA	2 / 6	12.8	U	NA	26.0
Technetium-99	pCi/g	2 / 4	278.0	U	NA	6 / 6	695.0	U	NA	695.0
Thorium-228	pCi/g	4 / 4	56.0	U	NA	6 / 6	28.1	U	NA	56.0
Thorium-230	pCi/g	4 / 4	5600.0	U	NA	6 / 6	314.0	U	NA	5600.0
Thorium-232	pCi/g	4 / 4	39.0	U	NA	6 / 6	9.7	U	NA	39.0
Thorium-Total	mg/Kg					6 / 6	88.9	U	NA	0.1
Uranium-234	pCi/g	4 / 4	376.0	U	NA	6 / 6	1050.0	U	NA	1050.0
Uranium-235/236	pCi/g	4 / 4	49.0	U	NA	6 / 6	373.0	U	NA	373.0
Uranium-238	pCi/g	4 / 4	670.0	U	NA	6 / 6	1640.0	U	NA	1640.0
Uranium-Total	mg/Kg					6 / 6	2780.0	U	NA	2780.0

TABLE E.2-12
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]
Benzo(A)Anthracene	ug/Kg	2 / 4	890.0	U	NA					890.0
Benzo(A)Pyrene	ug/Kg	1 / 4	670.0	U	NA					670.0
Benzo(B)Fluoranthene	ug/Kg	1 / 4	710.0	U	NA					710.0
Benzo(G,H,I)Perylene	ug/Kg	1 / 4	230.0	U	NA					230.0
Benzo(K)Fluoranthene	ug/Kg	1 / 4	750.0	U	NA					750.0
Chrysene	ug/Kg	3 / 4	1000.0	U	NA					1000.0
Indeno(1,2,3-Cd)Pyrene	ug/Kg	1 / 4	270.0	U	NA					270.0
Phenanthrene	ug/Kg	4 / 4	2100.0	U	NA					2100.0

Notes:
1 – Distribution, N=Normal, L=Lognormal, U=Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% non
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data se is the lower of the maximum detected value or the 95% upper confidence limit.
4 – The 95th percentile background concentrations for subsurface soil are compared with maximum values.

TABLE E.2-13

CPCs IN THE SURFACE WATER OF THE CLEARWELL

Parameter	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Filtered/ Unfiltered	Representative Concentration[1]
Cyanide	ug/L	1 / 2	87.0	Unfiltered	87.0
Arsenic	ug/L	2 / 2	4.2	Unfiltered	4.2
Copper	ug/L	2 / 2	19.0	Unfiltered	19.0
Manganese	ug/L	2 / 2	20.0	Unfiltered	20.0
Selenium	ug/L	1 / 2	3.0	Unfiltered	3.0
Silver	ug/L	2 / 2	14.0	Unfiltered	14.0
Vanadium	ug/L	2 / 2	513.0	Unfiltered	513.0
Radium-226	pCi/L	2 / 2	1.1	Unfiltered	1.1
Technetium-99	pCi/L	2 / 2	4030.0	Unfiltered	4030.0
Thorium-230	pCi/L	1 / 2	0.4	Unfiltered	0.4
Uranium-234	pCi/L	2 / 2	1900.0	Unfiltered	1900.0
Uranium-235	pCi/L	2 / 2	120.0	Unfiltered	120.0
Uranium-238	pCi/L	2 / 2	6200.0	Unfiltered	6200.0
2-Nitrophenol	ug/L	1 / 2	4.0	Unfiltered	4.0
Acetone	ug/L	1 / 2	520.0	Unfiltered	520.0

Notes:
1 – Representative concentration is assumed to equal the maximum concentration detected.

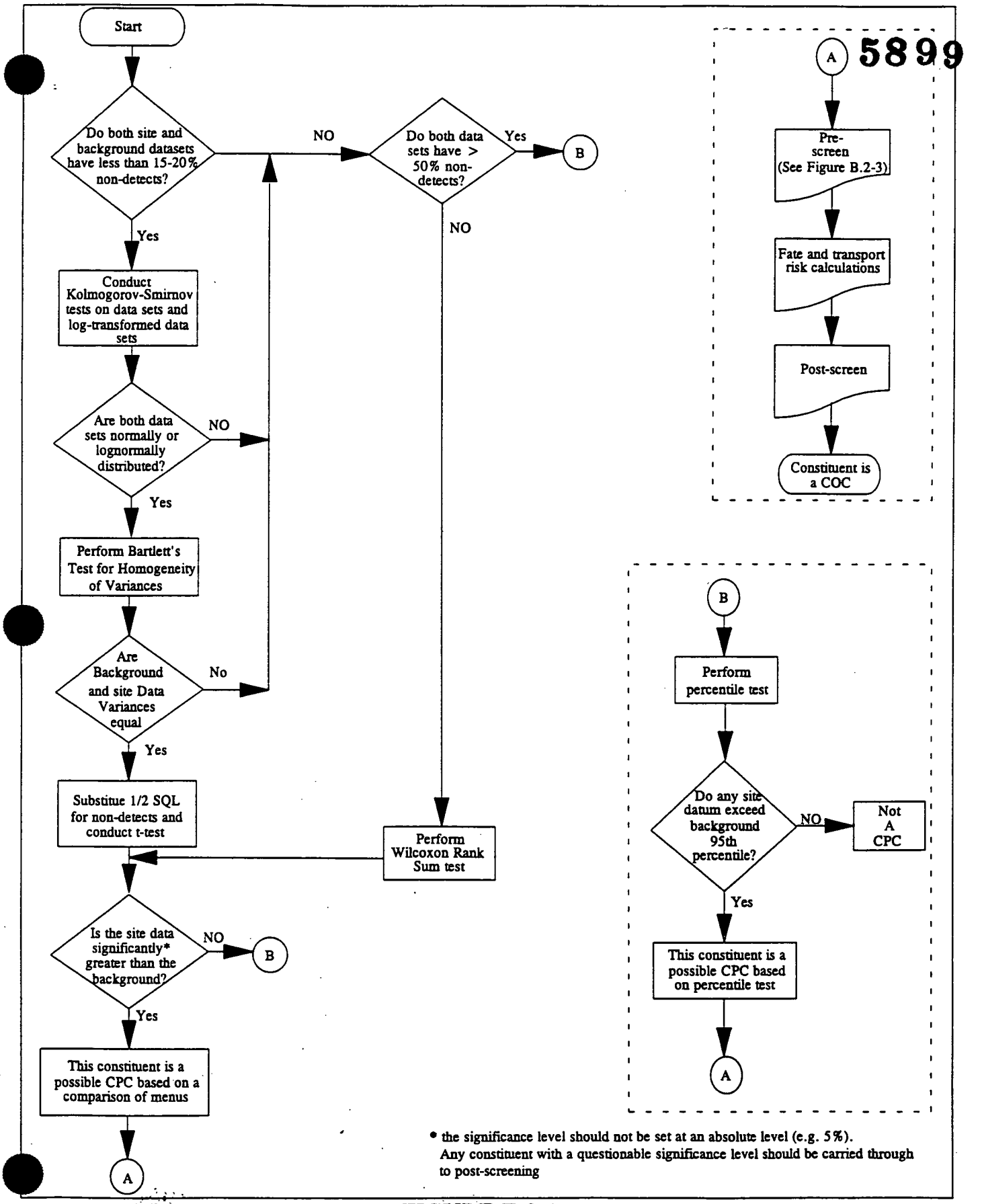

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FIGURE E.2-1
CONSTITUENT OF POTENTIAL CONCERN (CPC) SELECTION PROCESS

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E.3.0 HUMAN EXPOSURE ASSESSMENT

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The exposure assessment defines and evaluates the route, magnitude, frequency, and duration of exposure of a population to site-related constituents of potential concern (CPC) (identified in Section E.2.0). Exposure levels for specific receptor populations are estimated by a combination of direct measurements of chemical concentrations in the environment and fate and transport modeling (Section 5.0 and Appendix D of the Remedial Investigation Report (RI) which predicts concentrations of site contaminants in environmental media at potential points of exposure. Human activity patterns are also a key determinant in predicting the nature and magnitude of potential exposures. Factors relating to human activity include the frequency of contact with contaminated media, exposure duration, and the types of activities in which a person engages. These elements of the exposure assessment are integrated to provide a quantitative estimate of chemical exposure, which is then combined with information from the toxicity assessment (Section E.4.0) to estimate potential health risks to receptor populations (Section E.5.0). Attachment E.III presents example calculations for intake and risk based on the exposure models presented in this section. This attachment also gives chemical specific exposure values used to calculate intakes and risk for all receptors.

The general procedure for conducting an exposure assessment involves three stages:

- Characterize the physical setting
- Identify migration and exposure pathways
- Quantify exposure

In the first stage, the general physical characteristics of the site and characteristics of potential receptor populations are described. Site characteristics such as climate, vegetation, and hydrogeology are discussed in Section 3.0 of the Operablane Unit 1 RI report and summarized in Section E.3.2. Land use and demographic information are also evaluated in Section E.3.2 to identify and characterize current and potential future (hypothetical) receptor populations. In the second stage of the exposure analysis, the specific sources, releases, types, and locations of chemicals at the site; the environmental fate of chemical and radioactive constituents; and the locations and activities of potentially exposed populations are identified. These are examined to identify the predominant migration and exposure pathways for Operable Unit 1. Section E.3.3 presents the results of this analysis in the form of a conceptual site model for Operable Unit 1.

Exposure magnitude, frequency, and duration are then quantified for each identified pathway and receptor. Section E.3.4 presents the determination of exposure point concentrations, and Section E.3.5 presents information on the methods used to quantify exposure for various pathways. Section E.3.6 presents the results of the exposure assessment.

E.3.1 DEVIATIONS FROM THE RISK ASSESSMENT WORK PLAN ADDENDUM

This section presents Operable Unit 1-specific deviations from the Risk Assessment Work Plan Addendum (RAWPA)(DOE 1992a), which are relevant to the exposure assessments. These variations are presented in a series of brief summaries with the rationale for each deviation. Additional details are provided in the appropriate sections of the exposure assessment. Deviations generally applicable to the Operable Unit 1 risk assessment are presented in Section E.1.0. Exposure assessment-specific deviations are presented in this section.

E.3.1.1 Exposure Scenarios and Receptors

No trespassing youth is evaluated for Operable Unit 1 under current land use scenarios with existing access controls. Unlike several other operable units at the Fernald Environmental Management Project (FEMP), Operable Unit 1 is not only surrounded by the property fence, but by a second internal security fence as well. The fences, in combination with active security patrols, make it highly unlikely that a trespassing child could be exposed to the soil and/or waste pit contents under current land use conditions with active access controls. The trespassing youth is evaluated under current land use scenarios without access controls.

Another receptor presented in the Work Plan Addendum that is not addressed in this exposure assessment is the on-property building user. Under current land use conditions, no buildings exist within the Operable Unit 1 boundaries.

Two new receptors which do not appear in the RAWPA are evaluated in the Operable Unit 1 risk assessment. One is an expanded trespasser, intended to evaluate impacts on an individual who trespasses both as as child (12 years) and as an adult (32 years). The other receptor is the groundskeeper who tends the grass and performs general site maintenance.

E.3.1.2 Exposure Input Parameters

Several exposure input parameters were modified from those used in the Risk Assessment Work Plan Addendum (DOE 1992a), based on either the acquisition of more representative values and/or U.S. Environmental Protection Agency, Region V guidance. Specifically, revised soil ingestion rates for the resident farmer receptor were used in this risk assessment, as well as in the risk assessment conducted for Operable Unit 4. Derivation of this parameter is contained in Section E.3.5.6.5. Various dermal exposure parameters were also modified to incorporate EPA's dermal guidance documents (EPA 1992e). These deviations are discussed in Section E.3.5.6.9.

E.3.1.3 Exposure Estimation and Methodologies

In response to EPA comments received on the Risk Assessment Work Plan Addendum, an alternate inhalation model for showering exposure was used in this risk assessment. EPA indicated that a model by Andelman (EPA 1991f) was the preferred model for indoor inhalation of chemicals volatilized, so this model was incorporated in this document (as described in Section E.3.5.2.2).

EPA Region V made additional comments on the Work Plan regarding dermal exposures. This risk assessment incorporates the latest EPA dermal guidance (see Section E.3.5.2.3 for further discussion).

Publication of new slope factors for radionuclides also resulted in a change in the way direct radiation exposures are calculated from that described in the Risk Assessment Work Plan Addendum (see Section E.3.5.1.3).

E.3.2 CHARACTERIZATION OF EXPOSURE SETTING

The Operable Unit 1 Study Area includes part of the FEMP and its surrounding environment. The following is a summary description of Operable Unit 1 Study Area characteristics that may be affected by proposed remedial activities at the FEMP or that may have a bearing on the study. More detailed descriptions of the local geography, surface topography, demographics, geology and hydrogeology, and ecology are presented in Section 3.0 of the Operable Unit 1 RI Report.

E.3.2.1 Climate and Meteorology

Information on the local climate was gathered from two primary sources — an on-property meteorological system installed at the FEMP in 1986 and the National Weather Service Office at the Greater Cincinnati Northern Kentucky International Airport. The FEMP meteorological station was installed in 1986 to collect site-specific data for wind speed and direction, ambient air temperature, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation.

The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.2°F in January to 75.7°F in July. The highest temperature recorded from 1960 through 1989 was 103°F in July 1988, and the lowest was -25°F in January 1977. The average number of days per year with a minimum temperature of 32°F or less is 109 days, and the average number of days per year with a maximum temperature of 90°F or greater is 20 days. Yearly frost depth ranges from 30 to 36 inches.

The average annual precipitation for the Cincinnati area for the period of 1960 through 1989 was 40.56 inches and ranged from 27.99 inches in 1963 to 52.76 inches in 1979. The highest precipitation occurs during the spring and early summer; precipitation is typically lowest in late summer and fall. The average annual snowfall for the 1960 to 1989 period was 23.5 inches, with the heaviest snowfall in January. The total rainfall from January 1991 to January 1992 was 43.08 inches with the heaviest rainfall at 6.2 inches in November 1991. The total snowfall from January 1991 to January 1992 was 12.9 inches, with the heaviest snowfall at 4.3 inches in January 1992.

A study by IT Corporation (IT 1986) indicates that National Oceanic and Atmospheric Administration (NOAA) wind flow data from the airport at Cincinnati were sufficiently representative of local conditions to serve as a database for the years prior to the installation of the on-property meteorological system. The FEMP meteorological station data indicates that two major terrain features, the Great Miami River Valley and the ridges surrounding the site, affect the wind patterns.

Figure E.3-1 shows the wind pattern recorded from a 10-meter tower at the FEMP in 1992. Prevailing winds are from the southwest and west-southwest. Section 5 of the Operable Unit

1 RI Report presents a more detailed frequency distribution summary of the numerical data from which the FEMP wind rose was generated.

E.3.2.2 Topography and Surface Hydrology

Operable Unit 1 is located above the floodplain of the Great Miami River drainage basin. It rests on a relatively level plain at about 580 feet above MSL. Drainage from Operable Unit 1 is currently regulated by engineering controls. These controls are assumed to fail sometime in the future, allowing the study area's topography to determine the flow of surface water. Surface water drainage of Operable Unit 1 historically flowed from east to west into Paddys Run Creek (Paddys Run). Paddys Run, an intermittent tributary of the Great Miami River that runs along the western boundary of Operable Unit 1 lies between the waste storage area and the western property boundary of the FEMP.

Paddys Run originates north of the FEMP, flows southward along the western boundary of the facility, and enters the Great Miami River approximately 1.5 miles south of the southwest corner of the FEMP property at river mile 19.5. The stream is about 8.8 miles long and drains an area of approximately 15.8 square miles. Paddys Run is a steep-sided intermittent stream and its banks erode severely during high flow periods. This drainage has cut six feet or more through the silty clay near surface deposits upon which the facility is built. In 1961 and 1962, the course of the stream was altered to prevent it from eroding into the Operable Unit 1 Study Area (WEMCO 1987).

As stated previously, stream flow in Paddys Run is intermittent, occurring only during periods of high precipitation. The stream is ungauged and peak flows occurring during storm events have not been measured. Typical flows for the January through May period range from 0.2 to 4.0 cubic feet/second (ft^3/s), based on best engineering judgment.

E.3.2.3 Soil and Geology

Soils in the region of the FEMP were formed from materials deposited by the Wisconsin and Illinoisan glaciers. These parent materials consist mainly of glacial till, but also include sand, gravel, glacial-lake clays, and silt clays.

The major soils in the Operable Unit 1 Study Area are Fincastle silt loams, which also cover large areas west of the FEMP. These soils are light colored, medium acidic, and moderately

high in productivity when properly managed. Moisture-supplying capacity is moderate, as are fertility and organic content. The Fincastle series consists of deep, nearly level, somewhat poorly drained soils on broad flatlands. Permeability is low and the available water capacity is high. In areas where these soils are predominant, artificial drainage is required for moderate crop productivity. For a discussion of pit berms, refer to Section 1.0 of the RI.

There is also a considerable amount of fill present in the waste storage area. This fill material has been placed in the berms around the waste pits.

E.3.2.4 Groundwater

The FEMP overlies a 2- to 3-mile-wide buried Pleistocene Valley known as the New Haven Trough. This valley was formed by the ancestral Ohio River during the Pleistocene and subsequently filled with glacial outwash materials that were in turn covered by glacial overburden. The outwash deposits in this buried valley under the FEMP are a part of the Great Miami Aquifer, which is a widely distributed buried valley aquifer. The valley fill aquifer system serves as a major source of domestic, municipal, and industrial water in the southwestern Ohio area.

The distribution of the overburden materials beneath the Operable Unit 1 Study Area are discussed in detail in Section 3.0 of the Operable Unit 1 RI Report. Much of the material within 10 feet of the ground surface has been reworked by FEMP activities and is no longer considered native material. The thickness of the glacial material beneath the Operable Unit 1 Study Area before waste pit construction ranged from 0 feet along Paddys Run to over 40 feet at monitoring well 2027. The glacial overburden present beneath Operable Unit 1 is composed of primarily gray and brown clays and silts and represent Wisconsinan age glacial material. Sand and gravel stringers and beds found within the glacial overburden are undifferentiated glaciofluvial outwash deposits. Within the glacial overburden, beds and stringers of fine sand to coarse gravels are present. The more coarse-grained sediment at some locations in the waste storage area is continuous and can be correlated between two or more nearby wells. Several sand and gravel interbeds are present in the vicinity of Waste Pits 4 and 5, and may be hydraulically connected. Another sand and gravel interbed is observed in the vicinity of monitoring wells 1019, 1076, and 1021.

There is approximately 20 feet of unsaturated sand and gravel between the glacial overburden and the Great Miami Aquifer. Groundwater present in the sand and gravel interbeds is considered perched because it is present in the glacial overburden above the Great Miami Aquifer. Depth to the perched water is approximately 5 feet below the bottom of the waste pits. [Groundwater elevations within Operable Unit 1 tend to be highest in the vicinity of Waste Pits 4 and 6.] There is a relatively low perched water gradient across most of the waste storage area, before water levels drop off sharply toward Paddys Run. The perched groundwater table follows the general topography of the waste storage area and implies flow through the overburden from northeast to southwest.

Slug test data from FEMP investigations indicate that the perched water yields less than 5 gpm. However, at this gpm, it was not determined if this yield could be sustained over a period of time. It is not likely that any well in the perched groundwater zone could sustain a yield for a prolonged period of time (i.e., years of constant use), because the lateral extent of the most permeable zones is limited. Relative to the Great Miami Aquifer, the perched water does not have a significant yield. The yield of the Great Miami Aquifer is typically capable of more than 18.4 mgd (million gallons per day), between 2 to 5 orders of magnitude greater than that of the glacial overburden.

Groundwater flow in the glacial overburden varies from saturated to partially saturated to unsaturated flow in the waste storage area. Saturated groundwater flow is generally observed from late winter to late spring, when precipitation events are common and the fine-grained material present in the overburden is saturated. When the fine-grained material is saturated, groundwater is present in the more coarse-grained sand and gravel interbeds as well as the joints and fractures observed in the unstratified till. Partially saturated and unsaturated flows are observed during drier periods of the year, when the finer-grained materials (silt and clay) become unsaturated and water is no longer present in the more coarse interbeds (sand and gravel) and clay/fractures. Saturated flow conditions occur in the Great Miami Aquifer.

E.3.2.5 Vegetation and Wildlife

Ecological communities on the FEMP consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, and riparian woodlands. A total of 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of

amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates inhabit the FEMP.

Typical grasses found on the FEMP are red fescue, Kentucky bluegrass, timothy, and red top. Herbs include teasel, red and white clovers, and goldenrod. The dominant tree species in the pine plantations are white and Austrian pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shagbark hickory, and slippery elm. Dominant tree species in the riparian woodlands are eastern cottonwood, hackberry, American elm, and box elder. Mammal species observed on the FEMP include white-tailed deer, coyote, red fox, opossum, raccoon, groundhog, eastern cottontail, fox squirrel, and several species of bats. Common small mammals are the white-footed mouse, short-tailed shrew, meadow vole, meadow jumping mouse, and eastern chipmunk. The most common birds breeding on site include the mourning dove, American robin, blue jay, American crow, American goldfinch, northern bobwhite, and common grackle. Species occurring in the greatest density are the goldfinch, song sparrow, and robin. Raptor species observed on site are the northern harrier, red-shouldered hawk, Cooper's hawk, red-tailed hawk, and American kestrel. The eastern screech owl and great horned owl are also common. Amphibians and reptiles that occur on the FEMP include the American toad, spring peeper, eastern box turtle, and snapping turtle. Several species of snakes also occur on site, including the eastern garter snake, Butler's garter snake, black rat snake, northern water snake, and the queen snake. Approximately 130 insect families from 15 orders are represented in FEMP habitats. Leaf hoppers are abundant in all habitats, although less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

The results of a survey indicated that wetlands at the FEMP are limited to a forested wetland of approximately 50 acres in the northern portion of the facility and emergent wetlands associated with tributaries and drainage ditches that feed into Paddys Run (DOE 1992d). The stretch of Paddys Run adjacent to Operable Unit 1 is characterized as an unvegetated stream channel incised into surrounding uplands. Unvegetated stream channels do not meet the wetland criteria and would be classified as "other waters of the United States." As such, they would not be protected by wetlands regulations, but remedial actions affecting them would still be subject to the substantive requirements of the Clean Water Act.

E.3.2.6 Demography

The FEMP is located approximately 18 miles northwest of Cincinnati, and is the focal point of a regional market encompassing the following eight counties: Butler, Clermont, Hamilton, and Warren counties in Ohio; Boone, Campbell, and Kenton counties in Kentucky; and Dearborn County, Indiana. These eight counties also define the Cincinnati Consolidated Metropolitan Statistical Area. Population within the eight-county metropolitan area was more than 1.7 million in 1990, and within a 5-mile radius of the FEMP there was an estimated 22,927 residents. Labor force in the multi-county area was more than 920,000 with unemployment at approximately 5.5 percent in December of 1991.

The cities of Hamilton and Fairfield are located six and eight miles northeast of the FEMP, respectively. Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FEMP. Concentrations of residential units are situated (1) immediately north of the FEMP; (2) in Ross, and (3) directly east in a trailer park at the intersection of Willey Road and State Route 128. Other residences are scattered around the area, generally associated with farmsteads.

The nearest resident is located within 0.75 mile from the center of the facility. The nearest residences to the western FEMP property boundary (the boundary along the eastern side of Paddys Run Road) are located along the western side of Paddys Run Road. A dairy farm is located on Willey Road just outside the southeast corner of the FEMP property boundary (leased grazing areas include areas inside the FEMP property boundary). Several residences are located off Paddys Run Road approximately 0.5 mile south of the FEMP property boundary and along New Haven Road approximately 1 mile south of the FEMP property boundary. These residences are in the vicinity of the South Plume, a portion of the Great Miami Aquifer that contains a plume of uranium contamination that extends south of the FEMP property boundary approximately 0.75 mile.

E.3.2.7 Land Use

The land adjacent to the FEMP is primarily devoted to open land use such as agriculture and recreation. Agricultural activities include dairy, beef, corn, and soy bean production (refer to Figure E.1-3). Commercial activity is generally restricted to the village of Venice (Ross), approximately 3 miles northeast of the facility, and along State Route 128 just south of Fernald. More than 400 acres of the open land on the FEMP are currently being leased to

local dairymen for livestock grazing. Pine plantations are located northeast and southwest of the former Production Area. A considerable amount of the land within the boundaries of the FEMP are designated by the U.S. Department of Agriculture as prime agricultural land (USDA 1980, 1982).

Several industries, including Delta Steel, Albright & Wilson Chemical Company, Ruetgers-Nease Chemical Company, two commercial gravel operations, and a cement plant, are located south of the FEMP. Industrial use is concentrated along Paddys Run Road, in the village of Fernald, and in a small industrial park on State Route 128 between Willey Road and New Haven Road.

The Miami Whitewater Forest, a Hamilton County park is located within five miles of the FEMP. The former Camp Ross Trails, owned by the Great Rivers Girl Scout Council, is located approximately 1 mile northeast of the FEMP.

A security fence surrounds the entire FEMP property, and a second line of fences surrounds several internal areas, including Operable Unit 1. These fences are regularly patrolled by a full-time security force. These active (security patrols) and passive (fences) access controls are currently in place at the FEMP. No hunting or fishing is allowed on Operable Unit 1.

E.3.2.8 Future Land Use

It is difficult to develop reasonable future land use scenarios at government facilities. Because many current remedial alternatives include in situ, or continuing on-site waste management, a reasonable future land use scenario would be that the government retains control of the property and restricts access in perpetuity in order to prevent future exposures. This scenario is addressed in the Operable Unit 1 Baseline Risk Assessment by evaluating risks to the off-property farmer from future Operable Unit 1 sources.

In addition, because of the uncertainty associated with future sociopolitical activities, it is prudent to evaluate the effect of future potential exposures assuming that the government loses control of the land. For the purposes of the risk assessment, "future land use" refers to the unrestricted use of the property. Because some of the land surrounding the facility is currently used for farming, it is reasonable to assume that the FEMP property could be used as farm land at some time in the future. Scenarios that assume loss of institutional controls

provide the basis for determining the level of cleanup necessary in order to eliminate the need for ongoing institutional controls.

E.3.2.9 Critical Subpopulations

According to the Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A) (EPA 1989a), a baseline risk assessment must identify subpopulations of potential concern that could be at increased risk from radionuclide or chemical exposure from increased sensitivity, behavior patterns, and/or current or past exposures from other sources. These populations include infants and children, the elderly, pregnant and nursing women, individuals with chronic illnesses, and individuals previously exposed to chemicals or radionuclides during occupational activities or by residing in industrial areas. The current subpopulations of potential concern within five miles of the FEMP are identified below and are listed by the categories suggested by EPA (1989a). The information presented on sensitive subpopulations covers the area within five miles of the FEMP and covers the area within three to four miles of the leading edge of the South Plume. Within this distance from the South Plume the population difference based on 1990 census data is negligible and the descriptions of potential sensitive subpopulations are essentially the same. Subpopulations of potential concern are identified using 1990 census data.

- Schools — Northwest, Ross, and Southwest school districts provide public education from kindergarten through high school for children living within 5 miles of the FEMP. The 1989-90 total enrollment in the six schools from these districts FEMP was 3,316. No schools are located within 1 mile of the FEMP.
- Daycare Centers — No daycare facilities are located within 1 mile of the FEMP. Two daycare centers operate within the study area: 1) Ross County Day Nursery, with an average enrollment of 126 students per day and a total weekly enrollment of 180, is located north of the intersection of State Route 128 and U.S. 27 about two and one-half miles northeast of the center of the FEMP, and 2) Venice Presbyterian Pre-School, with an average daily enrollment of 30 and a total weekly enrollment of 110, is located in the village of Venice (Ross) approximately 2 miles northeast of the center of the FEMP.
- Hospitals, Nursing Homes, and Retirement Communities — No care facilities of these types operate within 5 miles of the FEMP.
- Residential Areas with Children — In 1988, approximately 58 adults and 29 children resided within 1 mile of the FEMP. Most of the residences within five miles of the FEMP are scattered and reflect the agricultural setting of the area. Population concentrations include Ross, Harrison, Shandon, Fernald, New Haven, New Baltimore, and one large trailer park. An estimated 8,140 children lived within 5 miles of the center of the FEMP in 1988.

- Commercial and Recreational Fisheries — No commercial fisheries operate within five miles of the center of the FEMP. Recreational fishing occurs on Whitewater Lake of the Miami Whitewater Forest Park. This heavily-stocked lake lies completely within five miles of the FEMP. The Great Miami River supports no commercial fisheries in the vicinity of the FEMP, but recreational fishing occurs downstream from the FEMP. The Ohio Department of Health issued a fishing advisory for PCBs in bottom-feeding fish in 1989 based on data collected by Ohio Environmental Protection Agency (OEPA). Chemical Lehman, another site on CERCLIS, is located in Ross, Ohio, approximately 2 miles from the FEMP.
- Major Industries Using Chemicals — No industrial facilities are located within one mile of the center of the FEMP. Two companies located within two miles of the FEMP center, Ruetgers-Nease Chemical Company and Albright and Wilson, store and handle chemicals. Collectively known as the Paddys Run Road Site, these facilities are classified as Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, are listed on the Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS), and are undergoing a state-led Remedial Investigation/Feasibility Study (RI/FS). Proctor & Gamble has a research facility approximately two miles east of the FEMP, which is listed on CERCLIS and has undergone a Screening Site Inspection by U.S. Environmental Protection Agency (EPA). Employees at these facilities are only considered a sensitive subpopulation if they reside within five miles of the FEMP.

Critical subpopulation, per se, are not evaluated quantitatively in the Operable Unit 1 baseline risk assessment. This demographic information is used to select receptors for the exposure assessments which provide an upperbound estimate on exposures to these sensitive populations. For example, exposures to children in off-property schools or day care facilities are not quantitatively evaluated. However, after careful consideration of the circumstances surrounding these children, it is concluded that exposures to these receptors will be much lower than exposures to the on-property resident child because of his low body weight and the accessibility to higher concentrations of constituents.

E.3.3 CONCEPTUAL SITE MODEL

Conceptual site models facilitate consistent and comprehensive evaluations of the risks to human health by creating a framework for identifying the paths by which human health may be impacted by contaminants found at Operable Unit 1. The conceptual site models depict the relationships between six elements necessary to construct a complete exposure pathway, as follows:

- Land use
- Sources and potential CPCs
- Release mechanisms

- Transport pathways
- Exposure mechanisms and exposure routes
- Receptors

Land use was the main delimiter used for risk presentation. As depicted in Table E.3-1, current and future land use scenarios are considered for this risk assessment. Under the current land use scenario, the site remains an industrial area. This situation is evaluated both with and without access controls. Two future land use configurations are evaluated. In one configuration, access restrictions continue and the area becomes a government reserve. The second scenario assumes that access controls are removed and the land returns to agricultural use.

The conceptual model developed for this assessment considers the sources that are assumed to be available, either currently or in the future. These sources include pits containing buried and exposed wastes, contaminated surface soil, or contaminated water in the open waste pits. Contaminants are released from these sources by mechanisms such as leaching to groundwater, erosion, volatilization, and overflow. Once released from the source(s), contaminants are transported in media such as air, groundwater, surface water, and sediment. Receptors may be exposed either directly or indirectly to contaminants in these media via a variety of mechanisms. The exposure mechanisms considered include using contaminated water for domestic and agricultural uses, raising plants and animals on contaminated soil, direct exposure to radiation, etc. These exposure mechanisms generally act along one or more exposure routes, such as ingestion or inhalation.

The conceptual site models indicate which exposure routes are carried through the quantitative risk assessment for each receptor under three land use definitions: current land use with access controls; current land use without access controls; and future land use. An objective of the development of the conceptual site model and analysis of exposure routes and receptors is to focus on those pathways and sources that contribute the most to the potential impacts on human health, and to provide the rationale for screening out other exposure pathways that are likely to pose minor risks.

E.3.3.1 Sources

Operations within the FEMP production area generated large quantities of liquid and solid wastes, and between 1952 and 1985, much of these wastes were disposed of in the waste

storage area. The radiological and chemical wastes in Operable Unit 1 represent a potential source of environmental contamination.

Operable Unit 1 is divided into eight waste pits and the surrounding soils. The eight waste pits are identified as Waste Pits 1 through 6, the Burn Waste Pit, and the Clearwell. At present, Waste Pits 5 and 6 and the Clearwell are filled with water. Waste Pits 1, 2, and 3 are covered by soil caps of varying thicknesses, and Waste Pit 4 is covered by a polyethylene cap on top of 6 feet of compacted clay. These waste pits represent the primary sources of concern in Operable Unit 1. Detailed descriptions of each waste pit, including its use and characteristics, are provided in the body of the RI Report. Subsurface soil outside the waste pits represents a minor source term in comparison to the wastes buried in the waste pits, thus, are not evaluated in this assessment.

In addition to the waste pits, surface soil both inside and outside of the waste pit boundaries has measurable levels of contamination available for transport via air and surface water erosion. These soils can also contribute to receptor exposures by direct contact, food chain, ingestion, and direct radiation pathways, and are therefore considered in the risk assessment.

E.3.3.2 Release Mechanisms

Two scenarios are defined with respect to release mechanisms and associated assumptions for the purpose of performing environmental fate and transport modeling:

- The current source term scenario
- The future source term scenario

These two source term scenarios bound the range of what may be reasonably expected to happen to the waste pits and soils in Operable Unit 1.

The current source term scenario used in this assessment reflects the physical state of the operable unit as it exists today. Land uses considered are current land use with or without access controls. The conceptual site model of the current source term, depicted in Figure E.3-2, is based on the following assumptions:

- Waste Pits 1, 2, and 3, and the Burn Pit are covered with soil
- Waste Pit 4 is covered with a RCRA cap (polyethylene over 6 feet of clay)
- Waste Pits 5 and 6 and the Clearwell are filled with water
- Infiltration through the site does not change
- Surface water runoff is collected by the existing drainage system (Removal Action 2)
- Vegetative cover remains unchanged
- The effects of radiological and chemical decay of the source are assumed to be minimal

Both solid and liquid source materials currently exist at Operable Unit 1. The release mechanisms for these sources are discussed separately. Sources containing solid materials are Waste Pits 1, 2, 3, and 4, the Burn Waste Pit, and remaining soil outside the waste pits themselves. Given the assumptions used to construct the current source term, release mechanisms acting on solid media are limited. Removal of exposed solid source materials can occur via wind erosion. Another mechanism releasing contaminants from solid wastes involves the emission of gases from the solid matrix as a result of either volatilization or radon generation. Releases via surface water runoff are not addressed in the current scenario, given the presence and assumed continued operation of the runoff control system. A secondary release mechanism from solid media is the uptake of contaminants in soil by plant roots and their subsequent ingestion (along with soil) by grazing cows should access controls be discontinued.

Releases from liquid source areas (Waste Pits 5 and 6 and the Clearwell) are not addressed in the current source term conceptual site model because the model is based on the assumption that the existing runoff collection system remains in operation. One secondary release mechanism considered, however, is the ingestion by cows of surface water from the waste pits or Clearwell should access controls be discontinued.

The conceptual model which uses the current source term does not consider existing contamination in groundwater or off-site sediment, as these media will be addressed in the Operable Unit 5 risk assessment. Only soil, surface water, and waste pit material from within the boundaries of Operable Unit 1 are considered in this assessment, as are groundwater,

surface water, and sediment contamination that has as its source the media within the boundaries of Operable Unit 1.

The future source term configuration is purely hypothetical. It assumes that the operable unit becomes part of a homestead, and is developed by considering both the site's current configuration and the processes that would act on it if all maintenance activities were discontinued. The future conceptual site model, shown in Figure E.3-3, is based on the following assumptions:

- The cover material over Waste Pits 1 and 2, and the Burn Waste Pit remains intact.
- The Waste Pit 4 polyethylene cap degrades and the clay material is exposed.
- Waste Pits 5 and 6 are only half-filled with water, and the other half of the waste pits' surface areas consist of exposed waste pit material as a result of evaporation or infiltration.
- Sediments on the bottom of the Clearwell remain covered with water because of its depth and steep sides.
- The cover material over Waste Pit 3 settles and buried wastes are exposed.
- Waste Pits 1 and 2 are irrigated and used to grow crops and animal feed.
- Infiltration through the site is altered by the changes in the water levels in the waste pits, the degraded cover of Waste Pit 3, and the use of irrigation on Waste Pits 1 and 2.
- Excess surface water runoff flows to Paddys Run.
- Vegetative cover is consistent with local agricultural practices and ecological succession.
- A house is placed on the most stable Waste Pit (Pit 4), and a well is drilled at the location producing the maximum risk.

The future scenario configuration is developed as described above for a number of reasons. Waste Pits 5 and 6 are assumed to be half-filled with water and have exposed waste material because the current waste "topography" is uneven and higher on one end than the other. Therefore, if water were to evaporate or infiltrate waste could be exposed. Half the area was used as an example.

Sediments in the Clearwell are assumed to remain covered with water. The sides of this pit are steep, and removal of part of the water would not result in exposure of sediments on the bottom.

It was assumed that the cover over Waste Pit 3 would settle because the pit material is semi-solid and therefore unstable. This instability is assumed to affect the integrity of the cover material, leading to settling and erosion of its exposed contents. In addition, because this pit is the largest in surface area and volume, exposing its contents is a conservative assumption.

The covers of Waste Pits 1, 2, and 4 and the Burn Pit were not assumed to erode in the future scenario. This assumption was made because the materials deposited within these waste pits consists primarily of solid (dry) wastes. Solid wastes are assumed to be more stable and less likely to settle and result in failure of the cover. Waste Pit 4 is covered with a RCRA cap (polyethylene over six feet of clay) that is assumed to significantly reduce or eliminate erosion of waste material. Waste Pits 1 and 2 and the Burn Pit are covered with soil and are assumed to be vegetated which significantly reduces erosion.

Of all the Waste pits, Pit 4 is considered to be the most stable. In addition, the groundwater beneath Waste Pit 4 is the most contaminated, therefore the installation of a well at this location was selected to be conservative. By default then, the home would also be constructed on this pit. However, the RCRA cap and high concentrations of contaminants in the pit material would retard grass growth, so topsoil was assumed to be emplaced after construction is complete.

Finally, since the resident farmer is being evaluated, the only area left for growing crops is Waste Pits 1 and 2. Their adjacent location makes this a suitable area. It was assumed that the soil caps remain intact, otherwise, crop growth would be unlikely to occur.

As with the current source term model, the conceptual site model does not consider existing groundwater, surface water, and sediment contamination, which are within the scope of Operable Unit 5.

Solid source areas are subject to additional release mechanisms from those considered for the current source term, as a result of the changed configuration that is assumed for these

scenarios. In addition to the mechanisms that apply to the current source term models, the following mechanisms are considered:

- Chemicals in solid source areas are subject to leaching by infiltrating rainwater. Chemicals in solution may migrate beyond the physical boundaries of the source area.
- Exposed waste pit materials can be released via surface water erosion, if the runoff collection system is no longer in operation. Constituents in the sources can be dissolved and transported in either ionic or colloidal form.

Sources that primarily contain liquids include Waste Pits 5 and 6 and the Clearwell. Under the future source term definition, the liquids in these sources may leach through the bottoms or sides of the individual units and eventually reach the groundwater. The liquids can also be transported via surface water runoff if the waste pits overflow. Escaped liquids can then flow over the ground surface and enter local drainage features, where they can flow in conjunction with the surface water.

The source terms considered for the groundwater transport modeling are limited to those materials that leach from the waste material and cover material inside the waste pit boundaries. Subsurface soil material located outside the waste pits exhibit much lower contaminant concentrations, and therefore are not considered in the modeling (see Appendix D).

E.3.3.3 Transport/Exposure Media

Once released to the environment, CPCs can enter several media which then convey the contaminants to the vicinity of a receptor. Media transporting contamination from a source are called transport media in this assessment. Once contamination has been transported to the vicinity of a receptor, the receptor can be exposed during contact with one or more contaminated media. These media, called exposure media in this assessment, may or may not be the same media that originally transported the contamination to that location. The following subsections describe the transport and exposure media considered in this assessment.

Air

Air can contain suspended particulates and/or gaseous contaminants that originate at Operable Unit 1. Bulk movement of air can then convey the particulates and gases to a receptor location. Thus air can serve as both a transport medium and an exposure medium.

Surface Water

Surface water can contain contaminants in either dissolved or suspended form. Standing water is currently found in Waste Pits 5 and 6 and the Clearwell. This surface water can serve as an exposure medium in both the current and future source terms. In addition, surface water plays another role at this operable unit. Under the Consent Agreement, EPA required an interim removal action to collect, transfer, and treat surface water runoff from the waste storage area prior to its discharge to the Great Miami River. As part of this removal action, a storm water runoff control system was created for the waste storage area. It is felt that these engineering controls are not permanent, therefore operation of the runoff control system is considered as part of the baseline conditions for the Operable Unit 1 Baseline Risk Assessment for the current, but not the future, exposure scenarios.

Without the existing runoff control system, surface water could flow over the ground surface and carry dissolved or suspended contaminants to the Great Miami River via Paddys Run. Paddys Run itself is not considered to be a reservoir of surface water because of its intermittent flow in this area. Therefore, surface water is considered to be both a transport medium and an exposure medium.

The existing contamination in surface water bodies such as Paddys Run, the outfall ditch, and the Great Miami River is considered within the scope of Operable Unit 5; however, the future impact of sources within Operable Unit 1 on Paddys Run and the Great Miami River via surface water erosion is included in the scope of the conceptual model for Operable Unit 1. Among the source terms are the surface soil within the Operable Unit 1 boundaries and the waste from the waste pits after their soil cover erodes away.

Groundwater can contain dissolved contaminants that have leached from the source areas. The principle source of potable water in the vicinity of the FEMP is the Great Miami Aquifer, which is located beneath most the FEMP and Operable Unit 1. The bulk flow of groundwater in this aquifer can convey contaminants to local and distant receptors. Thus

groundwater can serve as both a transport medium and an exposure medium under this scenario.

Transport mechanisms to the groundwater can potentially contaminate the aquifer from source terms in Operable Unit 1. The source terms included in groundwater transport modeling are limited to leaching from the waste material inside the waste pits. Leaching from the surface and subsurface soils (outside of the waste pits) in Operable Unit 1 is not included in the groundwater transport modeling because these sources exhibit far lower contaminant concentrations and quantities of contaminants than the waste pit wastes themselves.

The depositional characteristics and the hydrostratigraphic units present beneath Operable Unit 1 impart the following general contaminant transport characteristics to solutes migrating from the individual waste areas.

- Solute migration potential — The fractured nature of the weathered tills confer a high migration potential for solutes. Solute migration can also occur through the unweathered till, but at a much slower rate. Once the solute reaches the glacial outwash, the solute migration potential is high, based on the high hydraulic conductivity of the matrix.

- Aquifer intercommunication — The glacial environment limits the intercommunication between perched water-bearing zones. Communication between the upper water-bearing zones within the till and the Great Miami Aquifer is likely over an extended period of time. Communication between upper and lower zones within the Great Miami Aquifer will be extremely limited due the presence of 10- to 20-foot thick clay aquitard. Therefore, transverse (vertical) dispersion will be the only mechanism for contaminant migration between the upper and the lower zones.

- Adsorption/attenuation characteristics — The layers found within the glacial overburden generally have sufficient organic carbon content to cause retardation of organic constituents. The clay mineralogy would result in significant cation retardation for inorganic constituents. Given the till matrix, it is also unlikely that all of the available sites for adsorption would be used by solutes; therefore, it is unlikely that adsorption/attenuation breakthrough would occur. Adsorption/attenuation will occur at lower rates in the regional aquifer due to the lower organic carbon and clay content in the outwash.

Based upon the general hydrogeologic and contaminant transport characteristics, there is a potential pathway from the waste areas through the vadose zone to the regional aquifer.

Given the high energy depositional characteristics of the glacial outwash, the pathway would extend from the aquifer-vadose interface to downgradient receptors.

Perched Water

Perched water is found in the vadose zone above lenses of less permeable soil. While the volume and quality of the perched water in the Operable Unit 1 area precludes its use as a consistent water supply, EPA Region V has requested that risks from drinking water be quantified for any perched water detected beneath the FEMP. Therefore, perched water is included as an exposure medium in the conceptual site model for the future source term configuration. Perched water can also serve as a transport medium for contaminants to reach the underlying Great Miami River.

Sediment

Sediment is created by the erosion of soil and/or waste material by flowing surface water. The future source term configuration is based on an assumption that the existing runoff control system is no longer in operation, and therefore that the impacts of eroded sediment on Paddys Run and the Great Miami River are considered. Sediment is treated only as an exposure medium in this assessment because the bulk movement of surface water actually transports the sediment downstream.

Grazing Livestock and Food Crops

Domestically raised food can be contaminated in a variety of ways. The roots of vegetables and fruit can draw contaminants from the surrounding soil and pass them along to edible portions of the plant. Under the current source term conditions, contaminants can also be deposited on plant surfaces by aerial deposition of dust. Animal products, such as beef and milk products (consumption of milk, milk products and dairy products refer to consumption of all products made from milk and are used interchangeably throughout the text), can become contaminated when animals are fed contaminated food or water, or are grazed in areas containing contaminated soil. Since plants and animals can be moved from the source area to a receptor, they are considered both a transport medium and an exposure medium in this assessment.

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In addition to the transport/exposure media discussed for the current source term configuration, another aspect should be considered. Not only can food crops become

contaminated via aerial deposition, they can also become contaminated via irrigation with contaminated groundwater or surface water (e.g., Great Miami River). This scenario is considered in the future source term evaluation.

E.3.3.4 Exposure Mechanisms and Exposure Routes

A receptor can come into contact with contaminants in a variety of ways, which are generally the result of interactions between a receptor's behavior or lifestyle and exposure medium.

This assessment defines an exposure mechanism as a stylized description of the behavior that brings a receptor into contact with a contaminated medium.

Exposure routes are divided into two types — internal exposure and external exposure. Internal exposures occur when contaminants are introduced directly into the human body. These are inhalation, ingestion, and absorption across dermal surfaces. External exposures can occur independently of any physical contact with a medium. Such exposures are only considered for radionuclides and result from irradiation of an individual by penetrating radiation from a radioactive source.

Immersion in Air

This pathway is based on the scenario that a receptor is immersed in air that contains suspended particulates, gases such as radon, and volatile organic vapors originating in soil or waste. Subsequent exposures can occur either via inhalation or penetrating radiation.

Aerial Deposition onto Soil and Plants

Airborne particulates tend to settle out of the air over time. When these particulates settle out over farmland, they can be deposited on the surfaces of plants or onto surface soil. This contamination can remain affixed to the outside of the plant or fall to the ground, where some will be absorbed through the plant's roots. These plants are then used directly as food, or are fed to livestock. Exposures can occur either through the direct (but incidental) ingestion of or dermal contact with contaminated soil; via ingestion of fruit, vegetables, meat, or dairy products; or via penetrating radiation.

Direct Contact

Receptors may come into direct contact with contaminated soil or waste pit material. During the receptor's period of contact, the individual may be exposed via inadvertent ingestion of a small amount of soil or waste or dermal absorption of certain contaminants.

Harvesting Crops and Livestock

This exposure mechanism is based on harvesting contaminated food crops and/or animal products for human consumption. Food crops grown for human or animal consumption may become contaminated in several ways — via irrigation with contaminated water or via uptake from contaminated soil. Contaminants in animal feed are subsequently bioaccumulated into edible tissue or milk, which can be ingested by local or distant residents.

Using Water from Shallow Well for Drinking

Perched groundwater at Operable Unit 1 lacks the volume and water quality necessary for use as a consistent water supply, although it is possible that limited use could occur. EPA Region V has requested that exposures to perched water be addressed. Therefore, ingestion and domestic uses of water from a shallow well installed in the perched water zones beneath Operable Unit 1 is included in the risk assessment in only the future source term model. The water to be used is considered to be derived from leaching through soil and waste pit material.

Using Water from Aquifer for Drinking, Domestic, and Agricultural Purposes

Groundwater in the Great Miami Aquifer has historically been used as the water supply in the vicinity of the FEMP. This exposure mechanism entails using this water to supply a small farm for all uses (ingestion, showering, cooking, irrigation of food crops, irrigation of animal feed, and stock water). Multiple exposure routes are considered — ingestion, dermal contact, inhalation during showering, and ingestion of food that has been directly or indirectly contaminated. Penetrating radiation from contaminated water was qualitatively eliminated from consideration because of the types of radionuclides reported, their low concentrations, and the shielding power of water.

Using Surface Water as Stock Water

If access controls are discontinued, it would be possible for grazing livestock to enter the operable unit and drink from the standing water in Waste Pits 5 and 6 or the Clearwell. Milk from dairy cows or beef from cattle could be ingested by either local or distant residents.

Recreational Use of Surface Water in Waste Pits

If access controls are discontinued and local memory of the former uses of the property is lost, it is possible that local children could use the wet Pits 1 for recreational purposes such as catching frogs or swimming. However, it should be noted that Waste Pits 5 and 6 are full of debris, and the water in the Clearwell is stagnant and laden with algae, therefore the water bodies are not considered to be attractive swimming locations. Children could, however, accidentally receive acute exposure via ingestion, dermal contact, inhalation of volatiles, and/or penetrating radiation.

Proximal Exposure

Exposures from radioactive material can occur when an individual is near or "proximal" to a radioactive source. Physical contact with a contaminated exposure medium is not necessary. These exposures increase as a receptor gets closer to the source of the radioactivity, so the exposures are related to the distance from the source. Penetrating radiation is the major concern in Operable Unit 1.

Using the Great Miami River for Drinking, Domestic, Agricultural, and Recreational Purposes

The Great Miami River is large enough to serve as a water supply for a small farm located near its banks. This water could be used for drinking, showering, cooking, irrigation of food crops, irrigation of animal feed, stock water, and recreational purposes such as swimming and fishing. Exposure routes could include ingestion, inhalation during showering, dermal contact, and food ingestion (including fish). Penetrating radiation from contaminated water was qualitatively eliminated from consideration because of the types of radionuclides reported, their low concentrations, and the shielding power of water.

E.3.3.5 Receptors

The receptors evaluated in the Operable Unit 1 risk assessment were selected by analyzing the interaction of current land use practices (Section E.3.2.7), the presence or absence of access

controls and the sources (Section E.3.3.1). Because contamination can migrate through environmental media over time, the source term configuration must also be considered when selecting receptors. The influence of these three considerations on receptor selection, and the receptors who might reasonably be exposed are presented in Table 3.1 and discussed below.

E.3.3.5.1 Receptors Considered Under Current Land Use With Access Controls - Current Source Terms

A security fence currently surrounds the entire FEMP property, and a second line of fences surrounds several internal areas, including Operable Unit 1. These fences are regularly patrolled by a full-time security force. These active (security patrols) and passive (fences) access controls are currently in place at the FEMP. During the past 40 years, these controls have proven successful in restricting unauthorized site access to intruders. No hunting or fishing is allowed in Operable Unit 1.

Thus when access controls are in place, the only exposure points that are regularly accessible to receptors are off-property locations. Because of the current nature and extent of contamination and the environmental transport dynamics of the operable unit, off-property locations were limited to areas immediately contiguous to the site. These locations are thought to present the reasonable maximum exposure (RME) for this scenario.

There is also a potential for an occasional site visitor to be exposed to contaminated media at Operable Unit 1. These exposures, however, are considered to be intermittent in nature.

The receptors selected under the current land use/access controls configuration are based on the assumption that the federal government maintains the site, and no capital improvements are made. The following receptors are considered in the Operable Unit 1 risk assessment under the current source term configuration:

- Off-Property RME Farmer — This hypothetical receptor lives immediately adjacent to the FEMP boundary and is affected only by those contaminants that are subject to transport through environmental media.
- Off-Property RME Child - Young children living off property are a subpopulation of concern because they may be more sensitive to a given exposure than an adult. This receptor (ages 0 to 6 years) could be exposed by the same mechanisms as those possibly affecting the RME Off-Property Farmer.

- Groundskeeper - This hypothetical receptor is an adult who performs regular maintenance of the grounds and equipment at the site over a 25 years period. This receptor regularly visits the Operable Unit 1 area during the course of his/her duties. Exposures may occur through dermal contact with soil, inhalation of particulates and gases, incidental ingestion of soil, and direct radiation.

Under the current source term configuration, no other receptors are identified.

E.3.3.5.2 Receptors Considered Under Current Land Use Without Access Controls - Current Source Term

This group of land users reflects the possibility that the current governmental/industrial use of the property continues but with less perimeter security. Maintenance on the site is assumed to cease, but no capital improvements are made. The following are receptors who may be reasonably considered exposed to the current levels of contamination:

- Off-Property RME Farmer — As described above.
- Off-Property RME Child - As described above.
- Groundskeeper - As described above.
- Trespassing Youth — This hypothetical receptor is an older child aged 6 to 18. Under the current land use scenario where access controls are eliminated, this receptor is assumed to play in the Operable Unit 1 area, and can therefore come into direct contact with on-site, contaminated media.
- Off-Property User of Meat and Milk — This receptor is an off-property resident who uses animal products from livestock grazed and watered on Operable Unit 1. It is described in the Risk Assessment Work Plan Addendum (DOE 1992a) as the on-property grazing receptor. The purpose of this receptor is to evaluate exposures to the subpopulation of people who might use beef and milk products from animals exposed to on-property media.

E.3.3.5.3 Receptors Considered Under Current Land Use Without Access Controls - Future Source Term

This group of land users reflects the possibility that governmental or industrial use of the property continues, but without perimeter security. Maintenance on the site is assumed to cease, but no capital improvements are considered. All receptors are considered to be exposed to predicted levels of contamination based on the future configuration of the source term. The following receptors are considered:

- Off-Property RME Farmer — This hypothetical receptor is assumed to live immediately adjacent to the FEMP property boundary. This receptor is affected only by those contaminants that are subject to environmental transport. 5899

- Off-Property RME Child - Young children living off property are a subpopulation of concern because they may be more sensitive to a given exposure than an adult. This receptor (ages 0 to 6 years) could be exposed by the same mechanisms as those possibly affecting the RME Off-Property Farmer.

- Trespassing Youth — This hypothetical receptor is an older child aged 6 to 18. He is not restricted by access controls, and therefore is considered to frequently play on the property. Direct contact with contaminated media can occur.

- Great Miami River User — This receptor lives immediately adjacent to the Great Miami River, downstream of the site. The major concern for this receptor is the exposure that could occur from regular use of the river water for drinking, domestic, agricultural, and recreational purposes.

- Off-Property User of Meat and Milk — This receptor is an off-property resident who uses animal products from livestock grazed and watered on Operable Unit 1. It is described in the Work Plan Addendum (WPA) (DOE 1992a) as the on-property grazing receptor.

E.3.3.5.4 Receptors Considered Under Future Land Use With Access Controls - Future Source Term

This group of land users reflects the possibility that government or industrial use of the property continues, with perimeter security. Maintenance on the site is assumed, but no capital expenditures are allocated for maintenance of the waste pit covers and liners. All receptors are considered to be exposed to predicted levels of contamination based on the future configuration of the source term. The following receptors are considered:

- Off-Property RME farmer - As described above.
- Off-Property RME child - As described above.
- Great Miami River User - As described above.
- Off-Property User of Meat and Milk Products - As described above.
- Groundskeeper - As described above
- Expanded Trespasser - This hypothetical composite individual (of an adult and a youth) is assumed to visit the site despite continued government ownership. Exposure pathways include inhalation of fugitive dusts, volatile organics, and gases, dermal contact with and incidental ingestion of site soil, incidental ingestion of surface water in Paddys Run, and external radiation exposure while on site. No

specific location was assigned as the expanded trespasser may wander over the entire operable unit.

E.3.3.5.5 Receptors Considered Under Future Land Use Without Access Controls - Future Source Term

Governmental use and control of the property could cease at some time in the future. This could conceivably allow individuals to enter the property, improve it, and take up permanent residence. In addition, contamination can migrate through environmental media over time. This increases the number of receptors and locations in which exposure could occur. Receptors who could be exposed if governmental use of the property ceases and it is released to the public with no restrictions are:

- On-Property RME Resident Adult — This receptor is an adult living and working on property.
- On-Property RME Resident Child — Young children living on property are a subpopulation of concern because they may be more sensitive to a given exposure than an adult. A young child (0 to 6 years age) residing on former FEMP property could be exposed directly to unremediated on-property soil and waste storage areas as a result of either natural environmental processes or human activities.
- On-Property Central Tendency (CT) Resident Adult — This scenario considers the risks to an on-property adult resident exposed via the same pathways as the RME resident adult, but with exposure parameters that are more representative of a central tendency. This CT scenario is evaluated to estimate risks that may be more representative of a typical future on-property resident.
- On-Property Home Builder — This receptor is assumed to be a construction worker or future resident involved in building a home in the Operable Unit 1 area.
- Off-Property RME farmer - As described above.
- Off-Property RME child - As described above.
- Great Miami River User - As described above.
- Off-Property User of Meat and Milk Products - As described above.

E.3.3.6 Complete Exposure Pathways

An exposure pathway is determined to be complete if there is 1) a source or a release of chemicals from a source; 2) an exposure point where contact can occur, and 3) an exposure route by which contaminants are taken into the body. This section summarizes the complete exposure pathways evaluated quantitatively in the risk assessment and provides the rationale for excluding those pathways that are not. Table E.3-2 presents a summary matrix of the

complete exposure pathways and receptors from the conceptual site model presented in Figure E.3-2. In Section E.5, risks will be calculated for each receptor under multiple exposure pathways, and the risks will then be summed to provide a total risk for each receptor.

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E.3.3.6.1 Pathways Under Current Land Use with Access Controls - Current Source Term

Under current conditions, as considered under current land use with active access controls, only two receptors are evaluated. The off-property RME farmer and child are the receptors who are considered to be the maximally exposed individuals under the current land use/access control scenario. These receptors are located about 500 meters southwest of the Burn Pit (based on the air modeling described in Appendix D) (Figure E.3-4, marked as "Maximum Off-Site Location Air"). The following exposures are considered quantitatively for this receptor:

- Inhalation of (off-property) ambient air containing radon, volatile organics, and respirable particulates PM-10 — Air concentrations are based on the modeling described in Appendix D. Volatile emissions from cloud immersion are not considered in this scenario, given their low concentrations in surface media, and penetrating radiation from cloud immersion is considered to be a minor exposure route for which there are no EPA-approved methods for calculation.

- Ingestion of vegetables and fruit affected by aerial deposition — Deposition of radionuclides and other contaminants adsorbed to suspended particulates on surface soil in which plants are grown or onto the vegetation itself results in absorption by the plants. The contaminants are derived from on-site surface soil and exposed waste pit material; off-property deposition information is derived via modeling of the suspended particulates. Other potential exposures resulting from the aerial deposition mechanism were considered to be minor routes of exposure (incidental ingestion of soil, dermal contact with soil, and penetrating radiation).

- Ingestion of meat and milk affected by aerial disposition - Deposition of particulates could also indirectly affect meat and milk consumed by this receptor. Particulates deposited on soil and vegetation can be ingested by grazing cows, and contaminants can subsequently be biotransferred to meat and milk.

Several other exposure routes were included in the conceptual site model but were not quantified in the risk assessment. Ingestion of beef and dairy products from cows grazed or watered on property was not considered because under current land use and access conditions, no cows get inside the inner security fence. Direct contact with contaminated surface soil or waste pit material is not considered because this receptor lives off-property and is not likely to

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come on property. Finally, again because the receptor is not assumed to come on the property, accidental exposures to surface water in the Clearwell were not considered.

The other receptor evaluated under current land use and access controls conditions is identified as the groundskeeper. The definition of this receptor presumes this person lives away from the site, and only experiences exposures when working on the property. The following exposure routes are addressed for the groundskeeper:

- Inhalation of air containing radon gas, volatile organics, and respirable particulates (PM-10) — Resuspension of exposed waste pit material and surface soils, as well as emission of radon gas, are considered for this receptor. Penetrating radiation from the air itself, which could possibly occur, is considered to be a minor exposure route.

- Proximal exposure to soil and waste pit material — Once inside the security fence, the groundskeeper could be exposed to contaminated surface soil and exposed waste pit material under current site conditions. The groundskeeper would be exposed via ingestion or dermal contact with soil and penetrating radiation.

This receptor is not assumed to ingest any plant or animal products grown on the property, nor is it considered likely that such a receptor would experience anything other than an accidental exposure to surface waters in the waste pits and Clearwell.

E.3.3.6.2 Pathways Under Current Land Use Without Access Controls - Current Source Term

If the government should retain ownership of the property, yet decrease site security, the number of receptors potentially exposed to Operable Unit 1-related contamination increases, as do the number of exposure routes that come into play. Five receptors are considered under these conditions.

The first two receptors considered are the off-property RME farmer and child. These receptors' exposures under this scenario are identical to those for current land use conditions with access controls. No additional exposure routes are considered.

The third receptor is a trespassing youth. This receptor is assumed to be exposed to soil and air while on property as follows:

- Direct Exposure to Soil - Given the lack of access controls considered under this scenario, a trespassing child could routinely be exposed to surface soil. Penetrating radiation exposures from either buried or exposed radioactive materials is considered to be a significant route of exposure, as are incidental ingestion and dermal contact with soil.
- Inhalation of Radon, Volatiles, and PM-10 Particulates - While the concentrations of volatiles are not expected to be significant for a local receptor based on the modeling results, the presence of radon and particulates could result in quantifiable exposure. The air concentrations to which a receptor could be exposed are based on the modeling discussed in Appendix D.

The trespassing child is assumed to use off-site water sources unaffected by contamination from Operable Unit 1 as potable water supplies and, therefore, would not experience ingestion, inhalation, or dermal contact exposures, nor would he be exposed indirectly through ingestion of fruit, vegetables, meat, or milk contaminated via aerial deposition or on-site grazing or watering.

Potential exposure to surface water in the Clearwell is considered, but was not included in the final quantitative exposure assessment because it is highly unlikely that the Clearwell would attract a trespasser. Although cattails grow near the Clearwell and frogs possibly exist, which might attract a youth to the area, the sides of the Clearwell are very steep and its water contains heavy algae growth, making it unsuitable for swimming or wading. Exposures would most likely be accidental. Based on such exposure times and intake rates, these acute exposures were judged to be insignificant in the total risk experienced by this receptor.

The fourth receptor considered, if current land use should continue without access controls, is the off-property user of meat and milk from cows grazed on-property. This is a distinct pathway that could affect sensitive subpopulations living far from the FEMP. The following pathways are considered:

- Ingestion of meat and milk contaminated via root uptake — Without access controls, it is possible that cows could graze in the vicinity of Operable Unit 1. In this case, contaminants in soil could be taken up by plant roots either directly or via aerial deposition. These feed crops (and some attached soil) would be ingested by cows, and contamination could be passed on to the consumer via beef or milk.
- Ingestion of meat and milk contaminated via surface water ingestion — It is also possible, should access controls be discontinued, that cows could ingest water from the Clearwell or Waste Pits 5 and 6. Contamination in these waters could be passed on to consumers via beef or milk.

The fifth receptor is the groundskeeper, who experiences exposures while working on site. This receptor's exposure routes are identical to those for current land use with access controls.

E.3.3.6.3 Pathways Considered Under Current Land Use without Access Controls - Future Source Term

If the government maintains access controls on the property but does not maintain the engineering controls, erosion and subsidance could expose waste materials. Six recepors are evaluated under this scenario. These receptors are exposed only to those contaminants that are transported to the receptor location. The following exposure pathways are considered in armerthe risk assessment:

- Domestic use of groundwater — Assuming that the waste pits and the Clearwell continue to exist and act as source areas of contamination, downgradient groundwater supplies could eventually be affected. Groundwater that is contaminated via leachate generation from the waste storage area could migrate to a downgradient receptor location. There a well could be installed to serve a home, and the residents could be exposed via ingestion, inhalation of volatiles and/or radon emitted during showering, and dermal contact during bathing or showering.

- Agricultural use of groundwater — This pathway assumes groundwater is used to grow food. Irrigation of crops and animal feed results in foliar deposition of contaminants onto plants and uptake on contaminants by plant roots. These plants are later harvested and eaten by humans or fed to livestock. This livestock also ingested soil contaminated by aerial deposition. Meat and milk from these animals are later consumed by humans.

- Inhalation of radon, volatiles, and particulates — Fugitive dust and gaseous emissions from the waste pit area could migrate off property and affect local residents. These receptors would not only be exposed directly to these emissions via inhalation, but could also be exposed via fallout onto soil and plants. The contaminants in the fallout could be transferred to edible plant material, and reach the receptor upon ingestion.

- Food contaminated by aerial deposition — This pathway assumes aerial suspension of exposed soil/waste, followed by foliar deposition onto plants. These plants are later harvested and eaten by humans. These plants are also used as forage and stored feed by livestock. Meat and milk from these animals are later consumed by humans.

A trespassing child was also considered under this land use/source term configuration. This receptor is assumed to be exposed soil, waste pit materials, air, and sediment while on property or playing in Paddys Run, as follows:

- Direct exposure to soil and waste pit contents — Given the lack of access controls considered under this scenario, a trespassing child could routinely be exposed to surface soil and exposed waste pit materials. Penetrating radiation exposures from either buried or exposed radioactive materials is considered to be a significant route of exposure, as are incidental ingestion and dermal contact with soil or exposed wastes.

- Inhalation of radon, volatiles, and PM-10 particulates — While the concentrations of volatiles are not expected to be significant for a local receptor based on the modeling results, the presence of radon and particulates could result in a quantifiable exposure. The air concentrations to which a receptor could be exposed are based on the modeling discussed in Appendix D.

- Direct contact with sediment in Paddys Run — With the runoff control system no longer in operation, soil could be eroded from the site and enter Paddys Run. At this point, trespassing children are the most likely receptors. They could be exposed via incidental ingestion or via dermal contact. Penetrating radiation exposures to these dispersed source materials would be less significant. Surface water exposure is not considered, as Paddys Run is not a permanent flowing stream in the vicinity of Operable Unit 1.

The trespassing child is assumed to use off-site water sources unaffected by contamination from Operable Unit 1 as potable water supplies, and therefore would not experience ingestion, inhalation, or dermal contact exposures, nor would he be exposed indirectly through ingestion of fruit, vegetables, meat, or milk contaminated via aerial deposition or on-site grazing or watering. For reasons mentioned previously (i.e., algae), exposures to water in the Clearwell would be limited to accidental, irregular acute exposures that result in a minor risk in comparison to the pathways described above.

A fourth receptor considered under this land use/source term scenario is the Great Miami River user. This receptor was developed to provide information on risks incurred by distant (hypothetical) receptors whose only mode of contact with Operable Unit 1 contamination is via runoff of soil and surface water to Paddys Run and the Great Miami River, where unsuspecting receptors could be exposed. The following exposure pathways are considered:

- Domestic use of Great Miami River water — The Great Miami River is a water body of adequate size and reliable supply to provide a source of potable water for a home located on the river. Receptors in this home could conceivably be exposed via ingestion, inhalation of volatiles and radon during showering, and dermal contact while bathing. Penetrating radiation in this supply would result in a minimal risk.

- Agricultural use of Great Miami River water — This pathway assumes Great Miami River water is used to grow food. Irrigation of crops and animal feed results in foliar deposition of contaminants onto plants and uptake on contaminants by plant roots. These plants are later harvested and eaten by humans or fed to livestock. This livestock also ingested soil contaminated by aerial deposition. Meat and milk from these animals are later consumed by humans.

- Exposure while swimming — It is likely that persons swimming in the Great Miami River could experience both an incidental ingestion and a dermal exposure to contaminants originating at Operable Unit 1. Sediment exposure is not considered, as Paddys Run has not been shown to transport contaminated sediment all the way to the river.

- Ingestion of fish from the Great Miami River — Local residents could catch fish in the river whose edible tissue has bioaccumulated Operable Unit 1-related contaminants.

The final receptor considered under the future source term, current land use scenario is the off-property user of meat and milk produced on site. The exposure pathways for this isolated receptor are listed below:

- Ingestion of meat and milk contaminated via root uptake from soil and subsequent grazing.

- Ingestion of meat and milk contaminated via aerial deposition onto soil and feed crop plant surfaces.

- Ingestion of meat and milk contaminated via direct ingestion of surface water by cows.

E.3.3.6.4 Exposures Under Future Land Use with Access Controls - Future Source Term

The RME receptors under this scenario are the off-property farmer and child. These receptors are exposed only to those contaminants that are transported to the receptor location. The following exposure pathways are considered in the risk assessment:

- Domestic use of groundwater — Assuming that the waste pits and the Clearwell continue to exist and act as source areas of contamination, downgradient groundwater supplies could eventually be affected. Groundwater that is contaminated via leachate generation from the waste storage area could migrate to a downgradient receptor location. There a well could be installed to serve a home, and the residents could be exposed via ingestion, inhalation of volatiles and/or radon emitted during showering, and dermal contact during bathing or showering.

- Agricultural use of groundwater — This pathway assumes groundwater is used to grow food. Irrigation of crops and animal feed results in foliar deposition of

contaminants onto plants and uptake on contaminants by plant roots. These plants are later harvested and eaten by humans or fed to livestock. This livestock also ingested soil contaminated by aerial deposition. Meat and milk from these animals are later consumed by humans.

- Inhalation of radon, volatiles, and particulates — Fugitive dust and gaseous emissions from the waste pit area could migrate off property and affect local residents. These receptors would not only be exposed directly to these emissions via inhalation, but could also be exposed via fallout onto soil and plants. The contaminants in the fallout could be transferred to edible plant material, and reach the receptor upon ingestion.

- Food contaminated by aerial deposition — This pathway assumes aerial suspension of exposed soil/waste, followed by foliar deposition onto plants. These plants are later harvested and eaten by humans. These plants are also used as forage and stored feed by livestock. Meat and milk from these animals are later consumed by humans.

The expanded trespasser was also considered under this land use/source term configuration. This receptor is assumed to be exposed to soil, waste pit materials, air, and sediment while on property or playing in Paddys Run, as follows:

- Direct exposure to soil and waste pit contents — Given the lack of access controls considered under this scenario, a trespassing child could routinely be exposed to surface soil and exposed waste pit materials. Penetrating radiation exposures from either buried or exposed radioactive materials is considered to be a significant route of exposure, as are incidental ingestion and dermal contact with soil or exposed wastes.

- Inhalation of radon, volatiles, and PM-10 particulates — While the concentrations of volatiles are not expected to be significant for a local receptor based on the modeling results, the presence of radon and particulates could result in a quantifiable exposure. The air concentrations to which a receptor could be exposed are based on the modeling discussed in Appendix D.

- Direct contact with sediment in Paddys Run — With the runoff control system no longer in operation, soil could be eroded from the site and enter Paddys Run. At this point, trespassing children are the most likely receptors. They could be exposed via incidental ingestion or via dermal contact. Penetrating radiation exposures to these dispersed source materials would be less significant. Surface water exposure is not considered, as Paddys Run is not a permanent flowing stream in the vicinity of Operable Unit 1.

The expanded trespasser is assumed to use off-site water sources unaffected by contamination from Operable Unit 1 as potable water supplies, and therefore would not experience ingestion, inhalation, or dermal contact exposures, nor would he be exposed indirectly through ingestion

of fruit, vegetables, meat, or milk contaminated via aerial deposition or on-site grazing or watering. For reasons mentioned previously (i.e., algae), exposures to water in the Clearwell would be limited to accidental, irregular acute exposures that result in a minor risk in comparison to the pathways described above.

E.3.3.6.5 Exposures Under Future Land Use Without Access Controls - Future Source Term

This scenario involves a completely separate set of receptors, as discussed in Section E.3.3.2.4. The purely hypothetical scenario involves construction of a home on property (exposure of a construction worker) and on-site residents (adults and children) living in the vicinity of Waste Pit 4. A well is assumed to be drilled to supply the domestic and agricultural needs of this family. These scenarios are also included in Table E.3-3 and are summarized below.

There are two scenarios evaluated for the on-site adult resident farmer, as outlined previously. The first is the RME scenario, which is intended to evaluate the reasonable maximum exposures that would be expected to occur; the second is the CT scenario, which is intended to evaluate a more central tendency set of exposures. In addition, an on-property resident child is also considered. The exposure pathways evaluated for the on-property resident farmer and child are as follows:

- Domestic use of groundwater from the Great Miami Aquifer — This scenario is based on the assumption that a well could be installed at some time in the future, should all governmental control of the property cease. This well is assumed to be drilled in the vicinity of Waste Pit 4, which contains the highest concentrations of contaminants. The contaminant concentrations used in this scenario are based on modeling to ascertain the risks associated with only the Operable Unit 1 source areas. Actual concentrations are addressed in the Operable Unit 5 risk assessment. A receptor is assumed to be exposed via ingestion, inhalation of volatiles during showering, and dermal contact while bathing. As mentioned under the current source term model, penetrating radiation from water would result in an insignificant exposure for which no calculation methods exist.

- Agricultural use of Great Miami Aquifer water — This pathway assumes Great Miami Aquifer water is used to grow food. Irrigation of crops and animal feed results in foliar deposition of contaminants onto plants and uptake on contaminants by plant roots. These plants are later harvested and eaten by humans or fed to livestock. This livestock also ingested soil contaminated by aerial deposition. Meat and milk from these animals are later consumed by humans.

- Ingestion of meat and milk produced on property — Several variations of this exposure pathway are considered for the on-property farmer, as for the off-property user of meat and milk. These scenarios are 1) root uptake by feed crops from buried or exposed waste pit contents and 2) direct ingestion of on-property surface water by cows. The meat and milk from these cows would be ingested by on-property residents.

- Ingestion of food contaminated by aerial deposition — This pathway assumes aerial suspension of exposed soil/waste, followed by foliar deposition onto plants. These plants are later harvested and eaten by humans. These plants are also used as forage and stored feed by livestock. Meat and milk from these animals are later consumed by humans.

- Direct contact with soil or waste pit material — While routinely engaged in farming activities (adults) or playing on-property (children), receptors could experience an exposure to contaminated surface soil (Waste Pits 1, 2, 4, and the Burn Waste Pit) or exposed waste pit material (Waste Pits 3, 5, and 6). Exposures could occur via incidental ingestion or dermal contact.

- Proximal exposure to buried or exposed radioactive sources — This exposure scenario incorporates exposures to either buried or exposed radioactive pit materials.

- Direct contact with sediment — It is also possible that adult receptors only (the resident child receptor is assumed to be aged 6 and under, and Paddys Run is 1,000 feet from the home site) could come in contact with contaminated sediment in Paddys Run if the runoff control system is no longer in operation. Exposures could occur via incidental ingestion and dermal contact, however, these exposures are expected to be infrequent in comparison to exposures around the home and fields.

- Inhalation of radon, volatiles, and PM-10 particulates - The presence of radon and particulates could result in a quantifiable exposure. The air concentrations to which a receptor could be exposed are based on the modeling discussed in Appendix D.

It is assumed that the adult receptors would not swim in the remaining surface water on property (the Clearwell or Waste Pits 5 and 6) given the assumption that these water bodies are only half-filled with water and contain debris and algae. Small children living on property are also assumed to not be exposed, as they are too young for unsupervised swimming and the water bodies are not attractive. It is recognized that intermittent, accidental exposures to surface waters could occur, but that the intakes from these exposures would be minimal in comparison to those from the routes and pathways described above.

Exposures to the RME farmer from the domestic use of perched water is considered only for ingestion, dermal contact, and inhalation of released volatiles because this groundwater zone

does not contain enough water to provide a continous supply of potable water for agricultural uses. The contaminant concentrations to which receptors could be exposed are based on the results of the groundwater modeling discussed in Appendix D.

Other potential pathways such as penetrating radiation from air or from materials deposited on plant surfaces would be insignificant.

The home builder (construction worker) was also evaluated for this scenario. This receptor is assumed to be exposed only while on property, and to use unaffected off-property sources for potable water supply and food. Therefore, his/her only exposures are assumed to be related to direct contact scenarios, as follows:

- Proximal exposure to buried waste pit contents — Exposure to penetrating radiation from these source areas could occur while the receptor is involved in construction activities of a limited duration.
- Direct contact with surface soil — This exposure pathway considers the potential exposures of an on-property home builder. Exposures could occur via incidental ingestion of or dermal contact with non-radiological contaminants.
- Inhalation of radon, volatiles, and particulates — While the surficial concentrations of volatile organic chemicals are minimal, exposures to radon and particulates could be significant. These exposures are assumed only to occur during the limited time this receptor is on property.

E.3.4 EXPOSURE POINT CONCENTRATIONS

The exposure point concentration is the concentration of a contaminant in an exposure medium that may be contacted by a real or hypothetical receptor. Determination of the exposure point concentration depends on several factors, such as:

- Availability of data
- Amount of data available to perform statistical analysis
- Background concentrations not attributed to the site
- Location of the potential receptor.

Current exposure concentrations for Operable Unit 1 are determined in two different ways. First, measured concentrations are used for current potential exposures to the waste pits and surrounding surface soils. Second, measured concentrations are used as input to air transport

models. To be consistent with the concept of the RME scenario, an estimate of the highest exposure that can reasonably be expected to occur requires a reasonable maximum estimate of the concentration of each contaminant in each exposure medium. Because of the uncertainty associated with any estimate of exposure concentrations, the upper 95 percent confidence limit on the arithmetic mean for either a normal or lognormal distribution is the recommended statistic (concentration value) to be constructed from measured contaminant concentration data and used in risk assessments (EPA 1992c). This term is generally called the upper confidence limit (UCL). The methodology used to calculate the UCL is discussed in Section 7.1.1 of the Work Plan Addendum (DOE 1992a), and summarized in Section E.2.0 of this report.

For future exposures to soil, groundwater, or air, surface soil and subsurface soil concentrations (UCLs) were used to approximate exposure point concentrations. Fate and transport models presented in Section 5.0 of the Operable Unit 1 RI Report were used to predict exposure point concentrations for future exposures to groundwater, surface water, and sediment, and for exposures to selected constituents in air. In addition, equilibrium conditions are considered for radionuclides.

Several of the scenarios evaluated incorporate an area-weighted average concentration rather than waste pit specific results. These types of scenarios, such as the adolescent trespasser or the site visitor, are based on the assumption that a receptor will move throughout the site. Therefore, an overall average UCL concentration is considered appropriate as an exposure concentration.

E.3.4.1 Surface Soil

Exposure point concentrations for current surface soil exposure pathways (such as the site visitor) are the UCLs determined from measured surface soil data. Table E.3-3 presents both the CPCs and the UCLs that are used to assess the exposures associated with surface soil at Operable Unit 1. These surface soil concentrations are also used in the future source term to evaluate exposures to crops grown on Waste Pits 1 and 2.

E.3.4.1.1 Radioactive Contaminants

Fourteen radionuclides were detected in Operable Unit 1 surface soils. Eight of these are naturally occurring radionuclides from the uranium, thorium, and actinium decay series (U-238, U-235, U-234, Th-232, Th-230, Th-228, Ra-226, and Ra-228). The remaining

radioisotopes (Cs-137, Sr-90, Tc-99, Pu-238, Pu-239/240, and Np-237) are produced by nuclear processes such as those found in a nuclear reactor. The radionuclides reported in the highest concentration are U-238, U-234, and Th-230.

E.3.4.1.2 Chemical Contaminants

The chemicals listed for evaluation in this risk assessment reflect the results of comparing on-property concentrations to background concentrations. Sixteen metals and Aroclor-1254 were detected in Operable Unit 1 surface soils and selected as CPCs. While several metals were present at concentrations only slightly greater than the background concentrations (e.g., arsenic), uranium was found at a notable concentration of 52.2 mg/kg.

E.3.4.2 Exposed Waste Pit Material

The eight waste pits contain a heterogeneous mix of chemicals reflecting the history of the processes carried out at the FEMP. These waste pits contain materials which can migrate through groundwater. In addition, if the caps and covers over these waste pits erode or are disturbed during construction of a home, the contents of these waste pits will be exposed, and exposures could occur in the same way as to surface soils. Thus, this assessment considers the UCLs of the subsurface soils and wastes in combination with the existing surface soil as the exposure point concentrations for future. In the future source term conceptual site model, the waste in Waste Pits 3, 5, and 6 will be exposed, but the soil covers will remain intact over the remainder of Operable Unit 1. Table E.3-4 presents the waste pit soil/waste concentrations that are used in the future exposure scenarios.

E.3.4.2.1 Radioactive Contaminants

In the future, radioactive decay will alter the detected concentrations in Operable Unit 1. To account for this, only those nuclides with half-lives greater than 25 years are explicitly evaluated. All shorter-lived nuclides are assumed to be in equilibrium with their longer-lived precursors and are included when risks to the parent nuclide is evaluated in the risk characterization phase of this assessment. Twelve radionuclides with half-lives greater than 25 years were detected in concentrations exceeding background levels in Operable Unit 1 waste pit sludge/soils. Six of these (U-238, U-235, U-234, Th-232, Th-230, and Ra-226) are naturally occurring radionuclides from the uranium, thorium, and actinium decay series. The remaining radioisotopes (Cs-137, Sr-90, Tc-99, Pu-238, Pu-239/240, and Np-237) are

produced by nuclear processes such as those found in a nuclear reactor. The radionuclides reported in the highest concentrations are U-238, U-234, and Th-230.

E.3.4.2.2 Chemical Contaminants

The chemicals listed for evaluation in this risk assessment reflect the results of applying the screening techniques described in Section E.2.0 of this appendix. Four distinct groups of chemicals were detected at significant levels: 1) polycyclic aromatic hydrocarbons (PAHs); 2) polychlorinated biphenyls (PCBs); 3) dioxins and furans; and 4) metals. A total of 19 metals detected in Waste Pits 3, 5, and 6 and the remaining surface soils and were selected as CPCs; as well as two PCBs, eight PAHs, ten dioxims/furans, pentachlorophenol tetrachloroethene, and other semivolatile and volatile organics. Because the future land use scenarios are based on the assumption that exposures could occur throughout the source area, an area-weighted average concentration was developed using the full area of Waste Pit 3 and other soils, and one-half the area of Waste Pits 5 and 6 (assuming half the waste pit material is exposed).

E.3.4.3 Waste Pit 4 Material

The future land use scenario considers the possibility that a home could be constructed on Pit 4, which is physically the most stable area of Operable Unit 1. It is assumed that once construction is complete, that topsoil would be emplaced for lawns. The pit is currently covered with a RCRA cap and synthetic cover, which are unsuitable for vegetative growth. The future exposure point concentrations for Pit 4 are listed in Table E.3-6.

E.3.4.3.1 Radioactive Contaminants

Fourteen radionuclides were detected in the contents of Pit 4. As discussed in Section E.3.4.1.1, several of these are naturally occurring radionuclides. As with the other future scenarios, only nuclides with half-lives greater than 25 years are evaluated.

E.3.4.3.2 Chemical Contaminants

The chemicals selected as CPCs for quantitative evaluation include 12 metals and 44 organics. The organics include numerous PAHs, dioxins, furans, PCBs, semivolatiles and volatiles.

E.3.4.4 Buried Pit Materials

Several of the defined exposure scenarios require the evaluation of penetrating radiation risks from buried waste pit contents. The buried contents of the waste pits produce radiation which

can expose humans on the ground surface. To assess the magnitudes of these exposures, a computer code called Microshield (Grove Engineering 1987) is used, as required by the WPA (DOE 1992a).

Microshield is capable of calculating the radiation dose rate for a variety of source and shield geometries, source materials, shield materials, and shield thicknesses. A limited amount of input information is required. Required input for Microshield includes information on the source, the types and concentrations of radionuclides present in the source being modeled, the shape and physical dimensions of the source and its cover (if any), and the density and physical makeup of the source and cover, and the distance from the source to the receptor.

The inventory of radionuclides is determined using the CPC tables in Section E.2.5. The physical characterization data required is obtained from the nature and extent section of the RI. The physical dimensions of the buried sources and any cover they may have is determined from the waste pit cross-sections provided in the RI. In most cases, the sources investigated have irregular shapes. A cylindrical source geometry with a volume and surface area equivalent to the irregularly shaped source is used for these calculations. This geometry produces the maximum dose rate for a given surface area. The distance to the receptor point is assumed to be one meter above the ground surface at the center of the source.

Microshield runs are performed on both current and future source term configurations as shown in Tables E.3-7 and E.3-8, respectively. The results of these computer runs are presented in Table E.3-9.

E.3.4.5 <u>On-Property Surface Water</u>

Waste Pits 5, 6, and the Clearwell, located in Operable Unit 1, currently contain standing water. Weighted average exposure point concentrations for current surface water exposure pathways are based on the UCLs determined from measured surface water data. Table E.3-10 presents the measured and weighted average concentrations from these ponds which are used to assess the current exposures associated with surface water currently in Operable Unit 1, such as watering of livestock. Table E.3-11 presents the concentrations for the future scenarios, which were adjusted using the reduced surface areas.

E.3.4.5.1 Radioactive Contaminants

Nine radionuclides were detected in the three ponds. The highest reported UCLs are associated with U-238 , U-234, and Tc-99. Of these, Tc-99 is of particular concern because of its mobility and ability to move through the human food chain. Concentrations of this nuclide are highest in the Clearwell and Waste Pit 6.

E.3.4.5.2 Chemical Contaminants

The list of chemicals detected in surface water includes eleven metals, and the following organics: benzene, methylene chloride, toluene, chloroform, tetrachlorothene, 2-nitrophenol, and acetone. Analytes found at the highest concentrations are vanadium and zinc, which were found at maximum concentrations of approximately 100 μg/L. The weighted average concentrations of most metals were not above the MCLs.

E.3.4.6 Off-Property Surface Water

Constituent concentrations in the Great Miami River were predicted using fate and transport modeling. Table E.3-12 lists the chemicals evaluated in the risk assessment and their predicted concentrations for the future source term. Section 5.0 of the Operable Unit 1 RI Report describes the model and modeling results in detail.

E.3.4.6.1 Radioactive Contaminants

The potential concentrations of eleven radionuclides in the Great Miami River are based on the assumption that the existing runoff control system no longer functions. Only U-238, U-235, U-234, Tc-99 are predicted to be present in the river at levels that are detectable using standard analytical techniques. All but U-238 and Tc-99 would be indistinguishable from background.

E.3.4.6.2 Chemical Contaminants

All the chemicals of significance (toxic or carcinogenic compounds) detected in surface soil were modeled via surface water and sediment transport into the Great Miami River. With the exception of uranium, most concentrations are well below standard analytical detection limits.

E.3.4.7 Sediment

Contaminants in sediments currently found in Paddys Run are being assessed by Operable Unit 5, therefore, exposure point concentrations for future sediment exposures associated with

contributions from Operable Unit 1 are determined by modeling. Table E.3-13 presents the predicted sediment concentrations with sediment assumed to exist in Paddys Run in the future.

E.3.4.7.1 Radioactive Contaminants

Radioactive contaminant concentrations in the sediment of Paddys Run are predicted, through modeling, to be dominated by U-238, U-234, and Th-230. The greatest concentration listed in Table E.3-13 is associated with U-238, and the least with Pu-239/240.

E.3.4.7.2 Chemical Contaminants

The chemicals listed for evaluation in this risk assessment reflect the results of applying the screening technique described in Section E.2.0 of this appendix. All the chemical concentrations predicted in Paddys Run are the same as the surface soil concentrations.

E.3.4.8 Groundwater

Current groundwater contamination is being assessed by Operable Unit 5. The Operable Unit 1 risk assessment is limited to investigating the future migration of groundwater from the sources within the operable unit boundaries and include evaluation of both the perched water and the Great Miami Aquifer.

Future exposure point concentrations for groundwater are determined from the results of geochemical and groundwater transport modeling, as described in Section 5.0 and Appendix D of the Operable Unit 1 RI Report. The geochemical and groundwater models and parameters are designed to provide high confidence that the risks attributed to the transport of contaminants in the groundwater will not be greater than the calculated values. These results are conservative and are not likely to actually occur.

This assessment focuses on chemicals that contribute significantly to the risks associated with groundwater exposures. This is done by examining predicted chemical concentrations in leachate seeping through the vadose zone (Section 5.1 of the Operable Unit 1 RI Report). A chemical carcinogen was selected for aquifer modeling and a detailed risk evaluation if its predicted concentration in the leachate before dilution in the aquifer was greater than 10 percent of EPA Region III screening values (EPA 1993b), which are based on an ingestion rate of 2 L/day for 30 years, or a 10^{-6} risk. Since there are currently no screening levels for radionuclides, screening levels were developed for the drinking water pathway using a target

risk of 10^{-7} in the leachate and a drinking water ingestion rate of 2 L/d over 70 years. The volume of water in the aquifer dilutes chemical concentrations in the leachate by at least a factor of 10, so the concentrations of carcinogens that were not selected are estimated to contribute risks of no more than 10^{-8}. Noncarcinogens were selected if the estimated concentration in the water would yield an intake equal to 10 percent of the screening value for noncarcinogens assuming the leachate was ingested at a rate of 2 L/day for 70 years. Dilution by aquifer water ensures that the exposure point concentrations of noncarcinogens that were not selected for a detailed evaluation will be less than 1 percent of the allowable intake for the noncarcinogen.

Table E.3-14 presents the predicted concentrations in groundwater both on property and just beyond the downgradient FEMP property boundary line. This table also includes the maximum contaminant concentrations in the perched water beneath the site. Development of the exposure concentrations via modeling was discussed in detail in Appendix D. The locations of calculated maximum on- and off-property risk associated with groundwater exposure are shown in Figure E.3-4.

This table also includes the maximum predicted contaminant concentrations in the perched water beneath the site. Development of the exposure concentrations was discussed in detail in Appendix D.

E.3.4.8.1 Radioactive Contaminants

In the perched water, U-234, U-235, U-238, Th-232, and Tc-99 are predicted at the greatest concentrations. Concentrations were converted to activities in Table E.3-14. The maximum concentration is occurring at the present time.

The groundwater modeling results predict that three isotopes of uranium and Ra-226 will be of concern for hypothetical future on-property residents. The activity of U-238 is three times greater than the activity of all other radionuclides together. The maximum on-site risk is predicted to occur about 500 years from the beginning of the modeled period.

Only isotopes of uranium are predicted to reach the off-property boundary in concentrations which might be detectable by standard analytical techniques. Of these radionuclides, U-238 is

expected to exhibit the highest activity in the hypothetical off-property well. These are predicted to occur about 600 years from now.

E.3.4.8.2 Chemical Contaminants

The results of the groundwater modeling produce a list of chemical constituents that includes both inorganics and organics. The principal inorganics include uranium, nickel, and boron in the perched aquifer. Based on existing concentrations in individual wells in the Greater Miami aquifer, arsenic, and barium are also found significant concentrations.

Only two organic compounds (tetrachloroethane and dichlorodifluoromethane) are predicted to reach the Greater Miami aquifer. Vinyl chloride and total PCB's, both of which passed the screening criteria, were not predicted to be present at the time of overall maximum risk (500 years).

E.3.4.9 Air

Airborne concentrations of contaminants from the waste storage areas of Operable Unit 1 were modeled for both current and future conditions at on-property and off-property locations. The model assumes mass loading (fugitive dust emissions) from surface soil, gas emission (radon and volatiles) to the air from each waste pit area, and the subsequent transport and dispersion of these contaminants. The model and parameters for air dispersion are described in Section 5.0 of the Operable Unit 1 RI Report.

Table E.3-15 lists the current on-property and off-property air concentrations for the current source term conditions, and Table E.3-16 lists those estimated for the future source term conditions. The chemicals listed for evaluation in this medium are those listed as CPCs in the surface soil and/or exposed waste pit materials. The locations of calculated maximum risk are shown in Figure E.3-4.

Only the PM-10 fraction was modeled. Actual deposition rates were not modeled for the Operable Unit 1 area, but a maximum deposition velocity and rate based on a worst case rate determined for the active flyash pile (Operable Unit 2) was used in food chain calculations.

E.3.4.9.1 Radioactive Contaminants

The highest annual average current air concentrations are used to evaluate potential exposures. Rn-222 currently produces the greatest on- and off-property concentrations, with no other radionuclide being within two orders of magnitude. Both on- and off-property maxima were reported.

The highest annual average future air concentrations are used to evaluate potential future exposures. These concentrations are generated from the future source term soil concentrations. Off-property air concentrations are less than the on-property concentrations by one to two orders of magnitude for most radionuclides.

E.3.4.9.2 Chemical Contaminants

The list of chemicals selected for air modeling included chemicals detected in surface and/or subsurface soil and waste pit material. The primary chemical contaminants for the air pathway include barium, manganese, nickel, and vanadium. Under future conditions, uranium and arsenic are also predicted at the receptor locations at notable concentrations. The concentrations of all organics are on the order of 10^{-7} mg/m^3 for both current and future conditions.

E.3.5 QUANTIFICATION OF EXPOSURE

Estimates of exposure are based on the contaminant concentrations at the exposure points (described in Section E.3.4) and scenario-specific assumptions and intake parameters. The models and equations used to quantify intakes are described in the Risk Assessment Work Plan Addendum (DOE 1992a) and have been obtained from EPA risk assessment guidance (EPA 1989a). In cases where models were not available from EPA, models developed by the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (NRC 1977) were used.

The method used to quantify chronic exposures at the FEMP employs the concept of the RME for each of the four land use/source term scenario combinations. The RME is the maximum exposure reasonably expected to occur at the site (EPA 1989a). If the RME is determined to be acceptable, then it is likely that all other lesser exposures at the site will also be acceptable. Exposures for the on-property resident, evaluated under future land use scenario without access controls, were also evaluated under CT conditions. The CT resident adult

farmer is presented as a separate receptor. Exposure pathways were equivalent to the on site RME resident farmer, but some exposure parameters were reduced to represent more realistic average exposure.

Exposures are dependent on measured or predicted concentrations of chemicals in environmental media and local land-use practices, and both are subject to change over time. This results in a large number of possible combinations of media, receptors, exposure pathways, and concentrations. Tables E.3-1, E.3-2 and E.3-3 present the combinations of receptors, land-use conditions, and concentrations (current or future) evaluated in this exposure assessment.

Exposure model parameters used in the Operable Unit 1 risk assessment are presented in Tables E.3-17 and E.3-18 for the current and future source term receptors, respectively. All parameters and equations are discussed in the FEMP Risk Assessment Work Plan Addendum (DOE 1992a) unless noted otherwise. Current and predicted future exposure point concentrations, which are combined with receptor-specific exposure parameters, are used to calculate intakes and risks.

This section presents the equations used to quantify the magnitude of exposure expected to result from all reasonable exposure pathways at the FEMP. Exposures are quantified using a set of equations and parameters which are unique to each exposure pathway. The exposure assessment process results in calculated daily intakes expressed as milligrams of chemical per kilogram of body weight per day (mg/kg-d) for hazardous chemicals and radioactivity intakes (expressed in pCi) for radionuclides.

E.3.5.1 Equations Quantifying Intakes and Exposures to Soil or Sediment

E.3.5.1.1 Incidental Ingestion

The estimation of intake of contaminants in soils or sediment is determined using the concentration in the soil or sediment at the location of interest. Evaluation of the soil and sediment ingestion pathway is performed for adults and children. Children represent a critical subpopulation for whom these exposure pathways may be significant. EPA guidance suggests that children may be exposed through the soil ingestion pathway at ages 1 through 6 (EPA 1989a). It is assumed that ingestion of sediments in stream beds away from the home involves slightly older children at ages 6 through 17. Evaluation of the soil/sediment

ingestion pathway is performed using Equations 7-7 and 7-8 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$\text{(radionuclides)}\quad I_{si} = (C_{si})(IR)(ED)(EF)(FI) \qquad \text{(E.3-1)}$$

$$\text{(chemicals)}\quad I_{si} = (C_{si})(IR)(CF)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-2)}$$

where

- I_{si} = intake from soil or sediment for contaminant i (pCi, rad) (mg/kg-d, chem)
- C_{si} = concentration of contaminant i in soil or sediment (pCi/g, rad) (mg/kg, chem)
- IR = ingestion rate (g/d, rad) (g/d, chem)
- CF = conversion factor 10^{-3} kg/g
- FI = fraction ingested from contaminated source (unitless)
- EF = exposure frequency (d/y)
- ED = exposure duration (y)
- BW = body weight (kg)
- AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.1.2 Dermal Contact

The estimation of intake of organic contaminants in soils or sediment via absorption through the skin is determined using the concentration in the soil or sediment at the location evaluated. Evaluation of the dermal absorption pathway is performed for adults and children. Children represent a critical subpopulation for whom these exposure pathways may be significant. EPA guidance suggests that children may be exposed through the dermal contact pathway at ages 1 through 6 (EPA 1989a). It is assumed that contact with sediments in stream beds away from the home involves slightly older children at ages 7 through 18. Dermal absorption from these sources is calculated using Equation 7-25 of the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$AB_{si} = (C_{si})(CF)(SA)(AF)(ABS)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-3)}$$

where

- AB_{si} = amount of ith constituent absorbed during contact with soil or sediment (mg/kg-d)
- C_{si} = concentration of ith constituent in soil or sediment (mg/kg)
- SA = skin surface area available for contact (cm^2/event)
- AF = skin adherence factor (mg/cm^2)
- ABS = absorption factor (unitless)
- CF = conversion factor; (10^{-6} kg/mg)
- EF = exposure frequency (events/y)
- ED = exposure duration (y)

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BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.1.3 Direct Radiation Exposure

The estimation of direct radiation exposure from soils or sediment is determined using the concentration in the soil or sediment at the location evaluated. Since the publication of DOE 1992a, EPA has published a new set of slope factors (EPA 1992b). Changes in these slope factors require the use of a different equation than the one originally presented in DOE 1992a to calculate risks resulting from external radiation exposures from soils. The new equation is:

$$TX = (C_s)(ED)(EF)(CF)[ET_{in}\ (1\text{-}SH_i) + ET_{out}\ (1\text{-}SH_o)] \qquad \text{(E.3-4)}$$

where

TX = time dependent activity concentration (pCi-y/g-lifetime)
C_s = concentration in surface soil or sediment (pCi/g)
ED = exposure duration (y/lifetime)
EF = exposure frequency (d/y)
ET_{in} = exposure time indoors on-site (h/d)
ET_{out} = exposure time outdoors on-site (h/d)
SH_i = indoor shielding factor (0.5, from Risk Assessment Work Plan Addendum)
SH_o = outdoor shielding factor outdoors (0, assumes no shielding)
CF = 1.142×10^{-4} y/h

Radionuclides are not evaluated as a dermal exposure because their mechanism of action differs (i.e., penetrating radiation differs from dermal absorption). Dermal absorption of organic chemicals was discussed in the preceding section.

E.3.5.2 Equations Quantifying Intakes and Exposures from Water

E.3.5.2.1 Water Ingestion Pathway

A receptor can ingest water by deliberately drinking it, or by accidentally swallowing water while swimming or wading. An estimate of intake from ingesting water is calculated from Equations 7-3 and 7-4 of DOE 1992a. The intake equations are:

$$\text{(radionuclides)}\ I_{wi} = (C_{wi})(IR)(FI)(ED)(EF) \qquad \text{(E.3-5)}$$

$$\text{(chemicals)}\ I_{wi} = (C_{wi})(IR)(FI)(ED)(EF)/(BW)(AT) \qquad \text{(E.3-6)}$$

where

I_{wi} = intake of ith contaminant from drinking water (pCi, rad) (mg/kg-d, chem)
C_{wi} = concentration of ith contaminant in water (pCi/L, rad) (mg/L, chem)
IR = ingestion rate (L/d)
FI = fraction ingested from source (unitless)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y [EPA 1991c]); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.2.2 Volatiles Released by Showering and Other Household Water Uses

The amount of a chemical taken into the body via exposure to volatilization of chemicals from showering is evaluated using the concentration of a chemical in the water source, as suggested by EPA (1992a; 1992b). Intake from the volatilization of chemicals in household water is calculated using the Andelman model (EPA 1991f):

$$\text{(radionuclides)}\ I_{wai} = (C_{wi})(K)(IR_i)(EF)(ED) \qquad \text{(E.3-7)}$$

$$\text{(chemicals)}\ I_{wai} = (C_{wi})(K)(IR_i)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-8)}$$

where

I_{wa} = intake of volatile "i" in water from inhalation (pCi, rad) (mg/kg-day, chem)
C_{wi} = concentration of constituent "i" in water (pCi/L, rad) (mg/L, chem)
K = volatilization factor (0.5 L/m^3)
IR_i = indoor inhalation rate (m^3/d)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y [EPA 1991c]); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

For volatile compounds, volatilization from groundwater can be an important exposure pathway from showering and other household uses of groundwater. However, for most heavy metals and, hence, most radionuclides at the FEMP, volatilization is not a significant pathway because they do not vaporize at room temperature. The notable exceptions to this are the isotopes of radon. Therefore, this exposure pathway will only be evaluated for radon and those organic chemicals with a Henry's Law constant greater than 1×10^{-5} and with a molecular weight of 200 g/mole or less (EPA 1991f).

E.3.5.2.3 Dermal Contact While Bathing, Swimming or Wading

The estimation of intake of contaminants in water via absorption through the skin is determined using the concentration of a chemical in the water source evaluated. Evaluation of the dermal absorption pathway is performed for both adults and children. The amount of a chemical taken into the body upon exposure via dermal contact is referred to as an absorbed dose. The absorbed dose is calculated using the dermal guidance contained in EPA 1989a, EPA 1992e, and EPA 1992h:

$$I_{ws} = (DA_{event})(EF)(ED)(SA)/(BW)(AT) \quad \text{(E.3-9)}$$

where

I_{ws} = intake through skin from showering (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
SA = surface area (cm^2)
EF = exposure frequency (event/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

DA_{event} can be calculated as:

$$DA_{event} = (C_v)(2)(K_p)(CF)[(6)(TAO)(ET)/\pi]^{+0.5} \text{ if } ET < t^*, \text{ or} \quad \text{(E.3-10)}$$

$$DA_{event} = (C_v)(K_p)(CF)\{[(ET)+(2)(TAO)(1+3B)]/(1+B)\} \text{ if } ET > t^* \quad \text{(E.3-11)}$$

where

C_v = concentration in the vehicle (mg/L)
K_p = permeability constant (cm/h)
TAO = lag time (h)
B = partitioning coefficient (unitless)
ET = exposure time
π = Pi (3.14)
t* = time to equilibrium conditions (hr)
CF = conversion factor (0.001L/cm^3)

These variables are defined in the Supplemental Guide to Risk Assessment Guidance for Superfund (EPA 1992e).

For showering the vehicle is domestic water, and for swimming the vehicle is river water. In either case, C_v equals concentration in the water (C_w). For most metals and, hence, most

radionuclides in Operable Unit 1, dermal absorption is not a significant pathway because penetration through the skin is minimal.

E.3.5.3 Equations Quantifying Intakes and Exposures from Inhalation

The amount of a contaminant a receptor takes in as a result of respiration is determined using the concentration of a chemical in the air. Equations 7-5 and 7-6, from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a), are used to quantify intake from the inhalation pathway:

$$\text{(radionuclides)}\ I_{ai} = (C_{ai})(IR)(ET)(EF)(ED) \qquad \text{(E.3-12)}$$

$$\text{(chemicals)}\ I_{ai} = (C_{ai})(IR)(ET)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-13)}$$

where

I_{ai} = intake from inhalation (pCi, rad) (mg/kg-d, chem)
C_{ai} = concentration in air (pCi/m^3, rad) (mg/m^3, chem)
IR = inhalation rate (m^3/h)
ET = exposure time (h/d)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg); and
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.4 Equations Quantifying Intakes and Exposures from Food

Consumption of contaminated food may contribute a measurable portion of the chemical intake experienced by a receptor from Operable Unit 1 at some time in the future. The food sources evaluated in this assessment include vegetables and fruit, beef, dairy products, and fish.

Transport through the food chain to humans is a concern at this operable unit, mainly under future conditions. Under current conditions humans are not expected to directly ingest vegetation growing within the operable unit. However, in the future, animals could be released within the operable unit to graze. In addition, contaminated water could be used to irrigate crops or feed, or used to water livestock. By these mechanisms, contaminants could find their way into the human food chain.

Contaminant concentrations in food can be estimated using the equations presented below. These methodologies are taken from the Work Plan Addendum (DOE 1992a).

E.3.5.4.1 Vegetable and Fruit Ingestion

The amount of a contaminant a receptor takes in as a result of consuming vegetables and fruit is determined using the concentration of a chemical in the edible portions of the plants.

The concentration in vegetables and fruit attributable to contaminated irrigation water is estimated using Equation 7-9 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$C_{vwi} = d_w \left[\frac{r_w(1-e^{-\lambda_w t_e})}{Y\lambda_w} + \frac{f_w B_{iv(2)} CF_p (1-e^{-\lambda_{di} t_{bw}})}{\rho\lambda_{di}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(E.3-14)}$$

where

C_{wvi}	=	concentration of ith contaminant in plants as a result of irrigating plants with contaminated water (pCi/g, rad) (mg/kg, chem)
λ_w	=	effective depletion constant of ith contaminant on the surface plants also known as the weathering removal rate (h^{-1})
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
λ_{di}	=	soil depletion constant (h^{-1})
$B_{iv(2)}$	=	dry soil to wet plant partitioning coefficient of ith contaminant (C_{iv}/C_s)
d_w	=	irrigation deposition rate (pCi/m^2-h, rad) (mg/m^2-h, chem)
f_w	=	fraction of year plant is irrigated (unitless)
ρ	=	effective dry surface density of the soil (g/m^2, rad) (kg/m^2, chem)
r_w	=	fraction of water borne material retained on plant surface (unitless)
t	=	growing season (h)
t_{bw}	=	duration of irrigation use (h)
t_h	=	duration of period between harvest and consumption (h)
Y	=	agricultural yield (g/m^2, rad) (kg/m^2, chem)

The soil depletion coefficient is calculated by

$$\lambda_{di} = \lambda_{ri} + \lambda_{Li} \qquad \text{(E.3-15)}$$

where the leaching coefficient (λ_{Li}) is calculated using the relationship (Baes and Sharp 1983):

$$\lambda_L = \frac{V_w}{z\,\theta \left[1 + \frac{K_d}{\theta} \right]} \qquad \text{(E.3-16)}$$

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and where

λ	=	Leach rate (h^{-1})
V_w	=	Percolation rate (nominally 0.0044 cm/h through Pits and 2)
z	=	Depth of surface soil (15 cm)
δ	=	Density of soil in root zone (nominally 1.5 g/cm^3)
K_d	=	Water to soil partitioning coefficient (cm^3/g)
θ	=	Moisture fraction of surface soil (measured at 0.17)

Vegetables and Fruits Contaminated by Aerial Deposition

Eating vegetables and fruit contaminated by aerial deposition of contaminated dust can contribute to the total intake of contaminants by humans. If measured concentrations in the plants are not available (e.g. future exposures), this concentration is estimated using Equation 7-10 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The equation used to estimate contaminant concentrations in vegetation is:

$$C_{avi} = d_d \left[\frac{r_d(1-e^{-\lambda_w t_e})}{Y\lambda_w} + \frac{f_d B_{iv(2)} CF_p (1-e^{-\lambda_{di} t_{bd}})}{\rho \lambda_{di}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(E.3-17)}$$

where

C_{avi}	=	concentration of the ith contaminant in/on vegetables and fruit (pCi/g, rad) (mg/kg, chem)
λ_w	=	effective depletion constant of ith contaminant on the surface plants, also known as the weathering rate (h^{-1})
λ_{di}	=	soil depletion constant (hr^{-1})
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
$B_{iv(2)}$	=	dry soil to wet plant partitioning coefficient of ith contaminant (C_{iv}/C_s)
CF_p	=	dry to wet weight conversion factor (0.428, food crops) (1.0, feed and forage)
C_{vdi}	=	concentration of ith contaminant in plants as a result of dust deposition on plants and surrounding soil (pCi/g, rad) (mg/g, chem)
d_d	=	constituent's deposition rate (pCi/m^2-h, rad) (mg/m^2-h, chem)
f_d	=	fraction of year plant is down wind (unitless)
r_d	=	fraction of airborne material retained on plant surface (unitless)
t_e	=	growing season (h)
t_{bd}	=	duration soil is exposed to airborne emissions (h)
t_h	=	duration of period between harvest and consumption (h); and
Y	=	agricultural yield (g/m^2, rad) (kg/m^2, chem)
ρ	=	effective dry surface soil density (g/m^2, rad) (kg/m^2, chem)

Equations 7-5 and 7-6 from DOE 1992 are used to quantify intake from the crop ingestion pathway:

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$$\text{(radionuclides)}\quad I_{avi} = (C_{avi})(IR)(FI)(EF)(ED) \qquad \text{(E.3-18)}$$

$$\text{(chemicals)}\quad I_{avi} = (C_{avi})(IR)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-19)}$$

where

I_{avi} = intake from vegetation (pCi, rad) (mg/kg-d, chem)
C_{avi} = total concentration of contaminants in vegetable (pCi/g, rad) (mg/kg, chem)
IR = ingestion rate (g/d, rad) (kg/d, chem)
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.4.2 Beef Ingestion

Beef (and milk) can become contaminated in three ways at this facility. The first way is through use of contaminated water as stock water. The second is by aerial deposition of contaminants on feed crops or forage, and the third is by direct ingestion of soil while grazing.

Beef and Dairy Products Produced with Contaminated Stock Water

This scenario assumes that water is used for stock water and irrigation of feed. Animals drinking the water ingest contaminants directly. Plants irrigated with water take up constituents via root uptake, and direct deposition onto exposed surfaces by irrigation water. If measured values are not available (e.g., future exposures), this concentration can be calculated using the methodology set forth in the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The concentration of a contaminant in animal products, such as beef or milk, is estimated using the following equation:

where

$$C_{Ai} = F_{Ai}[(C_{fi})(Q_f) + (C_{wi})(Q_w)]\, e^{-\lambda_i t_h} \qquad \text{(E.3-20)}$$

C_{Ai} = concentration of ith contaminant in the animal product (pCi/L for milk, pCi/g for beef, rad) (mg/L for milk, mg/kg for beef, chem)
C_{fi} = concentration of ith contaminant in feed (pCi/g, rad) (mg/kg, chem)
C_{wi} = concentration of contaminant in water (pCi/L, rad) (mg/L, chem)
F_{Ai} = element (stable) transfer coefficient that relates the daily intake by an animal to the concentration of ith contaminant in an edible portion of the animal product (d/L for milk, d/g for meat)

Q_f = consumption rate of contaminated feed by livestock (g/d, rad) (kg/day, chem)
Q_w = consumption rate of contaminated stock water by livestock (L/d)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h = duration of period between harvest and consumption (h)

Meat or Milk Downwind of Source

Forage, feed, and soils downwind of a potential source of contaminated dust can have contamination deposited on them by settling dust. Ingestion of these plants by livestock contributes to the body burden of these contaminants in livestock. Consumption of meat or milk from these animals contributes to the total intake of these contaminants by humans. The magnitude of the contaminant exposure by humans depends, in part, on the concentration of the constituent in the animal products. If measured values are not available (e.g. future exposures), this concentration can be calculated using the methodology set forth in the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The concentration of a contaminant in animal products, such as beef or milk, is estimated using the following equation:

$$C_{Ai} = F_{Ai}[(C_{afi})(Q_f) + (C_{agi})(Q_g) + (C_{asi})(Q_s)]\, e^{-\lambda_{ri} t_h} \qquad \text{(E.3-21)}$$

where

C_{Ai} = concentration of ith contaminant in the animal product (pCi/L for milk, pCi/g for beef, rad) (mg/L for milk, mg/kg for beef, chem)
C_{afi} = concentration of ith contaminant in feed (pCi/g, rad) (mg/kg, chem)
C_{agi} = concentration of ith contaminant in forage (pCi/g, rad) (mg/kg, chem)
C_{asi} = concentration of ith contaminant in soil (pCi/g, rad) (mg/kg, chem)
F_{Ai} = elemental transfer coefficient that relates the daily intake by an animal to the concentration of ith contaminant in an edible portion of the animal product (d/L for milk, d/g for meat)
Q_f = consumption rate of contaminated feed by livestock (g/d, rad) (kg/day, chem)
Q_g = consumption rate of contaminated forage by livestock (g/d, rad) (kg/day, chem)
Q_s = consumption rate of contaminated soil by livestock (g/d, rad) (kg/day, chem)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h = duration of period between harvest and consumption (h)

If measured values for the concentrations of constituents in stored feed are not available (e.g. future exposures), this concentration is estimated using Equation 7-9 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The equation is:

$$C_{vwi} = d_d \left[\frac{r_d(1-e^{-\lambda_w t_e})}{Y\lambda_w} + \frac{f_d B_{iv(1)} CF_p (1-e^{-\lambda_{di} t_{bw}})}{\rho \lambda_{di}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(E.3-22)}$$

where

C_{vwi} = concentration of ith contaminant in plants as a result of irrigating plants with contaminated water (pCi/g, rad) (mg/kg, chem)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
λ_w = effective depletion constant of ith contaminant on the surface plants also known as the weathering removal rate (h^{-1})
λ_{di} = soil depletion constant (hr^{-1})
$B_{iv(1)}$ = dry soil to wet plant partitioning coefficient of ith contaminant (C_{iv}/C_s)
CF_p = dry to wet weight conversion factor (0.428, food crops) (1.0, feed and forage)
d_d = deposition rate (pCi/m^2-h, rad) (mg/m^2-h, chem)
f_d = fraction of year plant is downwind (unitless)
ρ = effective dry surface density of the soil (g/m^2, rad) (kg/m^2, chem)
r_d = fraction of airborne material retained on plant surface (unitless)
t_e = growing season (h)
t_{bw} = duration of irrigation use (h)
t_h = duration of period between harvest and consumption (h)
Y = agricultural yield (g/m^2, rad) (kg/m^2, chem)

The amount of a contaminant a receptor takes in as a result of consuming beef is determined using the concentration of a chemical in the animal's flesh. Equations 7-17 and 7-18 from DOE 1992a are used to quantify intake from eating beef:

$$\text{(radionuclides)} \quad I_{Ai} = (C_{Ai})(IR)(FI)(EF)(ED) \qquad \text{(E.3-23)}$$

$$\text{(chemicals)} \quad I_{Ai} = (C_{Ai})(IR)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-24)}$$

where

I_{Ai} = intake of ith constituent from beef (pCi, rad) (mg/kg-d, chem)
C_{Ai} = concentration of ith contaminant in animal product (pCi/g, rad) (mg/kg, chem)
IR = ingestion rate (g/d, rad) (kg/d, chem)
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

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E.3.5.4.3 Consumption of Milk Products

The amount of a contaminant a receptor takes in as a result of consuming dairy products is determined using the concentration of a chemical in the animal's milk. Equations 7-17 and 7-18 from DOE 1992a are used to quantify intake from consuming dairy products:

$$\text{(radionuclides)} \quad I_{Ai} = (C_{Ai})(IR)(FI)(EF)(ED) \qquad \text{(E.3-25)}$$

$$\text{(chemicals)} \quad I_{Ai} = (C_{Ai})(IR)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-26)}$$

where

I_{Ai} = intake of ith constituent from dairy products (pCi, rad) (mg/kg-d, chem)
C_{Ai} = concentration of ith contaminant in animal product (pCi/L, rad) (mg/L, chem)
IR = ingestion rate (L/d)
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (d/y)
ED = exposure duration (y)
BW = body weight (kg)
AT = averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.4.4 Fish Ingestion

If measured concentrations of a constituent in fish are unknown, they are estimated using Equation 7-19 of the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$C_{Fi} = (C_{Wi})(BCF_{Fi})\, e^{-\lambda_{ri} t_h} \qquad \text{(E.3-27)}$$

where

C_{Fi} = concentration of the ith constituent in fish (pCi/g, rad) (mg/kg, chem)
C_{wi} = concentration of the ith constituent in surface water (pCi/L, rad) (mg/L, chem)
BCF_{Fi} = fish bioconcentration factor (pCi/g fish per pCi/L, rad) (mg/kg fish per mg/L, chem)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h = duration of period between harvest and consumption (h)

The amount of a contaminant a receptor takes in as a result of consuming local fish on a regular basis is determined by using the concentration of a chemical in the fish's flesh. Equations 7-17 and 7-18 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a) are used to quantify intake from consuming fish:

$$\text{(radionuclides)}\quad I_{Fi} = (C_{Fi})(IR)(FI)(EF)(ED) \qquad \text{(E.3-28)}$$

$$\text{(chemicals)}\quad I_{Fi} = (C_{Fi})(IR)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.3-29)}$$

where

I_{Fi}	=	intake of ith constituent from fish (pCi, rad) (mg/kg-d, chem)
C_{Fi}	=	concentration of ith contaminant in fish (pCi/g, rad) (mg/kg, chem)
IR	=	ingestion rate (g/d, rad) (kg/d, chem)
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

E.3.5.5 Indoor Radon Exposures

A resident living on soil or waste containing radium may incur exposures to radon entering their dwelling from the soil or waste beneath the structure. These risks must be considered along with risks from other sources when evaluating risks to a receptor living within Operable Unit 1.

This study evaluates risks from radon exposures to a resident occupying a home located on top of a pit containing buried waste. The conceptual model selected for this risk assessment assumes a home is built over Waste Pit 4, which is the most stable pit in Operable Unit 1. The home is assumed to be 3 m high, 20 m long and 10 m wide. The home is assumed to have an air exchange rate of 0.1 h^{-1}, which is characteristic of a tightly sealed, energy efficient home (Nero et al 1983).

It is likely that any house located over a waste pit would use slab-on-grade construction. Anyone excavating a basement for a house located over one of the Operable Unit 1 waste pits would soon discover they were digging in a waste disposal site. These people would probably leave to build their house elsewhere after digging into the waste, because few people would willingly choose to take up permanent residence over a waste pit. People using slab-on-grade construction while building their home may avoid digging into the waste and so remain unaware of their location relative to the buried waste.

The concrete slab beneath the hypothetical home is nominally 15 cm thick, and the permeability of the concrete is assumed to be equal to the soils beneath it. This is very

conservative, because the permeability of concrete to gas movement is normally several factors of ten lower than that of soil.

This analysis assumes the fluence rate of radon entering the home through the concrete slab equals the radon fluence rate emanating from the vent pipe penetrating the clay cap over Waste Pit 4. This is also a conservative assumption, because radon entering a slab-on-grade home would normally first have to move through the clay cap, allowing time for radioactive decay to decrease the radon fluence rate. Using data from the pipe neglects the impact of this delay time.

The fluence rate expressed as the radiological activity due to radon emanating from a square meter of soil in 1 second from the vent pipe was measured for three days over a five day period (Appendix C.1). The maximum measured fluence rates from these pipes was 0.005 $pCi/m^2/s$. This fluence rate is supported by process knowledge of the pit which indicates that no radium was buried there. The only source of radium would be as a result of decay from the uranium and thorium disposed there. Due to the long half-lives of these nuclides, no appreciable concentrations of radium are expected to be produced in the pit during the 1000-year study period. Therefore radon flux from the pit should remain low at the measured levels.

Using this conceptual model, and the radon fluence rate of 0.005 $pCi/m^2/s$, radon levels in the home attributable to the radon sources beneath the structure are calculated from the following equation, as adapted from Nero et al. 1983:

$$C_{Rn} = \frac{(J_{Rn})\ (A_s)\ (CF)\ [1 - e^{-(\lambda_{Rn} + \lambda_{Vent})\ t}]}{(\lambda_{Rn} + \lambda_{Vent})\ (V_{Home})} \qquad \text{(E.3-30)}$$

where

C_{Rn}	=	Concentration of radon in indoor air ($pCi \bullet L^{-1}$)
J_{Rn}	=	Radon fluence rate ($pCi \bullet m^{-2} \bullet s^{-1}$)
A_s	=	Surface area under structure (m^2)
CF	=	Unit conversion factor ($3.6\ s \bullet m^3 \bullet h^{-1} \bullet L^{-1}$)
λ_{Rn}	=	Radioactive decay coefficient of Rn-222 (h^{-1})
λ_{Vent}	=	Ventilation depletion coefficient of Rn-222 (h^{-1})
t	=	Time to equilibrium (h)
V_{Home}	=	Volume of home (m^3)

Radon air concentrations in the home are calculated to be approximately 0.06 pCi/L.

Intakes of radon are calculated using Equation E.3-12. Using this methodology, the total intake is directly proportional to the exposure concentration and the total volume inhaled. If the concentration is held constant, the intake is related to the inhalation rate and the total time spent breathing the indoor air over a lifetime. Based on these criteria, the resident farmer is selected as the RME receptor for indoor radon exposures.

Using Equation E.3-12, a RME resident farmer breathing indoor air containing 0.06 pCi/L at a rate of 15 m/d (EPA 1991f) for 350 d/y would inhale 16,500 pCi of radon during a 70 year lifetime. Risks associated with this exposure are presented in Section E.5.3.3.1.

E.3.5.6 Quantification of Intakes and Exposures from Multiple Pathways

The most probable scenarios involve simultaneous exposures via a number of pathways. The multiple exposure scenarios are evaluated by assuming the contributions from component pathways are cumulative. Thus, all the receptors evaluated are subject to more than one exposure pathway and have been evaluated accordingly.

E.3.5.7 Scenario-Specific Assumptions and Exposure Parameters

Exposure parameters are dependent on receptor-specific behavior patterns, and vary from receptor scenario to receptor scenario. The following sections begin with a brief description of each set of parameters used to evaluate exposures to hypothetical receptors during this assessment. This synopsis is followed by descriptions of any site-specific parameter values and their derivation. Tables E.3-16 and E.3-17 contain a summary of these parameters.

E.3.5.7.1 Exposure Duration (ED)

The exposure duration is the period of time a receptor is exposed in a lifetime. Tables E.3-16 and E.3-17 list the values and sources of the exposure durations used to calculate exposures to the hypothetical receptors evaluated in this assessment.

Because of the agricultural history of the area, the RME adult may be exposed over an entire 70-year lifetime. Therefore, the exposure duration selected for this receptor is 70 years. This value is over twice as long as the standard 30-year exposure presented in EPA 1991b. The 70-year value was determined in consultation with EPA Region V and applies to the off-

property RME resident adult farmer, the on-property RME resident adult farmer, the Great Miami River user, and the off-property user of beef and dairy products.

The RME child and the CT adult are assumed to receive exposures over 6 years and 9 years, respectively, as suggested by supplemental guidance (EPA 1991b). The trespassing youth is assumed to receive exposures while roaming randomly about the property between the ages of 6 and 18. EPA suggests this activity be evaluated over a period of 12 years (DOE 1992d). The home builder is evaluated to assess the health impacts of exposures incurred while building a home on the property. This activity is assumed to be completed within one year of groundbreaking (NRC 1984), so the exposure duration for the home builder is set at one year.

The Great Miami River user is also assumed to swim in the river. It is assumed that this receptor only swims during a 30-year period of the individual's life. Therefore, the exposure duration for this scenario is 30 years. Although there are no areas designated for swimming in the Great Miami River, it is assumed that a youth, 12 years of age, would use the Great Miami River for swimming, fishing and diving, through age 42. This age range was selected because the Great Miami River current makes the river unsafe for very young children to swim in and because there are no designated swimming areas to attract visitors. It is very unlike that anyone would use the river for recreational purposes over an entire lifetime. Therefore, the exposure duration assumed for this scenario is 30 years.

The extended trespasser is assumed to visit the site for 12 years as a youth (ages 6 to 18) and for 32 years as an adult (until age 50). The combined exposure duration for this receptor is 44 years.

E.3.5.7.2 Exposure Frequency

The exposure frequency is the number of days a receptor is exposed each year. Tables E.3-16 and E.3-17 list the values and sources of the exposure frequencies used to calculate exposures to the hypothetical receptors evaluated in this assessment.

The exposure frequency selected for scenarios involving a RME adult farmer or a RME child is the standard RME value of 350 days per year listed in EPA 1989a. The 350 days per year value applies to the off-property RME resident adult, the on-property RME resident adult, the on-property RME resident child, the off-property user of beef and dairy products, and the Great Miami River user. The Great Miami River user is also assumed to swim in the river.

The exposure frequency selected for this activity is five days per year as suggested by guidance (EPA 1989a).

The exposure frequency selected for scenarios involving a CT adult farmer is 275 days per year, as suggested by supplemental guidance (EPA 1991b). EPA Region V suggests the exposure frequency of the trespassing child to be set at 52 days per year (DOE 1992a). The extended trespasser is assumed to spend 110 days per year on site.

The home builder is evaluated to assess the health impacts of exposures incurred while building a home on the property. For this activity, it is assumed that a worker spends approximately 175 eight-hour days constructing a home.

E.3.5.7.3 Exposure Time

The exposure time is the amount of time a receptor is exposed each day. Tables E.3-16 and E.3-17 list the values and sources of the exposure times used to calculate exposures to the hypothetical receptors evaluated in this assessment.

The total gamma exposure time assumed for the RME farmer is 24 hours per day, 350 days per year for 70 years. However, the exposure time per day was divided into two exposure times, exposure time outdoors (ET_{out}) which assumes no shielding factor, and exposure time indoors (ET_{in}) which assumes a shielding factor of 0.5.

The RME adult farmer scenarios constructed for this assessment assume the receptor works outside of the residence for 2000 hours per year. Spreading this time over the 350 days per year of on-site exposure yields an average outdoor exposure time of 5.7 hours per day. This leaves an indoor exposure time of 18.3 hours per day for this receptor. Thus, about 25 percent of the receptor's time on-site is spent outside of the residence. These values apply to the off-property RME resident adult farmer and the on-property RME resident adult farmer. The on-property RME resident child is assumed to spend only 2 hours per day outdoors, for a total of 700 hours per year.

It is assumed that the CT resident adult farmer is exposed outdoors for 1,152 hours (equal to 48 days of continuous exposure) out of the 275 days spent within the boundaries of the operable unit each year (EPA 1993h). This is equivalent to an exposure time of 4.2 hours per day of exposure. It is assumed that the CT resident adult farmer is exposed outdoors

approximately 4.2 hours per day for 275 days per year, which is equivalent to 1155 hours of outdoor exposure in a year. This leaves an indoor exposure time of 19.8 hours per day for this receptor. Thus, about 20 percent of the receptor's time on-site is spent outside of the residence. These values apply only to the CT receptor.

The trespassing youth and the extended trespasser are assumed to spend time on the site. Current trespassing activities are minimal because Operable Unit 1 is currently surrounded by two fences and patrolled on a regular basis by a security force. If these patrols are relaxed, trespassing may occur, but the time spent on the property is unknown. EPA Region V suggests that the exposure time of the trespassing youth to be set at 4 hours per day if site-specific information is not available (DOE 1993d). The extended trespasser is assumed to spend 2 hours per day outdoors on the site.

The home builder is evaluated to assess the health impacts of exposures incurring while building a home on the property. This activity is assumed to be completed after 500 hours (NRC 1984). Assuming a worker constructs a house in 50 days, the total exposure time for the home builder is 10 hours per day. This time is divided equally into 5 hours per day outside of the structure and 5 hours per day inside of the structure.

The RME adult farmer and child receptors are assumed to receive skin exposures via bathing or showering once a day. Since no site-specific information on this activity is available, the adult exposure time selected for this activity is 0.25 hours per day, as suggested by guidance (EPA 1989a). The exposure time selected for the RME child performing this activity is 0.25 hour per day, as suggested by guidance (EPA 1992e).

The Great Miami River user is assumed to use the river for recreational swimming. Since no site-specific information on this activity is available, the exposure time selected for this activity is 0.2 hour per day, 5 days per year, as suggested by guidance (EPA 1992e).

E.3.5.7.4 Inhalation Rates

The inhalation rate is the volume of air inhaled daily by a receptor. Tables E.3-17 and E.3-18 list the values and sources of the inhalation rates used to calculate exposures to the hypothetical receptors evaluated in this assessment.

EPA suggests using a value of 20 cubic meters per day (0.83 m^3/h) as the inhalation rate for an RME adult (EPA 1989b). Due to a lack of information, this inhalation rate is used for the trespassing youth and all adult exposures, except those involving inhalation of volatiles and radon within the home and the visitor exposures. Inhalation of volatiles from water and radon in the home is evaluated using 15 cubic meters per day for the 18.3 h/d the receptor is inside the home (0.82 m^3/h) (EPA 1991f). The home builder is assumed to be more active than the average adult, so an inhalation rate of 2.5 m^3/h is used for the time this receptor is on site. The inhalation rate for the on-property RME child was set at 0.5 m^3/h, given the child's smaller lung capacity and time spent at rest.

E.3.5.7.5 Soil Ingestion Rates

The soil ingestion rate is the mass of soil ingested daily by a receptor. Tables E.3-17 and E.3-18 list the values and sources of the soil ingestion rates used to calculate exposures to the hypothetical receptors evaluated in this assessment.

A soil ingestion rate of 0.18 grams per day (DOE 1993f) was used to approximate lifetime exposure to the RME farmer. This value is based on ingestion rates for activities performed throughout the receptor's lifetime including childhood, youth and adult lifestages over a 70 year period. For the sake of this risk assessment, it is assumed that all soil ingested is from Operable Unit 1.

The literature was consulted to determine an appropriate soil incidental ingestion rate for a farmer. However, no default values were found. Therefore, this value was estimated assuming the following:

- Soil ingestion rate to use on days while tilling, plowing, planting or harvesting would use a higher average daily value of 0.48 g/day from EPA default exposure assumptions (EPA 1991j).

- For other activities, use an average daily soil ingestion rate of 0.1 g/day.

To determine the amount of time a RME farmer is engaged in these activities, a review of farming parameters (farm size and crop configuration) were considered for Hamilton County. The 1987 Census of Agriculture (U.S. DOC 1989) indicates that 1,284 of the 1,364 farms in Hamilton and Butler County (95 percent) are under 500 acres (5 percent are 500 acres or

above). Therefore, 500 acres was selected as the RME farm size. The soil ingestion rate for the CT farmer was based on similar farm configuration but using an average (CT) farm size of 125 acres. To determine the times associated with farming, a farmer was assumed to follow recommended agricultural practices for the region. A farmer is assumed to rotate their crops and plant 35 percent (175 acres) in corn, 35 percent in soybeans, 20 percent (100 acres) in wheat, and 10 percent (50 acres) in hay. It must be acknowledge that this configuration is a typical configuration and may represent an average value because each crop has a different time associated with field preparation, planting and harvesting. However, data is not available to determine a RME configuration. Therefore, an alternative configuration could result in a slightly higher or slightly lower exposure. A RME farm size (500 acres) was assumed to be adequate to compensate for this uncertainty.

Table E.3-17a presents the detailed calculations for soil ingestion rate for the RME and CT farmer. The U.S. Soil Conservation Service Field Technical Guide (U.S. SCS 1992) indicates that a farmer spends about 1.24 hours per acre farming corn, 1 hour per acre farming soybeans, 1.28 hours per acre farming wheat and 2.73 hours per acre farming hay. Assuming the farm configuration described above, an RME farmer would spend approximately 660 hours farming (plowing, discing, planting and/or harvesting). An additional 20 percent is added to this time to account for miscellaneous activities and the uncertainty with the farm configuration described above, to give a total of 800 hours, or 100 working days. Therefore, it is assumed that a farmer would incidentally ingest 0.48 g/day of soil for 100 days per year spent tilling the soil and 0.1 g/day for the remaining 250 days per year, for a combined average ingestion rate of 0.18 grams/day for 350 days per year, assuming an average (CT) farm produces a CT soil ingestion rate of 0.120 g/day.

The soil ingestion rates for the trespassing youth and extended trespasser (0.1g/day) and the on-property resident child (0.2g/day) are specified by EPA 1991j. It was assumed that all on-property receptors received 100 percent of their soil intake from the site. This includes the on-property RME child and adult, the on-property CT adult, and the home builder. The trespassing child was assumed to only receive 25 percent of his daily soil intake from the site, as only 4 of 16 waking hours are spent on property.

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E.3.5.7.6 Water Ingestion Rates

The water ingestion rate is the volume of water drunk daily by a receptor. Generally this intake is from drinking water, but may be from incidental ingestion during swimming. Tables

E.3-17 and E.3-18 list the values and sources of the water ingestion rates used to calculate exposures to the hypothetical receptors evaluated in this assessment.

This assessment uses a drinking water ingestion rate of 2 liters per day for the RME adult receptors and 1.4 liters per day for the RME child, as stipulated in EPA 1989a. EPA Region V suggests assuming that the CT adult drinks 1.4 liters per day (EPA 1992).

The hypothetical Great Miami River user accidentally ingests water while swimming in the river. The ingestion rate of this receptor is 0.05 liters per hour of exposure (EPA 1992e).

E.3.5.7.7 Food Consumption

Some of the hypothetical receptors evaluated consume vegetables, fruit, beef, and dairy products grown on-property. Tables E.3-17 and E.3-18 list the values and sources of the food consumption rates used to calculate exposures to the hypothetical receptors evaluated in this assessment.

The hypothetical RME adult farmer eats 80 grams per day of vegetables, 42 grams per day of fruit, and 75 grams of beef per day from home-grown sources. The RME adult consumes home-grown dairy products such as milk and cheese at the rate of 0.3 liters per day (EPA 1989a).

Discussions with EPA Region V are the sources of parameter values for the hypothetical CT adult farmer (EPA 1992). This receptor eats 50 grams per day of vegetables, 28 grams per day of fruit, and 50 grams of beef per day from home-grown sources. The RME adult farmer consumes home-grown dairy products such as milk and cheese at the rate of 0.3 liters per day (DOE 1992a), while the CT adult farmer was assigned a value of 0.2 liters per day, as per EPA Region V guidance.

There is no EPA guidance on food ingestion rates for children at this time. The values used in this assessment were derived during the development of the Work Plan Addendum (DOE 1992a) and are based on work performed by the U.S. Department of Agriculture (USDA 1986). The hypothetical RME child eats 40 grams per day of vegetables, 61.5 grams per day of fruit, and 29 grams of beef per day. The RME child consumes dairy products such as milk and cheese at the rate of 0.9 liters per day (NRC 1977).

E.3.5.7.8 Body Weights

The body weight is the mass of the receptor, in kilograms. This assessment uses the median body weight of 70 kilograms for all adult receptors, 43 kilograms for all older children and 15 kilograms for all young children, as stipulated in the Work Plan Addendum (DOE 1992a). Tables E.3-17 and E.3-18 list the values and sources of the body weights used to calculate exposures to the hypothetical receptors evaluated in this assessment.

E.3.5.7.9 Surface Areas

The surface area is the amount of the body's skin surface which is exposed as a result of a specific activity or group of activities. Tables E.3-17 and E.3-18 list the values and sources of the surface areas used to calculate exposures to the hypothetical receptors evaluated in this assessment.

EPA's interim report on dermal assessment (EPA 1992a) and supplemental guidance on dermal assessment (EPA 1992i) lists suggested values for surface areas. The surface areas used to evaluate exposures from dermal contact while bathing and swimming in this assessment are 2.3 square meters for all adult receptors, and 0.83 square meters for children. These values differ from those presented in the Work Plan Addendum, which predated the dermal guidance.

It was assumed that 25 percent of a receptor's total body surface area is accounted for by the hands, legs, arms, neck, and head, allowing for clothing (EPA 1992a). This factor results in exposed skin surface areas of 0.38 m^2 for the trespassing child 0.5 m^2 for adults, and 0.18 m^2 for the RME child. Again, these values differ from those presented in the Work Plan Addendum.

E.3.5.7.10 Adherence Factors

Uptake of chemicals through the skin from soil require that a sufficiently intimate intake be established between the soil and the skin. One of the factors that determine the quantity of chemical absorbed is the amount of soil that adheres to the skin. Tables E.3-17 and E.3-18 list the soil adherence values and sources used to estimate dermal uptake from soil. Following the suggestion of EPA (1992e), a factor of 1.0 mg/cm^2 is used for all RME evaluations and 0.2 is used for the CT adult farmer.

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E.3.5.7.11 Averaging Times

The averaging time is the duration of time, expressed in days, over which the period of exposure occurs. It is only used in the evaluation of chemical exposures. The averaging time selected depends on the health effect being evaluated. Long-term intakes of noncarcinogenic agents are calculated by averaging intakes over the period of exposure, as per EPA guidance (EPA 1989a). Carcinogenic intakes are averaged over the lifetime of the receptor. This approach is based on the contention that a high dose administered over a short period is equivalent to a low dose over a long period. Tables E.3-17 and E.3-18 list the values and sources of the averaging times used to calculate exposures to the hypothetical receptors evaluated in this assessment.

E.3.6 SUMMARY OF EXPOSURE ASSESSMENT

This exposure assessment evaluates the types and magnitudes of contact that a potential receptor may have with site-related constituents. A conceptual model for Operable Unit 1 has been developed to provide the basis for identifying and evaluating the potential risks to human health in this baseline risk assessment. The conceptual model served as framework for identifying the paths by which human health may be impacted by Operable Unit 1.

The materials in eight waste pits were treated as the primary sources of potential contamination in Operable Unit 1. These waste pits contain both chemical and radioactive constituents which can be released by a variety of mechanisms including leaching to groundwater, erosion by surface water and air, and human intrusion. The potential for these contaminants to be transported by groundwater, surface water, and air after their release is estimated in this assessment using mathematical models which attempt to quantify natural transport phenomena.

The potential for human exposures is also investigated. Particular emphasis is placed on identifying applicable receptors and exposure routes.

TABLE E.3–1

SUMMARY OF LAND USE SCENARIOS, SOURCE TERMS, ACCESS CONTROLS AND RECEPTORS

LAND USE	ACCESS CONTROLS	SOURCE TERM	RECEPTOR	Eval–uated (y/n)	COMMENTS	Air Model Used	Land Use Type
Current Land Use	With access controls	Current Source Term	Groundskeeper (new)	yes		Current	Government Control
			Off–property RME farmer	yes		Current	Government Control
			Off–property child (new)	yes		Current	Government Control
	Without access controls	Current Source Term	Groundskeeper (new)	no	risk same as with access controls		
			Off–property RME farmer	no	risk same as with access controls		
			Off–property child (new)	no	risk same as with access controls		
			Trespasser	yes		Current	Government Control
			Off–prop. user meat/milk	yes		Current	Government Control
	Without access controls	Future Source Term (i.e., Future Gov't ownership)	Off–property RME farmer	no	risk evaluated under future land use – agricult.		
			Off–property child (new)	no	risk evaluated under future land use – agricult.		
			Trespasser	yes		Future	Government Control
			Off–prop. user meat/milk	no	risk evaluated under future land use – agricult.		
			GMR user	yes		Future	Government Control
Future Land Use	With access controls	Future Source Term (i.e., Future Gov't ownership)	Expanded trespasser (new)	yes		Future	Government Control
			Groundskeeper (new)	yes		Future	Government Control
			Off–property RME farmer	no	risk evaluated under future land use – agricult.		
			Off–property child (new)	no	risk evaluated under future land use – agricult.		
			Off–prop. user meat/milk	no	risk evaluated under future land use – agricult.		
			GMR user	no	risk same as current land use, future source term		
	Without access controls	Future Source Term (i.e., Future Agricultural Use)	On–property RME farmer	yes		Future	Agricultural Use
			On–property child	yes		Future	Agricultural Use
			On–property CT farmer	yes		Future	Agricultural Use
			On–property RME farmer	yes	user of perched groundwater	Future	Agricultural Use
			Off–property RME farmer	yes		Future	Agricultural Use
			Off–property child (new)	yes		Future	Agricultural Use
			Home Builder	yes		Future	Agricultural Use
			Off–prop. user meat/milk	yes		Future	Agricultural Use
			GMR user	no	risk same as current land use, future source term		

TABLE E.3-2

SUMMARY OF EXPOSURE PATHWAYS QUANTITATIVELY EVALUATED IN RISK ASSESSMENT CURRENT LAND USE

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Off-property RME Farmer Off-property RME child	NA	• Inhalation of VOCs, radon, and particulates • Ingestion of vegetables and fruit • Ingestion of meat and milk products	NA	NA	NA
Groundskeeper	• Direct radiation • Dermal contact with soil • Incidental ingestion of soil	• Inhalation of VOCs, radon, and particulates	NA	NA	NA
Current Land Use Without Access Controls - Current Source Term					
Off-property RME Farmer Off-property RME child	NA	• Inhalation of VOCs, radon, and particulates • Ingestion of vegetables and fruit • Ingestion of meat and milk products	NA	NA	NA
Trespassing Child	• Incidental ingestion of surface soil • Dermal contact with surface soil • Direct radiation	• Inhalation of VOCs, radon, and particulates	NA	NA	NA
Off-property user of meat and milk products	• Ingestion of meat and milk products	NA	NA	• Ingestion of meat and mil products from livestock consuming water from Pits 5,6, and the Clearwell.	NA

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TABLE E.3-2
(Continued)

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Groundskeeping	• Direct radiation • Incidental Ingestion of surface soil • Dermal contact with surface soil	• Inhalation of VOC radon, and particulates	NA	NA	NA
		Current Land Use Without Access Controls - Future Source Term			
Off-property RME Resident Farmer Off-property RME child	NA	• Inhalation of VOCs, radon, and particulates • Ingestion of vegetables and fruit • Ingestion of meat and milk Products	• Ingestion of drinking water • Inhalation of VOCs and radon while showering • Dermal contact while bathing • Ingestion of vegetables and fruit • Ingestion of meat and milk products	NA	NA
Trespassing Child	• Incidental ingestion of surface soil and pit material • Dermal contact with surface soil and pit material • Direct radiation	• Inhalation of VOCs, radon, and particulates	NA	• Incidental ingestion of surface water (Paddys Run) • Dermal contact with surface water (Paddys Run)	• Incidental ingestion of sediment (Paddys Run) • Dermal contact • Direct radiation

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TABLE E.3-2
(Continued)

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Great Miami River user	NA	NA	NA	• Incidental ingestion while swimming (GMR) • Dermal contact while swimming (GMR) • Drinking water ingestion (GMR) • Inhalation of VOCs and radon (GMR) • Dermal contact while bathing (GMR) • Ingestion of vegetables and fruit (GMR) • Ingestion of meat and milk products (GMR) • Ingestion of fish (GMR)	NA
Off-property user of meat and milk products	• Ingestion of meat and milk products (Pits 1, 2)	NA	NA	• Ingestion of meat and milk products (Pits 5,6)	NA

NA = Not Applicable

TABLE E.3-3
SUMMARY OF EXPOSURE PATHWAYS QUANTITATIVELY EVALUATED IN RISK ASSESSMENT
FUTURE LAND USE

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Future Land Use With Access Controls - Future Source Term					
Expanded Trespasser	• Incidental ingestion of surface soils and pit material • Dermal contact with surface soils and pit materials • Direct irradiation	• Inhalation of VOCs, radon, and particulates	NA	• Dermal contact with surface water • Incidental ingestion of surface water	• Dermal contact with sediment • Incidental ingestion of sediment
Groundskeeper	• Incidental ingestion of surface soils • Dermal contact with surface soils and pit material • Direct irradiation	• Inhalation of VOCs, radon, and particulates	NA	NA	NA
Off-Property RME Farmer Off-Property RME Child	NA	• Inhalation of VOCs, radon, and particulates • Ingestion of vegetables and fruit • Ingestion of meat and milk products	• Ingestion of drinking water • Inhalation of volatiles and radon while showering • Dermal contact while bathing • Ingestion of vegetables and fruit • Ingestion of meat and milk products	NA	NA
Off-Property User of Meat/Milk Products	• Ingestion of meat and milk products	• Ingestion of meat and milk products	NA	• Ingestion of meat/milk products	NA

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TABLE E.3-3
(Continued)

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Future Land Use With Access Controls - Future Source Term					
GMR User	NA	NA	NA	• Dermal contact while swimming • Dermal contact while bathing • Ingestion of drinking water • Inhalation of volatiles/radon while showering • Incidental ingestion while swimming • Ingestion of vegetables and fruit • Ingestion of meat and milk products	NA

TABLE E.3-3
(Continued)

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Future Land Use With Access Controls - Future Source Term					
On-Property RME Resident Farmer On-Property RME Child On-Property CT Farmer	• Incidental ingestion of surface soil and pit material • Dermal contact with surface soil and pit materials • Direct radiation • Ingestion of vegetables and fruit (Pits 1,2) • Ingestion of meat and milk products (Pits 1,2)	• Inhalation of VOCs, radon, and particulates • Ingestion of vegetables and fruit • Ingestion of meat and milk products	• Ingestion of drinking water (perched groundwater evaluated for the On- Property RME Farmer) (Aquifer groundwater evaluated for the child, CT, and RME Farmer) • Dermal contact while bathing • Inhalation of volatiles and radon while showering • Ingestion of vegetables and fruit • Ingestion of meat and milk products	• Ingestion of meat and milk products	NA

TABLE E.3-3
(Continued)

Scenario/Receptor	Soil/Pit Contents	Air	Groundwater	Surface Water	Sediment
Future Land Use With Access Controls - Future Source Term					
Great Miami River User	NA	NA	NA	• Ingestion of drinking water (GMR) • Incidental ingestion while swimming (GMR) • Dermal contact while bathing • Dermal contact while swimming (GMR) • Inhalation of volatiles and radon during showering • Ingestion of fish (GMR)	• Incidental ingestion of sediment (GMR)
Off-Property RME Farmer Off-Property RME Child	NA	• Inhalation of VOCs, radon, and particulates • Ingestion of fruit and vegetables • Ingestion of meat and milk products	• Ingestion of drinking water • Dermal contact while bathing • Inhalation of volatiles and radon while showering	NA	NA
On-Property Home Builder	• Incidental ingestion of pit material (Pit 4) • Dermal contact with pit material (Pit 4) • Direct radiation	• Inhalation of VOCs, radon, and particulates	NA	NA	NA

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TABLE E.3-4

EXPOSURE POINT CONCENTRATIONS FOR SURFACE SOIL AND PIT COVERS CURRENT SOURCE TERM[a]

Radionuclides (pCi/g)	
Cesium-137	8.00E-01
Neptunium-237	5.00E-01
Plutonium-238	1.00E-01
Plutonium-239/240	2.00E-01
Radium-226	1.40E+00
Radium-228	2.20E+00
Strontium-90	1.50E+00
Technetium-99	5.60E+00
Thorium-228	7.80E+00
Thorium-230	1.50E+02
Thorium-232	5.50E+00
Uranium-234	1.20E+02
Uranium-235/236	1.90E+01
Uranium-238	7.90E+02
Inorganics (mg/Kg)	
Antimony	2.79E+01
Arsenic	8.20E+00
Beryllium	7.71E-01
Cadmium	5.86E+00
Thallium	7.00E-01
Thorium-Total	5.80E+00
Uranium-Total	4.13E+02
Organics (mg/Kg)	
PCBs	1.40E+00
Benzo(A)Anthracene	9.80E-02
Benzo(A)Pyrene	4.20E-02
Benzo(B)Fluoranthene	5.90E-02
Benzo(K)Fluoranthene	4.60E-02
Chrysene	8.80E-02

Notes:
[a] Concentration is the larger of the UCL/Max value calculated from CIS and RIFS (or WMC) databases.

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TABLE E.3-5

EXPOSURE POINT CONCENTRATIONS FOR EXPOSED PIT MATERIAL AND SURFACE SOIL FUTURE SOURCE TERM[a,b]

	Surface Soils	Pit 3[a]	Pit 5	Pit 6	Weighted Average
Area:	129,000	6,720	7,500	1,500	144,720
Radionuclides (pCi/g)					
Cesium-137	8.00E-01	5.00E-01	1.06E+02	3.10E+01	6.55E+00
Neptunium-237	5.00E-01	2.10E+00	8.30E+01	3.60E+00	4.88E+00
Plutonium-238	1.00E-01	1.00E+00	4.40E+00	1.40E+00	3.78E-01
Plutonium-239/240	2.00E-01	1.40E+01	1.30E+01	1.50E+01	1.66E+00
Radium-226	1.40E+00	4.51E+02	1.60E+02	4.34E+00	3.05E+01
Ruthenium-106	5.00E+00 [e]	4.20E+00	1.60E+00	5.00E+00 [e]	4.79E+00
Strontium-90	1.50E+00	5.20E+00	3.10E+01	5.10E+00	3.24E+00
Technetium-99	5.60E+00	1.11E+03	2.99E+03	1.64E+02	2.13E+02
Thorium-230	1.50E+00	1.14E+04	8.48E+03	4.52E+01	9.69E+02
Thorium-232[c]	5.50E+00	5.50E+02	5.50E+01	1.91E+02	3.53E+01
Uranium-234	1.20E+02	9.91E+02	1.25E+03	5.33E+03	2.73E+02
Uranium-235/236	1.90E+01	8.92E+01	7.90E+01	1.75E+03	4.33E+01
Uranium-238	7.90E+02	1.74E+03	1.47E+03	2.27E+04	1.10E+03
Inorganics (mg/Kg)					
Antimony	2.79E+01	6.35E+01	8.81E+01	3.00E-01 [e]	3.23E+01
Arsenic	5.60E+00	3.72E+04	2.80E+03	6.53E+01	1.88E+03
Barium	6.61E+01	1.44E+04	3.69E+04	9.50E+01	2.64E+03
Beryllium	7.71E-01	2.40E+01	1.80E+01	5.70E+00	2.79E+00
Cadmium	5.86E+00	3.86E+01	1.70E+01	5.70E+00	7.96E+00
Chromium	1.57E+01	2.34E+02	2.23E+02	3.00E+01	3.67E+01
Cobalt	1.09E+01	5.07E+01	4.40E+01	2.60E+01	1.46E+01
Copper	1.81E+01	2.33E+03	1.82E+04	2.22E+02	1.07E+03
Lead	1.61E+01	8.37E+02	2.36E+02	9.04E+01	6.64E+01
Manganese	6.12E+02	2.02E+04	4.74E+03	2.59E+02	1.73E+03
Mercury	2.00E-02 [e]	5.10E+00	1.80E+00	2.00E-02 [e]	3.48E-01
Molybdenum	4.50E+00	2.84E+02	1.35E+03	1.00E+01 [e]	8.73E+01
Nickel	3.01E+01	5.04E+02	2.47E+02	5.10E+01	6.36E+01
Selenium	6.00E-01	9.00E+01	1.80E+01	2.00E-01 [e]	5.65E+00
Silver	9.00E+00	4.18E+01	2.22E+01	1.58E+02	1.28E+01
Thallium	6.00E-01	1.20E+01	5.20E+01	1.08E+02	4.91E+00
Vanadium	2.14E+01	5.76E+03	5.38E+03	1.00E+02	5.66E+02
Thorium-Total	5.80E+00	3.57E+03	9.20E+01	NA	1.78E+02
Uranium-Total	4.14E+02	5.94E-03	2.75E+03	2.77E+04	7.98E+02
Fluoride	NA	2.35E+03	NA	NA	2.35E+03

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TABLE E.3-5

(Continued)

	Surface Soils[a]	Pit 3	Pit 5	Pit 6	Weighted Average
Area:	129,000	6,720	7,500	1,500	144,720
Organics (mg/Kg)					
PCBs	1.40E+00	8.20E+00	1.30E+00	8.10E-02	1.70E+00
Acenaphthylene	ND	9.60E-02	ND	ND	4.46E-03
Benzo(A)Anthracene	9.80E-02	3.60E-01	ND	ND	1.04E-01
Benzo(A)Pyrene	4.20E-02	2.80E-01	ND	ND	5.04E-02
Benzo(B)Fluoranthene	5.90E-02	5.60E-01	ND	ND	7.86E-02
Benzo(G,H,I)Perylene	ND	1.60E-01	ND	ND	7.43E-03
Benzo(K)Fluoranthene	4.60E-02	ND	ND	ND	4.10E-02
Chrysene	8.80E-02	3.70E-01	ND	ND	9.56E-02
Indeno(1,2,3-Cd)Pyrene	ND	1.30E-01	ND	ND	6.04E-03
N-Nitroso-Di-N-Propylamine	ND	4.60E-01	ND	ND	2.14E-02
Pentachlorophenol	ND	1.30E+00	ND	ND	6.04E-02
Phenanthrene	ND	5.80E-01	ND	ND	2.69E-02
2-Hexanone	ND	1.70E-02	ND	ND	7.89E-04
Tetrachlorodibenzofuran[d]	NA	2.00E-04	ND	ND	8.55E-05
Hexachlorodibenzo-p-dioxin[d]	NA	4.80E-05	ND	ND	2.05E-05
Hexachlorodibenzofuran[d]	NA	3.50E-04	ND	ND	1.50E-04
Heptachlorodibenzo-p-dioxin[d]	NA	1.70E-03	ND	ND	7.27E-04
Heptachlorodibenzofuran[d]	NA	2.10E-04	ND	ND	8.98E-05
Octachlorodibenzo-p-dioxin	NA	1.94E-02	ND	ND	8.29E-03
Octachlorodibenzofuran	NA	1.10E-03	ND	ND	4.70E-04
Tetrachloroethene	ND	2.20E-02	ND	2.90E+01	3.02E-01

Notes:
[a] Concentration is the larger of the UCL/Max value calculated from CIS and RIFS (or WMC) databases.
[b] A blank infers that the chemical is not a CPC for this area. Concentration is assumed to be zero.
[c] Exposure concentration for Thorium 232 in surface soil is based on the current concentration.
[d] Exposure concentration for dioxins and furans include all detected 2,3,7,8 congeners.
[e] Value reported is half the Sampling Reporting Limit.
NA = Constituent not analyzed for this source area. The area was removed from the averaging.
ND = Constituent was analyzed for, but not detected.

