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VOLUME 3 OF 5 PART II, PART III
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SITE-WIDE CHARACTERIZATION REPORT

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 3 of 5
PART II, PART III

AUGUST 1992

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

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PART II

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PART II
PRELIMINARY BASELINE RISK ASSESSMENT

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

AUGUST 1992

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LIST OF ACRONYMS

AMS	air monitoring station	
BEIR	Biological Effects of Ionizing Radiation	
CERCLA	Comprehensive Environmental Response Compensation and Liability Act	
CERCLIS	Comprehensive Environmental Response Compensation and Liability Information System	
CI	confidence interval	
CIS	Characterization and Investigation Study	
CLP	Contract Laboratory Program	
CRQL	Contract Required Quantitation Limit	
DCG	derived concentration guide	
DDT	dichloro-diphenyl-dichloro-ethane	
DOE	U.S. Department of Energy	
ECAO	Environmental Criteria Assessment Office	
EE/CA	Engineering Evaluation/Cost Analysis	
EIS	environmental impact statement	
EPA	U.S. Environmental Protection Agency	
FEMP	Fernald Environmental Management Project	
FIDLER	Field Instrument for Detection of Low Energy Radiation	
FMPC	Feed Materials Production Center	
GI	gastrointestinal	
GM	Geiger-Mueller	
GMR	Great Miami River	
HEAST	Health Effects Assessment Summary Tables	
HI	Hazard Index	
ICRP	International Council on Radiation Protection	
ILCR	incremental lifetime cancer risk	
IRIS	Integrated Risk Information System	
ISC	Industrial Source Complex	
ISCLT	Industrial Source Complex Long Term	
LOEL	lowest observed effects level	
LOAEL	lowest observed adverse effect level	
MSL	mean sea level	
MUSLE	Modified Universal Soil Loss Equation	

LIST OF ACRONYMS
(Continued)

NAAQS	National Ambient Air Quality Standards	1
NEPA	National Environmental Policy Act	2
NESHAPS	National Emission Standards for Hazardous Air Pollutants	3
NOEL	no observed effects level	4
NOAEL	no observed adverse effect level	5
OEPA	Ohio Environmental Protection Agency	6
ORP	Office of Radiation Programs	7
ORSANCO	Ohio River Valley Sanitation Commission	8
OU	operable unit	9
PBRA	Preliminary Baseline Risk Assessment	10
PCB	polychlorinated biphenyl	11
PIC	pressurized ionization chamber	12
QA/QC	quality assurance/quality control	13
QAPP	Quality Assurance Project Plan	14
RBQL	Risk-Based Quantitation Limit	15
RCRA	Resource Conservation and Recovery Act	16
RfD	reference dose	17
RI/FS	remedial investigation/feasibility study	18
RME	reasonable maximum exposure	19
RMP	Radiation Measurement Program	20
SOWC	Southern Ohio Water Company	21
SQL	sample quantitation limit	22
SSOD	Storm Sewer Outfall Ditch	23
SWCR	Site-Wide Characterization Report	24
SWOAPCA	Southwestern Ohio Air Pollution Control Agency	25
TCLP	Toxicity Characteristic Leaching Procedure	26
TIC	tentatively identified compound	27
UCL	upper 95% confidence limit on the mean	28
USLE	Universal Soil Loss Equation	29
UTL	upper 95% tolerance limit	30
WEMCO	Westinghouse Environmental Management Company of Ohio	31
WLM	working level month	32
WM	working months	33
WMCO	Westinghouse Materials Company of Ohio	34

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PART II SUMMARY

20B

PART II SUMMARY

INTRODUCTION

In accordance with the requirements of the Amended Consent Agreement, dated September 20, 1991, between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), a Preliminary Baseline Risk Assessment (PBRA) has been prepared for the Fernald Environmental Management Project (FEMP) (formerly the Feed Materials Production Center [FMPC]). This risk assessment fulfills the requirement for a PBRA for the entire FEMP site as specified in Section X, Paragraph I, of the Amended Consent Agreement. The role of the PBRA in the Remedial Investigation Feasibility Study (RI/FS) at the FEMP is discussed in greater detail in Section 2.0 of the RI/FS Risk Assessment Work Plan Addendum. The PBRA has been performed in accordance with the requirements specified in the Amended Consent Agreement and the methodologies presented in the Addendum.

The primary objective of this risk assessment is to present the site-wide risks for current and potential future exposure scenarios under baseline conditions. The PBRA characterizes the current and potential future threats to human health and the environment that may be posed by all constituents and all exposure pathways from the FEMP site. Baseline conditions are those conditions that prevail if no further action is taken at the site; however, the PBRA is performed taking into account the benefits of removal actions that were fully implemented as of December 1, 1991. The PBRA is based on all FEMP data available as of December 1, 1991.

DATA EVALUATION AND SELECTION OF CONSTITUENTS OF CONCERN

The first portion of the risk assessment involves compilation and evaluation of data that characterize the site and the selection of constituents of concern. In this portion of the risk assessment the sources of data that characterize the site are summarized, the methods for evaluating analytical results are described, and the selection of constituents of concern is defined.

The description of the sources of data that characterize the site includes consideration of those data that characterize the FEMP property and site-influenced environmental media, and those data used to characterize background levels that are not attributable to the site. The presentation of the methodology for evaluating data includes a summary of statistical approaches used to compare site-related data to background data, determine distributions of data, and summarize the distributions with statistical parameters. The selection of constituents of concern is presented and is based on the statistical data evaluation methods described and additional nonstatistical considerations from EPA risk assessment guidance.

Selected constituents of concern are presented in summary form in Section 2.0 by waste area and environmental medium. Statistical summary parameters presented include background upper tolerance limit values, and mean and upper confidence level site-related values.

EXPOSURE ASSESSMENT

The second portion of the risk assessment involves assessing potential exposures to selected constituents of concern that could impact potential human receptors. In this portion of the risk assessment the exposure setting is characterized, potential exposure pathways are formulated and selected for complete quantitative evaluation, and potential exposures are quantified for the selected site-specific exposure pathways.

The characterization of the exposure setting includes description of the physical setting and definition of potentially exposed receptors and land use assumptions employed to quantify potential exposures. The exposure pathway selection process begins with the development of all reasonable quantifiable exposure pathways by medium, land use type, and potentially exposed receptor. Each pathway that is quantitatively evaluated is described in detail and the basis for selecting or excluding each pathway for quantitative assessment is presented. The presentation of exposure quantification for the selected pathways and receptors includes the methods used to estimate receptor exposure point concentrations, including consideration of methods for estimating concentrations by using transport models. Estimated constituent exposure point concentrations and exposure parameter values are presented for each pathway quantitatively evaluated in the risk assessment. A discussion of contributions to uncertainty in the quantification of exposures appears at the end of Section 3.0.

TOXICITY ASSESSMENT

The third portion of the risk assessment involves assessing the toxicity or health impact of the constituents of concern selected in Section 2.0. The toxicity assessment presents available information on the health effects of constituents of concern. Detailed assessments of toxicity information are presented for primary constituents of concern at the site, and quantitative estimates of toxicity values are tabulated for all constituents of concern including the basis for quantitative toxicity estimates. Radionuclides, carcinogenic chemicals, and noncarcinogenic chemicals are addressed separately. The toxicity assessment includes identification of a number of uncertainties inherent in the quantitative toxicity estimates. These are important considerations because these estimates are used to characterize the risks to human health from exposure estimates quantified in Section 3.0.

RISK CHARACTERIZATION

The fourth portion of the risk assessment involves characterizing the risks associated with the exposure pathways selected in the exposure assessment. In this portion of the risk assessment the methodology used to quantify the risks and hazard indices is described, the quantitative risk results are presented in tabular form or in figures by land use scenario and exposure medium, the contributions to uncertainties

in the risks are identified and their impacts discussed, and the risk characterization is summarized. Section 5.5.4.1 summarizes the risk characterization results, Section 5.5.4.2 uses the risk information generated in this risk assessment to determine the preliminary site-wide RME individual and location, and Section 5.5.4.3 presents the risks calculated from background concentrations of site-related constituents of concern to provide perspective on both the methodology employed and the results obtained. The risk characterization results are discussed below.

SUMMARY RISK TABLES

Under the current land use scenario (with access controls) the radiological ILCRs exceed 1 x10^{-6} for each exposure medium. The highest ILCRs associated with radionuclides are about 3 x 10^{-4} for the off-property farmer (either surface or groundwater use) and the trespassing child (external radiation exposures). Chemical ILCRs indicate that risks from chemical carcinogens exceed 10^{-6} for exposure pathways associated with surface water, groundwater, and soil/waste. The ILCR calculated for the off-property farmer's exposures via groundwater is about 10^{-3}. ILCR's associated with the use of beef and dairy products grown with Great Miami River water or grazed on-property are 1 x 10^{-4} and 3 x 10^{-3}, respectively. The HI for the off-property farmer using groundwater is 280 (associated with intake of silver). The hazard indices of the off-property user of beef and dairy products produced using surface water from the Great Miami River and contaminated grazing land are 28 and 3.3 (associated with the intake of mercury), respectively.

Under the hypothetical current land-use scenario without access controls radiological ILCRs exceed 1 x10^{-6} for each exposure medium. The highest ILCRs for radionuclides in this scenario are 8 x10^{-3} for external radiation exposure of the trespassing child, 4 x 10^{-3} from using beef and dairy products from cattle raised on property, 3 x 10^{-3} for aerial exposures to the off-property farmer, 1 x 10^{-3} for scavenging activities, and 3 x 10^{-4} for the farmer using Great Miami River water and the off-property farmer using groundwater, respectively. With respect to pathways associated with soil and waste, the trespassing child scenario yields an ILCR of about 6 x 10^{-4}, and an HI of 1.5 (associated with intake of arsenic).

Under the future land-use scenario, the radiological ILCRs exceed 10^{-6} for all media. The radiological risk to the on-property farmer from exposure pathways associated with air, groundwater, soil/waste, and external radiation exposure are 2 x 10^{-2}, 1 x 10^{-2}, 3 x 10^{-1}, and 3 x 10^{-3}, respectively. The radiological ILCR for the hypothetical farmer using the Great Miami River is about 10^{-4} and the risk to an inhabitant of buildings and structures in the former production area is about 10^{-1}. ILCRs from chemical carcinogens in Table 5-46 reveal that the risks for the on-property farmer using groundwater and residing on contaminated soil/waste are approximately 10^{-3} and 10^{-1}, respectively. Hazard indices for the on-property farmer using groundwater and residing on contaminated soil/waste are 100 (uranium) and 150 (arsenic), respectively. The hazard index for an off-property user of surface water from the Great Miami River is 1.0 (associated with intake of uranium).

SITE-WIDE RME

The site-wide RME location is selected as the location which produces the greatest risks from all constituents, all sources, and all pathways. The information in Section 5.2 is used to determine this location for the current scenarios, and information in Section 5.3 is used to determine this location for the future scenarios.

Current Site-wide RME Location

It can be demonstrated that the highest CERCLA risks for radionuclides under current land use conditions (with access controls) are associated with groundwater wells to the south of the property. The estimated risks to the hypothetical off-property adjacent farmer from radionuclides exceed 3×10^{-4} for well 2061. Risks from exposures to airborne constituents are calculated to be 20% of these risks and extend to the east of the silos. Thus the adjacent off-property farmer using groundwater is the current preliminary site-wide RME individual. Due to prevailing weather patterns, the risks to this receptor (south of the FEMP) from air pathways are minor compared to those associated with groundwater use.

It is conceivable that the off-property farmer could use meat and dairy products from cattle raised on property. The presence of access controls limits additional risks to this hypothetical receptor from this pathway to about 2×10^{-4}.

Without existing access controls, the estimated CERCLA risks to the current hypothetical off-property receptor could increase to 1×10^{-1} from grazing on Pit 5 wastes. A closer examination of Pit 5 reveals that the surface area of the exposed pit wastes is too small to allow sustained grazing, and that it is not currently covered with vegetation. If this pit is removed from consideration for these reasons, risks for the off-property resident could approach 4×10^{-3} for this pathway. Thus, if access controls were removed, the current RME individual would shift to the off-property user of beef and dairy products grown on site.

Future Site-wide RME Location

It can be demonstrated that CERCLA risks from radionuclides in soils within Pits 3 and 5 are in excess of 10^{-1}. This is the location of maximum on-property risk. Both air and water exposures are estimated to produce risks which approach 10^{-2}. These risks are approximately 10% of the risks from Pit 3 soils. Therefore, risks from these soils dominate all other risks in the future scenario, and these locations must be carefully considered when locating the site-wide RME.

It is possible that a number of media could combine and produce a new aggregate risk exceeding the risks from waste pit soils. To investigate this, the magnitude and spatial distribution of risks from the air and groundwater plumes are examined, and compared to the magnitude and spatial distribution of risks associated with soils at the FEMP.

This comparison reveals a receptor in the SW Quadrant of the former production area could be exposed to risks in excess of 10^{-3} from soil, air and water pathways at the same time. The Plant 2/3 area is associated with some of the highest risks from soil pathways, outside of the waste pit area. These soil related risks are about 5 x 10^{-3}. If the silo caps fail in the next 1000 years, the center of the plume from the silos is predicted to pass over Plant 2/3 in the SW quadrant of the former production area. Risks from airborne contamination (both particulates and radon) in this area of the former production area could approach 10^{-3}. The use of groundwater beneath the southern portion of the former production area by a resident farmer could produce risks in excess of 10^{-3}.

Using information on the exposure point concentrations of the various media within the Plant 2/3 area, the risks from radionuclides were calculated for a variety of receptors. The relative sensitivities of four different receptors to radionuclides predicted to be present in air, water, and soil were quantitatively assessed. The combined risks from all media in the Plant 2/3 area do not approach those risks estimated for a farmer on waste pit soils. Therefore, the Plant 2/3 area is not considered further in the determination of the RME location.

Returning to the waste area, examination of the radiological risks from Pit 3 soils reveals a major portion of these risks can be attributed to external radiation exposure risks from radium-226 and its daughters. In addition, the risks from Pit 3 soils contain a sizable contribution from technetium-99 via the dairy product pathway. However, the data upon which the technetium-99 numbers are based may be suspect. These are unvalidated data available as of December 1, 1991, and yield exposure point concentrations well in excess of what may reasonably be suspected to be present, based on process history and data made available after December 1. This additional data, collected since December 1, 1991, will be presented in the Operable Unit 1 RI report to clarify this point. Additional contributors include lead-210 (vegetable and fruit), and thorium-232 (gamma). Even discounting the risks associated with technetium-99, risks in the waste area exceed 10^{-1} in places. Thus the farmer on the Operable Unit 1 waste pits appears to be the leading candidate for the preliminary site-wide maximally exposed individual for radionuclides.

Background Risks

ILCRs and HIs were calculated under the RME resident farmer scenario using the upper 95% confidence interval on the mean for regional background data as exposure point concentrations. This was the only data available as of December 1, 1991. These results should be used as a point of reference when interpreting risk results from radionuclides and inorganic chemicals in soils under this scenario.

Background concentrations of radionuclides in air, water, and soil yield ILCRs ranging from 10^{-7} to 10^{-4}. The aggregate radiological risks from background are calculated to be about 10^{-3}. The highest risk from a single radionuclide and pathway is about 10^{-3} from Rn-222 in air. Background levels of beryllium are calculated to produce an ILCR of approximately 3×10^{-5}.

Background concentrations of nine constituents in soil yield HIs greater than 0.2: arsenic (0.9), barium (0.5), chromium (0.2), cobalt (0.2), lead (0.9), manganese (1), mercury (3), thallium (5), and zinc (3).

Results of the PBRA will not be used to determine whether remediation is needed for waste areas at the FEMP. Operable Unit RI reports, including baseline risk assessments, will serve that purpose. Results of the PBRA indicate that application of the same exposure assumptions and model parameters in operable unit baseline risk assessments will lead to very high risk calculation results. Indeed, application of these exposure assumptions and model parameters for natural background concentrations of constituents (especially radionuclides) leads to lifetime cancer risks exceeding 10^{-2}.

Major uncertainties associated with the risk assessment results include those associated with source terms, land use assumptions and exposure scenarios, fate and transport models, exposure assessment parameters, and toxicity assessment. It is important to note that uncertainties associated with early stages of the risk assessment, e.g., with the data evaluation stage, are propagated through the subsequent stages of the risk assessment. The uncertainty analysis is not highly quantitative due to the nature and scope of an RI/FS risk assessment.

Of major importance in understanding risk results is that application of the future land-use scenario may significantly overestimate future risks. The resident farmer scenario is highly unlikely, although plausible. Most of the waste areas at the site are too small to support a resident farmer, who is assumed to live, farm, and raise livestock and vegetables on top of the waste area for 70 years. This assumption leads to a significant overestimation of the risk since the great majority of contaminants are located in these relatively small waste areas. Nevertheless, the assumption of the resident farmer for future land use provides the upper-bound values for the risk assessment.

ECOLOGICAL ASSESSMENT

The purpose of the ecological assessment is to estimate the potential present and future baseline risks of FEMP contaminants to ecological receptors. These receptors include all organisms, exclusive of humans and domestic animals, potentially exposed to FEMP contaminants. The ecological assessment focused on a group of indicator species selected to represent a variety of exposure pathways and trophic positions. Terrestrial vegetation was represented by a generic plant species. Terrestrial wildlife species to be evaluated were selected based on species abundance on the FEMP, trophic level position, and habitat requirements. The species evaluated were the white-tailed deer (*Odocoileus virginianus*), white-footed mouse (*Peromyscus leucopus*), raccoon (*Procyon lotor*), red fox (*Vulpes*),

muskrat (Ondatra zibethica), American robin (Turdus migratorius), and red-tailed hawk (Buteo jamaicensis).

The assessment examined risks to terrestrial organisms associated with contaminants in two environmental media -- surface soils, summarized for the entire site, and surface water in Paddys Run from the northern boundary of the FEMP to the confluence with the storm sewer outfall ditch. Risks to aquatic organisms were evaluated for exposure to contaminants in Paddys Run, the Great Miami River, and in runoff into the storm sewer outfall ditch. All nonradioactive and radioactive constituents identified as of potential concern in the human health risk assessment before screening of constituents of greatest human health risk were considered to be of concern for the ecological risk assessment. Estimated ecological risks associated with exposure to FEMP constituents of concern are primarily due to nonradioactive inorganic chemicals in soils, rather than to organic chemicals or radionuclides. This is true for both terrestrial and aquatic organisms and for plants as well as wildlife. In particular, estimated intakes of arsenic, cobalt, lead, and silver from FEMP soils were all higher than estimated no observed effect levels (NOELs) for at least six of the seven indicator species selected for this assessment. The relative hazards to individual species varied, but the white-footed mouse consistently had the highest hazard indices for these chemicals.

This can be attributed to the assumed intake by the mouse of insects (earthworms), which in turn were assumed to assimilate chemicals from soil with a transfer coefficient of 1.0. The American robin was also exposed to relatively high levels of soil contaminants via this pathway. Contaminant intake and associated hazard indexes for the top carnivores among the indicator species, the red fox and the red-tailed hawk, were sensitive to assumptions about muscle-to-muscle transfer factors, as described above. If muscle-to-muscle transfer is comparable to plant-to-beef transfer, the estimated hazard was relatively low, but increased dramatically when assumed to be 1.0.

Estimated hazards to terrestrial organisms of exposure to constituents of concern in FEMP surface waters were relatively low, with hazard indexes (HIs) greater than one only for arsenic, lead, molybdenum, and silver. These chemicals presented hazards to two, five, four, and three species, respectively, and the highest HI estimated was 5.0 for lead intake by the mouse. Surface water exposure is therefore unlikely to be a significant source of risk to terrestrial ecological receptors at the FEMP.

Estimated radiation doses to terrestrial organisms at the FEMP, originating from soil uptake by plants and earthworms, were below levels expected to cause detectable effects. However, as with inorganic chemicals, this conclusion is sensitive to assumptions about muscle-to-muscle transfer of radionuclides. Highly efficient transfer or biomagnification of uranium, in particular, could expose terrestrial wildlife at the FEMP to potentially harmful radiation levels. Radiation doses due to water intake were insignificant.

Exposure to radiological contaminants does not appear to pose a risk to aquatic organisms at the measured concentrations in the surface waters and sediments impacted by the FEMP. However, modelled concentrations of radionuclides in runoff from the FEMP into surface water would cause estimated exposures to exceed the upper limit of 1 rad/d for all aquatic organisms, except for muskrats. The most affected organisms would be aquatic plants, receiving a total dose from internal and external exposure of about 140 rad/d. The total dose to fish is minimally over the limit, at 1.6 rad/d, and the total dose to benthic macroinvertebrates is about 14 rad/d. Although the maximum concentrations at low flow were used in the source runoff calculations, the minimum values in the SSOD and Paddys Run are within the same magnitude of values. Doses to aquatic organisms in the Great Miami River would be well below 1 rad/d. The measured concentrations of cadmium, copper, mercury and silver in surface water exceeded chronic toxicity criteria for the protection of freshwater organisms.

Field studies on the impact of the FEMP on terrestrial and aquatic communities do not indicate any effects consistent with contaminant impacts, except for above-background levels of arsenic and mercury recorded in RI/FS plant samples. In addition, although potential impacts at the individual level were predicted for wildlife species, detrimental or adverse impacts have not been observed in the field. This suggests that the potential exposures predicted by modeling may not occur in the field or that the resulting potential effects may not occur. A comparison of the concentrations of inorganic chemical concentrations in FEMP soils to regional background values indicates that mean FEMP concentrations may be similar to the upper 95 percent confidence levels of background values. This suggests that ecological risks estimated using background values of inorganics would be comparable to those estimated for the FEMP, and emphasizes the conservative nature of the method used. Additional important sources of uncertainty include 1) the efficiency of contaminant transfer among trophic levels, in particular muscle-to-muscle transfer described previously, 2) the use of laboratory toxicity data to predict effects on species in the field, and 3) the assumptions and uncertainty factors incorporated into estimates of NOELs. Uncertainty associated with radiation dose assessment includes the assumptions that the dose is completely absorbed and that the radionuclides are uniformly distributed in tissue. Departures from these two assumptions would tend to decrease and increase tissue-specific doses, respectively.

Uncertainties in the assessment of toxic effects to aquatic biota include potential interactive effects of chemicals, differences between effects observed in the laboratory and those which may occur in the field, and differences in the relative sensitivities of species to chemicals.

In summary, although radionuclides are the most ubiquitous contaminants at the FEMP, estimated ecological risks to both terrestrial and aquatic organisms are primarily associated with nonradioactive inorganic chemicals. Although estimated risks are substantial in some instances, they are based on soil inorganic chemical concentrations comparable to background levels, and deleterious effects have not been observed in the field. This suggests that current FEMP-specific ecological risks are low, but that

remedial actions are appropriate to prevent potential future ecological harm as well as to limit human exposures to FEMP contaminants.

NEPA ANALYSIS

Included with the PBRA is a NEPA analysis of the environmental consequences of the no action alternative. This analysis was based on an evaluation of several assumptions including no further production at the facility; only the Silos 1 and 2, K-65 Decant Sump Tank, and Waste Pit 6 removal actions will be considered complete; mixed wastes will remain on-property and RCRA wastes will be shipped off-property and disposed of commercially; a gradual leakage of contaminants may occur and implemented removal actions may not eliminate all future migration of contaminants; existing FEMP monitoring systems and existing access restrictions will not continue in operation; and anticipated future land use scenarios include on-property residential use. Included in the analysis are air quality, surface waters, groundwater, wetlands, soils, ecology, socioeconomic factors, and cultural resources.

Under the no action alternative, the FEMP would effectively be abandoned and left as is. There would be no remedial action to mitigate existing sources of contamination or any media contaminated by previous activities at the site. In both current and future scenarios, the continued release of contaminants to various media is possible. These releases may result from deterioration of waste containment systems, continued air and water erosion of contaminated soils, or the various chemical/physical processes ongoing in groundwater. In addition to the possible threat to human health and the environment associated with no action at the site, the local economy may be impacted by public perceptions of the situation at the FEMP.

Despite the "no production" status of the FEMP, there is a potential for additional emissions to air. Currently, existing areas of contamination may continue to release to the air. In the future, the gradual deterioration of waste containment systems may expose additional contaminants to movement through resuspension in the air. The downwind concentrations of contaminants may vary widely, depending on atmospheric conditions.

Under the no action alternative, current impacts of the FEMP on the Great Miami River, Paddys Run, and the SSOD would continue. Impacts to the Great Miami River include releases of radionuclides and inorganic chemicals via the FEMP effluent line and Paddys Run. However, the existing site-related concentrations of these substances in the Great Miami River are virtually undetectable with the exception of uranium, which is low. Impacts to Paddys Run include radioactive and chemical contamination associated with erosion of contaminated soils from the waste pit area and the erosion of wastes or contaminated soils from the active flyash pile into the SSOD. Current potential impacts of the FEMP on Great Miami River, Paddys Run, and the SSOD sediments include radioactive and chemical contamination. Future impacts on sediments would be correlated with impacts on surface waters. Contamination of sediments at specific sites in Paddys Run is unlikely to be stable, due to the

highly variable flow regime in the stream, with consequent frequent transport and redeposition of stream bed material. The no action alternative would likely have no current or future impacts on floodplains in the Great Miami River and Paddys Run. Future indirect impacts on wetlands could vary widely as a result of erosion of wastes or contaminated soils.

Under the no action alternative, existing contaminated groundwater would continue migrating to currently unaffected areas. In the future, contaminant loading rates to the aquifer from most sources will increase. Many of these sources will continue releasing contaminants to the aquifer beyond 1000 years in the future. Contaminated perched groundwater might also migrate to the aquifer over time. The perched groundwater beneath the waste storage and former production areas pose the most serious threat. Under the no action alternative, groundwater modeling predicts future groundwater uranium concentrations much higher than those currently measured. Wastes remaining on the site are expected to migrate to the aquifer to form a large and highly concentrated uranium plume, extending beyond the eastern FEMP boundary. This plume is anticipated to remain above levels of concern beyond 1000 years in the future.

With implementation of the no action alternative, contaminated soils would continue to be lost to air, surface water and groundwater. Future impacts to FEMP soils may be associated with increased releases of contaminants through deterioration of waste containment systems, with related impacts to air, surface water and groundwater. These impacts are expected to be greater than under present conditions due to gradual release of wastes remaining on site, the abandonment of existing environmental monitoring systems, and the removal of existing land use and site access restrictions.

Overall, current and future impacts to the local ecology are associated primarily with exposure to nonradioactive inorganic chemicals, including arsenic and mercury. Current and future estimated radiation doses are relatively low compared to those reported to have chronic to acute effects on plants and animals. However, exposure to stored wastes, to the most contaminated soils on-property, or to the higher of predicted radionuclide concentrations in FEMP runoff could cause radiation doses hazardous to terrestrial and aquatic plants and animals.

The implementation of a no action alternative at the FEMP should not affect the local labor force, transportation systems, community services, utilities, recreation, housing, or cultural resources. Commercial establishments in the immediate vicinity might experience a decline in daytime clientele, however, this should not result in business failures. Land use adjacent to the FEMP should remain predominantly agricultural for the next 20 years. Value of adjacent land should remain slightly below similar properties farther from the site.

1.0

30A

1.0 INTRODUCTION TO THE PRELIMINARY BASELINE RISK ASSESSMENT

In accordance with the requirements of the Amended Consent Agreement, dated September 20, 1991, between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), a Preliminary Baseline Risk Assessment (PBRA) has been prepared for the Fernald Environmental Management Project (FEMP) (formerly the Feed Materials Production Center [FMPC]). This risk assessment fulfills the requirement for a PBRA for the entire FEMP site as specified in Section X, Paragraph I, of the Amended Consent Agreement. The role of the PBRA in the Remedial Investigation Feasibility Study (RI/FS) at the FEMP is discussed in greater detail in Section 2.0 of the RI/FS Risk Assessment Work Plan Addendum (Addendum) (DOE 1992a). The PBRA has been performed in accordance with the requirements specified in the Amended Consent Agreement and the methodologies presented in the Addendum. The use of methods and assumptions that deviate from or are not covered within the Addendum are identified appropriately.

1.1 OBJECTIVES

The primary objective of this risk assessment is to present the site-wide risks for potential current and future exposure scenarios under baseline conditions. The PBRA characterizes the current and potential future threats to human health and the environment that may be posed by all constituents and reasonable exposure pathways from the FEMP site. Baseline conditions are those conditions that prevail if no further action is taken to clean up the site; however, the PBRA is performed taking into account the benefits of removal actions that were fully implemented as of December 1, 1991. The PBRA is based on all data pertaining to the FEMP available as of December 1, 1991.

1.2 BACKGROUND

The baseline risk assessment process is depicted in Figure 1-1. The following tasks are performed in a baseline risk assessment:

- Identification of all radionuclides and chemicals of potential concern at the site
- Assessment of exposures to site-related radionuclides and chemicals of potential concern
- Assessment of the toxicity of site-related radionuclides and chemicals of potential concern
- Quantification of the risks to human health
- Quantification of the risks to ecological receptors

3578

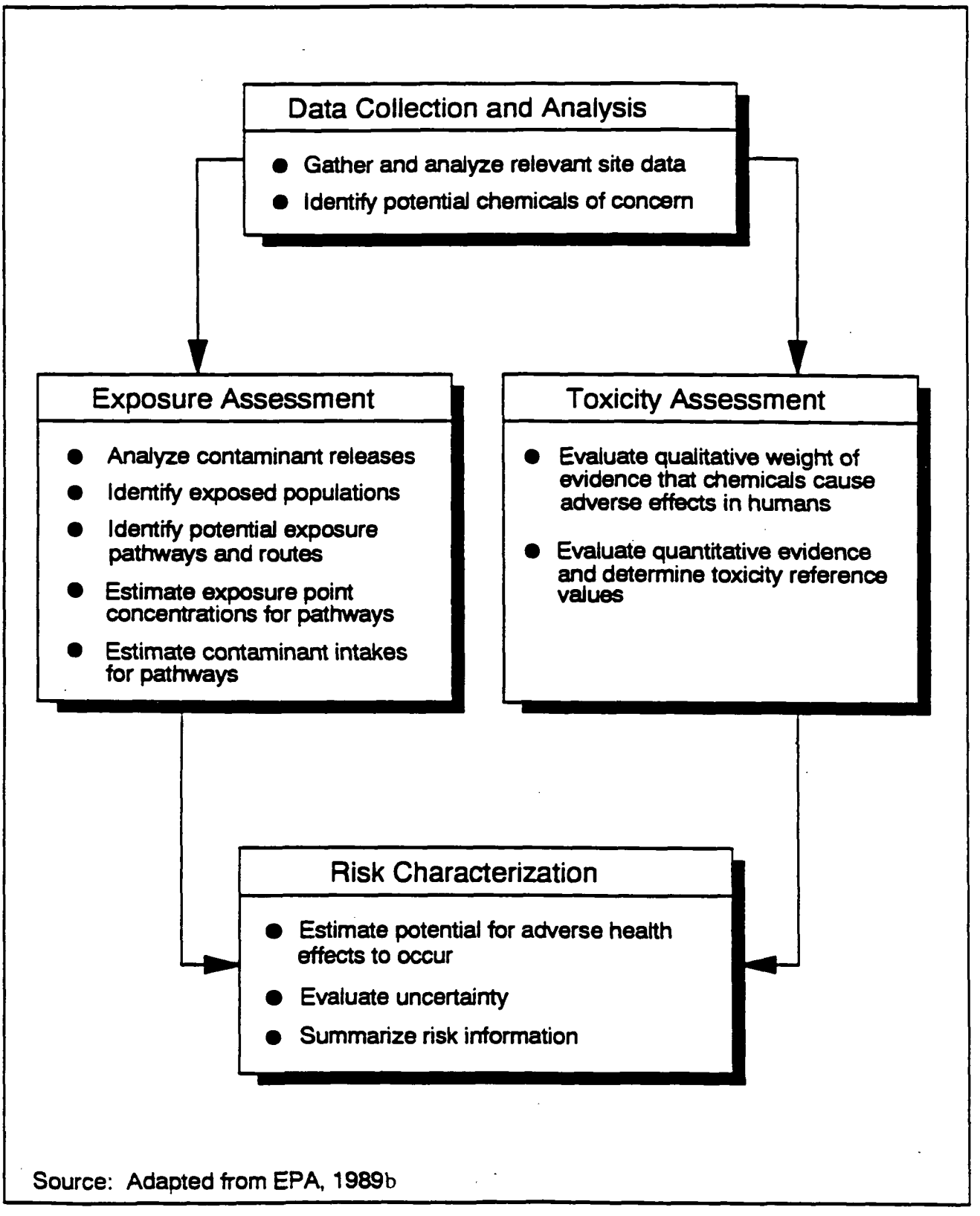


FIGURE 1-1
BASELINE RISK ASSESSMENT PROCESS

The risk assessment process produces results that characterize the potential threats to human health and the environment, satisfying the objective of the baseline risk assessment.

Data pertaining to the site conditions were assembled by DOE as part of the development of the RI/FS Work Plan. Since that time, a considerable amount of new information on the potential sources of contaminants and the nature and extent of environmental contamination at the site has been generated through the operable unit RIs and through other environmental programs at the FEMP. Although much of this information has been compiled and presented in draft reports for individual operable units, there has not been a presentation of all data to characterize the entire site. RI/FS risk assessment activities have produced a significant understanding of the baseline risks from the FEMP site on an operable unit basis. The baseline risk assessment activities support the operable unit RIs by evaluating the potential threat to human health and the environment in the absence of remedial action. However, the operable unit baseline risk assessments do not present the risks from the entire site.

1.3 SPECIAL CONSIDERATIONS FOR THE SITE-WIDE RISK ASSESSMENT

The PBRA addresses the entire FEMP site rather than individual operable units. In this site-wide assessment, the reasonable maximum exposure (RME) from all exposure pathways and all constituents is estimated. This assessment has not been performed previously for the RI/FS at the FEMP and is an important part of the RI/FS process. The site-wide RME attributable to all media may be determined by identifying the location at which the simultaneous exposure from all media is the reasonable maximum. Diagrams of the site depicting risk isopleths for individual environmental media facilitate determination of the RME.

In the PBRA, the transport of constituents in all media from all portions of the FEMP site is modeled for evaluations of potential future exposure pathways and for evaluations of potential current exposure pathways for which sample analytical results are not available. This modeling effort supports the exposure assessment process in the PBRA. This aspect of the baseline risk assessment also has not been performed previously for the RI/FS at the FEMP and is an important part of the RI/FS process.

The PBRA evaluates baseline conditions that include those removal actions that were fully implemented as of December 1, 1991, and for which postremoval action sample analytical results are available. This approach is consistent with the concept of a baseline risk assessment, which addresses the existing condition of the site. Because of the December 1, 1991 cutoff date for data used in the SWCR, some RI/FS data that will appear in later operable unit RI reports do not appear in the SWCR. In addition, because the scope of the SWCR does not require the use of validated data, while the scope of operable unit RI reports does require the use of validated data,

some RI/FS data appear in the SWCR that will not necessarily appear later in the operable unit RI reports.

The preliminary status of RI characterization of Operable Unit 3 limits the extent of risk assessment activities that are performed for these areas of the site in the SWCR. Sample analytical results available for drummed wastes (primarily uranium analyses) are used to estimate source terms for modeling potential future contributions to contamination of the regional aquifer. Analytical results of surface contamination surveys and radiation dose rate surveys in buildings and facilities are used to estimate potential exposures of on-property visitors or trespassers.

The PBRA is an important precursor of the operable unit FS Comprehensive Response Action Risk Evaluations to be appended to each operable unit FS report, as specified in the Amended Consent Agreement. The PBRA fulfills the need for an initial analysis of the no-action alternative for the entire site.

1.4 ORGANIZATION

The PBRA is Part II of the SWCR. Constituents of potential concern are identified in Section 2.0. This section discusses data sources used in the PBRA within the context of a hierarchy developed on the basis of data quality criteria. Section 2.0 also presents the methodology used to determine the constituents of potential concern and lists the constituents of potential concern in tabular form (Tables 2-3 through 2-29).

The exposure assessment is addressed in Section 3.0. This section discusses potential sources of constituents of concern, land use at the FEMP and surrounding area, and potentially exposed populations and subpopulations in a characterization of the site setting. Exposure pathways are identified, and the most significant pathways are selected and quantitatively evaluated. Finally, uncertainties in the exposure assessment are identified and their potential impacts are evaluated.

Section 4.0 presents the results of the toxicity assessment, including toxicity information for noncarcinogenic effects, carcinogenic effects, and constituents for which no EPA toxicity values are available. Uncertainties related to toxicity information are also presented.

Risks are characterized in Section 5.0. This section presents the risk characterization methodology and results for current and future land-use scenarios. Uncertainties associated with risk characterization are presented.

Section 6.0 presents the assessment of ecological effects from the site under baseline conditions. The ecological assessment covers impacts on terrestrial plants and animals and aquatic organisms.

The ecological assessment contains a brief summary of the habitats and potential ecological receptors at the FEMP and surrounding area, quantitative evaluations of direct and indirect exposures of ecological receptors including terrestrial plants and animals and aquatic organisms, and comparison of estimated exposure concentrations and radiation doses to values reported in the literature to cause effects.

Section 7.0 presents the National Environmental Policy Act (NEPA) Analysis of Environmental Consequences. This is an analysis of the environmental impacts of the no-action alternative on the entire FEMP site, which is required in accordance with DOE policy on NEPA/Comprehensive Environmental Response Compensation and Liability Act (CERCLA) integration as described in DOE Order 5400.4. The analysis addresses impacts on air quality, groundwater, surface water, the ecology, and socioeconomic impacts.

2.0

30.B

2.0 SELECTION OF CONSTITUENTS OF POTENTIAL CONCERN

This section of the baseline risk assessment presents the methodology for selecting constituents of potential concern and the results of this selection for the entire FEMP site. The primary method for selection of constituents of potential concern involves statistical comparison of constituent concentrations that can be attributed to the site with background concentrations. The constituents of potential concern identified in each of the source areas and the environmental media will be carried through the remainder of the risk assessment.

Section 2.1 provides a list of site-related data sources considered relevant for qualitative or quantitative use in the human health risk assessment. (Additional data sources suitable for the ecological risk assessments are presented in Section 6.0.) These data sources are presented in a hierarchy for use as described in the Addendum (DOE 1992a). The rationale for determining the hierarchy for data sources is reviewed. Before statistical evaluation and summarization were performed for the site-related data, the data were grouped according to the methods described in this section. The criteria for evaluating the suitability of these data for use in the quantitative risk assessment are also provided in Section 2.1.

Section 2.2 gives the criteria for determining whether a given constituent is of potential concern. The statistical approach for comparing the site-related concentrations with measured background concentrations is given. Non-statistical criteria used in conjunction with the statistical comparative methods to select constituents of potential concern are also discussed. These methods and criteria are summarized in Section 2.2 since they have been addressed in detail in the Addendum (DOE 1992a).

Section 2.3 presents the selected present and future constituents of potential concern by environmental medium or source medium as appropriate. Detailed information needed for selection such as frequency of detection, range of detected concentrations, distribution for site-related data, and the reason for inclusion or exclusion of each chemical or radionuclide as a constituent of potential concern are given in the data summary tables contained in Appendix R.

2.1 SITE-WIDE DATA SOURCES

Because the data obtained from the RI/FS and other studies serve a variety of purposes and exhibit varying levels of quality, only a subset of this information is generally useful for risk assessment. The data appropriate for risk assessment are used to:

- Characterize the site
- Model the fate and transport of constituents
- Estimate exposures.

All data used in the PBRA evaluations are previously existing, and not validated data. Data generated in the RI/FS process are given first consideration for use in the risk assessment because these data are the most current and most reliable based on the RI/FS quality assurance/quality control (QA/QC) practices. Existing databases generated by Westinghouse Environmental Management Company of Ohio (WEMCO), formerly Westinghouse Materials Company of Ohio (WMCO), and its subcontractors in the environmental monitoring program and in the Characterization Investigation Study (CIS) (Weston 1987) are considered as secondary sources because QA/QC procedures associated with these data are not fully documented. The primary data are used for quantitative risk assessment calculations. Secondary sources are used for quantitative risk assessment only when primary sources do not contain the necessary (or sufficient) data. If a secondary data source is used to assist the primary data source qualitatively, the use of the secondary data is described.

2.1.1 Data Sources Used for Risk Assessment

Data sources employed for the risk assessment are listed in Table 2-1 for the following environmental and source media:

- Silos 1, 2 and 3
- Air
- Surface water/sediment (including standing water in waste units)
- Groundwater
- Soil
  - Surface soil
  - Subsurface soil
- Plants, buildings, and drums in the former Production Area.

Use of the site-related data obtained from these data sources for the risk assessment are briefly described in Sections 2.1.1.1 through 2.1.1.7.

TABLE 2-1
SOURCES OF DATA USED FOR HUMAN HEALTH RISK ASSESSMENTS

SILO CONTENTS

Data Sources	Hierarchy
ASI/IT RI/FS database, 1991	First
Westinghouse Materials Company of Ohio (WMCO), May, June, and July 1989, Silo Contents	Second
Westinghouse Materials Company of Ohio (WMCO), 1985-1991, "Feed Materials Production Center Annual Environmental Monitoring Report"	Second
Westinghouse Environmental Management Company of Ohio (WEMCO), 1991, Environmental Monitoring Data	Second

AIR

Data Sources	Hierarchy
Westinghouse Materials Company of Ohio (WMCO), 1985-1990, "Feed Materials Production Center Annual Environmental Monitoring Report"	Second
Westinghouse Environmental Management Company of Ohio (WEMCO), 1991, Environmental Monitoring Data	Second

SURFACE WATER / SEDIMENTS

Data Sources	Hierarchy
ASI/IT RI/FS database, 1988-1991	First
Westinghouse Materials Company of Ohio (WMCO), 1985-1989	Second

GROUNDWATER

Data Sources	Hierarchy
ASI/IT RI/FS database, 1988-1991	First
ASI/IT, 1988, "RCRA Groundwater Monitoring Report, Vol. 6-Round 6 Sampling", prepared for Westinghouse Materials Company of Ohio (WMCO).	First

TABLE 2-1
(Continued)

SOILS

Radiation Measurement Programs

Data Sources	Hierarchy
ASI/IT RI/FS database, 1988-1991	First
Weston, 1987, "Characterization Investigation Study, Vol. 3: Radiological Survey of Surface Soils"	Second
EG&G, 1985, Energy Measurements "Aerial Radiological Survey of the Feed Materials Production Center (FMPC)."	Third

Surface Soil

Data Sources	Hierarchy
ASI/IT RI/FS database, 1988-1991	First
Weston, 1987, "Characterization Investigation Study, Vol. 3: Radiological Survey of Surface Soils"	Second

Subsurface Soil

Data Sources	Hierarchy
ASI/IT RI/FS database, 1988-1991	First
Weston, 1987, "Characterization Investigation Study, Vol. 1: Geophysical Survey"	Second
Weston, 1987, "Characterization Investigation Study, Vol. 2: Chemical and Radiological Analysis of the Waste Pits"	Second
Weston, 1987, "Characterization Investigation Study, Vol. 3: Radiological Survey of Surface Soils"	Second

PLANTS, BUILDINGS AND DRUMS (Operable Unit 3)

Data Sources	Hierarchy
Draft Operable Unit 3 Work Plan Addendum, Appendix A, 1992 (DOE 1992b)	First
Westinghouse Environmental Management Company of Ohio (WEMCO), 1991 (Memorandum from D. F. Smith to R. S. Shirley entitled "OU-3 Data Summary Tables," November 27, 1991).	Second

2.1.1.1 Silo Contents

Analytical results for silo contents sampled by WMCO during May, June, and July 1989 (WMCO 1989a) are summarized for quantifying groundwater modeling source terms. Additional silo content data were collected under the RI/FS and were only available for chemicals in Silo 2 as of December 1, 1991. This is also incorporated into the groundwater modeling source terms. Silo content data are also used as source terms for air modeling to estimate future radon concentration levels (see Section 2.1.1.2). Section R.1.0 of Appendix R contains silo content data.

2.1.1.2 Air

FEMP former production operations are the principal historical source of airborne radionuclide releases from the site. Deposition of historical airborne particulate emissions from the former Production Area was a major source of contamination for surface soil. Silos 1 and 2 (K-65 silos) are the predominant source of radon to the atmosphere at the FEMP. WEMCO regularly measures radon concentrations at various locations on the site. Two types of air monitoring are conducted on and off property at the FEMP. Radon monitoring stations are located near the K-65 silos and along the property boundary (see Figure 3-5 of Part I). Particulate air monitoring stations (see Figure 3-5 of Part I) monitor concentrations of uranium and other airborne radioactive particulates such as strontium-90 (Sr-90), technetium-99 (Tc-99), cesium-137 (Cs-137), ruthenium-106 (Ru-106), neptunium-237 (Np-237), and isotopes of radium, thorium, and plutonium. Nonradioactive airborne substances such as ammonia, hydrogen, fluoride, and nitric acid have been released from the FEMP in relatively small amounts. Concentrations of these substances in ambient air are not monitored. None of the six "criteria pollutants" (inhalable [PM 10] particulates, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone and lead) regulated under the Clean Air Act are routinely monitored in the immediate vicinity of the FEMP, because there are few sources of these pollutants nearby.

As indicated by the data obtained from radon monitoring stations at or near the silos, the emission of radon has been reduced recently to near-background levels by covering the residues in the silos with bentonite in November 1991 as part of the K-65 Silos Removal Action (EE/CA, DOE 1990a). Airborne radon concentration data from these radon monitoring stations have been collected preceding and following installation of bentonite in the K-65 silos. These data are summarized in Section R.2.0 of Appendix R. A comparison of the pre- and post-bentonite data illustrates the drastic reduction in radon concentrations at monitoring stations that was achieved by installation of the bentonite (see Section 2.3). Radon concentrations measured following installation of the bentonite provide an estimate of current on-property exposure levels, as well as a source term for air modeling of current off-property exposure levels.

Resuspension of residual contamination potentially contributes to current airborne contamination (see Section 4.1.2 in Part I). Site-related airborne particulate concentrations obtained from the air monitoring stations at the FEMP fenceline or off-property (WMCO 1991) are used to determine the Reasonable Maximum Exposure (RME) location for the exposure assessment for airborne contaminant transport pathways under current land-use conditions (see Section 3.0 of Part II for detail). For future land-use conditions, RME location(s) on and off the property are determined from airborne contaminants fate and transport modeling results (see Section 3.0 of Part II for detail). Potential future radon releases from the silos are considered. Because soil resuspension may be a major source for airborne contamination in the future, constituents of potential concern under future land-use conditions include many of the constituents identified in soil.