TABLE E.3–6

EXPOSURE POINT CONCENTRATIONS FOR PIT 4 FUTURE SOURCE TERM

	Source Concentration
Radionuclides (pCi/g)	
Neptunium–237	0.4
Plutonium–238	0.5
Plutonium–239/240	0.4
Radium–226	50.1
Ruthenium–106	1.1
Strontium–90	144
Technetium–99	225
Thorium–230	1815
Thorium–232	838
Uranium–234	4100
Uranium–235/236	934
Uranium–238	41900

TABLE E.3-7

MICROSHIELD INPUT PARAMETERS FOR CURRENT SOURCE TERM CONFIGURATION OF OU-1

	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5[1]	Pit 6[1]	Burn Pit
Geometry	Cylinder	Cylinder	Cylinder	Cylinder	NA	NA	Cylindrical
Source radius (m)	49.4	36.4	84.4	49.8	NA	NA	25.5
Source density (g/cm^3)	1.94	0.682	0.735	1.58	NA	NA	1.13
Shield No. 2							
density (g/cc)	1.5	1.5	1.5	1.5	NA	NA	1.5
thickness (m)	0.3	0.38	0.33	2.0	NA	NA	0.19
Air gap thickness (m)	0	0	0	0	NA	NA	0
Distance from source (m)	0	0	0	0	NA	NA	0
Source term*	Pit 1 material	Pit 2 material	Pit 3 material	Pit 4 material	NA	NA	Burn pit material

* The source term includes the daughters of all radionuclides in the current inventory. The daughter concentrations are obtained by calculating the concentration of the current inventory 120 years ago, then allowing the concentrations of the 120 years ago to decay for 120 years. This process brings the concentrations of the parent radionuclides back to their current values, and adds the daughter concentrations to the inventory as well.

[1] Water Covered.

TABLE E.3-8

MICROSHIELD INPUT PARAMETERS FOR FUTURE SOURCE TERM CONFIGURATION OF OPERABLE UNIT 1

	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	Pit 6	Burn Pit
Geometry	Cylinder	Cylinder	Cylinder	Cylinder	Rectangular	Rectangular	Cylinder
Source dimensions (m)	49.4∞	36.4∞	84.4∞	49.8∞	86.6 x 86.6 x 8.5	38.9 x 38.9 x 24	25.5∞
Source density (g/cm^3)	1.94	0.682	0.735	1.58	0.411	1.22	1.13
Shield 2							
Density (g/cc)	1.5	1.5	0	1.5	0	0	1.5
Thickness (m)	0.3	0.38	0	1.33	0	0	0.19
Air gap thickness (m)	0	0	0.001	0	0.01	0.01	0
Distance from source (m)	0	0	0.001	0	0.01	0.01	0
Source term	Pit 1 material	Pit 2 material	Pit 3 material	Pit 4 material	Pit 5 material	Pit 6 material	Burn pit material

TABLE E.3-9

DOSE RATES AT 1 METER ABOVE OPERABLE UNIT 1 SOURCE PITS[a] (mrem/hr)

	Current Source Term[b] Configuration	Future Source Term[b] Configuration
Pit 1	2.4×10^{-2}	2.4×10^{-2}
Pit 2	5.7×10^{-2}	5.7×10^{-2}
Pit 3	4.4×10^{-2}	1.3[c]
Pit 4	7.8×10^{-6}	7.8×10^{-6}
Pit 5	NA[d]	54[e]
Pit 6	NA[d]	156[e]
Burn Pit	0.14	0.14
Clearwell	NA[d]	NA[d]

[a]The source pits were modeled as circular slabs having a surface areas equal to each pit.
[b]Includes all radionuclides detected in the source plus their short-lived daughters.
[c]Pit 3 is assumed to have no soil cover in the future source term configuration.
[d]This pit is assumed to be covered with water.
[e]Pits 5 and 6 were modeled assuming half their contents are exposed to air in the future.

TABLE E.3-10

EXPOSURE POINT CONCENTRATIONS FOR ON-PROPERTY SURFACE WATER CURRENT SOURCE TERM

Pit:	Pit 5[a]	Pit 6	Clearwell	Weighted Average
Area:	15,000	3,010	2,740	20,750
Radionuclides (pCi/L)				
Cesium-137	90			65.06
Radium-226			1.1	0.15
Radium-228		31.3		4.54
Strontium-90	41			29.64
Technetium-99	320	3500	4030	1271.19
Thorium-230	0.1	0.3	0.4	0.17
Uranium-234	420	77	1900	565.68
Uranium-235/236	19	9.3	120	30.93
Uranium-238	400	460	6200	1174.58
Inorganics (mg/L)				
Cyanide	0.087		0.087	0.0744
Antimony	0.0045	0.0017		0.0035
Arsenic	0.0021		0.0042	0.0021
Barium	0.108			0.0781
Copper	0.021		0.019	0.0177
Lead	0.0029	0.0029		0.0025
Manganese			0.02	0.0026
Nickel	0.021			0.0152
Selenium	0.0021		0.003	0.0019
Silver			0.014	0.0018
Vanadium	0.047		0.513	0.1017
Organics (mg/L)				
Chloroform		0.003		0.0004
Tetrachloroethene		0.002		0.0003
Benzene	0.011			0.0080
Methylene Chloride	0.002			0.0014
Toluene	0.001	0.006		0.0016
2-Nitrophenol			0.004	0.0005
Acetone			0.52	0.0687

Note:
[a] A blank infers that the chemical is not a CPC for this area. Concentration is assumed to be zero.

TABLE E.3-11

EXPOSURE POINT CONCENTRATIONS FOR ON-PROPERTY SURFACE WATER FUTURE SOURCE TERM

Pit:	Pit 5[a]	Pit 6	Clearwell	Weighted Average
Area:	7,500	1,510	2,740	11,750
Radionuclides (pCi/L)				
Cesium-137	90			57.45
Radium-226			1.1	0.26
Strontium-90	41			26.17
Technetium-99	320	3500	4030	1593.80
Thorium-230	0.1	0.3	0.4	0.20
Thorium-232[b]		31.3		4.02
Uranium-234	420	77	1900	721.04
Uranium-235	19	9.3	120	41.31
Uranium-238	400	460	6200	1760.22
Inorganics (mg/L)				
Cyanide	0.087		0.087	0.0758
Antimony	0.0045	0.0017		0.0031
Arsenic	0.0021		0.0042	0.0023
Barium	0.108			0.0689
Copper	0.021		0.019	0.0178
Lead	0.0029	0.0029		0.0022
Manganese			0.02	0.0047
Nickel	0.021			0.0134
Selenium	0.0021		0.003	0.0020
Silver			0.014	0.0033
Vanadium	0.047		0.513	0.1496
Organics (mg/L)				
Chloroform		0.003		0.0004
Tetrachloroethene		0.002		0.0003
Benzene	0.011			0.0070
Methylene Chloride	0.002			0.0013
Toluene	0.001	0.006		0.0014
2-Nitrophenol			0.004	0.0009
Acetone			0.52	0.1213

Note:
[a] A blank infers that the chemical is not a CPC for this area. Concentration is assumed to be zero.
[b] Thorium 232 is assumed to be in equilibrium with Thorium 228 and Radium 228 and associated daughters

TABLE E.3-12

ESTIMATED EXPOSURE POINT CONCENTRATIONS GREAT MIAMI RIVER

Chemical	Concentration
Radionuclide (pCi/L)	
Cs-137	2.80×10^{-6}
Np-237	4.61×10^{-5}
Pu-238	1.20×10^{-6}
Pu-239/240	2.99×10^{-7}
Sr-90	8.72×10^{-4}
Tc-99	2.02×10^{-1}
Th-230	6.58×10^{-5}
Th-232	3.79×10^{-6}
U-234	2.53×10^{-2}
U-235/236	2.86×10^{-3}
U-238	1.03×10^{-1}
Inorganics and Organics (mg/L)	
Aroclor-1254	1.1×10^{-10}
Aroclor-1260	1.6×10^{-10}
Antimony	6.9×10^{-7}
Arsenic	1.0×10^{-7}
Barium	2.5×10^{-7}
Beryllium	3.1×10^{-9}
Cadmium	5.9×10^{-8}
Chromium	4.9×10^{-8}
Cobalt	9.6×10^{-8}
Copper	6.9×10^{-7}
Lead	2.7×10^{-8}
Manganese	1.6×10^{-5}
Molybdenum	2.4×10^{-7}
Nickel	2.3×10^{-7}
Silver	2.5×10^{-7}
Thallium	2.4×10^{-9}
Uranium[a]	3.1×10^{-4}
Vanadium	1.0×10^{-7}
Zinc	9.9×10^{-8}

[a]Calculated from radioisotopic results

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TABLE E.3-13

ESTIMATED EXPOSURE POINT CONCENTRATIONS PADDYS RUN SEDIMENT

Chemical	Concentration
Radiological (pCi/g)	
Cs-137	1.0×10^{0}
Np-237	5.0×10^{-1}
Pu-238	4.0×10^{-1}
Pu-239/240	1.0×10^{-1}
Sr-90	1.7×10^{0}
Tc-99	4.7×10^{0}
Th-230	7.5×10^{1}
Th-232	4.3×10^{0}
U-234	6.0×10^{1}
U-235/236	6.7×10^{0}
U-238	2.4×10^{2}
Organics (mg/kg)	
Aroclor-1254	1.4×10^{0}
Aroclor-1260	2.0×10^{-1}
Inorganics (mg/kg)	
Antimony	2.72×10^{1}
Arsenic	4.90×10^{0}
Barium	5.69×10^{1}
Beryllium	8.00×10^{-1}
Cadmium	5.80×10^{0}
Chromium	1.43×10^{1}
Cobalt	1.04×10^{1}
Copper	1.70×10^{1}
Lead	1.59×10^{1}
Manganese	5.74×10^{2}

TABLE E.3-13
(Continued)

Chemical	Concentration
Molybdenum	4.30×10^{0}
Nickel	2.94×10^{1}
Silver	8.89×10^{0}
Thallium	7.00×10^{-1}
Uranium[a]	7.30×10^{2}
Vanadium	1.96×10^{1}
Zinc	4.67×10^{1}

[a]Concentration calculated from radioisotopic results.

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TABLE E.3-14

MAXIMUM ESTIMATED EXPOSURE POINT CONCENTRATIONS ON- AND OFF-PROPERTY GROUNDWATER FUTURE SOURCE TERM

Constituents	Great Miami Aquifer On-Property (500 years)	Great Miami Aquifer Off-Property (500 years)	Perched Water On-Property
Radionuclides (pCi/L)			
Cs-137	NA[a]	NA	9.01×10^{1}
Np-237	1.16×10^{-4}	1.24×10^{-11}	7.47×10^{0}
Pu-238	1.33×10^{-1}	NA	4.89×10^{-1}
Pu-239/240	NA	NA	4.96×10^{-2}
Ra-226	1.78×10^{0}	NA	7.25×10^{1}
Sr-90	4.69×10^{-3}	5.9×10^{-6}	4.03×10^{1}
Tc-99	1.65×10^{1}	3.13×10^{0}	2.74×10^{3}
Th-230	1.04×10^{0}	NA	3.03×10^{-1}
Th-232	NA	NA	5.06×10^{-2}
U-234	8.83×10^{2}	6.24×10^{1}	1.49×10^{5}
U-235/238	2.05×10^{2}	1.44×10^{1}	2.76×10^{4}
U-238	4.18×10^{3}	2.95×10^{2}	4.29×10^{5}
Inorganics (mg/L)			
Antimony	1.75×10^{-1}	NA	9.56×10^{-1}
Arsenic	5.82×10^{-1}	NA	6.32×10^{-1}
Barium	6.51×10^{-1}	4.77×10^{-7}	1.96×10^{0}
Beryllium	NA	NA	2.04×10^{-2}
Boron	3.08×10^{-2}	6.77×10^{-3}	2.93×10^{0}
Cadmium	NA	NA	1.18×10^{-1}
Chromium	NA	NA	1.29×10^{-1}
Cobalt	NA	NA	3.38×10^{-1}
Copper	NA	NA	9.48×10^{-1}
Cyanide	4.22×10^{-6}	1.24×10^{-8}	3.60×10^{0}
Lead	5.80×10^{-2}	NA	6.91×10^{-1}

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TABLE E.3-14
(Continued)

Constituents	Great Miami Aquifer On-Property (500 years)	Great Miami Aquifer Off-Property (500 years)	Perched Water On-Property
Manganese	2.07×10^{0}	NA	2.41×10^{0}
Mercury	NA	NA	2.18×10^{-2}
Molybdenum	NA	NA	1.15×10^{2}
Nickel	NA	NA	2.13×10^{0}
Selenium	NA	NA	3.80×10^{-3}
Silver	NA	NA	6.67×10^{-2}
Thallium	NA	NA	7.54×10^{-1}
Tin	NA	NA	8.29×10^{0}
Uranium	1.26×10^{1}	8.87×10^{-1}	5.00×10^{2}
Vanadium	NA	NA	1.44×10^{0}
Zinc	NA	NA	1.79×10^{0}
Organics (mg/L)			
Aroclor-1248	NA	NA	5.0×10^{-2}
Aroclor-1254	NA	NA	1.0×10^{-1}
Acenaphthene	NA	NA	4.0×10^{-2}
Anthracene	NA	NA	4.0×10^{-2}
Benzo(a)anthracene	NA	NA	4.0×10^{-2}
Benzo(a)pyrene	NA	NA	4.0×10^{-2}
Benzo(b)fluoranthene	NA	NA	4.0×10^{-2}
Benzo(k)fluoranthene	NA	NA	4.0×10^{-2}
Chrysene	NA	NA	4.0×10^{-2}
Dibenzo(a,h)anthracene	NA	NA	1.0×10^{-2}
Fluoranthene	NA	NA	4.0×10^{-2}
Fluorene	NA	NA	4.0×10^{-2}
Indeno(1,2,3-cd)pyrene	NA	NA	4.0×10^{-2}
Naphthalene	NA	NA	1.6×10^{-2}
Phenanthrene	NA	NA	4.0×10^{-2}
Pyrene	NA	NA	4.0×10^{-2}
4-Nitrophenol	NA	NA	1.0×10^{-2}

TABLE E.3-14
(Continued)

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Constituents	Great Miami Aquifer On-Property (500 years)	Great Miami Aquifer Off-Property (500 years)	Perched Water On-Property
Pentachlorohenol	NA	NA	2.0×10^{-1}
Tetrachloroethene	NA	NA	1.4×10^{-1}
Vinyl chloride	NA	NA	1.0×10^{0}
TCDF[b]	NA	NA	5.3×10^{-6}
HpCDD[b]	NA	NA	9.4×10^{-7}
HpCDF[b]	NA	NA	2.0×10^{-6}
HxCDD[b]	NA	NA	7.5×10^{-7}
HxCDF[b]	NA	NA	1.2×10^{-6}
OCDD[b]	NA	NA	1.8×10^{-6}
OCDF[b]	NA	NA	1.1×10^{-6}
1,2,3,7,8-PeCDF[b]	NA	NA	1.0×10^{-6}
2,3,4,7,8-PeCDF[b]	NA	NA	1.1×10^{-6}

[a] NA - Not applicable. Contaminant did not pass screening or was not detected.

[b] TCDF = 2, 3, 7, 8 - Tetrachloradibenzofuran
HpCDD = 2, 3, 7, 8 - Heptachlorodibenzo-p-dioxin
HpCDF = 2, 3, 7, 8 - Heptachlorodibenzofuran
HxCDD = 2, 3, 7, 8 - Hexachlorodibenzo-p-dioxin
HxCDF = 2, 3, 7, 8 - Hexachlorodibenzofuran
OCDD = Octachlorodibenzo-p-dioxin
OCDF = Octachlorodibenzofuran
PeDF = Pentachlorodibenzofuran

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TABLE E.3-15

ESTIMATED EXPOSURE POINT CONCENTRATIONS
AIR - PM10
CURRENT SOURCE TERM

Airborne Contaminant	Maximum On-Property Location	Maximum Off-Property Location
Radionuclides (pCi/m^3)		
Cs-137	5.6×10^{-6}	4.3×10^{-7}
Np-237	3.5×10^{-6}	2.7×10^{-7}
Pu-238	7.0×10^{-7}	5.4×10^{-8}
Pu-239/240	1.4×10^{-6}	1.1×10^{-7}
Rn-222	3.0×10^{-5}	2.2×10^{-6}
Sr-90	1.1×10^{-5}	8.0×10^{-7}
Th-230	1.0×10^{-3}	8.0×10^{-5}
U-234	8.3×10^{-4}	6.3×10^{-5}
U-235/236	9.7×10^{-6}	9.7×10^{-6}
U-238	5.5×10^{-3}	4.3×10^{-4}
Chemicals (mg/m^3)		
Antimony	2×10^{-7}	1.5×10^{-8}
Beryllium	5.4×10^{-9}	4.1×10^{-10}
Cadmium	4.1×10^{-8}	3.20×10^{-9}
Chromium		
Uranium	2.9×10^{-6}	2.2×10^{-7}
Thorium	4.1×10^{-8}	3.1×10^{-9}
Aroclor-1254 pebs	9.9×10^{-9}	7.5×10^{-10}
Benzo (a) anthracene	6.9×10^{-10}	5.3×10^{-11}
Benzo (a) pyrene	3.0×10^{-10}	2.3×10^{-11}
Benzo (b) fluoranthene	4.2×10^{-10}	3.2×10^{-11}
Benzo (k) fluoranthene	3.6×10^{-10}	2.5×10^{-11}

TABLE E.3–16

ESTIMATED EXPOSURE POINT CONCENTRATIONS
AIR – PM10
FUTURE SOURCE TERM

	Government Reserve		Agricultural Use	
Airborne Contaminant	Maximum On–Property	Maximum Off–Property	Maximum On–Property	Maximum Off–Property
Radionuclides (pCi/m^3)				
Cs_{137+1d}	3.20E–03	1.30E–04	3.10E–03	1.30E–04
Np_{237+1d}	2.50E–03	1.10E–04	2.40E–03	1.10E–04
Pu_{238}	1.40E–04	7.90E–06	1.40E–04	8.50E–06
$Pu_{239/240}$	6.20E–04	5.10E–05	6.20E–04	5.10E–05
Ra_{226}	1.90E–02	1.30E–03	1.90E–02	1.30E–03
Rn_{222+4d}	3.60E–03	2.40E–04	3.70E–03	2.50E–04
Ru_{106}	1.80E–04	1.20E–05	1.80E–04	1.20E–05
Sr_{90}	9.30E–04	3.90E–05	9.00E–04	4.00E–05
Tc_{99}	9.20E–01	6.10E–03	8.90E–02	6.10E–03
Th_{230}	5.00E–01	3.70E–02	4.90E–01	3.70E–02
$Th_{232+10d}$	1.70E–02	1.00E–03	1.60E–02	1.00E–03
U_{234}	1.10E–01	4.50E–03	1.10E–01	4.60E–03
U_{235+1d}	3.00E–02	4.40E–04	3.00E–02	4.60E–04
U_{238+2d}	4.00E–01	8.90E–03	4.00E–01	9.70E–03
Inorganics (mg/m^3)				
Antimony	3.00E–06	2.60E–07	3.10E–06	2.90E–07
Arsenic	1.50E–03	9.30E–05	1.50E–03	9.30E–05
Barium	1.10E–03	7.60E–05	1.10E–03	7.60E–05
Beryllium	1.20E–06	7.40E–08	1.00E–06	8.00E–08
Cadmium	1.70E–06	1.20E–07	1.70E–06	1.20E–07
Chromium VI	1.00E–05	8.20E–07	1.00E–05	8.20E–07
Cobalt	2.20E–06	1.80E–07	2.20E–06	1.80E–07
Copper	5.40E–04	2.70E–05	5.30E–04	2.70E–05
Lead	1.50E–03	1.40E–05	1.50E–03	1.40E–05
Maganese	8.50E–04	5.40E–05	8.40E–04	5.40E–05
Mercury	2.10E–07	1.20E–08	2.10E–07	1.20E–08
Molybdenum	4.10E–05	2.30E–06	3.90E–05	2.30E–06
Nickel	2.20E–05	1.50E–06	2.10E–05	1.50E–06
Selenium	3.70E–06	2.20E–07	3.70E–06	2.20E–07
Silver	2.80E–06	1.20E–07	2.70E–06	1.20E–07
Thallium	2.20E–06	1.00E–07	2.50E–06	1.00E–07
Vanadium	2.50E–04	2.00E–05	2.50E–04	2.00E–05
Thorium–total	2.70E–06	1.10E–07	2.60E–06	1.20E–07
Uranium–total	5.20E–04	2.10E–05	5.10E–04	2.10E–05
Fluoride	9.70E–05	5.70E–06	9.60E–05	5.70E–06

TABLE E.3-16
(Continued)
ESTIMATED EXPOSURE POINT CONCENTRATIONS
AIR – PM10
FUTURE SOURCE TERM

	Government Reserve		Agricultural Use	
Airborne Contaminant	Maximum On-Property	Maximum Off-Property	Maximum On-Property	Maximum Off-Property
Organics (mg/m^3)				
Acenaphthylene	4.00E-09	2.30E-10	3.90E-09	2.30E-10
Benzo(g,h,i)perylene	6.60E-09	3.90E-10	6.50E-09	3.90E-10
Benzo(a)anthracene	1.60E-08	1.00E-09	1.60E-08	1.00E-09
Benzo(a)pyrene	1.20E-08	7.40E-10	1.20E-08	7.40E-10
Benzo(b)fluoranthene	2.40E-08	1.40E-09	2.40E-08	1.40E-09
Benzo(k)fluoranthene	1.00E-09	6.60E-11	1.00E-09	6.60E-11
chrysene	1.50E-08	9.00E-10	1.50E-08	9.00E-10
indeno(1,2,3-cd)pyrene	5.30E-09	3.20E-10	5.30E-09	3.20E-10
n-nitrosodipropylamine	1.90E-08	1.10E-09	1.90E-08	1.10E-09
pentachlorophenol	5.30E-08	3.20E-09	5.30E-08	3.20E-09
phenanthrene	2.40E-08	1.40E-09	2.40E-08	1.40E-09
2-hexanone	7.00E-10		6.90E-10	
Tetrachloroethene	4.80E-07	3.60E-09	4.70E-07	3.60E-09
PCBs	3.60E-07	2.30E-08	3.60E-07	2.30E-08
hexachlorodibenzo-p-dioxin	2.00E-12	1.20E-13	2.00E-12	1.20E-13
heptachlorodibenzo-p-dioxin	6.90E-11	4.10E-12	6.90E-11	4.10E-12
heptachlorodibenzofuran	8.60E-12	5.10E-13	8.60E-12	5.10E-13
octachlorodibenzo-p-dioxin	7.90E-10	4.70E-11	7.90E-10	4.70E-11
octachlorodibenzofuran	4.50E-11	2.70E-12	4.50E-11	2.70E-12
tetrachloroethene	4.70E-07	3.60E-09	4.70E-07	3.60E-09

TABLE E.3-17

EXPOSURE INPUT PARAMETERS
CURRENT LAND USE RECEPTORS

Pathway Parameters (units)	Trespassing Youth Age 7-18	Off-Property RME Resident Adult Farmer Age 1-70	Off-Property RME Resident Child Ages 0-6	User of Meat & Milk Grown Within Operable Unit 1 Age 1-70	On-Property Groundskeeper
All Pathways					
EF (day/yr)	52[a]	350[b]	350[b]	350[b]	35[e]
ED (yr)	12[a]	70[b]	6[b]	70[b]	25[d]
AT-Noncancer (day)	4380[b]	25550[b]	2190[b]	25550[b]	9125[b]
AT-Cancer (day)	25550[b]	25550[b]	25550[b]	25550[b]	25550[b]
BW (kg)	43[b]	70[b]	15[b]	70[b]	70[b]
Inhalation of dust, volatiles, and radon					
IR (m^3/hr)	0.83[b]	0.83[b]	0.5[k,l]	NA[c]	2.5[d]
IR indoor (m^3/d)	NA	15[m]	15[m]	NA	NA
ET indoors (hr/day)	NA	18.3[f]	22.0[f]	NA	NA
ET outdoors (hr/day)	4[a]	5.7[f]	2.0[f]	NA	8.0[d]
Incidental ingestion of soil					
IR (g/day)	0.1[b]	NA	NA	NA	0.1[b]
FI (unitless)	0.25[g]	NA	NA	NA	1.0
Dermal contact with soil					
SA (m^2)	0.42[h]	NA	NA	NA	.575[h]
AF (mg/cm^2)	1.0[h]	NA	NA	NA	1.0[h]
ABS (unitless)	csv	NA	NA	NA	csv[i]
External radiation exposure					
DR (mrem/hr)	csv[i]	NA	NA	NA	csv[i]
ET indoors (hr/day)	NA	NA	NA	NA	NA
ET outdoors (hr/day)	4[a]	NA	NA	NA	8.0[d]
SH indoors (unitless)	NA	NA	NA	NA	NA
SH outdoors (unitless)	0[b]	NA	NA	NA	0[b]

TABLE E.3-17
(Continued)

Pathway Parameters (units)	Trespassing Youth Age 7-18	Off-Property RME Resident Adult Farmer Age 1-70	Off-Property RME Resident Child Ages 0-6	User of Meat & Milk Grown Within Operable Unit 1 Age 1-70	On-Property Groundskeeper
Ingestion of vegetables, fruit, milk products, meat and fish					
$IR_{vegetables}$ (g/day)	NA	200[b,c]	100[j]	NA	NA
$FI_{vegetables}$ (unitless)	NA	0.40[c]	0.40[c]	NA	NA
IR_{fruits} (g/day)	NA	140[b,c]	204[j]	NA	NA
FI_{fruits} (unitless)	NA	0.30[c]	0.30[c]	NA	NA
IR_{Meat} (g/day)	NA	101[b]	39[b]	101[b]	NA
FI_{meat} (unitless)	NA	0.75[c]	0.75[c]	0.75[c]	NA
$IR_{milk\ products}$ (L/day)	NA	0.4[b]	0.9[b]	0.4[b]	NA
$FI_{milk\ products}$ (unitless)	NA	0.75[c]	0.75[c]	0.75[c]	NA
IR_{fish}	NA	NA	NA	NA	NA
Ingestion of drinking water					
IR (L/day)	NA	2.0[b]	1.0[b]	NA	NA
FI (unitless)	NA	1.0	1.0	NA	NA

[a] DOE 1993d Comment Responses - Site Wide Characterization Report, Assumes a youth trespasses on site 3 days/week for the months of June, July and August (36 days while the youth is not in school) plus 1 day/week for the months of April, May, September and October (16 days) for a total of 52 days, 4 hrs/day.
[b] DOE 1992a
[c] EPA 1990d
[d] EPA 1991j Standard Default Exposure Factors (OSWER Directive 9285.6-03).
[e] Assumes a groundskeeper spends 1 day/week, 35 weeks/yr on the grounds of OU2.
[f] Assumes the RME farmer works outdoors 2000 hours/year, and a resident child spends 700 hrs/yr outdoors.
[g] DOE 1993e, Response to Comment 265 of the OU4 RI, Adjusted based on 4 out of 16 (or 25%) waking hours spent on property.
[h] EPA 1992e
[i] csv - Chemical Specific Value.
[j] USDA 1986 NFCS, CSF II Report No. 85-1
[k] EPA 1993c
[l] EPA 1988c Derived from an algorithm relating respiratory route to body weight, corrected by a factor of 2.11.
[m] EPA 1991f
NA - Not applicable.

TABLE E.3–17A
CALCULATION OF SOIL INGESTION RATE FOR RME[a] AND CT[b] FARMER

	RME Farmer[a]		CT Farmer[b]	
Farm Size (acres)	500 RME farm size (95th percentile)		125 CT farm size (50th percentile)	
Acreage in corn	175 acres	35%	44 acres	35%
Acreage in soybeans	175 acres	35%	44 acres	35%
Acreage in wheat	100 acres	20%	25 acres	20%
Acreage in hay	50 acres	10%	13 acres	10%
Hours farming corn	217 hrs/yr	1.24 hrs/acre	54 hrs/yr	1.24 hrs/acre
Hours farming soybeans	175 hrs/yr	1 hrs/acre	44 hrs/yr	1 hrs/acre
Hours farming wheat	128 hrs/yr	1.28 hrs/acre	32 hrs/yr	1.28 hrs/acre
Hours farming hay	136.5 hrs/yr	2.73 hrs/acre	34 hrs/yr	2.73 hrs/acre
TOTAL:	656.5 hrs/yr		164 hrs/yr	
Hours Farming (Total + 20%)	800 hours		200 hours	
Days spent farming	100 days/yr		25 days/yr	
Years farming	50 years		50 years	
Ingest rate while farming	0.48 g/day		0.48 g/day	
Soil Ingestion farming	2400 g		600 g	
Days not farming	250 days/yr		325 days/yr	
Years farming	50 years		50 years	
Ingest rate for adult	0.1 g/day		0.1 g/day	
Soil Ingestion not farming	1250 g		1625 g	
Days for child	350 days/yr		350 days/yr	
Years as a child	6 years		6 years	
Ingest rate for child	0.2 g/day		0.2 g/day	
Soil Ingestion for child	420 g		420 g	
Days per year	350 days/yr		350 days/yr	
Years not farming	14 years		14 years	
Ingest rate for adult	0.1 g/day		0.1 g/day	
Soil Ingestion – not farming	490 g		490 g	
Soil ingestion over a lifetime	4560 g/lifetime		3135 g/lifetime	
Ave. Daily Soil Ingest. Rate	0.18 g/day		0.12 g/day	

[a] RME – Reasonable maximum exposure scenario.
[b] CT – Central tendancy scenario.

Reference

U.S. Dept. of Energry, 1989, Census of Agriculture, Geographic Area Series, Part 35, Ohio, State and County Data, U.S. Dept. of Commerce, Bureau of the Census.

U.S. Soil Conservation Service, 1992, Revised Field Office Technical Guide, U.S.D.A. Soil Conservation Service, Cincinnati, OH.

U.S. Soil Conservation Service, 1979, Soil Survey of Hamilton County, Ohio, U.S.D.A. Soil Conservation Service, Cincinnati, OH.

U.S. Soil Conservation Service, 1976, Soil Survey of Butler County, Ohio, U.S.D.A. Soil Conservation Service, Hamilton, OH.

TABLE E.3-18

EXPOSURE INPUT PARAMETERS
FUTURE LAND USE RECEPTORS

Pathway Parameters (units)	Trespassing Youth Age 7-18	Off-Property RME Resident Adult Farmer Age 1-70	Off-Property RME Resident Child Age 0-6	User of Meat & Milk Grown Within OU1 Age 1-70	User of Great Miami River Water Age 1-70	On-Property CT Resident Adult Farmer Age 1-70	On-Property RME Resident Adult Farmer Age 1-70	On-Property RME Resident Child Age 0-6	Expanded Trespasser Age 7-18	Expanded Trespasser Age 19-50	On-Property Groundskeeper	On-Property Home Building Age 19+
All pathways except where noted												
EF (day/yr)	52[a]	350[b]	350[b]	NA	350[b]	275[i]	350[b]	350[b]	110[m]	40[m]	35[p]	175[d]
ED (yr)	12[a]	70[b]	6[b]	NA	70[b]	9	70[b]	6[b]	12[m]	32[m]	25[s]	1[d]
BW (kg)	43[b]	70[b]	15[b]	NA	70[b]	70[b]	70[b]	15[b]	43[b]	70[b]	70[b]	70[b]
AT-Noncancer (day)	4380[b]	25550[b]	2190[b]	NA	25550[b]	3285[b]	25550[b]	2190[b]	4380[b]	11680[b]	9125[b]	175[b]
AT-Cancer (day)	25550[b]	25550[b]	25550[b]	NA	25550[b]	25550[b]	25550[b]	25550[b]	25550[b]	25550[b]	25550[b]	25550[b]
Inhalation of dusts, volatiles, and radon												
IR (m^3/hr)	0.83[b]	0.83[b]	0.5[c,e]	NA	NA	0.83[b]	0.83[b]	0.5[e]	0.83[b]	0.83[b]	2.5[s]	2.5[s]
IR indoor (m^3/d)	NA	15[f]	15[f]	NA	NA	15[f]	15[f]	15[f]	NA	NA	NA	NA
ET outdoors (hr/day)	4[a]	5.7[h]	2[j]	NA	NA	4.2[i]	5.7[h]	2[j]	2.0[m]	1.0[m]	8.0[s]	8[d]
Drinking water												
IR (L/day)	NA	2.0[b]	1.0[b]	NA	2.0[b]	1.4	2[b]	1.0[b]	NA	NA	NA	NA
FI (L/day)	NA	1.0[b]	1.0[b]	NA	1.0[b]	1.0[b]	1.0[b]	1.0[b]	NA	NA	NA	NA
Dermal contact while bathing												
SA (m^2)	NA	2.3[k]	0.8[k]	NA	2.3[k]	2.0[k]	2.3[k]	0.8[k]	NA	NA	NA	NA
DA_e (mg/cm_2-event)	NA	csv[l]	csv[l]	NA	csv	csv	csv	csv	NA	NA	NA	NA
ET (hr/day)	NA	0.25[k]	0.25[k]	NA	0.25[k]	0.17[k]	0.25[k]	0.25[k]	NA	NA	NA	NA
Incidental ingestion of surface water while swimming or wading												
IR (L/hr)	0.035[g]	NA	NA	NA	0.05[k]	NA	NA	NA	0.035[g]	NA	NA	NA
ET (hr/day)	1.0[a]	NA	NA	NA	2.6[k]	NA	NA	NA	1.0	NA	NA	NA
EF_{wading} (day/yr)	52[a]	NA	NA	NA	NA	NA	NA	NA	52[a]	NA	NA	NA
EF_{swim} (day/yr)	NA	NA	NA	NA	7[k]	NA	NA	NA	na	NA	NA	NA
ED (yrs)	12[a]	NA	NA	NA	30	NA	NA	NA	12[a]	NA	NA	NA

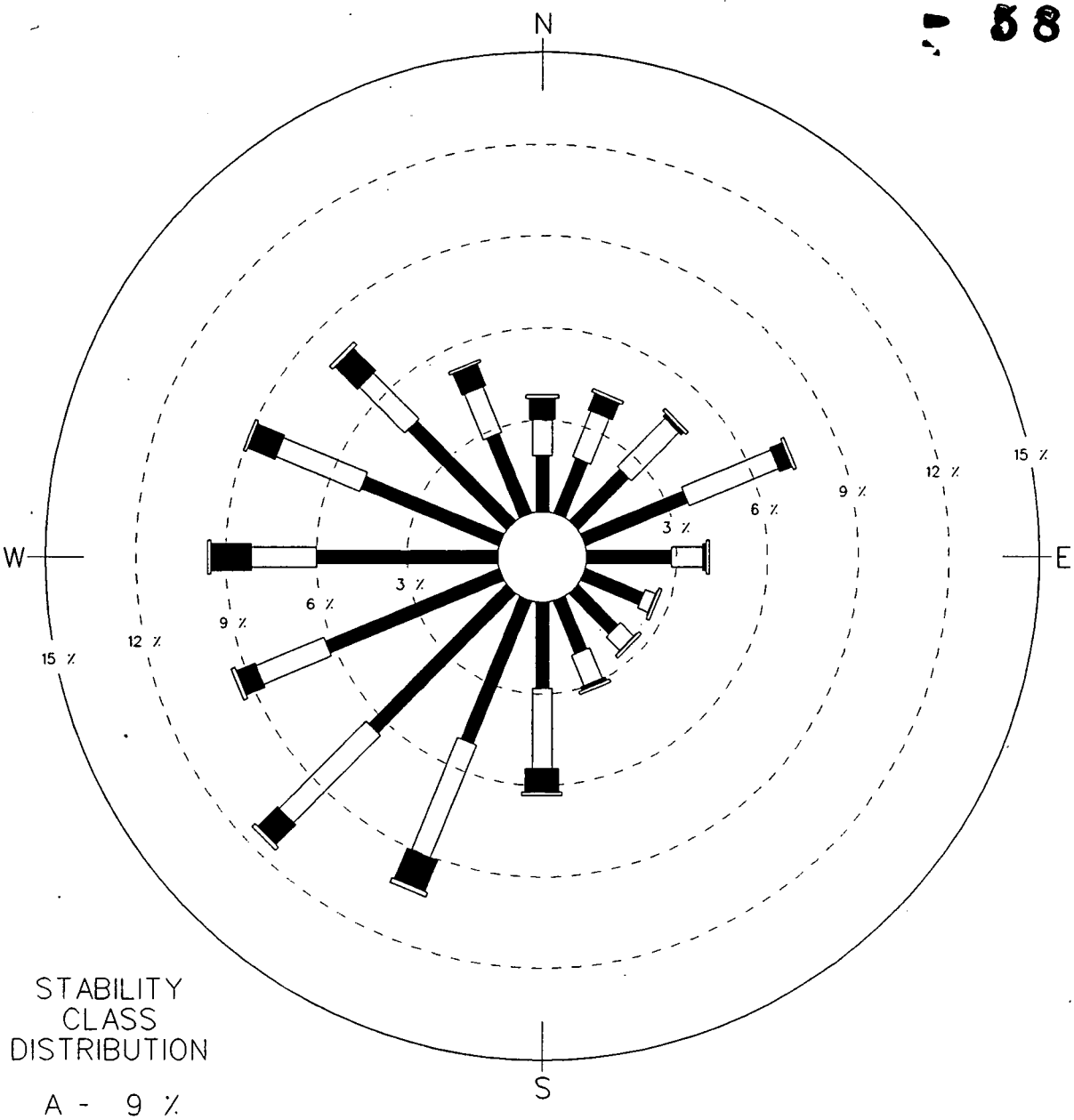
TABLE E.3-18
(Continued)

Pathway Parameters (units)	Trespassing Youth Age 7-18	Off-Property RME Resident Adult Farmer Age 1-70	Off-Property RME Resident Child Age 0-6	User of Meat & Milk Grown Within OU1 Age 1-70	User of Great Miami River Water Age 1-70	On-Property CT Resident Adult Farmer Age 1-70	On-Property RME Resident Adult Farmer Age 1-70	On-Property RME Resident Child Age 0-6	Expanded Trespasser Age 7-18	Expanded Trespasser Age 19-50	On-Property Groundskeeper	On-Property Home Building Age 19+
Dermal contact with surface water while swimming or wading												
SA (m^2)	5130[g]	NA	NA	NA	2.3[k]	NA	NA	NA	5130[g]	NA	NA	NA
DA_e (mg/cm^2-event)	csv[l]	NA	NA	NA	csv[l]	NA	NA	NA	csv[l]	NA	NA	NA
ET (hr/day)	1.0	NA	NA	NA	2.6[k]	NA	NA	NA	1.0	NA	NA	NA
EF_{swim} (day/yr)	NA	NA	NA	NA	7[k]	NA	NA	NA	NA	NA	NA	NA
EF_{wading} (day/yr)	52[a]	NA	NA	NA	NA	NA	NA	NA	52[a]	NA	NA	NA
ED (yrs)	12[a]	NA	NA	NA	30	NA	NA	NA	12[a]	NA	NA	NA
Incidental ingestion of soil/sediment[u]												
IR (g/day)	0.1[b]	NA	NA	NA	NA	0.122	0.18	0.2[b]	0.1[b]	0.1[b]	0.1[b]	0.48[s]
FI_{sed} (unitless)	0.06[t]	NA	NA	NA	NA	NA	NA	NA	0.1[t]	NA	NA	NA
FI_{soil} (unitless)	0.19[t]	NA	NA	NA	NA	1.0[b]	1.0[b]	1.0[b]	0.1[t]	.05[t]	1.0[b]	1.0[d]
Dermal contact with soil/sediment[u]												
SA (m^2)	0.42[k]	NA	NA	NA	NA	0.5[k]	0.575[k]	0.2[k]	.42[k]	.575[k]	.575[k]	0.575[k]
AF (mg/cm^2)	1.00[k]	NA	NA	NA	NA	0.2[k]	1.0[k]	1.0[k]	1.0[k]	1.0[k]	1.0[k]	1.0[k]
ABS (unitless)	csv	NA	NA	NA	NA	csv	csv	csv	csv	csv[l]	csv	csv
External radiation exposure												
DR (mrem/hr)	csv	NA	NA	NA	NA	csv	csv	csv	csv	csv	csv	csv
ET indoors (hr/day)	NA	NA	NA	NA	NA	19.8[i]	18.3[h]	22[j]	NA	NA	NA	4[d]
ET $outdoor_{sediment}$ (hr/day)	1[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ET $outdoors_{soil}$ (hr/day)	3[a]	NA	NA	NA	NA	4.2[i]	5.7[h]	2[j]	2.0[m]	1.0[m]	8.0[s]	4[d]
SH indoors (unitless)	NA	NA	NA	NA	NA	0.5[b]	0.5[b]	0.5[b]	NA	NA	NA	0.5[b]
SH outdoors (unitless)	0[b]	NA	NA	NA	NA	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

TABLE E.3-18
(Continued)

Pathway Parameters (units)	Trespassing Youth Age 7-18	Off-Property RME Resident Adult Farmer Age 1-70	Off-Property RME Resident Child Age 0-6	User of Meat & Milk Grown Within OU1 Age 1-70	User of Great Miami River Water Age 1-70	On-Property CT Resident Adult Farmer Age 1-70	On-Property RME Resident Adult Farmer Age 1-70	On-Property RME Resident Child Age 0-6	Expanded Trespasser Age 7-18	Expanded Trespasser Age 19-50	On-Property Groundskeeper	On-Property Home Building Age 19+
Ingestion of vegetables, fruit, meat, milk products and fish												
IR_{fruit} (g/day)	NA	140[b,n]	204[o,b]	NA	140[b]	140[n,b]	140[n,b]	204[o,b]	NA	NA	NA	NA
FI (unitless)	NA	0.3[n,b]	0.3[n,b]	NA	0.3[n,b]	0.2	0.3[n,b]	0.3[n,b]	NA	NA	NA	NA
$IR_{vegetables}$ (g/day)	NA	200[b,n]	100[o,b]	NA	200[b,n]	200[b]	200[n,b]	100[o,b]	NA	NA	NA	NA
FI (unitless)	NA	0.4[n,b]	0.4[n,b]	NA	0.4[n,b]	0.25	0.4[n,b]	0.4[n,b]	NA	NA	NA	NA
IR_{meat}(g/day)	NA	100[b]	39[o,b]	100[b]	100[b]	100[b]	100[b]	39[o,b]	NA	NA	NA	NA
FI (unitless)	NA	.75[b]	0.75[b]	.75[b]	0.75[b]	0.44	0.75[b]	0.75[b]	NA	NA	NA	NA
IR_{milk} (L/day)	NA	0.4[b]	0.9[b]	0.4[b]	0.4[b]	0.16	0.3[b]	0.9[b]	NA	NA	NA	NA
FI (unitless)	NA	.75[b]	0.75[b]	0.75[b]	0.75[b]	0.75[b]	0.75[b]	0.75[b]	NA	NA	NA	NA
IR(fish)	NA	NA	NA	NA	54[b]	NA	NA	NA	NA	NA	NA	NA

[a] DOE 1993d, Comment Responses - Site Wide Characterization Report. Assumes a youth trespasses on site 3 days/wk from June through August, plus 1 day/wk in April, May, September, and October, for a total of 52 days/yr, 4hr/day (of which one hour is spent playing in Paddys Run).
[b] DOE 1992a
[c] EPA 1993c
[d] Assumes a home builder spends 175 8-hour days building a home, spending 50% of his time working in/on the house, and 50% of the time working in/on the soil/waste.
[e] EPA 1988c,Derived from an algorithym relating respiratory rate to body rate, corrected by a factor of 2.11
[f] EPA, 1991f
[g] Assumes a youth swallows 0.035 L/hr while wading. Also assumes approximately 30% body surface area exposure for a wading scenario.
[h] Assumes the RME farmer spends 2000 hours outdoors during the 350 days of exposure a year (5.7 h/d = 2000 h/y / 350 d/y). Indoor duration is the remaining time in a day.
[i] EPA 1992j Assumes the CT farmer spends the equivalent of 48 days during a 275 day exposure period outdoors each year. (4.2 h/d = [24 h/d * 48 d/y]/275 d/y). Indoor duration is the remaining time in a day.
[j] Assumes a resident small child spends 700 hours/year outdoors.
[k] EPA 1992e, EPA/600/8-91/011b.
[l] csv - Chemical Specific Value.
[m] Assumes the expanded trespasser visits the site 110 days/yr (2 hr/day) as a youth, and 40 days/yr (1hr/day) as an adult for a total of 44 years. Only the youth plays in Paddys Run.
[n] EPA 1990d, EPA/600/8-89/043
[o] USDA 1986, NFCS, CSFII Report No. 85-1.
[p] Assumes the groundskeeper works in the on the grounds of OU1, 35 days/yr.
[q] NA - Not applicable.
[r] EPA 1991j
[t] DOE 1993e Response to Comment 265 of the OU4 RI (FI for soil and sediment are based on the number of hours exposed out of 16 waking hours).
[u] Parameters represent values used for exposure to both media, sediment, and soil which apply to that receptor.



STABILITY CLASS DISTRIBUTION

A - 9 %
B - 4 %
C - 4 %
D - 33 %
E - 27 %
F - 22 %

NOTES:

1. DIAGRAM OF THE FREQUENCY OF OCCURRENCE FOR EACH WIND DIRECTION. WIND DIRECTION IS THE DIRECTION FROM WHICH THE WIND IS BLOWING. EXAMPLE - WIND IS BLOWING FROM THE NORTH 4.8 PERCENT OF THE TIME.

2. RECORDED FROM A 33-FEET (10 METERS) TOWER DURING 1992.

LEGEND:

0-3	4-6	7-10	11-16	17-21	22-99
(57 %)	(32 %)	(10 %)	(0 %)	(0 %)	(0 %)

WIND SPEED SCALE (KNOTS)
(1 KNOT EQUALS 1.15 MPH)

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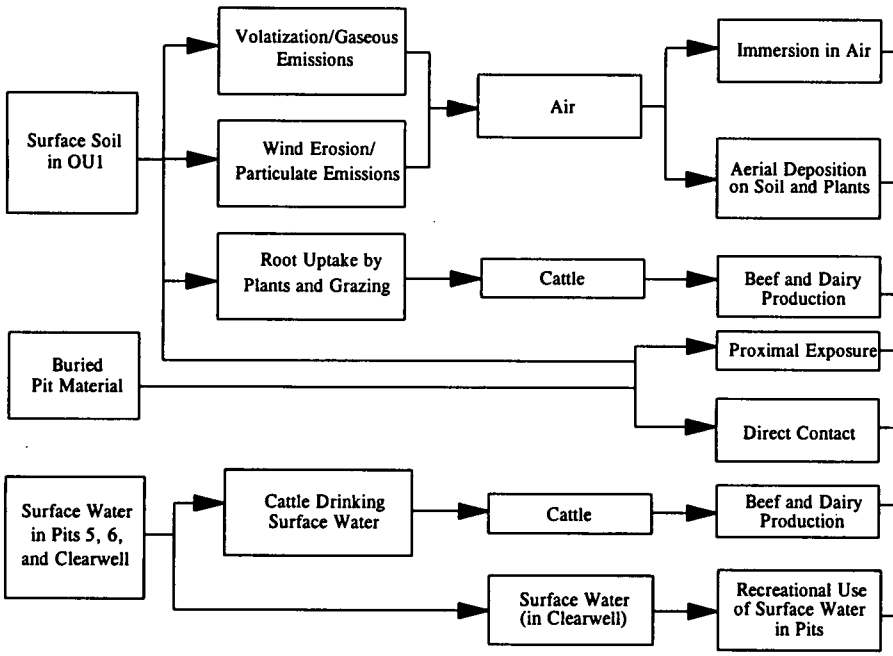
FIGURE E.3-1. WIND ROSE FOR THE FEMP SITE YEAR 1992

Cross-hatched boxes indicate exposure scenario evaluated.
RME = Reasonable Maximum Exposure
CT = Central Tendency



Exposure Route	Receptors: Current Land Use With Access Controls — Off-Property RME Resident	Current Land Use With Access Controls — Visitor	Current Land Use Without Access Controls — Off-Property RME Resident	Current Land Use Without Access Controls — Trespassing Child	Consumer of Animal Products
Inhalation					1
Penetrating Radiation	2,3	2,3	2,3	2,3	1
Incidental Ingestion of Soil	2	2	2	2	1
Food Ingestion		4		2,4	1
Dermal Contact	2,3	4	2	2,4	1
Penetrating Radiation	2,3	2,3,4	2,3	2,3,4	1
Food Ingestion	5	4	5	4	
Penetrating Radiation	2		2		1
Soil Ingestion	4	4	4		1
Dermal Contact	4	4	4		1
Food Ingestion	6	4	6	4	
Ingestion (while swimming)	4	2,4	4	2,4	1
Inhalation (of VOCs)	4	2,4	4	2,4	1
Dermal Contact	4	2,4	4	2,4	1
Penetrating Radiation	3,4	3,4	3,4	3,4	1

1) The objective of quantifying risks to this receptor is to isolate and evaluate the impact of using meat and dairy products produced on property.
2) Potential impact of exposure pathway is minor when compared to other exposure pathways for the same receptor.
3) EPA risk assessment methodology for radionuclides does not address this exposure route.
4) Exposure route not applicable to a transient or non-transient receptor. Exposure could be accidental.
5) This pathway is isolated and evaluated under the consumer of animal products scenario.
6) This receptor is assumed to obtain water for all needs from groundwater.

F:\FL4\FIGE3-2.DRW\JLM\8-1-94

FIGURE E.3-2 CONCEPTUAL MODEL OF CURRENT SOURCE TERM CONFIGURATION

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E-3-104

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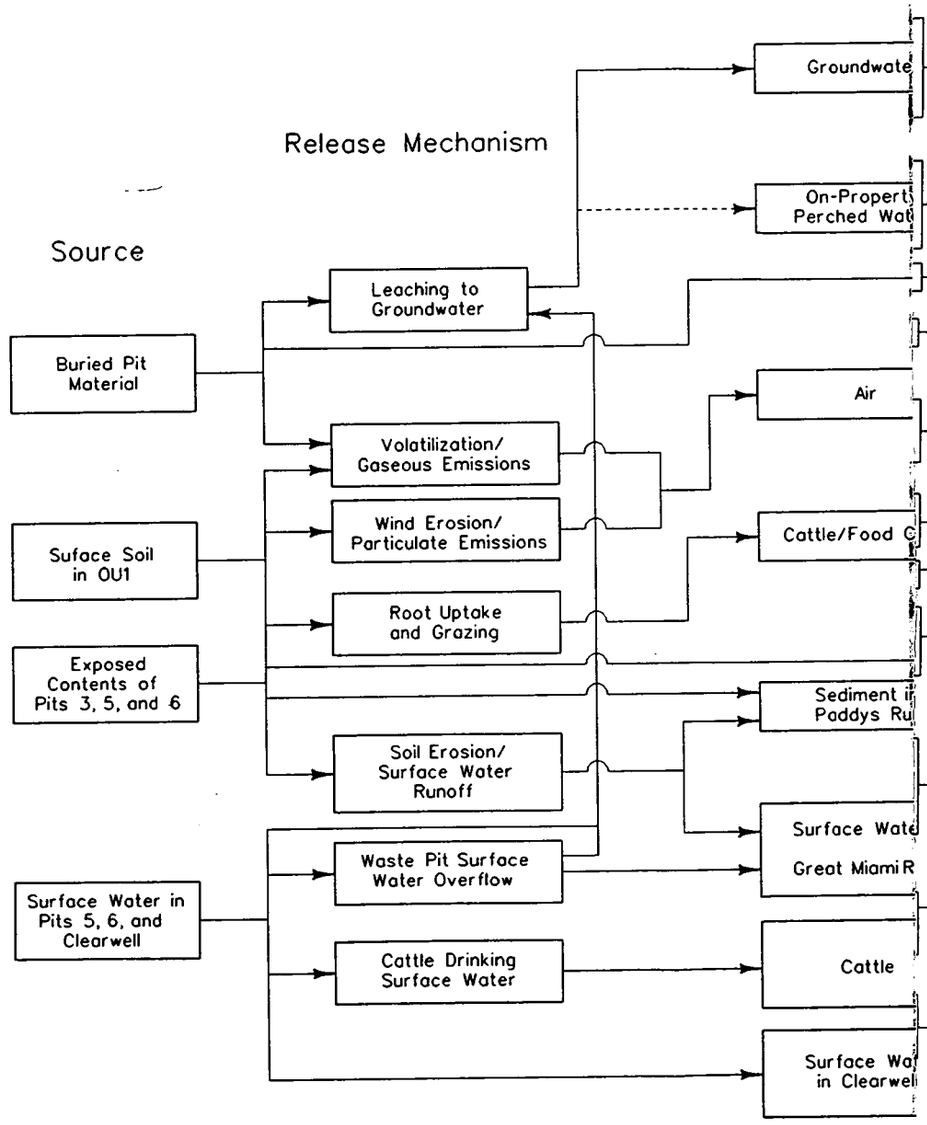
Indicates exposure scenario evaluated.
RME Reasonable Maximum Exposed
CT Central Tendency
------- Alternate Exposure Route



Exposure Route	Receptors: Current Land Use Without Access Controls				Receptors: Future Land Use					
	Off-Property RME Resident	Trespassing Child	Great Miami River User	Consumer of Meat and Milk	On-Property CT Resident	On-Property RME Resident	On-Property RME Child	Home Builder	Expanded Trespasser	Grounds Keeper
Drinking Water Ingestion		1	1,6	1,2				1	1	1
Inhalation (of VOCs)		1	1,6	1,2				1	1	1
Food Ingestion		1	1,6	1,2				1	1	1
Dermal Contact		1	1,6	1,2				1	1	1
Penetration Radiation	3,4	1	1,6	1,2	3,4	3,4	3,4	1	1	1
Water Ingestion	1	1	1,6	1,2	10		10	1	1	1
Dermal Contact	1	1	1,6	1,2	10		10	1	1	1
Inhalation (of VOCs)	1	1	1,6	1,2	10		10	1	1	1
Penetrating Radiation	5		6	2						
Inhalation			6	2						
Penetrating Radiation	3,4	3,4	6	2	3,4	3,4	3,4	3,4	3,4	3,4
Incidental Ingestion of Soil	3	3	6	2	3	3	3	3		
Food Ingestion		5	6	2				5	5	5
Dermal Contact	3	3	6	2	3	3	3	3		
Penetrating Radiation	3,4	3,4	6	2	3,4	3,4	3,4	3,4	3,4	3,4
Food Ingestion	8	8	6					8	5	5
Penetrating Radiation	7		6	2						
Soil Ingestion	7		6	2						
Sediment Ingestion	7		6	2	3	3	3	3		
Dermal Contact	7		6	2						
Drinking Water Ingestion	7	5		2	3,9	3,9	3,9	1	5	5
Ingestion (while swimming)	7	5		2	3,9	3,9	3,9	1	5	5
Inhalation (of VOCs)	7	5		2	3,9	3,9	3,9	1	5	5
Food Ingestion (Inc. Fish)	7	5		2	3,9	3,9	3,9	1	5	5
Dermal Contact	7	5		2	3,9	3,9	3,9	1	5	5
Penetrating Radiation	7	5	3	2	3,9	3,9	3,9	1	5	5
Food Ingestion	8	8	6					8	8	8
Ingestion (while swimming)	5	5	6	2	3	3	3	1	5	5
Inhalation (of VOCs)	5	5	6	2	3	3	3	1	5	5
Dermal Contact	5	5	6	2	3	3	3	1	5	5
Penetrating Radiation	4,5	4,5	6	2	3,4	3,4	3,4	1	5	5

1) This receptor is assumed to obtain water for all needs from off-property sources.
2) This receptor is assumed to be a distant resident whose only mode of exposure is through consumption of dairy products grown on the property.
3) Potential impact of exposure pathway is minor when compared to other exposure pathways for the same r
4) EPA risk assessment methodology for radionuclides does not address this exposure route.
5) Exposure route not applicable to a transient or non-resident receptor. Exposure could be accidental.

is assumed to be a distant resident whose only mode of exposure involves using the Great Miami River.
of quantifying risks to this receptor is to isolate and evaluate the impact of off-property exposures associated with farming.
is isolated and evaluated under the on-property grazing scenario.
that residents living on the property rarely leave, so access to the Great Miami River would be very limited.
is assumed to use groundwater for household use.

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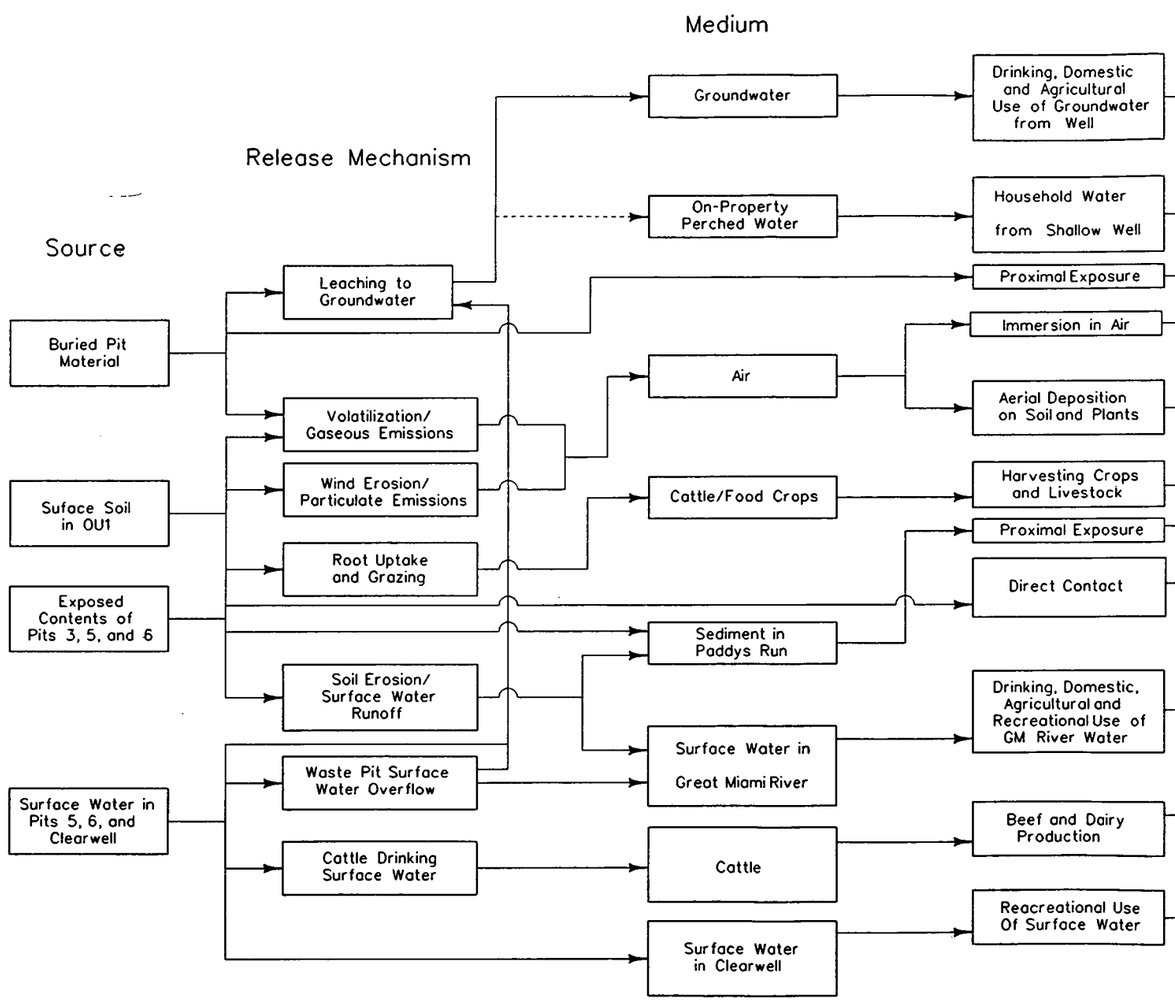
FIGURE E.3-3. CONCEPTUAL MODEL OF FUTURE SOURCE TERM CONFIGURATION

▒ Indicates exposure scenario evaluated.
RME Reasonable Maximum Exposed
CT Central Tendency
------- Alternate Exposure Route



Exposure Route	Receptors: Current Land Use Without Access Controls				Receptors: Future Land Use					
	Off-Property RME Resident	Trespassing Child	Great Miami River User	Consumer of Meat and Milk	On-Property CT Resident	On-Property RME Resident	On-Property RME Child	Home Builder	Expanded Trespasser	Grounds Keeper
Drinking Water Ingestion	▒	1	1,6	1,2	▒	▒	▒	1	1	1
Inhalation (of VOCs)	▒	1	1,6	1,2	▒	▒	▒	1	1	1
Food Ingestion	▒	1	1,6	1,2	▒	▒	▒	1	1	1
Dermal Contact	▒	1	1,6	1,2	▒	▒	▒	1	1	1
Penetration Radiation	3,4	1	1,6	1,2	3,4	3,4	3,4	1	1	1
Water Ingestion	1	1	1,6	1,2	10	▒	10	1	1	1
Dermal Contact	1	1	1,6	1,2	10	▒	10	1	1	1
Inhalation (of VOCs)	1	1	1,6	1,2	10	▒	10	1	1	1
Penetrating Radiation	5	▒	6	2	▒	▒	▒	▒	▒	▒
Inhalation	▒	▒	6	2	▒	▒	▒	▒	▒	▒
Penetrating Radiation	3,4	3,4	6	2	3,4	3,4	3,4	3,4	3,4	3,4
Incidental Ingestion of Soil	3	3	6	2	3	3	3	3	▒	▒
Food Ingestion	▒	5	6	2	▒	▒	▒	5	5	5
Dermal Contact	3	3	6	2	3	3	3	3	▒	▒
Penetrating Radiation	3,4	3,4	6	2	3,4	3,4	3,4	3,4	3,4	3,4
Food Ingestion	8	8	6	▒	▒	▒	▒	8	5	5
Penetrating Radiation	7	▒	6	2	▒	▒	▒	▒	▒	▒
Soil Ingestion	7	▒	6	2	▒	▒	▒	▒	▒	▒
Sediment Ingestion	7	▒	6	2	3	3	3	3	▒	▒
Dermal Contact	7	▒	6	2	▒	▒	▒	▒	▒	▒
Drinking Water Ingestion	7	5	▒	2	3,9	3,9	3,9	1	5	5
Ingestion (while swimming)	7	5	▒	2	3,9	3,9	3,9	1	5	5
Inhalation (of VOCs)	7	5	▒	2	3,9	3,9	3,9	1	5	5
Food Ingestion (Inc. Fish)	7	5	▒	2	3,9	3,9	3,9	1	5	5
Dermal Contact	7	5	▒	2	3,9	3,9	3,9	1	5	5
Penetrating Radiation	7	5	3	2	3,9	3,9	3,9	1	5	5
Food Ingestion	8	8	6	▒	▒	▒	▒	8	8	8
Ingestion (while swimming)	5	5	6	2	3	3	3	1	5	5
Inhalation (of VOCs)	5	5	6	2	3	3	3	1	5	5
Dermal Contact	5	5	6	2	3	3	3	1	5	5
Penetrating Radiation	4,5	4,5	6	2	3,4	3,4	3,4	1	5	5

1) This receptor is assumed to obtain water for all needs from off-property sources.
2) This receptor is assumed to be a distant resident whose only mode of exposure is through consumption of meat and dairy products grown on the property.
3) Potential impact of exposure pathway is minor when compared to other exposure pathways for the same receptor.
4) EPA risk assessment methodology for radionuclides does not address this exposure route.
5) Exposure route not applicable to a transient or non-resident receptor. Exposure could be accidental.
6) This receptor is assumed to be a distant resident whose only mode of exposure involves using the Great Miami River.
7) The objective of quantifying risks to this receptor is to isolate and evaluate the impact of off-property exposures associated with farming.
8) This pathway is isolated and evaluated under the on-property grazing scenario.
9) It is assumed that residents living on the property rarely leave, so access to the Great Miami River would be very limited.
10) This receptor is assumed to use groundwater for household use.

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FIGURE E.3-3. CONCEPTUAL MODEL OF FUTURE SOURCE TERM CONFIGURATION

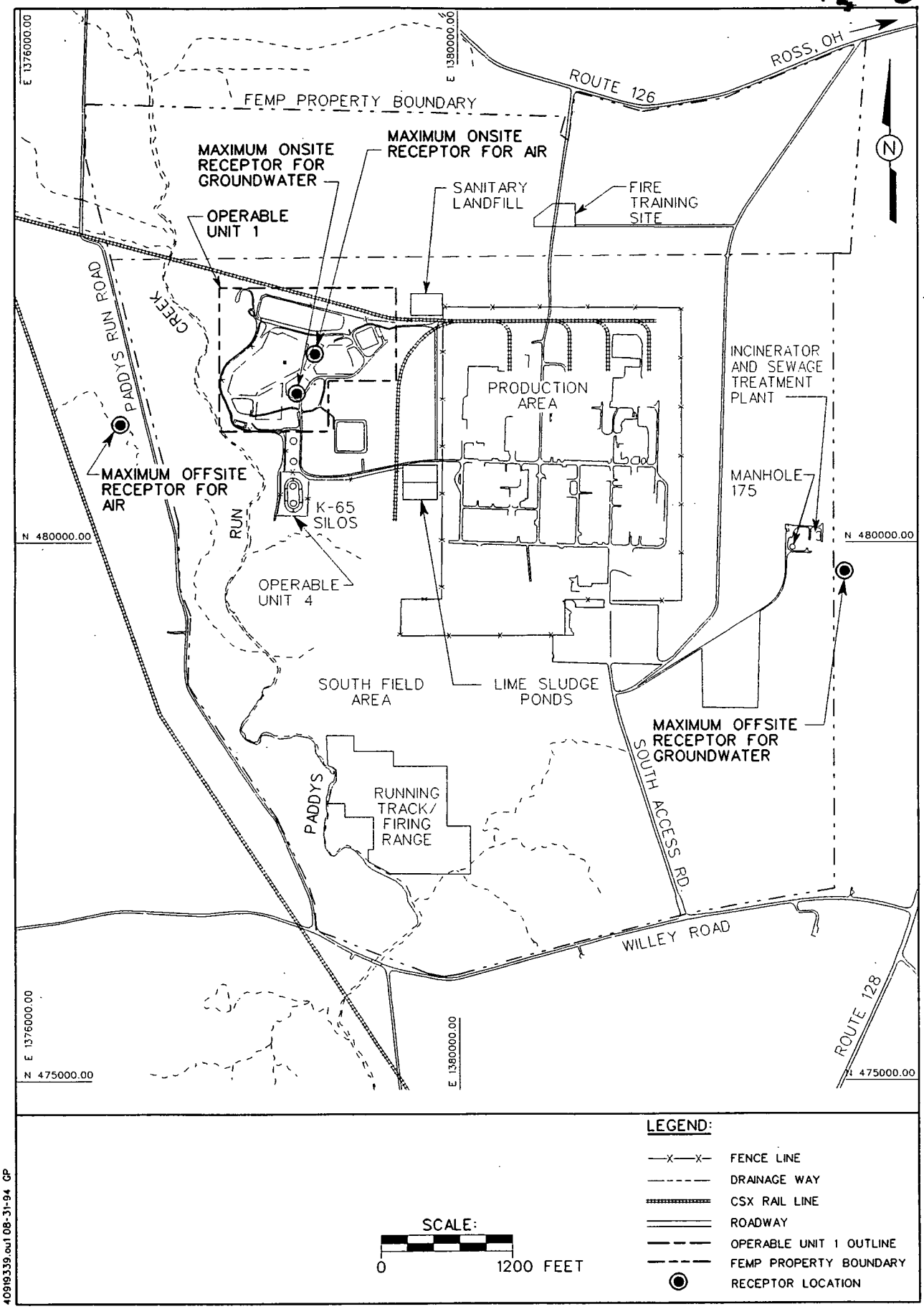

FIGURE E.3-4. RECEPTOR LOCATIONS USED TO EVALUATE AIR AND GROUNDWATER EXPOSURES FROM OU1

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000510

5899

E.4

E.4.0 TOXICITY ASSESSMENT

This toxicity assessment examines information concerning the potential human health effects of exposure to constituents of potential concern (CPC) in the Operable Unit 1 Study Area. Its goal is to provide, for each listed constituent, a quantitative estimate of the relationship between the magnitude and type of exposure and the severity or probability of human health effects. The toxicity values derived in this section are integrated with the exposure assessment (Section E.3.0) to characterize the potential for adverse health effects to occur.

The toxicological evaluation involves a critical review and interpretation of toxicity data from epidemiological, clinical, animal, and in vitro studies. This review of the scientific data ideally determines both the nature of the health effects associated with a particular chemical, and the probability that a given quantity of a chemical could result in an adverse effect. This analysis defines the relationship between the dose received and the incidence of an adverse effect for those chemicals selected in Sections E.2.0 and E.3.0 of this Appendix.

The entire toxicological data base is used to guide the derivation of cancer slope factors (CSFs) for carcinogenic effects and reference dose (RfD) values for noncarcinogenic effects. This data may include epidemiological studies, long-term animal bioassays, short-term tests, and comparisons of molecular structure. Data from these sources are reviewed to determine if a chemical is likely to be toxic to humans. Due to the lack of available human studies, however, the majority of toxicity data used to derive cancer slope factors and reference dose values comes from animal studies.

For noncarcinogenic effects, the most appropriate animal model, i.e., the species biologically most similar to the human, is identified. Pharmacokinetic data often enter into this determination. In the absence of sufficient data to identify the most appropriate animal model, the most sensitive animal species is chosen. The RfD is generally derived from the most comprehensive toxicology study that characterizes the dose-response relationship for the critical effect of the chemical. Preference is given to studies using the exposure route of concern; in the absence of such data, however, an RfD for one route of exposure may be extrapolated from data from a study that used a different route of exposure. Such extrapolation must take into account pharmacokinetic and toxicological differences between routes of exposure. Uncertainty factors are applied to the highest no-observed adverse effect

level (NOAEL) to adjust for inter- and intraspecies variation, deficiencies in the toxicological database, and use of subchronic rather than chronic animal studies. Additional uncertainty factors may be applied to estimate a NOAEL from a lowest observed adverse effect level (LOAEL) if the key study failed to determine a NOAEL. When chemical-specific data are not sufficient, an RfD may be derived from data for a chemical with structural and toxicologic similarity.

Cancer slope factors (CSFs) for weight-of-evidence Group A or B chemicals are generally derived from positive cancer studies that adequately identify the target organ in the test animal and characterize the dose-response relationship. CSFs are derived for Group C compounds for which the data are sufficient, but are not derived for Group D or E chemicals. No consideration is given to similarity in the animal and human target organ(s), because a chemical capable of inducing cancer in any animal tissue is considered potentially carcinogenic to humans. Preference is given to studies using the route of exposure of concern, in which normal physiologic function was not impaired, and in which exposure occurred during most of the animal's lifetime. Exposure and pharmacokinetic considerations are used to estimate equivalent human doses for computation of the slope factor. When a number of studies of similar quality are available, the data may be combined in the derivation of a slope factor.

Section E.4.1 presents the methodologies, assumptions, and sources of information used to perform the toxicity assessment for all Operable Unit 1 waste storage areas. An uncertainty analysis of the toxicity assessment is presented in Section E.4.2. Toxicological summaries for CPCs identified in Section E.2 are included in Section E.4.3.

E.4.1 TOXICITY INFORMATION FOR CONTAMINANTS OF POTENTIAL CONCERN

Certain chemical and radiological constituents found in Operable Unit 1 wastes are known or potential carcinogens in humans. It is generally assumed in health risk assessment that any dose of a carcinogen may result in cancer induction. The EPA assumes that a small number of molecular events can cause single-cell changes that can lead to uncontrolled cellular proliferation. This "nonthreshold" hypothesis assumes there is essentially no level of exposure that does not pose some level of carcinogenic risk.

As pointed out in EPA 1989a, certain fundamental differences exist between radionuclides and chemicals that somewhat simplify toxicity assessment for radionuclides. Because of these differences, the carcinogenic effects of radiation and chemicals are presented separately.

E.4.1.1 Radiocarcinogens

Some elements have isotopes consisting of unstable atoms (i.e., they undergo spontaneous transformation into more stable atoms). These isotopes are said to be radioactive, and the transformation process is known as radioactive decay. Radioactive decay is usually accompanied by the emission of charged particles and gamma rays. These emissions are called radiation. There are three types of radiation, which are potentially of concern at the FEMP: alpha, beta, and gamma. Alpha and beta radiation consist of charged particles capable of ionizing nearby matter. These radiations generally have little ability to penetrate deeply into adjacent matter, and can be interdicted by skin, air, and clothing. In most cases, the emission of an alpha or beta particle from an atom is followed by a release of x-rays or gamma radiation. Depending on their energies, these radiations may have considerably more penetration power than either alpha or beta radiation and are thus more difficult to shield.

Radiation exposures can be separated into external and internal exposures. External exposure occurs when the radionuclide is outside of the body. Because alpha and beta radiation generally have a low penetrating power, skin and air become effective radiation shields in most cases. Therefore, external exposures to gamma radiation are the primary concern at environmental levels. Internal exposure occurs after the radionuclide enters the body via inhalation or ingestion. For internal exposures, alpha and beta particles become more important because their energy is directly absorbed by living cells.

Inhalation and ingestion are the primary routes for internal exposure to radionuclides. Biologically significant exposures to alpha and beta emitters are more probable for internal exposure because the emitter is in direct contact with tissue. Once in the body, exposure depends on the absorption and retention characteristics of the radionuclide. These absorption and retention characteristics are based on the chemical form of the radionuclide in a compound and not on the isotopic form of the radionuclide. GI absorption factors and lung retention classifications for the radionuclides of concern are presented in Table E.4-1.

Radioactive contamination within Operable Unit 1 is characterized as low-level ionizing radiation. The principal adverse biological effects associated with ionizing radiation from radioactive substances in the environment are mutagenicity, teratogenicity, and carcinogenicity. Mutagenicity is the ability to induce genetic mutations in the nuclei of either body cells or reproductive cells. Teratogenicity is the ability to induce or increase the incidence of congenital malformations, which are permanent structural or functional deviations produced during embryonic growth and development. Carcinogenicity is the ability to produce cancer. The carcinogenicity of a radioactive isotope of an element depends on several factors including:

- The type of radiation emitted by the radioisotope
- The energy of the radiation emitted
- The radiological half-life of the isotope
- The retention and concentration characteristics of the radioisotope in the human body

Carcinogenicity is believed to be the limiting deleterious effect at the levels of radiation dose encountered within Operable Unit 1 and has been used as the sole basis for assessing the radiation-related human health risks of a site contaminated with radionuclides (EPA 1989a).

The relationship between radiation dose and health effects is relatively well characterized for high doses (i.e. >10 rad). Hence, risk estimates are strictly applicable only to large populations exposed to high levels of radiation. Lower levels of exposure may constitute a health risk, but a direct cause and effect relationship is difficult to establish because a particular effect in a specific individual can be produced by many different processes. For low doses, health effects are presumed to occur but can only be estimated statistically. Therefore, the risk of cancer incidence from exposure to low levels of ionizing radiation must be extrapolated from incidence data at higher doses.

Under CERCLA methodology, the EPA assumes a unit intake of, or external exposure to, a radionuclide over a lifetime. The annual radiation dose equivalent from the radionuclide to each organ in each year of life is calculated. The average excess number of all types of radiation-induced fatal cancers that occur in a year is then estimated for the corresponding

dose equivalents received during that year and relevant preceding years. The excess number of radiation-induced fatal cancers is derived from epidemiological data, extrapolation from high radiation doses to low doses, and hypothetical models for projecting risk through a lifetime. The relationship between cancer incidence and exposure to radioactive materials is quantified by using mathematical extrapolation models, which estimate the largest possible linear slope (within the 95 percent confidence limit) at low extrapolated doses consistent with the data. Because EPA is concerned with assessing cancer incidence, each radionuclide slope factor has been calculated by dividing the excess fatal cancer risk for that radionuclide by the mortality-to-incidence risk ratio (EPA 1989a) for the types of cancer induced by that radionuclide. This "radiocarcinogenicity slope factor" thus is characterized as the "maximum likelihood estimate of the age-averaged lifetime total excess cancer risk per unit intake or exposure" (EPA 1991b). That is, the true risk to humans, although not identifiable, is not likely to exceed this upperbound estimate; it may, in fact, be lower.

The EPA Office of Radiation Programs (ORP) has calculated cancer slope factors for radionuclides of potential concern at Superfund sites. These values are listed in EPA's *Health Effects Assessment Summary Tables* (HEAST, Table C) (EPA 1991b; EPA 1992b) and are presented as the risk of cancer incidence per unit intake of a radionuclide contaminant. The radionuclide slope factors used in this assessment are expressed in units of pCi^{-1} or g/pCi_{-y} and are presented in Table E.4-1.

E.4.1.2 Chemical Carcinogens

The toxicity information considered in the assessment of potential carcinogenic risks includes (1) a weight-of-evidence classification and (2) a slope factor. The weight-of-evidence classification qualitatively describes the likelihood that a chemical is a human carcinogen and is based on an evaluation of the available data from human and animal studies. A chemical may be placed in one of three groups in EPA's classification system to indicate its potential for carcinogenic effects: Group A, a human carcinogen; Group B1, or B2, a probable human carcinogen; and Group C, a possible human carcinogen. Chemicals that cannot be classified as human carcinogens because of a lack of data are placed in Group D, and those for which there is evidence of noncarcinogenicity in humans are placed in Group E.

The cancer slope factor is the toxicity value used to quantitatively express the carcinogenic hazard of cancer-causing constituents. It is defined as the upper-bound estimate of the

probability of cancer incidence per unit dose averaged over a lifetime. Slope factors are derived from studies of carcinogenicity in humans and/or laboratory animals and are typically calculated for compounds in Groups A, B1, and B2. Slope factors are specific to a chemical and route of exposure and expressed in units of $(mg/kg/day)^{-1}$ for both oral and inhalation routes. The induction of cancer by dermal absorption is evaluated using oral slope factors. Inhalation cancer toxicity values are usually expressed as inhalation unit risks in units of reciprocal $\mu g/m^3$ ($1/\mu g/m^3$). Because cancer risk characterization requires an estimate of reciprocal dose in units of 1/mg/kg-day, the inhalation unit risk must be converted to the mathematical equivalent of an inhalation cancer slope factor, or risk per unit dose (mg/kg-day). This is done by assuming humans weigh 70 kg and inhale 20 m^3 of air/day, i.e., the inhalation unit risk ($1/\mu g/m^3$) divided by 20 m^3/day, multiplied by 70 kg and multiplied by 1000 $\mu g/mg$ yields the mathematical equivalent of an inhalation slope factor (1/mg/kg-day). Slope factors for chemical constituents are presented in Table E.4-2. The primary sources of these toxicity values are EPA's *Integrated Risk Information System (IRIS)* (EPA 1993a) and the quarterly updated HEAST (EPA 1992b). Other EPA sources of cancer slope factors were also consulted when available. Surrogate chemicals were not used for cancer slope factor derivation unless the chemical similarity was very close and the derivation was highly defensible.

E.4.1.3 Noncarcinogenic Chemicals

For noncarcinogens, it is assumed that a dose exists below which no adverse health effects will be seen. Below this "threshold" dose, exposure to a chemical can be tolerated without adverse effects. For noncarcinogens, a range of exposure exists that can be tolerated without adverse effects. Toxic effects are manifested only when physiologic protective mechanisms are overcome by exposures to a constituent above its threshold level. Maternal and developmental endpoints are considered systemic toxicity.

The potential for noncarcinogenic health effects resulting from exposure to chemical contaminants is assessed by comparing an exposure estimate (intake) to a reference dose (RfD). The RfD is expressed in units of mg/kg/day and represents a daily intake of contaminant per kilogram of body weight that is not sufficient to cause the threshold effect of concern for the contaminant. An RfD is specific to the chemical, the route of exposure, and the duration over which the exposure occurs. Separate RfDs are presented for ingestion and inhalation pathways. EPA (1992b) presents reference concentrations (RfCs) for the inhalation route. Inhalation noncancer toxicity values are usually expressed as inhalation concentrations

(RfCs) in units of mg/m^3. Because noncancer risk characterization requires an estimate of dose in units of mg/kg-day, the inhalation RfC must be converted to an inhalation RfD the inhalation RfC. This is done by assuming humans weigh 70 kg and inhale 20 m^3 of air per day (i.e., the inhalation RfC (mg/m^3) multiplied by 20 m^3/day and divided by 70 kg yields an inhalation RfD (mg/kg-day). To derive an RfD, the EPA reviews all relevant human and animal studies for each compound and selects the study (studies) pertinent to the derivation of the specific RfD. Each study is evaluated to determine the no-observed-adverse-effect level (NOAEL) or, if data are inadequate for such a determination, the lowest-observed-adverse-effect level (LOAEL). The NOAEL corresponds to the dose, in mg/kg-d that can be administered over a lifetime without inducing observable adverse effects. The LOAEL corresponds to the lowest daily dose, in mg/kg-d, that can be administered over a lifetime that induces an observable adverse effect. The toxic effect characterized by the LOAEL is referred to as the "critical effect". To derive an RfD, the NOAEL (or LOAEL) is divided by uncertainty factors to ensure that the RfD will be protective of human health. Uncertainty factors are applied to account for (1) extrapolation of data from laboratory animals to humans (interspecies extrapolation), (2) variation in human sensitivity to the toxic effects of a compound (intraspecies differences), (3) derivation of a chronic RfD based on a subchronic rather than a chronic study, and/or (4) derivation of an RfD from the LOAEL rather than the NOAEL. In addition to these uncertainty factors, modifying factors between 0 and 10 may be applied to reflect additional qualitative considerations in evaluating the data. For most compounds, the modifying factor is 1.

Reference doses for noncarcinogenic CPCs are presented in Table E.4-3. The primary source of values for reference doses is IRIS, an on-line database that contains current health risk and regulatory information for many chemicals (EPA 1993a). The RfDs and RfCs are also tabulated in HEAST (EPA 1992b). Other EPA sources of provisional RfD values were also consulted when available. Surrogate chemicals were not used for derivation of an RfD unless the chemical similarity was very close and the derivation was highly defensible.

E.4.1.4 Dose-Response Assessment for Chemicals with No Toxicity Information

For a number of chemicals or chemical classes there is inadequate data for quantitative dose-response assessment. Examples of these chemical classes for Operable Unit 1 include potentially carcinogenic PAHs, PCBs and dioxins and furans. For these chemical classes,

alternative means were used for quantitative dose-response assessment. A summary of these alternative methods is provided below.

- The carcinogenicity of all polychlorinated biphenyl (PCB) isomers is assumed to be equal to the carcinogenicity of Aroclor-1260 because dose-response data for other isomers are inconclusive.

- The carcinogenicity of dioxins and furans are determined using EPA's revised 1989 "Toxicity Equivalency Factors" (TEFs) (EPA 1990d). These TEFs were determined with the basic assumption that selected dioxins and furans are carcinogenic.

- The carcinogenicity of PAHs is determined initially using the benzo(a)pyrene cancer slope factors, and refined using a relative potency approach (Clement 1988, 1990).

For risk assessment purposes, mixtures of chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) can be evaluated using EPA's toxicity equivalency method. This approach, based on available toxicological data, uses derived TEFs to convert the concentration of CDD or CDF congeners into an equivalent concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). Table E.4-4 presents the TEFs for a variety of CDD and CDF congeners. Congeners containing chlorines at the 2,3,7, and 8 positions are considered to be more toxic, and congeners without chlorines at those positions are assigned a TEF of "0." However, to be more conservative, all unspecified congeners are assumed to be the more toxic form.

Carcinogenic risks associated with PAHs are evaluated using the relative potency approach described by Clement (1988 and 1990). This approach, approved by EPA Region V, considers the relative potency of the individual PAHs and allows site-specific relative concentrations to be expressed in the risk assessment. The relative potency factors for PAHs are presented in Table E.4-5.

E.4.1.5 Dermal Reference Doses and Cancer Slope Factors

Dermal RfD values and cancer slope factors are derived from the corresponding oral values. In the derivation of a dermal RfD, the oral RfD is multiplied by the gastrointestinal (GI) absorption factor, expressed as a fraction. The resulting dermal RfD is an RfD based on absorbed dose, which is the appropriate value with which to compare a dermal dose, because dermal doses are expressed as absorbed rather than exposure doses. In a similar manner, and for the same reasons, a dermal cancer slope factor is derived by dividing the oral cancer slope

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factor by the GI absorption efficiency. The oral slope factor is divided, rather than multiplied, by the GI absorption efficiency because cancer slope factors are expressed as reciprocal dose. Dermal cancer slope factors and dermal RfD values for the chemicals of concern in Operable Unit 1 are presented in Tables E.4-2 and E.4.3, respectively.

The most important consideration regarding the uncertainty associated with a dermal RfD or cancer slope factor is the accuracy of the GI absorption efficiency factor. For this reason, the toxicity profiles presented in Section E.4.3 contain pharmacokinetics sections in which the oral absorption data are evaluated. Where appropriate, the low (most conservative) end of the range of available GI absorption data for humans is used in the derivation of the dermal RfD or cancer slope factor. When the human data are insufficient, animal data are used. Data from high-dose experiments are not used if more suitable data are available and it appears that saturation of the GI absorption process could have occurred.

When sufficient quantitative data were not located, a default GI absorption factor was used. As noted by EPA (1989a), the GI absorption of many metals from the GI tract is limited, and 0.05 is a reasonable default for metals and inorganic substances.

EPA (1989a) did not recommend a separate default value for organic chemicals. A compilation of data for 19 organic chemicals presented GI absorption efficiencies ranging from 0.5 to 1.0. All but 3 of the 19 chemicals had GI absorption efficiencies of at least 0.9, indicating that organic chemicals are generally readily absorbed. The arithmetic average of the GI efficiencies for the 19 organic chemicals, 0.91368, equivalent to 0.9 when rounded to one significant figure, appears to be a reasonable default GI absorption efficiency factor for organic chemicals. The default of 0.9 for GI absorption is used for organic chemicals for which quantitative data were not sufficient. The GI efficiency factors used to derive the dermal cancer slope factors and dermal RfD values are presented in Tables E.4-2, and E.4-3, respectively.

Table E.4-6 contains information on several chemical properties used in the estimation of dermal intakes. These parameters serve as input to dermal exposure equations presented in Section E.3.

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E.4.2 TOXICITY PROFILES

This subsection presents more detailed toxicity information for individual CPCs as well as for the other compounds identified at Operable Unit 1. This information includes summary descriptions of toxicity, based on critical studies used as a basis for the toxicity value; toxic effects resulting from chronic exposure; and the critical toxic effect observed or target organ affected. Profiles of chemicals are arranged in alphabetical order.

E.4.2.1 Acenaphthylene

E.4.2.1.1 Noncancer Toxicity

Noncancer toxicity data were not located for acenaphthylene, but the chemical is structurally very similar to acenaphthene. Acenaphthene appears to be a mild hepatotoxicant, and possibly a nephrotoxicant, in rodents (EPA 1993a). It is reasonable to suspect that acenaphthylene may induce similar effects.

E.4.2.1.2 Carcinogenicity

The EPA (1993a) classifies acenaphthylene as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans), based on no human cancer data and inadequate cancer data in animals. The animal data consist of an inadequately reported lifetime skin painting study in which skin tumors were not observed in mice treated with acenaphthylene (Cook 1932). Tumors were observed in mice treated with other PAHs.

E.4.2.2 Acetone

E.4.2.2.1 Noncancer Toxicity

Studies of workers exposed to acetone revealed irritation of the ocular and respiratory tract mucosa, and, at high concentrations, central nervous system (CNS) effects (American Conference of Governmental Industrial Hygienists [ACGIH] 1991). Rats exposed by inhalation to high concentrations exhibited narcosis and slight decreases in organ and body weight, compared with controls, but no clinical pathological or histopathological evidence of organ damage. Inhalation reference concentration (RfC) values were not located for acetone. Oral toxicity data are limited to a comprehensive 90-day gavage study in rats, in which 100 mg/kg/day was a no-observed-effect-level (NOEL) and 500 mg/kg/day was the lowest-observed-adverse-effect-level (LOAEL) associated with increased liver and kidney weight and tubular nephropathy (EPA 1993a). A verified RfD for chronic oral exposure of 0.1 mg/kg/day was derived by applying an uncertainty factor of 1000 to the NOEL of 100 mg/kg/day. The

EPA (1992b) presented a provisional subchronic oral RfD of 1 mg/kg/day, based on the same NOEL and an uncertainty factor of 100. The target organs for inhalation exposure to acetone are the CNS and the respiratory and ocular mucosa. Target organs for oral exposure are the liver and kidney.

E.4.2.2.2 Carcinogenicity

Acetone is classified as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) based on a lack of human or animal carcinogenicity data (EPA 1993a).

E.4.2.3 Ammonia

E.4.2.3.1 Noncancer Toxicity

Ammonia is produced naturally as an end product of protein metabolism (Sax and Lewis 1987). Ammonia excreted in expired air may arise from the bacterial action in the mouth (EPA 1993a). Nasal and throat irritation are consistent findings in humans exposed to ≥50 parts per million (ppm) in the air (Ferguson et al. 1977). No significant increase in ocular, dermal, or respiratory irritation was reported by workers, and no decrement in lung function was measured in workers exposed to a time weighted average (TWA) concentration of 9.2 ppm (Holness et al. 1989). Lung function tests, however, may not be the most sensitive indicators of ammonia toxicity, as explained below.

In animals exposed to ≤500 ppm, lesions including irritation and hyperplasia were restricted to the upper respiratory tract (Gamble and Clough 1976; Flury et al. 1983; EPA 1993a). At these concentrations, virtually the entire inhaled dose was taken up by the upper respiratory mucosa because of the high solubility and reactivity of ammonia. At higher concentrations, ammonia penetrated to the lungs and induced congestion, edema, and hemorrhage (Anderson et al. 1964). Congestion of the spleen and liver may arise from ammonia-induced impairment of pulmonary circulation.

The EPA (1993a) derived an RfC of 0.1 milligram per cubic meter (mg/m^3) for chronic inhalation exposure to ammonia, based on the no-observed-adverse-effect-level (NOAEL) of 9.2 ppm (6.4 mg/m^3) in the occupational study previously described. An uncertainty factor of 30 was applied, 10 to provide protection for sensitive individuals and 3 to account for deficiencies in the database, including lack of chronic data, proximity of the human NOAEL to

an animal LOAEL, and lack of reproductive and developmental data. Confidence in the RfC was medium.

E.4.2.3.2 Carcinogenicity

The EPA (1993a) has not evaluated the carcinogenicity of ammonia.

E.4.2.4 Antimony

E.4.2.4.1 Pharmacokinetics

Ingested antimony is absorbed slowly and incompletely from the gastrointestinal (GI) tract (Iffland 1988). Within a few days of acute exposure, highest tissue concentrations are found in the liver, kidney, and thyroid. Organs of storage include skin, bone, and teeth. Highest concentrations in deceased smelter workers (inhalation exposure) occurred in the lungs and skeleton. Excretion is largely via the urine or feces, although some is incorporated into the hair.

E.4.2.4.2 Noncancer Toxicity

Acute intoxication from ingestion of large doses of antimony induces GI disturbances, dehydration, and cardiac effects in humans (Iffland 1988). Chronic effects from occupational exposure include irritation of the respiratory tract, pneumoconiosis, pustular eruptions of the skin called "antimony spots," allergic contact dermatitis, and cardiac effects, including abnormalities of the electrocardiograph (ECG) and myocardial changes. Cardiac effects were also observed in rats and rabbits exposed by inhalation for six weeks and in animals (dogs, and possibly other species) treated by intravenous injection (Elinder and Friberg 1986a).

Chronic oral exposure studies in laboratory animals include two briefly reported lifetime drinking water studies in rats and mice (Kanisawa and Schroeder 1969; Schroeder et al. 1970). The only dose tested, 5 ppm potassium antimony tartrate, resulted in reduced longevity in both species and in reduced mean heart weight in the rats. The EPA (1993a) verified an RfD of 0.0004 mg/kg/day for chronic oral exposure to antimony from the LOAEL of 5 ppm potassium antimony tartrate (0.35 mg antimony/kg body weight-day) in the lifetime study in rats (Schroeder et al. 1970). An uncertainty factor of 1000 was applied; factors of 10 each for inter- and intraspecies variation and to estimate an NOAEL from an LOAEL. The heart is considered a likely target organ for chronic oral exposure of humans.

E.4.2.4.3 Carcinogenicity

Data were not located regarding the carcinogenicity of antimony to humans. Antimony fed to rats did not produce an excess of tumors (Goyer 1991), but a high frequency of lung tumors was observed in rats exposed by inhalation to antimony trioxide for one year (Elinder and Friberg 1986a). Antimony is classified in EPA cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans) (EPA 1987a).

E.4.2.5 Arsenic

E.4.2.5.1 Pharmacokinetics

Several studies confirm that soluble inorganic arsenic compounds and organic arsenic compounds are almost completely (>90 percent) absorbed from the GI tract in both animals and humans (Ishinishi et al. 1986). The absorption efficiency of insoluble inorganic arsenic compounds depends on particle size and stomach pH. Initial distribution of absorbed arsenic is to the liver, kidneys, and lungs, followed by redistribution to hair, nails, teeth, bone, and skin, which are considered tissues of accumulation. Arsenic has a longer half-life in the blood of rats, compared with other animals and humans, because of firm binding to the hemoglobin in erythrocytes.

Metabolism of inorganic arsenic includes reversible oxidation-reduction so that both arsenite (valence of 3) and arsenate (valence of 5) are present in the urine of animals treated with arsenic of either valence (Ishinishi et al. 1986). Arsenite is subsequently oxidized and methylated by a saturable mechanism to form mono- or dimethylarsenate; the latter is the predominant metabolite in the urine of animals or humans. Organic arsenic compounds (arsenilic acid, cacodylic acid) are not readily converted to inorganic arsenic. Excretion of organic or inorganic arsenic is largely via the urine, but considerable species variation exists. Continuously exposed humans appear to excrete 60 to 70 percent of their daily intake of arsenate or arsenite via the urine.

E.4.2.5.2 Noncancer Toxicity

A lethal dose of arsenic trioxide in humans is 70 to 180 mg (approximately 50 to 140 mg arsenic; Ishinishi et al. 1986). Acute oral exposure of humans to high doses of arsenic produce liver swelling, skin lesions, disturbed heart function, and neurological effects. The only noncancer effects in humans clearly attributable to chronic oral exposure to arsenic are dermal hyperpigmentation and keratosis, as revealed by studies of several hundred Chinese

exposed to naturally occurring arsenic in well water (Tseng 1977; Tseng et al. 1968; EPA 1993a). Similar effects were observed in persons exposed to high levels of arsenic in water in Utah and the northern part of Mexico (Cebrian et al. 1983; Southwick et al. 1983). Occupational (predominantly inhalation) exposure is also associated with neurological deficits, anemia, and cardiovascular effects (Ishinishi et al. 1986), but concomitant exposure to other chemicals cannot be ruled out. The EPA (1993a) derived an RfD of 0.3 μg/kg/day for chronic oral exposure, based on an NOAEL of 0.8 μg/kg/day for skin lesions from the Chinese data. The principal target organ for arsenic appears to be the skin. The nervous system and cardiovascular systems appear to be less significant target organs. Inorganic arsenic may be an essential nutrient, exerting beneficial effects on growth, health, and feed conversion efficiency (Underwood 1977).

E.4.2.5.3 Carcinogenicity

Inorganic arsenic is clearly a carcinogen in humans. Inhalation exposure is associated with increased risk of lung cancer in persons employed as smelter workers, in arsenical pesticide applicators, and in a population residing near a pesticide manufacturing plant (EPA 1993a). Oral exposure to high levels in well water is associated with increased risk of skin cancer (Tseng 1977; EPA 1993a). Extensive animal testing with various forms of arsenic given by many routes of exposure to several species, however, has not demonstrated the carcinogenicity of arsenic (International Agency for Research on Cancer [IARC] 1980). The EPA (1993a) classifies inorganic arsenic in cancer weight-of-evidence Group A (human carcinogen), and recommends an oral unit risk of 0.00005 μg/L in drinking water, based on the incidence of skin cancer in the Tseng (1977) study. The EPA (1993a) notes that the uncertainties associated with the oral unit risk are considerably less than those for most carcinogens, so that the unit risk might be reduced an order of magnitude. An inhalation unit risk of 0.0043 per $\mu g/m^3$ was derived for inorganic arsenic from the incidence of lung cancer in occupationally exposed men (EPA 1993a).

E.4.2.6 Barium

E.4.2.6.1 Noncancer Toxicity

Barium is a naturally occurring alkaline earth metal that comprises approximately 0.04 percent of the earth's crust (Reeves 1986a). Acute oral toxicity was manifested by GI upset, altered cardiac performance, and transient hypertension, convulsions, and muscular paralysis. Repeated oral exposures were associated with hypertension. Occupational exposure to

insoluble barium sulfate induced benign pneumoconiosis (ACGIH 1991). The EPA (1993a) presented a verified chronic oral RfD of 0.07 mg/kg/day, based on an NOAEL of 0.21 mg/kg/day in a ten-week study in humans exposed to barium in drinking water and an uncertainty factor of 3. The EPA (1992b) presented the same value as a provisional RfD for subchronic oral exposure. A provisional chronic inhalation RfC of 0.0005 mg/m^3 and a provisional subchronic inhalation RfC of 0.005 were based on an NOEL for fetotoxicity in a four-month intermittent-exposure inhalation study in rats (EPA 1992b). Uncertainty factors of 1000 and 100 were used for the chronic and subchronic RfC values, respectively. The chronic and subchronic inhalation RfC values are equivalent to 0.0001 and 0.001 mg/kg/day, assuming a human inhalation rate of 20 m^3/day and body weight of 70 kg. Barium is principally a muscle toxin. Its targets are the GI system, skeletal muscle, the cardiovascular system, and the fetus.

E.4.2.6.2 Carcinogenicity

The EPA (1992f) classifies barium as a cancer weight-of-evidence Group D substance (not classifiable as to carcinogenicity in humans). Cancer risk is not estimated for Group D substances.

E.4.2.7 Benzene

E.4.2.7.1 Noncancer Toxicity

In humans, short-term inhalation exposure to benzene induced CNS effects such as drowsiness, dizziness, and headaches; long-term exposure induced anemia (ACGIH 1991). Oral dosing in animals induced hematopoietic effects (Agency for Toxic Substances and Disease Registry [ATSDR] 1989a). Neither oral nor inhalation RfD or RfC values were located for benzene. The CNS and the hematopoietic system are the target organs of benzene.

E.4.2.7.2 Carcinogenicity

The EPA (1993a) classifies benzene in cancer weight-of-evidence Group A (human carcinogen) based on several studies of increased risk of nonlymphocytic leukemia associated with occupational exposure, supported by an increased incidence of neoplasia in rats and mice exposed by inhalation and gavage. A verified oral slope factor of 0.029 per mg/kg/day and inhalation unit risk of 8.3E-06 μg/m^3 is based on the increased incidence of leukemia in several occupational (inhalation exposure) studies. The inhalation unit risk is equivalent to

0.029 per mg/kg/day, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans.

E.4.2.8 Benzoic Acid

E.4.2.8.1 Noncancer Toxicity

There are no reports of toxicity in humans associated with ingestion of 0.9 to 34 mg benzoic acid/day, and the compound is classified as Generally Regarded as Safe (GRAS) by the U.S. Food and Drug Administration (FDA) (EPA 1993a). Effects observed in oral studies in rats and mice were limited to decreased resistance to stress and reduced food and water intake accompanied by decreased growth rate. The EPA (1993a) presented a verified chronic oral RfD of 4 mg/kg/day, based on the upper range of daily intake estimated by the FDA and an uncertainty factor of 1. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. Data are inadequate to identify a target organ for the toxicity of benzoic acid.

E.4.2.8.2 Carcinogenicity

Cancer data consist of a lifetime drinking water study and a five-generation reproduction study in mice that showed no evidence of a carcinogenic effect. The EPA (1993a) classifies benzoic acid as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans). Quantitative risk estimates are not derived for Group D compounds.

E.4.2.9 Beryllium

E.4.2.9.1 Noncancer Toxicity

Beryllium has a low order of toxicity when ingested because it is poorly absorbed from the GI tract (Reeves 1986b). Occupational exposure was associated with dermatitis, acute pneumonitis, and chronic pulmonary granulomatosis (berylliosis). Berylliosis was also observed in humans living in the vicinity of a beryllium plant. Similar pulmonary effects were observed in laboratory animals subjected to inhalation exposure. A verified chronic oral RfD value of 0.005 mg/kg/day was based on an NOAEL in a lifetime drinking water study in rats and an uncertainty factor of 100 (EPA 1993a). The EPA (1992b) presented the same value as a provisional subchronic oral RfD. The target organ for inhalation exposure appears to be the lung; a target organ is not identified for oral exposure.

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E.4.2.9.2 Carcinogenicity

The EPA (1993a) classifies beryllium in cancer weight-of-evidence Group B2 (probable human carcinogen) based on inadequate human (occupational) cancer data and sufficient animal data. A significant increase in lung tumors occurred in rats and in rhesus monkeys subjected to inhalation exposure or intratracheal instillation of a variety of beryllium compounds. Osteogenic sarcomas were induced in rabbits and mice, but not in rats or guinea pigs, injected intravenously with various beryllium compounds. Oral studies in animals yielded inconclusive results. The EPA (1993a) derived an oral slope factor of 4.3 per mg/kg/day from a statistically nonsignificant increase in total tumors in a lifetime drinking water study in rats. An inhalation unit risk of 0.0024 per $\mu g/m^3$, equivalent to 8.4 per mg/kg/day (assuming an inhalation rate of 20 m^3/day and body weight of 70 kg for humans), was derived from an occupational study.

E.4.2.10 Bis(2-ethylhexyl)phthalate (di[2-ethylhexyl]phthalate)

E.4.2.10.1 Noncancer Toxicity

The acute oral toxicity of bis(2-ethylhexyl)phthalate is very low; oral $LD_{50/30}$ (lethal dose to 50 percent of population within 30 days without medical treatment) values in rats and mice were 33,800 and 26,300 mg/kg, respectively (ACGIH 1991). Repeated high-dose oral exposures were associated with decreased growth, altered organ weights, testicular degeneration, and developmental effects. The EPA (1993a) presented a verified chronic oral RfD of 0.02 mg/kg/day based on an LOAEL for increased relative liver weight in guinea pigs and an uncertainty factor of 1000. The EPA (1992b) adopted the chronic oral RfD as the provisional subchronic oral RfD. The principal target organs for the toxicity of bis(2-ethylhexyl)phthalate are the liver and testis.

E.4.2.10.2 Carcinogenicity

The EPA (1993a) classifies bis(2-ethylhexyl)phthalate in cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate human cancer data (one limited occupational study) and sufficient cancer data in laboratory animals. An oral slope factor of 0.014 per mg/kg/day was based on the increased incidence of liver tumors in a dietary study in male mice.

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E.4.2.11 Boron

E.4.2.11.1 Noncancer Toxicity

Acute exposure to boron compounds was associated with GI irritation and CNS depression (ACGIH 1991). Occupational exposure induced respiratory tract irritation. Several dietary and drinking water studies with boron (chemical form not specified) in dogs, rats, and mice identified testicular atrophy and impaired spermatogenesis as the critical effect of oral exposure (EPA 1993a). Other effects included reduced body and organ weights, reduced ovulation in female rats, and possibly increased extramedullary hematopoiesis in the spleen. The EPA (1993a) presented a verified RfD of 0.09 mg/kg/day for chronic oral exposure to boron, based on an NOAEL in a two-year dietary study in dogs (form of boron not specified). An uncertainty factor of 100 was used. The chronic oral RfD was adopted as the provisional subchronic oral RfD (EPA 1992b). The principal target organs of boron are the testis, respiratory mucosa, and CNS.

E.4.2.11.2 Carcinogenicity

Data were not located regarding the carcinogenicity of boron.

E.4.2.12 Bromodichloromethane

E.4.2.12.1 Noncancer Toxicity

Chronic gavage treatment with bromodichloromethane induced histopathologic evidence of degeneration of the liver and kidney in rats and mice, and hyperplastic lesions of the thyroid in the mice (EPA 1993a). The EPA (1993a) presented a verified chronic oral RfD of 0.02 mg/kg/day based on an NOAEL for kidney effects in mice and an uncertainty factor of 1000. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. The principal target organs of bromodichloromethane are the liver and kidney; the thyroid may be a target in mice.

E.4.2.12.2 Carcinogenicity

The EPA (1993a) classifies bromodichloromethane in cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate human data and sufficient animal data. The human data consist of epidemiologic studies that associate chlorination of drinking water with increased risk of several different types of cancer. Bromodichloromethane is one of several trihalogenated methanes formed from the interaction of chlorine with organic matter in water. Animal studies associated treatment with several different tumor types in rats and

mice. The EPA (1993a) presented a verified oral slope factor of 0.13 per mg/kg/day, based on the increased incidence of liver tumors in mice treated by gavage. An inhalation risk estimate was not derived.

E.4.2.13 2-Butanone (Methyl Ethyl Ketone)

E.4.2.13.1 Noncancer Toxicity

Toxicity data for oral exposure to 2-butanone were not located. The EPA (1993a) presented a verified RfD for chronic oral exposure of 0.05 mg/kg/day, based on an NOAEL in a 12-week inhalation exposure study in rats and an uncertainty factor of 1000. The provisional subchronic oral RfD is 0.5 mg/kg/day, based on the same study and an uncertainty factor of 100 (EPA 1992b).

Humans exposed to 2-butanone vapor reported slight nose and throat irritation (EPA 1993a). The critical effect of inhalation exposure of animals to 2-butanone appears to be developmental toxicity. The EPA (1993a) presented a verified chronic inhalation RfC of 1 mg/m^3, equivalent to 0.3 mg/kg/day for a 70-kg human inhaling 20 m^3 of air/day, based on an NOAEL for developmental effects in mice and an uncertainty factor of 3000. The EPA (1992b) presented a provisional subchronic inhalation RfC of 3 mg/m^3, based on the 12-week study described in the previous paragraph, but mathematically derived by an obsolete methodology. A more defensible approach would be to adopt the chronic inhalation RfC of 1 mg/m^3 as being protective for subchronic exposure as well. The subchronic RfC of 1 mg/m^3 is equivalent to 0.3 mg/kg/day, as previously described.

Target organs for 2-butanone are the fetus, respiratory tract, and the CNS.

E.4.2.13.2 Carcinogenicity

EPA (1993a) classifies 2-butanone as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans). Quantitative risk estimates are not derived for Group D compounds.

E.4.2.14 Cadmium

E.4.2.14.1 Pharmacokinetics

Estimates of cadmium uptake by the respiratory tract range from 10 to 50 percent; uptake is greatest for fumes and small particles and least for large dust particles (Friberg et al. 1986;

Goyer 1991). GI absorption of ingested cadmium is ordinarily 5 to 8 percent, but may reach 20 percent in cases of serious dietary iron deficiency. Highest tissue levels are normally found in the kidneys followed by the liver, although levels in the liver may exceed those in the kidneys of persons suffering from cadmium-induced renal dysfunction. The half-life of cadmium in the kidneys and liver may be as long as 10-30 years. Fecal and urinary excretion of cadmium are approximately equivalent in normal humans exposed to small amounts. Urinary excretion increases markedly in humans with cadmium-induced renal disease.

E.4.2.14.2 Noncancer Toxicity

Acute inhalation exposure to fumes or particles of cadmium induces respiratory symptoms, general weakness, and, in severe cases, respiratory insufficiency, shock, and death (Friberg et al. 1986). Acute oral exposure induces GI disturbances. Chronic inhalation exposure induces pulmonary emphysema, and chronic exposure by either route consistently produces renal tubular disease in humans and laboratory animals. Proteinuria is a reliable early indicator of cadmium-induced kidney disease. The combination of pulmonary emphysema and renal tubular disease, if severe, may result in early mortality. Painful osteomalacia and osteoporosis may arise from altered metabolism of bone minerals secondary to renal damage. The combination of renal and skeletal damage is called itai-itai disease in Japan. Cadmium exposure has been associated with liver damage, but the liver appears to be less sensitive than the kidney. The kidney is the primary target organ of cadmium toxicity. The EPA (1993a) derived chronic oral RfD values of 0.5 μg/kg/day for cadmium ingested in water and 1 μg/kg/day for cadmium ingested in food, based on a toxicokinetic model that predicted NOAELs from renal cortical concentrations of cadmium. The different RfD values reflect assumed differences in GI absorption of cadmium from water (5 percent) and food (2.5 percent).

E.4.2.14.3 Carcinogenicity

Carcinogenicity data in humans consist of several occupational studies that associate cadmium exposure with lung cancer, but concomitant exposure to other carcinogenic chemicals and smoking were not adequately controlled. Other occupational studies reported significantly increased risk of prostatic cancer, but this effect was not observed in the largest occupational study of workers exposed to high levels (Thun et al. 1985). The animal data consist of an inhalation study in rats that showed a significant increase in lung tumors, and several parenteral injection studies that produced injection site tumors. No evidence of

carcinogenicity, however, was observed in seven oral studies in rats and mice. The EPA (1993a) classifies cadmium a cancer weight-of-evidence Group B1 substance for inhalation exposure on the basis of limited evidence of carcinogenicity in humans and sufficient evidence in animals. The data were insufficient to classify cadmium as carcinogenic to humans exposed by the oral route. The EPA (1993a) derived an inhalation unit risk of 0.0018 $\mu g/m^3$ from the occupational exposure study by Thun et al. (1985).

E.4.2.15 Carbon Tetrachloride

E.4.2.15.1 Noncancer Toxicity

Carbon tetrachloride is a classic hepatotoxicant in humans and animals exposed by any route (ATSDR 1989b). High exposure levels also induced kidney effects in animals. Occupational exposure was associated with CNS and liver effects (ACGIH 1991). The EPA (1993a) presented a verified chronic oral RfD of 0.0007 mg/kg/day based on an NOAEL for liver lesions in a 12-week gavage study in rats and an uncertainty factor of 1000. The EPA (1992b) presented a subchronic oral RfD of 0.007 mg/kg/day, based on the same NOAEL and an uncertainty factor of 100. The principal target organs for the toxicity of carbon tetrachloride are the liver and the CNS. The kidney is also a target in animals exposed to high levels.

E.4.2.15.2 Carcinogenicity

Carbon tetrachloride is classified in cancer weight-of-evidence Group B2 (probable human carcinogen), based on increased incidence of liver tumors in rats, mice, and hamsters treated orally or by subcutaneous injection (EPA 1993a). A verified oral slope factor of 0.13 per mg/kg/day was based on liver tumor data from gavage studies in all three species previously mentioned. An inhalation unit risk of 1.5E-05 per $\mu g/m^3$, equivalent to 0.053 per mg/kg/day, was derived from the same data and an inhalation absorption factor of 0.4, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans.

E.4.2.16 Chlorobenzene

E.4.2.16.1 Noncancer Toxicity

Oral exposure of animals to chlorobenzene induced liver effects (EPA 1993a). Inhalation exposure of animals induced narcosis and other CNS effects as well as lung, liver, and kidney changes (ACGIH 1991). Minimal occupational exposure data indicated that chlorobenzene induces respiratory tract irritation and CNS effects (headache) in workers exposed to high

levels. The EPA (1993a) presented a verified chronic oral RfD of 0.02 mg/kg/day, based on an NOAEL for liver lesions in a 13-week oral study in dogs and an uncertainty factor of 1000. The EPA (1992b) presented a provisional subchronic oral RfD of 0.2 mg/kg/day, based on the same NOAEL and an uncertainty factor of 100. A provisional chronic inhalation RfC of 0.02 mg/m^3 is based on an LOAEL for liver and kidney effects in rats exposed by inhalation for 120 days and an uncertainty factor of 10,000 (EPA 1992b). The provisional subchronic inhalation RfC, based on the same LOAEL and an uncertainty factor of 1000, is 0.2 mg/m^3. The chronic and subchronic inhalation RfC values are equivalent to 0.006 and 0.06 mg/kg/day, respectively, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans. Target organs for the toxicity of chlorobenzene include the liver, CNS, lung, and kidney.

E.4.2.16.2 Carcinogenicity

Chlorobenzene is classified as an EPA cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity for humans), based on no available human cancer data and inadequate animal data (EPA 1993a). Quantitative risk estimates are not derived for Group D compounds.

E.4.2.17 Chloroform

E.4.2.17.1 Noncancer Toxicity

Oral or inhalation exposure of animals to chloroform was associated with liver and kidney damage (ACGIH 1991; EPA 1993a). In humans, acute inhalation exposure to high levels induced narcosis, ventricular fibrillation, and death (ACGIH 1991). Limited occupational data associated chronic exposure to chloroform with CNS depression, digestive disturbances, and enlarged livers. The EPA (1993a) presented a verified chronic oral RfD of 0.01 mg/kg/day based on an LOAEL for fatty cyst formation in the livers of dogs treated orally for 7.5 years and an uncertainty factor of 1000. The same value was presented as a provisional subchronic oral RfD (EPA 1992b). Target organs for the toxicity of chloroform include the liver and kidney for oral and inhalation exposure, and the heart and CNS for inhalation exposure.

E.4.2.17.2 Carcinogenicity

Chloroform is classified as a cancer weight-of-evidence Group B2 compound (probable human carcinogen), based on increased incidence of several tumor types in rats and liver tumors in

mice (EPA 1993a). Human carcinogenicity data are inadequate. An oral slope factor of 0.0061 per mg/kg/day was derived from the incidence of kidney tumors in rats treated with chloroform in drinking water for two years. An inhalation unit risk of 2.3E-05 per $\mu g/m^3$ was based on the incidence of hepatocellular carcinomas in mice treated by gavage for 78 weeks. The inhalation unit risk is equivalent to 0.081 per mg/kg/day, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans.

E.4.2.18 4-Chloro-3-methylphenol (p-chloro-m-cresol)

E.4.2.18.1 Noncancer Toxicity

Toxicologic data for 4-chloro-3-methylphenol were very limited. The oral lethal dose to 50 percent of the population ($LD_{50/30}$) in rats was determined to be 500 mg/kg (Sax 1984).

E.4.2.18.2 Carcinogenicity

Data were not located regarding the carcinogenicity of 4-chloro-3-methylphenol.

E.4.2.19 2-Chlorophenol

E.4.2.19.1 Noncancer Toxicity

Little information was located regarding the noncancer toxicity of 2-chlorophenol. Oral $LD_{50/30}$ values ranged from 440 to 670 mg/kg (Sax 1984). The EPA (1993a) presented a verified chronic oral RfD of 0.005 mg/kg/day based on an NOAEL for reproductive effects in a subchronic drinking water study in rats and an uncertainty factor of 1000. The EPA (1992b) presented a provisional subchronic oral RfD of 0.05 mg/kg/day based on the same NOAEL and an uncertainty factor of 100. The fetus appears to be a target organ for the oral toxicity of 2-chlorophenol.

E.4.2.19.2 Carcinogenicity

Data were not located regarding the carcinogenicity of 2-chlorophenol.

E.4.2.20 4-Chlorophenyl Phenyl Ether (4-Chlorodiphenyl Ether)

E.4.2.20.1 Noncancer Toxicity

The toxicity of the chlorinated phenyl ethers increases with the extent of chlorination (Kirwin and Sandmeyer 1981). The mono-, di-, and tri-chlorophenyl ethers do not present a serious hazard in the industrial setting. The most noteworthy effect of exposure to the more highly chlorinated phenyl ethers is acneform dermatitis, suggestive of the chloracne induced by

dibenzo-p-dioxins, PCBs, and polychlorinated dibenzofurans (PCDFs), all of which are structurally similar to the chlorinated phenyl ethers.

For monochlorophenyl phenyl ether (position of the chlorine not specified), the smallest single oral dose that caused mortality in guinea pigs within 30 days of treatment was 600 mg/kg (Kirwin and Sandmeyer 1981). In repeated dose gavage studies in rabbits (5 days/week for 4 weeks), 100 mg/kg was without effect.

E.4.2.20.2 Carcinogenicity

Data were not located regarding the carcinogenicity of 4-chlorophenyl phenyl ether. 4-Bromophenyl phenyl ether, which is structurally very similar to 4-chlorophenyl phenyl ether, was negative in the Strain A mouse pulmonary tumor assay following intraperitoneal treatment (Theiss et al. 1977).

E.4.2.21 3-Chloropropene (Allyl Chloride)

E.4.2.21.1 Noncancer Toxicity

The compound 3-chloropropene is more commonly known by its synonym, allyl chloride (EPA 1993a). The compound was shown to induce peripheral neuropathy, manifested as motor and sensory deficits, in occupationally exposed humans (He et al. 1980, 1985). Exposure concentrations were not sufficiently quantified to locate thresholds for these effects. An earlier study associated occupational exposure with liver damage (Hausler and Lenich 1968), but the study was flawed and could not be properly evaluated. It does not appear that neurological endpoints were examined in this study.

Clinical, electromyographic, and histopathologic evidence of peripheral neuropathy were observed in rabbits and a cat intermittently exposed to 3-chloropropene in air for ≥ 3 months (Boquin et al. 1982). Rats, guinea pigs, and rabbits exposed via inhalation also developed degenerative lesions in the kidneys (Quast et al. 1982; Torkelson et al. 1959). Rabbits and mice treated by subcutaneous and oral dosing, respectively, also showed neurologic and kidney effects. It is unclear whether exposure to 3-chloropropene induces liver effects in animals.

The EPA (1993a) derived an RfC of 0.001 mg/m^3 for chronic inhalation exposure to 3-chloropropene, based on an NOAEL of approximately 5 ppm (17 mg/m^3) for peripheral

neuropathy in rabbits (Boquin et al. 1982). An uncertainty factor of 3000 was applied; factors of 10 each for expansion from subchronic to chronic exposure, for protection for sensitive human subpopulations, and for deficiencies in the database (including lack of adequate developmental and reproductive toxicity data, and a factor of 3 to reflect the uncertainty in the animal-to-human dosimetric extrapolation.

E.4.2.21.2 Carcinogenicity

Cancer data include an increased incidence of squamous cell papillomas and carcinomas in mice in an inadequate gavage study in rats and mice (National Cancer Institute [NCI] 1978b), an increase in lung tumor multiplicity in strain A/St mice treated by intraperitoneal injection (Theiss et al. 1979), and tumor initiation in the two-stage skin-painting test in mice (Van Duuren et al. 1979). On the basis of these data, EPA (1993a) classifies 3-chloropropene as a cancer weight-of-evidence Group C compound (possible human carcinogen). The data were inadequate for quantitative estimation of carcinogenic potency.

E.4.2.22 Chromium

E.4.2.22.1 Noncancer Toxicity

In nature, chromium (III) predominates over chromium (VI) (Langård and Norseth 1986). Little chromium (VI) exists in biological materials, except shortly after exposure, because reduction to chromium (III) occurs rapidly. Chromium (III) is considered a nutritionally essential trace element and is considerably less toxic than chromium (IV). No effects were observed in rats consuming 1800 mg chromium (III)/kg/day in the diet for over two years (EPA 1993a). The NOEL of 1800 mg/kg/day and an uncertainty factor of 1000 was the basis for a verified chronic oral RfD of 1 mg/kg/day (EPA 1993a). The same NOEL and an uncertainty factor of 100 was the basis for a provisional subchronic oral RfD of 10 mg/kg/day (EPA 1993a).

Acute oral exposure of humans to high doses of chromium (VI) induced neurological effects, GI hemorrhage and fluid loss, and kidney and liver effects. Parenteral dosing of animals with chromium (VI) is selectively toxic to the kidney tubules. An NOAEL of 2.4 mg chromium (VI)/kg/day in a one-year drinking water study in rats and an uncertainty factor of 500 was the basis of a verified RfD of 0.005 mg/kg/day for chronic oral exposure (EPA 1993a). The same NOAEL and an uncertainty factor of 100 was the basis of a provisional subchronic oral RfD of 0.02 mg/kg/day (EPA 1993a).

Occupational (inhalation and dermal) exposure to chromium (III) compounds induced dermatitis (ACGIH 1991). Similar exposure to chromium (VI) induced ulcerative and allergic contact dermatitis, irritation of the upper respiratory tract including ulceration of the mucosa and perforation of the nasal septum, and possibly kidney effects. Inhalation RfC values were not located.

A target organ was not identified for chromium (III). The kidney appears to be the principal target organ for repeated oral dosing with chromium (VI). Additional target organs for dermal and inhalation exposure include the skin and respiratory tract.

E.4.2.22.2 Carcinogenicity

Data were not located regarding the carcinogenicity of chromium (III). The EPA (1993a) classifies chromium (VI) in cancer weight-of-evidence Group A (human carcinogen), based on the consistent observation of increased risk of lung cancer in occupational studies of workers in chromate production or the chrome pigment industry. Parenteral dosing of animals with chromium (VI) compounds consistently induced injection-site tumors. There is no evidence that oral exposure to chromium (VI) induces cancer. An inhalation unit risk of 0.012 per $\mu g/m^3$, equivalent to 41 per mg/kg/day, assuming humans inhale 20 m^3/day and weigh 70 kg, was based on increased risk of lung cancer deaths in chromate production workers.

E.4.2.23 Chlordane

Technical chlordane is a mixture of at least 50 related compounds (ATSDR 1989c). The principal components of the mixture are cis- and trans-chlordane, heptachlor, cis- and trans-nonachlor, and alpha-, beta- and gamma-chlordene. Each component has its own environmental fate and transport kinetics, so it is unlikely that the chlordane identified at the site would have the same chemical composition as technical chlordane. It is unclear which chlordane component(s) were found at the site.

E.4.2.23.1 Pharmacokinetics

Kinetic studies in rats, in which the area under the curve was compared following intravenous and oral dosing, indicate that approximately 80 percent of an oral dose of trans-chlordane is absorbed from the GI tract (Ohno et al. 1986). In animals, absorbed chlordane is distributed most rapidly to the liver and kidneys, probably because of the extensive vascularity of these organs (Ohno et al. 1986), followed by redistribution to adipose tissue (Barnett and Dorough

1974). In humans, levels of chlordane residues in adipose tissue increase with increasing duration of exposure (ATSDR 1989c). Metabolism involves principally oxidation, dechlorination, and conjugation, yielding lipophilic products that accumulate in adipose tissue as well as more polar products that are excreted. Chlordane residues are excreted principally through the bile, although considerable species differences occur. Lactation is an important mechanism of excretion of chlordane residues retained in body fat.

E.4.2.23.2 Noncancer Toxicity

An acute oral lethal dose of chlordane in humans is estimated to be 25 to 50 mg/kg (ATSDR 1989c). Symptoms of acute oral or inhalation intoxication in humans consistently include GI disturbances such as vomiting, cramps, and diarrhea, and neurological effects including headache, irritability, dizziness, incoordination, convulsions, and coma. Data were not located regarding symptoms or effects in humans chronically exposed by the oral route, and no noncancer effects were observed in several studies of occupationally exposed humans. Mild liver lesions were observed in chronic oral studies in rats and mice. Prenatal or early postnatal exposure of mice to chlordane damages the developing immune system and nervous system. Target organs of chlordane include the liver, nervous system, and the fetus and neonate.

The EPA (1993a) derived an RfD of 0.06 μg/kg/day for chronic oral exposure to chlordane, based on an NOEL of 0.055 mg/kg/day for liver effects in a 30-month dietary study in rats (Velsicol Chemical Co. 1983). An uncertainty factor of 1000 was applied; factors of 10 each for inter- and intraspecies variation, and to reflect deficiencies in the database.

E.4.2.23.3 Carcinogenicity

The EPA (1993a) classifies chlordane in cancer weight-of-evidence Group B2, based on inadequate evidence in humans and sufficient evidence in animals. The human data consist of several epidemiologic studies of chlordane manufacturing workers and pesticide applicators. The only indication of a carcinogenic effect was a borderline significantly increased incidence of bladder cancer in one study of pesticide applicators, but chlordane exposure was not quantified and the workers were concomitantly exposed to other carcinogenic pesticides. The animal data consist of several studies in which oral exposure induced a dose-related increase in the incidence of liver tumors. The evidence for carcinogenicity in rats is equivocal. The

EPA (1993a) derived an oral slope factor of 1.3 per mg/kg/day and an inhalation unit risk of 0.00037 per $\mu g/m^3$ based on liver tumor incidence in two dietary studies in mice.

E.4.2.24 Cobalt

E.4.2.24.1 Noncancer Toxicity

Acute high oral or parenteral doses of cobalt in humans or animals induced myocardial degeneration often leading to mortality, erythropoiesis, enlarged thyroid, and, in animals, renal tubular degeneration (Elinder and Friberg 1986b). Chronic ingestion from the consumption of beer containing high concentrations of cobalt was associated with "beer-drinkers cardiomyopathy," which includes polycythemia and goiter, as well as marked myocardial degeneration and mortality. The therapeutic use of 0.16 to 0.32 mg cobalt/kg/day in anemic, anephric dialysis patients for 12 to 32 weeks induced a significant, but reversible, rise in blood hemoglobin concentration (EPA 1992g).

Occupational (inhalation and dermal) exposure was associated with allergic dermatitis, chronic interstitial pneumonitis, reversibly impaired lung function, occupational asthma, and myocardial effects (ACGIH 1991). Cobalt was determined to be the etiologic factor in hard metal disease, the syndrome of respiratory symptoms, and pneumoconiosis associated with inhalation exposure to dusts containing tungsten carbide with cobalt powder as a binder (Elinder and Friberg 1986b). The lowest occupational air concentration of cobalt associated with hard metal disease was 0.003 mg cobalt/m^3 (Sprince et al. 1988). It should be noted that the workers were also exposed to tungsten and sometimes to titanium, tantalum, and niobium (Elinder and Friberg 1986b). Similar lung effects were seen in animals exposed to cobalt by inhalation.

The developmental toxicity of cobalt was tested in rodents treated orally with cobalt chloride (EPA 1992g). Maternal effects (unspecified) were reported in rats treated with 5.4 to 21.8 mg cobalt/kg/day from gestation day 14 through lactation day 21. Effects on the offspring included stunted growth at 5.4 mg cobalt/kg/day and reduced survival at 21.8 mg cobalt/kg/day. In rats treated with 6.2, 12.4, or 24.8 mg cobalt/kg/day on gestation days 6 through 15, maternal effects included reduced food consumption and body weight gain and altered hematologic parameters, although it is unclear at what dose level(s) these effects occurred. There were no effects on fetal survival, although a nonsignificant increase in fetal

stunting was observed in rats treated with ≥12.4 mg cobalt/kg/day. Mice treated with 81.7 mg cobalt/kg/day had reduced maternal weight gain, but no fetal effects.

Several studies reported testicular degeneration and atrophy in rats treated with cobalt chloride in the diet or drinking water at concentrations equivalent to doses of 5.7 to 30.2 mg cobalt/kg/day (EPA 1992g).

Cobalt is nutritionally essential as a cofactor in cyanocobalamin (vitamin B12) (EPA 1992g). Cobalt is universally present in the diet. Average daily adult dietary intakes of cobalt range from 0.16 to 0.58 mg/day (0.002 to 0.008 mg/kg/day, assuming adults weigh 70 kg) (Tipton et al. 1966; Schroeder et al. 1967). In 9- to 12-year-old children, dietary intakes of cobalt range from 0.3 to 1.77 mg/day (Murthy et al. 1971; NRC 1989). Assuming an average weight for children in this age range of 28 kg (NRC 1989), the dietary intakes are equivalent to 0.01 to 0.06 mg/kg/day.

The EPA (1992g) concluded that the oral toxicity data were insufficient for derivation of an oral RfD for cobalt. The relatively well characterized dietary intake data, however, can provide useful guidance. The EPA (1992g) noted that the upper range of dietary intake for children, 0.06 mg/kg/day, was below the level associated with enhanced erythropoiesis in anephric patients. Therefore, the upper range of dietary intake, 0.06 mg cobalt/kg/day, can be considered a guidance level for the oral intake of cobalt and can be used in place of an oral RfD in CERCLA and RCRA baseline risk assessments.

The EPA (1990b) derived an interim inhalation RfC from the LOAEL of 0.003 mg cobalt/m^3 associated with hard metal disease in occupationally exposed humans (Sprince et al. 1988). Correcting for intermittent occupational exposure (10 m^3 of air inhaled per work day/20 m^3 of air inhaled per day x 5 work days per week/7 days per week) yielded an adjusted LOAEL of 0.001 mg/m^3. Application of an uncertainty factor of 1000 resulted in an interim chronic inhalation RfC of 1E-06 mg/m^3. Assuming humans inhale 20 m^3 of air/day and weigh 70 kg, the RfC is equivalent to 2.9E-07 mg/kg/day, rounded to 3E-07 mg/kg/day.

Important target organs in orally exposed humans are the heart, erythrocyte, and thyroid. Target organs for occupational exposure are the skin, lungs, and heart.

E.4.2.24.2 Carcinogenicity

Data regarding the carcinogenicity of cobalt were not located.

E.4.2.25 Copper

E.4.2.25.1 Noncancer Toxicity

Copper is a nutritionally essential element that functions as a cofactor in several enzyme systems (Aaseth and Norseth 1986). Acute exposure to large oral doses of copper salts was associated with GI disturbances, hemolysis, and liver and kidney lesions. Chronic oral toxicity in humans has not been reported. Chronic oral exposure of animals was associated with an iron-deficiency type of anemia, hemolysis, and lesions in the liver and kidneys. Occupational exposure may induce metal fume fever, and, in cases of chronic exposure to high levels, hemolysis and anemia (ACGIH 1991). Neither oral nor inhalation RfD or RfC values were located for copper. The target organs for copper are the erythrocyte, liver, kidney, and, for inhalation exposure, the lung.

E.4.2.25.2 Carcinogenicity

Copper is classified in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans) (EPA 1993a). Quantitative risk estimates are not derived for Group D chemicals.

E.4.2.26 Cyanide

E.4.2.26.1 Noncancer Toxicity

Acute exposure to cyanide induced histotoxic hypoxia (inability of the tissues to use oxygen); death was due to central respiratory arrest (Smith 1991). Chronic dietary exposure to cyanide was associated with reduced body weight gain, decreased thyroid activity, myelin degeneration, and reduced fertility in rats (EPA 1993a). The EPA (1993a) presented a verified RfD of 0.02 mg/kg/day for oral exposure to cyanide, based on an NOAEL in a two-year study in rats that consumed food fumigated with hydrogen cyanide, and an uncertainty factor of 500. The same value was adopted as the provisional RfD for subchronic oral exposure (EPA 1992b). The target organs for acute exposure are the CNS, respiratory system, and cardiovascular system (ACGIH 1991). Target organs for chronic oral exposure to cyanide appear to be the thyroid and nervous system.

E.4.2.26.2 Carcinogenicity

The EPA (1993a) classifies cyanide as a cancer weight-of-evidence Group D substance (not classifiable as to carcinogenicity to humans). Quantitative risk estimates are not derived for Group D chemicals.

E.4.2.27 4,4-Dichlorodiphenyltrichloroethane (DDT)

E.4.2.27.1 Noncancer Toxicity

The CNS is an important target organ in humans acutely exposed to DDT. Symptoms include altered sensory perception, headache, nausea, disequilibrium, confusion, tremors, and convulsions (Hayes 1982; ATSDR 1989d). Tremors and hyperirritability were observed in chronically exposed animals (NCI 1978c; Rossi et al. 1977). The liver appears to be the other important target organ, at least in animals. Liver effects include enzyme induction, increased liver weight, increased serum levels of liver enzymes, hepatocellular hypertrophy, and necrosis (ATSDR 1989d). The EPA (1993a) derived an RfD of 0.5 μg/kg/day for chronic oral exposure from an NOEL of 0.05 mg/kg/day for liver effects in a 15- to 27-week feeding study in rats (Laug et al. 1950). An uncertainty factor of 100 was applied with factors of 10 each for inter- and intraspecies variation.

E.4.2.27.2 Carcinogenicity

The DDT is classified by EPA (1993a) as a cancer weight-of-evidence Group B2 compound (probable human carcinogen), on the basis of inadequate human data and sufficient animal data. The human data consist of occupational studies of insufficient duration to identify a carcinogenic effect, and conflicting studies regarding tissue concentrations of DDT residues in cancer victims compared with controls (EPA 1993a). The EPA (1993a) derived an oral slope factor of 0.34 per mg/kg/day and an inhalation unit risk of 0.000097 per $\mu g/m^3$ from the incidence of benign and malignant liver tumors in several oral studies in mice and rats.

E.4.2.28 Dibenzofuran

E.4.2.28.1 Noncancer Toxicity

Although data associated the PCDFs with chloracne and other effects in humans (ATSDR 1992), data were not located regarding the oral or inhalation toxicity of unsubstituted dibenzofuran. Neither oral nor inhalation RfD or RfC values for dibenzofuran were located. Target organs for dibenzofuran have not been identified.

E.4.2.28.2 Carcinogenicity

Although data associated the PCDFs with cancer in humans (ATSDR 1992), data were not located regarding the carcinogenicity of unsubstituted dibenzofuran. The EPA (1993a) classifies dibenzofuran a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) because of the lack of data. Cancer risks are not estimated for Group D compounds.

E.4.2.29 Dibenzo-p-dioxins/Dibenzofurans

Specific congeners and homologues of these classes of interest at this site include all 2,3,7,8-chlorinated derivatives, unspecified tetrachlorodibenzofurans, and unspecified hexachlorodibenzofurans.

E.4.2.29.1 Noncancer Toxicity

Of the members of these classes, the toxicity of 2,3,7,8-TCDD has been studied most extensively. The only effect in humans clearly attributable to 2,3,7,8-TCDD was chloracne (ATSDR 1989e). The data, however, also associated exposure to 2,3,7,8-TCDD with hepatotoxicity and neurotoxicity in humans. In animals, toxicity of 2,3,7,8-TCDD is most commonly manifested as a wasting syndrome with thymic atrophy, terminating in death, with a large number of organ systems showing nonspecific effects. Chronic treatment of animals with 2,3,7,8-TCDD or a mixture of two isomers of hexachlorodibenzo-p-dioxin resulted in liver damage. Immunologic effects may be among the more sensitive endpoints of exposure to the PCDDs in animals. In animals 2,3,7,8-TCDD is a developmental and reproductive toxicant. No verified or provisional noncancer toxicity values were located for any of the chemicals of interest in these classes (EPA 1993a, 1992b).

E.4.2.29.2 Carcinogenicity

Data regarding the carcinogenicity of 2,3,7,8-TCDD to humans, obtained from epidemiologic studies of workers exposed to pesticides or to other chlorinated chemicals known to be contaminated with 2,3,7,8-TCDD, are conflicting (ATSDR 1989e). The interpretation of these studies is not clear because exposure to 2,3,7,8-TCDD was not quantified, multiple routes of exposure (dermal, inhalation, oral) were involved, and the workers were exposed to other potentially carcinogenic compounds. In animals, however, 2,3,7,8-TCDD is clearly carcinogenic, inducing thyroid, lung, and liver tumors in orally treated rats and mice (EPA 1985). Similarly, oral treatment with a mixture of two hexachlorodibenzo-p-dioxin isomers

induced liver tumors in rats and mice. On the basis of the animal data, 2,3,7,8-TCDD and the hexachlorodibenzo-p-dioxins were assigned to EPA cancer weight-of-evidence Group B2 (probable human carcinogen). Although the other PCDDs and PCDFs were not formally classified as to carcinogenicity to humans, for regulatory purposes they are treated as probable human carcinogens.

The EPA (1992b) presents provisional oral and inhalation slope factors for 2,3,7,8-TCDD of 150,000 per mg/kg/day, based on the incidence of liver and lung tumors in an oral study in rats (Kociba et al. 1978).

Much less is known about the toxicity of other CDD and CDF congeners. Based on available toxicity data, EPA has developed a method for expressing toxicities of these compounds in terms of equivalent amounts of 2,3,7,8-TCDD. "Toxicity equivalency factors", or TEFs, are used to convert the concentration of a given CDD/CDF into an equivalent concentration of 2,3,7,8-TCDD. The TEF approach has been applied in the risk assessment of dioxins and furans for Operable Unit 1. Table D.4-3 presents the TEFs developed by EPA (1990d).

E.4.2.30 Di-n-butylphthalate (dibutylphthalate)

E.4.2.30.1 Noncancer Toxicity

The oral and inhalation toxicities of di-n-butylphthalate appear to be quite low (ACGIH 1991). Oral doses of 2000 mg/kg/day for 10 days induced testicular degeneration in mice and guinea pigs, but not in rats or hamsters. A one-year dietary study with di-n-butylphthalate resulted in mortality of half the rats within the first week; no adverse effects were observed in the survivors (EPA 1993a). A verified chronic oral RfD of 0.1 mg/kg/day was derived from the NOAEL in the one-year rat study and an uncertainty factor of 1000. The same NOAEL and an uncertainty factor of 100 were the basis of a provisional subchronic oral RfD of 1 mg/kg/day (EPA 1992b). The testis appears to be a target organ for oral exposure in some species.

E.4.2.30.2 Carcinogenicity

The EPA (1993a) classifies di-n-butylphthalate in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans), based on an absence of human or animal cancer data. Quantitative risk estimates are not derived for Group D chemicals.

E.4.2.31 3,3'-Dichlorobenzidine

E.4.2.31.1 Noncancer Toxicity

The oral toxicity of 3,3'-dichlorobenzidine appears to be low. The oral $LD_{50/30}$ in rats is 7000 mg/kg, and 9 of 14 rats survived gavage treatment with 700 mg/kg for >288 days (ACGIH 1991). The EPA (1993a) reviewed the available inhalation data and concluded that the data were insufficient for derivation of an RfC for chronic inhalation exposure.

E.4.2.31.2 Carcinogenicity

Epidemiology studies failed to implicate 3,3'-dichlorobenzidine as a human carcinogen (Gadian 1975; Gerarde and Gerarde 1974; MacIntyre 1975), but several flaws in these studies seriously compromised their sensitivity (EPA 1993a). 3,3'-Dichlorobenzidine was associated with tumors in several sites in rats, in the liver and urinary bladder in dogs, in the liver in mice, and in the urinary bladder in hamsters (Osanai 1976; Safiotti et al. 1967; Stula et al. 1975, 1978). The EPA (1993a) classified 3,3'-dichlorobenzidine as a cancer weight-of-evidence Group B2 compound, and derived a slope factor for oral exposure of 0.45 per mg/kg/day, based on the incidence of mammary adenocarcinomas in female rats (Stula et al. 1975).

E.4.2.32 Dichlorodifluoromethane

E.4.2.32.1 Noncancer Toxicity

Oral exposure to dichlorodifluoromethane induces a low order of toxicity. In a two-year study, 150 mg/kg/day decreased the rate of body weight gain in female rats; no effects were observed in rats receiving 15 mg/kg/day (Sherman 1974). The method of oral dosing (diet or gavage) was unclear. No clinical signs, organ weight effects, or histopathologic alterations were observed in rats treated with 430 mg/kg/day for 10 days or in dogs treated with 90 mg/kg/day for 90 days (Clayton 1967). The EPA (1993a) derived an RfD of 0.2 mg/kg/day for chronic oral exposure from the NOEL of 15 mg/kg/day in the two-year rat study. An uncertainty factor of 100 was applied with factors of 10 each for inter- and intraspecies variation.

E.4.2.32.2 Carcinogenicity

Data were not located in EPA (1993a) regarding the carcinogenicity of dichlorodifluoromethane.

E.4.2.33 1,1-Dichloroethane

E.4.2.33.1 Noncancer Toxicity

CNS depression was the critical effect of oral or inhalation exposure of animals to 1,1-dichloroethane (ACGIH 1991). Kidney damage was observed in cats, but not laboratory rodents, exposed by inhalation. Inhalation exposure of humans was associated with CNS depression and respiratory tract and ocular irritation. The EPA (1992b) presented a provisional chronic oral RfD of 0.1 mg/kg/day based on an NOEL in a 13-week intermittent exposure inhalation study in rats and an uncertainty factor of 1000. A provisional subchronic oral RfD of 1 mg/kg/day was based on the same NOEL and an uncertainty factor of 100. The EPA (1992b) presented a provisional chronic inhalation RfC of 0.5 mg/m^3 based on an NOEL for kidney damage in cats exposed by inhalation to 1,1-dichloroethane and an uncertainty factor of 1000. A provisional subchronic inhalation RfC of 5 mg/m^3 was based on the same NOEL and an uncertainty factor of 100. The chronic and subchronic inhalation RfC values are equivalent to 0.1 and 1 mg/kg/day, respectively, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans. Target organs for the toxicity of 1,1-dichloroethane are the CNS and kidney (in the cat) for oral exposure, and the CNS and respiratory and ocular mucosa for inhalation exposure.

E.4.2.33.2 Carcinogenicity

EPA classifies 1,1-dichloroethane as a cancer weight-of-evidence Group C compound (possible human carcinogen), based on no human cancer data and limited evidence of carcinogenicity in animals (EPA 1993a). The data were considered to be inadequate for quantitative cancer baseline risk assessment.

E.4.2.34 1,2-Dichloroethane

E.4.2.34.1 Noncancer Toxicity

Oral or inhalation exposure of humans or laboratory animals to 1,2-dichloroethane induced liver and kidney effects (ACGIH 1991). Inhalation exposure also induced pulmonary congestion or edema, and, in humans, CNS depression. Neither oral nor inhalation RfD or RfC values were located. The target organs for 1,2-dichloroethane toxicity are the liver, kidney, lung, and CNS.

E.4.2.34.2 Carcinogenicity

EPA classifies 1,2-dichloroethane as a cancer weight-of-evidence Group B2 compound (probable human carcinogen), based on the induction of several tumor types in rats and mice treated by gavage, and on the induction of benign lung papillomas in mice after dermal application (EPA 1993a). The EPA (1993a) presented a slope factor for oral exposure of 0.091 per mg/kg/day, and a unit risk for inhalation exposure of 2.6E-05 per $\mu g/m^3$, based on the incidence of vascular system hemangiosarcomas in male rats in the gavage study. The inhalation unit risk is equivalent to 0.091 per mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg.

E.4.2.35 1,1-Dichloroethene

E.4.2.35.1 Noncancer Toxicity

Chronic oral exposure of laboratory animals to 1,1-dichloroethene induced liver effects (EPA 1993a). In animals, inhalation exposure induced degenerative changes in the liver and kidneys (ATSDR 1989f). No health effects were observed in a limited study of 138 exposed workers (ACGIH 1986). The EPA (1993a) presented a verified RfD for chronic oral exposure of 0.009 mg/kg/day, based on an NOAEL for liver effects in a chronic drinking water study in rats and an uncertainty factor of 1000. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. The liver and kidneys are the target organs for exposure to 1,1-dichloroethene.

E.4.2.35.2 Carcinogenicity

EPA classifies 1,1-dichloroethene as a cancer weight-of-evidence Group C compound (possible human carcinogen), based on an inadequate occupational exposure cancer study, limited data in several animal studies, its mutagenicity and ability to alkylate deoxyribonucleic acid (DNA), and its structural similarity to vinyl chloride, a known human carcinogen (EPA 1993a). The eighteen available animal studies (11 by inhalation exposure, 5 by oral exposure, and 1 each by dermal application and subcutaneous injection) were limited in sensitivity by various deficiencies in design. Credible evidence that 1,1-dichloroethene was a complete carcinogen was provided only by one 12-month inhalation study in mice, in which the incidence of kidney adenocarcinomas was significantly greater in the high-dose males than in the control males. A slope factor of 0.6 per mg/kg/day for oral exposure was based on the increased incidence of adrenal pheochromocytomas in male rats treated by gavage for two years, even though the increase was not statistically significant. A unit risk for inhalation

exposure of 5.0E-05 per $\mu g/m^3$ was based on the incidence of kidney adenocarcinomas in male mice in the inhalation study mentioned above. The unit risk is equivalent to 0.175 per mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg.

E.4.2.36 cis-1,2-Dichloroethene (c-1,2-Dichloroethylene)

E.4.2.36.1 Noncancer Toxicity

Repeated oral exposure of rats to cis-1,2-dichloroethene was associated with signs of anemia (decreased hematocrit and hemoglobin) (EPA 1992b). Inhalation exposure to isomeric mixtures of 1,2-dichloroethene induced narcosis, and mixed isomers of 1,2-dichloroethene were used as an anesthetic gas (ACGIH 1991). The EPA (1992b) presented a provisional chronic oral RfD of 0.01 mg/kg/day based on an NOAEL for signs of anemia in rats and an uncertainty factor of 3000. A provisional subchronic oral RfD of 0.1 mg/kg/day was derived from the same NOAEL and an uncertainty factor of 300. Target organs appear to be the erythrocyte for oral exposure and the CNS for inhalation exposure.

E.4.2.36.2 Carcinogenicity

The EPA (1993a) classifies cis-1,2-dichloroethene as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans), based on an absence of human or animal cancer data. Quantitative estimates of cancer risk are not derived for Group D chemicals.

E.4.2.37 trans-1,2-Dichloroethene (t-1,2-Dichloroethylene)

E.4.2.37.1 Noncancer Toxicity

The oral $LD_{50/30}$ for trans-1,2-dichloroethene in rats was 1275 mg/kg; death was preceded by CNS and respiratory depression (ACGIH 1991). Histopathologic examination revealed lesions in the lungs and heart. Prolonged oral administration induced clinicopathologic evidence of mild liver damage (EPA 1993a). An NOAEL for this effect in a 90-day drinking water study in mice and an uncertainty factor of 1000 was the basis for a verified chronic oral RfD of 0.02 mg/kg/day. A provisional subchronic oral RfD of 0.2 mg/kg/day was derived from the same NOAEL and an uncertainty factor of 100 (EPA 1992b). The target organs for inhalation exposure to trans-1,2-dichloroethene are the CNS, heart, and lungs; the liver appears to be the principal target of oral exposure.

E.4.2.37.2 Carcinogenicity

Data regarding the carcinogenicity of trans-1,2-dichloroethene were not located.

E.4.2.38 Dichlorofluoromethane

E.4.2.38.1 Noncancer Toxicity

Acute inhalation exposure of laboratory animals to high levels of dichlorofluoromethane produced CNS depression and narcosis, possible lung and liver pathology, and cardiac sensitization (ACGIH 1991). Prolonged inhalation exposure was associated with severe liver damage and cirrhosis and fetal loss. Neither oral nor inhalation RfD or RfC values were located for dichlorofluoromethane. The CNS, liver, lung and heart are the target organs for inhalation exposure to dichlorofluoromethane.

E.4.2.38.2 Carcinogenicity

Data were not located regarding the carcinogenicity of dichlorofluoromethane.

E.4.2.39 Diethyl Phthalate

E.4.2.39.1 Noncancer Toxicity

Diethyl phthalate appears to have a low order of chronic oral toxicity. Reduced food intake and growth rate were the only effects observed in rats fed a diet containing 5 percent diethyl phthalate (3,160 mg/kg bw-day) for 16 weeks (Brown et al. 1978). No effects were observed in rats similarly treated with 1 percent in the diet (750 mg/kg bw-day). In a two-year study, retarded growth and reduced food efficiency were observed in rats fed a diet containing 5 percent diethyl phthalate (Food Research Laboratories, Inc. 1955). No effects were observed in rats similarly fed a diet containing 2.5 percent diethyl phthalate. Intraperitoneal injection of pregnant rats induced mild developmental effects (Singh et al. 1972).

The acute oral toxicity of diethyl phthalate is very low; the $LD_{50/30}$ in rats was 9500 to 31,000 mg/kg (ACGIH 1991). Repeated oral treatment reduced food intake, body weight gain, and food efficiency (body weight gain/unit food intake), and altered organ weights, but produced no histopathologic lesions (EPA 1993a). Based on an NOAEL for decreased weight gain and altered organ weights in a subchronic dietary study in rats and an uncertainty factor of 1000, EPA (1993a) derived a verified chronic oral RfD of 0.8 mg/kg/day. A provisional subchronic oral RfD of 8 mg/kg/day was based on the same NOAEL and an uncertainty

factor of 100 (EPA 1992b). The data were not sufficient to identify target organs for the toxicity of diethyl phthalate.

The EPA (1993a) derived an RfD of 0.8 mg/kg/day for chronic oral exposure from the NOAEL of 750 mg/kg/day in the 16-week feeding study in rats (Brown et al. 1978). An uncertainty factor of 1000 was applied with factors of 10 each for inter- and intraspecies variation, and to expand from subchronic to chronic exposure.

E.4.2.39.2 Carcinogenicity

The EPA (1993a) classifies diethyl phthalate as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) on the basis of no cancer data in humans and inadequate cancer data in animals. The only long-term studies, the 16-week and 2-year dietary studies described above, were not designed to measure carcinogenicity. Quantitative risk estimates are not derived for Group D compounds.

E.4.2.40 2,4-Dimethylphenol

E.4.2.40.1 Noncancer Toxicity

Little is known about the toxicity of 2,4-dimethylphenol. The EPA (1993a) presented a chronic oral RfD of 0.02 mg/kg/day based on an NOAEL for nervous system effects and blood alterations in orally treated mice and an uncertainty factor of 3000. The EPA (1992b) presented a subchronic oral RfD of 0.2 mg/kg/day based on the same NOAEL and an uncertainty factor of 300. The nervous system and blood may be target organs for the oral toxicity of 2,4-dimethylphenol.

E.4.2.40.2 Carcinogenicity

No information was found on the carcinogenicity of 2,4-dimethylphenol.

E.4.2.41 Di-n-octylphthalate

E.4.2.41.1 Noncancer Toxicity

The oral $LD_{50/30}$ for di-n-octylphthalate in mice was 6513 mg/kg (Sax 1984). Intraperitoneal injection in rats during organogenesis induced teratogenicity. The EPA (1992b) presented a provisional chronic and subchronic oral RfD of 0.02 mg/kg/day, based on an LOAEL for increased liver and kidney weight and serum biochemical evidence of liver damage in a

dietary study in rats. An uncertainty factor of 1000 was used. The data suggested that the liver, kidney, and fetus are the target organs for the toxicity of di-n-octylphthalate.

E.4.2.41.2 Carcinogenicity

No information regarding the carcinogenicity of di-n-octylphthalate was found.

E.4.2.42 1,4-Dioxane

E.4.2.42.1 Noncancer Toxicity

The acute oral toxicity of 1,4-dioxane is low; $LD_{50/30}$ values in laboratory animals ranged from 2000 to 6000 mg/kg (ACGIH 1991). Repeated oral exposure was associated with severe liver and kidney pathology. Inhalation studies in laboratory animals failed to identify adverse effects. Liver and kidney pathology were observed in workers exposed to high levels in the air. Neither oral nor inhalation RfD or RfC values were located for 1,4-dioxane. The target organs for oral exposure to 1,4-dioxane are the liver and kidney.

E.4.2.42.2 Carcinogenicity

Cancer studies consistently associated drinking water exposure of rats to 1,4-dioxane with increased incidence of nasal cavity and liver tumors (EPA 1993a). Drinking water exposure of mice resulted in increased incidence of liver tumors. An inhalation study in rats was negative. Occupational studies are inadequate to implicate 1,4-dioxane as a human carcinogen. On the basis of sufficient evidence for carcinogenicity in animals and inadequate evidence in humans, 1,4-dioxane is classified a cancer weight-of-evidence Group B2 compound (probable human carcinogen). The EPA (1993a) derived an oral slope factor of 0.011 per mg/kg/day, based on carcinomas of the nasal turbinates in orally exposed rats. Risk associated with inhalation exposure was not estimated.

E.4.2.43 Ethyl Benzene

E.4.2.43.1 Noncancer Toxicity

Subchronic to chronic oral or inhalation exposure of laboratory animals to ethyl benzene induced mild liver and kidney lesions (EPA 1993a). Acute inhalation exposure induced irritation of the mucous membranes in animals and humans, and prolonged inhalation exposure induced testicular degeneration in rabbits and monkeys (ACGIH 1991). The EPA (1993a) presented a verified chronic oral RfD for ethyl benzene of 0.1 mg/kg/day based on an NOEL for liver and kidney toxicity in female rats in a subchronic gavage study and an

uncertainty factor of 1000. The EPA (1992b) presented a provisional subchronic oral RfD of 1 mg/kg/day based on the same NOEL and an uncertainty factor of 100. The EPA (1993a) also presented a verified chronic inhalation RfC of 1 mg/m^3 derived from studies on developmental effects in rats and rabbits and an uncertainty factor of 300. The same value was adopted as the provisional subchronic inhalation exposure (EPA 1992b). The inhalation RfC is equivalent to 0.3 mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. Target organs for exposure to ethyl benzene include the liver, kidneys, and testes, and, for inhalation exposure, the mucous membranes.

E.4.2.43.2 Carcinogenicity

Ethyl benzene is classified as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) (EPA 1993a) based on an absence of human or animal cancer studies. Quantitative estimates are not derived for Group D chemicals.

E.4.2.44 Ethyl Parathion (Parathion)

Ethyl parathion is generally known by its synonym, parathion (EPA 1993a).

E.4.2.44.1 Noncancer Toxicity

Parathion is a cholinesterase inhibitor that produces signs and symptoms of muscarinic stimulation (parasympathetic stimulation: increased secretion, bronchial constriction, miosis, GI cramps, and diarrhea) and nicotinic stimulation followed by blockade (tachycardia, hypertension, muscle fasciculation, tremors, muscle weakness, flaccid paralysis) (Ecobichon 1991). In occupational exposure, reduced blood cholinesterase activity is a more sensitive endpoint than symptoms of toxicity (ACGIH 1986). The EPA (1992b) presented a provisional chronic and subchronic oral RfD of 0.006 mg/kg/day, based on an NOAEL for decreased erythrocyte cholinesterase activity in orally dosed humans and an uncertainty factor of 10. The target organ for parathion is the nervous system.

E.4.2.44.2 Carcinogenicity

The EPA (1993a) classifies parathion as a cancer weight-of-evidence Group C compound (possible human carcinogen), based on no human data and an increased frequency of adrenal cortical and thyroid tumors observed in a dietary study in rats. Quantitative risk estimates were not available.

E.4.2.45 2-Hexanone (methyl n-butyl ketone)

E.4.2.45.1 Noncancer Toxicity

The acute oral toxicity of 2-hexanone is low, with an oral $LD_{50/30}$ for rats of 2600 mg/kg (ACGIH 1986). The classic effect of occupational (dermal and inhalation) exposure to 2-hexanone is peripheral neuropathy. The same effect was observed in inhalation experiments with laboratory animals. The data are inadequate for derivation of oral or inhalation RfD or RfC values (EPA 1992b). The peripheral nerves are the target organ for the toxicity of 2-hexanone.

E.4.2.45.2 Carcinogenicity

Data were not located regarding the carcinogenicity of 2-hexanone.

E.4.2.46 Isobutyl Alcohol

E.4.2.46.1 Noncancer Toxicity

Oral or inhalation exposure to isobutyl alcohol induced CNS depression, liver and kidney effects, and decreased erythrocyte count in laboratory animals (ACGIH 1986; EPA 1993a). The EPA (1993a) presented a verified chronic oral RfD of 0.3 mg/kg/day based on an NOEL for CNS effects in orally treated rats and an uncertainty factor of 1000. The EPA (1992b) presented a provisional subchronic oral RfD of 3 mg/kg/day based on the same NOEL and an uncertainty factor of 100. Target organs for the toxicity of isobutyl alcohol are the CNS, liver, kidney, and erythrocyte.

E.4.2.46.2 Carcinogenicity

Data regarding the carcinogenicity of isobutyl alcohol were not located.

E.4.2.47 Lead

E.4.2.47.1 Pharmacokinetics

Studies in humans indicate that an average of 10 percent of ingested lead is absorbed, but estimates as high as 40 percent were obtained in some individuals (Tsuchiya 1986). Nutritional factors have a profound effect on GI absorption efficiency. Children absorb ingested lead more efficiently than adults; absorption efficiencies up to 53 percent were recorded for children three months to eight years of age. Similar results were obtained for laboratory animals; absorption efficiencies of 5 to 10 percent were obtained for adults and $\geq$50 percent were obtained for young animals. The deposition rate of inhaled lead averages

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approximately 30 to 50 percent, depending on particle size, with as much as 60 percent deposition of very small particles (0.03 μm) near highways. All lead deposited in the lungs is eventually absorbed.

Approximately 95 percent of the lead in the blood is located in the erythrocytes (EPA 1990c). Lead in the plasma exchanges with several body compartments, including the internal organs, bone, and several excretory pathways. In humans, lead concentrations in bone increase with age (Tsuchiya 1986). About 90 percent of the body burden of lead is located in the skeleton. Neonatal blood concentrations are about 85 percent of maternal concentrations (EPA 1990c). Excretion of absorbed lead is principally through the urine, although GI secretion, biliary excretion, and loss through hair, nails, and sweat are also significant.

E.4.2.47.2 Noncancer Toxicity

The noncancer toxicity of lead to humans has been well characterized through decades of medical observation and scientific research (EPA 1993a). The principal effects of acute oral exposure are colic with diffuse paroxysmal abdominal pain (probably due to vagal irritation), anemia, and, in severe cases, acute encephalopathy, particularly in children (Tsuchiya 1986). The primary effects of long-term exposure are neurological and hematological. Limited occupational data indicate that long-term exposure to lead may induce kidney damage. The principal target organs of lead toxicity are the erythrocyte and the nervous system. Some of the effects on the blood, particularly changes in levels of certain blood enzymes, and subtle neurobehavioral changes in children, appear to occur at levels so low as to be considered nonthreshold effects.

HEAST (EPA 1993g) presents no inhalation RfC for lead, but refers to the National Ambient Air Quality Standard (NAAQS) for lead. However, this NAAQS standard is not useful in determining the impact of lead on children under the age of seven and; therefore, was not used in the Operable Unit 1 baseline risk assessment. The NAAQS for lead is 1.5 $\mu g/m^3$, averaged quarterly (EPA 1992b). The NAAQS is equivalent to 0.00043 mg/kg/day, assuming a body weight of 70 kg and an inhalation rate of 20 m^3/day.

The EPA (1990c, 1993a) determined that it is inappropriate to derive an RfD for oral exposure to lead for several reasons. First, the use of an RfD assumes that a threshold for toxicity exists, below which adverse effects are not expected to occur; however, the most

sensitive effects of lead exposure, impaired neurobehavioral development in children and altered blood enzyme levels associated with anemia, may occur at blood lead concentrations so low as to be considered practically nonthreshold in nature. Second, RfD values are specific for the route of exposure for which they are derived. Lead, however, is ubiquitous, so that exposure occurs from virtually all media and by all pathways simultaneously, making it practically impossible to quantify the contribution to blood lead from any one route of exposure. Finally, the dose-response relationships common to many toxicants, and upon which derivation of an RfD is based, do not hold true for lead. This is because the fate of lead within the body depends, in part, on the amount and rate of previous exposures, the age of the recipient, and the rate of exposure. There is, however, a reasonably good correlation between blood lead concentration and effect. Therefore, blood lead concentration is the appropriate parameter on which to base the regulation of lead.

The EPA UBK lead model is an iterated set of equations that estimate blood lead concentration in children aged 0 to 7 years (EPA 1990c; 1991c). The biokinetic part of the model describes the movement of lead between the plasma and several body compartments and estimates the resultant blood lead concentration. The rate of the movement of lead between the plasma and each compartment is a function of the transition or residence time (i.e., the mean time for lead to leave the plasma and enter a given compartment, or the mean residence time for lead in that compartment). Compartments modeled include the erythrocytes, liver, kidneys, all the other soft tissue of the body, cortical bone, and trabecular bone. Excretory pathways and their rates are also modeled. These include the mean time for excretion from the plasma to the urine, from the liver to the bile, and from the other soft tissues to the hair, skin, sweat, etc. The model permits the user to adjust the transition and residence times. Version 0.99d of the IEUBK model for lead, which resulted from Science Advisory Board review of versions 0.5 and 0.6, is currently being distributed.

EPA guidance (EPA 1989k) establishes an interim soil cleanup level for lead of 500 to 1000 parts per million (ppm) to be applied at Superfund sites. This range is considered by EPA to be protective for direct contact with lead-contaminated soils in residential settings. The guidance adopts recommendations of the Centers for Disease Control and is to be followed when current or predicted land use is residential. Version 0.99 of the 1UBK model has undergone Science Advisory Board review and is currently being distributed.

E.4.2.47.3 Carcinogenicity

EPA (1993a) classifies lead in cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate evidence of cancer in humans and sufficient animal evidence. The human data consist of several epidemiologic occupational studies that yielded confusing results. All of the studies lacked quantitative exposure data and failed to control for smoking and concomitant exposure to other possibly carcinogenic metals. Rat and mouse bioassays showed statistically significant increases in renal tumors following dietary and subcutaneous exposure to several soluble lead salts. Various lead compounds were observed to induce chromosomal alterations in vivo and in vitro, sister chromatid exchange in exposed workers, and cell transformation in Syrian hamster embryo cells; to enhance simian adenovirus induction; and to alter molecular processes that regulate gene expression. EPA (1993a) declined to estimate risk for oral exposure to lead because many factors (e.g., age, general health, nutritional status, existing body burden and duration of exposure) influence the bioavailability of ingested lead, introducing a great deal of uncertainty into any estimate of risk.

E.4.2.48 Malathion

E.4.2.48.1 Noncancer Toxicity

Malathion is an organic phosphorothioate that induces parasympathetic and CNS effects by inhibiting acetylcholinesterase activity at the nerve synapse (Ecobichon 1991). The acute oral toxicity of malathion is low, with an $LD_{50/30}$ in rats of approximately 2,100 mg/kg (ACGIH 1986). Acute effects include GI cramps, diarrhea, salivation, muscle fasciculations, and tremors. Effects are preceded by reduced cholinesterase activity in the tissues, particularly in the erythrocytes and plasma. Symptoms in intoxicated humans included CNS symptoms such as emotional instability, confusion, and memory loss consistent with cholinesterase inhibition. Fatal cases showed damage to the myocardium and the pericardial blood vessels.

Effects observed in prolonged oral exposure studies in laboratory animals included reduced body weights and cholinesterase inhibition (EPA 1993a). The EPA (1993a) derived an RfD of 0.02 mg/kg/day for chronic oral exposure from an NOEL of 0.23 mg/kg/day for erythrocyte cholinesterase inhibition in human volunteers ingesting 16 mg/day for 47 days (Moeller and Rider 1962). An uncertainty factor of 10 was applied to account for variations in sensitivity within the human population. The EPA (1992b) presented the same value as a

provisional subchronic oral RfD. The target organs for the toxicity of malathion are the nervous system and the heart.

E.4.2.48.2 Carcinogenicity

Malathion has not yet been reviewed by the EPA for evidence of carcinogenicity to humans (EPA 1993a).

E.4.2.49 Manganese

E.4.2.49.1 Noncancer Toxicity

Manganese is nutritionally required in humans for normal growth and health (EPA 1993a) Humans exposed to approximately 0.8 mg manganese/kg/day in drinking water exhibited lethargy, mental disturbances (1/16 committed suicide), and other neurologic effects. The elderly appeared to be more sensitive than children. Oral treatment of laboratory rodents induced biochemical changes in the brain, but rodents did not exhibit the neurological signs exhibited by humans. Occupational exposure to high concentrations in air induced a generally typical spectrum of neurological effects, and increased incidence of pneumonia (ACGIH 1986).

Very recently, the chronic oral RfD for manganese was removed from IRIS (EPA 1993a). The subchronic oral RfD presented by EPA (1992b) was the same value as the chronic oral RfD. It seems prudent to remove the subchronic oral RfD as well, to reflect EPA's lack of confidence in this derivation. The EPA (1993a) presented a verified chronic inhalation RfC of 0.0004 mg/m^3 based on an LOAEL for respiratory symptoms and psychomotor disturbances in occupationally exposed humans and an uncertainty factor of 900. The EPA (1992b) presented the same value as a subchronic inhalation RfC. The inhalation RfC is equivalent to 0.0001 mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. The CNS and respiratory tract are target organs of inhalation exposure to manganese.

E.4.2.49.2 Carcinogenicity

The EPA (1993a) classifies manganese in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans). Quantitative cancer risk estimates are not derived for Group D chemicals.

E.4.2.50 Mercury

Mercury occurs in three forms: elemental, organic, and inorganic. Although the toxicity of all forms is mediated by the mercury cation, the extent of absorption and pattern of distribution within the body, which determines the effects observed, depends on the form to which the organism is exposed (Goyer 1991). Bacterial activity in the environment converts inorganic mercury to methyl mercury (Berlin 1986a). It is likely that either inorganic mercury or methyl mercury may be taken up by plants and enter the food chain, and this discussion will focus on inorganic and methyl mercury. Exposure to elemental mercury, which is more likely to occur in an occupational setting, is not discussed herein.

E.4.2.50.1 Pharmacokinetics

The GI absorption of inorganic mercury salts is about 2 to 10 percent in humans, and slightly higher in experimental animals (Berlin 1986a; Goyer 1991). Inorganic mercury in the blood is roughly equally divided between the plasma and erythrocytes. Distribution is preferentially to the kidney, with somewhat lower concentrations found in the liver, and even lower levels found in the skin, spleen, testes, and brain (Berlin 1986a). Inorganic mercury is excreted principally through the feces and urine, with minor pathways including the secretions of exocrine glands and exhalation of elemental mercury vapor.

Methyl mercury is nearly completely (90 to 95 percent) absorbed from the GI tract (Berlin 1986a). The concentration of methyl mercury in the erythrocytes is about 10 times that in the plasma. Methyl mercury leaves the blood slowly, showing particular affinity for the brain, particularly in primates. In rats, 1 percent of the body burden of methyl mercury is found in the brain, but in humans, 10 percent of the body burden is found in the brain. Somewhat lower levels are found in the liver and kidney. During pregnancy, methyl mercury accumulates in the fetal brain, often at levels higher than in the maternal brain. Most tissues except the brain transform methyl mercury to inorganic mercury. Excretion of methyl mercury is principally via the bile, with a half-life of 70 days in humans not suffering from toxicity. Following exposure to methyl mercury, some of the mercury in the bile exists as methyl mercury and some as the inorganic form. The inorganic form is largely passed in the feces, but the methyl mercury is subject to enterohepatic recirculation. Another important excretory pathway for methyl mercury is lactation.

E.4.2.50.2 Noncancer Toxicity

Target organs for inorganic or methyl mercury include the kidney, nervous system, fetus, and neonate. Acute oral exposure to high doses of inorganic mercury causes severe damage to the GI mucosa because of the corrosive nature of mercury salts, which may lead to bloody diarrhea, shock, circulatory collapse, and death (Berlin 1986a; Goyer 1991). Acute sublethal poisoning induces severe kidney damage. Chronic exposure induces an autoimmune glomerular disease and renal tubular injury. The EPA (1992b) presented a verified RfD of 0.3 μg/mg-day for chronic oral exposure to inorganic mercury, based on kidney effects in rats.

Acute or chronic exposure to methyl mercury leads to neurologic dysfunction (Berlin 1986a; Goyer 1991). The region of the nervous system affected is species-dependent. Methyl mercury poisoning in rats induces peripheral nerve damage and kidney effects. In humans, the sensory cortex appears to be the most sensitive. The brain of the fetus and the neonate may be unusually sensitive to methyl mercury; retarded neurologic development was observed in prenatally exposed children whose mothers showed no clinical signs of poisoning. The EPA (1993a) derived an RfD of 0.3 μg/kg/day for chronic oral exposure to methyl mercury based on neurological effects in environmentally exposed humans. In this derivation, an intake of 3 μg/kg/day was an LOAEL corresponding to a blood level of 200 ng/mL, which was associated with CNS effects. An uncertainty factor of 10 was used to estimate an NOAEL from an LOAEL.

E.4.2.50.3 Carcinogenicity

The EPA (1993a) classifies inorganic mercury in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans), based on no data regarding cancer in humans, and inadequate animal and supporting data. In an intraperitoneal injection study with metallic mercury in rats, sarcomas developed only in those tissues in direct contact with the test material (Druckrey et al. 1957). A two-year dietary study in rats with mercuric acetate (inorganic mercury) yielded no evidence of carcinogenicity (Fitzhugh et al. 1950). In mice, however, dietary exposure to high doses of mercury chloride for up to 78 weeks induced renal adenomas and adenocarcinomas (Mitsumori et al. 1981). The EPA has not yet evaluated the carcinogenicity of organic mercury. No carcinogenic effect, however, was observed in a two-year feeding study with phenylmercuric acetate in rats (Fitzhugh et al. 1950).

E.4.2.51 Methylene Chloride

E.4.2.51.1 Noncancer Toxicity

Occupational exposure to high concentrations of methylene chloride may induce liver damage (ACGIH 1986). Liver effects were induced in animals by inhalation or oral exposure (EPA 1993a). The EPA (1993a) presented a verified chronic oral RfD for methylene chloride of 0.06 mg/kg/day based on an NOAEL for liver toxicity in male and female rats in chronic drinking water studies and an uncertainty factor of 100. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. The EPA (1992b) also presented a provisional subchronic and chronic inhalation RfC of 3 mg/m^3, derived from an NOAEL for liver toxicity in a two-year intermittent exposure inhalation study in rats and an uncertainty factor of 100. The inhalation RfC is equivalent to 0.9 mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. The principal target organ for methylene chloride is the liver.

E.4.2.51.2 Carcinogenicity

Methylene chloride is classified in EPA cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate human data and sufficient evidence of carcinogenicity in animals (EPA 1993a). Animal inhalation studies showed increased incidence of hepatocellular neoplasms and alveolar/bronchiolar neoplasms in male and female mice, mammary tumors in rats of either sex, salivary gland sarcomas in male rats, and leukemia in female rats. Oral studies were inconclusive. An oral slope factor of 0.0075 per mg/kg/day was based on the incidence of liver tumors in two inhalation studies in mice. An inhalation unit risk of 4.7E-07 per μg/m^3 was based on the incidence of liver and lung tumors in one inhalation study. The inhalation unit risk is equivalent to 0.0016 per mg/kg/day, based on inhaled dose, assuming humans inhale 20 m^3 of air/day and weigh 70 kg.

E.4.2.52 2-Methylnaphthalene

E.4.2.52.1 Noncancer Toxicity

Data located regarding the noncancer toxicity of 2-methylnaphthalene are limited to an oral lowest dose associated with lethality (LD_{Lo}) in rats of 5,000 mg/kg (Sax 1984). Neither oral nor inhalation RfD or RfC values were located.

E.4.2.52.2 Carcinogenicity

Data regarding the carcinogenicity of 2-methylnaphthalene were not located.

E.4.2.53 Methyl Parathion

E.4.2.53.1 Noncancer Toxicity

Methyl parathion inhibited cholinesterase activity in animals and humans, reduced erythrocyte count, hematocrit and blood hemoglobin concentration, and may have induced degeneration in the peripheral nerves of laboratory animals (EPA 1993a). The EPA (1993a) presented a verified RfD of 0.00025 mg/kg/day for chronic oral exposure based on an NOEL for cholinesterase inhibition and effects on the erythrocytes in a two-year dietary study in rats. An uncertainty factor of 100 was used. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. Target organs of methyl parathion are the erythrocyte and nervous system.

E.4.2.53.2 Carcinogenicity

Data regarding the carcinogenicity of methyl parathion were not located.

E.4.2.54 4-Methyl-2-Pentanone (Methyl Isobutyl Ketone)

The compound 4-methyl-2-pentanone is more commonly known by its synonym, methyl isobutyl ketone (MIBK).

E.4.2.54.1 Noncancer Toxicity

The acute toxicity of MIBK is low; oral $LD_{50/30}$ values in rats, mice, and guinea pigs ranged from 1,600 to approximately 4,600 mg/kg (Krasavage et al. 1982). In a 13-week gavage study in rats, 50 mg/kg/day was an NOEL for liver and kidney effects (EPA 1992b). Acute exposure of laboratory animals to high concentrations in air induced narcosis and death (Krasavage et al. 1982). Repeated inhalation exposures induced CNS effects and increased the kidney- and liver-to-body-weight ratios. Occupational exposure was associated with CNS and GI effects, and, at high concentrations, ocular irritation (ACGIH 1986).

The EPA (1992b) presented a provisional chronic oral RfD of 0.05 mg/kg/day based on the oral NOEL in rats and an uncertainty factor of 1000. The same NOEL and an uncertainty factor of 100 was the basis of a provisional subchronic oral RfD of 0.5 mg/kg/day. A provisional chronic inhalation RfC of 0.08 mg/m^3 was based on an NOEL for increased kidney and liver weights in a 90-day inhalation study in rats and an uncertainty factor of 1000. A provisional subchronic inhalation RfC of 0.8 mg/m^3 was derived from the same inhalation NOEL and an uncertainty factor of 100. The chronic and subchronic inhalation

RfC values are equivalent to 0.02 and 0.2 mg/kg/day, respectively, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans. The principal target organ for MIBK is the CNS.

E.4.2.54.2 Carcinogenicity

Data were not located regarding the carcinogenicity of MIBK.

E.4.2.55 2-Methylphenol (o-cresol)

E.4.2.55.1 Noncancer Toxicity

The oral toxicity of 2-methylphenol is low; the $LD_{50/30}$ in rats was 1,350 mg/kg (ACGIH 1991). Ingestion by animals or humans of mixed isomers of methylphenol was associated with corrosion of the GI tissues, kidney tubular, pancreatic and liver damage, and nodular pneumonia. Occupational exposure of humans or inhalation exposure of animals to mixed isomers of methylphenol was associated with neurological effects, impaired kidney function, and irritation of the respiratory tract. The EPA (1993a) presented a verified chronic oral RfD of 0.05 mg/kg/day based on an NOAEL for decreased body weight and neurotoxicity in a gavage study in rats and an uncertainty factor of 1000. The EPA (1992b) presented a subchronic oral RfD of 0.5 mg/kg/day based on the same NOAEL and an uncertainty factor of 100. Principal target organs are the nervous system, respiratory mucosa, liver, and kidney.

E.4.2.55.2 Carcinogenicity

Methylphenol isomers were tumor promoters in the two-stage mouse skin tumor initiation-promotion test (ACGIH 1991). The EPA (1993a) classified 2-methylphenol as a cancer weight-of-evidence Group C compound (possible human carcinogen), but derived no quantitative risk estimates for either oral or inhalation exposure.

E.4.2.56 3-Methylphenol

E.4.2.56.1 Noncancer Toxicity

The compound 3-methylphenol is often known by its primary synonym, m-cresol. The chemical produced CNS effects (salivation, urination, tachypnea, hypoactivity, tremors) and reduced food consumption and growth rate in rats treated by gavage for 90 days (EPA 1986a, 1987b). There appeared to be no functional or morphologic effects on the other organs of the body. The EPA (1992b) derived an RfD of 0.05 mg/kg/day from an NOAEL of 50

mg/kg/day in the 90-day rat study (EPA 1986a, 1987b). An uncertainty factor of 1000 was applied with factors of 10 each for inter- and intraspecies variation, and to expand from subchronic to chronic exposure.

Inhalation data are limited to a study that associated exposure to approximately 6 to 9 mg/m^3 with hematopoietic and respiratory tract effects in rats and nasopharyngeal irritation in humans (Uzhdavini et al. 1972). The data were insufficient for derivation of an RfC for chronic inhalation exposure (EPA 1992b).

E.4.2.56.2 Carcinogenicity

The EPA (1993a) classifies 3-methylphenol as a cancer weight-of-evidence Group C compound (possible human carcinogen), based on inadequate data in humans and limited data for carcinogenicity in animals. The human data consist of anecdotal data associating occupational exposure with a case of carcinoma of the urinary bladder and a case of carcinoma of the vocal cords, but a causal association is not credible. Animal studies identify 3-methylphenol as a tumor promoter in the two-stage skin-painting assay in mice, but the data were not sufficient for quantitative risk estimation.

E.4.2.57 4-Methylphenol (p-cresol)

E.4.2.57.1 Noncancer Toxicity

The oral toxicity of 4-methylphenol is low; the $LD_{50/30}$ in rats is 1,800 mg/kg (ACGIH 1991). Ingestion by animals or humans of mixed isomers of methylphenol was associated with corrosion of the GI tissues, kidney tubular, pancreatic and liver damage, and nodular pneumonia. Occupational exposure of humans or inhalation exposure of animals to mixed isomers of methylphenol was associated with neurological effects, impaired kidney function and irritation of the respiratory tract. The EPA (1992b) presented a provisional chronic oral RfD of 0.05 mg/kg/day based on an NOAEL for decreased body weight and neurotoxicity in a gavage study in rats and an uncertainty factor of 1000. The EPA (1992b) also presented a provisional subchronic oral RfD of 0.5 mg/kg/day based on the same NOAEL and an uncertainty factor of 100. Principal target organs are the nervous system, respiratory mucosa, liver and kidney.

E.4.2.57.2 Carcinogenicity

Methylphenol isomers are tumor promoters in the two-stage mouse skin tumor initiation-promotion test (ACGIH 1991). The EPA (1993a) classifies 2-methylphenol as a cancer weight-of-evidence Group C compound (possible human carcinogen), but derives no quantitative risk estimates for either oral or inhalation exposure.

E.4.2.58 Molybdenum

E.4.2.58.1 Noncancer Toxicity

Molybdenum is a nutritionally essential trace element involved in copper and sulfur metabolism (Friberg and Lener 1986). Chronic molybdenum poisoning in livestock (teart disease) results from a molybdenum-copper imbalance and is characterized by anemia, GI disturbances, bone disorders, and growth depression. In laboratory animals, excess molybdenum induced effects in the liver, kidneys, and spleen. Gout-like symptoms were observed in humans living in a high molybdenum, low copper area. A few cases of pneumoconiosis were reported in occupationally exposed workers. The EPA (1992b) presented a provisional chronic oral RfD of 0.005 mg/kg/day based on an LOAEL in humans exposed to high levels in water and diet and an uncertainty factor of 30. A provisional subchronic oral RfD of 0.04 mg/kg/day was based on an NOAEL for biochemical changes in the blood of humans exposed to high levels in water and an uncertainty factor of 1000. Target organs for molybdenum toxicity include the erythrocyte, liver, and kidney.

E.4.2.58.2 Carcinogenicity

Data regarding the carcinogenicity of molybdenum were not located.

E.4.2.59 Neptunium

Neptunium is the element of atomic number 93, just beyond uranium in the periodic table. Neptunium isotopes have not presented unusual problems in occupational radiation protection, nor have they, until recently, been of special environmental concern. Attention has recently been directed to the potential environmental exposure to the long-lived NP-237, which is estimated to be the principal surviving component of high level nuclear waste after ten or twenty thousand years. Np-237 has a half-life of 2.14×10^6 years, and is primarily produced in nuclear reactors via the (n,2n) and (β) nuclear reactions with uranium. Its presence in the high-level nuclear waste, and its presumed environmental mobility, has made it an isotope with special environmental concern. It has been estimated that Np-237 may be the most

hazardous remaining constituent of high-level nuclear waste during the interval from 10,000 to 30,000 years following disposal.

E.4.2.59.1 Pharmacokinetics

The fraction of ingested neptunium absorbed from the gastrointestinal tract into blood (F_1) is currently assumed to be 0.01 (ICRP 1980). This value was based on experimental data involving a large group of rats which were fed with doses of neptunium exceeding 1 mg/kg. When the dietary dose is lower than 1 mg/kg, the fraction F_1 was in order of 0.001 or less. Data on distribution and retention of neptunium in rats indicate that its metabolic behavior is similar to that of plutonium. However, there are some indications that neptunium may distribute more like calcium than like plutonium in the skeleton. Forty-five percent of the neptunium leaving the transfer compartment will be translocated to mineral bone. Another 45 percent will be transported to the liver, and 0.035 percent or 0.011 percent to the testes or to the ovaries, respectively. The remaining neptunium leaving the transfer compartment is assumed to go directly to excreta. The biological half-life of neptunium is about 100 years in mineral bone, about 40 years in the liver, and it is assumed that neptunium is permanently retained in the gonads. These retention and translocation data were based on the ICRP common model for systemic distribution and retention of all transuranic elements. The model itself was largely based on plutonium data.

E.4.2.59.2 Noncancer Toxicity

All animal toxicity studies with neptunium have employed Np-237. Because of its low specific activity (0.76 mCi/g), the chemical toxicity effects of Np-237 are often observed to the exclusion of radiation effects. Soviet data in this area were studied by Moskalev et al (NCRP 1988). The concern was not with the chemical effects. Although such effects might be a controlling factor in an acute exposure to Np-237, they would not be an important factor at the usual levels of concern in radiation protection, and certainly not at the very low levels of potential environmental exposure. Therefore, health effects are assessed only with respect to carcinogenicity.

E.4.2.59.3 Carcinogenicity

Effects of neptunium exposure have not been studied in man. For radiation protection purposes it was assumed that radiation dose resulting from neptunium deposition in organs and tissues will result in biomedical effects similar to those observed following the exposure

of humans to other sources of ionizing radiation. The very limited data on neptunium effects in animals provide no direct useful estimates of risk to humans. These data play no direct role in establishing neptunium standards; they can nevertheless help to validate these standards through comparisons with other animal studies employing other radionuclides.

Long-term radiation effects of Np-237 have been studied only in rats. Genetic effects have not been studied. Bone cancer has been the predominant long-term effect of low-level injections of Np-237; both lung and bone cancer incidences are elevated following inhalation exposure. There is no indication that neptunium at low exposure levels constitutes a unique health risk unpredictable from its general radiological characteristics.

The annual limits of intake of Np-237 as recommended by NCRP (NCRP 1987) recommendations for annual limits on intake) are as follows:

Oral ingestion	0.6 μCi	based on non-stochastic limits
	2.0 μCi	based on stochastic limits
Inhalation	0.005 μCi	based on non-stochastic limits
	0.010 μCi	based on stochastic limits

The non-stochastic limit or dose equivalent applies to bone surface.

E.4.2.60 Nickel

E.4.2.60.1 Noncancer Toxicity

In a subchronic gavage study with nickel chloride in water, clinical signs of toxicity in rats included lethargy, ataxia, irregular breathing, reduced body temperature, salivation, and discolored extremities (EPA 1993a). Inhalation exposure was associated with asthma and pulmonary fibrosis in welders using nickel alloys (ACGIH 1986). Lung effects were observed in laboratory animals exposed by inhalation. The EPA (1993a) presented a verified RfD of 0.02 for chronic oral exposure to nickel, based on an NOAEL for decreased organ and body weights in a two-year dietary study with nickel sulfate in rats and an uncertainty factor of 300. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. The CNS appears to be the target organ for the oral toxicity of nickel. The lung is clearly the target organ for inhalation exposure.

E.4.2.60.2 Carcinogenicity

Occupational exposure to nickel was associated with increased risk of nasal, laryngeal and lung cancer (ATSDR 1988a). Inhalation exposure of rats to nickel subsulfide increased the incidence of lung tumors. The EPA (1993a) presents a cancer weight-of-evidence Group A classification (human carcinogen) for nickel, and presents an inhalation unit risk of 0.00024 per $\mu g/m^3$ for nickel refinery dust. The unit risk is equivalent to 0.84 per mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. The quantitative estimate was derived from the human occupational studies.

E.4.2.61 Nitrate Nitrogen, Nitrite Nitrogen

E.4.2.61.1 Noncancer Toxicity

The oral toxicity of nitrate is mediated by its reduction to nitrite by the microflora of the GI tract (EPA 1993a). Nitrite induces oxidation of hemoglobin to methemoglobin, which is incapable of transporting oxygen from the lungs to the tissues. Human toxicity is generally associated with high levels of nitrate or nitrite in drinking water. Infants are the most sensitive members of the population. The EPA (1993a) presented a verified chronic oral RfD for nitrate of 1.6 mg nitrate nitrogen/kg/day, based on an NOAEL for methemoglobinemia in infants and an uncertainty factor of 1. The EPA (1993a) also presented a verified chronic oral RfD for nitrite of 0.1 mg nitrite nitrogen/kg/day, based on the same NOAEL and an uncertainty factor of 10. The EPA (1992b) adopted the chronic oral RfD for nitrite nitrogen as sufficiently protective for subchronic inhalation as well. The target tissue for the toxicity of nitrate or nitrite is the erythrocyte.

E.4.2.61.2 Carcinogenicity

Data regarding the carcinogenicity of uncombined nitrate or nitrite were not located. Nitrite can combine with secondary amines in food or other nitrogenous compounds to form nitrosamines or other N-nitroso compounds, many of which are important animal carcinogens (Menzer 1991).

E.4.2.62 N-nitrosodiphenylamine (Diphenylnitrosamine)

E.4.2.62.1 Noncancer Toxicity

The acute oral toxicity of N-nitrosodiphenylamine is low; oral $LD_{50/30}$ values in rats and mice are 1650 and 3850 mg/kg, respectively (Sax 1984). Data regarding the noncancer effects of repeated oral or inhalation exposure were not located.

E.4.2.62.2 Carcinogenicity

The EPA (1993a) classifies N-nitrosodiphenylamine in cancer weight-of-evidence Group B2 (probable human carcinogen), based on inadequate human data and sufficient evidence for carcinogenicity in animals. A verified oral slope factor of 0.0049 per mg/kg/day was based on increased incidence of bladder tumors in a chronic drinking water study in rats.

E.4.2.63 4-Nitroaniline

E.4.2.63.1 Pharmacokinetics

Data regarding the extent of gastrointestinal absorption of 4-nitroaniline were not located in the available literature. Data regarding the dinitrobenzenes, however, suggest that absorption from the gastrointestinal tract may be substantial (EPA 1980b). 4-Nitroaniline is readily absorbed through the skin (ACGIH 1986). Lacking more quantitative data, default values for absorption efficiency of 0.9 for gastrointestinal absorption and 0.3 for dermal uptake from soil (EPA 1993d) appear to be reasonable.

E.4.2.63.2 Noncancer Toxicity

Oral LD_{50} values of 810, 450, and 750 mg/kg were reported for mice, guinea pigs, and rats, respectively (Sax 1984), which suggests moderate toxicity by the oral route. Acute effects in humans include neurologic symptoms consistent with methemoglobinemia and hemolytic anemia (ACGIH 1986; Sax 1984). Chronic effects in laboratory animals include liver pathology (Sax 1984). An oral RfD of 0.003 mg/kg-day was located, but the basis of this derivation is unclear (EPA 1993c). Data regarding inhalation exposure were not located.

E.4.2.63.3 Carcinogenicity

Data regarding the carcinogenicity of 4-nitroaniline were not located in the available literature.

E.4.2.64 4-Nitrophenol

E.4.2.64.1 Pharmacokinetics

Data regarding the pharmacokinetics of 4-nitrophenol were not located. Lacking more quantitative data, default values for absorption efficiency of 0.9 for gastrointestinal absorption and 0.3 for dermal uptake from soil (EPA 1993c) appear to be reasonable.

E.4.2.64.2 Noncancer Toxicity

Oral LD_{50} values of 467 and 350 mg/kg were reported for mice and rats, respectively (Sax 1984), which suggests moderate toxicity by the oral routes. Chronic effects in laboratory animals include liver pathology, splenomegaly and neurologic signs (EPA 1980b). An oral RfD of 0.008 mg/kg-day was located, but the basis of this derivation is unclear (EPA 1993e). Data regarding inhalation exposure were not located.

E.4.2.64.3 Carcinogenicity

EPA (1993b) assigned 4-nitroaniline to EPA weight-of-evidence Group D, not classifiable as to carcinogenicity to humans.

E.4.2.65 Pentachlorophenol

E.4.2.65.1 Noncancer Toxicity

Acute inhalation exposure to mists or dusts of pentachlorophenol was associated with vascular damage culminating in heart failure (ACGIH 1986). Survivors suffered from impaired autonomic function, circulation, and vision. Chronic oral exposure was associated with liver and kidney lesions (EPA 1993a). The EPA (1993a) presented a verified chronic oral RfD of 0.03 mg/kg/day based on an NOAEL for liver and kidney effects in a chronic dietary study in rats and an uncertainty factor of 100. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. Target organs for the toxicity of pentachlorophenol include the circulatory and nervous systems, and the liver and kidney.

E.4.2.65.2 Carcinogenicity

The EPA (1993a) classifies pentachlorophenol in cancer weight-of-evidence Group B2 (probable human carcinogen) on the basis of inadequate human data and sufficient animal data. The animal data consisted of dietary studies in mice that show an increased incidence of liver, adrenal and vascular tumors, and studies in rats that show no carcinogenic effect. The test material used in these studies was approximately 90 percent pure, and was contaminated with tri- and tetrachlorophenol, hexachlorobenzene, PCDDs, and PCDFs. The EPA (1993a) presented a verified oral slope factor of 0.12 per mg/kg/day, based on the incidence of liver, adrenal, and vascular tumors in orally exposed mice.

E.4.2.66 Phenol

E.4.2.66.1 Noncancer Toxicity

Oral $LD_{50/30}$ values for phenol were 300 mg/kg in mice and 414 mg/kg in rats (Sax 1984). Subchronic and chronic oral exposure were associated with depressed growth rate, possibly due to decreased water or food intake, and kidney damage (EPA 1993a). The fetus appears to be more sensitive than adults, showing decreased body weights at doses that are not maternally toxic. Exposure of animals to phenol vapors was associated with damage to the lungs, heart, liver, and kidneys (ACGIH 1986). Phenol vapors are absorbed through the skin as readily as through the lungs. The EPA (1993a) presented a verified chronic oral RfD of 0.6 mg/kg/day, based on an NOAEL for reduced fetal body weight in rats treated by gavage and an uncertainty factor of 100. The EPA (1992b) presented the same value as a provisional RfD for subchronic oral exposure. The principal target organs for the toxicity of phenol are the kidney and the fetus.

E.4.2.66.2 Carcinogenicity

The EPA (1993a) classifies phenol in cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans), based on the absence of cancer data in humans and inadequate animal data. Quantitative risk estimates are not derived for Group D compounds.

E.4.2.67 Plutonium

Plutonium is a silvery-white radioactive metal that exists as a solid under normal conditions. There are several isotopes of plutonium, the most common ones are Pu-238 and Pu-239 with half-lives of 90 years and 24,000 years, respectively.

Only small amounts of plutonium occur naturally. However, large amounts have been produced by man in nuclear reactors. Most environmental plutonium exists as oxides and nitrates. Measurable amounts of plutonium were released to the environment by atmospheric testing of nuclear weapons and by accidents at weapons production, and utilization facilities. In addition, accidents involving weapons transport, satellite re-entry, and the Chernobyl reactor fire have also released smaller amounts of plutonium to the atmosphere. The average levels in U. S. soils, from all sources are currently about 2 mCi/Km^2.

E.4.2.67.1 Pharmacokinetics

Absorption of plutonium from the gastrointestinal tract is minimal following an oral ingestion. It is dependent on age, chemical form, stomach content, dietary intake, oxidation state, administration media, and other nutritional factors. A rapid decrease in absorption was seen with increasing age. In hamsters between 1 day and 30 days of age, absorption of plutonium decreased from 3.5 to 0.003 percent of the administered dose (ATSDR 1990b). In humans, the fraction of plutonium absorbed from the gastrointestinal tract into the blood (F_1) is 0.001 for highly soluble plutonium compounds and 1×10^{-5} for highly insoluble compounds. However, the most likely pathway of human exposure to plutonium is by inhalation. Once inhaled, the amount of plutonium which is retained by the lungs is dependent on several factors, such as the particle size and the chemical form of plutonium. The fraction of the highly soluble compounds which transfer from the lungs to the blood is 0.001 for Class W, and 1×10^{-5} for Class Y compounds. The ICRP task group concluded that no plutonium compounds should be assigned to inhalation Class D. Studies have indicated that plutonium is a lung, skeletal, and liver carcinogen in animals depending on its chemical form, route of exposure, and species. Plutonium-239 dioxide is insoluble, therefore, it is primarily retained by the lung and associated lymph nodes after inhalation. Soluble Pu-238 is translocated from the lung to the bone and liver.

E.4.2.67.2 Noncancer Toxicity

Radiation pneumonitis, characterized by alveolar edema, fibrosis, and pulmonary hyperplasia and metaplasia were observed in dogs, mice, rats, hamsters, and baboons following high levels of inhalation exposure to Pu-239 or Pu-238 dioxide. Increases in liver enzymes were also observed after a single inhalation exposure to Pu-239 nitrate which resulted in 4.4×10^5 pCi/kg. Osseous atrophy and radiation osteodystrophy were observed 4,000 days post-exposure in dogs given a single inhalation exposure to Pu-238 dioxide.

Gastrointestinal effects were observed in neonatal rats following administration by gavage of 1×10^5 pCi/kg or 3.3×10^8 pCi/kg of Pu-239 citrate. In the lower dose group, mild hypertrophy of crypts of small intestines, which form the secretion of the small intestines, was observed 11 days post-exposure. Total disappearance of epithelial cells and crypts, combined with intestinal hemorrhaging, was observed in the higher dose group.

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No studies were located regarding gastrointestinal, cardiovascular, renal, or dermal effects in humans or animals after inhalation exposure to plutonium. Similarly, no studies regarding respiratory, cardiovascular, hematological, musculoskeletal, hepatic, renal, or dermal effects in humans or animals after oral exposure to plutonium were located.

E.4.2.67.3 Carcinogenicity

Experiments in dogs have provided the most data on radiation-induced cancer following inhalation exposure to plutonium. The most frequently observed cancer in dogs treated with Pu-239 dioxide was lung cancer. The majority of lung tumors in dogs were broncholar-alveolar carcinoma. When dogs are treated with a more soluble form of Pu-239 or with Pu-238, plutonium translocates from the lungs to other sites, where liver and bone tumors, in addition to lung tumors, have been reported. However, lung tumors were the primary cause of death in dogs exposed to Pu-239 dioxide at an initial lung deposition as low as 2.1×10^4 Pci/kg. On the other hand, osteosarcomas was the primary cause of cancer death upon exposure to Pu-239 dioxide. Statistically significant increases in lung cancer have been reported in rats with lung deposition levels of 3.1×10^4 Pci of Pu-238 per kg body weight.

E.4.2.68 Polyaromatic Hydrocarbons

PAHs are a large class of ubiquitous natural and anthropogenic chemicals, all with similar chemical structures (ATSDR 1990a). There are 16 individual PAHs listed among the CPCs for Operable Unit 1.

E.4.2.68.1 Pharmacokinetics

Although quantitative absorption data for the PAHs were not located, benzo(a)pyrene was readily absorbed across the GI (Rees et al. 1971) and respiratory epithelia (Kotin et al. 1969; Vainich et al. 1976). The high lipophilicity of other compounds in this class suggests that other PAHs also would be readily absorbed across GI and respiratory epithelia.

Benzo(a)pyrene was distributed widely in the tissues of treated rats and mice, but primarily to tissues high in fat, such as adipose tissue and mammary gland (Kotin et al. 1969; Schlede et al. 1970a). Patterns of tissue distribution of other PAHs would be expected to be similar because of the high lipophilicity of the members of this class.

Studies of the metabolism of benzo(a)pyrene provide information relevant to other PAHs because of the structural similarities of all members of the class. Metabolism involves microsomal mixed function oxidase hydroxylation of one or more of the phenyl rings with the formation of phenols and dihydrodiols, probably via formation of arene oxide intermediates (EPA 1979a). The dihydrodiols may be further oxidized to diol epoxides, which, for certain members of the class, are known to be the ultimate carcinogens (LaVoie et al. 1982). Conjugation with glutathione or glucuronic acid, and reduction to tetrahydrotetrols are important detoxification pathways. Metabolism of naphthalene resulted in the formation of 1,2-naphthoquinone, which induced cataract formation and retinal damage in rats and rabbits.

Excretion of benzo(a)pyrene or dibenzo(a,h)anthracene residues was reported to be rapid, although quantitative data were not located (EPA 1979b). Excretion occurred mainly via the feces, probably largely due to biliary secretion (Schlede et al. 1970a, 1970b). The EPA (1980a) concluded that accumulation in the body tissues of PAHs from chronic low level exposure would be unlikely.

E.4.2.68.2 Noncancer Toxicity

Of the PAHs of concern, oral noncancer toxicity data are available for acenaphthene, anthracene, fluoranthene, fluorene, and naphthalene. Newborn infants, children, and adults exposed to naphthalene by ingestion, inhalation, or possibly by skin contact developed hemolytic anemia with associated jaundice and occasionally renal disease (EPA 1979c). In a 13-week gavage study in rats, treatment with 50 mg naphthalene/kg, 5 days/week for 13 weeks (35.7 mg/kg/day) induced no effects; higher doses presumably reduced the growth rate (National Toxicology Program [NTP] 1980). Application of an uncertainty factor of 1000 yielded a provisional RfD for chronic oral exposure of 0.04 mg/kg/day (EPA 1992b). The very mild effect (decreased growth rate) apparently observed at higher doses suggests that the RfD is very conservatively protective.

Acenaphthene appears to be a mild hepatotoxicant, and possibly a nephrotoxicant, in rodents (EPA 1993a). In a comprehensive 90-day toxicity study in mice, gavage treatment with 175 mg/kg/day was an NOAEL; liver weight changes accompanied by hepatocellular hypertrophy and elevated cholesterol levels occurred in mice treated with 350 or 700 mg/kg/day (EPA 1989e). Oral treatment of rats and mice for 32 days with 2,000 mg/kg/day resulted in weight loss and mild liver and kidney lesions (Knobloch et al. 1969). The EPA (1993a) verified a

chronic oral RfD for acenaphthene of 0.06 mg/kg/day based on an NOAEL for liver effects in a subchronic gavage study in mice and an uncertainty factor of 3000. An uncertainty factor of 3000 was used with factors of 10 each for inter- and intraspecies variation and to expand from subchronic to chronic exposure, and a factor of 3 to reflect gaps in the database, namely lack of adequate data in a second species and lack of developmental and reproductive data. Confidence in the database was low because of the data gaps. Confidence in the critical study was low because the effects were considered adaptive, rather than adverse, which implies that the RfD is extremely conservative. The EPA (1992b) presented a provisional subchronic oral RfD of 0.6 based on the same NOAEL and an uncertainty factor of 300. Target organs for acenaphthene include the liver and kidney.

The toxic potency of anthracene appears to be very low. In a chronic study in rats, doses of 5 to 15 mg/rat (16 to 48 mg/kg/day) via the diet had no effect on longevity or gross or histopathologic appearance on unspecified tissues (Schmahl 1955). Gavage treatment of mice with 1,000 mg/kg/day for at least 90 days had no effects on a comprehensive range of toxicologic parameters (EPA 1989f). The NOEL of 1,000 mg/kg/day in mice and an uncertainty factor of 3000 (10 each for inter- and intraspecies variation, and 30 for the use of a subchronic study and an incomplete database) yielded a verified RfD for chronic oral exposure of 0.3 mg/kg/day (EPA 1993a). The EPA (1992b) presented a provisional subchronic oral RfD of 3 mg/kg/day based on the same NOEL and an uncertainty factor of 300. The data were inadequate to define target organs for the toxicity of anthracene.

Fluoranthene appears to be toxic to the liver, kidney, and blood. In a comprehensive 13-week gavage study in mice, 125 mg/kg/day was an NOAEL and 250 mg/kg/day was an LOAEL (EPA 1988c). The verified chronic oral RfD for fluoranthene is 0.04 mg/kg/day, based on the NOAEL in a comprehensive 13-week gavage study of 125 mg/kg/day in mice and an uncertainty factor of 3000 (EPA 1993a). The uncertainty factor of 3000 includes factors of 10 each for inter- and intraspecies variation, and a factor of 30 to expand from subchronic to chronic exposure and to reflect an incomplete database. A provisional subchronic oral RfD of 0.4 mg/kg/day was derived from the same NOAEL and an uncertainty factor of 300. The liver, kidney, and blood appear to be the target organs for the toxicity of fluoranthene.

The critical effects of oral exposure to fluorene appear to be hemolytic anemia and CNS effects. In mice treated by gavage for 13 weeks, 125 mg/kg/day was an NOAEL and 250 mg/kg/day was an LOAEL (EPA 1989g). A verified chronic oral RfD for fluorene of 0.04 mg/kg/day was based on the NOAEL of 125 mg/kg/day for hemolytic anemia in mice (EPA 1993a). An uncertainty factor of 3000 was used with factors of 10 each for inter- and intraspecies variation and to expand from subchronic to chronic exposure, and a factor of 3 to reflect gaps in the database. The EPA (1992b) presented a provisional subchronic oral RfD of 0.4 mg/kg/day based on the same NOAEL and an uncertainty factor of 300. The target organs of fluorene toxicity are the erythrocyte and the CNS.

Newborn infants, children, and adults exposed to naphthalene by ingestion, inhalation, or possibly by skin contact developed hemolytic anemia with jaundice and, occasionally, renal disease (EPA 1980a). In a 13-week gavage study in rats, treatment with naphthalene reduced the growth rate (EPA 1992b). Application of an uncertainty factor of 1000 to the rat NOEL yielded a provisional RfD for subchronic and chronic oral exposure of 0.04 mg/kg/day (EPA 1992b). The erythrocyte and the kidney appear to be the target organs for the toxicity of naphthalene.

Mild kidney lesions appear to be the critical effects of pyrene. In mice treated by gavage for 13 weeks, 75 mg/kg/day was an NOAEL and 125 mg/kg/day was an LOAEL (EPA 1989h). Even in mice treated with 250 mg/kg/day the lesions were considered minimal to mild. The EPA (1993a) verified a chronic oral RfD for pyrene of 0.03 mg/kg/day based on the NOAEL in mice and an uncertainty factor of 3000 (10 each for inter- and intraspecies variation and to expand from subchronic to chronic exposure, and a factor of 3 to reflect gaps in the database). The EPA (1992b) presented a provisional subchronic oral RfD of 0.3 mg/kg/day based on the same NOAEL and an uncertainty factor of 300. The kidney is the target organ for the toxicity of pyrene.

E.4.2.68.3 Carcinogenicity

The PAHs are ubiquitous, being released to the environment from anthropogenic as well as from natural sources (ATSDR 1987). Benzo(a)pyrene is the most extensively studied member of the class, inducing tumors in multiple tissues of virtually all laboratory species tested by all routes of exposure. Although epidemiology studies suggested that complex mixtures that contain PAHs (coal tar, soots, coke oven emissions, cigarette smoke) are carcinogenic to

humans (EPA 1993a), the carcinogenicity cannot be attributed to PAHs alone because of the presence of other potentially carcinogenic substances in these mixtures (ATSDR 1987). In addition, recent investigations showed that the PAH fraction of roofing tar, cigarette smoke, and coke oven emissions accounted for only 0.1 to 8 percent of the total mutagenic activity of the unfractionated complex mixture in Salmonella (Lewtas 1988). Aromatic amines, nitrogen heterocyclic compounds, highly oxygenated quinones, diones, and nitrooxygenated compounds, none of which would be expected to arise from in vivo metabolism of PAHs, probably accounted for the majority of the mutagenicity of coke oven emissions and cigarette smoke. Furthermore, coal tar, which contains a mixture of many PAHs, has a long history of use in the clinical treatment of a variety of skin disorders in humans (ATSDR 1987).

Because of the lack of human cancer data, assignment of individual PAHs to EPA cancer weight-of-evidence groups was based largely on the results of animal studies with large doses of purified compound (EPA 1993a). Frequently, unnatural routes of exposure, including implants of the test chemical in beeswax and trioctanoin in the lungs of female Osborne-Mendel rats, intratracheal instillation, and subcutaneous or intraperitoneal injection, were used. Of the PAHs of concern, no EPA cancer weight-of-evidence group classification was provided for acenaphthene (EPA 1993a). Anthracene, benzo(g,h,i)perylene, fluoranthene, fluorene, and naphthalene were classified in Group D (not classifiable as to carcinogenicity to humans), and benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene were classified in Group B2 (probable human carcinogens).

The EPA (1993a) verified a slope factor for oral exposure to benzo(a)pyrene of 7.3 per mg/kg/day, based on several dietary studies in mice and rats. Neither verified nor provisional quantitative risk estimates were available for the other PAHs in Group B2. The EPA (1980a) promulgated an ambient water quality criterion for "total carcinogenic PAHs," based on an oral slope factor derived from a study with benzo(a)pyrene, as being sufficiently protective for the class. Largely because of this precedent, the quantitative risk estimates for benzo(a)pyrene were adopted for the other carcinogenic PAHs when quantitative estimates were needed.

Recent reevaluations of the carcinogenity and mutagenicity of the Group B2 PAHs suggest that there are large differences between individual PAHs in cancer potency (Krewski et al.

1989). Based on the available cancer and mutagenicity data, and assuming that there is a constant relative potency between different carcinogens across different bioassay systems and that the PAHs under consideration have similar dose-response curves, Thorslund and Charnley (1988) derived relative potency values for several PAHs. A more recent Toxicity Equivalency Function (TEF) scheme for the Group B2 PAHs was based only on the induction of lung epidermoid carcinomas in female Osborne-Mendel rats in the lung-implantation experiments (Clement International 1990). The most defensible TEFs and the associated oral and inhalation slope factors are presented in Table E.4-4.

E.4.2.69 Polychlorinated Biphenyls

E.4.2.69.1 Noncancer Toxicity

Epidemiologic studies of women in the United States associated oral PCB exposure with low birth weight or retarded musculoskeletal or neurobehavioral development of their infants (ATSDR 1991). Oral studies in animals established the liver as the target organ in all species, and the thyroid as an additional target organ in the rat. Effects observed in monkeys included gastritis, anemia, chloracne-like dermatitis, and immunosuppression. Oral treatment of animals induced developmental effects, including retarded neurobehavioral and learning development in monkeys. Neither subchronic nor chronic oral RfD values were located for any of the aroclors.

Occupational exposure to PCBs was associated with upper respiratory tract and ocular irritation, loss of appetite, liver enlargement, increased serum concentrations of liver enzymes, skin irritation, rashes and chloracne, and, in heavily exposed female workers, decreased birth weight of their infants (ATSDR 1991). Concurrent exposure to other chemicals confounded the interpretation of the occupational exposure studies. Laboratory animals exposed by inhalation to Aroclor-1254 vapors exhibited moderate liver degeneration, decreased body weight gain and slight renal tubular degeneration. Neither subchronic nor chronic inhalation RfC values were available.

Target organs for PCBs include the skin, liver, fetus, and neonate.

E.4.2.69.2 Carcinogenicity

The EPA (1993a) classifies the PCBs as EPA cancer weight-of-evidence Group B2 substances (probable human carcinogens), based on inadequate data in humans and sufficient data in

animals. The human data consist of several epidemiologic occupational and accidental oral exposure studies with serious limitations, including poorly quantified concentrations of PCBs and durations of exposure, and probable exposures to other potential carcinogens.

The animal data consist of several oral studies in rats and mice with various aroclors, kanechlors, or clophens (commercial PCB mixtures manufactured in the United States, Japan and Germany, respectively) that reported increased incidence of liver tumors in both species (EPA 1993a).

The EPA (1993a) presents a verified oral slope factor of 7.7 per mg/kg/day for all PCBs based on liver tumors in rats treated with Aroclor-1260.

E.4.2.70 2-Propanol (Isopropyl Alcohol)

E.4.2.70.1 Noncancer Toxicity

Inhalation exposure of laboratory animals to high concentrations of 2-propanol induced narcosis (ACGIH 1986). Humans exposed to more moderate levels experienced mild irritation of the ocular and respiratory tract epithelia. Neither oral nor inhalation RfD or RfC values were located for 2-propanol. The principal target organ appears to be the CNS.

E.4.2.70.2 Carcinogenicity

There are no data implicating 2-propanol as a carcinogen (ACGIH 1986).

E.4.2.71 Radium

E.4.2.71.1 Noncancer Toxicity

No toxic effects of exposure to radium are documented and EPA has not developed an RfD for radium; therefore, the health hazard for radium is associated with potential radiocarcinogenic effects.

E.4.2.71.2 Carcinogenicity

Four isotopes of radium occur naturally, Ra-223 (actinium series), Ra-224 and Ra-228 (thorium series), Ra-226 (uranium series); therefore, radium is ubiquitous in the earth's crust and common in groundwater, mineral deposits, soil, food products, and common building materials. Ra-226 has the longest half-life (1,600 years) and decays by alpha particle emission. Ra-223 and Ra-224 are also alpha-particle emitters, and Ra-228 is a beta-particle

emitter. The primary uses of radium have been for manufacturing luminous dials and instrument faces and for internal radiation therapy. Thus, the bulk of the human data on effects from intake of radium are available from studies of radium dial painters and medical patients administered therapeutic doses of radium.

Radium introduced into the body generates decay products including gaseous isotopes of radon. Rn-222 generated in the body persists long enough that it easily diffuses into the bloodstream and accumulates in the sinuses of the head, significantly reducing the alpha dose to the radium accumulating tissues but increasing the dose in the sinus regions of the body. Ultimately the bone tissues are the principal site of radium accumulation because of the similar chemical behavior of radium compared to calcium (National Academy of Sciences [NAS] 1988). In the bone tissues the radium is initially deposited in endosteal bone surface tissue. There is then a redistribution to the bone volume where the radium resides with a long retention time.

Dose Response Data - Human and Animal

The following discussion of data concerning the health effects of exposure to radium is summarized from the report of the Biological Effects of Ionizing Radiation (BEIR) IV Committee on radon and other alpha emitters (NAS 1988). The epidemiological studies of humans were initially motivated by the appearance of cancer and other effects associated with occupational exposures to Ra-224, Ra-226, and Ra-228 (radium dial painters). In the dial painting context, there was the potential to ingest significant quantities of radium that were known to be harmful. The second most significant study group comprised the ankylosing spondylitis patients, who were administered doses of radium solutions for therapeutic reasons. The focus of most studies is on bone cancer, cancer of the paranasal sinuses, and cancer of the mastoid air cells because the association of these effects with radium exposure is well known.

Although epidemiological investigations have documented the association between radium exposure and carcinogenic effects, there has been considerable debate over the dose-response relationship involved. Bone cancer incidence has been plotted against a variety of parameters that represent a measure of radium exposure such as absorbed dose to the skeleton, pure radium equivalents, and cumulative rad-years (Evans 1966). The results indicate a nonlinear relationship fits the data. A separate analysis of the same bone cancer induction data confirms

the finding of a nonlinear fit (Mays and Lloyd 1972). The conclusion from both of these analyses is that a linear nonthreshold relationship is likely to significantly overpredict cancer incidence at low doses. Later reassessments present a linear-quadratic-exponential dose-response relationship (Rowland et al. 1971, 1978a, 1978b, 1983) and a dependence of incidence on the square of radium intake normalized to body weight (Marshall and Groer 1977).

Two extensive studies of ankylosing spondylitis patients treated in Germany with solutions of Ra-224 are most noteworthy. In the first, a 900-patient cohort treated with a Ra-224 colloid during the period from 1946 to 1951 with a follow-up period for more than 30 years revealed bone cancer incidence associated with the high absorbed doses from the therapeutic treatments (Spiess 1969; Spiess and Mays 1970, Mays 1973). In the second, a cohort of about 1400 patients treated with small doses of Ra-224 for ankylosing spondylitis showed a similar association between dose and cancer induction (Spiess 1969; Spiess and Mays 1970; Mays 1973). The analyses are consistent with a variety of dose-response relationships; however, none could be disproved because of the scatter in the data.

Cancers of the paranasal sinuses and the mastoid air cells have been associated with exposure to Ra-226 and Ra-228 since the 1930s (Martland 1939). These effects were initially seen in the radium dial painters, who received high absorbed doses from the quantities of radium they ingested. Excess incidence is quite evident in comparison to the natural incidence, which is very low. After exposure to radium, these types of cancers are expressed later than bone cancers (Evans et al. 1969; Finkel et al. 1969; Rowland et al. 1971; Rundo et al. 1986).

As discussed previously, Rn-222 generated in the body persists long enough that it easily diffuses into the bloodstream and accumulates in the sinuses of the head, significantly increasing the dose in the sinus regions of the body. Studies of cancers of the sinuses and mastoid cells conducted in beagle dogs injected with a variety of alpha-emitting radionuclides reveal excess incidence of these cancers (Schlenker 1980). Not all of the tumors were induced by alpha emitters that produce a gaseous decay product; therefore, a gaseous decay product is not essential to induction. Nevertheless, the risk of these cancers from Ra-226 and its decay products (including Rn-222) is considered significantly greater than from other alpha-emitting radionuclides.

The incidence of leukemia and other blood diseases is linked to radium ingested among the radium dial painters. Development of anemias and leukopenia (low leukocyte count) has been demonstrated in the dial painters (Martland 1931). Evans' study (Evans 1966) included leukemia and anemia as possible effects of radium accumulation in the body. Finkel (Finkel et al. 1969) found cases of leukemia and aplastic anemia in studies of the radium dial painters exposed during the period from 1918 to 1933. Among a cohort of 634 female dial painters first employed before 1930, three deaths attributable to leukemia were found (Polednak 1978). This exceeds expectations because the natural incidence of leukemia is very low. An epidemiological study of 1285 women employed as dial painters before 1930 and 1185 employed between 1930 and 1949 (when radium contamination and exposures were much lower) revealed standard mortality ratios of 73 and 221, respectively (Stebbings et al. 1984). However, the most comprehensive and definitive study of U.S. dial painters includes all workers employed before 1970 (Spiers et al. 1983). Among the worker cohort of 2940 persons, 10 cases of leukemia were found. The expected number of natural cases for this group would be 9.2 cases. The study concludes that the incidence in the cohort does not differ significantly from natural incidence (Spiers et al. 1983). In summary, the accumulation of very high levels of radium is associated with severe anemias and leukemia (NAS 1988). However, at lower levels of accumulation, such as those experienced by the majority of U.S. radium dial painters, especially in later years, the accumulated radium does not appear to significantly increase the risk of leukemia (NAS 1988).

The BEIR IV Committee presents a cancer risk factor of 200E-06 per rad for bone sarcomas from protracted exposure to radium in its report on radon and other alpha emitters (NAS 1988).

E.4.2.72 Radon and Progeny

E.4.2.72.1 Noncancer Toxicity

There are no known toxic effects of exposure to radon gas or its short-lived progeny. However, short-lived radon progeny decay to long-lived lead (Pb) progeny. Because lead is a chemical toxicant, significant accumulations of lead would pose a potential source of lead for exposure pathways to receptors.

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E.4.2.72.2 Carcinogenicity

Exposure to air contaminated with radon gas and associated airborne progeny has been linked to increased risk of lung cancer. The risk is attributed to inhalation of the short-lived progeny of radon that are attached to particulates, which lodge in the lung passages and produce a radiation dose that causes lung cancer. Radon progeny that do not lodge in the lung passages are exhaled, and do not deliver a radiation dose. The induction of lung cancer results when the bronchial epithelium of the lung passages is exposed to alpha particles emitted from decaying radon progeny (e.g., Po-214 and Po-218) lodged in the lung passages.

Three isotopes of radon are of potential concern, one associated with each of the three natural decay series. Rn-222, Rn-220, and Rn-219 are members of the uranium, thorium, and actinium decay series, respectively. Rn-222 (half-life 3.82 days) is the isotope of primary concern because its half-life and mobility as an inert gas facilitate its migration to outdoor and indoor areas, thus potentially exposing receptors to elevated concentrations of Rn-222 and its short-lived progeny. Rn-220 (half-life 55.6 seconds) and Rn-219 (half-life 3.96 seconds) are generally of less concern because their very short half-lives often result in decay before there is sufficient opportunity for migration of the gas and accumulation of elevated quantities where receptors may be exposed. For example, all three isotopes of radon may be of concern in air in buildings that contain the appropriate parent radionuclides (in the form of surface contamination or drummed material for example). However, Rn-220 and Rn-219 are not expected to be released from a source such as the K-65 silos because their shorter half-lives would cause them to decay before migrating out of the waste matrix or out of the containment provided by the silos.

Dose Response Data - Human and Animal

The following discussion regarding the health effects of exposure to radon and radon progeny is summarized from the report of the BEIR IV Committee on radon and other alpha emitters (NAS 1988). The radiological effect of concern from exposure is lung cancer.

The lung cancer hazard associated with working in underground mines was first recognized by Harting and Hesse in 1879 as a result of autopsy studies of European miners (Harting and Hesse 1879). The most important human populations studied with regard to radon progeny exposure are the underground miners exposed to widely differing concentrations of airborne Rn-222 progeny in mines (National Council on Radiation Protection and Measurements

[NCRP] 1984a). The lung cancer mortality risk estimates for radon progeny exposure published by the BEIR IV Committee (NAS 1988) are based on an epidemiological study of these underground miner populations. The assessment of the risk from exposure to radon progeny by the BEIR IV Committee represents the most recent comprehensive examination of estimated health risks associated with exposure.

The BEIR IV Committee relies heavily on data from four principal studies of miners: Ontario uranium miners, Saskatchewan uranium miners, Swedish metal miners, and Colorado Plateau uranium miners. Underground miners exposed to radon progeny (in the mines) have an increased risk of lung cancer as demonstrated in these epidemiological study populations. Animals experimentally exposed to airborne radon progeny also develop lung cancers. Animal studies have provided information on the dose response relationship and the effects of variation in exposure rate, physical characteristics of the lung, and air quality to supplement the information available from the human epidemiological studies. Thus, both human epidemiological data and animal experimental data indicate that exposure to radon progeny induces lung cancer and describe the relationship between exposure and health effect as a function of influencing factors.

In its study of the human epidemiological data, the BEIR IV Committee has reevaluated the primary data (e.g., exposure histories and mortality) for the four principal epidemiological study groups of underground miners exposed to radon progeny. From this reevaluation, the BEIR IV Committee has developed estimates of the risk of fatal lung cancer. The BEIR IV lifetime risk estimate from lifetime exposure to radon progeny is 350E-06 excess fatal lung cancers per cumulative working level month (WLM) exposure. The WLM is defined as cumulative exposure to an airborne concentration of short-lived radon progeny (equal to one working level) for a period of one working month. It must be noted that this estimate is quantified as fatal lung cancer risk, is based primarily on epidemiological studies of humans, and is expressed per unit cumulative exposure to progeny (WLM^{-1}). The EPA slope factors address cancer incidence, are based on calculated radiation doses to organs and tissues, and are expressed per unit radioactivity intake (pCi^{-1}). Thus, the EPA and BEIR IV risk estimates are not directly comparable. The EPA cancer slope factors are used for assessments of risk attributable to radon and radon progeny exposure. It is also noted that EPA adopted a nominal risk estimate of 360E-06 per WLM for use in the National Emission Standards for Hazardous Air Pollutants (NESHAP) (EPA 1989a). This estimate is based primarily on

EPA's consideration of the BEIR IV assessment; however, EPA did average radon risk estimates derived from BEIR IV and International Commission on Radiation Protection (ICRP) models to calculate the estimate of 360E-06 per WLM.

Although the carcinogenicity of radon progeny is established and the hazards of exposure during mining are well recognized, the hazards of exposure in other environments have not yet been adequately quantified (NAS 1988). A few exploratory epidemiological studies of lung cancer risk associated with radon progeny exposure in homes have been conducted; however, the results are inconclusive and inadequate for the purpose of risk estimation (NAS 1988).

The model developed by the BEIR IV Committee may be used to estimate risks under other environmental conditions to which persons may be routinely exposed; however, it must be recognized that the BEIR IV Committee's model is based on epidemiological evaluations of occupational exposure conditions in underground mines. Therefore, assumptions must be made regarding the similarity of exposed populations, levels of exposure, and factors such as cigarette smoking when using the model for nonoccupational conditions such as in indoor home environments and other environmental settings.

Using the risk factor from the BEIR IV report (NAS 1988) of 350E-06 WLM^{-1} for lung cancer mortality from inhalation of Rn-222 and progeny, and by assuming 51.5 working months (WM) per year (8760 hr/yr divided by 170 hrs worked/month), 100 pCi radon/liter air, short-lived Rn-222 progeny present in 50 percent equilibrium, and an inhalation rate of 20 m^3 day for 365 days/year, one can derive a lung cancer mortality risk factor of 1.2E-11 per pCi. The EPA cancer slope factor from the HEAST publication for inhalation of Rn-222 plus progeny is 7.7E-12 per pCi (EPA 1992b). It must be noted that the BEIR IV risk estimate pertains to lung cancer mortality while the EPA cancer slope factors all pertain to cancer induction rather than cancer fatality.

E.4.2.73 Selenium

E.4.2.73.1 Noncancer Toxicity

Selenium is a nutritionally essential trace element that is an integral part of the enzyme glutathione peroxidase and other proteins (Högberg and Alexander 1986). The National Research Council (1989) recommended dietary allowances (RDAs) for humans range from 10

to 75 μg/day. Chronic ingestion of 5 mg/day (0.071 mg/kg/day, assuming humans weigh 70 kg) induced selenosis in humans, characterized by abnormal hair and nail formation (Högberg and Alexander 1986). Effects in domestic grazing animals exposed to high levels of selenium included emaciation, lameness, and loss of hair and hooves. Occupational exposure to selenium fume or various selenium compounds was associated with intense ocular and respiratory tract irritation, chemical pneumonia, skin rashes, garlic odor to the breath, metallic taste in the mouth, and various socio-psychological effects (ACGIH 1986). The EPA (1993a) presented a verified RfD of 0.005 mg/kg/day for chronic oral exposure to selenourea, based on effects in humans exposed to selenium in high selenium areas. An uncertainty factor of 3 was used. The EPA (1992b) presented the same value as a provisional subchronic oral RfD. The principal target organs for oral exposure to selenium are the skin, including the nails and hair, and, in animals, the hooves and joints. Targets for inhalation or dermal exposure include the skin and mucous membranes of the eyes and respiratory tract, and possibly the CNS.

E.4.2.73.2 Carcinogenicity

An impressive body of data indicates that selenium exerts an anticarcinogenic effect (Högberg and Alexander 1986). In laboratory animals, selenium supplementation decreased the incidence of chemical-induced cancers. In humans, the incidence of lymphomas and cancers of the breast, digestive tract, and lung were lower in geographic areas with high soil selenium levels. Occupational data suggest that selenium may protect against lung cancer. Several animal tests with various deficiencies in design and conduct equivocally associated exposure to selenium with cancer induction. In a well controlled oral experiment, selenium sulfide was associated with an increase in the incidence of liver tumors in rats, and with liver and lung tumors in mice. On the basis of this study, EPA (1993a) classified selenium sulfide a cancer weight-of-evidence Group B2 compound (probable human carcinogen), but declined to derive quantitative risk estimates. Selenium and other selenium compounds were classified in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans) (EPA 1993a). Quantitative risk estimates are not derived for Group D substances.

E.4.2.74 Silver

E.4.2.74.1 Pharmacokinetics

The GI absorption of ingested silver in animals was estimated at ≤ 10 percent; however, absorption of 18 percent was estimated for one human subject given silver acetate (Fowler and

Nordberg 1986). Highest tissue levels are located in the liver; lower levels are located in the lungs, brain, spleen, bone marrow, muscle, and skin (Fowler and Nordberg 1986; Goyer 1991). Excretion is virtually entirely through the bile. The excretion kinetics appear to be species- and organ-dependent. In humans, the apparent half-life for silver in the liver is approximately 50 days. Silver in skin also appeared to have a long half-life (not quantified).

E.4.2.74.2 Noncancer Toxicity

Silver compounds have been used in dentistry, medicinally in the treatment of burns, as a local disinfectant, and as a drinking water disinfectant (Fowler and Nordberg 1986). The classical syndrome of toxicity, called argyria, is a blue-gray to nearly black discoloration of areas of the skin or the viscera resulting from deposition of microscopic granules of silver compounds in the affected tissues. Argyria results from occupational (inhalation), parenteral, or oral exposure. The EPA (1993a) derived an RfD of 3 μg/kg/day for chronic oral exposure, based on an LOAEL for argyria estimated at 5.2 μg/kg/day in a person who ingested silver acetate as an anti-smoking aid for 2.5 years (East et al. 1980). Data from other cases of argyria involving medicinal (oral and intravenous) treatment were considered in this evaluation. An uncertainty factor of two was applied because the critical effect is considered to be only minimally severe.

E.4.2.74.3 Carcinogenicity

The EPA (1993a) classifies silver in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans). The human data consist of no evidence in the literature of cancer despite frequent medical use of silver compounds. The animal data are limited to studies of implanted silver foil or injected metallic silver that provided unconvincing indications of a carcinogenic response relevant to humans.

E.4.2.75 Strontium

Strontium is a naturally-occurring element that is very similar to calcium in structure. Strontium-90 (Sr-90) is one of the most common radioisotopes of strontium. Sr-90 is a pure beta-particle emitter that is in equilibrium with its decay product, yttrium-90, also a beta-particle emitter. The half-life of Sr-90 is approximately 29 years. Sr-90 is a product of nuclear fission. Much of the Sr-90 in the environment is a result of fallout from atmospheric testing of nuclear weapons. The estimated global inventory of Sr-90 (as a result of fallout) at

the end of 1980 was approximately ten million Ci (United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR] 1982). Since the mid-1970s nuclear power reactors and fuel reprocessing plants have produced a large inventory of Sr-90 as a result of their operations and waste generation (NCRP 1991). Because of the potential for accidents, this source of Sr-90 has become of greater concern than fallout from atmospheric testing. Sr-90 sources have been used in medical therapy, polymerization of plastic, synthesis of organic compounds, and sterilization of surgical and medical supplies (Menhinick 1966).

E.4.2.75.1 Pharmacokinetics

Because of strontium's chemical similarity to calcium, the ultimate site of accumulation is bone tissue. When strontium is taken into the body, an average of 30 percent is absorbed from the GI tract (NCRP 1991). The portion that is absorbed is distributed to either bone volume; plasma, extracellular fluid, soft-tissue, and bone surface; or is eliminated from the body. Early studies found that although strontium and calcium are chemically similar, biological systems do not use strontium as effectively as they do calcium, i.e., the systems discriminate between strontium and calcium.

E.4.2.75.2 Chemical Toxicity

Several papers were located in the literature which address the question of noncancer toxicity of strontium. Storey (1961) performed an experiment on young and adult rats. He fed young (40 to 60 g) and adult (200 to 250 g) female rats diets with varying strontium levels. For young rats, the strontium doses corresponded to 190, 380, 750, 1,000, 1,500, and 3,000 mg/kg/day, and for adult rats 95, 190, 375, 750, and 1,500 mg/kg/day. Young rats were found to be affected more severely at lower dietary strontium levels than were adult rats. In young rats, at 380 mg/kg/day, the epiphyseal plate was irregular and slightly widened; however, at 750 mg/kg/day, this plate was severely irregular. Changes observed with doses at 380 mg/kg/day and higher were inhibition of calcification, as evidenced by increasing width of epiphyseal cartilage, presence of uncalcified bone matrix, and decreased ash weight of bone. In adults rats, the first obvious bone change occurred at the 750 mg/kg/day dose level and included slightly wider than normal epiphyseal cartilage plate that was irregularly increased in length and width. Based on these results, an NOAEL of 190 mg/kg/day and an LOAEL of 380 mg/kg/day were identified for young rats. For adult rats, an NOAEL of 375 mg/kg/day and an LOAEL of 750 mg/kg/day were given.

Marie et. al. (1985) administered stable strontium to male rats. The purpose of the study was to determine the effect of low doses of stable strontium on mineral homeostasis and bone histology. The authors concluded that an oral dose lower than 633 mg/kg-day did not produce adverse effects on body growth or bone mineralization. Rats with a dose of 633 mg/kg-day showed signs of increased mineralization lag time; excessive osteoid thickness associated with a decline in the rate of calcification, which resulted in slow growth rate; and a decreased double-labeled osteoid surface, which resulted in defective long bone growth. This study identified an NOAEL of 525 mg/kg/day and an LOAEL of 633 mg/kg/day.

Pertinent data to derive an oral RfD based on the toxicity of stable strontium in humans were not located in the available literature.

E.4.2.75.3 Carcinogenicity

NCRP Report No. 110 (1991) cites a number of papers that address the radiocarcinogenicity of strontium. These papers were published by different authors and the experiments were conducted in different laboratories on different animals such as mice, rats, cats, dogs, and monkeys. The experiments have shown that high radiation doses to skeletal tissues from radioactive strontium (Sr-90 or Sr-89) would produce bone sarcomas, carcinomas of the nasopharynx and head sinuses, squamous cell carcinomas in tissues within the mouth, or hematopoietic neoplasia (leukemia) and dysplasia.

There is clear evidence in these experiments that the dosage pattern, the total dose, and the age at irradiation can have a significant effect on the outcome of exposure. However, lower doses of radiation from Sr-90 produced a very low incidence, or not at all, from this radionuclide (i.e., no bone sarcomas were seen at individual average skeletal doses in a study conducted on dogs with doses between 1 and 18 Gray (Gy).

There have been no cases of human exposure to Sr-90 on record which would provide direct guidance concerning the kinds of effects to be expected or their frequency. Attempts to study effects due to Sr-90 present in fallout were beset by two difficulties: (1) No criteria were known that would distinguish unambiguously the pathological effects due to Sr-90 from those occurring naturally, (2) The excess of incidence to be expected at world-wide fallout levels was so low that only studies on very large populations could even potentially yield a statistically significant result. Such studies have been attempted for humans, but careful

evaluation of the statistics confirms the expectation that whatever excess of incidence may be present is masked by variation in incidence among the population groups studied, differences in recording data, and normal statistical fluctuations of the data for such groups. Thus, no statistically significant excess of biological effects due to Sr-90 exposure at levels characteristic of world-wide fallout has been demonstrated.

Lacking direct data on humans with Sr-90, one can attempt to estimate hazard on the basis of experience in man with other forms of radiation or on the basis of dose effect relations seen in experimental animals exposed to Sr-90. Thus, the observation that bone sarcomas have been produced in humans by skeletally-deposited radium and that leukemias have been produced by exposure to x-rays and atomic bomb radiation, suggest that significant skeletal doses from Sr-90 could produce bone sarcomas and leukemias in people.

E.4.2.76 Styrene

E.4.2.76.1 Noncancer Toxicity

Inhalation exposure of humans to styrene was associated with unspecified unpleasant symptoms and neurological impairment (ACGIH 1986). Subchronic oral exposure of animals induced liver and kidney lesions and hematologic and histopathologic evidence of hemolysis (EPA 1993a). The EPA (1993a) presented a verified chronic oral RfD of 0.2 mg/kg/day, based on an NOAEL for effects on erythrocytes and the liver in dogs and an uncertainty factor of 1000. The EPA (1992b) presented a provisional subchronic RfD of 2 mg/kg/day based on the same NOAEL and an uncertainty factor of 100. The EPA (1992b) also presented provisional inhalation RfC values of 1 mg/m^3 for chronic exposure and 10 mg/m^3 for subchronic exposure, based on an NOAEL for CNS effects in humans exposed for 8 hours. An uncertainty factor of 30 was used for derivation of the chronic RfC and an uncertainty factor of 10 was used for the subchronic RfC. The chronic and subchronic RfC values are equivalent to 0.3 mg/kg/day and 3 mg/kg/day, respectively, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. The principal target organs for inhalation exposure to styrene appear to be the CNS. Target organs for oral exposure include the liver, kidney, and erythrocyte.

E.4.2.76.2 Carcinogenicity

An appropriate cancer weight-of-evidence classification for styrene has not yet been decided by the EPA (1992h). Therefore, no classification and no quantitative estimates are presented.

E.4.2.77 Technetium

Technetium (Tc) is a radioactive element, with three isotopes having half-lives of more than 1 year. Tc-99 and Tc-96 isotopes are used in medicine and metallurgy. Tc-99 is a beta-emitting radionuclide that is produced with a high yield during the nuclear fission of U-235 and plutonium-239 (Pu-239). Of these, only Tc-99 is of potential concern in Operable Unit 1. It is quite mobile in the environment and tends to concentrate in the food chain.

E.4.2.77.1 Pharmacokinetics

The human effects data are primarily based on experimental results from volunteer subjects who received one dose of either Tc-99 or Tc-96 followed by 8 to 10 days of urine and fecal sampling as well as whole-body counting. It is found that the technetium accumulates in the bladder within 10 minutes after an injection. After two hours the technetium is localized primarily in the salivary-thyroid glands, stomach, liver, and bladder.

E.4.2.77.2 Noncancer Toxicity

Of the brief information available on the toxicity of Tc-99, it appears that it is quite toxic to plants. Gerber (1989) studied the toxic effects of Tc-99 on rats; he concluded that a critical organ could be the thyroid because of its preferential accumulation of technetium. He fed the rats diets containing 10 μg of Tc-99 per gram of food (10 μg/g) and 50 μg/g. It was found that thyroids, followed by kidneys, displayed the highest activities. Considerable amounts of technetium were also found in the liver, spleen, lung, and pancreas; the muscle and brain contained little technetium. The radiation dose administered to the thyroid after feeding 10 μg/g of Tc-99 for 13 weeks was estimated at 10 to 20 Gy. This dose was believed to be at the borderline where effects of radiation may be expected. Therefore, the question of chemical toxicity damage at higher doses of Tc-99 becomes more pronounced.

The authors concluded that in view of the large amounts of technetium to which the animals were exposed, it is unlikely that technetium could represent a significant nonstochastic risk to humans under any condition imaginable in the context of radiation protection. Earlier studies in rats (Van Bruwaene et al. 1986) have demonstrated that damage to the thyroid or reduction in fertility is detectable at a concentration of 10 μg of Tc-99 per gram of food, but not a concentration of 1 μg/g.

Coffey and Hayes have studied the radiation dosimetry and chemical toxicity of Tc-99. They injected mice via the tail vein with 210 to 360 mg of Na $^{99}TcO_4$ per kilogram of body weight, they found that the intravenous $LD_{50/30}$ dose of Na $^{99}TcO_4$ in mice is 240 mg/kg. Earlier studies predicted that a given chemical dose may be about a factor of 10 more toxic in humans than in mice. This means that 24 mg/kg would be the extrapolated $LD_{50/30}$ for Na $^{99}TcO_4$ in humans. Since $LD_{50/30}$ is the lethal dose to 50 percent of a population in 30 days, it is of course not an acceptable risk for occupational or environmental exposures.

Probably no more than 1 percent of the $LD_{50/30}$ dose would be an acceptable risk, i.e., 0.24 mg/kg. This is equal to 16.8 mg of Na $^{99}TcO_4$ in a 70-kg individual, or 151 μCi of Tc-99, which is less than 4 percent of the current annual limit intake (ALI) of 4,000 μCi. The authors have concluded that the chemical toxicity of Tc-99 may be more important than its radiation risk in the event of accidental intake of Tc-99.

E.4.2.77.3 Carcinogenicity

Data on the carcinogenicity of technetium were not located in literature. Gerber (1989) studied the histology of rats fed with 10 and 50 μg/g of Tc-99. Of the 24 animals studied, one case of papillary adenoma was found after treatment with 10 μg/g Tc-99. This, of course, is insufficient to prove the carcinogenic effect of technetium, and therefore more research is needed to study the cancerous effects of technetium.

E.4.2.78 1,1,2,2-Tetrachloroethane (Tetrachloroethane)

E.4.2.78.1 Noncancer Toxicity

Chronic oral exposure of laboratory animals to 1,1,2,2-tetrachloroethane was associated with liver and kidney effects (ATSDR 1989g). Acute occupational exposure to high levels was associated with CNS effects; prolonged exposure to more moderate levels was associated with GI disturbances and liver damage (ACGIH 1986). Inhalation exposure studies in animals confirm that 1,1,2,2-tetrachloroethane is highly hepatotoxic. Neither oral nor inhalation RfD or RfC values were located. The target organs for 1,1,2,2-tetrachloroethane are the liver, kidney, and the CNS.

E.4.2.78.2 Carcinogenicity

Oral treatment with 1,1,2,2-tetrachloroethane induced a highly significant dose-related increase in hepatocellular carcinomas in rats (ATSDR 1989g). Occupational data regarding

carcinogenicity in humans are inadequate. The EPA (1993a) classifies 1,1,2,2-tetrachloroethane as a cancer weight-of-evidence Group C compound (possible human carcinogen), based on liver tumors in mice, and derived an oral slope factor of 0.2 per mg/kg/day. The same data serve as the basis for an inhalation unit risk of 5.8E-05 per $\mu g/m^3$, which is equivalent to 0.2 per mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg.

E.4.2.79 Tetrachloroethene (Tetrachloroethylene)

E.4.2.79.1 Noncancer Toxicity

Occupational (inhalation and dermal) exposure to tetrachloroethene was associated with neurologic effects, beginning with incoordination and progressing to dizziness, headache, vertigo, and unconsciousness (ACGIH 1986). The EPA (1993a) presented a verified chronic oral RfD for tetrachloroethene of 0.01 mg/kg/day based on an NOAEL for liver toxicity in mice in a subchronic gavage study, and on an NOEL for depressed body weight gain in rats in a subchronic drinking water study. An uncertainty factor of 1000 was used. The EPA (1992b) presented a provisional subchronic oral RfD of 0.1 mg/kg/day based on the same NOEL and an uncertainty factor of 100. The CNS is the principal target organ for inhalation exposure and the liver is the principal target organ for oral exposure to tetrachloroethene.

E.4.2.79.2 Carcinogenicity

Inhalation exposure to tetrachloroethene induced mononuclear cell leukemia in rats, and inhalation or oral exposure induced hepatocellular carcinomas in mice (ATSDR 1988b). Occupational exposure data do not suggest a carcinogenic role for tetrachloroethene in humans (ACGIH 1986). Interpretation of the data regarding the carcinogenicity of tetrachloroethene is controversial, and the EPA (1992h) has not adopted a final position on the cancer weight-of-evidence classification or quantitative risk estimates for tetrachloroethene. For this reason, the cancer evaluation of tetrachloroethene was removed from the 1992 HEAST (EPA 1992b). Currently, EPA believes the weight-of-evidence to be on the C-B2 continuum (possible-probable human carcinogen), and offers slope factors of 0.052 per mg/kg/day for oral exposure and 0.002 per mg/kg/day for inhalation exposure as being useful.

E.4.2.80 Thallium, Soluble Salts

E.4.2.80.1 Noncancer Toxicity

Thallium is highly toxic; acute ingestion by humans or laboratory animals induced gastroenteritis, neurological dysfunction, and renal and liver damage (Kazantzis 1986). Chronic ingestion of more moderate doses characteristically caused alopecia. Thallium was used medicinally to induce alopecia in cases of ringworm of the scalp, sometimes with disastrous results. In industrial (inhalation, oral, dermal) exposure, neurologic signs preceded alopecia, suggesting that the nervous system is more sensitive than the hair follicle. The EPA (1993a) presented verified chronic oral RfD values for several thallium salts (thallium acetate, thallium carbonate, thallium chloride, thallium nitrate, and thallium sulfate) based on increased incidence of alopecia and increased serum levels of liver enzymes indicative of hepatocellular damage in rats treated with thallium sulfate for 90 days. An oral RfD for thallium alone, however, was not located. Target organs for thallium include the GI tract (acute exposure), nervous system, skin, kidney, and liver.

E.4.2.80.2 Carcinogenicity

Several thallium compounds (thallium oxide, thallium acetate, thallium carbonate, thallium chloride, thallium nitrate, thallium sulfate) were classified as cancer weight-of-evidence Group D substances (not classifiable as to carcinogenicity to humans) (EPA 1993a). No weight-of-evidence classification was located for thallium alone.

E.4.2.81 Thorium

E.4.2.81.1 Noncancer Toxicity

No toxic effects of exposure to thorium are documented and EPA has not developed an RfD for thorium; therefore, the health hazard for thorium is associated with potential radiocarcinogenic effects.

E.4.2.81.2 Carcinogenicity

Natural thorium is present in the earth's crust as a primordial element. The Th-232 isotope accounts for approximately 100 percent of the mass abundance of thorium; however, the radioactivities of other isotopes of thorium exist as members of the three natural decay series. The half-life of Th-232 is very long (approximately 10^{10} years), thus the specific activity is relatively low and the rate of decay is slow. Th-232 decays by alpha particle emission as do most of the progeny in the thorium natural decay series.

Thorium has been used historically as a medical imaging agent because it is a heavy atom that provides contrast in radiographic imaging techniques. In this role thorium has been used commercially as Thorotrast, a 25 percent colloidal solution of thorium dioxide. Thorotrast has been used extensively in the U.S., Europe, and Japan as an intravascular contrast agent for cerebral and limb angiography. Thorotrast has also been injected into the spleen for hepatolienography and into nasal and paranasal sinuses. These uses of Thorotrast result in deposition of the thorium (and subsequent decay products) in tissues and organs of the body, most frequently in the reticuloendothelial tissues in bone (NAS 1988). Once deposited in these tissues, alpha particle emissions from the decay of Th-232 and its progeny irradiate the tissues for long periods of time at low dose rates. The following discussion of the study of health effects from exposure to thorium is summarized from the report of the BEIR IV Committee on radon and other alpha emitters (NAS 1988).

Dose Response Data - Human

The human data on health effects of exposure to thorium are primarily based on epidemiological studies of Thorotrast patients in five studies including German patients, Portuguese patients, Japanese patients, Danish patients, and American patients. In the study of German Thorotrast patients (van Kaick et al. 1978a, 1978b, 1983, 1984a, 1984b, 1986) 5,159 patients and 5,151 controls were followed from 1933 and 1935, respectively. The Thorotrast patients underwent intravascular injections of Thorotrast to enhance the imaging of cerebral and limb angiography. The results of the follow-up analysis indicate an excess of malignant cancers, most notably liver cancers and leukemias, among the patients relative to the controls.

The study of Portuguese Thorotrast patients (Abbatt 1973; de Motta et al. 1979; Horta et al. 1978) involves about 2,500 patients and 2,000 controls with a follow-up period of about 30 years. The patients were exposed to Thorotrast during the period from 1929 to 1955, with roughly 60 percent receiving Thorotrast doses for cerebral angiography. The results of the study show a significant excess of malignant cancer deaths among the patients compared to the control group. Particularly notable are the excess patient liver malignancies compared to the controls.

The study of Japanese Thorotrast patients (Kato et al. 1979, 1983; Mori et al. 1979a, 1979b, 1983, 1986) includes 282 patients who were administered Thorotrast for angiography and

hepatolienography during World War II. The follow-up period spans 38 to 46 years, and results reveal that patient mortality from malignant liver cancers, other malignant cancers, blood diseases, and cirrhosis of the liver is significantly higher than in the control group.

The study of Danish Thorotrast patients (Faber 1973, 1977, 1978, 1979, 1983, 1986) involves 1319 Danes injected with Thorotrast during the period from 1935 to 1946. The epidemiological analysis reveals excess GI malignancies, liver malignancies, malignancies of the lung, and leukemia deaths in patients compared to control individuals. The excess of liver malignancies and leukemias is most notable in the study.

The study of American Thorotrast patients (Falk et al. 1979) is a preliminary epidemiological assessment of Thorotrast patients exposed during the period from 1964 to 1976. All patients had received Thorotrast for either hepatolienography or cerebral angiography. A liver cancer incidence is evident in the investigation and is reportedly continuing to increase. Further follow-up of these individuals is needed.

All five of these human epidemiological studies indicate an excess of malignant cancers among the Thorotrast patients compared to the controls. The excess malignancies are predominantly of the liver and blood (leukemia) types.

Estimation of Excess Risk from Thorotrast Administration

The human epidemiological evidence from studies of the Thorotrast patients represents the primary source of data from which an estimate of risk can be derived (NAS 1988). These data can be used to derive estimates of risk for liver cancer and leukemia; however, such estimates would only strictly apply to conditions of intravascular Thorotrast injection. The BEIR IV report derives a risk estimate of up to 300E-06 per rad of alpha particle radiation to the liver, and emphasizes that these estimates are for Thorotrast, not thorium. The emphasis is because the dosimetry of other isotopes of thorium will differ from that of the Th-232 in the Thorotrast colloid form. The BEIR IV report also derives a risk estimate of up to 60E-06 per rad of alpha radiation to bone marrow for leukemia, and a value of up to 120E-06 per rad alpha radiation to the skeleton without marrow for bone cancer (NAS 1988).

Dose Response Data - Animal

Experimental studies of animals administered modified Thorotrast solutions have provided insight concerning the possible influence on carcinogenicity of Thorotrast in humans from a "foreign body effect" (from the colloid solution), or a toxicological effect of the thorium in addition to a radiation dose effect. Studies in mice have been performed using Thorotrast solutions fortified with Th-230 to increase the specific activity of alpha emissions delivering radiation dose to tissues, conventional Thorotrast, and zirconium dioxide solution (Zirconotrast). There was no evidence of increased carcinogenicity of Thorotrast relative to Zirconotrast (Bensted 1967). Rabbits injected with Th-230 enriched Thorotrast revealed a shortened latency period (Faber 1973) associated with the higher specific activity solution. The metabolic distribution of Thorotrast and other colloid solutions has been examined in mice, rabbits, rats, and dogs including zirconium and hafnium dioxide colloids. The organ distribution of the Thorotrast and associated progeny in these animals was found to be comparable to that in humans (Riedel et al. 1979, 1983). The other colloids failed to reveal significantly different effects attributable to their distributions compared to the Thorotrast (Riedel et al. 1979, 1983).

A study of dose response and whether a foreign body effect occurs was conducted by administering different Th-230 enrichments of Thorotrast (causing variation in dose rate) and by administering different volumes of Thorotrast (dilutions maintaining constant dose rate) to rats (Wesch et al. 1973, 1983). Results of frequency of cancers followed a linear dependence with dose rate; however, variation of the volume of Thorotrast administered did not correlate with frequency of induction. Although cancer risk did not increase with volume of Thorotrast at a constant dose rate, the latent period was shortened (Wesch et al. 1973, 1983).

Additional studies in rats involved injection with Zirconotrast enriched with Th-228. Cancer induction in the animals was elevated and the cancers induced were similar to those induced in humans by Thorotrast (Wesch et al. 1986). The frequency of cancer induction was dose rate dependent and the Zirconotrast without Th-228 did not induce excess cancers (Wesch et al. 1986).

In summary, the animal experimental evidence indicates that Thorotrast induces cancers as a result of the radiation dose delivered by the solution. The physical presence of particles in

the colloid solution and the chemical effect of the thorium are not likely to influence the induction of cancer (NAS 1988).

E.4.2.82 Inorganic Tin

E.4.2.82.1 Pharmacokinetics

Estimates of the gastrointestinal absorption efficiency of tin in humans and animals range from 0.6 percent to 5 percent (Magos 1986). The data suggest that tin in the +2 valence state is more readily absorbed than tin in the +4 valence state. Species differences in gastrointestinal absorption appear to be slight. Absorption efficiency appears to be somewhat greater when the administered dose is smaller. From these data, it appears that an estimate of 5 percent (0.05) is a reasonable estimate of gastrointestinal absorption efficiency. Data regarding dermal uptake of tin were not located.

E.4.2.82.2 Noncancer Toxicity

Industrial (inhalation) exposure to tin dust results in a benign pneumoconiosis called stannosis (Magos 1986). Acute oral exposure causes gastroenteritis (nausea and diarrhea) in humans. Other effects in animals include anemia, interference with calcium metabolism, and liver and kidney lesions. A chronic oral RfD of 0.66 mg/kg-day was based on a NOAEL for liver and kidney lesions of 2,000 ppm stannous chloride in the diet in a two-year study in rats (EPA 1992b). An uncertainty factor of 100 was applied. The chronic oral RfD was considered sufficiently protective for subchronic exposure as well.

E.4.2.82.3 Carcinogenicity

Data regarding the carcinogenicity of tin were not located in the available literature.

E.4.2.83 Toluene

E.4.2.83.1 Noncancer Toxicity

In a subchronic gavage study, high doses of toluene induced slight changes in liver and kidney weights in rats (EPA 1993a). Inhalation exposure of laboratory animals or humans was associated primarily with CNS depression (ATSDR 1989h). Recent developmental toxicity studies in animals suggest that the fetus or offspring may be unusually sensitive to effects on the developing nervous system. The EPA (1993a) presented a verified chronic oral RfD for toluene of 0.2 mg/kg/day based on an NOAEL for changes in liver and kidney weights in rats in a 13-week gavage study and an uncertainty factor of 1000. A provisional subchronic oral

RfD of 2 mg/kg/day was based on the same NOAEL and an uncertainty factor of 100 (EPA 1992b). The EPA (1993a) presented a verified chronic inhalation RfC of 0.4 mg/m^3 based on an LOAEL for neurological effects in occupationally exposed humans and an uncertainty factor of 300. The EPA (1992b) presented a provisional subchronic inhalation RfC of 2 mg/m^3, based on an NOAEL for CNS effects and mucosal irritation in humans and an uncertainty factor of 100. The chronic inhalation RfC is equivalent to 0.1 mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. Similarly estimated, the subchronic inhalation RfC is equivalent to 0.6 mg/kg/day.

E.4.2.83.2 Carcinogenicity

Toluene is classified as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans), based on no human data and inadequate animal data (EPA 1993a). Quantitative risk estimates are not derived for Group D substances.

E.4.2.84 Tributyl Phosphate

E.4.2.84.1 Noncancer Toxicity

Tributyl phosphate exhibits rather low acute oral toxicity; the oral single-dose $LD_{50/30}$ in rats was 3,000 mg/kg (ACGIH 1986). The compound is a weak cholinesterase inhibitor and induces paralysis and anesthesia, as well as lung edema, when given orally or parenterally (ACGIH 1986; Sandmeyer and Kirwin 1981). Irritation of the skin and mucous membranes and lung edema results from inhalation exposure. Occupational exposure to 15 mg/m^3 was associated with headache and nausea.

E.4.2.84.2 Carcinogenicity

Data were not located regarding the carcinogenicity of tributyl phosphate. However, the compound was negative for mutagenicity in Salmonella and Drosophila.

E.4.2.85 1,1,1-Trichloroethane

E.4.2.85.1 Noncancer Toxicity

The toxicity of oral exposure to 1,1,1-trichloroethane is low (ACGIH 1986). Chronic ingestion by laboratory animals reduced growth rate, but produced little pathology in internal organs (ATSDR 1990a). Acute inhalation exposure of humans or animals to high levels induced death due to narcosis or cardiac sensitization (ACGIH 1986). Occupational exposure was not associated with systemic effects. The EPA (1992b) presented a provisional chronic

oral RfD for 1,1,1-trichloroethane of 0.09 mg/kg/day based on an NOAEL for slight growth retardation in guinea pigs in subchronic intermittent exposure inhalation studies and an uncertainty factor of 1000. A provisional subchronic oral RfD of 0.9 mg/kg/day was based on the same NOAEL and an uncertainty factor of 100. A provisional chronic inhalation RfC of 1 mg/m^3 was derived from the same NOAEL and an uncertainty factor of 1000. The provisional subchronic inhalation RfC, based on the same NOAEL and an uncertainty factor of 100, was 10 mg/m^3. The chronic and subchronic inhalation RfC values are equivalent to 0.3 and 3 mg/kg/day, respectively, assuming humans inhale 20 m^3 of air/day and weigh 70 kg. Target organs for inhalation exposure to 1,1,1-trichloroethane are the CNS and heart.

E.4.2.85.2 Carcinogenicity

The EPA (1993a) classifies 1,1,1-trichloroethane as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans). There are no reported human cancer data, and animal studies (78-week gavage studies in rats and mice, and a 12-month inhalation study in rats) were inadequate to determine the carcinogenicity of 1,1,1-trichloroethane in animals. Quantitative cancer risk estimates are not derived for Group D compounds.

E.4.2.86 Trichloroethene

E.4.2.86.1 Noncancer Toxicity

Little is known about the toxicity of prolonged oral exposure to trichloroethene. Acute inhalation exposure to high levels induced anesthesia, tachypnea, and ventricular arrhythmias (ACGIH 1986). Occupational exposure was associated with headache, dizziness, lassitude, and other CNS effects. Prolonged inhalation exposure of animals affected the liver and kidneys. Neither oral nor inhalation RfD or RfC values were located for trichloroethene. The principal target organs for trichloroethene are the CNS and heart, and, to a lesser extent, the liver and kidney.

E.4.2.86.2 Carcinogenicity

Carcinogenicity studies in laboratory animals showed increased incidence of hepatocellular carcinomas (gavage exposure) and malignant lymphomas (inhalation exposure) in mice and increased incidence of renal adenocarcinomas in male rats (gavage) (EPA 1988d). Cancer studies in humans were inadequate. Interpretation of the data regarding the carcinogenicity of trichloroethene is controversial, and the EPA (1992h) has not adopted a final position on a

cancer weight-of-evidence classification or quantitative risk estimates for trichloroethene. For this reason, trichloroethene was removed from the IRIS and the 1992 HEAST (EPA 1992b). Currently, EPA believes the weight-of-evidence to be on the C-B2 continuum (possible-probable human carcinogen), and offers slope factors of 0.011 per mg/kg/day for oral exposure and 0.006 per mg/kg/day for inhalation exposure as being useful.

E.4.2.87 Trichlorofluoromethane

E.4.2.87.1 Noncancer Toxicity

One study reported no effects in rats and dogs exposed to levels equivalent to doses somewhat higher than those in the NCI (1978d) gavage study (Leuschner et al. 1983). These concentrations of trichlorofluoromethane induced mild narcosis and transient cardiac sensitization (ACGIH 1986). Provisional chronic and subchronic inhalation RfC values of 0.7 and 7 mg/m^3, respectively, were derived from an LOAEL for impaired kidney function and pulmonary inflammation in dogs continuously exposed to trichlorofluoromethane in air for 90 days. Uncertainty factors of 10,000 and 1000 were used for the chronic and subchronic inhalation RfC values, respectively. The chronic and subchronic RfC values are equivalent to 0.2 and 2 mg/kg/day, respectively, assuming humans inhale 20 m^3 of air/day and weigh 70 kg.

A dose of 2.5 mL/kg (3700 mg/kg, assuming a density of 1.494 g/mL [Budavari 1989]) produced neither fatalities not liver necrosis in rats.

The EPA (1993a) derived a verified chronic oral RfD of 0.3 mg/kg/day from the LOAEL for reduced survival of 349 mg/kg/day. This 78-week gavage study in rats and mice was associated with decreased survival in both species, even at the lowest dose tested (349 mg/kg/day) (NCI 1978). The cause of death was not ascertained, but pleuritis and pericarditis were observed in some of the treated rats. An uncertainty factor of 1000 was applied when calculating the RFD; factors of 10 each for inter- and intraspecies variation, and to estimate an NOAEL from an LOAEL. A provisional subchronic oral RfD of 0.7 mg/kg/day was based on an LOAEL for decreased body weights in a 6-week gavage study in rats and an uncertainty factor of 1000 (EPA 1992b). Target organs for trichlorofluoromethane include the CNS, heart, and kidney.

E.4.2.87.2 Carcinogenicity

Trichlorofluoromethane has not yet been reviewed by the EPA for evidence of carcinogenicity to humans (EPA 1993a).

E.4.2.88 1,1,2-Trichloro-1,2,2-trifluoroethane

E.4.2.88.1 Noncancer Toxicity

The acute oral toxicity of 1,1,2-trichloro-1,2,2-trifluoroethane is low (ACGIH 1986). Occupational exposure to moderate levels was not associated with adverse effects, although acute exposure to grossly high levels was implicated in several dry-cleaning fatalities. CNS effects were observed in humans exposed to high levels. Inhalation exposure to very high levels in animals sensitized the heart to epinephrine, resulting in serious cardiac arrhythmia. The EPA (1993a) presented a verified chronic oral RfD of 30 mg/kg/day based on an NOAEL from an occupational study and an uncertainty factor of 10. The EPA (1992b) presented a provisional subchronic oral RfD of 3 mg/kg/day, based on an NOEL in an inhalation study in rats and an uncertainty factor of 100. It is clear that the provisional subchronic oral RfD is inappropriate because it implies that the toxic potency of subchronic exposure is greater than the toxic potency of chronic exposure. For this reason, the chronic oral RfD of 30 mg/kg/day is adopted as sufficiently protective for subchronic exposure. The EPA (1992b) also presented 27 mg/m^3 as a provisional subchronic and chronic inhalation RfC, based on the rat inhalation data and an uncertainty factor of 100. The inhalation RfC is equivalent to 8 mg/kg/day, assuming an inhalation rate of 20 m^3/day and a body weight of 70 kg for humans. Target organs for inhalation exposure to 1,1,2-trichloro-1,2,2-trifluoroethane are the CNS and the heart.

E.4.2.88.2 Carcinogenicity

There were no reports of carcinogenicity associated with 1,1,2-trichloro-1,2,2-trifluoroethane (ACGIH 1986).

E.4.2.89 2,4,5-Trichlorophenol

E.4.2.89.1 Pharmacokinetics

Data regarding the pharmacokinetics of 2,4,5-trichlorophenol were not located in the available literature. The log K_{ow} of 3.69 for 2,4,6-trichlorophenol, a structurally similar compound (Howard 1989), suggests that 2,4,5-trichlorophenol is probably strongly lipophilic, and that it would be absorbed from the gastrointestinal tract and through the skin. Default values for

absorption efficiency of 0.9 for gastrointestinal absorption and 0.3 for dermal uptake from soil (EPA 1993d) appear to be reasonable.

E.4.2.89.2 Noncancer Effects

A chronic oral RfD of 0.1 mg/kg-day is based on a NOEL for liver and kidney effects in a subchronic study in rats (EPA 1993a). An uncertainty factor of 1000 was applied; factors of 10 each to expand from subchronic to chronic exposure, to extrapolate from animals to humans, and to account for the range of variability in human sensitivity. The subchronic oral RfD of 1.0 mg/kg-day was based on the same study and an uncertainty factor of 100 (EPA 1992b). The data were insufficient for derivation of a toxicity value for inhalation exposure.

E.4.2.89.3 Carcinogenicity

Data were not located regarding the carcinogenicity of 2,4,5-trichlorophenol. 2,4,6-Trichlorophenol, which is structurally similar to 2,4,5-trichlorophenol, is considered a probable human carcinogen (EPA weight-of-evidence Group B2) based on increased incidence of lymphomas or leukemias in male rats and hepatocellular adenomas of carcinomas in male and female mice (EPA 1993a).

E.4.2.90 Uranium

E.4.2.90.1 Noncancer Toxicity

The only chemical toxicity effect in humans unequivocally attributed to soluble uranium salts is kidney damage, involving the proximal convoluted tubule, and manifested initially as albuminuria and increased urinary catalase (Berlin and Rudell 1986b). Rabbits were more sensitive than dogs or rats. Treatment of rabbits and dogs with soluble uranium salts also induced neurologic signs and pathological changes of the nervous system. EPA (1993a) presented a verified RfD of 0.003 mg/kg/day for chronic oral exposure to soluble uranium salts. The basis was an LOAEL for kidney damage in rabbits treated with uranyl nitrate hexahydrate in the diet for 30 days, and an uncertainty factor of 1000. A subchronic oral RfD was not located. The principal target organ for the chemical toxicity of soluble salts of uranium is the kidney; the CNS may be an additional target organ.

E.4.2.90.2 Carcinogenicity

Uranium can induce cancer as a result of intake into the body through inhalation or ingestion pathways. The induction of cancer results when organs and tissues of the body are exposed to

alpha particles emitted from decaying uranium atoms. Alpha particles are energetic emissions that cause molecular ionizations in a very dense pattern along a short path through matter. The effect of an alpha particle is highly localized due to the short path length traveled (low penetrability) and the ability of the particle to produce many ionizations. The ionization events cause biological damage that is believed to be responsible for inducing cells to become cancerous. Although other energetic emissions from radioactive decay of atoms (such as beta particles and gamma rays) also cause molecular ionizations, these radiations do not produce the density of ionizations that alpha particles produce. The dense pattern of ionizations caused by alpha particles and the low penetrability of alpha particles are the factors that determine uranium is an internal exposure hazard. Alpha particles are not an external exposure hazard because they do not penetrate sensitive tissues from outside the body. The outer layers of the skin stop the alpha particles before they can penetrate to and damage sensitive tissues of inner layers.

The type of uranium (e.g. natural, enriched, depleted) under consideration is important because different types of uranium have different specific activities (the amount of radioactivity per unit mass). The magnitude of the specific activity of the uranium reflects the number of alpha particles emitted per unit mass. This has a direct impact on the magnitude of the radiological dose delivered internally after the uranium enters the body. Naturally-occurring uranium and uranium processed from natural uranium is a mixture of U-234, U-235, and U-238. The difference between natural, enriched, and depleted uranium is defined by the percent U-235 mass enrichment. The higher the U-235 enrichment, the higher the specific activity of the mixture.

The following discussion of human data concerning health effects of uranium exposure is summarized from the report of the BEIR IV Committee on radon and other alpha emitters (NAS 1988). Convincing epidemiological evidence of uranium-induced radiocarcinogenic effects in humans is difficult to obtain. Available epidemiological evidence comes from studies of workers involved in uranium mining and milling operations. It has been noted for some time that uranium workers are at risk of increased cancer mortality; however, inhalation of airborne radon progeny rather than uranium particulates is considered the predominant source of radiation damage to the respiratory tract in uranium miners. Simultaneous exposures to radon progeny and other elements present in uranium ore are considered

confounding factors in studies of uranium miners intended to specifically examine the radiological effects of exposure to uranium.

Risk estimation for exposure to uranium is based heavily on the carcinogenic effects of other alpha-emitting radionuclides and animal experiments involving exposure to uranium. Available human epidemiological studies are discussed as follows.

Epidemiological surveys of uranium workers began in the United States in 1950 (Miller et al. 1956) and reports of increased cancer risk among uranium millers in Europe first began in 1959 (Rockstroh 1959). In contrast, other studies have indicated that there is little evidence of a health hazard to workers in the uranium processing industry (Ely 1959). The BEIR IV report (NAS 1988) cautions that the validity of epidemiological studies on effects of uranium must be considered in the context of the power or ability of the studies to detect an effect if one existed. This question is important with regard to all of the available epidemiological studies on uranium effects.

An early U.S. Public Health Service study of uranium miners and millers in the Colorado Plateau reported no increase in mortality in the cohort of uranium millers studied (Wagoner et al. 1964). A more detailed study with longer follow-up of the same cohort was performed (Archer et al. 1973). The number of deaths available for analysis was almost equal to the expected number of deaths determined among controls. Interpretation of the results is complicated by the fact that exposure data are not available, the excess cases include three diagnostic categories, precautions taken to exclude individuals with underground mining exposure through previous employment were not stated, and the analysis was not performed in relation to the length of exposure. The study does not provide strong evidence that uranium has a specific effect because of the weak epidemiological power of the study.

Studies of uranium workers exposed to enriched uranium have been performed. A study of workers at the enrichment facility in Oak Ridge between 1943 and 1947 indicated that the mortality of the study cohort was not increased for lung cancer, bone cancer, or nephrotoxic disorders (Polednak and Frome 1986). This study is weakened by the fact that it is based on exposures of short duration (typically 1 to 2 years), which does not provide conclusive evidence concerning health effects from long-term (chronic) exposure. Subsequent study of a cohort from the same population was performed to examine lung cancer risk from inhalation

exposure of uranium dust (Cookfair et al. 1983). The results indicate an increased risk among the group of workers hired at an age over 45, and the magnitude of the increase was greater for higher exposures.

A retrospective study of uranium mill workers from the Colorado Plateau was conducted to examine the health risks of uranium exposure in the absence of uranium mining (Waxweiler et al. 1983). The findings of the study were not statistically significant and are mitigated by the small number of deaths available for workers employed for at least five years. The results did not reveal an increase in lung cancer deaths and did not conclusively demonstrate an increased nephrotoxic effect.

The available epidemiological studies fail to conclusively demonstrate health effects from chronic exposure to uranium dust involved in uranium mining and milling operations. However, it is not necessarily concluded that the epidemiological data conclusively demonstrate the absence of effect. This is because the power of the studies is limited, weakened by short worker exposure durations, inadequate estimates of uranium exposures, and insufficient worker follow-up time to adequately evaluate long-term effects.

In conclusion, chronic exposure to uranium should be controlled on the basis of nephrotoxicity more than by radiocarcinogenicity from alpha particle emissions (NAS 1988). Quantification of the risk from chronic exposure to uranium alpha particles cannot be determined from published epidemiological studies because of confounding factors and the limited power of the studies to detect increased rates of cancer incidence or mortality (NAS 1988). Therefore, the BEIR IV Committee presents a risk estimate for uranium based on the carcinogenic effects of other alpha-emitting radionuclides and animal experiments involving exposure to uranium. The most probable radiogenic effect is an increase in bone sarcomas. The likelihood of sarcomas from exposure to naturally-occurring uranium is considered low and only demonstratable if a linear dose-response relationship is assumed (Mays et al. 1985). If the dose-response relationship is quadratic, then virtually no effect would be expected from naturally-occurring uranium. Assuming a linear dose-response relationship and a constant nonoccupational uranium intake of 1 pCi/day the risk of bone sarcoma induction over a lifetime is estimated to be 1.5 bone sarcomas per million persons (1.5E-06) (Mays et al. 1985). This is compared to a natural incidence of 750 bone sarcomas in the absence of excess exposure.

Assuming a constant nonoccupational uranium intake rate of 1 pCi/day, an exposure frequency of 365 days/year, and a lifetime of 70 years, a lifetime intake of uranium of nearly 26,000 pCi is calculated. Using the risk factor from Mays (Mays et al. 1985) and dividing by the calculated lifetime intake, one can derive a risk factor of 5.9E-11 per pCi. Comparison of this risk factor with the cancer slope factors from HEAST for ingestion of U-234, U-235, and U-238 indicates that the ratios of the HEAST values to the former value are 2.4, 2.2, and 2.2, respectively.

The following discussion of experimental animal data concerning health effects of uranium exposure is summarized from the report of the BEIR IV Committee on radon and other alpha emitters (NAS 1988). The effect of bone cancer induction is addressed first, followed by the effect of lung cancer induction.

The discussion involving human epidemiological evidence identified the bone surfaces as the most probable target tissue for exposure to uranium and bone sarcoma as the carcinogenic effect of concern. Radiocarcinogenic effects including bone sarcoma and head carcinoma have also been observed in animals and humans from exposure to isotopes of radium, and studies involving exposure of mice to high specific activity U-232 and U-233 also reveal an increase in bone sarcomas. Soviet researchers have demonstrated that highly enriched uranium, which has a high specific activity, induces bone sarcomas in rats. These results indicate that intake of high specific activity, alpha-particle-emitting radionuclides increases the risk of these cancers in animals. It would be reasonable to expect high specific activity uranium to induce bone sarcomas in humans; however, the likelihood that low specific activity, naturally-occurring uranium induces bone sarcomas is low.

The discussion of human epidemiological evidence states that an estimate of the excess risk of bone sarcoma in humans from chronic ingestion of uranium has been developed (Mays et al. 1985). This risk estimate is based on a linear dose-response relationship for Ra-226. Therefore, it is assumed that the response to alpha particles from uranium exposure is similar to the response to alpha particles from Ra-226. This assumption is dependent in part on the metabolic behavior of uranium relative to radium. There is evidence indicating that uranium seeks bone tissue in a manner similar but not identical to that of radium. Uranium-233 administered to beagle dogs has been shown to initially deposit nonuniformly on bone surfaces; however, redistribution occurs (within approximately one year) to produce a

distribution through the bone volume that is similar to the distribution of radium (Stevens et al. 1980). Distribution of uranium throughout the bone volume in dogs has also been reported by Rowland and Farnham (1969) and Bruenger (personal communication with BEIR IV Committee, 1986 not available in bibliography).

The induction of malignant tumors in the lung is of concern for exposure to uranium by inhalation. As previously discussed, uranium emits alpha particles, which can deposit a highly localized radiation dose to sensitive tissues in the passages of the respiratory tract if particulate uranium is deposited in those passageways. The effects of inhalation of insoluble forms of uranium have been studied in rats, dogs, and monkeys for both short and prolonged exposure scenarios (Leach et al. 1970, 1973). Affected sites for insoluble forms of uranium are the tissues of the lung and the pulmonary lymph nodes. Chronic inhalation of uranium in these studies produced fibrosis of lung tissue and induction of malignant lung tumors. Data from those inhalation studies that involved dogs have been reanalyzed (Durbin and Wrenn 1975), leading to the conclusion that neoplastic changes (tumor induction) began in epithelial cells of the lungs in 21 percent of the dogs after a cumulative lung dose of 160 rads.

Another study involving exposure of rats to U-232 and U-233 (as uranyl nitrate) by inhalation reveals an increase in malignant lung tumors and bone sarcomas (Ballou et al. 1980). However, the significance of the bone sarcomas (osteosarcomas) is questionable because the rats exposed to control aerosols also developed these tumors. The osteosarcomas are not statistically significant because of their appearance in the control rats. The results of this study of high specific activity U-232 and U-233 labeled uranyl nitrate can lead to the reasonable expectation that such exposure can induce malignant lung tumors in humans. However, the findings of this work do not provide the data needed to convincingly extrapolate a risk coefficient for human exposure.

E.4.2.91 Vanadium

E.4.2.91.1 Noncancer Toxicity

The oral toxicity of vanadium compounds to humans is very low (Lagerkvist et al. 1986), probably because little vanadium is absorbed from the GI tract. Effects in humans exposed by inhalation include upper and lower respiratory tract irritation. A provisional subchronic and chronic oral RfD of 0.007 mg/kg/day was derived from an NOEL in rats in a lifetime drinking water study with vanadyl sulfate and an uncertainty factor of 100 (EPA 1992b). A

target organ could not be identified for oral exposure. The respiratory tract is the target organ for inhalation exposure.

E.4.2.91.2 Carcinogenicity

No information was located regarding the carcinogenicity of vanadium.

E.4.2.92 Vinyl Chloride

E.4.2.92.1 Noncancer Toxicity

Data were not located regarding oral exposure of humans to vinyl chloride (ATSDR 1989i). In rats, lifetime dietary ingestion of vinyl chloride slightly but significantly increased mortality and induced mild histopathologic effects in the liver. Several early occupational studies associated vinyl chloride exposure with a syndrome known as vinyl chloride disease, which includes acroosteolysis (dissolution of the ends of the distal phalanges of the hands), circulatory disturbances in the extremities, Raynaud syndrome (sudden, recurrent bilateral cyanosis of the digits), scleroderma, hematologic effects, effects on the lungs, and impaired liver function and liver damage. Mild neurologic effects were also associated with occupational exposure. Long-term inhalation studies in rats and mice identified elevated relative liver weight as a sensitive indicator of liver effects. Neither inhalation RfC values nor oral RfD values for vinyl chloride were located. The principal target organs for vinyl chloride appear to be the CNS and the liver.

E.4.2.92.2 Carcinogenicity

The EPA (1992b) lists vinyl chloride as an EPA cancer weight-of-evidence Group A compound (human carcinogen) and presents a verified oral slope factor of 1.9 per mg/kg/day, based on the increased incidence of liver and lung tumors in a lifetime dietary study in rats. An inhalation unit risk of 8.4E-05 per $\mu g/m^3$, equivalent to 0.3 per mg/kg/day, assuming humans inhale 20 m^3 of air/day and weigh 70 kg, is based on liver tumors in rats intermittently exposed by inhalation for 12 months.

E.4.2.93 Xylenes

E.4.2.93.1 Noncancer Toxicity

Prolonged oral exposure of animals to xylenes was associated with CNS signs and increased mortality, without histopathological alterations in the internal organs (EPA 1993a). Occupational exposure to xylenes induced CNS effects and GI disturbances (ACGIH 1986).

Other effects attributed to occupational exposure to xylene (blood dyscrasias, and heart, liver, and kidney damage) may have arisen from concurrent exposure to other chemicals. The EPA (1993a) presented a chronic oral RfD for total xylenes of 2 mg/kg/day based on an NOAEL for hyperactivity and decreased body weight and increased mortality in male rats in chronic gavage studies. An uncertainty factor of 100 was used. The EPA (1992b) presented a subchronic oral RfD of 4 mg/kg/day based on an NOEL for body weight effects in a 13-week gavage study in rats and an uncertainty factor of 100. Inhalation RfC values for xylenes are considered not verifiable by the RfD/RfC Work Group (EPA 1992b). The CNS is the principal target organ for xylenes.

E.4.2.93.2 Carcinogenicity

Xylene is classified as a cancer weight-of-evidence Group D compound (not classifiable as to carcinogenicity to humans) (EPA 1993a). There are no reported human cancer data, and gavage animal studies in rat and mice of both sexes did not result in significant increases in tumor incidence. Quantitative risk estimates are not derived for Group D substances.

E.4.2.94 Zinc

E.4.2.94.1 Pharmacokinetics

Zinc is a nutritionally required trace element. Estimates of the efficiency of GI absorption of zinc in animals range from < 10 to 90 percent (Elinder 1986c). Estimates in normal humans range from approximately 20 to 77 percent (Elinder 1986c; Goyer 1991). The net absorption of zinc appears to be homeostatically controlled, but it is unclear whether GI absorption, intestinal secretion, or both are regulated. Distribution of absorbed zinc is primarily to the liver (Goyer 1991), with subsequent redistribution to bone, muscle, and kidney (Elinder 1986c). Highest tissue concentrations are found in the prostate. Excretion appears to be principally through the feces, in part from biliary secretion, but the relative importance of fecal and urinary excretion is species-dependent. The half-life of zinc absorbed from the GI tracts of humans in normal zinc homeostasis is approximately 162 to 500 days.

E.4.2.94.2 Noncancer Toxicity

Humans exposed to high concentrations of aerosols of zinc compounds may experience severe pulmonary damage and death (Elinder 1986c). The usual occupational exposure is to freshly formed fumes of zinc, which can induce a reversible syndrome known as metal fume fever. Orally, zinc exhibits a low order of acute toxicity. Animals dosed with 100 times dietary

requirement showed no evidence of toxicity (Goyer 1991). In humans, acute poisoning from foods or beverages prepared in galvanized containers is characterized by GI upset (Elinder 1986c). Chronic oral toxicity in animals is associated with poor growth, GI inflammation, arthritis, lameness, and a microcytic, hypochromic anemia (Elinder 1986c), possibly secondary to copper deficiency (Underwood 1977). The EPA (1992b) presented a verified RfD of 0.2 mg/kg/day for chronic oral exposure to zinc, based on anemia in humans.

E.4.2.94.3 Carcinogenicity

The EPA (1993a) classifies zinc in cancer weight-of-evidence Group D (not classifiable as to carcinogenicity to humans) based on inadequate evidence for carcinogenicity in humans and animals. The human data consist largely of occupational exposure studies not designed to detect a carcinogenic response, and of reports that prostatic zinc concentrations were lower in cancerous than in noncancerous tissue. The animal data consist of several dietary, drinking water, and zinc injection studies, none of which provided convincing data for a carcinogenic response.

TABLE E.4-1

DOSE-RESPONSE DATA FOR RADIONUCLIDE CONSTITUENTS OF POTENTIAL CONCERN

Radionuclide[a]	Abbreviation Used	GI Abs. Factor	ICRP Lung Class[c]	Cancer Slope Factor Oral $(pCi)^{-1}$	Cancer Slope Factor Inhalation $(pCi)^{-1}$	Cancer Slope Factor External $(pCi)^{-1}$	Source
Cesium-137	Cs_{137+1d}	1	D	2.80E-11	1.90E-11	2.00E-06	EPA 1993g
Neptunium-237	Np_{237+1d}	0.001	W	2.20E-10	2.90E-08	4.30E-07	EPA 1993g
Plutonium-238	Pu_{238}	0.001	Y	2.20E-10	3.90E-08	2.80E-11	EPA 1993g
Plutonium-239/240	$Pu_{239/240}$	0.001	Y	2.30E-10	3.80E-08	2.70E-11	EPA 1993g
Radium-226	Ra_{226+5d}	0.2	W	1.20E-10	3.00E-09	6.00E-06	EPA 1993g
Radium-226	Ra_{226+8d}	0.2	W	7.80E-10	7.00E-09	6.00E-06	EPA 1993g
Radium-228	Ra_{228+1d}	0.2	W	1.00E-10	6.90E-10	2.90E-06	EPA 1993g
Ruthenium-106	Ru_{106}	0.05	Y	9.50E-12	4.40E-10	NA	EPA 1993g
Strontium-90	Sr_{90+1d}	0.3	D	3.60E-11	6.20E-11	NA	EPA 1993g
Technetium-99	Tc_{99}	0.8	W	1.30E-12	8.30E-12	6.00E-13	EPA 1993g
Thorium-228	Th_{228+7d}	0.0002	Y	5.50E-11	7.80E-08	5.60E-06	EPA 1993g
Thorium-230	Th_{230}	0.0002	Y	1.30E-11	2.90E-08	5.40E-11	EPA 1993g
Thorium-232	Th_{232}	0.0002	Y	1.20E-11	2.80E-08	2.60E-11	EPA 1993g
Thorium-232	$Th_{232+10d}$[b]	0.2	W	1.70E-10	1.10E-07	8.50E-06	EPA 1993g
Uranium-234	U_{234}	0.05	Y	1.60E-11	2.60E-08	3.00E-11	EPA 1993g
Uranium-235/236	U_{235+1d}	0.05	Y	1.60E-11	2.50E-08	2.40E-07	EPA 1993g
Uranium-238	U_{238+2d}	0.05	Y	2.80E-11	5.20E-08	3.60E-08	EPA 1993g
Radon-222	Rn_{222+1d}	1	*	1.70E-12	7.70E-12	5.90E-06	EPA 1993g

Notes:
NA = Not Applicable
[a] Radionucludes include all daughters (+d), where applicable.
[b] In future land use scenarios, Thorium 232 is assumed to be in equilibrium with Thorium 228 and Radium 228 and their associated daughters.
[c] Classification recommended by the ICRP for half-life for clearance from the lung. "Y" = years, "W" = weeks, "D" = days, * = gas

TABLE E.4-2
CANCER SLOPE FACTORS FOR CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN

	Carcinogenic Classification	GI Abs. Factor	Cancer Slope Factor Oral $(mg/Kg/day)^{-1}$	Cancer Slope Factor Inhalation $(mg/Kg/day)^{-1}$	Cancer Slope Factor Dermal $(mg/Kg/day)^{-1}$	Tumor Site Oral	Tumor Site Inhalation	References
cyanide	D	0.72	ND	ND	ND	ND	ND	ND
antimony	D	0.15	ND	ND	ND	ND	ND	d
arsenic	A	0.95	1.75E+00	1.50E+01	1.84E+00	skin, lung	respiratory tract	e
barium	D	0.91	ND	ND	ND	ND	ND	d
beryllium	B2	0.01	4.30E+00	8.40E+00	4.30E+02	gross tumors	lung	e
boron	ND	0.05	ND	ND	ND	ND	ND	ND
cadmium (food)	B1	0.03	ND	6.30E+00	ND	ND	respiratory tract	e
cadmium (water)	B1	0.03	ND	6.30E+00	ND	ND	respiratory tract	e
chromium vi	A	0.45	ND	4.20E+01	ND	ND	respiratory tract	e
cobalt	ND	0.45	ND	ND	ND	ND	ND	ND
copper	D	0.60	ND	ND	ND	ND	ND	e
lead	B2	ND	ND	ND	ND	kidney	ND	e
manganese	D	0.03	ND	ND	ND	ND	ND	e
mercury	D	0.15	ND	ND	ND	ND	ND	e
molybdenum	D	0.38	ND	ND	ND	ND	ND	d
nickel	A	0.05	ND	8.40E-01	ND	ND	respiratory tract	e
selenium	D	0.80	ND	ND	ND	liver, lung	ND	e
silver	D	0.05	ND	ND	ND	ND	ND	e
thallium	ND	1.00	ND	ND	ND	ND	ND	e
vanadium	ND	0.05	ND	ND	ND	ND	ND	d
thorium-total	A	ND	ND	ND	ND	ND	ND	f
uranium-total	A	0.05	ND	ND	ND	ND	ND	f
fluoride	ND	1.00	ND	ND	ND	ND	ND	ND
pcb s	B2	0.75	7.70E+00	ND	1.03E+01	liver	ND	e
acenaphthylene	D	0.43	ND	ND	ND	ND	ND	e
2-methylnaphthalene	ND	1.00	ND	ND	ND	ND	ND	ND
4-chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	B2	0.9	3.40E-01	3.40E-01	3.78E-01	liver	ND	e,g
benzo(a)anthracene	B2	0.43	ND	ND	ND	ND	ND	h
benzo(a)pyrene	B2	0.43	7.30E+00	6.10E+00	ND	stomach	respiratory tract	e,g
benzo(b)fluoranthene	B2	0.43	ND	ND	ND	ND	ND	e
benzo(g,h,i)perylene	D	0.43	ND	ND	ND	ND	ND	e
benzo(k)fluoranthene	B2	0.43	ND	ND	ND	ND	ND	h
chrysene	B2	0.43	ND	ND	ND	lymphoma, skin	ND	e
dibenzo(a,h)anthracene	B2	0.43	ND	ND	ND	ND	ND	h
dibenzofuran	D	ND	ND	ND	ND	ND	ND	e

TABLE E.4–2

(Contiuned)

	Carcinogenic Classification	GI Abs. Factor	Cancer Slope Factor Oral $(mg/Kg/day)^{-1}$	Inhalation $(mg/Kg/day)^{-1}$	Dermal $(mg/Kg/day)^{-1}$	Tumor Site Oral	Inhalation	References
indeno(1,2,3–cd)pyrene	B2	0.43	ND	ND	ND	ND	ND	h
n–nitrosodipropylamine	B2	0.90	7.00E+00	ND	7.80E+00	multiple	ND	e
pentachlorophenol	B2	0.90	1.20E–01	ND	1.33E–01	liver	ND	e
phenanthrene	D	0.90	ND	ND	ND	ND	ND	e
tributyl phosphate	D	0.90	ND	ND	ND	ND	ND	j
2–hexanone	ND	0.90	ND	ND	ND	ND	ND	ND
3–chloropropene	C	ND	ND	ND	ND	ND	ND	e
benzene	A	0.90	2.90E–02	2.92E–02	3.20E–02	leukemia	leukemia	e
vinyl chloride	A	0.90	1.90E+00	3.00E–01	2.11E+00	ND	ND	g
tetrachlorodibenzo–p–dioxin[c]	B2	0.50	1.50E+05	1.50E+05	3.00E+05	respiratory system, liver	ND	e,g
tetrachlorodibenzofuran[c]	B2	0.50	ND	ND	ND	ND	ND	ND
pentachlorodibenzofuran[c]	B2	0.50	ND	ND	ND	ND	ND	ND
hexachlorodibenzo–p–dioxin[c]	B2	0.50	ND	ND	ND	ND	ND	ND
hexachlorodibenzofuran[c]	B2	0.50	ND	ND	ND	ND	ND	ND
heptachlorodibenzo–p–dioxin[c]	B2	0.50	ND	ND	ND	ND	ND	ND
heptachlorodibenzofuran[c]	B2	0.50	ND	ND	ND	ND	ND	ND
octachlorodibenzo–p–dioxin[c]	B2	0.50	ND	ND	ND	ND	ND	ND
octachlorodibenzofuran[c]	B2	0.50	ND	ND	ND	ND	ND	ND
chloroform	B2	1.00	6.10E–03	8.10E–02	6.10E–03	kidney	liver	e
tetrachloroethene	C–B2	0.90	5.20E–02	2.00E–03	5.78E–02	lung	lung	g
methylene chloride	B2	1.00	7.50E–03	1.60E–03	7.50E–03	liver	lung, liver	e
toluene	D	1.00	ND	ND	ND	ND	ND	e
2–nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND
acetone	D	0.83	ND	ND	ND	ND	ND	e

[a]Cancer weight of evidence Group A = human carcinogen; Group B1 and B2 = probable human carcinogen; Group C = possible human carcinogen; Group D = not classified as to humans; Group E = evidence of noncarcinogenicity to humans.
[b]Derived from inhalation unit risk
[c]Dioxin and Furans Carcinogenicity is based on the 2,3,7,8 Congeners
[d]EPA 1993e, "Drinking Water Regulations and Health Advisories"
[e]EPA 1993a, IRIS
[f]The carcinogenicity of uranium is attributed to its radioactivity; see Table E.4–1
[g]EPA 1993g, HEAST
[h]The oral and inhalation cancer slope factors for benzo(a)pyrene are used for the other polyaromatic hydrocarbons assigned to cancer classification B2 (see Toxicologica profiles for PAHs for additional information)
[i]EPA 1992h RATS (Risk Assessment Teleconference for Superfund) Meeting Notes, May 13, 1992.
[j]EPA 1993d, Memorandum from J. Dollarhide ECAO to P. Van Leeuwen, Region V, 7/21/93, including Attachments 1–6.
[k] = No Data

TABLE E.4-3

REFERENCE DOSES FOR CHEMICALS OF POTENTIAL CONCERN

	GI Abs. Factor	Reference Dose Oral (mg/Kg/day)	Reference Dose Inhalation (mg/Kg/day)	Reference Dose Dermal (mg/Kg/day)	Target Organ[a] Oral	Target Organ[a] Inhalation	Reference
cyanide	0.72	2.00E-02	ND	ND	Central nervous system	ND	b
antimony	0.15	4.00E-04	ND	6.00E-05	Liver	ND	b
arsenic	0.95	3.00E-04	ND	2.85E-04	Skin	ND	b
barium	0.91	7.00E-02	1.43E-04	6.37E-02	Cardiovascular system	Fetus	b,d
beryllium	0.01	5.00E-03	ND	5.00E-05	ND	ND	b
boron	0.05	9.00E-02	5.71E-03	4.50E-03	Testis	Respiratory system	b,d
cadmium (food)	0.05	1.00E-03	ND	5.00E-05	Kidney	Cancer (See table E.4-2	b,d
cadmium (water)	0.05	5.00E-04	ND	2.50E-05	Kidney	Cancer (See table E.4-2	b
chromium vi	0.5	5.00E-03	ND	2.25E-03	ND	ND	b
cobalt	0.45	6.00E-02	3.00E-07	2.70E-02	Central nervous system	Respiratory system	e,f
copper	0.6	ND	ND	ND	GI system irritation	ND	i
lead	ND	ND	ND	ND	Central nervous system	Central nervous system	b
manganese (food)	0.03	1.40E-01	1.14E-04	4.20E-03	Central nervous system	Respiratory system	b
manganese (water)	0.03	5.00E-03	1.14E-04	0.00015	Central nervous system	Respiratory system	
mercury	0.15	3.00E-04	8.57E-05	4.50E-05	Kidney	Central nervous sytem	b
molybdenum	0.38	5.00E-03	ND	1.90E-03	Liver	ND	b
nickel	0.1	2.00E-02	ND	1.00E-03	ND	Cancer (See table E, 4-2	b
selenium	0.8	5.00E-03	ND	4.00E-03	Skin	ND	b
silver	0.05	5.00E-03	ND	ND	ND	ND	b
thallium	1	7.00E-05	ND	7.00E-05	Central nervous system	ND	b,g
vanadium	0.05	7.00E-03	ND	3.50E-04	ND	ND	d
thorium-total	ND	ND	ND	ND	ND	ND	ND
uranium-total	0.05	3.00E-03	ND	1.50E-04	kidney	ND	b
fluoride	1	6.00E-02	ND	6.00E+02	Teeth	ND	b
pcbs	0.75	ND	ND	ND	Fetus	ND	b, h
acenaphthylene	0.43	ND	ND	ND	ND	ND	ND
2-methylnaphthalene	1	ND	ND	ND	ND	ND	ND
4-chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	ND
benzo(a)anthracene	0.43	ND	ND	ND	ND	ND	ND
benzo(a)pyrene	0.43	ND	ND	ND	ND	ND	ND
benzo(b)fluoranthene	0.43	ND	ND	ND	ND	ND	ND
benzo(g,h,i)perylene	0.43	ND	ND	ND	ND	ND	ND
benzo(k)fluoranthene	0.43	NA	NA	ND	ND	ND	ND
chrysene	0.43	NA	NA	ND	ND	ND	ND

TABLE E.4-3
(Continued)

	GI Abs. Factor	Reference Dose Oral (mg/Kg/day)	Reference Dose Inhalation (mg/Kg/day)	Reference Dose Dermal (mg/Kg/day)	Target Organ[a] Oral	Target Organ[a] Inhalation	Reference
dibenzo(a,h)anthracene	0.43	NA	NA	ND	ND	ND	ND
dibenzofuran	0.9	4.00E-03	ND	3.60E-03	ND	ND	b
indeno(1,2,3-cd)pyrene	0.43	ND	ND	ND	ND	ND	i
n-nitrosodipropylamine	0.9	ND	ND	ND	ND	ND	b
pentachlorophenol	0.9	3.00E-02	ND	2.70E-02	Liver, Kidney	ND	b
phenanthrene	0.9	ND	ND	ND	ND	ND	ND
tributyl phosphate	0.9	5.00E-03	ND	ND	ND	ND	i
2-hexanone	0.9	4.00E-02	ND	ND	ND	ND	i
3-chloropropene	ND	ND	1.00E-03	ND	ND	ND	b
benzene	0.9	ND	ND	ND	ND	ND	b
vinyl chloride	0.9	ND	ND	ND	ND	ND	ND
tetrachlorodibenzo-p-dioxin	0.5	ND	ND	ND	Fetus	ND	b
tetrachlorodibenzofuran	0.5	ND	ND	ND	ND	ND	ND
pentachlorodibenzofuran	0.5	ND	ND	ND	ND	ND	ND
hexachlorodibenzo-p-dioxin	0.5	ND	ND	ND	ND	ND	ND
hexachlorodibenzofuran	0.5	ND	ND	ND	ND	ND	ND
heptachlorodibenzo-p-dioxin	0.5	ND	ND	ND	ND	ND	ND
heptachlorodibenzofuran	0.5	ND	ND	ND	ND	ND	ND
octachlorodibenzo-p-dioxin	0.5	ND	ND	ND	ND	ND	ND
octachlorodibenzofuran	0.5	ND	ND	ND	ND	ND	ND
chloroform	ND	1.00E-02	ND	1.00E-02	Liver, Fetus	ND	b,d
tetrachloroethene	0.9	1.00E-02	ND	9.00E-03	Liver	ND	b
methylene chloride	1	6.10E-02	8.57E-01	6.10E-02	Liver	Liver	b,d
toluene	1	2.00E-01	1.14E-01	2.00E-01	Liver	Central nervous system	b,d
2-nitrophenol	ND	ND	ND	ND	ND	ND	ND
acetone	0.83	1.00E-01	ND	8.30E-02	Liver	ND	b

[a]Derived from inhalation RfC, by assuming a 70kg adult inhales $20m^3$ of air per day.
[b]EPA 1993g, IRIS
[c]NC = no data
[d]EPA 1993g, Health Effects Assessment Summary Tables, (HEAST) Annual FY 93 and March update
[e]EPA 1992g, Memorandum from D.L. Forman, U.S. EPA Region VII, Philadelphia, Pennsylvania, "Subject: Colbalt toxicity," dated March 12, 1992.
[f]ECAO "Risk Assessment Issue Paper for: Provisional RfD for Colbalt (7440-48-4), dated 12/92 1992
[g]Derived by analogy to thallium sulfate, adjusting for differences in molecular weight.
[h]Based on anology to Aroclor - 1016
[i]EPA 1993d, Memorandum from J. Dollarhide, ECAO to P. VanLeeuwan, Region V, 7/21/93.

TABLE E.4-4

DIOXIN AND FURAN TOXICITY EQUIVALENCY FACTORS[a]

Compound	TEF
Dioxins	
Mono-, Di-, and Trichlorodibenzo-p-dioxins	0
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	1
Other TCDDS	0
2,3,7,8-Pentachlorodibenzo-p-dioxin (PeCDDs)	0.5
Other PeCDDs	0
2,3,7,8-Hexachlorodibenzo-p-dioxins (HxCDDs)	0.1
Other HxCDDs	0
2,3,7,8-Heptachlorodibenzo-p-dioxin (HpCDD)	0.01
Other HpCDDs	0
Octachlorodibenzo-p-dioxin (OCDD)	0.001
Furans	
Mono-, Di-, and Trichlorodibenzo-p-furans	0
2,3,7,8-Tetrachlorodibenzo-p-furan (TCDF)	0.1
Other TCDFs	0
1,2,3,7,8-Pentachlorodibenzo-p-furan (PeCDF)	0.05
2,3,4,7,8-Pentachlorodibenzo-p-furan (PeCDF)	0.5
Other PeCDFs	0
2,3,7,8-Hexachlorodibenzo-p-furans (HxCDFs)	0.1
Other HxCDFs	0
2,3,7,8-Heptachlorodibenzo-p-furans (HpCDFs)	0.01
Other HpCDFs	0
Octachlorodibenzo-p-furan (OCDF)	0.001

[a]EPA 1989j

TABLE E.4-5

TOXICITY EQUIVALENCY FACTORS (TEFs)[a] AND CORRESPONDING ORAL AND INHALATION SLOPE FACTORS FOR THE GROUP B2 PAHs

PAH	Relative Potency	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Slope Factor $(mg/kg\text{-}day)^{-1}$
Benzo(a)pyrene	1.0	7.3	6.1
Benzo(a)anthracene	0.1	0.73	0.61
Benzo(b)fluoranthene	0.1	0.73	0.61
Benzo(k)fluoranthene	0.01	0.073	0.061
Chrysene	0.001	0.0073	0.0061
Dibenzo(a,h)anthracene	1.0	7.3	6.1
Indeno(1,2,3-cd)pyrene	0.1	0.73	0.61

[a]EPA, 1993f

TABLE E.4-6

DERMAL ABSORPTION COEFFICIENTS AND HENRY'S LAW CONSTANTS USED IN EXPOSURE MODEL

Constituent	Soil Absorption Coefficient (unitless)	Henry's Law Constant ($atm\text{-}m^3/mol$)	Log K_{ow}[f]
Inorganics			
Ammonia	1.00×10^{-2}[c]	ND[h]	ND
Antimony	1.00×10^{-2}[b]	ND	ND
Arsenic	1.00×10^{-3}[c]	ND	ND
Barium	1.00×10^{-2}[b]	ND	ND
Beryllium	1.00×10^{-2}[b]	ND	ND
Boron	1.00×10^{-2}[b]	ND	ND
Cadmium (food)	1.00×10^{-2}[b]	ND	ND
Chromium	1.00×10^{-2}[b]	ND	ND
Cobalt	1.00×10^{-2}[b]	ND	ND
Cyanide	1.00×10^{-2}[b]	ND	ND
Copper	1.00×10^{-3}[c]	ND	ND
Fluoride	1.00×10^{-2}[c]	ND	ND
Lead	1.00×10^{-2}[b]	ND	ND
Manganese	1.00×10^{-2}[b]	ND	ND
Mercury	5.00×10^{-2}[c]	ND	ND
Molybdenum	1.00×10^{-2}[b]	ND	ND
Nickel	5.00×10^{-4}[e]	ND	ND
Nitrate	ND	ND	ND
Phosphorous	1.00×10^{-1}[c]	ND	ND
Selenium	1.00×10^{-2}[b]	ND	ND
Silver	1.00×10^{-2}[b]	ND	ND
Thallium	1.00×10^{-2}[b]	ND	ND
Tin	1.00×10^{-3}[b]	ND	ND

TABLE E.4-6
(Continued)

Constituent	Soil Absorption Coefficient (unitless)	Henry's Law Constant (atm-m^3/mol)	Log K_{ow}[f]
Uranium	1.00×10^{-2}[b]	ND	ND
Vanadium	1.00×10^{-3}[c]	ND	ND
Zinc	1.00×10^{-2}[b]	ND	ND
Volatile Organics			
Benzene	5.00×10^{-4}[c]	5.59×10^{-3}[f]	2.13
Tetrachloroethene	4.00×10^{-1}[c]	2.87×10^{-2}[f]	2.53
Vinyl Chloride	3.00×10^{-1}[c]	8.19×10^{-2}[f]	1.36
Semivolatile Organics			
2-Methylnaphthalene	3.00×10^{-1}[c]	ND	3.86
3,3'-Dichlorobenzidine	ND	ND	3.51
Acenaphthylene	3.00×10^{-1}[c]	1.14×10^{-4}[f]	4.07
Acenaphthene	3.00×10^{-1}[c]	ND	3.92
Anthracene	4.00×10^{-1}[c]	8.60×10^{-3}[f]	4.45
Benzo(g,h,i)perylene	3.00×10^{-1}[c]	5.34×10^{-8}[d]	7.23
Dichlorodifluoromethane	3.00×10^{-1}[c]	ND	2.16[e]
Dioxins	3.00×10^{-2}[g]	ND	6.80 based on CDD
Furans	3.00×10^{-2}[g]	ND	5.82
Fluoranthene	3.00×10^{-1}[c]	6.50×10^{-6}[f]	4.95
Fluorene	3.00×10^{-1}[c]	6.42×10^{-5}[f]	4.18
4-Nitroaniline	3.00×10^{-1}[c]	ND	ND
4-Nitrophenol	3.00×10^{-1}[c]	1.91×10^{0}[f]	1.91
Naphthalene	3.00×10^{-1}[c]	ND	3.30
Pentachlorophenol	3.00×10^{-1}[c]	2.75×10^{-6}[f]	5.86
Phenanthrene	3.00×10^{-1}[c]	3.93×10^{-5}[f]	4.46
Pyrene	3.00×10^{-1}[c]	5.10×10^{-6}[f]	5.18
Tributyl phosphate	3.00×10^{-1}[c]	ND	4.00

TABLE E.4-6
(Continued)

Constituent	Soil Absorption Coefficient (unitless)	Henry's Law Constant (atm-m^3/mol)	Log K_{ow}[f]
Pesticide/PCBs			
Aroclor-1016	3.00×10^{-1}[c]	1.07×10^{-3}[f]	6.50
Aroclor-1221	3.00×10^{-1}[c]	1.07×10^{-3}[f]	6.50
Aroclor-1242	3.00×10^{-1}[c]	3.43×10^{-4}[f]	6.50
Aroclor-1248	3.00×10^{-1}[c]	4.40×10^{-4}[f]	6.50
Aroclor-1254	3.00×10^{-1}[c]	8.37×10^{-3}[f]	6.50
Aroclor-1260	3.00×10^{-1}[c]	3.36×10^{-4}[f]	6.50
4,4'-DDT	3.00×10^{-1}[c]	3.89×10^{-5}[f]	6.36

[a]EPA, 1992d, the default value for inorganics is 1×10^{-3}, the experimental value for cadmium. Organic K_ps were estimated using the regression equation: $\text{Log } K_p = -2.72 + 0.71 \log K_{ow} - 0.0061 \text{ MW}$.
[b]Wester et al. (1991).
[c]EPA 1993d, Memorandum from J. Dollarhide ECAO to P. VanLeeuwen Region V, 7/21/93, including Attachments 1-6.
[d]Superfund Public Health Evaluation Manual, October 1986, (SPHEM).
[e]EPA, 1992h.
[f]K_{ow}s obtained from EPA 1992e "Dermal Exposure Assessment"; or EPA 1991, Werl Treatability Database
[g]ATSDR, 1989, "Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-dioxin", Atlanta, GA.
[h]ND - Not determined.

E.5.0 HEALTH RISK CHARACTERIZATION

This section provides a characterization of the potential human health risks associated with the exposure to chemicals and radionuclides originating in Operable Unit 1. Section E.5.1 presents the methods used to estimate the type and magnitude of health risks associated with radionuclide and chemical exposures, and Section E.5.2 presents the results of the risk assessment calculations for measured and modeled current concentrations of constituents in the Operable Unit 1 source areas. Section E.5.3 presents the results of the risk assessment calculations for estimated future concentrations of radionuclides and chemicals in the Operable Unit 1 source areas. Section E.5.4 contains a summary of the results.

E.5.1 RISK CHARACTERIZATION METHODOLOGY

Potential human health risks resulting from exposure to radionuclides and nonradioactive chemicals are estimated using methods established by the EPA, including, but not limited to, Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (EPA 1989a). Methods described by the EPA are health-protective and are likely to overestimate rather than underestimate risk. The methodologies used to assess radiological and chemical risks differ slightly.

EPA's CERCLA methodology, which is set forth in recent guidance such as the Risk Assessment Guidance for Superfund and its supporting documents, uses specific algorithms to calculate human health risks as a function of chemical concentration, human exposure parameters, and toxicity. The product of the chemical concentration and the exposure parameters results in determination of an intake, as shown in Attachment E.III.