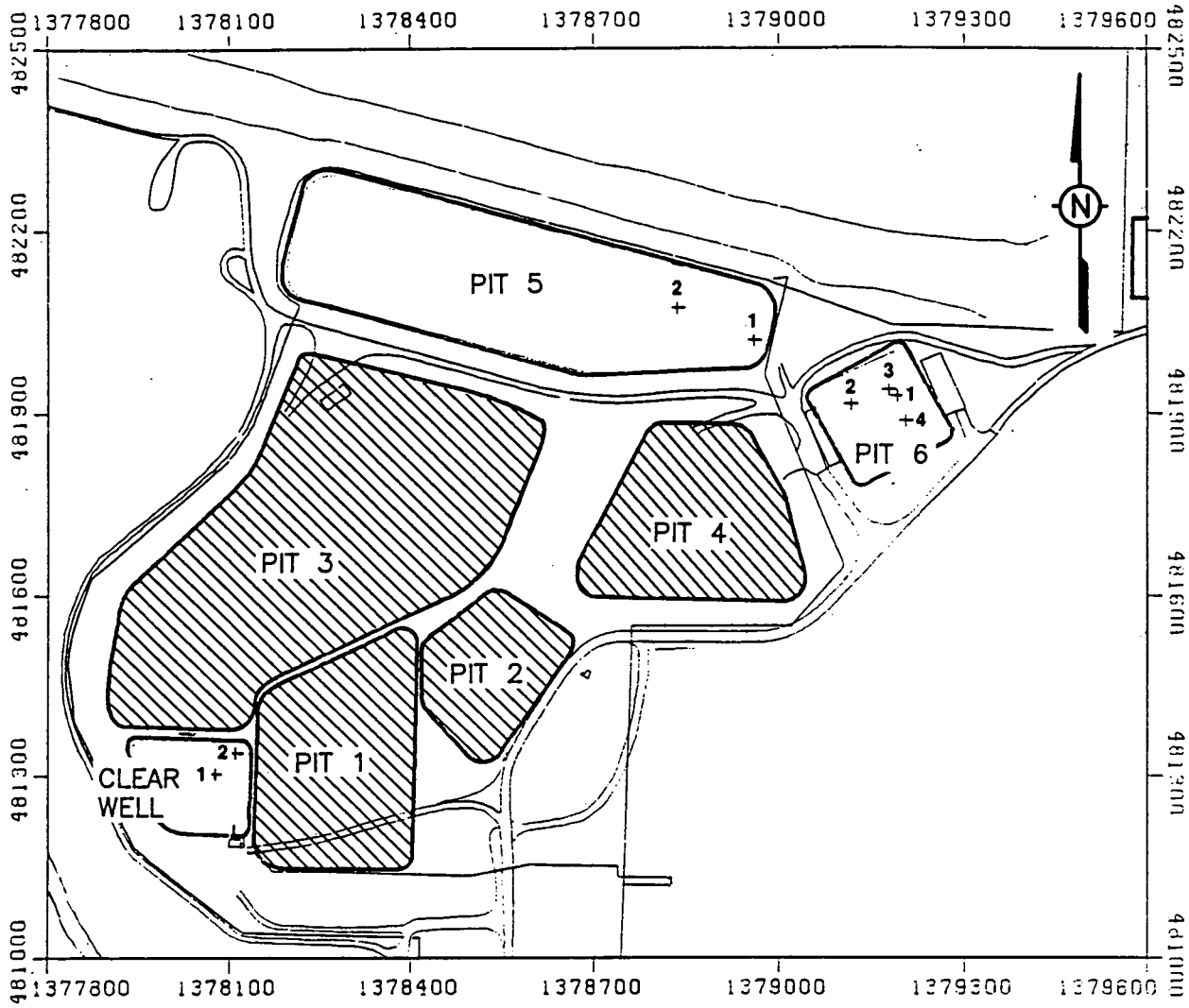
Historical and current airborne releases of radionuclides from the FEMP have been monitored and reported by WMCO (WMCO 1986; 1987; 1988; 1989b; 1990; 1991) to assess potential airborne hazards. A discussion of other air quality studies for the site and in urban locations is presented in Section 3.1.2 and 3.2.2 of Part I, respectively.

2.1.1.3 Surface Water and Sediment (Including Standing Water in Waste Units)

Surface water and sediment samplings have been conducted on and off the FEMP as part of the RI (standing water in the waste pits and the Clearwell has been sampled by CIS). Sample locations by RI/FS encompass the Great Miami River, the Storm Sewer Outfall Ditch (SSOD), Paddys Run, and various drainage ditches leading to Paddys Run or the SSOD. Figures 3-6 through 3-18 of Part I present RI/FS surface water and sediment sample locations. CIS sample locations for standing water in the waste pits and Clearwell are shown in Figure 2-1.

Analytical results for RI/FS surface water and sediment samples are summarized separately for different surface water bodies as follows:

- The Great Miami River upstream of the FEMP main effluent line
- The Great Miami River between the FEMP main effluent line and the confluence with Paddys Run
- The Great Miami River downstream of the confluence with Paddys Run
- Paddys Run upstream of the FEMP northern property boundary
- Paddys Run between the FEMP northern property boundary and the confluence with the SSOD



STATE PLANE COORDINATE SYSTEM

OHIO SOUTH ZONE

LEGEND:

PITS 1, 2, 3, AND 4 HAVE BEEN COVERED WITH SOIL

2+ SAMPLE LOCATIONS

SITE WIDE BASELINE RISK ASSESSMENT
313327-A-105/KNOX

FIGURE 2-1 STANDING WATER SAMPLE LOCATIONS IN THE WASTE STORAGE AREA

42

- Paddys Run downstream of the confluence with the SSOD
- SSOD
- Various drainage ditches that lead to Paddys Run or the SSOD

Statistical summary tables for these analytical results are provided in Section R.3.0 of Appendix R. CIS sampling locations for surface water include standing water locations in the waste pits and the Clearwell. Analytical results for CIS standing water samples are grouped in the following manner (Waste Pit 1 through 4 have been covered with soil):

- Standing water in Waste Pit 5
- Standing water in Waste Pit 6
- Standing water in the Clearwell

The analytical results are summarized in Section R.3.0 of Appendix R.

Sediment sampling has also been performed by CIS for locations other than along the Great Miami River and Paddys Run (e.g., various drainage ditches or puddles). These data are also summarized in Section R.3.0 of Appendix R.

To supplement the limited data from RI/FS sampling of sediment in the SSOD and in Paddys Run downstream of the SSOD, analytical results for WEMCO sediment samples are summarized independently and in combination with data from RI/FS sampling for these two areas.

2.1.1.4 Groundwater

Groundwater data are obtained from Resource Conservation and Recovery Act (RCRA) and RI/FS groundwater sampling programs. They include analytical results for radionuclides, and organic and inorganic chemicals for the 1000-, 2000-, 3000-, and 4000-series monitoring wells. (The well series has been explained in Section 3.1.4 of Part I.)

1000-Series Wells

The perched groundwater zone, as monitored by a network of wells designated as the 1000-series wells, is contained within sand lenses in the glacial overburden. The perched groundwater is neither currently being used as a source of drinking water for human consumption near the FEMP nor for livestock drinking water. For risk assessment purposes, leachate concentrations need to be determined for the constituents of potential concern for groundwater modeling because perched water can potentially infiltrate into the Great Miami Aquifer. Perched water

data beneath the Plant 2/3, Plant 6, Plant 9, and the Pilot Plant areas (Figure 2-2), which contain the greatest contamination as shown by previous investigations, are summarized separately for selecting constituents of potential concern. Other perched water data are also summarized, but because they are not significant source terms (see data summaries in Section R.4.0 of Appendix R), the data are qualitatively used in characterizing the nature and extent of contamination for perched water (see Section 4.1.4 of Part I).

Off-Property Wells (2000- and 3000-series)

Analytical results for 2000- and 3000-series wells off the FEMP property are used to determine exposure point concentrations for quantifying the groundwater RME locations for current land-use conditions (sample analytical results from the site-related wells for the entire site have been summarized by depth and the results are presented in Appendix M). Twenty-one wells which contain relatively greater contamination were selected from a total of 85 off-property wells as potential RME groundwater well locations. These wells are: 2015, 2060, 2061, 2094, 2095, 2097, 2106, 2126, 2127, 2128, 2129, 2384, 2391, 2393, 2558, 3043, 3066, 3094, 3126, 3127, and 3128 (see Figures 5-4 and 5-5 of Part II for locations of the 21 wells). Section 3.3 of Part II contains an explanation of how the 21 wells were selected. A statistical evaluation was performed on the concentration for all constituents of potential concern for each of the 21 wells and has been summarized in Section R.4.0 of Appendix R. The groundwater RME location(s) for current land-use conditions was then determined from these 21 off-property wells (see Section 3.3 of Part II) based on the statistically evaluated concentrations of the constituents of potential concern.

The groundwater RME location(s) for future land-use conditions was determined using groundwater fate and transport modeling results (see Section 3.0 of Part II).

2.1.1.5 Soil

Radiation Measurement Programs

The RI/FS Radiation Measurement Program (RMP) used various radiation detection instruments to perform external radiation surveys for identifying locations of elevated levels of radioactivity in surface soils. These identified locations were selected for soil sampling in a subsequent study, the Surface Soil Sampling Program. Portable instruments such as the pressurized ionization chamber (PIC), large volume scintillation detectors, and Field Instruments for Detection of Low-Energy Radiation (FIDLERs) were used in the program. Because the measured field radiation readings were used to indicate locations at which soil sampling would be performed, these radiation measurements are only employed qualitatively in the risk assessment.

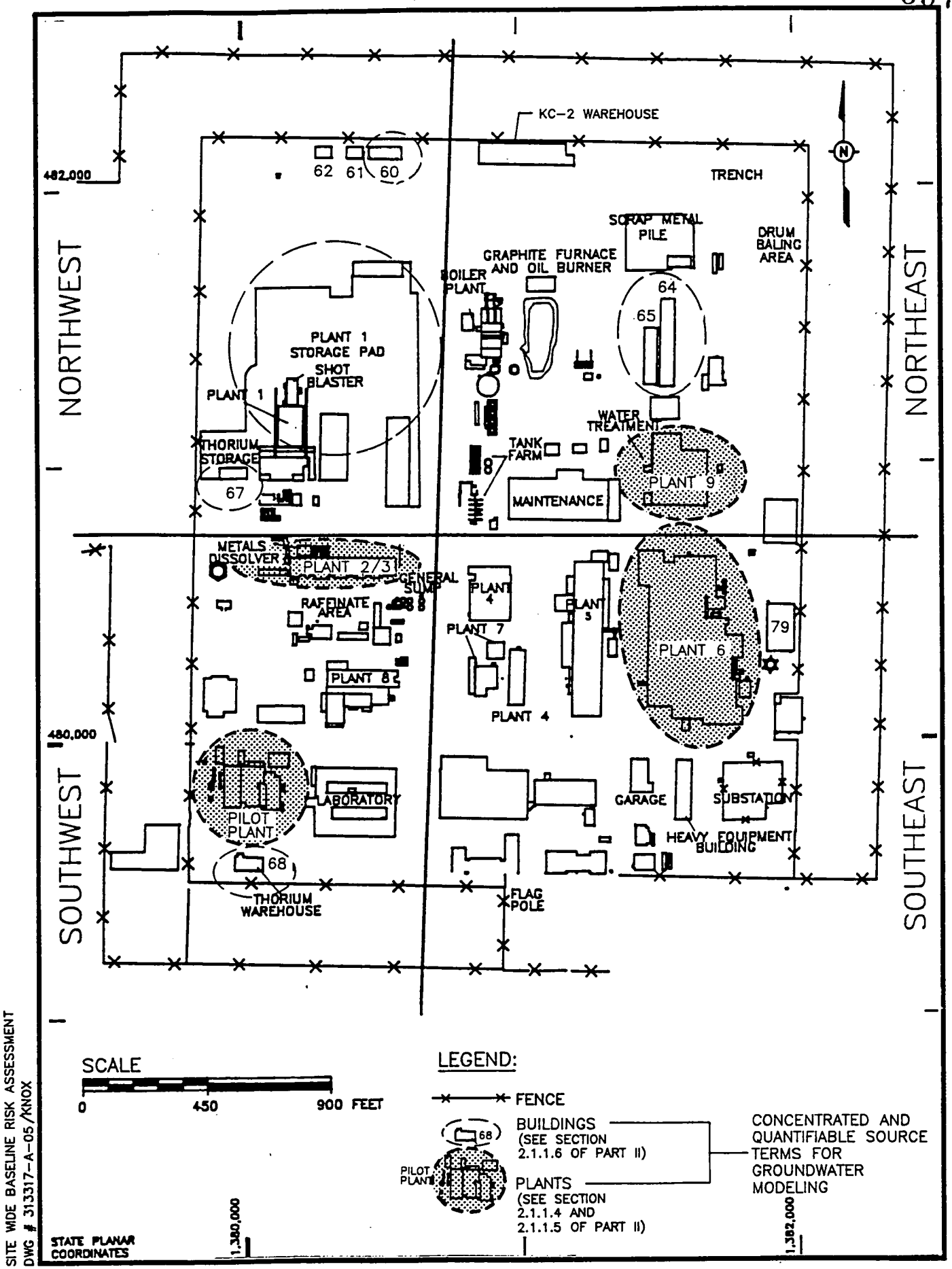


FIGURE 2-2 GROUNDWATER MODELING SOURCE TERMS FOR THE PRODUCTION AREAS

45

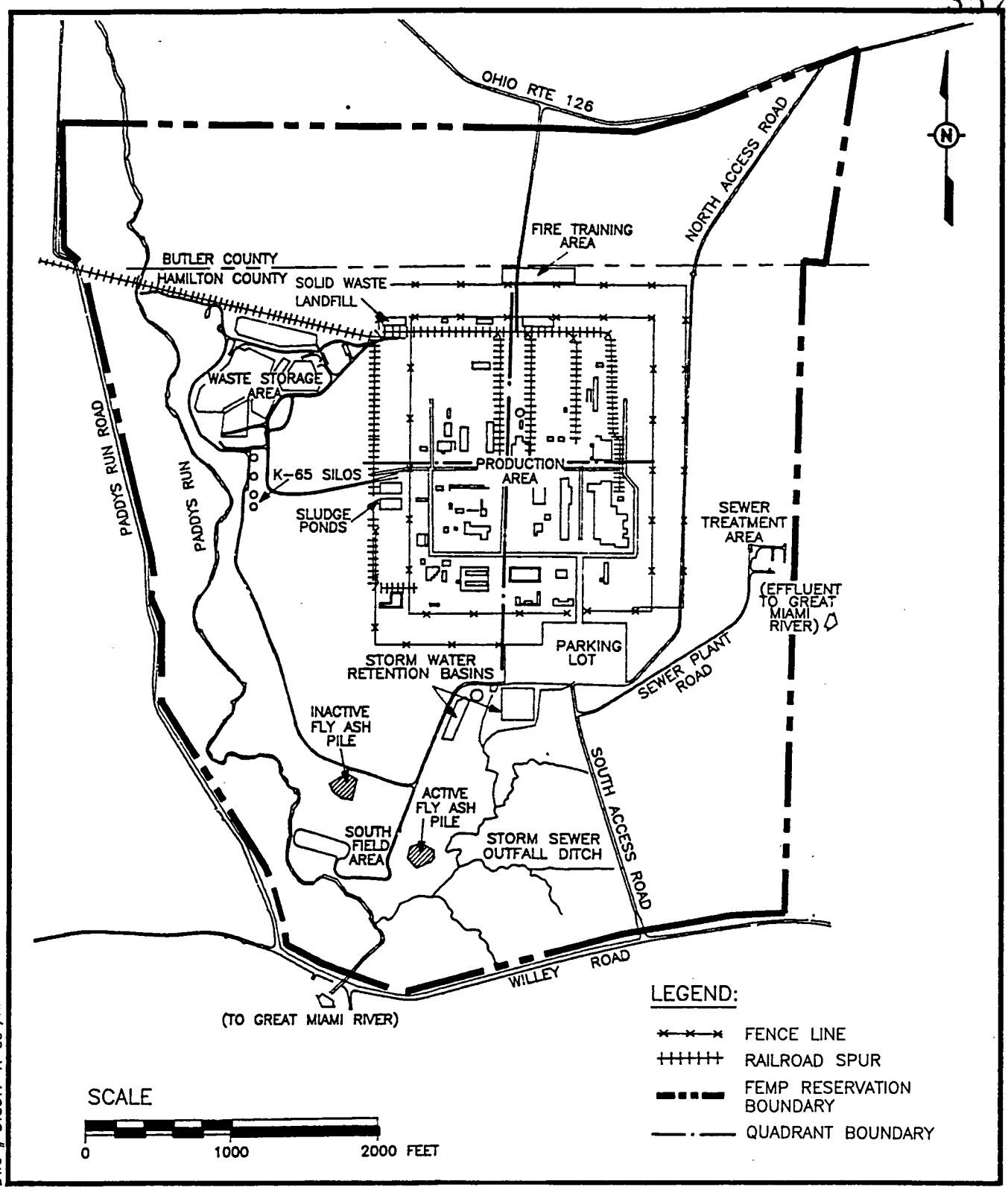
Surface Soil

Surface soil samples were collected and analyzed as part of the characterization task for surface soil in the RI/FS. Both biased sampling and systematic sampling of surface soils were performed. Samples were analyzed for 16 radionuclides, total uranium (by mass), and total thorium (by mass). The analyzed radionuclides include: Cs-137, Np-237, plutonium-238 (Pu-238), Pu-239/240, radium-226 (Ra-226), Ra-228, Sr-90, Tc-99, thorium-228 (Th-228), Th-230, Th-232, uranium-234 (U-234), U-235/236, and U-238. Analyses of surface soils for organic and inorganic chemicals were also performed for many of the samples.

Based on the results of the RI/FS RMP the sampling program for surface soils in the RI emphasized the former Production Area, the incinerator area near the sanitary sewage treatment plant, and the waste storage area (Operable Units 1, 2, and 4) because these areas exhibit greater surface soil contamination. The former Production Area is the ultimate origin of all FEMP wastes; the waste storage areas are contaminated as a result of waste handling and storage activities; and the incinerator area is contaminated because waste materials were transferred from the former Production Area. Some surface soil samples were collected outside of these areas. These samples constituted the majority of the non-biased samples.

Sample analytical results for surface soil at the site from different locations are presented in groups and also for the entire site for summarization (Figure 2-3). The areas illustrated in Figure 2-3 are assembled according to the physical and chemical characteristics of the surface soil, existing operable unit RI information on contamination types and areas, and fate and transport modeling needs. The groups are:

- Four quadrants of the former Production Area
- Waste pit area
  - Waste Pits 1 through 6
  - Burn Pits
  - Clearwell
- Active Flyash Pile
- Inactive Flyash Pile
- South Field
- Incinerator/wastewater treatment facility area



WASTE STORAGE AREA

- Waste Pit Area
  - Waste pits 1–6
  - burn pits, and
  - clear well
- Solid Waste Units
  - Inactive and active flyash piles
  - South Field disposal areas
  - Lime sludge ponds, and
  - Solid waste landfill

FIGURE 2–3 DATA SUMMARIZATION FOR SOILS

- Area surrounding Silos 1, 2, and 3
- Remaining site excluding the above areas
- Entire site.

Sample analytical results for soil depths between 0 and 6 inches (0 - 0.15m) and soil depths between 0 to 18 inches (0 - 0.46m) are summarized separately in order to select constituents of potential concern in surface soil. The reason for summarizing these data sets separately by depth range is to address different needs in fate and transport modeling and exposure assessment. Data summary for depth range of 0-6 inches (0-0.15 m) was needed for air and surface water modelings and exposure assessments for pathways such as incidental soil ingestion, dermal contact with soil, etc. These modelings and pathways involve soil in the top layer of the surface. Data summary for depth range of 0-18 inches (0-0.46 m) was needed for groundwater modeling and exposure assessments such as root uptake of vegetables, on-site home builders, etc. These modeling and pathways involve exposure to deeper layers of soil. Details of using these data summary for different depth ranges can be found in Section 3.0 of Part II. Generally, only RI/FS data are presented, except for those areas where the RI/FS data are too limited for use in quantitative risk assessment. In such cases, analytical results from CIS sampling efforts are used to supplement the RI/FS data. These supplementary data are presented separately and in combination with RI/FS data in Section R.5.0 of Appendix R. The CIS data were used to supplement the RI/FS data for the following areas: the Active Flyash Pile, the Inactive Flyash Pile, and the South Field.

Subsurface Soil

Subsurface soil sampling analytical data are used in the risk assessment to quantify source terms for groundwater and air modeling (assuming the caps on the waste pits fail in the future) for future land-use scenarios (see Section 3.0 of Part II). Previous investigations indicate that infiltration of contaminants from subsurface soils to the underlying aquifer is currently predominant in the:

- Waste pit area (Operable Unit 1)
- Solid waste units (Operable Unit 2)
- Former Production Area

Because the RI/FS data available as of December 1, 1991, are limited for subsurface soil in these areas, the CIS data for the Operable Unit 1 and Operable Unit 2 areas are used to supplement the RI/FS data. Data are presented separately by source and are also presented in combined summaries, when appropriate, in Section R.6.0 of Appendix R.

Results of samples collected for subsurface contents for each area within Operable Unit 1 and Operable Unit 2 were evaluated to determine constituents of potential concern for these areas. These constituents are considered as potential groundwater modeling source terms as well as potential sources of direct exposure in the future. However, only constituents predicted to reach the aquifer at levels exceeding risk-based screening concentrations are the groundwater constituents of concern for future land-use scenarios (see Section 3.0 of Part II).

Direct radiation measurements were reported for the waste pit area, Active and Inactive Flyash Piles, and the South Field using the FIDLER instrument (Weston 1987). The measurements were used to locate areas of contamination on the surface of these waste areas, which were subsequently designated as sample locations for borings. The field radiation measurements from the CIS study are only used qualitatively in the risk assessment.

In the former Production Area, subsurface soil beneath the Plant 2/3, Plant 6, Plant 9, and the Pilot Plant areas, as displayed in Figure 2-2, shows much deeper contamination than other areas (ASI 1991). Analytical results for samples from the RI/FS study are summarized for boreholes within these plant areas for selection of constituents of potential concern in subsurface soils and estimating potential source terms for groundwater fate and transport modeling. Data for other, less contaminated locations within the former Production Area are also summarized in Section R.6.0 of Appendix R, but are not used quantitatively in the risk assessment.

2.1.1.6 Plants, Buildings, and Drums

Contamination data for plants, buildings, and drums within the former Production Area are limited as of December 1, 1991. These data have been included in the Draft Operable Unit 3 Work Plan Addendum (DOE 1992b) which summarizes analytical or survey results from various investigations and sampling efforts. Thorium drum inventories within Buildings 60, 64, 65, 67, 68, and uranium sampling analytical results from Plant-1 Pad (Figure 2-2) are summarized for use in groundwater modeling source terms (see Appendix O). These are the major source terms in the former Production Area that can be quantified with data available as of December 1, 1991.

Radiological contamination survey results are available for some of the structures and equipment within the former Production Area. The nature and extent of contamination for these surveyed structures and equipment are discussed in Section 4.0 of Part I. The survey results will be used as part of the exposure assessment.

2.1.1.7 Ecological Data

The RI/FS database also includes the results from a number of special studies conducted as part of the RI/FS which support the ecological risk assessment. These special studies include:

- Analyses of radionuclides and chemicals in vegetation, terrestrial animals, and aquatic organisms collected from the FEMP
- Surveys of macroinvertebrate communities in Paddys Run and the Great Miami River
- Toxicity tests of liquid effluents from the FEMP
- Delineation of jurisdictional wetlands on FEMP property
- Toxicity tests of soil and sediment samples from the FEMP.

Analytical results of samples from these special studies were summarized for the ecological risk assessment and are presented in Section 6.0 of Part II.

2.1.2 Background Data Sources

Background levels of chemicals and radionuclides include naturally-occurring levels and concentrations that are present in the environment due to anthropogenic, non-site sources (EPA 1989a). In addition to the background samples collected during the RI/FS, background data are obtained from a variety of sources presented in Table 2-2. Data from these sources are used in RI/FS risk assessments according to the following hierarchy:

- Data to be considered first are site-specific background data obtained from the RI/FS database, including data collected during removal actions.
- If background data from site-specific sources are insufficient, a second group of data will be considered. This group includes other site-specific background data from sources such as the environmental monitoring annual reports, county soil surveys, and site-specific studies that complement the RI/FS background characterization process (e.g., CIS, or the Facemire ecological survey of the FEMP site [Facemire et al. 1990]).
- If background data from the first two groups are insufficient, a third group of data will be considered. This group includes regional data obtained from state and local sources or peer reviewed literature.

If there are no background data for a contaminant in a specific medium, a background level of zero will be assumed for that contaminant in the specific medium. The sampling plan for the site-specific background soil concentrations has been conducted in early 1992 (DOE 1992c). Subsequent operable unit RIs will be using these background soil data for risk assessment.

TABLE 2-2
SOURCES OF BACKGROUND LEVELS IN ADDITION TO THE RI/FS STUDY

Medium	Constituents	Sources
Air	Radiological	WEMCO Environmental Monitoring Annual Reports[a]
External Radiation Exposure	Photon-Emitting Radionuclides	WEMCO Environmental Monitoring Annual Reports[a]
Groundwater	Chemical	RCRA Groundwater Background Wells
	Radiological	RCRA Groundwater Background Wells
Surface Water	Radiological	WEMCO Environmental Monitoring Annual Reports[a]
Sediment	Chemical	Shacklette et al. 1984 (Indiana/Ohio data only),
	Radiological	Myrick et al. 1983 (Indiana/Ohio data only)
Soil	Chemical	Shacklette et al. 1984 (Indiana/Ohio data only),
	Radiological	Myrick et al. 1983 (Indiana/Ohio data only)

[a] Westinghouse Environmental Monitoring Annual Reports - WMCO 1986; WMCO 1987; WMCO 1988; WMCO 1989b; WMCO 1990; WMCO 1991.

2.1.3 Data Analysis Considerations

Analytical data obtained from the sources listed in Tables 2-1 and 2-2 were evaluated prior to use in the quantitative risk assessments. The methodology used to obtain specific data for the baseline risk assessment is described in Section 3.0 of Part II. The criteria for evaluating the appropriateness of the data are based primarily on EPA guidance (EPA 1989b). These criteria are listed as follows:

- The methodology used to obtain concentration data and chemical forms was considered. Data obtained via the following analytical methods were not considered appropriate for the quantitative risk assessment: (1) analytical methods that were not specific for a particular chemical or radionuclide (except total uranium and total thorium), such as total organic carbon or total organic halogen, and (2) field screening instruments such as HNus, organic vapor analyzers, FIDLERs, alpha-particle scintillation detectors, and Geiger-Mueller (GM) detectors.

- Matrix spike and matrix spike duplicate data acquired in the RI/FS sampling program as stipulated in Volume 5 of the Quality Assurance Project Plan (QAPP) (DOE 1988) were analyzed. Analytical results for chemicals were reported using Contract Laboratory Program (CLP) data qualifiers. These qualifiers guided the use of data in the quantitative risk assessment, as suggested in Exhibit 5-4 of EPA's Risk Assessment Guidance for Superfund, Part A (EPA 1989b). Analytical results for radiological constituents were reported as stipulated in the QAPP (DOE 1988).

- Estimated quantitative results such as those identified by a "J" qualifier were used in the risk assessment (EPA 1989b). The "J" qualifier is the most encountered data qualifier in Superfund data packages. Under the CLP, the "J" qualifier describes an estimated value either for a tentatively identified compound or when a compound is present (spectral identification criteria are met), but the value is less than the Contract Required Quantitation Limit (CRQL).

- If a constituent was not detected in a sample, the result for that sample was reported at the sample quantitation limit (SQL) and given a "U" qualifier (or "<" for radiological data). If there is at least one positive detection for a constituent, data qualified with a "U" or "<" were included in the data analysis at a value equal to 1/2 the SQL. However, unusually high sample quantitation limits for a chemical constituent were not included in the data analysis if they exceeded both the CRQL and a Risk-Based Quantitation Limit (RBQL) for that chemical (see Appendix N for more details). Also, if inclusion of data qualified with a "U" or "<" caused the calculated exposure concentration to exceed the maximum detected concentration for a particular sample set, the maximum detected value was used as the exposure concentration.

- Tentatively identified compounds (TICs) were included in the analysis only if historical site information suggested the TICs may have been present at the site. If TICs appeared often or at high concentrations, further evaluation of TICs were performed (EPA 1989b).

2.2 SELECTION METHODOLOGY

A constituent is considered of potential concern for a given medium and area unless one of the following criteria are met:

- The constituent was not detected in any of the samples analyzed.
- The site-related concentrations of the constituent do not exceed the upper 95 percent tolerance limit (UTL) of the background distribution (see Section 2.2.1 of Part II).
- The constituent is an essential nutrient or common dietary element such as potassium, present at concentrations only slightly above naturally-occurring levels, and toxic only at doses much higher than those that could be associated with the FEMP.
- The constituent is a nontoxic, ubiquitous compound such as silicon.
- The constituent is detected in blanks associated with the site-related sample at sufficient levels (i.e., site-related sample concentrations are less than five times the highest concentration detected in the blanks) to indicate that the measurements in the site-related sample are probably artifacts (e.g., as a result of contamination during sampling or laboratory analysis).
- The constituent is a general class of compounds unsuitable for use in quantitative risk assessment (e.g., total organic carbon).

These selection criteria are discussed in detail in the following sections.

2.2.1 Statistical Method for Selecting Constituents of Potential Concern

A crucial part of the selection process is the use of statistical tests to compare concentration measurements for a given constituent at the site with measurements obtained in the background area. The Upper Tolerance Limit test (or UTL test) will be used to conduct the comparison. The UTL test determines if a measurement for a given constituent exceeds the upper 95 percent confidence limit for the 95th quantile (i.e., the upper 95 percent tolerance limit) of the background distribution. If so, the test indicates that the site contains at least one relatively high concentration, which needs to receive proper attention. Thus, background concentration data obtained from the RI/FS study and the additional sources listed in Table 2-2 are essential for identifying constituents of potential concern.

The UTL is calculated for the background concentration data by one of two methods, depending on whether the background distribution is normal or log normal. Procedures for calculating the UTL have been given in detail in Section 4.0 of the Addendum (DOE 1992a), and are not reproduced in this report. If the concentration for a given constituent in a specific medium from

the site exceeds the UTL of the background concentration of the constituent in the same medium, the constituent is considered as a constituent of potential concern unless it can be eliminated on the basis of the nonstatistical criteria.

The UTL has been constructed for constituents that have sufficient background measurements for a given medium. Appendix T presents the UTL values and associated information for the background data.

Site-related data were compared with UTL values in the process of selecting constituents of potential concern (see Appendix R).

2.2.2 Nonstatistical Criteria for Selecting Constituents of Potential Concern (for Chemicals Only)

Nonstatistical criteria for classifying constituents as not of potential concern include (EPA 1989b):

- Chemicals constituents that are not identified as chemicals of potential concern include: "(1) essential human nutrients such as sodium, potassium, magnesium, calcium, and iron, (2) present at low concentrations (i.e., only slightly above naturally-occurring levels), and (3) toxic only at very high doses (i.e., much higher than those that could be associated with the site)" (EPA 1989b). Concentrations of essential nutrients at the site are compared to background concentrations according to the UTL test in order to determine constituents of potential concern with respect to items (2) and (3). This criterion is not applied to radioactive isotopes of the essential nutrients.

- Chemical constituents are not identified as constituents of potential concern if they are common laboratory contaminants and if all sample concentration results are less than ten times the highest blank concentration. Common laboratory contaminants include acetone, 2-butanone, methylene chloride, toluene, and the phthalate esters (EPA 1989b). Many laboratory blanks were analyzed. Available results were incorporated into the selection of chemicals of potential concern in Appendix R. However, most results were not available as of December 1, 1991. Hence, most common laboratory contaminants are currently included as chemicals of potential concern even though these constituents could be probably introduced during collection, transport, or laboratory procedures. Other chemicals are eliminated if all results are less than five times the highest concentration detected in a blank (EPA 1989b).

- General classes of compounds such as total organic nitrogen are eliminated as constituents of potential concern because they are inappropriate for use in quantitative evaluation of risk.

- Compounds that are ubiquitous and generally considered to be nontoxic (e.g., chloride or silicon) are not considered to be constituents of potential concern.

Whenever a large number of chemical constituents have been identified as of potential concern, a concentration-toxicity screening procedure (EPA 1989b) may be used to identify chemical constituents in a particular medium that are most likely to contribute significantly to risks calculated for exposure scenarios involving that medium. Note that this procedure is not applied to the ecological assessment. In the concentration-toxicity screening procedure, a risk factor is calculated by multiplying the maximum detected concentration of the constituent by its toxicity value, i.e., either the slope factor or the inverse of the reference dose (1/RfD). In other words, the screening is performed using the following:

$$R_{ij} = (C_{ij})(T_i) \qquad (6\text{-}1)$$

where

R_{ij} = risk factor for the ith chemical in the jth medium
C_{ij} = maximum detected concentration of the ith chemical in the jth medium
T_i = toxicity value for the ith chemical (1/RfD for noncarcinogens or the cancer slope factor for carcinogens)

From these values the total risk factor for a medium, R_j, is calculated as

$$R_j = \sum_i R_{ij} = \sum_i (C_{ij})(T_i) \qquad (6\text{-}2)$$

Separate total risk factors are calculated for carcinogenic and noncarcinogenic effects for each chemical. The ratio of the chemical-specific risk factor (R_{ij}) to the total risk factor (R_j) approximates the relative contribution to the overall risk for each chemical constituent in the medium. Chemicals for which this ratio (R_{ij} to R_j) is less than 0.01 are eliminated from further consideration in the quantitative risk assessment (EPA 1989b).

2.3 CONSTITUENTS OF POTENTIAL CONCERN

The selection criteria discussed in the previous section were applied to data grouped by subareas of interest within a medium. Reasons to include or not to include a constituent as of potential concern are presented in Appendix R. The selected constituents of potential concern to be carried through the quantitative risk assessment are displayed in Tables 2-3 through 2-29. Data are presented as described in Section 2.1 of Part II for silo contents, air, surface water/sediment, groundwater, surface soil, subsurface soil, and plants/buildings/drums. Data sources used for performing the data summary have been indicated in the table titles. Each medium/source is subdivided into distinct subareas of interest. The mean concentration and the associated upper 95 percent confidence limit on the mean (UCL) for the selected constituents of potential concern are presented for each subarea of interest within each medium. The UCLs presented in these tables are used as input information for modeling constituent fate and transport in the exposure

TABLE 2-3
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR OPERABLE UNIT 4 SILO CONTENTS[a]

Constituents of Potential Concern	Background (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Silos 1 and 2 (pCi/g)	Radionuclide Concentration Silo 3 (pCi/g)
Ac-227	0.097		581 (780)
Pa-231	0.097		557 (756)
Pb-210	2.2	122000 (176000)[b]	2620 (4730)
Ra-224	1.5		290 (367)
Ra-226	2.2	113000 (140000)	2970 (3870)
Ra-228	1.5		298 (406)
Th-228	1.5	286 (355)	590 (747)
Th-230	2.1	28900 (34500)	49200 (58300)
Th-232	1.5	321 (435)	656 (962)
U-234	2.1	773 (934)	1480 (1730)
U-235	0.097	39.2 (49.1)	94 (117)
U-238	2.1	704 (854)	1500 (1780)
Uranium (mg/kg)	6.3	2110 (2560)	2960 (3690)

[a] Constituents that are selected as constituents of potential concern for contents from at least one silo are listed in the table.

[b] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-4
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR OPERABLE UNIT 4 SILO CONTENTS[a]

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Silos 1 and 2 (mg/kg)	Chemical Concentration Silo 3 (mg/kg)
ORGANICS			
1,4-Dioxane	0	(0.078)[c]	
2-Butanone	0	9.1 (11.6)[d]	13.3 (15.6)
4-Methyl-2-Pentanone	0	0.85 (1.58)	
Acetone	0	1.47 (2.18)	5.25 (8.39)
Aroclor-1248	0	3.08 (5.23)	
Aroclor-1254	0	3.74 (7.62)	
Aroclor-1260	0	(0.34)	
bis(2-Ethylhexyl)phthalate	0	0.87 (1.67)	(0.040)
Chloroform	0	0.6 (1.5)	0.694 (0.782)
Chloromethane	0		(0.14)
Cyanide	0	2.82 (4.66)	
Di-n-octyl Phthalate	0	0.455 (0.820)	
Fluoranthene	0	(0.064)	
Methylene chloride	0	2.3 (6.3)	1.68 (2.35)
Nitrate	0	3910 (5110)	
Pyrene	0	(0.047)	
Pyridine	0	(0.045)	
Styrene	0	0.018 (0.189)	
Toluene	0	0.160 (0.219)	3.40 (6.45)
Total Xylenes	0	(0.20)	
Trichloroethane	0	(0.12)	

TABLE 2-4
(Continued)

Constituent of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Silos 1 and 2 (mg/kg)	Chemical Concentration Silo 3 (mg/kg)
INORGANICS			
Antimony		13.3 (21.4)	
Arsenic	20.5	214 (454)	1950 (3070)
Barium	814	4480 (5880)	
Beryllium	2.15	1.85 (2.51)	24.2 (29.1)
Boron		(57.7)	
Cadmium	11.1	5.04 (7.15)	59.8 (91.4)
Chromium	102	51.9 (81.5)	288 (388)
Cobalt	21.4	777 (1040)	2104 (2820)
Copper	58.6	367 (537)	2550 (3280)
Lead	37.3	40100 (52500)	1730 (2380)
Manganese	15800		4380 (5160)
Mercury	0.292	0.81 (1.23)	0.43 (0.69)
Molybdenum	8.85	(449)	
Nickel	39.4	1190 (1490)	2970 (4160)
Selenium	1.17	127 (148)	174 (226)
Silicon		(764)	
Silver	8.03	12.1 (16.0)	15.9 (18.4)
Sulfate		8840 (11200)	
Thallium	10.9	0.634 (0.920)	19.0 (50.2)
Vanadium	172	155 (193)	1820 (3360)
Zinc	113	47.7 (80.8)	450 (535)

[a] Constituents that are selected as constituents of potential concern for contents from at least one silo are listed in the table.

[b] Background data are not available if there is not an entry.

[c] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.1.0 of Appendix R). The upper 95% confidence limit on the mean (UCL) is substituted by the maximum detected concentration given in the parentheses.

[d] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-5
COMPARISON OF MEASURED CONCENTRATIONS OF RADON PRIOR TO (OCTOBER 1991) AND FOLLOWING (DECEMBER 1991) INSTALLATION OF BENTONITE IN THE K-65 SILOS[a]

Monitoring Stations	Radon Concentrations October 1991 (pCi/ℓ)[b]	Radon Concentrations December 1991 (pCi/ℓ)[c]
AMS-1	0.80 (0.83)[d]	0.60 (0.62)
AMS-5	1.43 (1.54)	0.59 (0.61)
AMS-6	1.22 (1.29)	0.59 (0.61)
AMS-7	1.67 (1.81)	0.58 (0.60)
K-65, NW	6.67 (7.51)	0.95 (1.00)
K-65, SW	8.56 (9.70)	1.24 (1.31)
K-65, NE	18.0 (21.1)	1.16 (1.23)
K-65, SE	23.4 (30.8)	1.22 (1.31)
Plant 2/3	1.28 (1.36)	0.52 (0.54)
Plant 5	1.15 (1.20)	0.65 (0.67)
Pilot Plant	1.75 (1.86)	0.79 (0.82)
Administration Building	1.20 (1.27)	0.69 (0.72)
In Vivo Building	1.15 (1.22)	0.55 (0.56)

a Detailed summaries of radon concentration are given in Section R.2.0 of Appendix R.

b Background concentration (UTL) for radon in air for October 1991 is 1.84 pCi/L (WEMCO, Environmental Monitoring Monthly Data, October 1991).

c Background concentration (UTL) for radon in air for December 1991 is 1.16 pCi/L (WEMCO, Environmental Monitoring Monthly Data, December 1991).

d First value is the constituent mean concentrations; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-6
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE WATER[a]
(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration GMR Upstream of Main Effluent Line (pCi/ℓ)	Radionuclide Concentration GMR Between Effluent Line and Paddys Run (pCi/ℓ)	Radionuclide Concentration GMR Downstream of Paddys Run (pCi/ℓ)	Radionuclide Concentration Paddys Run Upstream of N. Boundary of FEMP (pCi/ℓ)	Radionuclide Concentration Paddys Run Between N. Boundary of FEMP and SSOD (pCi/ℓ)	Radionuclide Concentration Paddys Run Downstream of SSOD (pCi/ℓ)	Radionuclide Concentration SSOD (pCi/ℓ)	Radionuclide Concentration Drainage Ditches (pCi/ℓ)
Ra-226		0.65(0.91)[c]			No Data Available as of Dec. 1, 1991				0.64 (0.80)
Ra-228				1.83 (2.35)					1.89 (2.45)
Sr-90						3.32 (5.67)			
Tc-99			20.3 (27.5)						29.3 (44.7)
Th-228		0.58 (0.71)	0.62 (0.75)	0.68 (0.99)			0.92 (1.67)		
Th-230				0.57 (0.69)		1.15 (2.26)	0.83 (1.24)		
U-234	0.78	0.55 (0.63)	0.99 (1.22)	0.88 (1.14)		3.09 (3.95)	2.13 (3.76)		171 (653)
U-235/236	0.035								12.5 (51.5)
U-238	0.78		0.90 (1.09)	0.78 (1.06)		3.60 (5.25)	3.06 (4.50)	(1.30)[d]	499 (2840)
Uranium[e]	2.37		3.00 (3.00)	3.00 (3.00)		11.0 (16.0)	8.00 (11.0)	13.0 (24.0)	3036 (9318)
Thorium[e]						0.002 (0.003)			

a Constituents that are selected as constituents of potential concern for surface water from at least one surface water body are listed in the table.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentrations; value in parentheses is the 95% confidence limit on the mean (UCL).

d Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.3.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

e Concentrations for uranium and thorium are in units of μg/L.

TABLE 2-7
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE WATER[a]
(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration GMR Upstream of Main Effluent Line (mg/ℓ)	Chemical Concentration GMR Between Effluent Line and Paddys Run (mg/ℓ)	Chemical Concentration GMR Downstream of Paddys Run (mg/ℓ)	Chemical Concentration Paddys Run Upstream of N. Boundary of FEMP (mg/ℓ)	Chemical Concentration Paddys Run Between N. Boundary of FEMP and SSOD (mg/ℓ)	Chemical Concentration Paddys Run Downstream of SSOD (mg/ℓ)	Chemical Concentration SSOD (mg/ℓ)	Chemical Concentration Drainage Ditches (mg/ℓ)
ORGANICS									
Acetone	0				No Data Available as of Dec. 1, 1991				0.003 (0.004)[c]
bis(2-Ethylhexyl) phthalate	0					(0.004)[d]	(0.002)		0.004 (0.004)
Di-n-butyl phthalate	0								0.004 (0.003)
Diethyl phthalate	0					(0.002)			0.005 (0.003)
Methylene chloride	0								0.002 (0.001)
N-Nitro-sodiphenyl-amine	0					(0.004)			
INORGANICS									
Ammonia		0.29 (0.85)	0.50 (0.80)	0.46 (0.71)	No Data Available as of Dec. 1, 1991	0.19 (0.34)	0.08 (0.12)		0.11 (0.16)
Antimony						(0.003)			
Arsenic			0.001 (0.002)			0.002 (0.004)	0.002 (0.003)		0.002 (0.007)
Barium		(0.05)	0.048 (0.049)	(0.04)		0.05 (0.06)	0.043 (0.047)	(0.04)	0.05 (0.06)
Beryllium						(0.001)			0.001 (0.002)
Cadmium		(0.01)	0.003 (0.003)	(0.002)		0.003 (0.003)	0.004 (0.005)		0.003 (0.005)
Chromium		(0.006)	0.002 (0.004)			0.02 (0.03)	0.015 (0.020)	(0.007)	0.03 (0.04)
Cobalt									0.008 (0.014)
Copper		(0.012)	0.011 (0.014)	(0.007)		0.01 (0.01)	0.009 (0.012)	(0.011)	0.019 (0.024)

TABLE 2-7
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration GMR Upstream of Main Effluent Line (mg/ℓ)	Chemical Concentration GMR Between Effluent Line and Paddys Run (mg/ℓ)	Chemical Concentration GMR Downstream of Paddys Run (mg/ℓ)	Chemical Concentration Paddys Run Upstream of N. Boundary of FEMP (mg/ℓ)	Chemical Concentration Paddys Run Between N. Boundary of FEMP and SSOD (mg/ℓ)	Chemical Concentration Paddys Run Downstream of SSOD (mg/ℓ)	Chemical Concentration SSOD (mg/ℓ)	Chemical Concentration Drainage Ditches (mg/ℓ)
Lead		(0.005)	0.003 (0.003)	(0.006)	No Data Available as of Dec. 1, 1991	0.003 (0.006)	0.002 (0.007)	(0.003)	0.002 (0.007)
Manganese		(0.010)	0.009 (0.009)	(0.012)		0.02 (0.03)	0.02 (0.03)	(0.010)	0.08 (0.12)
Mercury		(0.010)	0.000 (0.001)	(0.002)		0.0002 (0.0003)	0.00012 (0.00019)	(0.0003)	0.0005 (0.0008)
Molybdenum		(0.007)				0.008 (0.014)			0.01 (0.03)
Nickel		(0.013)	0.011 (0.011)	(0.007)		0.01 (0.02)			0.01 (0.02)
Nitrate		3.71 (6.33)	3.34 (7.68)	2.18 (3.60)		4.27 (7.80)	3.91 (7.48)	(5.44)	3.63 (10.90)
Selenium				(0.002)		0.002 (0.005)			0.002 (0.005)
Silver						0.006 (0.010)	0.01 (0.02)		
Vanadium						0.01 (0.02)			0.02 (0.03)
Zinc						(0.04)			0.02 (0.03)

[a] Constituents that are selected as constituents of potential concern for at least one surface water body are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.3.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-8
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SEDIMENT[a]
(Data Sources: RI/FS and WMCO)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration GMR Upstream of Main Effluent Line (pCi/g)	Radionuclide Concentration GMR Between Effluent Line and Paddys Run (pCi/g)	Radionuclide Concentration GMR Downstream of Paddys Run (pCi/g)	Radionuclide Concentration Paddys Run Upstream of N. Boundary of FEMP (pCi/g)	Radionuclide Concentration Paddys Run Between N. Boundary of FEMP and SSOD (pCi/g)	Radionuclide Concentration Paddys Run Downstream of SSOD (pCi/g)	Radionuclide Concentration SSOD (pCi/g)	Radionuclide Concentration Drainage Ditches (pCi/g)
Pu-238					No Data Available as of Dec. 1, 1991		0.015 (0.024)[c]	0.015 (0.023)	
Pu-239/240							0.01 (0.01)	0.02 (0.03)	
Ra-224	1.5							0.70 (0.85)	
Ra-226	2.2							0.76 (0.87)	1.10 (1.70)
Ra-228	1.5							0.63 (0.81)	1.13 (1.67)
Sr-90		0.40 (0.59)	0.41 (0.57)	0.31 (0.43)					
Tc-99							0.46 (0.48)		
Th-230	2.1		1.03 (1.46)				0.63 (0.72)	1.28 (1.59)	
U-234	2.1						0.65 (0.77)	4.10 (7.45)	
U-235	0.097							0.59 (0.70)	
U-238	2.1						0.72 (0.87)	4.82 (9.92)	
Uranium[d]	6.3					1.92 (3.03)	2.00 (3.00)	(9.00)[e]	24.0 (36.9)
Thorium[d]	13.4	(3.00)	2.33 (3.00)	(2.0)					

a Constituents that are selected as constituents of potential concern for sediment from at least one surface water body are listed in the table.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

d Concentrations for uranium and thorium are in units of mg/kg.

e Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.3.0 of Appendix R). The upper 95% confidence limit on the mean is substituted by the maximum detected concentration given in the parentheses.