E.5.1.1 Radiocarcinogenic Risks

Procedures for estimating the incremental lifetime cancer risks (ILCRs) as a result of cumulative, lifetime exposure (i.e., a 70-year average life span) to a radionuclide are discussed in the following sections.

E.5.1.1.1 Methodology for Internal Radiation Exposures

Risk characterization for internal exposures to radionuclides (e.g., intake via inhalation or ingestion) is calculated as follows:

$$ILCR_i = (Intake_i)(CSF_i) \qquad (E.5\text{-}1)$$

where

$ILCR_i$	=	Incremental Lifetime Cancer Risk, expressed as a unitless probability
$intake_i$	=	Intake of radionuclide "i" (pCi)
CSF_i	=	Cancer Slope Factor of radionuclide "i" (pCi-1)

E.5.1.1.2 Methodology for External Radiation Exposures

Risk characterization for external exposure to gamma-emitting radionuclides in contaminated surface soil is calculated as follows:

$$ILCR_{ei} = (Intake_{exti})(CSF_{exti}) \qquad (E.5\text{-}2)$$

where

$ILCR_{ei}$	=	Incremental Lifetime Cancer Risk, expressed as a unitless probability
$Intake_{exti}$	=	Intake of radionuclide "i" (pCi-y/g)
CSF_{exti}	=	Cancer Slope Factor (external) of radionuclide "i" $(pCi\text{-}y/g)^{-1}$

External intakes account for contributions to the total risk from decay products (radioactive progeny). For example, the ILCR due to continuous, lifetime external exposure to soil contaminated with Ra-226 and its progeny, assuming secular equilibrium (all members of the decay series disintegrate by the same number of atoms per unit of time), includes the risks contributed by Ra-226 and each decay product that emits photon radiation such as Lead-214 (Pb-214) and Bismuth-214 (Bi-214).

E.5.1.2 Chemical Risks

Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. In addition, some carcinogenic chemicals may also present a toxic (noncarcinogenic) hazard. Potential impacts from these chemicals are characterized for both types of health effects.

E.5.1.2.1 Methodology for Carcinogens

Risks attributed to exposure to chemical carcinogens are estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. At low doses, the ILCR is determined as follows (EPA 1989a):

$$ILCR_i = (Intake_i)(CSF_i) \qquad (E.5\text{-}3)$$

where

ILCR	=	Incremental Lifetime Cancer Risk, expressed as a unitless probability
$Intake_i$	=	Intake of chemical "i" (mg/kg/day)
CSF_i	=	Cancer Slope Factor of chemical "i" $(mg/kg/day)^{-1}$

Risks below 1×10^{-6} (a risk less than 1 in 1 million) are generally considered to be acceptable by the EPA, and risks greater than 1×10^{-4} (1 in 10,000) are generally considered to be unacceptable by the agency (EPA 1990e).

When carcinogenic risks exceed 1×10^{-2} using the above methodology, EPA (1989a) specifies that the one-hit model be used as follows:

$$Risk = 1\text{-}exp^{(-intake)(CSFi)} \qquad (E.5\text{-}4)$$

E.5.1.2.2 Methodology for Noncarcinogens

The risks associated with the effects of noncarcinogenic hazardous chemicals are evaluated by comparing an exposure level or intake to an RfD. The ratio of the intake to the RfD is called the Hazard Quotient (HQ) (EPA 1989a) and is defined as:

$$HQ = Intake_i/RfD_i \qquad (E.5\text{-}5)$$

where

HQ	=	Hazard Quotient (unitless)
$Intake_i$	=	Intake of chemical "i" (mg/kg/day)
RfD_i	=	Reference dose of chemical "i" (mg/kg/day)

Chemical exposures were evaluated using chronic RfD values.

This approach is different from the probabilistic approach used to evaluate carcinogens. An HQ of 0.01 does not imply a 1 in 100 chance of an adverse effect, but indicates only that the estimated intake is 100 times less than the reference dose. An HQ of unity (1) indicates that the intake is equal to the RfD. If the HQ is greater than 1, exposure to that chemical at detected concentrations have the potential to cause adverse health effects.

E.5.1.3 Exposures to Multiple Constituents

Environmental media at Operable Unit 1 contain multiple chemicals and radioactive constituents. For a given pathway with simultaneous exposure of a receptor to several carcinogens, the following equation is used to sum cancer risks:

$$Risk_P = Risk\ (chem_1) + Risk\ (chem_2) + \ldots\ Risk\ (chem_i) \qquad (E.5\text{-}6)$$

where

$Risk_P$ = Total pathway risk of cancer incidence
$Risk\ (chem_i)$ = Individual carcinogenic chemical risk

In the case of simultaneous exposure of a receptor to several noncarcinogens, a Hazard Index (HI) is calculated as the sum of the HQs by:

$$HI = HQ_1 + HQ_2 + \ldots + HQ_i \qquad (E.5\text{-}7)$$

When hazard indices exceed unity, target organ effects become important to refine risk estimates (EPA 1989a). The primary target organ for systemic effects is presented in Table E.4-3. The usefulness of target organ assessment diminishes greatly when the hazard index greatly exceeds unity or when all of the hazard posed is exerted by one or two chemicals and pathways. This is the case in the Operable Unit 1 systemic assessment; when the Hazard Index exceeds 1.0, one or more individual chemicals have Hazard Quotients that also exceed 1.0. Therefore, target organ analysis will not be pursued in this baseline risk assessment.

E.5.1.4 Multiple Pathways

Multiple exposure pathways are assumed for the hypothetical receptors evaluated in this assessment. The risks from various exposure pathways are additive to a receptor experiencing more than one of them. For example, the risks from drinking water and the risks from inhalation incurred by the same individual are summed to determine the total risk to that receptor.

E.5.2 RISK ESTIMATES FOR CURRENT SITE CONDITIONS

As described in Section E.3.0, several hypothetical receptor populations are evaluated in the risk assessment for the current land use scenario. All exposures addressed in this section are based on the current source term (i.e., waste pit covers are intact, no surface runoff, etc.).

Two receptors, the trespassing child and the on-property groundskeeper, are assumed to incur exposures while within the operable unit boundaries. Three additional hypothetical receptors are considered to be off-property receptors because they are potentially exposed to constituents that migrate off-property. These receptors are an off-property resident farmer, an off-property resident child and a user of beef and milk products. A "composite" resident is also considered, which assumes a person is exposed to both migrating constituents as well as to food produced on-property, and that the individual trespassed as a child.

This section and all following sections are organized around general risk summary tables that present total radio- and chemocarcinogenic risk and Hazard Indices by exposure route for each receptor. All detailed (i.e., chemical-specific) information is contained in Attachment E.IV.

E.5.2.1 Risk Estimates for Current Land Use with Access Controls

This scenario assumes the government restricts access to the operable unit and maintains the existing engineering controls on the waste pits. Risks to three receptors were evaluated under this land use scenario:

- A groundskeeper
- An off-property resident farmer
- An off-property resident child

Air modeling was used to identify the points of maximum on-property and off-property risk. In brief, once the transport criteria were fixed and the source (soil) concentrations were input, the resulting air concentrations were combined with the composite radiological and chemical intake and dose-response factors to determine the grid location of maximum risk (Figure E.3-4). In the case of on-site exposures, this point was the 0,0 coordinate, which is located in the center of the Burn Pit. The point of maximum risk off-property is identified as a point at the fenceline approximately 450 meters west and 150 meters south of the center of the Burn Pit. All risks discussed for the on-site and off-site air concentrations for this land use, access control, and source term configuration are based on the predicted air concentrations at that point, for whatever time frame is specified for a particular scenario/receptor.

E.5.2.2 Risks to the Groundskeeper

The hypothetical groundskeeper is an adult who is expected to be occupationally exposed on a routine basis over a period of 25 years. This receptor is assumed to receive exposures from incidental ingestion of soil, dermal contact with soil, inhalation of fugitive dust, and from external gamma radiation from both buried waste pit material and surface soil. The exposure input parameters used in evaluating this receptor were presented in Table E.3-17. Detailed chemical-specific risk estimates and hazard quotients are presented in Tables E.IV-1 and E.IV-2, and are also summarized in Tables E.5-1 and E.5-2. Note that cancer risks for chemicals in Table E.5-1 are presented two ways. The first method was based on the toxicity equivalency factor (TEF) approach for assessing risk to potentially carcinogenic polynuclear aromatic hydrocarbons (PAHs). The second method was based on the assumption that all carcinogenic PAHs have the same cancer slope factor as benzo(a)pyrene. Both approaches are presented to allow a comparison of results.

Radionuclides

Inhalation of fugitive dust, and penetrating radiation from both soil and buried waste pit materials are the primary exposure routes of concern for this receptor. Uranium and thorium isotopes are the primary contributors to the inhalation risk; and uranium, thorium, and radium isotopes produce the most significant external gamma exposures. The total risk from radionuclides for this receptor are 1×10^{-4}.

Chemical Carcinogens

Dermal contact exposures under the defined exposure scenario produce calculated risks of 1×10^{-5}. This risk is due to the presence of beryllium and PCBs at concentrations 0.8 mg/Kg and 1.4 mg/kg in on-property surface soils.

Chemical Toxicants

Most of the metals found in the soil are not toxic via inhalation. Direct contact exposures produce a Hazard Index of 0.3 for this receptor; therefore, the potential for systemic effects are low. Dermal absorption of uranium (413.5 mg/Kg) in surface soil is the primary driver of the Hazard Index. The estimated Hazard Index for soil ingestion is 0.03. These Hazard Indices are well below unity, and therefore the onset of toxic effects is unlikely for this receptor.

E.5.2.3 Risks to the Off-Property Resident Farmer

At the current time, no homes are located at the point of maximum risk via the air exposure pathways. However, a hypothetical receptor was developed based on the assumption that he would be subject to indirect (air) exposures from the property for a period of 70 years. A more detailed description of this receptor and the parameter values used in calculating risks are presented in Section E.3.5 of this report. For the current scenarios, this receptor's risks are also summarized on Tables E.5-1 and E.5-2. Detailed, chemical-specific risks and hazard quotients are presented in Tables E.IV-3 and E.IV-4.

Radionuclides

The hypothetical off-property resident exposed to the predicted concentrations of radionuclides in air incurs a total calculated risk of 3×10^{-6}, as shown in Table E.5-1. Table E.IV-3 indicates that these risks are primarily associated with inhalation of thorium and uranium isotopes. Risks from inhalation constitute almost 100 percent of the total air pathway risks.

Chemical Carcinogens

Exposure of the off-property resident adult is also considered for the predicted air concentrations of chemicals originating in the surface soil at the FEMP. Multiple exposure routes are considered, such as inhalation of dust and ingestion of foodstuffs affected by dust. The risk from any one of the food pathways exceed the risk incurred via inhalation. A hypothetical receptor is expected to experience a total chemical carcinogenic risk of 2×10^{-7}, which is more than an order of magnitude below the risks attributable to the radionuclides.

There are two major contributors to the total chemical carcinogenic risk. The first is total PCBs, which present the primary component of the food pathways risk. The metals cadmium and beryllium produce the highest risk via inhalation of fugitive dust.

Chemical Toxicants

A number of metals were found in the surface soils, and are subject to off-property transport via fugitive dust emissions. While many of these metals are not toxic via inhalation, aerial deposition on foodstuffs can contribute to the total Hazard Index. As shown in Table E.5-2, the total Hazard Index for this receptor is 0.00027.

E.5.2.4 Risks to the Off-Property Resident Child

A hypothetical child receptor was developed to compliment the off-property resident adult and permit evaluation of health risks to a critical potential subpopulation. This receptor is based on the assumption that the individual would be subject to indirect (air) exposures from the property for a period of 6 years. A more detailed description of this receptor and the parameter values used in calculating risks are presented in Section E.3.5 of this report. For the current scenarios, this receptor's risks are also summarized on Tables E.5-1 and E.5-2. Detailed, chemical-specific risks and hazard quotients are presented in Tables E.IV-5 and E.IV-6.

Radionuclides

The hypothetical off-property child who is exposed to the predicted concentrations of radionuclides from air incurs a total calculated risk of 2×10^{-7}, as shown in Table E.5-1. Table E.IV-5 indicates that these risks are primarily associated with the presence of thorium and uranium isotopes. Risks from inhalation constitute almost 100 percent of the total air pathway risks.

Chemical Carcinogens

Exposure of the off-property resident child is also considered for the predicted air concentrations of chemicals originating in the surface soil at the FEMP. Risks from any one food pathway exceed the risks incurred via inhalation. This hypothetical receptor is expected to experience total chemical carcinogenic risks of 8×10^{-8}.

There are two major contributors to the total chemical carcinogenic risks. The first is total PCBs, which present the primary component of the food pathways risks. The metals cadmium and beryllium produce the highest risks via inhalation of fugitive dust.

Chemical Toxicants

A number of metals were found in the surface soils, and are subject to off-property transport via fugitive dust emissions. While many of these metals are not toxic via inhalation, the fallout on foodstuffs can contribute to the total Hazard Index. As shown in Table E.5-2, the total Hazard Index for this receptor is 0.0013.

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E.5.3 CURRENT LAND USE WITHOUT ACCESS CONTROLS

This scenario assumes industrial use of the site continues and that access controls and engineering controls on the property are relaxed or discontinued. Over time, uncontrolled erosion and subsidence could expose waste. Therefore, both the current and future source term configurations were considered when evaluating this land use scenario.

Air modeling was used to identify the points of maximum on-property and off-property risk for both source term configurations. Once the transport criteria were fixed and the source (soil) concentrations were input, the resulting air concentrations were combined with the composite radiological and chemical intake and dose-response factors to determine the grid location of maximum risk (Figure E.3-4). In the case of on-site exposures, this point was the 0,0 coordinate, which is located in the center of the Burn Pit. The point of maximum off-property risk is identified as a point at the fenceline approximately 450 meters west and 150 meters south of the center of the Burn Pit. All risks discussed for the on-site and off-site air concentrations for these land uses, access control and source term configurations are based on the predicted air concentrations at that point, for whatever time frame is specified for a particular scenario/receptor.

The groundwater modeling exercise for the future source term determined the location of the maximum carcinogenic risk in much the same manner as that described for the air modeling. A grid was established, and once the contaminant plume migration was predicted for each grid node, the composite intakes and risks were applied to the predicted concentrations of each modeled constituent at each node. Once the point of maximum risk was determined, the concentrations of all contaminants at that point were evaluated. The point of maximum off-property risk via groundwater exposure is located east of the fenceline (Figures E.5-1 and E.5-2). Modeled constituents are estimated to reach a maximum total risk at that location in approximately 680 years. The point of maximum on-property risk is located just down-gradient of Waste Pit 4, (Figures E.5-1 and E.5-2) and the maximum concentrations leaching from the waste pits is expected in 630 years. These receptor locations were shown in Figure E.3-4.

E.5.3.1 Current Source Term Configuration

Risks to five hypothetical receptors and one composite receptor were assessed under this current land use scenario using the current source term:

- A groundskeeper
- An off-property resident farmer
- An off-property resident child
- A trespassing youth
- A person ingesting meat and milk products from animals grazed and watered on the operable unit.
- A composite off-property receptor combining some of the behaviors of the trespassing youth, off-property resident farmer, and the off-property user of meat and milk products.

Risks to the groundskeeper, the off-property resident farmer, and the off-property resident child are the same as those presented under current land use with access controls (Section 5.2.1). Risks to the trespassing youth and the off-property user of meat and milk products are presented below.

E.5.3.1.1 Risks to the Trespassing Youth

The hypothetical trespassing youth is postulated to receive exposures while wandering randomly through the study area, and is evaluated to explore potential risks to a subpopulation of potential concern. This receptor is assumed to be an older child, aged 6 to 18 years old. A more detailed description of this receptor and the parameter values used in calculating risks are presented in Section E.3.5 of this report. Chemical-specific risk estimates and hazard quotients are presented in Tables E.IV-7 and E.IV-8, and are summarized by pathway and media in Tables E.5-1 and E.5-2.

Radionuclides

The measured and modeled concentrations of radionuclides in surface soil and air produce a total calculated risk of 5×10^{-5}, as shown in Table E.5-1. Penetrating radiation from buried waste pit material, and external gamma exposure to uranium isotopes in surface soil contribute over 95% of the total risk. Uranium and thorium isotopes (in equilibrium with their short-lived daughters) are the primary radionuclides of concern in the air and account for almost 100 percent of the risk from inhalation.

Chemical Carcinogens

If exposed to the concentrations of contaminants currently found in surface soil or modeled to exist in air, the trespassing child would incur total calculated risks of 9×10^{-6}. These total

risks include risks of about 9 x 10^{-6} from dermal contact and incidental ingestion of soil containing total PCBs and beryllium. Dermal contact with soil produces over 95 percent of the total incremental cancer risks from chemicals.

Chemical Toxicants

Dermal contact with current measured concentrations of noncarcinogenic chemicals found in the surface soil produce over 97% of the calculated Hazard Index of about 0.5 from all pathways (Table E.5-2). Uranium, cadmium, and antimony are the primary contributors to the total Hazard Index for this receptor. The results indicate exposures to noncarcinogenic compounds by a trespassing child would be unlikely to result in any adverse (toxic) health effects.

E.5.3.1.2 Risks to the Off-Property User of Meat and Milk Products

The final receptor considered under the current land use/current source configuration is an off-property adult who routinely (over a period of 70 years) ingests meat and milk products from cows grazed and watered in the Operable Unit 1 area. This scenario is based on the current surface soil and surface water concentrations, and uses the exposure input parameters presented in Table E.3-17. This receptor could only be exposed should land use controls be discontinued. The risks are summarized in Tables E.5-1 (carcinogenic risks) and E.5-2 (Hazard Indices). Tables E.IV-9 and E.IV-10 present the detailed risks and hazard quotients for each chemical, exposure route, and medium.

Radionuclides

The total incremental lifetime cancer risk incurred by the off-property user of meat and milk products produced on site is 7 x 10^{-4} for the radionuclides. Ingestion of milk products is the route that produces the maximum risks. This exposure scenario's risks are driven by the uranium isotopes, Tc-99, Sr-90, and Cs-137. With the exception of the uranium isotopes, which were found at high activities, Tc-99, Sr-90, and Cs-137 are highly mobile in the environment and readily transfer from soil to the food chain.

Chemical Carcinogens

For this scenario and receptor, biotransfer from soil to plant material and hence to meat or milk controls the total carcinogenic risks from chemicals. Total risks to the off-property

resident exposed in this manner are about 9 x 10^{-4}, and is almost solely attributable to soil biotransfer of PCBs and benzo(a)pyrene to meat and milk.

Chemical Toxicants

This off-property receptor adult incurs a Hazard Index of 2.9 via all routes of exposure. Ingestion of meat from cows grazed on the property produces a Hazard Index greater than 1.0. Antimony, cadmium, and uranium are the primary contributors to the Hazard Index for food pathways originating in soil, while silver is most significant for the water pathways. These Hazard Indices are summarized in Table E.5-2.

E.5.3.1.3 Risks to a Composite Off-Property Receptor

It is conceivable that a local resident could not only live downwind of the waste pits, but could also ingest locally produced meat or milk products and have trespassed on the site as a child. In this unlikely case, the total risks incurred by this receptor would be the total risks for three of the receptors presented above. When exposures overlap, the more conservative value is considered. For example, both the off-property resident adult and the off-property user of meat and milk products consume animal products at the same rate, only the activity giving the higher exposure (consumption of meat and milk products grown on-site) is counted toward the total exposure to the composite off-property resident.

The total radiological risk would be about 6 x 10^{-4}. This accounts for direct radiation exposures and soil ingestion/dermal contact as a trespassing youth (5 x 10^{-5}), inhalation of dust and ingestion of vegetables and fruits affected by aerial deposition (3 x 10^{-6}), and ingestion of meat and milk products produced on property (5 x 10^{-4}).

The total chemical carcinogenic risk for this composite receptor would be 5 x 10^{-4} for the same routes of exposure. Of the radionuclides, Sr-90 and uranium in the soil are most significant, and total PCBs are the most significant risk drivers for the chemical carcinogens.

The composite HI for this receptor is 3 for all pathways. Again, it is the biotransfer from soil to vegetation and into the food chain that drives this risk. Cadmium, antimony, and uranium are the primary noncarcinogenic analytes in this exposure scenario.

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E.5.3.2 Future Source Term Configuration

Risks to five hypothetical receptors and one composite receptor were assessed for the future source term under this land use scenario:

- An off-property resident farmer
- An off-property resident child
- A trespassing youth
- A person using meat and milk products from animals grazed and water on the operable unit
- A person using the Great Miami River for domestic, agricultural, and recreational use
- A composite off-property receptor combining some of the behaviors of the trespassing youth, off-property resident farmer, and the off-property user of meat and milk products

Risks to the off-property resident farmer, and the off-property resident child are the same as those presented under current land use with access controls (Section 5.2.2.1). Risks to the off-property user of meat and milk products are the same as those under future land use without access controls presented in Section 5.5 below. Risks to the trespassing youth, the Great Miami River User, and composite receptors are presented below.

E.5.3.2.1 Risks to the Trespassing Youth

Under the current land use, future source term configuration, it is possible that an older child could trespass on the property over a period of 12 years. This receptor could be exposed to site-related contaminants via inhalation of fugitive dust and radon, via penetrating gamma radiation from buried waste pit material, and via direct contact with surface soil, exposed waste pit material, surface water, and sediment in Paddys Run that originated as soil within the Operable Unit 1 boundaries. ILCRs and hazard quotients for this receptor are summarized in Table E.5-3 and E.5-4, and the detailed calculations are contained in Tables E.IV-11 and E.IV-12.

Radionuclides

Exposures to fugitive dust emissions and external exposure from exposed waste pit material and surface soil result in roughly equal risks (8×10^{-5} and 1×10^{-4}), and account for almost 100 percent of the total radiocarcinogenic risk (2×10^{-4}) for this receptor. The primary

contributors to this risk are Th-230 and Ra-226 found in the exposed waste pit materials from Waste Pits 3, 5, and 6. Other routes of exposure such as sediment or soil ingestion and external exposure to sediment result in risks one or more orders of magnitude lower.

Chemical Carcinogens

The total chemical carcinogenic risk for the trespassing youth is 1×10^{-4}. Inhalation of fugitive dust, incidental ingestion of soil, and dermal contact with soil result in the greatest individual pathway risks (4×10^{-5}, 4×10^{-5}, and 4×10^{-5}, respectively) for this receptor. These risks are driven by the presence of arsenic and beryllium in the soil. Organic compounds such as PCBs and dioxins result in risks one or more orders of magnitude lower than the metals. For example, total risks for all PCBs via soil ingestion and dermal contact are 3×10^{-6} and all chlorinated dioxins and furans result in total soil pathway risks of 5×10^{-8}.

Chemical Toxicants

Inhalation of resuspended soil produces a Hazard Quotient of 1.9 for this receptor. No one constituent produces a Hazard Index exceeding 1. Dermal contact with soil containing uranium and ingestion of soil containing arsenic contribute almost 60 percent of the Hazard Index for this receptor.

E.5.3.2.2 Great Miami River User

This hypothetical adult receptor is assumed to live adjacent to the Great Miami River and use untreated river water for all domestic uses, as well as for swimming and as a source of fish, over a period of 70 years. The Great Miami River user is evaluated to explore the risks to an off-property subpopulation of concern. A more detailed description of this receptor and the input parameters used to calculate risks is contained in Section E.3. Risks and HIs for this receptor are contained in Tables E.IV-13 and E.IV-14, and are summarized in Tables E.5-3 and E.5-4.

Radionuclides

The total incremental cancer risk from radionuclides incurred by this hypothetical receptor is 3×10^{-7}, which is within the range generally considered to be acceptable (EPA 1990e). Of all the pathways evaluated, routine ingestion of the river water as a potable water source produces over 70 percent of the risk. U-238, which is predicted to reach the river at a

concentration of 0.1 pCi/L, contributes about 80 percent of the risks from drinking water. U-234 and Sr-90 make up essentially all of the remaining risk from radionuclides.

Chemical Carcinogens

The total incremental cancer risk from chemical carcinogens in river water is about 3×10^{-8}. Ingestion of fish dominates this pathway, contributing 60 percent to the total. Total PCB's in fish are calculated to produce risks of 2×10^{-8}.

Chemical Toxicants

The Hazard Quotient for this receptor is 0.004. The predicted level of uranium in the river water is the major contributor to this HI.

E.5.3.2.3 Risks to a Composite Off-Property Receptor

A composite off-property receptor is also considered in this risk assessment. It is considered possible that a local resident could trespass on the site, live downwind or down-gradient of the site as an adult, and regularly ingest meat or milk products grown on property.

Radionuclides

The total radiological risks associated with these multiple exposures are 1×10^{-3}. Uranium and thorium isotopes (for the direct contact and inhalation scenarios) and U-238 (for the food ingestion pathways) are the most significant contributors to the risk.

Chemical Carcinogens

Arsenic, beryllium, and benzo(a)anthracene found in the soil drive the carcinogenic risks for this hypothetical composite receptor. The food pathways (ingestion of fruits and vegetables affected by dust from the site, ingestion of meat and milk products from cows grazed on the site) and dermal contact cause the major portion of the risk. The total pathway risk for this receptor from carcinogenic chemicals is about 1×10^{-3}.

Chemical Toxicants

There are several metals that contribute to the Hazard Index of 20 for the composite off-property receptor. Uranium in groundwater contributes over half of this Hazard Index.

E.5.4 FUTURE LAND USE WITH ACCESS CONTROLS (GOVERNMENT RESERVE)

This scenario postulates the government retains ownership of the operable unit and continues to restrict access to the site, but does not maintain the engineering controls of the pits, allowing erosion and subsidence to expose waste. The receptors associated with this scenario include:

- An adult trespasser who also trespassed as a youth (an "expanded trespasser")
- A groundskeeper
- An off-property resident farmer
- An off-property resident child
- A person using meat and milk products from animals grazed and water on the operable unit.
- A person using the Great Miami River for domestic, agricultural, and recreational use.
- A composite off-property receptor combining some of the behaviors of the adult trespasser, the off-property resident farmer, and the off-property user of meat and milk products.

Risks to the off-property resident farmer, off-property resident child, and off-property user of meat and milk products are the same as those presented under future land use with the future source term. The Great Miami River user is the same as those listed under current land use with the future source term (Section 5.3). Risks to the remaining receptors are presented below.

E.5.4.1 Expanded Trespasser

The hypothetical trespassing adult is assumed to receive exposures while wandering randomly through the study area, and is evaluated to explore potential risks to a subpopulation of potential concern. A more detailed description of this receptor and the parameter values used in calculating risks are presented in Section E.3.5 of this report. Chemical-specific risk estimates and hazard quotients are presented in Tables E.IV-15 and E.IV-16, and are summarized by pathway and media in Tables E.5-5 and E.5-6.

Radionuclides

The measured and modeled concentrations of radionuclides in surface soil and air produce a total calculated risk of 4×10^{-4}, as shown in Table E.5-5. Air (inhalation exposures only), penetrating radiation from buried waste pit material, and external gamma exposure to

radionuclides in surface soil contribute most of the total radiological risks from the air. Uranium and thorium isotopes (in equilibrium with their short-lived daughters) are the primary radionuclides of concern in the air and account for almost 100 percent of the total radiological risks from the air. Uranium, thorium, and radium isotopes are the primary components of the external exposure risk.

Chemical Carcinogens

If exposed to the concentrations of contaminants currently found in surface soil or predicted to exist in air, the expanded trespasser would incur a total risk of 3×10^{-4}. This total risk includes 6×10^{-5} from the inhalation of fugitive dust containing arsenic and chromium VI, and a risk of about 2×10^{-4} from dermal contact with total PCBs, arsenic, and beryllium.

Chemical Toxicants

The current measured concentrations of noncarcinogenic chemicals found in the surface soil and predicted concentrations of these contaminants in air produce calculated Hazard Indices of about 0.3 from inhalation of fugitive dust, 0.5 from incidental ingestion, and 3 from dermal contact with soil, for a total Hazard Index of 4 from all pathways. Hazard Indices are summarized in Table E.5-6. Dermal contact with soil containing uranium is the primary contributor to the total Hazard Index for this receptor (Hazard Index = 2). The results indicate that exposure to uranium in soil by the expanded trespasser suggests that adverse health (toxic) effects are possible under the proposed conditions.

E.5.4.2 Groundskeeper

The proposed groundskeeper scenario evaluates exposures and health impacts of an adult who receives occupational exposures during landscaping and routine maintenance activities within the operable unit boundaries. As stated in Section E.3, this receptor is expected to come into direct contact with the soil, and be exposed via inhalation of fugitive dust and external gamma radiation from both buried waste pit material and surface soil. The exposure input parameters used in evaluating this receptor were presented in Table E.3-17. Detailed chemical-specific risk estimates and hazard quotients are presented in Tables E.IV-17 and E.IV-18, and are also summarized in Tables E.5-5 and E.5-6.

Radionuclides

Inhalation of fugitive dust, and external exposure to radionuclides in soil, are the primary exposure routes of concern for this receptor. Uranium and thorium isotopes are the primary contributors to the inhalation risk, while thorium and radium isotopes produce the most significant external gamma exposures. The total risks from radionuclides for this receptor are 1×10^{-3}.

Chemical Carcinogens

The total incidental risk from chemical carcinogens for the groundskeeper is 4×10^{-4}. The inhalation risk under the defined exposure scenario is 2×10^{-4}, while incidental ingestion of soil contributes an additional 40% of the total risks. These risks are due primarily to the presence of arsenic and beryllium in surface soil and resuspended dust.

Chemical Toxicants

As with the expanded trespasser, cobalt (Hazard Quotient = 0.2), barium (Hazard Quotient = 0.2), and manganese (Hazard Quotient = 0.2) in fugitive dust are the primary drivers of the Hazard Index for inhalation. Arsenic in ingested soil (Hazard Quotient = 0.9) and dermal absorption of uranium from soil (Hazard Quotient = 0.4) contribute most of the remaining Hazard Index. The estimated HI is 2.2 for all routes of exposure.

E.5.5 FUTURE LAND USE WITHOUT ACCESS CONTROLS

This scenario assume the government relinquishes ownership of the site. Access controls are discontinued, allowing neighboring land uses to encroach on the site. Maintenance of engineering controls cease, allowing erosion and subsidence to expose waste. Since maximum exposures to the remaining receptors occur in the future when waste pit material is exposed and runoff control does not exist, the probability of adverse human health effects is greater than with the current source term configuration. Risks to five hypothetical on-site and four hypothetical off-site receptors were evaluated for the future source term under this land use scenario:

- An on-property RME farmer
- An on-property child
- An on-property CT farmer
- An on-property farmer using water from pockets of perched water

- A person building a home
- An off-property resident farmer
- An off-property resident child
- A person using meat and milk products from animals grazed and water on the operable unit.
- A person using the Great Miami River for domestic, agricultural, and recreational use.

Risks to the Great Miami River User are the same as those discussed under current land use with the future source term (Section 5.3). Risks to these remaining receptors are presented below.

E.5.5.1 On-Property RME Farmer

This receptor is defined as an on-property resident farmer who spends his entire lifetime living and working on the Operable Unit 1 area. He receives direct exposures from a number of media by virtue of spending his life on property. The point of maximum exposure for this individual is considered to be in the vicinity of Waste Pit 4 and the Burn Pit (Figure E.3-4). The total risks for this receptor are summarized in Table E.5-7 (carcinogenic risks) and E.5-8 (Hazard Indices), and chemical-specific risks and hazard quotients are contained in Tables E.IV-19 and E.IV-20.

Radionuclides

External exposure to radionuclides in surface soil and waste pit materials contribute about 60 percent to the total risk of 5×10^{-2}. Uranium, radium and thorium isotopes in the soil/waste pit material are the major contributors to the risk (45 percent). Ingestion of groundwater and crops irrigated with groundwater at the predicted time of maximum risk (after 500 years) would result in calculated risks of 2×10^{-2} and 5×10^{-3}, respectively. Isotopes of uranium and thorium are the major contributors to the ingestion risk. Inhalation of fugitive dust contributes another 5×10^{-3}.

Other pathways and exposures are much smaller than these calculated risks. For example, risks associated with exposures to radon entering a home from the soil beneath it are about 1×10^{-7}.

Chemical Carcinogens

The total risk associated with exposure to chemical carcinogens (5×10^{-2}) is due primarily to various exposures to groundwater containing carcinogenic metals such as arsenic, and the incidental ingestion soil. Soil pathway risks are driven by the presence of arsenic in the soil.

Chemical Toxicants

The total Hazard Index for the on-property RME resident is 540. While the numbers should not be interpreted as a probability, it can be said that groundwater represents the most significant portion of this total (Hazard Index = 360). Ingestion of crops irrigated with groundwater (HI = 120), and incidental ingestion of soil (HI = 17) are also likely to result in adverse (toxic) health effects. Uranium, antimony, and arsenic contribute over 90 percent to the total Hazard Index for groundwater exposures.

E.5.5.2 On-Property Child

This hypothetical child receptor is assumed to reside within the Operable Unit 1 study area for a period of 6 years. A more detailed description of this receptor and the parameter values used in calculating risks are presented in Section E.3.5 of this report. This receptor is evaluated to assess the impacts of chemicals on the critical subpopulation of children assumed to reside within the operable unit.

The carcinogenic risks for this receptor are summarized in Table E.5-7, and the Hazard Indices are summarized in Table E.5-8. Detailed results are contained in Tables E.IV-21 and E.IV-22.

Radionuclides

The total radiocarcinogenic risk for the RME child receptor is estimated at 3×10^{-3}, which is an order of magnitude less than that predicted for the RME resident adult receptor. External exposure to exposed waste pit material and ingestion of contaminated groundwater together present almost 80 percent of the total risk. Uranium, thorium, and radium isotopes are the primary constituents of this risk.

Chemical Carcinogens

Table E.5-7 indicates that the total chemical carcinogenic risks from all evaluated pathways is 2×10^{-2}. Ingestion of drinking water from the Great Miami aquifer and ingestion of fruits

and vegetables irrigated with groundwater contribute about half of the total risk. Metals are the primary carcinogenic constituents.

Another 25 percent of the total risk is caused by direct exposures to surface soil and exposed waste pit material. Arsenic, beryllium, and total PCBs contribute most of the total risk.

Chemical Toxicants

The total Hazard Index for the RME child is 1600, as shown on Table E.5-8. The results of the risk assessment indicate that ingestion of groundwater contributes over 50 percent of the total Hazard Index. Food pathways also play a major role in the risk, both via air pathways and groundwater pathways. Uranium in soil and exposed waste pit material and groundwater is one of the major toxicants acting on potential child receptors at this facility.

Concentrations of lead in soil at Operable Unit 1 were compared to interim soil cleanup levels of 500 to 1000 ppm, which is recommended for use at Superfund sites where current or predicted land use is residential (EPA 1989k). The area-weighted average lead concentration of 52 ppm for Operable Unit 1 soils is well below this recommended range, indicating that lead levels are not expected to pose a significant health hazard to sensitive receptors, including children.

E.5.5.3 On-Property CT Farmer

This hypothetical receptor is defined as residing on the Operable Unit 1 study area for a period of 9 years, with all exposure routes considered using the parameters presented in Table E.3-18. Although this receptor is similar to the RME resident adult discussed in the preceding section, parameter values have been selected to evaluate risks that are closer to the expected average values.

As suggested by EPA guidance (EPA 1992d), the resident CT adult is included in this assessment because calculated risks to this receptor provide a useful perspective on the uncertainty involved with exposure parameters used in calculating risks to the RME adult. While the central tendency evaluation calculates an incidence of health effects that is closer to the expected average incidence rate, it is important to note that many of the parameter values used exceed the average values.

The risks for this receptor are also presented in Tables E.5-7 and E.5-8. Chemical-specific information on risks and individual pathways is contained in Tables E.IV-23 and E.IV-24.

Radionuclides

The overall risk from radionuclides for the CT receptor (4×10^{-3}) is about 10 percent of that calculated for the RME receptor (5×10^{-2}). The primary sources of risk (i.e., pathways, media, and contaminants) follow approximately the same distribution.

Chemical Carcinogens

Calculated incremental lifetime cancer risks from chemical exposure for the CT resident adult total 4×10^{-3}, without consideration of ingestion of water from the perched aquifer. Again, the carcinogenic metals like arsenic drive the risks, especially via ingestion of drinking water and ingestion of fruits and vegetables. Ingestion of surface soil while working outdoors is also a notable component of the total risk.

Chemical Toxicants

The toxic effects due to on-property exposures via food ingestion pathways followed closely by groundwater ingestion dominate the total Hazard Index (290) for this receptor. Ingestion of drinking water and ingestion of food crops affected by aerial deposition are the primary components of this HI. Again, the toxic metals drive this risk, particularly arsenic and uranium.

E.5.5.4 On-Property RME Farmer Using Perched Water for Domestic Purposes

This receptor is defined as an on-property resident farmer who spends his entire lifetime living and working on the Operable Unit 1 area. The single distinguishing difference between this receptor and the resident farmer discussed in Section E.5.5.1 is the source of the individual's domestic water. This receptor uses water from the pockets of perched water within the operable unit. Because the perched water is unlikely to provide a consistent water supply for routine agricultural uses, only ingestion and domestic water use are considered for this medium. As in the previous case, this resident farmer also receives direct exposures from a number of media by virtue of spending his life on property. The point of maximum exposure for this individual is considered to be in the vicinity of Waste Pit 4 and the Burn Pit. The total risks for this receptor are summarized in Table E.5-7 (carcinogenic risks) and E.5-8

(Hazard Indices), and chemical-specific risks and hazard quotients are contained in Tables E.IV-25 and E.IV-26. 5899

Radionuclides

The total radionuclide risk for this receptor is calculated to be 6 x 10^{-1}, using the one-hit risk model. Calculated risks from ingestion of perched groundwater containing 429,000 Pci/L of uranium (6 x 10^{-1}, using the one hit risk model) dominate the risks from all other pathways combined.

Chemical Carcinogens

The total risk associated with exposure to chemical carcinogens (9 x 10^{-1}, using the one hit model). Risks associated with bathing in water from the perched aquifer are calculated to be about 80 percent of the risk. This risk is mainly attributable to the presence of total PCBs and total tetrachlorodibenzofuran. Other dioxins and furans also contribute significant additions to the risks from dermal contact exposures. Ingestion of groundwater contributes most of the remaining risks.

Chemical Toxicants

The total Hazard Index for the on-property RME resident is 6100. While the numbers should not be interpreted as a probability, it can be said that ingestion of uranium, molybdenum, and thallium in water contribute over 90 percent of the total Hazard Index.

E.5.5.5 Off-Property Resident Adult Farmer

This receptor has the same characteristics as the off-property resident evaluated under the current source term. The only difference is that this person could now experience additional exposures related to changes in the site configuration, such as erosion of soil caps over the waste pit material and increased leaching. The cancer risks and hazard quotients for this receptor are summarized in Tables E.5-7 and E.5-8, and the detailed chemical-specific information is contained in Tables E.IV-27 and E.IV-28. Total carcinogenic risks for all groundwater routes of exposure are shown in Figures E.5-1.

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Radionuclides

The total radiocarcinogenic risks calculated for this hypothetical receptor are 2 x 10^{-3}. The most significant routes of exposure for the off-property resident are the inhalation of fugitive dust (2 x 10^{-4}), ingestion of fruits and vegetables irrigated with groundwater (4 x 10^{-4}) and ingestion of drinking water (1 x 10^{-3}). The risks associated with uranium and thorium isotopes is about 98 percent of the total risk from inhalation. U-238 contributes more than 80 percent of the drinking water ingestion risks and about 85% of the total radiological risks for all groundwater pathways (including food ingestion).

Chemical Carcinogens

None of the modeled groundwater chemical constituents reaching the fenceline are carcinogenic via ingestion and therefore carcinogenic risks via the groundwater pathway are zero. Arsenic and nickel are carcinogenic via inhalation but metals do not volatilize during showering. The total chemical carcinogenic risk for the off-property RME resident is 3 x 10^{-4}, ingestion of fruit and vegetables contaminated by air transport accounts for over 50 percent of the total. Predicted levels of arsenic in fugitive dust emissions contribute over 95% percent of the total calculated risk for all pathways.

Chemical Toxicants

As shown in Table E.5-8, the total Hazard Index for all exposure routes for the off-property RME resident is 32. Uranium is the only constituent producing a calculated Hazard Index greater than 1 (HI = 30) Ingestion of uranium in groundwater produces about 70 percent of the total Hazard Index. Uranium in vegetables irrigated with ground water contributes another 20 percent to the total.

E.5.5.6 Off-property Resident Child

This receptor has the same characteristics as the off-property resident adult farmer evaluated under the future source term (Section E.5.5.7). This child (ages 0 to 6) could now experience additional exposures related to changes in the site configuration, such as erosion of soil caps over the waste pit material and increased leaching. The cancer risks and hazard quotients for this receptor are summarized in Tables E.5-7 and E.5-8, and the detailed chemical-specific information is contained in Tables E.IV-29 and E.IV-30.

Radionuclides

The total radiocarcinogenic risk calculated for this hypothetical receptor is 1 x 10^{-4}. The most significant routes of exposure for the off-property child are ingestion of groundwater (6 x 10^{-5}), and ingestion of fruits and vegetables irrigated with groundwater (3 x 10^{-5}). U-238 contributes more than 80 percent of the drinking water ingestion risk and about 85 percent of the total radiological risk for all groundwater pathways.

Chemical Carcinogens

None of the modeled groundwater chemical constituents reaching the fenceline are carcinogenic via ingestion and therefore carcinogenic risks via the groundwater pathway are zero. Arsenic and nickel are carcinogenic via inhalation but metals do not volatilize during showering. The total chemical carcinogenic risk for the off-property RME resident child is 7 x 10^{-5}, ingestion of fruit and vegetables contaminated by aerial deposition accounts for over 70 percent of the total. Predicted levels of arsenic in fugitive dust emissions contribute over 95% percent of the total calculated risk for all pathways.

Chemical Toxicants

As shown in Table E.5-8, the total Hazard Index for all exposure routes for the off-property RME resident child is 90. Uranium is the only constituent producing a calculated Hazard Index greater than 1 (HI = 87). Ingestion of uranium in groundwater produces about 70 percent of the total Hazard Index. Uranium in vegetables irrigated with ground water contributes another 20 percent to the total.

E.5.5.7 Home Builder

The home builder spends 175 days in one year on the property while building a house. A more detailed description of this receptor and the parameter values used in calculating risks are presented in Section 3.3 of this report. This receptor is evaluated to assess the impacts of chemicals on anyone building a home within the operable unit. Health impacts from this activity may be considered by themselves or in combination with other RME receptor activities such as the on- or off-property RME adult or the trespassing child. However, given the fact that these total risks are one or more orders of magnitude lower than the risks presented for the future residents, they would have little impact on the overall risk.

This receptor is assumed to be exposed to surface soils and exposed waste pit materials. Ingestion and dermal contact with the soil, inhalation of fugitive dust, and external radiation exposures were considered for this receptor. The risks are summarized in Tables E.5-7 and E.5-8, and details are presented in Tables E.IV-31 and E.IV-32.

Radionuclides

The total radiocarcinogenic risks experienced by this hypothetical receptor is 2×10^{-4}. This risk is largely due to inhalation of Th-230 and U-238 in dust. A second significant exposure is attributable to external radiation from Ra-226 and Th-232 in soils. These two exposures routes provide about 94 percent of the total radiological risk to the homebuilder.

Chemical Carcinogens

Chemical carcinogenic risks (2×10^{-4}) for this receptor are comparable to the radiocarcinogenic risk. Inhalation of fugitive dust and incidental ingestion of soil containing arsenic contributes about 95 percent of the total risks.

Chemical Toxicants

The Hazard Index resulting from ingestion of soil while building a home (6) is primarily caused by the presence of arsenic in surface soil. The total Hazard Index from all pathways for this receptor is 60.

E.5.5.8 Off-Property User of Meat and Milk Products

This receptor was described in detail in Sections E.5.2.2.2 and E.3 of this report. The total carcinogenic risks and Hazard Indices experienced by this receptor are contained in Tables E.5-7 and E.5-8, and chemical-specific risks for each pathway/medium combination are contained in Tables E.IV-33 and E.IV-34.

Radionuclides

The total incremental lifetime cancer risk from radionuclides associated with the production of food on the Operable Unit 1 area approaches 8×10^{-4}. Ingestion of dairy products over a period of 70 years by this hypothetical off-property receptor contributes over 80% of the risks, due primarily to U-238, Cs-137, and Tc-99 in water; and to U-238 and Sr-90 in surface soil.

Chemical Carcinogens

As with the current land use/source term configuration, it is the ingestion of food products from cows grazed on property (versus livestock watering on property) that drive the risks. Ingestion of meat results in a total risk of 2×10^{-3}, and ingestion of milk has an associated risk of 6×10^{-4}. Total PCBs and arsenic are the major components of the total risk for these pathways. Total risks associated with cows drinking surface water from the pits are lower (6×10^{-6}) than from the soil pathways (8×10^{-4}) or air pathways (8×10^{-4}) and are the result of the presence of arsenic in the on-site water-filled waste pits at weighted average concentration of 0.002 mg/L.

Chemical Toxicants

The total Hazard Index from the food pathways originating in soil, surface water, and air deposition on soil is 4.9. Grazing of cows in areas containing arsenic, antimony, cadmium, silver, or uranium can result in an unacceptable Hazard Index to the defined receptor.

E.5.6 SUMMARY OF HEALTH RISK CHARACTERIZATION

The selection of CPCs for evaluation in this baseline risk assessment was a key step in the risk assessment process. Contaminants were selected on the basis of the history of site operations and an evaluation of characterization data with respect to the distribution and concentration of contaminants in the various media at the site and the potential contribution of individual contaminants to overall health effects. Confidence is high that the significant contaminants were identified because considerable information is available from the site characterization effort and few contaminants were eliminated as CPCs. The CPCs include 15 long-lived radionuclides and numerous chemicals consisting of metals and organic compounds such as PAHs, PCBs, and dioxins and furans. Most of the radionuclides have short-lived daughters that are evaluated concurrently with the parent radionuclides, unless specifically included. Low levels of radionuclides are spread throughout the soils of Operable Unit 1. Eight waste pits contain large inventories of waste with high concentrations of a number of chemicals and radionuclides.

Cancer induction is the only health effect considered for the radionuclides detected in Operable Unit 1 with the exception of total uranium. Many of the chemicals are classified as carcinogenic and were evaluated are potential carcinogens. This assessment indicates that

metals (particularly arsenic) and radionuclides (particularly U-238, Th-232, and their short-lived progeny) are the contaminants contributing most significantly to risks.

Toxic effects other than carcinogenesis are considered for many of the metals and chemicals detected in Operable Unit 1. Several of the metals evaluated are present in concentrations which exceed the levels thought to produce toxic effects. Uranium, arsenic, and antimony are most notable.

Health effects associated with exposures to lead could not be quantitatively assessed because of the unavailability of toxicity values. However, when the UCL concentration of lead in the soil is compared to the EPA's recommended values, the results indicated that lead in soil is not a major concern for the identified exposure routes and site configurations.

Receptors and exposure pathways were identified in this baseline risk assessment on the basis of site-specific considerations of current land use and reasonable projections of future land use that considered the time frame of this analysis. Confidence is high that the main exposure pathways and potential receptors have been identified and evaluated. Although additional receptors and activities could be identified, exposures would be similar to or less than those estimated for the specific receptors and pathways considered in this analysis. Standard (conservative) intake parameters were used for the assessment of the inhalation and ingestion pathways, and, although some uncertainty exists with respect to these values, this uncertainty is not expected to significantly affect the analysis.

The potential for health effects from exposure to site-related contaminants was estimated for on-property receptors and in adjacent off-property areas impacted by site releases. The on-property exposure points evaluated in this baseline risk assessment were operable unit soil, outdoor air and the waste pits. To focus the discussion, the magnitude of the total estimated carcinogenic risks and HIs are discussed relative to remedial action goals for an NPL site, as defined by the EPA (1989a, 1990e). These goals are an ILCR of 10^{-6} to 10^{-4} and an HI not to exceed 1 for toxic effects other than cancer.

E.5.6.1 Summary of Health Effects Under Current Land Use

This section summarizes the calculated health risks for the current land use scenarios. Only the maximally exposed individuals (MEI) are addressed.

Under continuing access controls, a groundskeeper and an off-property farm family are evaluated. The MEI under this land use is the groundskeeper (Tables E.5-9 and E.5-10). The total calculated risks to this receptor approach 1 x 10^{-4}, while the total HI for this receptor is less than unity. External radiation from surface soil and buried pit materials dominates exposures to this receptor (9 x 10^{-5}). Uranium in surface soils and uranium and radium in buried pit materials contribute the largest portion of this radiation exposure. Absorption of beryllium from direct contact with surface soil contributes the largest portion of the chemical risk (about 10 percent of the total risks from both chemical and radiological constituents). In general, the risk assessment has shown that organic chemicals are not a major concern at this site under current land use/source term conditions. For example, the largest single source of carcinogenic risk from an organic chemical to the MEI is dermal contact with PCBs in soil, which produce a calculated risk of about 2 x 10^{-6}.

When access controls are discontinued, it is assumed that maintenance of site engineering controls will also cease. This may eventually expose buried pit material through erosion and subsidence. Therefore, this land use was evaluated using both the current and a potential future source term to explore the impacts of a weathered source term potential receptors. Five receptors were evaluated under this land use. They are the off-property farmer, the off-property child, the Great Miami River User, the off-property user of meat and milk products, and the groundskeeper. The individual exhibiting the highest risks under this land use if the source remains in it current configuration is the off-property user of meat and milk products (Table E.5-11). The risks under the current source term are about 1 x 10^{-3} and are dominated by PCBs taken up by grazing cows. In the future, the off-property farmer is the individual receiving the highest calculated risks (2 x 10^{-3}). Uranium in drinking water contributes more than 50 percent of this risk, and uranium uptake by crops irrigated with uranium add an additional 15 percent. Arsenic on resuspended particulates increases in importance, in future, producing just over 13 percent of the total calculated future risk. Table E.5-12 presents the hazard indices for the maximally exposed individuals. Under the current source term, the MEI for toxic effects is the off-property user of meat and milk products (the same as the MEI for risks). The HI for this individual is just over 2, and is dominated by the uptake of uranium, antimony and cadmium by grazing cows. In the future, the MEI becomes the off-property child, whose HI of about 90 is dominated by uranium in drinking water (70 percent).

E.5.6.2 Summary of Health Effects Under Future Land Use

This section summarizes the calculated health effects for the future land use scenarios evaluated by chemical, by pathway, and by media. Emphasis is given to the constituents which clearly dominate the assessment, and the discussion focuses on the maximally exposed individuals.

If government use of the site changes or ceases, additional uses of the land are possible. To investigate the human health impacts of this possibility, a variety of scenarios were examined. One such land use, government reserve, postulates that ownership of the site is retained by the government, but that site maintenance and strict access controls are relaxed. Six receptors were evaluated under this scenario. They are the off-property farmer, the off-property child, the groundskeeper, the extended trespasser, the off-property user of meat and milk, and the Great Miami River user. The off-property farmer is the individual receiving the highest calculated risks under the government reserve scenario (Table 5-13). The risks to this receptor (2×10^{-3}) are dominated by uranium in groundwater (75 percent), followed by arsenic in air (13 percent). The off-property child receives the highest HI (90, on Table E.5-14). Uranium in drinking water contributes 90 percent of this value.

Unrestricted use of the site was examined by removing the groundskeeper from the list of receptors evaluated for the government reserve, adding a home builder, and placing a farm family within the operable unit boundaries. In this case, the on-property farmer (Table E.5-13) receives the highest calculated risks (1×10^{-1} using the one hit model). Over a third of these risks are attributable to arsenic in groundwater beneath the pits, and over 25 percent of the total risks are from ingestion of arsenic in drinking water. Another twenty percent of the risks are attributable to uranium in groundwater. External radiation from surface soil contributes an additional 20 percent of the risks (2×10^{-2}). The on-property child would be assigned the highest HI. The results presented in Table E.5-14 indicate that 70 percent of the HI for this receptor (HI = 1600) is attributable to uranium in groundwater (70 percent). Another 12 percent is due to arsenic in groundwater. In addition, several of the metals produce exposures that generate HIs exceeding 1 (Table E.IV-22).

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TABLE E.5-1

TOTAL CARCINOGENIC RISKS
CURRENT LAND USE, CURRENT SOURCE TERM [a]

Source Medium	Exposure Route	RECEPTORS WITH ACCESS CONTROLS									ADDITIONAL RECEPTORS WITHOUT ACCESS CONTROLS					
		On-property Groundskeeper			Off-property Farmer			Off-property Young Child			Trespassing Youth			Off-property User of Meat and Milk Products		
		Radiological	Chemical[b] (TEF for PAHs)	Chemical[b] (BaP for PAHs)	Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)	Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)	Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)	Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)
Air																
	Inhalation	6E-06	1E-08	1E-08	3E-06	6E-09	6E-09	2E-07	1E-09	1E-09	7E-07	2E-09	2E-09	NA	NA	NA
	Ingestion of Fruits and Vegetables	NA	NA	NA	2E-08	3E-08	3E-08	2E-09	9E-09	9E-09	NA	NA	NA	NA	NA	NA
	Ingestion of Meat	NA	NA	NA	3E-10	5E-08	5E-08	1E-11	8E-09	8E-09	NA	NA	NA	NA	NA	NA
	Ingestion of Milk Products	NA	NA	NA	3E-09	6E-08	7E-08	6E-10	6E-08	6E-08	NA	NA	NA	NA	NA	NA
Surface Soil																
	Incidental Ingestion	2E-06	1E-06	1E-06	NA	NA	NA	NA	NA	NA	4E-07	4E-07	4E-07	NA	NA	NA
	Dermal Contact	NA	1E-05	1E-05	NA	NA	NA	NA	NA	NA	NA	9E-06	9E-06	NA	NA	NA
	External Exposure	7E-05	NA	NA	NA	NA	NA	NA	NA	NA	3E-05	NA	NA	NA	NA	NA
	Ingestion of Meat	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7E-05	4E-04	5E-04
	Ingestion of Milk Products	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4E-04	5E-04	5E-04
Buried Pit Material																
	External Exposure	5E-05	NA	NA	NA	NA	NA	NA	NA	NA	2E-05	NA	NA	NA	NA	NA
On-property Surface Water																
	Ingestion of Meat	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5E-05	5E-06	5E-06
	Ingestion of Milk Products	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2E-04	6E-07	6E-07
Subtotal:		1E-04	1E-05	1E-05	3E-06	2E-07	2E-07	2E-07	8E-08	8E-08	5E-05	9E-06	9E-06	7E-04	9E-04	1E-03
Total Carcinogenic Risk:			1E-04	1E-04		3E-06	3E-06		2E-07	2E-07		5E-05	5E-05		2E-03	2E-03

NA - Not Applicable. Exposure route not evaluated for this receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum that would result from adding the values in the table, due to rounding. Refer to Attachment E.IV for specific values.

[b] Separate carcinogenic risk values were calculated assuming the toxicity equivalency factors (TEF approach) for PAHs and assuming all PAHs as carcinogenic as benzo(a)pyrene (BaP approach).

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TABLE E.5–2

TOTAL HAZARD INDICES
CURRENT LAND USE, CURRENT SOURCE TERM

		WITH ACCESS CONTROLS			ADDITIONAL RECEPTORS WITHOUT ACCESS CONTROLS	
Source Medium	Exposure Route	Groundskeeper	Off–property Farmer	Off–property Young Child	Trespassing Youth	Off–property User of Meat and Milk Products
Air						
	Inhalation	0.0E+00	0.0E+00	0.0E+00	0.0E+00	NA
	Ingestion of Fruits and Vegetables	NA	1.7E–04	6.8E–04	NA	NA
	Ingestion of Meat	NA	5.7E–05	1.0E–04	NA	NA
	Ingestion of Milk Products	NA	4.9E–05	5.2E–04	NA	NA
Surface Soil						
	Incidental Ingestion	3.4E–02	NA	NA	2.1E–02	NA
	Dermal Contact	2.7E–01	NA	NA	4.7E–01	NA
	External Exposure	NA	NA	NA	NA	NA
	Ingestion of Meat	NA	NA	NA	NA	1.3E+00
	Ingestion of Milk Products	NA	NA	NA	NA	1.4E+00
On–property Surface Water						
	Ingestion of Meat	NA	NA	NA	NA	8.4E–02
	Ingestion of Milk Products	NA	NA	NA	NA	1.5E–01
Total Hazard Index:		3.0E–01	2.7E–04	1.3E–03	4.9E–01	2.9E+00

NA – Not Applicable. Exposure route not evaluated for this receptor.

TABLE E.5–3

TOTAL CARCINOGENIC RISKS
CURRENT LAND USE, FUTURE SOURCE TERM [a]

Medium	Exposure Route	Trespassing Youth			Great Miami River User		
		Radiological	Chemical[b] (TEF for PAHs)	Chemical[b] (BaP for PAHs)	Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)
Air							
	Inhalation	8E–05	4E–05	4E–05	NA	NA	NA
Surface Soil							
	Incidental Ingestion	1E–06	4E–05	4E–05	NA	NA	NA
	Dermal Contact	NA	4E–05	4E–05	NA	NA	NA
	External Exposure	1E–04	NA	NA	NA	NA	NA
Buried Pit Material							
	External Exposure	7E–06	NA	NA	NA	NA	NA
Paddys Run Surface Water							
	Incidental Ingestion	7E–08	4E–09	4E–09	NA	NA	NA
	Dermal Contact	NA	5E–08	5E–08	NA	NA	NA
Paddys Run Sediment							
	Incidental Ingestion	4E–08	8E–08	8E–08	NA	NA	NA
	Dermal Contact	NA	9E–06	9E–06	NA	NA	NA
	External Exposure	3E–06	NA	NA	NA	NA	NA
Great Miami River Surface Water							
	Ingestion	NA	NA	NA	2E–07	5E–09	5E–09
	Ingestion of Fruits and Vegetables	NA	NA	NA	5E–08	2E–09	2E–09
	Ingestion of Meat	NA	NA	NA	2E–09	3E–10	3E–10
	Ingestion of Milk Products	NA	NA	NA	1E–08	1E–10	1E–10
	Inhalation of VOCs	NA	NA	NA	NA	0E+00	0E+00
	Dermal Contact while Bathing	NA	NA	NA	NA	3E–09	3E–09
	Dermal Contact while Swimming	NA	NA	NA	NA	2E–10	2E–10
	Incidental Ingestion while Swimming	NA	NA	NA	1E–10	3E–12	3E–12
	Ingestion of Fish	NA	NA	NA	7E–09	2E–08	2E–08
Subtotal:		2E–04	1E–04	1E–04	3E–07	3E–08	3E–08
Total Carcinogenic Risk:			3E–04	3E–04		3E–07	3E–07

NA – Not Applicable. Exposure route not evaluated for this receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum that would result from adding the values in the table, due to rounding.
Refer to Attachment E.IV for specific values.

[b] Separate carcinogenic risk values were calculated assuming the toxicity equivalency factors (TEF approach) for PAHs and and assuming all PAHs as carcinogenic as benzo(a)pyrene (BaP approach).

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TABLE E.5-4

TOTAL HAZARD INDEX
CURRENT LAND USE, FUTURE SOURCE TERM

Source Medium	Exposure Route	Trespassing Youth	Great Miami River User
Air			
	Inhalation	2.5E-01	NA
Surface Soil			
	Incidental Ingestion	4.4E-01	NA
	Dermal Contact	1.1E+00	NA
Paddys Run Surface Water			
	Incidental Ingestion	1.0E-02	NA
	Dermal Contact	2.9E-02	NA
Paddys Run Sediment			
	Incidental Ingestion	2.3E-03	NA
	Dermal Contact	1.1E-01	NA
Great Miami River Surface Water			
	Ingestion	NA	2.9E-03
	Ingestion of Fruits and Vegetables	NA	9.0E-04
	Ingestion of Meat	NA	1.4E-05
	Ingestion of Milk Products	NA	9.9E-05
	Inhalation of VOCs	NA	0.0E+00
	Dermal Contact while Bathing	NA	1.6E-04
	Dermal Contact while Swimming	NA	3.5E-05
	Incidental Ingestion while Swimming	NA	1.6E-06
	Ingestion of Fish	NA	5.7E-05
Total Hazard Index:		1.9E+00	4.2E-03

NA – Not Applicable. Exposure route not evaluated for this receptor.

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TABLE E.5-5

TOTAL CARCINOGENIC RISKS
FUTURE LAND USE (GOVERNMENT RESERVE), FUTURE SOURCE TERM [a]

Source Medium	Exposure Route	On-property Groundskeeper			Expanded Trespasser		
		Radiological	Chemical[b] (TEF for PAHs)	Chemical[b] (BaP for PAHs)	Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)
Air							
	Inhalation	7E-04	2E-04	2E-04	1E-04	6E-05	6E-05
Surface Soil and Exposed Waste Pit Contents							
	Incidental Ingestion	7E-06	2E-04	2E-04	2E-06	5E-05	5E-05
	Dermal Contact	NA	5E-05	5E-05	NA	2E-04	2E-04
	External Exposure	4E-04	NA	NA	3E-04	NA	NA
Buried Pit Material							
	External Exposure	5E-05	NA	NA	3E-05	NA	NA
Paddys Run Surface Water							
	Incidental Ingestion	NA	NA	NA	7E-08	4E-09	4E-09
	Dermal Contact	NA	NA	NA	NA	5E-08	5E-08
Paddys Run Sediment							
	Incidental Ingestion	NA	NA	NA	4E-08	8E-08	8E-08
	Dermal Contact	NA	NA	NA	NA	9E-06	9E-06
	External Exposure	NA	NA	NA	3E-06	NA	NA
Subtotal:		1E-03	4E-04	4E-04	4E-04	3E-04	3E-04
Total Carcinogenic Risk:			2E-03	2E-03		7E-04	7E-04

NA – Not Applicable. Exposure route not evaluated for this receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum that would result from adding the values in the table, due to rounding.
Refer to Attachment E.IV for specific values.

[b] Separate carcinogenic risk values were calculated assuming the toxicity equivalency factors (TEF approach) for PAHs and assuming all PAHs as carcinogenic as benzo(a)pyrene (BaP approach).

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TABLE E.5-6

TOTAL HAZARD INDEX
FUTURE LAND USE (GOVERNMENT RESERVE)
FUTURE SOURCE TERM

Source Medium	Exposure Route	Groundskeeper	Expanded Trespasser
Air			
	Inhalation	6.2E-01	2.9E-01
Surface Soil and Exposed Waste Pit Contents			
	Incidental Ingestion	9.5E-01	5.4E-01
	Dermal Contact	6.1E-01	3.0E+00
Paddys Run Surface Water			
	Incidental Ingestion	NA	1.0E-02
	Dermal Contact	NA	2.9E-02
Paddys Run Sediment			
	Incidental Ingestion	NA	2.3E-03
	Dermal Contact	NA	1.1E-01
Total Hazard Index:		2.2E+00	4.0E+00

NA – Not Applicable. Exposure route not evaluated for this receptor.

TABLE E.5-7

TOTAL CARCINOGENIC RISKS
FUTURE LAND USE (AGRICULTURAL USE)
FUTURE SOURCE TERM [a]

Source Medium	Exposure Route	On-property RME Farmer [b] Radiological	Chemical [c] (TEF for PAHs)	Chemical [c] (BaP for PAHs)	On-property RME Farmer Use of Perched Groundwater [b] Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)	On-property CT Farmer Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)	On-property Young Child Radiological	Chemical (TEF for PAHs)	Chemical (BaP for PAHs)
Air													
	Inhalation	5E-03	1E-03	1E-03	5E-03	1E-03	1E-03	4E-04	1E-04	1E-04	9E-05	1E-04	1E-04
	Ingestion of Fruits and Vegetables	6E-05	2E-03	2E-03	6E-05	2E-03	2E-03	4E-06	2E-04	2E-04	4E-06	9E-04	9E-04
	Ingestion of Meat	2E-06	7E-04	7E-04	2E-06	7E-04	7E-04	1E-07	4E-05	4E-05	5E-08	1E-04	1E-04
	Ingestion of Milk Products	1E-05	1E-04	1E-04	1E-05	1E-04	1E-04	6E-07	6E-06	6E-06	2E-06	1E-04	1E-04
Exposed Waste Pit Materials													
	Incidental Ingestion	4E-04	8E-03	8E-03	4E-04	8E-03	8E-03	2E-05	6E-04	6E-04	3E-05	4E-03	4E-03
	Dermal Contact	NA	1E-03	1E-03	NA	1E-03	1E-03	NA	2E-05	2E-05	NA	2E-04	2E-04
	External Exposure	2E-02	NA	NA	2E-02	NA	NA	2E-03	NA	NA	2E-03	NA	NA
Surface Soil													
	Ingestion of Fruits and Vegetables	2E-04	2E-04	2E-04	2E-04	2E-04	2E-04	1E-05	1E-05	1E-05	1E-05	6E-05	6E-05
	Ingestion of Meat	7E-05	4E-04	5E-04	7E-05	4E-04	5E-04	5E-06	3E-05	3E-05	2E-06	7E-05	7E-05
	Ingestion of Milk Products	4E-04	5E-04	5E-04	4E-04	5E-04	6E-04	2E-05	2E-05	3E-05	9E-05	4E-04	5E-04
Buried Pit Material													
	External Exposure	1E-03	NA	NA	1E-03	NA	NA	2E-04	NA	NA	2E-07	NA	NA
On-property Surface Water													
	Ingestion of Meat	5E-05	5E-06	5E-06	5E-05	5E-06	5E-06	4E-06	4E-07	4E-07	2E-06	8E-07	8E-07
	Ingestion of Milk Products	2E-04	7E-07	7E-07	2E-04	7E-07	7E-07	1E-05	4E-08	4E-08	4E-05	6E-07	6E-07
Groundwater													
	Ingestion	2E-02	3E-02	3E-02	6E-01	1E-01	2E-01	1E-03	2E-03	2E-03	7E-04	6E-03	6E-03
	Ingestion of Fruits and Vegetables	5E-03	1E-02	1E-02	5E-03	1E-02	1E-02	3E-04	6E-04	6E-04	4E-04	3E-03	3E-03
	Ingestion of Meat	4E-05	1E-03	1E-03	4E-05	1E-03	1E-03	3E-06	9E-05	9E-05	1E-06	2E-04	2E-04
	Ingestion of Milk Products	5E-04	2E-04	2E-04	5E-04	2E-04	2E-04	3E-05	9E-06	9E-06	9E-05	2E-04	2E-04
	Inhalation of VOCs	NA	1E-13	1E-13	NA	3E-02	3E-02	NA	1E-14	1E-14	NA	5E-14	5E-14
	Dermal Contact while Bathing	NA	8E-05	8E-05	NA	9E-01	9E-01	NA	5E-06	5E-06	NA	1E-05	1E-05
Subtotal:		5E-02	5E-02	5E-02	6E-01	9E-01	9E-01	4E-03	4E-03	4E-03	3E-03	1E-02	2E-02
Total Carcinogenic Risk:			1E-01	1E-01		1E+00	1E+00		8E-03	8E-03		2E-02	2E-02

TABLE E.5-7 (con't)

TOTAL CARCINOGENIC RISKS
FUTURE LAND USE (AGRICULTURAL USE)
FUTURE SOURCE TERM[a]

Source Medium	Exposure Route	Off-property Farmer			Off-property Young Child			On-property Homebuilder			Off-property User of Meat and Milk Products		
			Chemical[b]			Chemical			Chemical			Chemical	
		Radiological	(TEF for PAHs)	(BaP for PAHs)	Radiological	(TEF for PAHs)	(BaP for PAHs)	Radiological	(TEF for PAHs)	(BaP for PAHs)	Radiological	(TEF for PAHs)	(BaP for PAHs)
Air													
	Inhalation	2E-04	9E-05	9E-05	4E-06	8E-06	8E-06	1E-04	4E-05	4E-05	NA	NA	NA
	Ingestion of Fruits and Vegetables	3E-06	2E-04	2E-04	2E-07	5E-05	5E-05	NA	NA	NA	NA	NA	NA
	Ingestion of Meat	9E-08	4E-05	4E-05	3E-09	6E-06	6E-06	NA	NA	NA	2E-06	7E-04	7E-04
	Ingestion of Milk Products	6E-07	7E-06	7E-06	1E-07	6E-06	6E-06	NA	NA	NA	1E-05	1E-04	1E-04
Exposed Waste Pit Materials													
	Incidental Ingestion	NA	NA	NA	NA	NA	NA	7E-06	2E-04	2E-04	NA	NA	NA
	Dermal Contact	NA	NA	NA	NA	NA	NA	NA	9E-06	9E-06	NA	NA	NA
	External Exposure	NA	NA	NA	NA	NA	NA	7E-05	NA	NA	NA	NA	NA
Surface Soil													
	Ingestion of Fruits and Vegetables	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ingestion of Meat	NA	NA	NA	NA	NA	NA	NA	NA	NA	7E-05	4E-04	5E-04
	Ingestion of Milk Products	NA	NA	NA	NA	NA	NA	NA	NA	NA	4E-04	5E-04	5E-04
Buried Pit Material													
	External Exposure	NA	NA	NA	NA	NA	NA	7E-09	NA	NA	NA	NA	NA
On-property Surface Water													
	Ingestion of Meat	NA	NA	NA	NA	NA	NA	NA	NA	NA	5E-05	5E-06	5E-06
	Ingestion of Milk Products	NA	NA	NA	NA	NA	NA	NA	NA	NA	2E-04	7E-07	7E-07
Groundwater													
	Ingestion	1E-03	0E+00	0E+00	6E-05	0E+00	0E+00	NA	NA	NA	NA	NA	NA
	Ingestion of Fruits and Vegetables	4E-04	0E+00	0E+00	3E-05	0E+00	0E+00	NA	NA	NA	NA	NA	NA
	Ingestion of Meat	3E-06	0E+00	0E+00	1E-07	0E+00	0E+00	NA	NA	NA	NA	NA	NA
	Ingestion of Milk Products	4E-05	0E+00	0E+00	7E-06	0E+00	0E+00	NA	NA	NA	NA	NA	NA
	Inhalation of VOCs	NA	0E+00	0E+00	NA	0E+00	0E+00	NA	NA	NA	NA	NA	NA
	Dermal Contact while Bathing	NA	0E+00	0E+00	NA	0E+00	0E+00	NA	NA	NA	NA	NA	NA
Subtotal:		2E-03	3E-04	3E-04	1E-04	7E-05	7E-05	2E-04	2E-04	2E-04	8E-04	2E-03	2E-03
Total Carcinogenic Risk:			2E-03	2E-03		2E-04	2E-04		4E-04	4E-04		2E-03	3E-03

NA - Not Applicable. Exposure route not evaluated for this receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum that would result from adding the values in the table, due to rounding. **Refer to Attachment E.IV for specific values.**

[b] Risks calculated and total summed based on the use of the 1-hit equation for calculating risks from higher doses (EPA 1989a), therefore, total risks will not exceed 1.0 for this receptor.

[c] Separate carcinogenic risk values were calculated assuming the toxicity equivalency factors (TEF approach) for PAHs and assuming all PAHs as carcinogenic as benzo(a)pyrene (BaP approach).

TABLE E.5-8

TOTAL HAZARD INDEX
FUTURE LAND USE (AGRICULTURAL USE)
FUTURE SOURCE TERM

Source Medium	Exposure Route	On-property RME Farmer	On-property RME Farmer (User of Perched GW)	On-property CT Farmer	On-property Young Child	Off-property Farmer	Off-property Young Child	Homebuilder	Off-property User of Meat and Milk Products
Air									
	Inhalation	1.5E+00	1.5E+00	8.4E-01	1.4E+00	1.0E-01	1.0E-01	6.4E+00	NA
	Ingestion of Fruits and Vegetables	5.1E+00	5.1E+00	2.6E+00	2.1E+01	3.1E-01	1.3E+00	NA	NA
	Ingestion of Meat	1.5E+00	1.5E+00	8.0E-01	2.8E+00	9.0E-02	1.6E-01	NA	1.5E+00
	Ingestion of Milk Products	3.3E-01	3.3E-01	1.4E-01	3.5E+00	1.8E-02	2.0E-01	NA	3.3E-01
Exposed Waste Pit Materials									
	Incidental Ingestion	1.7E+01	1.7E+01	9.1E+00	8.9E+01	NA	NA	4.7E+01	NA
	Dermal Contact	6.1E+00	6.1E+00	8.4E-01	9.9E+00	NA	NA	6.4E+00	NA
Surface Soil									
	Ingestion of Fruits and Vegetables	2.6E+00	2.6E+00	1.3E+00	1.1E+01	NA	NA	NA	NA
	Ingestion of Meat	1.3E+00	1.3E+00	6.8E-01	2.3E+00	NA	NA	NA	1.3E+00
	Ingestion of Milk Products	1.4E+00	1.4E+00	5.7E-01	1.4E+01	NA	NA	NA	1.4E+00
Buried Pit Material									
	External Exposure	NA	NA	NA	NA	NA	NA	NA	NA
On-property Surface Water									
	Ingestion of Meat	9.3E-02	9.3E-02	4.8E-02	1.7E-01	NA	NA	NA	9.3E-02
	Ingestion of Milk Products	2.4E-01	2.4E-01	9.9E-02	2.5E+00	NA	NA	NA	2.4E-01
Groundwater									
	Ingestion	3.6E+02	5.6E+03	2.0E+02	8.4E+02	2.2E+01	5.2E+01	NA	NA
	Ingestion of Fruits and Vegetables	1.2E+02	1.2E+02	5.8E+01	4.7E+02	6.7E+00	2.7E+01	NA	NA
	Ingestion of Meat	4.7E+00	4.7E+00	2.5E+00	8.5E+00	5.0E-02	8.9E-02	NA	NA
	Ingestion of Milk Products	9.0E+00	9.0E+00	3.8E+00	9.5E+01	6.1E-01	6.5E+00	NA	NA
	Inhalation of VOCs	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	NA	NA
	Dermal Contact while Bathing	1.7E+01	2.7E+02	8.0E+00	2.8E+01	1.3E+00	2.1E+00	NA	NA
Subtotal:		5.4E+02	6.1E+03	2.9E+02	1.6E+03	3.2E+01	9.0E+01	6.0E+01	4.9E+00

NA – Not Applicable. Exposure route not evaluated for this receptor.

TABLE E.5–9

SUMMARY OF RISKS CANCER RISKS
CURRENT LAND USE, WITH ACCESS CONTROLS
CURRENT SOURCE TERM, MAXIMALLY EXPOSED INDIVIDUALS

MEI Receptor:			Groundskeeper			
				Radiocarcinogenic	Chemocarcinogenic	
Media	Risk	Percent of Total Risk	Major Risk Contributors	%	Major Risk Contributors	%
Air	6E–06	4.2%	U_{238}	84.7%	(chemicals	
			Th_{230}	8.6%	contributed	
			U_{234}	6.4%	less than 1%	
					of total risk)	
Surface Soil	9E–05	63.2%	Th_{228}	38.8%	beryllium	10.5%
			U_{238}	27.7%	total PCBs	2.1%
			Ra_{228}	7.5%		
Buried Pit Materials	5E–05	32.6%	NA		NA	
TOTAL:	1E–04					

TABLE E.5-10

SUMMARY OF HAZARD INDICES
CURRENT LAND USE, WITH ACCESS CONTROLS
CURRENT SOURCE TERM, MAXIMALLY EXPOSED INDIVIDUALS

MEI Receptor: Groundskeeper

Media	Hazard Index	Percent of Total	Chemical Toxicants Major Contributors	%
Air	0.0E+00		NA	
Surface Soil	3.0E-01	100.0%	uranium-total	82.4%
			antimony	16.1%
			cadmium	3.4%
Buried Pit Materials	NA		NA	
TOTAL:	3.0E-01			

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TABLE E.5-11

SUMMARY OF RISKS CANCER RISKS
CURRENT LAND USE, WITHOUT ACCESS CONTROLS
MAXIMALLY EXPOSED INDIVIDUALS

MEI Receptor:	Current Source Term						Future Source Term					
	Off-property User of Meat and Milk Products						Off-property Farmer					
			Radiocarcinogenic		Chemocarcinogenic				Radiocarcinogenic		Chemocarcinogenic	
Media	Risk	Percent of Total Risk	Major Risk Contributors	%	Major Risk Contributors	%	Risk	Percent of Total Risk	Major Risk Contributors	%	Major Risk Contributors	%
Air	NA		NA		NA		5E-04	23.1%	Th_{230}	23.5%	arsenic	55.6%
									U_{238}	11.4%		
									U_{234}	2.7%		
Surface Soil	1E-03	83.3%	U_{238}	9.8%	total PCBs	77.0%	NA		NA		NA	
			Sr_{90}	7.8%	benzo(a)pyrene	2.0%						
			Cs_{137}	1.0%								
On-property Surface Water	2E-04	19.2%	Cs_{137}	39.1%	arsenic	2.4%	NA		NA		NA	
			Tc_{99}	25.7%								
			U_{238}	20.7%								
Groundwater							2E-03	76.9%	U_{238}	87.1%	(There are no	
									U_{234}	10.4%	carcinogenic chemicals	
									$U_{235/236}$	2.4%	in offsite groundwater)	
TOTAL:	2E-03						2E-03					

TABLE E.5-12

SUMMARY OF HAZARD INDICES
CURRENT LAND USE, WITHOUT ACCESS CONTROLS
MAXIMALLY EXPOSED INDIVIDUALS

MEI Receptor:	Current Source Term: Off-property User of Meat and Milk Products				Future Source Term: Off-property Young Child			
			Chemical Toxicants				Chemical Toxicants	
Media	Hazard Index	Percent of Total	Major Contributors	%	Hazard Index	Percent of Total	Major Contributors	%
Air	NA		NA		1.7E+00	1.9%	arsenic	81.9%
							barium	3.6%
							cobalt	2.2%
Surface Soil	2.7E+00	91.7%	antimony	47.7%	NA		NA	
			cadmium	34.7%				
			uranium-total	15.3%				
On-property Surface Water	2.3E-01	9.6%	silver	49.6%	NA		NA	
			antimony	14.1%				
			vanadium	8.5%				
Groundwater	NA		NA		8.8E+01	98.1%	uranium-total	100.0%
TOTAL:	2.9E+00				9.0E+01			

TABLE E.5-13

SUMMARY OF RISKS CANCER RISKS
FUTURE LAND USE, FUTURE SOURCE TERM
MAXIMALLY EXPOSED INDIVIDUALS

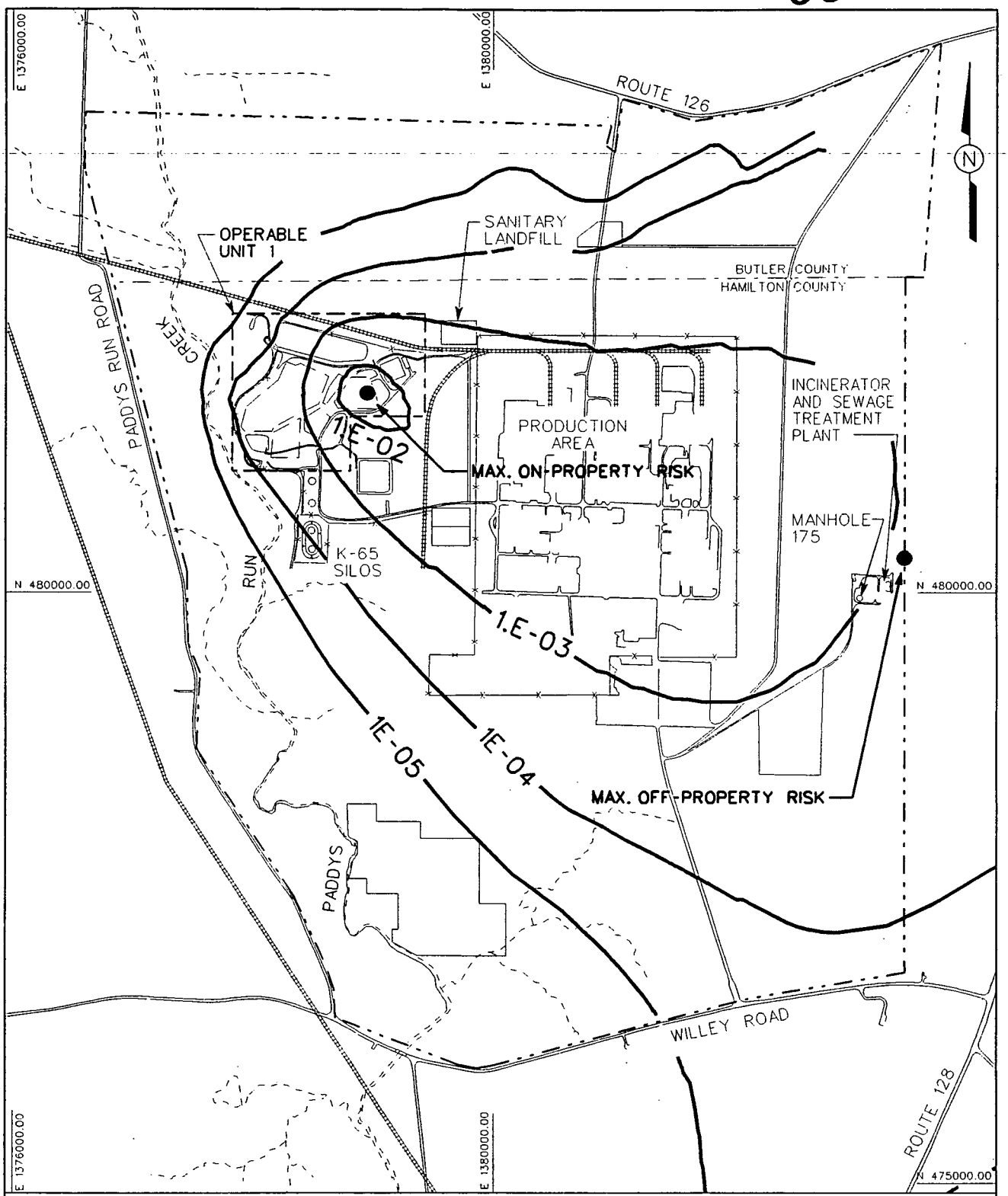
MEI Receptor:	With Access Controls (Future Government Reserve)						Without Access Controls (Future Agricultural Use)					
	Off-property Farmer						On-property RME Farmer					
			Radiocar		Chemocarcinogenic				Radioca		Chemocarcinogenic	
Media	Risk	Percent of Total Risk	Major Risk Contributors	%	Major Risk Contributors	%	Risk	Percent of Total Risk	Major Risk Contributors	%	Major Risk Contributors	%
Air	5E-04	23.1%	Th_{230}	24.5%	arsenic	56.3%	1E-02	9.1%	U_{238}	25.5%	arsenic	49.5%
			U_{238}	11.5%					Th_{230}	16.9%		
			U_{234}	2.7%					U_{234}	3.5%		
Surface Soil/Exposed Waste	NA		NA		NA		3E-02	30.2%	Th_{232}	34.8%	arsenic	26.5%
									Ra_{226}	23.4%	beryllium	3.1%
									U_{238}	6.1%	total PCBs	3.0%
Buried Pit Materials	NA		NA		NA		1E-03	1.1%	NA		NA	
On-property Surface Water	NA		NA		NA		3E-04	0.2%	Cs_{137}	30.4%	arsenic	2.4%
									Tc_{99}	28.5%		
									U_{238}	27.1%		
Groundwater	2E-03	76.9%	U_{238}	87.1%	(There are no		6E-02	59.3%	U_{238}	31.7%	arsenic	63.4%
			U_{234}	10.4%	carcinogenic chemicals				U_{234}	3.8%		
			$U_{235/236}$	2.4%	in offsite groundwater)							
TOTAL:	2E-03						1E-01 [a]					

[a] The total risk for the on-property RME farmer is calculated based on the 1-hit equation for high dose (EPA 1989a).

TABLE E.5-14

SUMMARY OF HAZARD INDICES
FUTURE LAND USE, FUTURE SOURCE TERM
MAXIMALLY EXPOSED INDIVIDUALS

MEI Receptor:	With Access Controls (Future Government Reserve) Off-property Child				Without Access Controls (Future Agricultural Use) On-property Child			
			Chemical Toxicants				Chemical Toxicants	
Media	Hazard Index	Percent of Total	Major Contributors	%	Hazard Index	Percent of Total	Major Contributors	%
Air	1.7E+00	1.9%	arsenic	81.9%	2.8E+01	1.8%	arsenic	79.6%
			barium	3.6%			thallium	3.4%
			cobalt	2.2%			barium	3.2%
Surface Soil/Exposed Waste	NA		NA		1.2E+02	7.9%	arsenic	66.3%
							uranium-total	12.4%
							cadmium	8.3%
Buried Pit Materials	NA		NA		NA		NA	
On-property Surface Water	NA		NA		2.7E+00	0.2%	silver	78.3%
							antimony	4.5%
							barium	3.6%
Groundwater	8.8E+01	98.1%	uranium-total	100.0%	1.4E+03	90.1%	uranium-total	80.3%
							arsenic	14.3%
							antimony	4.7%
TOTAL:	9.0E+01				1.6E+03			



NOTES:

1. MAX. ON-PROPERTY RISK- 2.2×10^{-2} (500 YRS.)
2. MAX. OFF-PROPERTY RISK- 1.7×10^{-3} (660 YRS.)

SCALE:

0 1200 FEET

LEGEND:

—x—x— FENCE LINE
DRAINAGE WAY
CSX RAIL LINE
ROADWAY
OPERABLE UNIT 1 OUTLINE
FEMP PROPERTY BOUNDARY
—1E-05— RISK CONTOUR

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FIGURE E.5-1. TOTAL CARCINOGENIC RISK TO THE RME FARMER FROM URANIUM ASSOCIATED WITH GROUNDWATER USE

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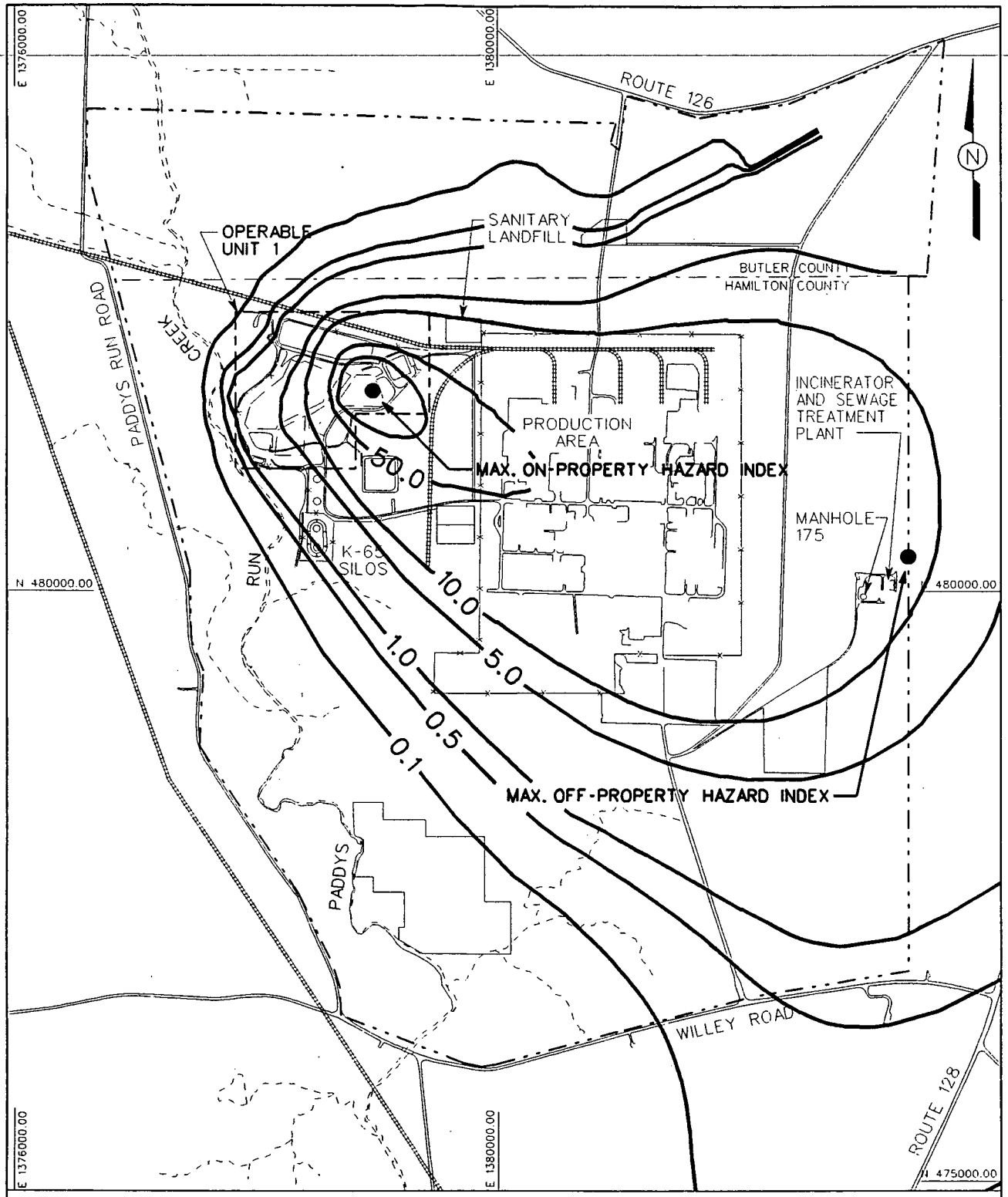

NOTES:

1. MAX. ON-PROPERTY HAZARD INDEX= 2.9×10^2 (500 YRS.)
2. MAX. OFF-PROPERTY HAZARD INDEX= 2.2×10^1 (660 YRS.)

SCALE:

0 1200 FEET

LEGEND:

—X—X— FENCE LINE
— — — — DRAINAGE WAY
CSX RAIL LINE
ROADWAY
— — — OPERABLE UNIT 1 OUTLINE
— — — FEMP PROPERTY BOUNDARY
— 100 — HAZARD INDEX CONTOUR

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FIGURE E.5-2. HAZARD INDEX FOR THE RME FARMER FROM URANIUM ASSOCIATED WITH GROUNDWATER USE

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E.6.0 UNCERTAINTIES

The types and magnitudes of uncertainties associated with each stage of the process are of major importance for evaluating and interpreting risk assessments at the FEMP. Uncertainties associated with calculations that occur in the risk assessment may be magnified in the final results. While it is not possible to eliminate all uncertainties from the analysis, they must be identified and discussed to determine their significance when making risk management decisions. This section presents an analysis of the major uncertainties contributing to the final results of the Operable Unit 1 baseline risk assessment.

E.6.1 TERMINOLOGY

This section introduces the evaluation of uncertainties inherent in the risk assessment process. Uncertainty is a measure of inaccuracy that must be considered in each step of the CPC selection process, exposure and toxicity assessments and risk characterization presented in the preceding sections. Each portion of the analysis contributes to the uncertainty of the final risk assessment. Uncertainty in CPC selection is primarily associated with the analytical data and procedures used to include or exclude constituents as CPCs. Uncertainty associated with the exposure assessment includes variations in sample analytical results, the values used for variables as input to a given intake route, the methods used and assumptions made to determine exposure point concentrations, the accuracy with which a particular fate and transport model represents actual environmental processes, and the manner in which the exposure scenario is developed. Uncertainty associated with the toxicity assessment includes the quality of the existing data to support a dose-response assessment, the high-to-low dose and interspecies extrapolations for dose-response relationships, and the weight of evidence used for determining the carcinogenicity of CPCs. Uncertainty associated with risk characterization includes that associated with exposure to multiple chemicals (i.e., additivity of dose, synergisms and antagonisms among chemicals, and the particular mode of action for each chemical), and the cumulative uncertainty from combining conservative assumptions made in the data, exposure assessment, and toxicity assessment. Each of these categories of potential uncertainty is discussed in this section.

Generally, risk assessments carry two types of uncertainty, measurement and informational uncertainty; each merits consideration. Measurement uncertainty refers to the usual variance that accompanies scientific measurements (e.g., instrument uncertainty associated with

contaminant concentrations). This type of uncertainty is generally associated with the analytical data, which impacts CPC selection and calculation of exposure point concentrations. The risk assessment results reflect the accumulated variances of the individual measured values used. A different kind of uncertainty stems from inadequate availability of information needed to complete the toxicity and exposure assessments. Often this informational gap is significant, such as the absence of information on the effects of human exposure to low doses of a chemical or on the biological mechanism of action of an agent (EPA 1992d).

Once the risk assessment is complete, the results must be reviewed and evaluated to identify the type and magnitude of uncertainty involved. Reliance on results from a risk assessment without consideration of uncertainties, limitations, and assumptions inherent in the risk assessment process can often be misleading. For example, to account for uncertainties in the development of exposure assumptions, conservative estimates must be made to ensure that the particular assumptions made are protective of all sensitive subpopulations, or maximum exposed individuals. If a number of conservative assumptions are combined in an exposure model, the resulting calculations can propagate the uncertainties associated with those assumptions, producing a much larger uncertainty for the final results. Thus, both the risk assessment's results and the uncertainties associated with those results should be considered when making risk management decisions.

This interpretation is especially relevant when resulting risk numbers exceed the point-of-departure for defining acceptable risk. For example, when a calculated risk incorporating a high degree of uncertainty falls below an acceptable risk level (e.g., below an incremental lifetime cancer risk [ILCR] of 10^{-6}), the interpretation is straight forward. However, when calculated risks, incorporating a high degree of uncertainty, fall above an acceptable risk level (e.g., exceed an ILCR of 10^{-4}), decision making can be difficult unless all of the uncertainties inherent in the calculations are carefully considered.

The actual risk may be one, two, or even three orders of magnitude smaller than the one calculated, which could lead risk managers to make a decision which is unnecessarily protective. This situation may occur in a Superfund risk assessment when the estimated risks are based on limited information. Calculations, exposure parameters, conservative assumptions on lifestyles and land-use scenarios, and maximum or near-maximum values for many of the modeling and exposure variables must be carefully assessed to ensure that the

risks are not underestimated. The combination of conservative assumptions over a number of areas often results in high risk values as a result of high uncertainty. Characterization of risk based on overly conservative model parameters, scenarios, and assumptions does not convey realistic information and is often misleading if reviewed out of context. A risk estimate for an RME individual in a Superfund risk assessment has been frequently and mistakenly viewed as an average risk to the receptor population being evaluated (EPA 1992d).

Such conservatism has been incorporated into the RME scenarios for Operable Unit 1 risk assessment. Although it is possible that the exposure, dose, and sensitivity combinations assumed might occur in the receptor population of interest, the probability of an individual actually receiving this degree of exposure is expected to be low.

Recent EPA guidance on risk assessment (EPA 1992d) requires risk assessors to use exposure and toxicity assumptions that are from the "high end" and "central tendency" of their distributions. These values correspond to the reasonable maximum exposure (RME) and central tendency (CT) scenarios, respectively, for the risk assessment. The RME scenario is to be a combination of average and upper-bound assumptions that estimate the reasonable maximum exposure for that pathway. The resulting risk for the RME scenario is assumed to fall between the average (i.e., the CT scenario) and the upper-bound scenario (a scenario that is based on all maximum values). The CT scenario is a combination of all average and median values for exposure parameters that provide an estimate of average risk posed to the receptor population being considered. It should be noted here that the CT scenario used in Operable Unit 1 incorporates many maximal values by direction of EPA Region V staff. The purpose for consideration of risks from both the CT and RME scenarios is to provide bounds on the expected risks posed by the site.

The ultimate goal of the risk assessment process is to provide an objective, realistic, and balanced risk estimate for making risk management decisions at the FEMP. In the past, Superfund risk assessments based on the "Risk Assessment Guidance for Superfund" (EPA 1989a) yielded calculated risks only for RME scenarios. The Operable Unit 1 RI incorporates this concept into the risk assessments at the FEMP. Accordingly, the risk assessment for Operable Unit 1 includes an additional scenario considering some average assumptions for the on-property resident adult. Based on the future land-use scenario, the on-property resident adult constitutes the most important receptor since they have the highest risk. This attempt at

characterizing the CT scenario side-by-side with the RME scenario presents a more realistic estimate of the range of possible risk for this receptor. Efforts will continue to incorporate the guidance as more exposure data at the FEMP become available and the additional guidance on estimating CT is completed by EPA.

E.6.2 SOURCES OF UNCERTAINTY IN OPERABLE UNIT 1

As noted previously, uncertainties are associated with the information and data used for the selection of CPCs, exposure and toxicity assessments, and risk characterization for the Operable Unit 1 baseline risk assessment. Uncertainty in the selection of CPCs is associated with the analytical data. In the exposure assessment, these uncertainties are the result of a number of factors, including assumptions on land use and receptors, assumptions made for parameters and parameter variability (random errors or natural variations), and the necessity of using computer models to predict complex environmental interactions. Uncertainty associated with the toxicity assessment is associated with the dose-response data. As EPA has pointed out in their guidance for human health risk assessments, "it is more important to identify the key site-related variables and assumptions that contribute most to the uncertainty than to precisely quantify the degree of uncertainty in the risk assessment" (EPA 1989a). Uncertainties are evaluated in this section to provide a basis for interpreting the overall quality of the risk assessment results. Sources of uncertainty are discussed below.

E.6.2.1 Selection of Constituents of Potential Concern

Uncertainty associated with the selection process used to determine the CPCs in Operable Unit 1 can be attributed to the following major sources:

- Soil and groundwater data do not exist for the area directly beneath the waste pits and were inferred from indirect data sources. Data taken from adjacent borings and wells were used to estimate these conditions. These data were also used to determine which constituents are migrating toward the aquifer, and at what rate this migration is occurring.

- Sample results from the RI/FS and CIS sampling programs could not be combined, and, therefore, were evaluated separately in the data evaluation process. Each sampling and analysis program identified chemicals that were not identified by the other. This introduces uncertainties in the presence or absence of some of the chemicals reported and limits that data that is used to statistically determine source concentrations.

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- CIS samples taken from the split-spoon sampler were immediately dissected into discrete depth samples for radiological analysis. Composites of the remaining soil were made in the open air and placed into sampling containers. As a result, concentrations of volatile chemicals may be underestimated since they may have volatized during this sampling procedure.

- Evaluation of the existing data raises the question as to whether all pockets of elevated contamination have been identified. In general, it is believed that they have been identified for most radionuclides at the FEMP because CIS sampling locations were generally biased, based on high radiation measurements in the field. This is particularly important because risks from radionuclides dominate the overall risks to all receptors evaluated in this risk assessment. No conclusion can be drawn for chemical constituents detected on the property.

- Sample analytical techniques produce results that have an unknown degree of uncertainty associated with them. These uncertainties are documented by using data qualifiers to reflect the assumed degree of certainty of measurement. These analytical uncertainties affect the selection of CPCs or the calculation of exposure point concentrations (either measured or modeled) that may be based on a particular analytical result.

- Concentrations of inorganics and radionuclides are compared to background concentrations to determine if their presence is do to naturally occurring concentrations from native soils or are due to site activities. However, sampling procedures for groundwater and air used to determine background concentrations have high detection limits. A chemical that was not detected during background sampling could result in the erroneous inclusion of a chemical from those selected for further evaluation.

- The RI organics data for the waste pit material were rejected during validation because of holding time problems and sampling techniques. However, several compounds were noted, and the exclusion of these compounds as CPCs may underestimate risks.

- A limited number of samples exist for some media types in the waste pit area. There is a limited database for pit cover surface soils, and there were no analyses for volatile and semi-volatile organic compounds in any Operable Unit 1 surface soil samples. A limited database has the potential to introduce either false positive results (i.e., introducing constituents as CPCs that are not site related), or false negative results (i.e., eliminating compounds that may be legitimate CPCs because they are site related and could contribute to site risks). It is anticipated that the limited database for Operable Unit 1 may introduce false negatives and as a result underestimate potential human health risks from exposure to organic chemicals.

- Concentration terms for surface soil were derived from results recorded from 0 to 24 inches in depth. Since surface soil contamination levels are usually greater in the first 6 inches of soil, this approximation may underestimate risks from exposure to surface soil.

The cumulative impacts of these uncertainties on the results of the exposure and risk assessments are judged to be low to moderate (i.e., are assumed to result in over or underestimation of risk by an order of magnitude or more). This is because a few constituents contribute the majority of the cancer risk for most receptors. Two examples are external radiation exposure from U-238 and its immediate progeny, and arsenic in water. Risks from these constituents each exceed 10^{-4} by themselves. The relative contributions of these two constituents to the total risk are very significant: The impact to the total risk would be slight if other chemicals were added or deleted from the list of CPCs selected for evaluation in this risk assessment.

E.6.2.2 Uncertainty in Exposure Assessment

Sources of uncertainty for the exposure assessment arise from calculation of exposure point concentrations, selection of receptors, determination of land use scenarios and selection of exposure factors.

E.6.2.2.1 Exposure Point Concentrations

Uncertainty associated with calculation of exposure point concentrations in Operable Unit 1 can be attributed to the following sources:

- The material in the waste pits has been determined to be very heterogeneous in nature. In the effort to obtain radiological samples at the most contaminated locations, a radiological survey of the study area was conducted. Waste pit borings were placed at the locations having the highest gross radiation measurements. Selection of sampling locations in this way leads to a positive bias in the calculation of exposure point concentrations for certain radionuclides and uncertainty in the representativeness of the samples.

- According to the "Risk Assessment Guidance for Superfund" (EPA 1989a), the UCLs are used for all exposure concentrations. This means that 95 percent of the time, the actual mean concentration can be less than the value used in the exposure assessment. Conversely, 5 percent of the time the actual mean concentration can be greater than the value used in the exposure assessment. Therefore the exposure assessment may underestimate the exposures in 5 percent of the cases, and overestimate exposures 95 percent of the time.

- A limited number of samples for some waste pits introduces high uncertainty in the determination of exposure point concentrations for some compounds.

- Sample analytical techniques produce results that have a degree of uncertainty associated with them. These uncertainties are documented by using data qualifiers to reflect the degree of uncertainty of measurement. These analytical uncertainties

affect the exposure point concentrations (either measured or modeled) that may be based on a particular analytical result.

- There is also large uncertainty when exposure concentrations were based on the maximum detected concentration. The conservative approach was taken in the statistical interpretation of the RI and CIS data bases (i.e., if less than four detections, the maximum concentration is used as the representative), and may result in an overestimation of the concentrations to which a receptor could be exposed.

Predicted concentrations were used as exposure point concentrations when measured data were not available (e.g., the future). These predictions were made using mathematical representations (models) of the natural systems found or suspected to exist in the study area. Due to the complexity of natural environments, conservative assumptions were often used in these models to calculate exposure point concentrations. When a number of conservative assumptions are combined into one fate and transport model, uncertainties can be compounded and provide very conservative estimates of the exposure point concentration. These assumptions are typically made to avoid underestimating the concentrations of contaminants in transport or exposure media (e.g., air or groundwater). As a result, transport parameters are chosen from the upper bound of possible alternative values and the uncertainties associated with modeled concentrations will generally be much larger than those associated with measured data. Uncertainties associated with modeled exposure point concentrations in Operable Unit 1 can be attributed to the following sources:

- The geochemical model has several sources of uncertainty associated with it. The conceptual model assumes that mineral phases represent the actual solid phases of a chemical in the waste material. In addition, the geochemical model assumes dissolution and precipitation kinetics are instantaneous, and it does not evaluate adsorption processes. This leads to estimates of concentrations that are too high or too low.

- A limited number of organic chemicals can be accommodated by the geochemical model used to determine Leachate B concentrations in the till. This leads to low estimates of leachate concentrations for some inorganic constituents if complexation occurs with organic chemicals not present in the database.

- Total contact between the waste and the leaching fluid and no containment of the leachate concentrations are assumed. This produces higher estimated concentrations of Leachate B available for transport to the aquifer than would be anticipated under actual conditions. This uncertainty is reduced by the availability of in situ leachate concentrations for most chemicals in most sources.

- Use of Toxicity Characteristic Leaching Procedure (TCLP) data to characterize leachate concentrations in the natural environment adds conservatism to the groundwater fate and transport modeling process because TCLP leaching is performed with an acidic solution. This tends to overestimate the leachate concentration of inorganics over natural (more neutral) leaching conditions.

- The selection of parameters related to the attenuation and retardation of constituents is a major uncertainty in the analysis. The attenuation and retardation factors of every constituent except uranium were determined after an extensive literature search. It should be noted here that the actual retardation factors at the FEMP may not follow the assumed literature values, particularly over the long term. Site-specific attenuation and retardation factors are used when available. The use of site-specific values are assumed to result in lower uncertainty than using literature values.

- The organic decay rates at the FEMP were determined after an extensive literature search. The actual decay rates may or may not follow the assumed literature values because of site-specific conditions. The use of site data to determine organic decay rates is assumed to result in lower uncertainty than that resulting from the use of literature values.

- Transport through the vadose zone is approximated by using a one-dimensional model and assuming the zone is homogeneous. The unsaturated seepage flow rate is a function of several parameters, such as porosity, residual saturation, and pore size distribution index. Due to the heterogeneous nature of the till, these parameters change from location to location and from depth to depth.

- The total mass of each contaminant is calculated by multiplying the UCL by the volume of the entire waste area, thus assuming the UCL concentration is uniformly distributed through the entire source.

- The fate and transport modeling uses a "70-year rule" for these constituents where no or inadequate leachate data exist. This "rule" assumes all the chemical leaches from a particular waste unit in 70 years. This method is considered very conservative for compounds that are insoluble but may underestimate the maximum exposure for soluble compounds. The application of this procedure in a risk assessment primarily effects three of the systematic toxicants, which were evaluated in the Operable Unit 1 baseline risk assessment: benzo[g,h,i]perylene; fluoranthene; and phenanthrene). However, the application of this methodology to these constituents is considered conservative because these particular compounds have rather low solubilities and high partitioning coefficients. PAHs, in general, contribute an insignificant proportion to the total hazard index. Therefore, the application of this assumption is assumed to have a low impact on the risk assessment.

- Air modeling is based on a number of conservative assumptions. In combination these assumptions appear to overestimate the exposure point concentrations for air based on site air monitoring data and according to a literature search for typical ambient air PM_{10} measurements for EPA Region V. The long-term average PM_{10} concentrations calculated are comparable to measured dust concentrations on

constructions. This uncertainty is expected to moderately overestimate risk (i.e., overestimate risks by 1 to 2 orders-of-magnitude).

- Contaminant concentrations for the surface soil over Waste Pits 1-4 is not available. Air modeling is performed assuming that soil concentrations over the pits is equal to contaminant levels of surface soil between the pits. The impact of this assumption is assumed to be low to moderate.

- The future configuration of the waste pits is uncertain at this time; thus, a reasonable worst-case configuration is used to determine source concentrations for both air and surface water modeling. If the actual configuration differs from that used in this evaluation, the future source concentrations may change and the models will have incorrectly estimated the exposure point concentrations.

- The transport models individually made assumptions regarding the fate of individual constituents within source media. However, these models were not combined or linked to consider assumptions made regarding depletion of chemicals from one model and the effect of that assumption on another model (i.e., the leaching models did not consider source depletion from volatilization or fugitive emissions and the air emissions models did not consider losses via leaching). Furthermore, the direct exposure pathways to a particular source (i.e., incidental ingestion of surface soil) did not consider source depletion by leaching, surface water transport, or air emissions. Consequently, this assumption is considered very conservative.

These uncertainties for modeling collectively are assumed to moderately overestimate the concentrations expected in groundwater and for aerial deposition (i.e., overestimate concentration and risk by a factor of one to two orders of magnitude).

Models were also used to calculate chemical concentrations in plants and animals. Each time concentrations at one level in the food chain are extrapolated from a lower level, uncertainty is introduced into the result. For example, soil-to-plant transfer factors (B_{iv} values) generally represent the maximum amount of contaminant transfer that may occur. In reality, the contaminant transfer is quite dependent on the form of the constituent (e.g., metal species) and other site-related physical conditions (e.g., soil type). Thus actual site transfer factors are unknown. The values chosen are intended to be conservative and they are likely to overestimate risk.

E.6.2.2.2 Determination of Land Uses

A major uncertainty associated with predicting future exposures at the FEMP is the future disposition of the property itself. Because it is not possible to accurately predict what the future uses of the land may be the most conservative (rather than the most likely) land use is

evaluated, as stipulated by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). As noted in Section E.3.0, one of the on-property residents evaluated under future land use for Operable Unit 1 is the resident farmer. It is unlikely that the waste pits and surrounding soils could support a viable agricultural receptor, but the assumption of the resident farmer for future land use provides a worst-case scenario regarding future land use in the exposure assessment.

E.6.2.2.3 Selection of Receptors

The receptors selected for evaluation in this assessment have been generally selected to reflect and encompass those types of activities which may produce the reasonable maximum exposure individual. Some of these receptors, such as the on-property resident farmer living on the open waste pit, can possibly exist in the future but this scenario is considered very unlikely based on the use of this area for waste disposition. Risks from such a receptor may overstate probable risk from future use of the property when considered against more plausible land use alternatives. Uncertainty associated with the selection of receptors in the current land use scenario is assumed to be low (over- or underestimate risks by a one order of magnitude or less) because the current site environmental setting and configuration was the basis for selection of these receptors. Uncertainty associated with receptors identified in the future land use scenario is high (i.e., potential to overestimate risk by two or more orders-of-magnitude) due to the low probability of the site being used as a residence or for agricultural purposes.

E.6.2.2.4 Determination of Exposure Factors

Each exposure factor selected for use in this risk assessment has some uncertainty associated with it. Generally these factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid the underestimation of exposure, this risk assessment followed EPA's recommendation and used the 95th percentile for most of the exposure parameters used in this risk assessment. In other words, the values selected represent the observed or expected habits of a small percentage of the population (usually the upper 5 or 10 percent). For example, the resident farmer scenarios were assumed to inhale air at the location of the highest annual average concentration for 350 days per year for 70 years. Seventy years represents the maximum exposure duration and is not based on a statistical assessment of local or regional residence time for farm families. This factor tends to overestimate risk.

Generally, the uncertainty can be assessed quantitatively for a number of assumptions made in determining factors for calculating exposure and intakes. Many of these parameters were determined from statistical analyses on human population characteristics. Often the database used to summarize a particular exposure parameter (i.e., inhalation rate) is quite large. Consequently, the values chosen for such variables in the RME scenario have low uncertainty (i.e., over or underestimate risks by one order of magnitude or less). For many parameters for which limited information exists (i.e., dermal adsorption of organic chemicals from soils) there is greater uncertainty. However, there is often sufficient data to estimate these parameters with low uncertainty. Few intake parameters have high uncertainty associated with them. In the risk assessment for Operable Unit 1, the particular exposure parameters with the greatest uncertainty are judged to be those associated with time (combination of frequency and duration on the site). The particular exposure pathway with the combination of exposure parameters with the highest uncertainty is dermal contact, which is assumed to result in moderate uncertainty (over- or underestimate actual exposure by one to two orders of magnitude) for exposure.

Many of the quantities used to calculate exposures and risks in this report are selected from a distribution of possible values. For the RME scenarios, the value representing the 95th percentile is generally selected for each parameter to assure that the assessment bounds the actual risks from a postulated exposure. This risk number is used in risk management decisions, but does not indicate what a more average exposure might be, or what risk range might be expected for individuals in the exposed population. To address these issues, a risk estimate closer to the central tendency is presented for the maximally exposed individual using the CT scenario described in Section E.3. The range of risk for this receptor from the CT scenario to the RME scenario seeks to incorporate the range of uncertainty regarding intake assumptions for this receptor.

E.6.2.3 Toxicity Assessment

Uncertainty associated with the toxicity assessment is associated with hazard assessment and dose-response evaluations for CPCs. The hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using either the IARC (1987) or EPA (1986b) methods. Positive animal cancer test data suggest that human tissue(s)

may also manifest a carcinogenic response; however, animal data do not always accurately predict the same response on the same target tissue in humans. In the hazard assessment of noncancer effects, however, positive animal data suggest the nature of the possible adverse effects (i.e., the target tissues and type of effects) anticipated to occur in humans (EPA 1989i).

Uncertainty in hazard assessment arises from the nature and quality (sensitivity and selectivity) of the animal and human data. Uncertainty is decreased when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose-related; when pharmacokinetic data indicate a similar fate in animals and humans; when postulated mechanisms of toxicity are similar for humans and animals; and when the CPC is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainty in the dose-response evaluation includes the determination of a slope factor for the carcinogenic assessment and derivation of an RfD or RfC for the noncarcinogenic assessment. Uncertainty is introduced from interspecies (animal-to-human) extrapolation, which, in the absence of quantitative pharmacokinetic, dosimetric, or mechanistic data, is usually based on consideration of interspecies differences in basic metabolism. Uncertainty also results from intraspecies, or individual, variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so that intragroup biological variation is minimal. However the human population of concern may reflect a great deal of heterogeneity including unusual sensitivity or tolerance to the CPC. Even toxicity data from human occupational exposures reflect a bias because only those individuals sufficiently healthy to attend work regularly and those not unusually sensitive to the CPC, are likely to be occupationally exposed. Finally, uncertainty arises from the quality of the key study (from which the quantitative estimate is derived) and the database. For cancer effects, the uncertainty associated with dose-response factors is mitigated by assuming the 95 percent upper bound for the slope factor. Another source of uncertainty regarding quantitative risk estimation for the carcinogenic assessment is the method by which high dose data animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from animal data, is based on a nonthreshold assumption of carcinogenesis. An impressive body of evidence, however, suggests that epigenetic carcinogens, as well as many genotoxic

carcinogens, have a threshold below which they are noncarcinogenic (Williams and Weisburger 1991); therefore, the use of the linearized multistage model is conservative for chemicals that exhibit a threshold for carcinogenicity.

For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD or RfC to mitigate poor quality of the key study or gaps in the database. Additional uncertainty for noncancer effects arises from use of an effect level in the estimation of an RfD or RfC, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an additional uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises from estimation of an RfD or RfC for chronic exposure from less than chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the less than chronic study. Uncertainty in the derivation of reference doses is mitigated by the use of uncertainty and modifying factors that normally range between three and ten. Uncertainty factors (UF) and modifying factors (MF) are assigned as follows:

- A UF of ten is used to account for sensitive subpopulations.
- A UF of ten is used when extrapolating from animals to humans to account for interspecies variability.
- A UF of ten is applied to a NOAEL (no observed adverse effect level) derived from a subchronic study rather than a chronic study.
- A UF of ten is applied to a LOAEL (lowest observed adverse effect level) to estimate a NOAEL.
- An MF from zero to ten is applied to data to reflect the quality of the data from the critical study used to derive the reference dose.

As a result, a combination of uncertainty and modifying factors may exceed 100, 1000, or more for a particular compound. These uncertainty factors are discussed in Section E.4 for the CPCs in Operable Unit 1.

Uncertainty arises in the dose-response assessment for Operable Unit 1 for values derived for principle CPCs from studies with limitations. As an example of this type of uncertainty, consider the toxicity information for uranium. Uranium as an alpha particle emitter is also

considered a carcinogen; however, absolute evidence of uranium-induced excess human cancer risks are very difficult to obtain. This is largely because the human data available for radiocarcinogenic effects of uranium exposure are for underground miners, who are also simultaneously exposed to radon and radon progeny as a confounding factor. The studies of humans frequently lack information concerning uranium exposure, potential uranium exposure through previous employment, concurrent smoking patterns, or concurrent radon exposure levels. Accurate exposure data are needed to more definitively determine the risk attributable to uranium exposure. The human studies of cancer from exposure to uranium frequently reveal a slight excess risk above the natural risk. These facts weaken the power of the human studies to detect any excess risk. These uncertainties are not well known or easily determined and, as a consequence, introduce moderate to high uncertainty into the Operable Unit 1 risk assessment.

Other toxicity information used in the Operable Unit 1 risk assessment that introduces uncertainty include:

- The EPA inhalation slope factor of 7.7 x 10^{-12} pCi^{-1} for Rn-222 plus its daughters is used to calculate risks resulting from indoor inhalation of radon gases. The EPA bases this slope factor on a 50% equilibrium ratio between Rn-222 and its short-lived daughters. Studies cited in NCRP Report No. 78 (NCRP 1984a) report a lower value for this equilibrium ratio in indoor air (i.e.: 100/50/30/20/20 for Ra-222, Po-218, Pb-214, Bi-214, and Po-214, respectively). Since the concentration of daughters expected in indoor air is lower than the EPA assumption, the slope factor is probably conservative in this respect.

- PAHs that are classified as B2 probable human carcinogens for which no toxicity data were available are evaluated using benzo(a)pyrene toxicity data. This assumption likely leads to an overestimation of the carcinogenicity of those PAHs because conservative assumptions were used to relate their carcinogenicity to that of benzo(a)pyrene. However, when toxicity equivalency factors were used in this assessment to evaluate their carcinogenicity, this may either underestimate or overestimate the carcinogenic risks. Overall, this increased conservatism does not significantly impact the overall risks from Operable Unit 1 since the majority of risks are posed by other CPCs.

- The only PCB with positive carcinogenicity results is Aroclor-1260. The carcinogenicity of all PCB isomers were assumed to be equal to the carcinogenicity of Aroclor-1260 because the dose-response data for other isomers are inconclusive. Statistically significant cancer results were not seen for Aroclors with lower percentages of chlorine atoms. The conservatism introduced in the evaluation of PCBs is not anticipated to impact the selection of CPCs for final risks because they did not exceed the concentration-toxicity screen.

- As with PAHs, the carcinogenicity of dioxins and furans other than the 2,3,7,8-isomer were determined using EPA's revised Toxicity Equivalency Factors (TEFs) in the absence

of toxicity values for the different isomers (EPA 1989j). The TEFs are based on the assumption that all dioxin and furan congeners are carcinogenic. This may introduce a large positive bias to the results of the assessment.

A significant source of uncertainty for calculating risks from radionuclides in surface soil is the use of EPA slope factors for external radiation exposure. In deriving these slope factors, EPA has assumed that an individual continuously stands on an infinitely thick slab of soil with a uniform radionuclide concentration. To manage complicated calculations for photon attenuation and scattering in soil, EPA has assumed that the activity in the slab source is present on an infinite plane with uniform surface concentration. The slope factors for external radiation exposure are, therefore, based on calculated exposures (and associated risks of cancer incidence) from the hypothetical plane source.

In addition, EPA calculates slope factors for ingestion of many radionuclides using the maximum value for the GI absorption factor. The actual chemical form(s) that influence the magnitude of the GI absorption factor have not been considered.

To summarize, the uncertainty associated with the toxicity assessment is chemical-specific since it depends on the existing information used to derive the dose-response factor. In general, this uncertainty tends to be more high (overestimate risks by two or more orders of magnitude) for the chemical risk assessment, but tends to be low (overestimate risks by an order or magnitude or less) for radionuclides. This difference is the result of animal versus human data used for chemical and radiological compounds, respectively.

E.6.2.4 Risk Characterization

Uncertainty in risk characterization results from assumptions made regarding additivity of effects from exposure to multiple compounds from various exposure routes. High uncertainty exists when summing cancer risks or hazard indices for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Often compounds affect different organs, have different mechanisms of action, and differ in their fate in the body where additivity is not appropriate. However, the assumption of additivity is made to provide a conservative estimate of risk. This particular source of uncertainty is insignificant for Operable Unit 1 because the majority of cancer risks and hazard index is due to a few constituents of potential concern (CPCs).

Risk characterization does not consider antagonistic or synergistic effects. Little to no information is available to determine the potential for antagonism or synergism for CPCs. Therefore, this

uncertainty cannot be discussed based on the impact on the risk assessment since it has the potential to either over-or under-estimate potential human health risks.

The additivity of risks from radionuclides and chemical carcinogens is the subject of considerable debate. EPA guidance (EPA 1989a) indicates that the two sets of estimates should be considered separately because 1) chemical CSFs are developed using laboratory experiments and radionuclide toxicity values are based on human epidemiological data, and 2) chemical CSFs represent an upper bound limit value while radionuclide slope factors are "best estimates." Therefore, cancer risks from exposure to radionuclides are presented separately from those from chemical CPCs.

E.6.3 Summary of Uncertainties in Operable Unit 1 Baseline Risk Assessment

Uncertainties encountered during the preparation of this assessment vary from waste pit to waste pit because their individual physical and chemical characterizations vary. While many of the uncertainties listed in these tables are shared between operable units, others are limited to a few of the waste pits. Table E.6-1 presents a qualitative evaluation of the uncertainties described in the preceding sections.

Although uncertainties arise from many sources, those deriving from the toxicity assessment (i.e., determination of dose-response factors) provide the greatest uncertainty for the chemical risk assessment because few chemical dose-response factors are based on human epidemiological studies. Thus, extrapolations from animal studies must be made. For the radiological assessment, the greatest uncertainty arises from the exposure assessment where exposure point concentration are often based on the maximum reported analytical result, and where conservative assumptions were made regarding future land uses and exposure scenarios. Unlike chemical toxicity data, radiological dose-response factors are derived from human studies which is assumed to result in lower uncertainty.

Generally, uncertainty arises wherever data gaps exist. Data gaps in the risk assessment were mitigated by making conservative assumptions for individual parameters. Significant uncertainty results for those particular pathways that required fate and transport modeling to support the assessment of exposure. Such uncertainty was generated for the air and groundwater pathways of exposure. Thus, interpretation of risk from these media must consider the high uncertainty. Also, certain exposure pathways for a particular medium tend to have higher or lower uncertainty depending on their assumptions. For example, incidental ingestion of soils by residents tends to have significantly less uncertainty than ingestion of fruits and vegetables, and meat and milk raised on

contaminated soils. These latter exposure pathways must make some assumptions regarding their uptake from soil to plant and plant to live stock while the soil ingestion pathway does not.

Receptors with the highest uncertainty in the current source term are the off-property resident farmer and off-property user of meat/milk from livestock grazed on site. The off-property resident farmer scenario is evaluated based on modeled concentrations for the air pathway and results in high uncertainty. The bioaccumulation of CPCs into meat/milk are modeled, and as a result, provide moderate to high uncertainty for this receptor. The greatest uncertainty in the risk assessment of Operable Unit 1 is associated with the assumptions made in the future source. These particular receptors include the on-property resident farmer, Great Miami River user, and off-property used of meat and milk. For the on-property resident farmer and home builder, the highest uncertainty is associated with the proposed land used and potential exposure pathway. This receptor scenario is included in response to guidance and is anticipated to have a low likelihood of occurrence due to the history of the site and the particular waste management activities within Operable Unit 1. Uncertainty associated with the off-property resident farmer and Great Miami River water user is primarily the result of surface water and air modeling used to support those scenarios. The modeling assumptions are conservative, which result in conservative estimates for the exposure point concentrations.

Taken together, the uncertainties identified with site data, exposure parameters, fate and transport, toxicity assessment and risk characterization are judged to be high (i.e., potential to over-estimate risk by two or more orders of magnitude).

E.6.3.1 Risk Sensitivity Impact Analysis (1993 Supplemental Sampling Program).

In late June/early July 1993, twenty-nine additional surface soil samples were collected from an area in and around Operable Unit 1. To accomplish this field sampling, a portion of an OU1 Technical Engineering Data Acquisition Program (TEDAP), which was in initial planning stages, was accelerated to fully utilize field resources and laboratory capacity which would become available between demobilizing OU2's RI field program and mobilizing OU5's field program. The purpose of this sampling program was to supplement available data used to describe the nature and extent of contamination in OU1, to provide additional confidence in calculations and modeling that supported the baseline risk assessment, and to support preliminary remedial design.

Due to the time required to select CPCs, perform fate and transport modeling, enter data into the database, calculate risks and to write the text of the baseline risk assessment, it was required that the

database be frozen at a date substantially prior to the document submittal. Therefore, data from the 1993 sampling event was not included in the baseline risk assessment. However, the 1993 data was quantitatively evaluated and included in this section. A sensitivity analysis of the 1993 data to the total database was performed.

Data from the 1993 sampling event is presented in Appendix G-4. The following provides an evaluation of the 1993 data and its potential impact on the risk values presented in the baseline risk assessment. As all risks can be directly related to the source terms, the impact analysis was performed by evaluating changes to the source term. As presented here-in, the presence of additional constituents or increased concentrations of existing constituents found in the 1993 data have no impact on the incremental lifetime cancer risks or hazard quotients reported in the baseline risk assessment nor do they impact the existing list of COCs.

Methodology

A four step process was used to evaluate the 1993 surface soil data as it relates to the baseline risk assessment. In the first step, the 1993 surface soil data were statistically evaluated and compared to background in order to identify contaminants of potential concern (COPCs). Statistical methods used to perform this evaluation are described in Section E.2.

In step 2, the COPCs from the 1993 data set were compared to the RI surface soil values. This comparison identified chemicals/radionuclides that were not previously detected and chemicals/radionuclides which were detected in concentrations greater than those previously reported. COPCs passing this test were retained. All other constituents were dismissed from further consideration.

In step 3, the retained COPCs were subjected to a toxicity screen, using the methodology described in Section E.2, to screen out those constituents that were considered to be benign or innocuous. Chemicals passing this test were identified as CPCs.

Step four consisted of a qualitative risk evaluation. For those CPCs which were not considered in the RI report and for those CPCs whose concentration increased by 20 percent or more over the value used in the RI report, a semi-quantitative analysis was performed to estimate the magnitude of the associated change in the baseline risk assessment for all predominant pathways.

Screening Criteria

Table E.6-1 lists the chemicals/radionuclides detected in the RI and the 1993 surface soil sampling, the representative concentrations of the detected constituents (as defined in Section E.2.2.2), and the representative concentrations used in the baseline risk assessment. Column 7 identifies those constituents which have representative concentrations above background levels (COPCs). In column 8, the COPCs are divided into four categories. The noted categories, shown below, identify those constituents which required evaluation to determine if the 1993 data might impact the baseline risk assessment. The CPC and Screen Code columns identify those constituents that are CPCs. For those constituents not considered to be a CPC, a screening code(s) is listed.

1. The representative concentration from the 1993 data is less than or equal to the representative concentration derived from the RI data. No change to the representative concentration is required and the constituent need not be considered further.

2. The constituent was originally screened from the baseline risk assessment (i.e., the constituent was not a CPC), but the representative concentration from the 1993 data is greater than the representative concentration from the RI data. The constituent should be evaluated to determine if the increase in representative concentration will cause the constituent to become a CPC which may then impact the baseline risk assessment.

3. The constituent was defined as a CPC and considered in the baseline risk assessment and the representative concentration from the 1993 data is greater than the representative concentration used in the baseline risk assessment. The constituent should be evaluated to determine if the increase in representative concentration has an impact on the baseline risk assessment.

4. The constituent was detected in the 1993 sampling event but was not previously detected during RI sampling. The constituent should be evaluated to determine if the addition of the constituent has an impact on the baseline risk assessment.

Those chemicals/radionuclides which were identified as CPCs and which fell into category 3 or 4 are shaded in Table E.6-1 and listed separately in Table E.6-2. Four CPCs were detected at higher concentrations than previously reported. In addition, two of the chemicals/radionuclides detected in the 1993 data were found to be CPCs which had not been previously detected in the RI samples. The ratio of the 1993 representative concentrations for the CPCs to the representative concentrations used in the

baseline risk assessment are shown in Table E.6-2. All ratios indicate that the 1993 data would result in small increases in the representative concentration terms over those used in the baseline risk assessment.

Identification of Critical Exposure Receptors and Pathways

The radiological and chemical RME receptors, predominant exposure pathways, and the major risk contributors for each land-use scenario were evaluated for the soil/air pathways in the RI report, Attachment E.IV. The scenarios that resulted in the highest risk were the off-property user of meat and dairy products for current land use and the on-property resident farmer for future land use. Of the two scenarios, the future on-property resident farmer scenario has the higher total risk. Therefore, the future on-property resident farmer scenario was used to perform a sensitivity analysis for the constituents listed in Table E.6-2.

Sensitivity Analysis

As presented below, an analysis of the additional constituents, or of the increased concentrations of existing constituents found in the 1993 data, indicates no additional impact on the incremental lifetime cancer risk or hazard quotient nor do they impact the existing list of COCs.

As shown in Table E.6-1, 1993 radionuclide representative concentrations are less than those used in the baseline risk assessment, with the exception of Np-237 which is greater by approximately 30 percent. For radionuclides, the greatest risk to the on-site resident farmer is due to external exposure. The fractional contribution of Np-237 to the total radiological risk from external exposure is 0.22 percent, as calculated from the data in Table E.IV-16. Since the external risk from any uniformly distributed gamma emitting radionuclide is proportional to its concentration, increasing the concentration by approximately 30 percent will increase the risk value for Np-237 by 30 percent. However, Np-237 contributes less than 0.5 percent to the total risk. Thus, use of the increased representative concentration of Np-237 from the 1993 data would result in a negligible increase (30% x 0.5% = 1.5%) in the total risk value reported for this scenario.

Thorium-total, benzo(a)pyrene, and benzo(b)fluoranthene represent the only CPCs whose representative concentrations from the 1993 surface soil data are greater than the representative concentrations used in the baseline risk assessment. In the case of total-thorium, the 1993 representative concentration is greater than the RI representative concentration by a factor of 2.0. Total-thorium was not used in calculating

either the incremental lifetime cancer risk (ILCR) nor the hazard quotient (HQ), so the noted increase has no effect on the total risk.

The total ILCR for the incidental ingestion pathway of the on-site resident farmer is 1.4×10^{-2}, see Table E.IV-16. Benzo(a)pyrene and benzo(b)fluoranthene contribute less than 0.005 percent of the total risk, having risk values of 6.9×10^{-7} and 1.8×10^{-7}, respectively. The increases in the representative concentrations for benzo(a)pyrene and benzo(b)fluoranthene result in a negligible increase in the total risk.

With regard to the additional CPCs, phenanthrene is identified as a class D chemical. There are no reference values for phenanthrene in IRIS, HEAST, or the EPA screening document used for toxicity screening. Thus, it is not considered to be a chemical of concern. Octochlorodibenzo-p-dioxin (OCDD) was detected in the 1993 surface soil data at a representative concentration of 0.9 ppb. The baseline risk assessment model was used to evaluate the associated risk under worst-case conditions. The model was run for the RME resident farmer under the future source term, future scenario. The model considered the contribution of risk due to OCDD in surface soil via all applicable pathways used in the baseline risk assessment. The calculated incremental lifetime causes risk to the RME resident farmer due to 0.9 ppb of OCDD in surface soil is 5.1×10^{-5}. Under this same scenario, the total risk due to non-radiological constituents in surface soil is 5.4×10^{-2}. In other words, the risk due to OCDD is 1/1000th of the total ILCR due to non-radiological constituents in surface soil. Based upon this comparison, it is projected that the presence of 0.9 ppb OCDD in Operable Unit 1 surface soil has virtually no impact on on-site risk values presented in the baseline risk assessment.

E.6.3.2 Evaluation of TICs

Based upon the methods used for the analysis, validation and the quantification of COCs, a number of tentatively identified compounds (TICs) were removed from the list of chemicals destined for quantitative analysis. These constituents were removed based upon the protocol established in the risk assessment guidelines. Qualifiers used for evaluation of these constituents indicate the positive nature of the compound and the concentration was in question and insufficiently reliable for quantitative assessment. However, a qualitative toxicological evaluation of Operable Unit 1's TICs was prepared, in order to ascertain the degree of uncertainty they impose.

The evaluation of potential toxicity and contribution to site risk of TICs is examined in relation to the chemical classes to which they belong. Related target organ systems, and a toxic effect, based upon

estimated levels and the potential for exposure were also considered. A list of TICs and their chemical classes are presented. Estimated maximum concentrations are in (μg/kg) unless otherwise noted.

E.6.3.2.1 General Discussion

Tentatively identified compounds are defined as those compounds that may result from chromatographic responses that exceed 10 percent of the response of the nearest internal standard (EPA 1989a). Reporting requirements for analyses presume a maximum of 10 TICs to be reported for volatiles and a maximum of 20 TICs to be reported for semivolatiles. In general, TICs may be associated with the presence of blank contamination, laboratory artifacts such as aldol condensation products, chromatographic column bleed, biological compounds present in soil, residual compounds from previous analyses, degradation products and exotic organics, esters, and nitrogenous compounds from soil and plant life, as well as other contaminants.

Organic compounds may exhibit response factors in the range of 0.05 to 2.0, as opposed to a factor of 1.0 for equal chromatographic responses based upon the reference to the nearest internal standard. Due to the variability in potential response factors of organic compounds, when no internal standard is available, then estimation of TIC presence, origin, or concentration is made more difficult. Given a response factor range of 0.05 to 2.0, the quantitative sum of all TICs in a given sample with 10 parts per million, could have an actual value as low as 0.25 parts per million, or a maximum value as high as 400 parts per million. The range, which may be reduced with additional analyses or evaluations, is based on the uncertainty of identification, response, and concentration. The TICs listed in Table E-6-4 such as tributyl phosphate and the several solvents may be associated with residual process products or materials.

Tentatively identified compounds were found in 25 of 61 semivolatile samples and 17 of 68 volatile samples of pit material. Concentrations were detected at the low ug/kg (ppb) levels, and occasionally in the low parts per million range (mg/kg). Generally, their presence in deeper pit media (below 4 feet) and the low concentrations of many constituents would preclude any serious cause for concern.

The potential for toxicity of TICs is qualitative since their estimated levels are uncertain and the availability of experimental or clinical information on dose response and toxicity for most TICs is non-existent.

Chromatographic separation and analysis is known to produce synthetic artifacts. Degradation and/or condensation products are well known and occur on the solid phase during separation. Such compounds are usually present in low concentrations and usually of varying composition.

The disparity of the magnitude of concentrations between the results of concurrent analyses of total organic contents and TIC items adds to uncertainty, suggesting these estimated values cannot be relied upon as factual. Accordingly, toxicity cannot be adequately defined.

E.6.3.2.2 Toxicity Assessment By TIC Classes

Table E.6-4 presents the TICs found in Operable Unit 1 by compound class.

Alcohol-Glycols

Most alcohols and glycols do not usually present a serious hazard to most individuals, even in the industrial setting. Specific compounds such as methanol and ethylene glycol are involved in either widespread or isolated instances of intoxication.

Industrial exposure to most alcohols and glycol compounds rarely produce symptoms of chronic systemic intoxication. Methanol can cause blindness in humans and ethylene glycol has produced fatalities. Toxicity from the vapors are generally to the conjunctivae of the eyes and the mucous membranes of the upper respiratory tract and possibly the skin. The low vapor pressure of the low molecular weight alcohols (ethanol and methanol) and glycols (ethylene glycol) would not achieve significant air concentrations unless the compound was heated or sprayed as a mist. Also at the soil depths discussed above, they would not be likely to produce concern. Although they have narcotic properties, they are much less prominent than those associated with solvent or halogenated hydrocarbons. Alcohols are rapidly removed from the body via the dehydrogenase enzymes present in the liver. The potential for toxicity rests on the amount consumed; generally large doses are required for toxicity.

Propanols have little potential for serious or chronic toxicity. Ingestion causes symptoms typical of ethanol intoxication; central nervous system depression, drowsiness and headaches. Butanols have been shown to be toxic when ingested, but systemic effects have not been noted at concentrations below 100 parts per million. At 200 parts per million air concentration, optic irritation, blurred vision, burning and lacrimation of the eyes are noted. Pentanols are irritating and narcotic and produce illness when ingested. Methanol, 2-propanol, 2-butanol and 2-methyl propanol mimic the effects of ethanol poisoning and, like

many ketones, can increase the hepatic effects of halogenated hydrocarbons. Toxicologically, this group appears to be of very little significance to risk.

Hexanol (like hexane) can be metabolized to 2, 5-hexanedione. This metabolite may initiate nerve damage and if the exposure is chronic, it could cause serious peripheral neuropathies. However, this occurs only under chronic exposure and at fairly high concentrations (such as 500 parts per million for hexane). It is generally found in the industrial setting. This is unlikely at the FEMP. Alcohol solvents are liquid and highly volatile. Because of their widespread use there is a potential for adverse effects from the industrial setting. FEMP concentrations of the alcohols do not contribute to the site risk.

CONCLUSION: IMPACT FROM ALCOHOLS/GLYCOLS ON RISK IS PROBABLY LOW

Aldehydes/Ketones

Together this group comprises a group of chemicals known as carbonyl compounds. There are a few that are toxicologically important and affect the eyes, skin and mucous membranes. Some are irritants of the eyes, skin and mucous membranes. However, their metabolism is too rapid to produce any cumulative effects needed for systemic toxicity. Halogenated ketones can be considered highly toxic; however there are no such compounds in this list of TICs. Derivatives of butanone and 2-hexanone can produce both chronic and short-term effects, especially to muscle/nerve tissue causing peripheral polyneuropathies.

2-heptanone, 2-pentanone, methyl isobutyl ketone is also used as a solvent for lacquer thinner. Its strong odor limits use and minimizes exposures. Most of these compounds irritate the mucous membranes and are strongly narcotic at higher concentrations, possibly requiring levels above 200 parts per million to demonstrate these effects.

CONCLUSION: IMPACT ON RISK FROM ALDEHYDE/KETONES IS PROBABLY LOW.

Aliphatics

The aliphatic hydrocarbons includes saturated as well as unsaturated compounds. They are products of petroleum cracking. The lower weight compounds are gaseous (methane, ethane, propane, and butanes). The pentane series (C_5-C_{16}) tends to be volatile liquids. These materials are not chronic toxins. These are simple asphyxiants and tend only to displace oxygen when present in high concentration causing hypoxia. In general the saturated hydrocarbons (C_4-C_8) show very strong narcotic properties. Heavier

members of the series are not highly volatile and require heat to generate vapor concentrations capable of causing narcosis.

The hexane molecule is capable of peripheral neuropathies. Large doses over long periods of time would be required for this adverse effect to occur. The closely related pentane and heptane molecules (C_5 and C_7), are unlikely to cause any such adverse effects. However, high concentrations of vapors from heptane (C_7) and octane (C_8) molecules can cause giddiness, vertigo headache and anesthetic stupor. These symptoms tend to be reversible and full recovery generally occurs. Based upon the levels and at the depths present of these materials in the pits, these responses are unlikely.

CONCLUSION: THE IMPACT ON RISK FROM ALIPHATICS IS PROBABLY LOW.

Amino/Nitro Compounds

Aromatic amino and nitro compounds are fundamental to manufacture of explosives, pharmaceuticals, herbicides, plastic, paint and rubber industries. Aniline and coal tar dyes are products that contain nitrogen groups. There are general toxic properties characteristic of this group in that many of these compounds can cause methemoglobinemia. However, some are proven to be bladder carcinogens while others affect the oxidative phosphorylation mechanism.

Several herbicides contain nitrile compounds. The nitriles have been shown to cause headache, fever, dizziness, vomiting, weight loss and leg myalgia. The lethal dose in rats occurs at levels above 270 mg/kg.

CONCLUSION:IMPACT TO RISK FROM AMINO/NITRO GROUPS IS PROBABLY MODERATE.

Aromatic/Polyaromatic Hydrocarbons

Among the aromatics, benzene presents the greatest potential threat to human health due to its known potential to cause leukemia. Related alkyl benzene compounds have the potential to cause central nervous system narcosis. However, the alkylbenzenes tend to be relatively non-toxic except at high concentrations during acute exposures.

Pyridines are a special group of compounds, that are fat soluble and tend to penetrate the intact corneal epithelium, then rapidly reaches the iris and causes iritis. This causes leakage of proteins and leukocytes if sufficient concentrations develop.

Polyaromatic compounds such as the chlorinated biphenyls, phenanthrene and anthracene were identified as COCs and the risk was quantified. However, additional compounds, could increase the risk for adverse effects, such as skin chloracne. However, these compounds require a certain molecular shape and if present, induce the hepatic enzyme, arylhydrocarbon hydroxylase which correlates highly with chloracne. These agents are capable of initiating other adverse skin reactions and considered to be skin carcinogens. They may be considered as co-carcinogens. They could increase the impact on risk.

CONCLUSION: THE IMPACT ON SITE RISK FROM AROMATIC/POLYAROMATIC HYDROCARBONS IS PROBABLY MODERATE.

Carboxylic Acids

Carboxylic acids are soluble forms of compounds that are easily conjugated by the liver enzymes and are rapidly removed from tissue due to their high solubility as conjugated polar compounds. Toxicity of these compounds is generally unknown: however, due to their high solubility and rapid removal from the body, effects would appear to be minimal.

CONCLUSION: IMPACT ON RISK FROM CARBOXYLIC ACIDS IS PROBABLY LOW.

Esters

Esters are chemical compounds that are formed when an organic radical group (R) replaces the hydrogen atom in an organic acid. Generally these compounds are found in the plastics industry either as resins, as plasticizers or as solvents for lacquers. Generally, esters of organic acids tend to be of low toxicity; although there are exceptions. The more saturated the compound, the more likely it will be harmless. Higher levels of double bonds in these molecules tend to increase the ability for skin irritation.

Esters used as plasticizers, with the exception of certain phosphate esters, are usually physiologically inert. In those instances from exposure to acrylates, methacrylates, crotonates and vinyl and allyl esters are the source of exposure, toxicity demonstrated by conjunctivitis, upper respiratory irritation and pulmonary edema may occur.

Tributyl phosphate (TBP) ester has found use as a solvent in the uranium extraction process. Its harmful effects are limited to the respiratory system, the skin and eyes. There do not appear to be any chronic manifestations of exposure. As with most acute toxins, removal of the source will allow reverse of the symptoms. The ACGIH established an air level of 1300 mg/m^3 TBP as immediately dangerous to life.

As a rule, mammalian metabolic systems have broads classes of esterase enzymes present in the liver and kidney to hydrolyze the linkages of foreign compounds. They are rapid in their action and remove such materials from the body quickly through increased solubility.

CONCLUSION: THE IMPACT TO RISK FROM THESE ESTERS IS PROBABLY LOW.

Furans

Furans cause irritation of the eyes and upper respiratory system. Nausea, dizziness and headaches are a symptom of exposures above 200 parts per million. Carcinogenicity in furans is assumed and although furans are a significant compound class with respect to risk, the relatively few TICs in this class that were reported would indicate that the impact on total risk is low.

CONCLUSION: THE IMPACT ON RISK IS PROBABLY LOW FROM THESE FURANS.

Dimethyl Sulfide

The impact from this compound is unknown. Toxicity data is lacking and precludes an evaluation of any possible toxic effects.

CONCLUSION: THE IMPACT TO RISK IS UNKNOWN.

Unknown Organic Compounds

There are a number of unidentified unknowns present in the LIST OF TICs; their impact on risk cannot be evaluated.

CONCLUSION: THE IMPACT ON RISK IS UNKNOWN.

E.6.3.2.3 Overall Impact of TICs on Risk

The overall impact on risk from these compounds is low. This is due to the fact that these materials are primarily from the lower horizons of pit material. Although there is risk of hazard from the exposure to the eyes and skin, this appears to be minimal because the source material has a very low level concentration in the pit materials. The volume of soil required for ingestion to produce an adverse effect from these levels of materials would be in excess of a few kilograms and is highly unlikely. Any possible risk, would likely be occupational, considering its likely that a construction or remedial worker, digging in the soil, would be exposed to the pit media.

These materials may be present due to the various reasons stated previously and/or present due to existing biological (plants, insects, microbes) products present naturally in the soils. This would tend to reduce the expectation that these materials would be toxic, except under fairly large exposure conditions. Although plant alkaloids can be toxic, there are few only at very small amounts and it would require the receptor to consume inordinately large volumes of pit material to reach toxic levels.

Under chronic conditions of exposure, a positive impact on risk always exists. The primary potential of such materials is to irritate the mucous membranes of the eyes and the respiratory tract. Given their presence in the pit materials, the impact is minimal, if at all.

The variability of these TIC compounds suggest residues from many biological activities, not likely associated with the site process activity. Together with the very low ppb levels, it reaffirms our belief that the presence of these tentatively identified compounds, at levels estimated, are unlikely to negatively impact human health and site risk.

The question of the degree of impact is a professional judgment: the certainty of its lack of impact on risk is fairly high. Given the low concentrations and locations of TICs, and the lack of complete exposure pathways, the degree of impact on total baseline risk is considered to be minimal.

TABLE E.6–1
EVALUATION OF POTENTIAL IMPACT OF 1993 SURFACE SOIL ON THE BASELINE RISK ASSESSMENT

1	2	3	4	5	6	7	8	9	10
Parameters	Units	CIS Representative Concentration	92 RI Representative Concentration	93 RI Representative Concentration	RI Representative Concentration	COPC	Category (1)	CPC	Screen Code (2)
Octachlorodibenzo–p–dioxin	µg/Kg			0.90		Y	4	Yes	
Aluminum	µg/Kg		8091102.55	11389106.41	0.00	Y	2	No	A
Antimony	µg/Kg		27856.01		27856.01	Y	1	Yes	
Arsenic	µg/Kg		5569.88	12100.00	0.00	N	2	No	A
Barium	µg/Kg		66095.08	76375.43	0.00	N	2	No	A
Beryllium	µg/Kg		771.44	580.00	771.44	Y	1	Yes	
Cadmium	µg/Kg		5862.71		5862.71	Y	1	Yes	
Calcium	µg/Kg		117759186.58	84018294.84	0.00	Y	1	No	B
Chromium	µg/Kg		15690.58	13697.99	0.00	Y	1	No	A
Cobalt	µg/Kg		10912.83	6554.91	0.00	N	1	No	A
Copper	µg/Kg		18058.91	18607.54	0.00	Y	2	No	J
Iron	µg/Kg		16809547.17	18444958.31	0.00	N	2	No	A
Lead	µg/Kg		16082.15	13273.52	0.00	N	1	No	A
Magnesium	µg/Kg		26467969.78	25936941.12	0.00	Y	1	No	B
Manganese	µg/Kg		611931.87	563547.86	0.00	N	1	No	A
Molybdenum	µg/Kg		4463.01	5400.00	0.00	Y	2	No	J
Nickel	µg/Kg		30099.62	16991.19	0.00	Y	1	No	J
Potassium	µg/Kg		976001.84	1481900.82	0.00	Y	2	No	A
Selenium	µg/Kg		620.00		0.00	Y	1	No	A
Silicon	µg/Kg			825169.17	0.00	N	4	No	D
Silver	µg/Kg		9001.36	4400.30	0.00	Y	1	No	J
Sodium	µg/Kg		140190.20	160504.41	0.00	Y	2	No	B
Thallium	µg/Kg		680.00		0.00	N	1	No	A
Vanadium	µg/Kg		21364.41	28730.05	0.00	N	2	No	A
Zinc	µg/Kg		49486.97	53086.40	0.00	N	2	No	A
Cyanide	µg/Kg		710.00	330.00	0.00	N	1	No	J
Aroclor–1254	µg/Kg		1400.00		1400.00	Y	1	Yes	
Cesium–137	pCi/g	1.11		0.19	1.11	Y	1	Yes	
Neptunium–237	pCi/g	0.50		0.63	0.50	Y	3	Yes	
Plutonium–238	pCi/g	0.70		0.20	0.70	Y	1	Yes	
Plutonium–239/240	pCi/g	0.60		0.17	0.60	Y	1	Yes	
Radium–226	pCi/g		1.35	2.08	0.00	N	2	No	A
Radium–228	pCi/g		2.22	1.14	0.00	N	1	No	A
Strontium–90	pCi/g	1.40	0.90	0.60	1.40	Y	1	Yes	

TABLE E.6–1
(Continued)

1	2	3	4	5	6	7	8	9	10
Parameters	Units	CIS Representative Concentration	92 RI Representative Concentration	93 RI Representative Concentration	RI Representative Concentration	COPC	Category (1)	CPC	Screen Code (2)
Technetium–99	pCi/g	33.00	0.90	0.61	0.00	N	1	No	A
Thorium–228	pCi/g	17.00	2.19	1.47	0.00	N	1	No	A
Thorium–230	pCi/g	219.00	3.45	17.50	219.00	Y	1	Yes	
Thorium–232	pCi/g	11.00	1.20	1.24	0.00	N	1	No	A
Thorium–Total	µg/Kg		5800.00	11310.00	5800.00	Y	3	Yes	K
Uranium–234	pCi/g	78.22	17.53	5.63	78.22	Y	1	Yes	
Uranium–235	pCi/g	25.00			25.00	Y	1	Yes	
Uranium–235/236	pCi/g		3.91	0.44	3.91	Y	1	Yes	
Uranium–238	pCi/g	738.00	103.70	20.69	738.00	Y	1	Yes	
Uranium–Total	µg/Kg		414000.00	63830.00	414000.00	Y	1	Yes	
2–Methylnaphthalene	µg/Kg			240.00	0.00	Y	4	No	E
4–Methylphenol	µg/Kg		390.00		0.00	Y	1	No	J
Acenaphthene	µg/Kg			280.00	0.00	Y	4	No	E
Anthracene	µg/Kg			66.00	0.00	Y	4	No	E
Benzo(A)Anthracene	µg/Kg		98.00	77.00	98.00	Y	1	Yes	
Benzo(A)Pyrene	µg/Kg		42.00	86.00	42.00	Y	3	Yes	
Benzo(B)Fluoranthene	µg/Kg		59.00	160.00	59.00	Y	3	Yes	
Benzo(K)Fluoranthene	µg/Kg		46.00		46.00	Y	1	Yes	
Benzo(g,h,i)perylene	µg/Kg			67.00	0.00	Y	4	No	E
Benzoic Acid	µg/Kg		73.00		0.00	Y	1	No	J
bis(2–Chloroisopropyl) ether	µg/Kg			44.00	0.00	Y	4	No	E
bis(2–Ethylhexyl)phthalate	µg/Kg		847.59	1452.71	0.00	Y	2	No	J
Carbazole	µg/Kg			76.00	0.00	Y	4	No	J
Chrysene	µg/Kg		88.00	77.00	88.00	Y	1	Yes	
Di–n–butyl phthalate	µg/Kg			71.00	0.00	Y	4	No	J
Dibenzofuran	µg/Kg			150.00	0.00	Y	4	No	E
Fluoranthene	µg/Kg		98.00	130.00	0.00	Y	2	No	J
Fluorene	µg/Kg			80.00	0.00	Y	4	No	I
Indeno(1,2,3–cd)pyrene	µg/Kg			64.00	0.00	Y	4	No	J
Naphthalene	µg/Kg			1000.00	0.00	Y	4	No	E
p–Chloroaniline	µg/Kg			500.00	0.00	Y	4	No	J
Phenanthrene	µg/Kg			240.00		Y	4	Yes	
Phenol	µg/Kg		110.00		0.00	Y	1	No	J
Pyrene	µg/Kg		130.00	110.00	0.00	Y	1	No	J

TABLE E.6–1
(Continued)

1	2	3	4	5	6	7	8	9	10
Parameters	Units	CIS Representative Concentration	92 RI Representative Concentration	93 RI Representative Concentration	RI Representative Concentration	COPC	Category (1)	CPC	Screen Code (2)
1,1,1–Trichloroethane	µg/Kg			1.00	0.00	Y	4	No	E
1,1–Dichloroethane	µg/Kg			2.00	0.00	Y	4	No	I,J
2–Butanone	µg/Kg		3.00	2.00	0.00	Y	1	No	J
2–Hexanone	µg/Kg			2.00	0.00	Y	4	No	E,I
4–Methyl–2–Pentanone	µg/Kg		1.00		0.00	Y	1	No	J
Acetone	µg/Kg		26.00	3.00	0.00	Y	1	No	J
Benzene	µg/Kg			3.00		Y	4	No	E
Chlorobenzene	µg/Kg			10.00		Y	4	No	E,I
Methylene Chloride	µg/Kg		51.00		0.00	Y	1	No	J
Toluene	µg/Kg		1.00	10.00	0.00	Y	2	No	J
Trichloroethene	µg/Kg			4.00		Y	4	No	J
Xylenes, Total	µg/Kg			2.00		Y	4	No	J

(1)
1 – Representative concentration from 1993 data lower than representative concentration from RI.
No change to representative concentration required.
2 – For a constituent which was screened out during the RI (i.e., the constituent was not considered to be a CPC), the representative concentration from the 1993 data is greater than the representative concentration from the RI. The data should be evaluated to determine if it would cause the constituent to become a CPC or will screen out.
3 – For a constituent which was not screened out under the RI (i.e., the constituent was considered to be a CPC), the representative concentration from the 1993 data is greater than the representative concentration used in the RI. The resulting increase in the RI should be evaluated for potential impact to the baseline risk assessment.
4 – The constituent was detected in the 1993 data but was not detected in previous RI sampling. The constituent should be evaluated to determine if its addition has an impact on the baseline risk assessment.

(2)
A – Concentration is not statistically different from background
B – Essential macronutrient with no known toxic effects
D – Ubiquitous element in soil not toxic except at high levels
E – Chemical detected a less than or equal to 5 % of time in samples
I – Vapor pressure < 10 mmHg at 20 degrees C
J – HQ value < 0.01 or ILCR < 10–7 in Region III screening criteria (EPA,1993c)
K – CPC retained but not quantitatively evaluated in risk assessment

TABLE E.6–2
CPCs FROM 1993 SURFACE SOIL DATA WITH POTENTIAL IMPACT TO THE BASELINE RISK ASSESSMENT

	Concentration (μg/kg)		Concentration
	1993 Data	RI Report	Ratio
Existing CPCs			
Benzo(a)pyrene	86.0	42.0	2.0
Benzo(b)fluoranthene	160.0	59.0	2.7
Neptunium–237[1]	0.63	0.50	1.3
Total Thorium	11310.0	5800.0	2.0
Additional CPCs			
Octachlorodibenzo–p–dioxin	0.9		
Phenanthrene	240.0		

[1] pCi/g

TABLE E.6-3

UNCERTAINTIES ASSOCIATED WITH ESTIMATED RISKS FROM OPERABLE UNIT 1

Source of Uncertainty	Magnitude[a]	Expected Direction[b]	Remark
Selection of CPCs:			
• Adequacy of database	Low to Moderate	Increases or decreases conservatism	CPCs may be underestimated. Principal constituents were identified.
Exposure Assessment:			
• Calculated exposure point concentrations			
- positive bias in sampling	Moderate	Increases conservatism	Source concentrations based on 95% UCL or maximum. Sampling was biased for radiological CPCs
- conservative modeling assumptions	High	Increases conservatism	Modeled concentrations were conservative.
• Determination of land uses			
- current scenario	Low	Increases conservatism	Scenario based on current environmental setting
- future scenario	High	Increases conservatism	Worst case scenario assumed.
• Assumptions for source terms			
- current source term	Low	Increases or decreases conservatism	Current source term assumes waste pits covered and surface water runoff treated.
- future source term	Moderate	Increases conservatism	Future source term assumes failure of Waste Pit 3 cover.
• Selection of receptors			Scenario based on current environmental setting.
- current scenario	Low	Increases conservatism	Worst case scenario assumed.
- future scenario	High	Increases conservatism	
• Determination of exposure factors	Low to moderate	Increases conservatism	Receptor and exposure pathway specific.

TABLE E.6-3
(Continued)

Source of Uncertainty	Magnitude[a]	Expected Direction[b]	Remark
Toxicity Assessment:			
• Dose-response assessment			
- chemical CPCs	High	Increases conservatism	Dose-response based on animal data.
- radiological CPCs			
internal	Low	Increases conservatism	Dose-response based on human data.
external	Moderate to high	Increases conservatism	Conservative assumptions made for external exposure.
• Other OU1 CPCs			
- dose-response for PAHs	Low	Increases conservatism	PAHs pose low risk.
- dose-response for PCBs	Low	Increases conservatism	PCBs pose relatively low risk.
- dose-response for dioxins/furans	Low	Increases conservatism	Furans/dioxins relatively low risk.
- dose-response for Rn-222 (indoors)	Low to moderate	Increases conservatism	Assumptions for indoor Rn-222 differ from those made for the CSF.
Risk Characterization:			
• Additivity	Low to moderate	Increases conservatism	Health effects dominated from few CPCs and exposure pathways.
• Effect of tentatively identified compounds (TICs)	Low	Decreases conservatism	Relatively few TICs.
• Failure to consider antagonism	Unknown	Increases conservatism	Data unknown.
• Failure to consider synergism	Unknown	Decreases conservatism	Data unknown.
• Failure to consider segregation of HIs	Low	Increases conservatism	HIs dominated by few CPCs and exposure pathways.
Overall	High	Increases conservatism	High uncertainty from combining low, moderate, and highly uncertain parameters.

[a] Magnitude is assessed qualitatively based on professional judgment and includes the following:
Low-impact risk by a factor of 10 or less.
Moderate-impact risk by a factor of 10 to 100.
High-impact risk by a factor of 100 or more.

[b] Direction is assessed qualitatively where an increased conservatism increases final health effects and a decreased conservatism decreases final health effects calculated in risk assessment.

TABLE E.6-4
LIST OF TICS BY CLASS[a]

ALCOHOL/GLYCOL
3-methyl-2-butanol(13000)
4-butanediol-diacetate(370)
2-butoxyethanol(28)
2-cyclohexanemethanol(78)
dodecylcyclohexanol(14000)
2-propyl-1-heptanol(47)
tetrahydropyran-2,3-diol(4900)
2,4-dimethyl pentanol(31)
tetracontanol(5800)
undecen-1-ol(34)

ALDEHYDE/KETONE
1-(3-ethyloziranyl)-7-ethanone(680)
2-ethoxy-1,2-diphenyl ethanone(160)
butanal(140)
3-methyl-2-butanone(13mg/kg)
6-acetyloxy-2-hexanone(22mg/kg)
dihydroxy-2-hexanone(450)
5-methyl-3-hexen-2-one(660)
3h-naphtha-2,1-b-pyran-3-one(2700)
2h-pyran-2,3-diol-tetrahydrodiacetate(5180)

ALIPHATICS
bicyclononane(61)
1,4-dimethylcyclooctane(32)
bicycloheptane(220)
azabicyclohexane(190)
decyl-cyclohexane(2400)
eicosyl-cyclopentane(2300)
1-methyl-1,4-cyclohexadiene(30)
1-methyl-3-(1-methylethyl)-cyclopentane(55)
cyclopropane(4700)
hexatriacontane(910)
tetra-1,3-dioxalane(410)
2-methyl-6-propyldodecane(200)
2-methyl-4,5-nonadiene(61)
2-methyl-1-propene(45)
4-methyloctane(190)
spirodecane(1000)
tetradecane(590)
tricyclodecane(140)
1,3,6-trioxocane(39)
tri-tetracontane(240)

AMINO/NITRO COMPOUNDS
2,4-pentadiene nitrile(45)
2-methyl-1-nitropropane(20)
1,4-dibutyl-tetrazine(2300)

AROMATIC/POLYAROMATIC
cyclohexyloxy-benzene(2500)
1-choloromethyl-isobenzene(25)
Isoquinolinium(6400)
decahydronaphthalene(150)
dibenzothiophene(1500)
5h-indeno-1,2-pyridine(41mg/kg)
pentachlorobiphenyl(6.8mg/kg))
tetrachlorobiphenyl(2.0mg/kg)
benzanthracene(22mg/kg)
cyclopentaphenanthrene(3000)
methylphenanthrene(15mg/kg)

CARBOXYLIC ACIDS
2,4-dinitrobenzeneacetic acid(4000)
hexanedioic acid(16mg/kg)
1-phenyl-cyclopropane-carboxylic acid(57)
2-methylpentanoic acid(6600)
octadecanoic acid(4400)

ESTERS (of the following acids)
tributylphosphoric acid(7700)
hexanedioic acid(12.0mg/kg)

FURANS
tetrahydrofuran(14)
2-propylfuran(1200)

SULFUR COMPOUNDS
dimethyl sulfide(40)

UNKNOWNS
C_6 THROUGH C_{30}

[a] All concentrations are reported in μg/kg, unless otherwise noted. These concentrations are considered to be relatively low (ppb range), as compared to the detected analytes on the target analyte list.

E.7.0 SUMMARY AND COMPARISON TO BACKGROUND

The baseline risk assessment was performed in accordance with available EPA guidance and follows the guidelines for performing risk assessments at the FEMP, as described in the Risk Assessment Work Plan Addendum (DOE 1992a). This section contains a summary of the Baseline Risk Assessment in Section E.7.1 and information on risks associated with natural (background) soils is presented in Section E.7.2.

E.7.1 RISK ASSESSMENT SUMMARY

A summary was performed on the available chemical and radiological data for determination of constituents of potential concern (CPCs) for the quantitative baseline risk assessment. The data for each pit were summarized separately and CPCs were determined for each pit. The CPC list includes radionuclides, inorganics, and organic compounds. Radionuclide CPCs are of the uranium and thorium series along with trace amounts of their fission products. Inorganics detected at concentrations above background include arsenic, lead, and antimony. Organic chemicals that were selected as potential CPCs included polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and other volatile and semi-volatile organic compounds.

Potential human health effects, calculated for OU1, were evaluated based on the range of acceptable risk under CERCLA. These generally acceptable risk ranges are an ILCR of 10^{-6} to 10^{-4} and an HI of less than 1 (EPA 1992d). In general, estimated cancer risks associated with the scenarios involving current chemical concentrations and continued access controls are in the range of 10^{-6} to 10^{-4}. However, for the scenarios that assume access control will be lost, or for those scenarios that assume exposures to calculate future concentrations, ILCRs are generally greater than 10^{-4} and most HIs are greater than 1. In fact, the total calculated ILCRs associated with chemical exposures by the on-property RME resident adult are about 1 x 10^{-1} (1 in 10 chance of developing cancer) for the future land use scenario.

Carcinogenic risks and Hazard Indices for identified receptors under current land use and current source term conditions are summarized in Tables E.7-1 and E.7-2, respectively. The receptors associated with this scenario were identified based on consideration of site access controls. The groundskeeper, off-property RME resident farmer, and off-property young

child were considered applicable for consideration with current access controls. The receptors considered applicable if access controls were removed are the trespassing youth, off-property RME resident farmer and child, and off-property user of meat and dairy products (an individual that would ingest meat and dairy products from livestock grazed on-site). With access controls, the exposure pathway contributing the greatest risk is external exposure of the groundskeeper to radiological constituents in buried pit materials. Under current land use without access controls the principle exposure pathways from the current source term are biotransfer of chemical CPCs into meat and milk products. The receptor with the greatest risk for current land use, current source term is the off-property user of meat and milk products from cows grazed on site with a total carcinogenic risks of 2×10^{-3}. The primary contributors to this risk are total PCBs and U-238 in the surface soil and Cs-137 in surface water as a result of their biotransfer to meat and milk products. The Hazard Indices for all these receptors are acceptable (less than 1) except for the off-property user of meat and milk products with a hazard index of 2.9. Antimony and cadmium in surface soils are the systemic toxins most significantly contributing to total cancer risk.

Tables E.7-3 and E.7-4 contain a summary of risks associated with current land use and future source term. Assumptions were made for the future source term regarding the configuration of the operable unit that would result in higher exposure to stored waste materials. The receptors given in Tables E.7-3 and E.7-4 include the trespassing youth and Great Miami River User (i.e., an individual that uses the river as a source of domestic water and for recreational purposes). A number of other receptors were also identified as relevant under current land use, future source term. These receptors include the off-property farmer and child, and off-property user of meat and milk products. The cancer risks and hazard indices are not dependent upon on-site land uses, and therefore, are applicable under the current and future land use scenarios. The cancer risks and hazard indices are presented under future land use, future source term evaluation.

Cancer risks for the current land use, future source term range from 3×10^{-7} for the Great Miami River User to 2×10^{-3} for the off-property RME farmer. The pathway contributing the majority of risk is ingestion of groundwater by the off-property RME farmer with uranium isotopes the primary contributors to total cancer risk. Total hazard indices range from 0.004 (Great Miami River User) to 90 for the off-property child. Groundwater was the pathway contributing the majority to the total hazard index for this receptor. Other exposure pathways

with a cancer risk in excess of 10^{-4}, or a hazard index in excess of 1, include inhalation of particulates (off-property farmer), ingestion of fruits and vegetables (off-property farmer and child), and ingestion of meat and milk products (off-property user of meat and milk products and off-property child).

Tables E.7-5 and E.7-6 present a summary of risks for on-property receptors associated with future land use with access controls (i.e., future government reserve), future source term. These receptors include the expanded trespasser, an individual that would trespass on the site both as a youth and as an adult, and a future groundskeeper. The risks summarized above for the off-property receptors (i.e., the off-property RME farmer and child, off-property user of meat and milk products, Great Miami River user) would also apply for this scenario. For on-property receptors, cancer risks range from 7×10^{-4}, for the expanded trespasser, to 2×10^{-3} for the groundskeeper. Hazard indices range from 2.2 (groundskeeper) to 4 (expanded trespasser). For the off-property receptors, cancer risks range from 3×10^{-7} for the Great Miami River User to 2×10^{-3} for the off-property RME farmer. Total hazard indices range from 0.004 (Great Miami River User) to 90 for the off-property child.

Tables E.7-7 and E.7-8 present a summary of risks for on-property receptors associated with future land use without access controls, future source term. Under this scenario, it was assumed the site would return to agricultural use. Potential receptors that were evaluated under this scenario include the RME on-property farmer, on-property child, homebuilder, off-property RME farmer and child, off-property user of meat and milk products, and Great Miami River user. Cancer risks range from 4×10^{-4} for the homebuilder to 1×10^{-1} for the on-property RME farmer. If the RME farmer is assumed to consume perched groundwater, potential cancer risks approach unity. Total hazard indices range from 4.9 for the off-property user of meat and milk products to 1600. The hazard index for the on-property RME farmer that consumes perched groundwater is 6100.

The maximum exposed individuals for the future source term and future land use scenario are the on-property RME resident farmer (carcinogenic assessment) and on-property RME child (noncarcinogenic assessment). The exposure pathway providing the largest single contribution to the overall risk is ingestion of water from the Great Miami River Aquifer for both radiological and chemical carcinogens and for chemical systemic toxicants.

Other routes of exposure that contribute cancer risks exceeding 10^{-4} or a hazard quotient greater than 1 for these receptors include inhalation of dust, ingestion of food products affected by aerial deposition, penetrating radiation from surface soils and buried pit material, direct contact with soil and exposed pit material, domestic and agricultural use of groundwater, and ingestion of meat and dairy products from cows grazed and watered on site. Total radiocarcinogenic and chemical carcinogenic risks are approximately 1×10^{-1} for all these routes of exposure combined. Individually, ingestion of groundwater containing metals (arsenic) and U-238 contributes almost half of this receptor's total risk followed by external exposure to surface soils and buried pit materials and inhalation of dust. Uranium and thorium isotopes and arsenic are the major carcinogens for these exposure pathways.

Routine consumption of perched water by the RME resident farmer (a highly unlikely scenario given the low yield of this water and the shallow depth of a more reliable, better quality aquifer) presents a cancer risk approaching unity primarily from concentrations of U-238.

E.7.2 RISKS FROM NATURAL BACKGROUND

All site-related risks in the risk assessment are calculated without accounting for the contribution from natural background. In many cases, the concentrations of CPCs in the soil at the OU1 waste pits are only slightly above natural background concentrations, but the ILCRs or HIs for these site-related concentrations are often greater than 10^{-4} and 1 respectively. Background contributions provide a useful point of comparison for site-related risk estimates.

Risks and hazard quotients are calculated for background concentrations of CPCs in soil. These results are presented in Tables E.7-9 and E.7-10. Exposure assumptions and models used for these background calculations are the same as those used for evaluating site-related risks to the RME on-property resident farmer. Soil concentrations used for background risk calculations are the UCL values determined for the site-specific background soil sample analytical results.

Background cancer risks from radionuclides and their short-lived progeny are 2×10^{-3}. The health risk attributable to the naturally occurring radioactive isotope of potassium, K-40, is slightly larger (within the same order of magnitude) than all other radioisotopes combined.

The risk from K-40 was not included in the total risk because K-40 was not selected as a CPC for this operable unit. Including it in the total risk from background could bias decisions if the total background risk were compared directly with the total site-related risks calculated in this report. K-40 is included separately because it is a ubiquitous component of background. Discounting the contribution from K-40, the exposure pathway that contributes nearly all of this risk is external radiation exposure from Ra-226, Th-228, and Ra-228 (and their short-lived progeny) in surface soil. It is important to note that the overall lifetime risk, as calculated by CERCLA methodology, from natural background radiation sources (such as cosmic radiation, naturally occurring radionuclides in surface soil, and radon) is approximately 1×10^{-2}. Background risks from arsenic and beryllium in soil at background concentrations also exceed 1×10^{-4}.

Background Hazard Quotients were calculated for natural background concentrations of inorganic chemicals in soil. Results of these calculations for the RME on-property resident adult are given in Table E-7.10. Again, the soil concentrations used are the site-specific background soil sample analytical results UCLs. The Hazard Index for background concentrations of inorganics is 8. The HQs estimated using the background UCLs and the methodology described in Section E.1 through E.5 exceed 0.1 for five metals (arsenic, boron, cadmium, manganese, and thallium), and the HQ for natural background levels of mercury exceeds 1.0. The results of the background risk calculation and the potential for toxic effects to occur from natural background concentrations of radionuclides and inorganic chemicals suggest that the risk assessment methodology has a conservative bias.

E.7.3 CONCLUSIONS

This appendix presents the results of the baseline risk assessment for each of the waste pits in Operable Unit 1. The methods, models, and parameters that have been used are in accordance with the Risk Assessment Work Plan Addendum (DOE 1992a), with exceptions noted in the text preceding sections of this appendix.

The emphasis on identifying potential uncertainties in Section E.6.0 of the risk assessment is not intended to discredit the calculation results, but to emphasize that conservative assumptions have been made whenever there is a lack of information or the information is incomplete. Refinement of waste pit characterization data, exposure assessment models and parameters, and risk characterization information will reduce these uncertainties.

TABLE E.7-1

INCREMENTAL LIFETIME CANCER RISK SUMMARY CURRENT LAND USE, CURRENT SOURCE TERM [a]

Media	Groundskeeper	Off-property Farmer	Off-property Young Child	Trespassing Youth	Off-property User of Meat and Milk Products
Air					
Radiocarcinogenic Risk	6E-06	3E-06	2E-07	7E-07	NA
Chemical Carcinogenic Risk	1E-08	2E-07	8E-08	2E-09	NA
Total[b]:	6E-06	3E-06	2E-07	7E-07	NA
Surface Soil					
Radiocarcinogenic Risk	8E-05	NA	NA	3E-05	5E-04
Chemical Carcinogenic Risk	1E-05	NA	NA	9E-06	9E-04
Total[b]:	9E-05	NA	NA	4E-05	1E-03
Buried Pit Material					
Radiocarcinogenic Risk	5E-05	NA	NA	2E-05	NA
Chemical Carcinogenic Risk	NA	NA	NA	NA	NA
Total[b]:	5E-05	NA	NA	2E-05	NA
On-property Surface Water					
Radiocarcinogenic Risk	NA	NA	NA	NA	2E-04
Chemical Carcinogenic Risk	NA	NA	NA	NA	6E-06
Total[b]:	NA	NA	NA	NA	2E-04
Sum All Media					
Radiocarcinogenic Risk	1E-04	3E-06	2E-07	5E-05	7E-04
Chemical Carcinogenic Risk	1E-05	2E-07	8E-08	9E-06	9E-04
Total[b]:	1E-04	3E-06	2E-07	5E-05	2E-03

NA – Not applicable. Exposure route not evaluated for receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum would result from adding the values in the table, due to rounding. Refer to Attachment E.IV for specific values.

[b] Radiocarcinogenic and chemocarcinogenic risks are not truly additive. A total is provided for reference only.

TABLE E.7–2

HAZARD INDEX SUMMARY
CURRENT LAND USE, CURRENT SOURCE TERM

Media	Groundskeeper	Off–property Farmer	Off–property Young Child	Trespassing Youth	Off–property User of Meat and Milk Products
Air	0.0E+00	2.7E–04	1.3E–03	0.0E+00	NA
Surface Soil	3.0E–01	NA	NA	4.9E–01	2.7E+00
On–property Surface Water	NA	NA	NA	NA	2.3E–01
Sum All Media	3.0E–01	2.7E–04	1.3E–03	4.9E–01	2.9E+00

NA – Not applicable. Exposure route not evaluated for receptor.

TABLE E.7-3

INCREMENTAL LIFETIME CANCER RISK SUMMARY CURRENT LAND USE, FUTURE SOURCE TERM [a]

Medium	Trespassing Youth	Great Miami River User
Air		
Radiocarcinogenic Risk	8E-05	NA
Chemical Carcinogenic Risk	4E-05	NA
Total[b]:	1E-04	NA
Surface Soil		
Radiocarcinogenic Risk	1E-04	NA
Chemical Carcinogenic Risk	7E-05	NA
Total[b]:	2E-04	NA
Buried Pit Material		
Radiocarcinogenic Risk	7E-06	NA
Chemical Carcinogenic Risk	NA	NA
Total[b]:	7E-06	NA
Paddys Run Surface Water		
Radiocarcinogenic Risk	7E-08	NA
Chemical Carcinogenic Risk	6E-08	NA
Total[b]:	1E-07	NA
Paddys Run Sediment		
Radiocarcinogenic Risk	4E-06	NA
Chemical Carcinogenic Risk	9E-06	NA
Total[b]:	1E-05	NA
Great Miami River Surface Water		
Radiocarcinogenic Risk	NA	3E-07
Chemical Carcinogenic Risk	NA	3E-08
Total[b]:	NA	3E-07
All Media		
Radiocarcinogenic Risk	2E-04	3E-07
Chemical Carcinogenic Risk	1E-04	3E-08
Total[b]:	3E-04	3E-07

NA – Not Applicable. Exposure route not evaluated for this receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum that would result from adding the values in the table, due to rounding. Refer to Attachment E.IV for specific values.

[b] Radiocarcinogenic risk and chemocarcinogenic risk are not truly additive. A total is provided for reference only.

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TABLE E.7-4

HAZARD INDEX SUMMARY
CURRENT LAND USE, FUTURE SOURCE TERM

Medium	Trespassing Youth	Great Miami River User
Air	2.5E-01	NA
Surface Soil	1.5E+00	NA
Paddys Run Surface Water	3.9E-02	NA
Paddys Run Sediment	1.1E-01	NA
Great Miami River Surface Water	NA	4.2E-03
All Media	1.9E+00	4.2E-03

NA – Not Applicable. Exposure route not evaluated for this receptor.

TABLE E.7-5

INCREMENTAL LIFETIME CANCER RISK SUMMARY
FUTURE LAND USE (GOVERNMENT RESERVE)
FUTURE SOURCE TERM [a]

Medium	On-property Groundskeeper	Expanded Trespasser
Air		
Radiocarcinogenic Risk	7E-04	1E-04
Chemical Carcinogenic Risk	2E-04	6E-05
Total[b]:	9E-04	2E-04
Surface Soil/Exposed Pit Material		
Radiocarcinogenic Risk	4E-04	3E-04
Chemical Carcinogenic Risk	2E-04	2E-04
Total[b]:	7E-04	5E-04
Buried Pit Material		
Radiocarcinogenic Risk	5E-05	3E-05
Chemical Carcinogenic Risk	NA	NA
Total[b]:	5E-05	3E-05
Paddys Run Surface Water		
Radiocarcinogenic Risk	NA	7E-08
Chemical Carcinogenic Risk	NA	6E-08
Total[b]:	NA	1E-07
Paddys Run Sediment		
Radiocarcinogenic Risk	NA	4E-06
Chemical Carcinogenic Risk	NA	9E-06
Total[b]:	NA	1E-05
All Media		
Radiocarcinogenic Risk	1E-03	4E-04
Chemical Carcinogenic Risk	4E-04	3E-04
Total[b]:	2E-03	7E-04

NA – Not Applicable. Exposure route not evaluated for this receptor.

[a] This table includes values that have been rounded to one significant figure. Therefore, the total number may be higher or lower than the sum that would result from adding the value in the table, due to rounding. Refer to Attachment E.IV for specific values.

[b] Radiocarcinogenic risk and chemocarcinogenic risk are not truly additive. A total is provided for reference only.

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TABLE E.7-6

HAZARD INDEX SUMMARY
FUTURE LAND USE (GOVERNMENT RESERVE)
FUTURE SOURCE TERM

Medium	Groundskeeper	Expanded Trespasser
Air	6.2E-01	2.9E-01
Surface Soil/Exposed Pit Material	1.6E+00	3.5E+00
Paddys Run Surface Water	NA	3.9E-02
Paddys Run Sediment	NA	1.1E-01
All Media	2.2E+00	4.0E+00

NA – Not Applicable. Exposure route not evaluated for this receptor.

TABLE E.7–7

INCREMENTAL LIFETIME CANCER RISK SUMMARY
FUTURE LAND USE (AGRICULTURAL USE)
FUTURE SOURCE TERM [a]

Media	On–property RME Farmer[c]	On–property RME Farmer[c] (User of Perched GW)	On–property CT Farmer	On–property Young Child	Off–property Farmer	Off–property Young Child	Homebuilder	Off–property User of Meat and Milk Products
Air								
Radiocarcinogenic Risk	5E–03	5E–03	4E–04	9E–05	2E–04	4E–06	1E–04	1E–05
Chemical Carcinogenic Risk	5E–03	5E–03	3E–04	1E–03	3E–04	7E–05	4E–05	8E–04
Total[b]:	1E–02	1E–02	7E–04	1E–03	5E–04	8E–05	2E–04	8E–04
Exposed Waste Pit Materials								
Radiocarcinogenic Risk	2E–02	2E–02	2E–03	2E–03	NA	NA	7E–05	NA
Chemical Carcinogenic Risk	9E–03	9E–03	6E–04	4E–03	NA	NA	2E–04	NA
Total[b]:	3E–02	3E–02	3E–03	6E–03	NA	NA	2E–04	NA
Surface Soil								
Radiocarcinogenic Risk	7E–04	7E–04	4E–05	1E–04	NA	NA	NA	5E–04
Chemical Carcinogenic Risk	1E–03	1E–03	6E–05	5E–04	NA	NA	NA	9E–04
Total[b]:	2E–03	2E–03	1E–04	6E–04	NA	NA	NA	1E–03
Buried Pit Material								
Radiocarcinogenic Risk	1E–03	1E–03	2E–04	2E–07	NA	NA	7E–09	NA
Chemical Carcinogenic Risk	NA	NA	NA	NA	NA	NA	NA	NA
Total[b]:	1E–03	1E–03	2E–04	2E–07	NA	NA	7E–09	NA
On–property Surface Water								
Radiocarcinogenic Risk	3E–04	3E–04	1E–05	4E–05	NA	NA	NA	3E–04
Chemical Carcinogenic Risk	6E–06	6E–06	4E–07	1E–06	NA	NA	NA	6E–06
Total[b]:	3E–04	3E–04	1E–05	4E–05	NA	NA	NA	3E–04
Groundwater								
Radiocarcinogenic Risk	2E–02	5E–01 b	2E–03	1E–03	2E–03	9E–05	NA	NA
Chemical Carcinogenic Risk	4E–02	9E–01 b	3E–03	9E–03	0E+00	0E+00	NA	NA
Total[b]:	6E–02	1E+00 b	4E–03	1E–02	2E–03	9E–05	NA	NA
All Media								
Radiocarcinogenic Risk	5E–02	5E–01 b	4E–03	3E–03	2E–03	1E–04	2E–04	8E–04
Chemical Carcinogenic Risk	5E–02	9E–01 b	4E–03	1E–02	3E–04	7E–05	2E–04	2E–03
Total[b]:	1E–01	1E+00 b	8E–03	2E–02	2E–03	2E–04	4E–04	2E–03

NA – Not applicable. Exposure route not evaluated for receptor.

[a] This table includes values that have been rounded to one significant fugure. Therefore, the total number may be higher or lower than the sum that would result from adding the values in the table, due to rounding. Refer to Attachment E.IV for specific values.

[b] Radiocarcinogenic and chemocarcinogenic risks are not truly additive. A total is provided for reference only.

[c] Risks calculated and total summed based on the use of the 1–hit equation for calculating risks from higher doses (EPA 1989a), therefore, total risks will not exceed 1.0.

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TABLE E.7–8

HAZARD INDEX SUMMARY
FUTURE LAND USE (AGRICULTURAL USE)
FUTURE SOURCE TERM

Media	On–property RME Farmer	On–property RME Farmer (User of Perched GW)	On–property CT Farmer	On–property Young Child	Off–property Farmer	Off–property Young Child	Homebuilder	Off–property User of Meat and Milk Products
Air	8.4E+00	8.4E+00	4.3E+00	2.8E+01	5.2E–01	1.7E+00	6.4E+00	1.9E+00
Exposed Waste Pit Materials	2.3E+01	2.3E+01	9.9E+00	9.8E+01	NA	NA	5.4E+01	NA
Surface Soil	5.3E+00	5.3E+00	2.6E+00	2.7E+01	NA	NA	NA	2.7E+00
On–property Surface Water	3.3E–01	3.3E–01	1.5E–01	2.7E+00	NA	NA	NA	3.3E–01
Groundwater	5.0E+02	6.0E+03	2.7E+02	1.4E+03	3.1E+01	8.8E+01	NA	NA
All Media	5.4E+02	6.1E+03	2.9E+02	1.6E+03	3.2E+01	9.0E+01	6.0E+01	4.9E+00

NA – Not applicable. Exposure route not evaluated for receptor.

TABLE E.7-9

INCREMENTAL LIFETIME CANCER RISKS FOR SOIL PATHWAYS
RME RESIDENT FARMER
NATURAL BACKGROUND CONCENTRATIONS

Radionuclide	0"-6" UCL Background Soil Concentration[a] (pCi/g)	Background Risk	Cancer Risks Operable Unit 1[e]
Cs-137 + 1 dtr	4.4×10^{-1}	4×10^{-5}	4×10^{-4}
Ra-226 + 8 dtrs	1.2×10^{0}	3×10^{-4}	1×10^{-2}
Th-230	1.5×10^{0}	1×10^{-7}	1×10^{-4}
Th-232 + 10 dtrs	1.1×10^{0}	4×10^{-4}	2×10^{-2}
U-234	1.0×10^{0}	3×10^{-7}	3×10^{-5}
U-235 + 1 dtr	8.8×10^{-2}	9×10^{-7}	4×10^{-4}
U-238 + 2 dtrs	1.1×10^{0}	2×10^{-6}	1×10^{-3}
K-40[d]	1.7×10^{1}	1×10^{-3}[d]	NA
Total Risk	--	**7×10^{-4}**[d]	**4×10^{-2}**

Chemical	0"-6" UCL Background Soil Concentration[b] (mg/kg)	Background Risk	Cancer Risks Operable Unit 1
Arsenic	6.0×10^{0}	2×10^{-4}	1×10^{-2}
Beryllium[c]	6.0×10^{-1}	2×10^{-4}	1×10^{-3}
Total Risk	--	**4×10^{-4}**	**1×10^{-2}**

[a]Radionuclide UCL background concentrations in soil (0"-6") are obtained from Attachment E.I, Table E.I-5.
[b]Chemical UCL background concentrations in soil (0"-6") are obtained from Attachment E.I, Table E.I-4.
[c]UCL was not calculated; frequency of detection was 1/30.
[d]The background risk for K-40 was not included in total background risk because K-40 was not selected as a CPC for this operable unit. Including it in the total risk from background could bias decisions if the total background risk were compared directly with the total site-related risks calculated in this report. It is included here because it is a ubiquitous component of background.
[e]Total cancer risks for Operable Unit 1 include risk to background concentrations of CPCs.

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TABLE E.7-10

TOXIC EFFECTS FOR SOIL PATHWAYS
RME RESIDENT FARMER
NATURAL BACKGROUND CONCENTRATIONS

Chemical	0"-6" UCL Background Soil Concentration[a] (mg/kg)	Background Hazard Quotient	Hazard Quotients Operable Unit 1
Arsenic	6.0×10^{0}	0.4	26
Beryllium[b]	6.0×10^{-1}	0.009	0.05
Barium	7.9×10^{0}	0.04	0.1
Boron	1.2×10^{1}	0.5	0.004
Cadmium	4.0×10^{-1}	0.1	1.5
Chromium	1.2×10^{1}	0.008	0.06
Cobalt	1.1×10^{1}	0.008	0.009
Manganese	9.8×10^{2}	0.9	0.8
Mercury[b]	3.0×10^{-1}	6	0.04
Molybdenum	ND[c]	--	0.2
Nickel	1.3×10^{1}	0.08	0.1
Silver	ND	--	3
Thallium[b]	5.8×10^{-1}	0.3	0.2
Uranium[d]	2.3×10^{0}	0.02	5
Vanadium	2.2×10^{1}	0.03	0.6
Total Hazard Index	--	**8**	**38**

[a]Chemical UCL background concentrations in soil (0"-6") are obtained from Attachment E.I,
Table E.I-4.
[b]UCL was not calculated; frequency of detection was 1/30 and maximum is presented.
[c]ND - Not detected.
[d]Total uranium arithmetic mean background concentration in soil is obtained from Table 4- 9 of the CERCLA/RCRA Background Soil Study (March 19, 1993).

References

REFERENCES

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Aaseth, J. and T. Norseth, 1986, "Copper," Handbook on the Toxicology of Metals, Vol. II, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Elsevier Science Publishers B. V., New York, pp. 233-254.

Abbatt, J. D., 1973, "Human Leukemic Risk Data Derived from Portuguese Thorotrast Experience," Radionuclide Carcinogenesis, CONG-72055, C. D. Sander, R. H. Busch, J. E. Ballou, and J. E. Mahlum, eds., U.S. Atomic Energy Commission, Washington, DC, pp. 451-464.

Agency for Toxic Substances and Disease Registry (ATSDR), 1987, Toxicological Profile for Benzo[a]Pyrene, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1988a, Toxicological Profile for Nickel, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1988b, Toxicological Profile for Tetrachloroethylene, Draft for Public Comment, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989a, Toxicological Profile for Benzene, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989b, Toxicological Profile for Carbon Tetrachloride, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989c, Toxicological Profile for Chlordane, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989d, Toxicological Profile for p,p'-DDT, p,p'-DDE, p,p'-DDD, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989e, Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-dioxin, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989f, Toxicological Profile for 1,1-Dichloroethene, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989g, Toxicological Profile for 1,1,2,2-Tetrachloroethane, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1989i, Toxicological Profile for Vinyl Chloride, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1990a, Toxicological Profile for Polycyclic Aromatic Hydrocarbons: Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i,)perylene, Chrysene, Dibenzo(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Phenanthrene, Pyrene, Draft for Public Comment, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry, 1990b, Toxicological Profile for Plutonium, Draft for Public Comment, U.S. Public Health Service, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR), 1992, Toxicological Profile for Selected PCBs (Aroclor-1260, -1254, -1248, -1242, -1232, -1221, and -1016), U.S. Public Health Service, Atlanta, GA, (Draft for public comment).

American Conference of Governmental Industrial Hygienists (ACGIH), 1986, Documentation of the Threshold Limit Values and Biological Exposure Indices, 5th ed., Cincinnati, OH.

American Conference of Governmental Industrial Hygienists (ACGIH), 1991, Documentation of the Threshold Limit Values and Biological Exposure Indices, 6th ed., Cincinnati, OH.

Anderson, D. P., C. W. Beard, and R. P. Hanson, 1964, "The Adverse Effects of Ammonia on Chickens Including Resistance to Infection With Newcastle Disease Virus," Avian Diseases, Vol. 8, pp. 369-379, (Cited in EPA 1992).

Archer, V. E., J. K. Wagoner, and F. E. Lundin, 1973, "Cancer Mortality Among Uranium Mill Workers," Journal of Occupational Medicine, Vol. 15, pp. 11-14.

Ballou, J. E., R. A. Gies, G. E. Dagle, M. D. Tolley, and A. C. Case, 1980, "Deposition and Late Effects of Inhaled $^{232}UO_2(NO_3)$ in Rats," PNL Annual Report 1980 (Biomedical Sciences) PNL-3700 P & L, Richland, WA, p. 142ff.

Barnett, J. R. and H. W. Dorough, 1974, "Metabolism of Chlordane in Rats," Journal of Agricultural and Food Chemistry, Vol. 22, pp. 612-619 (Cited in ATSDR 1989).

Bensted, J. P. M., 1967, "Experimental Studies in Mice on the Late Effects of Radioactive and Nonradioactive Contrast Media," American New York Academy of Sciences, Vol. 145, pp. 728-733.

Berlin, M, 1986a, "Mercury," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 387-445.

Berlin, M. and B. Rudell, 1986b, "Uranium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 623-637.

Boquin, L., D. Shuwei, Y. Airu, X. YinLin, G. Taibao, and C. Tao, 1982, "Studies on the Toxicity of Allyl Chloride," Ecotoxicology and Environmental Safety, Vol. 6, pp. 19-27 (Cited in EPA 1992).

Brown, D., K. R. Butterworth, I. F. Gaunt, P. Grasso, and S. D. Gangolli, 1978, "Short-term Oral Toxicity Study of Diethyl Phthalate in the Rat," Food and Cosmetic Toxicology, Vol. 16, pp. 415-422 (Cited in EPA 1992).

Budavari, S., Ed., 1989, The Merck Index, An Encyclopedia of Chemicals, Drugs, and Biologicals, 11th ed., Rahway, NJ: Merck and Co., Inc., p. 1517.

Cebrian, M. E., A. Albores, M. Aguilar, and E. Blakely, 1983, "Chronic Arsenic Poisoning in the North of Mexico," Human Toxicology, Vol. 2, pp. 121-133 (Cited in EPA 1992).

Clayton, W. J., Jr., 1967, "Fluorocarbon Toxicity and Biological Action," Fluorine Chemistry Review, Vol. 1, pp. 197-252 (Cited in EPA 1992).

Clement, Apr. 1988, Comparative Potency Approach for Estimating the Cancer Risk Associated with Exposure to Mixtures of Polycyclic Aromatic Hydrocarbons, Interim Final Report, ICF - Clement Association.

Clement International, 1990, "Development of Relative Potency Estimates for PAHs and Hydrocarbon Combustion Product Fractions Compared to Benzo[a]Pyrene and Their Use in Carcinogen Risk Assessments," prepared for the U.S. EPA, Washington, DC.

Cook, J. W., 1932, "The Production of Cancer by Pure Hydrocarbons -- Part II," Proceedings of the Royal Society of London S.B., Vol. 11, pp. 485-496 (Cited in EPA 1992).

Cookfair, D. L., W. L. Beck, C. Shy, C. C. Lushbaugh, and C. L Sowder, 1983, "Lung Cancer Among Workers at a Uranium Processing Plant," Proceedings of the Health Physics Society, presented at Epidemiology Applied to Health Physics, pp. 398-406.

de Motta, L. C., J. da Silva Horta, and M. H. Tavares, 1979, "Prospective Epidemiological Study of Thorotrast-Exposed Patients in Portugal," Environmental Research, Vol. 18, pp. 152-172.

Druckrey, H., H. Hamperl, and D. Schmahl, 1957, "Carcinogenic Action of Metallic Mercury After Intraperitoneal Administration in Rats," Zeitschrift Fur Krebsforschung und Klinische Onkologie, Vol. 61, pp. 511-519 (Cited in EPA 1992b).

Durbin, P. W. and M. E. Wrenn, 1975, "Metabolism and Effects of Uranium in Animals," M. E. Wrenn, ed., Conference on Occupational Health Experience with Uranium, ERDA-93, U.S. Energy Research and Development Administration, Washington, DC, pp. 67-129.

East, B. W., K. Boddy, E. D. Williams, D. MacIntyre, and A. L. McLay, 1980, "Silver Retention, Total Body Silver and Tissue Silver Concentrations in Argyria Associated with Exposure to an Anti-smoking Remedy Containing Silver Acetate," Clinical and Experimental Dermatology, Vol. 5, pp. 305-311 (Cited in EPA 1992).

Ecobichon, D. J., 1991, "Toxic Effects of Pesticides," Casarett and Doull's Toxicology, the Basic Science of Poisons, M. O. Amdur, J. Doull, and C. D. Klaassen, eds., 4th ed., Pergamon Press, New York, pp. 565-622.

Elinder, C. G. and L. Friberg, 1986a, "Antimony," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 26-42.

Elinder, C. G and L. Friberg, 1986b, "Cobalt," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, Elsevier Science Publishers B. V., New York, pp. 211-232.

Elinder, C. G., 1986c, "Zinc," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 664-679.

Ely, T. S., 1959, "Medical Findings Summary," Symposium on Occupational Health Experience and Practices in the Uranium Industry, HASL-58, Office of Technical Services, Department of Commerce, Washington, DC.

Evans, R. D., A. T. Keane, F. J. Kolenkow, W. R. Neal, and M. M. Shanahan, 1969, "Radiogenic Tumors in the Radium and Mesothorium Cases Studied at M.I.T.," Delayed Effects of Bone-Seeking

Radionuclides, C. W. Mays, W. S. S. Jee, R. D. Lloyd, B. J. Stover, J. H. Dougherty, and G. N. Taylor, eds., University of Utah Press, Salt Lake City, UT, pp. 157-194.

Evans, R. D., 1966, "The Effect of Skeletally Deposited Alpha-Ray Emitters in Man," British Journal of Radiology, Vol. 39, pp. 881-895.

Faber, M., 1973, Proceedings of the Third International Meeting on the Toxicity of Thorotrast, Riso Report, Danish Atomic Energy Commission, M. Faber, ed., Copenhagen, Denmark, pp. 137-147.

Faber, M., 1977, "Epidemiology of Thorotrast Malignancies in Man," Review Paper Prepared for the Work Health Organization Scientific Group on the Long Term Effects of Radium and Thorium in Man, World Health Organization Working Paper 12, World Health Organization, Geneva, Switzerland.

Faber, M., 1978, "Malignancies in Danish Thorotrast Patients," Health Physics, Vol. 35, pp. 154-158.

Faber, M., 1979, "Twenty-eight Years of Continuous Follow-up of Patients Injected with Thorotrast for Cerebral Angiography," Environmental Research, Vol. 18, pp. 37-43.

Faber, M., 1983, "Current (1981) Status of the Danish Thorotrast Study," Health Physics, Vol. 44, Suppl. 1, pp. 259-260.

Faber, M., 1986, "Observations on the Danish Thorotrast Patients," Strahlentherapie, Vol. 80, pp. 140-142.

Falk, H., N. C. Telles, K. G. Ishak, L. B. Thomas, and H. Popper, 1979, "Epidemiology of Thorotrast-Induced Hepatic Angiosarcoma in the United States," Environmental Research, Vol. 18, pp. 65-73.

Ferguson, W. S., W. C. Koch, L. B. Webster, and J. R. Gould, 1977, "Human Physiological Response and Adaptation to Ammonia," Journal of Occupational Medicine, Vol. 19, pp. 319-326 (Cited in EPA 1992).

Finkel, A. J., C. E. Miller, and R. J. Hasterlik, 1969, "Radium-Induced Malignant Tumors in Man," Delayed Effects of Bone-Seeking Radionuclides, J. Mays, R. D. Lloyd, B. J. Stover, J. H. Dougherty, and G. N. Taylor, eds., University of Utah Press, Salt Lake City, UT, pp. 195-225.

Fitzhugh, O. G., A. A. Nelson, E. P. Laug et al., 1950, "Chronic Oral Toxicities of Mercuri-phenyl and Mercuric Salts," Archives of Industrial Hygiene and Occupational Medicine, Vol. 2, pp. 433-442 (Cited in ATSDR 1989_).

Flury, K. E., D. E. Dines, J. R. Rodarte, and R. Rodgers, 1983, "Airway Obstruction Due to Inhalation of Ammonia," Mayo Clinic Proceedings, Vol. 58, pp. 389-393 (Cited in EPA 1992).

Food Research Laboratories, Inc., 1955, "Toxicological Studies of Diethyl Phthalate," Laboratory no. 67567, Celanese Corp. of America, Summit Research Laboratories, Summit, NJ (Cited in EPA 1992).

Fowler, B. A. and G. F. Nordberg, 1986, "Silver," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 521-531.

Friberg, L., T. Kjellström, and G. F. Nordberg, 1986, "Cadmium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 130-184.

Friberg, L. and J. Lener, 1986, "Molybdenum," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, Elsevier Science Publishers B. V., New York, p. 446-461.

Gadian, T., 1975, "Carcinogens in Industry, With Special Reference to Dichlorobenzidine," Chemistry and Industry, Vol. 4, pp. 821-831 (Cited in EPA 1992).

Gamble, M. R. and G. Clough, 1976, "Ammonia Build-up in Animal Boxes and Its Effect on Rat Tracheal Epithelium," Laboratory Animal, Vol. 10, pp. 93-104 (Cited in EPA 1992).

Gerber, G. B., M. Hegela, J. VanKerkom, R. Kirchmann, J. R. Maisin, and M. Lambiet-cullire, 1989, "Technitium Dose to Man," Health Physics, Vol. 57, No. 2 (August), pp. 345-350.

Gilbert, R.O., 1987, "Statistical Methods for Environmental Pollution Monitoring," Van Nostrand Reinhold, New York.

Goyer, R. A., 1991, "Toxic Effects of Metals," Casarett and Doull's Toxicology, the Basic Science of Poisons, M. O. Amdur, J. Doull, and C. D. Klaassen, eds., 4th ed., Pergamon Press, New York, pp. 623-680.

Harting, F. H. and W. Hesse, 1879, "Der Lungenkrebs, die Bergkrnkheit in den Schneeberger Gruben," Vierteljahrsschr. f. Gerichtl. Med. u. Offentl. Gensundheitswesen, Vol. 30, pp. 296-309, Vol. 31, pp. 102-132, 313-337.

Hausler, M. and R. Lenich, 1968, "Effect of Chronic Occupational Allyl Chloride Exposure," Archives of Toxicology, Vol. 23, pp. 209-214 (Cited in EPA 1992).

Hayes, M. A., 1987, "Carcinogenic and Mutagenic Effects of PCBs," S. Safe, ed., Environmental Toxin Series, Vol. A. Polychlorinated Biphenyls (PCBs): Mammalian and Environmental Toxicology, Springer-Verlag., New York, pp. 77-95.

He, F., D. Shen, Y. Guo, and B. Lu, 1980, "Toxic Polyneuropathy Due to Chronic Allyl Chloride Intoxication: A Clinical and Experimental Study," Chinese Medical Journal, Vol. 93, pp. 177-182 (Cited in EPA 1992).

He, F., B. Lu, S. Zhang, S. Dong, A. Yu, and B. Wang, 1985, "Chronic Allyl Chloride Poisoning, An Epidemiology, Clinical, Toxicological and Neuropathological Study," Giornale Italiano Di Medicina Lavoro (Pavia), Vol. 7, pp. 5-15 (Cited in EPA 1992).

Högberg, J. and J. Alexander, 1986, "Selenium," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B.V., New York, pp. 482-520.

Holness, D. L., J. T. Purdham, and J. R. Nethercott, 1989, "Acute and Chronic Respiratory Effects of Occupational Exposure to Ammonia," American Industrial Hygiene Association J., Vol. 50, pp. 646-650 (Cited in EPA 1992).

Horta, J. da Silva, M. E. Horta, L. C. da Motta, and M. H. Tavares, 1978, "Malignancies in Portuguese Thorotrast Patients," Health Physics, Vol. 35, pp. 137-152.

Howard, P. H., Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume I, Large Production and Priority Pollutants, Lewis Publishers, Chelsea, MI.

Iffland, R., 1988, "Antimony," Handbook on Toxicity of Inorganic Compounds, Seiler, H. G., H. Sigel, and A. Sigel, eds., Marcel Dekker, Inc., New York, pp. 67-76.

International Agency for Research on Cancer (IARC), 1980, IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man, Vol. 23, Some Metals and Metallic Compounds, World Health Organization, Lyon, France (Cited in EPA 1992).

International Agency for Research on Cancer (IARC), 1987, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs, Vols. 1 to 42, Preamble, Supplement 7, WHO: Lyon, France, pp. 17-34.

Ishinishi, N., K. Tsuchiya, M. Vahter, and B. A. Fowler, 1986, "Arsenic," Handbook on the Toxicology of Metals, L. Friberg, G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 43-83.

IT Corporation (IT), 1986, "Final Interim Report - Air, Soil Water and Health Risk Assessment in the Vicinity of the FMPC, Fernald, OH." Report and Data Package prepared for the U.S. Department of Energy in Support of the Fernald Litigation, Oak Ridge Operations Office, Oak Ridge, TN.

Kanisawa, M. and H. A. Schroeder, 1969, "Life Term Studies on the Effect of Trace Elements on Spontaneous Tumors in Mice and Rats," Cancer Research, Vol. 29, pp. 892-895 (Cited in EPA 1992).

Kazantzis, G., 1986, "Thallium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 549-567.

Kato, Y., T. Mori, and T. Kumatori, 1979, "Thorotrast Dosimetric Study in Japan," Environmental Research, Vol. 18, pp. 32-36.

Kato, Y., T. Mori, and T. Kumatori, 1983, "Estimated Absorbed Dose in Tissues and Radiation Effects in Japanese Thorotrast Patients," Health Physics, Vol. 44, Suppl. 1, pp. 273-279.

Kirwin, C. J. and E. E. Sandmeyer, 1981, "Ethers," Clayton, G. D. and F. E. Clayton, eds., Patty's Industrial Hygiene and Toxicology, Vol. II A, 3rd ed. revised, John Wiley and Sons, New York, pp. 2491-2565.

Knobloch, K., S. Szendzikowski, and A. Slusarczyk-Zalobona, 1969, "Acute and Subacute Toxicity of Acenaphthene and Acenaphthylene," Med. Pracy (Polish), Vol. 20, pp. 210-222, (Pol.) (Cited in EPA 1992a).

Kociba, R. J., D. G. Keyes, J. E. Bower, et al., 1978, "Results of a Two-year Chronic Toxicity and Oncogenicity Study of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Rats," Toxicology and Applied Pharmacology, Vol. 46, pp. 279-303 (Cited in EPA 1985, 1992b).

Kotin, P., et al., 1969, "Distribution, Retention and Elimination of c^{14}-3,4-Benzopyrene After Administration to Mice and Rats," Journal of the National Cancer Institute, Vol. 23, pp. 541 (Cited in EPA 1980a).

Krasavage, W. J., J. L. O'Donoghue, and G. D. Divincenzo, 1982, "Ketones," G. D. Clayton and F. E. Clayton, eds., Patty's Industrial Hygiene and Toxicology, 3rd ed. revised, Vol. 2C, John Wiley and Sons, New York, pp. 4747-4751; 4787-4800.

Krewski, D., T. Thorslund, and J. Withey, 1989, "Carcinogenic Risk Assessment of Complex Mixtures," Toxicology and Industrial Health, Vol. 5, pp. 851-867.

Lagerkvist, B., G. F. Nordberg, and V. Vouk, 1986, "Vanadium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, p. 638-663.

Land, C. E., 1975, "Table of Confidence Limits for Linear Functions of the Normal Mean and Variance, "Selected Tables in Mathematical Statistics, Vol. III, ed. Institute of Mathematical Statistics, American Mathematical Society, Providence, RI, 403 pps.

Langård, S. and T. Norseth, 1986, "Chromium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, Elsevier Science Publishers B. V., New York, pp. 185-210.

Laug, E. P., A. A. Nelson, O. G. Fitzhugh, and F. M. Kunze, 1950, "Liver Cell Alteration and DDT Storage in the Fat of the Rat Induced by Dietary Levels of 1-50 ppm DDT," Journal of Pharmacology and Experimental Therapy, Vol. 98, pp. 268-273 (Cited in EPA 1992).

LaVoie, E. J., S. Amin, S. S. Hecht, K. Furuya, and D. Hoffmann, 1982, "Tumor Initiating Activity of Dihydrodiols of Benzo[b]fluoranthene, Benzo[j]fluoranthene and Benzo[k]fluoranthene, Carcinogenesis," Vol. 3(1), pp. 49-52 (Cited in EPA 1992a).

Leach, L. J., E. A. Maynard, H. C. Hodge, J. K. Scott, C. L. Yuile, G. E. Sylvester, and H. B. Wilson, 1970, "A Five-Year Inhalation Study with Natural Uranium Dioxide (UO^2) Dust - I. Retention and Biologic Effect in the Monkey, Dog, and Rat," Health Physics, Vol. 18, pp. 599-612.

Leach, L. J., C. L. Yuile, H. C. Hodge, G. E. Sylvester, and H. B. Wilson, 1973, "A Five Year Inhalation Study with Natural Uranium Dioxide (UO^2) Dust - II. Postexposure Retention and Biologic Effects in the Monkey, Dog, and Rat," Health Physics, Vol. 25, pp. 239-258.

Lewtas, J., 1988, "Genotoxicity of Complex Mixtures: Strategies for the Identification and Comparative Assessment of Airborne Mutagens and Carcinogens from Combustion Sources," Fundamentals of Applied Toxicology, Vol. 10, pp. 571-589.

Lilliefors, H. W., 1967, "On the Kolmogorov-Smirnov test for normality with mean and variance unkown", Journal of the American Statistical Association, American Statistical Association, 64:399-402.

Magos, L., 1986, "Tin" in Handbook on the Toxicology of Metals, Second Edition, Vol. II: Specific Metals, L. Fribert, G. F. Norberg, and V. B. Vouk, Eds., Elsevier Science Publishers, New York, pp. 568-593.

Maritz, J.S., 1981, Distribution - Free Statistical Methods, Chapman and Hall publ.

Marie, P. J., M. T. Garba, M. Holt and L. Mivavet, 1985, "Effects of Low Doses of Stable Sr on Bone Metabolism in Rats," Minerology Electrolyte Metabolism Vol. 11, pp. 5-13.

Marshall, J. H. and P. G. Groer, 1977, "A Theory of the Induction of Bone Cancer by Alpha Radiation," Radiation Research, Vol. 71, pp. 149-192.

Martland, H. S., 1931 "The Occurrence of Malignancy in Radioactive Persons," American Journal of Cancer, Vol. 15, pp. 2435-2516.

Mays, C. W., R. E. Rowland, and A. F. Stehney, 1985, "Cancer Risk From the Lifetime Intake of Radium and Uranium Isotopes," Health Physics, Vol. 48, pp. 635-647.

Mays, C. W., 1973, "Cancer Induction in Man from Internal Radioactivity," Health Physics, Vol. 25, pp. 585-592.

Mays, C. W. and R. D. Lloyd, 1972, "Bone Sarcoma Incidence vs. Alpha Particle Dose," Radiobiology of Plutonium, B. J. Stover and W. S. S. Jee, eds., The J. W. Press, Salt Lake City, UT, pp. 409-430.

Miller, S. E., D. A. Holiday, and H. N. Doyle, 1956, "Health Protection of Uranium Miners and Millers," Archives of Industrial Health, Vol. 15, pp. 48-55.

Mitsumori, K., K. Maita, T. Saito, S. Tsuda and Y. Shikasu, 1981, "Carcinogenicity of Methylmercury Chloride in ICR Mice: Preliminary Note on Renal Carcinogens," Cancer Letter, Vol. 12, pp. 305-310 (Cited in EPA 1992b).

Moeller, H. C. and J. A. Rider, 1962, "Plasma and Red Blood Cell Cholinesterase Activity as Indications of the Threshold of Incipient Toxicity of Ethyl-p-nitrophenyl Thionobenzenephosphorate (EPN) and Malathion in Human Beings," Toxicology and Applied Pharmacology, Vol. 4, pp. 123-130 (Cited in EPA 1992).

Mori, T., Y. Kato, T. Shimamine, and S. Watanabe, 1979a, "Statistical Analysis of Japanese Thorotrast-Administered Autopsy Cases," Environmental Research, International Meeting on the Toxicity of Thorotrast and Other Alpha-Emitting Heavy Elements, Lisbon, Portugal, Vol. 18, pp. 231-244.

Mori, T., T. Maruyama, Y. Kato, and S. Takahashi, 1979b, "Epidemiological Follow-up Study of Japanese Thorotrast Cases," Environmental Research, Vol. 18, pp. 44-54.

Mori, T., Y. Kato, T. Kumatori, T. Maruyama, and S. Hatakeyama, 1983, "Epidemiological Follow-up Study of Japanese Thorotrast Cases - 1980," Health Physics, Vol. 44, Suppl. 1, pp. 261-272.

Mori, T., T. Kumatori, Y. Kato, S. Hatakeyama, R. Kamiyama, W. Mori, H. Irie, T. Maruyama, and S. Iwata, 1986, "Present Status of Medical Study on Thorotrast-Administered Patients in Japan," Strahlentherapie, Vol. 80, pp. 123-134.

Murthy, G. K., U. Rhea, and J. T. Peeler, 1971, "Levels of Antimony, Cadmium, Chromium, Cobalt, Manganese, and Zinc in Institutional Total Diets," Environmental Science and Technology, Vol. 5, pp. 436-442 (Cited in EPA 1992).

National Academy of Sciences (NAS), 1988, "Committee on the Biological Effects of Ionizing Radiations (BEIR IV), Health Risks of Radon and Other Internally Deposited Alpha-Emitters," National Academy of Sciences, National Academy Press, Washington, DC.

000724

National Cancer Institute (NCI), 1978b, "Bioassay of Allyl Chloride for Possible Carcinogenicity," Carcinogenesis Technical Report Series, NCI-CG-TR-73, PB-287516 (Cited in EPA 1992).

National Cancer Institute (NCI), 1978c, "Bioassays of DDT, TDE, and p,p'-DDE for Possible Carcinogenicity," NCI Report No. 131, DHEW Publ. No. (NIH) 78-1386 (Cited in ATSDR 1989).

National Cancer Institute (NCI), 1978d, "Bioassay of Trichlorofluoromethane for Possible Carcinogenicity," Report No. 106, PHS/NIH, DHEW Publ. No. 78-1356 (Cited in EPA 1992).

National Council on Radiation Protection and Measurements (NCRP), Aug. 1991, "Some Aspects of Strontium Radiobiology," NCRP Report No. 110, National Council on Radiation Protection and Measurement, Bethesda, MD.

National Council on Radiation Protection and Measurements (NCRP), 1984, "Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States," NCRP Report 78, National Council on Radiation Protection and Measurement, Bethesda, MD.

National Council on Radiation Protection and Measurements (NCRP), 1984, "Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment. NCRP Report No. 76, National Council on Radiation Protection and Measurements, Washington, DC.

National Council on Radiation Protection and Measurement (NCRP), 1988, "Neptunium Radiation Protection Guidelines," NCRP Report No. 90.

National Council on Radiation Protection and Measurements (NCRP), 1989, "Screening Techniques for Determining Compliance with Environmental Standards," NCRP Commentary No.3, National Council on Radiation Protection and Measurements, Washington, DC.

National Research Council (NRC), 1989, "Recommended Dietary Allowances," 10th ed., National Academy Press, Washington, DC.

National Toxicology Program (NTP), 1980, Unpublished Subchronic Toxicity Study: Naphthalene (c52904), Fisher-344 Rats, Prepared by Battelle's Columbus Laboratories under subcontract No. 76-34-106002 (Cited in EPA 1992b).

Nero, A. V., M. L. Boegel, C. D. Hollowell, J. G. Ingersoll, and W. W. Nazaroff, 1983, "Radon Concentrations and infiltration Rates Measured in Conventional and Energy-Efficient Houses," Health Physics, Vol. 45, pp. 401-405.

Ohno, Y., T. Kawanishi, and A. Takahashi, 1986, "Comparisons of the Toxicokinetic Parameters in Rats Determined for Low and High Dose of Gamma-chlordane," Journal of Toxicological Science, Vol. 11, pp. 111-124 (Cited in ATSDR 1989_).

Osanai, H., 1976, "An Experimental Study on Hepatoma Caused by Aromatic Amines," Rodo Kagaku, Vol. 52, pp. 179-201 (Cited in EPA 1992).

Polednak, A. P., 1978, "Bone Cancer Among Female Radium Dial Workers. Latency Periods and Incidence Rates by Time After Exposure," Journal of the National Cancer Institute, Vol. 60, pp. 77-82.

Polednak, A. P. and E. L. Frome, 1986, "Mortality Among Men Employed Between 1943 and 1947 at a Uranium Processing Plant," Journal of Occupational Medicing, Vol. 23, pp. 169-178.

Quast, J. F., J. W. Henck, D. J. Schuetz, D. A. Dittneber, and M. J. McKenna, 1982, "Allyl Chloride - Subchronic Studies, IB - Results of an Inhalation 4-day Probe and 90-day Subchronic Study in Laboratory Rodents," OTS Document #FYI-AX-O782-0199 (Cited in EPA 1992).

Rees, E. O., et al., 1971, "A Study of the Mechanism of Intestinal Absorption of Benzo(a)pyrene," Biochemical and Biophysical Act, Vol. 255, p. 96 (Cited in EPA 1980a).

Reeves, A. L., 1986a, "Barium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, Elsevier Science Publishers B. V., New York, pp. 84-94.

Reeves, A. L., 1986b, "Beryllium," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, Elsevier Science Publishers B. V., New York, pp. 95-116.

Riedel, W., R. Hirschberg, A. Kaul, S. Schmier, and U. Walter, 1979, "Comparative Investigations on the Biokinetics of Colloidal Thorium, Zirconium, and Nafnium Dioxides in Animals," Environmental Research, Vol. 18, pp. 127-139.

Riedel, W., W. Dalheimer, A. Said, and U. Walter, 1983, "Recent Results of the Physical and Biological Properties of Thorotrast Equivalent Colloids," Health Physics, Vol. 44, Suppl. 1, pp. 293-298.

Rockstroh, H., 1959, "Zur Atiologie des Bronchialkrebses in Arsen Verabeitenden Nickelhutten. Beitrag zur Syncarcinogenese des berufkrebes," Arch. Geschwulstforsch, Vol. 14, pp. 151-162.

Rossi, L., M. Ravera, G. Repetti et al., 1977, "Long-term Administration of DDT or Phenobarbital in Wistar Rats," International Journal of Cancer, Vol. 19, pp. 179-185 (Cited in ATSDR 1989).

Rowland, R. E. and J. E. Farnham, 1969, "The Deposition of Uranium in Bone," Health Physics, Vol. 17, pp. 139-144.

Rowland, R. E., A. T. Keane, and P. M. Failla, 1971, "The Appearance Times of Radium-Induced Malignancies," Radiological Physics Division Annual Report, Report No. ANL-7860, Part II, Argonne National Laboratory, Argonne, IL, pp. 20-22.

Rowland. R. E., A. F. Stehney, and H. F. Lucas, Jr., 1978a, "Dose-Response Relationships for Female Radium Dial Workers," Radiation Research, Vol. 76, pp. 368-383.

Rowland, R. E., A. F. Stehney, A. M. Brues, M. S. Littman, A. T. Keane, B. C. Pattern, and M. M. Shanahan, 1978b, "Current Status of the Study of ^{226}Ra and ^{228}Ra in Humans at the Center for Human Radiobiology," Health Physics, Vol. 35, pp. 159-166.

Rowland, R. E., A. F. Stehney, and H. F. Lucas, 1983, "Dose-Response Relationships for Radium-Induced Bone Sarcomas," Health Physics, Vol. 44, Suppl. 1, pp. 15-31.

Rundo, J., A. T. Keane, H. F. Lucas, R. A. Schlenker, J. H. Stebbings, and A. F. Stehney, 1986, "Current (1984) Status of the Study of ^{226}Ra and ^{228}Ra in Humans at the Center for Human Radiobiology," Radiobiology of Radium and Thorotrast, W. Gossner, G. B. Gerber, U. Hagen, and A. Luz, eds., Urban and Schwarzenberg, Munich, West Germany, pp. 14-21.

Saffiotti, U., F. Cefis, R. Montesano, and A. R. Sellakumar, 1967, "Induction of Bladder Cancer in Hamsters Fed Aromatic Amines," Bladder Cancer, A Symposium, Aesculapius Publishing Co, Birmingham, AL, pp. 129-135 (Cited in EPA 1992).

Sandmeyer, E. E. and C. J. Kirwin, 1981, "Esters," Clayton, G. D. and F. E. Clayton, eds., Patty's Industrial Hygiene and Toxicology, Vol. II A, 3rd ed. revised, John Wiley and Sons, New York, pp. 2259-2412.

Saric, J. A., U.S. Environmental Protection Agency, March 11, 1992, [Letter to J. R. Craig, U.S. DOE, Subject: Draft Final Risk Assessment Work Plan Addendum].

Saric, J. A., U.S. Environmental Protection Agency, December 2, 1991, [Letter to J. R. Craig, U.S. DOE, Subject: Risk Assessment Work Plan Addendum].

Sax, N. I. and R. J. Lewis, Sr., eds., 1987, Hawley's Condensed Chemical Dictionary, 11th ed., Van Nostrand Reinhold Co., New York, pp. 63-64.

Sax, N. I., 1984, Dangerous Properties of Industrial Materials, 6th ed., Van Nostrand Reinhold Co., New York.

Schlede, E. et al., 1970a, "Effect of Enzyme Induction on the Metabolism and Tissue Distribution of Benzo(a)pyrene," Cancer Research, Vol. 30, p. 2893 (Cited in EPA 1980a).

Schlede, E., et al., 1970b, "Stimulatory Effect of Benzo(a)pyrene and Phenobarbital Pretreatment on the Biliary Excretion of Benzo(a)pyrene Metabolites in the Rat," Cancer Research, Vol. 30, p. 2898 (Cited in EPA 1980a).

Schlenker, R. A., 1980, "Dosimetry of Paranasal Sinus and Mastoid Epithelia in Radium-Exposed Humans," Radiological and Enviornmental Research Division Annual Report, No. ANL-80-115, Part II, Argonne National Laboratory, Argonne, IL, pp. 1-21.

Schmahl, D., 1955, "Examination of the Carcinogenic Action of Naphthalene and Anthracene in Rats, Z. Krebsforsch, Vol. 60, pp. 697-710 (Cited in EPA 1992a).

Schroeder, H. A., A. P. Nason, and I. H. Tipton, 1967, "Essential Trace Elements in Man: Cobalt, Journal of Chronic Diseases, Vol. 20, pp. 869-890 (Cited in EPA 1992_).

Schroeder, H. A., M. Mitchner, and A. P. Nasor, 1970, "Zirconium, Niobium, Antimony, Vanadium and Lead in Rats: Life Term Studies," Journal of Nutrition, Vol. 100, pp. 59-66 (Cited in EPA 1992_).

Shapiro, S. S., and M. B. Wilk, 1965, "An analysis of variance test for normality (complete samples)," Biometrica, 52:591-611."

Shapiro, S. S., and R. S. Francia, 1972, "An approximate analysis of variance test for normality," Journal of the American Statistical Association, American Statistical Association, 67:215-216.

Sherman, H., 1974, "Long-term Feeding Studies in Rats and Dogs with Dichlorodifluoromethane (Freon 12 Food Freezant)," Medical Research Project No. 1388, Haskell Laboratory Report No. 24-74, Unpublished, Courtesy of du Pont de Nemours Co. (Cited in EPA 1992).

Singh, A. R., W. H. Lawrence and J. Autian, 1972, "Teratogenicity of Phthalate Esters in Rats, Journal of Pharmacological Science, Vol. 61, pp. 51-55 (Cited in EPA 1992_).

Smith, R. P., 1991, "Toxic Responses of the Blood," Casarett and Doull's Toxicology, the Basic Science of Poisons, M. O. Amdur, J. Doull, and C. D. Klaassen, eds., 4th ed., Pergamon Press, New York, pp. 257-281.

Southwick, J. W., A. E. Western, M. M. Beck et al., 1983, "An Epidemiological Study of Arsenic in Drinking Water in Millard County, Utah," Lederer, W. H. and R. J. Fensterheim, eds., Arsenic: Industrial, Biomedical, Environmental Perspectives, Van Nostrand Reinhold Co., New York, pp. 210-225 (Cited in EPA 1992).

Spiers, F. W., H. F. Lucas, J. Rundo, and G. A. Anast, 1983, "Leukemia Incidence in the U.S. Dial Workers," Health Physics, Vol. 44, Suppl. 1, pp. 65-72.

Spiess, H., 1969, "^{224}Ra-Induced Tumors in Children and Adults," Delayed Effects of Bone-seeking Radionuclides, C. W. Mays, W. S. S. Jee, R. D. Lloyd, B. J. Stover, J. H. Dougherty, and G. N. Taylor, eds., University of Utah Press, Salt Lake City, UT, pp. 227-247.

Spiess, H. and C. W. Mays, 1970, "Bone Cancers Induces by Ra-224 (ThX) in Children and Adults," Health Physics, Vol. 19, pp. 713-729.

Sprince, N. L., L. C. Oliver, E. A. Eisen et al., 1988, "Cobalt Exposure and Lung Disease in Tungsten Carbide Production: A Cross-sectional Study of Current Workers," American Review of Respiratory Diseases, Vol. 138, pp. 1220-1226 (Cited in EPA 1990).

Stebbings, J. H., H. F. Lucas, and A. F. Stehney, 1984, "Mortality from Cancers of Major Sites in Female Radium Dial Workers," American Journal of Industrial Medicing, Vol. 5, pp. 435-459.

Stevens, W., F. W. Bruenger, D. R. Atherton, J. M. Smith, and G. N. Taylor, 1980, "The Distribution and Retention of Hexavalent ^{233}U in the Beagle," Radiation Research, Vol. 83, pp. 109-126.

Storey, E., 1961," Strontium "Rickets" Bone Calcium and Strontium Changes," Astral. Ann. Med., Vol. 10, pp. 213-222.

Stula, E. F., H. Sherman, J. A. Zapp, and J. W. Clayton, 1975, "Experimental Neoplasia in Rats from Oral Administration of 3,3'-Dichlorobenzidine, 4,4'-Metheylene-bis(2-chloroaniline), and 4,4'-Methylene-bis(2-methylanaline)," Toxicology and Applied Pharmacology, Vol. 31, pp. 159-176 (Cited in EPA 1992).

Stula, E. F., J. R. Barnes, H. Sherman, C. F. Reinhardt, and J. A. Zapp, 1978, "Liver and Urinary Bladder Tumors in Dogs from 3,3'-Dichlorobenzidine," Journal of Environmental Pathology and Toxicology, Vol. 1, pp. 475-490 (Cited in EPA 1992).

Theiss, J. C., G. D. Stoner, M. B. Shimkin, and E. K. Weisburger, 1977, "Test for Carcinogenicity of Organic Contaminants of United States Drinking Waters by Pulmonary Tumor Response in Strain A Mice," Cancer Research, Vol. 37, pp. 2717-2720 (Cited in EPA 1984).

Theiss, J. C., M. B. Shimkin, and L. A. Poirer, 1979, "Induction of Pulmonary Adenomas in Strain A Mice by Substituted Organohalides," Cancer Research, Vol. 39, pp. 391-395 (Cited in EPA 1992).

Thorslund, T. and G. Charnley, 1988, "Comparative Potency Approach for Estimating the Cancer Risk Associated with Exposure to Mixtures of Polycyclic Aromatic Hydrocarbons," ICF-Clement Associates, Washington, DC (Cited in Krewski et al. 1989; cited as Clement Associates 1988 in EPA 1991).

Thun, M. J., T. M. Schnorr, A. B. Smith, and W. E. Halperin, 1985, "Mortality Among a Cohort of U.S. Cadmium Production Workers: An Update," Journal of the National Cancer Institute, Vol. 74, pp. 325-333 (Cited in EPA 1992).

Tipton, I. H., P. L. Stewart, and P. G. Martin, 1966, "Trace Elements in Diets and Excreta," Health Physics, Vol. 12, pp. 1683-1689 (Cited in EPA 1992).

Torkelson, T. R., M. A. Wolf, F. Oyen, and V. K. Rowe, 1959, "Vapor Toxicity of Allyl Chloride as Determined on Laboratory Animals," American Industrial Hygiene Association J. Vol. 20, pp. 217-223 (Cited in EPA 1992).

Tseng, W. P., H. M. Chu, S. W. How, J. M. Fong, C. S. Lin, and S. Yeh, 1968, "Prevalence of Skin Cancer in an Endemic Area of Chronic Arsenicism in Taiwan," Journal of the National Cancer Institute Vol. 40, pp. 453-463 (Cited in EPA 1992).

Tseng, W. P., 1977, "Effects and Dose-response Relationships of Skin Cancer and Blackfoot Disease with Arsenic," Environmental Health Perspectives, Vol. 19, pp. 109-119 (Cited in EPA 1992).

Tsuchiya, K., 1986, "Lead," Handbook on the Toxicology of Metals, Friberg, L., G. F. Nordberg, and V. B. Vouk, eds., Vol. II, 2nd ed., Elsevier Science Publishers B. V., New York, pp. 298-353.

Underwood, E. J., 1977, Trace Elements in Human and Animal Nutrition, 4th ed., Academic Press, New York.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1982, "Ionizing Radiation: Sources and Biological Effects," Report to the General Assembly, with Annexes, United Nations Scientific Committee on the Effects of Atomic Radiation, New York, NY.

U.S. Dept. of Agriculture, 1986, "National Food Consumption Survey," CSF II Report No. 85-1.

U.S. Dept. of Agriculture, 1992, Soil Conservation Service (SCS) 1992 Revised Field Office Technical Guide, Soil Concervation Service, Columbus, Ohio.

U.S. Dept. of Energy, 1992a, "Risk Assessment Work Plan Addendum," prepared for Remedial Investigation and Feasibility Study, Fernald Environmental Management Project, U.S. Dept. of Energy, Fernald Field Office, Fernald, OH.

U.S. Dept. of Energy, 1992d, "Operable Unit 3 Work Plan Addendum, Fernald Environmental Management Project, Fernald, OH, Remedial Investigation and Feasibility Study," U.S. Dept. of Energy, Fernald Office, Fernald, OH.

U.S. Department of Energy, 1992d, Responses to U.S. EPA and Ohio EPA Technical Comments on teh Site-Wide Characterization Report Response Document, November 1992.

U.S. Dept. of Energy, 1993a, "Characterization of Background Water Quality for Streams and Groundwater," Fernald Environmental Management Project, May 1993, Draft.

U.S. Dept. of Energy, 1993b, "CERCLA/RCRA Background Soil Study," Fernald Environmental Management Project, RI/FS, March 1993 Final.

U.S. Dept. of Energy, 1993c, "Site-Wide Characterization Report," Fernald Environmental Management Project, March 1993, Final.

U.S. Department of Energy, 1993d, "Responses/Actions to U.S. EPA and Ohio EPA Technical Comments on Part II for the SWCR Response Document issued November, 1992."

U.S. Department of Energy, 1993f, Remedial Investigation Report for Operable Unit 4, Final Draft, Prepared for the Fernald Environmental Management Project, Fernald, OH.

U.S. Environmental Protection Agency (EPA), 1979a, Multimedia Health Assessment Document for Polycyclic Organic Matter, Prepared under contract by J. Santodonato et al., Syracuse Research Corporation (Cited in EPA 1980a).

U.S. Environmental Protection Agency (EPA), 1979b, Polynuclear Aromatic Hydrocarbons: Ambient Water Quality Criteria (Draft) (Cited in EPA 1980a).

U.S. Environmental Protection Agency (EPA), 1979c, Naphthalene: Ambient Water Quality Criteria, (Draft) (Cited in EPA 1980a).

U.S. Environmental Protection Agency (EPA), 1980a, Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons, Office of Water Regulations and Standards, Washington, DC, EPA 440/5-80-069, NTIS PB81-117806 (Cited in ATSDR 1987).

U.S. Environmental Protection Agency (EPA), 1980b, Identification and Listing of Hazardous Waste Under RCRA, Subtitle C, Section 3001, Health and Environmental Effects Profiles, Office of Solid Waste, Washington, DC, NTIS No. PB81 190019.

U.S. Environmental Protection Agency (EPA), 1985, Health Assessment Document for Polychlorinated Dibenzo-p-Dioxins, Office of Health and Environmental Assessment, Washington, DC, EPA/600/8-84/014F, NTIS No. PB86-122546.

U.S. Environmental Protection Agency (EPA), 1986a, o, m, p-Cresol, 90-Day oral subchronic toxicity studies in rats, Office of Solid Waste, Washington, DC (Cited in EPA 1992).

U.S. Environmental Protection Agency (EPA), 1986b, "Guidelines for Carcinogen Risk Assessment," Federal Register 51 (185), pp. 33992-34003.

U.S. Environmental Protection Agency (EPA), 1987a, Health Effects Assessment for Antimony and Compounds, Prepared by Office of Health and Environmental Assessment, Cincinnati, OH, for the Office of Solid Waste and Emergency Response, Washington, DC, EPA/600/8-88/018, NTIS PB 88-179445.

U.S. Environmental Protection Agency (EPA), 1987b, o, m, p-Cresol, 90-Day oral subchronic neurotoxicity study in rats, Office of Solid Waste, Washington, DC (Cited in EPA 1992).

U.S. Environmental Protection Agency (EPA), 1988a, "Laboratory Data Validation - Functional Guidelines For Evaluating Organic Analyses," EPA, Hazardous Site Evaluation Division, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1988b, "Laboratory Data Validation - Functional Guidelines For Evaluating Inorganic Analyses," EPA, Hazardous Site Evaluation Division, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1988c, 13-Week mouse oral subchronic toxicity study, Prepared by Toxicity Research Laboratories, Ltd., Muskegon, MI for Office of Solid Waste, Washington, DC (Cited in EPA 1992a).

U.S. Environmental Protection Agency (EPA), 1988d, Health Effects Assessment for Trichloroethylene, Prepared by the Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Solid Waste and Emergency Response, Washington, DC, EPA/600/8-89/097, NTIS No. PB90-142498.

U.S. Environmental Protection Agency (EPA), 1989a, "Risk Assessment Guidance for Superfund: Human Health Manual, Part A, Interim Final," EPA/540/1-89/002, EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1989b, "Exposure Factors Handbook," EPA/600/8-89/043, EPA, Office of Health and Environmental Assessment, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1989c, "Methods for Evaluating the Attainment of Cleanup Standards, Vol. 1: Soils and Solid Media," EPA/230/02-89-042, Office of Policy, Planning, and Evaluation, Washington, DC.,

U.S. Environmental Protection Agency (EPA), 1989d, "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance," EPA/530-SW-89-026, EPA, Office of Solid Waste, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1989e, Mouse oral subchronic study with acenaphthene, Study conducted by Hazelton Laboratories, Inc., for the Office of Solid Waste, Washington, DC (Cited in EPA 1992a).

U.S. Environmental Protection Agency (EPA), 1989f, Subchronic toxicity in mice with anthracene, Final Report, Hazelton Laboratories America, Inc, prepared for Office of Solid Waste, Washington, DC (Cited in EPA 1992a).

U.S. Environmental Protection Agency (EPA), 1989g, Mouse oral subchronic toxicity study, prepared by Toxicity Research Laboratories, Ltd., Muskegon, MI for Office of Solid Waste, Washington, DC (Cited in EPA 1992a).

U.S. Environmental Protection Agency (EPA), 1989h, Mouse oral subchronic toxicity of pyrene, Study conducted by Toxicity Research Laboratories, Muskegon, MI for the Office of Solid Waste, Washington, DC (Cited in EPA 1992a).

U.S. Environmental Protection Agency (EPA), 1989i, "General Quantitative Risk Assessment Guidelines for Noncancer Health Effects," prepared by the Office of Health and Environmental Assessment for the Risk Assessment Forum, ECAO-CIN-538, Cincinnati, OH.

U.S. Environmental Protection Agency (EPA), 1989k, "Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites, OSWER Directive No. 9355.4-02, September 1989.

U.S. Environmental Protection Agency (EPA), 1990a, "Statistical Methods for Evaluating the Attainment of Cleanup Standards, Vol. 1 and Vol. 3: Background-Based Standards for Soils and Solid Media," prepared for the EPA under a Related Services Agreement with the U.S. Dept. of Energy, Contract DE-AC06-76RLO 1830, by Pacific Northwest Laboratory, Richland, WA.

U.S. Environmental Protection Agency (EPA), 1990b, Memorandum from Pei-Fung Hurst, ECAO, Cincinnati, OH to R. Riccio, EPA Region III, Philadelphia, PA, Subject: Toxicity of Cobalt (Halby Chemical/Wilmington, Delaware), dated October 9, 1990.

U.S. Environmental Protection Agency (EPA), 1990c, Technical Support Document for Lead, Prepared by the Chemical Hazard Assessment Division, Syracuse Research Corporation, under contract to the Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. Environmental Protection Agency (EPA), 1990d, Exposure Factor Handbook, EPA/600/8-89/043.

U.S. Enviromental Protection Agency (EPA), 1990e. "40 CFR Part 300, National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule" as presented in teh Federal Register, Vol. 55, No. 46, pg. 8848.

U.S. Environmental Protection Agency (EPA), 1991a, "Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Vol. I, Supplemental Guidance, Standard Default Exposure Factors, Interim Final," EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1991b, "Health Effects Assessment Summary Tables, FY - 1991," OERR 9200.6-303(91-1), EPA, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1991c, "User's Guide for Lead: A PC Software Application of the Uptake/Biokinetic Model Version 0.50," prepared by Syracuse Research Corporation Under Contract No. 68-CO-0043 for the Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. Environmental Protection Agency (EPA), 1991f, "Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual, Part B, Development of Risk-Based Preliminary Remediation Goals." Pubication 9285.7-01B. EPA, Office of Emergency and Remedial Response.

U.S. Environmental Protection Agency (EPA), 1991i, "Update on OSWER Soil Lead Cleanup Guidance, Memorandum from D. R. Clay, Office of Solid Waste and Emergency Response, August 1991.

U.S. Environmental Protection Agency (EPA), 1991j, Standard Default Exposure Factors, (OSWER Directive 9285.6-03).

U.S. Environmental Protection Agency (EPA), 1992a, "Risk Assessment Guidance for Superfund, Vol. I, HHEM, Supplemental Guidance for Superfund, Dermal Risk Assessment, Interim Guidance, Public 9285.7-01B. EPA, OERR.

U.S. Environmental Protection Agency (EPA), 1992c, "Supplemental Guidance to RAGS: Calculating the Concentration Term," prepared by the Office of Solid Waste and Emergency Response, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1992d, "Guidance on Risk Characterization for Risk Assessors and Risk Managers," memorandum dated February 26, 1992.

U.S. Environmental Protection Agency (EPA), 1992e, "Dermal Exposure Assessment: Principles and Applications," EPA/600/8-91/011B, prepared by the Office of Research and Development, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1992f, "Drinking Water Regulations and Health Advisories," Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1992g, Memorandum from D. L. Forman, U.S. EPA Region III, Philadelphia, PA, Subject: Cobalt Toxicity, dated March 12, 1992.

U.S. Environmental Protection Agency (EPA), 1992h, Risk Assessment Teleconference for Superfund (RATS), May 13, 1992 meeting notes, Superfund Technical Support Center, Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. Environmental Protection Agency (EPA) 1992i, "Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual. Supplemental Guidance for Superfund, Dermal Risk Assessment, Inerim Guidance." Publication 9285.7-01B. EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Enviromental Protection Agency, 1992, "[Telephone conversation on December 3, 1992 between Pat Van Leeuwen of U.S. EPA Region V, and M. Bollenbacher and V. Chadambariah of IT Corporation, on exposure parameters to be used in the Operable Unit 1 Risk Assessment for the Central Tendency exposure parameters and the soil ingestion rate for the RME farmer.]"

U.S. Environmental Protection Agency (EPA), 1993a, "Integrated Risk Information System (IRIS)" computer database, EPA, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1993d, Memorandum from J. Dollaride, ECAO, to P. VanLeeuwen, EPA Region V, July 21, 1993. Attachment G: "Review of Position Paper on Proposed Modifications to Soil Cleanup Levels."

U.S. Environmental Protection Agency (EPA), 1993e, "Drinking Water Regulations and Health Advisories," May 1993, Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1993f, "Provisional Guidance for Qualitative Risk Assessment of Polycyclic Aromatic Hydrocarbons," March 1993, ECAO-CIN-842.

U.S. Environmental Protection Agency (EPA), 1992g, "Health Effects Assessment Summary Tables, Annual Update FY 1993," including Suppl. A, March 1993, prepared by the Environmental Criteria and Assessment Office, Cincinnati, OH, for the Office of Emergency and Remedial Response, Washington, DC.

U.S. Nuclear Regulatory Commission 1984b (NRC), De Minimis, Waste Impacts Analysis Methodology, NUREG/CR-3585.

Uzhdavini, E. R., I. K. Astaf'yeva, A. A. Mamayeva, and G. Z. Bakhtizina, 1972, "Inhalation Toxicity of o-Cresol," Tr. Ufimskogo Nauchno-Issledovatel'skogo Instituta Gigiyeny Profzabolevaniya, Vol. 7, pp. 115-119, (English translation) (Cited in EPA 1992).

Vainich, et al., 1976, "The Fate of Intratracheally Instilled Benzo(a)pyrene in the Isolated Perfused Rat Lung of Both Control and 20-Methylcholanthrene Pretreated," Research Communications in Chemical Pathology and Pharmacology, Vol. 13, pp. 259 (Cited in EPA 1980).

Van Bruwaene, R. Hegela, M. Gerber, G. B. Kirchmann, and R. Maisin, 1986, "Toxicity of Long-term Application of Dietary Technitium to Rats and the Offspring Bound to Food," Desmet, G. Myttenaere, C. eds., Technitium in the Environment, Elsevier App. Science Publ., London, New York, pp. 385-398.

Van Duuren, B. L., B. M. Goldschmidt, G. Loewengart, A. C. Smith, S. Melchionne, I. Seldman, and D. Roth, 1979, "Carcinogenicity of Halogenated Olefinic and Aliphatic Hydrocarbons in Mice," Journal of the National Cancer Institute, Vol. 63, pp. 1433-1439 (Cited in EPA 1992).

van Kaick, G., A. Kaul, D. Lorenz, H. Muth, K. Wegener, and H. Wesch, 1978a, "Late Effects and Tissue Dose in Thorotrast Patients. Recent Results of the German Thorotrast Study," Late Biological Effects of Ionizing Radiation, International Atomic Energy Agency, Vienna, Austria, Vol. 1, pp. 263-276.

van Kaick, G., D. Lorenz, H. Muth, and A. Kaul, 1978b, "Malignancies in German Thorotrast Patients and Estimated Tissue Dose," Health Physics, Vol. 35, pp. 127-136.

van Kaick, G., H. Muth, and A. Kaul, H. Immich, D. Liebermann, D. Lorenz, W. J. Lorenz, H. Luhrs, K. E. Scheer, G. Wagner, K. Wegener, and H. Wesch, 1983, "Recent Results of German Thorotrast Study -Epidemiological Results and Dose Effect Relationships in Thorotrast Patients," Health Physics, Vol. 44, Supp. 1, pp. 299-306.

van Kaick, G., H. Muth, A. Kaul, H. Immich, D. Liebermann, D. Lorenz, W. J. Lorenz, W. J. Luhrs, K. E. Scheer, G. Wagner, K. Wegener, and H. Wesch, 1984a, "Results of the German Thorotrast Study," Radiation Carcinogenesis, Epidemiology and Biological Significance, J. D. Boice, Jr. and J. F. Fraumeni, Jr., eds., Raven, NY.

van Kaick, G., H. Muth, and A. Kaul, 1984b, "The German Thorotrast Study," Results of Epidemiological, Clinical and Biophysical Examinations on Radiation-Induced Late Effects in Man Caused by Incorporated Colloidal Thorium Dioxide (Thorotrast), Report No. EUR 9504 EN, Commission of the European Communities, Luxembourg, Germany.

van Kaick, G., H. Muth, A. Kaul, H. Wesch, H. Immich, D. Liebermann, W. J. Lorenz, H. Luhrs, K. E. Scheer, G. Wagner, and K. Wegener, 1986, "Report on the German Thorotrast Study," Strahlentherapie, Vol. 80, pp. 114-118.

Velsicol Chemical Co., 1983, "Thirty-month Chronic Toxicity and Tumorigenicity Test in Rats by Chlordane Technical," Unpublished study by Research Institute for Animal Science in Biochemistry and Toxicology (RIASBT), Japan (Cited in ATSDR 1989; EPA 1992).

Wagoner, J. K., V. E. Archer, B. E. Carroll, and D. A. Holaday, 1964, "Cancer Mortality Patterns Amongst U.S. Uranium Miners and Millers, 1950 Through 1962," Journal of the National Cancer Institute, Vol. 32, pp. 787-801.

Watkins, J. S. and A. M. Speiker, 1971 "Seismic Refraction Survey of Pleistocene Drainage Channels in the Lower Great Miami River Valley, Ohio," USGS Professional Paper 605-B.

Waxweiler, R. J., V. E. Archer, R. J. Roscoe, A. Watanabe, and J. J. Thun, 1983, "Mortality Patterns Among a Retrospective Cohort of Uranium Mill Workers," Proceedings of the Health Physics Society, presented at Epidemiology Applied to Health Physics, pp. 428-435.

Wesch, H., H. Kampmann, and K. Wegener, 1973, "Assessment of Organ Distribution of Thorium by Neutron-Activation-Analysis," Proceedings of the Third International Meeting on the Toxicity of Thorotrast, Riso Report 294, M. Faber, ed., Danish Atomic Energy Commission, Copenhagen, Denmark, pp. 52-60.

Wesch, H., W. Riedel, K. Wegener, A. Kaul, H. Immich, K. Hasenohrl, H. Muth, and G. van Kaick, 1983, "Recent Results of the German Thorotrast Study - Statistical Evaluation of Animal Experiments With Regard to the Nonradiation Effect in Human Thorotrastosis," Health Physics, Vol. 44, Suppl. 1, pp. 317-321.

Wesch, H., U. W. Riedel, K. Hasenohrl, K. Wegener, A. Kaul, H. Muth, and G. van Kaick, 1986, "German Thorotrast Study: Results of the Long-Term Animal Studies on the Effect of Incorporated Radioactive and Nonradioactive Particles," Strahlentherapie, Vol. 80, pp. 186-188.

Westinghouse Environmental Management Company of Ohio (WEMCO), 1987, "Feed Materials Production Center Environmental Monitoring Annual Report for 1986," FMPC-2076, WEMCO, Cincinnati, OH, prepared for U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Williams, G. M. and J. H. Weisburger, 1991, "Chemical Carcinogenesis," M. O. Amdur, J. Doull, and C.D. Klaassen, eds., Casarett and Doull's Toxicology, the Basic Science of Poisons, 4th ed., Pergamon Press, New York, pp. 127-200.

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TABLE E.I-1

BACKGROUND CONCENTRATIONS OF RADON IN AIR

Radionuclide	Date	Frequency of Detection	Range of Detection (pCi/L)	Distribution	Arithmetic Mean (pCi/L)	Upper 95% UCL on Arithmetic Mean (pCi/L)
Rn-222	10/91	741/741	0.100 - 2.700	Lognormal	0.866	0.899
Rn-222	12/91	741/741	0.200 - 2.400	Lognormal	0.611	0.630

TABLE E.I-2

SUMMARY STATISTICS FOR BACKGROUND CONCENTRATIONS OF RADIONUCLIDES AND INORGANIC CHEMICALS IN GREAT MIAMI RIVER WATER

Constituent	Total Analysis	Total Detection	Detection Frequency (%)	Minimum Detection	Maximum Detection	Maximum SQL	Median
Radionuclides (pCi/g)[a]							
Np-237	5	0	0	-	-	1	<1
Pu-238	5	0	0	-	-	1	<1
Pu-239/240	5	0	0	-	-	1	<1
Ra-226	5	0	0	-	-	1	<1
Ra-228	5	0	0	-	-	3	<3
Sr-90	4	0	0	-	-	5	<5
Tc-99	5	0	0	-	-	30	<30
Th-228	5	0	0	-	-	1	<1
Th-230	5	0	0	-	-	1	<1
Th-232	5	0	0	-	-	1	<1
U-234	5	1	20	-	1.1	1	<1
U-235/236	5	0	0	-	-	1	<1
U-238	5	0	0	-	-	1	<1
Chemical (μg/L)							
Ammonia	3	3	100	0.1	1.2	NA	0.11
Arsenic	2	0	0	NA	NA	0.002	<0.002
Barium	3	3	100	0.0493	0.100	NA	0.089
Cadmium	4	1	25	0.006	0.0098	0.005	0.006
Calcium	4	3	75	61.2	77	NA	70.5
Chloride	3	3	100	17.99	325	NA	135
Chromium	4	0	0	NA	NA	0.02	<0.002
Copper	4	0	0	NA	NA	0.01	<0.01
Fluoride	3	3	100	0.31	0.9	NA	0.82
Iron	4	2	50	0.164	0.22	0.005	0.095
Lead	3	0	0	NA	NA	0.01	0.005
Magnesium	4	4	100	21.5	34.9	NA	31.05
Manganese	4	2	50	0.08	0.0089	0.02	0.045
Mercury	4	1	25	NA	0.0095	0.0002	<0.0002
Molybdenum	4	1	25	NA	0.02	0.02	<0.02

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TABLE E.I-2
(Continued)

Constituent	Total Analysis	Total Detection	Detection Frequency (%)	Minimum Detection	Maximum Detection	Maximum SQL	Median
Nickel	4	1	25	NA	0.0105	0.02	<0.02
Nitrate	3	3	100	0.4	6.58	NA	3.2
Phosphorus	3	3	100	0.299	1.1	NA	0.59
Potassium	3	3	100	2.3	6.2	NA	4.03
Selenium	2	0	0	NA	NA	0.002	<0.002
Silver	5	0	0	NA	NA	0.1	<0.03
Sodium	4	4	100	12.9	77.2	NA	72.9
Sulfate	3	3	100	114.9	4310	NA	138
Uranium-Total[b]	5	3	60	1	1	1	1

[a] Samples were not analyzed for Cs-137, Ru-106, Th-total,a nd U-235.
[b] Additional statistics for U-total: arithmetic mean is 0.8, arithmetic standard deviation is 0.3, geometric mean is 0.8, and geometric standard deviation is 1.5

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TABLE E.I-3

BACKGROUND CONCENTRATIONS OF RADIONUCLIDES AND INORGANIC CHEMICALS IN THE GREAT MIAMI AQUIFER

Constituent	Total Analyses	Total Detections	Detection Frequency	Minimum Detection	Maximum Detection	Median	Arithmetic Mean	95% UCL on Arithmetic Mean
Radionuclides (pCi/L)								
Cs-137	5	0	0	-	-	<20	NA	NA
Np-237	103	0	0	-	-	<1	NA	NA
Pu-238	105	0	0	-	-	<1	NA	NA
Pu-239/240	105	0	0	-	-	<1	NA	NA
Ra-226	95	6	6	1.1	8.5	<1	NA	NA
Ra-228	91	8	9	3.1	5.5	<3	NA	NA
Ru-106	6	0	0	-	-	<150	NA	NA
Sr-90	107	0	0	-	-	<5	NA	NA
Tc-99	114	1	1	-	36	<30	NA	NA
Th-228	119	8	7	1.2	2.9	<1	NA	NA
Th-230	119	10	8	1.2	3.44	<1	NA	NA
Th-232	108	0	0	-	-	<1	NA	NA
Th-Total	86	4	5	2	6.14	<3	NA	NA
U-234	118	7	6	1.2	4.2	<1	NA	NA
U-235	3	0	0	-	-	<1	NA	NA
U-235/236	115	0	0	-	-	<1	NA	NA
U-238	118	4	3	0.9	4.4	<1	NA	NA

TABLE E.I-3
(Continued)

Constituent	Total Analyses	Total Detections	Detection Frequency	Minimum Detection	Maximum Detection	Median	Arithmetic Mean	95% UCL on Arithmetic Mean
Inorganic Chemicals (μg/L)								
Aluminum	23	19	83	0.06	0.18	0.087	0.097	0.117
Ammonia	105	36	34	0.1	13	<0.01	0.71	N/A
Antimony	7	1	14	N/A	0.038	<0.03	N/A	N/A
Arsenic	89	24	27	0.002	0.55	<0.002	0.032	N/A
Barium	116	102	88	0.006	0.79	0.05	0.15	0.19
Beryllium	13	7	54	0.001	0.002	0.001	0.001	0.002
Cadmium	114	25	22	0.002	0.017	<0.005	0.003	N/A
Calcium	119	118	99	1.0	181	91	96	101
Chloride	117	102	87	0.02	120	18	24	28
Chromium	120	45	38	0.01	0.56	<0.02	0.02	N/A
Cobalt	13	0	0	<0.01	<0.02	<0.01	N/A	N/A
Copper	120	38	32	0.01	0.27	<0.01	0.019	N/A
Cyanide	5	0	0	<0.002	<0.005	<0.005	N/A	N/A
Fluoride	118	111	94	0.05	1.9	0.27	0.35	0.41
Hexavalent Chromium	2	1	50	N/A	0.05	0.028	N/A	N/A
Iron	119	79	66	0.007	5.5	0.19	1.1	1.4
Lead	83	17	21	0.003	0.14	<0.002	0.006	N/A
Magnesium	118	118	100	0.5	47	27	27	28

TABLE E.I-3
(Continued)

Constituent	Total Analyses	Total Detections	Detection Frequency	Minimum Detection	Maximum Detection	Median	Arithmetic Mean	95% UCL on Arithmetic Mean
Manganese	114	88	77	0.002	0.9	0.05	0.15	0.19
Mercury	112	13	12	0.0002	0.0031	<0.0002	0.0002	N/A
Molybdenum	111	24	22	0.004	0.04	<0.02	0.012	N/A
Nickel	120	20	17	0.012	0.78	<0.02	0.019	N/A
Nitrate	69	57	83	0.014	25	1.0	3.4	4.6
Phosphorous	106	75	71	0.01	3.1	0.05	0.21	0.29
Potassium	113	105	93	0.66	14	1.8	2.1	2.4
Selenium	80	5	6.3	0.002	0.006	<0.002	0.002	N/A
Silicon	10	10	100	2	6.1	3.1	3.6	4.7
Silver	118	19	16	0.01	0.11	<0.01	0.007	N/A
Sodium	114	114	100	0.61	55	12	16	19
Sulfate	118	108	92	2.8	321	48	61	72
Sulfide	14	3	21	0.001	30	<0.05	4.4	N/A
Thallium	7	0	0	<0.001	<0.04	<0.001	N/A	N/A
Tin	3	0	0	N/A	<0.03	<0.03	N/A	N/A
Uranium	113	51	45	0.80	3.1	<1	0.71	0.82
Vanadium	23	19	83	0.01	0.025	0.016	0.015	0.018
Zinc	13	13	100	0.009	3.0	0.037	0.27	0.77

TABLE E.I–4

SUMMARY STATISTICS FOR BACKGROUND CONCENTRATIONS OF INORGANIC CHEMICALS IN SOIL

PARAMETER	Dataset	Unit	Hits	Min. Hit	Max. Hit	Min. SQL	Max. SQL	Distribution	Concentration Term	95th P
ALUMINUM	0" – 6"	mg/kg	30 / 30	5350	15000			LogNormal	8,812.15	11,880.19
	36" – 54"	mg/kg	51 / 51	3250	16100			LogNormal	9737.08	16063.97
ANTIMONY	0" – 6"	mg/kg	0 / 30			7.1	8.8	Undefined		
	36" – 54"	mg/kg	0 / 37			3.5	7.4	Undefined		
ARSENIC	0" – 6"	mg/kg	26 / 30	3.4	9.2	2.9	5.6	Normal	5.56	8.20
	36" – 54"	mg/kg	44 / 51	1.6	14.5	3.5	8.7	LogNormal	5.65	9.57
BARIUM	0" – 6"	mg/kg	29 / 29	31	94.1			LogNormal	67.70	94.10
	36" – 54"	mg/kg	51 / 51	13.7	134			LogNormal	67.17	119.17
BERYLLIUM	0" – 6"	mg/kg	1 / 30	0.6	0.6	0.47	0.59	Undefined	0.60	0.60
	36" – 54"	mg/kg	15 / 50	0.48	0.68	0.23	0.48	Undefined	0.48	0.62
BORON	0" – 6"	mg/kg	11 / 29	12.6	25.4	12.2	14.7	Undefined	12.60	25.10
	36" – 54"	mg/kg	49 / 51	18.6	47.1	12.1	12.1	Normal	31.27	42.95
CADMIUM	0" – 6"	mg/kg	6 / 30	0.52	0.95	0.47	0.72	Undefined	0.52	0.87
	36" – 54"	mg/kg	6 / 51	0.47	1.3	0.23	0.61	Undefined	0.47	0.91
CALCIUM	0" – 6"	mg/kg	30 / 30	856	5340			LogNormal	2,581.16	4,339.17
	36" – 54"	mg/kg	51 / 51	3310	335000			Undefined	108000.00	150000.00
CHROMIUM	0" – 6"	mg/kg	30 / 30	6.7	17.7			LogNormal	11.62	15.50
	36" – 54"	mg/kg	51 / 51	4.5	22.4			LogNormal	12.63	20.68
COBALT	0" – 6"	mg/kg	30 / 30	4.3	16.5			Normal	10.78	14.16
	36" – 54"	mg/kg	51 / 51	3.6	17.9			LogNormal	10.04	15.75
COPPER	0" – 6"	mg/kg	27 / 30	3.2	17.3	2.4	2.9	Normal	8.60	14.07
	36" – 54"	mg/kg	50 / 51	6.8	24.3	8.2	8.2	LogNormal	13.41	20.03
CYANIDE	0" – 6"	mg/kg	12 / 30	0.14	0.29	0.12	0.15	Undefined	0.15	0.27
	36" – 54"	mg/kg	2 / 50	0.13	0.17	0.1	0.12	Undefined	0.13	0.13
IRON	0" – 6"	mg/kg	30 / 30	9370	24900			Normal	16,244.47	21,728.17
	36" – 54"	mg/kg	51 / 51	8970	30700			LogNormal	20138.49	30700.00
LEAD	0" – 6"	mg/kg	28 / 30	11	36.4	15.6	21.2	LogNormal	18.90	26.40
	36" – 54"	mg/kg	47 / 51	3	18.4	5.7	11.7	LogNormal	9.52	15.58

TABLE E.I–4
(Continue)

PARAMETER	Dataset	Unit	Hits	Min. Hit	Max. Hit	Min. SQL	Max. SQL	Distribution	Concentration Term	95th P
MAGNESIUM	0" – 6"	mg/kg	30 / 30	1020	3590			LogNormal	1,926.10	2,776.97
	36" – 54"	mg/kg	51 / 51	2930	54100			Normal	24206.82	42648.21
MANGANESE	0" – 6"	mg/kg	29 / 29	189	1500			LogNormal	814.16	1,348.04
	36" – 54"	mg/kg	51 / 51	251	1750			Undefined	534.00	1300.00
MERCURY	0" – 6"	mg/kg	2 / 30	0.12	0.3	0.12	0.14	Undefined	0.12	0.12
	36" – 54"	mg/kg	1 / 51	0.29	0.29	0.1	0.22	Undefined	0.29	0.29
MOLYBDENUM	0" – 6"	mg/kg	0 / 30			2.4	2.9	Undefined		
	36" – 54"	mg/kg	1 / 51	2.7	2.7	1.2	2.5	Undefined	2.70	2.70
NICKEL	0" – 6"	mg/kg	29 / 30	5.8	22.7	4.9	4.9	LogNormal	12.72	20.87
	36" – 54"	mg/kg	51 / 51	8.5	41.9			LogNormal	21.90	34.35
POTASSIUM	0" – 6"	mg/kg	29 / 30	374	1590	260	260	Normal	834.25	1,231.34
	36" – 54"	mg/kg	51 / 51	340	2180			LogNormal	1178.62	1979.99
SELENIUM	0" – 6"	mg/kg	1 / 30	0.72	0.72	0.36	0.88	Undefined	0.72	0.72
	36" – 54"	mg/kg	0 / 51			0.25	0.73	Undefined		
SILICON	0" – 6"	mg/kg	29 / 29	480	2230			LogNormal	1,276.44	1,797.03
	36" – 54"	mg/kg	51 / 51	449	1850			LogNormal	1060.12	1593.08
SILVER	0" – 6"	mg/kg	0 / 30			2.4	2.9	Undefined		
	36" – 54"	mg/kg	0 / 51			1.2	2.5	Undefined		
SODIUM	0" – 6"	mg/kg	27 / 30	26.9	54.7	24.9	26.8	Normal	37.50	51.10
	36" – 54"	mg/kg	51 / 51	53.8	345			Undefined	131.00	285.00
THALLIUM	0" – 6"	mg/kg	1 / 30	0.58	0.58	0.36	0.59	Undefined	0.58	0.58
	36" – 54"	mg/kg	3 / 51	0.49	0.55	0.17	0.49	Undefined	0.49	0.49
VANADIUM	0" – 6"	mg/kg	30 / 30	11.3	32.7			LogNormal	22.28	30.37
	36" – 54"	mg/kg	51 / 51	8.4	44.5			Undefined	18.50	37.80
ZINC	0" – 6"	mg/kg	30 / 30	29.4	70			LogNormal	44.60	59.61
	36" – 54"	mg/kg	51 / 51	27.3	101			LogNormal	52.29	72.58

TABLE E.I-5

SUMMARY STATISTICS FOR BACKGROUND CONCENTRATIONS OF RADIONUCLIDES IN SOIL

Parameter	Dataset	Units	Hits	Min. Hit	Max. Hit	Min. SQL	Max. SQL	Distribution	Concentration	95th P
ACTINIUM-227	0" – 6"	pCi/g	1 / 30	0.09	0.09	0.04	0.06	Undefined	0.09	0.09
	36" – 54"	pCi/g	3 / 51	0.06	0.1	0.03	0.07	Undefined	0.06	0.06
CESIUM-137	0" – 6"	pCi/g	30 / 30	0.15	0.71			LogNormal	0.44	0.71
	36" – 54"	pCi/g	0 / 51			0.01	0.01	Undefined		
LEAD-210	0" – 6"	pCi/g	30 / 30	0.53	1.3			LogNormal	1.00	1.30
	36" – 54"	pCi/g	43 / 51	0.31	0.97	0.3	0.3	Undefined	0.57	0.81
POTASSIUM-40	0" – 6"	pCi/g	30 / 30	13.1	21.4			LogNormal	16.89	19.71
	36" – 54"	pCi/g	51 / 51	8.6	31			LogNormal	18.71	27.76
PROTACTINIUM-231	0" – 6"	pCi/g	0 / 30			0.26	0.4	Undefined		
	36" – 54"	pCi/g	0 / 51			0.16	0.45	Undefined		
RADIUM-224	0" – 6"	pCi/g	30 / 30	0.54	0.93			Undefined	0.86	0.90
	36" – 54"	pCi/g	51 / 51	0.29	1.07			LogNormal	0.66	1.01
RADIUM-226	0" – 6"	pCi/g	30 / 30	0.85	1.48			Normal	1.22	1.42
	36" – 54"	pCi/g	51 / 51	0.59	1.61			Undefined	0.88	1.47
RADIUM-228	0" – 6"	pCi/g	30 / 30	0.8	1.27			Normal	1.10	1.25
	36" – 54"	pCi/g	51 / 51	0.36	1.37			LogNormal	0.85	1.31
RUTHENIUM-106	0" – 6"	pCi/g	0 / 30			0.07	0.09	Undefined		
	36" – 54"	pCi/g	0 / 51			0.04	0.11	Undefined		
STRONTIUM-90	0" – 6"	pCi/g	0 / 30			0.5	0.5	Undefined		
	36" – 54"	pCi/g	1 / 51	0.56	0.56	0.5	0.5	Undefined	0.56	0.56
TECHNETIUM-99	0" – 6"	pCi/g	0 / 30			0.9	0.9	Undefined		
	36" – 54"	pCi/g	0 / 51			0.9	0.9	Undefined		
THORIUM-228	0" – 6"	pCi/g	29 / 30	0.68	1.43	0.6	0.6	Normal	1.12	1.43
	36" – 54"	pCi/g	41 / 51	0.6	1.39	0.6	1	Normal	0.88	1.33

TABLE E.I–5
(Continue)

Parameter	Dataset	Units	Hits	Min. Hit	Max. Hit	Min. SQL	Max. SQL	Distribution	Concentration	95th P
THORIUM–230	0" – 6"	pCi/g	29 / 30	0.9	2.01	0.6	0.6	Normal	1.50	1.97
	36" – 54"	pCi/g	45 / 51	0.62	2.34	0.6	1	Normal	1.24	1.88
THORIUM–232	0" – 6"	pCi/g	30 / 30	0.64	1.52			LogNormal	1.08	1.36
	36" – 54"	pCi/g	36 / 51	0.63	1.35	0.6	1	Undefined	0.85	1.26
THORIUM–TOTAL	0" – 6"	ug/g	2 / 2	8.31	10.7			Undefined	10.70	10.70
	36" – 54"	ug/g	3 / 3	8.24	9.47			Undefined	9.47	9.47
URANIUM–234	0" – 6"	pCi/g	30 / 30	0.67	1.31			LogNormal	1.04	1.24
	36" – 54"	pCi/g	47 / 51	0.48	1.3	0.6	0.6	Undefined	0.73	1.04
URANIUM–235/236	0" – 6"	pCi/g	27 / 30	0.03	0.2	0.05	0.07	LogNormal	0.09	0.15
	36" – 54"	pCi/g	46 / 51	0.03	0.2	0.02	0.11	Undefined	0.06	0.15
URANIUM–238	0" – 6"	pCi/g	30 / 30	0.85	1.33			LogNormal	1.08	1.22
	36" – 54"	pCi/g	48 / 51	0.6	1.23	0.6	0.6	Normal	0.84	1.12

E.II

ATTACHMENT E.II
LEGEND

A Based on the t-test, WRS test or in conjunction with the 95th percentile confidence limit (CL) on the arithmetic mean, the constituent concentration is not statistically higher than 95th percentile background concentrations.

B Essential macronutrients for which there are no known toxic effects at the concentrations defined.

C Essential micronutrients for which there are no toxic effects at the concentrations found.

D Ubiquitous elements in soil, not toxic except at high levels

E Nonspecific chemical classes that are either too general to be useful for risk assessment or for which chemical-specific results are presented in the same analysisNot a specific chemical that is evaluated in a human health risk assessment.

F Chemicals that present a HQ less than 0.1 or ILCR lower than 10^{-7} when evaluated against screening criteria calculated from EPA RAGS Part B (EPA 1991f).

G No dose response data available. Retained as CPC but not quantitatively assessed.

TABLE E.II–1
SUMMARY OF PIT 1 ANALYTICAL RESULTS

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Aluminum	mg/Kg	5 / 5	20200.0	U	NA	6 / 6	4690.0	U	NA	20200.0	16064.0	No	D
Antimony	mg/Kg	1 / 5	0.4	U	NA	6 / 6	125.0	U	NA	125.0	NA "NA	Yes	
Arsenic	mg/Kg	5 / 5	15.0	U	NA	5 / 6	1.7	U	NA	15.0	9.6	Yes	
Barium	mg/Kg	5 / 5	365.0	U	NA	6 / 6	439.0	U	NA	439.0	119.2	No	F
Beryllium	mg/Kg	4 / 5	2.2	U	NA	6 / 6	12.5	U	NA	12.5	0.6	Yes	
Boron	mg/Kg					4 / 5	1650.0	U	NA	1650.0	43.0	No	F
Cadmium	mg/Kg	4 / 5	5.0	U	NA	6 / 6	18.5	U	NA	18.5	0.9	Yes	
Calcium	mg/Kg	1 / 5	4760.0	U	NA	6 / 6	197000.0	U	NA	197000.0	150000.0	No	B
Chromium	mg/Kg	5 / 5	46.0	U	NA	6 / 6	347.0	U	NA	347.0	20.7	Yes	
Cobalt	mg/Kg	3 / 5	28.0	U	NA	6 / 6	46.8	U	NA	46.8	15.8	No	F
Copper	mg/Kg	1 / 5	20.0	U	NA	6 / 6	113.0	U	NA	113.0	20.0	No	F
Iron	mg/Kg	5 / 5	19700.0	U	NA	6 / 6	2610.0	U	NA	19700.0	30700.0	No	A
Lead	mg/Kg	1 / 5	17.0	U	NA	5 / 5	53.4	U	NA	53.4	15.6	Yes	G
Magnesium	mg/Kg	1 / 5	7610.0	U	NA	6 / 6	129000.0	U	NA	129000.0	42648.2	No	F
Manganese	mg/Kg	5 / 5	2910.0	U	NA	6 / 6	3720.0	U	NA	3720.0	1300.0	No	F
Mercury	mg/Kg	1 / 5	0.3	U	NA		NA "NA			0.3	0.3	No	F
Molybdenum	mg/Kg					6 / 6	32.7	U	NA	32.7	2.7	No	F
Nickel	mg/Kg	5 / 5	65.0	U	NA	6 / 6	57.4	U	NA	65.0	34.4	No	F
Potassium	mg/Kg	5 / 5	2560.0	U	NA	6 / 6	1210.0	U	NA	2560.0	1980.0	No	B
Silicon	mg/Kg					5 / 5	7190.0	U	NA	7190.0	1593.1	No	D
Silver	mg/Kg	4 / 5	33.0	U	NA	6 / 6	189.0	U	NA	189.0	NA "NA	Yes	
Sodium	mg/Kg	4 / 5	3640.0	U	NA	5 / 6	1930.0	U	NA	3640.0	285.0	No	B
Thallium	mg/Kg	1 / 5	0.3	U	NA	1 / 6	0.5	U	NA	0.5	0.5	No	A
Vanadium	mg/Kg	5 / 5	67.0	U	NA	6 / 6	142.0	U	NA	142.0	37.8	No	F
Zinc	mg/Kg	3 / 5	58.0	U	NA	6 / 6	24.9	U	NA	58.0	72.6	No	A
4,4'–DDT	ug/Kg	1 / 6	1600.0	U	NA		NA "NA			1600.0		Yes	
Aroclor 1221	ug/Kg		NA "NA			1 / 6	4600.0	U	NA	4600.0		Yes	
Aroclor 1248	ug/Kg	1 / 6	3500.0	U	NA	5 / 6	10000.0	U	NA	10000.0		Yes	
Aroclor 1254	ug/Kg	6 / 6	11500.0	U	NA	5 / 5	13000.0	U	NA	13000.0		Yes	
Aroclor 1260	ug/Kg	2 / 6	7800.0	U	NA		NA "NA			7800.0		Yes	

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TABLE E.II–1
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Cesium–137	pCi/g	1 / 5	1.1	U	NA	1 / 6	0.3	U	NA	1.1	NA "NA	Yes	
Plutonium–238	pCi/g					1 / 5	1.0	U	NA	1.0		Yes	
Plutonium–239/240	pCi/g					1 / 6	1.0	U	NA	1.0		Yes	
Radium–226	pCi/g					5 / 6	99.6	U	NA	99.6	1.5	Yes	
Radium–228	pCi/g					5 / 6	41.0	U	NA	41.0	1.3	Yes	
Ruthenium–106						1 / 6	2.4	U	NA	2.4	NA "NA	Yes	
Strontium–90						5 / 6	7.7	U	NA	7.7	0.6	Yes	
Technetium–99	pCi/g	1 / 5	15.0	U	NA	1 / 6	1.1	U	NA	15.0	NA "NA	Yes	
Thorium–228	pCi/g	5 / 5	52.0	U	NA	2 / 4	790.0	U	NA	790.0	1.3	Yes	
Thorium–230	pCi/g	5 / 5	3600.0	U	NA	4 / 4	5460.0	U	NA	5460.0	1.9	Yes	
Thorium–232	pCi/g	5 / 5	55.0	U	NA	2 / 4	490.0	U	NA	490.0	1.3	Yes	
Thorium–Total	mg/Kg					2 / 4	4400.0	U	NA	4400.0	9.5	Yes	G
Uranium–234	pCi/g	5 / 5	1180.0	U	NA	4 / 4	830.0	U	NA	1180.0	1.0	Yes	
Uranium–235/236	pCi/g	5 / 5	151.0	U	NA	5 / 5	259.0	U	NA	259.0	0.2	Yes	
Uranium–238	pCi/g	5 / 5	6980.0	U	NA	5 / 5	16160.0	U	NA	16160.0	1.1	Yes	
Uranium–Total	mg/Kg					6 / 6	48480.0	U	NA	48480.0		Yes	
2–Methylnaphthalene	ug/Kg	2 / 6	240.0	U	NA		NA "NA			240.0		Yes	G
3,3'–Dichlorobenzidine	ug/Kg	1 / 6	130.0	U	NA		NA "NA			130.0		No	F
Anthracene	ug/Kg	1 / 6	74.0	U	NA		NA "NA			74.0		No	F
Benzo(A)Anthracene	ug/Kg	2 / 6	100.0	U	NA		NA "NA			100.0		Yes	
Benzo(A)Pyrene	ug/Kg	1 / 6	140.0	U	NA		NA "NA			140.0		Yes	
Benzo(B)Fluoranthene	ug/Kg	5 / 6	330.0	U	NA		NA "NA			330.0		Yes	
Benzo(K)Fluoranthene	ug/Kg	1 / 6	140.0	U	NA		NA "NA			140.0		Yes	
Bis(2–Ethylhexyl)Phthalate	ug/Kg	2 / 6	1800.0	U	NA		NA "NA			1800.0		No	F
Chrysene	ug/Kg	5 / 6	540.0	U	NA		NA "NA			540.0		Yes	
Di–N–Octylphthalate	ug/Kg	4 / 6	830.0	U	NA		NA "NA			830.0		No	F
Fluoranthene	ug/Kg	6 / 6	430.0	U	NA		NA "NA			430.0		No	F
Naphthalene	ug/Kg	2 / 6	67.0	U	NA		NA "NA			67.0		No	F
Phenanthrene	ug/Kg	6 / 6	2400.0	U	NA		NA "NA			2400.0		Yes	G
Pyrene	ug/Kg	6 / 6	360.0	U	NA		NA "NA			360.0		No	F
1,1,1–Trichloroethane	ug/Kg	1 / 4	120.0	U	NA		NA "NA			120.0		No	F
2–Butanone	ug/Kg	4 / 4	3800.0	U	NA		NA "NA			3800.0		No	F
Acetone	ug/Kg	1 / 4	320.0	U	NA		NA "NA			320.0		No	F

TABLE E.II-1
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Chloroform	ug/Kg	2 / 4	210.0	U	NA		NA "NA			210.0		No	F
Ethylbenzene	ug/Kg	2 / 4	55.0	U	NA		NA "NA			55.0		No	F
Methylene Chloride	ug/Kg	2 / 4	180.0	U	NA		NA "NA			180.0		No	F
Toluene	ug/Kg	2 / 4	96.0	U	NA		NA "NA			96.0		No	F
1,2,3,4,6,7,8-HpCDD[4]	ug/Kg					5 / 6	1.2	U	NA	1.2		Yes	
1,2,3,4,6,7,8-HpCDF[4]	ug/Kg					5 / 6	1.2	U	NA	1.2		Yes	
1,2,3,4,7,8-HxCDF[4]	ug/Kg					3 / 6	0.8	U	NA	0.8		Yes	
1,2,3,6,7,8-HxCDD[4]	ug/Kg					4 / 6	0.8	U	NA	0.8		Yes	
1,2,3,6,7,8-HxCDF[4]	ug/Kg					3 / 6	0.3	U	NA	0.3		Yes	
1,2,3,7,8,9-HxCDD[4]	ug/Kg					3 / 6	0.5	U	NA	0.5		Yes	
1,2,3,7,8-PeCDF[4]	ug/Kg					5 / 6	1.2	U	NA	1.2		Yes	
2,3,4,6,7,8-HxCDF[4]	ug/Kg					3 / 6	0.4	U	NA	0.4		Yes	
2,3,4,7,8-PeCDF[4]	ug/Kg					4 / 6	1.2	U	NA	1.2		Yes	
2,3,7,8-TCDF[4]	ug/Kg					5 / 6	14.0	U	NA	14.0		Yes	
Heptachlorodibenzo-p-dioxin	ug/Kg					5 / 6	2.3	U	NA	2.3		Yes	
Heptachlorodibenzofuran	ug/Kg					5 / 6	2.7	U	NA	2.7		Yes	
Hexachlorodibenzo-p-dioxin	ug/Kg					5 / 6	4.9	U	NA	4.9		Yes	
Hexachlorodibenzofuran	ug/Kg					4 / 6	2.9	U	NA	2.9		Yes	
Octachlorodibenzo-p-dioxin	ug/Kg					5 / 6	0.7	U	NA	0.7		Yes	
Octachlorodibenzofuran	ug/Kg					3 / 6	0.8	U	NA	0.8		Yes	
Pentachlorodibenzofuran	ug/Kg					5 / 6	7.9	U	NA	7.9		Yes	
Tetrachlorodibenzofuran	ug/Kg					6 / 6	35.0	U	NA	35.0		Yes	
Ammonia	ug/Kg					1 / 1	48000.0	U	NA	48000.0		No	E
Cyanide	mg/Kg					3 / 6	730.0	U	NA	730.0		No	F
Phosphorus	ug/Kg					1 / 1	6730.0	U	NA	6730.0		No	B
Total Kjeldahl Nitrogen	ug/Kg					1 / 1	47700.0	U	NA	47700.0		No	E
Total Organic Carbon	ug/Kg					3 / 3	33600000.0	U	NA	33600000.0		No	E
1,4 Dioxane	ug/Kg					2 / 4	57.7	U	NA	57.7		No	F

Notes:

1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).

2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.

3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.

4 – TCDD = Tetrachlorodibenzo-p-dioxin
PeCDD = Pentachlorodibenzo-p-dioxin
HxCDD = Hexachlorodibenzo-p-dioxin
HpCCD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenz-p-dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

5 – The 95th percentile background concentrations for subsurface soils are compared with maximum values.

TABLE E.II-2
SUMMARY OF PIT 2 ANALYTICAL RESULTS

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Aluminum	mg/Kg	5 / 5	22400.0	U	NA	4 / 4	23100.0	U	NA	23100.0	16064.0	No	D
Antimony	mg/Kg	2 / 5	1.2	U	NA	4 / 4	55.4	U	NA	55.4	NA	Yes	
Arsenic	mg/Kg	5 / 5	10.0	U	NA	4 / 4	423.0	U	NA	423.0	9.6	Yes	
Barium	mg/Kg	5 / 5	208.0	U	NA	4 / 4	1920.0	U	NA	1920.0	119.2	Yes	
Beryllium	mg/Kg	5 / 5	8.9	U	NA	4 / 4	26.9	U	NA	26.9	0.6	Yes	
Boron	mg/Kg					4 / 4	238.0	U	NA	238.0	43.0	No	F
Cadmium	mg/Kg	5 / 5	9.6	U	NA	4 / 4	12.8	U	NA	12.8	0.9	Yes	
Calcium	mg/Kg	5 / 5	80100.0	U	NA	4 / 4	104000.0	U	NA	104000.0	150000.0	No	B
Chromium	mg/Kg	5 / 5	91.0	U	NA	4 / 4	282.0	U	NA	282.0	20.7	Yes	
Cobalt	mg/Kg	5 / 5	451.0	U	NA	4 / 4	1470.0	U	NA	1470.0	15.8	No	F
Copper	mg/Kg	5 / 5	329.0	U	NA	4 / 4	1340.0	U	NA	1340.0	20.0	Yes	
Iron	mg/Kg	5 / 5	24000.0	U	NA	4 / 4	39200.0	U	NA	39200.0	30700.0	No	B
Lead	mg/Kg	5 / 5	190.0	U	NA	4 / 4	758.0	U	NA	758.0	15.6	Yes	
Magnesium	mg/Kg	5 / 5	26700.0	U	NA	4 / 4	67900.0	U	NA	67900.0	42648.2	No	B
Manganese	mg/Kg	5 / 5	917.0	U	NA	4 / 4	2850.0	U	NA	2850.0	1300.0	No	F
Mercury	mg/Kg	4 / 5	0.7	U	NA	4 / 4	2.6	U	NA	2.6	0.3	No	F
Molybdenum	mg/Kg					4 / 4	215.0	U	NA	215.0	2.7	Yes	
Nickel	mg/Kg	5 / 5	609.0	U	NA	4 / 4	1740.0	U	NA	1740.0	34.4	Yes	
Potassium	mg/Kg	5 / 5	4320.0	U	NA	4 / 4	10800.0	U	NA	10800.0	1980.0	No	B
Selenium	mg/Kg	3 / 5	10.0	U	NA	4 / 4	131.0	U	NA	131.0		No	F
Silicon	mg/Kg					4 / 4	2640.0	U	NA	2640.0	1593.1	No	D
Silver	mg/Kg	3 / 5	23.0	U	NA	4 / 4	42.5	U	NA	42.5	NA	No	F
Sodium	mg/Kg	5 / 5	2300.0	U	NA	4 / 4	8710.0	U	NA	8710.0	285.0	No	B
Thallium	mg/Kg					1 / 4	2.4	U	NA	2.4	0.5	Yes	
Vanadium	mg/Kg	5 / 5	106.0	U	NA	4 / 4	594.0	U	NA	594.0	37.8	Yes	
Zinc	mg/Kg	5 / 5	3250.0	U	NA	4 / 4	488.0	U	NA	3250.0	72.6	No	F
4,4-DDT	ug/Kg	2 / 5	1400.0	U	NA					1400.0		Yes	
Aroclor 1248	ug/Kg	1 / 5	321.0	U	NA	2 / 4	4900.0	U	NA	4900.0		Yes	
Aroclor 1254	ug/Kg	1 / 5	323.0	U	NA					323.0		Yes	
Cesium-137	pCi/g	2 / 5	3.6	U	NA	1 / 4	0.5	U	NA	3.6	NA	Yes	
Plutonium-238	pCi/g	2 / 5	0.1	U	NA					0.1	NA	Yes	
Plutonium-239/240	pCi/g	2 / 5	0.6	U	NA					0.6	NA	Yes	
Radium-226	pCi/g					4 / 4	951.0	U	NA	951.0	1.5	Yes	
Radium-228	pCi/g					4 / 4	437.0	U	NA	437.0	1.3	Yes	
Ruthenium-106	pCi/g					1 / 4	4.0	U	NA	4.0	NA	Yes	
Strontium-90	pCi/g					3 / 4	4.0	U	NA	4.0	0.6	Yes	
Technetium-99	pCi/g	3 / 5	618.0	U	NA	1 / 4	1.6	U	NA	618.0	NA	Yes	
Thorium-228	pCi/g	5 / 5	164.0	U	NA	2 / 2	697.0	U	NA	697.0	1.3	Yes	
Thorium-230	pCi/g	5 / 5	3980.0	U	NA	2 / 2	18400.0	U	NA	18400.0	1.9	Yes	
Thorium-232	pCi/g	5 / 5	88.0	U	NA	2 / 2	340.0	U	NA	340.0	1.3	Yes	
Thorium-Total	mg/kg					2 / 2	2780.0	U	NA	2780.0	9.5	Yes	

TABLE E.II-2
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Uranium-234	pCi/g	5 / 5	18200.0	U	NA	2 / 2	1651.0	U	NA	18200.0	1.0	Yes	
Uranium-235/236	pCi/g	5 / 5	8780.0	U	NA	2 / 2	130.0	U	NA	130.0	0.2	Yes	
Uranium-238	pCi/g	5 / 5	17900.0	U	NA	2 / 2	1861.0	U	NA	17900.0	1.1	Yes	
Uranium-Total	mg/kg					4 / 4	5803.0	U	NA	5803.0		Yes	
2-Chlorophenol	ug/Kg					1 / 7	220.0	U	NA	220.0		No	F
2,4-Dimethylphenol	ug/Kg	1 / 5	150.0	U	NA					150.0		No	F
2-Methylnaphthalene	ug/Kg	2 / 5	7000.0	U	NA	3 / 7	7800.0	U	NA	7800.0		Yes	
4-Chloro-3-Methylphenol	ug/Kg					1 / 7	230.0	U	NA	230.0		Yes	
4-Methylphenol	ug/Kg	1 / 5	350.0	U	NA	1 / 7	190.0	U	NA	350.0		No	F
4-Nitroaniline	ug/Kg	1 / 5	4900.0	U	NA					4900.0		No	F
4-Nitrophenol	ug/Kg					1 / 7	190.0	U	NA	190.0		No	F
Acenaphthene	ug/Kg	3 / 5	43000.0	U	NA	3 / 7	31000.0	U	NA	43000.0		No	F
Acenaphthylene	ug/Kg					1 / 7	110.0	U	NA	110.0		Yes	G
Anthracene	ug/Kg	4 / 5	120000.0	U	NA	3 / 7	56000.0	U	NA	120000.0		No	F
Benzo(A)Anthracene	ug/Kg	5 / 5	130000.0	U	NA	3 / 7	100000.0	U	NA	130000.0		Yes	
Benzo(A)Pyrene	ug/Kg	4 / 5	120000.0	U	NA	3 / 7	68000.0	U	NA	120000.0		Yes	
Benzo(B)Fluoranthene	ug/Kg	5 / 5	110000.0	U	NA	3 / 7	130000.0	U	NA	130000.0		Yes	
Benzo(G,H,I)Perylene	ug/Kg	3 / 5	42000.0	U	NA	3 / 7	42000.0	U	NA	42000.0		Yes	G
Benzo(K)Fluoranthene	ug/Kg	4 / 5	75000.0	U	NA	3 / 7	44000.0	U	NA	75000.0		Yes	
Benzoic Acid	ug/Kg					4 / 7	850.0	U	NA	850.0		No	F
Chrysene	ug/Kg	4 / 5	4200.0	U	NA	2 / 7	86000.0	U	NA	86000.0		Yes	
Di-N-Butylphthalate	ug/Kg	1 / 5	96.0	U	NA					96.0		No	F
Di-N-Octylphthalate	ug/Kg	4 / 5	570.0	U	NA	1 / 7	480.0	U	NA	570.0		No	F
Dibenzo(A,H)Anthracene	ug/Kg	2 / 5	16000.0	U	NA	3 / 7	20000.0	U	NA	20000.0		Yes	
Dibenzofuran	ug/Kg	3 / 5	36000.0	U	NA	3 / 7	21000.0	U	NA	36000.0		Yes	
Diethyl Phthalate	ug/Kg					1 / 7	110.0	U	NA	110.0		No	F
Fluoranthene	ug/Kg	5 / 5	490000.0	U	NA	5 / 7	280000.0	U	NA	490000.0		Yes	
Fluorene	ug/Kg	3 / 5	62000.0	U	NA	3 / 7	37000.0	U	NA	62000.0		No	F
Indeno(1,2,3-Cd)Pyrene	ug/Kg	3 / 5	46000.0	U	NA	3 / 7	37000.0	U	NA	46000.0		Yes	
N-Nitrosodiphenylamine	ug/Kg					1 / 7	170.0	U	NA	170.0		No	F
Naphthalene	ug/Kg	3 / 5	16000.0	U	NA	3 / 7	23000.0	U	NA	23000.0		No	F
Pentachlorophenol	ug/Kg					2 / 7	1600.0	U	NA	1600.0		Yes	
Phenanthrene	ug/Kg	5 / 5	370000.0	U	NA	5 / 7	280000.0	U	NA	370000.0		Yes	
Phenol	ug/Kg	1 / 5	330.0	U	NA	2 / 7	230.0	U	NA	330.0		No	F
Pyrene	ug/Kg	5 / 5	250000.0	U	NA	5 / 7	230000.0	U	NA	250000.0		Yes	
Tributyl Phosphate	ug/Kg					4 / 4	39000.0	U	NA	39000.0		Yes	
Bis(2-Ethylhexyl) Phthalate	ug/Kg					1 / 7	980.0	U	NA	980.0		No	F
1,1,1-Trichloroethane	ug/Kg	1 / 4	150.0	U	NA	8 / 10	150.0	N	113.9	150.0		No	F
1,1-Dichloroethane	ug/Kg					7 / 10	23.0	L	12.4	12.4		No	F
1,1-Dichloroethene	ug/Kg					6 / 10	120.0	U	NA	120.0		Yes	

TABLE E.II–2
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
1,2–Dichloroethane	ug/Kg					7 / 10	20.0	L	16.7	16.7		No	F
1,4–Dioxane	ug/Kg					2 / 3	654.0	U	NA	654.0		No	F
2–Butanone	ug/Kg	2 / 2	2700.0	U	NA					2700.0		No	F
Acetone	ug/Kg	2 / 4	540.0	U	NA	2 / 6	71.0	U	NA	540.0		No	F
Benzene	ug/Kg					1 / 10	4.0	U	NA	4.0		Yes	
Chloroform	ug/Kg					7 / 10	84.0	L	67.6	67.6		No	F
Ethylbenzene	ug/Kg	1 / 4	48.0	U	NA	2 / 10	26.0	U	NA	48.0		No	F
Methylene Chloride	ug/Kg	2 / 4	200.0	U	NA	1 / 8	66.0	U	NA	200.0		No	F
Tetrachlorethene	ug/Kg					1 / 10	45.0	U	NA	45.0		No	F
Total Xylenes	ug/Kg	1 / 4	260.0	U	NA	1 / 10	15.0	U	NA	260.0		No	F
Trichloroethene	ug/Kg					1 / 10	7.0	U	NA	7.0		No	F
Vinyl Chloride	ug/Kg	1 / 4	670.0	U	NA	6 / 10	1900.0	U	NA	1900.0		Yes	
1,2,3,4,6,7,8–HpCDD[4]	ug/Kg					2 / 4	3.8	U	NA	3.8		Yes	
1,2,3,4,6,7,8–HpCDF[4]	ug/Kg					1 / 4	1.0	U	NA	1.0		Yes	
1,2,3,4,7,8–HxCDF[4]	ug/Kg					1 / 4	0.3	U	NA	0.3		Yes	
HpCDD[4]	ug/Kg					3 / 4	8.1	U	NA	8.1		Yes	
HpCDF[4]	ug/Kg					3 / 4	5.9	U	NA	5.9		Yes	
HxCDD[4]	ug/Kg					1 / 4	0.3	U	NA	0.3		Yes	
HxCDF[4]	ug/Kg					2 / 4	2.7	U	NA	2.7		Yes	
OCDD[4]	ug/Kg					4 / 4	45.9	U	NA	45.9		Yes	
OCDF[4]	ug/Kg					3 / 4	4.9	U	NA	4.9		Yes	
PeCDF[4]	ug/Kg					1 / 4	0.6	U	NA	0.6		Yes	
Ammonia	ug/Kg					2 / 4	2400.0	U	NA	2400.0		No	E
Chloride	ug/Kg					2 / 2	4898000.0	U	NA	4898000.0		No	D
Cyanide	ug/Kg					4 / 4	2900.0	U	NA	2900.0		No	F
Nitrate	ug/Kg					2 / 2	9054000.0	U	NA	9054000.0		No	C
Oil And Grease	ug/Kg					3 / 3	16000000.0	U	NA	16000000.0		No	E
Phosphate	ug/Kg					2 / 2	1235000.0	U	NA	1235000.0		No	C
Phosphorus	ug/Kg					3 / 3	43703000.0	U	NA	43703000.0		No	B
Sulfate	ug/Kg					2 / 2	739000.0	U	NA	739000.0		No	D
Total Organic Carbon	ug/Kg					2 / 2	113712000.0	U	NA	113712000.0		No	E
Total Organic Nitrogen	ug/Kg					2 / 4	11700000.0	U	NA	11700000.0		No	E

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – TCDD = Tetrachlorodibenzo–p–dioxin
PeCDD = Pentachlorodibenzo–p–dioxin
HxCDD = Hexachlorodibenzo–p–dioxin
HpCCD = Heptachlorodibenzo–p–dioxin
OCDD = Octachlorodibenz–p–dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran
5 – The 95th percentile background concentration for subsurface soils are compared with maximum values.

TABLE E.II–3

SUMMARY OF PIT 3 ANALYTICAL RESULTS

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %	CPC?	Justify
Aluminum	mg/Kg	7 / 7	64100.0	L	46238.2	6 / 6	17400.0	U	NA	46238.2	16064.0	No	D
Antimony	mg/Kg	2 / 7	18	U	NA	4 / 6	63.5	U	NA	63.5	0.0	Yes	
Arsenic	mg/Kg	7 / 7	3050	N	1970.1	6 / 6	37200.0	U	NA	37200.0	9.6	Yes	
Barium	mg/Kg	7 / 7	14400	U	NA	6 / 6	3570.0	U	NA	14400.0	119.2	Yes	
Beryllium	mg/Kg	7 / 7	24	L	42.8	6 / 6	10.7	U	NA	24.0	0.6	Yes	
Boron	mg/Kg		0		0.0	4 / 6	236.0	U	NA	236.0	43.0	No	F
Cadmium	mg/Kg	7 / 7	13	L	13.4	6 / 6	38.6	U	NA	38.6	0.9	Yes	
Calcium	mg/Kg	7 / 7	178000	L	153622.1	6 / 6	190000.0	U	NA	190000.0	150000.0	No	B
Chromium	mg/Kg	7 / 7	152	L	271.0	6 / 6	234.0	U	NA	234.0	20.7	yes	
Cobalt	mg/Kg	7 / 7	21	L	23.9	6 / 6	50.7	U	NA	50.7	15.8	No	F
Copper	mg/Kg	4 / 7	2330	U	NA	6 / 6	2010.0	U	NA	2330.0	20.0	Yes	
Iron	mg/Kg	7 / 7	26900	U	NA	6 / 6	25800.0	U	NA	26900.0	30700.0	No	A
Lead	mg/Kg	5 / 7	613	U	NA	6 / 6	837.0	U	NA	837.0	15.6	Yes	G
Magnesium	mg/Kg	7 / 7	51600	L	39326.0	6 / 6	51700.0	U	NA	51700.0	42648.2	No	B
Manganese	mg/Kg	7 / 7	10600	L	18063.6	6 / 6	20200.0	U	NA	20200.0	1300.0	Yes	
Mercury	mg/Kg	5 / 7	4	U	NA	5 / 6	5.1	U	NA	5.1	0.3	No	F
Molybdenum	mg/Kg		0		0.0	6 / 6	284.0	U	NA	284.0	2.7	Yes	
Nickel	mg/Kg	7 / 7	504	L	1120.6	6 / 6	292.0	U	NA	504.0	34.4	Yes	
Potassium	mg/Kg	7 / 7	3180	N	2716.4	6 / 6	3370.0	U	NA	3370.0	1980.0	No	C
Selenium	mg/Kg	5 / 7	90	U	NA	5 / 6	6.0	U	NA	90.0		No	F
Silicon	mg/Kg		0		0.0	6 / 6	5000.0	U	NA	5000.0	1593.1	No	D
Silver	mg/Kg	4 / 7	8.1	U	NA	6 / 6	41.8	U	NA	41.8		No	F
Sodium	mg/Kg	7 / 7	7640	L	7115.1	6 / 6	10100.0	U	NA	10100.0	285.0	No	B
Thallium	mg/Kg	3 / 7	12	U	NA	4 / 6	4.1	U	NA	12.0	0.5	Yes	
Tin	mg/Kg		0		0.0	1 / 5	191.0	U	NA	191.0		No	F
Vanadium	mg/Kg	7 / 7	9700	N	5756.7	6 / 6	2200.0	U	NA	5756.7	37.8	Yes	
Zinc	mg/Kg	3 / 7	311	U	NA	6 / 6	325.0	U	NA	325.0	72.6	No	F
Aroclor–1248	ug/Kg					4 / 6	4800.0	U	NA	4800.0		Yes	
Aroclor–1254	ug/Kg	2 / 7	550.0	U	NA	5 / 6	3400.0	U	NA	3400.0		Yes	
Cesium–137	pCi/g					1 / 6	0.5	U	NA	0.5		Yes	
Neptunium–237	pCi/g	3 / 7	2.1	U	NA					2.1		Yes	
Plutonium–238	pCi/g	3 / 7	1.0	U	NA	1 / 5	1.0	U	NA	1.0		Yes	
Plutonium–239/240	pCi/g	3 / 7	14.0	U	NA	2 / 5	1.6	U	NA	14.0		Yes	
Radium–226	pCi/g					6 / 6	451.0	U	NA	451.0	1.5	Yes	
Radium–228	pCi/g					6 / 6	241.0	U	NA	241.0	1.3	Yes	
Ruthenium–106	pCi/g					2 / 6	4.2	U	NA	4.2	0.0	Yes	
Strontium–90	pCi/g	1 / 7	5.2	U	NA	3 / 6	4.9	U	NA	5.2	0.6	Yes	

TABLE E.II–3
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Max Hit	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %	CPC?	Justify
Technetium–99	pCi/g	6 / 7	1110.0	U	NA	6 / 6	33.0	U	NA	1110.0	0.0	Yes	
Thorium–228	pCi/g	7 / 7	40.0	L	174.5	4 / 5	554.0	U	NA	554.0	1.3	Yes	
Thorium–230	pCi/g	7 / 7	11680.0	N	9115.9	6 / 6	11370.0	U	NA	11370.0	1.9	Yes	
Thorium–232	pCi/g	7 / 7	59.0	U	NA	4 / 5	396.0	U	NA	396.0	1.3	Yes	
Thorium–Total	mg/Kg					4 / 5	3570.0	U	NA	3570.0	9.5	Yes	
Uranium–234	pCi/g	7 / 7	475.0	L	986.8	4 / 4	991.0	U	NA	991.0	1.0	Yes	
Uranium–235/236	pCi/g	7 / 7	21.0	N	17.6	5 / 5	89.2	U	NA	89.2	0.2	Yes	
Uranium–238	pCi/g	7 / 7	1380.0	L	1260.7	6 / 6	1740.0	U	NA	1740.0	1.1	Yes	
Uranium–Total	mg/Kg					6 / 6	5938.0	U	NA	5938.0		Yes	
Acenaphthylene	ug/Kg					1 / 4	96.0	U	NA	96.0		Yes	G
Anthracene	ug/Kg					1 / 7	130.0	U	NA	130.0		No	F
Benzo(A)Anthracene	ug/Kg	1 / 7	60.0	U	NA	1 / 7	360.0	U	NA	360.0		Yes	
Benzo(A)Pyrene	ug/Kg					1 / 7	280.0	U	NA	280.0		Yes	
Benzo(B)Fluoranthene	ug/Kg	1 / 7	110.0	U	NA	1 / 7	560.0	U	NA	560.0		Yes	
Benzo(G,H,I)Perylene	ug/Kg					1 / 7	160.0	U	NA	160.0		Yes	G
Benzoic Acid	ug/Kg					2 / 4	370.0	U	NA	370.0		No	F
Chrysene	ug/Kg	1 / 7	75.0	U	NA	1 / 7	370.0	U	NA	370.0		Yes	
Di–N–Butylphthalate	ug/Kg	3 / 7	84.0	U	NA	2 / 7	310.0	U	NA	310.0		No	F
Diethyl Phthalate	ug/Kg					2 / 4	4300.0	U	NA	4300.0		No	F
Fluoranthene	ug/Kg	1 / 7	230.0	U	NA	2 / 7	720.0	U	NA	720.0		No	F
Indeno(1,2,3–Cd)Pyrene	ug/Kg					1 / 7	130.0	U	NA	130.0		Yes	
Isophorone	ug/Kg					3 / 5	470.0	U	NA	470.0		No	F
N–Nitroso–Di–N–Propylamine	ug/Kg					2 / 4	460.0	U	NA	460.0		Yes	
Pentachlorophenol	ug/Kg	2 / 6	1300.0	U	NA	5 / 5	1000.0	U	NA	1300.0		Yes	
Phenanthrene	ug/Kg	1 / 7	120.0	U	NA	2 / 7	580.0	U	NA	580.0		Yes	G
Pyrene	ug/Kg	1 / 7	190.0	U	NA	2 / 7	620.0	U	NA	620.0		No	F
Bis(2–Ethylhexyl) Phthalate	ug/Kg	6 / 7	1100.0	U	NA	7 / 7	840.0	N	620.6	1100.0		No	F
1,1,1–Trichloroethane	ug/Kg					2 / 10	170.0	U	NA	170.0		No	F
2–Butanone	ug/Kg	1 / 1	3600.0	U	NA	3 / 6	86.0	U	NA	3600.0		No	F
2–Hexanone	ug/Kg					4 / 10	17.0	U	NA	17.0		Yes	G
4–Methyl–2–Pentanone	ug/Kg					4 / 10	17.0	U	NA	17.0		No	F
Acetone	ug/Kg					3 / 6	1200.0	U	NA	1200.0		No	F
Chloroform	ug/Kg					5 / 10	110.0	U	NA	110.0		No	F
Methylene Chloride	ug/Kg	1 / 1	420.0	U	NA	2 / 10	92.0	U	NA	420.0		No	F
Tetrachlorethene	ug/Kg					5 / 10	22.0	U	NA	22.0		No	F
Toluene	ug/Kg					1 / 10	8.0	U	NA	8.0		No	F

TABLE E.II–3
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Max Hit	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	CPC?	Justify
Trichloroethene	ug/Kg					1 / 10	6.0	U	NA	6.0	No	F
Trichlorofluoromethane	ug/Kg					1 / 2	4.1	U	NA	4.1	No	F
1,2,3,4,6,7,8–HpCDD[4]	ug/Kg					5 / 6	1.7	U	NA	1.7	Yes	
1,2,3,4,6,7,8–HpCDF[4]	ug/Kg					3 / 6	0.2	U	NA	0.2	Yes	
1,2,3,6,7,8–HxCDD[4]	ug/Kg					1 / 6	0.0	U	NA	0.0	Yes	
HpCDD[4]	ug/Kg					5 / 6	3.2	U	NA	3.2	Yes	
HpCDF[4]	ug/Kg					5 / 6	1.0	U	NA	1.0	Yes	
HxCDD[4]	ug/Kg					1 / 6	0.3	U	NA	0.3	Yes	
HxCDF[4]	ug/Kg					4 / 6	0.4	U	NA	0.4	Yes	
OCDD[4]	ug/Kg					6 / 6	19.4	U	NA	19.4	Yes	
OCDF[4]	ug/Kg					5 / 6	1.1	U	NA	1.1	Yes	
Tetrachlorodibenzofuran	ug/Kg					1 / 6	0.2	U	NA	0.2	Yes	
Chloride	ug/Kg					4 / 4	23700000.0	U	NA	23700000.0	No	D
Cyanide	ug/Kg					3 / 6	1700.0	U	NA	1700.0	No	F
Fluoride	ug/Kg					2 / 5	2350000.0	U	NA	2350000.0	Yes	
Nitrate	ug/Kg					4 / 4	57400000.0	U	NA	57400000.0	No	C
Oil And Grease	ug/Kg					4 / 4	1510000.0	U	NA	1510000.0	No	E
Phosphorus	ug/Kg					6 / 6	57817000.0	U	NA	57817000.0	No	C
Sulfate	ug/Kg					4 / 4	44345000.0	U	NA	44345000.0	No	D
Sulfide	ug/Kg					1 / 2	8600.0	U	NA	8600.0	No	D
Total Organic Carbon	ug/Kg					2 / 2	176000000.0	U	NA	176000000.0	No	E
Total Organic Nitrogen	ug/Kg					6 / 6	8914000.0	U	NA	8914000.0	No	E

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – TCDD = Tetrachlorodibenzo–p–dioxin
PeCDD = Pentachlorodibenzo–p–dioxin
HxCDD = Hexachlorodibenzo–p–dioxin
HpCCD = Heptachlorodibenzo–p–dioxin
OCDD = Octachlorodibenz–p–dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran

TABLE E.II–4

SUMMARY OF PIT 4 ANALYTICAL RESULTS

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Aluminum	mg/Kg	4 / 4	10300.0	U	NA	5 / 5	10700.0	U	NA	10700.0	16064.0	No	A
Antimony	mg/Kg	1 / 4	0.5	U	NA	4 / 5	317.0	U	NA	317.0	NA	Yes	
Arsenic	mg/Kg	2 / 4	4.6	U	NA	5 / 5	6.5	U	NA	6.5	9.6	No	A
Barium	mg/Kg	4 / 4	6670.0	U	NA	5 / 5	3720.0	U	NA	6670.0	119.2	No	F
Beryllium	mg/Kg	4 / 4	13.0	U	NA	3 / 5	50.6	U	NA	50.6	0.6	Yes	
Boron	mg/Kg					5 / 5	1010.0	U	NA	1010.0	43.0	No	F
Cadmium	mg/Kg	3 / 4	29.0	U	NA	5 / 5	34.8	U	NA	34.8	0.9	Yes	
Calcium	mg/Kg	4 / 4	61200.0	U	NA	5 / 5	32700.0	U	NA	61200.0	150000.0	No	A
Chromium	mg/Kg	4 / 4	94.0	U	NA	5 / 5	1500.0	U	NA	1500.0	20.7	Yes	
Cobalt	mg/Kg	3 / 4	84.0	U	NA	4 / 5	183.0	U	NA	183.0	15.8	No	F
Copper	mg/Kg	4 / 4	188.0	U	NA	5 / 5	482.0	U	NA	482.0	20.0	No	F
Iron	mg/Kg	4 / 4	16100.0	U	NA	5 / 5	7420.0	U	NA	16100.0	30700.0	No	A
Lead	mg/Kg	4 / 4	63.0	U	NA	5 / 5	63.2	U	NA	63.2	15.6	Yes	
Magnesium	mg/Kg	4 / 4	24300.0	U	NA	5 / 5	34000.0	U	NA	34000.0	42648.2	No	A
Manganese	mg/Kg	4 / 4	3600.0	U	NA	5 / 5	5620.0	U	NA	5620.0	1300.0	Yes	
Mercury	mg/Kg	3 / 4	0.6	U	NA	3 / 5	0.6	U	NA	0.6	0.3	No	F
Molybdenum	mg/Kg					5 / 5	95.6	U	NA	95.6	2.7	No	F
Nickel	mg/Kg	4 / 4	50.0	U	NA	5 / 5	223.0	U	NA	223.0	34.4	Yes	
Potassium	mg/Kg	4 / 4	1920.0	U	NA	5 / 5	4210.0	U	NA	4210.0	1980.0	No	A
Silicon	mg/Kg		NA			5 / 5	4080.0	U	NA	4080.0	1593.1	No	D
Silver	mg/Kg	3 / 4	444.0	U	NA	5 / 5	755.0	U	NA	755.0	NA	Yes	
Sodium	mg/Kg	4 / 4	1240.0	U	NA	5 / 5	2280.0	U	NA	2280.0	285.0	No	B
Tin	mg/Kg	3 / 3	87.0	U	NA	4 / 5	133.0	U	NA	133.0		No	D
Vanadium	mg/Kg	4 / 4	235.0	U	NA	5 / 5	558.0	U	NA	558.0	37.8	Yes	
Zinc	mg/Kg	4 / 4	84.0	U	NA	5 / 5	200.0	U	NA	200.0	72.6	No	F
Aroclor 1242	ug/Kg	2 / 5	1034.0	U	NA					1034.0		Yes	
Aroclor 1248	ug/Kg	3 / 5	854.0	U	NA	4 / 6	7500.0	U	NA	7500.0		Yes	
Aroclor 1254	ug/Kg	5 / 5	1008.0	U	NA	3 / 6	6800.0	U	NA	6800.0		Yes	
Neptunium–237	pCi/g	1 / 4	0.4	U	NA					0.4		Yes	
Plutonium–238	pCi/g	2 / 4	0.5	U	NA					0.5	NA	Yes	
Plutonium–239/240	pCi/g	1 / 4	0.4	U	NA					0.4	NA	Yes	
Radium–226	pCi/g					5 / 6	50.1	U	NA	50.1	1.5	Yes	
Radium–228	pCi/g					6 / 6	141.0	U	NA	141.0	1.3	Yes	
Ruthenium–106	pCi/g					1 / 6	1.1	U	NA	1.1	NA	Yes	
Strontium–90	pCi/g					5 / 6	144.0	U	NA	144.0	0.6	Yes	

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TABLE E.II–4
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Technetium–99	pCi/g	4 / 4	225.0	U	NA	5 / 6	9.4	U	NA	225.0	NA	Yes	
Thorium–228	pCi/g	4 / 4	395.0	U	NA	4 / 4	2469.0	U	NA	2469.0	1.3	Yes	
Thorium–230	pCi/g	4 / 4	566.0	U	NA	6 / 6	1815.0	U	NA	1815.0	1.9	Yes	
Thorium–232	pCi/g	4 / 4	92.0	U	NA	4 / 4	838.0	U	NA	838.0	1.3	Yes	
Thorium–Total	mg/Kg					4 / 4	7565.0	U	NA	7565.0	9.5	Yes	
Uranium–234	pCi/g	4 / 4	2320.0	U	NA	3 /3	4100.0	U	NA	4100.0	1.0	Yes	
Uranium–235/236	pCi/g	4 / 4	426.0	U	NA	4 / 4	934.0	U	NA	934.0	0.2	Yes	
Uranium–238	pCi/g	4 / 4	15800.0	U	NA	4 / 4	41900.0	U	NA	41900.0	1.1	Yes	
Uranium–Total	mg/Kg					6 / 6	0.1	U	NA	0.1		Yes	
2,4–Dimethylphenol	ug/Kg	1 / 5	240.0	U	NA					240.0		No	F
2,4–Dichlorophenol	ug/Kg					1 / 9	230.0	U	NA	230.0		No	F
2,4–Dinitrophenol	ug/Kg					1 / 9	47.0	U	NA	47.0		No	F
2–Methylnaphthalene	ug/Kg	2 / 5	1100.0	U	NA	2 / 9	480.0	U	NA	1100.0		Yes	G
2–Methylphenol	ug/Kg	1 / 5	96.0	U	NA					96.0		No	F
4–Methylphenol	ug/Kg	1 / 5	360.0	U	NA					360.0		No	F
4–Chloro–3–Methylphenol	ug/Kg					2 / 9	77.0	U	NA	77.0		Yes	G
Acenaphthene	ug/Kg	3 / 5	1900.0	U	NA	2 / 9	1900.0	U	NA	1900.0		No	F
Anthracene	ug/Kg	4 / 5	3300.0	U	NA	2 / 9	2700.0	U	NA	3300.0		No	F
Benzo(A)Anthracene	ug/Kg	5 / 5	4100.0	U	NA	2 / 9	4700.0	U	NA	4700.0		Yes	
Benzo(A)Pyrene	ug/Kg	4 / 5	4800.0	U	NA	2 / 9	2900.0	U	NA	4800.0		Yes	
Benzo(B)Fluoranthene	ug/Kg	4 / 5	5800.0	U	NA	2 / 9	5200.0	U	NA	5800.0		Yes	
Benzo(G,H,I)Perylene	ug/Kg	3 / 5	1300.0	U	NA	1 / 9	990.0	U	NA	1300.0		Yes	G
Benzo(K)Fluoranthene	ug/Kg	4 / 5	3700.0	U	NA					3700.0		Yes	
Benzoic Acid	ug/Kg					6 / 9	580.0	U	NA	580.0		No	F
Bis(2–Ethylhexyl) Phthalate	ug/Kg	3 / 5	270.0	U	NA	6 / 9	2700.0	U	NA	2700.0		No	F
Chrysene	ug/Kg	5 / 5	4500.0	U	NA	2 / 9	3300.0	U	NA	4500.0		Yes	
Di–N–Butyl Phthalate	ug/Kg	4 / 5	490.0	U	NA	2 / 9	150.0	U	NA	490.0		No	F
Di–N–Octyl Phthalate	ug/Kg	2 / 5	190.0	U	NA	6 / 9	1000.0	U	NA	1000.0		No	F
Dibenzo(A,H)Anthracene	ug/Kg	2 / 5	560.0	U	NA					560.0		Yes	
Dibenzofuran	ug/Kg	4 / 5	1700.0	U	NA	2 / 9	1200.0	U	NA	1700.0		Yes	
Diethyl Phthalate	ug/Kg					1 / 9	89.0	U	NA	89.0		No	F
Fluoranthene	ug/Kg	5 / 5	18000.0	U	NA	2 / 9	11000.0	U	NA	18000.0		No	F
Fluorene	ug/Kg	4 / 5	3400.0	U	NA	2 / 9	2000.0	U	NA	3400.0		No	F
Indeno(1,2,3–Cd)Pyrene	ug/Kg	4 / 5	1400.0	U	NA	1 / 9	990.0	U	NA	1400.0		Yes	

TABLE E.II-4
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	CPC?	Justify
Naphthalene	ug/Kg	4 / 5	2700.0	U	NA	2 / 9	740.0	U	NA	2700.0	No	F
Phenanthrene	ug/Kg	5 / 5	16000.0	U	NA	2 / 9	12000.0	U	NA	16000.0	Yes	
Phenol	ug/Kg	1 / 5	310.0	U	NA					310.0	No	F
Pyrene	ug/Kg	5 / 5	6600.0	U	NA	2 / 9	9000.0	U	NA	9000.0	No	F
Tributyl Phosphate	ug/Kg					2 / 2	72000.0	U	NA	72000.0	Yes	G
1,1,1-Trichloroethane	ug/Kg	1 / 4	120.0	U	NA	6 / 9	140.0	U	NA	140.0	No	F
1,1-Dichloroethane	ug/Kg					6 / 9	330.0	U	NA	330.0	No	F
1,1-Dichloroethene	ug/Kg					3 / 9	11.0	U	NA	11.0	No	F
1,2-Dichloroethane	ug/Kg					1 / 9	3.0	U	NA	3.0	No	F
1,2-Dichloroethylene	ug/Kg					3 / 9	110.0	U	NA	110.0	No	F
2-Butanone	ug/Kg	1 / 1	100.0	U	NA	2 / 7	59.0	U	NA	100.0	No	F
2-Hexanone	ug/Kg					4 / 9	29.0	U	NA	29.0	Yes	G
3-Chloropropene	ug/Kg					1 / 2	3.0	U	NA	3.0	Yes	G
4-Methyl-2-Pentanone	ug/Kg					5 / 9	83.0	U	NA	83.0	No	F
Acetone	ug/Kg	1 / 4	350.0	U	NA	1 / 6	17.0	U	NA	350.0	No	F
Benzene	ug/Kg					1 / 9	14.0	U	NA	14.0	Yes	
Carbon Tetrachloride	ug/Kg					1 / 9	2.0	U	NA	2.0	No	F
Carbon Disulfide	ug/Kg					1 / 9	3.0	U	NA	3.0	No	F
Chloroethane	ug/Kg					1 / 9	35.0	U	NA	35.0	No	F
Chloroform	ug/Kg	4 / 4	1300.0	U	NA	6 / 9	630.0	U	NA	1300.0	No	F
Ethylbenzene	ug/Kg					3 / 9	28.0	U	NA	28.0	No	F
Isobutyl Alcohol	ug/Kg					1 / 2	17.0	U	NA	17.0	No	F
Methylene Chloride	ug/Kg	3 / 4	2200.0	U	NA	3 / 9	230.0	U	NA	2200.0	No	F
Styrene	ug/Kg					1 / 9	3.0	U	NA	3.0	No	F
Tetrachlorethene	ug/Kg	1 / 3	530.0	U	NA	6 / 8	240.0	U	NA	530.0	No	F
Toluene	ug/Kg	2 / 4	67.0	U	NA	4 / 9	33.0	U	NA	67.0	No	F
Trans-1,2-Dichloroethene	ug/Kg	1 / 4	60.0	U	NA					60.0	No	F
Total Xylenes	ug/Kg					5 / 9	230.0	U	NA	230.0	No	F
Trichloroethene	ug/Kg	1 / 4	300.0	U	NA	7 / 9	210.0	U	NA	300.0	No	F
Trichlorofluoromethane	ug/Kg					1 / 2	2.0	U	NA	2.0	No	F
Vinyl Chloride	ug/Kg					2 / 9	14.0	U	NA	14.0	Yes	
1,2,3,4,6,7,8-HpCDD[4]	ug/Kg					4 / 6	2.6	U	NA	2.6	Yes	
1,2,3,4,6,7,8-HpCDF[4]	ug/Kg					5 / 6	3.2	U	NA	3.2	Yes	
1,2,3,4,7,8,9-HpCDD[4]	ug/Kg					3 / 6	2.4	U	NA	2.4	Yes	

TABLE E.II-4
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	CPC?	Justify
1,2,3,4,7,8-HxCDD[4]	ug/Kg					1 / 6	0.1	U	NA	0.1	Yes	
1,2,3,4,7,8-HxCDF[4]	ug/Kg					5 / 6	2.9	U	NA	2.9	Yes	
1,2,3,6,7,8-HxCDD[4]	ug/Kg					2 / 6	0.2	U	NA	0.2	Yes	
1,2,3,6,7,8-HxCDF[4]	ug/Kg					5 / 6	1.1	U	NA	1.1	Yes	
1,2,3,7,8,9-HxCDD[4]	ug/Kg					2 / 6	0.2	U	NA	0.2	Yes	
1,2,3,7,8,9-HxCDF[4]	ug/Kg					3 / 6	0.8	U	NA	0.8	Yes	
1,2,3,7,8-PeCDF[4]	ug/Kg					5 / 6	2.1	U	NA	2.1	Yes	
2,3,4,6,7,8-HxCDF[4]	ug/Kg					4 / 6	1.2	U	NA	1.2	Yes	
2,3,4,7,8-PeCDF[4]	ug/Kg					5 / 6	2.7	U	NA	2.7	Yes	
2,3,7,8-TCDF[4]	ug/Kg					5 / 6	9.9	U	NA	9.9	Yes	
HpCDD[4]	ug/Kg					5 / 6	4.0	U	NA	4.0	Yes	
HpCDF[4]	ug/Kg					5 / 6	4.4	U	NA	4.4	Yes	
HxCDD[4]	ug/Kg					4 / 6	2.7	U	NA	2.7	Yes	
HxCDF[4]	ug/Kg					5 / 6	8.5	U	NA	8.5	Yes	
OCDD[4]	ug/Kg					5 / 6	9.0	U	NA	9.0	Yes	
OCDF[4]	ug/Kg					4 / 6	4.9	U	NA	4.9	Yes	
PeCDF[4]	ug/Kg					5 / 6	15.3	U	NA	15.3	Yes	
TCDD[4]	ug/Kg					2 / 6	0.5	U	NA	0.5	Yes	
TCDF[4]	ug/Kg					6 / 6	34.1	U	NA	34.1	Yes	
Ammonia	ug/Kg					2 / 3	235000.0	U	NA	235000.0	No	E
Chloride	ug/Kg					1 / 2	53000.0	U	NA	53000.0	No	D
Cyanide	ug/Kg					1 / 5	240.0	U	NA	240.0	No	F
Fluoride	ug/Kg					1 / 2	3793000.0	U	NA	3793000.0	Yes	
Oil And Grease	ug/Kg					3 / 4	17902000.0	U	NA	17902000.0	No	E
Phosphorus	ug/Kg					4 / 4	146000.0	U	NA	146000.0	No	B
Sulfide	ug/Kg					1 / 2	29100.0	U	NA	29100.0	No	D
Total Organic Carbon	ug/Kg					2 / 2	53646000.0	U	NA	53646000.0	No	E
Total Organic Nitrogen	ug/Kg					4 / 4	833200.0	U	NA	833200.0	No	E

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – TCDD = Tetrachlorodibenzo-p-dioxin
PeCDD = Pentachlorodibenzo-p-dioxin
HxCDD = Hexachlorodibenzo-p-dioxin
HpCDD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenz-p-dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran
5 – The 95th percentile background concentrations for subsurface soil are compared to maximum values.