TABLE 2-9
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SEDIMENT[a]
(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration GMR Upstream of Main Effluent Line (mg/kg)	Chemical Concentration GMR Between Effluent Line and Paddys Run (mg/kg)	Chemical Concentration GMR Downstream of Paddys Run (mg/kg)	Chemical Concentration Paddys Run Upstream of N. Boundary of FEMP (mg/kg)	Chemical Concentration Paddys Run Between N. Boundary of FEMP and SSOD (mg/kg)	Chemical Concentration Paddys Run Downstream of SSOD (mg/kg)	Chemical Concentration SSOD (mg/kg)	Chemical Concentration Drainage Ditches (mg/kg)
ORGANICS									
2-Butanone	0	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991			(0.01)	No Data Available as of Dec. 1, 1991	
2-Hexanone	0						(0.01)		
Acetone	0				(0.02)	(0.008)	(0.01)		(0.09)
bis (2-Ethylhexyl) phthalate	0				(0.46)	(0.59)	(0.40)		
Di-n-butyl phthalate	0				(0.039)	(0.06)			
Methylene Chloride	0				(0.007)	(0.02)	(0.001)		(0.02)
INORGANICS									
Ammonia		No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991				No Data Available as of Dec. 1, 1991	(93.6)[c]
Mercury	0.29								(1.70)
Nitrate									(2.76)

[a] Constituents that are selected as constituents of potential concern for sediment from at least one surface water body are listed in the table.

[b] Background data are not available if there is not an entry.

[c] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.3.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-10
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR STANDING WATER IN THE WASTE STORAGE AREAS[a]

(Data Source: CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/ℓ)	Radionuclide Concentration Waste Pit 4 (pCi/ℓ)	Radionuclide Concentration Waste Pit 5 (pCi/ℓ)	Radionuclide Concentration Waste Pit 6 (pCi/ℓ)	Radionuclide Concentration Clearwell (pCi/ℓ)
Cs-137			(90)[c]		
Ra-226					(1.1)
Ra-228				7.5 (12.1)[d]	(12.0)
Sr-90			(47)		
Tc-99		(190)	(320)	535 (600)	(4000)
Th-230		(0.2)	(0.1)	0.16 (0.29)	(0.4)
U-234	0.78	(3400)	(420)	59.3 (77.0)	(1900)
U-235	0.035	(220)	(19)	5.9 (9.0)	(120)
U-238	0.78	(11400)	(400)	297 (460)	(6200)

[a] Constituents that are selected as constituents of potential concern for standing water from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.3.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

[d] First value is the constituent mean concentrations; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-11
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR STANDING WATER IN THE WASTE STORAGE AREAS[a]

(Data Source: CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration Waste Pit 4 (mg/ℓ)	Chemical Concentration Waste Pit 5 (mg/ℓ)	Chemical Concentration Waste Pit 6 (mg/ℓ)	Chemical Concentration Clearwell (mg/ℓ)
ORGANICS					
1,1-dichloroethene	0	(0.006)[c]			
2-nitrophenol	0				(0.004)
Acetone	0	(0.017)		(0.003)	(0.005)
Benzene	0		(0.01)		
Bis(2-ethylhexyl)phthalate	0	(0.004)		(0.01)	(0.004)
Chlorobenzene	0			(0.006)	
Chloroform	0			0.002 (0.003)[d]	(0.007)
Cyanide	0		(0.087)		(0.09)
Di-n-butyl phthalate	0		(0.001)	(0.006)	(0.001)
Methylene Chloride	0	(0.004)		0.003 (0.004)	(0.002)
Phenol	0	(0.005)			
Tetrachloroethene	0			0.002 (0.002)	
Toluene	0		(0.001)	0.001 (0.002)	
INORGANICS					
Aluminum				0.42 (0.49)	
Arsenic, soluble		(0.01)			
Copper		(0.046)			(0.03)
Manganese		(0.051)			(0.03)
Mercury				(0.0002)	(0.0007)
Nitrate	0			(29.5)	
Nitrate/Nitrite	0		(1395)	17.1 (20.3)	(266)
Silver					(0.02)
Vanadium		(0.059)			
Zinc			(0.094)	(0.11)	

TABLE 2-11
(Continued)

[a] Constituents that are selected as constituents of potential concern for standing water from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.3.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

[d] First value is the constituent mean concentrations; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-12
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SELECTED OFF-PROPERTY WELLS[a]
(Data Sources: RI/FS and RCRA)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/ℓ)	Radionuclide Concentration Well #2015 (pCi/ℓ)	Radionuclide Concentration Well #2060 (pCi/ℓ)	Radionuclide Concentration Well #2061 (pCi/ℓ)	Radionuclide Concentration Well #2094 (pCi/ℓ)	Radionuclide Concentration Well #2095 (pCi/ℓ)	Radionuclide Concentration Well #2097 (pCi/ℓ)	Radionuclide Concentration Well #2106 (pCi/ℓ)
Ra-226	<1	0.67 (1.00)[c]			1.61 (4.11)	0.80 (1.52)		
Ra-228	<3	2.25 (3.68)	1.88 (2.66)		2.04 (2.70)			
Sr-90								3.45 (5.47)
Tc-99								
Th-228	<1	0.61 (0.77)	0.71 (1.46)		0.97 (1.57)	0.71 (0.99)		0.74 (1.25)
Th-230	<1		0.77 (1.12)		0.64 (0.91)	0.66 (1.11)	0.58 (0.75)	
Th-232	<1							
Thorium (mg/ℓ)								
U-234	<1	59.3 (61.9)	67.9 (79.5)	90.6 (99.7)	1.07 (3.41)	44.0 (54.0)	0.65 (0.95)	15.1 (23.7)
U-235	<1	2.74 (3.17)	3.67 (4.36)	4.29 (5.20)	0.66 (1.11)	2.03 (2.67)		1.32 (1.60)
U-238	<1	60.7 (65.2)	71.9 (86.6)	90.8 (100.5)	1.08 (3.46)	46.0 (56.2)	0.67 (1.00)	15.5 (24.9)
Uranium (mg/ℓ)		0.20 (0.23)	0.24 (0.28)	0.27 (0.30)	0.002 (0.009)	0.15 (0.18)	0.001 (0.002)	0.05 (0.09)

TABLE 2-12
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Well #2126 (pCi/ℓ)	Radionuclide Concentration Well #2127 (pCi/ℓ)	Radionuclide Concentration Well #2128 (pCi/ℓ)	Radionuclide Concentration Well #2129 (pCi/ℓ)	Radionuclide Concentration Well #2384 (pCi/ℓ)	Radionuclide Concentration Well #2391 (pCi/ℓ)	Radionuclide Concentration Well #2393 (pCi/ℓ)
Ra-226	<1				1.03 (1.71)		(1.72)[d]	
Ra-228	<3	1.79 (2.38)						
Sr-90			4.9 (10.5)	7.5 (15.8)				
Tc-99		29.2 (57.7)						
Th-228	<1	0.79 (1.43)	0.75 (1.34)	0.95 (2.02)	1.09 (1.72)	(1.52)	(2.25)	
Th-230	<1	0.62 (0.93)		0.71 (1.19)		(3.44)	(1.51)	(1.58)
Th-232	<1		0.65 (1.00)		0.72 (1.15)		(1.48)	
Thorium (mg/ℓ)			0.004 (0.008)		0.002 (0.005)		(0.01)	
U-234	<1	1.02 (1.68)	3.43 (8.09)	2.58 (3.72)	1.15 (1.80)		(1.29)	(1.02)
U-235	<1							
U-238	<1	0.95 (1.64)	3.82 (9.24)	1.92 (3.35)	1.22 (1.98)		(1.14)	(1.09)
Uranium (mg/ℓ)		0.00046 (0.00028)	0.01 (0.03)	0.007 (0.015)	0.001 (0.005)	(0.002)	(0.02)	(0.003)

TABLE 2-12
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Well #2558 (pCi/ℓ)	Radionuclide Concentration Well #3043 (pCi/ℓ)	Radionuclide Concentration Well #3066 (pCi/ℓ)	Radionuclide Concentration Well #3094 (pCi/ℓ)	Radionuclide Concentration Well #3126 (pCi/ℓ)	Radionuclide Concentration Well #3127 (pCi/ℓ)	Radionuclide Concentration Well #3128 (pCi/ℓ)
Ra-226	<1	0.77 (1.39)	1.34 (4.07)	1.13 (1.90)	3.18 (4.71)			1.20 (7.76)
Ra-228	<3	2.07 (2.92)	1.98 (2.95)		3.92 (6.22)			
Sr-90								
Tc-99								
Th-228	<1	0.77 (1.39)	0.66 (0.96)			0.81 (1.48)	0.64 (0.87)	1.14 (1.77)
Th-230	<1							0.67 (0.94)
Th-232	<1							
Thorium (mg/ℓ)								
U-234	<1	1.10 (2.03)				0.86 (1.40)	0.79 (1.91)	2.2 (11.9)
U-235	<1							0.65 (0.98)
U-238	<1	1.18 (1.91)				0.82 (1.50)	0.77 (1.76)	1.9 (11.0)
Uranium (mg/ℓ)		0.005 (0.007)		0.001 (0.001)	0.000 (0.001)	0.002 (0.005)	0.001 (0.002)	0.003 (0.027)

[a] Constituents that are selected as constituents of potential concern for groundwater from at least one well are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.4.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-13
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SELECTED OFF-PROPERTY WELLS[a]
(Data Source: RI/FS and RCRA)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration Well #2015 (mg/ℓ)	Chemical Concentration Well #2060 (mg/ℓ)	Chemical Concentration Well #2061 (mg/ℓ)	Chemical Concentration Well #2094 (mg/ℓ)	Chemical Concentration Well #2095 (mg/ℓ)	Chemical Concentration Well #2097 (mg/ℓ)	Chemical Concentration Well #2106 (mg/ℓ)
ORGANICS								
1,1,1-Trichloroethane	0	(0.006)[c]	(0.006)			(0.001)		(0.010)
2-Butanone	0	(0.035)	(0.006)			(0.006)		(0.007)
2-Hexanone	0					(0.001)		
Acetone	0	(0.004)	(0.003)		(0.011)	(0.002)		(0.003)
Benzene	0				(0.160)			
bis(2-Ethylhexyl) phthalate	0	(0.001)						
Carbon disulfide	0							
Chloroform	0	(0.002)						
Di-n-butyl phthalate	0				(0.003)			
Ethyl benzene	0				(0.001)			
Fluoride	0.470	0.75 (1.21)						
Methylene chloride	0	(0.047)	(0.005)		(0.008)	(0.002)		(0.005)
Toluene	0				(0.004)			
Total xylenes	0				(0.190)			
Trichloroethene	0							
INORGANICS								
Ammonia	7.100		0.070 (0.096)[d]	0.121 (0.207)	1.25 (2.66)	0.064 (0.092)		(0.002)
Antimony		(0.001)						
Arsenic	0.050			0.078 (0.260)	0.204 (0.247)			
Barium	0.051		0.045 (0.054)		1.06 (1.24)	0.048 (0.051)		
Beryllium	0.001				(0.001)			
Cadmium	0.003	0.002 (0.003)	0.002 (0.002)	0.003 (0.005)	0.007 (0.011)	0.003 (0.004)		0.004 (0.006)
Chromium	0.039	0.020 (0.041)	0.017 (0.027)	0.018 (0.030)	0.017 (0.027)	0.019 (0.024)		0.023 (0.028)
Copper							0.011 (0.014)	

TABLE 2-13
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Chemical Concentration Well #2015 (mg/ℓ)	Chemical Concentration Well #2060 (mg/ℓ)	Chemical Concentration Well #2061 (mg/ℓ)	Chemical Concentration Well #2094 (mg/ℓ)	Chemical Concentration Well #2095 (mg/ℓ)	Chemical Concentration Well #2097 (mg/ℓ)	Chemical Concentration Well #2106 (mg/ℓ)
Lead		0.008 (0.016)		0.003 (0.004)	0.002 (0.004)	0.003 (0.012)		0.002 (0.005)
Manganese	0.011			0.011 (0.017)	0.178 (0.223)	0.009 (0.016)		0.011 (0.015)
Mercury			0.000 (0.001)		0.002 (0.005)	0.000 (0.002)	0.0002 (0.0003)	
Molybdenum	0.014		0.016 (0.025)	0.012 (0.019)	0.012 (0.012)	0.005 (0.009)	0.013 (0.028)	
Nickel					0.024 (0.042)	0.009 (0.012)	0.013 (0.017)	
Nitrate	0.25/19.4[e]						3.89 (7.84)	
Selenium				0.001 (0.002)				0.001 (0.002)
Silver			0.007 (0.012)	0.005 (0.009)		0.007 (0.012)	0.009 (0.016)	0.008 (0.023)
Thallium								
Vanadium	0.020	(0.019)		(0.017)	0.008 (0.011)	0.009 (0.016)		(0.014)
Zinc		(0.243)	(0.098)		(0.017)	(0.038)		(0.238)

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TABLE 2-13
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Chemical Concentration Well #2126 (mg/ℓ)	Chemical Concentration Well #2127 (mg/ℓ)	Chemical Concentration Well #2128 (mg/ℓ)	Chemical Concentration Well #2129 (mg/ℓ)	Chemical Concentration Well #2384 (mg/ℓ)	Chemical Concentration Well #2391 (mg/ℓ)	Chemical Concentration Well #2393 (mg/ℓ)
ORGANICS								
1,1,1-Trichloroethane								
2-Butanone					(0.004)			
2-Hexanone								
Acetone					(0.006)			
Ammonia	7.100		0.58 (1.64)	0.053 (0.060)	0.64 (1.50)			
Benzene								
bis(2-Ethylhexyl) phthalate								
Carbon disulfide								
Chloroform								
Di-n-butyl phthalate								
Ethyl benzene								
Fluoride	0.470							
Methylene chloride								
Nitrate	0.25/19.4[c]	79 (265)		101 (333)	16.1 (43.2)	(6.87)		
Toluene								
Total xylenes								
Trichloroethene								
INORGANICS								
Antimony								
Arsenic	0.050				0.064 (0.094)			
Barium	0.051		0.132 (0.163)					
Beryllium	0.001				(0.001)			
Cadmium	0.003	0.004 (0.005)	0.003 (0.004)	0.003 (0.005)	0.005 (0.007)		(0.005)	(0.005)
Chromium	0.039	0.027 (0.031)	0.028 (0.039)	0.025 (0.026)	0.020 (0.024)	(0.045)		(0.031)
Copper						(0.013)		
Lead			0.003 (0.005)	0.004 (0.012)	0.004 (0.006)			(0.004)

TABLE 2-13
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Chemical Concentration Well #2126 (mg/ℓ)	Chemical Concentration Well #2127 (mg/ℓ)	Chemical Concentration Well #2128 (mg/ℓ)	Chemical Concentration Well #2129 (mg/ℓ)	Chemical Concentration Well #2384 (mg/ℓ)	Chemical Concentration Well #2391 (mg/ℓ)	Chemical Concentration Well #2393 (mg/ℓ)
Manganese	0.011	0.076 (0.095)	0.87 (2.12)	0.021 (0.037)	0.038 (0.083)			(0.078)
Mercury								
Molybdenum	0.014	0.009 (0.013)		0.007 (0.012)	0.015 (0.018)			(0.090)
Nickel		0.015 (0.027)	0.010 (0.011)		0.015 (0.025)	(0.030)		(0.020)
Selenium					0.002 (0.004)			
Silver		0.019 (0.025)	0.008 (0.013)	0.017 (0.025)	0.013 (0.018)	(0.023)		(0.015)
Thallium								
Vanadium	0.020	0.014 (0.022)	0.018 (0.021)	0.011 (0.016)	0.014 (0.018)	(0.025)	(0.016)	(0.013)
Zinc					(0.032)			(1.20)

TABLE 2-13
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Chemical Concentration Well #2558 (mg/ℓ)	Chemical Concentration Well #3043 (mg/ℓ)	Chemical Concentration Well #3066 (mg/ℓ)	Chemical Concentration Well #3094 (mg/ℓ)	Chemical Concentration Well #3126 (mg/ℓ)	Chemical Concentration Well #3127 (mg/ℓ)	Chemical Concentration Well #3128 (mg/ℓ)
ORGANICS								
1,1,1-Trichloroethane								
2-Butanone						(0.004)		
2-Hexanone								
Acetone			(0.005)	(0.011)		(0.007)		
Ammonia	7.100	0.097 (0.120)	5.8 (11.2)	17.0 (28.6)	2.29 (3.50)	0.191 (0.415)		0.082 (0.150)
Benzene						(0.001)		
bis(2-Ethylhexyl) phthalate			(0.015)					
Carbon disulfide			(0.003)					
Chloroform								
Di-n-butyl phthalate			(0.010)					
Ethyl benzene								
Fluoride	0.470							
Methylene chloride			(0.008)	(0.007)		(0.002)		
Nitrate	0.25/19.4[e]			0.49 (1.30)		113 (373)		
Toluene			(0.003)	(0.002)		(0.005)		
Total xylenes								
Trichloroethene			(0.002)					
INORGANICS								
Antimony								
Arsenic	0.050				0.318 (0.388)		5.2 (16.3)	0.074 (0.081)
Barium	0.051					(0.002)		
Beryllium	0.001		(0.002)		0.004 (0.006)	0.004 (0.008)	0.64 (2.01)	0.003 (0.004)
Cadmium	0.003	(0.005)	0.003 (0.005)		0.018 (0.028)	0.031 (0.045)	4.8 (14.9)	0.028 (0.038)
Chromium	0.039	(0.024)						
Copper			0.010 (0.016)		0.008 (0.018)	0.003 (0.006)	0.73 (2.26)	
Lead								

TABLE 2-13
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Chemical Concentration Well #2558 (mg/ℓ)	Chemical Concentration Well #3043 (mg/ℓ)	Chemical Concentration Well #3066 (mg/ℓ)	Chemical Concentration Well #3094 (mg/ℓ)	Chemical Concentration Well #3126 (mg/ℓ)	Chemical Concentration Well #3127 (mg/ℓ)	Chemical Concentration Well #3128 (mg/ℓ)
Manganese	0.011	(0.029)			0.208 (0.249)	0.069 (0.194)	15.3 (47.7)	0.221 (0.229)
Mercury			0.0001 (0.0002)	0.000 (0.001)	0.001 (0.001)	0.001 (0.003)	0.002 (0.005)	
Molybdenum	0.014		0.019 (0.030)	0.016 (0.020)	0.020 (0.029)			
Nickel			0.015 (0.020)	0.015 (0.021)	0.046 (0.066)	0.018 (0.028)	0.011 (0.013)	
Selenium			0.002 (0.005)				0.004 (0.009)	
Silver		(0.024)	0.006 (0.009)	0.007 (0.013)		0.013 (0.022)	3.9 (12.2)	0.017 (0.023)
Thallium						(0.002)		
Vanadium	0.020	(0.012)	(0.023)	(0.026)	(0.012)	0.021 (0.035)	2.61 (8.72)	0.012 (0.012)
Zinc		(2.30)				(0.030)		

[a] Constituents that are selected as constituents of potential concern for groundwater from at least one of the 21 wells are listed in the table.

[b] Background data are not available if there is not an entry.

[c] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.4.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

[d] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[e] Background concentrations for nitrate are 0.25 mg/L and 19.4 mg/L for Shandon Flow and Dry Fork Flow, respectively.

TABLE 2-14
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR PERCHED WATER IN THE PRODUCTION AREA[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/ℓ)	Radionuclide Concentration Plant 2/3 (pCi/ℓ)	Radionuclide Concentration Plant 6 (pCi/ℓ)	Radionuclide Concentration Plant 9 (pCi/ℓ)	Radionuclide Concentration Pilot Plant (pCi/ℓ)	Radionuclide Concentration Remainder of the Production Area (pCi/ℓ)
Ra-226	<1	2.38 (3.34)[c]	0.70 (1.00)		(4.70)[d]	0.92 (1.17)
Ra-228	<3	2.41 (4.14)	5.5 (16.6)	(21.7)	(14.3)	1.57 (1.70)
Sr-90	0	2.71 (3.02)	2.97 (3.82)		(6.78)	2.68 (3.02)
Tc-99	0	1480 (10300)	697 (1170)	(2280)		75 (152)
Th-228	<1	0.84 (1.15)	1.10 (1.72)	(4.07)	(49.7)	1.31 (1.74)
Th-230	<1	1.54 (2.15)	1.60 (2.92)	(6.98)	(16.6)	0.79 (1.01)
Th-232	<1	1.30 (1.80)	1.37 (2.57)	(3.13)	(40.8)	0.761 (0.969)
Thorium (mg/ℓ)		0.010 (0.015)	0.026 (0.045)	(0.028)	(0.368)	0.012 (0.026)
U-234	<1	6820 (50600)	16200 (25400)	(128000)	(433)	1650 (12800)
U-235	<1	687 (5840)	986 (2960)	(7490)	(41.7)	3.70 (8.82)
U-238	<1	7300 (56800)	22000 (81000)	(122000)	(429)	1440 (8850)
Uranium (mg/ℓ)		19.3 (40.8)	76 (109)	131 (696)	1.77 (9.44)	1.64 (3.03)

[a] Constituents that are selected as constituents of potential concern for perched water from at least one of the plants are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.4.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-15
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR PERCHED WATER IN THE PRODUCTION AREA[a]
(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration Plant 2/3 (mg/ℓ)	Chemical Concentration Plant 6 (mg/ℓ)	Chemical Concentration Plant 9 (mg/ℓ)	Chemical Concentration Pilot Plant (mg/ℓ)
ORGANICS					
1,1,1-Trichloroethane	0	0.022 (0.109)[c]	(0.310)[d]	0.120 (0.140)	0.012 (0.032)
1,1,2-Trichloroethane	0			0.002 (0.002)	
1,1-Dichloroethane	0	0.021 (0.080)	(0.074)	0.018 (0.120)	0.012 (0.030)
1,1-Dichloroethene	0	0.005 (0.007)	(0.460)	0.051 (0.088)	0.003 (0.003)
1,2-Dichlorobenzene	0	0.005 (0.004)			
1,2-Dichloroethane	0	0.002 (0.001)	(0.086)	0.005 (0.026)	
1,2-Dichloroethylene	0	0.003 (0.004)	(0.430)	0.013 (0.022)	0.024 (0.550)
2,6-Dinitrotoluene	0			(0.006)	
2-Butanone	0	0.005 (0.005)	(0.067)	0.006 (0.008)	0.003 (0.002)
4-Methyl-2-pentanone	0	0.005 (0.002)			
Acetone	0	0.003 (0.004)	(0.009)	0.003 (0.004)	0.003 (0.003)
Benzene	0		(0.001)		
Carbon disulfide	0	0.002 (0.003)			
Carbon Tetrachloride	0		(0.005)		
Chloroform	0		(0.026)		
Cyanide	0	0.003 (0.004)	(0.248)	0.007 (0.012)	0.003 (0.006)

TABLE 2-15
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration Plant 2/3 (mg/ℓ)	Chemical Concentration Plant 6 (mg/ℓ)	Chemical Concentration Plant 9 (mg/ℓ)	Chemical Concentration Pilot Plant (mg/ℓ)
Heptachlor epoxide	0			0.000 (0.000)	
Methylene chloride	0	0.005 (0.010)	(0.028)	0.005 (0.011)	0.003 (0.004)
Phenol	0				0.004 (0.001)
Tetrachloroethene	0	0.002 (0.002)	(0.014)	0.058 (0.350)	0.026 (0.043)
Toluene				0.002 (0.001)	0.002 (0.001)
Tributyl phosphate		0.051 (0.450)			
Trichloroethene		0.002 (0.003)	(1.40)	1.29 (6.40)	0.024 (0.092)
Vinyl chloride		0.005 (0.002)		0.004 (0.002)	0.006 (0.007)
INORGANICS					
Ammonia	0.36		0.29 (1.98)		
Antimony		0.032 (0.042)	(0.068)	0.154 (0.310)	
Arsenic					0.002 (0.003)
Barium	0.13	0.087 (0.116)	0.170 (0.452)	0.124 (0.174)	0.093 (0.164)
Beryllium	0.001	0.003 (0.005)	(0.034)	0.030 (0.076)	
Cadmium	0.003	0.007 (0.010)	0.007 (0.028)	0.029 (0.039)	0.005 (0.006)
Chromium	0.076	0.097 (0.180)	0.040 (0.460)	0.90 (2.14)	
Cobalt		0.012 (0.017)	(0.089)	0.084 (0.206)	
Copper	0.046	0.021 (0.039)	0.010 (0.057)	0.174 (0.409)	

TABLE 2-15
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/ℓ)	Chemical Concentration Plant 2/3 (mg/ℓ)	Chemical Concentration Plant 6 (mg/ℓ)	Chemical Concentration Plant 9 (mg/ℓ)	Chemical Concentration Pilot Plant (mg/ℓ)
Lead	0.005		0.002 (0.004)	0.003 (0.007)	
Manganese	0.2	0.44 (1.93)	0.13 (1.37)	1.05 (1.13)	0.29 (1.79)
Mercury		0.0003 (0.0006)	0.0002 (0.0003)	0.0002 (0.0003)	0.0002 (0.0003)
Molybdenum		0.008 (0.015)	0.037 (0.053)	(0.140)	(0.018)
Nickel	0.10		0.029 (0.152)	0.142 (0.264)	
Nitrate	0.34	119 (386)	182 (843)	27.1 (51.1)	0.150 (0.351)
Selenium					0.001 (0.002)
Silver		0.041 (0.066)	0.013 (0.139)	0.367 (0.847)	0.019 (0.021)
Thallium		0.001 (0.001)			0.001 (0.002)
Vanadium	0.023	0.035 (0.057)	(0.299)	0.290 (0.691)	
Zinc	0.039		(0.268)		

a Constituents that are selected as constituents of potential concern for perched water from at least one plant are listed in the table.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

d Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.4.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-16
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL AT DEPTHS FROM 0 TO 6 INCHES IN THE WASTE AREAS (OU 1 AND OU 2)[a]

(Data Sources: RI/FS and CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Entire Site (0 - 6") (pCi/g)	Radionuclide Concentration Waste Storage Areas (0 - 6") (pCi/g)	Radionuclide Concentration Inactive Flyash (0 - 6") (pCi/g)	Radionuclide Concentration Active Flyash (0 - 6") (pCi/g)	Radionuclide Concentration South Field Area (0 - 6") (pCi/g)
Cs-137		0.574 (0.632)[c]	0.404 (0.433)	0.435 (0.700)		0.432 (0.466)
Np-237			0.118 (0.144)			
Pu-238		0.336 (0.358)	0.179 (0.210)			
Pu-239/240		0.323 (0.336)	0.180 (0.213)			
Ra-226	2.2	18.7 (37.8)	2.13 (2.35)	17.5 (48.9)		21.2 (28.0)
Ra-228	1.5	9.4 (14.5)	10.5 (32.0)			
Ru-106			2.81 (3.03)			
Sr-90		0.87 (1.02)	0.277 (0.330)			
Tc-99		0.709 (0.771)	1.74 (2.38)			
Th-228	1.5	4.65 (6.73)	5.4 (10.6)			4.7 (20.7)
Th-230	2.1	48.4 (88.9)	343 (1578)	(59.0)[d]		30 (128)
Th-232	1.5	5.50 (7.79)	2.56 (2.86)	0.72 (1.80)		1.66 (1.89)
U-234	2.1	58.4 (77.4)	116 (209)	(82.0)		197 (519)
U-235	0.097	0.868 (0.992)	12.0 (24.3)	(1.90)		19.6 (34.3)
U-238	2.1	72.1 (95.7)	221 (267)	13.0 (37.4)	3.83 (2.80)	12.4 (13.8)
Uranium (mg/kg)	6.3	216 (307)	508 (2050)			

[a] Constituents that are selected as constituents of potential concern for surface soil (0-6") from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.5.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-17
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL AT DEPTHS FROM 0 TO 18 INCHES IN THE WASTE AREAS (OU 1 AND OU 2)[a]

(Data Sources: RI/FS and CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Entire Site (0 - 18") (pCi/g)	Radionuclide Concentration Waste Storage Areas (Waste Pits and Burn Pit) (0 - 18") (pCi/g)	Radionuclide Concentration Inactive Flyash (0 - 18") (pCi/g)	Radionuclide Concentration Active Flyash (0 - 18") (pCi/g)	Radionuclide Concentration South Field Area (0 - 18") (pCi/g)
Cs-137		0.485 (0.533)[c]	0.389 (0.415)	0.481 (0.700)	No Data Available as of Dec. 1, 1991	0.423 (0.454)
Np-237			0.120 (0.148)			
Pu-238		0.352 (0.374)	0.142 (0.179)			
Pu-239/240		0.322 (0.333)	0.308 (0.523)			
Ra-226	2.2	22.0 (40.0)	2.16 (2.38)	22.7 (35.0)		21.6 (27.5)
Ra-228	1.5	8.8 (12.9)	10.5 (32.0)			
Ru-106			2.76 (2.96)			2.97 (3.24)
Sr-90		0.846 (0.969)	0.279 (0.328)			
Tc-99		0.739 (0.799)	1.92 (2.71)			
Th-228	1.5	4.72 (6.40)	6.2 (12.0)			8.5 (30.5)
Th-230	2.1	50.2 (83.9)	308 (1154)	(59.0)[d]		145 (471)
Th-232	1.5	5.28 (7.13)	2.66 (2.94)	1.94 (2.30)		1.72 (1.95)
U-234	2.1	80 (104)	126 (222)	(82.0)		160 (255)
U-235	0.097	3.94 (4.84)	13.2 (26.0)	(1.90)		15.3 (15.2)
U-238	2.1	105 (136)	202 (241)	13.9 (21.6)		12.1 (13.3)
Uranium (mg/kg)	6.3	324 (437)	508 (2050)			

[a] Constituents that are selected as constituents of potential concern for surface soil (0-18") from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.5.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-18
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL AT DEPTHS FROM 0 TO 6 INCHES IN THE WASTE AREAS (OU 1 AND OU 2)[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Entire Site (0-6") (mg/kg)	Chemical Concentration Waste Storage Areas (0 - 6") (mg/kg)	Chemical Concentration Inactive Flyash (0 - 6") (mg/kg)	Chemical Concentration Active Flyash (0 - 6") (mg/kg)	Chemical Concentration South Field Area (0 - 6") (mg/kg)
ORGANICS						
1,1,1-Trichloroethane	0	0.003 (0.004)[c]		No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991
1,2-Dichloroethylene	0	0.003 (0.001)				
2-Butanone	0	0.007 (0.015)				
2-Methylnaphthalene	0	0.266 (0.406)				
4-Methyl-2-pentanone	0	0.005 (0.003)				
Acenaphthene	0	0.406 (0.739)				
Acetone	0	0.012 (0.016)				
Anthracene	0	0.424 (0.810)				
Aroclor-1254	0	0.37 (1.50)	0.260 (0.720)			
Aroclor-1260	0	0.88 (1.96)	(0.037)[d]			
Benzo(a)anthracene	0	0.59 (2.49)				
Benzo(a)pyrene	0	0.89 (6.61)				
Benzo(b)fluoranthene	0	0.60 (2.70)				
Benzo(g,h,i)perylene	0	0.69 (2.06)				
Benzo(k)fluoranthene	0	1.26 (2.64)				
Benzoic acid	0	2.205 (0.250)				
beta-BHC	0	0.015 (0.023)				
bis(2-Ethylhexyl) phthalate	0	0.435 (0.709)				
Carbon disulfide	0	0.003 (0.003)				
Chlorobenzene	0	0.003 (0.001)				
Chloroform	0	0.004 (0.006)				
Chrysene	0	0.71 (2.75)				
Cyanide	0	0.112 (0.142)	0.100 (0.155)			
Dibenzo(a,h)anthracene	0	0.46 (1.12)				

TABLE 2-18
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Entire Site (0-6") (mg/kg)	Chemical Concentration Waste Storage Areas (0 - 6") (mg/kg)	Chemical Concentration Inactive Flyash (0 - 6") (mg/kg)	Chemical Concentration Active Flyash (0 - 6") (mg/kg)	Chemical Concentration South Field Area (0 - 6") (mg/kg)
Dibenzofuran	0	0.456 (0.759)		No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991
Fluoranthene	0	4.5 (33.0)				
Fluorene	0	0.71 (1.24)				
Indeno(1,2,3-cd)pyrene	0	0.64 (1.90)				
Methylene chloride	0	0.018 (0.022)				
N-Nitrosodiphenylamine	0	0.376 (0.200)				
Naphthalene	0	0.397 (0.589)				
Phenanthrene	0	3.4 (22.0)				
Pyrene	0	3.60 (7.32)				
Tetrachloroethene	0	0.003 (0.004)				
Toluene	0	0.002 (0.003)				
Tributyl phosphate	0	(1.20)				
Trichloroethene	0	0.004 (0.007)				
INORGANICS						
Antimony		22.3 (24.4)	25.5 (27.2)	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991
Arsenic	20.5	6.47 (7.14)				
Barium	815	141 (209)				
Beryllium	2.1	0.874 (0.946)				
Cobalt	21	11.8 (13.0)				
Copper	58.6	34.8 (58.3)				
Lead	37	33.0 (48.7)				
Mercury	0.29	0.124 (0.166)				
Nickel	39	30.3 (32.7)	26.2 (29.2)			
Silver	8.0	7.27 (7.92)	8.29 (8.90)			
Zinc	113	82 (100)				

TABLE 2-18
(Continued)

[a] Constituents that are selected as constituents of potential concern for surface soil (0-6") from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.5.0 of Appendix) and the maximum detected concentration is given in the parentheses.

TABLE 2-19
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN
FOR SURFACE SOIL AT DEPTHS FROM 0 TO 18 INCHES IN THE WASTE AREAS (OU 1 AND OU 2)[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Entire Site (0 - 18") (mg/kg)	Chemical Concentration Waste Storage Areas (0 - 18") (mg/kg)	Chemical Concentration Inactive Flyash (0 - 18") (mg/kg)	Chemical Concentration Active Flyash (0 - 18") (mg/kg)	Chemical Concentration South Field Area (0 - 18") (mg/kg)
ORGANICS						
1,1,1-Trichloroethane	0	0.004 (0.005)[c]		No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991
1,1,2,2-Tetrachloroethane	0	0.003 (0.004)				
1,1,2-Trichloroethane	0	0.003 (0.003)				
1,1-Dichloroethane	0	0.003 (0.004)				
1,1-Dichloroethene	0	0.004 (0.005)				
1,2-Dichloroethylene	0	0.003 (0.004)				
2-Butanone	0	0.006 (0.007)				
2-Hexanone	0	0.006 (0.004)				
2-Methylnaphthalene	0	0.200 (0.223)				
4-Methyl-2-pentanone	0	0.006 (0.006)				
Acenaphthene	0	0.238 (0.277)				
Acetone	0	0.014 (0.018)				
Anthracene	0	0.238 (0.282)				
Aroclor-1254	0	0.53 (1.07)	0.050 (0.214)			
Aroclor-1260	0	0.67 (2.80)	(0.037)			
Benzene	0	0.003 (0.003)				
Benzo(a)anthracene	0	0.246 (0.323)				
Benzo(a)pyrene	0	3.1 (24.0)				
Benzo(b)fluoranthene	0	0.260 (0.344)				
Benzo(g,h,i)perylene	0	0.256 (0.320)				
Benzo(k)fluoranthene	0	0.245 (0.302)				
Benzoic acid	0	1.321 (0.250)				
beta-BHC	0	0.014 (0.019)				
bis(2-Ethylhexyl)phthalate	0	0.250 (0.315)				

TABLE 2-19
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Entire Site (0 - 18") (mg/kg)	Chemical Concentration Waste Storage Areas (0 - 18") (mg/kg)	Chemical Concentration Inactive Flyash (0 - 18") (mg/kg)	Chemical Concentration Active Flyash (0 - 18") (mg/kg)	Chemical Concentration South Field Area (0 - 18") (mg/kg)
Carbon disulfide	0	0.003 (0.004)		No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991
Chlorobenzene	0	0.003 (0.003)				
Chloroform	0	0.003 (0.004)				
Chrysene	0	0.272 (0.355)				
Cyanide	0	0.111 (0.133)	0.179 (0.279)			
Di-n-butyl phthalate	0	0.280 (0.049)				
Dibenzo(a,h)anthracene	0	0.229 (0.270)				
Dibenzofuran	0	0.207 (0.238)				
Ethyl benzene	0	0.003 (0.003)				
Fluoranthene	0	0.286 (0.384)				
Fluorene	0	0.235 (0.272)				
Indeno(1,2,3-cd)pyrene	0	0.247 (0.307)				
Methylene chloride	0	0.018 (0.022)				
N-Nitrosodiphenylamine	0	0.252 (0.200)				
Naphthalene	0	0.221 (0.251)				
Phenanthrene	0	0.507 (0.805)				
Phenol	0	0.270 (0.200)				
Pyrene	0	0.296 (0.389)				
Styrene	0	0.003 (0.003)				
Tetrachloroethene	0	0.004 (0.005)				
Toluene	0	0.003 (0.003)				
Total xylenes	0	0.003 (0.003)				
Tributyl phosphate	0	0.61 (1.14)				
Trichloroethene	0	0.004 (0.005)				

TABLE 2-19
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Entire Site (0 - 18") (mg/kg)	Chemical Concentration Waste Storage Areas (0 - 18") (mg/kg)	Chemical Concentration Inactive Flyash (0 - 18") (mg/kg)	Chemical Concentration Active Flyash (0 - 18") (mg/kg)	Chemical Concentration South Field Area (0 - 18") (mg/kg)
INORGANICS						
Antimony		16.5 (18.3)	25.5 (27.2)	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991	No Data Available as of Dec. 1, 1991
Arsenic	20.5	7.03 (8.45)				
Barium	815	122 (154)				
Beryllium	2.1	0.929 (0.985)				
Cobalt	21	11.8 (12.9)				
Copper	58.6	29.0 (42.9)				
Lead	37	31.6 (41.5)				
Mercury	0.29	0.084 (0.097)				
Nickel	39	30.3 (32.6)	26.2 (29.2)			
Selenium	1.2	0.260 (0.283)				
Silver	8.0	5.73 (6.27)	8.29 (8.90)			
Zinc	113	84.0 (98.1)				

[a] Constituents that are selected as constituents of potential concern for surface soil (0-18") from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-20
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL (EXCLUDING WASTE AREAS) BETWEEN 0 AND 6 INCHES[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Northeast Quadrant of Production Area (0-6") (pCi/g)	Radionuclide Concentration Northwest Quadrant of Production Area (0-6") (pCi/g)	Radionuclide Concentration Southeast Quadrant of Production Area (0-6") (pCi/g)	Radionuclide Concentration Southwest Quadrant of Production Area (0-6") (pCi/g)	Radionuclide Concentration Incinerator/ Waste Water Treatment Facility (0-6") (pCi/g)	Radionuclide Concentration Silo Area (0-6") (pCi/g)	Radionuclide Concentration Remainder of the Site (0-6") (pCi/g)
Cs-137		0.45 (0.51)[c]	0.39 (0.70)	1.35 (2.86)	0.64 (1.13)	0.53 (0.63)		0.57 (0.62)
Pu-238					1.28 (2.95)	0.37 (0.46)		0.32 (0.33)
Pu-239/240				0.35 (0.45)	0.67 (1.12)	0.36 (0.44)		0.32 (0.34)
Ra-226	2.2	1.86 (2.33)	188 (507)	1.49 (1.82)	1.25 (1.63)	11.6 (22.3)	1.70 (2.95)	14.4 (36.8)
Ra-228	1.5	23.1 (59.7)	10.1 (43.7)	1.68 (2.37)	92 (158)	2.82 (4.26)	1.31 (1.50)	1.50 (1.95)
Sr-90		0.46 (0.64)	0.41 (0.62)	0.45 (0.72)	0.64 (1.03)	1.26 (1.76)	1.14 (1.69)	0.79 (0.91)
Tc-99		0.91 (1.12)	0.59 (0.83)	0.76 (1.03)	18.7 (38.0)	1.69 (2.61)	0.57 (0.78)	0.60 (0.64)
Th-228	1.5	3.22 (3.75)	5.5 (15.6)	1.95 (2.95)	42 (308)	3.10 (4.69)		1.63 (2.00)
Th-230	2.1	317 (836)	210 (530)	7.5 (18.0)	52 (280)	50 (155)	3.06 (3.71)	7.7 (16.3)
Th-232	1.5	12.9 (27.0)	7.9 (31.4)	1.99 (3.52)	43 (283)	3.90 (6.31)	1.17 (1.41)	1.19 (1.28)
U-234	2.1	300 (146)	354 (1690)	125 (596)	1330 (13300)	1400 (7880)	4.13 (6.64)	11.6 (13.9)
U-235	0.097	4.50 (4.95)	19 (104)	6.1 (35.3)	65 (487)	102 (727)		0.51 (0.55)
U-238	2.1	308 (779)	391 (1930)	136 (704)	1380 (14300)	1780 (10500)	6.5 (18.7)	15.6 (18.9)
Uranium (mg/kg)	6.3	91 (110)	68 (121)	491 (3070)	1980 (17300)	2390 (23000)	21.6 (64.0)	54.6 (72.1)

[a] Constituents that are selected as constituents of potential concern for surface soil (0-6") from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-21
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL (EXCLUDING WASTE AREAS) WITHIN 0 TO 18 INCHES[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Northeast Quadrant of Production Area (0-18") (pCi/g)	Radionuclide Concentration Northwest Quadrant of Production Area (0-18") (pCi/g)	Radionuclide Concentration Southeast Quadrant of Production Area (0-18") (pCi/g)	Radionuclide Concentration Southwest Quadrant of Production Area (0-18") (pCi/g)	Radionuclide Concentration Incinerator/ Waste Water Treatment Facility (0-18") (pCi/g)	Radionuclide Concentration Silo Area (0-18") (pCi/g)	Radionuclide Concentration Remainder of the Site (0-18") (pCi/g)
Cs-137		0.31 (0.36)[c]	0.38 ((0.52)	0.25 (0.38)	0.39 (0.52)	0.45 (0.54)	No Data Available as of Dec. 1, 1991	0.55 (0.59)
Pu-238			0.32 (0.35)	0.36 (0.47)	1.07 (1.77)	0.45 (0.57)		0.32 (0.33)
Pu-239/240				0.34 (0.40)	0.50 (0.67)	0.35 (0.41)		0.32 (0.34)
Ra-226	2.2	1.49 (1.74)	190 (393)	1.47 (1.74)	1.19 (1.34)	9.7 (18.2)		13.6 (34.6)
Ra-228	1.5	12.6 (31.2)	5.7 (12.4)	1.61 (2.12)	48 (151)	2.88 (4.06)		1.65 (2.10)
Sr-90		0.50 (0.62)	0.52 (0.72)	0.44 (0.62)	0.52 (0.69)	1.21 (1.65)		0.79 (0.90)
Tc-99		0.86 (1.07)	0.57 (0.69)	0.76 (1.05)	1.25 (1.82)	6.8 (14.4)		1.03 (1.34)
Th-228	1.5	1.78 (2.18)	4.25 (7.85)	1.85 (2.60)	23.7 (59.3)	3.15 (4.43)		1.53 (1.67)
Th-230	2.1	166 (431)	208 (416)	17.8 (38.2)	27.0 (61.1)	77 (250)		7.5 (15.6)
Th-232	1.5	7.2 (14.5)	5.5 (12.1)	1.97 (2.85)	30.0 (88.9)	3.91 (5.91)		1.19 (1.28)
U-234	2.1	53.0 (85.1)	174 (419)	118 (309)	673 (1930)	1540 (6820)		24.4 (43.0)
U-235	0.097	2.55 (3.87)	8.7 (21.3)	6.1 (21.8)	31.9 (79.0)	105 (487)		1.11 (1.47)
U-238	2.1	61.1 (97.7)	223 (537)	131 (420)	710 (2060)	1910 (8810)		19.9 (24.5)
Uranium (mg/kg)	6.3	107 (146)	447 (766)	428 (1460)	1130 (2810)	2080 (21800)		87 (118)

[a] Constituents that are selected as constituents of potential concern for surface soil (0-18") from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First values are the constituent mean concentrations; values in parentheses are the 95% confidence limit on the mean.

TABLE 2-22
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL (EXCLUDING WASTE AREAS) WITHIN 0 TO 6 INCHES[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Northeast Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Northwest Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Southeast Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Southwest Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Incinerator/ Waste Water Treatment Facility (0-6") (mg/kg)	Chemical Concentration Silo Area (0-6") (mg/kg)	Chemical Concentration Remainder of the Site (0-6") (mg/kg)
ORGANICS								
1,1,1-Trichloroethane	0	0.003 (0.005)[c]						
1,1,2,2-Tetrachloroethane	0							
1,1,2-Trichloroethane	0							
1,1-Dichloroethane	0							
1,1-Dichloroethene	0							
1,2-Dichloroethylene	0	0.002 (0.001)						
2-Butanone	0	0.008 (0.016)			0.006 (0.009)			
2-Hexanone	0							
2-Methylnaphthalene	0	0.303 (0.559)						
4-Methyl-2-pentanone	0	0.005 (0.003)						
Acenaphthene	0	1.11 (2.60)			0.50 (1.09)			
Acetone	0	0.011 (0.016)			0.012 (0.021)			(0.015)[d]
Anthracene	0	1.28 (3.26)			0.75 (1.85)			
Aroclor-1254	0	0.78 (1.20)	0.44 (1.50)		0.420 (0.890)		(0.030)	0.047 (0.106)
Aroclor-1260	0	(2.80)			(1.00)			
Benzene	0							
Benzo(a)anthracene	0	5.3 (16.1)			1.58 (4.59)			
Benzo(a)pyrene	0	8.8 (24.0)			1.87 (5.10)			
Benzo(b)fluoranthene	0	10.4 (32.9)			1.30 (3.97)			
Benzo(g,h,i)perylene	0	3.6 (10.3)			1.13 (3.15)			
Benzo(k)fluoranthene	0	0.93 (2.60)			1.50 (4.27)			
Benzoic acid	0	2.792 (0.250)						

TABLE 2-22
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Northeast Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Northwest Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Southeast Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Southwest Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Incinerator/ Waste Water Treatment Facility (0-6") (mg/kg)	Chemical Concentration Silo Area (0-6") (mg/kg)	Chemical Concentration Remainder of the Site (0-6") (mg/kg)
beta-BHC	0	0.063 (0.100)			0.058 (0.146)			
bis(2-Ethylhexyl) phthalate	0	0.619 (0.780)			0.213 (0.180)			
Carbon disulfide	0	0.003 (0.003)						
Chlorobenzene	0	0.003 (0.001)						
Chloroform	0	0.006 (0.010)						
Chrysene	0	5.0 (15.3)			2.09 (6.12)			
Cyanide	0	4.7 (14.4)	.13 (.22)		0.22 (0.38)			0.082 (0.106)
Di-n-butyl phthalate	0							
Dibenzo(a,h)anthracene	0	1.97 (5.85)			0.53 (1.29)			
Dibenzofuran	0	0.59 (1.19)			0.30 (0.51)			
Ethyl benzene	0							
Fluoranthene	0	6.3 (17.1)			2.43 (6.50)			
Fluorene	0	0.86 (1.85)			0.52 (1.16)			
Indeno(1,2,3-cd)pyrene	0	3.8 (11.1)			0.90 (2.47)			
Methylene chloride	0	0.020 (0.026)			0.015 (0.021)			(0.025)
N-Nitrosodiphenylamine	0	0.480 (0.200)			0.252 (0.100)			
Naphthalene	0	0.473 (0.851)						
Phenanthrene	0	4.0 (11.3)			2.52 (7.47)			
Phenol	0							
Pyrene	0	4.6 (11.7)			2.43 (6.49)			
Styrene	0							
Tetrachloroethene	0	0.004 (0.007)			0.002 (0.002)			
Toluene	0	0.003 (0.003)			0.002 (0.002)			
Tributyl phosphate	0				(1.20)			
Trichloroethene	0	0.005 (0.011)			0.003 (0.004)			

TABLE 2-22
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Northeast Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Northwest Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Southeast Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Southwest Quadrant of Production Area (0-6") (mg/kg)	Chemical Concentration Incinerator/ Waste Water Treatment Facility (0-6") (mg/kg)	Chemical Concentration Silo Area (0-6") (mg/kg)	Chemical Concentration Remainder of the Site (0-6") (mg/kg)
INORGANICS								
Arsenic	20.5	8.8 (14.6)						7.67 (9.44)
Barium	815		204 (407)					
Beryllium	2.1				1.20 (2.01)			
Cobalt	21.0		16.6 (20.9)					
Copper	58.6	28.4 (44.0)	91 (128)					
Lead	37.0	68 (124)	34.7 (56.5)		120 (298)			
Mercury	0.29	0.243 (0.405)			0.582 (0.970)			
Nickel	39.0	44.4 (58.9)	33.2 (38.2)		32.1 (50.0)			26.4 (29.2)
Silver	8.0		8.25 (8.87)		4.1 (11.1)		7.37 (8.40)	8.08 (9.20)
Zinc	113	221 (335)	75.0 (99.7)		200 (316)			

[a] Constituents that are selected as constituents of potential concern for surface soil (0-6") from at least one area are listed in the table. Constituents analyzed for but not detected in any of the areas can be found in Section R.5 of Appendix R.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.5.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-23
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SURFACE SOIL (EXCLUDING WASTE AREAS) WITHIN 0 TO 18 INCHES[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Northeast Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Northwest Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Southeast Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Southwest Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Incinerator/ Wastewater Treatment Facility (0-18") (mg/kg)	Chemical Concentration Silo Area (0-18") (mg/kg)	Chemical Concentration Remainder of the Site (0-18") (mg/kg)
ORGANICS								
1,1,1-Trichloroethane	0	0.004 (0.005)[c]		No Data Available as of Dec. 1, 1991		No Data Available as of Dec. 1, 1991		
1,1,2,2-Tetrachloroethane	0	0.008 (0.016)						
1,1,2-Trichloroethane	0	0.003 (0.004)						
1,1-Dichloroethane	0	0.004 (0.004)						
1,1-Dichloroethene	0	0.004 (0.005)			0.003 (0.003)			
1,2-Dichloroethylene	0	0.003 (0.004)			0.003 (0.002)			
2-Butanone	0	0.006 (0.007)	(0.008)[d]		0.010 (0.035)			
2-Hexanone	0	0.006 (0.004)						(0.003)
2-Methylnaphthalene	0	0.201 (0.232)						
4-Methyl-2-pentanone	0	0.006 (0.007)						(0.002)
Acenaphthene	0	0.239 (0.285)			0.359 (0.617)			
Acetone	0	0.016 (0.022)	0.008		0.010 (0.016)			(0.015)
Anthracene	0	0.235 (0.283)			0.267 (0.470)			
Aroclor-1254	0	0.58 (2.46)	0.44 (1.50)		0.370 (0.717)		(0.030)	0.032 (0.102)
Aroclor-1260	0	0.82 (1.65)			0.54 (1.00)			
Benzene	0	0.003 (0.002)			0.003 (0.004)			
Benzo(a)anthracene	0	0.231 (0.315)			0.346 (0.877)			
Benzo(a)pyrene	0	0.93 (6.00)			0.34 (1.32)			
Benzo(b)fluoranthene	0	0.256 (0.360)			0.304 (0.676)			
Benzo(g,h,i)perylene	0	0.251 (0.322)			0.309 (0.670)			
Benzo(k)fluoranthene	0	0.224 (0.277)			0.386 (0.902)			
Benzoic acid	0	1.093 (0.250)			1.129 (0.088)			
beta-BHC	0	0.011 (0.014)			0.038 (0.076)			
bis(2-Ethylhexyl) phthalate	0	0.293 (0.387)			0.145 (0.180)			

TABLE 2-23
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Northeast Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Northwest Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Southeast Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Southwest Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Incinerator/ Wastewater Treatment Facility (0-18") (mg/kg)	Chemical Concentration Silo Area (0-18") (mg/kg)	Chemical Concentration Remainder of the Site (0-18") (mg/kg)
Carbon disulfide	0	0.003 (0.003)		No Data Available as of Dec. 1, 1991		No Data Available as of Dec. 1, 1991		
Chlorobenzene	0	0.003 (0.003)			0.003 (0.004)			
Chloroform	0	0.004 (0.006)	(0.004)					
Chrysene	0	0.250 (0.336)			0.44 (1.12)			
Cyanide	0	0.128 (0.192)	0.131 (0.204)		0.182 (0.251)			0.081 (0.014)
Di-n-butyl phthalate	0	0.234 (0.049)			0.256 (0.046)			
Dibenzo(a,h)anthracene	0	0.416 (0.750)			0.355 (0.665)			
Dibenzofuran	0	0.209 (0.245			0.253 (0.353)			
Ethyl benzene	0	0.003 (0.003)						
Fluoranthene	0	0.252 (0.350)			1.6 (10.0)			
Fluorene	0	0.241 (0.280)			0.359 (0.639)			
Indeno(1,2,3-cd)pyrene	0	0.250 (0.321)			0.54 (1.18)			
Methylene chloride	0	0.018 (0.022)	(0.029)		0.014 (0.021)		(0.003)	(0.038)
N-Nitrosodiphenylamine	0	0.266 (0.200)			0.216 (0.130)			
Naphthalene	0	0.217 (0.255)						
Phenanthrene	0	0.421 (0.714)			0.48 (1.29)			
Phenol	0	0.233 (0.200)			0.256 (0.069)			
Pyrene	0	0.259 (0.353)			0.57 (1.20)			
Styrene	0	0.003 (0.003)						
Tetrachloroethene	0	0.005 (0.007)			0.003 (0.002)			
Toluene	0	0.003 (0.003)	(0.007)		0.003 (0.003)		(0.002)	
Total xylenes	0	0.003 (0.003)						
Tributyl phosphate	0				(1.20)			
Trichloroethene	0	0.004 (0.006)	(0.003)		0.003 (0.004)			

TABLE 2-23
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Northeast Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Northwest Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Southeast Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Southwest Quadrant of Production Area (0-18") (mg/kg)	Chemical Concentration Incinerator/ Wastewater Treatment Facility (0-18") (mg/kg)	Chemical Concentration Silo Area (0-18") (mg/kg)	Chemical Concentration Remainder of the Site (0-18") (mg/kg)
INORGANICS								
Antimony		8.37 (9.82)	25.9 (30.4)	No Data Available as of Dec. 1, 1991		No Data Available as of Dec. 1, 1991	26.3 (29.7)	24.4 (26.8)
Arsenic	20.5	8.3 (11.8)						7.38 (9.18)
Barium	815		189(363)					
Beryllium	2.1				1.07 (1.48)			
Cobalt	21	11.6 (12.9)	16.5 (20.0)					
Copper	58.6	21.3 (24.0)	81.3 (95.3)		22.9 (34.7)			
Lead	37	29.7 (40.8)	31.9 (49.7)		114 (440)			
Mercury	0.29	0.116 (0.148)	0.080 (0.126)		0.598 (0.977)			
Nickel	39	32.0 (36.3)	34.0 (38.3)		31.5 (41.8)			25.9 (28.7)
Selenium	1.2	0.299 (0.371)						
Silver	8.0		7.41 (8.54)		0.63 (4.11)		7.37 (8.40)	7.76 (8.70)
Zinc	113	95 (128)	72.7 (91.1)		193 (266)			

a Constituents that are selected as constituents of potential concern for surface soil (0-18") from at least one area are listed in the table. Constituents analyzed for but not detected in surface area (0-18") from any of the area can be found in Section R.5 of Appendix R.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

d Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.5.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-24
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SUBSURFACE SOILS IN WASTE STORAGE AREAS (OU 1)[a]
(Data Source: CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Burn Pits (pCi/g)	Radionuclide Concentration Clearwell (pCi/g)	Radionuclide Concentration Waste Pit 1 (pCi/g)	Radionuclide Concentration Waste Pit 2 (pCi/g)	Radionuclide Concentration Waste Pit 3 (pCi/g)	Radionuclide Concentration Waste Pit 4 (pCi/g)	Radionuclide Concentration Waste Pit 5 (pCi/g)	Radionuclide Concentration Waste Pit 6 (pCi/g)
Am-241						39.7 (49.1)[c]			
Cs-137			190 (406)	1.7 (1.1)	1.88 (2.43)	1.34 (1.67)		1.94 (2.34)	5.64 (7.71)
Np-237		0.18 (0.45)	1.28 (2.53)			0.21 (0.45)	0.19 (0.37)	5.1 (19.4)	2.48 (4.26)
Pu-238		0.10 (0.21)	0.06 (0.09)		0.07 (0.10)	0.11 (0.24)	0.28 (0.50)	1.99 (3.64)	0.70 (1.29)
Pu-239/240		0.10 (0.19)			0.08 (0.24)	0.43 (1.83)	0.20 (0.37)	5.03 (9.72)	8.7 (14.3)
Ra-226	2.2	2.12 (2.61)	160 (438)	41.9 (65.2)	129 (430)	194 (428)	19.4 (31.3)	103 (119)	6.52 (7.93)
Ru-106				12.3 (9.8)	17.5 (21.9)				
Sr-90			4.4 (19.5)			0.78 (1.96)		3.8 (10.0)	1.8 (3.7)
Tc-99		7.0 (71.1)	133 (293)	1.30 (4.99)	9 (135)	455 (2190)	41 (225)	1100 (1840)	133 (162)
Th-228	1.5	7.5 (12.5)	28.8 (50.7)	15.1 (33.1)	42 (112)	26.7 (82.0)	44 (248)	77 (120)	0.95 (1.92)
Th-230	2.1	30.7 (89.0)	618 (4290)	1020 (2750)	553 (3320)	10500 (17300)	428 (566)	9880 (15000)	26.5 (39.6)
Th-232	1.5	4.13 (5.58)	18.9 (37.2)	18.7 (21.9)	42 (100)	17.0 (23.9)	32.8 (55.7)	36.3 (45.7)	6.3 (1.2)
U-234	2.1	135 (252)	285 (365)	486 (834)	487 (4180)	251 (355)	441 (1750)	567 (875)	3420 (5060)
U-235	0.097	8.4 (16.1)	35.0 (48.3)	41.2 (91.3)	59 (1390)	29.4 (74.8)	95 (332)	28.9 (32.2)	1040 (1750)
U-238	2.1	106 (180)	622 (670)	754 (1140)	1920 (6100)	190 (242)	2340 (4600)	195 (248)	6990 (10600)

a Constituents that are selected as constituents of potential concern for subsurface soil from at least one area are listed in the table.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-25
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SUBSURFACE SOILS IN WASTE STORAGE AREAS (OU 1)[a]
(Data Sources: RI/FS and CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Pit 1 (mg/kg)	Chemical Concentration Pit 2 (mg/kg)	Chemical Concentration Pit 3 (mg/kg)	Chemical Concentration Pit 4 (mg/kg)	Chemical Concentration Pit 5 (mg/kg)	Chemical Concentration Pit 6 (mg/kg)	Chemical Concentration Burn Pit (mg/kg)	Chemical Concentration Clearwell (mg/kg)
ORGANICS									
1,1,1-Trichloroethane	0	0.05 (0.11)[c]	(0.15)[d]		(0.12)			0.003 (0.002)	
1,1,2,2-Tetrachloroethane	0						(29.0)		
1,1-Dichloroethane	0							0.01 (0.11)	
2,4-Dimethylphenol	0		(0.15)						
2-Butanone	0	1.4 (2.3)	(2.7)	(3.6)	(7.9)		1.0 (1.4)	0.032 (0.067)	
2-Hexanone	0							0.005 (0.002)	
2-Methylnaphthalene	0	(0.22)	(8.0)					(0.05)	
3,3-Dichlorobenzidine(3)	0	(0.13)							
4,4-DDT	0	(1.6)	(1.4)						
4-Chlorophenyl-phenylether	0		(62.0)						
4-Methyl-2-pentanone	0							0.007 (0.006)	
4-Methylphenol	0		(0.35)						
Acenaphthene	0		31.0 (50.0)		(0.17)				
Acetone	0	0.14 (0.22)	(0.54)	0.16 (0.24)	0.33 (0.52)	(0.63)	1.8 (3.0)	0.16 (0.24)	1.4 (1.8)

TABLE 2-25
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Pit 1 (mg/kg)	Chemical Concentration Pit 2 (mg/kg)	Chemical Concentration Pit 3 (mg/kg)	Chemical Concentration Pit 4 (mg/kg)	Chemical Concentration Pit 5 (mg/kg)	Chemical Concentration Pit 6 (mg/kg)	Chemical Concentration Burn Pit (mg/kg)	Chemical Concentration Clearwell (mg/kg)
Anthracene	0	(0.074)	1 (120)		(0.51)				
Aroclor-1016	0							(0.29)	
Aroclor-1242	0				(1.0)			(0.29)	
Aroclor-1248	0	(3.5)	(0.32)		(0.85)	(0.55)		(0.20)	(0.31)
Aroclor-1254	0	4.6 (9.2)	(0.32)	0.14 (0.25)	0.6 (1.0)	(0.75)	(0.081)	1.8 (2.7)	0.24 (0.74)
Aroclor-1260	0	(7.0)	(1.8)						
Benzo(a)anthracene	0	(0.18)	3 (104)	(0.06)	0.40 (0.75)			0.09 (0.15)	(0.14)
Benzo(a)pyrene	0	(0.14)	65 (140)		(0.55)			(0.16)	
Benzo(b)fluoranthene	0	0.14 (0.30)	1.1 (46.6)	(0.11)	(0.51)			0.10 (0.16)	
Benzo(g,h.i)perylene	0		31 (52)		0.12 (0.17)			(0.085)	
Benzo(k)fluoranthene	0	(0.14)	49 (120)		(0.56)				
Bis(2-ethythexyl)phthalate	0	(1.7)	(0.36)	0.48 (0.78)	(0.27)	0.4 (1.2)	(0.91)	0.7 (1.9)	(0.27)
Carbon disulfide	0							0.003 (0.001)	
Carbon Tetrachloride	0	0.003 (0.002)							
Chlorobenzene	0							0.003 (0.002)	
Chloroform	0	0.11 (0.20)			0.2 (1.3)				
Chrysene	0	0.25 (0.47)	1.3 (74.8)	(0.075)	0.50 (0.76)			0.078 (0.083)	(0.15)

TABLE 2-25
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Pit 1 (mg/kg)	Chemical Concentration Pit 2 (mg/kg)	Chemical Concentration Pit 3 (mg/kg)	Chemical Concentration Pit 4 (mg/kg)	Chemical Concentration Pit 5 (mg/kg)	Chemical Concentration Pit 6 (mg/kg)	Chemical Concentration Burn Pit (mg/kg)	Chemical Concentration Clearwell (mg/kg)
Cyanide	0								(9.2)
Di-n-butyl phthalate	0	0.083 (0.092)	0.17 (0.38)	0.084 (0.084)	(0.49)	0.17 (0.25)		0.11 (0.21)	(0.12)
Di-n-octyl phthalate	0	0.36 (0.73)	0.28 (0.52)		(0.17)			0.09 (0.12)	
Dibenzo(a,h)anthracene	0		(16)		(0.17)				
Dibenzofuran	0		(36)		(0.16)				
Ethyl parathion	0				0.22 (0.86)				
Ethyl benzene	0	0.018 (0.037)	(0.048)					0.03 (0.19)	
Fluoranthene	0	0.24 (0.39)	3 (190)	(0.23)	1.4 (2.2)			0.22 (0.34)	
Fluorene	0		(62)		(0.31)				
Indeno(1,2,3-cd)pyrene	0		33 (52)		0.17 (0.18)			(0.078)	
Malathion	0				(0.67)				
Methyl parathion	0				1.1 (2.1)				
Methylene chloride	0	0.08 (0.13)	(0.2)	(0.42)	(0.23)	0.25 (0.39)	(0.7)	0.06 (0.11)	(0.64)
N-nitrosodiphenylamine	0			(0.13)					
Naphthalene	0	(0.054)	(16)		0.10 (0.11)				
Pentachlorophenol	0			(1.3)				(2.6)	

TABLE 2-25
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Pit 1 (mg/kg)	Chemical Concentration Pit 2 (mg/kg)	Chemical Concentration Pit 3 (mg/kg)	Chemical Concentration Pit 4 (mg/kg)	Chemical Concentration Pit 5 (mg/kg)	Chemical Concentration Pit 6 (mg/kg)	Chemical Concentration Burn Pit (mg/kg)	Chemical Concentration Clearwell (mg/kg)
Phenanthrene	0	0.4 (1.3)	2 (150)	(0.12)	1.3 (2.1)			0.16 (0.23)	(0.24)
Phenol	0		(0.33)		(0.83)	(0.2)		(0.65)	
Pyrene	0	0.17 (0.29)	2 (130)	(0.19)	0.9 (1.4)			0.14 (0.21)	(0.29)
Tetrachloroethene	0	0.03 (0.21)			(30)			0.02 (0.15)	
Toluene	0	0.029 (0.055)			(0.067)		(0.44)	0.02 (0.042)	
Total Xylenes	0	0.010 (0.022)	(0.26)				0.63 (0.75)	0.15 (0.74)	
Trans-1,2-dichloroethene	0				(0.06)				
Trichloroethene	0	0.005(0.019)			(0.3)		(0.17)		
Vinyl chloride	0		(0.67)					0.006 (0.003)	
INORGANICS									
Antimony						(28)		(13)	
Arsenic	20.5			1050 (2000)		530 (1500)			
Barium	815			2000 (7400)	2400 (5900)	21300 (29000)		270 (1100)	2300 (6900)
Beryllium	2.2		3.9 (8.9)	10 (17)	(13)	9 (13)	(5.7)	3 (16)	(9.1)
Boron								(48)	
Cadmium	11.1			6.0 (9.3)	11 (29)	(17)		4 (26)	
Chromium	103			58 (120)		120 (180)			

TABLE 2-25
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Pit 1 (mg/kg)	Chemical Concentration Pit 2 (mg/kg)	Chemical Concentration Pit 3 (mg/kg)	Chemical Concentration Pit 4 (mg/kg)	Chemical Concentration Pit 5 (mg/kg)	Chemical Concentration Pit 6 (mg/kg)	Chemical Concentration Burn Pit (mg/kg)	Chemical Concentration Clearwell (mg/kg)
Cobalt	21.4	(28)	61 (340)		(84)	33 (44)	(26)	45 (100)	
Copper	58.6	33 (78)	120 (280)	1100 (1900)	72 (160)	2300 (3100)	110 (220)	76 (260)	650 (1100)
Lead	37	21 (57)	84 (170)	230 (410)	43 (62)	160 (200)	30 (59)	58 (280)	47 (83)
Manganese	1,144			1400 (3600)	2600 (3600)	1800 (3200)		500 (1700)	1200 (1700)
Mercury	0.29	(0.36)	0.5 (0.7)	1.2 (3.4)	0.39 (0.63)	1.1 (1.5)		0.29 (0.91)	1.2 (4.4)
Molybdenum	8.8							(19.3)	
Nickel	39.4	30 (60)	110 (450)	88 (230)	30 (50)	130 (200)	22 (46)	35 (68)	(67)
Selenium	1.17		3.0 (10.2)	50 (90)		4.6 (7.5)			(3.7)
Silicon								(1200)	
Silver	8.0	7.4 (33.1)	(23.2)		150 (440)	(9.4)	(160)	41 (510)	
Vanadium	172			870 (5300)	95 (240)	2700 (4300)		60 (130)	390 (2600)
Zinc	113		220 (1900)	130 (220)		180 (200)		110 (510)	110 (190)

[a] Constituents that are selected as constituents of potential concern for subsurface soil from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.6.0 of Appendix R) and the maximum detected concentration is given in parentheses.

TABLE 2-26
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SUBSURFACE SOILS IN SOLID WASTE UNITS (OU 2)[a]

(Data Source: RI/FS and CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Active Flyash Pile (pCi/g)	Radionuclide Concentration Inactive Flyash Pile (pCi/g)	Radionuclide Concentration North Lime Sludge Pond (pCi/g)	Radionuclide Concentration South Lime Sludge Pond (pCi/g)	Radionuclide Concentration South Field (pCi/g)	Radionuclide Concentration Landfill (pCi/g)
Cs-137					0.28 (0.34)[c]		
Pb-210	2.23	(4.0)[d]	(5.0)			7.6 (20.2)	
Pu-238							0.19 (0.10)
Pu-239/240							
Ra-226	2.23	1.60 (2.44)	2.22 (2.53)	0.50 (0.64)	0.54 (0.65)	1.8 (2.3)	0.84 (0.96)
Ra-228	1.48	2.44 (3.29)	1.76 (2.53)		0.20 (0.30)	3.08 (9.18)	1.31 (2.41)
Ru-106						2.90 (3.42)	
Sr-90		1.4 (2.0)	0.83 (1.25)	0.5 (2.2)			0.72 (1.13)
Th-228	1.48	2.59 (3.56)	2.16 (2.76)	0.20 (0.20)		7.5 (38.0)	1.6 (2.4)
Th-230	2.11	3.1 (4.0)	4.01 (6.85)	3.7 (20.0)	3.0 (7.0)	5.7 (19.0)	2.75 (4.06)
Th-232	1.48	1.2 (1.8)	1.9 (2.1)	0.43 (0.58)	0.37 (0.46)	3.15 (4.58)	1.79 (2.32)
Thorium (mg/kg)	13.4	19.6 (45.8)	14.3 (21.3)				9.67 (16.6)
U-234	2.11	3.7 (4.7)	8.3 (27.5)	2.4 (2.5)	2.3 (3.1)	8.2 (15.0)	8.8 (28.0)
U-235	0.097	(0.20)	0.49 (1.21)	0.13 (0.20)	0.17 (0.30)	0.40 (0.80)	0.61 (1.02)
U-238	2.11	4.28 (5.34)	9.3 (11.6)	3.60 (4.63)	3.73 (4.18)	9.5 (10.7)	11.3 (14.4)
Uranium (mg/kg)	6.3	15.3 (21.6)	57 (587)				37 (150)

[a] Constituents that are selected as constituents of potential concern for subsurface soil from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.6.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-27
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SUBSURFACE SOILS IN SOLID WASTE UNITS (OU 2)[a]
(Data Sources: RI/FS and CIS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Active Flyash Pile (mg/kg)	Chemical Concentration Inactive Flyash Pile (mg/kg)	Chemical Concentration Landfill (mg/kg)	Chemical Concentration North Lime Sludge Ponds (mg/kg)	Chemical Concentration South Lime Sludge Ponds (mg/kg)	Chemical Concentration South Field (mg/kg)
ORGANICS							
1,1,1-Trichloroethane	0	0.010 (0.031)[c]	0.008 (0.024)				
1,1,2-trichloro-1,2,2-trifluo	0				(0.081)		
1,1-Dichloroethane	0			(0.13)[d]	(0.003)		
1,1-Dichloroethene	0	0.003 (0.002)					
2,4-Dimethylphenol	0			0.21 (0.24)			
2-Butanone	0			0.04 (0.12)		(1.8)	
2-Chlorophenol	0	0.195 (0.048)					
2-Methylnaphthalene	0	0.21 (0.16)		0.5 (3.4)			
2-Methyphenol	0			(0.096)			
4-Chloro-3-methylphenol	0	0.197 (0.058)					
4-Methyl-2-pentanone	0		0.006 (0.002)				
4-Methylphenol	0			0.25 (0.36)			
4-Nitrophenol	0	(0.048)					
Acenaphthene	0			1.2 (8.5)			
Acetone	0	0.025 (0.061)	0.017 (0.041)	0.14 (0.19)	0.11 (0.15)	(0.14)	0.24 (0.25)
Anthracene	0			1.3 (2.4)			
Aroclor-1242	0		(0.006)	0.22 (0.68)			0.053 (0.093)

TABLE 2-27
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Active Flyash Pile (mg/kg)	Chemical Concentration Inactive Flyash Pile (mg/kg)	Chemical Concentration Landfill (mg/kg)	Chemical Concentration North Lime Sludge Ponds (mg/kg)	Chemical Concentration South Lime Sludge Ponds (mg/kg)	Chemical Concentration South Field (mg/kg)
Aroclor-1248	0			(0.57)	(1.2)		
Aroclor-1254	0		(0.29)	(0.72)			0.39 (0.62)
Aroclor-1260	0	(0.038)					0.23 (0.42)
Benzo(a)anthracene	0			0.4 (1.6)			
Benzo(a)pyrene	0			0.9 (6.6)			
Benzo(b)fluoranthene	0		0.202 (0.093)	0.4 (1.7)			
Benzo(g,h,i)perylene	0			0.8 (2.7)			
Benzo(k)fluoranthene	0			0.5 (2.0)			
Benzoic acid	0	0.809 (0.073)	1.09 (0.15)			(0.16)	
bis(2-Ethylhexyl)phthalate	0	0.27 (0.58)		(0.15)	0.20 (0.31)	0.26 (0.31)	
Bromodichloromethane	0	0.003 (0.002)					
Butyl benzyl phthalate	0			0.24 (0.32)	(2.8)		
Carbon disulfide	0		0.003 (0.003)		0.008 (0.009)		
Chlordane	0				(1.2)		
Chloroform	0	0.004 (0.006)					
Chrysene	0			0.6 (2.5)			
Cyanide	0	0.16 (0.28)	0.49 (0.70)	(0.79)			
Di-n-butyl phthalate	0			0.17 (0.28)	0.10 (0.12)	(0.073)	
Di-n-octyl phthalate	0			0.26 (0.35)			
Dibenzo(a,h)anthracene	0			0.8 (1.6)			

TABLE 2-27
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Active Flyash Pile (mg/kg)	Chemical Concentration Inactive Flyash Pile (mg/kg)	Chemical Concentration Landfill (mg/kg)	Chemical Concentration North Lime Sludge Ponds (mg/kg)	Chemical Concentration South Lime Sludge Ponds (mg/kg)	Chemical Concentration South Field (mg/kg)
Dibenzofuran	0			1.1 (1.7)			
Ethyl benzene	0			0.03 (0.09)			
Fluoranthene	0			0.6 (1.3)			
Fluorene	0			1.2 (2.2)			
Indeno(1,2,3-cd)pyrene	0			0.7 (2.7)			
Methylene chloride	0			0.09 (0.14)	0.024 (0.026)	0.18 (0.24)	(0.11)
N-nitrosodiphenylamine	0			(0.067)			
Naphthalene	0	0.200 (0.082)		1.2 (16.2)			
Phenanthrene	0	0.179 (0.072)		0.6 (1.3)			
Phenol	0	0.197 (0.058)	0.32 (0.31)	0.24 (0.31)	(0.61)	(0.089)	
Pyrene	0			0.6 (1.9)			
Tetrachloroethene	0			0.034 (0.097)			
Toluene	0	0.004 (0.006)	0.003 (0.003)	0.06 (0.18)	(0.020)		
Total xylenes	0			0.01 (0.32)			
INORGANICS							
Antimony		5.5 (9.2)	7.4 (11.0)				
Arsenic	20.5	30.5 (66.5)	17.8 (35.4)				
Beryllium	2.15	2.4 (3.4)	2.4 (5.8)				
Boron				(26.6)			
Cobalt	21.4						14.3 (20.9)

TABLE 2-27
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Active Flyash Pile (mg/kg)	Chemical Concentration Inactive Flyash Pile (mg/kg)	Chemical Concentration Landfill (mg/kg)	Chemical Concentration North Lime Sludge Ponds (mg/kg)	Chemical Concentration South Lime Sludge Ponds (mg/kg)	Chemical Concentration South Field (mg/kg)
Copper	58.6	35.8 (66.1)					
Lead	37.3	27.3 (52.9)	27.4 (67.1)	30.3 (61.9)			
Manganese	1144						603 (824)
Mercury	0.29	0.11 (0.20)	0.11 (0.18)		(0.30)		0.336 (0.851)
Molybdenum	8.85	12.7 (16.3)	6.0 (9.4)	(11.2)			
Nickel	39.4	25.5 (31.9)		22.6 (31.8)			23.4 (33.9)
Selenium	1.17	3.2 (5.4)	1.8 (2.5)				
Silicon				(701)			
Silver	8.03	2.2 (4.4)		(12.5)			
Zinc	113	55.0 (83.0)		65.0 (98.6)			

[a] Constituents that are selected as constituents of potential concern for subsurface soil from at least one area are listed in the table.

[b] Background data are not available if there is not an entry.

[c] First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

[d] Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.6.0 of Appendix R) and the maximum detected concentration is given in the parentheses.

TABLE 2-28
RADIOLOGICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SUBSURFACE SOIL IN THE PRODUCTION AREA[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (pCi/g)	Radionuclide Concentration Plant 2/3 (pCi/g)	Radionuclide Concentration Plant 6 (pCi/g)	Radionuclide Concentration Plant 9 (pCi/g)	Radionuclide Concentration Pilot Plant (pCi/g)	Radionuclide Concentration Remainder of the Production Area (pCi/g)
Cs-137		0.14 (0.16)[c]		0.12 (0.14)	0.22 (0.37)	0.188 (0.234)
Np-237		0.54 (0.70)		0.34 (0.42)		
Pu-238		0.33 (0.35)	0.37 (0.44)		0.43 (0.66)	0.341 (0.380)
Pu-239/240		0.35 (0.39)	0.34 (0.38)		0.37 (0.48)	0.335 (0.372)
Ra-226	2.2	3.0 (4.6)	0.75 (0.82)	0.74 (0.80)	5.3 (11.0)	1.05 (1.45)
Ra-228	1.5	1.07 (1.37)	0.67 (0.75)	1.48 (2.84)	15.6 (59.3)	1.77 (2.20)
Sr-90		0.75 (1.13)	0.50 (0.62)	0.47 (0.77)	0.41 (0.52)	0.61 (0.71)
Tc-99		0.94 (1.16)	0.84 (1.09)	0.78 (1.44)	1.37 (2.48)	3.99 (7.24)
Th-228	1.5	1.07 (1.39)	1.37 (1.97)	1.14 (1.59)	2.96 (4.99)	1.62 (1.99)
Th-230	2.1	13.0 (30.7)	1.80 (2.31)	5.3 (12.3)	4.93 (7.56)	3.51 (4.53)
Th-232	1.5	1.03 (1.29)	0.78 (0.93)	5.0 (12.3)	1.9 (2.8)	1.43 (1.75)
Thorium (mg/kg)	13.4	8.59 (9.70)	7.8 (9.6)	26.4 (54.1)	18.7 (25.8)	9.7 (11.6)
U-234	2.1	350 (1340)	304 (1110)	58.7 (85.0)	99 (137)	72 (121)
U-235/236	0.097	23.8 (68.7)	1.5 (2.2)	9.6 (36.2)	6.0 (17.3)	3.64 (5.22)
U-238	2.1	346 (1300)	351 (1310)	52.1 (76.3)	93 (270)	73 (122)
Uranium (mg/kg)	6.3	165 (254)	784 (2390)	54.7 (98.7)	270 (698)	64.8 (86.5)

TABLE 2-28
(Continued)

a Constituents that are selected as constituents of potential concern for subsurface soil from at least one plant are listed in the table.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

TABLE 2-29
CHEMICAL CONSTITUENTS OF POTENTIAL CONCERN FOR SUBSURFACE SOILS IN THE PRODUCTION AREA[a]

(Data Source: RI/FS)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Plant 2/3 (mg/kg)	Chemical Concentration Plant 6 (mg/kg)	Chemical Concentration Plant 9 (mg/kg)	Chemical Concentration Pilot Plant (mg/kg)
ORGANICS					
1,1,1-Trichloroethane	0	0.003 (0.004)[c]	0.003 (0.002)	0.005 (0.010)	0.008 (0.031)
1,1,2,2-Tetrachloroethane	0				0.006 (0.016)
1,1,2-Trichloroethane	0				0.083 (0.002)
1,1-Dichloroethane	0	0.006 (0.016)			0.085 (0.027)
1,1-Dichloroethene	0	0.004 (0.002)	0.005 (0.009)	0.003(0.004)	0.004 (0.007)
1,2-Dichloroethane	0				0.083 (0.002)
1,2-Dichloroethylene	0		0.011 (0.019)	0.005 (0.006)	0.006 (0.020)
2-Butanone	0	0.015 (0.056)	0.008 (0.014)	0.006 (0.007)	0.3 (2.4)
2-Hexanone	0		0.006 (0.003)	0.005 (0.001)	
4-Methyl-2-Pentanone	0	0.005 (0.002)	0.005 (0.003)	0.006 (0.007)	0.008 (0.017)
Acenaphthene	0				0.32 (0.54)
Acetone	0	0.026 (0.084)	0.047 (0.079)	0.012 (0.016)	0.190 (0.061)
Anthracene	0				0.24 (0.39)
Aroclor-1221	0		0.056 (0.083)		
Aroclor-1254	0	(0.36)[d]			0.31 (0.68)
Aroclor-1260	0				0.60 (0.96)

TABLE 2-29
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Plant 2/3 (mg/kg)	Chemical Concentration Plant 6 (mg/kg)	Chemical Concentration Plant 9 (mg/kg)	Chemical Concentration Pilot Plant (mg/kg)
Benzene	0				0.083 (0.005)
Benzo(a)anthracene	0				0.35 (0.62)
Benzo(a)pyrene	0				0.8 (3.5)
Benzo(b)fluoranthene	0				0.26 (0.44)
Benzo(g,h,i)perylene	0				0.30 (0.49)
Benzo(k)fluoranthene	0				0.36 (0.62)
Benzoic acid	0	1.2 (0.088)			1.100 (0.059)
Beta-BHC	0		0.06 (0.25)		0.012 (0.023)
bis(2-Ethylhexyl) phthalate	0	0.31 (0.18)	0.21 (0.25)	(0.32)	0.32 (0.49)
Bromodichloromethane	0			0.004 (0.004)	
Carbon disulfide	0			0.003 (0.004)	0.083 (0.004)
Chlorobenzene	0				0.083 (0.005)
Chloroform	0		0.003 (0.003)	0.004 (0.006)	0.083 (0.002)
Chrysene	0				0.40 (0.73)
Cyanide	0		0.28 (0.45)		
Di-n-butyl phthalate	0				0.42 (0.66)
Di-n-Octyl Phthalate	0		0.21 (0.23)		
Dibenzo(a,h)anthracene	0				0.31 (0.53)

TABLE 2-29
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Plant 2/3 (mg/kg)	Chemical Concentration Plant 6 (mg/kg)	Chemical Concentration Plant 9 (mg/kg)	Chemical Concentration Pilot Plant (mg/kg)
Dibenzofuran	0				0.23 (0.32)
Ethyl benzene	0	0.005 (0.003)	0.003 (0.002)		0.082 (0.001)
Fluoranthene	0	0.28 (0.081)			1.3 (6.5)
Fluorene	0				0.32 (0.55)
Indeno(1,2,3-cd)pyrene	0				0.5 (0.9)
Methylene chloride	0	0.017 (0.037)	0.013 (0.017)	0.015 (0.017)	0.7 (1.9)
N-Nitroso-di-n-propylamine	0	(0.63)			
N-Nitrosodiphenylamine	0	0.20 (0.13)			
Phenanthrene	0	(0.088)			0.38 (0.72)
Phenol	0				0.24 (0.07)
Pyrene	0				0.39 (0.78)
Tetrachloroethene	0		0.003 (0.003)	0.004 (0.005)	0.012 (0.084)
Toluene	0	0.007 (0.014)	0.003 (0.004)	0.003 (0.002)	0.08 (0.01)
Total Xylenes	0	0.007 (0.012)	0.004 (0.004)		0.008 (0.044)
Tributyl phosphate	0	(1.2)			
Trichloroethane	0		0.004 (0.008)	0.006 (0.011)	0.008 (0.028)
Vinyl chloride	0		0.006 (0.003)		0.006 (0.006)
INORGANICS					

TABLE 2-29
(Continued)

Constituents of Potential Concern	Background[b] (upper 95% tolerance limit or maximum measurement) (mg/kg)	Chemical Concentration Plant 2/3 (mg/kg)	Chemical Concentration Plant 6 (mg/kg)	Chemical Concentration Plant 9 (mg/kg)	Chemical Concentration Pilot Plant (mg/kg)
Antimony			14.4 (19.0)	(19.2)	1.8 (9.3)
Arsenic	20.5	11.0 (26.5)	2.9 (3.5)		
Barium	815	69.2 (78.9)	58 (89)		472 (3610)
Beryllium	2.15	1.7 (2.4)	0.61 (0.74)		
Lead	37.3	312 (440)			25.1 (44.4)
Manganese	1144				395 (600)
Mercury	0.29	0.7 (1.3)			0.31 (0.85)
Nickel	39.4	43 (50)			23.4 (30.0)
Silver	8.0	7.3 (17.2)			2.8 (4.3)
Zinc	113	113 (247)			122 (174)

a Constituents that are selected as constituents of potential concern for subsurface soil from at least one plant are listed in the table.

b Background data are not available if there is not an entry.

c First value is the constituent mean concentration; value in parentheses is the 95% confidence limit on the mean (UCL).

d Mean concentration is not applicable for sample size ≤ 2 (see the corresponding summary tables in Section R.6.0 of Appendix R) and the maximum detected concentration given in the parentheses.

assessment (Section 3.0 of Part II) or as the exposure point concentrations for risk calculations (Section 5.0 of Part II)[1]. The statistical methodology to construct UCLs has been given in detail in Section 7.0 of the RI/FS Risk Assessment Work Plan Addendum (DOE 1992a) and is not repeated here. The UTL for background concentrations associated with each of the selected constituents of potential concern for a specific medium is also given in the tables (see Section 2.2.1 and Appendix T). Additional information on site-related data such as frequency of detection, range of detected concentrations, distribution, and the reason for inclusion as a constituent of potential concern can be found in the data summary tables contained in Appendix R.

Tables 2-3 and 2-4 list constituents of potential concern inside the Operable Unit 4 silos. Section R.1.0 of Appendix R presents additional information regarding the sample results for the contents of Operable Unit 4 silos.

Table 2-5 provides a comparison of the radon concentrations measured prior to, and following, installation of the bentonite in the K-65 silos. Section R.2.0 of Appendix R presents additional information.

Tables 2-6 through 2-9 list constituents of potential concern identified for surface water and sediment in the Great Miami River, Paddys Run, and the SSOD; Tables 2-10 and 2-11 list constituents of potential concern in standing water for the waste storage area. Section R.3.0 of Appendix R presents additional information regarding the sample results for surface water and sediment. Exposures to these constituents of potential concern, which are mainly by direct ingestion or water use, are assessed in Section 3.0 of Part II. Tables 2-12 and 2-13 provide data on constituents of potential concern in groundwater from off-property wells. These data are used in evaluating exposure under the current land-use scenario. Tables 2-14 and 2-15 provide data for perched water in the former Production Area (Plant 2/3, Plant 6, Plant 9, and Pilot Plant areas). These data are used in estimating source terms for groundwater modeling. Section R.4.0 of Appendix R contains information pertaining to perched water in additional areas that were not

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[1] Note that in a few cases (for an example see Table 2-19) the mean concentration for a chemical constituent can be found to be greater than the "UCL" in the parentheses. The reason is that the SQL in these cases, which takes into account sample characteristics, sample preparation, and the analytical adjustment, varies greatly from sample to sample in the data set. Since a value equal to 1/2 the SQL is used as the concentration for the non-detects to estimate the concentration mean (see Section 2.1.3 of Part II), high SQL values would result in a high calculated mean and UCL. If the calculated UCL exceeds the maximum detected value, the calculated UCL is replaced by the maximum detected value (EPA 1989a) in the parentheses; and the maximum detected value sometimes is lower than the calculated mean.

considered to be significant as source terms for groundwater. Groundwater data summarized by aquifer depth (Appendix M) are not used in the quantitative risk assessment.

Tables 2-16 through 2-23 present selected constituents of potential concern in surface soil within depths of 0 to 6 inches (0 - 0.15m) and 0 - 18 inches (0 - 0.46m) for the waste storage area and for other areas on the site. Fate and transport modeling of the constituents of potential concern from the soil due to dust resuspension (0 to 6 inches), erosion (0 to 6 inches), or crop/forage root uptake (0 to 18 inches) is described in Section 3.0. Direct ingestion of surface soil and dermal contact with surface soil are also considered in Section 3.0 as potential exposure routes.

Tables 2-24 through 2-29 present constituents of potential concern identified for subsurface soils in each waste unit in the waste areas (Operable Unit 1 and Operable Unit 2), various sections of the former Production Area (Plant 2/3, Plant 6, Plant 9, and Pilot Plant areas), and the incinerator area. Concentrations of the constituents of potential concern (i.e., UCLs) given in these tables are used to estimate source terms for air and groundwater modeling efforts and are used as exposure concentrations for direct contact in the future land-use scenario. Section R.6.0 of Appendix R contains summaries of data for additional areas of the FEMP that do not contribute significantly to potential exposures.

The constituents of potential concern that are listed in the preceding tables may be eliminated from further consideration if they are not present at potential receptor locations as a result of fate and transport modeling (Section 3.0). For example, constituents of potential concern in source areas for groundwater modeling may never reach the regional aquifer as a consequence of fate and transport processes such as retardation, absorption, radioactive decay, or chemical degradation. The constituents would not be present in the regional aquifer for subsequent exposure calculations and, hence, would not be constituents of potential concern for the exposure assessment for groundwater pathways.

3.0

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3.0 EXPOSURE ASSESSMENT

3.1 EXPOSURE SETTING

The site setting influences the types of transport mechanisms and receptor exposures that may occur in the vicinity of the site. Evaluation of the site setting involves examining the physical environment and populations (potential receptors) in the vicinity of the FEMP that could be exposed to constituents at the site.

3.1.1 Physical Setting

The physical setting of the site includes the local geography, surface topography, demographics, geology and hydrogeology, and ecology. A detailed description of the physical setting of the FEMP is presented in Part I of this report. A summary description of the physical setting at the FEMP is given in this section.

3.1.1.1 Geography

The FEMP covers approximately 1050 acres (425 ha) of land in rural areas of Hamilton and Butler counties in southwestern Ohio. The facility is located approximately 18 miles (29 km) northwest of Cincinnati, Ohio. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are located within a few miles of the FEMP.

3.1.1.2 Surface Topography

The main physiographic features in the area are gently rolling uplands, steep hillsides along the major streams, and the Great Miami River Valley. This relatively broad, flat-bottomed valley is flanked on either side by bluffs that rise to a maximum of 300 feet (91 m) above the general level of the valley floor. Maximum elevation along the northern boundary of the FEMP property is a little more than 700 feet (210 m) above mean sea level (MSL). The former Production Area and the waste storage area rest on a relatively level plain at about 580 feet (177 m) above MSL. The plain slopes from 600 feet (180 m) above MSL along the eastern boundary of the FEMP to 570 feet (170 m) above MSL at Silos 1 and 2, and then drops off toward Paddys Run at an elevation of 550 feet (165 m) above MSL.

3.1.1.3 Surface Hydrology

The primary surface drainage feature of the FEMP is Paddys Run, an intermittent stream. A tributary of the Great Miami River, Paddys Run flows from north to south near the western boundary of the FEMP property. Paddys Run has historically received direct runoff from the western areas of the FEMP, including the silos and waste storage areas. One branch of Paddys Run, now known as the SSOD, drains the southern end of the former Production Area and feeds into the stream, approximately 650 feet (200 m) upstream of the southern boundary of the FEMP. The remainder of the FEMP generally drains from east to west into Paddys Run.