TABLE E.II–5

SUMMARY OF PIT 5 ANALYTICAL RESULTS

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[4]	CPC?	Justify
Aluminum	mg/Kg	6 / 6	15400.0	U	NA	10 / 10	11900.0	N	10285.2	15400.0	16064.0	No	A
Antimony	mg/Kg	5 / 6	64.0	U	NA	10 / 10	88.1	L	96.2	88.1	NA	Yes	
Arsenic	mg/Kg	6 / 6	2800.0	U	NA	8 / 10	715.0	N	561.3	2800.0	9.6	Yes	
Barium	mg/Kg	6 / 6	36900.0	U	NA	10 / 10	18100.0	L	12941.7	36900.0	119.2	Yes	
Beryllium	mg/Kg	6 / 6	18.0	U	NA	10 / 10	22.4	N	14.4	18.0	0.6	Yes	
Cadmium	mg/Kg	4 / 6	17.0	U	NA	10 / 10	4.7	L	3.5	17.0	0.9	Yes	
Calcium	mg/Kg	6 / 6	206000.0	U	NA	10 / 10	250000.0	N	213927.7	213927.7	150000.0	No	B
Chromium	mg/Kg	6 / 6	223.0	U	NA	10 / 10	108.0	L	92.5	223.0	20.7	Yes	
Cobalt	mg/Kg	4 / 6	44.0	U	NA	10 / 10	17.1	L	12.0	44.0	15.8	Yes	
Copper	mg/Kg	5 / 6	18200.0	U	NA	10 / 10	8680.0	N	5300.9	18200.0	20.0	Yes	
Iron	mg/Kg	6 / 6	17900.0	U	NA	10 / 10	20700.0	L	15401.4	17900.0	30700.0	No	A
Lead	mg/Kg	5 / 6	236.0	U	NA	10 / 10	134.0	L	109.8	236.0	15.6	Yes	G
Magnesium	mg/Kg	6 / 6	63200.0	U	NA	10 / 10	43000.0	N	38520.2	63200.0	42648.2	No	B
Manganese	mg/Kg	6 / 6	4740.0	U	NA	10 / 10	599.0	N	501.6	4740.0	1300.0	Yes	
Mercury	mg/Kg	6 / 6	1.8	U	NA	10 / 10	1.5	N	1.1	1.8	0.3	No	F
Molybdenum	mg/Kg					10 / 10	1350.0	L	1931.9	1350.0	2.7	Yes	
Nickel	mg/Kg	6 / 6	247.0	U	NA	10 / 10	189.0	N	138.6	247.0	34.4	Yes	
Potassium	mg/Kg	3 / 5	1490.0	U	NA	10 / 10	2160.0	L	1605.5	1605.5	1980.0	No	B
Selenium	mg/Kg	5 / 6	18.0	U	NA		NA		NA	18.0		No	F
Silver	mg/Kg	2 / 6	9.4	U	NA	6 / 10	22.2	U	NA	22.2	NA	No	F
Sodium	mg/Kg	6 / 6	9980.0	U	NA	10 / 10	16300.0	L	12207.0	12207.0	285.0	No	B
Thallium	mg/Kg	4 / 6	11.0	U	NA	4 / 10	52.0	U	NA	52.0	0.5	Yes	
Tin	mg/Kg					10 / 10	92.8	L	66.1	66.1		No	F
Vanadium	mg/Kg	6 / 6	5380.0	U	NA	10 / 10	4530.0	N	2794.5	5380.0	37.8	Yes	
Zinc	mg/Kg	4 / 6	211.0	U	NA	10 / 10	278.0	N	215.0	215.0	72.6	No	F
Aroclor 1248	ug/Kg	2 / 6	550.0	U	NA					550.0		Yes	
Aroclor 1254	ug/Kg	2 / 6	750.0	U	NA					750.0		Yes	
Cesium–137	pCi/g	2 / 6	76.0	U	NA	10 / 10	106.0	L	223.5	106.0	NA	Yes	
Gross Alpha	pCi/g					10 / 10	9400.0	L	5684.8	5684.8		No	E
Gross Beta	pCi/g					10 / 10	1280.0	L	1044.3	1044.3		No	E
Neptunium–237	pCi/g	5 / 6	19.0	U	NA	3 / 3	83.0	U	NA	83.0		Yes	
Plutonium–238	pCi/g	5 / 6	4.4	U	NA	3 / 10	0.3	U	NA	4.4	NA	Yes	
Plutonium–239/240	pCi/g	5 / 6	13.0	U	NA	5 / 10	3.7	U	NA	13.0	NA	Yes	

TABLE E.II-5
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[4]	CPC?	Justify
Potassium-40	pCi/g					1 / 1	11.0	U	NA	11.0	19.7	No	A
Radium-226	pCi/g					10 / 10	180.0	L	159.9	159.9	1.5	Yes	
Radium-228	pCi/g					9 / 10	49.0	N	32.6	32.6	1.3	Yes	
Ruthenium-106	pCi/g					2 / 10	1.6	U	NA	1.6	NA	Yes	
Strontium-90	pCi/g	6 / 6	31.0	U	NA	9 / 10	18.0	N	9.7	31.0	0.6	Yes	
Technetium-99	pCi/g	6 / 6	2990.0	U	NA	10 / 10	3020.0	L	2247.5	2990.0	NA	Yes	
Thorium-228	pCi/g	6 / 6	44.0	U	NA	10 / 10	38.0	U	NA	44.0	1.3	Yes	
Thorium-230	pCi/g	6 / 6	8480.0	U	NA	10 / 10	2600.0	U	NA	8480.0	1.9	Yes	
Thorium-232	pCi/g	6 / 6	55.0	U	NA	7 / 10	10.0	U	NA	55.0	1.3	Yes	
Thorium-Total	mg/Kg					8 / 10	92.0	U	92.0	92.0	9.5	Yes	
Uranium-234	pCi/g	6 / 6	1250.0	U	NA	10 / 10	1400.0	N	892.9	1250.0	1.0	Yes	
Uranium-235/236	pCi/g	6 / 6	79.0	U	NA	5 / 10	58.0	U	NA	58.0	0.2	Yes	
Uranium-238	pCi/g	6 / 6	1230.0	U	NA	10 / 10	2800.0	L	1473.4	1473.4	1.1	Yes	
Uranium-Total	mg/Kg					10 / 10	3700.0	N	2770.0	2770.0		Yes	
Bis(2-Ethylhexyl)Phthalate	ug/Kg	4 / 6	2300.0	U	NA					2300.0		No	F
C-10 Unk Hydrocarbon	ug/Kg	1 / 1	2100.0	U	NA					2100.0		No	E
Di-N-Butylphthalate	ug/Kg	1 / 6	56.0	U	NA					56.0		No	F
Phenol	ug/Kg	1 / 6	200.0	U	NA					200.0		No	F
Acetone	ug/Kg	3 / 6	6300.0	U	NA					6300.0		No	F
Methylene Chloride	ug/Kg	4 / 6	410.0	U	NA					410.0		No	F
Ammonia, As Nitrogen	ug/Kg					10 / 10	2410000.0	N	1477992.6	1477992.6		No	E
Chloride	ug/Kg					7 / 10	1380000.0	L	856647.2	856647.2		No	D
Nitrate/Nitrite	ug/Kg					10 / 10	53800000.0	L	39983391.6	39983391.6		No	C
Sulfate	ug/Kg					4 / 4	6790000.0	U	NA	6790000.0		No	D
Total Kjeldahl Nitrogen	ug/Kg					10 / 10	1940000.0	L	1776582.2	1776582.2		No	E
Total Organic Carbon	ug/Kg					10 / 10	35000000.0	N	27138934.9	27138934.9		No	E
Total Organic Nitrogen	ug/Kg					10 / 10	626000.0	N	428847.7	428847.7		No	E
Total Phosphorus	ug/Kg					10 / 10	1097000.0	L	867175.3	867175.3		No	E

Notes:
1 - Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 - NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 - The representative concentration is the maximum of the UCL/Max value from either the CIS or WMC data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 - The 95th percentile background concentrations for subsurface soil are compared to maximum values.

TABLE E.II-6

SUMMARY OF PIT 6 ANALYTICAL RESULTS

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Aluminum	mg/kg	1 / 1	4730.0	U	NA	9 / 9	22800.0	N	17621.0	17621.0	16064.0	No	D
Arsenic	mg/kg	1 / 1	7.6	U	NA	9 / 9	76.7	L	65.3	65.3	9.6	Yes	
Barium	mg/kg	1 / 1	95.0	U	NA	9 / 9	71.7	N	60.4	95.0	119.2	No	F
Beryllium	mg/kg	1 / 1	5.7	U	NA	9 / 9	2.1	N	1.5	5.7	0.6	Yes	
Cadmium	mg/kg	1 / 1	5.7	U	NA	1 / 9	1.3	U	NA	5.7	0.9	Yes	
Calcium	mg/kg	1 / 1	22200.0	U	NA	9 / 9	157000.0	N	121629.4	121629.4	150000.0	No	B
Chromium	mg/kg	1 / 1	30.0	U	NA	4 / 9	8.3	U	NA	30.0	20.7	No	F
Cobalt	mg/kg	1 / 1	26.0	U	NA	5 / 9	5.4	U	NA	26.0	15.8	No	F
Copper	mg/kg	1 / 1	222.0	U	NA	4 / 9	10.8	U	NA	222.0	20.0	No	F
Iron	mg/kg	1 / 1	2750.0	U	NA	9 / 9	18300.0	N	13783.0	13783.0	30700.0	No	C
Lead	mg/kg	1 / 1	60.0	U	NA	9 / 9	113.0	L	90.4	90.4	15.6	Yes	G
Magnesium	mg/kg	1 / 1	32100.0	U	NA	9 / 9	41900.0	L	28975.5	32100.0	42648.2	No	B
Manganese	mg/kg	1 / 1	35.0	U	NA	9 / 9	318.0	N	259.5	259.5	1300.0	No	A
Nickel	mg/kg	1 / 1	51.0	U	NA	9 / 9	22.7	N	20.5	51.0	34.4	No	F
Potassium	mg/kg	1 / 1	913.0	U	NA	9 / 9	6390.0	N	4862.2	4862.2	1980.0	No	B
Silver	mg/kg	1 / 1	158.0	U	NA	7 / 9	9.2	L	12.7	158.0		Yes	
Sodium	mg/kg	1 / 1	600.0	U	NA	9 / 9	586.0	L	500.3	600.0	285.0	No	B
Thallium	mg/kg					5 / 9	108.0	U	NA	NA	0.5	No	
Tin	mg/kg					6 / 9	21.5	U	NA	NA		No	F
Vanadium	mg/kg	1 / 1	100.0	U	NA				NA	100.0	37.8	No	F
Zinc	mg/kg	1 / 1	48.0	U	NA	9 / 9	61.0	N	50.9	50.9	72.6	No	F
Aroclor 1254	ug/Kg	1 / 4	81.0	U	NA					81.0		Yes	
Cesium-137	pCi/g	3 / 4	31.0	U	NA	9 / 9	14.0	N	10.6	31.0	NA	Yes	
Gross Alpha	pCi/g					9 / 9	14000.0	L	13552.5	13552.5		No	E
Gross Beta	pCi/g					9 / 9	23000.0	L	19612.7	19612.7		No	E
Neptunium-237	pCi/g	4 / 4	3.6	U	NA					3.6		Yes	
Plutonium-238	pCi/g	4 / 4	1.4	U	NA	6 / 9	1.0	U	NA	1.4	NA	Yes	
Plutonium-239/240	pCi/g	4 / 4	15.0	U	NA	9 / 9	14.0	N	11.1	15.0	NA	Yes	
Radium-226	pCi/g					9 / 9	4.9	L	4.3	4.3	1.5	Yes	
Radium-228	pCi/g					9 / 9	191.0	L	257.5	191.0	1.3	Yes	
Strontium-90	pCi/g	4 / 4	5.1	U	NA	6 / 9	4.8	U	NA	5.1	0.6	Yes	

TABLE E.II–6
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	Constituent is CPC?	
Technetium–99	pCi/g	4 / 4	164.0	U	NA	5 / 9	45.0	U	NA	164.0	NA	Yes	
Thorium–228	pCi/g	4 / 4	1.2	U	NA	9 / 9	1.7	N	1.5	1.5	1.3	Yes	
Thorium–230	pCi/g	4 / 4	44.0	U	NA	9 / 9	62.0	N	45.2	45.2	1.9	Yes	
Thorium–232	pCi/g	4 / 4	1.2	U	NA	9 / 9	1.0	N	0.7	1.2	1.3	Yes	
Uranium–234	pCi/g	4 / 4	5330.0	U	NA	9 / 9	4064.0	L	3455.2	5330.0	1.0	Yes	
Uranium–235/236	pCi/g	4 / 4	1750.0	U	NA	9 / 9	337.0	L	286.4	1750.0	0.2	Yes	
Uranium–238	pCi/g	4 / 4	18700.0	U	NA	9 / 9	28746.0	L	22721.3	22721.3	1.1	Yes	
Uranium–Total	mg/kg					9 / 9	27733.0	L	45960.0	27733.0		Yes	
Bis(2–Ethylhexyl)Phthalate	ug/Kg	2 / 4	910.0	U	NA					910.0		No	F
2–Butanone	ug/Kg	1 / 4	530.0	U	NA					530.0		No	F
Butanoic Acid, Methyl Ester4	ug/Kg	2 / 2	6.0	U	NA					6.0		No	D
Methylene Chloride	ug/Kg	1 / 3	280.0	U	NA					280.0		No	F
Tetrachloroethene	ug/Kg	4 / 4	29000.0	U	NA					29000.0		Yes	
Trichloroethene	ug/Kg	1 / 4	170.0	U	NA					170.0		No	F
Ammonia, As Nitrogen	ug/Kg					9 / 9	141000.0	U	NA	141000.0		No	E
Bromide	ug/Kg					1 / 9	366000.0	U	NA	366000.0		No	E
Chloride	ug/Kg					5 / 9	2250000.0	U	NA	2250000.0		No	D
Nitrate/Nitrite	ug/Kg					4 / 9	55400.0	U	NA	55400.0		No	C
Oil & Grease	ug/Kg					2 / 9	46000.0	U	NA	46000.0		No	E
Sulfate	ug/Kg					3 / 9	1610000.0	U	NA	1610000.0		No	D
Total Kjeldahl Nitrogen	ug/Kg					9 / 9	1030000.0	N	834942.4	834942.4		No	E
Total Organic Carbon	ug/Kg					9 / 9	35000000.0	N	23108430.1	23108430.1		No	E
Total Organic Nitrogen	ug/Kg					8 / 8	982000.0	L	823404.0	823404.0		No	E
Total Phosphorus	ug/Kg					9 / 9	3850000.0	N	3019032.8	3019032.8		No	E

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RI/FS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – Laboratory contaminant, not considered a CPC.
5 – The 95th percentile background concentrations for subsurface soil are compared with maximum values.

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TABLE E.II–7

SUMMARY OF SURFACE SOIL (0–24 INCHES DEEP) ANALYTICAL DATA

Parameters	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Dist.[1]	CIS Data: Representative Concentration[2]	RIFS Data: Frequency of Detection	RIFS Data: Maximum Value	RIFS Data: Dist.[1]	RIFS Data: Representative Concentration[2]	Representative Concentration[2]	Background 95 %[4]	Constituent is CPC?	
Aluminum	mg/Kg					17 / 17	13500.0	L	8091.1	8091.1	11880.9	No	D
Antimony	mg/Kg					17 / 17	32.8	L	27.9	27.9		Yes	
Arsenic	mg/Kg					17 / 17	11.2	L	5.6	5.6	8.2	No	A
Barium	mg/Kg					17 / 17	123.0	L	66.1	66.1	94.1	No	A
Beryllium	mg/Kg					17 / 17	1.0	L	0.8	0.8	0.6	Yes	
Cadmium	mg/Kg					17 / 17	7.7	L	5.9	5.9	0.9	Yes	
Calcium	mg/Kg					17 / 17	155000.0	N	117759.2	117759.2	4339.2	No	B
Chromium	mg/Kg					17 / 17	24.5	N	15.7	15.7	15.5	No	F
Cobalt	mg/Kg					17 / 17	17.0	L	10.9	10.9	14.2	No	A
Copper	mg/Kg					17 / 17	25.9	L	18.1	18.1	14.1	No	F
Iron	mg/Kg					17 / 17	24500.0	N	16809.5	16809.5	21728.2	No	A
Lead	mg/Kg					17 / 17	34.3	L	16.1	16.1	26.4	No	A
Magnesium	mg/Kg					17 / 17	39000.0	N	26468.0	26468.0	2777.0	No	B
Manganese	mg/Kg					17 / 17	841.0	L	611.9	611.9	1348.0	No	A
Molybdenum	mg/Kg					16 / 17	5.7	N	4.5	4.5		No	F
Nickel	mg/Kg					17 / 17	50.2	L	30.1	30.1	20.9	No	F
Potassium	mg/Kg					17 / 17	1300.0	N	976.0	976.0	1231.3	No	A
Selenium	mg/Kg					2 / 17	0.6	U	0.6	0.6	0.7	No	A
Silver	mg/Kg					17 / 17	10.3	N	9.0	9.0		No	F
Sodium	mg/Kg					15 / 16	185.0	L	140.2	140.2	51.1	No	B
Thallium	mg/Kg					1 / 17	0.7	U	0.7	0.7	0.6	No	F
Vanadium	mg/Kg					17 / 17	33.0	L	21.4	21.4	30.4	No	A
Zinc	mg/Kg					17 / 17	79.9	L	49.5	49.5	59.6	No	A
Aroclor–1254	ug/Kg					3 / 17	1400.0	U	1400.0	1400.0		Yes	
Cesium–137	pCi/g	11 / 24	6	L	0.8					0.8	0.7	Yes	
Neptunium–237	pCi/g	1 / 24	0.5	U	0.5					0.5		Yes	
Plutonium–238	pCi/g	4 / 24	0.7	U	0.1					0.1		Yes	
Plutonium–239/240	pCi/g	4 / 24	0.6	U	0.2					0.2		Yes	
Radium–226	pCi/g					10 / 13	2.2	N	1.4	1.4	1.4	Yes	
Radium–228	pCi/g					10 / 13	4.7	L	2.2	2.2	1.3	Yes	
Strontium–90	pCi/g	1 / 24	1.5	U	1.5	3 / 11	0.9	U	0.9	1.5		Yes	
Technetium–99	pCi/g	10 / 24	58	U	5.6	1 / 12	0.9	U	0.9	5.6		Yes	

TABLE E.II–7
(Continued)

Parameters	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Dist.[1]	CIS Data: Representative Concentration[2]	RIFS Data: Frequency of Detection	RIFS Data: Maximum Value	RIFS Data: Dist.[1]	RIFS Data: Representative Concentration[2]	Representative Concentration[3]	Background 95 %[4]	Constituent is CPC?	
Thorium–228	pCi/g	20 / 24	48.0	U	7.8	11 / 11	4.1	L	2.2	7.8	1.4	Yes	
Thorium–230	pCi/g	22 / 24	972.0	U	146.0	11 / 11	6.1	L	3.5	146.0	2.0	Yes	
Thorium–232	pCi/g	19 / 24	31.0	U	5.5	11 / 11	1.6	L	1.2	5.5	1.4	Yes	
Thorium–Total	mg/Kg					1 / 1	5.8	U	5.8	5.8	10.7	Yes	G
Uranium–234	pCi/g	24 / 24	241.0	L	117.5	13 / 13	28.5	L	17.5	117.5	1.2	Yes	
Uranium–235/236	pCi/g	24 / 24	51.0	U	18.6	5 / 13	3.9	U	3.9	18.6	0.2	Yes	
Uranium–238	pCi/g	24 / 24	1500.0	U	788.0	13 / 13	103.7	L	103.7	788.0	1.2	Yes	
Uranium–Total	mg/Kg					9 / 9	413.5	U	413.5	413.5		Yes	
4–Methylphenol	ug/Kg					1 / 16	390.0	U	390.0	390.0		No	F
Benzo(A)Anthracene	ug/Kg					1 / 16	98.0	U	98.0	98.0		Yes	
Benzo(A)Pyrene	ug/Kg					1 / 16	42.0	U	42.0	42.0		Yes	
Benzo(B)Fluoranthene	ug/Kg					1 / 16	59.0	U	59.0	59.0		Yes	
Benzo(K)Fluoranthene	ug/Kg					1 / 16	46.0	U	46.0	46.0		Yes	
Benzoic Acid	ug/Kg					3 / 16	73.0	U	73.0	73.0		No	F
Chrysene	ug/Kg					1 / 16	88.0	U	88.0	88.0		Yes	
Fluoranthene	ug/Kg					1 / 16	98.0	U	98.0	98.0		No	F
Phenol	ug/Kg					3 / 16	110.0	U	110.0	110.0		No	F
Pyrene	ug/Kg					2 / 16	130.0	U	130.0	130.0		No	F
Bis(2–Ethylhexyl) Phthalate	ug/Kg					8 / 16	1300.0	L	847.6	847.6		No	F
2–Butanone	ug/Kg					1 / 16	3.0	U	3.0	3.0		No	F
4–Methyl–2–Pentanone	ug/Kg					1 / 16	1.0	U	1.0	1.0		No	F
Acetone	ug/Kg					1 / 16	26.0	U	26.0	26.0		No	F
Methylene Chloride	ug/Kg					1 / 16	51.0	U	51.0	51.0		No	F
Toluene	ug/Kg					2 / 16	1.0	U	1.0	1.0		No	F
Cyanide	ug/Kg					4 / 17	7100.0	U	7100.0	7100.0		No	F

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – The representative concentration for the CIS or RIFS data sets is the either the maximum value or 95% UCL value. If the distribution could not be determined but there were more than 7 detects, the non–parametric 95th percentile was used as the representative concentration.
3 – The representative concentration for surface soils is the maximum of the representative concentration from either the CIS or RIFS data.
4 – The 95th percentile background concentrations for surface soil are compared with maximum values.

TABLE E.II–8

SUMMARY OF ANALYTICAL RESULTS FOR BURN PIT

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Aluminum	mg/Kg	7 / 7	11900.0	N	9343.5	4 / 4	8550.0	U	NA	8550.0	16064.0	No	A
Antimony	mg/Kg	1 / 7	0.6	U	NA	2 / 4	17.8	U	NA	17.8	NA	Yes	
Arsenic	mg/Kg	5 / 7	21.0	U	NA	4 / 4	39.2	U	NA	39.2	9.6	Yes	
Barium	mg/Kg	5 / 7	7100.0	U	NA	4 / 4	299.0	U	NA	299.0	119.2	Yes	
Beryllium	mg/Kg	5 / 7	16.0	U	NA	4 / 4	1.9	U	NA	1.9	0.6	Yes	
Boron	mg/Kg					2 / 3	48.2	U	NA	48.2	43.0	No	F
Cadmium	mg/Kg	7 / 7	35.0	U	NA	4 / 4	5.4	U	NA	5.4	0.9	Yes	
Calcium	mg/Kg	7 / 7	116000.0	L	164991.3	4 / 4	88900.0	U	NA	88900.0	150000.0	No	A
Chromium	mg/Kg	7 / 7	88.0	U	NA	4 / 4	91.2	U	NA	91.2	20.7	Yes	
Cobalt	mg/Kg	6 / 7	104.0	U	NA	4 / 4	111.0	U	NA	111.0	15.8	Yes	
Copper	mg/Kg	4 / 7	166.0	U	NA	4 / 4	259.0	U	NA	259.0	20.0	No	F
Iron	mg/Kg	7 / 7	17400.0	L	18269.5	4 / 4	31200.0	U	NA	31200.0	30700.0	No	B
Lead	mg/Kg	5 / 7	53.0	U	NA	4 / 4	279.0	U	NA	279.0	15.6	Yes	
Magnesium	mg/Kg	7 / 7	57100.0	L	68154.4	4 / 4	25700.0	U	NA	25700.0	42648.2	No	A
Manganese	mg/Kg	7 / 7	1720.0	L	1466.4	4 / 4	962.0	U	NA	962.0	1300.0	No	F
Mercury	mg/Kg	2 / 7	0.2	U	NA	3 / 4	1.2	U	NA	1.2	0.3	No	F
Molybdenum	mg/Kg					4 / 4	24.8	U	NA	24.8	2.7	No	F
Nickel	mg/Kg	6 / 7	60.0	U	NA	4 / 4	206.0	U	NA	206.0	34.4	Yes	
Potassium	mg/Kg	7 / 7	1450.0	L	1184.4	4 / 4	1410.0	U	NA	1410.0	1980.0	No	A
Selenium	mg/Kg	1 / 5	0.5	U	NA	4 / 4	2.0	U	NA	2.0		No	F
Silicon	mg/Kg					3 / 3	1350.0	U	NA	1350.0	1593.1	No	A
Silver	mg/Kg	2 / 6	506.0	U	NA	4 / 4	21.6	U	NA	21.6	NA	Yes	
Sodium	mg/Kg	5 / 6	1270.0	U	NA	4 / 4	812.0	U	NA	812.0	285.0	No	B
Thallium	mg/Kg	2 / 6	0.5	U	NA					0.0	0.5	No	F
Vanadium	mg/Kg	3 / 6	290.0	U	NA	4 / 4	43.3	U	NA	43.3	37.8	Yes	
Zinc	mg/Kg	6 / 6	75.0	U	NA	4 / 4	505.0	U	NA	505.0	72.6	No	F
Aroclor 1242	ug/Kg	1 / 7	290.0	U	NA					290.0		Yes	
Aroclor 1248	ug/Kg	1 / 7	200.0	U	NA					200.0		Yes	
Aroclor 1254	ug/Kg	5 / 7	2700.0	U	NA	3 / 4	7700.0	U	NA	7700.0		Yes	
Neptunium–237	pCi/g	2 / 6	0.6	U	NA					0.6		Yes	
Plutonium–238	pCi/g	1 / 6	0.5	U	NA					0.5	NA	Yes	
Plutonium–239/240	pCi/g	1 / 6	0.4	U	NA					0.4	NA	Yes	
Radium–226	pCi/g				NA	4 / 4	39.2	U	NA	39.2	1.5	Yes	
Radium–228	pCi/g				NA	4 / 4	10.4	U	NA	10.4	1.3	Yes	

TABLE E.II-8
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[5]	CPC?	Justify
Ruthenium-106	pCi/g				NA	2 / 4	1.5	U	NA	1.5	NA	Yes	
Strontium-90	pCi/g				NA	1 / 4	0.5	U	NA	0.5	0.6	No	A
Technetium-99	pCi/g	4 / 6	64.0	U	NA	4 / 4	3.3	U	NA	64.0	NA	Yes	
Thorium-228	pCi/g	6 / 6	19.0	U	NA	4 / 4	900.0	U	NA	900.0	1.3	Yes	
Thorium-230	pCi/g	6 / 6	218.0	U	NA	4 / 4	4530.0	U	NA	4530.0	1.9	Yes	
Thorium-232	pCi/g	6 / 6	21.0	U	NA	4 / 4	410.0	U	NA	410.0	1.3	Yes	
Thorium-Total	mg/Kg				NA	4 / 4	3700.0	U	NA	3.7	9.5	Yes	G
Uranium-234	pCi/g	6 / 6	415.0	U	NA	4 / 4	1711.0	U	NA	1711.0	1.0	Yes	
Uranium-235/236	pCi/g	6 / 6	27.0	U	NA	4 / 4	102.0	U	NA	102.0	0.2	Yes	
Uranium-238	pCi/g	6 / 6	454.0	U	NA	4 / 4	1996.0	U	NA	1996.0	1.1	Yes	
Uranium-Total	mg/Kg				NA	4 / 4	4458.0	U	NA	4.5	NA	Yes	
2-Methylnaphthalene	ug/Kg	1 / 7	50.0	U	NA	2 / 5	820.0	U	NA	820.0		Yes	G
Acenaphthene	ug/Kg				NA	1 / 5	1100.0	U	NA	1100.0		No	F
Anthracene	ug/Kg				NA	1 / 5	3100.0	U	NA	3100.0		No	F
Benzo(A)Anthracene	ug/Kg	4 / 7	170.0	U	NA	2 / 5	6300.0	U	NA	6300.0		Yes	
Benzo(A)Pyrene	ug/Kg	1 / 7	160.0	U	NA	2 / 5	3900.0	U	NA	3900.0		Yes	
Benzo(B)Fluoranthene	ug/Kg	4 / 7	170.0	U	NA	1 / 5	9600.0	U	NA	9600.0		Yes	
Benzo(G,H,I)Perylene	ug/Kg	1 / 7	85.0	U	NA	2 / 5	2900.0	U	NA	2900.0		Yes	
Benzo(K)Fluoranthene	ug/Kg	1 / 7	200.0	U	NA	1 / 5	340.0	U	NA	340.0		Yes	
Bis(2-Ethylhexyl) Phthalate	ug/Kg	5 / 7	2000.0	U	NA	3 / 5	9700.0	U	NA	9700.0		Yes	
Chrysene	ug/Kg	3 / 7	83.0	U	NA	2 / 5	7000.0	U	NA	7000.0		Yes	
Di-N-Butylphthalate	ug/Kg	4 / 7	210.0	U	NA					210.0		No	F
Di-N-Octylphthalate	ug/Kg	4 / 7	130.0	U	NA					130.0		No	F
Dibenzofuran	ug/Kg				NA	1 / 5	900.0	U	NA	900.0		Yes	
Diethyl Phthalate	ug/Kg				NA	1 / 5	80.0	U	NA	80.0		No	F
Fluoranthene	ug/Kg	3 / 7	210.0	U	NA	2 / 5	16000.0	U	NA	16000.0		No	F
Fluorene	ug/Kg				NA	2 / 5	1700.0	U	NA	1700.0		No	F
Indeno(1,2,3-Cd)Pyrene	ug/Kg	1 / 7	78.0	U	NA	2 / 5	2200.0	U	NA	2200.0		Yes	
Naphthalene	ug/Kg				NA	1 / 5	200.0	U	NA	200.0		No	F
Pentachlorophenol	ug/Kg	2 / 7	2600.0	U	NA					2600.0		Yes	
Phenanthrene	ug/Kg	4 / 7	190.0	U	NA	3 / 5	15000.0	U	NA	15000.0		Yes	G
Phenol	ug/Kg	3 / 7	650.0	U	NA					650.0		No	F
Pyrene	ug/Kg	3 / 7	140.0	U	NA	3 / 5	14000.0	U	NA	14000.0		No	F
1,1,1-Trichloroethane	ug/Kg				NA	1 / 4	2.0	U	NA	2.0		No	F

TABLE E.II-8
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %	CPC?	Justify
1,1-Dichloroethane	ug/Kg				NA	2 / 5	110.0	U	NA	NA		No	F
2-Butanone	ug/Kg	1 / 2	70.0	U	NA	1 / 4	41.0	U	NA	NA		No	F
2-Hexanone	ug/Kg				NA	1 / 4	2.0	U	NA	2.0		Yes	G
4-Methyl-2-Pentanone	ug/Kg				NA	1 / 4	6.0	U	NA	NA		No	F
Acetone	ug/Kg				NA	4 / 5	100.0	U	NA	NA		No	F
Carbon Disulfide	ug/Kg				NA	1 / 4	1.0	U	NA	NA		No	F
Chlorobenzene	ug/Kg				NA	1 / 4	2.0	U	NA	NA		No	F
Ethylbenzene	ug/Kg	1 / 6	270.0	U	NA	3 / 4	28.0	U	NA	NA		No	F
Methylene Chloride	ug/Kg				NA	1 / 5	56.0	U	NA	NA		No	F
Tetrachloroethene	ug/Kg	2 / 6	260.0	U	NA					NA		No	F
Toluene	ug/Kg	1 / 6	50.0	U	NA	1 / 4	3.0	U	NA	NA		No	F
Total Xylenes	ug/Kg	1 / 6	890.0	U	NA	3 / 4	190.0	U	NA	NA		No	F
Vinyl Chloride	ug/Kg				NA	1 / 4	3.0	U	NA	3.0		Yes	
1,2,3,4,6,7,8-HpCDD[4]	ug/Kg				NA	2 / 4	0.5	U	NA	0.5		Yes	
1,2,3,4,6,7,8-HpCDF[4]	ug/Kg				NA	2 / 4	0.3	U	NA	0.3		Yes	
1,2,3,4,7,8,9-HpCDD[4]	ug/Kg				NA	1 / 4	0.3	U	NA	0.3		Yes	
HpCDD[4]	ug/Kg				NA	2 / 4	1.0	U	NA	1.0		Yes	
HpCDF[4]	ug/Kg				NA	1 / 4	0.3	U	NA	0.3		Yes	
OCDD[4]	ug/Kg				NA	2 / 4	4.0	U	NA	4.0		Yes	
OCDF[4]	ug/Kg				NA	2 / 4	0.3	U	NA	0.3		Yes	
Chloride	ug/Kg				NA	1 / 1	192000.0	U	NA	NA		No	D
Cyanide	ug/Kg				NA	2 / 4	210.0	U	NA	NA		No	F
Fluoride	ug/Kg				NA	1 / 1	49100.0	U	NA	NA		No	F
Phosphorus	ug/Kg				NA	2 / 2	783000.0	U	NA	NA		No	C
Sulfate	ug/Kg				NA	1 / 1	172000.0	U	NA	NA		No	D
Sulfide	ug/Kg				NA	1 / 2	59200.0	U	NA	NA		No	D
Total Organic Carbon	ug/Kg				NA	1 / 1	152000000.0	U	NA	NA		No	E
Total Organic Nitrogen	ug/Kg				NA	2 / 2	642000.0	U	NA	NA		No	E

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – TCDD = Tetrachlorodibenzo-p-dioxin
PeCDD = Pentachlorodibenzo-p-dioxin
HxCDD = Hexachlorodibenzo-p-dioxin
HpCCD = Heptachlorodibenzo-p-dioxin
OCDD = Octachlorodibenzo-p-dioxin
TCDF = Tetrachlorodibenzofuran
PeCDF = Pentachlorodibenzofuran
HxCDF = Hexachlorodibenzofuran
HpCDF = Heptachlodibenzofuran
OCDF = Octachlorodibenzofuran
5 – The 95thpercentile background concentrations for subsurface soil are compared with maximum values.

TABLE E.II–9

SUMMARY OF ANALYTICAL RESULTS FOR CLEARWELL

		CIS Data				RIFS Data							
Parameter	Units	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Frequency of Detection	Maximum Value	Dist.[1]	95% UCL[2]	Representative Concentration[3]	Background 95 %[4]	Constituent is CPC?	
Aluminum	mg/Kg	4 / 4	23800.0	U	NA	7 / 7	20700.0	N	19460.5	23800.0	16064.0	No	D
Antimony	mg/Kg	2 / 4	32.0	U	NA	5 / 7	10.9	U	NA	32.0	NA	Yes	
Arsenic	mg/Kg	4 / 4	18.0	U	NA	6 / 7	59.1	U	NA	59.1	9.6	Yes	
Barium	mg/Kg	4 / 4	6910.0	U	NA	7 / 7	1790.0	N	1569.9	6910.0	119.2	Yes	
Beryllium	mg/Kg	4 / 4	9.1	U	NA	7 / 7	2.9	L	3.2	9.1	0.6	Yes	
Cadmium	mg/Kg	2 / 4	7.2	U	NA	7 / 7	2.9	L	7.0	7.2	0.9	Yes	
Calcium	mg/Kg	4 / 4	183000.0	U	NA	7 / 7	177000.0	N	165419.4	183000.0	150000.0	No	C
Chromium	mg/Kg	4 / 4	76.0	U	NA	7 / 7	196.0	N	148.4	148.4	20.7	Yes	
Cobalt	mg/Kg	2 / 4	23.0	U	NA	7 / 7	25.7	L	23.4	23.4	15.8	No	F
Copper	mg/Kg	4 / 4	1120.0	U	NA	7 / 7	3320.0	L	18483.3	3320.0	20.0	Yes	
Iron	mg/Kg	4 / 4	21100.0	U	NA	7 / 7	20300.0	N	19434.5	21100.0	30700.0	No	A
Lead	mg/Kg	4 / 4	83.0	U	NA	7 / 7	588.0	N	417.1	417.1	15.6	Yes	
Magnesium	mg/Kg	4 / 4	44600.0	U	NA	7 / 7	27200.0	N	24831.4	44600.0	42648.2	No	B
Manganese	mg/Kg	4 / 4	1660.0	U	NA	7 / 7	19800.0	N	12661.4	12661.4	1300.0	Yes	
Mercury	mg/Kg	4 / 4	4.4	U	NA	7 / 7	1.6	L	3.0	4.4	0.3	No	F
Molybdenum	mg/Kg					7 / 7	40.9	L	149.4	40.9	2.7	No	F
Nickel	mg/Kg	4 / 4	67.0	U	NA	7 / 7	228.0	N	160.5	160.5	34.4	No	F
Potassium	mg/Kg	4 / 4	3650.0	U	NA	7 / 7	4820.0	N	4622.8	4622.8	1980.0	No	B
Selenium	mg/Kg	1 / 4	3.7	U	NA	4 / 7	0.9	U	NA	3.7		No	F
Silver	mg/Kg	1 / 4	3.3	U	NA	6 / 7	12.7	U	NA	12.7	NA	No	F
Sodium	mg/Kg	4 / 4	3500.0	U	NA	7 / 7	1020.0	L	962.0	3500.0	285.0	No	B
Thallium	mg/Kg	1 / 4	2.1	U	NA	4 / 7	1.6	U	NA	2.1	0.5	Yes	
Tin	mg/Kg					6 / 7	24.1	U	NA	24.1		No	F
Vanadium	mg/Kg	4 / 4	2600.0	U	NA	7 / 7	285.0	L	351.5	2600.0	37.8	Yes	
Zinc	mg/Kg	4 / 4	194.0	U	NA	7 / 7	314.0	N	240.2	240.2	72.6	No	F
Aroclor 1242	ug/Kg	1 / 4	121.0	U	NA					121.0		Yes	
Aroclor 1248	ug/Kg	1 / 4	308.0	U	NA					308.0		Yes	
Aroclor 1254	ug/Kg	4 / 4	737.0	U	NA					737.0		Yes	
Cesium–137	pCi/g	4 / 4	450.0	U	NA	6 / 6	71.4	U	NA	450.0	NA	Yes	
Gross Alpha	pCi/g					6 / 6	2050.0	U	NA	2050.0		No	D
Gross Beta	pCi/g					6 / 6	1830.0	U	NA	1830.0		No	D
Neptunium–237	pCi/g	3 / 4	2.2	U	NA	4 / 6	1.8	U	NA	2.2		Yes	
Plutonium–238	pCi/g					5 / 6	0.5	U	NA	0.5	NA	Yes	
Plutonium–239/240	pCi/g					5 / 6	0.5	U	NA	0.5	NA	Yes	

TABLE E.II–9
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Background 95 %[4]	Constituent is CPC?	
Radium–226	pCi/g					6 / 6	170.0	U	NA	170.0	1.5	Yes	
Radium–228	pCi/g					6 / 6	26.4	U	NA	26.4	1.3	Yes	
Strontium–90	pCi/g	4 / 4	26.0	U	NA	2 / 6	12.8	U	NA	26.0	0.6	Yes	
Technetium–99	pCi/g	2 / 4	278.0	U	NA	6 / 6	695.0	U	NA	695.0	NA	Yes	
Thorium–228	pCi/g	4 / 4	56.0	U	NA	6 / 6	28.1	U	NA	56.0	1.3	Yes	
Thorium–230	pCi/g	4 / 4	5600.0	U	NA	6 / 6	314.0	U	NA	5600.0	1.9	Yes	
Thorium–232	pCi/g	4 / 4	39.0	U	NA	6 / 6	9.7	U	NA	39.0	1.3	Yes	
Thorium–Total	mg/Kg					6 / 6	88.9	U	NA	0.1	9.5	Yes	
Uranium–234	pCi/g	4 / 4	376.0	U	NA	6 / 6	1050.0	U	NA	1050.0	1.0	Yes	
Uranium–235/236	pCi/g	4 / 4	49.0	U	NA	6 / 6	373.0	U	NA	373.0	0.2	Yes	
Uranium–238	pCi/g	4 / 4	670.0	U	NA	6 / 6	1640.0	U	NA	1640.0	1.1	Yes	
Uranium–Total	mg/Kg					6 / 6	2780.0	U	NA	2780.0	NA	Yes	
2,4,5–Trichlorophenol	ug/Kg	1 / 4	6200.0	U	NA					6200.0		No	F
Anthracene	ug/Kg	1 / 4	450.0	U	NA					450.0		No	F
Benzo(A)Anthracene	ug/Kg	2 / 4	890.0	U	NA					890.0		Yes	
Benzo(A)Pyrene	ug/Kg	1 / 4	670.0	U	NA					670.0		Yes	
Benzo(B)Fluoranthene	ug/Kg	1 / 4	710.0	U	NA					710.0		Yes	
Benzo(G,H,I)Perylene	ug/Kg	1 / 4	230.0	U	NA					230.0		Yes	G
Benzo(K)Fluoranthene	ug/Kg	1 / 4	750.0	U	NA					750.0		Yes	
Bis(2–Ethylhexyl)Phthalate	ug/Kg	3 / 4	560.0	U	NA					560.0		No	F
Chrysene	ug/Kg	3 / 4	1000.0	U	NA					1000.0		Yes	
Di–N–Butylphthalate	ug/Kg	2 / 4	1700.0	U	NA					1700.0		No	F
Diethyl Phthalate	ug/Kg	1 / 4	410.0	U	NA					410.0		No	F
Fluoranthene	ug/Kg	1 / 4	3100.0	U	NA					3100.0		No	F
Fluorene	ug/Kg	1 / 4	280.0	U	NA					280.0		No	F
Indeno(1,2,3–Cd)Pyrene	ug/Kg	1 / 4	270.0	U	NA					270.0		Yes	
Phenanthrene	ug/Kg	4 / 4	2100.0	U	NA					2100.0		Yes	G
Pyrene	ug/Kg	3 / 4	1400.0	U	NA					1400.0		No	F
Acetone	ug/Kg	1 / 3	2000.0	U	NA					2000.0		No	F
Methylene Chloride	ug/Kg	1 / 3	870.0	U	NA					870.0		No	F
Ammonia, As Nitrogen	ug/Kg					5 / 5	151000.0	U	NA	151000.0		No	E
Cyanide	ug/Kg	1 / 4	9200.0	U	NA	4 / 7	1470.0	U	NA	9200.0		No	F

TABLE E.II–9
(Continued)

Parameter	Units	CIS Data Frequency of Detection	CIS Data Maximum Value	CIS Data Dist.[1]	CIS Data 95% UCL[2]	RIFS Data Frequency of Detection	RIFS Data Maximum Value	RIFS Data Dist.[1]	RIFS Data 95% UCL[2]	Representative Concentration[3]	Constituent is CPC?	
Nitrate/Nitrite	ug/Kg					5 / 7	69000.0	U	NA	69000.0	No	C
Oil & Grease	ug/Kg					6 / 6	288000.0	U	NA	288000.0	No	E
Sulfate	ug/Kg					4 / 4	572000.0	U	NA	572000.0	No	D
Total Kjeldahl Nitrogen	ug/Kg					7 / 7	1060000.0	N	1007147.4	1007147.4	No	E
Total Organic Carbon	ug/Kg					7 / 7	108000000.0	L	696196201.5	108000000.0	No	E
Total Organic Nitrogen	ug/Kg					4 / 4	909000.0	U	NA	909000.0	No	E

Notes:
1 – Distribution, N = Normal, L = Lognormal, U = Undetermined (normality is not assumed for data sets with less than 7 detects or more than 50% nondetects).
2 – NA is given if the distribution of the dataset can not be determined, if there are less than seven samples or if there are more than 50% nondetects.
3 – The representative concentration is the maximum of the UCL/Max value from either the CIS or RIFS data. The UCL/Max value from each data set is the lower of the maximum detected value or the 95% upper confidence limit.
4 – The 95th percentile background concentrations for subsurface soil are compared with maximum values.

TABLE E.II–10

SUMMARY OF SURFACE WATER DATA FOR PIT 5

Parameter	Units	CIS Data Frequency Detection	CIS Data Maximum Value	CIS Data Filtered/ Unfiltered	Representative Concentration[1]	Constituent is CPC? (yes/no)	
Cyanide	ug/L	2 / 2	87.0	Unfiltered	87.0	Yes	
Antimony	ug/L	2 / 2	4.5	Unfiltered	4.5	Yes	
Arsenic	ug/L	2 / 2	2.1	Unfiltered	2.1	Yes	
Barium	ug/L	2 / 2	108.0	Unfiltered	108.0	Yes	
Calcium	ug/L	2 / 2	184000.0	Unfiltered	NA	No	B
Copper	ug/L	2 / 2	21.0	Unfiltered	21.0	Yes	
Lead	ug/L	2 / 2	2.9	Unfiltered	2.9	Yes	G
Magnesium	ug/L	2 / 2	387000.0	Unfiltered	NA	No	B
Nickel	ug/L	2 / 2	21.0	Unfiltered	21.0	Yes	
Potassium	ug/L	2 / 2	92000.0	Unfiltered	NA	No	B
Selenium	ug/L	2 / 2	2.1	Unfiltered	2.1	Yes	
Sodium	ug/L	2 / 2	1320000.0	Unfiltered	NA	No	B
Vanadium	ug/L	2 / 2	47.0	Unfiltered	47.0	Yes	
Zinc	ug/L	2 / 2	94.0	Unfiltered	NA	No	F
Cesium–137	pCi/L	2 / 2	90.0	Unfiltered	90.0	Yes	
Strontium–90	pCi/L	2 / 2	41.0	Unfiltered	41.0	Yes	
Technetium–99	pCi/L	2 / 2	320.0	Unfiltered	320.0	Yes	
Thorium–230	pCi/L	2 / 2	0.1	Unfiltered	0.1	Yes	
Uranium–234	pCi/L	2 / 2	420.0	Unfiltered	420.0	Yes	
Uranium–235	pCi/L	2 / 2	19.0	Unfiltered	19.0	Yes	
Uranium–238	pCi/L	2 / 2	400.0	Unfiltered	400.0	Yes	
Benzene	ug/L	2 / 2	11.0	Unfiltered	11.0	Yes	
Methylene Chloride	ug/L	2 / 2	2.0	Unfiltered	2.0	Yes	
Toluene	ug/L	2 / 2	1.0	Unfiltered	1.0	Yes	

Notes:
1 – Representative concentration is assumed to equal the maximum concentration detected.

TABLE E.II–11

SUMMARY OF SURFACE WATER DATA FOR PIT 6

Parameter	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Filtered/ Unfiltered	Constituent is CPC? (yes/no)		Representative Concentration[1]
Aluminum	ug/L	4 / 5	492.0	Unfiltered	No	F	NA
Antimony	ug/L	1 / 5	1.7	Unfiltered	Yes		1.7
Calcium	ug/L	5 / 5	111000.0	Unfiltered	No	B	NA
Iron	ug/L	1 / 5	16.0	Unfiltered	No	C	NA
Lead	ug/L	1 / 5	2.9	Unfiltered	Yes	G	2.9
Magnesium	ug/L	5 / 5	2430.0	Unfiltered	No	B	NA
Potassium	ug/L	5 / 5	42000.0	Unfiltered	No	B	NA
Sodium	ug/L	5 / 5	103000.0	Unfiltered	No	B	NA
Zinc	ug/L	1 / 5	8.0	Unfiltered	No	F	NA
Radium–228	pCi/L	5 / 5	31.3	Unfiltered	Yes		31.3
Technetium–99	pCi/L	5 / 5	3500.0	Unfiltered	Yes		3500.0
Thorium–230	pCi/L	2 / 5	0.3	Unfiltered	Yes		0.3
Uranium–234	pCi/L	5 / 5	77.0	Unfiltered	Yes		77.0
Uranium–235	pCi/L	5 / 5	9.3	Unfiltered	Yes		9.3
Uranium–238	pCi/L	5 / 5	460.0	Unfiltered	Yes		460.0
Chloroform	ug/L	4 / 5	3.0	Unfiltered	Yes		3.0
Tetrachloroethene	ug/L	5 / 5	2.0	Unfiltered	Yes		2.0
Toluene	ug/L	4 / 5	6.0	Unfiltered	Yes		6.0

Notes:
1 – Representative concentration is assumed to equal the maximum concentration detected.

TABLE E.II–12

SUMMARY OF SURFACE WATER DATA FOR CLEARWELL

Parameter	Units	CIS Data: Frequency of Detection	CIS Data: Maximum Value	CIS Data: Filtered/ Unfiltered	Constituent is CPC? (yes/no)		Representative Concentration[1]
Cyanide	ug/L	1 / 2	87.0	Unfiltered	Yes		87.0
Arsenic	ug/L	2 / 2	4.2	Unfiltered	Yes		4.2
Calcium	ug/L	2 / 2	112000.0	Unfiltered	No	B	NA
Copper	ug/L	2 / 2	19.0	Unfiltered	Yes		19.0
Iron	ug/L	2 / 2	33.0	Unfiltered	No	C	NA
Magnesium	ug/L	2 / 2	155000.0	Unfiltered	No	B	NA
Manganese	ug/L	2 / 2	20.0	Unfiltered	Yes		20.0
Potassium	ug/L	2 / 2	28000.0	Unfiltered	No	B	NA
Selenium	ug/L	1 / 2	3.0	Unfiltered	Yes		3.0
Silver	ug/L	2 / 2	14.0	Unfiltered	Yes		14.0
Sodium	ug/L	2 / 2	504000.0	Unfiltered	No	B	NA
Vanadium	ug/L	2 / 2	513.0	Unfiltered	Yes		513.0
Zinc	ug/L	2 / 2	47.0	Unfiltered	No	F	NA
Radium–226	pCi/L	2 / 2	1.1	Unfiltered	Yes		1.1
Technetium–99	pCi/L	2 / 2	4030.0	Unfiltered	Yes		4030.0
Thorium–230	pCi/L	1 / 2	0.4	Unfiltered	Yes		0.4
Uranium–234	pCi/L	2 / 2	1900.0	Unfiltered	Yes		1900.0
Uranium–235	pCi/L	2 / 2	120.0	Unfiltered	Yes		120.0
Uranium–238	pCi/L	2 / 2	6200.0	Unfiltered	Yes		6200.0
2–Nitrophenol	ug/L	1 / 2	4.0	Unfiltered	Yes	G	4.0
Acetone	ug/L	1 / 2	520.0	Unfiltered	Yes		520.0

Notes:
1 – Representative concentration is assumed to equal the maximum concentration detected.

TABLE E.II–13
TOXICITY SCREENING CRITERIA FOR CHEMICALS

Constituent	Dose–Response Oral CSF (mg/Kg/day)$^{-1}$	Inhalation CSF (mg/Kg/day)$^{-1}$	Oral RfD (mg/Kg/day)	Inhalation RfD (mg/Kg/day)	EPA Part B Soil Screening Value[a] (mg/Kg)	EPA Part B Surface Water Screening Value[a] (mg/L)
aluminum	ND	ND	ND	ND	ND	ND
antimony	ND	ND	4.00E–04	ND	1.08E+01	1.46E–03
arsenic	1.75E+00	1.50E+01	3.00E–04	ND	3.66E–02	4.86E–06
barium	ND	ND	7.00E–02	1.43E–04	1.89E+03	2.56E–01
beryllium	4.30E+00	8.40E+00	5.00E–03	ND	1.49E–02	1.98E–06
boron	ND	ND	9.00E–02	5.71E–03	2.43E+03	3.29E–01
cadmium	ND	6.30E+00	1.00E–03	ND	2.70E+01	3.65E–03
chromium vi	ND	4.20E+01	5.00E–03	ND	1.35E+02	1.83E–02
cobalt	ND	ND	6.00E–02	3.00E–07	1.62E+03	2.19E–01
copper	ND	ND	3.70E–02	ND	9.99E+02	1.35E–01
cyanide	ND	ND	2.00E–02	ND	5.40E+02	7.30E–02
lead	ND	ND	ND	ND	ND	ND
magnesium	ND	ND	9.70E+00	ND	2.62E+05	3.54E+01
manganese	ND	ND	1.40E–01	1.14E–04	3.78E+03	5.11E–01
mercury	ND	ND	3.00E–04	8.57E–05	8.10E+00	1.10E–03
molybdenum	ND	ND	5.00E–03	ND	1.35E+02	1.83E–02
nickel	ND	8.40E–01	2.00E–02	ND	5.40E+02	7.30E–02
selenium	ND	ND	5.00E–03	ND	1.35E+02	1.83E–02
silver	ND	ND	5.00E–03	ND	1.35E+02	1.83E–02
thallium	ND	ND	7.00E–05	ND	1.89E+00	2.56E–04
uranium–total	ND	ND	3.00E–03	ND	8.10E+01	1.10E–02
vanadium	ND	ND	7.00E–03	ND	1.89E+02	2.56E–02
zinc	ND	ND	3.00E–01	ND	8.10E+03	1.10E+00
1,1,1–trichloroethane	ND	ND	ND	2.86E–01	ND	2.78E–01
1,1,2,2–tetrachloroethane	2.00E–01	2.03E–01	ND	ND	3.20E–01	8.84E–06
1,1,2–trichloroethane	5.70E–02	5.70E–02	4.00E–03	ND	1.12E+00	3.14E–05
1,1–dichloroethane	ND	ND	ND	1.43E–01	ND	1.39E–01
1,1–dichloroethene	6.10E–01	1.80E–01	9.00E–03	ND	1.05E–01	6.61E–06
1,2,4–trichlorobenzene	ND	ND	1.00E–02	2.57E–03	2.70E+02	2.34E–03
1,2–dichloroethane	9.10E–02	9.10E–02	ND	ND	7.03E–01	1.97E–05
1,2–dichloroethene	ND	ND	9.00E–03	ND	2.43E+02	3.29E–02
1,2–dichloropropane	ND	6.80E–02	ND	1.14E–03	ND	3.33E–05
1,4–dichlorobenzene	2.40E–02	ND	ND	2.29E–01	2.67E+00	3.54E–04
2,4,6–trichlorophenol	1.10E–02	1.10E–02	ND	ND	5.82E+00	1.63E–04
2,4–dichlorophenol	ND	ND	3.00E–03	ND	8.10E+01	1.10E–02
2,4–dinitrophenol	ND	ND	2.00E–03	ND	5.40E+01	7.30E–03
2,4–dinitrotoluene	6.80E–01	ND	2.00E–03	ND	9.41E–02	1.25E–05
2,6–dinitrotoluene	6.80E–01	ND	1.00E–03	ND	9.41E–02	1.25E–05
2–chlorophenol	ND	ND	5.00E–03	ND	1.35E+02	1.83E–02
2–hexanone	ND	ND	4.00E–02	ND	1.08E+03	1.46E–01
2–methylnaphthalene	ND	ND	ND	ND	ND	ND
2–nitroanaline	ND	ND	ND	5.71E–05	ND	5.56E–05
2–nitrophenol	ND	ND	ND	ND	ND	ND
3,3'–dichlorobenzidene	4.50E–01	ND	ND	ND	1.42E–01	1.89E–05
3–chloropropene	ND	ND	ND	ND	ND	ND

TABLE E.II-13
(con't)

Constituent	Dose-Response Oral CSF (mg/Kg/day)$^{-1}$	Inhalation CSF (mg/Kg/day)$^{-1}$	Oral RfD (mg/Kg/day)	Inhalation RfD (mg/Kg/day)	EPA Part B Soil Screening Value[a] (mg/Kg)	EPA Part B Surface Water Screening Value[a] (mg/L)
3-nitroanaline	ND	ND	3.00E-03	ND	8.10E+01	1.10E-02
4-chloro-3-methylphenol	ND	ND	ND	ND	ND	ND
4-nitrophenol	ND	ND	6.00E-02	ND	1.62E+03	2.19E-01
acetone	ND	ND	1.00E-01	ND	2.70E+03	3.65E-01
benzene	2.90E-02	2.92E-02	ND	ND	2.21E+00	6.14E-05
bis(2-ethylhexyl)phthalate	1.40E-02	ND	2.00E-02	ND	4.57E+00	6.07E-04
bromodichloromethane	6.20E-02	ND	2.00E-02	ND	1.03E+00	1.37E-04
bromoform	7.90E-03	3.90E-03	2.00E-02	ND	8.10E+00	1.08E-03
carbazole	2.00E-02	ND	ND	ND	3.20E+00	4.25E-04
carbon disulfide	ND	ND	1.00E-01	2.86E-03	2.70E+03	2.76E-03
carbon tetrachloride	1.31E-01	5.30E-02	7.00E-04	ND	4.89E-01	2.58E-05
chlorobenzene	ND	ND	2.00E-02	5.71E-03	5.40E+02	5.17E-03
chloroform	6.10E-03	8.10E-02	1.00E-02	ND	1.05E+01	2.74E-05
chloromethane	1.30E-02	6.30E-03	ND	ND	4.92E+00	2.32E-04
dibromochloromethane	8.40E-02	ND	2.00E-02	ND	7.62E-01	1.01E-04
hexachlorobenzene	1.60E+00	1.60E+00	8.00E-04	ND	4.00E-02	5.31E-06
hexachloroethane	1.40E-02	1.40E-02	1.00E-03	ND	4.57E+00	6.07E-04
methylene chloride	7.50E-03	1.60E-03	6.10E-02	8.57E-01	8.53E+00	6.30E-04
n-nitrosodiphenylamine	4.90E-03	ND	ND	ND	1.31E+01	1.73E-03
n-nitrosodipropylamine	7.00E+00	ND	ND	ND	9.14E-03	1.21E-06
pentachlorophenol	1.20E-01	ND	3.00E-02	ND	5.33E-01	7.08E-05
styrene	3.00E-02	ND	2.00E-01	2.86E-01	2.13E+00	2.83E-04
tetrachloroethene	5.20E-02	2.00E-03	1.00E-02	ND	1.23E+00	1.43E-04
toluene	ND	ND	2.00E-01	1.14E-01	5.40E+03	9.65E-02
tributyl phosphate	ND	ND	5.00E-03	ND	1.35E+02	1.83E-02
trichloroethene	1.10E-02	6.00E-03	ND	ND	5.82E+00	2.54E-04
vinyl chloride	1.90E+00	3.00E-01	ND	ND	3.37E-02	2.81E-06
acenaphthylene	ND	ND	ND	ND	ND	ND
benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND
fluoranthene	ND	ND	4.00E-02	ND	1.08E+03	1.46E-01
phenanthrene	ND	ND	ND	ND	ND	ND
benzo(a)anthracene	7.30E-01	6.10E-01	ND	ND	8.77E-02	1.16E-05
benzo(a)pyrene	7.30E+00	6.10E+00	ND	ND	8.77E-03	1.16E-06
benzo(b)fluoranthene	7.30E-01	6.10E-01	ND	ND	8.77E-02	1.16E-05
benzo(k)fluoranthene	7.30E-02	6.10E-02	ND	ND	8.77E-01	1.16E-04
chrysene	7.30E-03	6.10E-03	ND	ND	8.77E+00	1.16E-03
dibenzo(a,h)anthracene	7.30E+00	6.10E+00	ND	ND	8.77E-03	1.16E-06
indeno(1,2,3-cd)pyrene	7.30E-01	6.10E-01	ND	ND	8.77E-02	1.16E-05
4,4-ddd	2.40E-01	ND	ND	ND	2.67E-01	3.54E-05
4,4-dde	3.40E-01	ND	ND	ND	1.88E-01	2.50E-05
4,4'-ddt	3.40E-01	3.40E-01	5.00E-04	ND	1.88E-01	2.50E-05
aldrin	1.70E+01	1.70E+01	3.00E-05	ND	3.76E-03	5.00E-07
alpha bhc	6.30E+00	6.30E+00	ND	ND	1.02E-02	1.35E-06
aroclor-1248	7.70E+00	ND	ND	ND	8.31E-03	1.10E-06

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TABLE E.II-13
(con't)

Constituent	Dose-Response Oral CSF (mg/Kg/day)$^{-1}$	Inhalation CSF (mg/Kg/day)$^{-1}$	Oral RfD (mg/Kg/day)	Inhalation RfD (mg/Kg/day)	EPA Part B Soil Screening Value[a] (mg/Kg)	EPA Part B Surface Water Screening Value[a] (mg/L)
aroclor-1254	7.70E+00	ND	ND	ND	8.31E-03	1.10E-06
aroclor-1260	7.70E+00	ND	ND	ND	8.31E-03	1.10E-06
beta bhc	1.80E+00	1.90E+00	ND	ND	3.56E-02	4.72E-06
chlorodane	1.30E+00	1.30E+00	6.00E-05	ND	4.92E-02	6.54E-06
delta bhc	ND	ND	ND	ND	ND	ND
diazinon	ND	ND	9.00E-04	ND	2.43E+01	3.29E-03
dieldrin	1.60E+01	1.60E+01	5.00E-05	ND	4.00E-03	5.31E-07
endosulfan I	ND	ND	ND	ND	ND	ND
endosulfan II	ND	ND	ND	ND	ND	ND
endrin	ND	ND	3.00E-04	ND	8.10E+00	1.10E-03
gamma chlorodane	ND	ND	ND	ND	ND	ND
heptachlor	4.50E+00	4.50E+00	5.00E-04	ND	1.42E-02	1.89E-06
heptachlor epoxide	9.10E+00	9.10E+00	1.30E-05	ND	7.03E-03	9.34E-07
lindane	ND	ND	3.00E-04	ND	8.10E+00	1.10E-03
malathion	ND	ND	2.00E-02	ND	5.40E+02	7.30E-02
methoxychlor	ND	ND	5.00E-03	ND	1.35E+02	1.83E-02
toxaphene	1.10E+00	1.10E+00	ND	ND	5.82E-02	7.73E-06
heptachlorodibenzofuran	1.50E+03	1.50E+03	ND	ND	4.27E-05	5.67E-09
heptachlorodibenzo-p-dioxi	1.50E+03	1.50E+03	ND	ND	4.27E-05	5.67E-09
hexachlorodibenzofuran	1.50E+04	1.50E+04	ND	ND	4.27E-06	5.67E-10
hexachlorodibenzo-p-dioxin	1.50E+04	1.50E+04	ND	ND	4.27E-06	5.67E-10
octachlorodibenzofuran	1.50E+02	1.50E+02	ND	ND	4.27E-04	5.67E-08
octachlorodibenzo-p-dioxin	1.50E+02	1.50E+02	ND	ND	4.27E-04	5.67E-08
pentachlorodibenzofuran	7.50E+03	7.50E+03	ND	ND	8.53E-06	1.13E-09
tetrachlorodibenzofuran	1.50E+04	1.50E+04	ND	ND	4.27E-06	5.67E-10
tetrachlorodibenzo-p-dioxin	1.50E+05	1.50E+05	ND	ND	4.27E-07	5.67E-11

Note:

[a] Screening value selected is lower of values based on cancer risk level of 10^{-7} or HQ of 0.1.

ND – No data.

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E.III

ATTACHMENT E.III

EXAMPLE CALCULATIONS OF INTAKES AND RISKS FOR OPERABLE UNIT 1 BASELINE RISK ASSESSMENT

ATTACHMENT E.III

EXAMPLE CALCULATIONS OF INTAKES AND RISKS FOR OPERABLE UNIT 1 BASELINE RISK ASSESSMENT

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E.III.1 INTRODUCTION

EPA's CERCLA methodology, which is set forth in recent guidance such as the Risk Assessment Guidance for Superfund Volume 1, Human Health Evaluation Manual (Part A) (EPA 1989a) and its supporting documents, uses a specific methodology to calculate human health effects. Exposures are first quantified using a set of equations and parameters that are unique to each exposure pathway. The exposure assessment process results in calculated daily intakes (expressed in mg/kg-d) for hazardous chemical contaminants and radioactivity intakes (expressed in pCi) for radionuclide contaminants. The calculated intakes are multiplied then by an appropriate slope factor to calculate risk, or divided by a constituent's Rfd to yield a Hazard Index (HQ). The exposure-to-risk relationship represented by the slope factors cited in the Health Effects Summary Tables (HEAST) (1992b), are linear below risk levels of 10^{-2}. This assessment uses the linear relationship to calculate combined Incremental Lifetime Cancer Risks (ILCRs) up to 1×10^{-2}. The relationship becomes exponential between cancer risk levels of 10^{-2} and 10^{-1}, but remains essentially linear (to within 10 percent) up to a risk value of 2×10^{-1}. Since the methodology employed in this assessment yields calculated risks in excess of 10^{-2} for OU1, Risks above this risk range are calculated using the one-hit methodology presented in Section 8.2.1 of EPA guidance (EPA 1989a).

This section presents examples of the calculations used to quantify the magnitude of exposure, risk, and toxic health effects expected to result from all reasonable exposure pathways involving U-238 at the FEMP. This radionuclide is chosen for these examples because it is present in all media, and uranium contributes to both risk and toxic effects calculated for the operable unit. All parameters and equations are drawn from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a) unless noted otherwise. Tables E.3-15 and E.3-16 in the Baseline Risk Assessment and Table E.III-1 of this attachment list the parameters used to evaluate the exposures examined in this assessment.

For convenience, the equations used to quantify risk are grouped together according to exposure media. The exposure media considered are water, air, and soil. Exposures from sediment are included in the group detailing the soil exposure pathways. Section E.III.2

presents the methodology followed for exposures to air, Section E.III.3 describes the methodology followed for exposures to water, and Section E.III.4 relates the methodology followed for exposures to soil.

E.III.2 AIR EXPOSURES

The on-property resident RME is used to illustrate the calculation of risks associated with air pathways. This hypothetical individual is the limiting receptor for air exposures from Operable Unit 1.

E.III.2.1 Inhalation

Equations 7-5 and 7-6 from the Risk Assessment Work Plan Addendum (DOE 1992a) are used to quantify intake from the inhalation pathway:

$$\text{(radionuclides)}\ I_{ai} = (C_{ai})(IR)(ET)(EF)(ED) \qquad \text{(E.III-1)}$$

$$\text{(chemicals)}\ I_{ai} = (C_{ai})(IR)(ET)(EF)(ED)/(BW)(AT) \qquad \text{(E.III-2)}$$

where

I_{ai}	=	intake from inhalation (pCi, rad) (mg/kg-d, chem)
C_{ai}	=	concentration in air (pCi/m^3, rad) (mg/m^3, chem)
IR	=	inhalation rate (m^3/h)
ET	=	exposure time (h/d)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg); and
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

Intakes resulting from inhaling air containing 1 pCi/m^3 of U-238 have been selected for the example calculation. The inhalation rate for an adult is 0.83 m^3/h. The exposure duration is 70 years (ED = 70 y/lifetime) and the exposure frequency is 350 days out of every year (EF = 350 d/y). The exposure time is 5.7 h/d (ET = 5.7 h/d). Substituting these values into Equation E.III-1 yields:

$$I_{a\,U238} = (1\ \text{pCi/m}^3)(0.83\ \text{m}^3\text{/h})(5.7\ \text{h/d})(350\ \text{d/y})(70\ \text{y/lifetime}) \qquad \text{(E.III-3)}$$

$$I_{a\,U238} = 115{,}910\ \text{pCi/lifetime}$$

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The exposure model used in this scenario responds linearly to changes in concentration. After rounding to three significant figures, each pCi/m^3 of U-238 in air is calculated to result in an incremental lifetime intake of about 116,000 pCi of U-238 via respiration.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{a\ U238} = SF_{inh\ U238} \times I_{a\ U238} \qquad \text{(E.III-4)}$$

where

$ILCR_{a\ U238}$ = ILCR from breathing air (r/lifetime)

$SF_{inh\ i}$ = Slope factor for inhalation of constituent "i" (r/pCi)

The relationship between air concentration and risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake of U-238 calculated in Equation E.III-3 and the inhalation slope factor for U-238, 5.2 x 10^{-8} r/pCi, for $SF_{inh\ i}$ into Equation E.III-4. This yields:

$$ILCR_{a\ U238} = (5.2 \times 10^{-8}\ \text{r/pCi})(115910\ \text{pCi/lifetime}) \qquad \text{(E.III-5)}$$

$$ILCR_{a\ U238} = 0.00603\ \text{r/lifetime}$$

Because the exposure model used in this scenario responds linearly to changes in concentration, each additional pCi/m^3 of U-238 in air is predicted to result in a calculated excess risk of 6 x 10^{-3}.

E.III.2.2 Ingestion of Vegetables Contaminated by Aerial Deposition

Eating vegetables contaminated by aerial deposition of contaminated dust can contribute to the total intake of contaminants by humans. Estimating the magnitude of this intake is a two step process. First the concentration in the vegetables is estimated. Then the lifetime intake is calculated. If measured values are not available (e.g. future exposures), this concentration is estimated using Equation 7-10 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The intake equation is:

$$C_{avi} = d_d \left[\frac{r_d(1-e^{-L\lambda_{di}t_e})}{Y\lambda_w} + \frac{f_d B_{iv(n)} CF_p (1-e^{-\lambda_{di} t_{bd}})}{\rho \lambda_{di}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(E.III-6)}$$

where

C_{avi}	=	concentration of the ith contaminant in/on vegetables and fruit (pCi/g, rad) (mg/kg, chem)
λ_{di}	=	effective depletion constant of ith contaminant in surface soils due to radioactive decay, chemical degradation, and leaching (h^{-1})
λ_w	=	effective depletion constant of ith contaminant on the surface plants also known as the weathering removal rate (h^{-1})
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
$B_{iv(n)}$	=	dry soil to wet plant partitioning coefficient of ith contaminant in feed and forage (n=1) or food crops (n=2) (C_{iv}/C_s)
CF_p	=	Dry to wet weight conversion factor (0.428 for crops, Baes and Sharp, 1984; 1.0 for feed and forage)
d_d	=	constituent's deposition rate (pCi/m^2-h, rad) (mg/m^2-h, chem)
f_d	=	fraction of year plant is down wind (unitless)
r_d	=	fraction of airborne material retained on plant surface (unitless)
t_e	=	growing season (h)
t_{bd}	=	duration soil is exposed to airborne emissions (h)
t_h	=	duration of period between harvest and consumption (h)
Y	=	agricultural yield (g/m^2, rad)(kg/m^2, chem)
ρ	=	effective dry surface soil density (g/m^2, rad)(kg/m^2, chem)

Values for these variables are given in Table E.III-1.

The soil depletion coefficient is calculated by

$$\lambda_{di} = \lambda_{ri} + \lambda_{Li} \qquad \text{(E.III-7)}$$

where the leaching coefficient (λ_{Li}) is calculated using the relationship (Baes and Sharp 1983):

$$\lambda_L = \frac{V_w}{z\,\theta \left[1 + \sigma \frac{K_d}{\theta} \right]} \qquad \text{(E.III-8)}$$

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and

λ_{Li} = Leach rate (h^{-1})
V_w = Percolation rate (nominally 0.0044 cm/h through Pits 1and 2)
z = Depth of surface soil (15 cm)
σ = Density of soil in root zone (nominally 1.5 g/cm^3)
K_d = Water to soil partitioning coefficient (cm^3/g)
θ = Moisture fraction of surface soil (measured at 0.17)

When measured air concentration data are available, the aerial deposition rate of a constituent per unit area (d_d) is estimated by multiplying the concentration in air by the mean deposition velocity (V m/h):

$$d_d = (C_{a\,U238}\ pCi/m^3)(V\ m/h) \qquad \text{(E.III-9)}$$

Vegetables grown in air containing particles of U-238 have been selected for the example calculation. Assuming that the mean deposition velocity for dust in the study area (V) is about 0.0018 m/s (EPA 1991e), the aerial deposition rate of U-238 (d_d) per unit area calculated by Equation E.III-9 is pCi/m^2/h. Assuming the vegetables are centered in the study area, they will always be downwind, so (f_d) is unity (1). The duration of time which the vegetable plot is exposed to aerial deposition during the study period (t_{bd}) is 1,000 years (8.76 x 10^6 h). The fraction of airborne material retained on the plant surface (r_d) is 0.25. The weathering removal rate (λ_w) is 0.0021 h^{-1}. The dry soil to dry plant partitioning coefficient of U-238 in the reproductive portions of vegetables ($B_{iv(2)}$) is 4 x 10^{-3}. The dry plant mass to wet plant mass ratio is 0.428 (CF_p). The effective dry surface density of the soil (ρ) is 225,000 g/m^2. The agricultural yield is 1,500 g/m^2 (Y), and the growing season (t_e) is 1440 hours. The period between harvest and consumption (t_h) is 24 hours. The radiological decay constant of U-238 (λ_{ri}) is 1.77 x 10^{-14} h^{-1}. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches unity (1) (i.e. no significant decay). A value of 1.61 x 10^{-5} is calculated for λ_{Li} using Equation E.III-8 and a K_d of 12 cm^3/g from Appendix D. The effective depletion constant (λ_{di}) is calculated from Equation E.III-7 to be 1.61 x 10^{-5}. Substituting these parameter values into Equation E.III-5 and simplifying yields:

$$C_{avi} = (6.48 pCi/m^2/h)\left[\frac{(0.25)(1-e^{-(0.0021\,h^{-1})(1440\,h)})}{(1500\,g/m^2)(0.0021\,h^{-1})} + \frac{(1)(0.004)(0.483)(1-e^{-((1.61x10^{-5}h^{-1})(8760000\,h))})}{(225000\,g/m^2)(1.61x10^{-5}h^{-1})}\right]$$

(E.III-10)

$$C_{av\ U238} = 0.492\ pCi/g$$

Once the constituent's concentration in the vegetables and fruit is estimated, the resulting intake by humans can be estimated using Equations 7-15 and 7-16 of the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$\text{(radionuclides)}\ I_{avi} = (C_{avi})(IR)(FI)(EF)(ED) \qquad \text{(E.III-11)}$$

$$\text{(chemicals)}\ I_{avi} = (C_{avi})(IR)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.III-12)}$$

where

I_{avi}	=	intake from vegetation (pCi, rad) (mg/kg-d, chem)
C_{avi}	=	total concentration of contaminants in vegetable (pCi/g, rad) (mg/kg, chem)
IR	=	ingestion rate (g/d, rad) (kg, chem)
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg); and
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y).

Continuing the example begun in Equation E.III-10, ingestion of vegetables and fruit containing a U-238 concentration of C_{avi} of 0.492 pCi/g of for a 70-year lifetime has been selected to illustrate the methodology used to calculate human intake of constituents from plants. The exposure frequency is 350 days per year (EF = 350 d/y). The consumption rate of fruit and vegetables grown in the study area is 122 grams per day (FI x IR = 122 g/d). The exposure duration (ED) is 70 y/lifetime. The lifetime intake of U-238 from this food supply is given by Equation E.III-11. Using the presented parameter values, this becomes:

$$I_{av\ U238} = (0.492\ pCi/g)(122\ g/d)(350d/y)(70\ y/lifetime) \qquad \text{(E.III-13)}$$

$$I_{av\ U238} = 1{,}470{,}588\ pCi/lifetime$$

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Because the exposure models used in this scenario respond linearly to changes in concentration, they estimate that each additional pCi/m^3 of U-238 in air will produce an incremental lifetime intake of about 1,470,588 pCi U-238 via this pathway. 5899

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{av\ U238} = SF_{ing\ i} \times I_{av\ U238} \qquad \text{(E.III-14)}$$

where

$ILCR_{av\ U238}$ = ILCR from ingestion of vegetables contaminated by aerial deposition (r/lifetime)
$SF_{ing\ i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The linear relationship between air concentration and risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake from fruit and vegetable consumption calculation in Equation 13 and the ingestion of slope factor for U-238 ($SF_{ing\ U238}$ = 2.8 x 10^{-11} r/pCi), for Equation E.III-14. This yields:

$$ILCR_{av\ U238} = (2.8 \times 10^{-11}\ \text{r/pCi})(1{,}470{,}588\ \text{pCi//lifetime}) \qquad \text{(E.III-15)}$$
$$ILCR_{av\ U238} = 4.1 \times 10^{-5}\ \text{r/lifetime}$$

Because the exposure model used in this scenario responds linearly to changes in concentration, each additional pCi/m^3 of U-238 in air is predicted to result in a calculated excess risk of 4 x 10^{-5}.

E.III.2.3 Ingestion of Meat or Milk Downwind of Source

Forage, feed, and soils downwind of a potential source of contaminated dust can have contamination deposited on them by settling dust. Ingestion of these plants by livestock contributes to the body burden of these contaminants in livestock. Consumption of meat or milk from these animals contributes to the total intake of these contaminants by humans.

The magnitude of the contaminant exposure by humans depends, in part, on the concentration of the constituent in the animal products. If measured values are not available (e.g. future exposures), this concentration can be calculated using the methodology set forth in the FEMP

Risk Assessment Work Plan Addendum (DOE 1992a). The concentration of a contaminant in animal products, such as beef or milk, is estimated using the following equation:

$$C_{Ai} = F_{Ai}[(C_{afi})(Q_f) + (C_{agi})(Q_g) + (C_{asi})(Q_s)]\, e^{-\lambda_{ri} t_h} \qquad \text{(E.III-16)}$$

where

C_{Ai}	=	concentration of ith contaminant in the animal product (pCi/mL for milk, pCi/g for beef, rad) (mg/L for milk, mg/g for beef, chem)
C_{afi}	=	concentration of ith contaminant in feed (pCi/g, rad) (mg/kg, chem)
C_{agi}	=	concentration of ith contaminant in forage (pCi/g, rad) (mg/kg, chem)
C_{asi}	=	concentration of ith contaminant in soil (pCi/g, rad) (mg/kg, chem)
F_{Ai}	=	elemental transfer coefficient that relates the daily intake by an animal to the concentration of ith contaminant in an edible portion of the animal product (d/L for milk, d/g for meat)
Q_f	=	consumption rate of contaminated feed by livestock (g/d, rad) (kg/d, chem)
Q_g	=	consumption rate of contaminated forage by livestock (g/d, rad) (kg/d, chem)
Q_s	=	consumption rate of contaminated soil by livestock (g/d, rad) (kg/d, chem)
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h	=	duration of period between harvest and consumption (h)

Estimating the magnitude of this intake is a two step process. First, the concentration in the soil, feed, and forage is estimated. If measured values are not available (e.g. future exposures), this concentration is estimated. The amount attributable to dust deposition is calculated using Equation E.III-6. In the second step, the concentrations in animal products (meat and milk) are calculated.

Uptake of contaminants by feed and forage grown downwind of air emissions containing 1 pCi/m^3 have been selected as an example calculation for this pathway. Assuming that the mean deposition velocity for dust in the study area (V) is about 0.0018 m/s (EPA 1991), the aerial deposition rate of U-238 (d_d) per unit area calculated by Equation E.III-9 is 6.48 pCi/m^2/h. Assuming the plants are centered in the study area, they will always be downwind, so (f_d) is unity (1). The duration of time in which the plants and surrounding soil are exposed to aerial deposition during the study period is 1,000 years (t_{bd} = 8,760,000 h). The fraction of airborne material retained on the plant surface (r_d) is 0.25. The weathering removal rate (λ_w) is 0.0021 h^{-1}. The dry soil to dry plant partitioning coefficient of U-238 in the feed and forage ($B_{iv(1)}$) is 8.5 x 10^{-3}. The dry plant mass to wet plant mass ratio for this case is 1.0. The effective dry surface density of the soil (ρ) is 225,000 g/m^2. The agricultural yield (Y) is 800 g/m^2, and the growing season (t_e) is 3312 hours for feed and 720 hours for forage.

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The period between harvest and consumption (t_h) is 6,160 hours for feed and 0 hours for forage. The radiological decay constant of U-238 (λ_{ri}) is 1.77 x 10^{-14} h^{-1}. This value is so small that the exp($-\lambda_{ri}$ t_h) term approaches a value of 1 (i.e. no significant decay) for both the forage and the feed calculations. A value of 1.61 x 10^{-5} is calculated for $\lambda_{d\ U238}$ using a K_d of 12 cm^3/g obtained from Appendix D. Chemical degradation does not apply and is set equal to zero (0). Substituting the parameter values for forage into Equation E.III-6 and simplifying yields:

$$C_{avi} = (6.48 pCi/m^2/h)\left[\frac{(0.25)(1-e^{-(0.0021\,h^{-1})(720\,h)})}{(800\,g/m^2)(0.0021\,h^{-1})} + \frac{(1)(0.0085)(1)(1-e^{-(0.0000161\,h^{-1})(8760000\,h)})}{(225000\,g/m^2)(0.0000161\,h^{-1})}\right] \quad \text{(E.III-17)}$$

$$C_{ag\ U238} = 0.767 \text{ pCi/g}$$

Substituting the parameter values for feed into Equation E.III-6 and simplifying yields:

$$C_{avi} = (6.48 pCi/m^2/h)\left[\frac{(0.25)(1-e^{-(0.0021\,h^{-1})(3312\,h)})}{(800\,g/m^2)(0.0021\,h^{-1})} + \frac{(1)(0.0085)(1)(1-e^{-(0.0000161\,h^{-1})(8760000\,h)})}{(225000\,g/m^2)(0.0000161\,h^{-1})}\right] \quad \text{(E.III-18)}$$

$$C_{af\ U238} = 0.979 \text{ pCi/g}$$

Cows also consume soil while grazing. Concentrations in the soil attributable to aerial deposition can be calculated by multiplying the aerial deposition rate by the second term in parentheses in Equation E.III-6. Since the medium of interest is the soil itself, and not a plant growing in the soil, the $B_{iv(2)}$ term is removed leaving:

$$C_{si} = d_d \frac{f_d(1-e^{-\lambda_d t_{ed}})}{\rho\lambda_d}\ x\ e^{-\lambda_{ri} t_h} \quad \text{(E.III-19)}$$

Substituting previously-described variables in Section E.III.3 into this equation produces an estimated soil concentration of:

$$C_{si} = 6.48 pCi/m^2/h \frac{(1)(1-e^{-(1.61 x 10^{-5})(8760000 h)})}{(225000 g/m^2)(1.61 x 10^{-5})}(1) \qquad \text{(E.III-20)}$$

$$C_{as\ U238} = 1.78 \text{ pCi/g}$$

Once the concentrations in feed, forage, and soil have been estimated, concentrations in the animal products can be calculated using Equation E.III-16. Continuing the example begun in Equation E.III-17, the concentrations of U-238 in feed, forage, and soil attributable to dust deposition are about 0.979 pCi/g, 0.767 pCi/g, and 1.78 pCi/g, respectively. In this study, a cow is assumed to consume 25,000 g/d of stored feed (Q_f), 25,000 g/d of forage (Q_g), and 500 g/d of soil (Q_s). The food-to-beef biotransfer factor ($F_{m\ U238}$) is 2.0 x 10^{-7} d/g and the food-to-milk biotransfer factor ($F_{d\ U238}$) is 6.0 x 10^{-7} d/ml. The period between harvest and consumption (t_h) is 480 hours for beef and is 24 hours for milk. The radiological decay constant of U-238 λ_{ri} is 1.77 x 10^{-10} y^{-1}. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches a value of 1 (i.e. no significant decay) for both the beef and milk calculations. Substituting the presented parameter values for beef into Equation E.III-16 yields a meat concentration ($C_{Ai} = C_{m\ U238}$) of:

$$C_{am\ U238} = (2.0 \times 10^{-7} \text{ d/g})[(0.979 \text{ pCi/g})(25000 \text{ g/d}) + (0.767 \text{ pCi/g})(25000 \text{ g/d}) + (1.78 \text{ pCi/g})(500 \text{ g/d})] \qquad \text{(E.III-21)}$$

$$C_{am\ U238} = 0.00891 \text{ pCi/g}$$

Using the presented parameter values for milk yields a U-238 concentration in milk ($C_{Ai} = C_{d\ U238}$) of:

$$C_{ad\ U238} = (6.0 \times 10^{-7} \text{ d/mL})[((0.979 \text{ pCi/g})(25000 \text{ g/d}) + (0.767 \text{ pCi/g})(25000 \text{ g/d}) + (1.78 \text{ pCi/g}) \qquad \text{(E.III-22)}$$

$$C_{ad\ U238} = 0.0267 \text{ pCi/mL})$$

Once the constituent's concentration in the animal product is estimated, the resulting intake by humans can be estimated using Equations 7-17 and 7-18 of the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$\text{(radionuclides)} \quad I_{Ai} = (C_{Ai})(IR)(FI)(EF)(ED) \qquad \text{(E.III-23)}$$

$$\text{(chemicals)} \quad I_{Ai} = (C_{Ai})(IR)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.III-24)}$$

where

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I_{Ai}	=	intake of ith constituent from animal product (pCi, rad) (mg/kg-d, chem)
C_{Ai}	=	concentration of ith contaminant in animal product (pCi/g beef or pCi/mL, rad) (mg/kg beef or mg/L milk, chem)
IR	=	ingestion rate (g beef/d or mL milk/d, rad) (kg beef/d or L milk/d, chem)
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

The calculated concentration of U-238 in beef and milk in the example scenario is about 0.00891 pCi/g and 0.0267 pCi/mL, respectively. The exposure frequency is 350 days per year (EF = 350 d/y). The fraction ingested from the contaminated source (FI x IR) is 75 g/d for beef and 300 mL/d for milk. The exposure duration (ED) is 70 years in days. After substituting the appropriate parameter values for beef ingestion into Equation E.III-24, the lifetime intake of U-238 from eating beef ($I_{Ai} = I_{am\ U238}$) is estimated as:

$$I_{am\ U238} = (0.00891\ \text{pCi/g})(75\ \text{g/d})[(350\ \text{d/y})(70\ \text{y/lifetime}) \qquad \text{(E.III-25)}$$

$$I_{am\ U238} = 16{,}372\ \text{pCi/lifetime}$$

After substituting the appropriate parameter values for milk ingestion into Equation E.III-23, the lifetime intake of U-238 from consuming dairy products ($I_{Ai} = I_{ad\ U238}$) is calculated as:

$$I_{ad\ U238} = (0.0267\ \text{pCi/mL})(300\ \text{mL/d})(350\ \text{d/y})(70\ \text{y/lifetime}) \qquad \text{(E.III-26)}$$

$$I_{ad\ U238} = 196{,}245\ \text{pCi/lifetime}$$

The total intake from ingesting meat and dairy products raised on feed and forage grown in air containing U-238 ($I_{aA\ U238}$) is:

$$I_{aA\ U238} = I_{am\ U238} + I_{ad\ U238} \qquad \text{(E.III-27)}$$

$$I_{aA\ U238} = (16{,}372\ \text{pCi/lifetime}) + (196{,}245\ \text{pCi/lifetime})$$

$$I_{aA\ U238} = 212{,}617\ \text{pCi/lifetime}$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they estimate that each additional pCi/m^3 of U-238 in air will produce an incremental lifetime intake of about 213,000 pCi of U-238 via these pathways.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{aA\ U238} = SF_{ing\ i} \times I_{aA\ U238} \qquad \text{(E.III-28)}$$

where

$ILCR_{aA\ U238}$ = ILCR from ingestion of meat or milk downwind of source (r/lifetime)
$SF_{ing\ i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The relationship between air concentration and risk for this receptor, pathway, and radionuclide is determined by the lifetime intake of U-238 from animal products calculated in Equation E.III-27 and substituting the ingestion slope factor for U-238, 2.8×10^{-11} r/pCi, for $SF_{ing\ i}$ into Equation E.IV-28. This yields:

$$ILCR_{aA\ U238} = (2.8 \times 10^{-11}\ \text{r/pCi})(212{,}617\ \text{pCi/lifetime}) \qquad \text{(E.III-29)}$$
$$ILCR_{aA\ U238} = 5.95 \times 10^{-6}\ \text{r/lifetime}$$

Because the exposure model used in this scenario responds linearly to changes in concentration, each additional pCi/m^3 of U-238 in air is predicted to result in a calculated excess risk of 6×10^{-6}.

E.III.2.4 Calculation of an ILCR from a Combination of All Airborne Exposure Pathways

In some situations, a hypothetical resident both inhales air containing suspended material and ingests crops grown in areas of experiencing aerial deposition. The total risks to the same receptor from these two pathways may be calculated as:

$$ILCR_{air\ i} = (I_{ai})(SF_{inh\ i}) + (I_{avi} + I_{aAi})(SF_{ing\ i}) \qquad \text{(E.III-30)}$$

where

$ILCR_{air\ i}$ = ILCR (risk of cancer incidence/lifetime)
I_{ai} = intake from inhaling constituent "i" (pCi/lifetime)
I_{avi} = intake of constituent "i" in food crops from aerial deposition (pCi/lifetime)

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I_{aAi}	=	intake of constituent "i" in animal products from aerial deposition (pCi/lifetime)
$SF_{ing\ i}$	=	Slope factor for ingestion of constituent "i" (r/pCi)
$SF_{inh\ i}$	=	Slope factor for inhalation of constituent "i" (r/pCi)

A farmer living downwind of a plume of U-238 particles has been selected as the example for this calculation. The total intake by inhalation for this hypothetical receptor for each pCi of U-238 per m^3 of air is calculated in Section E.III.1. Similarly, the intake from each pCi of U-238 per m^3 of air from eating vegetables and animal products grown downwind of air emissions are calculated in Sections E.III.1.2 and E.III.1.3. Substituting these values into Equation E.III-30, along with the appropriate HEAST Slope Factors of inhalation and ingestion of uranium, yields:

$$ILCR_{air\ U238} = (115{,}910\ \text{pCi/lifetime})(5.2 \times 10^{-8}\ \text{r/pCi}) + [(1{,}470{,}588\ \text{pCi/lifetime}) + (212{,}617\ \text{pCi/lifetime})](2.8 \times 10^{-11}\ \text{r/pCi}) \quad \text{(E.III-31)}$$

$$ILCR_{air\ U238} = 6.1 \times 10^{-3}\ \text{r/lifetime}$$

The exposure model used in this scenario respond linearly to changes in concentration. Therefore each additional pCi/m^3 of U-238 in air results in a calculated excess risk of 6×10^{-3} r/lifetime to the resident adult from these airborne exposures.

E.III.3 WATER EXPOSURES

The Great Miami River User Scenario is used to demonstrate the calculation of intakes and risks associated with using river water containing U-238. Examples are also included demonstrating the application of the methodology to vinyl chloride.

E.III.3.1 Drinking Water Ingestion Pathway

Ingestion of contaminated drinking water can be a major contributor to environmental intakes of a constituent of potential concern (CPC). An estimate of intake from drinking water is calculated from Equations 7-3 and 7-4 of the Risk Assessment Work Plan Addendum (DOE 1992a). The intake equations are:

$$\text{(radionuclides)}\quad I_{wi} = (C_{wi})(IR)(FI)(ED)(EF) \quad \text{(E.III-32)}$$

$$\text{(chemicals)}\quad I_{wi} = (C_{wi})(IR)(FI)(ED)(EF)/(BW)(AT) \quad \text{(E.III-33)}$$

where

I_{wi}	=	intake of ith contaminant from drinking water (pCi, rad) (mg/kg-d, chem)
C_{wi}	=	i^{th} concentration in water (pCi/L, rad) (mg/L, chem)
IR	=	ingestion rate (L/d)
FI	=	fraction ingested from source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg); and
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y [EPA 1991c]); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

Ingestion of water containing U-238 by a resident adult for a 70-year lifetime is selected for the example calculation. The ingestion rate (IR) is 2 L/d. The exposure frequency is 350 days per year (EF = 350 d/y). The exposure duration (ED) is 70 years. The lifetime intake is given by Equation E.III-32, above. Using the presented parameter values, this becomes:

$$I_{w\,U238} = (C_{w\,U238}\ \text{pCi/L})(2\ \text{L/d})(70\ \text{y})(350\ \text{d/y}) \qquad \text{(E.III-34)}$$
$$I_{w\,U238} = (C_{w\,U238}\ \text{pCi/L})(49{,}000\ \text{L/lifetime})$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each pCi/L of U-238 in water will produce a lifetime intake of 49,000 pCi of U-238 via this one pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{w\,U238} = SF_{ing\,i} \times I_{w\,U238} \qquad \text{(E.III-35)}$$

where

$ILCR_{w\,U238}$	= ILCR from ingestion of drinking water (r/lifetime)
$SF_{ing\,i}$	= Slope factor for ingestion of constituent "i" (r/pCi)

The relationship between water concentration and risk for this receptor, pathway, and r-adionuclide is determined by combining equations E.III-34 and E.III-35 and substituting the ingestion slope factor for U-238, 2.8×10^{-11} r/pCi, for $SF_{ing\,i}$. This yields:

$$ILCR_{w\,U238} = (2.8 \times 10^{-11}\ \text{r/pCi})(C_{w\,U238}\ \text{pCi/L})(49000\ \text{L/lifetime}) \qquad \text{(E.III.36)}$$
$$ILCR_{w\,U238} = (C_{w\,U238}\ \text{pCi/L})(1.4 \times 10^{-6}\ \text{r-L/pCi-lifetime})$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/L of U-238 in water will produce an incremental lifetime cancer risk of about 1 x 10^{-6} via this one pathway.

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E.III.3.2 Incidental Ingestion of Surface Water While Swimming

People living near bodies of water receiving contaminated runoff may accidentally ingest contaminated water while swimming. Intake from incidental ingestion of surface water while swimming is quantified using Equations E.III-32 and E.III-33.

Ingestion of surface water containing U-238 ($C_{w\ U238}$) while swimming has been selected for the example calculation. The ingestion rate (IR) is 0.05 L/h. The exposure time (ET) is 2.6 h/d, the exposure frequency is 7 days per year (EF = 7 d/y), and the exposure duration (ED) is 70 years. The lifetime intake for U-238 is estimated using Equation E.III-32, above. Using the presented parameter values, this becomes:

$$I_{s\ U238} = (C_{w\ U238}\ \text{pCi/L})(0.05\ \text{L/h})(2.6\ \text{h/d})(7\ \text{d/y})(70\ \text{y}) \qquad \text{(E.III-37)}$$

$$I_{s\ U238} = (C_{w\ U238}\ \text{pCi/L})(64\ \text{L/lifetime})$$

Since the exposure models used in this scenario respond linearly to changes in concentration, each pCi/L of U-238 in water will produce a lifetime intake of 64 pCi of U-238 via this one pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{s\ U238} = SF_{ing\ i} \times I_{s\ U238} \qquad \text{(E.III-38)}$$

where

$ILCR_{s\ U238}$	=	ILCR from incidental ingestion of surface water while swimming (r/lifetime)
$SF_{ing\ i}$	=	Slope factor for ingestion of constituent "i" (r/pCi)

The relationship between water concentration and risk for this receptor, pathway, and radionuclide is determined by combining Equations E.III-37 and E.III-38 and substituting the ingestion slope factor for U-238, 2.8 x 10^{-11} r/pCi, for $SF_{ing\ i}$. This yields:

$$ILCR_{s\,U238} = (2.8 \times 10^{-11}\ r/pCi)(64\ pCi/lifetime) \qquad (E.III\text{-}39)$$

$$ILCR_{s\,U238} = 1.8 \times 10^{-9}\ r\text{-}L/pCi\text{-}lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/L of U-238 in water will produce an incremental lifetime cancer risk of about 2×10^{-8} via this one pathway.

E.III.3.3 Volatiles Released by Showering and Other Household Water Uses

The amount of a chemical taken into the body via exposure to volatilization of chemicals from showering is evaluated using the concentration of a chemical in the water source. Intake from the volatilization of chemicals in household water is calculated using the Andelman model presented (EPA 1991f):

$$\text{(radionuclides)}\ I_{wa} = (C_{wi})(K)(IR_i)(EF)(ED) \qquad (E.III\text{-}40)$$

$$\text{(chemicals)}\ I_{wa} = (C_{wi})(K)(IR_i)(EF)(ED)/(BW)(AT) \qquad (E.III\text{-}41)$$

where

I_{wa}	=	intake of volatiles in water from inhalation (pCi, rad)(mg/kg-d,chem)
C_{wi}	=	concentration of constituent "i" in water (mg/L)
K	=	volatilization factor (0.5 L/m^3)
IR	=	indoor inhalation rate (m^3/d)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d); for carcinogens, AT equals (ED) (365 d/y [EPA 1991c]); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

For most metals, and hence most radionuclides in Operable Unit 1, volatilization is not a significant pathway because they do not vaporize at room temperature. The notable radioactive exceptions are the isotopes of radon. Therefore, this pathway is not quantitatively presented for uranium. An example of this pathway is presented for vinyl chloride in Section E.III.3.9.

E.III.3.4 Dermal Contact While Bathing

The estimation of intake of contaminants in water via absorption though the skin is determined using the concentration of a chemical in the water source evaluated. Evaluation of the dermal absorption pathway is performed for adults and children. The amount of a chemical taken into the body upon exposure via dermal contact is referred to as an absorbed dose. The absorbed dose can be calculated using EPA's dermal guidance (EPA 1989a, EPA 1992e, and EPA 1992h):

$$I_{ws} = (DA_{event})(EV)(EF)(ED)(SA)/(BW)(AT) \quad \text{(E.III-42)}$$

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where

I_{ws}	=	Intake though skin from showering (mg/kg-d)
DA_{event}	=	Absorbed dose per event (mg/cm^2-event)
EV	=	Event frequency (event/d)
SA	=	Surface area (cm^2)
EF	=	Exposure frequency (d/y)
ED	=	Exposure duration (y)
BW	=	Body weight (kg)
AT	=	Averaging time (for carcinogens, AT = 25550 d)

DA_{event} can be calculated as:

$$DA_{event} = (C_v)(2)(K_p)[(6)(\tau)(ET)/\pi]^{0.5} \quad \text{if } t_{event}<t^*, \text{ or} \quad \text{(E.III-43)}$$

$$DA_{event} = (C_v)(K_p)[(t_{event})(2)(\tau)(1+3B)]/(1+B) \quad \text{if } t_{event}>t^* \quad \text{(E.III-44)}$$

where

C_v	=	Concentration in the vehicle (mg/L)
K_p	=	Permeability constant (cm/h)
τ	=	Lag time (h)
B	=	Partitioning coefficient (unitless)
t_{event}	=	Time of event (h)
π	=	Pi (3.14)
t^*	=	Time required for steady state absorption to be reached (h)

For showering, the vehicle is domestic water, and for swimming, the vehicle is river water. In either case, C_v equals the concentration in the water (C_w). For most metals, and hence most radionuclides in Operable Unit 1, dermal absorption is not a significant pathway because penetration though the skin is minimal. See Section E.III.3.9 for an example of this pathway using methyl chloride.

E.III.3.5 Irrigation of Vegetables

Eating vegetables irrigated with contaminated water can contribute to the total intake of contaminants by humans. Estimating the magnitude of this intake is a two-step process. First the concentration in the vegetables must be estimated. In the second step, the human intake of constituent is calculated. If measured constituent concentration in plants are not available (e.g. future exposures) this concentration is estimated using Equation 7-9 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The equation is:

$$C_{vwi} = d_w \left[\frac{r_w(1-e^{-\lambda_{di} t_e})}{Y\lambda_w} + \frac{f_w B_{iv(2)} CF_p (1-e^{-\lambda_{di} t_{bw}})}{\rho \lambda_{di}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(E.III-45)}$$

where

C_{wvi}	=	concentration of ith contaminant in plants as a result of irrigating plants with contaminated water (pCi/g, rad) (mg/kg, chem)
λ_{di}	=	effective depletion constant of ith contaminant from first 15 cm inches of soil. This includes radioactive decay, chemical degradation, and leaching (h^{-1}).
λ_w	=	effective depletion constant of ith contaminant on the surface plants also known as the weathering removal rate (h^{-1})
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
$B_{iv(2)}$	=	dry soil to wet plant partitioning coefficient of ith contaminant in food crops (C_{iv}/C_s)
CF_p	=	Dry plant mass to wet plant mass ratio. (0.428 for food crops)
d_w	=	irrigation deposition rate (pCi/m^2-h, rad) (mg/m^2-h, chem)
f_w	=	fraction of year plant is irrigated (unitless)
ρ	=	effective dry surface density of the soil (g/m^2, rad) (kg/m^2, chem)
r_w	=	fraction of water borne material retained on plant surface (unitless)
t_e	=	growing season (h)
t_{bw}	=	duration of irrigation use (h)
t_h	=	duration of period between harvest and consumption (h)
Y	=	agricultural yield (g/m^2, rad) (kg/m^2, chem)

Vegetables irrigated with water containing U-238 ($C_{w\,U238}$) have been selected for the example calculation. The mean irrigation rate (d_w) per unit area is 0.081 L/m^2-h, so the rate of constituent deposition by irrigation is ($C_{w\,U238}$ pCi/L) (0.081 L/m^2-h), and the fraction of the growing season that the plant is irrigated (f_w) is 1. The duration of the study period is 1000 years (t_{bw} = 8.76 x 10^6 h). The fraction of waterborne material retained on the plant surface (r_w) is 0.2. The weathering removal rate (λ_w) is 0.0021 h^{-1}. The dry soil to wet plant partitioning coefficient of U-238 in the reproductive portions of vegetables ($B_{iv(2)}$) is 4 x 10^{-3}. The dry plant mass to wet plant mass ratio is 0.428. The effective dry surface density of the soil is (ρ) 225,000 g/m^2. The agricultural yield is (Y) 1,500 g/m^2. The growing season t_e is 1,440 hours. The period between harvest and consumption (t_h) is 24 hours. The radiological decay constant of U-238 λ_{ri} is 1.77 x 10^{-14} h^{-1}. This value is so small that the $\exp(-\lambda_{ri}\, t_h)$ term approaches a value of 1 (i.e. no significant decay). A value of 1.61 x 10^{-5} is calculated for λ_{Li} using Equation E.III-8 and a Kd of 12 cm^3/g from Appendix D. The effective depletion coefficient (λ_{di}) is calculated from Equation E.III-7 to be 1.61 x 10^{-5}. Substituting these parameter values into Equation E.III-457 and simplifying yields:

$$C_{avi} = (0.081\,pCi/m^2/h)\left[\frac{(0.2)(1-e^{-(0.0021h^{-1})(1440h)})}{(1500\,g/m^2)(0.0021\,h^{-1})} + \frac{(1)(0.004)(0.483)(1-e^{-((1.61x10^{-5}h^{-1})(8760000h))})}{(225000\,g/m^2)(1.61x10^{-5}h^{-1})}\right]$$

(E.III-46)

$$C_{wv\ U238} = 0.00493\ pCi/g$$

Once the constituent's concentration in the vegetables is estimated, the resulting intake by humans can be estimated using Equations E.III-11 or E.III-12. Continuing the example begun in Equation E.III-46, humans ingest vegetables from the study area for a 70-year lifetime. The calculated concentration of U-238 in vegetables and fruit is about 0.00493 pCi/g. The exposure frequency is 350 days out of per year (EF = 350 d/y). The consumption rate of vegetables and fruit grown in the study area is 122 grams per day (FI x IR). The exposure duration (ED) is 70 years per lifetime. The lifetime intake of U-238 from this food supply may be estimated by Equation E.III-11. Using the presented parameter values, this becomes:

$$I_{v\ U238} = (0.00493\ pCi/g)(122\ g/d)(350\ d/y)(70\ y/lifetime) \qquad \text{(E.III-47)}$$

$$I_{v\ U238} = 14{,}736\ pCi/lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, each additional pCi/L of U-238 in water will produce an incremental lifetime intake of 14,736 pCi of U-238 via this one pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{v\ U238} = SF_{ing\ i} \times I_{v\ U238} \qquad \text{(E.III-48)}$$

where

$ILCR_{v\ U238}$ = ILCR from irrigation of vegetables (r/lifetime)

$SF_{ing\ i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The relationship between water concentration and risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake of U-238 eating vegetables and fruit calculated in Equation E.III-47 and the ingestion slope factor for U-238, 2.8 x 10^{-11} r/pCi, for $SF_{ing\ i}$ into Equation E.III-48. This yields:

$$ILCR_{v\,U238} = (2.8 \times 10^{-11}\ r/pCi)(14{,}736\ pCi/lifetime) \qquad \text{(E.III-49)}$$

$$ILCR_{v\,U238} = 4.1 \times 10^{-7}\ r/lifetime)$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/L of U-238 in water will produce an incremental lifetime cancer risk of about 4×10^{-7} via this one pathway.

E.III.3.6 Ingestion of Beef and Dairy Products Produced with River Water

This scenario assumes that river water is used for stock water and irrigation of feed. Animals drinking the water ingest contaminants directly. Plants irrigated with water take up constituents via root uptake and direct deposition onto exposed surfaces by irrigation water. Ingestion of these plants by livestock also contributes to the body burden of these contaminants in the animals. Humans using products from these animals can ingest the contamination contained in them as well.

The magnitude of the contaminant exposure by humans depends, in part, on the concentration of the constituent in the animal products. If measured values are not available (e.g. future exposures), this concentration can be calculated using the methodology set forth in the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The concentration of a contaminant in animal products, such as beef or milk, is estimated using the following equation:

$$C_{Ai} = F_{Ai}[(C_{fi})(Q_f) + (C_{wi})(Q_w)]\, e^{-\lambda_{ri} t_h} \qquad \text{(E.III-50)}$$

where

C_{Ai}	=	concentration of ith contaminant in the animal product (pCi/mL for milk, pCi/g for beef, rad) (mg/L for milk, mg/kg for beef, chem)
C_{fi}	=	concentration of ith contaminant in feed (pCi/g, rad) (mg/kg, chem)
C_{wi}	=	concentration of contaminant in water (pCi/L, rad) (mg/L, chem)
F_{Ai}	=	element (stable) transfer coefficient that relates the daily intake by an animal to the concentration of ith contaminant in an edible portion of the animal product (d/L for milk, d/g for meat)
Q_f	=	consumption rate of contaminated feed by livestock (g/d, rad) (kg/d, chem)
Q_w	=	consumption rate of contaminated stock water by livestock (L/d)
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h	=	duration of period between harvest and consumption (h)

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If measured values for the concentrations of constituents in stored feed are not available (e.g., future exposures), this concentration is estimated using Equation 7-9 from the Risk Assessment Work Plan Addendum (DOE 1992a). The equation is:

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$$C_{vwi} = d_w \left[\frac{r_w(1-e^{-\lambda_w t_e})}{Y\lambda_w} + \frac{f_w CF_p B_{iv(1)}(1-e^{-\lambda_{di} t_{bw}})}{\rho\lambda_{di}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(E.III-51)}$$

where

C_{vwi}	=	concentration of ith contaminant in plants as a result of irrigating plants with contaminated water (pCi/g, rad) (mg/kg, chem)
λ_{di}	=	effective depletion constant of ith contaminant in surface soils due to radioactive decay, chemical degradation, and leaching (h^{-1})
λ_w	=	effective depletion constant of ith contaminant on the surface plants also known as the weathering removal rate (h^{-1})
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
$B_{iv(1)}$	=	dry soil to wet plant partitioning coefficient of ith contaminant (C_{iv}/C_s) in animal feed
CF_p	=	Dry plant mass to wet plant mass ratio for feed and forage (1.0)
d_w	=	irrigation deposition rate (pCi/m^2-h, rad) (mg/m^2-h, chem)
f_w	=	fraction of year plant is irrigated (unitless)
ρ	=	effective dry surface density of the soil (g/m^2)
r_w	=	fraction of water borne material retained on plant surface (unitless)
t_e	=	growing season (h)
t_{bw}	=	duration of irrigation use (h)
t_h	=	duration of period between harvest and consumption (h)
Y	=	agricultural yield (g/m^2)

The soil depletion coefficient is calculated by using equations E.III-7 and E.III-8.

This example assumes that stored feed is irrigated with river water containing U-238. The mean irrigation rate (d_w) per unit area is 0.081 L/m^2-h, so the rate of constituent deposition by irrigation is 0.081 pCi/m^2-h and the fraction of the growing season the plant is irrigated (f_w) is 1. The duration of the study period (t_{bw}) is 1,000 years (8,760,000 h). The fraction of waterborne material retained on the plant surface (r_w) is 0.2. The weathering removal rate (λ_w) is 0.0021 h^{-1}. The dry soil to wet plant partitioning coefficient of U-238 in the reproductive portions of feed ($B_{iv(2)}$) is 8.5 x 10^{-3}. The effective dry surface density of the soil (λ) is 225,000 g/m^2. The agricultural yield (Y) is 800 g/m^2. The growing season (t_e) is 3,312 hours. The period between harvest and consumption (t_h) is 2,160 hours. The radiological decay constant (λ_{ri}) for U-238 is 1.77 x 10^{-14} h^{-1}. This value is so small that the exp($-\lambda_{ri}$ t_h) term

approaches a value of 1 (i.e., no significant decay). A value of 1.61×10^{-5} h^{-1} is calculated for λ_{Li} using Equation E.III-8 and a K_d of 12 cm^3/g (from Appendix D). Substituting these parameter values into Equation E.III-51 and simplifying yields:

$$C_{wvU238}=(0.081\,pCi/m^2/h)\left[\frac{(0.2)(1-e^{-(0.0021h^{-1})(3312h)})}{(800g/m^2)(0.0021\,h^{-1})}+\frac{(1)(0.0085)(1)(1-e^{-(0.0000161h^{-1})(8760000h)})}{(225000g/m^2)(0.0000161\,h^{-1})}\right]$$

(E.III-52)

$$C_{wvU238} = 0.00982 \text{ pCi/g}$$

Once the concentration in stored feed has been estimated, its contribution to constituent levels in beef and dairy products can be calculated using Equation E.III-50. Continuing the example begun in Equation E.III-53, the calculated concentration of U-238 in stored feed attributable to irrigation is about 9.82×10^{-3} pCi/g. In this study, a cow is assumed to consume 25,000 g/d of potentially contaminated feed (Q_f). The plant to beef and plant to milk biotransfer factors for U-238 in cows are 2×10^{-7} d/g ($F_{m\ U238}$) and 6×10^{-7} d/mL ($F_{d\ U238}$), respectively. The time between harvesting and consumption of stored feed is 2,160 hours. The radiological decay constant of U-238 λ_{ri} is 1.77×10^{-14} h^{-1}. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches a value of 1 (i.e. no significant decay) for both meat and milk calculations. Beef cows ingest about 50 L/d of water(Q_{Aw}), while milk cows ingest about 60 L/d.

Substituting parameter values for the beef ingestion scenario in Equation E.III-50 ($C_{Ai} = C_{wm\ U238}$) yields the concentration of U-238 in beef:

$$C_{wm\ U238} = (2.0 \times 10^{-7}\ d/g)[(25000\ g/d)(9.82 \times 10^{-3}\ pCi/g) + (50\ L/d)(1\ pCi/L)] \quad \text{(E.III-53)}$$

$$C_{wm\ U238} = 5.91 \times 10^{-5}\ pCi/g$$

Substituting parameter values for the milk ingestion scenario in Equation E.III-50 ($C_{Ai} = C_{wd\ U238}$) yields. The concentration of U-238 in milk:

$$C_{wd\ U238} = (6.0 \times 10^{-7}\ d/mL)[(25000\ g/d)(9.82 \times 10^{-3}\ pCi/g) + (60\ L/d)(1\ pCi/L)] \quad \text{(E.III-54)}$$

$$C_{wd\ U238} = 1.83 \times 10^{-4}\ pCi/mL$$

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Once the constituent's concentration in the animal product is estimated, the resulting intake by humans can be estimated using Equations E.III-23 and E.III-24. Continuing the example calculation, the farmer ingests beef containing 5.91 x 10^{-5} pCiL/g of U-238 ($C_{wm\ U238}$ in Equation E.III-53) and dairy products containing 1.83 x 10^{-4} pCi/mL of U-238 ($C_{wd\ U238}$ in Equation E.III-54) for each pCi/L of U-238 in water during a 70-year lifetime. The exposure frequency is 350 days per year (EF = 350 d/y). The fractions of beef and dairy products ingested from the contaminated source (FI x IR) are 75 g/d and 300 mL/d, respectively. The exposure duration (ED) is 70 years. The lifetime intake of U-238 from this supply of animal products is given by Equation E.III-23. Substituting the selected parameter values for the beef ingestion scenario, this becomes:

$$I_{wm\ U238} = (5.91 \times 10^{-5}\ \text{pCi/g})(75\ \text{g/d})(350\ \text{d/y})(70\ \text{y/lifetime}) \qquad \text{(E.III-55)}$$

$$I_{wm\ U238} = 109\ \text{pCi/lifetime}$$

Substituting the selected parameter values for the dairy products ingestion scenario, this becomes:

$$I_{wd\ U238} = (1.83 \times 10^{-4}\ \text{pCi/mL})(300\ \text{mL/d})(350\ \text{d/y})(70\ \text{y/lifetime}) \qquad \text{(E.III-56)}$$

$$I_{wd\ U238} = 1{,}345\ \text{pCi/lifetime}$$

Because the exposure models used in this scenario respond linearly to changes in concentration, each pCi/L of U-238 in water will produce an incremental lifetime intake of 109 pCi U-238 via the beef ingestion pathway and 1345 pCi of U-238 via the milk ingestion pathway.

The ILCR to this receptor for these pathways from this radionuclide is:

$$ILCR_{m\ U238} = SF_{ing\ i} \times I_{m\ U238}\ \text{(beef)}$$

or

$$ILCR_{d\ U238} = SF_{ing\ i} \times I_{d\ U238}\ \text{(dairy)} \qquad \text{(E.III-57)}$$

where

$ILCR_{m\ U238}$ or $ILCR_{d\ U238}$ = ILCR from ingestion of beef or dairy products produced with river water (r/lifetime)

$SF_{ing\ i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The relationship between air concentration and risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake of U-238 calculated in Equations E.III-55 and E.III-56 and the ingestion slope factor for U-238, 2.8 x 10^{-11} r/pCi, for $SF_{ing\ i}$ into Equation E.III-57. This yields:

Beef:

$$ILCR_{m\ U238} = (2.8 \times 10^{-11}\ r/pCi)(109\ pCi/lifetime) \qquad \text{(E.III-58)}$$
$$ILCR_{m\ U238} = 3.1 \times 10^{-9}\ r/lifetime$$

Dairy:

$$ILCR_{d\ U238} = (2.8 \times 10^{-11}\ r/pCi)(1345\ pCi/lifetime) \qquad \text{(E.III-59)}$$
$$ILCR_{d\ U238} = 3.8 \times 10^{-8}\ r/lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/L of U-238 in water will produce an incremental lifetime cancer risk of about 3 x 10^{-9} via the beef pathway, and 4 x 10^{-8} via the milk pathway.

E.III.3.7 Ingestion of Fish

If measured concentrations of a constituent in fish are unknown, they are estimated using Equation 7-19 of the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$C_{Fi} = (C_{Wi})(BCF_{Fi})\, e^{-\lambda_{ri} t_h} \qquad \text{(E.III-60)}$$

where

C_{Fi}	=	concentration of the ith constituent in fish (pCi/kg, rad) (mg/kg, chem)
C_{wi}	=	concentration of the ith constituent in surface water (pCi/L, rad) (mg/L, chem)
BCF_{Fi}	=	fish bioconcentration factor (pCi/g fish per pCi/L, rad) (mg/kg fish per mg/L, chem)
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h	=	duration of period between harvest and consumption (h)

Fish in water containing U-238 have been selected for the example calculation. The biotransfer factor from water to fish ($BCF_{F\ U238}$) is 0.002 L/g (USNRC 1984)). The period between harvest and consumption (t_h) is 24 hours. The radiological decay constant of U-238 (λ_{ri}) is 1.77 x 10^{-14} h^{-1}. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches a value of

1 (i.e. no significant decay). Substituting these parameter values into Equation E.III-60 produces:

$$C_{F\,U238} = (1\ pCi/L)(0.002\ L/g)(1) \qquad \text{(E.III-61)}$$

$$C_{F\,U238} = 0.002\ pCi/g$$

Once the concentration in fish has been estimated, intake can be calculated as:

$$\text{(radionuclides) } I_{Fi} = (C_{Fi})(IR)(FI)(ED)(EF) \qquad \text{(E.III-62)}$$

$$\text{(chemicals) } I_{Fi} = (C_{Fi})(IR)(FI)(ED)(EF)/(BW)(AT) \qquad \text{(E.III-63)}$$

where

I_{Fi}	=	intake of ith constituent from fish ingestion (pCi, rad) (mg/kg-d, chem)
C_{Fi}	=	concentration of ith constituent in fish (pCi/g, rad) (mg/kg, chem)
IR	=	ingestion rate (g/d, rad) (kg/g, chem)
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

Continuing the previous example, it is assumed that a recreational fisherman ingests 54 grams of fish per day (IR x FI) from the study area for 70 years (ED). The exposure frequency (EF) is 350 d/y. The concentration of U-238 in fish from Equation E.III-61 is 0.002 pCi/g. Substituting these parameters into Equation E.III-62 yields:

$$I_{F\,U238} = (0.002\ pCi/g)(54\ g/d)(350\ d/y)\ (70\ y/lifetime) \qquad \text{(E.III-64)}$$

$$I_{F\,U238} = 2{,}646\ pCi/lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, each additional pCi/L of U-238 present in water will produce an incremental lifetime intake of 2,646 pCi of U-238 via this one pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{F\,U238} = SF_{ing\,i} \times I_{F\,U238} \qquad \text{(E.III-65)}$$

where

$ILCR_{F\,U238}$ = ILCR from ingestion of fish (r/lifetime)
$SF_{ing\,i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake calculated in Equation E.III-64 and the ingestion slope factor for U-238, 2.8×10^{-11} r/pCi, for $SF_{ing\,i}$ into Equation E.III-65. This yields:

$$ILCR_{F\,U238} = (2.8 \times 10^{-11}\ r/pCi)(C_{w\,U238}\ pCi/L)(2646\ L/lifetime) \qquad \text{(E.III-66)}$$

$$ILCR_{F\,U238} = 7.4 \times 10^{-8}\ r/lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/L of U-238 in water will produce an incremental lifetime cancer risk of about 7×10^{-8} via this pathway.

E.III.3.8 Calculation of ILCR for Great Miami River User Scenario

In this scenario, a hypothetical farmer uses river water for drinking, domestic uses, irrigation, stock water, and recreation (fishing and swimming). The total risks to the same receptor from these exposure pathways may be calculated as:

$$ILCR_{water\,i} = (I_{wi} + I_{wvi} + I_{wmi} + I_{wdi} + I_{wsi} + I_{wFi} + I_{wbi} + I_{wsia}) \times SF_{ing\,i} + (I_{wgi} \times SF_{inh\,i}) \qquad \text{(E.III-67)}$$

where

$ILCR_{water\,i}$	=	incremental Lifetime Cancer Risk (risk of cancer incidence/lifetime)
I_{wi}	=	intake from drinking water (pCi/lifetime)
I_{wvi}	=	intake from ingesting vegetables and fruit (pCi/lifetime)
I_{wmi}	=	intake from ingesting meat (pCi/lifetime)
I_{wdi}	=	intake from ingesting dairy products (pCi/lifetime)
I_{wsi}	=	intake from incidental ingestion while swimming (pCi/lifetime)
I_{wFi}	=	intake from eating fish (pCi/lifetime)
I_{wbi}	=	intake from absorption while bathing (pCi/lifetime)
I_{wsia}	=	intake from absorption while swimming (pCi/lifetime)
I_{wgi}	=	intake from inhalation while bathing (pCi/lifetime)
$SF_{ing\,i}$	=	HEAST slope factor for ingestion of constituent i (r/pCi)
$SF_{inh\,i}$	=	HEAST slope factor for inhalation of constituent i (r/pCi)

A farmer living adjacent to the Great Miami River has been selected as the example for this calculation. The total intake for this hypothetical receptor for each pCi/L of U-238 in water

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from these pathways have been calculated in Sections E.III.3.1 though E.III.3.8. Substituting these values into Equation E.III-67, along with the appropriate HEAST slope factors for ingestion and inhalation of uranium, yields:

$$ILCR_{water\ U238} = \{[(49000\ pCi/lifetime) + (64\ pCi/lifetime) + (14736\ pCi/lifetime) + (109\ pCi/lifetime) + (1345\ pCi/lifetime) + (2646\ pCi/lifetime)] \times 2.8 \times 10^{-11}\ r\text{-}pCi \quad \text{(E.III-68)}$$

$$ILCR_{water\ U238} = 1.9 \times 10^{-6}\ r\text{-}/lifetime)$$

The exposure models used in this combined pathway scenario respond linearly to changes in concentration. Therefore, each additional pCi/L of U-238 present in Great Miami River water will produce an incremental lifetime cancer risk of about 2×10^{-6} r-pCi/L-lifetime from the water pathways investigated.

E.III.3.9 Risk Calculations for Vinyl Chloride in Water

An additional example has been prepared to demonstrate the application of the methodology to vinyl chloride exposures to the resident farmer from the drinking water, dermal contact, and volatilization pathways. The example ends with the calculation of one aggregate risk, which combines the exposures from these three pathways.

Drinking Water

The equation used to estimate intake from drinking water is adapted from EPA guidance (EPA 1989a).

$$I_{wd} = (C_w)(IR_o)(ED)(EF)(FI)/(BW)(AT) \quad \text{(E.III-69)}$$

where

I_{wd}	=	Intake from drinking water (mg/kg-d)
C_w	=	Concentration in water (mg/L)
IR_o	=	Ingestion rate (2 L/d)
EF	=	Exposure frequency (350 d/y)
ED	=	Exposure duration (70 y)
FI	=	Fraction ingested from the contaminated source (1)
BW	=	Body weight (70 kg)
AT	=	Averaging time (for carcinogens, AT = 25,550 d)

The relationship of concentration to intake for this receptor, pathway, and chemical is determined by substituting the constants listed above into Equation E.III.69:

$$I_{wd} = (1\ mg/L)(2\ L/d)(70\ y)(350\ d/y)(1)/[(70kg)(25{,}550\ d)] \quad \text{(E.III-70)}$$
$$I_{wd} = 0.027\ mg/kg\text{-}d$$

Incremental lifetime risk to this receptor, for this pathway, from this chemical is:

$$ILCR_d = SF_o \times I_{wd} \quad \text{(E.III-71)}$$

where

$ILCR_d$ = Incremental lifetime cancer risk from drinking water (unitless)
I_{wd} = Intake from drinking water (mg/kg-d)
SF_o = Slope factor (1.9 r-kg-d/mg-lifetime)

The risk for this receptor, pathway, and chemical is determined by substituting the lifetime intake calculated in Equation E.III-70 and vinyl chloride's oral slope factor (1.9 r-kg-d/mg-lifetime) for SF_o into Equation E.III-71. This yields:

$$ILCR_d = (1.9\ r\text{-}kg\text{-}d/mg\text{-}lifetime)(0.027\ mg/kg\text{-}d) \quad \text{(E.III-72)}$$
$$ILCR_d = 0.051\ r/Lifetime$$

Thus, each additional mg/L of vinyl chloride in water will yield a calculated excess risk of 5×10^{-2} for this receptor and pathway.

Volatilization

Intake from volatilization of chemicals in household water is calculated using the Andelman model (EPA 1991b).

$$I_{wa} = (C_w)(K)(IR_i)(EF)(ED)/(BW)(AT) \quad \text{(E.III-73)}$$

where

I_{wa} = Intake from inhaling chemicals volatilized from water to air (mg/kg-d)
C_w = Concentration in water (mg/L)
K = Volatilization factor (0.5 L/m^3)
IR_i = Inhalation rate (15 m^3/d)
EF = Exposure frequency (350 d/y)
ED = Exposure duration (70 y)

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BW = Body weight (70 kg)
AT = Averaging time (for carcinogens, AT = 25,550 d)

Since t_{event} is less that t* for this exposure, the intake of this chemical by this receptor via this pathway is calculated by substituting the constants listed above into Equation III-73:

$$I_{wa} = (1\ mg/L)(0.5\ L/m^3/d)(15\ m^3/d)(350\ d/y)(70\ y)/(70\ kg)(25{,}550\ d)$$
$$I_{wa} = 0.10\ mg/kg\text{-}d \qquad \text{(E.III-74)}$$

The Incremental Lifetime Cancer Risk to this receptor, for this pathway, from this chemical is:

$$ILCR_v = SF_i \times I_{wa} \qquad \text{(E.III-75)}$$

where

$ILCR_v$ = Incremental lifetime cancer risk from volatilization (unitless)
I_{wa} = Intake from drinking water (mg/kg-d)
SF_i = Slope factor (0.3 r-kg-d/mg-lifetime)

The risk for this receptor, pathway, and chemical is determined by substituting the lifetime intake calculated by Equation E.III-74 and the inhalation slope factor of vinyl chloride for SF_i into Equation E.III-75. This yields:

$$ILCR_v = (0.3\ r\text{-}kg\text{-}d/mg\text{-}lifetime)(0.10\ mg/d\text{-}kg) \qquad \text{(E.III-76)}$$
$$ILCR_v = 0.030\ r/lifetime$$

Thus, each additional mg/L of vinyl chloride in water will yield a calculated excess risk of 3 x 10^{-2} r/lifetime for this receptor and pathway.

Dermal Contact:

The following sample calculation shows the method used to quantify exposure via dermal contact with water (i.e. from swimming, showering, bathing, etc.) (EPA 1989a, 1992b, 1992c). In the example given below, dermal contact with household water containing vinyl chloride is calculated.

$$I_{ws} = (DA_{event})(EV)(EF)(ED)(CF)(SA)/(BW)(AT) \qquad \text{(E.III-77)}$$

where

I_{ws} = Intake though skin from showering or bathing (mg/kg-d)
DA_{event} = Absorbed dose per event (mg/cm^2-event)
EV = Event frequency (event/d)
SA = Surface area (cm^2)
EF = Exposure frequency (d/y)
ED = Exposure duration (y)
CF = Conversion factor (0.001 L/cm^3)
BW = Body weight (kg)
AT = Averaging time (for carcinogens, AT = 25,550 d)

DA_{event} can be calculated as:

$$DA_{event} = (C_w)(2)(K_p)[(6)(TAO)(t_{event})/\pi]^{0.5} \text{ if } t_{event} < t^*, \text{ or}$$
$$DA_{event} = (C_w)(K_p)\{[(t_{event})+(2)(TAO)(1+3B)]/(1+B) \text{ if } t_{event} > t^*$$

where

C_w = Concentration in water (mg/L)
K_p = Permeability constant (0.0073 cm/h)
TAO = Lag time (0.21 h)
B = Partitioning coefficient (unitless)
t_{event} = Time of event (0.25 h)
π = Pi (3.14)
t^* = Time to steady state conditions (0.5)

For showering, the vehicle is domestic water, and for swimming the vehicle is river water. In either case, C_w equals concentration in the water (C_w).

The intake for this receptor, pathway, and chemical is determined by substituting the constants listed above into Equation E.III-77:

$$I_{ws} = (1 \text{ mg/L})(2)(0.0073 \text{ cm/h})[(6)(0.21 \text{ h})(0.25 \text{ h})/(3.14)]^{0.5}$$
$$\times (1 \text{ event/d})(350 \text{ d/y})(70 \text{ y})(20{,}000 \text{ cm}^2)(0.001 \text{ L/cm}^3)/(70 \text{ kg})(25{,}550 \text{ d})$$
$$I_{ws} = 0.00127 \text{ mg/kg-d} \qquad \text{(E.III-78)}$$

Incremental lifetime risk to this receptor, for this pathway, from this chemical is:

$$ILCR_s = SF_s \times I_{ws} \qquad \text{(E.III-79)}$$

where

$ILCR_s$ = Incremental lifetime cancer risk from dermal exposures (unitless)
I_{ws} = Intake though skin from showering or bathing (mg/kg-d)
SF_s = Dermal slope factor (1.9 r-kg-d/mg-lifetime)

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SF_s is derived by dividing the oral slope factor (1.9 r-kg-d/mg-lifetime) by the GI absorption factor for vinyl chloride (0.9), yielding a value for SF_s of 2.1 r-kg-d/mg-lifetime. The relationship between intake and risk for this receptor, pathway, and chemical is determined by combining Equations E.III-78 and E.III-79 and substituting the dermal slope factor of vinyl chloride for SF_s. This yields:

$$ILCR_s = (2.1 \text{ r-kg-d/mg-lifetime})(0.013 \text{ mg/kg-d}) \qquad \text{(E.III-80)}$$
$$ILCR_s = 0.0027 \text{ r/lifetime}$$

Thus, each mg/L of vinyl chloride in water will yield a calculated excess risk of about 3×10^{-3} for this receptor and pathway.

Equations E.III-70, E.III-74, and E.III-78 may be used to calculate the incremental lifetime risk of cancer incidence to a resident adult from exposures related to drinking water, inhalation of volatiles from household water, or dermal contact with water for a given concentration of vinyl chloride in water. The risks from these pathways are additive to a receptor experiencing more than one of them. The combined risks from all three of these pathways ($ILCR_t$) is calculated by adding these risks together:

$$ILCR_t = ILCR_d + ILCR_v + ILCR_s \qquad \text{(E.III-81)}$$
$$ILCR_t = (0.051 \text{ r/lifetime}) + (0.030 \text{ r/lifetime}) + (0.0027 \text{ r/lifetime})$$
$$ILCR_t = 0.084 \text{ r/lifetime}$$

The calculated excess risk to the resident adult from each additinal pCi/L of vinyl chloride in water from these three pathways is calculated to be about 8×10^{-2}/lifetime.

E.III.4 SOIL AND SEDIMENT EXPOSURES

The on-property resident RME is used to illustrate the calculation of risks associated with U238 in soil.

E.III.4.1 Incidental Ingestion of Soil or Sediment

Evaluation of the soil/sediment ingestion pathway is performed using Equations 7-7 and 7-8 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$\text{(radionuclides)} \quad I_{si} = (C_{si})(IR)(ED)(EF)(FI) \qquad \text{(E.III-82)}$$
$$\text{(chemicals)} \quad I_{si} = (C_{si})(IR)(CF)(FI)(EF)(ED)/(BW)(AT) \qquad \text{(E.III-83)}$$

where

I_{si}	=	intake from soil or sediment for constituent i (pCi, rad) (mg/kg-d, chem)
C_{si}	=	concentration of constituent i in soil or sediment (pCi/g, rad) (mg/kg, chem)
IR	=	ingestion rate (g/d, rad) (kg/d, chem)
CF	=	conversion factor 10^{-6} kg/mg
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (d/y)
ED	=	exposure duration (y)
BW	=	body weight (kg)
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

Incidental ingestion of soil by the hypothetical on-property receptor has been selected to illustrate how intakes via the soil ingestion pathway are estimated. The time weighted average annual ingestion rate of soil over a 70 year lifetime from the study area (IR x FI) is about 0.18 g/d. The exposure frequency is 350 days per year (EF = 350 d/y), and the exposure duration (ED) is 70 y/lifetime. Substituting these parameter values into Equation E.III-82 yields:

$$I_{s\,U238} = (1\ \text{pCi/g})(0.18\ \text{g/d})(350\ \text{d/y})(70\ \text{y/lifetime}) \qquad \text{(E.III-84)}$$
$$I_{s\,U238} = 4{,}410\ \text{pCi/lifetime}$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they estimate that each additional pCi/g of U-238 in soil will produce an incremental lifetime intake of about 4,410 pCi of U-238 via this pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{s\,U238} = SF_{ing\,i} \times I_{s\,U238} \qquad \text{(E.III-85)}$$

where

$ILCR_{s\,U238}$ = ILCR from incidental ingestion of soil or sediment (r/lifetime)

$SF_{ing\,i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake of U-238 calculated in Equation E.III-84 and the ingestion slope factor for U-238, 2.8 x 10^{-11} r/pCi, for $SF_{ing\,i}$ into Equation E.III-85. This yields:

$$ILCR_{s\,U238} = (2.8 \times 10^{-11}\ \text{r/pCi})(4{,}410/\text{lifetime}) \qquad \text{(E.III-86)}$$

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$$ILCR_{s\,U238} = (C_{s\,U238}\ pCi/g)(1.2 \times 10^{-7}\ r\text{-}g/pCi\text{-}lifetime)$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/g of U-238 in soil will produce an incremental lifetime cancer risk of about 1×10^{-7} via this pathway.

E.III.4.2 Dermal Contact with Soil or Sediment

Dermal absorption may also occur upon contact with contaminated soil and sediment and is calculated using Equation 7-23 of the FEMP Risk Assessment Work Plan Addendum (DOE 1992a):

$$AB_{si} = (C_{si})(CF)(SA)(AF)(ABS)(ED)(EF)/(BW)(AT) \qquad \text{(E.III-87)}$$

where

AB_{si}	=	amount of ith constituent absorbed during contact with soil or sediment (mg/kg-d)
C_{si}	=	concentration of ith constituent in soil or sediment (mg/kg)
SA	=	skin surface area available for contact (cm^2/event)
AF	=	skin adherence factor (mg/cm^2)
ABS	=	absorption factor (unitless)
CF	=	conversion factor; (10^{-6} kg/mg)
ED	=	exposure duration (y)
EF	=	exposure frequency (event/y)
BW	=	body weight (kg)
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/y); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/y)

For most metals, dermal absorption is not a significant pathway because penetration though the skin is minimal. These example calculations are being performed for U-238, a metal. Hence, exposures via this pathway are not quantitatively presented for this example.

E.III.4.3 Ingestion of Vegetables Grown in Contaminated Soil

Plants grown in contaminated soil take up contaminants via root uptake. Ingestion of these plants by humans contributes to the total intake of contaminants by humans. Estimating the magnitude of this intake is a two step process. First, concentrations in the plants are estimated. Human intake of constituents in vegetables is then estimated in the second step. If measured plan concentrations are not available (e.g. future exposures), concentrations in the plants are estimated using Equation 7-11 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The equation is:

$$C_{svi} = (C_{si})B_{iv(2)}CF_p e^{-\lambda_{ri} t_h} \qquad \text{(E.III-88)}$$

where

C_{svi} = concentration of ith contaminant in food crops (pCi/g, rad) (mg/kg, chem)
C_{si} = concentration of ith contaminant in soil (pCi/g, rad) (mg/kg, chem)
$B_{iv(2)}$ = dry soil to dry plant partitioning coefficient of ith contaminant in food crops (C_{iv}/C_s)
CF_p = dry plant mass to wet plant mass ratio (unitless)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h = duration of period between harvest and consumption (h)

Vegetable and fruits grown in soil containing U-238 are selected to illustrate how contaminant concentrations in plants can be estimated from contaminant concentrations in soil. The dry soil to dry plant partitioning coefficient of U-238 in the reproductive portions of vegetables and fruits ($B_{iv(2)}$) is 4 x 10^{-3}. The dry plant mass to wet plant mass ratio is 0.428 (Baes and Sharp, 1984). The period between harvest and consumption (t_h) for vegetables is 24 hours, and 720 hours for fruit (DOE, 1992a). The radiological decay constant of U-238 (λ_{ri}) is 1.77 x 10^{-14} y^{-1}. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches a value of 1 (i.e. no significant decay). Substituting these parameter values into Equation E.III-88 and simplifying yields:

$$C_{sv\ U238} = (1\ pCi/g_{soil})(0.428)(4 \times 10^{-3}\ g_{soil}/g_{plant})(1) \qquad \text{(E.III-89)}$$
$$C_{sv\ U238} = 1.71 \times 10^{-3}\ pCi/g_{plant}$$

Once the concentration in crops has been estimated, the quantity ingested by the on-property resident can be calculated using Equations E.III-11 or E.III-12. Continuing the previous example, the calculated concentration of U-238 in crops ($C_{sv\ U238}$ in Equation E.III-89) is calculated to be 0.00171 pCi/g. The exposure frequency is 350 days per year (EF = 350 d/y). The consumption rate of vegetables and fruit grown in the study area is 122 grams per day (FI x IR). The exposure duration (ED) is 70 years. Substituting these parameter values into Equation E.III-11 and solving produces a lifetime ingestion via vegetables ($I_{sv\ U238}$) of:

$$I_{sv\ U238} = (0.00171\ pCi/g_{plant})(122\ g_{plant}/d)(70\ y/lifetime)(350d/y) \qquad \text{(E.III-90)}$$
$$I_{sv\ U238} = 5{,}111\ pCi/lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they estimate that each additional pCi/L of U-238 in water will produce an incremental lifetime intake of 5,111 pCi of U-238 via this pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{sv\ U238} = SF_{ing\ i} \times I_{sv\ U238} \qquad \text{(E.III-91)}$$

where

$ILCR_{sv\ U238}$ = ILCR from ingestion of vegetables grown in contaminated soil (r/lifetime)
$SF_{ing\ i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake of U-238 from eating vegetable and fruit calculated in Equation E.III-90 and the ingestion slope factor for U-238, 2.8×10^{-11} r/pCi, for $SF_{ing\ i}$ into Equation E.III-91. This yields:

$$ILCR_{sv\ U238} = (2.8 \times 10^{-11}\ \text{r/pCi})(5{,}111\ \text{pCi/lifetime}) \qquad \text{(E.III-92)}$$
$$ILCR_{sv\ U238} = 1.3 \times 10^{-7}\ \text{r/lifetime}$$

Because the exposure models used in this scenario respond linearly to changes in concentration, they predict that each additional pCi/g of U-238 in soil will produce an incremental lifetime cancer risk of about 1×10^{-7} via this pathway.

E.III.4.4 Ingestion of Meat or Milk

This scenario assumes that livestock is raised on contaminated soil. Feed and forage grown on contaminated soils take up constituents via root uptake. Ingestion of these plants by livestock contributes to the body burden of these contaminants in the animals. In addition to intake from contaminated feed and forage, cows may receive a significant intake from soil ingestion if the soil is also a source of contamination (Zach and Mayoh 1984). Humans using products from these animals can be exposed to the contamination contained in them.