However, the extreme northeast corner of the FEMP drains east toward the Great Miami River. Part I, Section 2.2.2 and Appendix P of this report present additional details on surface water hydrology.

3.1.1.4 Geology and Hydrogeology

The FEMP site is located on a dissected till plain left by Wisconsin glaciation. This plain overlies a two- to three-mile-wide (3-5 km) subterranean valley known as the New Haven Trough. This valley formed as a result of Pleistocene glaciation and subsequently filled with glacial outwash materials and till. The buried valley is approximately one-half to more than two miles wide and is U-shaped, having a broad, relatively flat bottom and steep valley walls. Interbedded glacial overburden deposits occur within the outwash deposits, but in most cases are of limited lateral extent. The overburden deposits are composed primarily of poorly sorted pebbles, cobbles, and boulders in a predominantly clay matrix.

Three flow systems of the Great Miami Aquifer converge in the vicinity of the FEMP reservation. As shown in Figure 3-1, groundwater in the Dry Fork Section of the New Haven Trough generally flows from west to east. Groundwater in the Shandon Tributary of the New Haven Trough generally flows to the southeast, and groundwater in the Ross Section of the New Haven Trough generally flows to the southwest. A flow divide located in the southern portion of the FEMP separates the Dry Fork Section groundwater flow from Shandon Tributary groundwater flow. The location of the divide fluctuates, depending on flow conditions; therefore mixing occurs along the divide. Groundwater from the Ross Section does not pass beneath the FEMP. A flow divide separating the Ross Section groundwater from Shandon Tributary groundwater is located east of the FEMP, as shown in Figure 3-1. This divide is influenced by pumping of the collector wells located within and near the "big bend" of the Great Miami River.

Surface and subsurface hydrology of the site are reported to be connected at various locations. Paddys Run loses flow to the top of the regional aquifer, which intersects the stream bed within the site boundaries. Natural gradients cause the groundwater beneath the FEMP to flow east to the Great Miami River (upstream from New Baltimore), or flow south through the branch of the bedrock channel west of New Baltimore. In either case, the Great Miami River is the ultimate receptor of groundwater from the FEMP area.

Groundwater is the source of water for industrial and domestic use in the area. The estimated pumping from the major well fields in the area averages approximately 18 million gallons per day (mgd). Additionally, there are smaller industrial, commercial, agricultural, and private groundwater users in the area. The residences in the area use either domestic wells or cisterns for water supplies. Generally, cisterns are used in areas underlain by bedrock. Many residents use bottled water for drinking because of the bad taste and smell of the water from some parts of

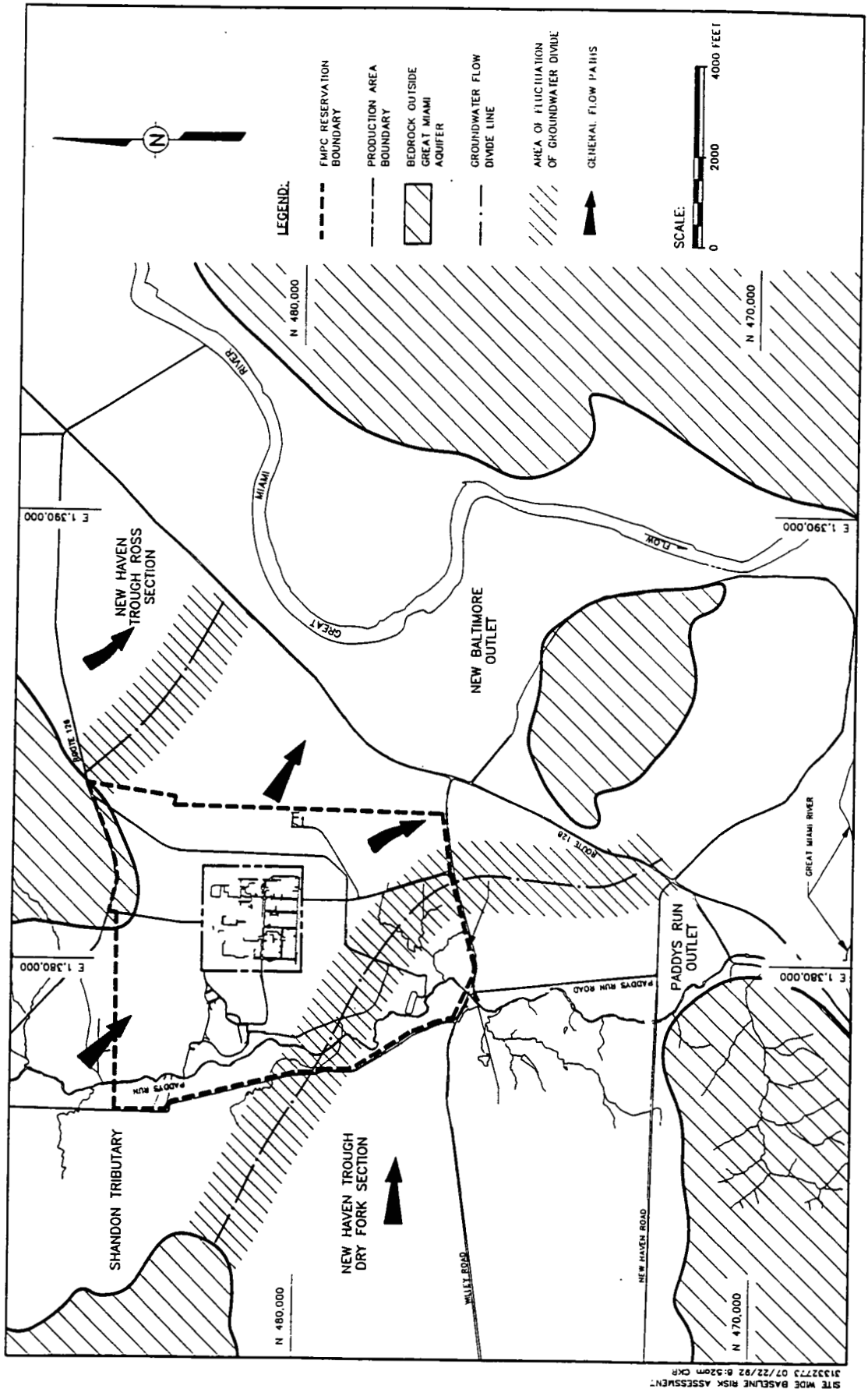

FIGURE 3–1. GROUNDWATER FLOW DIVIDES

the aquifer. Wells downgradient from the FEMP are generally completed in the upper part of the aquifer and pump only when there is a demand for water for domestic washing and sanitation.

Several large farms in the vicinity of the FEMP use groundwater. Two known irrigation wells on farms east of the site and northwest of Route 128 are currently being used for field irrigation. One farm on New Haven Road south of the property, between Route 128 and the village of New Baltimore, irrigates from a well. Farmers east and south of the FEMP, who are in close proximity to the Great Miami River, irrigate their fields with water from the river (Plummer 1990). See Part I, Section 2.2.3 and Appendix O for additional details on site geology and groundwater hydrology.

3.1.2 Potentially Exposed Populations

Human populations in the vicinity of the FEMP which may be exposed to constituents at the site have been identified (DOE 1992a). This section examines the locations and lifestyles of these populations to determine if they might reasonably be subject to potential exposures.

3.1.2.1 General Demographics

As an inactive industrial property undergoing characterization, remediation, and closure, there are no residences on the FEMP. The on-property worker population includes employees of DOE, WEMCO and other contractors. Workers are generally on the FEMP approximately eight hours per day, five days per week. Structures housing on-property workers are on approximately 200 acres (81 ha) in the center of the FEMP in the administration area and the production area.

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FEMP. Downtown Cincinnati is approximately 20 miles (32 km) southeast of the FEMP and the cities of Hamilton and Fairfield are six to eight miles (10 to 13 km) to the northeast. There is an estimated population of more than 24,000 within five miles (8 km) of the center of the FEMP. The nearest resident is within three quarters of a mile (1200 meters) 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. The Knollman Dairy Farm is located on Willey Road just outside the southeast corner of the FEMP property boundary (leased grazing areas include areas inside the property boundary). Several residences are located off Paddys Run Road approximately one-half mile (800 m) south of the FEMP property boundary and along New Haven Road approximately one mile (1600 m) 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 which extends south of the FEMP property boundary approximately three-quarters of a mile (1200 m).

3.1.2.2 Critical Subpopulations

Current subpopulations of potential concern within five miles (8 km) of the FEMP are identified below and are listed by the categories suggested by the EPA (1989b). The information presented on sensitive subpopulations covers the area within five miles (8 km) of the FEMP and includes an area extending between three and four miles beyond the leading edge of the South Plume. Population descriptions within this area are based on 1990 census data. The locations of potential receptor populations are normally specified with respect to the location of the source of emissions from a site. Because of the multiple sources of potential emissions from the FEMP, the center of the FEMP was chosen as the location to which the locations of potential receptor populations are referenced.

- Schools: No schools are located within one mile (1600 m) of the FEMP. The Northwest, Ross, and Southwest school districts provide public education from kindergarten through high school for children living within five miles (8 km) of the FEMP. The 1989-90 total enrollment in the six schools from these districts within five miles (8 km) of the FEMP totaled 3,316.

- Daycare Centers: No daycare facilities are located within one mile (1600 m) 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 SR 128 and US 27 about two and one-half miles (4 km) northeast of the center of the FEMP, (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 two miles (3 km) northeast of the center of the FEMP.

- Hospitals, Nursing Homes, and Retirement Communities: No care facilities of these types operate within five miles (8 km) of the FEMP.

- Residential Areas with Children: In 1988, approximately 58 adults and 29 children were residing within one mile (1600 m) of the FEMP. Most of the residences within five miles (8 km) 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 five miles of the center of the FEMP in 1988.

- Commercial and Recreational Fisheries: No commercial fisheries operate within five miles (1600 m) 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 (8 km) of the FEMP. The Great Miami River supports no commercial fisheries in the vicinity of the FEMP, but recreational fishing occurs downstream of the FEMP. The Ohio Department of Health issued a fishing advisory for (polychlorinated biphenyls) PCBs in bottom-feeding fish in 1989, based on data collected by Ohio EPA.

- Major Industries Using Chemicals: No industrial facilities are located within one mile (1600 m) of the center of the FEMP. Two companies located within two miles

(3 km) 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 CERCLA sites, are listed on the Comprehensive Environmental Response Compensation and Liability Information System (CERCLIS), and are undergoing a state-led RI/FS. Proctor & Gamble has a research facility approximately two miles (3 km) east of the FEMP which is listed on CERCLIS and has undergone a Screening Site Inspection by EPA. Employees at these facilities are only considered a sensitive subpopulation if they reside within five miles (8 km) of the FEMP.

3.1.3 Land Use

Identification of land use scenarios is discussed thoroughly in the Addendum (DOE 1992a). Three potential land-use scenarios that are addressed are:

- Current land use with current access controls
- Current land use with no access controls
- Future land use with no access controls

These land-use scenarios, and the impacts they have on the preliminary site-wide exposure assessment are presented below.

3.1.3.1 Current Land Use with Access Controls

Current land use surrounding the FEMP is mainly agricultural, with dairy, beef, corn, and soy bean production. Several industries, including Delta Steel, Albright & Wilson Chemical Company, Ruetgers-Nease Chemical Company, two commercial gravel operations, and a cement plant, are located to the south. The Miami Whitewater Forest and a Hamilton County park are located within five miles (8 km) of the FEMP.

A security fence surrounds the entire FEMP property, and a second line of fences surrounds several internal areas, including the production area and the waste disposal area. These fences are regularly patrolled by a large, full-time security force. These active (security patrols) and passive (fences) access controls are currently in place at the FEMP. Over the past 40 years, these controls have proven to be effective in restricting unauthorized site access to transient forays of limited duration (intruders). No hunting or fishing is allowed on the property, but approximately 400 acres of the FEMP are leased to a nearby resident for grazing of cattle.

3.1.3.2 Current Land Use with No Access Controls

The Amended Consent Agreement between DOE and EPA requires each Baseline Risk Assessment to "... include a scenario evaluating current conditions at the Site, assuming no further response actions and no institutional controls for the OU under consideration...". Therefore, this description of land use, known as the "current hypothetical scenario", was developed to address

this situation. The current hypothetical scenario stipulates that active access controls may not be considered when assessing the exposures incurred by a hypothetical receptor. Any activities requiring capital improvement/development (i.e., home building, planting and harvesting crops, etc.) are to be addressed when assessing the future land-use scenario. Receptors under this hypothetical scenario include those encountered under the current scenario with access controls, with the addition of an "on-property building user" and a "hunter". The major differences between the current land use and hypothetical scenarios are the frequency of exposure, and the source areas to which individuals may be exposed.

3.1.3.3 Future Land Use

It is difficult to develop reasonable future land-use scenarios at government facilities. Because the government is liable for waste disposed at a facility, the government is responsible for controlling future potential exposures to those wastes. For that reason, the most reasonable future land-use scenario would be government control and management of the property in perpetuity.

However, uncertainties associated with sociopolitical activities in the future make it prudent to evaluate future potential exposures assuming that the government loses control of the land. Given the current use of the land surrounding the facility, it is assumed that FEMP property could be used as farm land in the future. Thus, to address the reasonable maximum future exposure, use of the property as a resident farm is considered for the future land-use scenario. In addition, the exposures incurred by scavanging and invasive intrusion into a waste area by a home builder are investigated.

3.1.4 Receptors

Lifestyle/activity profiles of potential receptors have been constructed using the land-use descriptions presented in Section 3.1.3. These profiles have been grouped by their associated land-use scenario in this section.

3.1.4.1 Current Receptors Impacted by Access Controls

Current potential receptors who are impacted by the existing access controls at the FEMP property include:

- Visitor - This scenario addresses the potential exposures incurred by the activities of a regular visitor to the FEMP or one of its operable units who is not covered by the FEMP health and safety and radiation protection programs. An example of this scenario would be a delivery person making regular deliveries to the administration building in Operable Unit 3.

- Trespassing Child - This hypothetical scenario addresses the potential exposures incurred by the activities of a child, aged 6 through 17, who regularly trespasses on

the FEMP. Due to regular security patrols, this trespasser is assumed to be confined to areas near the property fenceline.

- On-property grazing - This scenario considers the risks associated with off-property use of animal products produced by cattle currently grazing on FEMP property. (See Part I, Figure 2-27).

3.1.4.2 Current Receptors Unaffected by Access Controls

Current potential receptors who are unaffected by existing access controls at the FEMP are:

- Off-property farmer - This scenario presumes a farm family lives immediately adjacent to the FEMP property boundary. The major concern for these receptors is the exposures they could received from regular use of groundwater for drinking, domestic and agricultural uses. This family could also be exposed to radiation from remote on-property sources, and to diffuse clouds of gases, vapors and dust.

- Off-property user of meat and dairy products grown on site - This scenario considers the risks associated with off-property use of animal products produced by cattle currently grazing on FEMP property.

- Great Miami River user - This scenario presumes a farm family lives immediately adjacent to the Great Miami River. The major concern for these receptors is the exposures they could receive from regular use of river water for drinking, domestic and agricultural uses. This scenario also includes exposures from swimming and eating fish caught in the river.

3.1.4.3 Current Receptors Assuming No Access Controls

Current receptors considered for the Preliminary Baseline Risk Assessment, assuming no access controls include:

- Trespassing Child - This hypothetical scenario addresses the potential exposures incurred by the activities of a child, aged 6 through 17, who regularly trespasses on the FEMP.

- Hunter - This hypothetical scenario assumes a hunter kills and consumes game animals from the site.

- On-property building user - This hypothetical scenario evaluates exposures resulting from salvage/scavenging activities. These activities could result in incidental ingestion of the waste or contaminated soil, inhalation of resuspended dust, and direct exposure to radiation.

3.1.4.4 Potential Future Receptors

Long-term risks to the public may be associated with the presence of hazardous substances remaining at the FEMP in the future. These long-term risks are evaluated for the assumed future land uses at the FEMP.

- Resident farm family - Examination of past and present local land-use practices suggests that it is reasonable to assume FEMP property could revert to residential and agricultural uses in the future, if government control ceases. Future receptors residing directly on former FEMP property could be exposed directly to contaminated soils, groundwater, surface water, or airborne emissions from unremediated on-property soils and waste areas as a result of natural or human activities.

  This farm family scenario assumes a family resides on FEMP property. Exposures from the property may result from activities associated with living on property and operating a family farm. The family is assumed to raise and eat food grown on property, ingest meat and diary products from cattle that graze on property, and drink water drawn from the Great Miami Aquifer directly beneath the property. Typical activities evaluated might include growing food, tending livestock, and general farm work. These activities might produce radiation exposures from nearby soils; dermal absorption through contact with contaminated soil and water; inhalation of gases, vapors and dust; and incidental ingestion of soil. Exposures for this scenario will be evaluated for both "typical" and "reasonable maximum" exposures.

- Construction intruder - Home builders comprise a second group of receptors which may be exposed to on-property contamination in the future. This scenario is referred to as the construction intruder scenario. It consists of an individual digging a basement and well, and building a house on the property. These activities might produce radiation exposures from nearby waste/soil, dermal absorption through direct contact with waste/soil, inhalation of gases, vapors, and dusts, and incidental ingestion of soil.

- Great Miami River user - This scenario presumes a farm family lives immediately adjacent to the Great Miami River. The major concern for these receptors is the exposures they could receive from regular use of river water for drinking, domestic and agricultural uses. This scenario also includes exposures from recreational use of the river. This recreational user is assumed to swim and fish. Potential exposure pathways are dermal contact with surface water, incidental ingestion of surface water, and ingestion of fish from the river. Due to the turbulence, strong currents, and poor water quality in the Great Miami River, swimming by a receptor on a regular basis is not very likely. Similarly, the poor quality (types) and small number of fish present in the Great Miami River indicate that consumption of fish from the river on a regular basis is not very likely. Nevertheless, these pathways and the recreational user are included in this scenario for comparison with other pathways and receptors.

- On-Property building user - This hypothetical scenario considers individuals who may enter FEMP buildings if access controls are removed at the site. These new residents are assumed to live in the structures and to salvage/scavenge/use

abandoned-in-place equipment. These activities could result in incidental ingestion of contaminated materials, inhalation of resuspended contaminants, and direct exposure to radiation.

3.2 SELECTION OF EXPOSURE PATHWAYS

There is a large number of potential exposure pathways at the FEMP. Each exposure pathway consists of a source of contamination, a transport pathway or exposure mechanism, and a hypothetical receptor. Potential exposure pathways for the FEMP are discussed in detail in the Addendum (DOE 1992a). A list of potential exposure pathways considered for the PBRA is presented in Table 3-1. The pathways are grouped according to source of contamination, transport pathway, and exposure medium. Table 3-1 includes a summary of potential exposure pathways associated with the land-use and receptor scenarios discussed in Section 3.1.

An evaluation of the potential exposure pathways for each receptor scenario was performed prior to the exposure assessment. This evaluation considered potential mechanisms of exposure (e.g., resuspension - airborne transport - inhalation) of each potential receptor, proximity of the potential receptor to contaminants, duration of potential exposures, and the relative contribution of each pathway to the overall exposure and risk. Results of the initial evaluation were used to screen insignificant or inappropriate pathways from further consideration in the quantitative exposure assessment. Exposure pathways for each receptor scenario for which the quantitative exposure assessment has been performed are noted in Table 3-1.

3.2.1 Soil/Waste Exposure Pathways

Potential exposures via these pathways begin with contaminated soil or waste materials as the source of contamination. This group of pathways contains the largest number of potential exposure pathways. Exposure to contaminated soil or waste materials requires that the hypothetical receptor is exposed directly to the contaminated soil or waste materials or that contaminants in the soil or waste materials are transported by air, surface water, or groundwater to the hypothetical receptor. These exposure pathways are therefore applicable to receptors that are on the FEMP property, with the exception of transport pathways and direct radiation

TABLE 3-1
POTENTIAL EXPOSURE PATHWAYS

Id No	Source	Pathway	Exposure Media or Mechanism	Current Land-Use Scenarios: With Access Controls		Unaffected By Access Controls			Without Access Controls			Future Land-Use Scenarios					
				1[a]	2[a]	3[a]	4[a]	5[a]	6[a]	7[a]	8[a]	9[a]	10[a]	11[a]	12[a]	13[a]	14[a]
1	Soil/Waste	Foliar deposition	Crops			•						•	•	•			
2	Soil/Waste	Groundwater-irrigation	Crops									•	•	•			
3	Soil/Waste	Root uptake	Crops									•	•	•			
4	Soil/Waste	Surface water-irrigation	Crops					•				•	•	•			•
5	Soil/Waste	Surface soil	Dermal contact		•				•	•		•	•	•	•	•	
6	Soil/Waste	Surface water-recreation	Dermal contact					•									•
7	Soil/Waste	Surface water-sediment	Dermal contact		•			•	•	•		•	•	•	•	•	•
8	Soil/Waste	Surface water-sediment	Direct ingestion		•			•	•	•		•	•	•	•	•	•
9	Soil/Waste	Surface soil	Direct ingestion		•				•	•		•	•	•	•	•	•
10	Soil/Waste	Groundwater-well	Domestic water									•	•	•			
11	Soil/Waste	Surface water	Domestic water					•									•
12	Soil/Waste	Groundwater-well	Drinking water									•	•	•			
13	Soil/Waste	Surface water	Drinking water					•									•
14	Soil/Waste	Surface water	Fish					•				•	•	•			•
15	Soil/Waste	Surface water-recreational	Incidental ingestion					•									•
16	Soil/Waste	Emission of gases to air	Inhalation	•		•				•		•	•	•	•	•	
17	Soil/Waste	Particulate resuspension	Inhalation	•		•				•		•	•	•	•	•	
18	Soil/Waste	Cloud immersion	Irradiation														
19	Soil/Waste	Proximal exposure	Irradiation	•	•	•			•	•		•	•	•	•	•	
20	Soil/Waste	Surface water-recreation	Irradiation														
21	Soil/Waste	Surface water-sediment	Irradiation					•	•			•	•	•			•
22	Soil/Waste	Ingestion by livestock	Meat & Milk				•				•	•	•	•			
23	Soil/Waste	Contaminated Foliage	Meat & Milk				•	•			•	•	•	•			•
24	Soil/Waste	Stock water	Meat & Milk				•	•			•	•	•	•			•
25	Structures	Salvage/dust	Ingestion							•		•	•	•	•		
26	Structures	Salvage/dust - gases	Inhalation							•		•	•	•	•		
27	Structures	Salvage/Irradiation	Irradiation							•		•	•	•	•		

TABLE 3-1
(Continued)

Id No	Source	Pathway	Exposure Media or Mechanism	Current Land-Use Scenarios								Future Land-Use Scenarios					
				With Access Controls		Unaffected By Access Controls			Without Access Controls								
				1[a]	2[a]	3[a]	4[a]	5[a]	6[a]	7[a]	8[a]	9[a]	10[a]	11[a]	12[a]	13[a]	14[a]
28	Groundwater	Irrigation of crops	Crops			•						•	•	•			
29	Groundwater	Well water	Domestic water			•						•	•	•			
30	Groundwater	Well water	Drinking water			•						•	•	•			
31	Groundwater	Irrigation of forage	Meat & Milk			•						•	•	•			
32	Groundwater	Stock water	Meat & Milk			•						•	•	•			
33	Surface water	Irrigation of crops	Crops					•				•	•	•			
34	Surface water	Recreation	Dermal contact					•	•								•
35	Surface water	Water use	Domestic water					•									•
36	Surface water	Water use	Drinking water					•									•
37	Surface water	Fishing	Fish					•									•
38	Surface water	Recreation	Incidental ingestion					•									•
39	Surface water	Recreation	Irradiation														
40	Surface water	Irrigation of forage	Meat & Milk					•				•	•	•			•
41	Surface water	Stock water	Meat & Milk				•	•			•	•	•	•			•
42	Sediment	Recreation	Dermal contact		•			•	•	•	•	•	•	•	•		•
43	Sediment	Recreation	Direct ingestion		•				•	•	•	•	•	•	•		•
44	Sediment	Recreation	Irradiation		•			•	•	•	•	•	•	•	•		•

[a]
1 Visitor
2 Trespassing Child
3 Adjacent Off-Property Farmer
4 User of Meat and Dairy Products Grown On-Property
5 Great Miami River Water User
6 Trespassing Child
7 Scavenger
8 Hunter
9 Typical On-Property Resident
10 On-Property Resident Farmer
11 On-Property Resident Child
12 On-Property Building User
13 Construction Intruder (Home Builder)
14 Great Miami River Water User

exposure to off-property receptors. Existing contamination of surface water or groundwater are addressed under surface water source-pathways and groundwater source-pathways, respectively, and the relative contribution of each pathway to the overall exposure and risk. Results of the initial evaluation were used to screen insignificant or inappropriate pathways from further consideration in the quantitative exposure assessment. Exposure pathways for each receptor scenario for which the quantitative exposure assessment has been performed are noted in Table 3-1.

3.2.1 Soil/Waste Exposure Pathways

Potential exposures via these pathways begin with contaminated soil or waste materials as the source of contamination. This group of pathways contains the largest number of potential exposure pathways. Exposure to contaminated soil or waste materials requires that the hypothetical receptor is exposed directly to the contaminated soil or waste materials or that contaminants in the soil or waste materials are transported by air, surface water, or groundwater to the hypothetical receptor. These exposure pathways are therefore applicable to receptors that are on the FEMP property, with the exception of transport pathways and direct radiation exposure to off-property receptors. Existing contamination of surface water or groundwater are addressed under surface water source-pathways and groundwater source-pathways, respectively.

Pathways numbered 1 through 24 in Table 3-1 are the potential exposure pathways for contaminated soil or waste materials. The cloud immersion-external irradiation pathway (number 18) has been eliminated from consideration due to the very low specific activities of radionuclides present at the FEMP. There is no mechanism by which a sufficient quantity of site-related radionuclides could become airborne for exposure via this pathway.

The surface water-recreation-irradiation pathway (number 20) has also been eliminated from consideration due to the low specific activities of radionuclides at the FEMP. Since water is an effective radiation shield, this pathway is significant only for gamma-ray-emitting radionuclides of high specific activities, and such radionuclides are not present in significant quantities at the FEMP.

Resuspended particulates from soil and waste areas can be transported via the air to off-property crops (pathway number 1) under current land-use scenarios. For future land use (on-property residents), this exposure pathway can occur. The difference in calculated exposures between current and future land use for off-property farmers will be dependant on the calculated concentrations of airborne contaminants that are deposited onto crops.

Contamination of food crops by root uptake by off-property crops as a consequence of airborne transport from on-property soil and waste areas is included in pathway number 1. Pathway number 3 applies to root uptake by food crops grown in soil and waste areas.

Dermal contact with soil or waste (pathway number 5) is included for the trespassing child, building users (no access controls) and construction intruders (future land use). Contributions from surface water (number 6) and sediment (number 7) for overall dermal contact exposure are included to account for exposures from transport from soil/waste. Dermal contact with surface water and sediment for current contamination of these media is addressed with pathway numbers 34 and 42 in Sections 3.2.4 and 3.2.5, respectively.

Direct ingestion of soil (pathway number 9) and sediment (pathway number 8) are considered plausible for the trespassing child, on-property building users, and users of the Great Miami River, but not for other receptors under current land use (with or without access controls). Both of these pathways are included for exposures for future land use.

Exposure scenarios for on-property surface water and groundwater (pathway numbers 10 through 15) for current land-use scenarios are not considered to be plausible. Off-property users of the Great Miami River are considered to be exposed by surface water pathways following transport of contaminants from soil/waste. All of these pathways are evaluated under future land-use assumptions.

Inhalation of airborne gases (e.g., radon) and particulates from soil and waste areas (pathway numbers 16 and 17) is included as a pathway for current and future land use, both on-property and off-property, provided that the exposure duration is long enough to produce a measurable intake. The trespassing child and the hunter are potential receptors for whom the frequency and duration of exposure to airborne contaminants on property are relatively short.

Direct radiation exposure to soil and waste areas (pathway number 19) is included for on-property and off-property receptors for current and future land use. Additionally, it is assumed that the on-property building user can receive direct radiation exposure to soil and waste-related sediment.

Ingestion of meat and milk from cattle that could ingest contaminated soil or contaminated foliage while grazing on FEMP property (pathway numbers 22 and 23) is included for the exposure assessment for current and future land use. Ingestion of water (stock water) in contact with waste areas (pathway number 24) is not included for current land use with access controls.

It is assumed that with no access controls, a hunter can consume meat from game that have ingested soil, waste materials, and surface water on FEMP property. Measured concentrations of

contaminants in deer meat and rabbits from the FEMP indicate that these concentrations are below detection limits.

3.2.2 Exposure Pathways Attributable to Salvage or Reuse of Structures

On-property contaminated structures (e.g., buildings) can be the source of exposures to receptors who enter these structures or to receptors that are exposed by transport of contaminants from the structures. Potential exposure pathways for contaminated structures are given Table 3-1. Direct ingestion of contaminants within structures (pathway number 25) can occur for receptors who go into these structures. Likely receptors for this exposure pathway when there are no access controls include scavengers and on-property residents.

Contaminants transported from structures by the air (pathway number 26) can potentially expose on-property and off-property receptors. Direct radiation exposures from radioactive contamination in on-property structures (pathway number 27) can occur for on-property or off-property receptors.

3.2.3 Groundwater Exposure Pathways

A plume of groundwater extending to the south of the property boundary (i.e., the South Plume) is currently the principle source of potential exposure to contaminated groundwater. Perched groundwater beneath the waste pits and the former Production Area contain elevated concentrations of contaminants. However, these perched water deposits are localized and do not contain water volumes sufficient to serve as sustained sources of potable water for a farm. Contaminants in the regional aquifer are therefore the exposure sources for groundwater exposure pathways.

Pathways 28 through 32 start with existing contaminated groundwater as the source of exposures. These pathways are considered significant for farm scenarios under current or future land use.

3.2.4 Surface Water Exposure Pathways

Surface water bodies near the FEMP that may be sources of site-related exposures are the Great Miami River, Paddys Run, and the SSOD. In addition, the FEMP contains ponds of standing water, such as Waste Pit 6. This risk assessment treats these surface impoundments as reservoirs of potentially contaminated surface water that can migrate off property, or be accessed on property by an intruder in the future. Potential exposure pathways for contaminants in surface water include pathways 33 through 41 (with pathway number 39 excluded for the same reason that pathway number 20 was excluded in Section 3.2.1).

3.2.5 Sediment Exposure Pathways

Contaminated sediment deposits are the source of potential exposure pathways 42 through 44 (Table 3-1). Sources of potentially contaminated sediment near the FEMP are Paddys Run and the SSOD. Sediment exposure pathways are of greatest concern for the trespassing child since it is assumed that the child may play in or near stream beds, such as Paddys Run or the SSOD.

3.3 EXPOSURE POINT CONCENTRATIONS

The exposure point concentration is the concentration of a contaminant in an exposure medium that will be contacted by a hypothetical receptor. Determination of the exposure concentration depends on factors such as:

- Availability of data from which an exposure concentration can be determined
- Statistical methodologies selected to determine the appropriate exposure concentration
- Potential contributions to contaminant concentrations from background concentrations not attributed to the site
- Location of the potential receptor.

Exposure point concentrations are determined by one of two methods - measurement results or modeling. In general, current exposure point concentrations represent the UCL determined from environmental sampling data for a given medium. The methods used for constructing the UCL for measurement results that are normally distributed and lognormally distributed are given in Section 7.1 of the Addendum (DOE 1992a). In some cases, the maximum measured concentration of a constituent in a medium is used as the current exposure point concentration. For current exposure to airborne contaminants, modeled concentrations are used.

Fate and transport modeling is used to determine exposure point concentrations for future land-use scenarios. Modeling is used for air, groundwater, surface water, and sediment exposure pathways. Model source terms are constructed using the UCL of the constituent concentrations in each source area. For future exposures to soil, constituent concentrations in subsurface soil are used as exposure point concentrations.

Transport media for which fate and transport modeling are required include air, groundwater, and surface water/sediment. Modeling of airborne concentrations of contaminants is needed for exposure pathways 1, 16, 17, 18, and 26 (Table 3-1). Groundwater fate and transport modeling are needed for exposure pathways 2, 10, 12, 28, 29, 30 31, and 32. Modeling of surface water

concentrations is needed for exposure pathways 4, 6, 11, 13, 14, 15, 33, 34, 35, 36, 37, 38, 40, and 41. Sediment concentrations must be determined for exposure pathways 7, 8, 21, 42, 43, and 44.

3.3.1 Air

Sixteen air monitoring stations (AMS) are located around the FEMP (see Figure 3-4 in Part I). In addition, 52 radon monitors have been installed in and around the site. Data collected from these monitoring stations are published in the WMCO Environmental Monitoring Annual Reports (WMCO 1986, 1987, 1988, 1989, 1990, 1991). Air monitoring data for 1991 are presented in Tables 4-9 and 4-10 of Part I.

Air monitoring stations were located generally to assess releases from production operations to off-property areas, not necessarily to monitor releases from future sources. Since air concentrations are needed for all on-property and off-property locations, it was determined that AMS data could not be used to determine exposure point concentrations to identify RME locations. The Industrial Source Complex Long Term (ISCLT) air model was used to estimate current and future air concentrations. Details about the method used to model atmospheric transport of constituents are provided in Appendix Q. Modeling results are presented for constituents that exceed a risk-based screening level calculated for the air exposure pathways given in Section 3.2, the exposure assessment models of Section 3.4, and the risk characterization information of Section 5.0. Listed constituents are those that were determined to have a calculated risk that exceeds approximately one percent of the risk from air exposure pathways.

3.3.1.1 Current Concentrations in Air

Results of modeling current exposure point concentrations for air are presented in Table 3-2. These results are used to evaluate the current off-property farmer. Modeled concentrations of hazardous chemicals are extremely low (10^{-6} $\mu g/m^3$), as much as six orders of magnitude (1,000,000 times) lower than current ambient air standards. For this reason, no evaluation of risks to hazardous chemicals is necessary.

3.3.1.2 Future Concentrations in Air

For future exposures to air, it was assumed that containment of all waste sources have degraded to the extent that they no longer provide any protection against release mechanisms. The results of air modeling used to determine future exposure point concentrations are summarized in Table 3-3.

3.3.2 Groundwater

3.3.2.1 Current Concentrations in Groundwater

No on-property residential wells currently exist at the FEMP. Therefore, current potential exposure point concentrations are determined using analytical results of groundwater samples

TABLE 3-2

EXPOSURE POINT CONCENTRATIONS FOR AIR FOR CURRENT LAND-USE SCENARIOS[a]

Constituent	Highest Off-Property Concentration	Estimated Concentration Elda School	Estimated Concentration Township School
Radionuclides (pCi/m^3)			
Th-230	2.0E-04	4.6E-06	1.2E-05
Th-232	1.2E-05	3.7E-07	5.8E-07
Ra-226	2.9E-05	6.0E-07	1.2E-06
U-234	1.1E-03	2.0E-05	2.7E-05
U-235	8.5E-05	9.8E-07	1.2E-06
U-238	1.5E-03	2.3E-05	3.0E-05
Radon	1.6E+01	7.3E-01	3.6E-01
Inorganics (μg/m^3)			
Arsenic	1.9E-06	3.0E-08	5.0E-08
Barium	7.1E-05	1.2E-06	2.1E-06
Beryllium	2.3E-07	5.0E-09	6.0E-09
Cadmium	7.9E-07	1.0E-08	1.0E-08
Chromium	4.0E-08	7.0E-10	3.0E-09
Cobalt	1.2E-06	2.0E-08	5.0E-08
Lead	2.3E-05	5.5E-07	8.2E-07
Manganese	6.3E-07	1.0E-08	5.0E-08
Mercury	7.0E-08	2.0E-09	2.0E-09
Organics (μg/m^3)			
Aroclor-1248	1.0E-10	2.0E-12	9.0E-12
Aroclor-1254	2.5E-07	5.0E-09	1.0E-08
Aroclor-1260	3.4E-07	5.0E-09	7.0E-09
Benzo(a)pyrene	2.8E-06	4.0E-08	5.0E-08

a Estimated current annual average concentration of resuspended airborne radionuclides and chemicals.
b Short-lived progeny are assumed to be present at the same concentration as the parent nuclides.

TABLE 3-3

EXPOSURE POINT CONCENTRATIONS FOR AIR FOR FUTURE LAND-USE SCENARIOS[a]

Constituent	Highest On-Property Concentration	Highest Off-Property Concentration	Estimated Concentration Elda School	Estimated Concentration Township School
Radionuclides[b] (pCi/m^3)				
Pa-231	3.1E-06	5.0E-07	4.6E-09	2.1E-08
Ra-226	7.6E-03	1.5E-04	2.0E-06	6.0E-06
Th-230	6.3E-03	2.9E-04	6.0E-06	2.2E-05
Th-232	1.1E-02	2.3E-04	2.0E-06	1.0E-06
U-233	3.1E-03	1.1E-05	3.0E-07	2.5E-08
U-234	8.4E-03	6.5E-04	1.8E-05	3.0E-05
U-235	3.8E-04	2.9E-05	1.0E-06	2.0E-06
U-238	8.6E-03	7.2E-04	2.1E-05	3.4E-05
Radon	2.4E+04	1.8E+02	2.4E+01	1.2E+01
Inorganics (µg/m^3)				
Arsenic	6.8E-04	3.1E-05	3.8E-07	1.8E-06
Barium	3.2E-03	1.2E-04	2.0E-06	8.8E-06
Chromium	4.1E-05	1.9E-06	2.0E-08	1.2E-07
Cobalt	1.2E-04	3.1E-06	4.0E-08	1.5E-07
Lead	2.9E-03	5.7E-05	5.8E-07	2.2E-06
Manganese	1.8E-03	6.4E-05	1.2E-06	5.0E-06

[a] Estimated future annual average concentrations of resuspended airborne radionuclides and chemicals if caps are removed. Modeling ignores source depletion by other transport pathways.

[b] Short-lived progeny are assumed to be present at the same concentration as the parent nuclides.

taken from off-property wells in the 2000, 3000, and 4000 series. A total of 85 such wells exist. Access to groundwater via on-property wells could occur with the loss of access controls, such as for future land-use scenarios.

Because of the large number of potential constituents and wells, this study focuses on those wells containing the highest concentrations of selected constituents. Arithmetic mean concentrations were calculated for each constituent detected in a given well. Some data sets contain a mixture of positively detected and nondetected results. A value of one-half the detection limit (or sample quantitation limit) was substituted for each nondetected result for calculation of the arithmetic mean.

Once the arithmetic mean concentrations in each well were computed, the data set was examined for trends. The mean concentration of each constituent was examined, one constituent at a time, to identify the well having the highest mean concentration for that constituent. This resulted in the selection of a well for each constituent. Since uranium is the most widely distributed constituent at the site and Ra-226, arsenic, and beryllium are prevalent in groundwater, three wells with the highest mean concentration for each of these constituents were selected for further study.

This selection process resulted in a list of 21 wells, each representing the potential current groundwater RME location for a selected constituent. Table 3-4 lists the identification numbers of these wells and the radionuclides and chemicals that are present at the highest mean concentrations for that contaminant.

Fifteen of these wells are 2000 series and six are 3000 series wells. Eighteen of the wells are located in the vicinity of the southern property boundary or the South Plume, corresponding to the Dry Fork aquifer flow. Two wells are located along the northwestern property boundary, associated with the Shandon Tributary aquifer flow, and one well is located east of the FEMP and is associated with the Ross aquifer flow. Because the Ross aquifer flow moves toward the site, any wells in this flow should not be affected by the site. The locations of the 21 wells are depicted in Figures 5-4 and 5-5.

A statistical evaluation was performed for the concentrations of all constituents of potential concern in each of the 21 wells listed in Table 3-4. The results of this statistical evaluation are presented in 42 data summary tables presented in Appendix R.

Preliminary risk calculations were performed to identify the wells that yield the highest overall risks. The results of these risk calculations were used to screen the number of wells to be evaluated further. The wells that yielded the highest radiological cancer risks, chemical cancer

TABLE 3-4

GROUNDWATER EXPOSURE POINT LOCATIONS AND CONTAMINANTS

2015	2060	2061	2094	2095
U-234	U-234	U-234	Ra-226	2-Hexanone
U-235/236	U-235/236	U-235/236	Acetone	
U-238	U-238	U-238	Arsenic	
Total-U	Total-U	Total-U	Benzene	
2-Butanone			Ethylbenzene	
Antimony			Total Xylenes	
Chloroform				
Methylene Chloride				
2097	**2106**	**2126**	**2127**	**2128**
Sulfide	1,1,1-Trichloroethane	Tc-99	Arsenic	Sr-90
2129	**2384**	**2391**	**2393**	**2558**
Beryllium	Th-230	Th-228	Molybdenum	Zinc
		Th-232		
		Total-Th		
3043	**3066**	**3094**	**3126**	**3127**
Beryllium	Acetone	Ra-226	Beryllium	Arsenic
Bis(2-ethylhexyl) phthalate	Ammonia	Ra-228	Thallium	Barium
Carbon disulfide			Nitrate	Cadmium
Di-n-butyl phthalate			Toluene	Chromium
Trichloroethene				Copper
3128				Lead
Ra-226				Manganese
				Mercury
				Nickel
				Selenium
				Silver
				Vanadium

risks, and chemical toxicity hazard indices for a current farmer scenario were identified. Eight wells were selected in accordance with these criteria. These wells are 2000- or 3000- series wells located in the contaminant plume centerline. These wells are identified as: 2015, 2060, 2061, 2094, 2095, 2558, 3126, and 3127. Measured concentrations (UCLs) for constituents of concern from each of these eight wells are listed in Tables 3-5 and 3-6.

The UCL for each non-radioactive chemical given in Table 3-6 is used directly as the exposure point concentration. For each radionuclide, the natural background groundwater concentration given in Table 2-12 is subtracted from the UCL given in Table 3-5 to determine the exposure point concentration. The background concentration is assumed to be equal to one-half of the analytical detection limit for radionuclides in Table 2-12. A natural background concentration of zero is assumed for fission products and transuranic radionuclides in groundwater.

Table 3-5 reveals that wells 2015, 2060, and 2061 are the RME locations for uranium contamination. These three wells are clustered near the southern FEMP property boundary in the South Plume. Well 2094, located along New Haven Road directly south of the FEMP, is the RME location for radium contamination. In Table 3-6, well 3127 is particularly notable because of the significant number of metals detected in water from this well.

3.3.2.2 Future Concentrations in Groundwater

Mathematical modeling is used to predict future groundwater concentrations at the FEMP. Appendix O provides a detailed description of this modeling. Table 3-7 summarizes the groundwater modeling results used as the exposure point concentrations during this risk assessment.

In summary, the concentration (UCL) of each contaminant in the waste area is multiplied by the total volume of the waste area to determine the total mass of each contaminant. For media which have limited analytical results for contaminant concentrations, the maximum concentration may be used as the representative concentration for the contaminant in that medium. This can lead to unrealistically high estimates of the total mass of contaminants in the waste area. The total mass of each contaminant is not allowed to be depleted from the waste area in less than 70 years (i.e., the source depletion time has a lower bound of 70 years). Potential contaminant concentrations in leachate seeping from the waste area and from the underlying soils are modeled with the geochemical model. Leachate concentrations are modeled through the vadose zone and into the regional aquifer to yield the calculated future concentrations in the aquifer directly below the waste area. Off-property concentrations of contaminants in groundwater are further modeled using the regional aquifer models, ST1D (IT 1990) and ODAST (Javendal et al. 1984). The calculated concentrations in the aquifer are used for exposure point concentrations for future groundwater exposures.

TABLE 3-5

EXPOSURE POINT CONCENTRATIONS FOR RADIONUCLIDES IN GROUNDWATER FOR CURRENT LAND-USE SCENARIOS, WITH AND WITHOUT ACCESS CONTROLS[a]

Constituents of Potential Concern	Well #2015 (pCi/ℓ)	Well #2060 (pCi/ℓ)	Well #2061 (pCi/ℓ)	Well #2094 (pCi/ℓ)	Well #2095 (pCi/ℓ)
Ra-226	1.0E+00	NA[b]	NA	4.1E+00	1.5E+00
Ra-228	3.7E+00	2.7E+00	NA	2.7E+00	NA
Sr-90	NA	NA	NA	NA	NA
Tc-99	NA	NA	NA	NA	NA
Th-228	7.7E-01	1.5E+00	NA	1.6E+00	9.9E-01
Th-230	NA	1.1E+00	NA	9.1E-01	1.1E+00
Th-232	NA	NA	NA	NA	NA
Thorium (mg/ℓ)	NA	NA	NA	NA	NA
U-234	6.2E+01	8.0E+01	1.0E+02	3.4E+00	5.4E+01
U-235	3.2E+00	4.4E+00	5.2E+00	1.1E+00	2.7E+00
U-238	6.5E+01	8.7E+01	1.0E+02	3.5E+00	5.6E+01
Uranium (mg/ℓ)	2.3E-01	2.8E-01	3.0E-01	9.0E-03	1.8E-01

TABLE 3-5
(Continued)

Constituents of Potential Concern	Well #2558 (pCi/ℓ)	Well #3126 (pCi/ℓ)	Well #3127 (pCi/ℓ)
Ra-226	1.4E+00	NA	NA
Ra-228	2.9E+00	NA	NA
Sr-90	NA	NA	NA
Tc-99	NA	NA	NA
Th-228	1.4E+00	1.5E+00	8.7E-01
Th-230	NA	NA	NA
Th-232	NA	NA	NA
Thorium (mg/ℓ)	NA	NA	NA
U-234	2.0E+00	1.4E+00	1.9E+00
U-235	NA	NA	NA
U-238	1.9E+00	1.5E+00	1.8E+00
Uranium (mg/ℓ)	7.0E-03	5.0E-03	2.0E-03

[a] Constituents that are selected as constituents of potential concern for groundwater from at least one well are listed in the table. Exposure point concentrations are the 95% confidence limit on the mean (UCL).
[b] NA = Not applicable.

TABLE 3-6

EXPOSURE POINT CONCENTRATIONS FOR CHEMICALS IN GROUNDWATER (mg/ℓ)
FOR CURRENT LAND-USE SCENARIOS,
WITH AND WITHOUT ACCESS CONTROLS[a]

Chemical	Well #2015	Well #2061	Well #2094	Well #2095	Well #2060
1,1,1-Trichloroethane	6.0E-03	NA[b]	NA	1.0E-03	6.0E-03
2-Butanone	3.5E-02	NA	NA	6.0E-03	6.0E-3
2-Hexanone	NA	NA	NA	1.0E-03	NA
Acetone	4.0E-03	NA	1.1E-02	2.0E-03	3.0E-03
Ammonia	NA	2.1E-01	2.7E+00	9.2E-02	9.6E-02
Antimony	1.0E-03	NA	NA	NA	NA
Arsenic	NA	2.6E-01	2.5E-01	NA	NA
Barium	NA	NA	1.2E+00	5.1E-02	5.4E-02
Benzene	NA	NA	1.6E-01	NA	NA
Beryllium	NA	NA	1.0E-03	NA	NA
Bis(2-ethylhexyl) phthalate	1.0E-03	NA	NA	NA	NA
Cadmium	3.0E-03	5.0E-03	1.1E-02	4.0E-03	2.0E-03
Carbon disulfide	NA	NA	NA	NA	NA
Chloroform	2.0E-03	NA	NA	NA	NA
Chromium	4.1E-02	3.0E-02	2.7E-02	2.4E-02	2.7E-02
Copper	NA	NA	NA	NA	NA
Di-n-butyl phthalate	NA	NA	3.0E-03	NA	NA
Ethylbenzene	NA	NA	1.0E-03	NA	NA
Fluoride	1.2E+00	NA	NA	NA	NA
Lead	1.6E-02	4.0E-03	4.0E-03	1.2E-02	NA
Manganese	NA	1.7E-02	2.2E-01	1.6E-02	NA
Mercury	NA	NA	5.0E-03	2.0E-03	1.0E-03
Methylene chloride	4.7E-02	NA	8.0E-03	2.0E-03	5.0E-03
Molybednum	NA	1.9E-02	1.2E-02	9.0E-03	2.5E-02
Nickel	NA	NA	4.2E-02	1.2E-02	NA
Nitrate	NA	NA	NA	NA	NA
Selenium	NA	2.0E-03	NA	NA	NA

TABLE 3-6
(Continued)

Chemical	Well #2015	Well #2061	Well #2094	Well #2095	Well #2060	
Silver	NA	9.0E-3	NA	1.2E-02	1.2E-02	1
Thallium	NA	NA	NA	NA	NA	2
Toluene	NA	NA	4.0E-03	NA	NA	3
Trichloroethene	NA	NA	NA	NA	NA	4
Uranium	2.3E-01	3.0E-01	9.0E-03	1.8E-01	2.8E-01	5
Vanadium	1.9E-02	1.7E-02	1.1E-02	1.6E-02	NA	6
Xylenes	NA	NA	1.9E-01	NA	NA	7
Zinc	2.4E-01	NA	1.7E-02	3.8E-02	9.8E-02	8

TABLE 3-6
(Continued)

Chemical	Well #2558	Well #3126	Well #3127
1,1,1-Trichloroethane	NA	NA	NA
2-Butanone	NA	4.0E-03	NA
2-Hexanone	NA	NA	NA
Acetone	NA	7.0E-03	NA
Ammonia	1.2E-01	4.2E-01	NA
Antimony	NA	NA	NA
Arsenic	NA	NA	NA
Barium	NA	NA	1.6E+01
Benzene	NA	1.0E-03	NA
Beryllium	NA	2.0E-03	NA
Bis(2-ethylhexyl) phthalate	NA	NA	NA
Cadmium	5.0E-03	8.0E-03	2.0E+00
Carbon disulfide	NA	NA	NA
Chloroform	NA	NA	NA
Chromium	2.4E-02	4.5E-02	1.5E+01
Copper	NA	NA	NA
Di-n-butyl phthalate	NA	NA	NA
Ethylbenzene	NA	NA	NA
Fluoride	NA	NA	NA
Lead	NA	6.0E-03	2.3E+00
Manganese	2.9E-02	1.9E-01	4.8E+01
Mercury	NA	3.0E-03	5.0E-03
Methylene chloride	NA	2.0E-03	NA
Molybednum	NA	NA	NA
Nickel	NA	2.8E-02	1.3E-02
Nitrate	NA	3.7E+02	NA
Selenium	NA	NA	9.0E-03
Silver	2.4E-02	2.2E-02	1.2E+01
Thallium	NA	2.0E-03	NA
Toluene	NA	5.0E-03	NA

TABLE 3-6
(Continued)

Chemical	Well #2558	Well #3126	Well #3127
Trichloroethene	NA	NA	NA
Uranium	7.0E-03	5.0E-03	2.0E-03
Vanadium	1.2E-02	3.5E-02	8.7E+00
Xylenes	NA	NA	NA
Zinc	2.3E+00	3.0E-02	NA

[a] Constituents that are selected as chemicals of potential concern for groundwater from at least one well are listed in the table. Exposure point concentrations are the 95 percent confidence limit on the mean (UCL).
[b] NA = Not applicable.

TABLE 3-7

EXPOSURE POINT CONCENTRATIONS FOR GROUNDWATER FOR FUTURE LAND-USE SCENARIOS

Constituent	Maximum Concentration in Aquifer[a]	Time of Maximum Concentration (yrs)	Location
Radionuclides (pCi/ℓ)			
Np-237	1.0E-01	700	OU1, Pit 3
Sr-90	2.6E-01	100	OU1, Pit 3
Tc-99	1.5E-02	100	OU1, Pit 3
Inorganics (μg/ℓ)			
Uranium	8.5E+03	300	OU3, Plant 9
Boron	4.1E-01	100	OU1, Burn Pit
Molybdenum	3.2E+01	700	OU2, Inactive Flyash Pile
Organics (μg/ℓ)			
4-chloro-3-methylphenol	5.9E-02	800	OU2, Active Flyash Pile
Vinyl chloride	7.2E-01	20	OU1, Pit 2

[a] Maximum model concentrations for constituents estimated to reach the aquifer beneath the FEMP.

As part of the programmatic approach for performing groundwater modeling at the FEMP, screening values were developed to eliminate inconsequential levels of contaminants from further considerations (DOE 1992a). The basis for the approach is that groundwater flow modeling is so resource intensive (man-hours and computer run time) that a limited number of runs can reasonably be made. These screening values represent 10^{-7} lifetime cancer risk levels for carcinogens and the equivalent of 20 percent of the allowable dose of each noncarcinogenic toxicant. These levels insure that any chemical that could contribute significantly to risk will be retained and modeled in the risk assessment. The calculation of the screening levels is performed in a manner that is consistent with the EPA risk assessment methodology presented in the Risk Assessment Work Plan Addendum (DOE 1992a) for the drinking water ingestion pathway.

3.3.3 Surface water

3.3.3.1 Current Concentrations in Surface Water

Concentrations of uranium and other constituents of potential concern have been measured in surface water bodies and drainage features on the FEMP, as well as several points along the Great Miami River. Section 3.2.3 of Part 1 describes these efforts, and Section 4.1.3 of Part 1 presents information on the nature and extent of contamination. Tables R.3-1 through R.3-22 of Appendix R present statistical evaluations of these data. These statistical evaluations were used to determine the current surface water exposure point concentrations presented in Table 3-8.

3.3.3.2 Future Concentrations in Surface water

Fate and transport modeling is used to determine the effect that future surface water runoff from the site would have on exposure point concentrations of surface water and sediment. The Modified Universal Soil Loss Equation (MUSLE), a commonly used soil loading model, was used to determine if soil runoff, and hence sorbed contaminant runoff, would contribute significantly to contaminant concentrations in Paddys Run and the SSOD. The model and modeling results are presented in Appendix P.

Paddys Run flows primarily from January to May, with estimated flow rates from approximately 6 to 100 liters per second (0.2 to 4.0 cubic feet per second). Peak flows have not been gauged (ASI 1990). Low and high flow rates for Paddys Run were used in the model to represent flows in the SSOD, since measured flow rates were not available for the SSOD as of December 1, 1991.

For each receiving water body, results have been presented for high flow conditions. It is likely that when appreciable quantities of rain fall on the FEMP, rain will also be falling on other parts of the Paddys Run Drainage Basin. Thus, the high flow rate is more indicative of stream flow

TABLE 3-8

EXPOSURE POINT CONCENTRATIONS FOR SURFACE WATER FOR CURRENT LAND-USE SCENARIOS, WITH AND WITHOUT ACCESS CONTROLS[a]

Constituents of Potential Concern	GMR Upstream of Main Effluent Line	GMR Between Effluent Line and Paddys Run	GMR Downstream of Paddys Run	Paddys Run Between N. Boundary of FEMP and SSOD	Paddys Run Downstream of SSOD	SSOD	Waste Pit 5	Waste Pit 6	Clearwell
Radionuclides (pCi/ℓ)									
Ra-226	9.1E-01	NA[b]	NA	NA	NA	NA	NA	NA	1.1E+00
Ra-228	NA	NA	2.4E+00	NA	NA	NA	NA	1.2E+01	1.2E+01
Sr-90	NA	NA	NA	5.7E+00	NA	NA	4.7E+01	NA	NA
Tc-99	NA	2.8E+01	NA	NA	NA	NA	3.2E+02	6.0E+02	4.0E+03
Th-228	7.1E-01	7.5E-01	9.9E-01	NA	1.7E+00	NA	NA	NA	NA
Th-230	NA	NA	6.9E-01	2.3E+00	1.2E+00	NA	1.0E-01	2.9E-01	4.0E-01
U-234	6.3E-01	1.2E+00	1.1E+00	4.0E+00	3.8E+00	NA	4.2E+02	7.7E+01	1.9E+03
U-235/236	NA	NA	NA	NA	NA	NA	1.9E+01	9.0E+00	1.2E+02
U-238	NA	1.1E+00	1.1E+00	5.2E+00	4.5E+00	1.3E+00[c]	4.0E+02	4.6E+02	6.2E+03
Uranium (μg/ℓ)	NA	3.0E+00	3.0E+00	1.6E+01	1.1E+01	2.4E+01[c]	1.2E+03	1.4E+03	1.8E+04
Thorium (μg/ℓ)	NA	NA	NA	3.0E-03	NA	NA	NA	NA	NA
Organics (mg/ℓ)									
Acetone	NA	NA	NA	NA	NA	NA	NA	3.0E-03	5.0E-03
bis(2-Ethylhexyl) phthalate	NA	NA	NA	4.0E-03[c]	2.0E-03[c]	NA	NA	1.0E-02	4.0E-03
Di-n-butyl phthalate	NA	NA	NA	NA	NA	NA	1.0E-03	6.0E-03	1.0E-03
Diethyl phthalate	NA	NA	NA	2.0E-03[c]	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	NA	NA	NA	4.0E-03	2.0E-03
N-Nitro-sodiphenyl-amine	NA	NA	NA	4.0E-03[c]	NA	NA	NA	NA	NA
Inorganics (mg/ℓ)									
Ammonia	8.5E-01	8.0E-01	7.1E-01	3.4E-01	1.2E-01	NA	NA	NA	NA
Antimony	NA	NA	NA	3.0E-03[c]	NA	NA	NA	NA	NA
Arsenic	NA	2.0E-03	NA	4.0E-03	3.0E-03	NA	NA	NA	NA
Barium	5.0E-02[c]	4.9E-02	4.0E-02[c]	6.0E-02	4.7E-02	4.0E-02[c]	NA	NA	NA
Beryllium	NA	NA	NA	1.0E-03	NA	NA	NA	NA	NA

TABLE 3-8
(Continued)

Constituents of Potential Concern	GMR Upstream of Main Effluent Line	GMR Between Effluent Line and Paddys Run	GMR Downstream of Paddys Run	Paddys Run Between N. Boundary of FEMP and SSOD	Paddys Run Downstream of SSOD	SSOD	Waste Pit 5	Waste Pit 6	Clearwell
Cadmium	1.0E-02[c]	3.0E-03	2.0E-03[c]	3.0E-03	5.0E-03	NA	NA	NA	NA
Chromium	6.0E-03[c]	4.0E-03	NA	3.0E-02	2.0E-02	7.0E-03[c]	NA	NA	NA
Cobalt	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	1.2E-02[c]	1.4E-02	7.0E-03[c]	1.0E-02	1.2E-02	1.1E-02[c]	NA	NA	3.0E-02
Lead	5.0E-03[c]	3.0E-03	6.0E-03[c]	6.0E-03	7.0E-03	3.0E-03[c]	NA	NA	NA
Manganese	1.0E-02[c]	9.0E-03	1.2E-02[c]	3.0E-02	3.0E-02	1.0E-02[c]	NA	NA	3.1E-02
Mercury	1.0E-02[c]	1.0E-03	2.0E-03[c]	3.0E-04	1.9E-04	3.0E-04[c]	NA	2.5E-04	7.2E-04
Molybdenum	7.0E-03[c]	NA	NA	1.4E-02	NA	NA	NA	NA	NA
Nickel	1.3E-02[c]	1.1E-02	7.0E-03[c]	2.0E-02	NA	NA	NA	NA	NA
Nitrate	6.3E+00	7.7E+00	3.6E+00[c]	7.8E+00	7.5E+00	5.4E+00[c]	NA	3.0E+01	NA
Selenium	NA	NA	2.0E-03[c]	5.0E-03	NA	NA	NA	NA	NA
Silver	NA	NA	NA	1.0E-02	2.0E-02	NA	NA	NA	1.6E-02
Vanadium	NA	NA	NA	2.0E-02	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	4.0E-02	NA	NA	9.4E-02	1.1E-01	NA

[a] Value is the 95% confidence limit on the mean (UCL) from Table 2-6 and 2-7. Constituents selected as chemicals of potential concern from at least one water body are listed in the table.
[b] NA - Not applicable.
[c] Value represents maximum detected concentration.

conditions during a storm event. For these reasons, the concentrations produced by high local flow conditions are selected for use as exposure point concentrations. This study assumes that future surface water concentrations in Pits 5, 6 and the Clearwell remain unchanged from current concentrations. The calculated exposure point concentrations are summarized in Table 3-9.

3.3.4 Soil/Waste

Exposure point concentrations for exposures to soil/waste are based on results of environmental sampling for both current and future exposures. As with several other media, exposure point concentrations with and without access controls are the same value.

3.3.4.1 Current Concentrations in Soil/Waste

Concentrations of constituents of potential concern have been measured in surface soils at a large number of on- and off-property locations. Section 3.1.5 of Part I describes these efforts, while Section 4.1.5 of Part I presents information on the nature and extent of contamination. Tables R.5-1 through R.5-42 (Appendix R) present statistical summaries of the surface soil data. These statistical evaluations determine the current soil exposure point concentrations presented in Table 3-10. Source areas listed in Table 3-10 are grouped according to location, availability of data, and appropriateness for modeling surface soil exposure pathways at the FEMP.

Characterization data for subsurface soils and waste forms are presented in Sections 3.1.1, 3.1.6, 3.2.1, and 3.2.6 of Part I. Concentrations (UCLs) of constituents of potential concern for subsurface soils/wastes are listed in Table 3-11. These data are taken from Table R.6-1 through R.6-71 of Appendix R. Source areas listed in Table 3-11 are grouped according to location, availability of data, and appropriateness as source terms for groundwater modeling for future exposures.

3.3.4.2 Future Concentrations in Soil/Waste

Future exposure point concentrations for surface soils are determined by assuming all caps have eroded from waste pits, all buildings have collapsed, and all containers have been compromised. Source depletion by other environmental transport mechanisms is not included. Subsurface soil concentrations presented in Table 3-11 represent an upper bound for future soil concentrations. These concentrations are used as surface soil concentrations for future exposure pathways from soil.

TABLE 3-9

EXPOSURE POINT CONCENTRATIONS FOR SURFACE WATER FOR FUTURE LAND-USE SCENARIOS

Constituents	Great Miami River
Radionuclides (pCi/ℓ)	
Cs-137	3.01E-04
Np-237	1.23E-05
Pu-238	1.59E-04
Pu-239/240	1.64E-04
Ra-226	1.95E-02
Ra-228	2.18E-03
Ru-106	1.82E-05
Sr-90	1.79E-03
Tc-99	2.23E-01
Th-228	1.09E-03
Th-230	9.97E-03
Th-232	7.79E-04
U-234	2.42E+01
U-235/236	1.26E+00
U-238	2.80E+01
Organics (mg/ℓ)	
1,1,1-Trichloroethane	2.72E-09
1,2-Dichloroethene	1.19E-09
2-Butanone	1.70E-07
2-Methylnapthalene	1.32E-08
2-Nitrophenol	NA[a]
4-Methyl-2-pentanone	1.54E-08
Acenaphthene	7.05E-08
Acetone	2.51E-07
Anthracene	2.85E-08
Aroclor-1254	5.06E-08

TABLE 3-9
(Continued)

Constituents	Great Miami River	
Aroclor-1260	4.80E-10	1
Benzene	NA	2
Benzo(a)anthracene	8.40E-09	3
Benzo(a)pyrene	5.01E-09	4
Benzo(b)fluoranthene	1.66E-09	5
Benzo(g,h,i)perylene	1.28E-10	6
Benzo(k)fluoranthene	1.44E-10	7
Benzoic acid	4.51E-07	8
Beta-BHC	5.68E-09	9
Bis(2-ethylhexyl) phthalate	7.87E-10	10
Carbondisulfide	3.11E-09	11
Chloroform	1.50E-08	12
Chlorobenzene	2.41E-10	13
Chrysene	8.53E-09	14
Cyanide	1.11E-04	15
Di-n-butyl-phthalate	NA	16
Dibenzofuran	2.04E-08	17
Dibenzo(a,h)anthracene	1.26E-09	18
Fluoranthene	1.77E-08	19
Fluorene	3.11E-08	20
Indeno(1,2,3-cd)pyrene	4.86E-11	21
Methylene chloride	1.89E-07	22
Napthalene	6.31E-08	23
N-nitrosodiphenylamine	3.45E-08	24
Phenanthrene	9.99E-08	25
Pyrene	1.88E-08	26
Tetrachloroethene	4.06E-09	27
Toluene	1.51E-09	28
Tributyl phosphate	1.54E-08	29

TABLE 3-9
(Continued)

Constituents	Great Miami River
Trichloroethene	6.69E-09
Inorganics (mg/ℓ)	
Antimony	1.39E-05
Arsenic	5.04E-06
Barium	3.74E-05
Beryllium	3.90E-07
Cobalt	5.48E-06
Copper	1.48E-05
Cyanide	NA
Lead	1.45E-05
Manganese	NA
Mercury	3.83E-07
Nickel	1.47E-05
Nitrate	NA
Nitrate/nitrite	NA
Silver	4.96E-06
Zinc	2.60E-05
Uranium	8.38E-02

[a] NA = Not applicable

TABLE 3-10

CONCENTRATIONS FOR SURFACE SOIL (0-6")
FOR CURRENT LAND-USE SCENARIOS

	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5
Radionuclide (pCi/g)						
Cs-137	7.0E-01	5.1E-01	1.1E+00	2.9E+00	4.3E-01	2.3E+00
Np-237	NA[a]	NA	NA	NA	1.4E-01	1.9E+01
Pu-238	NA	NA	3.0E+00	NA	2.1E-01	3.6E+00
Pu-239/240	NA	NA	1.1E+00	4.5E-01	2.1E-01	9.7E+00
Ra-226	5.1E+02	2.3E+00	1.6E+00	1.8E+00	2.4E+00	1.2E+02
Ra-228	4.4E+01	6.0E+01	1.6E+02	2.4E+00	3.2E+01	4.6E+01
Ru-106	NA	NA	NA	NA	3.0E+00	NA
Sr-90	6.2E-01	6.4E-01	1.0E+00	7.2E-01	3.3E-01	1.0E+01
Tc-99	8.3E-01	1.1E+00	3.8E+01	1.0E+00	2.4E+00	1.8E+03
Th-228	1.6E+01	3.8E+00	3.1E+02	3.0E+00	1.1E+01	1.2E+02
Th-230	5.3E+02	8.4E+02	2.8E+02	1.8E+01	1.6E+03	1.5E+04
Th-232	3.1E+01	2.7E+01	2.8E+02	3.5E+00	2.9E+00	4.6E+01
U-233	NA	NA	NA	NA	NA	NA
U-234	1.7E+03	1.5E+02	1.3E+04	6.0E+02	2.1E+02	8.8E+02
U-235	1.0E+02	5.0E+00	4.9E+02	3.5E+01	2.4E+01	3.2E+01
U-238	1.9E+03	7.8E+02	1.4E+04	7.0E+02	2.7E+02	2.5E+02

TABLE 3-10
(Continued)

	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5
Chemicals (mg/kg)						
1,1,1-Trichloroethane	NA	5.0E-03	NA	NA	NA	NA
1,2-Dichloroethene	NA	1.0E-03	NA	NA	NA	NA
2-Butanone	NA	1.6E-02	9.0E-03	NA	NA	NA
2-Methylnaphthalene	NA	5.6E-01	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	3.0E-03	NA	NA	NA	NA
Acenaphthene	NA	2.6E+00	1.1E+00	NA	NA	NA
Acetone	NA	1.6E-02	2.1E-02	NA	NA	6.3E-01
Anthracene	NA	3.3E+00	1.8E+00	NA	NA	NA
Antimony	3.1E+01	6.4E+00	NA	NA	2.7E+01	2.8E+01
Aroclor-1248	NA	NA	NA	NA	NA	5.5E-01
Aroclor-1254	1.5E+00	1.2E+00	8.9E-01	NA	7.2E-01	7.5E-01
Aroclor-1260	NA	2.8E+00	1.0E+00	NA	3.7E-02	NA
Arsenic	NA	1.5E+01	NA	NA	NA	1.5E+03
Barium	4.1E+02	NA	NA	NA	NA	2.9E+04
Benzene	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	1.6E+01	4.6E+00	NA	NA	NA
Benzo(a)pyrene	NA	2.4E+01	5.1E+00	NA	NA	NA

TABLE 3-10
(Continued)

	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5
Benzo(b)fluoranthene	NA	3.3E+01	4.0E+00	NA	NA	NA
Benzo(g,h,i)perylene	NA	1.0E+01	3.1E+00	NA	NA	NA
Benzo(k)fluoranthene	NA	2.6E+00	4.3E+00	NA	NA	NA
Benzoic acid	NA	2.5E-01	NA	NA	NA	NA
Beryllium	NA	NA	2.0E+00	NA	NA	1.3E+01
Beta-BHC	NA	1.0E-01	1.5E-01	NA	NA	NA
Bis(2-ethylhexyl) phthalate	NA	7.8E-01	1.8E-01	NA	NA	1.2E+00
Cadmium	NA	NA	NA	NA	NA	1.7E+01
Carbon disulfide	NA	3.0E-03	NA	NA	NA	NA
Chlorobenzene	NA	1.0E-03	NA	NA	NA	NA
Chloroform	NA	1.0E-02	NA	NA	NA	NA
Chromium	NA	NA	NA	NA	NA	1.8E+02
Chrysene	NA	1.5E+01	6.1E+00	NA	NA	NA
Cobalt	2.1E+01	1.4E+01	NA	NA	NA	4.4E+01
Copper	1.3E+02	4.4E+01	NA	NA	NA	3.1E+03
Cyanide	2.2E-01	1.4E+01	3.8E-01	NA	1.6E-01	NA
Di-n-butyl phthalate	NA	NA	NA	NA	NA	2.5E-01
Dibenzo(a,h)anthracene	NA	5.8E+00	1.3E+00	NA	NA	NA
Dibenzofuran	NA	1.2E+00	5.1E-01	NA	NA	NA

TABLE 3-10
(Continued)

	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5
Fluoranthene	NA	1.7E+01	6.5E+00	NA	NA	NA
Fluorene	NA	1.9E+00	1.2E+00	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NA	1.1E-01	2.5E+00	NA	NA	NA
Lead	5.7E+01	1.2E+02	3.0E+02	NA	NA	2.0E+02
Manganese	NA	NA	NA	NA	NA	3.2E+03
Mercury	NA	4.1E-01	9.7E-01	NA	NA	1.5E+00
Methylene chloride	NA	2.6E-02	2.1E-02	NA	NA	3.9E-01
N-Nitrosodiphenylamine	NA	2.0E-01	1.0E-01	NA	NA	NA
Naphthalene	NA	8.5E-01	NA	NA	NA	NA
Nickel	3.8E+01	5.9E+01	5.0E+01	NA	2.9E+01	2.0E+02
Phenanthrene	NA	1.1E+01	7.5E+00	NA	NA	NA
Phenol	NA	NA	NA	NA	NA	2.0E-01
Pyrene	NA	1.2E+01	6.5E+00	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	7.5E+00
Silver	8.9E+00	NA	1.1E+01	NA	8.9E+00	9.4E+00
Tetrachloroethene	NA	7.0E-03	2.0E-03	NA	NA	NA
Toluene	NA	3.0E-03	2.0E-03	NA	NA	NA
Tributyl phosphate	NA	NA	1.2E+00	NA	NA	NA
Trichloroethene	NA	1.1E-02	4.0E-03	NA	NA	NA

TABLE 3-10
(Continued)

	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5
Uranium	1.2E+02	1.1E+02	1.7E+04	3.1E+03	2.0E+03	7.5E+02
Vanadium	NA	NA	NA	NA	NA	4.3E+03
Zinc	1.0E+02	3.4E+02	3.2E+02	NA	NA	2.0E+02

TABLE 3-10
(Continued)

	Incinerator Area	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Radionuclide (pCi/g)					
Cs-137	6.2E-01	NA	7.0E-01	4.7E-01	6.2E-01
Np-237	NA	NA	NA	NA	NA
Pu-238	4.6E-01	NA	NA	NA	3.3E-01
Pu-239/240	4.4E-01	NA	NA	NA	3.4E-01
Ra-226	2.2E+01	7.0E-01	4.9E+01	2.8E+01	3.9E+01
Ra-228	4.3E+00	1.0E+00	1.8E+00	1.9E+00	2.0E+00
Ru-106	NA	NA	NA	NA	NA
Sr-90	1.8E+00	NA	NA	NA	9.0E-01
Tc-99	2.6E+00	NA	NA	NA	6.4E-01
Th-228	2.7E+00	1.0E+00	9.0E-01	2.1E+01	2.0E+00
Th-230	1.6E+02	NA	6.0E+00	1.3E+02	1.6E+01
Th-232	6.3E+00	1.0E+00	1.8E+00	1.9E+00	1.3E+00
U-233	NA	NA	NA	NA	NA
U-234	7.9E+03	NA	8.2E+01	5.2E+02	1.4E+01
U-235	7.3E+02	NA	1.9E+00	3.4E+01	5.5E-01
U-238	1.0E+04	2.8E+00	3.7E+01	1.4E+01	1.9E+01

TABLE 3-10
(Continued)

	Incinerator Area	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Chemicals (mg/kg)					
1,1,1-Trichloroethane	NA	NA	NA	NA	4.0E-03
1,2-Dichloroethene	NA	NA	NA	NA	1.0E-03
2-Butanone	NA	NA	NA	NA	1.5E-02
2-Methylnaphthalene	NA	NA	NA	NA	4.1E-01
4-Methyl-2-pentanone	NA	NA	NA	NA	3.0E-03
Acenaphthene	NA	NA	NA	NA	7.4E-01
Acetone	NA	NA	NA	NA	1.6E-02
Anthracene	NA	NA	NA	NA	8.1E-01
Antimony	NA	NA	NA	NA	2.4E+01
Aroclor-1248	NA	NA	NA	NA	NA
Aroclor-1254	NA	NA	NA	NA	1.5E+00
Aroclor-1260	NA	NA	NA	NA	2.0E+00
Arsenic	NA	NA	NA	NA	7.1E+00
Barium	NA	NA	NA	NA	2.1E+02
Benzene	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA	2.5E+00
Benzo(a)pyrene	NA	NA	NA	NA	6.6E+00
Benzo(b)fluoranthene	NA	NA	NA	NA	2.7E+00

TABLE 3-10
(Continued)

	Incinerator Area	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Benzo(g,h,i)perylene	NA	NA	NA	NA	2.1E+00
Benzo(k)fluoranthene	NA	NA	NA	NA	2.6E+00
Benzoic acid	NA	NA	NA	NA	2.5E-01
Beryllium	NA	NA	NA	NA	9.5E-01
Beta-BHC	NA	NA	NA	NA	2.3E-02
Bis(2-ethylhexyl) phthalate	NA	NA	NA	NA	7.1E-01
Cadmium	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	NA	3.0E-03
Chlorobenzene	NA	NA	NA	NA	1.0E-03
Chloroform	NA	NA	NA	NA	6.0E-03
Chromium	NA	NA	NA	NA	NA
Chrysene	NA	NA	NA	NA	2.8E+00
Cobalt	NA	NA	NA	NA	1.3E+01
Copper	NA	NA	NA	NA	5.8E+01
Cyanide	NA	NA	NA	NA	1.4E-01
Di-n-butyl phthalate	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	1.1E+00
Dibenzofuran	NA	NA	NA	NA	7.6E-01
Fluoranthene	NA	NA	NA	NA	3.3E+01

TABLE 3-10
(Continued)

	Incinerator Area	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Fluorene	NA	NA	NA	NA	1.2E+00
Indeno(1,2,3-cd)pyrene	NA	NA	NA	NA	1.9E+00
Lead	NA	NA	NA	NA	4.9E+01
Manganese	NA	NA	NA	NA	NA
Mercury	NA	NA	NA	NA	1.7E-01
Methylene chloride	NA	NA	NA	NA	2.2E-02
N-Nitrosodiphenylamine	NA	NA	NA	NA	2.0E-01
Naphthalene	NA	NA	NA	NA	5.9E-01
Nickel	NA	NA	NA	NA	3.3E+01
Phenanthrene	NA	NA	NA	NA	2.2E+01
Phenol	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	NA	7.3E+00
Selenium	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	7.9E+00
Tetrachloroethene	NA	NA	NA	NA	4.0E-03
Toluene	NA	NA	NA	NA	3.0E-03
Tributyl phosphate	NA	NA	NA	NA	1.2E+00
Trichloroethene	NA	NA	NA	NA	7.0E-03
Uranium	2.3E+04	8.3E+00	1.1E+02	5.7E+01	3.1E+02

TABLE 3-10
(Continued)

	Incinerator Area	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Vanadium	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	1.0E+02

[a] NA = Not applicable

TABLE 3-11

EXPOSURE POINT CONCENTRATIONS FOR SUBSURFACE SOIL FOR FUTURE LAND-USE SCENARIOS

	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Radionuclides (pCi/g)						
Am-241	NA[a]	NA	4.9E+01	NA	NA	NA
Cs-137	1.1E+00	2.4E+00	1.7E+00	NA	2.3E+00	NA
Np-237	NA	NA	4.5E-01	3.7E-01	1.9E+01	4.5E-01
Pa-231	NA	NA	NA	NA	NA	NA
Pu-238	NA	9.6E-02	2.4E-01	5.0E-01	3.6E+00	2.1E-01
Pu-239/240	NA	2.4E-01	1.8E+00	3.7E-01	9.7E+00	1.9E-01
Ra-226	6.5E+01	4.3E+02	4.3E+02	3.1E+01	1.2E+02	2.6E+00
Ru-106	9.8E+00	2.2E+01	NA	1.9E+01	NA	NA
Sr-90	NA	NA	2.0E+00	NA	1.0E+01	NA
Tc-99	5.0E+00	1.4E+02	2.2E+03	2.2E+02	1.8E+03	7.1E+01
Th-230	2.8E+03	3.3E+03	1.7E+04	5.7E+02	1.5E+04	8.9E+01
Th-232	2.2E+01	1.0E+02	2.4E+01	5.6E+01	4.6E+01	5.6E+00
U-233	NA	NA	NA	NA	NA	NA
U-234	8.3E+02	4.2E+03	3.6E+02	1.8E+03	8.8E+02	2.5E+02
U-235	9.1E+01	1.4E+03	7.5E+01	3.3E+02	3.2E+01	1.6E+01
U-238	1.1E+03	6.1E+03	2.4E+02	4.6E+03	2.5E+02	1.8E+02

TABLE 3-11
(Continued)

	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Chemicals (mg/kg)						
1,1,2-Trichloro-1,2,2-trifluoroethene	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	1.1E-01	1.5E-01	NA	1.2E-01	NA	2.0E-03
1,1,2-Trichloroethane	NA	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	NA	NA	NA
1,1-Dichloroethane	NA	NA	NA	NA	NA	1.1E-01
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	NA	NA	NA	NA	NA	NA
1,2-Dichloroethene	NA	NA	NA	NA	NA	NA
2,4-Dimethylphenol	NA	1.5E-01	NA	NA	NA	NA
2-Butanone	2.3E+00	2.7E+00	3.6E+00	7.9E+00	NA	6.7E-02
2-Chlorophenol	NA	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	NA	NA	2.0E-03
2-Methylnaphthalene	2.2E-01	8.0E+00	NA	NA	NA	5.0E-02
2-Methylphenol	NA	NA	NA	NA	NA	NA
3,3-Dichlorobenzidine	1.3E-01	NA	NA	NA	NA	NA
4,4-DDT	1.6E+00	1.4E+00	NA	NA	NA	NA
4-Chlorophenyl-phenylether	NA	6.2E+01	NA	NA	NA	NA
4-Chloro-3-methylphenol	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA	NA	NA	6.0E-03
4-Methylphenol	NA	3.5E-01	NA	NA	NA	NA
4-Nitrophenol	NA	NA	NA	NA	NA	NA

TABLE 3-11
(Continued)

	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Acenaphthene	NA	5.0E+01	NA	1.7E-01	NA	NA
Acetone	2.2E-01	5.4E-01	2.4E-01	5.2E-01	6.3E-01	2.4E-01
Ammonia	NA	NA	NA	NA	NA	NA
Anthracene	7.4E-02	1.2E+02	NA	5.1E-01	NA	NA
Antimony	NA	NA	NA	NA	2.8E+01	1.3E+01
Aroclor-1016	NA	NA	NA	NA	NA	2.9E-01
Aroclor-1221	NA	NA	NA	NA	NA	NA
Aroclor-1242	NA	NA	NA	1.0E+00	NA	2.9E-01
Aroclor-1248	3.5E+00	3.2E-01	NA	8.5E-01	5.5E-01	2.0E-01
Aroclor-1254	9.2E+00	3.2E-01	2.5E-01	1.0E+00	7.5E-01	2.7E+00
Aroclor-1260	7.0E+00	1.8E+00	NA	NA	NA	NA
Arsenic	NA	NA	2.0E+03	NA	1.5E+03	NA
Barium	NA	NA	7.4E+03	5.9E+03	2.9E+04	1.1E+03
Benzene	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	1.8E-01	1.0E+02	6.0E-02	7.5E-01	NA	1.5E-01
Benzo(a)pyrene	1.4E-01	1.4E+02	NA	5.5E-01	NA	1.6E-01
Benzo(b)fluoranthene	3.0E-01	4.7E+01	1.1E-01	5.1E-01	NA	1.6E-01
Benzo(g,h,i)perylene	NA	5.2E+01	NA	1.7E-01	NA	8.5E-02
Benzo(k)fluoranthene	1.4E-01	1.2E+02	NA	5.6E-01	NA	NA
Benzoic acid	NA	NA	NA	NA	NA	NA
Beryllium	NA	8.9E+00	1.7E+01	1.3E+01	1.3E+01	1.6E+01
Bis(2-ethylhexyl) phthalate	1.7E+00	3.6E-01	7.8E-01	2.7E-01	1.2E+00	1.9E+00

TABLE 3-11
(Continued)

	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Boron	NA	NA	NA	NA	NA	4.8E+01
BromodichloromEthane	NA	NA	NA	NA	NA	NA
Butyl benzyl phthalate	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	9.3E+00	2.9E+01	1.7E+01	2.6E+01
Carbon Tetrachloride	2.0E-03	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	NA	NA	1.0E-03
Chlordane	NA	NA	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	NA	NA	2.0E-03
Chloroform	2.0E-01	NA	NA	1.3E+00	NA	NA
Chromium	NA	NA	1.2E+02	NA	1.8E+02	NA
Chrysene	4.7E-01	7.5E+01	7.5E-02	7.6E-01	NA	8.3E-02
Cobalt	2.8E+01	3.4E+02	NA	8.4E+01	4.4E+01	1.0E+02
Copper	7.8E+01	2.8E+02	1.9E+03	1.6E+02	3.1E+03	2.6E+02
Cyanide	NA	NA	NA	NA	NA	NA
Di-n-butyl phthalate	9.2E-02	3.8E-01	8.4E-02	4.9E-01	2.5E-01	2.1E-01
Di-n-octyl phthalate	7.3E-01	5.2E-01	NA	1.7E-01	NA	1.2E-01
Dibenzo(a,h)anthracene	NA	1.6E+01	NA	1.7E-01	NA	NA
Dibenzofuran	NA	3.6E+01	NA	1.6E-01	NA	NA
Ethyl parathion	NA	NA	NA	8.6E-01	NA	NA
Ethylbenzene	3.7E-02	4.8E-02	NA	NA	NA	1.9E-01
Fluoranthene	3.8E-01	1.9E+02	2.3E-01	2.2E+00	NA	3.4E-01
Fluorene	NA	6.2E+01	NA	3.1E-01	NA	NA

TABLE 3-11
(Continued)

	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Indeno(1,2,3-cd)pyrene	NA	5.2E+01	NA	1.8E-01	NA	7.8E-02
Lead	5.7E+01	1.7E+02	4.1E+02	6.2E+01	2.1E+02	2.8E+02
Malathion	NA	NA	NA	6.7E-01	NA	NA
Manganese	2.4E+03	NA	3.6E+03	3.6E+03	3.2E+03	1.7E+03
Mercury	3.6E-01	7.0E-01	3.4E+00	6.3E-01	1.5E+00	9.1E-01
Methyl parathion	NA	NA	NA	2.1E+00	NA	NA
Methylene chloride	1.3E-01	2.0E-01	4.2E-01	2.3E-01	3.9E-01	1.1E-01
Molybednum	NA	NA	NA	NA	NA	1.9E+01
N-Nitroso-di-n-propylamine	NA	NA	NA	NA	NA	NA
N-Nitrosodiphenylamine	NA	NA	1.3E-01	NA	NA	NA
Naphthalene	5.4E-02	1.6E+01	NA	1.1E-01	NA	NA
Nickel	6.0E+01	4.5E+02	2.3E+02	5.0E+01	2.0E+02	6.8E+01
Nitrate	NA	NA	NA	NA	NA	NA
Pentachlorophenol	NA	NA	1.3E+00	NA	NA	2.6E+00
Phenanthrene	1.3E+00	1.5E+02	1.2E-01	2.1E+00	NA	2.3E-01
Phenol	NA	3.3E-01	NA	8.3E-01	2.0E-01	6.5E-01
Potassium	2.0E+03	NA	NA	NA	NA	NA
Pyrene	2.9E-01	1.3E+02	1.9E-01	1.4E+00	NA	2.0E-01
Selenium	NA	1.0E+01	9.0E+01	NA	7.5E+00	NA
Silicon	NA	NA	NA	NA	NA	1.2E+03
Silver	3.3E+01	2.3E+01	NA	4.4E+02	9.4E+00	5.1E+02
Tetrachloroethene	2.1E-01	NA	NA	3.0E+01	NA	1.5E-01

TABLE 3-11
(Continued)

	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Thallium	NA	NA	NA	NA	NA	NA
Toluene	5.5E-02	NA	NA	6.7E-02	NA	4.2E-02
Trans-1,2-dichloroethene	NA	NA	NA	6.0E-02	NA	NA
Tributyl phosphate	NA	NA	NA	NA	NA	NA
Trichloroethene	1.9E-02	NA	NA	3.0E-01	NA	NA
Uranium	3.4E+03	1.9E+04	7.6E+02	1.4E+04	7.5E+02	5.4E+02
Vanadium	NA	NA	5.3E+03	2.4E+02	4.3E+03	1.4E+02
Vinyl chloride	NA	6.7E-01	NA	NA	NA	3.0E-03
Xylenes	2.2E-02	2.6E-01	NA	NA	NA	7.4E-01
Zinc	NA	1.9E+03	2.2E+02	NA	2.0E+02	5.0E+02
Beta-BHC	NA	NA	NA	NA	NA	NA

TABLE 3-11
(Continued)

	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
Radionuclide (pCi/g)									
Am-241	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cs-137	NA	NA	NA	3.4E-01	NA	NA	NA	NA	NA
Np-237	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pa-231	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pu-238	1.0E-01	NA	NA	NA	NA	NA	NA	NA	NA
Pu-239/240	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ra-226	9.6E-01	2.4E+00	2.5E+00	NA	2.3E+00	NA	NA	NA	NA
Ru-106	NA	NA	NA	NA	3.4E+00	NA	NA	NA	NA
Sr-90	1.1E+00	2.0E+00	1.2E+00	NA	NA	NA	NA	NA	NA
Tc-99	NA	NA	NA	NA	NA	NA	NA	NA	NA
Th-230	4.1E+00	4.0E+00	6.8E+00	7.0E+00	1.9E+01	NA	NA	NA	NA
Th-232	2.3E+00	1.8E+00	2.1E+00	NA	4.6E+00	NA	NA	NA	NA
U-233	NA	NA	NA	NA	NA	NA	NA	NA	NA
U-234	2.8E+01	4.7E+00	2.8E+01	3.1E+00	1.5E+01	NA	NA	NA	NA
U-235	1.0E+00	2.0E-01	1.2E+00	3.0E-01	8.0E-01	NA	NA	NA	NA
U-238	1.4E+01	5.3E+00	1.2E+01	4.2E+00	1.1E+01	NA	NA	NA	NA
Chemicals (mg/kg)									
1,1,2-Trichloro-1,2,2-trifluoroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	3.1E-02	2.4E-02	NA	NA	4.0E-03	2.0E-03	1.0E-02	3.1E-02
1,1,2-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	2.0E-03

TABLE 3-11
(Continued)

	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
1,1,2,2-Tetrachloroethane	NA	NA	NA	NA	NA	NA	NA	NA	1.6E-02
1,1-Dichloroethane	1.3E-01	NA	NA	NA	NA	1.6E-02	NA	NA	2.7E-02
1,1-Dichloroethene	NA	2.0E-03	NA	NA	NA	2.0E-03	9.0E-03	4.0E-03	7.0E-03
1,2-Dichloroethane	NA		NA	NA	NA	NA	NA	NA	2.0E-03
1,2-Dichloroethene	NA	NA	NA	NA	NA	NA	1.9E-02	6.0E-03	2.0E-02
2,4-Dimethylphenol	2.4E-01	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone	1.2E-01	4.0E-03	NA	1.8E+00	NA	5.6E-02	1.4E-02	7.0E-03	2.4E+00
2-Chlorophenol	NA	4.8E-02	NA	NA	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	NA	NA	NA	3.0E-03	1.0E-03	NA
2-Methylnaphthalene	3.4E+00	1.6E-01	NA	NA	NA	NA	NA	NA	NA
2-Methylphenol	9.6E-02	NA	NA	NA	NA	NA	NA	NA	NA
3,3-Dichlorobenzidine	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4-DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chlorophenyl-phenylether	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloro-3-methylphenol	NA	5.8E-02	NA	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	2.0E-03	NA	NA	2.0E-03	3.0E-03	7.0E-03	1.7E-02
4-Methylphenol	3.6E-01	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitrophenol	NA	4.8E-02	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	8.5E+00	NA	NA	NA	NA	NA	NA	NA	5.4E-01
Acetone	1.9E-01	6.1E-02	4.1E-02	1.4E-01	2.5E-01	8.4E-02	7.9E-02	1.6E-02	6.1E-02
Ammonia	NA	NA	NA	NA	NA	NA	NA	NA	NA

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TABLE 3-11
(Continued)

	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
Anthracene	2.4E+00	NA	NA	NA	NA	NA	NA	NA	3.9E-01
Antimony	NA	9.2E+00	1.1E+01	NA	NA	NA	1.9E+01	1.9E+01	9.3E+00
Aroclor-1016	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1221	NA	NA	NA	NA	NA	NA	8.3E-02	NA	NA
Aroclor-1242	6.8E-01	NA	6.0E-03	NA	9.3E-02	NA	NA	NA	NA
Aroclor-1248	5.6E-01	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1254	7.2E-01	NA	2.9E-01	NA	6.2E-01	3.6E-01	NA	NA	6.8E-01
Aroclor-1260	NA	3.8E-02	NA	NA	4.2E-01	NA	NA	NA	9.6E-01
Arsenic	NA	6.6E+01	3.5E+01	NA	NA	2.6E+01	NA	NA	NA
Barium	NA	NA	NA	NA	NA	NA	NA	NA	3.6E+03
Benzene	NA	NA	NA	NA	NA	NA	NA	NA	5.0E-03
Benzo(a)anthracene	1.6E+00	NA	NA	NA	NA	NA	NA	NA	6.2E-01
Benzo(a)pyrene	6.6E+00	NA	NA	NA	NA	NA	NA	NA	3.5E+00
Benzo(b)fluoranthene	1.8E+00	NA	9.3E-02	NA	NA	NA	NA	NA	4.4E-01
Benzo(g,h,i)perylene	2.7E+00	NA	NA	NA	NA	NA	NA	NA	4.9E-01
Benzo(k)fluoranthene	2.0E+00	NA	NA	NA	NA	NA	NA	NA	6.2E-01
Benzoic acid	NA	7.3E-02	1.5E-01	1.6E-01	NA	8.8E-02	NA	NA	5.9E-02
Beryllium	NA	3.4E+00	5.8E+00	NA	NA	2.4E+00	NA	NA	NA
Bis(2-ethylhexyl) phthalate	1.5E-01	5.8E-01	NA	3.1E-01	NA	1.8E-01	2.4E-01	3.2E-01	4.9E-01
Boron	2.7E+01	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	NA	2.0E-03	NA	NA	NA	NA	NA	4.0E-03	NA

TABLE 3-11
(Continued)

	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
Butyl benzyl phthalate	3.2E-01	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	3.0E-03	NA	NA	NA	NA	4.0E-03	4.0E-03
Chlordane	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	NA	NA	NA	NA	NA	5.0E-03
Chloroform	NA	6.0E-03	NA	NA	NA	NA	3.0E-03	6.0E-03	2.0E-03
Chromium	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	2.5E+00	NA	NA	NA	NA	NA	NA	NA	7.3E-01
Cobalt	NA	NA	NA	NA	2.1E+01	NA	NA	NA	NA
Copper	NA	6.6E+01	NA	NA	NA	NA	NA	NA	NA
Cyanide	7.9E-01	2.8E-01	7.0E-01	NA	NA	NA	4.5E-01	NA	NA
Di-n-butyl phthalate	2.8E-01	NA	NA	7.3E-02	NA	NA	NA	NA	6.6E-01
Di-n-octyl phthalate	3.5E-01	NA	NA	NA	NA	NA	2.3E-01	NA	NA
Dibenzo(a,h)anthracene	1.6E+00	NA	NA	NA	NA	NA	NA	NA	5.3E-01
Dibenzofuran	1.7E+00	NA	NA	NA	NA	NA	NA	NA	3.2E-01
Ethyl parathion	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	9.1E-02	NA	NA	NA	NA	3.0E-03	2.0E-03	NA	1.0E-03
Fluoranthene	1.3E+00	NA	NA	NA	NA	8.1E-02	NA	NA	6.5E+00
Fluorene	2.2E+00	NA	NA	NA	NA	NA	NA	NA	5.5E-01
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 3-11
(Continued)

	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
Indeno(1,2,3-cd)pyrene	2.7E+00	5.3E+01	NA	NA	NA	NA	NA	NA	9.0E-01
Lead	6.2E+01	4.4E+01	6.7E+01	NA	NA	4.4E+02	NA	NA	4.4E+01
Malathion	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	8.2E+02	NA	NA	NA	6.0E+02
Mercury	NA	2.0E-01	1.8E-01	NA	8.5E-01	1.3E+00	NA	NA	8.4E-01
Methyl parathion	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	1.4E-01	NA	NA	2.4E-01	1.1E-01	3.7E-02	1.7E-02	1.7E-02	1.9E+00
Molybednum	1.1E+01	1.6E+01	9.4E+00	NA	NA	NA	NA	NA	NA
N-Nitroso-di-n-propylamine	NA	NA	NA	NA	NA	6.3E-01	NA	NA	NA
N-Nitrosodiphenylamine	6.7E-02	NA	NA	NA	NA	1.3E-01	NA	NA	NA
Naphthalene	1.6E+01	8.2E-02	NA	NA	NA	NA	NA	NA	NA
Nickel	3.2E+01	3.2E+01	NA	NA	3.4E+01	5.0E+01	NA	NA	3.0E+01
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	1.3E+00	7.2E-02	NA	NA	NA	8.8E-02	NA	NA	7.2E-01
Phenol	3.1E-01	5.8E-02	3.1E-01	8.9E-02	NA	NA	NA	NA	6.9E-02
Potassium	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	1.9E+00	NA	NA	NA	NA	NA	NA	NA	7.8E-01
Selenium	NA	5.4E+00	2.6E+00	NA	NA	NA	NA	NA	NA
Silicon	7.0E+02	NA	NA	NA	NA	NA	NA	NA	NA
Silver	1.2E+01	4.4E+00	NA	NA	NA	1.7E+01	NA	NA	4.3E+00

TABLE 3-11
(Continued)

	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
Tetrachloroethene	9.7E-02	NA	NA	NA	NA	NA	3.0E-03	5.0E-03	8.4E-02
Thallium	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	1.8E-01	6.0E-03	3.0E-03	NA	NA	1.4E-02	4.0E-03	2.0E-03	1.0E-02
Trans-1,2-dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tributyl phosphate	NA	NA	NA	NA	NA	1.2E+00	NA	NA	NA
Trichloroethene	NA	NA	NA	NA	NA	NA	8.0E-03	1.1E-02	2.8E-02
Uranium	1.5E+02	2.2E+01	5.9E+02	1.3E+01	3.2E+01	2.5E+02	3.9E+02	9.9E+01	7.0E+02
Vanadium	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	NA	NA	NA	3.0E-03	NA	6.0E-03
Xylenes	3.2E-01	NA	NA	NA	NA	1.2E-02	4.0E-03	NA	4.4E-02
Zinc	9.9E+01	8.3E+01	NA	NA	NA	2.5E+02	NA	NA	1.7E+02
Beta-BHC	NA	NA	NA	NA	NA	NA	2.5E-01	NA	2.3E-02

[a] NA = Not applicable

3.3.5 Sediments

3.3.5.1 Current Concentrations in Sediment

Concentrations of uranium and other constituents of potential concern have been measured in sediment from Paddys Run, the SSOD, and the Great Miami River. Section 3.1.3 of Part I describes these efforts, and Section 4.1.3 of Part I presents information on the nature and extent of this contamination. Tables R.3-23 through R.3-39 present statistical evaluations of these data. These statistical evaluations yield the current sediment exposure point concentrations presented in Table 3-12. Most exposure point concentrations are UCL values forradionuclides. Limited data requires that maximum concentrations be used for many hazardous chemicals.