The magnitude of the contaminant exposure by humans depends, in part, on the concentration of the constituent in the animal products. If measured values are not available (e.g. future exposures) this concentration can be calculated using the methodology set forth in the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The concentration of a contaminant in animal products, such as beef or milk, is estimated using the following equation:
where

$$C_{Ai} = F_{Ai}[(C_{fi})(Q_f) + (C_{gi})(Q_g) + (C_{Si})(Q_S)]\, e^{-\lambda_{ri} t_h} \qquad \text{(E.III-93)}$$

C_{Ai} = concentration of ith contaminant in the animal product, (pCi/L for milk, pCi/g for beef, rad) (mg/L for milk, mg/kg for beef, chem)
C_{si} = concentration of contaminant in soil (pCi/g, rad) (mg/kg, chem)
C_{gi} = concentration of ith contaminant in forage (pCi/g, rad) (mg/kg, chem)
C_{fi} = concentration of ith contaminant in feed (pCi/g, rad) (mg/kg, chem)
F_{Ai} = element (stable) transfer coefficient that relates the daily intake by an animal to the concentration of ith contaminant in an edible portion of the animal product (d/L for milk, d/g for beef) (d/L for milk, d/kg for beef)
Q_g = consumption rate of contaminated forage (pasture grass) (g/d, rad) (kg/d, chem)
Q_s = consumption rate of soil by livestock (g/d, rad) (kg/d, chem)
Q_f = consumption rate of contaminated feed by an animal (g/d, rad) (kg/d, chem)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h = duration of period between harvest and consumption (h)

If measured values for feed and forage are not available (e.g. future exposures), the concentration in these plants that is attributable to direct uptake from soil is estimated using Equation 7-11 from the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The equation is:

$$C_{s(p)i} = (C_{Si})\, B_{iv(1)}\, CF_p\, e^{-\lambda_{ri} t_h} \qquad \text{(E.III-94)}$$

where

$C_{s(p)i}$ = concentration of ith contaminant in the plant, where p = g is forage, and p = f is stored feed (pCi/g, rad) (mg/kg, chem)
C_{si} = concentration of ith contaminant in soil (pCi/g, rad) (mg/kg, chem)
$B_{iv(1)}$ = dry soil to dry plant partitioning coefficient of ith contaminant in forage (C_{sgi}/C_{si})
CF_p = dry plant mass to wet plant mass ratio (unitless)
λ_{ri} = radioactive or chemical decay constant of ith contaminant (h^{-1})
t_h = duration of period between harvest and consumption (h)

The concentration of U-238 in plants grown in soil U-238 ($C_{s(p)\ U238}$) has been selected to illustrate how contaminant concentrations in feed and forage can be estimated from contaminant concentrations in soil. The dry soil to wet plant partitioning coefficient of U-238 in feed and forage ($B_{iv(1)}$) is 8.5×10^{-3} g_{soil}/g_{plant}. The periods between harvest and consumption (t_h) of forage and stored feed are 0 hours and 2160 hours, respectively. The radiological decay constant of U-238 λ_{ri} is 1.77×10^{-14} h^{-1}. This value is so small that the

$\exp(-\lambda_{ri}\ t_h)$ term approaches a value of 1 (i.e. no significant decay) for both feed and forage calculations. Substituting these parameter values into Equation E.III-88 yields:

$$C_{s(g)\ U238} = C_{s(f)\ U238} = (1\ pCi/g_{soil})(8.5 \times 10^{-3}\ g_{soil}/g_{plant})(1) \qquad \text{(E.III-95)}$$
$$C_{s(g)\ U238} = C_{s(f)\ U238} = 8.5 \times 10^{-3}\ pCi/g_{plant}$$

Once the concentration in vegetation has been estimated, concentrations in the animal product can be calculated using Equation E.III-93. Continuing the example begun in Equation E.III-94, the calculated concentration of U-238 in feed and forage attributable to soil uptake ($C_{sf\ U238}$ and $C_{sg\ U238}$ in Equation E.III-88) is about $8.5 \times 10^{-3}\ pCi_l/g_{plant}$. The dry plant mass to wet plant mass ratio is 1.0. In this study, cows consume 25,000 g/d of potentially contaminated forage (Q_g), 25,000 g/d of potentially contaminated feed (Q_f), and 500 g/d of potentially contaminated soil (Q_s). The plant to beef and plant to milk biotransfer factors for U-238 in cows are 2.0×10^{-7} d/g (F_{mi}) and 6.0×10^{-7} d/mL (F_{di}), respectively. The times between harvesting and consumption (t_h) of meat and milk are 24 hours and 480 hours, respectively. The radiological decay constant of U-238 λ_r is $1.77 \times 10^{-14}\ h^{-1}$. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches a value of 1 (i.e. no significant decay) for both meat and milk calculations.

Substituting the parameter values presented for the beef cattle scenario in Equation E.III-93 yields a meat concentration ($C_{sm\ U238}$) of:

$$\begin{aligned} C_{sm\ U238} &= (2.0 \times 10^{-7}\ d/g_{meat})[(8.5 \times 10^{-3} pCi/g_{plant})(25000\ g_{plant}/d) \\ &\quad + (8.5 \times 10^{-3}\ pCi/g_{plant})(25000\ g_{plant}/d) + (1\ pCi/g_{soil})(500\ g_{soil}/d)] \qquad \text{(E.III-96)} \\ C_{sm\ U238} &= 0.000185\ pCi/g_{meat} \end{aligned}$$

Substituting the parameter values presented for the dairy scenario in Equation E.III-93 yields a milk concentration ($C_{sd\ U238}$) of:

$$\begin{aligned} C_{sd\ U238} &= (6.0 \times 10^{-7}\ d/mL_{milk})[(8.5 \times 10^{-3}\ pCi/g_{plant})(25000\ g_{plant}/d) \\ &\quad + (8.5 \times 10^{-3}\ pCi/g_{plant})(25000\ g_{plant}/d) + 1\ pCi/g_{soil})(500\ g_{soil}/d)] \qquad \text{(E.III-97)} \\ C_{sd\ U238} &= 0.000555\ pCi/mL_{milk} \end{aligned}$$

Once the concentrations of U-238 in animal products are known, the magnitude of intake by the on-property resident can be estimated. The farmer ingests beef containing 0.000185 pCi/g_{meat} of U-238 ($C_{sm\ U238}$ in Equation E.III-96) and dairy products containing 0.000555

pCi/mL$_{milk}$ pCi/g of U-238 ($C_{sd\ U238}$ in Equation E.III-97) for each pCi/g of U-238 in soil over a 70 year lifetime. The exposure frequency is 350 days per year (EF = 350 d/y). The fraction ingested from the contaminated source (FI x IR) is 75 g/d for beef, and 300 mL/d for dairy products. The exposure duration (ED) is 25,550 days. The lifetime intake of U-238 from this meat supply is calculated using Equation E.III-23.

Substituting the appropriate parameter values for the beef ingestion scenario produces a lifetime ingestion via meat ($I_{sm\ U238}$) of:

$$I_{sm\ U238} = (0.000185\ pCi/g_{meat})(75\ g_{meat}/d)(350\ d/y)(70\ y/lifetime) \qquad \text{(E.III-98)}$$

$$I_{sm\ U238} = 340\ pCi/lifetime)$$

Substituting the appropriate parameter values for the dairy product ingestion scenario produces a lifetime ingestion via dairy products ($I_{sd\ U238}$) of:

$$I_{sd\ U238} = (0.000555\ pCi/mL_{milk})(300\ mL_{milk}/d)(350\ d/y)(70\ y/lifetime) \qquad \text{(E.III-99)}$$

$$I_{sd\ U238} = (4079\ pCi/lifetime)$$

Because the exposure models used in this scenario respond linearly to changes in concentration, each additional pCi/g of U-238 in soil will produce an incremental lifetime intake of 340 pCi of U-238 via the beef ingestion pathway and an intake of 4079 pCi of U-238 via the dairy ingestion pathway.

The ILCR to this receptor for this pathway from this radionuclide is:

$$ILCR_{m\ U238} = SF_{ing\ i} \times I_{m\ U238}\ \text{(beef)}$$

or

$$ILCR_{d\ U238} = SF_{ing\ i} \times I_{d\ U238}\ \text{(dairy)} \qquad \text{(E.III-100)}$$

where

$ILCR_{m\ U238}$ or $ILCR_{d\ U238}$ = ILCR from ingestion of beef or dairy products (r/lifetime)
$SF_{ing\ i}$ = Slope factor for ingestion of constituent "i" (r/pCi)

The relationship between soil concentration and risk for this receptor, pathway, and radionuclide is determined by substituting the lifetime intake of U-238 from consuming beef

and dairy products calculated by Equations E.III-98 and E.III-99 and the U_{238} ingestion slope factor, 2.8 x 10^{-11} r/pCi, for $SF_{ing\ i}$ into Equation E.III-100. This yields:

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Beef:

$$ILCR_{m\ U238} = (2.8 \times 10^{-11}\ r/pCi)(340\ pCi/lifetime) \quad \text{(E-III.101)}$$
$$ILCR_{m\ U238} = 9.5 \times 10^{-9}\ r\text{-}g/pCi\text{-}lifetime$$

Dairy:

$$ILCR_{d\ U238} = (2.8 \times 10^{-11}\ r/pCi)(4079\ pCi/lifetime) \quad \text{(E-III.102)}$$
$$ILCR_{d\ U238} = 1.1 \times 10^{-7}\ r\text{-}g/pCi\text{-}lifetime$$

The exposure models used in this scenario respond linearly to changes in concentration. Therefore, each additional pCi/g of U-238 in soil will produce an incremental lifetime cancer risk of about 1 x 10^{-8} via the beef pathway, and 1 x 10^{-7} via the milk pathway.

E.III.4.5 Direct Radiation Exposure

Since the publication of the Risk Assessment Work Plan Addendum, EPA has published a new set of slope factors. Changes in these slope factors require the use of a different equation to calculate risks resulting from external radiation exposures from soils than the one originally presented in the Risk Assessment Work Plan Addendum. The new equation is:

$$ILCR_e = SF_{ext} \times C_s \times ED \times EF \times CF \times [ET_{in} \times (1-S_i) + ET_{out} \times (1-S_o)] \quad \text{(E.III-103)}$$

where

$ILCR_e$ = Incremental Lifetime Cancer Risk (r/lifetime)
C_s = concentration in surface soil (pCi/g)
SF_{ext} = HEAST Slope Factor (r - g/pCi -y)
ED = exposure duration (y/lifetime)
EF = exposure frequency (d/y)
ET_{in} = exposure time indoors on-site (h/d)
ET_{out} = exposure time outdoors on-site (h/d)
S_i = indoor shielding factor (0.5, from Risk Assessment Work Plan Addendum)
S_o = outdoor shielding factor outdoors (0, assumes no shielding)
CF = 1/8760 y/h

The risk to an on-property resident RME directly attributable to U-238 in soil is the example calculation. In this calculation, exposure duration (ED) is 70 years, and the exposure frequency is 350 days per year (EF = 350 d/y). The exposure time for outdoor activities assumes the resident is outdoors 2000 hours out of a 350 day year (ET_{out} = 2000 h/350 d).

The exposure time for indoor activities is the remainder of the time available (ET_{in} = 24 h/d - ET_{out}). The value for the indoor shielding factor (S_i) is 0.5, and the value for the outdoor shielding factor (S_o) is 0. Substituting these parameters into Equation E.III-103 yields:

$$ILCR_e = (SF_e)(1\ pCi/g)(70y/lifetime)(350d/y)(y/8760\ h) \times [(18.3\ h/d)(1-0.5)+(5.7\ h/d)(1-0.0)] \quad \text{(E.III-104)}$$

$$ILCR_e = 1.50 \times 10^{-6}\ r/Lifetime$$

Because the exposure models used in this scenario respond linearly to changes in concentration, each additional pCi/g of U-238 in soil will increase the source strength by 41.5 pCi-y/g-life and the risks by 1.50×10^{-6} r/Lifetime via the direct exposure pathway.

E.III.4.6 Calculation of Aggregate Risks For On-Property Resident from All Soil Pathways

In this scenario, a hypothetical resident ingests contaminated dirt, and crops, beef, and milk grown in or on contaminated soil. The receptor also receives exposures from direct dermal contact and direct irradiation. The total risks to the on-property resident RME exposed to soil from these pathways may be calculated as:

$$ILCR_{soil\ i} = (I_{s\ i} + I_{sv\ i} + I_{sm\ i} + I_{sd\ i} + I_{sa\ i}) \times SF_{ing\ i} + ILCR_{e\ i} \quad \text{(E.III-105)}$$

where

$ILCR_{soil\ i}$	=	incremental Lifetime Cancer Risk (risk of cancer incidence/lifetime);
$ILCR_{e\ i}$	=	incremental Lifetime Cancer Risk from direct radiation (risk of cancer incidence/lifetime).
$I_{s\ i}$	=	unit intake from soil (pCi/lifetime);
$I_{sv\ i}$	=	unit intake from ingesting vegetables and fruit (pCi/lifetime);
$I_{sm\ i}$	=	unit intake from ingesting meat (pCi/lifetime);
$I_{sd\ i}$	=	unit intake from ingesting dairy products (pCi/lifetime);
$I_{sa\ i}$	=	unit intake from absorption during dermal contact (pCi/lifetime); and
$SF_{ing\ i}$	=	HEAST slope factor for ingestion of constituent i (r/pCi).

The intake by this hypothetical receptor for each pCi/L of U-238 in soil from each of these pathways has been calculated in Sections E.III.4.1 though E.III.4.4. The ILCR from external exposure to direct radiation is presented in Section E.III.4.5. Substituting these values into Equation E.III-93, along with the appropriate HEAST Slope Factors for ingestion and inhalation of uranium, yields:

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$$ILCR_{soil\ U23} = \{[(4{,}410\ pCi/lifetime) + (11{,}956\ pCi/lifetime) + (340\ pCi/lifetime) + (4{,}079\ g/lifetime)] \times 2.8 \times 10^{-11} r/pCi + [(41.5\ pCi\text{-}y/g\text{-}life)(3.6 \times 10^{-8}\ r\text{-}g/y\text{-}pCi)] \quad (E.III\text{-}106)$$

$$ILCR_{soil\ U238} = (C_{s\ U238}\ pCi/g)(1.9 \times 10^{-6}\ r\text{-}g/pCi\text{-}lifetime)$$

The exposure models used in this scenario respond linearly to changes in concentration. Therefore, each additional pCi/g of U-238 in soil will produce an incremental lifetime cancer risk of about 2×10^{-6} r-g/pCi-lifetime to te RME resident farmer soil from all direct exposure pathways investigated.

TABLE E.III–1

SUMMARY OF PARTITIONING COEFFICIENTS AND TRANSFER FACTORS FOR FOOD PATHWAY MODELS FOR OU1

Constituent	Octanol–water Partioning Coefficient K_{ow}[a] (ml/ml)	Soil–water Partioning Coefficient K_d[a] (ml/g)	Leaching Coefficient $Lambda_{Li}$[b] (hr^{-1})	Decay Coefficient $Lambda_{ri}$[c] (hr^{-1})	Water–Fish Bioconcentration Factor F_{iF}[d] (L/g)	Soil–forage Biotransfer Factor Bv TF[e] (unitless)	Soil–crop Biotransfer Factor Br TF[f] (unitless)	Plant–beef Biotransfer Factor $F_{Bi}(beef)$[g] (d/g)	Plant–milk Biotransfer Factor $F_{Mi}(milk)$[h] (d/L)
Radionuclides									
Cs_{137+1d}	NA	1.81E+03	1.08E−07	2.62E−06	2.00E+00	8.00E−02	3.00E−02	2.00E−05	7.00E−03
Np_{237+1d}	NA	5.50E+01	3.55E−06	3.70E−11	1.00E−02	1.00E−01	1.00E−02	5.50E−08	5.00E−06
Pu_{238}	NA	1.70E+03	1.15E−07	9.02E−07	2.50E−02	4.50E−04	4.50E−05	5.00E−10	1.00E−07
$Pu_{239/240}$	NA	1.70E+03	1.15E−07	3.28E−09	2.50E−02	4.50E−04	4.50E−05	5.00E−10	1.00E−07
Ra_{226+5d}	NA	6.96E+02	2.81E−07	4.95E−08	5.00E−02	1.50E−02	1.50E−03	2.50E−07	4.50E−04
Ra_{226+8d}	NA	6.96E+02	2.81E−07	4.95E−08	5.00E−02	1.50E−02	1.50E−03	2.50E−07	4.50E−04
Ra_{228+1d}	NA	6.96E+02	2.81E−07	1.37E−05	5.00E−02	1.50E−02	1.50E−03	2.50E−07	4.50E−04
Ru_{106}	NA	8.00E+02	2.44E−07	7.84E−05	1.00E−02	7.50E−02	2.00E−02	2.00E−06	6.00E−07
Sr_{90+1d}	NA	1.00E+01	1.93E−05	2.77E−06	3.00E−02	2.50E+00	2.50E−01	3.00E−07	1.50E−03
Tc_{99}	NA	1.18E−01	8.45E−04	3.71E−10	1.50E−02	9.50E+00	1.50E+00	8.50E−06	1.00E−02
Th_{228+7d}	NA	5.80E+03	3.37E−08	4.14E−05	3.00E−02	8.50E−04	8.50E−05	6.00E−09	5.00E−06
Th_{230}	NA	5.80E+03	3.37E−08	1.03E−09	3.00E−02	8.50E−04	8.50E−05	6.00E−09	5.00E−06
Th_{232}	NA	5.80E+03	3.37E−08	5.63E−15	3.00E−02	8.50E−04	8.50E−05	6.00E−09	5.00E−06
$Th_{232+10D}$	NA	5.80E+03	3.37E−08	5.63E−15	3.00E−02	8.50E−04	8.50E−05	6.00E−09	5.00E−06
U_{234}	NA	1.20E+01	1.61E−05	3.24E−10	2.00E−03	8.50E−03	4.00E−03	2.00E−07	6.00E−04
U_{235}	NA	1.20E+01	1.61E−05	1.12E−13	2.00E−03	8.50E−03	4.00E−03	2.00E−07	6.00E−04
U_{235+1D}	NA	1.20E+01	1.61E−05	1.12E−13	2.00E−03	8.50E−03	4.00E−03	2.00E−07	6.00E−04
U_{238+2d}	NA	1.20E+01	1.61E−05	1.77E−14	2.00E−03	8.50E−03	4.00E−03	2.00E−07	6.00E−04

TABLE E.III-1
(Continued)

SUMMARY OF PARTITIONING COEFFICIENTS AND TRANSFER FACTORS FOR FOOD PATHWAY MODELS FOR OU1

Constituent	Octanol-water Partioning Coefficient K_{ow}[a] (ml/ml)	Soil-water Partioning Coefficient K_d[a] (ml/g)	Leaching Coefficient $Lambda_{Li}$[b] (hr^{-1})	Decay Coefficient $Lambda_{ri}$[c] (hr^{-1})	Water-Fish Bioconcentration Factor F_{iF}[d] (L/g)	Soil-forage Biotransfer Factor Bv TF[e] (unitless)	Soil-crop Biotransfer Factor Br TF[f] (unitless)	Plant-beef Biotransfer Factor F_{Bi}(beef)[g] (d/g)	Plant-milk Biotransfer Factor F_{Mi}(milk)[h] (d/L)
Inorganics									
cyanide	NA	4.29E-02	1.25E-03	NA	1.09E+00	2.43E+01	2.43E+01	5.63E-11	1.78E-08
antimony	NA	2.50E+02	7.82E-07	NA	1.00E+00	2.00E-01	3.00E-02	1.00E-06	1.00E-04
arsenic	NA	2.00E+02	9.77E-07	NA	4.40E+01	4.00E-02	6.00E-03	2.00E-06	6.00E-05
barium	NA	1.14E+03	1.72E-07	NA	ND	1.50E-01	1.50E-02	1.50E-07	3.50E-04
beryllium	NA	1.30E+03	1.50E-07	NA	1.90E+01	1.00E-02	1.50E-03	1.00E-06	9.00E-07
boron	NA	3.00E+00	6.28E-05	NA	ND	4.00E+00	2.00E+00	8.00E-07	1.50E-03
cadmium	NA	5.10E+02	3.83E-07	NA	8.10E+01	5.50E-01	1.50E-01	5.50E-07	1.00E-03
chromium vi	NA	1.50E+03	1.30E-07	NA	1.60E+01	7.50E-03	4.50E-03	5.50E-06	1.50E-03
cobalt	NA	5.50E+02	3.55E-07	NA	ND	2.00E-02	7.00E-03	2.00E-05	2.00E-03
copper	NA	1.25E+02	1.56E-06	NA	2.00E+02	4.00E-01	2.50E-01	1.00E-05	1.50E-03
lead	NA	3.00E+03	6.52E-08	NA	4.90E+01	4.50E-02	9.00E-03	3.00E-07	2.50E-04
manganese	NA	1.80E+02	1.09E-06	NA	ND	2.50E-01	5.00E-02	4.00E-07	3.50E-04
mercury	NA	1.00E+01	1.93E-05	NA	5.50E+03	9.00E-01	2.00E-01	2.50E-04	4.50E-04
molybdenum	NA	9.00E+01	2.17E-06	NA	ND	2.50E-01	6.00E-02	6.00E-06	1.50E-03
nickel	NA	6.50E+02	3.01E-07	NA	4.70E+01	6.00E-02	6.00E-02	6.00E-06	1.00E-03
selenium	NA	7.40E+02	2.64E-07	NA	1.60E+01	2.50E-02	2.50E-02	1.50E-05	4.00E-03
silver	NA	1.80E+02	1.09E-06	NA	3.10E+03	4.00E-01	1.00E-01	3.00E-06	2.00E-02
thallium	NA	1.50E+03	1.30E-07	NA	ND	4.00E-03	4.00E-04	4.00E-05	2.00E-03
vanadium	NA	1.00E+03	1.96E-07	NA	ND	5.50E-03	3.00E-03	2.50E-06	2.00E-05
thorium-total	NA	5.80E+03	3.37E-08	5.63E-15	3.00E-02	8.50E-04	8.50E-05	6.00E-09	5.00E-06
uranium-total	NA	1.20E+01	1.61E-05	1.77E-14	2.00E-03	8.50E-03	4.00E-03	2.00E-07	6.00E-04
fluoride	NA	ND	1.73E-03	NA	ND	ND	ND	ND	ND

TABLE E.III-1
(Continued)

SUMMARY OF PARTITIONING COEFFICIENTS AND TRANSFER FACTORS FOR FOOD PATHWAY MODELS FOR OU1

Constituent	Octanol-water Partioning Coefficient K_{ow}[a] (ml/ml)	Soil-water Partioning Coefficient K_d[a] (ml/g)	Leaching Coefficient $Lambda_{Li}$[b] (hr^{-1})	Decay Coefficient $Lambda_{ri}$[c] (hr^{-1})	Water-Fish Bioconcentration Factor F_{iF}[d] (L/g)	Soil-forage Biotransfer Factor Bv TF[e] (unitless)	Soil-crop Biotransfer Factor Br TF[f] (unitless)	Plant-beef Biotransfer Factor F_{Bi}(beef)[g] (d/g)	Plant-milk Biotransfer Factor F_{Mi}(milk)[h] (d/L)
Organics									
PCBs	3.16E+06	2.05E+04	9.54E-09	ND	2.25E+04	1.27E-02	1.27E-02	2.69E-05	8.50E-03
acenaphthylene	1.17E+04	2.30E+02	8.50E-07	1.20E-04	7.30E+02	1.72E-01	1.72E-01	2.95E-07	9.33E-05
2-methylnaphthalene	7.24E+03	1.39E+02	1.41E-06	ND	5.05E+02	2.28E-01	2.28E-01	1.82E-07	5.75E-05
4-chloro-3-methylphenol	1.26E+03	7.93E+00	2.43E-05	ND	1.34E+02	6.25E-01	6.25E-01	3.16E-08	1.00E-05
benzo(a)anthracene	4.57E+05	7.66E+03	2.55E-08	1.00E-05	1.07E+04	2.24E-02	2.24E-02	1.00E-05	3.18E-03
benzo(a)pyrene	1.26E+06	1.83E+04	1.07E-08	1.00E-05	2.06E+04	1.35E-02	1.35E-02	2.40E-05	7.59E-03
benzo(b)fluoranthene	1.32E+06	7.11E+04	2.75E-09	1.20E-05	5.80E+04	6.17E-03	6.17E-03	9.34E-05	2.95E-02
benzo(g,h,i)perylene	1.70E+07	3.25E+05	6.02E-10	1.10E-05	1.84E+05	2.56E-03	2.56E-03	4.27E-04	1.35E-01
benzo(k)fluoranthene	6.92E+06	1.32E+05	1.48E-09	3.30E-06	9.30E+04	4.31E-03	4.31E-03	1.74E-04	5.50E-02
chrysene	4.00E+05	7.66E+03	2.55E-08	7.10E-06	1.07E+04	2.24E-02	2.24E-02	1.00E-05	3.18E-03
dibenzo(a,h)anthracene	6.92E+06	1.79E+04	1.09E-08	7.50E-06	2.03E+04	1.37E-02	1.37E-02	2.34E-05	7.41E-03
dibenzofuran	1.32E+04	2.53E+02	7.73E-07	2.58E-04	7.97E+02	1.61E-01	1.61E-01	3.32E-07	1.05E-04
indeno(1,2,3-cd)pyrene	3.80E+06	8.75E+05	2.23E-10	1.00E-05	3.90E+05	1.45E-03	1.45E-03	1.15E-03	3.63E-01
n-nitrosodipropylamine	2.04E+01	1.29E-01	8.08E-04	ND	5.83E+00	6.77E+00	6.77E+00	5.13E-10	1.62E-07
pentachlorophenol	7.24E+05	1.95E+03	1.00E-07	1.90E-05	3.77E+03	4.93E-02	4.93E-02	2.56E-06	8.10E-04
phenanthrene	2.90E+04	5.55E+02	3.52E-07	3.60E-05	1.45E+03	1.02E-01	1.02E-01	7.28E-07	2.30E-04
tributyl phosphate	1.00E+04	6.30E+01	3.10E-06	ND	6.46E+02	1.89E-01	1.89E-01	2.51E-07	7.94E-05
2-hexanone	2.40E+01	4.59E-01	3.42E-04	ND	6.59E+00	6.17E+00	6.17E+00	6.03E-10	1.91E-07
3-chloropropene	9.12E+00	5.75E-02	1.15E-03	ND	3.16E+00	1.08E+01	1.08E+01	2.29E-10	7.24E-08
benzene	1.35E+02	2.59E+00	7.23E-05	4.00E-05	2.45E+01	2.27E+00	2.27E+00	3.39E-09	1.07E-06
vinyl chloride	2.29E+01	7.62E-02	1.03E-03	1.00E-05	1.68E+00	1.74E+01	1.74E+01	1.00E-10	3.16E-08

TABLE E.III–1
(Continued)

SUMMARY OF PARTITIONING COEFFICIENTS AND TRANSFER FACTORS FOR FOOD PATHWAY MODELS FOR OU1

Constituent	Octanol–water Partioning Coefficient K_{ow}[a] (ml/ml)	Soil–water Partioning Coefficient K_d[a] (ml/g)	Leaching Coefficient $Lambda_{Li}$[b] (hr^{-1})	Decay Coefficient $Lambda_{ri}$[c] (hr^{-1})	Water–Fish Bioconcentration Factor F_{iF}[d] (L/g)	Soil–forage Biotransfer Factor Bv TF[e] (unitless)	Soil–crop Biotransfer Factor Br TF[f] (unitless)	Plant–beef Biotransfer Factor F_{Bi}(beef)[g] (d/g)	Plant–milk Biotransfer Factor F_{Mi}(milk)[h] (d/L)
Organics (con't)									
tetrachlorodibenzo–p–dioxin	6.31E+06	6.60E+04	2.96E–09	2.60E–04	1.27E+05	3.39E–03	3.39E–03	2.63E–04	8.32E–02
tetrachlorodibenzofuran	6.61E+05	4.16E+03	4.70E–08	2.60E–04	1.56E+04	1.68E–02	1.68E–02	1.66E–05	5.25E–03
pentachlorodibenzofuran	6.61E+05	4.16E+03	4.70E–08	2.60E–04	1.56E+04	1.68E–02	1.68E–02	1.66E–05	5.25E–03
hexachlorodibenzo–p–dioxin	1.05E+07	8.40E+04	2.33E–09	2.60E–04	1.27E+05	3.39E–03	3.39E–03	2.63E–04	8.32E–02
hexachlorodibenzofuran	6.61E+05	1.80E+06	1.09E–10	2.60E–04	1.56E+04	1.68E–02	1.68E–02	1.66E–05	5.25E–03
heptachlorodibenzo–p–dioxin	1.05E+07	8.40E+04	2.33E–09	2.60E–04	1.27E+05	3.39E–03	3.39E–03	2.63E–04	8.32E–02
heptachlorodibenzofuran	6.61E+05	1.80E+06	1.09E–10	2.60E–04	1.56E+04	1.68E–02	1.68E–02	1.66E–05	5.25E–03
octachlorodibenzo–p–dioxin	1.05E+07	8.40E+04	2.33E–09	2.60E–04	1.27E+05	3.39E–03	3.39E–03	2.63E–04	8.32E–02
octachlorodibenzofuran	6.61E+05	1.80E+06	1.09E–10	2.60E–04	1.56E+04	1.68E–02	1.68E–02	1.66E–05	5.25E–03
chloroform	9.33E+01	1.79E+00	1.03E–04	1.58E–04	1.85E+01	2.81E+00	2.81E+00	2.34E–09	7.41E–07
tetrachloroethene	2.51E+03	6.49E+00	2.96E–05	1.80E–05	4.93E+01	1.34E+00	1.34E+00	8.52E–09	2.69E–06
methylene chloride	1.78E+01	3.41E–01	4.30E–04	1.03E–03	5.25E+00	7.33E+00	7.33E+00	4.47E–10	1.41E–07
toluene	5.37E+02	9.38E+00	2.06E–05	1.38E–04	6.52E+01	1.08E+00	1.08E+00	1.23E–08	3.89E–06
2–nitrophenol	6.17E+01	5.12E–01	3.13E–04	ND	1.67E+01	3.05E+00	3.05E+00	2.04E–09	6.46E–07
acetone	5.70E–01	1.09E–02	1.57E–03	1.03E–03	3.84E–01	5.36E+01	5.36E+01	1.43E–11	4.53E–09

Notes:

[a] Values are provided in Appendix D for radionuclides and inorganic chemicals. For organics, K_d calculated from K_{ow}. K_{ow}s calculated from either EPA 1992e "Dermal Exposure Assessment" or EPA WERL Database, Rev. 2.

[b] Calculated from K_d.

[c] For organics, refer to *Handbook of Environmental Degradation Rates*, Howard, et al., 1991. Lewis Publishers, Inc.

[d] For inorganics, refer to *Deminimus Waste Impacts Analysis Methodology*, NUREG/CR–3585, 1984. For organics, Log BCF = 0.76 Log K_{ow} – 0.23 (Lyman, et al. 1982).

[e] For inorganics, Baes and Sharp, 1984. For organics, Log Bv TF = –1.588 – 0.578 Log K_{ow}, (Travis and Arms, 1988).
$B_{iv(1)}$ is assumed to equal Bv TF.

[f] For inorganics, Baes and Sharp, 1984. For organics, Br Tf assumed equal to Bv TF.
Br TF is converted to $B_{iv(2)}$ by multiplying by 0.428 (dry–weight to wet–weight conversion factor [Baes. et al, 1983]).

[g] For inorganics, Baes and Sharp, 1984. For organics, Log F_{Bi} = –7.6 + Log K_{ow}, (Travis and Arms, 1988).

[h] For inorganics, Baes and Sharp, 1984. For organics, Log F_{Mi} = –8.1 + Log K_{ow}, (Travis and Arms, 1988).

TABLE E.III–2
INTAKES FOR CARCINOGENS FOR ON–PROPERTY GROUNDSKEEPER CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media	Air	Soil			Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides	pCi/life	pCi/life		pCi/life	mRem/life
Cs_{137+1d}	9.8E–02	7.0E+01	NA	6.4E–01	
Np_{237+1d}	6.1E–02	4.4E+01	NA	4.0E–01	
Pu_{238}	1.2E–02	8.8E+00	NA	8.0E–02	
$Pu_{239/240}$	2.5E–02	1.8E+01	NA	1.6E–01	
Ra_{226+8d}	1.7E–01	1.2E+02	NA	1.1E+00	
Ra_{228+1d}	2.7E–01	1.9E+02	NA	1.8E+00	
Sr_{90+1d}	1.9E–01	1.3E+02	NA	1.2E+00	
Tc_{99}	6.9E–01	4.9E+02	NA	4.5E+00	
Th_{228+7d}	9.6E–01	6.8E+02	NA	6.2E+00	
Th_{230}	1.8E+01	1.3E+04	NA	1.2E+02	
Th_{232}	6.7E–01	4.8E+02	NA	4.4E+00	
U_{234}	1.5E+01	1.0E+04	NA	9.4E+01	
U_{235+1D}	1.7E–01	1.6E+03	NA	1.5E+01	
U_{238+2d}	9.6E+01	6.9E+04	NA	6.3E+02	7.5E+01
Rn_{222+4d}	5.3E–01	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day		
arsenic	5.6E–10	4.0E–07	2.3E–08	NA	NA
beryllium	5.3E–11	3.8E–08	2.2E–08	NA	NA
cadmium	4.0E–10	2.9E–07	1.6E–07	NA	NA
lead	NA	NA	NA	NA	NA
nickel	NA	NA	NA	NA	NA
pcbs	9.7E–11	6.8E–08	1.2E–07	NA	NA
benzo(a)anthracene	6.8E–12	4.8E–09	NA	NA	NA
benzo(a)pyrene	2.9E–12	2.1E–09	NA	NA	NA
benzo(b)fluoranthene	4.1E–12	2.9E–09	NA	NA	NA
benzo(k)fluoranthene	3.5E–12	2.3E–09	NA	NA	NA
chrysene	NA	4.3E–09	NA	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
[a] Calculation of dose from penetrating radiation for groundskeeper is provided in Table E.IV–35.

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TABLE E.III–3
INTAKES FOR TOXICANTS FOR ON–PROPERTY GROUNDSKEEPER CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air	Soil		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	
cyanide	NA	NA	NA	NA
antimony	5.5E–09	3.8E–06	2.2E–06	NA
arsenic	1.6E–09	1.1E–06	6.5E–08	NA
barium	NA	NA	NA	NA
beryllium	1.5E–10	1.1E–07	6.1E–08	NA
cadmium	1.1E–09	8.0E–07	4.6E–07	NA
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	1.3E–10	9.6E–08	5.5E–08	NA
vanadium	NA	NA	NA	NA
thorium–total	1.1E–09	7.9E–07	1.4E–06	NA
uranium–total	7.9E–08	5.7E–05	3.3E–05	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III–4
INTAKES FOR CARCINOGENS FOR RME OFF–PROPERTY FARMER, CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life
Cs_{137+1d}	5.0E–02	8.1E–01	1.4E+00	2.0E+00
Np_{237+1d}	3.1E–02	4.2E–01	2.4E–03	8.7E–04
Pu_{238}	6.3E–03	7.9E–02	2.9E–06	2.3E–06
$Pu_{239/240}$	1.2E–02	1.6E–01	1.2E–05	9.8E–06
Ra_{226+8d}	8.8E–02	1.2E+00	5.1E–02	3.6E–01
Ra_{228+1d}	1.4E–01	1.7E+00	2.4E–02	1.8E–01
Sr_{90+1d}	9.3E–02	1.5E+00	9.1E–02	1.8E+00
Tc_{99}	3.5E–01	4.6E+00	2.8E+00	1.3E+01
Th_{228+7d}	4.9E–01	6.1E+00	1.9E–03	6.4E–03
Th_{230}	9.3E+00	1.2E+02	1.4E–01	4.7E–01
Th_{232}	3.4E–01	4.4E+00	5.3E–03	1.8E–02
U_{234}	7.3E+00	9.3E+01	1.0E+00	1.2E+01
U_{235+1D}	1.1E+00	1.4E+01	1.6E–01	1.9E+00
U_{238+2d}	5.0E+01	6.3E+02	7.0E+00	8.4E+01
Rn_{222+4d}	2.6E–01	1.8E+00	NA	NA
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
arsenic	2.8E–10	4.1E–09	1.0E–09	1.3E–10
beryllium	2.7E–11	4.0E–10	7.7E–11	2.8E–13
cadmium	2.1E–10	2.8E–08	3.7E–09	2.7E–08
lead	NA	NA	NA	NA
nickel	NA	NA	NA	NA
pcbs	4.9E–11	2.3E–09	6.6E–09	8.3E–09
benzo(a)anthracene	3.4E–12	4.6E–11	2.6E–11	3.3E–11
benzo(a)pyrene	1.5E–12	1.9E–11	2.6E–11	3.3E–11
benzo(b)fluoranthene	2.1E–12	2.6E–11	1.3E–10	1.7E–10
benzo(k)fluoranthene	1.6E–12	2.1E–11	2.2E–10	2.8E–10
chrysene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
benzene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

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TABLE E.III-5
INTAKES FOR TOXICANTS FOR RME OFF-PROPERTY FARMER, CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA
antimony	9.7E-10	2.4E-08	6.6E-09	2.6E-09
arsenic	2.8E-10	4.1E-09	1.0E-09	1.3E-10
barium	NA	NA	NA	NA
beryllium	2.7E-11	4.0E-10	7.7E-11	2.8E-13
cadmium	2.1E-10	2.8E-08	3.7E-09	2.7E-08
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	2.4E-11	3.2E-10	2.3E-09	4.5E-10
vanadium	NA	NA	NA	NA
thorium-total	2.0E-10	2.6E-09	3.1E-12	1.0E-11
uranium-total	1.4E-08	1.8E-07	2.0E-09	2.4E-08
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III-6
INTAKES FOR CARCINOGENS FOR RME OFF-PROPERTY CHILD, CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Radionuclides			pCi/	pCi/life
Cs_{137+1d}	2.6E-03	6.0E-02	4.7E-02	3.9E-01
Np_{237+1d}	1.6E-03	3.1E-02	7.9E-05	1.7E-04
Pu_{238}	3.2E-04	5.9E-03	9.5E-08	4.5E-07
$Pu_{239/240}$	6.4E-04	1.2E-02	4.1E-07	1.9E-06
Ra_{226+8d}	4.5E-03	9.1E-02	1.7E-03	7.1E-02
Ra_{228+1d}	7.1E-03	1.3E-01	8.0E-04	3.4E-02
Sr_{90+1d}	4.8E-03	1.1E-01	3.0E-03	3.5E-01
Tc_{99}	1.8E-02	3.4E-01	9.3E-02	2.6E+00
Th_{228+7d}	2.5E-02	4.5E-01	6.2E-05	1.2E-03
Th_{230}	4.8E-01	8.9E+00	4.7E-03	9.2E-02
Th_{232}	1.8E-02	3.3E-01	1.8E-04	3.4E-03
U_{234}	3.8E-01	6.9E+00	3.4E-02	2.4E+00
U_{235+1D}	5.8E-02	1.1E+00	5.3E-03	3.7E-01
U_{238+2d}	2.6E+00	4.7E+01	2.3E-01	1.6E+01
Rn_{222+4d}	1.3E-02	1.2E-01	NA	NA
Chemicals			mg/Kg	mg/Kg/day
arsenic	6.8E-11	1.4E-09	1.6E-10	1.1E-10
beryllium	6.4E-12	1.4E-10	1.2E-11	2.5E-13
cadmium	5.0E-11	9.6E-09	5.8E-10	2.5E-08
lead	NA	NA	NA	NA
nickel	NA	NA	NA	NA
pcbs	1.2E-11	7.9E-10	1.0E-09	7.5E-09
benzo(a)anthracene	8.3E-13	1.6E-11	4.0E-12	2.9E-11
benzo(a)pyrene	3.6E-13	6.7E-12	4.0E-12	3.0E-11
benzo(b)fluoranthene	5.0E-13	9.2E-12	2.1E-11	1.6E-10
benzo(k)fluoranthene	3.9E-13	7.3E-12	3.4E-11	2.5E-10
chrysene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
benzene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

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TABLE E.III-7
INTAKES FOR TOXICANTS FOR RME OFF-PROPERTY CHILD, CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Toxicants	mg/Kg/day			
cyanide	NA	NA	NA	NA
antimony	2.7E-09	9.8E-08	1.2E-08	2.8E-08
arsenic	NA	NA	NA	NA
barium	NA	NA	NA	NA
beryllium	7.5E-11	1.6E-09	1.4E-10	2.9E-12
cadmium	5.8E-10	1.1E-07	6.8E-09	2.9E-07
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	6.8E-11	1.3E-09	4.1E-09	4.8E-09
vanadium	NA	NA	NA	NA
thorium-total	5.6E-10	1.0E-08	5.6E-12	1.1E-10
uranium-total	4.0E-08	7.3E-07	3.6E-09	2.6E-07
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III–8
INTAKES FOR CARCINOGENS FOR TRESPASSING YOUTH
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air	Soil			Buried Pit Material
Exposure Pathways: Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides	pCi/life	pCi/life		pCi/life	mRem/life
Cs_{137+1d}	1.2E−02	1.2E+01	NA	2.3E−01	
Np_{237+1d}	7.3E−03	7.8E+00	NA	1.4E−01	
Pu_{238}	1.5E−03	1.6E+00	NA	2.8E−02	
$Pu_{239/240}$	2.9E−03	3.1E+00	NA	5.7E−02	
Ra_{226+8d}	2.0E−02	2.2E+01	NA	4.0E−01	
Ra_{228+1d}	3.2E−02	3.4E+01	NA	6.3E−01	
Sr_{90+1d}	2.3E−02	2.3E+01	NA	4.3E−01	
Tc_{99}	8.1E−02	8.7E+01	NA	1.6E+00	
Th_{228+7d}	1.1E−01	1.2E+02	NA	2.2E+00	
Th_{230}	2.1E+00	2.3E+03	NA	4.2E+01	
Th_{232}	8.0E−02	8.6E+01	NA	1.6E+00	
U_{234}	1.7E+00	1.8E+03	NA	3.3E+01	
U_{235+1D}	2.0E−02	2.9E+02	NA	5.3E+00	
U_{238+2d}	1.1E+01	1.2E+04	NA	2.2E+02	2.8E+01
Rn_{222+4d}	6.2E−02	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day		
arsenic	1.1E−10	1.2E−07	2.0E−08	NA	NA
beryllium	1.0E−11	1.1E−08	1.8E−08	NA	NA
cadmium	7.7E−11	8.3E−08	1.4E−07	NA	NA
lead	NA	NA	NA	NA	NA
nickel	NA	NA	NA	NA	NA
pcbs	1.9E−11	2.0E−08	1.0E−07	NA	NA
benzo(a)anthracene	1.3E−12	1.4E−09	NA	NA	NA
benzo(a)pyrene	5.7E−13	6.0E−10	NA	NA	NA
benzo(b)fluoranthene	7.9E−13	8.4E−10	NA	NA	NA
benzo(k)fluoranthene	6.8E−13	6.5E−10	NA	NA	NA
chrysene	NA	1.2E−09	NA	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
[a] Calculation of dose from penetrating radiation for trespassing youth is provided in Table E.IV–36.

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TABLE E.III–9
INTAKES FOR TOXICANTS FOR TRESPASSING YOUTH
CURRENT LAND USE, CURRENT SOURCE TERM

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Transfer Media:	Air	Soil		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	
cyanide	NA	NA	NA	NA
antimony	2.2E–09	2.3E–06	3.9E–06	NA
arsenic	6.3E–10	6.8E–07	1.1E–07	NA
barium	NA	NA	NA	NA
beryllium	5.9E–11	6.4E–08	1.1E–07	NA
cadmium	4.5E–10	4.9E–07	8.2E–07	NA
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	5.4E–11	5.8E–08	9.7E–08	NA
vanadium	NA	NA	NA	NA
thorium–total	4.5E–10	4.8E–07	2.4E–06	NA
uranium–total	3.2E–08	3.4E–05	5.8E–05	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III-10
INTAKES FOR CARCINOGENS FOR OFF-PROPERTY USER OF MEAT AND MILK PRODUCTS
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media	Soil		Surface Water	
Exposure Pathways / Contaminants of Concern	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life
Cs_{137+1d}	1.3E+05	1.8E+05	1.3E+06	1.9E+06
Np_{237+1d}	2.8E+02	1.0E+02	NA	NA
Pu_{238}	4.8E-02	3.8E-02	NA	NA
$Pu_{239/240}$	9.6E-02	7.7E-02	NA	NA
Ra_{226+8d}	8.0E+02	5.8E+03	4.7E+01	3.4E+02
Ra_{228+1d}	1.2E+03	9.0E+03	6.1E+02	4.6E+03
Sr_{90+1d}	1.0E+05	2.1E+06	2.1E+04	4.3E+05
Tc_{99}	4.2E+07	2.0E+08	7.8E+06	3.8E+07
Th_{228+7d}	4.6E+01	1.5E+02	NA	NA
Th_{230}	8.7E+02	2.9E+03	6.5E-01	2.2E+00
Th_{232}	3.3E+01	1.1E+02	NA	NA
U_{234}	4.0E+04	4.8E+05	6.1E+04	7.6E+05
U_{235+1D}	6.4E+03	7.6E+04	3.4E+03	4.2E+04
U_{238+2d}	2.7E+05	3.2E+06	1.3E+05	1.6E+06
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
arsenic	4.2E-05	5.1E-06	2.8E-06	3.5E-07
beryllium	7.9E-07	2.9E-09	NA	NA
cadmium	9.3E-05	6.7E-04	NA	NA
lead	NA	NA	1.9E-06	6.5E-06
nickel	NA	NA	1.8E-04	1.2E-04
pcbs	4.4E-05	5.5E-05	NA	NA
benzo(a)anthracene	1.6E-06	2.1E-06	NA	NA
benzo(a)pyrene	1.2E-06	1.5E-06	NA	NA
benzo(b)fluoranthene	4.5E-06	5.8E-06	NA	NA
benzo(k)fluoranthene	5.9E-06	7.4E-06	NA	NA
chrysene	1.5E-06	1.9E-06	NA	NA
chloroform	NA	NA	2.6E-10	3.6E-10
tetrachloroethene	NA	NA	1.4E-09	1.8E-09
benzene	NA	NA	1.2E-08	1.6E-08
methylene chloride	NA	NA	3.2E-11	7.2E-11

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

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TABLE E.III-11
INTAKES FOR TOXICANTS FOR OFF-PROPERTY USER OF MEAT AND MILK PRODUCTS
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Soil		Surface Water	
Exposure Pathways:	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	2.0E-09	2.6E-09
antimony	3.0E-04	1.2E-04	9.3E-06	3.7E-06
arsenic	4.2E-05	5.1E-06	2.8E-06	3.5E-07
barium	NA	NA	7.7E-05	7.2E-04
beryllium	7.9E-07	2.9E-09	NA	NA
cadmium	9.3E-05	6.7E-04	NA	NA
copper	NA	NA	4.7E-04	2.8E-04
lead	NA	NA	2.3E-06	7.7E-06
manganese	NA	NA	2.5E-06	8.9E-06
nickel	NA	NA	1.8E-04	1.2E-04
selenium	NA	NA	3.1E-05	3.3E-05
silver	NA	NA	2.0E-05	5.4E-04
thallium	2.0E-05	4.0E-06	NA	NA
vanadium	NA	NA	1.3E-04	4.2E-06
thorium-total	1.9E-08	6.5E-08	NA	NA
uranium-total	7.9E-05	9.4E-04	NA	NA
chloroform	NA	NA	2.6E-10	3.6E-10
tetrachloroethene	NA	NA	1.4E-09	1.8E-09
methylene chloride	NA	NA	3.2E-11	7.2E-11
toluene	NA	NA	5.2E-09	7.3E-09
2-nitrophenol	NA	NA	4.0E-10	5.2E-10
acetone	NA	NA	5.9E-11	1.3E-10

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III-12
INTAKES FOR CARCINOGENS FOR TRESPASSING YOUTH
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment			Buried Pit Material
Exposure Pathways:		Incidental Ingestion	Dermal Contact	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Contaminants of Concern	Inhalation									
Radionuclides	pCi/life	pCi/life		pCi/life	pCi/life		pCi/life		pCi/life	mRem/life
Cs_{137+1d}	6.6E+00	7.8E+01	NA	1.4E+00	5.1E-02	NA	3.7E+00	NA	7.1E-02	
Np_{237+1d}	5.2E+00	5.8E+01	NA	1.0E+00	8.4E-01	NA	1.9E+00	NA	3.6E-02	
Pu_{238}	2.9E-01	4.5E+00	NA	8.1E-02	2.2E-02	NA	1.5E+00	NA	2.8E-02	
$Pu_{239/240}$	1.3E+00	2.0E+01	NA	3.5E-01	5.4E-03	NA	3.7E-01	NA	7.1E-03	
Ra_{226+8d}	3.9E+01	3.6E+02	NA	6.5E+00	NA	NA	NA	NA	NA	
Ru_{106}	3.7E-01	5.7E+01	NA	1.0E+00	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.9E+00	3.8E+01	NA	6.9E-01	1.6E+01	NA	6.4E+00	NA	1.2E-01	
Tc_{99}	1.9E+03	2.5E+03	NA	4.6E+01	3.7E+03	NA	1.8E+01	NA	3.3E-01	
Th_{230}	1.0E+03	1.1E+04	NA	2.1E+02	1.2E+00	NA	2.8E+02	NA	5.3E+00	
$Th_{232+10d}$	3.5E+01	4.2E+02	NA	7.5E+00	6.9E-02	NA	1.6E+01	NA	3.1E-01	
U_{234}	2.3E+02	3.2E+03	NA	5.8E+01	4.6E+02	NA	2.2E+02	NA	4.3E+00	
U_{235+1D}	6.2E+01	5.1E+02	NA	9.3E+00	5.2E+01	NA	2.5E+01	NA	4.8E-01	
U_{238+2d}	8.3E+02	1.3E+04	NA	2.4E+02	1.9E+03	NA	9.0E+02	NA	1.7E+01	1.2E+01
Rn_{222+4d}	7.5E+00	NA	NA	NA	NA	NA	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		
arsenic	2.8E-06	2.0E-05	4.5E-06	NA	2.1E-09	3.0E-10	1.7E-08	1.2E-08	NA	NA
beryllium	2.3E-09	3.0E-08	6.7E-08	NA	5.2E-11	7.6E-12	2.7E-09	1.9E-08	NA	NA
cadmium	3.2E-09	8.6E-08	1.9E-07	NA	9.7E-10	1.4E-10	2.0E-08	1.4E-07	NA	NA
chromium vi	1.9E-08	4.0E-07	8.8E-07	NA	8.0E-10	2.3E-10	4.9E-08	3.4E-07	NA	NA
lead	2.8E-06	7.2E-07	1.6E-06	NA	4.5E-10	2.6E-13	5.4E-08	3.8E-07	NA	NA
nickel	4.1E-08	6.9E-07	7.6E-08	NA	3.8E-09	5.6E-11	1.0E-07	3.5E-08	NA	NA
pcbs	6.6E-10	1.8E-08	1.2E-07	NA	4.5E-12	4.8E-09	5.5E-09	1.1E-07	NA	NA
benzo(a)anthracene	2.8E-11	1.1E-09	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	2.3E-11	5.4E-10	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	4.3E-11	8.5E-10	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	4.9E-13	4.4E-10	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	2.8E-11	1.0E-09	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	1.0E-11	6.5E-11	NA	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	3.6E-11	2.3E-10	1.5E-09	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	1.0E-10	6.5E-10	4.3E-08	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	9.2E-13	6.1E-12	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	3.8E-15	2.2E-13	1.5E-12	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	1.6E-12	1.1E-11	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	1.3E-13	7.8E-12	5.2E-11	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	1.6E-14	9.7E-13	6.4E-12	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	1.5E-12	8.9E-11	5.9E-10	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	8.5E-14	5.1E-12	3.4E-11	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	9.1E-10	3.3E-09	2.9E-07	NA	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
[a] Calculation of dose from penetrating radiation for trespassing youth is provided in Table E.IV-37.

TABLE E.III-13
INTAKES FOR TOXICANTS FOR TRESPASSING YOUTH
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	
cyanide	NA	NA	NA	NA	1.0E-06	1.5E-07	NA	NA	NA
antimony	NA	NA	NA	NA	NA	NA	NA	NA	NA
arsenic	NA	NA	NA	NA	NA	NA	NA	NA	NA
barium	NA	NA	NA	NA	NA	NA	NA	NA	NA
beryllium	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	NA	NA	NA	NA	NA	NA	NA	NA	NA
chromium vi	1.1E-07	2.3E-06	5.1E-06	NA	4.7E-09	6.8E-10	2.8E-07	2.0E-06	NA
cobalt	2.4E-08	9.2E-07	2.0E-06	NA	9.3E-09	1.4E-09	2.1E-07	1.4E-06	NA
copper	5.9E-06	6.7E-05	1.5E-05	NA	6.7E-08	9.8E-09	3.4E-07	2.4E-07	NA
lead	1.6E-05	4.2E-06	9.2E-06	NA	2.6E-09	3.8E-10	3.2E-07	2.2E-06	NA
manganese	9.3E-06	1.1E-04	2.4E-04	NA	1.6E-06	2.3E-07	1.1E-05	8.0E-05	NA
mercury	2.3E-09	2.2E-08	4.8E-08	NA	4.9E-09	7.1E-10	NA	NA	NA
molybdenum	4.5E-07	5.5E-06	1.2E-05	NA	2.3E-08	3.4E-09	8.5E-08	6.0E-07	NA
nickel	2.4E-07	4.0E-06	8.9E-06	NA	2.2E-08	6.5E-09	5.8E-07	4.1E-06	NA
selenium	4.1E-08	3.6E-07	7.9E-07	NA	4.0E-10	2.3E-11	NA	NA	NA
silver	3.1E-08	8.1E-07	1.8E-07	NA	2.4E-08	3.6E-09	1.8E-07	1.2E-07	NA
thallium	2.9E-08	3.1E-07	6.8E-07	NA	2.3E-10	1.3E-13	1.4E-08	9.7E-08	NA
vanadium	2.7E-06	3.6E-05	7.9E-05	NA	9.6E-09	1.4E-09	3.9E-07	2.7E-06	NA
thorium-total	3.0E-08	1.1E-05	1.2E-04	NA	NA	NA	1.5E-05	5.1E-04	NA
uranium-total	5.7E-06	5.0E-05	1.1E-04	NA	3.0E-05	4.4E-06	NA	NA	NA
fluoride	1.1E-06	1.5E-04	1.6E-05	NA	NA	NA	NA	NA	NA
acenaphthylene	4.4E-11	2.8E-10	6.2E-10	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	7.3E-11	4.7E-10	1.0E-10	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	5.9E-10	3.8E-09	8.4E-09	NA	NA	NA	NA	NA	NA
phenanthrene	2.6E-10	1.7E-09	1.1E-08	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	7.7E-12	5.0E-11	3.3E-09	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	5.3E-09	1.9E-08	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III-14
INTAKES FOR CARCINOGENS FOR GREAT MIAMI RIVER USER
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media:	Surface Water								
Exposure Pathways: / Contaminants of Concern	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	Dermal Contact while Swimming	Incidental Ingestion while Swimming	Ingestion of Fish
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life				pCi/life	pCi/life
Cs_{137+1d}	1.4E-01	5.5E-02	5.7E-02	8.1E-02	NA	NA	NA	7.6E-05	3.2E+00
Np_{237+1d}	2.3E+00	7.3E-01	2.5E-03	9.4E-04	NA	NA	NA	1.3E-03	2.6E-01
Pu_{238}	5.9E-02	1.8E-02	3.2E-07	2.7E-07	NA	NA	NA	3.3E-05	1.7E-02
$Pu_{239/240}$	1.5E-02	4.4E-03	8.6E-08	7.1E-08	NA	NA	NA	8.2E-06	4.2E-03
Ra_{226+8d}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ru_{106}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sr_{90+1d}	4.3E+01	1.7E+01	6.2E-01	1.3E+01	NA	NA	NA	2.4E-02	1.5E+01
Tc_{99}	9.9E+03	3.1E+03	1.2E+03	6.0E+03	NA	NA	NA	5.5E+00	1.7E+03
Th_{230}	3.2E+00	9.8E-01	2.5E-04	8.7E-04	NA	NA	NA	1.8E-03	1.1E+00
$Th_{232+10d}$	1.9E-01	5.7E-02	1.5E-05	5.0E-05	NA	NA	NA	1.0E-04	6.4E-02
U_{234}	1.2E+03	3.7E+02	2.7E+00	3.4E+01	NA	NA	NA	6.9E-01	2.9E+01
U_{235+1D}	1.4E+02	4.2E+01	3.1E-01	3.9E+00	NA	NA	NA	7.8E-02	3.2E+00
U_{238+2d}	5.0E+03	1.5E+03	1.1E+01	1.4E+02	NA	NA	NA	2.8E+00	1.2E+02
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
arsenic	2.7E-09	9.8E-10	1.4E-10	1.6E-11	NA	7.9E-12	1.7E-12	1.5E-12	1.4E-09
beryllium	8.5E-11	3.1E-11	2.3E-12	8.5E-15	NA	2.4E-13	5.2E-14	4.7E-14	1.9E-11
cadmium	1.6E-09	6.2E-09	4.3E-10	3.1E-09	NA	4.6E-12	9.9E-13	9.0E-13	1.5E-09
chromium vi	1.3E-09	7.0E-10	1.8E-10	2.0E-10	NA	7.7E-12	1.6E-12	7.5E-13	2.5E-10
lead	7.4E-10	6.4E-10	2.5E-11	8.3E-11	NA	8.5E-15	1.8E-15	4.1E-13	4.2E-10
nickel	6.3E-09	1.3E-08	2.8E-09	1.9E-09	NA	1.8E-12	3.9E-13	3.5E-12	3.4E-09
pcbs	7.4E-12	9.6E-12	9.3E-12	1.2E-11	NA	3.1E-10	2.0E-11	4.1E-15	1.9E-09
benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

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TABLE E.III-15
INTAKES FOR TOXICANTS FOR GREAT MIAMI RIVER USER CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media:	Surface Water								
Exposure Pathways:	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	Dermal Contact while Swimming	Incidental Ingestion while Swimming	Ingestion of Fish
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA
antimony	1.9E-08	1.2E-08	1.8E-09	7.4E-10	NA	5.4E-11	1.2E-11	1.1E-11	2.2E-10
arsenic	2.7E-09	9.8E-10	1.4E-10	1.6E-11	NA	7.9E-12	1.7E-12	1.5E-12	1.4E-09
barium	6.8E-09	6.4E-09	2.5E-10	2.3E-09	NA	2.0E-11	4.2E-12	3.8E-12	NA
beryllium	8.5E-11	3.1E-11	2.3E-12	8.5E-15	NA	2.4E-13	5.2E-14	4.7E-14	1.9E-11
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	1.6E-09	6.2E-09	4.3E-10	3.1E-09	NA	4.6E-12	9.9E-13	9.0E-13	1.5E-09
chromium vi	1.3E-09	7.0E-10	1.8E-10	2.0E-10	NA	7.7E-12	1.6E-12	7.5E-13	2.5E-10
cobalt	2.6E-09	1.3E-09	1.5E-09	6.2E-10	NA	3.0E-12	6.5E-13	1.5E-12	NA
copper	1.9E-08	3.4E-08	1.8E-08	1.1E-08	NA	5.4E-11	1.2E-11	1.1E-11	4.4E-08
lead	7.4E-10	6.4E-10	2.5E-11	8.3E-11	NA	8.5E-15	1.8E-15	4.1E-13	4.2E-10
manganese	4.4E-07	3.2E-07	1.6E-08	5.5E-08	NA	1.3E-09	2.7E-10	2.4E-10	NA
mercury	NA	NA	NA	NA	NA	NA	NA	NA	NA
molybdenum	6.6E-09	3.7E-09	2.0E-09	2.0E-09	NA	1.9E-11	4.0E-12	3.7E-12	NA
nickel	6.3E-09	1.3E-08	2.8E-09	1.9E-09	NA	1.8E-12	3.9E-13	3.5E-12	3.4E-09
selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA
silver	6.8E-09	8.0E-09	2.8E-09	7.4E-08	NA	1.2E-11	2.5E-12	3.8E-12	2.5E-07
thallium	6.6E-11	2.1E-11	4.7E-11	9.6E-12	NA	1.9E-13	4.0E-14	3.7E-14	NA
vanadium	2.7E-09	1.1E-09	1.3E-10	4.2E-12	NA	7.9E-12	1.7E-12	1.5E-12	NA
thorium-total	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium-total	8.5E-06	2.6E-06	1.9E-08	2.3E-07	NA	2.4E-08	5.2E-09	4.7E-09	2.0E-10
fluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III-16
INTAKES FOR CARCINOGENS FOR EXPANDED TRESPASSER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment			Buried Pit Material
Exposure Pathways: / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides	pCi/life	pCi/life		pCi/life	pCi/life		pCi/life		pCi/life	mRem/life
Cs_{137+1d}	1.0E+01	1.3E+02	NA	3.2E+00	5.1E-02	NA	3.7E+00	NA	7.1E-02	
Np_{237+1d}	8.2E+00	9.6E+01	NA	2.4E+00	8.4E-01	NA	1.9E+00	NA	3.6E-02	
Pu_{238}	4.6E-01	7.4E+00	NA	1.9E-01	2.2E-02	NA	1.5E+00	NA	2.8E-02	
$Pu_{239/240}$	2.0E+00	3.3E+01	NA	8.2E-01	5.4E-03	NA	3.7E-01	NA	7.1E-03	
Ra_{226+8d}	6.2E+01	6.0E+02	NA	1.5E+01	NA	NA	NA	NA	NA	
Ru_{106}	5.9E-01	9.4E+01	NA	2.4E+00	NA	NA	NA	NA	NA	
Sr_{90+1d}	3.0E+00	6.4E+01	NA	1.6E+00	1.6E+01	NA	6.4E+00	NA	1.2E-01	
Tc_{99}	3.0E+03	4.2E+03	NA	1.1E+02	3.7E+03	NA	1.8E+01	NA	3.3E-01	
Th_{230}	1.6E+03	1.9E+04	NA	4.8E+02	1.2E+00	NA	2.8E+02	NA	5.3E+00	
$Th_{232+10d}$	5.6E+01	6.9E+02	NA	1.7E+01	6.9E-02	NA	1.6E+01	NA	3.1E-01	
U_{234}	3.6E+02	5.4E+03	NA	1.3E+02	4.6E+02	NA	2.2E+02	NA	4.3E+00	
U_{235+1D}	9.8E+01	8.5E+02	NA	2.1E+01	5.2E+01	NA	2.5E+01	NA	4.8E-01	
U_{238+2d}	1.3E+03	2.2E+04	NA	5.4E+02	1.9E+03	NA	9.0E+02	NA	1.7E+01	4.2E+01
Rn_{222+4d}	1.2E+01	NA	NA	NA	NA	NA	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		
arsenic	3.9E-06	2.9E-05	1.7E-05	NA	2.1E-09	3.0E-10	1.7E-08	1.2E-08	NA	NA
beryllium	3.1E-09	4.4E-08	2.6E-07	NA	5.2E-11	7.6E-12	2.7E-09	1.9E-08	NA	NA
cadmium	4.4E-09	1.2E-07	7.3E-07	NA	9.7E-10	1.4E-10	2.0E-08	1.4E-07	NA	NA
chromium vi	2.6E-08	5.7E-07	3.4E-06	NA	8.0E-10	2.3E-10	4.9E-08	3.4E-07	NA	NA
lead	3.9E-06	1.0E-06	6.1E-06	NA	4.5E-10	2.6E-13	5.4E-08	3.8E-07	NA	NA
nickel	5.7E-08	9.9E-07	2.9E-07	NA	3.8E-09	5.6E-11	1.0E-07	3.5E-08	NA	NA
pcbs	9.1E-10	2.6E-08	4.7E-07	NA	4.5E-12	4.8E-09	5.5E-09	1.1E-07	NA	NA
benzo(a)anthracene	3.9E-11	1.6E-09	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	3.1E-11	7.9E-10	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	6.0E-11	1.2E-09	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	6.8E-13	6.4E-10	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	3.9E-11	1.5E-09	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	1.4E-11	9.4E-11	NA	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	4.9E-11	3.3E-10	5.9E-09	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	1.4E-10	9.4E-10	1.7E-07	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	1.3E-12	2.3E-11	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	5.2E-15	3.2E-13	5.6E-12	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	2.3E-12	4.1E-11	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	1.8E-13	1.1E-11	2.0E-10	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	2.3E-14	1.4E-12	2.5E-11	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	2.1E-12	1.3E-10	2.3E-09	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	1.2E-13	7.3E-12	1.3E-10	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	1.2E-09	4.7E-09	1.1E-06	NA	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
[a] Calculation of dose from penetrating radiation for expanded trespasser is provided in Table E.IV-33.

TABLE E.III-17
INTAKES FOR TOXICANTS FOR EXPANDED TRESPASSER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	
cyanide	NA	NA	NA	NA	1.0E-06	1.5E-07	NA	NA	NA
antimony	NA	NA	NA	NA	NA	NA	NA	NA	NA
arsenic	NA	NA	NA	NA	NA	NA	NA	NA	NA
barium	NA	NA	NA	NA	NA	NA	NA	NA	NA
beryllium	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	NA	NA	NA	NA	NA	NA	NA	NA	NA
chromium vi	1.3E-07	2.9E-06	1.4E-05	NA	4.7E-09	6.8E-10	2.8E-07	2.0E-06	NA
cobalt	2.9E-08	1.1E-06	5.6E-06	NA	9.3E-09	1.4E-09	2.1E-07	1.4E-06	NA
copper	7.0E-06	8.3E-05	4.1E-05	NA	6.7E-08	9.8E-09	3.4E-07	2.4E-07	NA
lead	1.9E-05	5.2E-06	2.6E-05	NA	2.6E-09	3.8E-10	3.2E-07	2.2E-06	NA
manganese	1.1E-05	1.3E-04	6.6E-04	NA	1.6E-06	2.3E-07	1.1E-05	8.0E-05	NA
mercury	2.7E-09	2.7E-08	1.3E-07	NA	4.9E-09	7.1E-10	NA	NA	NA
molybdenum	5.3E-07	6.8E-06	3.4E-05	NA	2.3E-08	3.4E-09	8.5E-08	6.0E-07	NA
nickel	2.9E-07	5.0E-06	2.4E-05	NA	2.2E-08	6.5E-09	5.8E-07	4.1E-06	NA
selenium	4.8E-08	4.4E-07	2.2E-06	NA	4.0E-10	2.3E-11	NA	NA	NA
silver	3.6E-08	1.0E-06	4.9E-07	NA	2.4E-08	3.6E-09	1.8E-07	1.2E-07	NA
thallium	3.4E-08	3.8E-07	1.9E-06	NA	2.3E-10	1.3E-13	1.4E-08	9.7E-08	NA
vanadium	3.2E-06	4.4E-05	2.2E-04	NA	9.6E-09	1.4E-09	3.9E-07	2.7E-06	NA
thorium-total	3.5E-08	1.4E-05	3.4E-04	NA	NA	NA	1.5E-05	5.1E-04	NA
uranium-total	6.8E-06	6.2E-05	3.1E-04	NA	3.0E-05	4.4E-06	NA	NA	NA
fluoride	1.3E-06	1.8E-04	4.5E-05	NA	NA	NA	NA	NA	NA
acenaphthylene	5.2E-11	3.5E-10	1.7E-09	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	8.6E-11	5.8E-10	2.9E-10	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	7.0E-10	4.7E-09	2.3E-08	NA	NA	NA	NA	NA	NA
phenanthrene	3.1E-10	2.1E-09	3.1E-08	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	9.1E-12	6.2E-11	9.1E-09	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	6.2E-09	2.4E-08	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

TABLE E.III-18
INTAKES FOR CARCINOGENS FOR ON-PROPERTY GROUNDSKEEPER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material			Buried Pit Material
Exposure Pathways: Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides	pCi/life	pCi/life		pCi/life	mRem/life
Cs_{137+1d}	5.6E+01	5.7E+02	NA	5.2E+00	
Np_{237+1d}	4.4E+01	4.3E+02	NA	3.9E+00	
Pu_{238}	2.5E+00	3.3E+01	NA	3.0E-01	
$Pu_{239/240}$	1.1E+01	1.5E+02	NA	1.3E+00	
Ra_{226+8d}	3.3E+02	2.7E+03	NA	2.4E+01	
Ru_{106}	3.2E+00	4.2E+02	NA	3.8E+00	
Sr_{90+1d}	1.6E+01	2.8E+02	NA	2.6E+00	
Tc_{99}	1.6E+04	1.9E+04	NA	1.7E+02	
Th_{230}	8.8E+03	8.5E+04	NA	7.7E+02	
$Th_{232+10d}$	3.0E+02	3.1E+03	NA	2.8E+01	
U_{234}	1.9E+03	2.4E+04	NA	2.2E+02	
U_{235+1D}	5.3E+02	3.8E+03	NA	3.5E+01	
U_{238+2d}	7.0E+03	9.6E+04	NA	8.8E+02	7.5E+01
Rn_{222+4d}	6.3E+01	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day		
arsenic	1.5E-05	9.2E-05	5.3E-06	NA	NA
beryllium	1.2E-08	1.4E-07	7.9E-08	NA	NA
cadmium	1.7E-08	3.9E-07	2.2E-07	NA	NA
chromium vi	9.8E-08	1.8E-06	1.0E-06	NA	NA
lead	1.5E-05	3.2E-06	1.9E-06	NA	NA
nickel	2.2E-07	3.1E-06	8.9E-08	NA	NA
pcbs	3.4E-09	8.3E-08	1.4E-07	NA	NA
benzo(a)anthracene	1.5E-10	5.1E-09	NA	NA	NA
benzo(a)pyrene	1.2E-10	2.5E-09	NA	NA	NA
benzo(b)fluoranthene	2.3E-10	3.8E-09	NA	NA	NA
benzo(k)fluoranthene	2.5E-12	2.0E-09	NA	NA	NA
chrysene	1.5E-10	4.7E-09	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	5.3E-11	3.0E-10	NA	NA	NA
n-nitrosodipropylamine	1.9E-10	1.0E-09	1.8E-09	NA	NA
pentachlorophenol	5.3E-10	3.0E-09	5.1E-08	NA	NA
vinyl chloride	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	4.2E-12	7.2E-12	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	2.0E-14	1.0E-12	1.7E-12	NA	NA
hexachlorodibenzofuran	NA	7.3E-12	1.3E-11	NA	NA
heptachlorodibenzo-p-dioxin	6.8E-13	3.6E-11	6.1E-11	NA	NA
heptachlorodibenzofuran	8.5E-14	4.4E-12	7.6E-12	NA	NA
octachlorodibenzo-p-dioxin	7.8E-12	4.1E-10	7.0E-10	NA	NA
octachlorodibenzofuran	4.4E-13	2.3E-11	4.0E-11	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	4.7E-09	1.5E-08	3.4E-07	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
[a] Calculation of dose from penetrating radiation for groundskeeper is provided in Table E.IV-35.

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TABLE E.III-19
INTAKES FOR TOXICANTS FOR ON-PROPERTY GROUNDSKEEPER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	
cyanide	NA	NA	NA	NA
antimony	8.2E-08	4.4E-06	2.5E-06	NA
arsenic	4.1E-05	2.6E-04	1.5E-05	NA
barium	3.0E-05	3.6E-04	2.1E-04	NA
beryllium	3.3E-08	3.8E-07	2.2E-07	NA
boron	NA	NA	NA	NA
cadmium	4.7E-08	1.1E-06	6.3E-07	NA
chromium vi	2.7E-07	5.0E-06	2.9E-06	NA
cobalt	6.0E-08	2.0E-06	1.2E-06	NA
copper	1.5E-05	1.5E-04	8.4E-06	NA
lead	4.1E-05	9.1E-06	5.2E-06	NA
manganese	2.3E-05	2.4E-04	1.4E-04	NA
mercury	5.8E-09	4.8E-08	1.4E-07	NA
molybdenum	1.1E-06	1.2E-05	6.9E-06	NA
nickel	6.0E-07	8.7E-06	2.5E-07	NA
selenium	1.0E-07	7.7E-07	4.5E-07	NA
silver	7.7E-08	1.8E-06	1.0E-06	NA
thallium	7.1E-08	6.7E-07	3.9E-07	NA
vanadium	6.8E-06	7.8E-05	4.5E-06	NA
thorium-total	7.4E-08	2.4E-05	4.2E-05	NA
uranium-total	1.4E-05	1.1E-04	6.3E-05	NA
fluoride	2.7E-06	3.2E-04	5.6E-04	NA
acenaphthylene	1.1E-10	6.1E-10	1.1E-08	NA
2-methylnaphthalene	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA
benzo(g,h,i)perylene	1.8E-10	1.0E-09	NA	NA
dibenzofuran	NA	NA	NA	NA
pentachlorophenol	1.5E-09	8.3E-09	1.4E-07	NA
phenanthrene	6.6E-10	3.7E-09	6.4E-08	NA
tributyl phosphate	NA	NA	NA	NA
2-hexanone	1.9E-11	1.1E-10	NA	NA
3-chloropropene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	1.3E-08	4.1E-08	9.5E-07	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

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TABLE E.III–20
INTAKES FOR CARCINOGENS FOR RME ON–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater						Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	External Exposure[a]
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life		pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life			mRem/life
Cs_{137+1d}	3.6E+02	5.8E+03	1.0E+04	1.4E+04	3.1E+04	1.3E+05	1.8E+05	2.9E+04	NA	2.7E+02	1.2E+06	1.7E+06	NA	NA	NA	NA	NA	NA	
Np_{237+1d}	2.8E+02	3.8E+03	2.1E+01	7.7E+00	6.4E+03	2.8E+02	1.0E+02	2.2E+04	NA	2.0E+02	NA	NA	5.7E+00	1.8E+00	6.4E−03	2.4E−03	NA	NA	
Pu_{238}	1.6E+01	2.0E+02	7.4E−03	5.9E−03	5.8E+00	4.8E−02	3.8E−02	1.7E+03	NA	1.6E+01	NA	NA	6.5E+03	1.9E+03	3.6E−02	3.0E−02	NA	NA	
$Pu_{239/240}$	7.2E+01	9.1E+02	7.1E−02	5.7E−02	1.2E+01	9.6E−02	7.7E−02	7.3E+03	NA	6.9E+01	NA	NA	NA	NA	NA	NA	NA	NA	
Ra_{226+8d}	2.2E+03	3.1E+04	1.3E+03	9.2E+03	2.7E+03	8.0E+02	5.8E+03	1.3E+05	NA	1.3E+03	8.1E+01	5.9E+02	8.7E+04	3.0E+04	5.5E+02	4.0E+03	NA	NA	
Ru_{106}	2.1E+01	2.6E+02	2.6E+01	3.2E−02	NA	NA	NA	2.1E+04	NA	2.0E+02	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.0E+02	1.7E+03	1.0E+02	2.0E+03	4.8E+05	1.0E+05	2.1E+06	1.4E+04	NA	1.3E+02	1.9E+04	3.8E+05	2.3E+02	9.3E+01	3.4E+00	6.8E+01	NA	NA	
Tc_{99}	1.0E+04	1.4E+05	8.2E+04	3.9E+05	1.1E+07	4.2E+07	2.0E+08	9.4E+05	NA	8.8E+03	9.8E+06	4.7E+07	8.1E+05	2.5E+05	1.0E+05	4.9E+05	NA	NA	
Th_{230}	5.7E+04	7.3E+05	8.7E+02	2.9E+03	1.6E+04	8.7E+02	2.9E+03	4.3E+06	NA	4.0E+04	7.7E−01	2.6E+00	5.1E+04	1.6E+04	4.0E+00	1.4E+01	NA	NA	
$Th_{232+10d}$	1.9E+03	2.4E+04	2.8E+01	9.5E+01	6.0E+02	3.3E+01	1.1E+02	1.6E+05	NA	1.5E+03	1.5E+01	5.3E+01	NA	NA	NA	NA	NA	NA	
U_{234}	1.3E+04	1.6E+05	1.8E+03	2.2E+04	6.0E+05	4.0E+04	4.8E+05	1.2E+06	NA	1.1E+04	7.8E+04	9.7E+05	1.1E+08	3.4E+07	2.5E+05	3.1E+06	NA	NA	
U_{235+1D}	3.5E+03	4.4E+04	4.9E+02	5.9E+03	9.6E+04	6.4E+03	7.6E+04	1.9E+05	NA	1.8E+03	4.5E+03	5.6E+04	2.6E+07	7.7E+06	5.7E+04	7.1E+05	NA	NA	
U_{238+2d}	4.6E+04	5.9E+05	6.5E+03	7.9E+04	4.0E+06	2.7E+05	3.2E+06	4.9E+06	NA	4.6E+04	1.9E+05	2.4E+06	5.3E+08	1.6E+08	1.2E+06	1.5E+07	NA	NA	1.9E+03
Rn_{222+4d}	4.3E+02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	
arsenic	9.7E−05	1.4E−03	3.6E−04	4.3E−05	3.5E−05	4.2E−05	5.1E−06	4.6E−03	1.5E−04	NA	3.1E−06	3.8E−07	1.6E−02	5.7E−03	7.9E−04	9.6E−05	NA	4.6E−05	NA
beryllium	6.5E−08	9.7E−07	1.9E−07	6.8E−10	8.3E−07	7.9E−07	2.9E−09	6.9E−06	2.2E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	1.1E−07	1.5E−05	2.0E−06	1.4E−05	6.3E−04	9.3E−05	6.7E−04	2.0E−05	6.3E−06	NA	NA	NA	1.7E−14	6.6E−14	4.5E−15	3.3E−14	NA	5.0E−17	NA
chromium vi	6.5E−07	1.3E−05	9.9E−06	1.1E−05	NA	NA	NA	9.0E−05	2.9E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
lead	9.7E−05	3.1E−03	2.6E−04	8.8E−04	NA	NA	NA	1.6E−04	5.2E−05	NA	2.0E−06	6.8E−06	1.6E−03	1.4E−03	5.4E−05	1.8E−04	NA	1.8E−08	NA
nickel	1.4E−06	9.7E−05	4.6E−05	3.1E−05	NA	NA	NA	1.6E−04	2.5E−06	NA	1.6E−04	1.1E−04	NA	NA	NA	NA	NA	NA	NA
pcbs	2.3E−08	1.1E−06	3.2E−06	4.0E−06	1.3E−05	4.4E−05	5.5E−05	4.2E−06	4.0E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	1.0E−09	1.4E−08	7.7E−09	9.8E−09	1.6E−06	1.6E−06	2.1E−06	2.6E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	7.8E−10	1.0E−08	1.3E−08	1.7E−08	4.1E−07	1.2E−06	1.5E−06	1.2E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	1.6E−09	2.0E−08	1.0E−07	1.3E−07	2.6E−07	4.5E−06	5.8E−06	1.9E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	6.5E−11	8.4E−10	8.7E−09	1.1E−08	1.4E−07	5.9E−06	7.4E−06	1.0E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	9.7E−10	1.3E−08	7.6E−09	9.6E−09	1.4E−06	1.5E−06	1.9E−06	2.4E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	3.4E−10	4.3E−09	2.7E−07	3.5E−07	NA	NA	NA	1.5E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	1.2E−09	1.9E−08	5.5E−13	7.0E−13	NA	NA	NA	5.3E−08	5.0E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	3.4E−09	4.6E−08	6.4E−09	8.2E−09	NA	NA	NA	1.5E−07	1.4E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	2.1E−10	2.0E−10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	1.3E−13	1.5E−12	1.6E−11	2.2E−11	NA	NA	NA	5.1E−11	4.8E−11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	3.7E−10	3.5E−10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	4.5E−12	5.3E−11	5.4E−10	7.6E−10	NA	NA	NA	1.8E−09	1.7E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	5.6E−13	6.6E−12	4.2E−12	6.0E−12	NA	NA	NA	2.2E−10	2.1E−10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	5.1E−11	6.1E−10	6.1E−09	8.7E−09	NA	NA	NA	2.0E−08	2.0E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	2.9E−12	3.5E−11	2.2E−11	3.1E−11	NA	NA	NA	1.2E−09	1.1E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E−10	3.6E−10	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	3.0E−08	6.5E−07	3.3E−10	4.3E−10	NA	NA	NA	7.4E−07	9.5E−06	NA	1.4E−09	1.8E−09	1.7E−11	9.7E−12	2.9E−15	3.7E−15	6.5E−11	1.3E−11	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E−08	1.4E−08	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.9E−11	6.7E−11	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
[a] Calculation of dose from penetrating radiation for on–property RME farmer is provided in Table E.IV–39.

TABLE E.III–21
INTAKES FOR TOXICANTS FOR RME ON–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Soil			Exposed Waste Pit Material			Surface Water		Ground Water					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.0E−09	2.6E−09	1.2E−07	5.6E−08	1.1E−13	1.5E−13	NA	3.3E−10
antimony	2.0E−07	5.0E−06	1.4E−06	5.5E−07	6.0E−04	3.0E−04	1.2E−04	8.0E−05	2.5E−05	NA	8.0E−06	3.2E−06	4.8E−03	3.2E−03	4.7E−04	1.9E−04	NA	1.4E−05
arsenic	9.7E−05	1.4E−03	3.6E−04	4.3E−05	3.5E−05	4.2E−05	5.1E−06	4.6E−03	1.5E−04	NA	3.1E−06	3.8E−07	1.6E−02	5.7E−03	7.9E−04	9.6E−05	NA	4.6E−05
barium	7.1E−05	2.4E−03	1.8E−04	1.7E−03	NA	NA	NA	6.5E−03	2.1E−03	NA	6.8E−05	6.4E−04	1.8E−02	1.7E−02	6.4E−04	6.0E−03	NA	5.1E−05
beryllium	6.5E−08	9.7E−07	1.9E−07	6.8E−10	8.3E−07	7.9E−07	2.9E−09	6.9E−06	2.2E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.8E−03	1.7E−03	7.2E−05	5.5E−04	NA	8.0E−06
cadmium	1.1E−07	1.5E−05	2.0E−06	1.4E−05	6.3E−04	9.3E−05	6.7E−04	2.0E−05	6.3E−06	NA	NA	NA	1.7E−14	6.6E−14	4.5E−15	3.3E−14	NA	5.0E−17
chromium vi	6.5E−07	1.3E−05	9.9E−06	1.1E−05	NA	NA	NA	9.0E−05	2.9E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA
cobalt	1.4E−07	2.7E−06	7.2E−06	2.9E−06	NA	NA	NA	3.6E−05	1.2E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA
copper	3.4E−05	2.2E−03	2.3E−03	1.4E−03	NA	NA	NA	2.6E−03	8.4E−05	NA	4.7E−04	2.9E−04	NA	NA	NA	NA	NA	NA
lead	9.7E−05	3.1E−03	2.6E−04	8.8E−04	NA	NA	NA	1.6E−04	5.2E−05	NA	2.0E−06	6.8E−06	1.6E−03	1.4E−03	5.4E−05	1.8E−04	NA	1.8E−08
manganese	5.4E−05	1.5E−03	1.3E−04	4.7E−04	NA	NA	NA	4.3E−03	1.4E−03	NA	4.6E−06	1.6E−05	5.7E−02	4.2E−02	2.0E−03	7.1E−03	NA	1.6E−04
mercury	1.4E−08	2.2E−07	6.0E−06	4.3E−08	NA	NA	NA	8.6E−07	1.4E−06	NA	NA	NA	9.8E−06	3.9E−06	6.5E−05	4.8E−07	NA	2.8E−08
molybdenum	2.5E−06	5.4E−05	5.2E−05	5.2E−05	NA	NA	NA	2.2E−04	6.9E−05	NA	NA	NA	4.6E−04	2.6E−04	1.4E−04	1.4E−04	NA	1.3E−06
nickel	1.4E−06	9.7E−05	4.6E−05	3.1E−05	NA	NA	NA	1.6E−04	2.5E−06	NA	1.6E−04	1.1E−04	NA	NA	NA	NA	NA	NA
selenium	2.4E−07	9.5E−06	1.2E−05	1.3E−05	NA	NA	NA	1.4E−05	4.5E−06	NA	3.3E−05	3.5E−05	NA	NA	NA	NA	NA	NA
silver	1.7E−07	7.3E−06	4.9E−06	1.3E−04	NA	NA	NA	3.2E−05	1.0E−05	NA	3.7E−05	9.8E−04	NA	NA	NA	NA	NA	NA
thallium	1.6E−07	2.2E−06	1.5E−05	3.0E−06	2.0E−07	2.0E−05	4.0E−06	1.2E−05	3.9E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA
vanadium	1.6E−05	2.7E−04	8.8E−05	2.8E−06	NA	NA	NA	1.4E−03	4.5E−05	NA	1.9E−04	6.3E−06	NA	NA	NA	NA	NA	NA
thorium−total	1.7E−07	2.2E−06	2.6E−09	8.6E−09	3.5E−07	1.9E−08	6.5E−08	4.4E−04	4.2E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium−total	3.3E−05	4.2E−04	4.7E−06	5.6E−05	1.2E−03	7.9E−05	9.4E−04	2.0E−03	6.3E−04	NA	NA	NA	8.8E−01	2.6E−01	1.9E−03	2.4E−02	NA	2.5E−03
fluoride	6.2E−06	7.9E−05	NA	NA	NA	NA	NA	5.8E−03	5.6E−03	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	2.5E−10	3.2E−09	4.4E−11	5.9E−11	NA	NA	NA	1.1E−08	1.1E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA
−methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
−chloro−3−methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	4.2E−10	5.3E−09	1.2E−07	1.6E−07	NA	NA	NA	1.8E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	3.4E−09	4.6E−08	6.4E−09	8.2E−09	NA	NA	NA	1.5E−07	1.4E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	1.6E−09	2.1E−08	8.0E−10	1.0E−09	NA	NA	NA	6.6E−08	6.4E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−hexanone	4.5E−11	8.2E−10	2.9E−14	3.7E−14	NA	NA	NA	1.9E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3−chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E−10	3.6E−10	NA	NA	NA	NA	NA	NA
tetrachloroethene	3.0E−08	6.5E−07	3.3E−10	4.3E−10	NA	NA	NA	7.4E−07	9.5E−06	NA	1.4E−09	1.8E−09	1.7E−11	9.7E−12	2.9E−15	3.7E−15	6.5E−11	1.3E−11
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.9E−11	6.7E−11	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.6E−09	6.4E−09	NA	NA	NA	NA	NA	NA
2−nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.1E−10	9.3E−10	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E−10	2.3E−10	NA	NA	NA	NA	NA	NA

NA − Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

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TABLE E.III–22
INTAKES FOR CARCINOGENS FOR RME ON–PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater						Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	External Exposure[a]
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life		pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life			mRem/life
Cs_{137+1d}	6.5E+00	4.3E+02	3.4E+02	2.8E+03	2.3E+03	4.4E+03	3.6E+04	2.8E+03	NA	2.0E+01	3.9E+04	3.2E+05	NA	NA	NA	NA	NA	NA	
Np_{237+1d}	5.0E+00	2.8E+02	7.0E−01	1.5E+00	4.8E+02	9.2E+00	2.0E+01	2.1E+03	NA	1.5E+01	NA	NA	2.4E−01	1.4E−01	2.1E−04	4.6E−04	NA	NA	
Pu_{238}	2.9E−01	1.5E+01	2.5E−04	1.2E−03	4.3E−01	1.6E−03	7.5E−03	1.6E+02	NA	1.2E+00	NA	NA	2.8E+02	1.5E+02	1.2E−03	5.8E−03	NA	NA	
$Pu_{239/240}$	1.3E+00	6.8E+01	2.4E−03	1.1E−02	8.6E−01	3.2E−03	1.5E−02	7.0E+02	NA	5.2E+00	NA	NA	NA	NA	NA	NA	NA	NA	
Ra_{226+8d}	4.0E+01	2.3E+03	4.2E+01	1.8E+03	2.0E+02	2.7E+01	1.1E+03	1.3E+04	NA	9.5E+01	2.7E+00	1.1E+02	3.7E+03	2.2E+03	1.8E+01	7.9E+02	NA	NA	
Ru_{106}	3.8E−01	1.9E+01	8.6E−01	6.2E−03	NA	NA	NA	2.0E+03	NA	1.5E+01	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.9E+00	1.3E+02	3.4E+00	4.0E+02	3.6E+04	3.4E+03	4.0E+05	1.4E+03	NA	1.0E+01	6.2E+02	7.3E+04	9.8E+00	6.9E+00	1.1E−01	1.3E+01	NA	NA	
Tc_{99}	1.9E+02	1.0E+04	2.7E+03	7.5E+04	8.0E+05	1.4E+06	3.8E+07	8.9E+04	NA	6.6E+02	3.2E+05	9.1E+06	3.5E+04	1.9E+04	3.3E+03	9.5E+04	NA	NA	
Th_{230}	1.0E+03	5.4E+04	2.9E+01	5.6E+02	1.2E+03	2.9E+01	5.7E+02	4.1E+05	NA	3.0E+03	2.5E−02	5.1E−01	2.2E+03	1.2E+03	1.3E−01	2.7E+00	NA	NA	
$Th_{232+10d}$	3.4E+01	1.8E+03	9.4E−01	1.8E+01	4.5E+01	1.1E+00	2.1E+01	1.5E+04	NA	1.1E+02	5.1E−01	1.0E+01	NA	NA	NA	NA	NA	NA	
U_{234}	2.3E+02	1.2E+04	6.0E+01	4.2E+03	4.5E+04	1.3E+03	9.3E+04	1.1E+05	NA	8.5E+02	2.6E+03	1.9E+05	4.8E+06	2.5E+06	8.2E+03	6.0E+05	NA	NA	
U_{235+1D}	6.3E+01	3.3E+03	1.6E+01	1.1E+03	7.1E+03	2.1E+02	1.5E+04	1.8E+04	NA	1.3E+02	1.5E+02	1.1E+04	1.1E+06	5.8E+05	1.9E+03	1.4E+05	NA	NA	
U_{238+2d}	8.4E+02	4.4E+04	2.2E+02	1.5E+04	3.0E+05	8.9E+03	6.2E+05	4.6E+05	NA	3.4E+03	6.3E+03	4.6E+05	2.3E+07	1.2E+07	3.9E+04	2.8E+06	NA	NA	4.0E−01
Rn_{222+4d}	7.8E+00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	
arsenic	8.2E−06	4.9E−04	5.6E−05	3.9E−05	1.2E−05	6.5E−06	4.6E−06	2.1E−03	2.1E−05	NA	4.8E−07	3.4E−07	3.2E−03	2.0E−03	1.2E−04	8.7E−05	NA	6.4E−06	NA
beryllium	5.5E−09	3.4E−07	2.9E−08	6.1E−10	2.9E−07	1.2E−07	2.6E−09	3.1E−06	3.1E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	9.3E−09	5.1E−06	3.1E−07	1.3E−05	2.2E−04	1.4E−05	6.1E−04	8.7E−06	8.7E−07	NA	NA	NA	3.5E−15	2.3E−14	7.0E−16	3.0E−14	NA	6.9E−18	NA
chromium vi	5.5E−08	4.5E−06	1.5E−06	9.8E−06	NA	NA	NA	4.0E−05	4.0E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
lead	8.2E−06	1.1E−03	4.1E−05	8.0E−04	NA	NA	NA	7.3E−05	7.3E−06	NA	3.1E−07	6.2E−06	3.2E−04	4.8E−04	8.3E−06	1.6E−04	NA	2.5E−09	NA
nickel	1.2E−07	3.4E−05	7.1E−06	2.8E−05	NA	NA	NA	7.0E−05	3.5E−07	NA	2.5E−05	9.8E−05	NA	NA	NA	NA	NA	NA	NA
pcbs	2.0E−09	3.8E−07	4.9E−07	3.6E−06	4.4E−06	6.8E−06	5.0E−05	1.9E−06	5.6E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	8.8E−11	4.8E−09	1.2E−09	8.9E−09	5.4E−07	2.5E−07	1.9E−06	1.1E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	6.6E−11	3.5E−09	2.1E−09	1.6E−08	1.4E−07	1.9E−07	1.4E−06	5.5E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	1.3E−10	6.9E−09	1.6E−08	1.2E−07	9.0E−08	7.0E−07	5.2E−06	8.6E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	5.5E−12	2.9E−10	1.3E−09	1.0E−08	4.9E−08	9.1E−07	6.7E−06	4.5E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	8.2E−11	4.6E−09	1.2E−09	8.7E−09	4.9E−07	2.3E−07	1.7E−06	1.0E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	2.9E−11	1.5E−09	4.2E−08	3.2E−07	NA	NA	NA	6.6E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	1.0E−10	6.5E−09	8.5E−14	6.3E−13	NA	NA	NA	2.3E−08	7.0E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.9E−10	1.6E−08	9.9E−10	7.4E−09	NA	NA	NA	6.6E−08	2.0E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	9.4E−11	2.8E−11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	1.1E−14	5.3E−13	2.4E−12	2.0E−11	NA	NA	NA	2.2E−11	6.7E−12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	1.6E−10	4.9E−11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	3.8E−13	1.8E−11	8.3E−11	6.9E−10	NA	NA	NA	8.0E−10	2.4E−10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	4.7E−14	2.3E−12	6.5E−13	5.5E−12	NA	NA	NA	9.8E−11	3.0E−11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	4.3E−12	2.1E−10	9.5E−10	7.9E−09	NA	NA	NA	9.1E−09	2.7E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	2.5E−13	1.2E−11	3.4E−12	2.9E−11	NA	NA	NA	5.2E−10	1.5E−10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.0E−11	3.3E−10	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.6E−09	2.3E−07	5.2E−11	3.9E−10	NA	NA	NA	3.3E−07	1.3E−06	NA	2.1E−10	1.6E−09	3.5E−12	3.4E−12	4.4E−16	3.4E−15	2.6E−11	1.7E−12	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6E−09	1.3E−08	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.5E−12	6.1E−11	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
[a] Calculation of dose from penetrating radiation for on–property young child is provided in Table E.IV–40.

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TABLE E.III-23
INTAKES FOR TOXICANTS FOR RME ON-PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Soil			Exposed Waste Pit Material			Surface Water		Ground Water					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.7E-09	2.8E-08	2.7E-07	2.3E-07	2.0E-13	1.6E-12	NA	5.4E-10
antimony	2.0E-07	2.0E-05	2.5E-06	5.8E-06	2.4E-03	5.4E-04	1.3E-03	4.1E-04	4.1E-05	NA	1.4E-05	3.4E-05	1.1E-02	1.3E-02	8.4E-04	2.0E-03	NA	2.2E-05
arsenic	9.6E-05	5.7E-03	6.5E-04	4.6E-04	1.4E-04	7.6E-05	5.3E-05	2.4E-02	2.4E-04	NA	5.6E-06	4.0E-06	3.7E-02	2.3E-02	1.4E-03	1.0E-03	NA	7.4E-05
barium	7.0E-05	9.9E-03	3.3E-04	1.8E-02	NA	NA	NA	3.4E-02	3.4E-03	NA	1.2E-04	6.7E-03	4.2E-02	6.8E-02	1.2E-03	6.4E-02	NA	8.3E-05
beryllium	6.4E-08	3.9E-06	3.4E-07	7.2E-09	3.4E-06	1.4E-06	3.0E-08	3.6E-05	3.6E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.5E-03	6.8E-03	1.3E-04	5.8E-03	NA	1.3E-05
cadmium	1.1E-07	5.9E-05	3.6E-06	1.5E-04	2.5E-03	1.7E-04	7.1E-03	1.0E-04	1.0E-05	NA	NA	NA	4.0E-14	2.7E-13	8.2E-15	3.5E-13	NA	8.1E-17
chromium vi	6.4E-07	5.3E-05	1.8E-05	1.1E-04	NA	NA	NA	4.7E-04	4.7E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
cobalt	1.4E-07	1.1E-05	1.3E-05	3.0E-05	NA	NA	NA	1.9E-04	1.9E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
copper	3.4E-05	8.8E-03	4.1E-03	1.5E-02	NA	NA	NA	1.4E-02	1.4E-04	NA	8.6E-04	3.0E-03	NA	NA	NA	NA	NA	NA
lead	9.6E-05	1.2E-02	4.8E-04	9.3E-03	NA	NA	NA	8.5E-04	8.5E-05	NA	3.7E-06	7.2E-05	3.7E-03	5.6E-03	9.7E-05	1.9E-03	NA	3.0E-08
manganese	5.4E-05	6.0E-03	2.4E-04	5.0E-03	NA	NA	NA	2.2E-02	2.2E-03	NA	8.2E-06	1.7E-04	1.3E-01	1.7E-01	3.6E-03	7.5E-02	NA	2.6E-04
mercury	1.3E-08	8.8E-07	1.1E-05	4.5E-07	NA	NA	NA	4.4E-06	2.2E-06	NA	NA	NA	2.3E-05	1.6E-05	1.2E-04	5.1E-06	NA	4.6E-08
molybdenum	2.5E-06	2.2E-04	9.3E-05	5.5E-04	NA	NA	NA	1.1E-03	1.1E-04	NA	NA	NA	1.1E-03	1.1E-03	2.5E-04	1.5E-03	NA	2.2E-06
nickel	1.3E-06	3.9E-04	8.3E-05	3.2E-04	NA	NA	NA	8.1E-04	4.1E-06	NA	2.9E-04	1.1E-03	NA	NA	NA	NA	NA	NA
selenium	2.4E-07	3.9E-05	2.2E-05	1.4E-04	NA	NA	NA	7.2E-05	7.2E-06	NA	5.9E-05	3.7E-04	NA	NA	NA	NA	NA	NA
silver	1.7E-07	3.0E-05	8.8E-06	1.4E-03	NA	NA	NA	1.6E-04	1.6E-05	NA	6.6E-05	1.0E-02	NA	NA	NA	NA	NA	NA
thallium	1.6E-07	8.7E-06	2.7E-05	3.2E-05	8.1E-07	3.6E-05	4.3E-05	6.3E-05	6.3E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
vanadium	1.6E-05	1.1E-03	1.6E-04	3.0E-05	NA	NA	NA	7.2E-03	7.2E-05	NA	3.5E-04	6.6E-05	NA	NA	NA	NA	NA	NA
thorium-total	1.7E-07	8.8E-06	4.7E-09	9.1E-08	1.4E-06	3.5E-08	6.8E-07	2.3E-03	6.8E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium-total	3.3E-05	1.7E-03	8.4E-06	5.9E-04	4.8E-03	1.4E-04	1.0E-02	1.0E-02	1.0E-03	NA	NA	NA	2.0E+00	1.1E+00	3.5E-03	2.6E-01	NA	4.1E-03
fluoride	6.1E-06	3.2E-04	NA	NA	NA	NA	NA	3.0E-02	9.0E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	2.5E-10	1.3E-08	7.9E-11	6.2E-10	NA	NA	NA	5.7E-08	1.7E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	4.2E-10	2.2E-08	2.2E-07	1.7E-06	NA	NA	NA	9.5E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	3.4E-09	1.9E-07	1.2E-08	8.6E-08	NA	NA	NA	7.7E-07	2.3E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	1.5E-09	8.4E-08	1.4E-09	1.1E-08	NA	NA	NA	3.4E-07	1.0E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	4.4E-11	3.3E-09	5.3E-14	3.9E-13	NA	NA	NA	1.0E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.7E-10	3.9E-09	NA	NA	NA	NA	NA	NA
tetrachloroethene	3.0E-08	2.6E-06	6.0E-10	4.5E-09	NA	NA	NA	3.9E-06	1.5E-05	NA	2.5E-09	1.9E-08	4.0E-11	3.9E-11	5.2E-15	3.9E-14	3.0E-10	2.0E-11
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.3E-11	7.1E-10	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.2E-09	6.7E-08	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3E-09	9.8E-09	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.9E-10	2.5E-09	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

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TABLE E.III-24
INTAKES FOR CARCINOGENS FOR CT ON-PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater						Buried Pit Material
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	External Exposure[a]
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life		pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life			mRem/life
Cs_{137+1d}	2.7E+01	3.7E+02	6.9E+02	7.7E+02	2.0E+03	8.9E+03	1.0E+04	2.0E+03	NA	2.6E+01	7.8E+04	8.9E+04	NA	NA	NA	NA	NA	NA	
Np_{237+1d}	2.1E+01	2.4E+02	1.4E+00	4.2E-01	4.1E+02	1.9E+01	5.4E+00	1.5E+03	NA	1.9E+01	NA	NA	4.0E-01	1.2E-01	4.3E-04	1.3E-04	NA	NA	
Pu_{238}	1.2E+00	1.3E+01	5.0E-04	3.2E-04	3.7E-01	3.2E-03	2.1E-03	1.1E+02	NA	1.5E+00	NA	NA	4.6E+02	1.3E+02	2.4E-03	1.6E-03	NA	NA	
$Pu_{239/240}$	5.3E+00	5.9E+01	4.8E-03	3.1E-03	7.4E-01	6.5E-03	4.1E-03	5.0E+02	NA	6.6E+00	NA	NA	NA	NA	NA	NA	NA	NA	
Ra_{226+8d}	1.6E+02	2.0E+03	8.6E+01	4.9E+02	1.7E+02	5.4E+01	3.1E+02	9.2E+03	NA	1.2E+02	5.4E+00	3.2E+01	6.2E+03	1.9E+03	3.7E+01	2.2E+02	NA	NA	
Ru_{106}	1.6E+00	1.7E+01	1.7E+00	1.7E-03	NA	NA	NA	1.4E+03	NA	1.9E+01	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	7.8E+00	1.1E+02	6.9E+00	1.1E+02	3.1E+04	7.0E+03	1.1E+05	9.8E+02	NA	1.3E+01	1.3E+03	2.0E+04	1.6E+01	6.0E+00	2.3E-01	3.7E+00	NA	NA	
Tc_{99}	7.7E+02	8.8E+03	5.5E+03	2.1E+04	6.9E+05	2.8E+06	1.1E+07	6.4E+04	NA	8.5E+02	6.6E+05	2.5E+06	5.7E+04	1.6E+04	6.8E+03	2.6E+04	NA	NA	
Th_{230}	4.2E+03	4.7E+04	5.9E+01	1.6E+02	1.0E+03	5.9E+01	1.6E+02	2.9E+05	NA	3.9E+03	5.2E-02	1.4E-01	3.6E+03	1.0E+03	2.7E-01	7.4E-01	NA	NA	
$Th_{232+10d}$	1.4E+02	1.5E+03	1.9E+00	5.1E+00	3.9E+01	2.2E+00	5.9E+00	1.1E+04	NA	1.4E+02	1.0E+00	2.9E+00	NA	NA	NA	NA	NA	NA	
U_{234}	9.5E+02	1.0E+04	1.2E+02	1.2E+03	3.9E+04	2.7E+03	2.6E+04	8.2E+04	NA	1.1E+03	5.3E+03	5.2E+04	7.9E+06	2.2E+06	1.7E+04	1.7E+05	NA	NA	
U_{235+1D}	2.6E+02	2.9E+03	3.3E+01	3.2E+02	6.2E+03	4.3E+02	4.1E+03	1.3E+04	NA	1.7E+02	3.0E+02	3.0E+03	1.8E+06	5.0E+05	3.8E+03	3.8E+04	NA	NA	
U_{238+2d}	3.5E+03	3.8E+04	4.4E+02	4.2E+03	2.6E+05	1.8E+04	1.7E+05	3.3E+05	NA	4.4E+03	1.3E+04	1.3E+05	3.7E+07	1.0E+07	7.9E+04	7.8E+05	NA	NA	2.6E+02
Rn_{222+4d}	3.2E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	
arsenic	7.2E-06	9.1E-05	2.4E-05	2.3E-06	2.3E-06	2.8E-06	2.7E-07	3.2E-04	2.6E-06	NA	2.1E-07	2.0E-08	1.1E-03	3.7E-04	5.3E-05	5.2E-06	NA	2.7E-06	NA
beryllium	4.8E-09	6.3E-08	1.3E-08	3.6E-11	5.3E-08	5.3E-08	1.5E-10	4.7E-07	3.9E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	8.2E-09	9.4E-07	1.3E-07	7.8E-07	4.1E-05	6.2E-06	3.6E-05	1.3E-06	1.1E-07	NA	NA	NA	1.2E-15	4.3E-15	3.1E-16	1.8E-15	NA	3.0E-18	NA
chromium vi	4.8E-08	8.4E-07	6.6E-07	5.8E-07	NA	NA	NA	6.2E-06	5.1E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
lead	7.2E-06	2.0E-04	1.8E-05	4.7E-05	NA	NA	NA	1.1E-05	9.2E-07	NA	1.4E-07	3.7E-07	1.1E-04	8.9E-05	3.6E-06	9.6E-06	NA	1.1E-09	NA
nickel	1.0E-07	6.3E-06	3.1E-06	1.6E-06	NA	NA	NA	1.1E-05	4.4E-08	NA	1.1E-05	5.8E-06	NA	NA	NA	NA	NA	NA	NA
pcbs	1.7E-09	7.0E-08	2.1E-07	2.1E-07	8.2E-07	3.0E-06	3.0E-06	2.9E-07	7.0E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	7.7E-11	8.9E-10	5.2E-10	5.3E-10	1.0E-07	1.1E-07	1.1E-07	1.8E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	5.8E-11	6.5E-10	9.1E-10	9.2E-10	2.6E-08	8.1E-08	8.2E-08	8.5E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	1.2E-10	1.3E-09	6.8E-09	6.9E-09	1.7E-08	3.1E-07	3.1E-07	1.3E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	4.8E-12	5.5E-11	5.9E-10	6.0E-10	9.2E-09	3.9E-07	4.0E-07	6.9E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	7.2E-11	8.5E-10	5.1E-10	5.2E-10	9.1E-08	9.8E-08	1.0E-07	1.6E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	2.6E-11	2.8E-10	1.8E-08	1.9E-08	NA	NA	NA	1.0E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	9.2E-11	1.2E-09	3.7E-14	3.7E-14	NA	NA	NA	3.6E-09	8.9E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.6E-10	3.0E-09	4.3E-10	4.4E-10	NA	NA	NA	1.0E-08	2.5E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	1.4E-11	3.5E-12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	9.6E-15	9.9E-14	1.0E-12	1.2E-12	NA	NA	NA	3.5E-12	8.5E-13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	2.5E-11	6.2E-12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	3.3E-13	3.4E-12	3.6E-11	4.1E-11	NA	NA	NA	1.2E-10	3.0E-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	4.1E-14	4.3E-13	2.8E-13	3.2E-13	NA	NA	NA	1.5E-11	3.7E-12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	3.8E-12	3.9E-11	4.1E-10	4.7E-10	NA	NA	NA	1.4E-09	3.4E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	2.2E-13	2.2E-12	1.5E-12	1.7E-12	NA	NA	NA	7.9E-11	2.0E-11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.7E-11	2.0E-11	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.3E-09	4.2E-08	2.2E-11	2.3E-11	NA	NA	NA	5.1E-08	1.7E-07	NA	9.2E-11	9.6E-11	1.2E-12	6.2E-13	1.9E-16	2.0E-16	6.5E-12	9.1E-13	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.1E-10	7.4E-10	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.0E-12	3.6E-12	NA	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
[a] Calculation of dose from penetrating radiation for on-property CT farmer is provided in Table E.IV-41.

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TABLE E.III–25
INTAKES FOR TOXICANTS FOR CT ON–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Soil			Exposed Waste Pit Material			Surface Water		Ground Water					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.1E−09	1.1E−09	6.4E−08	2.8E−08	5.9E−14	6.1E−14	NA	1.5E−10
antimony	1.2E−07	2.5E−06	7.2E−07	2.3E−07	3.0E−04	1.6E−04	5.0E−05	4.2E−05	3.5E−06	NA	4.2E−06	1.3E−06	2.6E−03	1.6E−03	2.4E−04	7.8E−05	NA	6.4E−06
arsenic	5.6E−05	7.1E−04	1.9E−04	1.8E−05	1.8E−05	2.2E−05	2.1E−06	2.5E−03	2.0E−05	NA	1.6E−06	1.6E−07	8.8E−03	2.9E−03	4.1E−04	4.0E−05	NA	2.1E−05
barium	4.1E−05	1.2E−03	9.7E−05	7.2E−04	NA	NA	NA	3.5E−03	2.8E−04	NA	3.6E−05	2.7E−04	9.8E−03	8.4E−03	3.4E−04	2.5E−03	NA	2.4E−05
beryllium	3.8E−08	4.9E−07	9.9E−08	2.8E−10	4.2E−07	4.1E−07	1.2E−09	3.7E−06	3.0E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5E−03	8.4E−04	3.8E−05	2.3E−04	NA	3.7E−06
cadmium	6.4E−08	7.3E−06	1.0E−06	6.1E−06	3.2E−04	4.9E−05	2.8E−04	1.0E−05	8.6E−07	NA	NA	NA	9.5E−15	3.3E−14	2.4E−15	1.4E−14	NA	2.3E−17
chromium vi	3.8E−07	6.5E−06	5.2E−06	4.5E−06	NA	NA	NA	4.8E−05	4.0E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA
cobalt	8.3E−08	1.3E−06	3.8E−06	1.2E−06	NA	NA	NA	1.9E−05	1.6E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA
copper	2.0E−05	1.1E−03	1.2E−03	5.8E−04	NA	NA	NA	1.4E−03	1.2E−05	NA	2.5E−04	1.2E−04	NA	NA	NA	NA	NA	NA
lead	5.6E−05	1.5E−03	1.4E−04	3.7E−04	NA	NA	NA	8.7E−05	7.1E−06	NA	1.1E−06	2.8E−06	8.7E−04	6.9E−04	2.8E−05	7.5E−05	NA	8.5E−09
manganese	3.2E−05	7.5E−04	7.0E−05	2.0E−04	NA	NA	NA	2.3E−03	1.9E−04	NA	2.4E−06	6.7E−06	3.1E−02	2.1E−02	1.1E−03	3.0E−03	NA	7.6E−05
mercury	7.9E−09	1.1E−07	3.1E−06	1.8E−08	NA	NA	NA	4.6E−07	1.9E−07	NA	NA	NA	5.4E−06	2.0E−06	3.4E−05	2.0E−07	NA	1.3E−08
molybdenum	1.5E−06	2.7E−05	2.7E−05	2.2E−05	NA	NA	NA	1.1E−04	9.4E−06	NA	NA	NA	2.6E−04	1.3E−04	7.3E−05	5.9E−05	NA	6.2E−07
nickel	7.9E−07	4.9E−05	2.4E−05	1.3E−05	NA	NA	NA	8.4E−05	3.4E−07	NA	8.5E−05	4.5E−05	NA	NA	NA	NA	NA	NA
selenium	1.4E−07	4.8E−06	6.4E−06	5.5E−06	NA	NA	NA	7.4E−06	6.1E−07	NA	1.7E−05	1.5E−05	NA	NA	NA	NA	NA	NA
silver	1.0E−07	3.7E−06	2.6E−06	5.5E−05	NA	NA	NA	1.7E−05	1.4E−06	NA	1.9E−05	4.1E−04	NA	NA	NA	NA	NA	NA
thallium	9.4E−08	1.1E−06	8.0E−06	1.3E−06	1.0E−07	1.1E−05	1.7E−06	6.4E−06	5.3E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA
vanadium	9.4E−06	1.4E−04	4.6E−05	1.2E−06	NA	NA	NA	7.4E−04	6.1E−06	NA	1.0E−04	2.6E−06	NA	NA	NA	NA	NA	NA
thorium−total	9.8E−08	1.1E−06	1.4E−09	3.6E−09	1.8E−07	1.0E−08	2.7E−08	2.3E−04	5.7E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium−total	1.9E−05	2.1E−04	2.4E−06	2.3E−05	5.9E−04	4.1E−05	4.0E−04	1.0E−03	8.6E−05	NA	NA	NA	4.8E−01	1.3E−01	1.0E−03	1.0E−02	NA	1.2E−03
fluoride	3.6E−06	3.9E−05	NA	NA	NA	NA	NA	3.1E−03	7.6E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	1.5E−10	1.6E−09	2.3E−11	2.5E−11	NA	NA	NA	5.9E−09	1.4E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4−chloro−3−methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	2.4E−10	2.7E−09	6.5E−08	6.6E−08	NA	NA	NA	9.8E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.0E−09	2.3E−08	3.4E−09	3.4E−09	NA	NA	NA	7.9E−08	1.9E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	9.0E−10	1.0E−08	4.2E−10	4.3E−10	NA	NA	NA	3.5E−08	8.7E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−hexanone	2.6E−11	4.1E−10	1.5E−14	1.6E−14	NA	NA	NA	1.0E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3−chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.4E−10	1.5E−10	NA	NA	NA	NA	NA	NA
tetrachloroethene	1.8E−08	3.3E−07	1.7E−10	1.8E−10	NA	NA	NA	4.0E−07	1.3E−06	NA	7.1E−10	7.4E−10	9.5E−12	4.9E−12	1.5E−15	1.6E−15	5.1E−11	7.0E−12
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5E−11	2.8E−11	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.4E−09	2.7E−09	NA	NA	NA	NA	NA	NA
2−nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.7E−10	3.9E−10	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.4E−11	9.8E−11	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

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TABLE E.III–26
INTAKES FOR CARCINOGENS FOR RME ON–PROPERTY FARMER, USE OF PERCHED GROUNDWATER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Perched Groundwater			Great Miami Aquifer			Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk	Ingestion of Drinking Water	Inhalation of VOC's	Dermal Contact while Bathing	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	External Exposure[a]
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life		pCi/life	pCi/life	pCi/life	pCi/life			pCi/life	pCi/life	pCi/life	mRem/life
Cs_{137+1d}	3.6E+02	5.8E+03	1.0E+04	1.4E+04	3.1E+04	1.3E+05	1.8E+05	2.9E+04	NA	2.7E+02	1.2E+06	1.7E+06	4.4E+04	NA	NA	NA	NA	NA	
Np_{237+1d}	2.8E+02	3.8E+03	2.1E+01	7.7E+00	6.4E+03	2.8E+02	1.0E+02	2.2E+04	NA	2.0E+02	NA	NA	3.7E+05	NA	NA	1.8E+00	6.4E−03	2.4E−03	
Pu_{238}	1.6E+01	2.0E+02	7.4E−03	5.9E−03	5.8E+00	4.8E−02	3.8E−02	1.7E+03	NA	1.6E+01	NA	NA	2.4E+04	NA	NA	1.9E+03	3.6E−02	3.0E−02	
$Pu_{239/240}$	7.2E+01	9.1E+02	7.1E−02	5.7E−02	1.2E+01	9.6E−02	7.7E−02	7.3E+03	NA	6.9E+01	NA	NA	2.4E+03	NA	NA	NA	NA	NA	
Ra_{226+8d}	2.2E+03	3.1E+04	1.3E+03	9.2E+03	2.7E+03	8.0E+02	5.8E+03	1.3E+05	NA	1.3E+03	8.1E+01	5.9E+02	3.6E+06	NA	NA	3.0E+04	5.5E+02	4.0E+03	
Ru_{106}	2.1E+01	2.6E+02	2.6E+01	3.2E−02	NA	NA	NA	2.1E+04	NA	2.0E+02	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.0E+02	1.7E+03	1.0E+02	2.0E+03	4.8E+05	1.0E+05	2.1E+06	1.4E+04	NA	1.3E+02	1.9E+04	3.8E+05	2.0E+06	NA	NA	9.3E+01	3.4E+00	6.8E+01	
Tc_{99}	1.0E+04	1.4E+05	8.2E+04	3.9E+05	1.1E+07	4.2E+07	2.0E+08	9.4E+05	NA	8.8E+03	9.8E+06	4.7E+07	1.3E+08	NA	NA	2.5E+05	1.0E+05	4.9E+05	
Th_{230}	5.7E+04	7.3E+05	8.7E+02	2.9E+03	1.6E+04	8.7E+02	2.9E+03	4.3E+06	NA	4.0E+04	7.7E−01	2.6E+00	1.5E+04	NA	NA	1.6E+04	4.0E+00	1.4E+01	
$Th_{232+10d}$	1.9E+03	2.4E+04	2.8E+01	9.5E+01	6.0E+02	3.3E+01	1.1E+02	1.6E+05	NA	1.5E+03	1.5E+01	5.3E+01	2.5E+03	NA	NA	NA	NA	NA	
U_{234}	1.3E+04	1.6E+05	1.8E+03	2.2E+04	6.0E+05	4.0E+04	4.8E+05	1.2E+06	NA	1.1E+04	7.8E+04	9.7E+05	7.3E+09	NA	NA	3.4E+07	2.5E+05	3.1E+06	
U_{235+1D}	3.5E+03	4.4E+04	4.9E+02	5.9E+03	9.6E+04	6.4E+03	7.6E+04	1.9E+05	NA	1.8E+03	4.5E+03	5.6E+04	1.4E+09	NA	NA	7.7E+06	5.7E+04	7.1E+05	
U_{238+2d}	4.6E+04	5.9E+05	6.5E+03	7.9E+04	4.0E+06	2.7E+05	3.2E+06	4.9E+06	NA	4.6E+04	1.9E+05	2.4E+06	2.1E+10	NA	NA	1.6E+08	1.2E+06	1.5E+07	1.9E+03
Rn_{222+4d}	4.3E+02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	
arsenic	9.7E−05	1.4E−03	3.6E−04	4.3E−05	3.5E−05	4.2E−05	5.1E−06	4.6E−03	1.5E−04	NA	3.1E−06	3.8E−07	1.7E−02	NA	5.0E−05	5.7E−03	7.9E−04	9.6E−05	NA
beryllium	6.5E−08	9.7E−07	1.9E−07	6.8E−10	8.3E−07	7.9E−07	2.9E−09	6.9E−06	2.2E−06	NA	NA	NA	5.6E−04	NA	1.6E−06	NA	NA	NA	NA
cadmium	1.1E−07	1.5E−05	2.0E−06	1.4E−05	6.3E−04	9.3E−05	6.7E−04	2.0E−05	6.3E−06	NA	NA	NA	3.2E−03	NA	9.3E−06	6.6E−14	4.5E−15	3.3E−14	NA
chromium vi	6.5E−07	1.3E−05	9.9E−06	1.1E−05	NA	NA	NA	9.0E−05	2.9E−05	NA	NA	NA	3.5E−03	NA	2.0E−05	NA	NA	NA	NA
lead	9.7E−05	3.1E−03	2.6E−04	8.8E−04	NA	NA	NA	1.6E−04	5.2E−05	NA	2.0E−06	6.8E−06	1.9E−02	NA	2.2E−07	1.4E−03	5.4E−05	1.8E−04	NA
nickel	1.4E−06	9.7E−05	4.6E−05	3.1E−05	NA	NA	NA	1.6E−04	2.5E−06	NA	1.6E−04	1.1E−04	5.8E−02	NA	1.7E−05	NA	NA	NA	NA
pcbs	2.3E−08	1.1E−06	3.2E−06	4.0E−06	1.3E−05	4.4E−05	5.5E−05	4.2E−06	4.0E−06	NA	NA	NA	4.1E−03	NA	1.7E−01	NA	NA	NA	NA
benzo(a)anthracene	1.0E−09	1.4E−08	7.7E−09	9.8E−09	1.6E−06	1.6E−06	2.1E−06	2.6E−07	NA	NA	NA	NA	1.1E−03	NA	2.1E−02	NA	NA	NA	NA
benzo(a)pyrene	7.8E−10	1.0E−08	1.3E−08	1.7E−08	4.1E−07	1.2E−06	1.5E−06	1.2E−07	NA	NA	NA	NA	1.1E−03	NA	3.6E−02	NA	NA	NA	NA
benzo(b)fluoranthene	1.6E−09	2.0E−08	1.0E−07	1.3E−07	2.6E−07	4.5E−06	5.8E−06	1.9E−07	NA	NA	NA	NA	1.1E−03	NA	3.6E−02	NA	NA	NA	NA
benzo(k)fluoranthene	6.5E−11	8.4E−10	8.7E−09	1.1E−08	1.4E−07	5.9E−06	7.4E−06	1.0E−07	NA	NA	NA	NA	1.1E−03	NA	3.6E−02	NA	NA	NA	NA
chrysene	9.7E−10	1.3E−08	7.6E−09	9.6E−09	1.4E−06	1.5E−06	1.9E−06	2.4E−07	NA	NA	NA	NA	1.1E−03	NA	2.1E−02	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.7E−04	NA	2.5E−02	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	3.4E−10	4.3E−09	2.7E−07	3.5E−07	NA	NA	NA	1.5E−08	NA	NA	NA	NA	1.1E−03	NA	6.8E−02	NA	NA	NA	NA
n−nitrosodipropylamine	1.2E−09	1.9E−08	5.5E−13	7.0E−13	NA	NA	NA	5.3E−08	5.0E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	3.4E−09	4.6E−08	6.4E−09	8.2E−09	NA	NA	NA	1.5E−07	1.4E−06	NA	NA	NA	5.5E−03	NA	1.1E−01	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.7E−02	1.0E−01	1.5E−03	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	2.1E−10	2.0E−10	NA	NA	NA	1.5E−07	NA	9.2E−06	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.8E−08	NA	3.6E−06	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	1.3E−13	1.5E−12	1.6E−11	2.2E−11	NA	NA	NA	5.1E−11	4.8E−11	NA	NA	NA	2.1E−08	NA	1.3E−06	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	3.7E−10	3.5E−10	NA	NA	NA	3.3E−08	NA	2.1E−06	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	4.5E−12	5.3E−11	5.4E−10	7.6E−10	NA	NA	NA	1.8E−09	1.7E−09	NA	NA	NA	2.6E−08	NA	1.6E−06	NA	NA	NA	NA
heptachlorodibenzofuran	5.6E−13	6.6E−12	4.2E−12	6.0E−12	NA	NA	NA	2.2E−10	2.1E−10	NA	NA	NA	5.5E−08	NA	3.5E−06	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	5.1E−11	6.1E−10	6.1E−09	8.7E−09	NA	NA	NA	2.0E−08	2.0E−08	NA	NA	NA	4.9E−08	NA	3.1E−06	NA	NA	NA	NA
octachlorodibenzofuran	2.9E−12	3.5E−11	2.2E−11	3.1E−11	NA	NA	NA	1.2E−09	1.1E−09	NA	NA	NA	3.0E−08	NA	1.9E−06	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E−10	3.6E−10	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	3.0E−08	6.5E−07	3.3E−10	4.3E−10	NA	NA	NA	7.4E−07	9.5E−06	NA	1.4E−09	1.8E−09	3.8E−03	1.4E−02	2.8E−03	9.7E−12	2.9E−15	3.7E−15	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E−08	1.4E−08	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.9E−11	6.7E−11	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
[a] Calculation of dose from penetrating radiation for on–property RME farmer is provided in Table E.IV–39.

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TABLE E.III–27
INTAKES FOR TOXICANTS FOR RME ON–PROPERTY FARMER, USE OF PERCHED GROUNDWATER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Perched Groundwater			Great Miami Aquifer		
Exposure Pathways	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk	Ingestion of Dri Wa	Inhalation of VOC's	Dermal Contact while Bathing	Ingestion of Veget and F	Ingestion of Meat	Ingestion of Milk
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day		mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.0E−09	2.6E−09	9.9E−02	NA	2.8E−04	5.6E−08	1.1E−13	1.5E−13
antimony	2.0E−07	5.0E−06	1.4E−06	5.5E−07	6.0E−04	3.0E−04	1.2E−04	8.0E−05	2.5E−05	NA	8.0E−06	3.2E−06	2.6E−02	NA	7.5E−05	3.2E−03	4.7E−04	1.9E−04
arsenic	9.7E−05	1.4E−03	3.6E−04	4.3E−05	3.5E−05	4.2E−05	5.1E−06	4.6E−03	1.5E−04	NA	3.1E−06	3.8E−07	1.7E−02	NA	5.0E−05	5.7E−03	7.9E−04	9.6E−05
barium	7.1E−05	2.4E−03	1.8E−04	1.7E−03	NA	NA	NA	6.5E−03	2.1E−03	NA	6.8E−05	6.4E−04	5.4E−02	NA	1.5E−04	1.7E−02	6.4E−04	6.0E−03
beryllium	6.5E−08	9.7E−07	1.9E−07	6.8E−10	8.3E−07	7.9E−07	2.9E−09	6.9E−06	2.2E−06	NA	NA	NA	5.6E−04	NA	1.6E−06	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.0E−02	NA	2.3E−04	1.7E−03	7.2E−05	5.5E−04
cadmium	1.1E−07	1.5E−05	2.0E−06	1.4E−05	6.3E−04	9.3E−05	6.7E−04	2.0E−05	6.3E−06	NA	NA	NA	3.2E−03	NA	9.3E−06	6.6E−14	4.5E−15	3.3E−14
chromium vi	6.5E−07	1.3E−05	9.9E−06	1.1E−05	NA	NA	NA	9.0E−05	2.9E−05	NA	NA	NA	3.5E−03	NA	2.0E−05	NA	NA	NA
cobalt	1.4E−07	2.7E−06	7.2E−06	2.9E−06	NA	NA	NA	3.6E−05	1.2E−05	NA	NA	NA	9.3E−03	NA	1.1E−05	NA	NA	NA
copper	3.4E−05	2.2E−03	2.3E−03	1.4E−03	NA	NA	NA	2.6E−03	8.4E−05	NA	4.7E−04	2.9E−04	2.6E−02	NA	7.5E−05	NA	NA	NA
lead	9.7E−05	3.1E−03	2.6E−04	8.8E−04	NA	NA	NA	1.6E−04	5.2E−05	NA	2.0E−06	6.8E−06	1.9E−02	NA	2.2E−07	1.4E−03	5.4E−05	1.8E−04
manganese	5.4E−05	1.5E−03	1.3E−04	4.7E−04	NA	NA	NA	4.3E−03	1.4E−03	NA	4.6E−06	1.6E−05	6.6E−02	NA	1.9E−04	4.2E−02	2.0E−03	7.1E−03
mercury	1.4E−08	2.2E−07	6.0E−06	4.3E−08	NA	NA	NA	8.6E−07	1.4E−06	NA	NA	NA	6.0E−04	NA	1.7E−06	3.9E−06	6.5E−05	4.8E−07
molybdenum	2.5E−06	5.4E−05	5.2E−05	5.2E−05	NA	NA	NA	2.2E−04	6.9E−05	NA	NA	NA	3.2E+00	NA	9.1E−03	2.6E−04	1.4E−04	1.4E−04
nickel	1.4E−06	9.7E−05	4.6E−05	3.1E−05	NA	NA	NA	1.6E−04	2.5E−06	NA	1.6E−04	1.1E−04	5.8E−02	NA	1.7E−05	NA	NA	NA
selenium	2.4E−07	9.5E−06	1.2E−05	1.3E−05	NA	NA	NA	1.4E−05	4.5E−06	NA	3.3E−05	3.5E−05	1.0E−04	NA	3.0E−07	NA	NA	NA
silver	1.7E−07	7.3E−06	4.9E−06	1.3E−04	NA	NA	NA	3.2E−05	1.0E−05	NA	3.7E−05	9.8E−04	1.8E−03	NA	3.2E−06	NA	NA	NA
thallium	1.6E−07	2.2E−06	1.5E−05	3.0E−06	2.0E−07	2.0E−05	4.0E−06	1.2E−05	3.9E−06	NA	NA	NA	2.1E−02	NA	5.9E−05	NA	NA	NA
vanadium	1.6E−05	2.7E−04	8.8E−05	2.8E−06	NA	NA	NA	1.4E−03	4.5E−05	NA	1.9E−04	6.3E−06	3.9E−02	NA	1.1E−04	NA	NA	NA
thorium−total	1.7E−07	2.2E−06	2.6E−09	8.6E−09	3.5E−07	1.9E−08	6.5E−08	4.4E−04	4.2E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium−total	3.3E−05	4.2E−04	4.7E−06	5.6E−05	1.2E−03	7.9E−05	9.4E−04	2.0E−03	6.3E−04	NA	NA	NA	1.4E+01	NA	3.9E−02	2.6E−01	1.9E−03	2.4E−02
fluoride	6.2E−06	7.9E−05	NA	NA	NA	NA	NA	5.8E−03	5.6E−03	NA	NA	NA	NA	NA	NA	NA	NA	NA
cenaphthylene	2.5E−10	3.2E−09	4.4E−11	5.9E−11	NA	NA	NA	1.1E−08	1.1E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA
−methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4−chloro−3−methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	4.2E−10	5.3E−09	1.2E−07	1.6E−07	NA	NA	NA	1.8E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	3.4E−09	4.6E−08	6.4E−09	8.2E−09	NA	NA	NA	1.5E−07	1.4E−06	NA	NA	NA	5.5E−03	NA	1.1E−01	NA	NA	NA
phenanthrene	1.6E−09	2.1E−08	8.0E−10	1.0E−09	NA	NA	NA	6.6E−08	6.4E−07	NA	NA	NA	1.1E−03	4.1E−03	4.2E−03	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−hexanone	4.5E−11	8.2E−10	2.9E−14	3.7E−14	NA	NA	NA	1.9E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3−chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E−10	3.6E−10	NA	NA	NA	NA	NA	NA
tetrachloroethene	3.0E−08	6.5E−07	3.3E−10	4.3E−10	NA	NA	NA	7.4E−07	9.5E−06	NA	1.4E−09	1.8E−09	3.8E−03	1.4E−02	2.8E−03	9.7E−12	2.9E−15	3.7E−15
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.9E−11	6.7E−11	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.6E−09	6.4E−09	NA	NA	NA	NA	NA	NA
2−nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.1E−10	9.3E−10	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E−10	2.3E−10	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

TABLE E.III–28
INTAKES FOR CARCINOGENS FOR RME OFF–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Off–property Groundwater					
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life		
Cs_{137+1d}	1.5E+01	2.4E+02	4.3E+02	6.0E+02	NA	NA	NA	NA	NA	NA
Np_{237+1d}	1.3E+01	1.7E+02	9.7E−01	3.5E−01	6.1E−07	2.0E−07	6.8E−10	2.5E−10	NA	NA
Pu_{238}	9.9E−01	1.2E+01	4.5E−04	3.6E−04	NA	NA	NA	NA	NA	NA
$Pu_{239/240}$	5.9E+00	7.5E+01	5.9E−03	4.7E−03	NA	NA	NA	NA	NA	NA
Ra_{226+8d}	1.5E+02	2.1E+03	8.7E+01	6.3E+02	NA	NA	NA	NA	NA	NA
Ru_{106}	1.4E+00	1.7E+01	1.7E+00	2.1E−03	NA	NA	NA	NA	NA	NA
Sr_{90+1d}	4.6E+00	7.5E+01	4.5E+00	9.1E+01	2.9E−01	1.2E−01	4.2E−03	8.5E−02	NA	NA
Tc_{99}	7.1E+02	9.3E+03	5.6E+03	2.6E+04	1.5E+05	4.8E+04	1.9E+04	9.2E+04	NA	NA
Th_{230}	4.3E+03	5.5E+04	6.6E+01	2.2E+02	NA	NA	NA	NA	NA	NA
$Th_{232+10d}$	1.2E+02	1.5E+03	1.8E+00	5.9E+00	NA	NA	NA	NA	NA	NA
U_{234}	5.3E+02	6.8E+03	7.5E+01	9.0E+02	8.4E+06	2.5E+06	1.9E+04	2.3E+05	NA	NA
U_{235+1D}	5.3E+01	6.8E+02	7.5E+00	9.0E+01	2.0E+06	5.9E+05	4.4E+03	5.4E+04	NA	NA
U_{238+2d}	1.1E+03	1.4E+04	1.6E+02	1.9E+03	4.0E+07	1.2E+07	8.9E+04	1.1E+06	NA	NA
Rn_{222+4d}	2.9E+01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
arsenic	6.0E−06	8.8E−05	2.2E−05	2.7E−06	NA	NA	NA	NA	NA	NA
beryllium	5.2E−09	7.7E−08	1.5E−08	5.4E−11	NA	NA	NA	NA	NA	NA
cadmium	7.8E−09	1.0E−06	1.4E−07	1.0E−06	NA	NA	NA	NA	NA	NA
chromium vi	5.3E−08	1.1E−06	8.1E−07	8.8E−07	NA	NA	NA	NA	NA	NA
lead	9.1E−07	2.9E−05	2.5E−06	8.2E−06	NA	NA	NA	NA	NA	NA
nickel	9.7E−08	6.9E−06	3.3E−06	2.2E−06	NA	NA	NA	NA	NA	NA
pcbs	1.5E−09	6.9E−08	2.0E−07	2.5E−07	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	6.5E−11	8.6E−10	4.8E−10	6.1E−10	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	4.8E−11	6.2E−10	8.3E−10	1.1E−09	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	9.1E−11	1.2E−09	5.9E−09	7.5E−09	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	4.3E−12	5.6E−11	5.8E−10	7.3E−10	NA	NA	NA	NA	NA	NA
chrysene	5.8E−11	7.9E−10	4.5E−10	5.8E−10	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	2.1E−11	2.6E−10	1.7E−08	2.1E−08	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	7.1E−11	1.1E−09	3.2E−14	4.0E−14	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.1E−10	2.8E−09	3.9E−10	4.9E−10	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	7.8E−15	9.2E−14	9.3E−13	1.3E−12	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	2.7E−13	3.1E−12	3.2E−11	4.5E−11	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	3.3E−14	3.9E−13	2.5E−13	3.6E−13	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	3.0E−12	3.6E−11	3.7E−10	5.2E−10	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	1.7E−13	2.1E−12	1.3E−12	1.9E−12	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.3E−10	5.0E−09	2.6E−12	3.3E−12	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

TABLE E.III–29
INTAKES FOR TOXICANTS FOR RME OFF–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Ground Water					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	3.4E–10	1.6E–10	3.3E–16	4.3E–16	NA	9.8E–13
antimony	1.9E–08	4.7E–07	1.3E–07	5.1E–08	NA	NA	NA	NA	NA	NA
arsenic	6.0E–06	8.8E–05	2.2E–05	2.7E–06	NA	NA	NA	NA	NA	NA
barium	4.9E–06	1.7E–04	1.3E–05	1.2E–04	1.3E–08	1.2E–08	4.7E–10	4.4E–09	NA	3.8E–11
beryllium	5.2E–09	7.7E–08	1.5E–08	5.4E–11	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	7.2E–05	4.3E–05	1.9E–06	1.4E–05	NA	2.1E–07
cadmium	7.8E–09	1.0E–06	1.4E–07	1.0E–06	NA	NA	NA	NA	NA	NA
chromium vi	5.3E–08	1.1E–06	8.1E–07	8.8E–07	NA	NA	NA	NA	NA	NA
cobalt	1.2E–08	2.2E–07	5.9E–07	2.4E–07	NA	NA	NA	NA	NA	NA
copper	1.7E–06	1.1E–04	1.2E–04	7.0E–05	NA	NA	NA	NA	NA	NA
lead	9.1E–07	2.9E–05	2.5E–06	8.2E–06	NA	NA	NA	NA	NA	NA
manganese	3.5E–06	9.5E–05	8.6E–06	3.0E–05	NA	NA	NA	NA	NA	NA
mercury	7.8E–10	1.2E–08	3.4E–07	2.5E–09	1.0E–11	4.1E–12	6.9E–11	5.1E–13	NA	3.0E–14
molybdenum	1.5E–07	3.2E–06	3.1E–06	3.1E–06	5.1E–09	2.8E–09	1.5E–09	1.5E–09	NA	1.5E–11
nickel	9.7E–08	6.9E–06	3.3E–06	2.2E–06	NA	NA	NA	NA	NA	NA
selenium	1.4E–08	5.7E–07	7.3E–07	7.8E–07	NA	NA	NA	NA	NA	NA
silver	7.8E–09	3.3E–07	2.2E–07	5.8E–06	NA	NA	NA	NA	NA	NA
thallium	6.5E–09	8.6E–08	6.1E–07	1.2E–07	NA	NA	NA	NA	NA	NA
vanadium	1.3E–06	2.2E–05	7.0E–06	2.2E–07	NA	NA	NA	NA	NA	NA
thorium–total	7.8E–09	1.0E–07	1.2E–10	4.0E–10	NA	NA	NA	NA	NA	NA
uranium–total	1.4E–06	1.7E–05	1.9E–07	2.3E–06	6.7E–02	2.0E–02	1.5E–04	1.8E–03	NA	1.9E–04
fluoride	3.7E–07	4.7E–06	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	1.5E–11	1.9E–10	2.6E–12	3.5E–12	NA	NA	NA	NA	NA	NA
2–methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4–chloro–3–methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	2.5E–11	3.2E–10	7.5E–09	9.5E–09	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.1E–10	2.8E–09	3.9E–10	4.9E–10	NA	NA	NA	NA	NA	NA
phenanthrene	9.1E–11	1.2E–09	4.7E–11	6.0E–11	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3–chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.3E–10	5.0E–09	2.6E–12	3.3E–12	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

TABLE E.III–30
INTAKES FOR CARCINOGENS FOR RME OFF–PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Off–property Groundwater					
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life		
Cs_{137+1d}	2.7E–01	1.8E+01	1.4E+01	1.2E+02	NA	NA	NA	NA	NA	NA
Np_{237+1d}	2.3E–01	1.3E+01	3.2E–02	6.9E–02	2.6E–08	1.5E–08	2.3E–11	4.9E–11	NA	NA
Pu_{238}	1.8E–02	9.3E–01	1.5E–05	7.0E–05	NA	NA	NA	NA	NA	NA
$Pu_{239/240}$	1.1E–01	5.6E+00	1.9E–04	9.1E–04	NA	NA	NA	NA	NA	NA
Ra_{226+8d}	2.7E+00	1.6E+02	2.9E+00	1.2E+02	NA	NA	NA	NA	NA	NA
Ru_{106}	2.5E–02	1.3E+00	5.7E–02	4.2E–04	NA	NA	NA	NA	NA	NA
Sr_{90+1d}	8.4E–02	5.6E+00	1.5E–01	1.8E+01	1.2E–02	8.7E–03	1.4E–04	1.7E–02	NA	NA
Tc_{99}	1.3E+01	6.9E+02	1.9E+02	5.1E+03	6.6E+03	3.6E+03	6.4E+02	1.8E+04	NA	NA
Th_{230}	7.8E+01	4.1E+03	2.2E+00	4.3E+01	NA	NA	NA	NA	NA	NA
$Th_{232+10d}$	2.1E+00	1.1E+02	5.9E–02	1.2E+00	NA	NA	NA	NA	NA	NA
U_{234}	9.7E+00	5.0E+02	2.5E+00	1.8E+02	3.6E+05	1.9E+05	6.2E+02	4.5E+04	NA	NA
U_{235+1D}	9.7E–01	5.0E+01	2.5E–01	1.8E+01	8.4E+04	4.4E+04	1.4E+02	1.0E+04	NA	NA
U_{238+2d}	2.0E+01	1.1E+03	5.3E+00	3.7E+02	1.7E+06	9.0E+05	3.0E+03	2.2E+05	NA	NA
Rn_{222+4d}	5.3E–01	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
arsenic	5.1E–07	3.1E–05	3.4E–06	2.4E–06	NA	NA	NA	NA	NA	NA
beryllium	4.4E–10	2.7E–08	2.3E–09	4.9E–11	NA	NA	NA	NA	NA	NA
cadmium	6.6E–10	3.6E–07	2.2E–08	9.3E–07	NA	NA	NA	NA	NA	NA
chromium vi	4.5E–09	3.7E–07	1.3E–07	8.0E–07	NA	NA	NA	NA	NA	NA
lead	7.7E–08	1.0E–05	3.8E–07	7.5E–06	NA	NA	NA	NA	NA	NA
nickel	8.2E–09	2.4E–06	5.1E–07	2.0E–06	NA	NA	NA	NA	NA	NA
pcbs	1.3E–10	2.4E–08	3.1E–08	2.3E–07	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	5.5E–12	3.0E–10	7.5E–11	5.6E–10	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	4.1E–12	2.2E–10	1.3E–10	9.6E–10	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	7.7E–12	4.0E–10	9.1E–10	6.8E–09	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	3.6E–13	1.9E–11	8.9E–11	6.6E–10	NA	NA	NA	NA	NA	NA
chrysene	4.9E–12	2.8E–10	7.0E–11	5.2E–10	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3–cd)pyrene	1.8E–12	9.1E–11	2.6E–09	1.9E–08	NA	NA	NA	NA	NA	NA
n–nitrosodipropylamine	6.0E–12	3.8E–10	4.9E–15	3.7E–14	NA	NA	NA	NA	NA	NA
pentachlorophenol	1.8E–11	9.6E–10	6.0E–11	4.5E–10	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo–p–dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo–p–dioxin	6.6E–16	3.2E–14	1.4E–13	1.2E–12	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo–p–dioxin	2.2E–14	1.1E–12	4.9E–12	4.1E–11	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	2.8E–15	1.4E–13	3.9E–14	3.2E–13	NA	NA	NA	NA	NA	NA
octachlorodibenzo–p–dioxin	2.6E–13	1.3E–11	5.7E–11	4.7E–10	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	1.5E–14	7.2E–13	2.1E–13	1.7E–12	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.0E–11	1.7E–09	4.0E–13	3.0E–12	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

TABLE E.III-31
INTAKES FOR TOXICANTS FOR RME OFF-PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Ground Water					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	7.9E-10	6.6E-10	6.0E-16	4.6E-15	NA	1.6E-12
antimony	1.9E-08	1.9E-06	2.3E-07	5.4E-07	NA	NA	NA	NA	NA	NA
arsenic	5.9E-06	3.6E-04	4.0E-05	2.8E-05	NA	NA	NA	NA	NA	NA
barium	4.9E-06	6.8E-04	2.3E-05	1.3E-03	3.0E-08	5.0E-08	8.5E-10	4.7E-08	NA	6.1E-11
beryllium	5.1E-09	3.1E-07	2.7E-08	5.7E-10	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	1.7E-04	1.7E-04	3.4E-06	1.5E-04	NA	3.4E-07
cadmium	7.7E-09	4.2E-06	2.5E-07	1.1E-05	NA	NA	NA	NA	NA	NA
chromium vi	5.2E-08	4.3E-06	1.5E-06	9.3E-06	NA	NA	NA	NA	NA	NA
cobalt	1.2E-08	8.8E-07	1.1E-06	2.5E-06	NA	NA	NA	NA	NA	NA
copper	1.7E-06	4.5E-04	2.1E-04	7.4E-04	NA	NA	NA	NA	NA	NA
lead	8.9E-07	1.2E-04	4.4E-06	8.7E-05	NA	NA	NA	NA	NA	NA
manganese	3.5E-06	3.9E-04	1.6E-05	3.2E-04	NA	NA	NA	NA	NA	NA
mercury	7.7E-10	5.0E-08	6.2E-07	2.6E-08	2.4E-11	1.7E-11	1.2E-10	5.3E-12	NA	4.9E-14
molybdenum	1.5E-07	1.3E-05	5.5E-06	3.2E-05	1.2E-08	1.1E-08	2.7E-09	1.6E-08	NA	2.4E-11
nickel	9.6E-08	2.8E-05	5.9E-06	2.3E-05	NA	NA	NA	NA	NA	NA
selenium	1.4E-08	2.3E-06	1.3E-06	8.2E-06	NA	NA	NA	NA	NA	NA
silver	7.7E-09	1.3E-06	3.9E-07	6.1E-05	NA	NA	NA	NA	NA	NA
thallium	6.4E-09	3.5E-07	1.1E-06	1.3E-06	NA	NA	NA	NA	NA	NA
vanadium	1.3E-06	8.7E-05	1.3E-05	2.4E-06	NA	NA	NA	NA	NA	NA
thorium-total	7.7E-09	4.0E-07	2.2E-10	4.2E-09	NA	NA	NA	NA	NA	NA
uranium-total	1.3E-06	7.0E-05	3.5E-07	2.4E-05	1.6E-01	8.2E-02	2.7E-04	1.9E-02	NA	3.1E-04
fluoride	3.6E-07	1.9E-05	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	1.5E-11	7.7E-10	4.7E-12	3.7E-11	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	2.5E-11	1.3E-09	1.3E-08	1.0E-07	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.0E-10	1.1E-08	7.0E-10	5.2E-09	NA	NA	NA	NA	NA	NA
phenanthrene	8.9E-11	4.9E-09	8.4E-11	6.4E-10	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.3E-10	2.0E-08	4.6E-12	3.4E-11	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

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TABLE E.III-32
INTAKES FOR CARCINOGENS FOR ON-PROPERTY HOME BUILDER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material			Buried Pit Material
Exposure Pathways: Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	mRem/life
Cs_{137+1d}	1.1E+01	5.5E+02	NA	7.9E-01	
Np_{237+1d}	8.4E+00	4.1E+02	NA	5.9E-01	
Pu_{238}	4.9E-01	3.2E+01	NA	4.5E-02	
$Pu_{239/240}$	2.2E+00	1.4E+02	NA	2.0E-01	
Ra_{226+8d}	6.7E+01	2.6E+03	NA	3.7E+00	
Ru_{106}	6.3E-01	4.0E+02	NA	5.7E-01	
Sr_{90+1d}	3.2E+00	2.7E+02	NA	3.9E-01	
Tc_{99}	3.1E+02	1.8E+04	NA	2.6E+01	
Th_{230}	1.7E+03	8.1E+04	NA	1.2E+02	
$Th_{232+10d}$	5.6E+01	3.0E+03	NA	4.2E+00	
U_{234}	3.9E+02	2.3E+04	NA	3.3E+01	
U_{235+1D}	1.1E+02	3.6E+03	NA	5.2E+00	
U_{238+2d}	1.4E+03	9.2E+04	NA	1.3E+02	1.1E-02
Rn_{222+4d}	1.3E+01	NA	NA	NA	
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day		
arsenic	2.9E-06	8.8E-05	1.1E-06	NA	NA
beryllium	2.0E-09	1.3E-07	1.6E-08	NA	NA
cadmium	3.3E-09	3.7E-07	4.5E-08	NA	NA
chromium vi	2.0E-08	1.7E-06	2.1E-07	NA	NA
lead	2.9E-06	3.1E-06	3.7E-07	NA	NA
nickel	4.1E-08	3.0E-06	1.8E-08	NA	NA
pcbs	7.0E-10	8.0E-08	2.9E-08	NA	NA
benzo(a)anthracene	3.1E-11	4.9E-09	NA	NA	NA
benzo(a)pyrene	2.3E-11	2.4E-09	NA	NA	NA
benzo(b)fluoranthene	4.7E-11	3.7E-09	NA	NA	NA
benzo(k)fluoranthene	2.0E-12	1.9E-09	NA	NA	NA
chrysene	2.9E-11	4.5E-09	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	1.0E-11	2.8E-10	NA	NA	NA
n-nitrosodipropylamine	3.7E-11	1.0E-09	3.6E-10	NA	NA
pentachlorophenol	1.0E-10	2.8E-09	1.0E-08	NA	NA
vinyl chloride	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	4.0E-12	1.4E-12	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	3.9E-15	9.6E-13	3.5E-13	NA	NA
hexachlorodibenzofuran	NA	7.0E-12	2.5E-12	NA	NA
heptachlorodibenzo-p-dioxin	1.4E-13	3.4E-11	1.2E-11	NA	NA
heptachlorodibenzofuran	1.7E-14	4.2E-12	1.5E-12	NA	NA
octachlorodibenzo-p-dioxin	1.5E-12	3.9E-10	1.4E-10	NA	NA
octachlorodibenzofuran	8.8E-14	2.2E-11	7.9E-12	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	9.2E-10	1.4E-08	6.8E-08	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
[a] Calculation of dose from penetrating radiation for homebuilder is provided in Table E.IV-42.

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TABLE E.III-33
INTAKES FOR TOXICANTS FOR ON-PROPERTY HOME BUILDER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	
cyanide	NA	NA	NA	NA
antimony	8.9E-07	2.2E-04	2.7E-05	NA
arsenic	4.3E-04	1.3E-02	1.5E-04	NA
barium	3.1E-04	1.8E-02	2.2E-03	NA
beryllium	2.9E-07	1.9E-05	2.3E-06	NA
boron	NA	NA	NA	NA
cadmium	4.9E-07	5.5E-05	6.5E-06	NA
chromium vi	2.9E-06	2.5E-04	3.0E-05	NA
cobalt	6.3E-07	1.0E-04	1.2E-05	NA
copper	1.5E-04	7.3E-03	8.8E-05	NA
lead	4.3E-04	4.6E-04	5.5E-05	NA
manganese	2.4E-04	1.2E-02	1.4E-03	NA
mercury	6.0E-08	2.4E-06	1.4E-06	NA
molybdenum	1.1E-05	6.0E-04	7.2E-05	NA
nickel	6.0E-06	4.4E-04	2.6E-06	NA
selenium	1.1E-06	3.9E-05	4.6E-06	NA
silver	7.7E-07	8.8E-05	1.1E-05	NA
thallium	7.1E-07	3.4E-05	4.0E-06	NA
vanadium	7.1E-05	3.9E-03	4.6E-05	NA
thorium-total	7.4E-07	1.2E-03	4.4E-04	NA
uranium-total	1.5E-04	5.5E-03	6.6E-04	NA
fluoride	2.7E-05	1.6E-02	5.8E-03	NA
acenaphthylene	1.1E-09	3.1E-08	1.1E-07	NA
2-methylnaphthalene	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA
benzo(g,h,i)perylene	1.9E-09	5.1E-08	NA	NA
dibenzofuran	NA	NA	NA	NA
pentachlorophenol	1.5E-08	4.1E-07	1.5E-06	NA
phenanthrene	6.9E-09	1.8E-07	6.6E-07	NA
tributyl phosphate	NA	NA	NA	NA
2-hexanone	2.0E-10	5.4E-09	NA	NA
3-chloropropene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	1.3E-07	2.1E-06	9.9E-06	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.