3.3.5.2 Future Concentrations in Sediment

Surface water/sediment modeling provides estimates of future sediment exposure point concentrations in Paddys Run, the SSOD, and the Great Miami River. The surface water/sediment modeling methodology, model parameter values, and results are presented in Appendix P. Results of modeling of future concentration of sediment indicate that the concentrations of sediment are less than future soil concentrations. Since future exposure pathways combine exposure to soil and sediment, soil concentrations are used as exposure point concentrations for soil/sediment pathways.

3.3.6 Structures

Characterization data are still being acquired for structures and materials at the FEMP. The exposure assessment for scenarios involving receptors who enter structures is based on existing characterization data. The data consist primarily of monitoring data used to characterize occupational hazards at the FEMP. These data include radiological surface contamination measurements on abandoned-in-place (AIP) equipment in selected FEMP plants, and airborne radioactivity within these plants. In addition, uranium concentration in the dust is available for selected plants at the FEMP. These concentrations were measured by Boback et. al. (Boback et al. 1987) while production activities were in progress. External radiation exposure rates were available only for Building 79 (a warehouse east of Plant 6, see Figure 2-2 of Part II) as of December 1, 1991. Because data sources that can be used to quantify exposures were limited and were available for a few buildings, a quantitative exposure assessment (for ingestion and inhalation only) can be reasonably performed for only Plants 1, 4, and 9. These data are summarized in Table 3-13. There are no appropriate characterization data for chemicals in structures suitable for quantitative exposure and risk assessments.

It is assumed that individuals may enter FEMP buildings if access controls are removed. The measured uranium concentration in dust is used as the primary source concentration for ingestion of contaminants (pathway number 25) by these receptors. For the purpose of estimating the

TABLE 3-12

EXPOSURE POINT CONCENTRATIONS FOR SEDIMENT FOR CURRENT LAND-USE SCENARIOS[a]

Constituents of Potential Concern	GMR Upstream of Main Effluent Line	GMR Between Effluent Line and Paddys Run	GMR Downstream of Paddys Run	Paddys Run Upstream of N. Boundary of FEMP	Paddys Run Between N. Boundary of FEMP and SSOD	Paddys Run Downstream of SSOD	SSOD
Radionuclides (pCi/g)							
Pu-238				b		2.4E-02	2.3E-02
Pu-239/240				b		1.0E-02	3.0E-02
Ra-224				b			8.5E-01
Ra-226				b			8.7E-01
Ra-228				b			8.1E-01
Sr-90	5.9E-01	5.7E-01	4.3E-01	b			
Tc-99				b		4.8E-01	
Th-230		1.5E+00		b		7.2E-01	1.6E+00
U-234				b		7.7E-01	7.5E+00
U-235				b			7.0E-01
U-238				b		8.7E-01	9.9E+00
Uranium (µg/g)				b	3.0E+00	3.0E+00	9.0E+00
Thorium (µg/g)	3.0E+00	3.0E+00	2.0E+00	b			
Organics (mg/kg)[a]							
2-Butanone	b	b	b			1.0E-02	b
2-Hexanone	b	b	b			1.0E-02	b
Acetone	b	b	b	2.0E-02	8.0E-03	1.0E-02	b
bis (2-Ethylhexyl) phthalate	b	b	b	4.6E-01	5.9E-01	4.0E-01	b
Di-n-butyl phthalate	b	b	b	3.9E-02	6.0E-02		b
Methylene chloride	b	b	b	7.0E-03	2.0E-02	1.0E-03	b

TABLE 3-12
(Continued)

Constituents of Potential Concern	GMR Upstream of Main Effluent Line	GMR Between Effluent Line and Paddys Run	GMR Downstream of Paddys Run	Paddys Run Upstream of N. Boundary of FEMP	Paddys Run Between N. Boundary of FEMP and SSOD	Paddys Run Downstream of SSOD	SSOD
Inorganics (mg/kg)[c]							
Ammonia	b	b	b				b
Mercury	b	b	b				b
Nitrate	b	b	b				b

[a] Values represent maximum detected concentration.
[b] No Data Available as of December 1, 1991.
[c] Constituents that are selected as constituents of potential concern for sediment from at least one surface water body are listed in the table. Value is the 95% confidence limit on the mean (UCL) from Tables 2-8 and 2-9.

TABLE 3-13
EXPOSURE POINT CONCENTRATIONS OF ALPHA-PARTICLE EMITTERS

Building	Geometric Mean Highest Alpha Removable[a] (pCi)	Monitored Airborne Alpha[b] (pCi/mℓ)	Uranium Concentration in Dust[c] (g/g)
Plant 1	2.3×10^{2}	1.4×10^{-1}	3.5×10^{-1}
Plant 9	[d]	1.3×10^{-1}	5.5×10^{-1}
Plant 4	3.6×10^{2}	1.1×10^{-1}	7.3×10^{-1}

[a] Used for 12-hour salvaging/working exposure.
[b] Used for 12-hour resting exposure.
[c] Measurements were performed in 1985, while the former Production Area was operating, and are reported in Boback, et al., 1985.
[d] Measurements of removable alpha contamination are not available as of December 1, 1991.

intake from inhalation of contaminants, scavenging and resting are considered for these receptors. The exposure point concentrations for scavenging and resting are described below.

Salvaging

Receptors are assumed to disturb removable contamination on the AIP equipment during the salvaging activity. Estimated airborne concentrations of resuspended contaminants are used as the source concentrations for inhalation of contaminants (pathway number 26) during this activity.

Resting

Measured airborne concentrations of alpha- and beta-particle emitters are used as exposure point concentrations for the inhalation pathway (number 26) for the receptors during resting.

3.3.7 Radiation Exposure Rates

External radiation exposure rates of penetrating radiations (gamma rays and x-rays) emitted from sources in the waste pits and the waste storage silos (K-65 silos) are determined by using measured data and modeling performed using the MICROSHIELD computer code (Grove 1988). Measured data are available only for locations at the manways on the tops of Silos 1 and 2. Exposure rate measurement data are not available for the waste pits. Table 3-14 presents radiation dose rates measured at Silo 1 and Silo 2 manway locations in November 1991, just prior to installation of bentonite and during December 1991 and January, February, and March 1992, following installation of bentonite. The range of values and mean values are presented for each manway.

Radiation dose rates calculated with the MICROSHIELD computer code for areas near Silos 1 and 2 are in good agreement with measured radiation dose rates in the same area. Radiation dose rates calculated for locations above Pits 1 and 2 are in the range of natural background dose rates. Calculated dose rates for locations above Pit 3, Pit 4, and the Burn Pit are a fraction of natural background dose rates.

3.4 QUANTIFICATION OF EXPOSURE

Exposures are quantified using the methods, models, and parameters specified in the Addendum (DOE 1992a) with exceptions as noted below. The exposure parameters used to assess current potential exposures are listed in Table 3-15. Exposure parameters for future potential exposures are listed in Table 3-16.

The exposure assessment process results in calculated daily intakes (expressed in mg/kg/day) for hazardous chemical contaminants and radioactivity intakes (expressed in pCi) for radionuclide contaminants. These calculated exposure assessment results are subsequently used in the risk characterization to quantify human health risks. Intake results are not tabulated separately from

TABLE 3-14
K-65 SILO MANWAY DOSE RATE MEASUREMENTS[a]

	Silo 1			
Date	SE Manway	SW Manway	NE Manway	NW Manway
11/08/91	135.0	130.0	140.0	175.0
12/03/91	8.4	7.0	6.3	6.9
12/05/91	6.0	4.5	6.5	6.5
12/06/91	6.4	5.2	6.3	7.9
12/09/91	6.4	5.2	6.3	7.9
12/10/91	6.0	6.0	5.0	6.0
12/18/91	5.0	4.5	4.5	3.7
12/20/91	3.9	3.5	4.3	5.3
12/21/91	4.8	4.1	2.3	5.5
12/22/91	6.0	5.5	6.0	6.0
01/06/92	4.3	NA[b]	3.9	4.5
01/07/92	3.6	NA	3.7	3.9
01/09/92	7.0	NA	5.0	4.0
01/10/92	6.0	NA	7.0	4.0
01/13/92	7.0	NA	7.5	7.0
01/23/92	8.0	NA	8.0	9.0
02/03/92	4.5	NA	4.9	4.8
02/10/92	3.7	3.5	3.5	4.2
02/11/92	3.4	3.3	3.6	3.0
02/12/92	3.4	3.0	3.0	3.5
02/17/92	7.0	7.0	7.0	8.0
02/18/92	5.5	5.5	6.0	7.0
02/20/92	7.0	6.0	6.0	7.0
02/24/92	5.0	5.0	5.0	6.0
02/25/92	5.0	4.5	5.0	5.5
02/28/92	4.1	4.1	4.0	4.3
03/05/92	3.5	3.4	3.6	4.2
03/06/92	3.4	3.2	3.7	4.2
03/11/92	9.0	8.0	7.0	9.0
# of Samples[c]	28	21	28	28
Minimum	3.4	3	2.3	3
Maximum	9	8	8	9
Arith. Mean	5.5	4.9	5.2	5.7
Stand. Dev.	1.6	1.4	1.5	1.7

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TABLE 3-14
(Continued)

	Silo 2			
	SE Manway	SW Manway	NE Manway	NW Manway
11/08/91	200.0	185.0	215.0	204.0
12/03/91	15.0	15.0	10.0	15.0
12/05/91	9.0	8.5	9.1	8.0
12/06/91	9.3	8.1	9.3	8.7
12/09/91	9.3	8.1	9.3	8.7
12/10/91	6.0	7.0	5.0	5.0
12/18/91	4.2	4.0	3.5	3.0
12/20/91	4.2	3.2	2.3	2.3
12/21/91	2.7	3.2	2.7	3.0
12/22/91	3.7	3.8	3.0	3.1
01/06/92	3.2	3.1	2.7	2.3
01/07/92	2.8	3.1	2.3	2.1
01/09/92	3.4	3.2	2.5	2.5
01/10/92	3.5	3.0	2.5	2.3
01/13/92	3.5	3.4	2.8	2.6
01/23/92	4.0	3.5	3.3	3.3
02/03/92	3.5	3.6	2.4	2.5
02/10/92	3.8	3.9	3.0	2.7
02/11/92	2.7	2.9	2.3	2.5
02/12/92	3.4	3.5	2.5	2.4
02/17/92	3.8	3.7	2.7	3.1
02/18/92	3.5	4.0	3.0	2.8
02/20/92	2.8	3.5	2.5	2.5
02/24/92	3.8	4.0	3.0	2.6
02/25/92	2.9	4.2	2.9	2.7
02/28/92	2.7	3.2	2.3	2.0
03/05/92	3.2	3.2	2.0	2.1
03/06/92	3.0	3.4	2.0	1.7
03/11/92	4.0	4.8	3.0	3.3
# of Samples[c]	28	28	28	28
Minimum	2.7	2.9	2	1.7
Maximum	15	15	10	15
Arith. Mean	4.5	4.6	3.7	3.7
Stand. Dev.	2.8	2.6	2.4	2.9

[a] All dose rate measurements reported in mR/hr.
[b] NA indicates that data not available.
[c] Statistics are performed on samples taken after December 1, 1991.

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TABLE 3-15
PARAMETERS USED TO ESTIMATE CURRENT POTENTIAL EXPOSURES

	Receptors for which Access Controls Uniquely Define Exposure Factors			Receptors whose Exposure Factors Are Unaffected by the Presence of Access Controls					Receptors whose Exposure Factors Are Uniquely Defined by a Lack of Access Controls			
Pathway [Addendum Pathway No.] Parameter (units)	Visitor Age 19-70		Trespassing Child Access Controls Age 7-18	Off-Property Farmer Age 1-70		Off-property User of Meat & Milk Grown On-site Age 1-70	Off-Property User of GM River Water Age 1-70		Hunter Age 19-70	Trespassing Child w/o Access Controls Age 7-18	On-property Building User/ Scavenger Age 19-70	
Inhalation [16, 17, 26]												
IR (m3/hr)	0.83	a	NA	0.83	a	NA	NA		NA	NA	0.83	a
ET (hr/d)	2	b	NA	5.7	d	NA	NA		NA	NA	12	e
EF (d/yr)	250	b	NA	350	d	NA	NA		NA	NA	100	e
ED (yr)	25	b	NA	70	a	NA	NA		NA	NA	1	e
BW (kg)	70	a	NA	70	a	NA	NA		NA	NA	70	a
AT-Noncancer (d)	9125	a	NA	25550	a	NA	NA		NA	NA	365	e
AT-Cancer (d)	25550	a	NA	25550	a	NA	NA		NA	NA	25550	a
Drinking water [13, 30, 36]												
IR x FI (L/d)	NA		NA	2	a	NA	2	a	NA	NA	NA	
EF (d/yr)	NA		NA	350	a	NA	350	a	NA	NA	NA	
ED (yr)	NA		NA	70	a	NA	70	a	NA	NA	NA	
BW (kg)	NA		NA	70	a	NA	70	a	NA	NA	NA	
AT-Noncancer (d)	NA		NA	25550	a	NA	25550	a	NA	NA	NA	
AT-Cancer (d)	NA		NA	25550	a	NA	25550	a	NA	NA	NA	
Inhalation of volatiles released from water by showering and other household uses [11, 29, 35]												
IR (m3/hr)	NA		NA	0.83	a	NA	0.83	a	NA	NA	NA	
ET (hr/d)	NA		NA	0.17	f	NA	0.17	f	NA	NA	NA	
EF (d/yr)	NA		NA	350	a	NA	350	a	NA	NA	NA	
ED (yr)	NA		NA	70	a	NA	70	a	NA	NA	NA	
BW (kg)	NA		NA	70	a	NA	70	a	NA	NA	NA	
AT-Noncancer (d)	NA		NA	25550	a	NA	25550	a	NA	NA	NA	
AT-Cancer (d)	NA		NA	25550	a	NA	25550	a	NA	NA	NA	
Dermal contact while bathing [11, 29, 35]												
SA (m2)	NA		NA	1.81	a	NA	1.81	a	NA	NA	NA	
PC (cm/hr)	NA		NA	csv		NA	csv		NA	NA	NA	
ET (hr/d)	NA		NA	0.17	f	NA	0.17	f	NA	NA	NA	
EF (d/yr)	NA		NA	350	a	NA	350	a	NA	NA	NA	
ED (yr)	NA		NA	70	a	NA	70	a	NA	NA	NA	
BW (kg)	NA		NA	70	a	NA	70	a	NA	NA	NA	
AT-Noncancer (d)	NA		NA	25550	a	NA	25550	a	NA	NA	NA	
AT-Cancer (d)	NA		NA	25550	a	NA	25550	a	NA	NA	NA	
Incidental ingestion while swimming [15, 38]												
IR x FI (L/hr)	NA		NA	NA		NA	0.05	g	NA	NA	NA	
ET (hr/d)	NA		NA	NA		NA	2.6	f	NA	NA	NA	
EF (d/yr)	NA		NA	NA		NA	7	g	NA	NA	NA	
ED (yr)	NA		NA	NA		NA	30	g	NA	NA	NA	
BW (kg)	NA		NA	NA		NA	70	a	NA	NA	NA	
AT-Noncancer (d)	NA		NA	NA		NA	10950	a	NA	NA	NA	
AT-Cancer (d)	NA		NA	NA		NA	25550	a	NA	NA	NA	
Dermal contact while swimming [6, 34]												
SA (m2)	NA		NA	NA		NA	1.81	a	NA	NA	NA	
PC (cm/hr)	NA		NA	NA		NA	csv		NA	NA	NA	
ET (hr/d)	NA		NA	NA		NA	2.6	f	NA	NA	NA	
EF (d/yr)	NA		NA	NA		NA	7	g	NA	NA	NA	
ED (yr)	NA		NA	NA		NA	30	g	NA	NA	NA	
BW (kg)	NA		NA	NA		NA	70	a	NA	NA	NA	
AT-Noncancer (d)	NA		NA	NA		NA	10950	a	NA	NA	NA	
AT-Cancer (d)	NA		NA	NA		NA	25550	a	NA	NA	NA	

TABLE 3-15 (CONTINUED)
PARAMETERS USED TO ESTIMATE CURRENT POTENTIAL EXPOSURES

Pathway [Addendum Pathway No.] Parameter (units)	Receptors for which Access Controls Uniquely Define Exposure Factors: Visitor Age 19-70		Trespassing Child Access Controls Age 7-18		Receptors whose Exposure Factors Are Unaffected by the Presence of Access Controls: Off-Property Farmer Age 1-70		Off-property User of Meat & Milk Grown On-site Age 1-70		Off-Property User of GM River Water Age 1-70		Receptors whose Exposure Factors Are Uniquely Defined by a Lack of Access Controls: Hunter Age 19-70		Trespassing Child w/o Access Controls Age 7-18		On-property Building User/ Scavenger Age 19-70	
Incidental ingestion of soil/sediment [8, 9, 25, 43]																
IR (g/d)	NA		0.1	a	NA		NA		NA		NA		0.1	a	0.1	a
FI	NA		0.1	h	NA		NA		NA		NA		0.1	h	1	i
EF (d/yr)	NA		4	c	NA		NA		NA		NA		120	j	100	e
ED (yr)	NA		12	a	NA		NA		NA		NA		12	a	1	e
BW (kg)	NA		43	a	NA		NA		NA		NA		43	a	70	a
AT-Noncancer (d)	NA		4380	a	NA		NA		NA		NA		4380	a	365	e
AT-Cancer (d)	NA		25550	a	NA		NA		NA		NA		25550	a	25550	a
Dermal contact with soil/sediment [5, 7, 42]																
SA (m2)	NA		0.135	a	NA		NA		NA		NA		0.135	a	NA	
AF (mg/cm2)	NA		1.45	f	NA		NA		NA		NA		1.45	f	NA	
ABS (unitless)	NA		csv		NA		NA		NA		NA		csv		NA	
EF (d/yr)	NA		4	c	NA		NA		NA		NA		120	j	NA	
ED (yr)	NA		12	a	NA		NA		NA		NA		12	a	NA	
BW (kg)	NA		43	a	NA		NA		NA		NA		43	a	NA	
AT-Noncancer (d)	NA		4380	a	NA		NA		NA		NA		4380	a	NA	
AT-Cancer (d)	NA		25550	a	NA		NA		NA		NA		25550	a	NA	
External radiation exposure [19, 21, 27, 44]																
DR (mrem/hr)	csv		csv		csv		NA		NA		NA		csv		NA	
ET indoors (hr/d)	NA		NA		NA		NA		NA		NA		NA		NA	
ET outdoors (hr/d)	2	b	2	c	5.7	d	NA		NA		NA		2	j	NA	
EF (d/yr)	250	b	4	c	350	d	NA		NA		NA		120	j	NA	
ED (yr)	25	b	12	a	70	a	NA		NA		NA		12	a	NA	
SH indoors (unitless)	NA		NA		NA		NA		NA		NA		NA		NA	
SH outdoors (unitless)	0	a	0	a	0	a	NA		NA		NA		0	a	NA	
Ingestion of vegetables and fruit [1, 3, 4, 28, 33]																
IR x FI (g/d)	NA		NA		122	a	NA		122	a	NA		NA		NA	
EF (d/yr)	NA		NA		350	a	NA		350	a	NA		NA		NA	
ED (yr)	NA		NA		70	a	NA		70	a	NA		NA		NA	
BW (kg)	NA		NA		70	a	NA		70	a	NA		NA		NA	
AT-Noncancer (d)	NA		NA		25550	a	NA		25550	a	NA		NA		NA	
AT-Cancer (d)	NA		NA		25550	a	NA		25550	a	NA		NA		NA	
Ingestion of meat [22, 23, 24, 31, 32, 40, 41]																
IR x FI (g/d)	NA		NA		75	a	75	a	75	a	75	a	NA		NA	
EF (d/yr)	NA		NA		350	a	350	a	350	a	10	i	NA		NA	
ED (yr)	NA		NA		70	a	70	a	70	a	30	i	NA		NA	
BW (kg)	NA		NA		70	a	70	a	70	a	70	a	NA		NA	
AT-Noncancer (d)	NA		NA		25550	a	25550	a	25550	a	10950	a	NA		NA	
AT-Cancer (d)	NA		NA		25550	a	25550	a	25550	a	25550	a	NA		NA	
Ingestion of milk [22, 23, 24, 31, 32, 40, 41]																
IR x FI (L/d)	NA		NA		0.3	a	0.3	a	0.3	a	NA		NA		NA	
EF (d/yr)	NA		NA		350	a	350	a	350	a	NA		NA		NA	
ED (yr)	NA		NA		70	a	70	a	70	a	NA		NA		NA	
BW (kg)	NA		NA		70	a	70	a	70	a	NA		NA		NA	
AT-Noncancer (d)	NA		NA		25550	a	25550	a	25550	a	NA		NA		NA	
AT-Cancer (d)	NA		NA		25550	a	25550	a	25550	a	NA		NA		NA	
Ingestion of fish [14, 37]																
IR x FI (g/d)	NA		NA		NA		NA		54	a	NA		NA		NA	
EF (d/yr)	NA		NA		NA		NA		350	a	NA		NA		NA	
ED (yr)	NA		NA		NA		NA		30	a	NA		NA		NA	
BW (kg)	NA		NA		NA		NA		70	a	NA		NA		NA	
AT-Noncancer (d)	NA		NA		NA		NA		10950	a	NA		NA		NA	
AT-Cancer (d)	NA		NA		NA		NA		25550	a	NA		NA		NA	

a - DOE 1992, Risk Assessment Work Plan Addendum
b - Assumed value. Based on probable activity pattern for a delivery person.
c - Assumes a typical child spends 8 hrs/year on-property when access is restricted.
d - Assumes a farmer works outdoors for 2000 hrs/year.
e - Assumed value, scavenger scenario (12 hrs working, 12 hrs resting).
f - EPA 1991, Interim Guidance for Dermal Exposure Assessment, p 10-2.
g - EPA 1989 HHEM, pp 6-36 & 6-38
h - Assumed value, based on fraction of day spent on site.
i - Assumes a recreational hunter eats fame 10 times/year for 30 yrs.
j - Assumes a typical child can spend 240 hrs/year on-property if access is unrestricted.
csv - Chemical specific value
NA - Not applicable

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TABLE 3-16 (CONTINUED)
PARAMETERS USED TO ESTIMATE FUTURE POTENTIAL EXPOSURES

Pathway [Addendum Pathway No.] Parameter (units)	Farmer Using GM River Age 1-70		Typical On-property Resident Age 1-70		RME On-property Farmer Age 1-70		On-property Resident Child Age 1-6		On-property Home Builder Age 19+		On-property Building User/ Scavenger Age 19+	
Incidental ingestion of soil/sediment [8, 9, 25, 43]												
IR (g/d)	NA		0.01	i	0.109	a	0.2	a	0.1	a	0.1	a
FI	NA		1	j	1	j	1	j	1	j	1	j
EF (d/yr)	NA		350	a	350	a	350	a	50	d	350	e
ED (yr)	NA		9	b	70	a	6	a	1	d	30	e
BW (kg)	NA		70	a	70	a	15	a	70	a	70	a
AT-Noncancer (d)	NA		3285	b	25550	a	2190	a	365	d	10950	e
AT-Cancer (d)	NA		25550	a	25550	a	25550	a	25550	a	25550	a
Dermal contact with soil/sediment [5, 7, 42]												
SA (m2)	NA		0.193	a	0.193	a	0.7	a	0.193	a	NA	a
AF (mg/cm2)	NA		1.45	i	1.45	i	1.45	i	1.45	i	NA	i
ABS (unitless)	NA		csv		csv		csv		csv		NA	
EF (d/yr)	NA		350	a	350	a	350	a	50	d	NA	e
ED (yr)	NA		9	b	70	a	6	a	1	d	NA	e
BW (kg)	NA		70	a	70	a	15	a	70	a	NA	a
AT-Noncancer (d)	NA		3285	a	25550	a	2190	a	365	d	NA	e
AT-Cancer (d)	NA		25550	a	25550	a	25550	a	25550	a	NA	a
External radiation exposure [19, 21, 27, 44]												
DR (mrem/hr)	NA		csv		csv		csv		csv		NA	
ET indoors (hr/d)	NA		18.3	b	18.3	b	22	c	5	k	NA	k
ET outdoors (hr/d)	NA		5.7	b	5.7	b	2	c	5	k	NA	k
EF (d/yr)	NA		350	a	350	a	350	a	50	d	NA	e
ED (yr)	NA		9	b	70	a	6	a	1	d	NA	e
SH indoors (unitless)	NA		0.5	a	0.5	a	0.5	a	0.5	a	NA	a
SH outdoors (unitless)	NA		0	a	0	a	0	a	0	a	NA	a
Ingestion of vegetables and fruit [1, 2, 3, 4, 28, 33]												
IR x FI (g/d)	122	a	122	a	122	a	101.5	l	NA		NA	
EF (d/yr)	350	a	350	a	350	a	350	a	NA		NA	
ED (yr)	70	a	9	f	70	a	6	a	NA		NA	
BW (kg)	70	a	70	a	70	a	15	a	NA		NA	
AT-Noncancer (d)	25550	a	3285	a	25550	a	2190	a	NA		NA	
AT-Cancer (d)	25550	a	25550	a	25550	a	25550	a	NA		NA	
Ingestion of meat [22, 23, 24, 31, 32, 40, 41]												
IR x FI (g/d)	75	a	75	a	75	a	29	a	NA		NA	
EF (d/yr)	350	a	350	a	350	a	350	a	NA		NA	
ED (yr)	70	a	9	f	70	a	6	a	NA		NA	
BW (kg)	70	a	70	a	70	a	15	a	NA		NA	
AT-Noncancer (d)	25550	a	3285	a	25550	a	2190	a	NA		NA	
AT-Cancer (d)	25550	a	25550	a	25550	a	25550	a	NA		NA	
Ingestion of milk [22, 23, 24, 31, 32, 40, 41]												
IR x FI (L/d)	0.3	a	0.3	a	0.3	a	0.9	a	NA		NA	
EF (d/yr)	350	a	350	a	350	a	350	a	NA		NA	
ED (yr)	70	a	9	f	70	a	6	a	NA		NA	
BW (kg)	70	a	70	a	70	a	15	a	NA		NA	
AT-Noncancer (d)	25550	a	3285	a	25550	a	2190	a	NA		NA	
AT-Cancer (d)	25550	a	25550	a	25550	a	25550	a	NA		NA	
Ingestion of fish [14, 37]												
IR x FI (g/d)	54	a	NA		NA		NA		NA		NA	
EF (d/yr)	350	a	NA		NA		NA		NA		NA	
ED (yr)	30	f	NA		NA		NA		NA		NA	
BW (kg)	70	a	NA		NA		NA		NA		NA	
AT-Noncancer (d)	10950	a	NA		NA		NA		NA		NA	
AT-Cancer (d)	25550	a	NA		NA		NA		NA		NA	

a - DOE 1992, Risk Assessment Work Plan Addendum
b - Assumes a farmer works outdoors 2000 hrs/year.
c - Assumes a resident small child spends 700 h/yr outdoors.
d - Assumes a home builder spends 500 hours building a home (NRC 1985, Impacts BRC).
e - Assumes scavenger resides at site (8-hr salvaging, and 16-hr resting.)
f - EPA 1991 Oswer Standard Default Exposure Parameters
g - EPA 1991, Interim Guidance for Dermal Exposure Assessment, p 10-2.
h - EPA 1989 HHEM, pp 6-36 & 6-38
i - Estimated, using range in EPA 1989 EF Handbook, p 2-57
j - Assumed value, based on fraction of day spent on site.
k - Assumes the worker spends 50% of his time working in/on the house, and 50% of the time working in/on the soil/waste.
l - USDA 1986a in WPA reference list

csv - Chemical specific value
NA - Not applicable

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TABLE 3-16
PARAMETERS USED TO ESTIMATE FUTURE POTENTIAL EXPOSURES

Pathway [Addendum Pathway No.] Parameter (units)	Farmer Using GM River Age 1-70		Typical On-property Resident Age 1-70		RME On-property Farmer Age 1-70		On-property Resident Child Age 1-6		On-property Home Builder Age 19+		On-property Building User/ Scavenger Age 19+	
Inhalation of dusts, volatiles, and radon [16, 17, 26]												
IR (m3/hr)	NA		0.83	a	0.83	a	0.83	a	0.83	a	0.83	a
ET indoors (hr/d)	NA		18.3	b	18.3	b	22	c	5	d	24	e
ET outdoors (hr/d)	NA		5.7	b	5.7	b	2	c	5	d	0	e
EF (d/yr)	NA		350	a	350	a	350	c	50	d	350	e
ED (yr)	NA		9	f	70	a	6	a	1	d	30	e
BW (kg)	NA		70	a	70	a	15	a	70	a	70	a
AT-Noncancer (d)	NA		3285	f	25550	a	2190	a	365	d	10950	e
AT-Cancer (d)	NA		25550	a	25550	a	25550	a	25550	a	25550	a
Drinking water [12, 13, 30, 36]												
IR x FI (L/d)	2	a	2	a	2	a	1.4	a	NA		NA	
EF (d/yr)	350	a	350	a	350	a	350	a	NA		NA	
ED (yr)	70	a	9	f	70	a	6	a	NA		NA	
BW (kg)	70	a	70	a	70	a	15	a	NA		NA	
AT-Noncancer (d)	25550	a	3285	f	25550	a	2190	a	NA		NA	
AT-Cancer (d)	25550	a	25550	a	25550	a	25550	a	NA		NA	
Inhalation of volatiles released from water by showering and other household uses [10, 11, 29, 35]												
IR (m3/hr)	0.83	a	0.83	a	0.83	a	NA		NA		NA	
ET (hr/d)	0.17	g	0.17	g	0.17	g	NA		NA		NA	
EF (d/yr)	350	a	350	a	350	a	NA		NA		NA	
ED (yr)	70	a	9	b	70	a	NA		NA		NA	
BW (kg)	70	a	70	a	70	a	NA		NA		NA	
AT-Noncancer (d)	25550	a	3285	b	25550	a	NA		NA		NA	
AT-Cancer (d)	25550	a	25550	a	25550	a	NA		NA		NA	
Dermal contact while bathing [10, 11, 29, 35]												
SA (m2)	1.81	a	1.81	a	1.81	a	NA		NA		NA	
PC (cm/hr)	csv		csv		csv		NA		NA		NA	
ET (hr/d)	0.17	g	0.17	g	0.17	g	NA		NA		NA	
EF (d/yr)	350	a	350	a	350	a	NA		NA		NA	
ED (yr)	70	a	9	b	70	a	NA		NA		NA	
BW (kg)	70	a	70	a	70	a	NA		NA		NA	
AT-Noncancer (d)	25550	a	3285	b	25550	a	NA		NA		NA	
AT-Cancer (d)	25550	a	25550	a	25550	a	NA		NA		NA	
Incidental ingestion while swimming [15, 38]												
IR x FI (L/hr)	0.05	h	NA		NA		NA		NA		NA	
ET (hr/d)	2.6	g	NA		NA		NA		NA		NA	
EF (d/yr)	7	h	NA		NA		NA		NA		NA	
ED (yr)	30	h	NA		NA		NA		NA		NA	
BW (kg)	70	a	NA		NA		NA		NA		NA	
AT-Noncancer (d)	10950	a	NA		NA		NA		NA		NA	
AT-Cancer (d)	25550	a	NA		NA		NA		NA		NA	
Dermal contact while swimming [6, 34]												
SA (m2)	1.81	a	NA		NA		NA		NA		NA	
PC (cm/hr)	csv		NA		NA		NA		NA		NA	
ET (hr/d)	2.6	g	NA		NA		NA		NA		NA	
EF (d/yr)	7	h	NA		NA		NA		NA		NA	
ED (yr)	30	h	NA		NA		NA		NA		NA	
BW (kg)	70	a	NA		NA		NA		NA		NA	
AT-Noncancer (d)	10950	a	NA		NA		NA		NA		NA	
AT-Cancer (d)	25550	a	NA		NA		NA		NA		NA	

the risk characterization results since the calculation of intake is an intermediate result in risk calculations and is not used as the final expression of human health hazard. The significance of the calculated intake per unit concentration of each contaminant in an exposure medium is that this quantity is multiplied by the risk per unit intake (for each contaminant) to obtain the risk per unit concentration or "unit risk factor" for each contaminant. The methodology for calculating unit risk factors is discussed in Appendix S.

Inhalation of Volatiles Released by Household Water Use

Intake from inhalation of volatiles released during showering and other household water use is quantified using the following equations (EPA 1991e):

$$I_{sh} = (I_s + I_h)(EF)(ED)/[(BW)(AT)] \qquad (3\text{-}1)$$

where

- I_{sh} = Intake from inhalation of volatiles released during showering and other household water use (mg/kg/day)
- I_s = Intake from inhalation of volatiles released during showering (mg/day)
- I_h = Intake from inhalation of volatiles released during other household water use (mg/day)
- EF = Exposure frequency (350 days/yr)
- ED = Exposure duration (70 yrs)
- BW = Body weight (70 kg)
- AT = Averaging time (days); for noncarcinogens equals (ED)(365 days/yr); for carcinogens (365 days/yr)(70-year lifetime)

The equation used for estimating inhalation exposure due to showering (Murphy 1987) is shown below:

$$I_s = \left[\frac{(10^3)(N_s)(T_s)(IR)(C_w)(F)}{(a)(V)}\right] \times \left[1 + \left(\frac{1}{(a)(T_s)}\right)(e^{(-a \cdot T_s)} - 1)\right] \times \left[1 - e^{-\frac{H}{0.93 + 1.48 \times 10^{-3}}}\right] \qquad (3\text{-}2)$$

where

- I_s = Estimated inhalation exposure during showering (mg/day)
- N_s = Average number of showers per day (1)
- T_s = Average length of shower (hrs/shower) (0.5)
- IR = Average inhalation rate (m^3/hr) (0.83)
- C_w = Concentration in water (mg/ℓ) (chemical-specific)
- F = Shower water flow rate (m^3/hr) (0.48)
- a = Air exchange rate between shower and rest of house (hrs^{-1}) (12)
- V = Volume of shower or bathroom (m^3) (12)
- H = Henry's Law Constant (atm • m^3/mol) (chemical-specific)

The equation for estimating exposure via inhalation of volatiles released during non-showering household water use (Murphy, 1987) is as follows:

$$I_h = [\frac{(T_h)(I)(C_w)(Q_w)(M)}{(Q_a)}] \times [1 - e^{\frac{-H}{1.26 + (2 \times 10^{-3})}}] \quad (3\text{-}3)$$

where

I_h = estimated inhalation exposure from household water use (mg/day)
T_h = time spent at home inside (hrs/day)
I = inhalation rate (m^3/hr)
C_w = concentration in water (mg/l)
Q_w = quantity of water used inside daily (l/day)
M = mixing factor (unitless)
Q_a = volume air exchange rate for home (m^3/day)
H = Henry's Law Constant (atm*m^3/mol)

The quantity of household water used, Q_w, is assumed to be 980 ℓ/day. A mixing factor, M, of 0.5 is used. The volume air exchange rate, Q_a, is assumed to be 8700 m^3/day, based on a 1600 ft^2 x 8 ft home volume and an air exchange rate of 1 hr^{-1} (Murphy 1987).

Dermal Contact Parameters

Chemical-specific parameters for calculating exposures via dermal contact were not listed in the Addendum (DOE 1992a). Permeability coefficients for water (showering or swimming) used in this assessment are taken from EPA's Interim Guidance for Dermal Exposure Assessment (EPA 1991e). Absorption factors for dermal exposure to metals in soil are taken from Wester et al. (1991). For organic compounds in soil, dermal absorption factors are taken from McKone (1990).

3.5 UNCERTAINTIES RELATED TO THE EXPOSURE ASSESSMENT

As with any risk assessment, there are uncertainties associated with the exposure assessment of the PBRA. There are uncertainties with each step of the exposure assessment process, including the determination of source terms, identification of potential receptor scenarios, exposure pathway analysis, and intake assessment. Source terms for the FEMP were quantified based on characterization data available as of December 1, 1991. Although some additional data available on the RI/FS database was included in the source term summaries presented in Appendix R, the December 1, 1991 cut-off date was generally in effect. Additional characterization data will be presented in operable unit-specific baseline risk assessments. The representativeness of the source term data for each area considered in the PBRA will be realized as subsequent data are acquired.

Site characterization data for many constituents (e.g., uranium, thorium, and radium) were acquired under a sampling and analysis program having a bias toward collecting and analyzing

samples expected to have the highest concentrations (Weston 1987, DOE 1988). Although non-biased sampling data are included in the data sets, many (if not most) of the data summarized in Appendix R are data having positive bias.

Use of the UCL (or in some cases, the maximum detected value) as the concentration for each constituent in each source area provides a simplified value (concentration) for a complex site having large areas of slightly elevated contaminants, interspersed with smaller localized areas having much higher concentrations. Although the FEMP was divided into several source areas, small localized areas of higher concentrations are noted at the FEMP. Characterization data for these areas dominate the descriptive statistics (e.g., UCLs) for the source terms.

A wide range of potential receptor scenarios was presented in Section 3.1. Receptor scenarios for "access controls" and "no access controls", both now and in the future, are selected to represent exposure scenarios having the highest potential exposure. These scenarios, along with the specific exposure assessment parameters for each, lead to great overestimation of exposures for these hypothetical receptors.

Exposure pathways identified in Section 3.2 for the receptor scenarios were selected through a screening process. Reasonable care was taken to include pathways that could contribute more than one percent of the overall risk. Pathways that contribute less than one percent of the overall risk are not included. Considering the overall uncertainties inherent to the risk assessment process, the potential exclusion of pathways of limited significance should not impact the conclusions of the PBRA. The exposure pathways included in the exposure assessment have been sufficient to quantify the reasonable, upper-bound exposures that could occur at the FEMP.

Exposure point concentrations presented in Section 3.3 are determined with a combination of measurement results and fate and transport modeling. The impacts of localized contamination on the determination of measured contaminant concentration statistics (e.g., UCLs) was discussed previously. Fate and transport modeling was performed for air, groundwater, surface water, and sediment to predict exposure point concentrations under the future land-use scenarios and to supplement measurement data. Each of the models used in the exposure assessment was selected to provide reasonable, upper-bound estimates of exposure point concentrations. Model parameters were selected (usually in the absence of site-specific parameters) to maximize the calculated exposure point concentrations. For example, the approach of groundwater modeling used to estimate future exposure concentrations resulting from migration of contaminants from soil or waste areas, assumed that uranium was present in very mobile chemical forms. Generally, this assumption has not been supported by the available characterization data at the site. Additional data are being acquired to address this issue, but in the absence of such data, high mobility of uranium in soil and waste areas is generally assumed.

Calculation of potential intakes of contaminants was discussed in Section 3.4. Calculated intakes were not presented since this is an interim step to the calculated risks presented in Section 5.0. The models (and formulae) used for intake calculations are generally accepted as the most appropriate for any exposure assessment. Specific model parameters were selected to provide reasonable, upper-bound estimates of intake. Discussions of the appropriateness of each selected parameter are given in numerous references cited in the Addendum (DOE 1992a). It can be concluded, however, that the selected parameters will lead to overestimates, rather than underestimates, of the potential intakes by hypothetical receptors.

3.6 SUMMARY

The exposure setting (Section 3.1), exposure pathways (Section 3.2), and the intake assessment models and parameters (Section 3.4) are used to determine the intake quantities per unit concentration of contaminants. Combination of this information with risk characterization data of Section 4.0 gives the risk per unit concentration "unit risk factors" given in Appendix S. The risk from each contaminant via each exposure pathway and medium is therefore the unit risk factor times the exposure point concentration. This method is described in Section 5.1. This simplification of the risk calculation process focuses on the determination of the unit risk factors (contaminant-specific, pathway-specific, and medium-specific) and exposure point concentrations (measured or modeled).

3.6.1 Air

Under current land-use conditions, with and without access controls, a resident may live at the FEMP property boundary. Current airborne concentrations of radionuclides in off-property areas estimated using air transport modeling are as much as 30 times background levels. These estimated concentrations are at the property boundary immediately downwind of the major potential sources at the FEMP. Radionuclide concentrations estimated at the two schools do not exceed background levels. On-property concentrations of airborne radioactive contaminants that could be encountered if access controls are removed, are estimated to be as much as 150 times background levels.

For future land-use assumptions, off-property concentrations of Rn-222, Th-230, and Ra-226 are calculated to exceed background concentrations at the two schools. Calculations of future concentrations assume loss of containment (caps, silos/buildings, etc.) of the waste. Although airborne concentrations of U-238, U-235, and U-234 are not estimated to greatly increase on-property in the future, airborne concentrations of Th-232, Th-230, Ra-226 and U-233 are significant.

Modeled air concentrations for hazardous chemicals under current and future land-use scenarios are extremely low, at 10^{-6} $\mu g/m^3$ levels. Assuming a 70-kg person inhales 0.83 m^3 or air per hour,

24 hours a day, and is on-property 350 days per year for 70 years, the hazard index (HI) for lead associated with the modeled concentrations would be 10^{-6}. Concentrations for future receptors are approximately 100 times higher than off-property concentrations. Again using the lead example, estimated intakes and corresponding risks would be several orders of magnitude below toxic threshold levels. Because of the low estimated values, the air pathway will not be considered as a viable pathway for both current and future land-use scenarios in the risk characterization for chemicals.

3.6.2 Groundwater

Current exposure point concentrations for a given radionuclide in groundwater are based on sampling results for the off-property wells having the highest concentrations of that contaminant. Concentrations of U-238, U-235, and U-234 are much as 300 times background in some of the wells, but concentrations in most wells do not differ significantly from background concentrations. Technetium-99 (Tc-99) and Sr-90 are detected in a total of four wells, suggesting isolated sources of these radionuclides. Thorium isotopes and Ra-226 do not differ significantly from background.

Future concentrations of uranium isotopes in groundwater, predicted by transport modeling, are calculated to be significantly above background concentrations. Other radionuclides (Tc-99, Sr-90, and Np-237) are calculated to be present in groundwater in the future. Modeled results are presented in Table 3-7.