000855

TABLE E.III-34
INTAKES FOR CARCINOGENS FOR OFF-PROPERTY USER OF MEAT AND MILK PRODUCTS, FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air		Surface Soil		Surface Water	
Exposure Pathways: Contaminants of Concern	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Radionuclides	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life	pCi/life
Cs_{137+1d}	1.0E+04	1.4E+04	1.3E+05	1.8E+05	1.2E+06	1.7E+06
Np_{237+1d}	2.1E+01	7.7E+00	2.8E+02	1.0E+02	NA	NA
Pu_{238}	7.4E-03	5.9E-03	4.8E-02	3.8E-02	NA	NA
$Pu_{239/240}$	7.1E-02	5.7E-02	9.6E-02	7.7E-02	NA	NA
Ra_{226+8d}	1.3E+03	9.2E+03	8.0E+02	5.8E+03	8.1E+01	5.9E+02
Ru_{106}	2.6E+01	3.2E-02	NA	NA	NA	NA
Sr_{90+1d}	1.0E+02	2.0E+03	1.0E+05	2.1E+06	1.9E+04	3.8E+05
Tc_{99}	8.2E+04	3.9E+05	4.2E+07	2.0E+08	9.8E+06	4.7E+07
Th_{230}	8.7E+02	2.9E+03	8.7E+02	2.9E+03	7.7E-01	2.6E+00
$Th_{232+10d}$	2.8E+01	9.5E+01	3.3E+01	1.1E+02	1.5E+01	5.3E+01
U_{234}	1.8E+03	2.2E+04	4.0E+04	4.8E+05	7.8E+04	9.7E+05
U_{235+1D}	4.9E+02	5.9E+03	6.4E+03	7.6E+04	4.5E+03	5.6E+04
U_{238+2d}	6.5E+03	7.9E+04	2.7E+05	3.2E+06	1.9E+05	2.4E+06
Chemicals	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
arsenic	3.6E-04	4.3E-05	4.2E-05	5.1E-06	3.1E-06	3.8E-07
beryllium	1.9E-07	6.8E-10	7.9E-07	2.9E-09	NA	NA
cadmium	2.0E-06	1.4E-05	9.3E-05	6.7E-04	NA	NA
chromium vi	9.9E-06	1.1E-05	NA	NA	NA	NA
lead	2.6E-04	8.8E-04	NA	NA	2.0E-06	6.8E-06
nickel	4.6E-05	3.1E-05	NA	NA	1.6E-04	1.1E-04
pcbs	3.2E-06	4.0E-06	4.4E-05	5.5E-05	NA	NA
benzo(a)anthracene	7.7E-09	9.8E-09	1.6E-06	2.1E-06	NA	NA
benzo(a)pyrene	1.3E-08	1.7E-08	1.2E-06	1.5E-06	NA	NA
benzo(b)fluoranthene	1.0E-07	1.3E-07	4.5E-06	5.8E-06	NA	NA
benzo(k)fluoranthene	8.7E-09	1.1E-08	5.9E-06	7.4E-06	NA	NA
chrysene	7.6E-09	9.6E-09	1.5E-06	1.9E-06	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	2.7E-07	3.5E-07	NA	NA	NA	NA
n-nitrosodipropylamine	5.5E-13	7.0E-13	NA	NA	NA	NA
pentachlorophenol	6.4E-09	8.2E-09	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	1.6E-11	2.2E-11	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	5.4E-10	7.6E-10	NA	NA	NA	NA
heptachlorodibenzofuran	4.2E-12	6.0E-12	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	6.1E-09	8.7E-09	NA	NA	NA	NA
octachlorodibenzofuran	2.2E-11	3.1E-11	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	2.6E-10	3.6E-10
tetrachloroethene	3.3E-10	4.3E-10	NA	NA	1.4E-09	1.8E-09
benzene	NA	NA	NA	NA	1.0E-08	1.4E-08
methylene chloride	NA	NA	NA	NA	2.9E-11	6.7E-11

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

TABLE E.III-35
INTAKES FOR TOXICANTS FOR OFF-PROPERTY USER OF MEAT AND MILK PRODUCTS, FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air		Surface Soil		Surface Water	
Exposure Pathways:	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Toxicants	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day	mg/Kg/day
cyanide	NA	NA	NA	NA	2.0E-09	2.6E-09
antimony	1.4E-06	5.5E-07	3.0E-04	1.2E-04	8.0E-06	3.2E-06
arsenic	3.6E-04	4.3E-05	4.2E-05	5.1E-06	3.1E-06	3.8E-07
barium	1.8E-04	1.7E-03	NA	NA	6.8E-05	6.4E-04
beryllium	1.9E-07	6.8E-10	7.9E-07	2.9E-09	NA	NA
boron	NA	NA	NA	NA	NA	NA
cadmium	2.0E-06	1.4E-05	9.3E-05	6.7E-04	NA	NA
chromium vi	9.9E-06	1.1E-05	NA	NA	NA	NA
cobalt	7.2E-06	2.9E-06	NA	NA	NA	NA
copper	2.3E-03	1.4E-03	NA	NA	4.7E-04	2.9E-04
lead	2.6E-04	8.8E-04	NA	NA	2.0E-06	6.8E-06
manganese	1.3E-04	4.7E-04	NA	NA	4.6E-06	1.6E-05
mercury	6.0E-06	4.3E-08	NA	NA	NA	NA
molybdenum	5.2E-05	5.2E-05	NA	NA	NA	NA
nickel	4.6E-05	3.1E-05	NA	NA	1.6E-04	1.1E-04
selenium	1.2E-05	1.3E-05	NA	NA	3.3E-05	3.5E-05
silver	4.9E-06	1.3E-04	NA	NA	3.7E-05	9.8E-04
thallium	1.5E-05	3.0E-06	2.0E-05	4.0E-06	NA	NA
vanadium	8.8E-05	2.8E-06	NA	NA	1.9E-04	6.3E-06
thorium-total	2.6E-09	8.6E-09	1.9E-08	6.5E-08	NA	NA
uranium-total	4.7E-06	5.6E-05	7.9E-05	9.4E-04	NA	NA
fluoride	NA	NA	NA	NA	NA	NA
acenaphthylene	4.4E-11	5.9E-11	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	1.2E-07	1.6E-07	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA
pentachlorophenol	6.4E-09	8.2E-09	NA	NA	NA	NA
phenanthrene	8.0E-10	1.0E-09	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA
2-hexanone	2.9E-14	3.7E-14	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	2.6E-10	3.6E-10
tetrachloroethene	3.3E-10	4.3E-10	NA	NA	1.4E-09	1.8E-09
methylene chloride	NA	NA	NA	NA	2.9E-11	6.7E-11
toluene	NA	NA	NA	NA	4.6E-09	6.4E-09
2-nitrophenol	NA	NA	NA	NA	7.1E-10	9.3E-10
acetone	NA	NA	NA	NA	1.0E-10	2.3E-10

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..

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E.IV

TABLE E.IV-1
ILCRs FOR ON-PROPERTY GROUNDSKEEPER CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air	Soil			Buried Pit Material
Exposure Pathways: / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact[b]	External Exposure	External Exposure[a]
Radionuclides					
Cs_{137+1d}	1.9E-12	2.0E-09	NA	1.3E-06	
Np_{237+1d}	1.8E-09	9.6E-09	NA	1.7E-07	
Pu_{238}	4.8E-10	1.9E-09	NA	2.2E-12	
$Pu_{239/240}$	9.3E-10	4.0E-09	NA	4.3E-12	
Ra_{226+8d}	1.2E-09	9.6E-08	NA	6.7E-06	
Ra_{228+1d}	1.9E-10	1.9E-08	NA	5.1E-06	
Sr_{90+1d}	1.2E-11	4.7E-09	NA	ND	
Tc_{99}	5.7E-12	6.4E-10	NA	2.7E-12	
Th_{228+7d}	7.5E-08	3.8E-08	NA	3.5E-05	
Th_{230}	5.1E-07	1.7E-07	NA	6.3E-09	
Th_{232}	1.9E-08	5.8E-09	NA	1.1E-10	
U_{234}	3.8E-07	1.6E-07	NA	2.8E-09	
U_{235+1D}	4.3E-09	2.6E-08	NA	3.6E-06	
U_{238+2d}	5.0E-06	1.9E-06	NA	2.3E-05	
Rn_{222+4d}	4.0E-12	NA	NA	NA	
Total Radionuclides	6.0E-06	2.5E-06		7.4E-05	4.6E-05
Chemicals					
arsenic	8.4E-09	7.0E-07	4.2E-08	NA	NA
beryllium	4.4E-10	1.6E-07	9.3E-06	NA	NA
cadmium	2.5E-09	ND	ND	NA	NA
lead	NA	NA	NA	NA	NA
nickel	NA	NA	NA	NA	NA
pcbs	ND	5.3E-07	1.2E-06	NA	NA
benzo(a)anthracene	4.1E-12	3.5E-09	3.5E-09	NA	NA
benzo(a)pyrene	1.8E-11	1.5E-08	1.5E-08	NA	NA
benzo(b)fluoranthene	2.5E-12	2.1E-09	2.1E-09	NA	NA
benzo(k)fluoranthene	2.1E-13	1.6E-10	1.6E-10	NA	NA
chrysene	NA	1.4E-10	1.4E-10	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA
Sum Chem. (TEF for PAHs):	1.1E-08	1.4E-06	1.1E-05		
Sum Chem. (BaP for PAHs):	1.1E-08	1.5E-06	1.1E-05		
TOTAL ALL (TEF):	6.0E-06	3.9E-06	1.1E-05	7.4E-05	4.6E-05
TOTAL ALL (BaP):	6.0E-06	4.0E-06	1.1E-05	7.4E-05	4.6E-05

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from to exposure to buried gamma radiation sources.
[b] Risk from dermal contact with PAHs is assumed to equal the risk from oral ingestion of PAHs.

TABLE E.IV-2
HAZARD QUOTIENTS FOR ON-PROPERTY GROUNDKEEPER CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air	Soil		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants				
cyanide	NA	NA	NA	NA
antimony	ND	9.6E-03	3.7E-02	NA
arsenic	ND	3.7E-03	2.3E-04	NA
barium	NA	NA	NA	NA
beryllium	ND	2.1E-05	1.2E-03	NA
cadmium	ND	8.0E-04	9.2E-03	NA
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	ND	1.4E-03	7.9E-04	NA
vanadium	NA	NA	NA	NA
thorium-total	ND	ND	ND	NA
uranium-total	ND	1.9E-02	2.2E-01	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA
TOTAL:	0.0E+00	3.4E-02	2.7E-01	

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

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TABLE E.IV–3
ILCRs FOR RME OFF–PROPERTY FARMER
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Radionuclides				
Cs_{137+1d}	9.5E–13	2.3E–11	4.0E–11	5.6E–11
Np_{237+1d}	9.1E–10	9.3E–11	5.3E–13	1.9E–13
Pu_{238}	2.5E–10	1.7E–11	6.3E–16	5.1E–16
$Pu_{239/240}$	4.7E–10	3.6E–11	2.8E–15	2.3E–15
Ra_{226+8d}	6.1E–10	9.6E–10	4.0E–11	2.8E–10
Ra_{228+1d}	9.5E–11	1.7E–10	2.4E–12	1.8E–11
Sr_{90+1d}	5.8E–12	5.4E–11	3.3E–12	6.6E–11
Tc_{99}	2.9E–12	6.0E–12	3.6E–12	1.7E–11
Th_{228+7d}	3.8E–08	3.4E–10	1.0E–13	3.5E–13
Th_{230}	2.7E–07	1.5E–09	1.8E–12	6.1E–12
Th_{232}	9.6E–09	5.3E–11	6.3E–14	2.1E–13
U_{234}	1.9E–07	1.5E–09	1.7E–11	2.0E–10
U_{235+1D}	2.8E–08	2.3E–10	2.5E–12	3.1E–11
U_{238+2d}	2.6E–06	1.8E–08	2.0E–10	2.3E–09
Rn_{222+4d}	2.0E–12	ND	ND	ND
Total Radionuclides	3.1E–06	2.3E–08	3.1E–10	3.0E–09
Chemicals				
arsenic	4.2E–09	7.2E–09	1.8E–09	2.2E–10
beryllium	2.2E–10	1.7E–09	3.3E–10	1.2E–12
cadmium	1.3E–09	ND	ND	ND
lead	NA	NA	NA	NA
nickel	NA	NA	NA	NA
pcbs	ND	1.7E–08	5.1E–08	6.4E–08
benzo(a)anthracene	2.1E–12	3.3E–11	1.9E–11	2.4E–11
benzo(a)pyrene	9.1E–12	1.4E–10	1.9E–10	2.4E–10
benzo(b)fluoranthene	1.3E–12	1.9E–11	9.9E–11	1.3E–10
benzo(k)fluoranthene	9.9E–14	1.5E–12	1.6E–11	2.0E–11
chrysene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
benzene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
Sum Chem. (TEF for PAHs):	5.8E–09	2.7E–08	5.3E–08	6.5E–08
Sum Chem. (BaP for PAHs):	5.8E–09	2.7E–08	5.4E–08	6.6E–08
TOTAL ALL (TEF):	3.1E–06	4.9E–08	5.3E–08	6.8E–08
TOTAL ALL (BaP):	3.1E–06	4.9E–08	5.4E–08	6.9E–08

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–4
HAZARD QUOTIENTS FOR RME OFF–PROPERTY FARMER
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Toxicants				
cyanide	NA	NA	NA	NA
antimony	ND	6.0E–05	1.7E–05	6.6E–06
arsenic	ND	1.4E–05	3.5E–06	4.2E–07
barium	NA	NA	NA	NA
beryllium	ND	7.9E–08	1.5E–08	5.6E–11
cadmium	ND	2.8E–05	3.7E–06	2.7E–05
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	ND	4.6E–06	3.2E–05	6.5E–06
vanadium	NA	NA	NA	NA
thorium–total	ND	ND	ND	ND
uranium–total	ND	6.0E–05	6.7E–07	8.1E–06
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA
TOTAL:	0.0E+00	1.7E–04	5.7E–05	4.9E–05

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–5
ILCRs FOR RME OFF–PROPERTY CHILD
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Radionuclides				
Cs_{137+1d}	4.9E–14	1.7E–12	1.3E–12	1.1E–11
Np_{237+1d}	4.7E–11	6.9E–12	1.7E–14	3.7E–14
Pu_{238}	1.3E–11	1.3E–12	2.1E–17	9.8E–17
$Pu_{239/240}$	2.4E–11	2.7E–12	9.3E–17	4.4E–16
Ra_{226+8d}	3.2E–11	7.1E–11	1.3E–12	5.5E–11
Ra_{228+1d}	4.9E–12	1.3E–11	8.0E–14	3.4E–12
Sr_{90+1d}	3.0E–13	4.0E–12	1.1E–13	1.3E–11
Tc_{99}	1.5E–13	4.5E–13	1.2E–13	3.3E–12
Th_{228+7d}	2.0E–09	2.5E–11	3.4E–15	6.8E–14
Th_{230}	1.4E–08	1.2E–10	6.1E–14	1.2E–12
Th_{232}	5.0E–10	3.9E–12	2.1E–15	4.1E–14
U_{234}	9.8E–09	1.1E–10	5.5E–13	3.9E–11
U_{235+1D}	1.5E–09	1.7E–11	8.4E–14	5.9E–12
U_{238+2d}	1.3E–07	1.3E–09	6.5E–12	4.6E–10
Rn_{222+4d}	1.0E–13	ND	ND	ND
Total Radionuclides	1.6E–07	1.7E–09	1.0E–11	5.9E–10
Chemicals				
arsenic	1.0E–09	2.5E–09	2.8E–10	2.0E–10
beryllium	5.4E–11	5.9E–10	5.1E–11	1.1E–12
cadmium	3.1E–10	ND	ND	ND
lead	NA	NA	NA	NA
nickel	NA	NA	NA	NA
pcbs	ND	6.0E–09	7.8E–09	5.8E–08
benzo(a)anthracene	5.0E–13	1.2E–11	2.9E–12	2.2E–11
benzo(a)pyrene	2.2E–12	4.9E–11	2.9E–11	2.2E–10
benzo(b)fluoranthene	3.0E–13	6.7E–12	1.5E–11	1.1E–10
benzo(k)fluoranthene	2.4E–14	5.4E–13	2.5E–12	1.8E–11
chrysene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
benzene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
Sum Chem. (TEF for PAHs):	1.4E–09	9.2E–09	8.2E–09	5.9E–08
Sum Chem. (BaP for PAHs):	1.4E–09	9.3E–09	8.4E–09	6.0E–08
TOTAL ALL (TEF):	1.6E–07	1.1E–08	8.2E–09	5.9E–08
TOTAL ALL (BaP):	1.6E–07	1.1E–08	8.4E–09	6.0E–08

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–6
HAZARD QUOTIENTS FOR OFF–PROPERTY CHILD
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air			
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products
Toxicants				
cyanide	NA	NA	NA	NA
antimony	ND	2.4E–04	3.0E–05	7.0E–05
arsenic	ND	5.6E–05	6.3E–06	4.4E–06
barium	NA	NA	NA	NA
beryllium	ND	3.2E–07	2.8E–08	5.9E–10
cadmium	ND	1.1E–04	6.8E–06	2.9E–04
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	ND	1.9E–05	5.8E–05	6.8E–05
vanadium	NA	NA	NA	NA
thorium–total	ND	ND	ND	ND
uranium–total	ND	2.4E–04	1.2E–06	8.5E–05
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA
TOTAL:	0.0E+00	6.8E–04	1.0E–04	5.2E–04

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV-7
ILCRs FOR TRESPASSING YOUTH
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air	Soil			Buried Pit Material
Exposure Pathways: / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact[b]	External Exposure	External Exposure[a]
Radionuclides					
Cs_{137+1d}	2.2E-13	3.5E-10	NA	4.6E-07	
Np_{237+1d}	2.1E-10	1.7E-09	NA	6.1E-08	
Pu_{238}	5.7E-11	3.4E-10	NA	8.0E-13	
$Pu_{239/240}$	1.1E-10	7.2E-10	NA	1.5E-12	
Ra_{226+8d}	1.4E-10	1.7E-08	NA	2.4E-06	
Ra_{228+1d}	2.2E-11	3.4E-09	NA	1.8E-06	
Sr_{90+1d}	1.4E-12	8.4E-10	NA	ND	
Tc_{99}	6.7E-13	1.1E-10	NA	9.6E-13	
Th_{228+7d}	8.8E-09	6.7E-09	NA	1.2E-05	
Th_{230}	6.0E-08	3.0E-08	NA	2.2E-09	
Th_{232}	2.2E-09	1.0E-09	NA	4.1E-11	
U_{234}	4.5E-08	2.9E-08	NA	1.0E-09	
U_{235+1D}	5.0E-10	4.7E-09	NA	1.3E-06	
U_{238+2d}	5.9E-07	3.4E-07	NA	8.1E-06	
Rn_{222+4d}	4.8E-13	NA	NA	NA	
Total Radionuclides	7.1E-07	4.4E-07		2.7E-05	1.7E-05
Chemicals					
arsenic	1.6E-09	2.0E-07	3.6E-08	NA	NA
beryllium	8.6E-11	4.7E-08	7.9E-06	NA	NA
cadmium	4.9E-10	ND	ND	NA	NA
lead	NA	NA	NA	NA	NA
nickel	NA	NA	NA	NA	NA
pcbs	ND	1.5E-07	1.0E-06	NA	NA
benzo(a)anthracene	7.9E-13	1.0E-09	1.0E-09	NA	NA
benzo(a)pyrene	3.5E-12	4.4E-09	4.4E-09	NA	NA
benzo(b)fluoranthene	4.8E-13	6.1E-10	6.1E-10	NA	NA
benzo(k)fluoranthene	4.1E-14	4.8E-11	4.8E-11	NA	NA
chrysene	NA	4.0E-11	4.0E-11	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA
Sum Chem. (TEF for PAHs):	2.2E-09	4.1E-07	9.0E-06		
Sum Chem. (BaP for PAHs):	2.2E-09	4.3E-07	9.0E-06		
TOTAL ALL (TEF):	7.1E-07	8.5E-07	9.0E-06	2.7E-05	1.7E-05
TOTAL ALL (BaP):	7.1E-07	8.7E-07	9.0E-06	2.7E-05	1.7E-05

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources.
[b] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV-8
HAZARD QUOTIENTS FOR TRESPASSING YOUTH
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Air	Soil		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants				
cyanide	NA	NA	NA	NA
antimony	ND	5.8E-03	6.5E-02	NA
arsenic	ND	2.3E-03	4.0E-04	NA
barium	NA	NA	NA	NA
beryllium	ND	1.3E-05	2.1E-03	NA
cadmium	ND	4.9E-04	1.6E-02	NA
copper	NA	NA	NA	NA
lead	NA	NA	NA	NA
manganese	NA	NA	NA	NA
nickel	NA	NA	NA	NA
selenium	NA	NA	NA	NA
silver	NA	NA	NA	NA
thallium	ND	8.3E-04	1.4E-03	NA
vanadium	NA	NA	NA	NA
thorium-total	ND	ND	ND	NA
uranium-total	ND	1.1E-02	3.8E-01	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA
TOTAL:	0.0E+00	2.1E-02	4.7E-01	

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

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TABLE E.IV–9
ILCRs FOR OFF–PROPERTY USER OF MEAT AND MILK PRODUCTS CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Soil		Surface Water	
Exposure Pathways: / Contaminants of Concern	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Radionuclides				
Cs_{137+1d}	3.7E–06	5.2E–06	3.7E–05	5.3E–05
Np_{237+1d}	6.1E–08	2.2E–08	NA	NA
Pu_{238}	1.1E–11	8.4E–12	NA	NA
$Pu_{239/240}$	2.2E–11	1.8E–11	NA	NA
Ra_{226+8d}	6.3E–07	4.5E–06	3.6E–08	2.7E–07
Ra_{228+1d}	1.2E–07	9.0E–07	6.1E–08	4.6E–07
Sr_{90+1d}	3.7E–06	7.4E–05	7.6E–07	1.5E–05
Tc_{99}	5.4E–05	2.5E–04	1.0E–05	4.9E–05
Th_{228+7d}	2.5E–09	8.5E–09	NA	NA
Th_{230}	1.1E–08	3.8E–08	8.5E–12	2.9E–11
Th_{232}	3.9E–10	1.3E–09	NA	NA
U_{234}	6.4E–07	7.7E–06	9.8E–07	1.2E–05
U_{235+1D}	1.0E–07	1.2E–06	5.4E–08	6.7E–07
U_{238+2d}	7.5E–06	9.0E–05	3.6E–06	4.4E–05
Total Radionuclides	7.1E–05	4.4E–04	5.2E–05	1.7E–04
Chemicals				
arsenic	7.4E–05	8.8E–06	5.0E–06	6.1E–07
beryllium	3.4E–06	1.2E–08	NA	NA
cadmium	ND	ND	NA	NA
lead	NA	NA	ND	ND
nickel	NA	NA	ND	ND
pcbs	3.4E–04	4.3E–04	NA	NA
benzo(a)anthracene	1.2E–06	1.5E–06	NA	NA
benzo(a)pyrene	8.8E–06	1.1E–05	NA	NA
benzo(b)fluoranthene	3.3E–06	4.2E–06	NA	NA
benzo(k)fluoranthene	4.3E–07	5.4E–07	NA	NA
chrysene	4.7E–08	5.9E–08	NA	NA
chloroform	NA	NA	1.6E–12	2.2E–12
tetrachloroethene	NA	NA	7.1E–11	9.2E–11
benzene	NA	NA	3.5E–10	4.6E–10
methylene chloride	NA	NA	2.4E–13	5.4E–13
Sum Chem. (TEF for PAHs):	4.3E–04	4.5E–04	5.0E–06	6.1E–07
Sum Chem. (BaP for PAHs):	4.8E–04	5.2E–04	5.0E–06	6.1E–07
TOTAL ALL (TEF):	5.0E–04	8.9E–04	5.7E–05	1.8E–04
TOTAL ALL (BaP):	5.5E–04	9.5E–04	5.7E–05	1.8E–04

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–10
HAZARD QUOTIENTS FOR OFF–PROPERTY USER OF MEAT AND MILK PRODUCTS
CURRENT LAND USE, CURRENT SOURCE TERM

Transfer Media:	Soil		Surface Water	
Exposure Pathways:	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Toxicants				
cyanide	NA	NA	1.0E–07	1.3E–07
antimony	7.5E–01	3.0E–01	2.3E–02	9.4E–03
arsenic	1.4E–01	1.7E–02	9.5E–03	1.2E–03
barium	NA	NA	1.1E–03	1.0E–02
beryllium	1.6E–04	5.7E–07	NA	NA
cadmium	9.3E–02	6.7E–01	NA	NA
copper	NA	NA	1.2E–02	7.1E–03
lead	NA	NA	ND	ND
manganese	NA	NA	1.8E–05	6.3E–05
nickel	NA	NA	9.2E–03	6.1E–03
selenium	NA	NA	6.2E–03	6.7E–03
silver	NA	NA	4.0E–03	1.1E–01
thallium	2.9E–01	5.8E–02	NA	NA
vanadium	NA	NA	1.9E–02	6.1E–04
thorium–total	ND	ND	NA	NA
uranium–total	2.6E–02	3.1E–01	NA	NA
chloroform	NA	NA	2.6E–08	3.6E–08
tetrachloroethene	NA	NA	1.4E–07	1.8E–07
methylene chloride	NA	NA	5.2E–10	1.2E–09
toluene	NA	NA	2.6E–08	3.6E–08
2–nitrophenol	NA	NA	ND	ND
acetone	NA	NA	5.9E–10	1.3E–09
TOTAL:	1.3E+00	1.4E+00	8.4E–02	1.5E–01

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

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TABLE E.IV-11
ILCRs FOR TRESPASSING YOUTH
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment			Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact[b]	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides										
Cs_{137+1d}	1.3E-10	2.2E-09	NA	2.8E-06	1.4E-12	NA	1.0E-10	NA	1.4E-07	
Np_{237+1d}	1.5E-07	1.3E-08	NA	4.5E-07	1.8E-10	NA	4.1E-10	NA	1.5E-08	
Pu_{238}	1.1E-08	9.9E-10	NA	2.3E-12	4.8E-12	NA	3.3E-10	NA	8.0E-13	
$Pu_{239/240}$	4.9E-08	4.5E-09	NA	9.6E-12	1.2E-12	NA	8.6E-11	NA	1.9E-13	
Ra_{226+8d}	2.8E-07	2.8E-07	NA	3.9E-05	NA	NA	NA	NA	NA	
Ru_{106}	1.6E-10	5.4E-10	NA	ND	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.2E-10	1.4E-09	NA	ND	5.6E-10	NA	2.3E-10	NA	ND	
Tc_{99}	1.6E-08	3.3E-09	NA	2.7E-11	4.8E-09	NA	2.3E-11	NA	2.0E-13	
Th_{230}	3.0E-05	1.5E-07	NA	1.1E-08	1.6E-11	NA	3.7E-09	NA	2.9E-10	
$Th_{232+10d}$	3.9E-06	7.1E-08	NA	6.4E-05	1.2E-11	NA	2.7E-09	NA	2.6E-06	
U_{234}	5.9E-06	5.2E-08	NA	1.8E-09	7.3E-09	NA	3.6E-09	NA	1.3E-10	
U_{235+1D}	1.6E-06	8.2E-09	NA	2.2E-06	8.3E-10	NA	4.0E-10	NA	1.1E-07	
U_{238+2d}	4.3E-05	3.7E-07	NA	8.5E-06	5.2E-08	NA	2.5E-08	NA	6.2E-07	
Rn_{222+4d}	5.7E-11	NA	NA	NA	NA	NA	NA	NA	NA	
Total Radionuclides	8.5E-05	9.5E-07		1.2E-04	6.6E-08		3.7E-08		3.5E-06	7.2E-06
Chemicals										
arsenic	4.2E-05	3.6E-05	8.3E-06	NA	3.6E-09	5.6E-10	2.9E-08	2.2E-08	NA	NA
beryllium	1.9E-08	1.3E-07	2.9E-05	NA	2.2E-10	3.3E-09	1.2E-08	8.2E-06	NA	NA
cadmium	2.0E-08	ND	ND	NA	ND	ND	ND	ND	NA	NA
chromium vi	7.9E-07	ND	ND	NA	ND	ND	ND	ND	NA	NA
lead	ND	ND	ND	NA	ND	ND	ND	ND	NA	NA
nickel	3.5E-08	ND	ND	NA	ND	ND	ND	ND	NA	NA
pcbs	ND	1.4E-07	1.2E-06	NA	3.5E-11	5.0E-08	4.2E-08	1.2E-06	NA	NA
benzo(a)anthracene	1.7E-11	8.2E-10	8.2E-10	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	1.4E-10	4.0E-09	4.0E-09	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	2.6E-11	6.2E-10	6.2E-10	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	3.0E-14	3.2E-11	3.2E-11	NA	NA	NA	NA	NA	NA	NA
chrysene	7.6E-13	3.3E-11	3.3E-11	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	6.2E-12	4.8E-11	4.8E-11	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	ND	1.6E-09	1.2E-08	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	7.8E-11	5.8E-09	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	1.4E-08	1.8E-07	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	5.7E-11	3.3E-09	4.4E-08	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	2.4E-08	3.2E-07	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	2.0E-10	1.2E-08	1.6E-07	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	2.5E-11	1.5E-09	1.9E-08	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	2.3E-10	1.3E-08	1.8E-07	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	1.3E-11	7.6E-10	1.0E-08	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	1.8E-12	1.7E-10	1.7E-08	NA	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	4.3E-05	3.6E-05	3.9E-05		3.9E-09	5.3E-08	8.3E-08	9.4E-06		
Sum Chem (BaP for PAHs):	4.3E-05	3.6E-05	3.9E-05		3.9E-09	5.3E-08	8.3E-08	9.4E-06		
TOTAL ALL (TEF Approach):	1.3E-04	3.7E-05	3.9E-05	1.2E-04	7.0E-08	5.3E-08	1.2E-07	9.4E-06	3.5E-06	7.2E-06
TOTAL ALL (BaP Approach):	1.3E-04	3.7E-05	3.9E-05	1.2E-04	7.0E-08	5.3E-08	1.2E-07	9.4E-06	3.5E-06	7.2E-06

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources.
[b] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV-12
HAZARD QUOTIENTS FOR TRESPASSING YOUTH
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment		
Exposure Pathways	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants									
cyanide	NA	NA	NA	NA	5.1E-05	ND	NA	NA	NA
antimony	ND	5.1E-03	7.5E-02	NA	1.6E-04	1.6E-04	1.4E-03	6.3E-02	NA
arsenic	ND	3.9E-01	9.2E-02	NA	4.0E-05	6.2E-06	3.2E-04	2.4E-04	NA
barium	8.5E-02	2.4E-03	5.8E-03	NA	3.5E-07	5.6E-08	1.6E-05	1.2E-04	NA
beryllium	ND	3.5E-05	7.8E-03	NA	6.0E-08	8.8E-07	3.2E-06	2.2E-03	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	ND	5.0E-04	2.2E-02	NA	5.7E-06	1.7E-05	1.2E-04	1.6E-02	NA
chromium vi	ND	4.6E-04	2.0E-02	NA	9.3E-07	5.5E-06	5.7E-05	8.0E-03	NA
cobalt	8.1E-02	1.5E-05	7.5E-05	NA	1.5E-07	2.0E-08	3.4E-06	5.4E-05	NA
copper	ND	1.7E-03	ND	NA	1.7E-06	ND	8.4E-06	ND	NA
lead	ND	ND	ND	NA	ND	ND	ND	ND	NA
manganese	8.2E-02	7.8E-04	5.7E-02	NA	1.1E-05	5.5E-05	8.2E-05	1.9E-02	NA
mercury	2.7E-05	7.3E-05	5.4E-03	NA	1.6E-05	1.6E-05	NA	NA	NA
molybdenum	ND	1.1E-03	6.4E-03	NA	4.7E-06	1.8E-06	1.7E-05	3.1E-04	NA
nickel	ND	2.0E-04	2.2E-04	NA	1.1E-06	1.6E-07	2.9E-05	1.0E-04	NA
selenium	ND	7.1E-05	2.0E-04	NA	8.0E-08	1.5E-08	NA	NA	NA
silver	ND	1.6E-04	ND	NA	4.8E-06	ND	3.5E-05	ND	NA
thallium	ND	4.4E-03	9.8E-03	NA	3.3E-06	4.8E-07	2.0E-04	1.4E-03	NA
vanadium	ND	5.1E-03	2.3E-02	NA	1.4E-06	4.0E-06	5.6E-05	7.8E-04	NA
thorium-total	ND	ND	ND	NA	NA	NA	ND	ND	NA
uranium-total	ND	1.7E-02	7.4E-01	NA	9.9E-03	2.9E-02	NA	NA	NA
fluoride	ND	2.5E-03	1.6E-02	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.3E-07	9.3E-06	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	ND	1.2E-09	ND	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	1.9E-06	1.9E-04	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA
SUM	2.5E-01	4.4E-01	1.1E+00		1.0E-02	2.9E-02	2.3E-03	1.1E-01	

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND - No data for toxicity assessment for exposure pathway.

TABLE E.IV-13
ILCRs FOR GREAT MIAMI RIVER USER
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media:	Surface Water								
Exposure Pathways: / Contaminants of Concern	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	Dermal Contact while Swimming	Incidental Ingestion while Swimming	Ingestion of Fish
Radionuclides									
Cs_{137+1d}	3.8E-12	1.5E-12	1.6E-12	2.3E-12	NA	NA	NA	2.1E-15	8.9E-11
Np_{237+1d}	5.0E-10	1.6E-10	5.6E-13	2.1E-13	NA	NA	NA	2.8E-13	5.8E-11
Pu_{238}	1.3E-11	3.9E-12	7.1E-17	5.9E-17	NA	NA	NA	7.2E-15	3.7E-12
$Pu_{239/240}$	3.4E-12	1.0E-12	2.0E-17	1.6E-17	NA	NA	NA	1.9E-15	9.7E-13
Ra_{226+8d}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ru_{106}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sr_{90+1d}	1.5E-09	6.2E-10	2.2E-11	4.5E-10	NA	NA	NA	8.6E-13	5.3E-10
Tc_{99}	1.3E-08	4.1E-09	1.6E-09	7.8E-09	NA	NA	NA	7.2E-12	2.2E-09
Th_{230}	4.2E-11	1.3E-11	3.3E-15	1.1E-14	NA	NA	NA	2.3E-14	1.5E-11
$Th_{232+10d}$	3.2E-11	9.6E-12	2.5E-15	8.5E-15	NA	NA	NA	1.8E-14	1.1E-11
U_{234}	2.0E-08	6.0E-09	4.4E-11	5.5E-10	NA	NA	NA	1.1E-11	4.6E-10
U_{235+1D}	2.2E-09	6.7E-10	5.0E-12	6.2E-11	NA	NA	NA	1.2E-12	5.2E-11
U_{238+2d}	1.4E-07	4.3E-08	3.1E-10	3.9E-09	NA	NA	NA	7.9E-11	3.3E-09
Total Radionuclides	1.8E-07	5.4E-08	2.0E-09	1.3E-08				9.9E-11	6.7E-09
Chemicals									
arsenic	4.8E-09	1.7E-09	2.4E-10	2.9E-11	NA	1.5E-11	3.1E-12	2.7E-12	2.4E-09
beryllium	3.7E-10	1.3E-10	1.0E-11	3.6E-14	NA	1.0E-10	2.2E-11	2.0E-13	8.0E-11
cadmium	ND	ND	ND	ND	NA	ND	ND	ND	ND
chromium vi	ND	ND	ND	ND	NA	ND	ND	ND	ND
lead	ND	ND	ND	ND	NA	ND	ND	ND	ND
nickel	ND	ND	ND	ND	NA	ND	ND	ND	ND
pcbs	5.7E-11	7.4E-11	7.2E-11	9.1E-11	NA	3.2E-09	2.1E-10	3.2E-14	1.5E-08
benzo(a)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	5.2E-09	1.9E-09	3.2E-10	1.2E-10	0.0E+00	3.3E-09	2.4E-10	2.9E-12	1.7E-08
Sum Chem (BaP for PAHs):	5.2E-09	1.9E-09	3.2E-10	1.2E-10	0.0E+00	3.3E-09	2.4E-10	2.9E-12	1.7E-08
TOTAL ALL (TEF Approach):	1.8E-07	5.6E-08	2.3E-09	1.3E-08	0.0E+00	3.3E-09	2.4E-10	1.0E-10	2.4E-08
TOTAL ALL (BaP Approach):	1.8E-07	5.6E-08	2.3E-09	1.3E-08	0.0E+00	3.3E-09	2.4E-10	1.0E-10	2.4E-08

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–14
HAZARD QUOTIENTS FOR GREAT MIAMI RIVER USER
CURRENT LAND USE, FUTURE SOURCE TERM

Transfer Media:	Surface Water								
Exposure Pathways:	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	Dermal Contact while Swimming	Incidental Ingestion while Swimming	Ingestion of Fish
Toxicants									
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA
antimony	4.7E–05	3.1E–05	4.6E–06	1.8E–06	NA	9.1E–07	1.9E–07	2.6E–08	5.5E–07
arsenic	9.1E–06	3.3E–06	4.5E–07	5.5E–08	NA	2.8E–08	5.9E–09	5.1E–09	4.6E–06
barium	9.8E–08	9.2E–08	3.5E–09	3.3E–08	NA	3.1E–10	6.6E–11	5.5E–11	ND
beryllium	1.7E–08	6.2E–09	4.6E–10	1.7E–12	NA	4.9E–09	1.0E–09	9.5E–12	3.7E–09
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	1.6E–06	6.2E–06	4.3E–07	3.1E–06	NA	9.3E–08	2.0E–08	9.0E–10	1.5E–06
chromium vi	2.7E–07	1.4E–07	3.6E–08	3.9E–08	NA	3.1E–08	6.6E–09	1.5E–10	5.0E–08
cobalt	4.4E–08	2.1E–08	2.5E–08	1.0E–08	NA	1.1E–10	2.4E–11	2.4E–11	ND
copper	4.7E–07	8.5E–07	4.6E–07	2.8E–07	NA	ND	ND	2.6E–10	1.1E–06
lead	ND	ND	ND	ND	NA	ND	ND	ND	ND
manganese	3.1E–06	2.3E–06	1.1E–07	3.9E–07	NA	3.0E–07	6.4E–08	1.7E–09	ND
mercury	NA	NA	NA	NA	NA	NA	NA	NA	NA
molybdenum	1.3E–06	7.3E–07	3.9E–07	4.0E–07	NA	9.9E–09	2.1E–09	7.3E–10	ND
nickel	3.2E–07	6.4E–07	1.4E–07	9.3E–08	NA	9.1E–10	1.9E–10	1.8E–10	1.7E–07
selenium	NA	NA	NA	NA	NA	NA	NA	NA	NA
silver	1.4E–06	1.6E–06	5.6E–07	1.5E–05	NA	ND	ND	7.6E–10	4.9E–05
thallium	9.4E–07	3.0E–07	6.7E–07	1.4E–07	NA	2.7E–09	5.8E–10	5.2E–10	ND
vanadium	3.9E–07	1.6E–07	1.8E–08	6.0E–10	NA	2.3E–08	4.8E–09	2.2E–10	ND
thorium–total	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium–total	2.8E–03	8.5E–04	6.3E–06	7.8E–05	NA	1.6E–04	3.5E–05	1.6E–06	6.6E–08
fluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
4–chloro–3–methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA
3–chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL:	2.9E–03	9.0E–04	1.4E–05	9.9E–05	0.0E+00	1.6E–04	3.5E–05	1.6E–06	5.7E–05

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–15
ILCRs FOR EXPANDED TRESPASSER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment			Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact[b]	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure	External Exposure[a]
Radionuclides										
Cs_{137+1d}	2.0E−10	3.6E−09	NA	6.5E−06	1.4E−12	NA	1.0E−10	NA	1.4E−07	
Np_{237+1d}	2.4E−07	2.1E−08	NA	1.0E−06	1.8E−10	NA	4.1E−10	NA	1.5E−08	
Pu_{238}	1.8E−08	1.6E−09	NA	5.2E−12	4.8E−12	NA	3.3E−10	NA	8.0E−13	
$Pu_{239/240}$	7.7E−08	7.5E−09	NA	2.2E−11	1.2E−12	NA	8.6E−11	NA	1.9E−13	
Ra_{226+8d}	4.3E−07	4.7E−07	NA	9.0E−05	NA	NA	NA	NA	NA	
Ru_{106}	2.6E−10	8.9E−10	NA	ND	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.9E−10	2.3E−09	NA	ND	5.6E−10	NA	2.3E−10	NA	ND	
Tc_{99}	2.5E−08	5.4E−09	NA	6.3E−11	4.8E−09	NA	2.3E−11	NA	2.0E−13	
Th_{230}	4.7E−05	2.5E−07	NA	2.6E−08	1.6E−11	NA	3.7E−09	NA	2.9E−10	
$Th_{232+10d}$	6.1E−06	1.2E−07	NA	1.5E−04	1.2E−11	NA	2.7E−09	NA	2.6E−06	
U_{234}	9.3E−06	8.6E−08	NA	4.0E−09	7.3E−09	NA	3.6E−09	NA	1.3E−10	
U_{235+1D}	2.5E−06	1.4E−08	NA	5.1E−06	8.3E−10	NA	4.0E−10	NA	1.1E−07	
U_{238+2d}	6.8E−05	6.0E−07	NA	2.0E−05	5.2E−08	NA	2.5E−08	NA	6.2E−07	
Rn_{222+4d}	9.1E−11	NA	NA	NA	NA	NA	NA	NA	NA	
Total Radionuclides	1.3E−04	1.6E−06		2.7E−04	6.6E−08		3.7E−08		3.5E−06	2.6E−05
Chemicals										
arsenic	5.8E−05	5.1E−05	3.2E−05	NA	3.6E−09	5.6E−10	2.9E−08	2.2E−08	NA	NA
beryllium	2.6E−08	1.9E−07	1.1E−04	NA	2.2E−10	3.3E−09	1.2E−08	8.2E−06	NA	NA
cadmium	2.8E−08	ND	ND	NA	ND	ND	ND	ND	NA	NA
chromium vi	1.1E−06	ND	ND	NA	ND	ND	ND	ND	NA	NA
lead	ND	ND	ND	NA	ND	ND	ND	ND	NA	NA
nickel	4.8E−08	ND	ND	NA	ND	ND	ND	ND	NA	NA
pcbs	ND	2.0E−07	4.8E−06	NA	3.5E−11	5.0E−08	4.2E−08	1.2E−06	NA	NA
benzo(a)anthracene	2.4E−11	1.2E−09	1.2E−09	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	1.9E−10	5.7E−09	5.7E−09	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	3.6E−11	8.9E−10	8.9E−10	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	4.1E−14	4.7E−11	4.7E−11	NA	NA	NA	NA	NA	NA	NA
chrysene	1.0E−12	4.8E−11	4.8E−11	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	8.6E−12	6.9E−11	6.9E−11	NA	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	ND	2.3E−09	4.6E−08	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.1E−10	2.2E−08	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	2.0E−08	7.0E−07	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	7.8E−11	4.8E−09	1.7E−07	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	3.5E−08	1.2E−06	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	2.7E−10	1.7E−08	6.0E−07	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	3.4E−11	2.1E−09	7.4E−08	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	3.1E−10	1.9E−08	6.8E−07	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	1.8E−11	1.1E−09	3.9E−08	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	2.5E−12	2.4E−10	6.4E−08	NA	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	6.0E−05	5.2E−05	1.5E−04		3.9E−09	5.3E−08	8.3E−08	9.4E−06		
Sum Chem (BaP for PAHs):	6.0E−05	5.2E−05	1.5E−04		3.9E−09	5.3E−08	8.3E−08	9.4E−06		
TOTAL ALL (TEF Approach):	1.9E−04	5.3E−05	1.5E−04	2.7E−04	7.0E−08	5.3E−08	1.2E−07	9.4E−06	3.5E−06	2.6E−05
TOTAL ALL (BaP Approach):	1.9E−04	5.3E−05	1.5E−04	2.7E−04	7.0E−08	5.3E−08	1.2E−07	9.4E−06	3.5E−06	2.6E−05

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources.
[b] Risk from dermal contact to PAH's is assumed to equal risk from oral ingestion of PAH's.

TABLE E.IV–16
HAZARD QUOTIENTS FOR EXPANDED TRESPASSER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air	Surface Soil and Exposed Pit Material			Paddys Run Surface Water		Paddys Run Sediment		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure	Incidental Ingestion	Dermal Contact	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants									
cyanide	NA	NA	NA	NA	5.1E–05	ND	NA	NA	NA
antimony	ND	6.3E–03	2.1E–01	NA	1.6E–04	1.6E–04	1.4E–03	6.3E–02	NA
arsenic	ND	4.9E–01	2.5E–01	NA	4.0E–05	6.2E–06	3.2E–04	2.4E–04	NA
barium	1.0E–01	2.9E–03	1.6E–02	NA	3.5E–07	5.6E–08	1.6E–05	1.2E–04	NA
beryllium	ND	4.4E–05	2.1E–02	NA	6.0E–08	8.8E–07	3.2E–06	2.2E–03	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	ND	6.2E–04	6.1E–02	NA	5.7E–06	1.7E–05	1.2E–04	1.6E–02	NA
chromium vi	ND	5.7E–04	5.6E–02	NA	9.3E–07	5.5E–06	5.7E–05	8.0E–03	NA
cobalt	9.5E–02	1.9E–05	2.1E–04	NA	1.5E–07	2.0E–08	3.4E–06	5.4E–05	NA
copper	ND	2.1E–03	ND	NA	1.7E–06	ND	8.4E–06	ND	NA
lead	ND	ND	ND	NA	ND	ND	ND	ND	NA
manganese	9.7E–02	9.6E–04	1.6E–01	NA	1.1E–05	5.5E–05	8.2E–05	1.9E–02	NA
mercury	3.2E–05	9.0E–05	1.5E–02	NA	1.6E–05	1.6E–05	NA	NA	NA
molybdenum	ND	1.4E–03	1.8E–02	NA	4.7E–06	1.8E–06	1.7E–05	3.1E–04	NA
nickel	ND	2.5E–04	6.1E–04	NA	1.1E–06	1.6E–07	2.9E–05	1.0E–04	NA
selenium	ND	8.8E–05	5.4E–04	NA	8.0E–08	1.5E–08	NA	NA	NA
silver	ND	2.0E–04	ND	NA	4.8E–06	ND	3.5E–05	ND	NA
thallium	ND	5.5E–03	2.7E–02	NA	3.3E–06	4.8E–07	2.0E–04	1.4E–03	NA
vanadium	ND	6.3E–03	6.2E–02	NA	1.4E–06	4.0E–06	5.6E–05	7.8E–04	NA
thorium–total	ND	ND	ND	NA	NA	NA	ND	ND	NA
uranium–total	ND	2.1E–02	2.0E+00	NA	9.9E–03	2.9E–02	NA	NA	NA
fluoride	ND	3.1E–03	4.5E–02	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	NA	NA	NA	NA	NA	NA
2–methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA
4–chloro–3–methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.6E–07	2.6E–05	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–hexanone	ND	1.5E–09	ND	NA	NA	NA	NA	NA	NA
3–chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	2.4E–06	5.2E–04	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL:	2.9E–01	5.4E–01	3.0E+00		1.0E–02	2.9E–02	2.3E–03	1.1E–01	

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV-17
ILCRs FOR ON-PROPERTY GROUNDSKEEPER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material			Buried Pit Material
Exposure Pathways: / Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact[b]	External Exposure	External Exposure[a]
Radionuclides					
Cs_{137+1d}	1.1E-09	1.6E-08	NA	1.0E-05	
Np_{237+1d}	1.3E-06	9.4E-08	NA	1.7E-06	
Pu_{238}	9.6E-08	7.3E-09	NA	8.5E-12	
$Pu_{239/240}$	4.1E-07	3.3E-08	NA	3.6E-11	
Ra_{226+8d}	2.3E-06	2.1E-06	NA	1.5E-04	
Ru_{106}	1.4E-09	4.0E-09	NA	ND	
Sr_{90+1d}	1.0E-09	1.0E-08	NA	ND	
Tc_{99}	1.3E-07	2.4E-08	NA	1.0E-10	
Th_{230}	2.5E-04	1.1E-06	NA	4.2E-08	
$Th_{232+10d}$	3.3E-05	5.3E-07	NA	2.4E-04	
U_{234}	5.0E-05	3.8E-07	NA	6.5E-09	
U_{235+1D}	1.3E-05	6.1E-08	NA	8.3E-06	
U_{238+2d}	3.6E-04	2.7E-06	NA	3.2E-05	
Rn_{222+4d}	4.9E-10	NA	NA	NA	
Total Radionuclides	7.2E-04	7.0E-06		4.4E-04	4.7E-05
Chemicals					
arsenic	2.2E-04	1.6E-04	9.7E-06	NA	NA
beryllium	9.9E-08	5.9E-07	3.4E-05	NA	NA
cadmium	1.0E-07	ND	ND	NA	NA
chromium vi	4.1E-06	ND	ND	NA	NA
lead	ND	ND	ND	NA	NA
nickel	1.8E-07	ND	ND	NA	NA
pcbs	ND	6.4E-07	1.5E-06	NA	NA
benzo(a)anthracene	9.0E-11	3.7E-09	3.7E-09	NA	NA
benzo(a)pyrene	7.2E-10	1.8E-08	1.8E-08	NA	NA
benzo(b)fluoranthene	1.4E-10	2.8E-09	2.8E-09	NA	NA
benzo(k)fluoranthene	1.6E-13	1.5E-10	1.5E-10	NA	NA
chrysene	3.9E-12	1.5E-10	1.5E-10	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	3.2E-11	2.2E-10	2.2E-10	NA	NA
n-nitrosodipropylamine	ND	7.3E-09	1.4E-08	NA	NA
pentachlorophenol	ND	3.5E-10	6.8E-09	NA	NA
vinyl chloride	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	6.3E-08	2.2E-07	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	2.9E-10	1.5E-08	5.2E-08	NA	NA
hexachlorodibenzofuran	NA	1.1E-07	3.8E-07	NA	NA
heptachlorodibenzo-p-dioxin	1.0E-09	5.3E-08	1.8E-07	NA	NA
heptachlorodibenzofuran	1.3E-10	6.6E-09	2.3E-08	NA	NA
octachlorodibenzo-p-dioxin	1.2E-09	6.1E-08	2.1E-07	NA	NA
octachlorodibenzofuran	6.6E-11	3.4E-09	1.2E-08	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	9.4E-12	7.7E-10	2.0E-08	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	2.2E-04	1.6E-04	4.6E-05		
Sum Chem (BaP for PAHs):	2.2E-04	1.6E-04	4.6E-05		
TOTAL ALL (TEF for PAHs):	9.4E-04	1.7E-04	4.6E-05	4.4E-04	4.7E-05
TOTAL ALL (BaP for PAHs):	9.4E-04	1.7E-04	4.6E-05	4.4E-04	4.7E-05

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources.
[b] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV–18
HAZARD QUOTIENTS FOR ON–PROPERTY GROUNDKEEPER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants				
cyanide	NA	NA	NA	NA
antimony	ND	1.1E–02	4.2E–02	NA
arsenic	ND	8.6E–01	5.2E–02	NA
barium	2.1E–01	5.2E–03	3.3E–03	NA
beryllium	ND	7.7E–05	4.4E–03	NA
boron	NA	NA	NA	NA
cadmium	ND	1.1E–03	1.3E–02	NA
chromium vi	ND	1.0E–03	1.2E–02	NA
cobalt	2.0E–01	3.3E–05	4.3E–05	NA
copper	ND	3.7E–03	ND	NA
lead	ND	ND	ND	NA
manganese	2.0E–01	1.7E–03	3.2E–02	NA
mercury	6.7E–05	1.6E–04	3.0E–03	NA
molybdenum	ND	2.4E–03	3.6E–03	NA
nickel	ND	4.4E–04	1.3E–04	NA
selenium	ND	1.5E–04	1.1E–04	NA
silver	ND	3.5E–04	ND	NA
thallium	ND	9.6E–03	5.5E–03	NA
vanadium	ND	1.1E–02	1.3E–02	NA
thorium–total	ND	ND	ND	NA
uranium–total	ND	3.6E–02	4.2E–01	NA
fluoride	ND	5.4E–03	9.3E–03	NA
acenaphthylene	ND	ND	ND	NA
2–methylnaphthalene	NA	NA	NA	NA
4–chloro–3–methylphenol	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	NA
dibenzofuran	NA	NA	NA	NA
pentachlorophenol	ND	2.8E–07	5.3E–06	NA
phenanthrene	ND	ND	ND	NA
tributyl phosphate	NA	NA	NA	NA
2–hexanone	ND	2.7E–09	ND	NA
3–chloropropene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	ND	4.1E–06	1.1E–04	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2–nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA
TOTAL:	6.2E–01	9.5E–01	6.1E–01	

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

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TABLE E.IV–19
ILCRs FOR RME ON–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater						Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact[b]	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	External Exposure[a]
Radionuclides																			
Cs_{137+1d}	6.8E−09	1.6E−07	2.9E−07	4.0E−07	8.6E−07	3.7E−06	5.2E−06	8.1E−07	NA	5.4E−04	3.3E−05	4.6E−05	NA	NA	NA	NA	NA	NA	
Np_{237+1d}	8.1E−06	8.3E−07	4.7E−09	1.7E−09	1.4E−06	6.1E−08	2.2E−08	4.7E−06	NA	8.7E−05	NA	NA	1.3E−09	4.1E−10	1.4E−12	5.2E−13	NA	NA	
Pu_{238}	6.3E−07	4.5E−08	1.6E−12	1.3E−12	1.3E−09	1.1E−11	8.4E−12	3.7E−07	NA	4.4E−10	NA	NA	1.4E−06	4.3E−07	7.9E−12	6.5E−12	NA	NA	
$Pu_{239/240}$	2.7E−06	2.1E−07	1.6E−11	1.3E−11	2.6E−09	2.2E−11	1.8E−11	1.7E−06	NA	1.9E−09	NA	NA	NA	NA	NA	NA	NA	NA	
Ra_{226+8d}	1.5E−05	2.4E−05	9.9E−07	7.1E−06	2.1E−06	6.3E−07	4.5E−06	1.0E−04	NA	7.6E−03	6.3E−08	4.6E−07	6.8E−05	2.3E−05	4.3E−07	3.2E−06	NA	NA	
Ru_{106}	9.2E−09	2.5E−09	2.5E−10	3.1E−13	NA	NA	NA	2.0E−07	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	6.5E−09	6.1E−08	3.7E−09	7.3E−08	1.7E−05	3.7E−06	7.4E−05	5.1E−07	NA	ND	6.7E−07	1.4E−05	8.3E−09	3.3E−09	1.2E−10	2.4E−09	NA	NA	
Tc_{99}	8.6E−08	1.8E−07	1.1E−07	5.0E−07	1.4E−05	5.4E−05	2.5E−04	1.2E−06	NA	5.3E−09	1.3E−05	6.1E−05	1.1E−06	3.3E−07	1.3E−07	6.3E−07	NA	NA	
Th_{230}	1.6E−03	9.5E−06	1.1E−08	3.8E−08	2.1E−07	1.1E−08	3.8E−08	5.6E−05	NA	2.2E−06	1.0E−11	3.4E−11	6.6E−07	2.0E−07	5.2E−11	1.8E−10	NA	NA	
$Th_{232+10d}$	2.0E−04	4.0E−06	4.8E−09	1.6E−08	1.0E−07	5.6E−09	1.9E−08	2.6E−05	NA	1.2E−02	2.6E−09	9.0E−09	NA	NA	NA	NA	NA	NA	
U_{234}	3.3E−04	2.6E−06	2.9E−08	3.5E−07	9.6E−06	6.4E−07	7.7E−06	1.9E−05	NA	3.4E−07	1.3E−06	1.6E−05	1.8E−03	5.4E−04	4.0E−06	4.9E−05	NA	NA	
U_{235+1D}	8.7E−05	7.1E−07	7.9E−09	9.4E−08	1.5E−06	1.0E−07	1.2E−06	3.1E−06	NA	4.3E−04	7.2E−08	8.9E−07	4.1E−04	1.2E−04	9.1E−07	1.1E−05	NA	NA	
U_{238+2d}	2.4E−03	1.6E−05	1.8E−07	2.2E−06	1.1E−04	7.5E−06	9.0E−05	1.4E−04	NA	1.6E−03	5.4E−06	6.6E−05	1.5E−02	4.5E−03	3.3E−05	4.1E−04	NA	NA	
Rn_{222+4d}	3.3E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Total Radionuclides	4.7E−03	5.9E−05	1.6E−06	1.1E−05	1.6E−04	7.0E−05	4.4E−04	3.5E−04		2.3E−02	5.3E−05	2.0E−04	1.7E−02	5.1E−03	3.8E−05	4.7E−04			1.2E−03
Chemicals																			
arsenic	1.5E−03	2.5E−03	6.3E−04	7.5E−05	6.2E−05	7.4E−05	8.8E−06	8.1E−03	2.7E−04	NA	5.5E−06	6.6E−07	2.8E−02	9.9E−03	1.4E−03	1.7E−04	ND	8.4E−05	NA
beryllium	5.4E−07	4.2E−06	8.1E−07	2.9E−09	3.6E−06	3.4E−06	1.2E−08	3.0E−05	9.5E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	6.9E−07	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	ND	ND	ND	ND	ND	ND	NA
chromium vi	2.7E−05	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	NA
nickel	1.1E−06	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
pcbs	ND	8.4E−06	2.4E−05	3.1E−05	9.8E−05	3.4E−04	4.3E−04	3.2E−05	4.1E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	6.3E−10	1.0E−08	5.6E−09	7.2E−09	1.1E−06	1.2E−06	1.5E−06	1.9E−07	1.9E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	4.7E−09	7.4E−08	9.8E−08	1.2E−07	3.0E−06	8.8E−06	1.1E−05	9.1E−07	9.1E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	9.5E−10	1.4E−08	7.4E−08	9.4E−08	1.9E−07	3.3E−06	4.2E−06	1.4E−07	1.4E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	4.0E−12	6.2E−11	6.4E−10	8.1E−10	1.0E−08	4.3E−07	5.4E−07	7.4E−09	7.4E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	2.6E−11	4.2E−10	2.4E−10	3.1E−10	4.5E−08	4.7E−08	5.9E−08	7.6E−09	7.6E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	2.1E−10	3.2E−09	2.0E−07	2.5E−07	NA	NA	NA	1.1E−08	1.1E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	ND	1.3E−07	3.9E−12	4.9E−12	NA	NA	NA	3.7E−07	3.9E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	5.5E−09	7.7E−10	9.8E−10	NA	NA	NA	1.8E−08	1.9E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	3.2E−06	6.1E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	1.9E−09	2.3E−08	2.3E−07	3.3E−07	NA	NA	NA	7.6E−07	1.5E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	5.5E−06	1.1E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	6.7E−09	7.9E−08	8.0E−07	1.1E−06	NA	NA	NA	2.7E−06	5.2E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	8.4E−10	9.9E−09	6.3E−09	9.0E−09	NA	NA	NA	3.3E−07	6.4E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	7.7E−09	9.1E−08	9.2E−07	1.3E−06	NA	NA	NA	3.1E−06	5.9E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	4.4E−10	5.2E−09	3.3E−09	4.7E−09	NA	NA	NA	1.7E−07	3.3E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6E−12	2.2E−12	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	6.1E−11	3.4E−08	1.7E−11	2.2E−11	NA	NA	NA	3.9E−08	5.5E−07	NA	7.1E−11	9.2E−11	9.0E−13	5.0E−13	1.5E−16	1.9E−16	1.3E−13	7.2E−13	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.0E−10	4.0E−10	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.2E−13	5.0E−13	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	1.5E−03	2.5E−03	6.6E−04	1.1E−04	1.7E−04	4.3E−04	4.5E−04	8.2E−03	1.3E−03		5.5E−06	6.6E−07	2.8E−02	9.9E−03	1.4E−03	1.7E−04	1.3E−13	8.4E−05	
Sum Chem (BaP for PAHs):	1.5E−03	2.5E−03	6.6E−04	1.1E−04	1.9E−04	4.8E−04	5.2E−04	8.2E−03	1.3E−03		5.5E−06	6.6E−07	2.8E−02	9.9E−03	1.4E−03	1.7E−04	1.3E−13	8.4E−05	
TOTAL ALL (TEF Approach):	6.2E−03	2.6E−03	6.6E−04	1.2E−04	3.3E−04	5.0E−04	8.9E−04	8.5E−03	1.3E−03	2.3E−02	5.8E−05	2.1E−04	4.5E−02	1.5E−02	1.4E−03	6.4E−04	1.3E−13	8.4E−05	1.2E−03
TOTAL ALL (BaP Approach):	6.2E−03	2.6E−03	6.6E−04	1.2E−04	3.5E−04	5.5E−04	9.5E−04	8.6E−03	1.3E−03	2.3E−02	5.8E−05	2.1E−04	4.5E−02	1.5E−02	1.4E−03	6.4E−04	1.3E−13	8.4E−05	1.2E−03

Notes:

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources.
[b] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV–20
HAZARD QUOTIENTS FOR RME ON–PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants																		
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E−07	1.3E−07	5.8E−06	2.8E−06	5.7E−12	7.3E−12	ND	ND
antimony	ND	1.2E−02	3.4E−03	1.4E−03	1.5E+00	7.5E−01	3.0E−01	2.0E−01	4.2E−01	NA	2.0E−02	8.0E−03	1.2E+01	7.9E+00	1.2E+00	4.7E−01	ND	2.3E−01
arsenic	ND	4.7E+00	1.2E+00	1.4E−01	1.2E−01	1.4E−01	1.7E−02	1.5E+01	5.2E−01	NA	1.0E−02	1.3E−03	5.3E+01	1.9E+01	2.6E+00	3.2E−01	ND	1.6E−01
barium	5.0E−01	3.5E−02	2.6E−03	2.5E−02	NA	NA	NA	9.3E−02	3.3E−02	NA	9.7E−04	9.1E−03	2.5E−01	2.4E−01	9.2E−03	8.6E−02	ND	8.0E−04
beryllium	ND	1.9E−04	3.8E−05	1.4E−07	1.7E−04	1.6E−04	5.7E−07	1.4E−03	4.4E−02	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.1E−02	1.9E−02	8.0E−04	6.1E−03	ND	1.8E−03
cadmium	ND	1.5E−02	2.0E−03	1.4E−02	6.3E−01	9.3E−02	6.7E−01	2.0E−02	1.3E−01	NA	NA	NA	1.7E−11	6.6E−11	4.5E−12	3.3E−11	ND	9.9E−13
chromium vi	ND	2.6E−03	2.0E−03	2.2E−03	NA	NA	NA	1.8E−02	1.2E−01	NA	NA	NA	NA	NA	NA	NA	NA	NA
cobalt	4.8E−01	4.4E−05	1.2E−04	4.8E−05	NA	NA	NA	6.0E−04	4.3E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA
copper	ND	5.4E−02	5.7E−02	3.4E−02	NA	NA	NA	6.6E−02	ND	NA	1.2E−02	7.1E−03	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND
manganese	4.8E−01	1.1E−02	9.6E−04	3.3E−03	NA	NA	NA	3.0E−02	3.2E−01	NA	3.3E−05	1.1E−04	4.1E−01	3.0E−01	1.4E−02	5.1E−02	ND	3.9E−02
mercury	1.6E−04	7.2E−04	2.0E−02	1.4E−04	NA	NA	NA	2.9E−03	3.0E−02	NA	NA	NA	3.3E−02	1.3E−02	2.2E−01	1.6E−03	ND	6.3E−04
molybdenum	ND	1.1E−02	1.0E−02	1.0E−02	NA	NA	NA	4.3E−02	3.6E−02	NA	NA	NA	9.3E−02	5.2E−02	2.8E−02	2.8E−02	ND	7.0E−04
nickel	ND	4.9E−03	2.3E−03	1.5E−03	NA	NA	NA	7.8E−03	1.3E−03	NA	8.1E−03	5.4E−03	NA	NA	NA	NA	NA	NA
selenium	ND	1.9E−03	2.4E−03	2.6E−03	NA	NA	NA	2.8E−03	1.1E−03	NA	6.5E−03	7.0E−03	NA	NA	NA	NA	NA	NA
silver	ND	1.5E−03	9.8E−04	2.6E−02	NA	NA	NA	6.3E−03	ND	NA	7.3E−03	2.0E−01	NA	NA	NA	NA	NA	NA
thallium	ND	3.1E−02	2.2E−01	4.3E−02	2.9E−03	2.9E−01	5.8E−02	1.7E−01	5.5E−02	NA	NA	NA	NA	NA	NA	NA	NA	NA
vanadium	ND	3.8E−02	1.3E−02	4.0E−04	NA	NA	NA	2.0E−01	1.3E−01	NA	2.7E−02	9.0E−04	NA	NA	NA	NA	NA	NA
thorium−total	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium−total	ND	1.4E−01	1.6E−03	1.9E−02	3.9E−01	2.6E−02	3.1E−01	6.6E−01	4.2E+00	NA	NA	NA	2.9E+02	8.3E+01	6.5E−01	8.0E+00	ND	1.7E+01
fluoride	ND	1.3E−03	ND	ND	NA	NA	NA	9.7E−02	9.3E−02	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4−chloro−3−methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.5E−06	2.1E−07	2.7E−07	NA	NA	NA	5.0E−06	5.3E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−hexanone	ND	2.1E−08	7.4E−13	9.3E−13	NA	NA	NA	4.9E−08	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
3−chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E−08	3.6E−08	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	6.5E−05	3.3E−08	4.3E−08	NA	NA	NA	7.4E−05	1.1E−03	NA	1.4E−07	1.8E−07	1.7E−09	9.7E−10	2.9E−13	3.7E−13	ND	1.4E−09
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.8E−10	1.1E−09	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.3E−08	3.2E−08	NA	NA	NA	NA	NA	NA
2−nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
TOTAL:	1.5E+00	5.1E+00	1.5E+00	3.3E−01	2.6E+00	1.3E+00	1.4E+00	1.7E+01	6.1E+00		9.3E−02	2.4E−01	3.6E+02	1.2E+02	4.7E+00	9.0E+00	0.0E+00	1.7E+01

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–21
ILCRs FOR RME ON–PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater						Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact[b]	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	External Exposure[a]
Radionuclides																			
Cs_{137+1d}	1.2E−10	1.2E−08	9.5E−09	7.8E−08	6.4E−08	1.2E−07	1.0E−06	7.7E−08	NA	4.1E−05	1.1E−06	9.0E−06	NA	NA	NA	NA	NA	NA	
Np_{237+1d}	1.5E−07	6.2E−08	1.5E−10	3.3E−10	1.0E−07	2.0E−09	4.3E−09	4.5E−07	NA	6.5E−06	NA	NA	5.4E−11	3.0E−11	4.7E−14	1.0E−13	NA	NA	
Pu_{238}	1.1E−08	3.4E−09	5.4E−14	2.5E−13	9.4E−11	3.5E−13	1.6E−12	3.5E−08	NA	3.3E−11	NA	NA	6.1E−08	3.2E−08	2.6E−13	1.3E−12	NA	NA	
$Pu_{239/240}$	4.9E−08	1.6E−08	5.4E−13	2.5E−12	2.0E−10	7.3E−13	3.4E−12	1.6E−07	NA	1.4E−10	NA	NA	NA	NA	NA	NA	NA	NA	
Ra_{226+8d}	2.8E−07	1.8E−06	3.3E−08	1.4E−06	1.6E−07	2.1E−08	8.8E−07	1.0E−05	NA	5.7E−04	2.1E−09	9.0E−08	2.9E−06	1.7E−06	1.4E−08	6.1E−07	NA	NA	
Ru_{106}	1.7E−10	1.8E−10	8.1E−12	5.9E−14	NA	NA	NA	1.9E−08	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	1.2E−10	4.5E−09	1.2E−10	1.4E−08	1.3E−06	1.2E−07	1.4E−05	4.9E−08	NA	ND	2.2E−08	2.6E−06	3.5E−10	2.5E−10	4.0E−12	4.7E−10	NA	NA	
Tc_{99}	1.6E−09	1.3E−08	3.5E−09	9.8E−08	1.0E−06	1.8E−06	4.9E−05	1.2E−07	NA	4.0E−10	4.2E−07	1.2E−05	4.5E−08	2.5E−08	4.4E−09	1.2E−07	NA	NA	
Th_{230}	3.0E−05	7.1E−07	3.7E−10	7.3E−09	1.5E−08	3.8E−10	7.4E−09	5.3E−06	NA	1.6E−07	3.3E−13	6.7E−12	2.8E−08	1.5E−08	1.7E−12	3.5E−11	NA	NA	
$Th_{232+10d}$	3.7E−06	3.0E−07	1.6E−10	3.1E−09	7.6E−09	1.9E−10	3.6E−09	2.5E−06	NA	9.4E−04	8.7E−11	1.8E−09	NA	NA	NA	NA	NA	NA	
U_{234}	6.0E−06	1.9E−07	9.5E−10	6.7E−08	7.2E−07	2.1E−08	1.5E−06	1.8E−06	NA	2.6E−08	4.2E−08	3.0E−06	7.7E−05	4.0E−05	1.3E−07	9.6E−06	NA	NA	
U_{235+1D}	1.6E−06	5.3E−08	2.6E−10	1.8E−08	1.1E−07	3.4E−09	2.4E−07	2.9E−07	NA	3.2E−05	2.4E−09	1.7E−07	1.8E−05	9.2E−06	3.0E−08	2.2E−06	NA	NA	
U_{238+2d}	4.4E−05	1.2E−06	6.1E−09	4.3E−07	8.4E−06	2.5E−07	1.7E−05	1.3E−05	NA	1.2E−04	1.8E−07	1.3E−05	6.4E−04	3.3E−04	1.1E−06	7.9E−05	NA	NA	
Rn_{222+4d}	6.0E−11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Total Radionuclides	8.5E−05	4.4E−06	5.4E−08	2.1E−06	1.2E−05	2.3E−06	8.5E−05	3.4E−05		1.7E−03	1.7E−06	4.0E−05	7.3E−04	3.8E−04	1.3E−06	9.2E−05			2.5E−07
Chemicals																			
arsenic	1.2E−04	8.6E−04	9.7E−05	6.8E−05	2.1E−05	1.1E−05	8.0E−06	3.6E−03	3.8E−05	NA	8.4E−07	6.0E−07	5.6E−03	3.5E−03	2.1E−04	1.5E−04	ND	1.2E−05	NA
beryllium	4.6E−08	1.4E−06	1.3E−07	2.6E−09	1.2E−06	5.3E−07	1.1E−08	1.3E−05	1.3E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	5.9E−08	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	ND	ND	ND	ND	ND	ND	NA
chromium vi	2.3E−06	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	NA
nickel	9.7E−08	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
pcbs	ND	2.9E−06	3.8E−06	2.8E−05	3.4E−05	5.2E−05	3.9E−04	1.4E−05	5.7E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	5.3E−11	3.5E−09	8.7E−10	6.5E−09	4.0E−07	1.8E−07	1.4E−06	8.3E−08	8.3E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	4.0E−10	2.6E−08	1.5E−08	1.1E−07	1.0E−06	1.4E−06	1.0E−05	4.0E−07	4.0E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	8.0E−11	5.0E−09	1.1E−08	8.5E−08	6.6E−08	5.1E−07	3.8E−06	6.3E−08	6.3E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	3.3E−13	2.1E−11	9.9E−11	7.3E−10	3.6E−09	6.6E−08	4.9E−07	3.3E−09	3.3E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	2.2E−12	1.5E−10	3.8E−11	2.8E−10	1.6E−08	7.2E−09	5.4E−08	3.4E−09	3.4E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	1.8E−11	1.1E−09	3.1E−08	2.3E−07	NA	NA	NA	4.8E−09	4.8E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	ND	4.6E−08	6.0E−13	4.4E−12	NA	NA	NA	1.6E−07	5.5E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.9E−09	1.2E−10	8.9E−10	NA	NA	NA	7.9E−09	2.6E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	1.4E−06	8.4E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	1.6E−10	8.0E−09	3.6E−08	3.0E−07	NA	NA	NA	3.4E−07	2.0E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	2.5E−06	1.5E−06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	5.7E−10	2.8E−08	1.2E−07	1.0E−06	NA	NA	NA	1.2E−06	7.2E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	7.1E−11	3.4E−09	9.8E−10	8.2E−09	NA	NA	NA	1.5E−07	8.9E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	6.5E−10	3.2E−08	1.4E−07	1.2E−06	NA	NA	NA	1.4E−06	8.2E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	3.7E−11	1.8E−09	5.1E−10	4.3E−09	NA	NA	NA	7.7E−08	4.6E−08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.4E−13	2.0E−12	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	5.2E−12	1.2E−08	2.7E−12	2.0E−11	NA	NA	NA	1.7E−08	7.6E−08	NA	1.1E−11	8.4E−11	1.8E−13	1.7E−13	2.3E−17	1.8E−16	5.2E−14	1.0E−13	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.7E−11	3.6E−10	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.4E−14	4.5E−13	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	1.3E−04	8.7E−04	1.0E−04	9.9E−05	5.8E−05	6.6E−05	4.1E−04	3.6E−03	1.8E−04		8.4E−07	6.0E−07	5.6E−03	3.5E−03	2.1E−04	1.5E−04	5.2E−14	1.2E−05	
Sum Chem (BaP for PAHs):	1.3E−04	8.7E−04	1.0E−04	1.0E−04	6.5E−05	7.4E−05	4.7E−04	3.6E−03	1.8E−04		8.4E−07	6.0E−07	5.6E−03	3.5E−03	2.1E−04	1.5E−04	5.2E−14	1.2E−05	
TOTAL ALL (TEF Approach)	2.1E−04	8.7E−04	1.0E−04	1.0E−04	7.0E−05	6.9E−05	5.0E−04	3.7E−03	1.8E−04	1.7E−03	2.6E−06	4.0E−05	6.3E−03	3.8E−03	2.1E−04	2.4E−04	5.2E−14	1.2E−05	2.5E−07
TOTAL ALL (BaP Approach)	2.1E−04	8.7E−04	1.0E−04	1.0E−04	7.6E−05	7.6E−05	5.5E−04	3.7E−03	1.8E−04	1.7E−03	2.6E−06	4.0E−05	6.3E−03	3.8E−03	2.1E−04	2.4E−04	5.2E−14	1.2E−05	2.5E−07

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources in pit 4.
[b] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV–22
HAZARD QUOTIENTS FOR RME ON–PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater					
Exposure Pathways / Toxicants	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.8E−07	1.4E−06	1.3E−05	1.1E−05	1.0E−11	7.8E−11	ND	ND
antimony	ND	5.1E−02	6.2E−03	1.4E−02	6.1E+00	1.4E+00	3.2E+00	1.0E+00	6.9E−01	NA	3.6E−02	8.5E−02	2.8E+01	3.2E+01	2.1E+00	4.9E+00	ND	3.7E−01
arsenic	ND	1.9E+01	2.2E+00	1.5E+00	4.8E−01	2.5E−01	1.8E−01	8.0E+01	8.4E−01	NA	1.9E−02	1.3E−02	1.2E+02	7.7E+01	4.7E+00	3.4E+00	ND	2.6E−01
barium	4.9E−01	1.4E−01	4.8E−03	2.6E−01	NA	NA	NA	4.8E−01	5.3E−02	NA	1.8E−03	9.6E−02	5.9E−01	9.7E−01	1.7E−02	9.1E−01	ND	1.3E−03
beryllium	ND	7.9E−04	6.8E−05	1.4E−06	6.7E−04	2.9E−04	6.0E−06	7.1E−03	7.1E−02	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.2E−02	7.5E−02	1.5E−03	6.5E−02	ND	2.9E−03
cadmium	ND	5.9E−02	3.6E−03	1.5E−01	2.5E+00	1.7E−01	7.1E+00	1.0E−01	2.0E−01	NA	NA	NA	4.0E−11	2.7E−10	8.2E−12	3.5E−10	ND	1.6E−12
chromium vi	ND	1.1E−02	3.6E−03	2.3E−02	NA	NA	NA	9.4E−02	1.9E−01	NA	NA	NA	NA	NA	NA	NA	NA	NA
cobalt	4.7E−01	1.8E−04	2.2E−04	5.1E−04	NA	NA	NA	3.1E−03	6.9E−04	NA	NA	NA	NA	NA	NA	NA	NA	NA
copper	ND	2.2E−01	1.0E−01	3.6E−01	NA	NA	NA	3.4E−01	ND	NA	2.1E−02	7.6E−02	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND
manganese	4.7E−01	4.3E−02	1.7E−03	3.5E−02	NA	NA	NA	1.6E−01	5.3E−01	NA	5.9E−05	1.2E−03	9.5E−01	1.2E+00	2.6E−02	5.3E−01	ND	6.3E−02
mercury	1.6E−04	2.9E−03	3.6E−02	1.5E−03	NA	NA	NA	1.5E−02	4.9E−02	NA	NA	NA	7.6E−02	5.3E−02	3.9E−01	1.7E−02	ND	1.0E−03
molybdenum	ND	4.4E−02	1.9E−02	1.1E−01	NA	NA	NA	2.2E−01	5.9E−02	NA	NA	NA	2.2E−01	2.1E−01	5.0E−02	3.0E−01	ND	1.1E−03
nickel	ND	2.0E−02	4.1E−03	1.6E−02	NA	NA	NA	4.1E−02	2.0E−03	NA	1.5E−02	5.7E−02	NA	NA	NA	NA	NA	NA
selenium	ND	7.7E−03	4.4E−03	2.8E−02	NA	NA	NA	1.4E−02	1.8E−03	NA	1.2E−02	7.4E−02	NA	NA	NA	NA	NA	NA
silver	ND	5.9E−03	1.8E−03	2.8E−01	NA	NA	NA	3.3E−02	ND	NA	1.3E−02	2.1E+00	NA	NA	NA	NA	NA	NA
thallium	ND	1.2E−01	3.9E−01	4.6E−01	1.2E−02	5.2E−01	6.1E−01	9.0E−01	9.0E−02	NA	NA	NA	NA	NA	NA	NA	NA	NA
vanadium	ND	1.6E−01	2.3E−02	4.2E−03	NA	NA	NA	1.0E+00	2.1E−01	NA	4.9E−02	9.5E−03	NA	NA	NA	NA	NA	NA
thorium−total	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium−total	ND	5.7E−01	2.8E−03	2.0E−01	1.6E+00	4.7E−02	3.3E+00	3.4E+00	6.8E+00	NA	NA	NA	6.8E+02	3.6E+02	1.2E+00	8.5E+01	ND	2.7E+01
fluoride	ND	5.3E−03	ND	ND	NA	NA	NA	5.0E−01	1.5E−01	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4−chloro−3−methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	6.2E−06	3.9E−07	2.9E−06	NA	NA	NA	2.6E−05	8.6E−05	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2−hexanone	ND	8.3E−08	1.3E−12	9.9E−12	NA	NA	NA	2.5E−07	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
3−chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.7E−08	3.9E−07	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	2.6E−04	6.0E−08	4.5E−07	NA	NA	NA	3.9E−04	1.7E−03	NA	2.5E−07	1.9E−06	4.0E−09	3.9E−09	5.2E−13	3.9E−12	ND	2.3E−09
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.7E−10	1.2E−08	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.1E−08	3.4E−07	NA	NA	NA	NA	NA	NA
2−nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
TOTAL:	1.4E+00	2.1E+01	2.8E+00	3.5E+00	1.1E+01	2.3E+00	1.4E+01	8.9E+01	9.9E+00		1.7E−01	2.5E+00	8.4E+02	4.7E+02	8.5E+00	9.5E+01	0.0E+00	2.8E+01

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV-23
ILCRs FOR CT ON-PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater						Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact[b]	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing	External Exposure[a]
Radionuclides																			
Cs_{137+1d}	5.1E-10	1.0E-08	1.9E-08	2.2E-08	5.5E-08	2.5E-07	2.8E-07	5.5E-08	NA	5.2E-05	2.2E-06	2.5E-06	NA	NA	NA	NA	NA	NA	
Np_{237+1d}	6.0E-07	5.3E-08	3.1E-10	9.1E-11	9.1E-08	4.1E-09	1.2E-09	3.2E-07	NA	8.4E-06	NA	NA	8.8E-11	2.6E-11	9.5E-14	2.8E-14	NA	NA	
Pu_{238}	4.7E-08	2.9E-09	1.1E-13	7.0E-14	8.2E-11	7.1E-13	4.6E-13	2.5E-08	NA	4.2E-11	NA	NA	1.0E-07	2.8E-08	5.3E-13	3.5E-13	NA	NA	
$Pu_{239/240}$	2.0E-07	1.4E-08	1.1E-12	7.1E-13	1.7E-10	1.5E-12	9.5E-13	1.2E-07	NA	1.8E-10	NA	NA	NA	NA	NA	NA	NA	NA	
Ra_{226+8d}	1.1E-06	1.6E-06	6.7E-08	3.9E-07	1.4E-07	4.2E-08	2.4E-07	7.2E-06	NA	7.3E-04	4.2E-09	2.5E-08	4.8E-06	1.5E-06	2.9E-08	1.7E-07	NA	NA	
Ru_{106}	6.8E-10	1.6E-10	1.7E-11	1.6E-14	NA	NA	NA	1.4E-08	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	4.8E-10	3.9E-09	2.5E-10	4.0E-09	1.1E-06	2.5E-07	4.0E-06	3.5E-08	NA	ND	4.5E-08	7.3E-07	5.9E-10	2.2E-10	8.1E-12	1.3E-10	NA	NA	
Tc_{99}	6.4E-09	1.1E-08	7.2E-09	2.7E-08	9.0E-07	3.6E-06	1.4E-05	8.4E-08	NA	5.1E-10	8.5E-07	3.3E-06	7.4E-08	2.1E-08	8.8E-09	3.4E-08	NA	NA	
Th_{230}	1.2E-04	6.1E-07	7.6E-10	2.0E-09	1.3E-08	7.6E-10	2.0E-09	3.8E-06	NA	2.1E-07	6.7E-13	1.8E-12	4.7E-08	1.3E-08	3.5E-12	9.6E-12	NA	NA	
$Th_{232+10d}$	1.5E-05	2.6E-07	3.3E-10	8.7E-10	6.6E-09	3.8E-10	1.0E-09	1.8E-06	NA	1.2E-03	1.8E-10	4.9E-10	NA	NA	NA	NA	NA	NA	
U_{234}	2.5E-05	1.7E-07	1.9E-09	1.9E-08	6.2E-07	4.3E-08	4.1E-07	1.3E-06	NA	3.3E-08	8.4E-08	8.4E-07	1.3E-04	3.5E-05	2.7E-07	2.7E-06	NA	NA	
U_{235+1D}	6.5E-06	4.6E-08	5.3E-10	5.1E-09	9.9E-08	6.8E-09	6.6E-08	2.1E-07	NA	4.1E-05	4.8E-09	4.8E-08	2.9E-05	8.0E-06	6.1E-08	6.1E-07	NA	NA	
U_{238+2d}	1.8E-04	1.1E-06	1.2E-08	1.2E-07	7.3E-06	5.1E-07	4.8E-06	9.3E-06	NA	1.6E-04	3.6E-07	3.6E-06	1.0E-03	2.9E-04	2.2E-06	2.2E-05	NA	NA	
Rn_{222+4d}	2.5E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Total Radionuclides	3.5E-04	3.8E-06	1.1E-07	5.8E-07	1.0E-05	4.7E-06	2.4E-05	2.4E-05		2.2E-03	3.5E-06	1.1E-05	1.2E-03	3.3E-04	2.6E-06	2.5E-05			1.6E-04
Chemicals																			
arsenic	1.1E-04	1.6E-04	4.2E-05	4.1E-06	4.0E-06	5.0E-06	4.8E-07	5.6E-04	4.8E-06	NA	3.7E-07	3.6E-08	2.0E-03	6.4E-04	9.3E-05	9.1E-06	ND	5.0E-06	NA
beryllium	4.1E-08	2.7E-07	5.4E-08	1.6E-10	2.3E-07	2.3E-07	6.6E-10	2.0E-06	1.7E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cadmium	5.2E-08	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	ND	ND	ND	ND	ND	ND	NA
chromium vi	2.0E-06	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	NA
nickel	8.5E-08	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA
pcbs	ND	5.4E-07	1.6E-06	1.7E-06	6.3E-06	2.3E-05	2.3E-05	2.2E-06	7.2E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	4.7E-11	6.5E-10	3.8E-10	3.9E-10	7.4E-08	8.0E-08	8.1E-08	1.3E-08	1.3E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	3.5E-10	4.8E-09	6.6E-09	6.7E-09	1.9E-07	5.9E-07	6.0E-07	6.2E-08	6.2E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	7.1E-11	9.3E-10	5.0E-09	5.1E-09	1.2E-08	2.2E-07	2.3E-07	9.7E-09	9.7E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	2.9E-13	4.0E-12	4.3E-11	4.3E-11	6.7E-10	2.9E-08	2.9E-08	5.1E-10	5.1E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chrysene	1.9E-12	2.7E-11	1.6E-11	1.7E-11	2.9E-09	3.2E-09	3.2E-09	5.2E-10	5.2E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	1.6E-11	2.0E-10	1.3E-08	1.4E-08	NA	NA	NA	7.4E-10	7.4E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	ND	8.5E-09	2.6E-13	2.6E-13	NA	NA	NA	2.5E-08	6.9E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	3.6E-10	5.2E-11	5.3E-11	NA	NA	NA	1.2E-09	3.3E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	2.2E-07	1.1E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	1.4E-10	1.5E-09	1.6E-08	1.8E-08	NA	NA	NA	5.2E-08	2.6E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	3.8E-07	1.9E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	5.0E-10	5.1E-09	5.4E-08	6.2E-08	NA	NA	NA	1.8E-07	9.1E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	6.2E-11	6.4E-10	4.3E-10	4.9E-10	NA	NA	NA	2.3E-08	1.1E-08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	5.7E-10	5.9E-09	6.2E-08	7.1E-08	NA	NA	NA	2.1E-07	1.0E-07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	3.3E-11	3.3E-10	2.2E-10	2.5E-10	NA	NA	NA	1.2E-08	5.9E-09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.1E-13	1.2E-13	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	4.5E-12	2.2E-09	1.2E-12	1.2E-12	NA	NA	NA	2.7E-09	9.7E-09	NA	4.8E-12	5.0E-12	6.4E-14	3.2E-14	1.0E-17	1.0E-17	1.3E-14	5.2E-14	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.0E-11	2.2E-11	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.5E-14	2.7E-14	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	1.1E-04	1.6E-04	4.4E-05	5.9E-06	1.1E-05	2.9E-05	2.4E-05	5.6E-04	2.3E-05		3.7E-07	3.6E-08	2.0E-03	6.4E-04	9.3E-05	9.1E-06	1.3E-14	5.0E-06	
Sum Chem (BaP for PAHs):	1.1E-04	1.6E-04	4.4E-05	6.0E-06	1.2E-05	3.2E-05	2.8E-05	5.6E-04	2.3E-05		3.7E-07	3.6E-08	2.0E-03	6.4E-04	9.3E-05	9.1E-06	1.3E-14	5.0E-06	
TOTAL ALL (TEF Approach):	4.6E-04	1.6E-04	4.4E-05	6.5E-06	2.1E-05	3.4E-05	4.8E-05	5.9E-04	2.3E-05	2.2E-03	3.9E-06	1.1E-05	3.2E-03	9.7E-04	9.5E-05	3.4E-05	1.3E-14	5.0E-06	1.6E-04
TOTAL ALL (BaP Approach):	4.6E-04	1.6E-04	4.4E-05	6.6E-06	2.2E-05	3.7E-05	5.1E-05	5.9E-04	2.3E-05	2.2E-03	3.9E-06	1.1E-05	3.2E-03	9.7E-04	9.5E-05	3.4E-05	1.3E-14	5.0E-06	1.6E-04

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources in pit 4.
[b] Risk from dermal contact to PAH's is assumed to equal risk from oral ingestion of PAH's.

TABLE E.IV-24
HAZARD QUOTIENTS FOR CT ON-PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Groundwater					
Exposure Pathways / Toxicants	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.4E-08	5.5E-08	3.2E-06	1.4E-06	3.0E-12	3.1E-12	NA	ND
antimony	ND	6.3E-03	1.8E-03	5.7E-04	7.5E-01	3.9E-01	1.3E-01	1.1E-01	5.8E-02	NA	1.0E-02	3.4E-03	6.6E+00	4.0E+00	6.1E-01	2.0E-01	NA	1.1E-01
arsenic	ND	2.4E+00	6.3E-01	6.0E-02	5.9E-02	7.4E-02	7.1E-03	8.2E+00	7.1E-02	NA	5.4E-03	5.3E-04	2.9E+01	9.5E+00	1.4E+00	1.3E-01	NA	7.5E-02
barium	2.9E-01	1.8E-02	1.4E-03	1.0E-02	NA	NA	NA	5.0E-02	4.5E-03	NA	5.1E-04	3.8E-03	1.4E-01	1.2E-01	4.8E-03	3.6E-02	NA	3.7E-04
beryllium	ND	9.7E-05	2.0E-05	5.7E-08	8.3E-05	8.3E-05	2.4E-07	7.3E-04	6.0E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.7E-02	9.3E-03	4.2E-04	2.6E-03	NA	8.3E-04
cadmium	ND	7.3E-03	1.0E-03	6.1E-03	3.2E-01	4.9E-02	2.8E-01	1.0E-02	1.7E-02	NA	NA	NA	9.5E-12	3.3E-11	2.4E-12	1.4E-11	NA	4.6E-13
chromium vi	ND	1.3E-03	1.0E-03	9.0E-04	NA	NA	NA	9.6E-03	1.6E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
cobalt	2.8E-01	2.2E-05	6.3E-05	2.0E-05	NA	NA	NA	3.2E-04	5.8E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
copper	ND	2.7E-02	3.0E-02	1.4E-02	NA	NA	NA	3.5E-02	ND	NA	6.2E-03	3.0E-03	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	NA	ND
manganese	2.8E-01	5.3E-03	5.0E-04	1.4E-03	NA	NA	NA	1.6E-02	4.4E-02	NA	1.7E-05	4.8E-05	2.2E-01	1.5E-01	7.5E-03	2.1E-02	NA	1.8E-02
mercury	9.2E-05	3.6E-04	1.0E-02	6.0E-05	NA	NA	NA	1.5E-03	4.2E-03	NA	NA	NA	1.8E-02	6.5E-03	1.1E-01	6.7E-04	NA	2.9E-04
molybdenum	ND	5.4E-03	5.4E-03	4.3E-03	NA	NA	NA	2.3E-02	4.9E-03	NA	NA	NA	5.1E-02	2.6E-02	1.5E-02	1.2E-02	NA	3.3E-04
nickel	ND	2.4E-03	1.2E-03	6.4E-04	NA	NA	NA	4.2E-03	1.7E-04	NA	4.2E-03	2.3E-03	NA	NA	NA	NA	NA	NA
selenium	ND	9.6E-04	1.3E-03	1.1E-03	NA	NA	NA	1.5E-03	1.5E-04	NA	3.4E-03	2.9E-03	NA	NA	NA	NA	NA	NA
silver	ND	7.4E-04	5.1E-04	1.1E-02	NA	NA	NA	3.4E-03	ND	NA	3.8E-03	8.2E-02	NA	NA	NA	NA	NA	NA
thallium	ND	1.5E-02	1.1E-01	1.8E-02	1.4E-03	1.5E-01	2.4E-02	9.2E-02	7.5E-03	NA	NA	NA	NA	NA	NA	NA	NA	NA
vanadium	ND	1.9E-02	6.6E-03	1.7E-04	NA	NA	NA	1.1E-01	1.7E-02	NA	1.4E-02	3.8E-04	NA	NA	NA	NA	NA	NA
thorium-total	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium-total	ND	7.0E-02	8.1E-04	7.8E-03	2.0E-01	1.4E-02	1.3E-01	3.5E-01	5.7E-01	NA	NA	NA	1.6E+02	4.4E+01	3.4E-01	3.4E+00	NA	7.8E+00
fluoride	ND	6.6E-04	ND	ND	NA	NA	NA	5.1E-02	1.3E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	7.7E-07	1.1E-07	1.1E-07	NA	NA	NA	2.6E-06	7.2E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	ND	1.0E-08	3.9E-13	3.9E-13	NA	NA	NA	2.6E-08	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.4E-08	1.5E-08	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	3.3E-05	1.7E-08	1.8E-08	NA	NA	NA	4.0E-05	1.4E-04	NA	7.1E-08	7.4E-08	9.5E-10	4.9E-10	1.5E-13	1.6E-13	NA	7.8E-10
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.5E-10	4.6E-10	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.2E-08	1.3E-08	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
TOTAL:	8.4E-01	2.6E+00	8.0E-01	1.4E-01	1.3E+00	6.8E-01	5.7E-01	9.1E+00	8.4E-01		4.8E-02	9.9E-02	2.0E+02	5.8E+01	2.5E+00	3.8E+00	0.0E+00	8.0E+00

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND - No data for toxicity assessment for exposure pathway.

TABLE E.IV–25
ILCRs FOR RME ON–PROPERTY FARMER, USE OF PERCHED GROUNDWATER[a]
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Perched Groundwater[a]			Great Miami Aquifer			Buried Pit Material
Exposure Pathways / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Incidental Ingestion	Dermal Contact[c]	External Exposure	Ingestion of Meat	Ingestion of Milk	Ingestion of Drinking Water	Inhalation of VOC's	Dermal Contact while Bathing[b]	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	External Exposure[b]
Radionuclides																			
Cs_{137+1d}	6.8E−09	1.6E−07	2.9E−07	4.0E−07	8.6E−07	3.7E−06	5.2E−06	8.1E−07	NA	5.4E−04	3.3E−05	4.6E−05	1.2E−06	NA	NA	NA	NA	NA	
Np_{237+1d}	8.1E−06	8.3E−07	4.7E−09	1.7E−09	1.4E−06	6.1E−08	2.2E−08	4.7E−06	NA	8.7E−05	NA	NA	8.1E−05	NA	NA	4.1E−10	1.4E−12	5.2E−13	
Pu_{238}	6.3E−07	4.5E−08	1.6E−12	1.3E−12	1.3E−09	1.1E−11	8.4E−12	3.7E−07	NA	4.4E−10	NA	NA	5.3E−06	NA	NA	4.3E−07	7.9E−12	6.5E−12	
$Pu_{239/240}$	2.7E−06	2.1E−07	1.6E−11	1.3E−11	2.6E−09	2.2E−11	1.8E−11	1.7E−06	NA	1.9E−09	NA	NA	5.6E−07	NA	NA	NA	NA	NA	
Ra_{226+8d}	1.5E−05	2.4E−05	9.9E−07	7.1E−06	2.1E−06	6.3E−07	4.5E−06	1.0E−04	NA	7.6E−03	6.3E−08	4.6E−07	2.8E−03	NA	NA	2.3E−05	4.3E−07	3.2E−06	
Ru_{106}	9.2E−09	2.5E−09	2.5E−10	3.1E−13	NA	NA	NA	2.0E−07	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	
Sr_{90+1d}	6.5E−09	6.1E−08	3.7E−09	7.3E−08	1.7E−05	3.7E−06	7.4E−05	5.1E−07	NA	ND	6.7E−07	1.4E−05	7.1E−05	NA	NA	3.3E−09	1.2E−10	2.4E−09	
Tc_{99}	8.6E−08	1.8E−07	1.1E−07	5.0E−07	1.4E−05	5.4E−05	2.5E−04	1.2E−06	NA	5.3E−09	1.3E−05	6.1E−05	1.7E−04	NA	NA	3.3E−07	1.3E−07	6.3E−07	
Th_{230}	1.6E−03	9.5E−06	1.1E−08	3.8E−08	2.1E−07	1.1E−08	3.8E−08	5.6E−05	NA	2.2E−06	1.0E−11	3.4E−11	1.9E−07	NA	NA	2.0E−07	5.2E−11	1.8E−10	
$Th_{232+10d}$	2.0E−04	4.0E−06	4.8E−09	1.6E−08	1.0E−07	5.6E−09	1.9E−08	2.6E−05	NA	1.2E−02	2.6E−09	9.0E−09	4.2E−07	NA	NA	NA	NA	NA	
U_{234}	3.3E−04	2.6E−06	2.9E−08	3.5E−07	9.6E−06	6.4E−07	7.7E−06	1.9E−05	NA	3.4E−07	1.3E−06	1.6E−05	1.1E−01	NA	NA	5.4E−04	4.0E−06	4.9E−05	
U_{235+1D}	8.7E−05	7.1E−07	7.9E−09	9.4E−08	1.5E−06	1.0E−07	1.2E−06	3.1E−06	NA	4.3E−04	7.2E−08	8.9E−07	2.1E−02	NA	NA	1.2E−04	9.1E−07	1.1E−05	
U_{238+2d}	2.4E−03	1.6E−05	1.8E−07	2.2E−06	1.1E−04	7.5E−06	9.0E−05	1.4E−04	NA	1.6E−03	5.4E−06	6.6E−05	4.4E−01	NA	NA	4.4E−03	3.3E−05	4.1E−04	
Rn_{222+4d}	3.3E−09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Total Radionuclides	4.7E−03	5.9E−05	1.6E−06	1.1E−05	1.6E−04	7.0E−05	4.4E−04	3.5E−04		2.3E−02	5.3E−05	2.0E−04	5.8E−01			5.1E−03	3.8E−05	4.7E−04	1.2E−03
Chemicals																			
arsenic	1.5E−03	2.5E−03	6.3E−04	7.5E−05	6.2E−05	7.4E−05	8.8E−06	8.1E−03	2.7E−04	NA	5.5E−06	6.6E−07	3.0E−02	ND	9.2E−05	9.9E−03	1.4E−03	1.7E−04	NA
beryllium	5.4E−07	4.2E−06	8.1E−07	2.9E−09	3.6E−06	3.4E−06	1.2E−08	3.0E−05	9.5E−04	NA	NA	NA	2.4E−03	ND	6.9E−04	NA	NA	NA	NA
cadmium	6.9E−07	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	ND	ND	ND	ND	ND	ND	NA
chromium vi	2.7E−05	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	ND	ND	ND	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	NA
nickel	1.1E−06	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	NA	NA	NA	NA
pcbs	ND	8.4E−06	2.4E−05	3.1E−05	9.8E−05	3.4E−04	4.3E−04	3.2E−05	4.1E−05	NA	NA	NA	3.1E−02	ND	8.3E−01	NA	NA	NA	NA
benzo(a)anthracene	9.2E−10	1.5E−08	8.2E−09	1.0E−08	1.7E−06	1.7E−06	2.2E−06	2.7E−07	2.7E−07	NA	NA	NA	1.2E−03	ND	1.2E−03	NA	NA	NA	NA
benzo(a)pyrene	4.7E−09	7.4E−08	9.8E−08	1.2E−07	3.0E−06	8.8E−06	1.1E−05	9.1E−07	9.1E−07	NA	NA	NA	8.0E−03	ND	8.0E−03	NA	NA	NA	NA
benzo(b)fluoranthene	1.2E−09	1.8E−08	9.1E−08	1.2E−07	2.3E−07	4.1E−06	5.2E−06	1.7E−07	1.7E−07	NA	NA	NA	9.8E−04	ND	9.8E−04	NA	NA	NA	NA
benzo(k)fluoranthene	2.1E−11	3.2E−10	3.3E−09	4.2E−09	5.4E−08	2.2E−06	2.8E−06	3.9E−08	3.9E−08	NA	NA	NA	4.2E−04	ND	4.2E−04	NA	NA	NA	NA
chrysene	0.0E+00	4.2E−10	2.4E−10	3.1E−10	4.5E−08	4.7E−08	5.9E−08	7.6E−09	7.6E−09	NA	NA	NA	3.5E−05	ND	3.5E−05	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.2E−03	ND	2.2E−03	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	0.0E+00	8.8E−09	5.6E−07	7.1E−07	NA	NA	NA	3.0E−08	3.0E−08	NA	NA	NA	2.2E−03	ND	2.2E−03	NA	NA	NA	NA
n−nitrosodipropylamine	ND	1.3E−07	3.9E−12	4.9E−12	NA	NA	NA	3.7E−07	3.9E−07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	5.5E−09	7.7E−10	9.8E−10	NA	NA	NA	1.8E−08	1.9E−07	NA	NA	NA	6.6E−04	ND	1.4E−02	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.1E−02	3.0E−02	3.1E−03	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	3.2E−06	6.1E−06	NA	NA	NA	2.2E−03	ND	2.4E−01	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.3E−04	ND	5.3E−02	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	1.9E−09	2.3E−08	2.3E−07	3.3E−07	NA	NA	NA	7.6E−07	1.5E−06	NA	NA	NA	3.1E−04	ND	3.8E−02	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	5.5E−06	1.1E−05	NA	NA	NA	4.9E−04	ND	6.1E−02	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	6.7E−09	7.9E−08	8.0E−07	1.1E−06	NA	NA	NA	2.7E−06	5.2E−06	NA	NA	NA	3.9E−05	ND	4.9E−03	NA	NA	NA	NA
heptachlorodibenzofuran	8.4E−10	9.9E−09	6.3E−09	9.0E−09	NA	NA	NA	3.3E−07	6.4E−07	NA	NA	NA	8.2E−05	ND	1.0E−02	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	7.7E−09	9.1E−08	9.2E−07	1.3E−06	NA	NA	NA	3.1E−06	5.9E−06	NA	NA	NA	7.4E−06	ND	9.4E−04	NA	NA	NA	NA
octachlorodibenzofuran	4.4E−10	5.2E−09	3.3E−09	4.7E−09	NA	NA	NA	1.7E−07	3.3E−07	NA	NA	NA	4.5E−06	ND	5.7E−04	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.6E−12	2.2E−12	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	6.1E−11	3.4E−08	1.7E−11	2.2E−11	NA	NA	NA	3.9E−08	5.5E−07	NA	7.1E−11	9.2E−11	2.0E−04	2.9E−05	1.6E−04	5.0E−13	1.5E−16	1.9E−16	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.0E−10	4.0E−10	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.2E−13	5.0E−13	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	1.5E−03	2.5E−03	6.6E−04	1.1E−04	1.7E−04	4.3E−04	4.6E−04	8.2E−03	1.3E−03		5.5E−06	6.6E−07	1.3E−01	3.0E−02	8.9E−01	9.9E−03	1.4E−03	1.7E−04	
Sum Chem (BaP for PAHs):	1.5E−03	2.5E−03	6.6E−04	1.1E−04	1.9E−04	5.2E−04	5.7E−04	8.2E−03	1.3E−03		5.5E−06	6.6E−07	1.7E−01	3.0E−02	8.9E−01	9.9E−03	1.4E−03	1.7E−04	
TOTAL ALL (TEF Approach):	6.2E−03	2.5E−03	6.6E−04	1.2E−04	3.3E−04	5.0E−04	8.9E−04	8.5E−03	1.3E−03	2.3E−02	5.8E−05	2.1E−04	7.1E−01	3.0E−02	8.9E−01	1.5E−02	1.4E−03	6.4E−04	1.2E−03
TOTAL ALL (BaP Approach):	6.2E−03	2.5E−03	6.6E−04	1.2E−04	3.5E−04	5.9E−04	1.0E−03	8.5E−03	1.3E−03	2.3E−02	5.8E−05	2.1E−04	7.5E−01	3.0E−02	8.9E−01	1.5E−02	1.4E−03	6.4E−04	1.2E−03

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.. ND – No data for toxicity assessment for exposure pathway.

[a] Risk calculated using 1–hit equation for calculating risks from higher dose (EPA, 1989a), therefore total risks will not exceed one and are not additive.

[b] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources.

[c] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV-26
HAZARD QUOTIENTS FOR RME ON-PROPERTY FARMER, USE OF PERCHED GROUNDWATER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air				Soil			Exposed Waste Pit Material			Surface Water		Perched Groundwater			Great Miami Aquifer		
Exposure Pathways / Toxicants	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk	Incidental Ingestion	Dermal Contact	External Exposure	Ingestion of Meat	Ingestion of Milk	Ingestion of Drinking Water	Inhalation of VOC's	Dermal Contact while Bathing	Ingestion of Veget and F	Ingestion of Meat	Ingestion of Milk
cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-07	1.3E-07	4.9E+00	ND	ND	2.8E-06	5.7E-12	7.3E-12
antimony	ND	1.2E-02	3.4E-03	1.4E-03	1.5E+00	7.5E-01	3.0E-01	2.0E-01	4.2E-01	NA	2.0E-02	8.0E-03	6.5E+01	ND	1.3E+00	7.9E+00	1.2E+00	4.7E-01
arsenic	ND	4.7E+00	1.2E+00	1.4E-01	1.2E-01	1.4E-01	1.7E-02	1.5E+01	5.2E-01	NA	1.0E-02	1.3E-03	5.8E+01	ND	1.7E-01	1.9E+01	2.6E+00	3.2E-01
barium	5.0E-01	3.5E-02	2.6E-03	2.5E-02	NA	NA	NA	9.3E-02	3.3E-02	NA	9.7E-04	9.1E-03	7.7E-01	ND	2.4E-03	2.4E-01	9.2E-03	8.6E-02
beryllium	ND	1.9E-04	3.8E-05	1.4E-07	1.7E-04	1.6E-04	5.7E-07	1.4E-03	4.4E-02	NA	NA	NA	1.1E-01	ND	3.2E-02	NA	NA	NA
boron	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.9E-01	ND	5.1E-02	1.9E-02	8.0E-04	6.1E-03
cadmium	ND	1.5E-02	2.0E-03	1.4E-02	6.3E-01	9.3E-02	6.7E-01	2.0E-02	1.3E-01	NA	NA	NA	3.2E+00	ND	1.9E-01	6.6E-11	4.5E-12	3.3E-11
chromium vi	ND	2.6E-03	2.0E-03	2.2E-03	NA	NA	NA	1.8E-02	1.2E-01	NA	NA	NA	7.1E-01	ND	8.1E-02	NA	NA	NA
cobalt	4.8E-01	4.4E-05	1.2E-04	4.8E-05	NA	NA	NA	6.0E-04	4.3E-04	NA	NA	NA	1.5E-01	ND	3.9E-04	NA	NA	NA
copper	ND	5.4E-02	5.7E-02	3.4E-02	NA	NA	NA	6.6E-02	ND	NA	1.2E-02	7.1E-03	6.5E-01	ND	ND	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND
manganese	4.8E-01	1.1E-02	9.6E-04	3.3E-03	NA	NA	NA	3.0E-02	3.2E-01	NA	3.3E-05	1.1E-04	4.7E-01	ND	4.5E-02	3.0E-01	1.4E-02	5.1E-02
mercury	1.6E-04	7.2E-04	2.0E-02	1.4E-04	NA	NA	NA	2.9E-03	3.0E-02	NA	NA	NA	2.0E+00	ND	3.8E-02	1.3E-02	2.2E-01	1.6E-03
molybdenum	ND	1.1E-02	1.0E-02	1.0E-02	NA	NA	NA	4.3E-02	3.6E-02	NA	NA	NA	6.3E+02	ND	4.8E+00	5.2E-02	2.8E-02	2.8E-02
nickel	ND	4.9E-03	2.3E-03	1.5E-03	NA	NA	NA	7.8E-03	1.3E-03	NA	8.1E-03	5.4E-03	2.9E+00	ND	8.4E-03	NA	NA	NA
selenium	ND	1.9E-03	2.4E-03	2.6E-03	NA	NA	NA	2.8E-03	1.1E-03	NA	6.5E-03	7.0E-03	2.1E-02	ND	7.5E-05	NA	NA	NA
silver	ND	1.5E-03	9.8E-04	2.6E-02	NA	NA	NA	6.3E-03	ND	NA	7.3E-03	2.0E-01	3.7E-01	ND	ND	NA	NA	NA
thallium	ND	3.1E-02	2.2E-01	4.3E-02	2.9E-03	2.9E-01	5.8E-02	1.7E-01	5.5E-02	NA	NA	NA	3.0E+02	ND	8.5E-01	NA	NA	NA
vanadium	ND	3.8E-02	1.3E-02	4.0E-04	NA	NA	NA	2.0E-01	1.3E-01	NA	2.7E-02	9.0E-04	5.6E+00	ND	3.2E-01	NA	NA	NA
thorium-total	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
uranium-total	ND	1.4E-01	1.6E-03	1.9E-02	3.9E-01	2.6E-02	3.1E-01	6.6E-01	4.2E+00	NA	NA	NA	4.6E+03	ND	2.6E+02	8.8E+01	6.5E-01	8.0E+00
fluoride	ND	1.3E-03	ND	ND	NA	NA	NA	9.7E-02	9.3E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.5E-06	2.1E-07	2.7E-07	NA	NA	NA	5.0E-06	5.3E-05	NA	NA	NA	1.8E-01	ND	4.0E+00	NA	NA	NA
phenanthrene	ND	ND	ND	ND	NA	NA	NA	ND	ND	NA	NA	NA	ND	ND	ND	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	ND	2.1E-08	7.4E-13	9.3E-13	NA	NA	NA	4.9E-08	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6E-08	3.6E-08	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	6.5E-05	3.3E-08	4.3E-08	NA	NA	NA	7.4E-05	1.1E-03	NA	1.4E-07	1.8E-07	3.8E-01	ND	3.1E-01	9.7E-10	2.9E-13	3.7E-13
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.8E-10	1.1E-09	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.3E-08	3.2E-08	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0E-09	2.3E-09	NA	NA	NA	NA	NA	NA
TOTAL:	1.5E+00	5.1E+00	1.5E+00	3.3E-01	2.6E+00	1.3E+00	1.4E+00	1.7E+01	6.1E+00		9.3E-02	2.4E-01	5.6E+03	0.0E+00	2.7E+02	1.2E+02	4.7E+00	9.0E+00

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND - No data for toxicity assessment for exposure pathway.

TABLE E.IV-27
ILCRs FOR RME OFF-PROPERTY FARMER
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Groundwater					
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Radionuclides										
Cs_{137+1d}	2.9E-10	6.8E-09	1.2E-08	1.7E-08	NA	NA	NA	NA	NA	NA
Np_{237+1d}	3.7E-07	3.8E-08	2.1E-10	7.8E-11	1.3E-16	4.3E-17	1.5E-19	5.6E-20	NA	NA
Pu_{238}	3.8E-08	2.7E-09	9.9E-14	7.9E-14	NA	NA	NA	NA	NA	NA
$Pu_{239/240}$	2.2E-07	1.7E-08	1.3E-12	1.1E-12	NA	NA	NA	NA	NA	NA
Ra_{226+8d}	1.1E-06	1.6E-06	6.8E-08	4.9E-07	NA	NA	NA	NA	NA	NA
Ru_{106}	6.1E-10	1.6E-10	1.6E-11	2.0E-14	NA	NA	NA	NA	NA	NA
Sr_{90+1d}	2.9E-10	2.7E-09	1.6E-10	3.3E-09	1.0E-11	4.2E-12	1.5E-13	3.1E-12	NA	NA
Tc_{99}	5.9E-09	1.2E-08	7.3E-09	3.4E-08	2.0E-07	6.3E-08	2.5E-08	1.2E-07	NA	NA
Th_{230}	1.2E-04	7.1E-07	8.5E-10	2.8E-09	NA	NA	NA	NA	NA	NA
$Th_{232+10d}$	1.3E-05	2.5E-07	3.0E-10	1.0E-09	NA	NA	NA	NA	NA	NA
U_{234}	1.4E-05	1.1E-07	1.2E-09	1.4E-08	1.3E-04	4.1E-05	3.0E-07	3.7E-06	NA	NA
U_{235+1D}	1.3E-06	1.1E-08	1.2E-10	1.4E-09	3.1E-05	9.5E-06	7.0E-08	8.6E-07	NA	NA
U_{238+2d}	5.8E-05	4.0E-07	4.4E-09	5.3E-08	1.1E-03	3.4E-04	2.5E-06	3.1E-05	NA	NA
Rn_{222+4d}	2.2E-10	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Radionuclides	2.1E-04	3.2E-06	9.5E-08	6.2E-07	1.3E-03	3.9E-04	2.9E-06	3.6E-05		
Chemicals										
arsenic	9.0E-05	1.5E-04	3.9E-05	4.7E-06	NA	NA	NA	NA	NA	NA
beryllium	4.4E-08	3.3E-07	6.5E-08	2.3E-10	NA	NA	NA	NA	NA	NA
cadmium	4.9E-08	ND	ND	ND	NA	NA	NA	NA	NA	NA
chromium vi	2.2E-06	ND	ND	ND	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
nickel	8.2E-08	ND	ND	ND	NA	NA	NA	NA	NA	NA
pcbs	ND	5.3E-07	1.6E-06	2.0E-06	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	4.0E-11	6.3E-10	3.5E-10	4.5E-10	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	2.9E-10	4.6E-09	6.1E-09	7.7E-09	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	5.5E-11	8.4E-10	4.3E-09	5.5E-09	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	2.6E-13	4.1E-12	4.2E-11	5.3E-11	NA	NA	NA	NA	NA	NA
chrysene	1.6E-12	2.5E-11	1.5E-11	1.9E-11	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	1.3E-11	1.9E-10	1.2E-08	1.5E-08	NA	NA	NA	NA	NA	NA
n-nitrosodipropylamine	ND	7.6E-09	2.2E-13	2.8E-13	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	3.3E-10	4.6E-11	5.9E-11	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	1.2E-10	1.4E-09	1.4E-08	2.0E-08	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo-p-dioxin	4.0E-10	4.7E-09	4.8E-08	6.8E-08	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	5.0E-11	5.9E-10	3.8E-10	5.4E-10	NA	NA	NA	NA	NA	NA
octachlorodibenzo-p-dioxin	4.6E-10	5.4E-09	5.5E-08	7.8E-08	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	2.6E-11	3.1E-10	2.0E-10	2.8E-10	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	4.7E-13	2.6E-10	1.3E-13	1.7E-13	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	9.3E-05	1.5E-04	4.1E-05	6.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sum Chem (BaP for PAHs):	9.3E-05	1.5E-04	4.1E-05	6.9E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOTAL ALL (TEF Approach):	3.1E-04	1.6E-04	4.1E-05	7.5E-06	1.3E-03	3.9E-04	2.9E-06	3.6E-05	0.0E+00	0.0E+00
TOTAL ALL (BaP Approach):	3.1E-04	1.6E-04	4.1E-05	7.5E-06	1.3E-03	3.9E-04	2.9E-06	3.6E-05	0.0E+00	0.0E+00

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND - No data for toxicity assessment for exposure pathway.

TABLE E.IV-28
HAZARD QUOTIENTS FOR RME OFF-PROPERTY FARMER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Groundwater					
Exposure Pathways: / Toxicants	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
cyanide	NA	NA	NA	NA	1.7E-08	8.2E-09	1.7E-14	2.2E-14	NA	ND
antimony	ND	1.2E-03	3.2E-04	1.3E-04	NA	NA	NA	NA	NA	NA
arsenic	ND	2.9E-01	7.4E-02	8.9E-03	NA	NA	NA	NA	NA	NA
barium	3.4E-02	2.4E-03	1.8E-04	1.7E-03	1.9E-07	1.8E-07	6.7E-09	6.3E-08	NA	5.9E-10
beryllium	ND	1.5E-05	3.0E-06	1.1E-08	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	8.0E-04	4.8E-04	2.1E-05	1.6E-04	NA	4.6E-05
cadmium	ND	1.0E-03	1.4E-04	1.0E-03	NA	NA	NA	NA	NA	NA
chromium vi	ND	2.1E-04	1.6E-04	1.8E-04	NA	NA	NA	NA	NA	NA
cobalt	3.9E-02	3.6E-06	9.8E-06	3.9E-06	NA	NA	NA	NA	NA	NA
copper	ND	2.8E-03	2.9E-03	1.8E-03	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
manganese	3.1E-02	6.8E-04	6.1E-05	2.2E-04	NA	NA	NA	NA	NA	NA
mercury	9.1E-06	4.1E-05	1.1E-03	8.2E-06	3.5E-08	1.4E-08	2.3E-07	1.7E-09	NA	6.6E-10
molybdenum	ND	6.4E-04	6.1E-04	6.1E-04	1.0E-06	5.6E-07	3.0E-07	3.0E-07	NA	7.6E-09
nickel	ND	3.5E-04	1.6E-04	1.1E-04	NA	NA	NA	NA	NA	NA
selenium	ND	1.1E-04	1.5E-04	1.6E-04	NA	NA	NA	NA	NA	NA
silver	ND	6.5E-05	4.3E-05	1.2E-03	NA	NA	NA	NA	NA	NA
thallium	ND	1.2E-03	8.7E-03	1.7E-03	NA	NA	NA	NA	NA	NA
vanadium	ND	3.1E-03	1.0E-03	3.2E-05	NA	NA	NA	NA	NA	NA
thorium-total	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
uranium-total	ND	5.8E-03	6.4E-05	7.7E-04	2.2E+01	6.7E+00	5.0E-02	6.1E-01	NA	1.3E+00
fluoride	ND	7.8E-05	ND	ND	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	9.2E-08	1.3E-08	1.6E-08	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	5.0E-07	2.6E-10	3.3E-10	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL:	1.0E-01	3.1E-01	9.0E-02	1.8E-02	2.2E+01	6.7E+00	5.0E-02	6.1E-01	0.0E+00	1.3E+00

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND - No data for toxicity assessment for exposure pathway.

TABLE E.IV–29
ILCRs FOR RME OFF–PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Groundwater					
Exposure Pathways: / Contaminants of Concern	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Radionuclides										
Cs_{137+1d}	5.2E−12	5.1E−10	4.0E−10	3.3E−09	NA	NA	NA	NA	NA	NA
Np_{237+1d}	6.7E−09	2.8E−09	7.1E−12	1.5E−11	5.7E−18	3.2E−18	5.0E−21	1.1E−20	NA	NA
Pu_{238}	7.0E−10	2.0E−10	3.3E−15	1.5E−14	NA	NA	NA	NA	NA	NA
$Pu_{239/240}$	4.1E−09	1.3E−09	4.5E−14	2.1E−13	NA	NA	NA	NA	NA	NA
Ra_{226+8d}	1.9E−08	1.2E−07	2.3E−09	9.5E−08	NA	NA	NA	NA	NA	NA
Ru_{106}	1.1E−11	1.2E−11	5.4E−13	4.0E−15	NA	NA	NA	NA	NA	NA
Sr_{90+1d}	5.2E−12	2.0E−10	5.4E−12	6.3E−10	4.5E−13	3.1E−13	5.0E−15	6.0E−13	NA	NA
Tc_{99}	1.1E−10	9.0E−10	2.4E−10	6.7E−09	8.5E−09	4.7E−09	8.3E−10	2.3E−08	NA	NA
Th_{230}	2.3E−06	5.3E−08	2.8E−11	5.5E−10	NA	NA	NA	NA	NA	NA
$Th_{232+10d}$	2.3E−07	1.9E−08	1.0E−11	2.0E−10	NA	NA	NA	NA	NA	NA
U_{234}	2.5E−07	8.1E−09	4.0E−11	2.8E−09	5.8E−06	3.0E−06	9.9E−09	7.2E−07	NA	NA
U_{235+1D}	2.4E−08	8.1E−10	4.0E−12	2.8E−10	1.3E−06	7.0E−07	2.3E−09	1.7E−07	NA	NA
U_{238+2d}	1.1E−06	3.0E−08	1.5E−10	1.0E−08	4.8E−05	2.5E−05	8.3E−08	6.0E−06	NA	NA
Rn_{222+4d}	4.0E−12	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Radionuclides	3.8E−06	2.4E−07	3.1E−09	1.2E−07	5.5E−05	2.9E−05	9.6E−08	6.9E−06		
Chemicals										
arsenic	7.6E−06	5.3E−05	6.0E−06	4.2E−06	NA	NA	NA	NA	NA	NA
beryllium	3.7E−09	1.2E−07	1.0E−08	2.1E−10	NA	NA	NA	NA	NA	NA
cadmium	4.1E−09	ND	ND	ND	NA	NA	NA	NA	NA	NA
chromium vi	1.9E−07	ND	ND	ND	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
nickel	6.9E−09	ND	ND	ND	NA	NA	NA	NA	NA	NA
pcbs	ND	1.9E−07	2.4E−07	1.8E−06	NA	NA	NA	NA	NA	NA
benzo(a)anthracene	3.3E−12	2.2E−10	5.4E−11	4.1E−10	NA	NA	NA	NA	NA	NA
benzo(a)pyrene	2.5E−11	1.6E−09	9.4E−10	7.0E−09	NA	NA	NA	NA	NA	NA
benzo(b)fluoranthene	4.7E−12	2.9E−10	6.7E−10	5.0E−09	NA	NA	NA	NA	NA	NA
benzo(k)fluoranthene	2.2E−14	1.4E−12	6.5E−12	4.8E−11	NA	NA	NA	NA	NA	NA
chrysene	1.3E−13	8.8E−12	2.3E−12	1.7E−11	NA	NA	NA	NA	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
indeno(1,2,3−cd)pyrene	1.1E−12	6.6E−11	1.9E−09	1.4E−08	NA	NA	NA	NA	NA	NA
n−nitrosodipropylamine	ND	2.7E−09	3.4E−14	2.6E−13	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	1.2E−10	7.2E−12	5.4E−11	NA	NA	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo−p−dioxin	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
hexachlorodibenzo−p−dioxin	9.9E−12	4.8E−10	2.2E−09	1.8E−08	NA	NA	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
heptachlorodibenzo−p−dioxin	3.4E−11	1.6E−09	7.4E−09	6.2E−08	NA	NA	NA	NA	NA	NA
heptachlorodibenzofuran	4.2E−12	2.0E−10	5.8E−11	4.9E−10	NA	NA	NA	NA	NA	NA
octachlorodibenzo−p−dioxin	3.9E−11	1.9E−09	8.5E−09	7.1E−08	NA	NA	NA	NA	NA	NA
octachlorodibenzofuran	2.2E−12	1.1E−10	3.1E−11	2.6E−10	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	3.9E−14	9.0E−11	2.1E−14	1.5E−13	NA	NA	NA	NA	NA	NA
benzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sum Chem (TEF for PAHs):	7.8E−06	5.4E−05	6.3E−06	6.2E−06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Sum Chem (BaP for PAHs):	7.8E−06	5.4E−05	6.3E−06	6.3E−06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
TOTAL ALL (TEF Approach):	1.2E−05	5.4E−05	6.3E−06	6.3E−06	5.5E−05	2.9E−05	9.6E−08	6.9E−06	0.0E+00	0.0E+00
TOTAL ALL (BaP Approach):	1.2E−05	5.4E−05	6.3E−06	6.4E−06	5.5E−05	2.9E−05	9.6E−08	6.9E−06	0.0E+00	0.0E+00

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV-30
HAZARD QUOTIENTS FOR RME OFF-PROPERTY CHILD
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air				Groundwater					
Exposure Pathways:	Inhalation	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Drinking Water	Ingestion of Vegetables and Fruits	Ingestion of Meat	Ingestion of Milk Products	Inhalation of VOC's	Dermal Contact while Bathing
Toxicants										
cyanide	NA	NA	NA	NA	4.0E-08	3.3E-08	3.0E-14	2.3E-13	NA	ND
antimony	ND	4.7E-03	5.8E-04	1.4E-03	NA	NA	NA	NA	NA	NA
arsenic	ND	1.2E+00	1.3E-01	9.4E-02	NA	NA	NA	NA	NA	NA
barium	3.4E-02	9.8E-03	3.3E-04	1.8E-02	4.4E-07	7.1E-07	1.2E-08	6.7E-07	NA	9.6E-10
beryllium	ND	6.3E-05	5.4E-06	1.1E-07	NA	NA	NA	NA	NA	NA
boron	NA	NA	NA	NA	1.9E-03	1.9E-03	3.7E-05	1.7E-03	NA	7.5E-05
cadmium	ND	4.2E-03	2.5E-04	1.1E-02	NA	NA	NA	NA	NA	NA
chromium vi	ND	8.7E-04	2.9E-04	1.9E-03	NA	NA	NA	NA	NA	NA
cobalt	3.8E-02	1.5E-05	1.8E-05	4.1E-05	NA	NA	NA	NA	NA	NA
copper	ND	1.1E-02	5.3E-03	1.9E-02	NA	NA	NA	NA	NA	NA
lead	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
manganese	3.0E-02	2.8E-03	1.1E-04	2.3E-03	NA	NA	NA	NA	NA	NA
mercury	8.9E-06	1.7E-04	2.1E-03	8.7E-05	8.1E-08	5.6E-08	4.2E-07	1.8E-08	NA	1.1E-09
molybdenum	ND	2.6E-03	1.1E-03	6.5E-03	2.4E-06	2.3E-06	5.4E-07	3.2E-06	NA	1.2E-08
nickel	ND	1.4E-03	3.0E-04	1.2E-03	NA	NA	NA	NA	NA	NA
selenium	ND	4.6E-04	2.6E-04	1.6E-03	NA	NA	NA	NA	NA	NA
silver	ND	2.6E-04	7.8E-05	1.2E-02	NA	NA	NA	NA	NA	NA
thallium	ND	5.0E-03	1.6E-02	1.8E-02	NA	NA	NA	NA	NA	NA
vanadium	ND	1.2E-02	1.8E-03	3.4E-04	NA	NA	NA	NA	NA	NA
thorium-total	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
uranium-total	ND	2.3E-02	1.2E-04	8.1E-03	5.2E+01	2.7E+01	8.9E-02	6.5E+00	NA	2.1E+00
fluoride	ND	3.1E-04	ND	ND	NA	NA	NA	NA	NA	NA
acenaphthylene	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pentachlorophenol	ND	3.7E-07	2.3E-08	1.7E-07	NA	NA	NA	NA	NA	NA
phenanthrene	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-chloropropene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
tetrachloroethene	ND	2.0E-06	4.6E-10	3.4E-09	NA	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL:	1.0E-01	1.3E+00	1.6E-01	2.0E-01	5.2E+01	2.7E+01	8.9E-02	6.5E+00	0.0E+00	2.1E+00

NA - Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND - No data for toxicity assessment for exposure pathway.

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TABLE E.IV-31
ILCRs FOR ON-PROPERTY HOME BUILDER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material			Buried Pit Material
Exposure Pathways: Contaminants of Concern	Inhalation	Incidental Ingestion	Dermal Contact[b]	External Exposure	External Exposure[a]
Radionuclides					
Cs_{137+1d}	2.1E-10	1.5E-08	NA	1.6E-06	
Np_{237+1d}	2.4E-07	9.0E-08	NA	2.5E-07	
Pu_{238}	1.9E-08	7.0E-09	NA	1.3E-12	
$Pu_{239/240}$	8.2E-08	3.2E-08	NA	5.4E-12	
Ra_{226+8d}	4.7E-07	2.0E-06	NA	2.2E-05	
Ru_{106}	2.8E-10	3.8E-09	NA	ND	
Sr_{90+1d}	2.0E-10	9.8E-09	NA	ND	
Tc_{99}	2.6E-09	2.3E-08	NA	1.5E-11	
Th_{230}	5.0E-05	1.1E-06	NA	6.3E-09	
$Th_{232+10d}$	6.2E-06	5.0E-07	NA	3.6E-05	
U_{234}	1.0E-05	3.7E-07	NA	9.8E-10	
U_{235+1D}	2.6E-06	5.8E-08	NA	1.2E-06	
U_{238+2d}	7.3E-05	2.6E-06	NA	4.7E-06	
Rn_{222+4d}	1.0E-10	NA	NA	NA	
Total Radionuclides	1.4E-04	6.8E-06		6.6E-05	6.8E-09
Chemicals					
arsenic	4.4E-05	1.5E-04	1.9E-06	NA	NA
beryllium	1.6E-08	5.6E-07	6.8E-06	NA	NA
cadmium	2.1E-08	ND	ND	NA	NA
chromium vi	8.2E-07	ND	ND	NA	NA
lead	ND	ND	ND	NA	NA
nickel	3.5E-08	ND	ND	NA	NA
pcbs	ND	6.1E-07	2.9E-07	NA	NA
benzo(a)anthracene	1.9E-11	3.6E-09	3.6E-09	NA	NA
benzo(a)pyrene	1.4E-10	1.7E-08	1.7E-08	NA	NA
benzo(b)fluoranthene	2.9E-11	2.7E-09	2.7E-09	NA	NA
benzo(k)fluoranthene	1.2E-13	1.4E-10	1.4E-10	NA	NA
chrysene	7.9E-13	1.4E-10	1.4E-10	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA
indeno(1,2,3-cd)pyrene	6.3E-12	2.1E-10	2.1E-10	NA	NA
n-nitrosodipropylamine	ND	7.0E-09	2.8E-09	NA	NA
pentachlorophenol	ND	3.4E-10	1.4E-09	NA	NA
vinyl chloride	NA	NA	NA	NA	NA
tetrachlorodibenzo-p-dioxin	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	6.0E-08	4.3E-08	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA
hexachlorodibenzo-p-dioxin	5.9E-11	1.4E-08	1.0E-08	NA	NA
hexachlorodibenzofuran	NA	1.1E-07	7.6E-08	NA	NA
heptachlorodibenzo-p-dioxin	2.0E-10	5.1E-08	3.7E-08	NA	NA
heptachlorodibenzofuran	2.5E-11	6.3E-09	4.5E-09	NA	NA
octachlorodibenzo-p-dioxin	2.3E-10	5.8E-08	4.2E-08	NA	NA
octachlorodibenzofuran	1.3E-11	3.3E-09	2.4E-09	NA	NA
chloroform	NA	NA	NA	NA	NA
tetrachloroethene	1.8E-12	7.4E-10	3.9E-09	NA	NA
benzene	NA	NA	NA	NA	NA
methylene chloride	NA	NA	NA	NA	NA
SUM (TEF for PAHs):	4.5E-05	1.6E-04	9.2E-06		
SUM (BaP for PAHs):	4.5E-05	1.6E-04	9.3E-06		
TOTAL RAD. & CHEM.	1.9E-04	1.6E-04	9.2E-06	6.6E-05	6.8E-09
TOTAL RAD. & CHEM.	1.9E-04	1.6E-04	9.3E-06	6.6E-05	6.8E-09

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.
[a] Risk from external radiation exposure is calculated from total exposure to all gamma radiation sources in pit 4.
[b] Risk from dermal contact with PAHs is assumed to equal risk from oral ingestion of PAHs.

TABLE E.IV-32
HAZARD QUOTIENTS FOR ON-PROPERTY HOME BUILDER FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air	Surface Soil and Exposed Waste Pit Material		
Exposure Pathways:	Inhalation	Incidental Ingestion	Dermal Contact	External Exposure
Toxicants				
cyanide	NA	NA	NA	NA
antimony	ND	5.5E-01	4.4E-01	NA
arsenic	ND	4.3E+01	5.4E-01	NA
barium	2.2E+00	2.6E-01	3.4E-02	NA
beryllium	ND	3.8E-03	4.6E-02	NA
boron	NA	NA	NA	NA
cadmium	ND	5.5E-02	1.3E-01	NA
chromium vi	ND	5.0E-02	1.2E-01	NA
cobalt	2.1E+00	1.7E-03	4.4E-04	NA
copper	ND	1.8E-01	ND	NA
lead	ND	ND	ND	NA
manganese	2.1E+00	8.5E-02	3.4E-01	NA
mercury	7.0E-04	8.0E-03	3.2E-02	NA
molybdenum	ND	1.2E-01	3.8E-02	NA
nickel	ND	2.2E-02	1.3E-03	NA
selenium	ND	7.7E-03	1.2E-03	NA
silver	ND	1.8E-02	ND	NA
thallium	ND	4.8E-01	5.8E-02	NA
vanadium	ND	5.5E-01	1.3E-01	NA
thorium-total	ND	ND	ND	NA
uranium-total	ND	1.8E+00	4.4E+00	NA
fluoride	ND	2.7E-01	9.7E-02	NA
acenaphthylene	ND	ND	ND	NA
2-methylnaphthalene	NA	NA	NA	NA
4-chloro-3-methylphenol	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	ND	NA
dibenzofuran	NA	NA	NA	NA
pentachlorophenol	ND	1.4E-05	5.5E-05	NA
phenanthrene	ND	ND	ND	NA
tributyl phosphate	NA	NA	NA	NA
2-hexanone	ND	1.4E-07	ND	NA
3-chloropropene	NA	NA	NA	NA
chloroform	NA	NA	NA	NA
tetrachloroethene	ND	2.1E-04	1.1E-03	NA
methylene chloride	NA	NA	NA	NA
toluene	NA	NA	NA	NA
2-nitrophenol	NA	NA	NA	NA
acetone	NA	NA	NA	NA
TOTAL:	6.4E+00	4.7E+01	6.4E+00	

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable.
ND – No data for toxicity assessment for exposure pathway.

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TABLE E.IV–33
ILCRs FOR OFF–PROPERTY USER OF MEAT AND MILK PRODUCTS
FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media	Air		Surface Soil		Surface Water	
Exposure Pathways / Contaminants of Concern	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Radionuclides						
Cs_{137+1d}	2.9E–07	4.0E–07	3.7E–06	5.2E–06	3.3E–05	4.6E–05
Np_{237+1d}	4.7E–09	1.7E–09	6.1E–08	2.2E–08	NA	NA
Pu_{238}	1.6E–12	1.3E–12	1.1E–11	8.4E–12	NA	NA
$Pu_{239/240}$	1.6E–11	1.3E–11	2.2E–11	1.8E–11	NA	NA
Ra_{226+8d}	9.9E–07	7.1E–06	6.3E–07	4.5E–06	6.3E–08	4.6E–07
Ru_{106}	2.5E–10	3.1E–13	NA	NA	NA	NA
Sr_{90+1d}	3.7E–09	7.3E–08	3.7E–06	7.4E–05	6.7E–07	1.4E–05
Tc_{99}	1.1E–07	5.0E–07	5.4E–05	2.5E–04	1.3E–05	6.1E–05
Th_{230}	1.1E–08	3.8E–08	1.1E–08	3.8E–08	1.0E–11	3.4E–11
$Th_{232+10d}$	4.8E–09	1.6E–08	5.6E–09	1.9E–08	2.6E–09	9.0E–09
U_{234}	2.9E–08	3.5E–07	6.4E–07	7.7E–06	1.3E–06	1.6E–05
U_{235+1D}	7.9E–09	9.4E–08	1.0E–07	1.2E–06	7.2E–08	8.9E–07
U_{238+2d}	1.8E–07	2.2E–06	7.5E–06	9.0E–05	5.4E–06	6.6E–05
Total Radionuclides	1.6E–06	1.1E–05	7.0E–05	4.4E–04	5.3E–05	2.0E–04
Chemicals						
arsenic	6.3E–04	7.5E–05	7.4E–05	8.8E–06	5.5E–06	6.6E–07
beryllium	8.1E–07	2.9E–09	3.4E–06	1.2E–08	NA	NA
cadmium	ND	ND	ND	ND	NA	NA
chromium vi	ND	ND	NA	NA	NA	NA
lead	ND	ND	NA	NA	ND	ND
nickel	ND	ND	NA	NA	ND	ND
pcbs	2.4E–05	3.1E–05	3.4E–04	4.3E–04	NA	NA
benzo(a)anthracene	5.6E–09	7.2E–09	1.2E–06	1.5E–06	NA	NA
benzo(a)pyrene	9.8E–08	1.2E–07	8.8E–06	1.1E–05	NA	NA
benzo(b)fluoranthene	7.4E–08	9.4E–08	3.3E–06	4.2E–06	NA	NA
benzo(k)fluoranthene	6.4E–10	8.1E–10	4.3E–07	5.4E–07	NA	NA
chrysene	2.4E–10	3.1E–10	4.7E–08	5.9E–08	NA	NA
dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA
indeno(1,2,3–cd)pyrene	2.0E–07	2.5E–07	NA	NA	NA	NA
n–nitrosodipropylamine	3.9E–12	4.9E–12	NA	NA	NA	NA
pentachlorophenol	7.7E–10	9.8E–10	NA	NA	NA	NA
vinyl chloride	NA	NA	NA	NA	NA	NA
tetrachlorodibenzo–p–dioxin	NA	NA	NA	NA	NA	NA
tetrachlorodibenzofuran	NA	NA	NA	NA	NA	NA
pentachlorodibenzofuran	NA	NA	NA	NA	NA	NA
hexachlorodibenzo–p–dioxin	2.3E–07	3.3E–07	NA	NA	NA	NA
hexachlorodibenzofuran	NA	NA	NA	NA	NA	NA
heptachlorodibenzo–p–dioxin	8.0E–07	1.1E–06	NA	NA	NA	NA
heptachlorodibenzofuran	6.3E–09	9.0E–09	NA	NA	NA	NA
octachlorodibenzo–p–dioxin	9.2E–07	1.3E–06	NA	NA	NA	NA
octachlorodibenzofuran	3.3E–09	4.7E–09	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	1.6E–12	2.2E–12
tetrachloroethene	1.7E–11	2.2E–11	NA	NA	7.1E–11	9.2E–11
benzene	NA	NA	NA	NA	3.0E–10	4.0E–10
methylene chloride	NA	NA	NA	NA	2.2E–13	5.0E–13
Sum Chem (TEF for PAHs):	6.6E–04	1.1E–04	4.3E–04	4.5E–04	5.5E–06	6.6E–07
Sum Chem (BaP for PAHs):	6.6E–04	1.1E–04	4.8E–04	5.2E–04	5.5E–06	6.6E–07
TOTAL ALL (TEF Approach):	6.6E–04	1.2E–04	5.0E–04	8.9E–04	5.8E–05	2.1E–04
TOTAL ALL (BaP Approach):	6.6E–04	1.2E–04	5.5E–04	9.5E–04	5.8E–05	2.1E–04

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV–34
HAZARD QUOTIENTS FOR OFF–PROPERTY USER OF MEAT AND MILK PRODUCTS FUTURE LAND USE, FUTURE SOURCE TERM

Transfer Media:	Air		Surface Soil		Surface Water	
Exposure Pathways:	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products	Ingestion of Meat	Ingestion of Milk Products
Toxicants						
cyanide	NA	NA	NA	NA	1.0E–07	1.3E–07
antimony	3.4E–03	1.4E–03	7.5E–01	3.0E–01	2.0E–02	8.0E–03
arsenic	1.2E+00	1.4E–01	1.4E–01	1.7E–02	1.0E–02	1.3E–03
barium	2.6E–03	2.5E–02	NA	NA	9.7E–04	9.1E–03
beryllium	3.8E–05	1.4E–07	1.6E–04	5.7E–07	NA	NA
boron	NA	NA	NA	NA	NA	NA
cadmium	2.0E–03	1.4E–02	9.3E–02	6.7E–01	NA	NA
chromium vi	2.0E–03	2.2E–03	NA	NA	NA	NA
cobalt	1.2E–04	4.8E–05	NA	NA	NA	NA
copper	5.7E–02	3.4E–02	NA	NA	1.2E–02	7.1E–03
lead	ND	ND	NA	NA	ND	ND
manganese	9.6E–04	3.3E–03	NA	NA	3.3E–05	1.1E–04
mercury	2.0E–02	1.4E–04	NA	NA	NA	NA
molybdenum	1.0E–02	1.0E–02	NA	NA	NA	NA
nickel	2.3E–03	1.5E–03	NA	NA	8.1E–03	5.4E–03
selenium	2.4E–03	2.6E–03	NA	NA	6.5E–03	7.0E–03
silver	9.8E–04	2.6E–02	NA	NA	7.3E–03	2.0E–01
thallium	2.2E–01	4.3E–02	2.9E–01	5.8E–02	NA	NA
vanadium	1.3E–02	4.0E–04	NA	NA	2.7E–02	9.0E–04
thorium–total	ND	ND	ND	ND	NA	NA
uranium–total	1.6E–03	1.9E–02	2.6E–02	3.1E–01	NA	NA
fluoride	ND	ND	NA	NA	NA	NA
acenaphthylene	ND	ND	NA	NA	NA	NA
2–methylnaphthalene	NA	NA	NA	NA	NA	NA
4–chloro–3–methylphenol	NA	NA	NA	NA	NA	NA
benzo(g,h,i)perylene	ND	ND	NA	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA
pentachlorophenol	2.1E–07	2.7E–07	NA	NA	NA	NA
phenanthrene	ND	ND	NA	NA	NA	NA
tributyl phosphate	NA	NA	NA	NA	NA	NA
2–hexanone	7.4E–13	9.3E–13	NA	NA	NA	NA
3–chloropropene	NA	NA	NA	NA	NA	NA
chloroform	NA	NA	NA	NA	2.6E–08	3.6E–08
tetrachloroethene	3.3E–08	4.3E–08	NA	NA	1.4E–07	1.8E–07
methylene chloride	NA	NA	NA	NA	4.8E–10	1.1E–09
toluene	NA	NA	NA	NA	2.3E–08	3.2E–08
2–nitrophenol	NA	NA	NA	NA	ND	ND
acetone	NA	NA	NA	NA	1.0E–09	2.3E–09
TOTAL:	1.5E+00	3.3E–01	1.3E+00	1.4E+00	9.3E–02	2.4E–01

NA – Not applicable. Chemical not a chemical of interest for media or exposure pathway not applicable..
ND – No data for toxicity assessment for exposure pathway.

TABLE E.IV-35

RISKS FROM PENETRATING RADIATION[a]
CURRENT CONDITIONS - BURIED PIT MATERIAL
GROUNDSKEEPER UNDER CURRENT LAND USE WITH ACCESS CONTROLS

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Dose Rate[c] (mRem/hr)	Total Exposure[d] (mRem/Life)	Risk[e] (risk/Life)
Pit 1	7680	0.051	0.024	8	5.0×10^{-6}
Pit 2	4170	0.028	0.057	11	6.8×10^{-6}
Pit 3	22400	0.148	0.044	44	2.7×10^{-5}
Pit 4	7790	0.052	7.8×10^{-6}	0.0026	1.6×10^{-9}
Pit 5	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Pit 6	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Burn Pit	2020	0.013	0.14	12	7.4×10^{-6}
Clearwell	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
				Total Risk	4.7×10^{-5}

[a]These risks are in addition to risks associated with penetrating radiation from surface soils.
[b]Calculated as the source area divided by the total area available to a roaming visitor. (Area of OU1 = 151000 m^2)
[c]Results of Microshield calculations (Table E.3-6)
[d]The product of the dose rate (mRem/hr), the exposure time (8 hr/d), the fraction of time exposed (unitless), the exposure frequency (35 d/y), and the exposure duration (25 years).
[e]The product of the total exposure (mRem/Life) and the dose-to-risk conversion factor from the WPA (6.2 E-7 risk/mRem) (DOE, 1993a)
[f]Source covered by deep standing water. Exposures to an individual standing on the shoreline are negligible.

TABLE E.IV-36

RISKS FROM PENETRATING RADIATION[a]
CURRENT CONDITIONS - BURIED PIT MATERIAL
TRESPASSING YOUTH UNDER FUTURE LAND USE WITHOUT ACCESS CONTROLS

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Dose Rate[c] (mRem/hr)	Total Exposure[d] (mRem/Life)	Risk[e] (risk/Life)
Pit 1	7680	0.051	0.024	3.0	1.9×10^{-6}
Pit 2	4170	0.028	0.057	3.9	2.4×10^{-6}
Pit 3	22400	0.148	0.044	16	1.0×10^{-5}
Pit 4	7790	0.052	7.8×10^{-6}	0.0010	6.3×10^{-10}
Pit 5	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Pit 6	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Burn Pit	2020	0.013	0.14	4.7	2.9×10^{-6}
Clearwell	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
				Total Risk	1.7×10^{-5}

[a] These risks are in addition to risks associated with penetrating radiation from surface soils.
[b] Calculated as the source area divided by the total area available to a roaming trespassing child. (Area of OU1 = 151000 m^2)
[c] Results of Microshield calculations (Table E.3-8)
[d] The product of the dose rate (mRem/hr), the exposure time (4 hr/d), the fraction of time exposed (unitless), the exposure frequency (52 d/y), and the exposure duration (12 years).
[e] The product of the total exposure (mRem/Life) and the dose-to-risk conversion factor from the WPA (6.2 E-7 risk/mRem) (DOE, 1993a).
[f] Source covered by deep standing water. Exposures to an individual standing on the shoreline are negligible.

TABLE E.IV-37

RISKS FROM PENETRATING RADIATION[a]
FUTURE CONDITIONS - BURIED PIT MATERIAL
TRESPASSING YOUTH UNDER CURRENT LAND USE WITHOUT ACCESS CONTROLS

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Dose Rate[c] (mRem/hr)	Total Exposure[d] (mRem/Life)	Risk[e] (Risk/Life)
Pit 1	7680	0.051	0.024	3.0	1.9×10^{-6}
Pit 2	4170	0.028	0.057	3.9	2.4×10^{-6}
Pit 3	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Pit 4	7790	0.052	7.8×10^{-6}	0.0010	6.3×10^{-10}
Pit 5	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]
Pit 6	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]
Burn Pit	2020	0.013	0.14	4.7	2.9×10^{-6}
Clearwell	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]
				Total Risk	7.2×10^{-6}

[a] These risks are in addition to risks associated with penetrating radiation from surface soils.
[b] Calculated as the source area divided by the total area available to a roaming trespasser. (Area of OU1 = 151000 m^2)
[c] Results of Microshield calculations (Table E.3-8).
[d] The product of the dose rate (mrem/hr), the exposure time (4 hr/d), the fraction of time exposed (unitless), the exposure frequency (52 d/y), and the exposure duration (12 years).
[e] The product of the total exposure (mrem/Life) and the dose to risk conversion factor from the WPA (6.2 E-7 risk/mrem) (DOE, 1993a).
[f] Source has no cover and exposed material is assessed as surface soil.
[g] Source covered by deep standing water. Exposures to an individual standing on the shoreline are negligible.

TABLE E.IV-38

RISKS FROM PENETRATING RADIATION[a]
FUTURE CONDITIONS - BURIED PIT MATERIAL
EXPANDED TRESPASSER UNDER FUTURE LAND USE WITH ACCESS CONTROLS

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Dose Rate[c] (mRem/hr)	Total Exposure[d] (mRem/Life)	Risk[e] (risk/Life)
Pit 1	7680	0.051	0.024	4.5	2.8×10^{-6}
Pit 2	4170	0.028	0.057	6	3.7×10^{-6}
Pit 3	22400	0.148	0.044	24	1.5×10^{-5}
Pit 4	7790	0.052	7.8×10^{-6}	0.0015	9.3×10^{-10}
Pit 5	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Pit 6	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
Burn Pit	2020	0.013	0.14	7.2	4.5×10^{-6}
Clearwell	NA[f]	NA[f]	NA[f]	NA[f]	NA[f]
				Total Risk	2.7×10^{-5}

[a] These risks are in addition to risks associated with penetrating radiation from surface soils.
[b] Calculated as the source area divided by the total area available to a roaming trespassing child. (Area of OU1 = 151000 m^2)
[c] Results of Microshield calculations (Table E.3-8)
[d] The product of the dose rate (mRem/hr), the exposure time (2 hr/d), the fraction of time exposed (unitless), the exposure frequency (110 d/y), and the exposure duration (44 years).
[e] The product of the total exposure (mRem/Life) and the dose-to-risk conversion factor from the WPA (6.2 E-7 risk/mRem) (DOE, 1993a).
[f] Source covered by deep standing water. Exposures to an individual standing on the shoreline are negligible.

TABLE E.IV-39

RISKS FROM PENETRATING RADIATION[a]
FUTURE CONDITIONS - BURIED PIT MATERIAL
ON-PROPERTY RME FARMER UNDER FUTURE LAND USE

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Total Time Spent Exposed to Source[c] (hr/Lifetime)	Dose Rate[d] (mRem/hr)	Total Exposure[e] (mRem/Life)	Risk[f] (risk/Life)
Pit 1	7680	0.051	31010	0.024	744	4.6×10^{-4}
Pit 2	4170	0.028	16838	0.057	960	6.0×10^{-4}
Pit 3	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]
Pit 4	7790	0.052	453159	7.8×10^{-6}	3.6	2.2×10^{-6}
Pit 5	NA[h]	NA[h]	NA[h]	NA [h]	NA[h]	NA[h]
Pit 6	NA[h]	NA[h]	NA[h]	NA [h]	NA[h]	NA[h]
Burn Pit	2020	0.013	1338	0.14	187	1.2×10^{-4}
Clearwell	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]
					Total Risk	1.2×10^{-3}

[a]These risks are in addition to risks associated with penetrating radiation from surface soils.
[b]Calculated as the source area divided by the total area available to an on-property adult. (Area of OU1 = 151,000 m^2).
[c]Assumes RME spends 350 d/y (8400 hr/y) on-property for 70 years. 2000 hr/y of this time is spent outdoors, and the remaining 6400 hr/y is spent indoors. The RME farms Pits 1 and 2 for 800 hr/y over 50 years. Thus the RME spends 448,200 hrs indoors in structures build on Pit 4; 40,000 hrs on Pits 1 and 2; and the remaining 100,000 hrs roaming randomly over the operable unit. Shielding by the home is not considered in this calculation.
[d]Results of Microshield calculations (Table E.3-8).
[e]The product of the dose rate (mRrem/hr), and the total time exposed (hr/lifetime).
[f]The product of the total exposure (mRrem/Life) and the dose to risk conversion factor from the WPA (6.2
E-7 risk/mRem) (DOE, 1993a).
[g]Cover over source is gone. Exposed waste treated as surface soil (Table E.IV-54).
[h]Source covered by deep standing water. Exposures to an individual standing on the shoreline are negligible.

TABLE E.IV-40

RISKS FROM PENETRATING RADIATION FUTURE CONDITIONS - BURIED PIT MATERIAL ON-PROPERTY CHILD UNDER FUTURE LAND USE[a]

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Total Time Spent Exposed to Source[c] (hr/Lifetime)	Dose Rate[d] (mrem/hr)	Total Exposure[e] (mRem/Life)	Risk[f] (risk/Life)
Pit 4	7790	1.0	50400	7.8×10^{-6}	0.4	2.4×10^{-7}
					Total Risk	2.4×10^{-7}

[a] These risks are in addition to risks associated with penetrating radiation from surface soils.
[b] The mobility of a child aged 1-6 is assumed to be restricted to vicinity of the home on Pit 4
[c] Assumes the child spends 24 hr/d, 350 d/y for 6 years in or near the home
[d] Results of Microshield calculations (Table E.3-8)
[e] The product of the total time exposed (hr/Life) and the dose rate (mRem/hr)
[f] The product of the total exposure (mRem/Life) and the dose to risk conversion factor from the WPA (6.2 E-07 risk/mRem) (DOE, 1993a)

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TABLE E.IV-41

RISKS FROM PENETRATING RADIATION FUTURE CONDITIONS - BURIED PIT MATERIAL ON-PROPERTY CT ADULT UNDER FUTURE LAND USE[a]

Source	Source Surface Area (m2)	Fraction of Time Exposed To Source Material[b] (unitless)	Total Time Spent Exposed to Source[c] (hr/Lifetime)	Dose Rate[d] (mRem/hr)	Total Exposure[e] (mRem/Life)	Risk[f] (risk/Life)
Pit 1	7680	0.051	4758	0.024	114	7.1×10^{-5}
Pit 2	4170	0.028	2583	0.057	147	9.1×10^{-5}
Pit 3	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]	NA[g]
Pit 4	7790	0.052	45093	7.8×10^{-6}	0.4	2.2×10^{-7}
Pit 5	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]
Pit 6	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]
Burn Pit	2020	0.013	24	0.14	3	2.1×10^{-6}
Clearwell	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]	NA[h]
					Total Risk	1.6×10^{-4}

[a]These risks are in addition to risks associated with penetrating radiation from surface soils.
[b]Calculated as the source area divided by the total area available to an on-property adult. (Area of OU1 = 151,000 m^2).
[c]Assumes the CT spends 250 d/y (6000 hr/y) for 9 years on-property. 1,000 hr/y of this time is spent outdoors and the remaining 5000 hr/y is spent indoors. The RME farms Pits 1 and 2 for 800 hr/y over 9 years. Thus the CT spends 45,000 hrs indoors in structures build on Pit 4; 7,200 hrs on Pits 1 and 2; and the remaining 1,800 hrs roaming randomly over the operable unit. Shielding by the home is not considered in this calculation.
[d]Results of Microshield calculations (Table E.3-8)
[e]The product of the dose rate (mrem/hr) and the total time exposed (hr/lifetime).
[f]The product of the total exposure (mrem/Life) and the dose to risk conversion factor from the WPA (6.2 E-7 risk/mrem) (DOE, 1993a)
[g]Cover over source is gone. Exposed waste treated as surface soil (Table E.IV-74)
[h]Source covered by deep standing water. Exposures to an individual standing on the shoreline are negligable.

TABLE E.IV-42

RISKS FROM PENETRATING RADIATION FUTURE CONDITIONS - BURIED PIT MATERIAL ON-PROPERTY HOME BUILDER UNDER FUTURE LAND USE[A]

Source	Source Surface Area (m^2)	Fraction of Time Exposed To Source Material[b] (unitless)	Total Time Spent Exposed to Source[c] (hr/Lifetime)	Dose Rate[d] (mRem/hr)	Total Exposure[e] (mRem/Life)	Risk[f] (risk/Life)
Pit 4	7790	1.0	1400	7.8×10^{-6}	1.1×10^{-2}	6.8×10^{-9}
					Total Risk	6.8×10^{-9}

[a] These risks are in addition to risks associated with penetrating radiation from surface soils.
[b] Assumes the home is built on Pit 4, as described in the conceptual model.
[c] Assumes the home builder builds a house in 175 days for 8 hours per day.
[d] Results of Microshield calculations (Table E.3-6)
[e] The product of the total time exposed (hr/Life) and the doserate (mRem/hr)
[f] The product of the total exposure (mrem/Life) and the dose to risk conversion factor from the WPA (6.2 E-7 risk/mRem) (DOE, 1993a)

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