Current concentrations of hazardous chemicals in groundwater (excluding perched groundwater) suggest that most organic chemicals detected are either common lab contaminants, such as acetone and methylene chloride, or they are detected at or below the CRQL.

Several inorganic chemicals have been detected in off-property wells. Several metals are detected at or below the background UTL in most wells, but are above the UTL in one or two isolated wells. For example, arsenic is at or below UTLs or CRQLs in all but two wells, 2061 and 2094. Well 3127, a well that penetrates into the lower portion of the aquifer, appears to have elevated concentrations of barium, cadmium, chromium, lead, manganese, silver, and vanadium. This isolated pocket of contamination underlies the small industrial area south of the FEMP property. Concentrations of metals in this one well are approximately 1000 times higher than background concentrations.

With the exception of uranium, future modeled groundwater concentrations are low (e.g., 10^{-3} $\mu g/\ell$).

3.6.3 Surface Water

Measured concentrations of uranium isotopes in surface water in on-property drainage ditches are significantly above background. Concentrations of radionuclides in surface water in off-property areas are not currently above background levels with the exception of Tc-99 in the Great Miami River.

Estimated concentrations of radionuclides in surface water at the FEMP in the future are significantly above background. However, modeling for future surface water concentrations assumes limited vegetative cover and general loss of containing structures for on-property wastes.

In general, concentrations of hazardous metals detected in surface water are at or below background groundwater UTLs, or are lower than CRQLs. In several cases the highest detected value is used to define the exposure point concentration. This may greatly overestimate the actual surface water concentrations of metals. Interestingly enough, the highest metal concentrations were detected upstream of the FEMP instead of downstream.

Estimated future surface water concentrations for chemicals are also at or below background groundwater concentrations and CRQLs. The exception to this is the estimated future uranium values. These are high due to the large estimated uranium source term calculated for the site.

3.6.4 Sediment

Measured concentrations of radionuclides in sediment are limited, but indicated that concentrations (UCLs) of uranium isotopes are as much as five times background soil concentrations. Other radionuclides are detected in sediment at very low concentrations.

Future concentrations of radionuclides in sediment are estimated to be as much as 300 times background for U-238, U-235, U-234, and several other radionuclides. However, models used to calculate future sediment concentrations assume limited vegetative cover at the FEMP and loss of containing structures for the wastes.

Measured concentrations of hazardous chemicals in sediment are also limited, thus, current exposure point concentrations are either not available, or are based on small data sets. Several common laboratory contaminants were detected in sediment samples, but are not expected to be present in the environment.

Future modeled concentrations of chemicals in sediment are also low, generally at natural background levels.

3.6.5 Soil/Waste

Numerous radionuclides have been detected in soil and waste areas at above-background levels at the FEMP. The most important of these radionuclides (in terms of measured concentrations) are: U-238, U-235, U-234, Th-232, Th-230, Th-228, Ra-228, and Ra-226. Other radionuclides were detected at above-background levels but not at levels as significant as for isotopes of uranium, thorium, and radium. These other radionuclides include Sr-90, Cs-137, Tc-99, and plutonium isotopes (at very low levels). Concentrations of radionuclides in soil and waste areas for future exposures are based on the assumption of disturbance of subsurface soil and loss of containing structures for wastes. The list of hazardous chemicals detected in surface and subsurface soils at the FEMP is extensive. Appendix R, Sections R.5 and R.6, present data summaries for the surface and subsurface soil data. These summaries identify each radionuclide and hazardous chemical detected and provide summary statistical parameters for each constituent. Most of the soil samples for hazardous chemicals represent concentrations in the actual waste units or in the former Production Area. Chemical analysis results for soil samples outside of these areas are limited. Volatile organic compounds (VOCs), semivolatiles, and pesticides have all been detected at low levels, generally in the parts per billion (ppb) to low parts per million (ppm) range. The highest concentrations are found in the waste pit area. Metals are also detected above background in the waste pits, at levels higher than other areas of the site. However, levels are not greatly elevated above background. For example, cadmium in Waste Pit 3, Waste Pit 4, and Waste Pit 5 appear to be within the background range of 1 to 11 mg/kg. Arsenic concentrations are as much as 100 times background in Waste Pit 3 and Waste Pit 5. Other metals, such as copper, are also significantly above background in the waste pit area. In general, it is unknown if the elevated metals levels exist in the surface and subsurface soils outside of the waste pit area since analyses for metals in soil are primarily limited to the waste pit area.

3.6.6 Structures

Exposure point concentration data for structures and equipment are limited for radiological and chemical contaminants. The uniqueness of the potential exposures of individuals inside structures is addressed separately in the risk characterization (Section 5.0).

3.6.7 Uncertainties

Although Section 3.5 emphasizes uncertainties in each step of the exposure assessment, it is essential to recognize the exposure assessment for what it is. The exposure assessment is a structured process for calculating potential exposures of hypothetical receptors according to specific exposure scenarios, specific fate and transport models and parameters, and specific intake models and parameters. The exposure assessment is not a reconstruction of exposures of individuals in the past. It provides a projection of potential exposures for current and future hypothetical receptors. The exposure assessment is the critical step in the risk assessment process,

leading to the determination of whether human health risks at a site are acceptable or unacceptable and whether remediation is necessary.

4.0

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4.0 TOXICITY ASSESSMENT

This toxicity assessment examines information concerning the potential effects of exposure to constituents of concern. The goal is to provide, for each constituent of potential concern, a quantitative estimate of the relationship between exposure and severity or probability of effect. The toxicity assessment in the PBRA contains a compilation of toxic and carcinogenic effects of constituents of potential concern followed by detailed evaluations of the major constituents of potential concern. The toxicity assessment for ecological effects is provided in Section 6.0, Ecological Assessment.

4.1 SUMMARY OF POTENTIAL HUMAN HEALTH EFFECTS FOR CONSTITUENTS OF POTENTIAL CONCERN

This section presents tabulated summary toxicity information for noncarcinogenic and carcinogenic effects, and briefly addresses those constituents for which EPA toxicity values have not been specified.

4.1.1 Noncarcinogens

Toxicity values for noncarcinogens are expressed as reference concentrations. A reference dose (RfD) is calculated from these reference concentrations. The RfD is the toxicity value used to quantitatively express the hazard of noncarcinogenic constituents. 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. The RfD is usually based on data from exposure of animals; therefore, an uncertainty factor is incorporated into the RfD to reduce the numerical value. The uncertainty factor is intended to account for uncertainties such as the extrapolation from animals to humans. Separate RfDs are presented for oral ingestion and inhalation pathways. Reference doses for noncarcinogenic constituents of concern are presented in Table 4-1. The primary source of values for reference doses is the Health Effects Assessment Summary Table (HEAST) information compiled by EPA (EPA 1992). Table 4-1 includes the uncertainty factors incorporated into RfDs.

4.1.2 Chemical Carcinogens

The cancer slope factor is the toxicity value used to quantitatively express the carcinogenic hazard of cancer causing constituents. The slope factor is expressed in units of $(mg/kg/day)^{-1}$ and represents the cancer risk per unit daily intake of carcinogenic chemical contaminant. Slope factors for chemical constituents are presented in Table 4-2. The primary source of these toxicity values is the HEAST information (EPA 1992).

TABLE 4-1

REFERENCE DOSES

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
INORGANICS							
Aluminum	ND	ND	ND	ND	ND	ND	a
Antimony	0.0004	ND	reduced lifespan, altered blood circulation	cancer	1000	ND	f
Arsenic	0.0003	ND	keratosis and hyperpigmentation	ND	1	ND	f
Barium	0.07	0.0001	increased blood pressure	fetotoxcity	100	1000	f
Beryllium	0.005	ND	None observed	ND	100	ND	f
Boron	0.09	ND	testicular lesions	NA	100	NA	
Cadmium (food)	0.001	ND	renal damage	cancer	10	ND	a
Cadmium (water)	0.0005	ND	renal damage	cancer	10	ND	a
Calcium	ND	ND	ND	ND	ND	ND	a
Chromium	0.005	0.00000057	Not defined	nasal mucosa atrophy	500	300	a
Cobalt	0.0026	0.00000791	cardiomyopathy	lung cancer	ND	ND	b,c,d
Copper	ND	ND	local GI irritation	ND	ND	ND	a

TABLE 4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
Cyanide	0.02	ND	weight loss, thyroid effects and myelin degeneration	ND	500	ND	a
Iron	ND	ND	ND	ND	ND	ND	a
Lead	0.00069	0.00065	CNS effects	CNS effects	ND	ND	e
Magnesium	ND	ND	ND	ND	ND	ND	a
Manganese	0.1	0.00011	No effect	respiratory symptoms; psychomotor disturbances	1	900	a
Mercury	0.0003	0.000086	kidney effects	neurotoxicity	1000	30	a
Molybdenum	0.005	ND	changes in biochemical indices	ND	1	ND	a
Nickel	0.02	ND	reduced body weight and organ weight	cancer	300	ND	a
Potassium	ND	ND	ND	ND	ND	ND	a
Selenium	0.005	ND	ND	ND	ND	ND	a
Silver	0.005	ND	argyria	ND	2	ND	a
Sodium	ND	ND	ND	ND	ND	ND	a
Thallium	0.00007	ND	increased SGOT and serum LDH levels, alopecia	ND	3000	ND	a
Vanadium	0.007	ND	None observed	ND	100	ND	a

TABLE 4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
Zinc	0.2	ND	anemia	ND	10	ND	a
VOLATILES							
1,1,1-Trichloroethane	0.09	0.3	hepatotoxicity	hepatotoxicity	1000	1000	a
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	a
1,1,2-Trichloro-1,2,2-trifluoroethane	3	7.7	decreased body weight	decreased body weight	100	100	a
1,1-Dichloroethane	0.1	0.1	none	kidney damage	1000	1000	a
1,1-Dichloroethene	0.009	ND	liver lesions	ND	1000	ND	a
1,2-c-Dichloroethene	0.01	ND	decreased hematocrit & hemaglobin	NA	3000	NA	a
1,2-t-Dichloroethene	0.02	ND	increased serum alkaline phosphatase	NA	1000	NA	
2-Butanone	0.05	0.09	fetotoxicity	CNS	1000	1000	a
2-Hexanone	ND	ND	ND	ND	ND	ND	
4-Methyl-2-pentanone	ND	ND	ND	ND	ND	ND	a
Acetone	0.1	ND	increased liver; kidney weight, nephrotoxicity	ND	1000	ND	f

TABLE 4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
Benzene	ND	ND	ND	ND	ND	ND	a
Bromodichloromethane	0.02	ND	renal cytomegaly	NA	1000	NA	
Carbon disulfide	0.1	0.0029	fetal toxicity, malformation	fetal toxicity	100	1000	a
Chlorobenzene	0.2	0.006	liver and kidney effects	liver and kidney effects	1000	10000	a
Chloroform	0.01	ND	liver lesions	ND	1000	ND	a
Ethylbenzene	0.01	1	hepatotoxicity and nephrototoxicity	developmental toxicity	1000	300	a
Methylene chloride	0.06	0.86	liver toxicity	ND	100	100	a
Tetrachloroethene	0.01	ND	hepatotoxicity	ND	1000	ND	a
Toluene	0.2	0.6	changes in liver and kidney weights	CNS effects, eyes and nose irritation	1000	100	a
Total Xylenes	2	0.09	hyperactivity, increased BW; increased mortality at higher dosage	CNS effects, nose and throat irritation	1000	100	a
Trichloroethene	ND	ND	ND	ND	ND	ND	a
Vinyl chloride	ND	ND	ND	ND	ND	ND	a

TABLE 4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
SEMI-VOLATILES							
2,4-Dimethylphenol	0.02	ND	neurological signs and hematological changes	ND	3000	3000	a
2-Chlorophenol	0.005	ND	reproductive effects	NA	1000	NA	
2-Methylnapthalene	ND	ND	ND	ND	ND	ND	a
2-Methylphenol	ND	ND	ND	ND	ND	ND	a
2-Propanol	ND	ND	ND	ND	ND	ND	a
4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	ND	
4-Methylphenol	ND	ND	ND	ND	ND	ND	a
Acenaphthene	0.06	ND	hepatotoxicity	ND	3000	ND	f
Anthracene	0.3	ND	no effects	ND	3000	ND	a
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND	a
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	a
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND	a
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND	a
Benzo(k)fluoranthene	ND	ND	ND	ND	ND	ND	a
Benzoic acid	4	ND	irritation, malaise	ND	1	1	a
Bis(2-ethylhexyl) phthalate	0.02	ND	increased relative liver weight	ND	1000	1000	a

TABLE 4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
Butyl benzyl phthalate	0.2	ND	effects on body weight gain, testes,liver,kidney	ND	1000	ND	a
Chrysene	ND	ND	ND	ND	ND	ND	a
Di-n-butyl phthalate	0.1	ND	mortality	ND	1000	ND	a
Di-n-octyl phthalate	0.02	ND	elevated liver and kidney weights	ND	1000	ND	a
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND	a
Dibenzofuran	0.01	ND	ND	ND	ND	ND	a
Ethyl parathion	ND	ND	ND	ND	ND	ND	a
Fluoranthene	0.04	ND	nephropathy, liver weight changes,hematological changes	ND	3000	ND	a
Fluorene	0.04	ND	hematological changes	ND	3000	ND	a
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND	a
N-nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	a
Napthalene	0.04	ND	dereased BW gain	ND	10000	ND	a
Pentachlorophenol	0.03	ND	liver and kidney pathology	ND	100	ND	a
Phenanthrene	ND	ND	ND	ND	ND	ND	a

TABLE 4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)	Effect of Concern		Uncertainty Factor		Reference
			Oral	Inhalation	Oral	Inhalation	
Phenol	0.6	ND	reduced fetal body weight	ND	100	ND	a
Pyrene	0.03	ND	renal effects	ND	3000	ND	a
Tetrachloroethane	ND	ND	ND	ND	ND	ND	a
PESTICIDES							
Aroclor-1242	ND	ND	ND	ND	ND	ND	f
Aroclor-1248	ND	ND	ND	ND	ND	ND	f
Aroclor-1254	ND	ND	ND	ND	ND	ND	f
Aroclor-1260	ND	ND	ND	ND	ND	ND	f
Chlordane	0.00006	ND	liver lesions	ND	1000	ND	a
1,4-Dioxane	ND	ND	ND	ND	ND	ND	
DDT	0.0005	ND	liver lesions	ND	100	ND	a
Methyl parathion	0.0025	ND	reduced hemoglobin,hematocrit and RCBs	ND	ND	ND	a
PCBs	0.000007	ND	ND	ND	ND	ND	a

List of references:
a - US EPA, Health Effects Summary Tables, Annual FY-1992
b - Schroeder,H.A.,Nason,A.P., and Tipton,I.H.(1967),"Essential trace elements in man: Cobalt," Journal of Chronic Diseases,20:869-890

TABLE 4-1
(Continued)

c - Goyer,R.A.(1986),Toxic effects of metals,"Chapter 19 in Casarett and Doull's Toxicology: The Basic Science of Poisons, Eds. Klaasen, C.D., Amdur, M.O.,and Doull,J., MacMillian Publishing Company, New York

d - US EPA, "Interim methods for development of inhalation reference doses," Office of Health and Environmental Assessment, EPA Publication No. EPA/600/8-88/066F, August 1989 (EPA 1989d).

e - Pocock,S.J., Shaper, A.G., Walker, M., Wale, C.J., Clayton, B.,Delves, T., Lacey, R.F., Packham, R.F., and Powell, P.(1983), Effect of tap water lead, waterhardness, alcohol, and cigarettes on blood lead concentrations," Journal of Epidemiology and Community Health, 37:1-7

f - IRIS

ND = no data available

TABLE 4-2

CANCER POTENCY FACTORS

Chemical	Oral Cancer Potency Factor [(mg/kg/day)-1]	Inhalation Cancer Potency Factor [(mg/kg/day)-1]	Tumor Site: Oral	Tumor Site: Inhalation	Cancer Classification	Reference
INORGANICS						
Aluminum	ND	ND	ND	ND	ND	a
Antimony	ND	ND	ND	ND	ND	f
Arsenic	ND	50	skin	respiratory tract	A	f
Barium	ND	ND	ND	ND	ND	f
Beryllium	4.3	8.4	total tumors	lung	B2	f
Boron	ND	ND	ND	ND	ND	
Cadmium (food)	ND	6.1	ND	respiratory tract	B1	a
Cadmium (water)	ND	6.1	ND	respiratory tract	B1	a
Calcium	ND	ND	ND	ND	ND	a
Chromium	ND	41	ND	lung	A	a
Cobalt	ND	ND	ND	ND	ND	b,c,d
Copper	ND	ND	ND	ND	D	a
Cyanide	ND	ND	ND	ND	ND	a
Iron	ND	ND	ND	ND	ND	a
Lead	ND	ND	ND	ND	B2	e
Magnesium	ND	ND	ND	ND	ND	a

TABLE 4-2
(Continued)

Chemical	Oral Cancer Potency Factor [(mg/kg/day)-1]	Inhalation Cancer Potency Factor [(mg/kg/day)-1]	Tumor Site: Oral	Tumor Site: Inhalation	Cancer Classification	Reference
Manganese	ND	ND	ND	ND	ND	a
Mercury	ND	ND	ND	ND	ND	a
Molybdenum	ND	ND	ND	ND	ND	a
Nickel	ND	0.84	ND	respiratory tract	A	a
Potassium	ND	ND	ND	ND	ND	a
Selenium	ND	ND	ND	ND	D	a
Silver	ND	ND	ND	ND	D	a
Sodium	ND	ND	ND	ND	ND	a
Thallium	ND	ND	ND	ND	ND	a
Vanadium	ND	ND	ND	ND	ND	a
Zinc	ND	ND	ND	ND	ND	a
VOLATILES						
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	a
1,1,2,2-Tetrachloroethane	0.2	0.2	liver	liver	C	a
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	ND	ND	ND	ND	a
1,1-Dichloroethane	ND	ND	hemangio sarcoma	ND	C	a
1,1-Dichloroethene	0.6	1.2	adrenal	kidney	C	a
1,2-c-Dichloroethene	ND	ND	ND	ND	ND	a

TABLE 4-2
(Continued)

Chemical	Oral Cancer Potency Factor [(mg/kg/day)-1]	Inhalation Cancer Potency Factor [(mg/kg/day)-1]	Tumor Site		Cancer Classification	Reference
			Oral	Inhalation		
1,2-t-Dichloroethene	ND	ND	ND	ND	ND	
2-Butanone	ND	ND	ND	ND	D	a
2-Hexanone	ND	ND	ND	ND	ND	
4-Methyl-2-pentanone	ND	ND	ND	ND	ND	a
Acetone	ND	ND	ND	ND	D	f
Benzene	0.029	0.029	leukemia	leukemia	B2	a
Bromodichloromethane	0.13	ND	liver	NA	B2	
Carbon disulfide	ND	ND	ND	ND	ND	a
Chlorobenzene	ND	ND	ND	ND	D	a
Chloroform	0.0061	0.081	kidney	liver	B2	a
Ethylbenzene	ND	ND	ND	ND	D	a
Methylene chloride	0.0075	0.000000000134	liver	lung, liver	B2	a
Tetrachloroethene	0.0512	0.000000000149	ND	ND	B2	a
Toluene	ND	ND	ND	ND		a
Total Xylenes	ND	ND	ND	ND	ND	a
Trichloroethene	0.011	0.017	ND	ND	B2	a
Vinyl chloride	1.9	0.3	lung	liver	A	a
SEMI-VOLATILES						
2,4-Dimethylphenol	ND	ND	ND	ND	ND	a

TABLE 4-2
(Continued)

Chemical	Oral Cancer Potency Factor [(mg/kg/day)-1]	Inhalation Cancer Potency Factor [(mg/kg/day)-1]	Tumor Site: Oral	Tumor Site: Inhalation	Cancer Classification	Reference
2-Chlorophenol	ND	ND	ND	ND	ND	
2-Methylnapthalene	ND	ND	ND	ND	ND	a
2-Methylphenol	ND	ND	ND	ND	ND	a
2-Propanol	ND	ND	ND	ND	ND	a
4-Chloro-3-methylphenol	ND	ND	ND	ND	ND	
4-Methylphenol	ND	ND	ND	ND	ND	a
Acenaphthene	ND	ND	ND	ND	ND	f
Anthracene	ND	ND	ND	ND	D	a
Benzo(a)anthracene	ND	ND	ND	ND	B2	a
Benzo(a)pyrene	5.8	6.1	stomach	respiratory tract	B2	a
Benzo(b)fluoranthene	ND	ND	ND	ND	B2	a
Benzo(g,h,i)perylene	ND	ND	ND	ND	D	a
Benzo(k)fluoranthene	ND	ND	ND	ND	B2	a
Benzoic acid	ND	ND			D	a
Bis(2-ethylhexyl) phthalate	0.014	ND	liver	ND	B2	a
Butyl benzyl phthalate	ND	ND	ND	ND	C	a
Chrysene	ND	ND	ND	ND	B2	a
Cyanide	ND	ND	ND	ND	ND	a
Di-n-butyl phthalate	ND	ND	ND	ND	D	a

TABLE 4-2
(Continued)

Chemical	Oral Cancer Potency Factor [(mg/kg/day)-1]	Inhalation Cancer Potency Factor [(mg/kg/day)-1]	Tumor Site		Cancer Classification	Reference
			Oral	Inhalation		
Di-n-octyl phthalate	ND	ND	ND	ND	ND	a
Dibenzo(a,h)anthracene	ND	ND	ND	ND	B2	a
Dibenzofuran	ND	ND	ND	ND	D	a
Ethyl parathion	ND	ND	ND	ND	ND	a
Fluoranthene	ND	ND	ND	ND	D	a
Fluorene	ND	ND	ND	ND	ND	a
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	B2	a
N-nitrosodiphenylamine	0.0049	ND	urinary bladder	ND	B2	a
Napthalene	ND	ND	ND	ND	D	a
Pentachlorophenol	0.12	ND	liver,adrenal, circulatory system		B2	a
Phenanthrene	ND	ND	ND	ND	D	a
Phenol	ND	ND	ND	ND	ND	a
Pyrene	ND	ND	ND	ND	ND	a
Tetrachloroethane	ND	ND	ND	ND	ND	a
PESTICIDES						
Aroclor-1242	ND	7.7	ND	ND	ND	f
Aroclor-1248	ND	7.7	ND	ND	ND	f

TABLE 4-2
(Continued)

Chemical	Oral Cancer Potency Factor [(mg/kg/day)-1]	Inhalation Cancer Potency Factor [(mg/kg/day)-1]	Tumor Site: Oral	Tumor Site: Inhalation	Cancer Classification	Reference
Aroclor-1254	ND	7.7	ND	ND	ND	f
Aroclor-1260	ND	7.7	ND	ND	ND	f
Chlordane	1.3	1.3	liver	liver	B2	a
1,4-Dioxane	0.011	ND	ND	ND	ND	
DDT	0.34	0.34	liver	liver	B2	a
Methyl parathion	ND	ND	ND	ND	ND	a
PCBs	7.7	ND	ND	ND	B2	a

List of references:

a - US EPA, Health Effects Summary Tables, Annual FY-1992

b - Schroeder,H.A.,Nason,A.P., and Tipton,I.H.(1967),"Essential trace elements in man: Cobalt," Journal of Chronic Diseases,20:869-890.

c - Goyer,R.A.(1986),Toxic effects of metals,"Chapter 19 in Casarett and Doull's Toxicology: The Basic Science of Poisons, Eds. Klaasen, C.D., Amdur, M.O.,and Doull,J., MacMillian Publishing Company, New York

d - US EPA, "Interim methods for development of inhalation reference doses," Office of Health and Environmental Assessment, EPA Publication No. EPA/600/8-88/066F, August 1989.

e - Pocock,S.J., Shaper, A.G., Walker, M., Wale, C.J., Clayton, B.,Delves, T., Lacey, R.F., Packham, R.F., and Powell, P.(1983), Effect of tap water lead, waterhardness, alcohol, and cigarettes on blood lead concentrations," Journal of Epidemiology and Community Health, 37:1-7.

f - IRIS

ND = no data available

4.1.3 Radiocarcinogens

Slope factors for radionuclide constituents are presented in Table 4-3. The radionuclide slope factor is expressed in units of $(pCi)^{-1}$ and represents the risk of cancer incidence per unit radioactivity intake of a radionuclide contaminant. The EPA HEAST is the source of slope factors for radionuclides (EPA 1992).

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 HEAST (Table C) and are subject to revision. A radionuclide slope factor is the "maximum likelihood estimate of the age-averaged lifetime total excess cancer risk per unit intake or exposure" (EPA 1991b).

To determine the slope factor for a radionuclide, EPA has calculated the annual radiation dose equivalent to each organ in each year of life, per unit intake or external exposure, over a lifetime. 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. A more detailed description of the methodology for determining slope factors is presented in Figure 4-1. 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. The relationship between cancer mortality and cancer incidence is illustrated in Figure 4-1. A mortality-to-incidence ratio is not incorporated into the cancer potency factors derived by EPA for non-radionuclide carcinogens; therefore, the basis for the cancer risk estimates for radionuclide and chemical carcinogens is not the same.

The EPA cancer slope factors for radionuclides are based on calculated radiation dose equivalents and subsequent expression as risks using a dose-based risk factor (these risk factors are specific to types of radiation emitted rather than to radionuclides). The dose equivalent calculation (the portion of the slope factor development methodology that involves less uncertainty) and the risk calculation (the portion of the slope factor development methodology that involves more uncertainty) are combined such that the lifetime radiation dose equivalent is not calculated separately. Thus, the use of the slope factor method to assess cancer risks for radionuclides yields only one answer, which incorporates the uncertainties of both the dose equivalent and cancer risk calculations.

TABLE 4-3
CANCER SLOPE FACTORS FOR RADIONUCLIDES

Radionuclide	ICRP Lung Class[a]	Inhalation $(pCi)^{-1}$	GI Absorption Factor (f_1)	Ingestion $(pCi)^{-1}$	Ground Surface (Risk/yr per pCi/g soil)
U-234	Y	2.6×10^{-08}	5.0×10^{-02}	1.6×10^{-11}	3.0×10^{-11}
U-235	Y	2.5×10^{-08}	5.0×10^{-02}	1.6×10^{-11}	2.4×10^{-07}
U-235 + D	Y	2.5×10^{-08}	5.0×10^{-02}	1.6×10^{-11}	2.4×10^{-07}
U-238	Y	2.4×10^{-08}	5.0×10^{-02}	1.6×10^{-11}	2.1×10^{-11}
U-238 + D	Y	5.2×10^{-08}	5.0×10^{-02}	2.8×10^{-11}	3.6×10^{-08}
Th-227	Y	4.9×10^{-09}	2.0×10^{-04}	4.5×10^{-12}	1.6×10^{-07}
Th-228	Y	7.7×10^{-08}	2.0×10^{-04}	1.1×10^{-11}	5.5×10^{-10}
Th-228 + D	Y	7.8×10^{-08}	2.0×10^{-04}	5.5×10^{-11}	5.6×10^{-06}
Th-230	Y	2.9×10^{-08}	2.0×10^{-04}	1.3×10^{-11}	5.4×10^{-11}
Th-231	Y	4.9×10^{-13}	2.0×10^{-04}	4.0×10^{-13}	2.3×10^{-09}
Th-232	Y	2.8×10^{-08}	2.0×10^{-04}	1.2×10^{-11}	2.6×10^{-11}
Th-234	Y	3.2×10^{-11}	2.0×10^{-04}	4.0×10^{-12}	3.5×10^{-09}
Ra-223	W	3.1×10^{-09}	2.0×10^{-01}	6.4×10^{-11}	2.3×10^{-07}
Ra-224	W	1.2×10^{-09}	2.0×10^{-01}	3.8×10^{-11}	2.3×10^{-08}
Ra-226	W	3.0×10^{-09}	2.0×10^{-01}	1.2×10^{-10}	1.2×10^{-08}
Ra-226 + D	W	3.0×10^{-09}	2.0×10^{-01}	1.2×10^{-10}	6.0×10^{-06}
Ra-228	W	6.6×10^{-10}	2.0×10^{-01}	1.0×10^{-10}	$0.0 \times 10^{+00}$
Ra-228 + D	W	6.9×10^{-10}	2.0×10^{-01}	1.0×10^{-10}	2.9×10^{-06}
Pa-231	Y	3.6×10^{-08}	1.0×10^{-03}	9.2×10^{-11}	2.6×10^{-08}
Pa-233	Y	8.6×10^{-12}	1.0×10^{-03}	1.0×10^{-12}	4.2×10^{-07}
Pa-234m	Y	1.6×10^{-15}	1.0×10^{-03}	5.8×10^{-15}	3.6×10^{-08}
Rn-219 (only)	•	4.6×10^{-14}	$1.0 \times 10^{+00}$	---------[b]	1.6×10^{-07}
Rn-220 (only)	•	1.2×10^{-13}	$1.0 \times 10^{+00}$	---------	1.7×10^{-09}
Rn-222 (only)	•	7.3×10^{-13}	$1.0 \times 10^{+00}$	1.4×10^{-12}	1.2×10^{-09}
Rn-222 + D	•	7.7×10^{-12}	$1.0 \times 10^{+00}$	1.7×10^{-12}	5.9×10^{-06}
Ac-227	Y	8.0×10^{-08}	1.0×10^{-03}	2.8×10^{-10}	2.6×10^{-11}
Ac-227 + D	Y	8.8×10^{-08}	1.0×10^{-03}	3.5×10^{-10}	8.5×10^{-07}
Ac-228	Y	2.6×10^{-11}	1.0×10^{-03}	5.0×10^{-13}	2.9×10^{-06}
Po-210	W	2.6×10^{-09}	1.0×10^{-01}	1.5×10^{-10}	2.9×10^{-11}

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TABLE 4-3
(Continued)

Radionuclide	ICRP Lung Class[a]	Inhalation $(pCi)^{-1}$	GI Absorption Factor (f_1)	Ingestion $(pCi)^{-1}$	Ground Surface (Risk/yr per pCi/g soil)
Po-212	W	6.1×10^{-22}	1.0×10^{-01}	2.2×10^{-23}	$0.0 \times 10^{+00}$
Po-214	W	2.8×10^{-19}	1.0×10^{-01}	1.0×10^{-20}	2.8×10^{-10}
Po-215	W	5.7×10^{-18}	1.0×10^{-01}	2.8×10^{-19}	4.6×10^{-10}
Po-216	W	4.8×10^{-16}	1.0×10^{-01}	3.0×10^{-17}	5.0×10^{-11}
Po-218	W	5.8×10^{-13}	1.0×10^{-01}	2.8×10^{-14}	$0.0 \times 10^{+00}$
Bi-210	W	8.0×10^{-11}	5.0×10^{-02}	1.6×10^{-12}	$0.0 \times 10^{+00}$
Bi-211	W	1.9×10^{-13}	5.0×10^{-02}	1.2×10^{-14}	1.3×10^{-07}
Bi-212	W	6.6×10^{-12}	5.0×10^{-02}	3.1×10^{-13}	5.9×10^{-07}
Bi-214	W	2.1×10^{-12}	5.0×10^{-02}	1.3×10^{-13}	5.3×10^{-06}
Pb-210	D	1.3×10^{-09}	2.0×10^{-01}	5.1×10^{-10}	1.3×10^{-10}
Pb-210 + D	D	4.0×10^{-09}	2.0×10^{-01}	6.6×10^{-10}	1.6×10^{-10}
Pb-211	D	2.8×10^{-12}	2.0×10^{-01}	1.8×10^{-13}	1.6×10^{-07}
Pb-212	D	4.3×10^{-11}	2.0×10^{-01}	5.5×10^{-12}	2.8×10^{-07}
Pb-214	D	2.9×10^{-12}	2.0×10^{-01}	1.7×10^{-13}	6.4×10^{-07}
Tl-207	D	4.5×10^{-15}	$1.0 \times 10^{+00}$	1.3×10^{-14}	7.5×10^{-09}
Tl-208	D	5.0×10^{-15}	$1.0 \times 10^{+00}$	1.8×10^{-14}	1.3×10^{-05}
Sr-90	D	5.6×10^{-11}	3.0×10^{-01}	3.3×10^{-11}	$0.0 \times 10^{+00}$
Sr-90 + D	D	6.2×10^{-11}	3.0×10^{-01}	3.6×10^{-11}	$0.0 \times 10^{+00}$
Y-90	Y	5.5×10^{-12}	1.0×10^{-04}	3.2×10^{-12}	$0.0 \times 10^{+00}$
Tc-99	W	8.3×10^{-12}	8.0×10^{-01}	1.3×10^{-12}	6.0×10^{-13}
Cs-137	D	1.9×10^{-11}	$1.0 \times 10^{+00}$	2.8×10^{-11}	$0.0 \times 10^{+00}$
Cs-137 + D	D	1.9×10^{-11}	$1.0 \times 10^{+00}$	2.8×10^{-11}	2.0×10^{-06}
Ba-137m	D	6.0×10^{-16}	1.0×10^{-01}	2.4×10^{-15}	2.0×10^{-06}
Np-237	W	2.9×10^{-08}	1.0×10^{-03}	2.2×10^{-10}	7.8×10^{-09}
Np-237 + D	W	2.9×10^{-08}	1.0×10^{-03}	2.2×10^{-10}	4.3×10^{-07}
Pu-238	Y	3.9×10^{-08}	1.0×10^{-03}	2.2×10^{-10}	2.8×10^{-11}
Pu-239	Y	3.8×10^{-08}	1.0×10^{-03}	2.3×10^{-10}	1.7×10^{-11}
Pu-240	Y	3.8×10^{-08}	1.0×10^{-03}	2.3×10^{-10}	2.7×10^{-11}

[a] Classification recommended by the ICRP for half-time for clearance from the lung. "Y" = years, "W" = weeks, "D" = days. "*" = gas

[b] No data available

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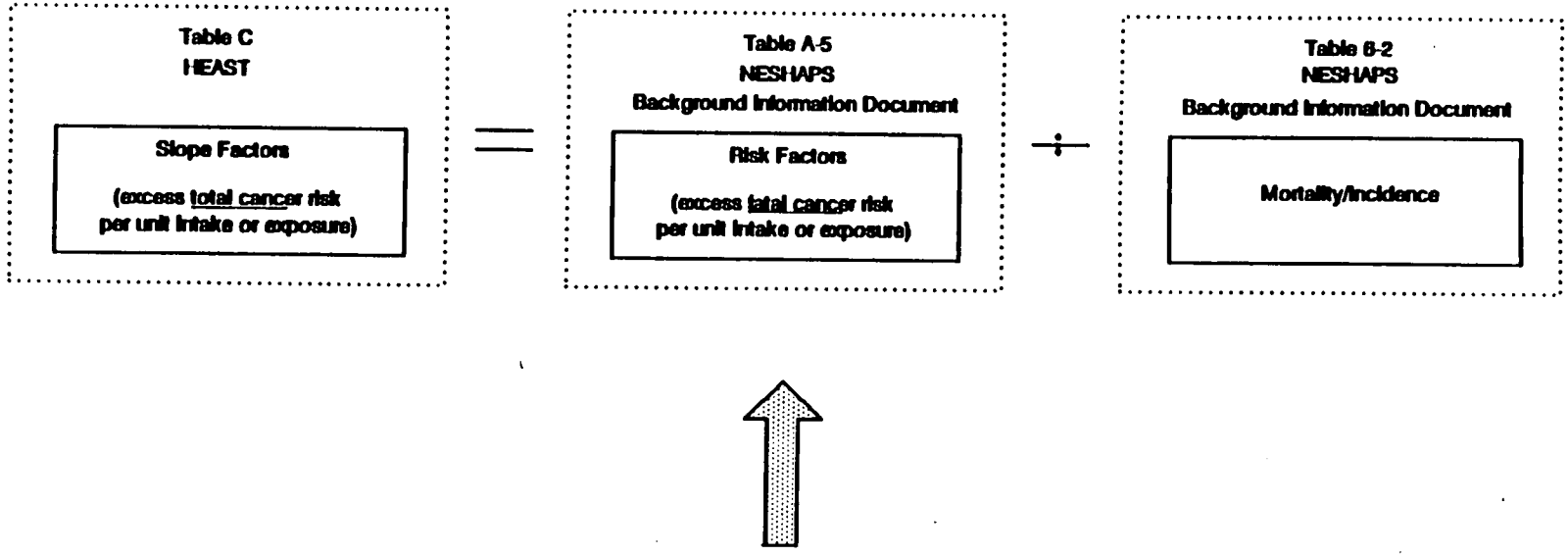

METHODOLOGY: To calculate the Risk Factors, EPA uses the computer code "RADRISK" which calculates the radiation dose and risk resulting from a unit intake of a given radionuclide The RADRISK code represents a synthesis and adaptation of two computer codes, INREM II and CAIRD.

INREM II – Calculates instantaneous dose rates and annual doses for each organ following unit intake or exposure. Developed at Oak Ridge National Laboratory.

RADRISK

CAIRD – Calculates risk using the annual doses calculated by INREM II to estimate the number of incremental fatalities in a cohort due to radiation induced cancer in the reference organ. This hypothetical cohort consists of 100,000 persons, born at the same time and and all subject to the same competing risks of death throughout their lifetime. The probability of dying at a particular age from a competing cause is calculated from the mortality rate for all causes for that age by applying the 1970 mortality data from the National Center for Health Statistics. (NCHS, 1975). Developed by EPA.

FIGURE 4-1. GENERAL METHODOLOGY FOR EPA SLOPE FACTOR DETERMINATION

4.1.4 Chemicals for which No EPA Toxicity Values Are Available

If it is found that an RfD or cancer slope factor is not available for a constituent and toxicity data from the peer reviewed literature must be used, estimated values will be developed with the assistance of EPA toxicologists from the EPA Environmental Criteria Assessment Office (ECAO).

4.2 DETAILED EVALUATIONS OF MAJOR CONSTITUENTS OF POTENTIAL CONCERN

This subsection presents more detailed toxicity information for individual constituents of potential concern. Detailed evaluations are presented for those constituents that are most prevalent in environmental media, that pose the highest risks if released into the environment, or that are of particular interest with respect to individual source terms at the site. Detailed evaluations are presented for the toxicological effects of uranium and the radiocarcinogenic effects of uranium, thorium, radium, and radon and radon progeny. These are the primary constituents of concern in existing environmental contamination at the FEMP site.

4.2.1 Uranium

4.2.1.1 Pharmacokinetics

In general, uranium compounds are not easily absorbed across the human gastrointestinal (GI) tract. Soluble uranium compounds demonstrate the best absorption, but in a study in which patients drank a solution of uranyl nitrate hexahydrate, a water soluble compound, only 0.5 to 5 percent of the dose was found to be absorbed (Hursh et al. 1969). Most recently, uranium metabolic models have estimated absorption from the GI tract to the blood to be 0.6 percent (Wrenn et al. 1987). Although human data concerning absorption by dermal exposure are sparse, water-insoluble uranium compounds are not absorbed in significant quantities across the skin and are not believed to pose a risk to humans by this exposure route (Yuile 1973).

Once absorbed into the bloodstream, uranium compounds are metabolically converted to uranyl ions. The uranyl ion acts as a ligand in the systemic circulation, binding to the plasma proteins and bicarbonate. Although this uranyl-bicarbonate complex is stable at the pH of the plasma, the pH of urine favors dissociation of the complex. This leaves the uranyl ion free to bind to the tissues in the proximal tubule wall of the nephrons of the kidney, resulting in cellular necrosis (Leggett 1989).

In addition to being the only soft tissue that stores uranium in any appreciable quantity, the kidney is the main organ of excretion (Hursh and Spoor 1973). Approximately 70 percent of an intake of uranium has been estimated to be excreted by the kidney within 24 hours of intake (Berlin and Rudell 1979). Uranium that is not excreted is stored in both the kidney and the

bone. Binding to the bone is thought to be caused by the affinity of uranium for the phosphate groups in the bone structure.

4.2.1.2 Chemical Toxicity

Dose Response Data - Human

Uranium is known to be a chemical toxicant, exposure to which leads to nephritis in the kidney. Human data on exposure to uranium compounds were collected from 1940 to 1960 from acute studies on terminal and volunteer patients. Single injections of 70 to 100 µg/kg of uranium nitrate to terminally ill patients resulted in proteinuria and increased levels of catalase in the urine (Berlin and Rudell 1979; Luessenhop et al. 1958). In another study, patients were given uranyl nitrate injections ranging from 6.3 to 71 µg/kg. One of the early signs of renal damage, the appearance of the enzyme catalase in the urine, occurred in patients receiving 55 to 71 µg/kg (Hursh and Spoor 1973; Leggett 1989).

Dose Response Data - Animal

Laboratory animals demonstrate a great deal of variation in their responses to acute intravenous toxicity studies, with rabbits and guinea pigs appearing to be the most sensitive. The acute intravenous toxicity of soluble uranium compounds like uranyl nitrate is very high; the approximate dose at which 50 percent of the test organisms did not survive (LD_{50}) for rabbits is 0.1 mg/kg, for guinea pigs 0.3 mg/kg, for rats 1 mg/kg, and for mice 10 to 20 mg/kg (Stokinger 1982).

In chronic animal experiments, sublethal threshold doses of uranium have been demonstrated (Leggett 1989). Although the exact mechanism of tolerance is not known, it is believed that regenerated kidney tissue is associated with tolerance. When uranium exposure ceases, the regenerated epithelium will be transformed into normal renal tubular tissue (Yuile 1973).

An extensive chronic feeding study was performed on rabbits, rats, and dogs for periods of 30 days, 1 year, and 2 years (Maynard and Hodge 1949). These animals received uranium doses of 2.8, 14, and 71 mg/kg/day in the diet. Rabbits were maintained for 30 days, dogs for 1 year, and rats for 1 to 2 years. For all species, water soluble compounds were more toxic than insoluble compounds. Lowest observed adverse effect levels (LOAELs) were established for all compounds and each species (Maynard and Hodge 1949). In all cases, the LOAEL could be established within the first 30 days (EPA 1991b). Of the three species, rabbits appeared to be the most sensitive with renal damage exhibited at all administered dose levels. The renal damage was judged to be only moderate at the lower doses, but moderately severe at the highest dose. Based on this, the lowest uranium dose of 2.8 mg/kg/day was established as the LOAEL by EPA (EPA 1991c).

Basis for Reference Dose

The EPA (EPA 1991c) has established an RfD for uranium of 3 μg/kg/day. In lieu of a no observed adverse effect level (NOAEL), the RfD is based on the LOAEL of 2.8 mg/kg/day (Maynard and Hodge 1949) and an uncertainty factor of 1000. The uncertainty factor accounts for intraspecies and interspecies variability in toxicological response and for the use of the LOAEL rather than an NOAEL. No factor was included to account for the short duration of the exposure (30 days) because it has been shown that chronic nephrotoxic effects can be adequately characterized with experiments of acute/subacute duration (EPA 1991c).

4.2.1.3 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.

Dose Response Data - Human

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 (1.5×10^{-6}) (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 5.9×10^{-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.

Dose Response Data - Animal

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.

4.2.2 Radon and Progeny

4.2.2.1 Chemical 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) daughters. Because lead is a chemical toxicant, significant accumulations of lead would pose a potential source of lead for exposure pathways to receptors.

4.2.2.2 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. Radon-222 (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 (NCRP 1984). 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 350 x 10^{-6} 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}). As discussed in Section 4.1.3, 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 360 x 10^{-6} per WLM for use in the National Emission Standards for Hazardous Air Pollutants (NESHAPS) (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 ICRP models to calculate the estimate of 360 x 10^{-6} 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 350 x 10^{-6} 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 1.2 x 10^{-11} per pCi. The EPA cancer slope factor from the HEAST publication for inhalation of Rn-222 plus progeny is 7.7 x 10^{-12} per pCi

(EPA 1992). 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.

4.2.3 Thorium

4.2.3.1 Chemical 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.

4.2.3.2 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 historically been used 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. 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).

Thorotrast has been used extensively in the United States, 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.

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) 5159 patients and 5151 controls were followed since 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; da Motta et al. 1979; Horta et al. 1978) involves about 2500 patients and 2000 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 1974. 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 300×10^{-6} 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 60 x 10^{-6} per rad of alpha radiation to bone marrow for leukemia, and a value of up to 120 x 10^{-6} 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 have been injected with Th-230 enriched Thorotrast revealing a shortened latency period (Faber 1973) associated with the higher specific activity solution. The metabolic distribution of Thorotrast and other colloid solutions have 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 Thorortrast (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 1986). The frequency of cancer induction was dose rate dependent and the Zirconotrast without Th-228 did not induce excess cancers (Wesch 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).

4.2.4 Radium

4.2.4.1 Chemical 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.

4.2.4.2 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 (1600 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 (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 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 reveals bone cancer incidence associated with the high absorbed doses from the therapeutic treatments (Spiess 1969; Spiess and Mays 1970, 1973). In the second, a cohort of about 1400 patients treated with small doses of Ra-224 for ankylosing spondylitis shows a similar association between dose and cancer induction (Spiess 1969; Spiess and Mays 1970, 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 above, 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 200×10^{-6} per rad for bone sarcomas from protracted exposure to radium in its report on radon and other alpha emitters (NAS 1988).

4.3 IDENTIFICATION OF UNCERTAINTIES RELATED TO THE TOXICITY ASSESSMENT

Uncertainties related to toxicity assessment are inherent to modeling dose-response relationships for exposure to constituents and to calculation of numerical estimators used to calculate health effects with a margin of safety. Examples of inherent uncertainties in numerical estimators include factors incorporated into RfD values and cancer slope factors in order to provide a margin of safety for use in human health assessments. The magnitude of these uncertainties is known. Examples of uncertainties inherent to modeling of dose-response relationships upon which RfD values and cancer slope factors are based include:

- Extrapolation of findings in animal experiments to humans
- Extrapolation of findings at high exposure levels to low exposure levels

- Extrapolation of findings from acute exposures to chronic exposures and/or occupational conditions to nonoccupational or environmental conditions

The magnitude of these uncertainties is not well known and estimates from different studies vary. Estimates also vary because information concerning some constituents and their associated health effects is comparatively scarce, while for others there is much more information available from health effects studies.

Uranium has been established as a chemical toxicant based on human and animal studies. The RfD for uranium is based on results of animal studies and is calculated incorporating an uncertainty factor of 1000 to provide a margin of safety for extrapolation to humans. Uranium as an alpha particle emitter is also considered a carcinogen; however, epidemiological evidence of uranium-induced excess cancer effects are very difficult to obtain. This is largely because the human data available for radiocarcinogenic effects of uranium exposure are from underground miners, who are also simultaneously exposed to radon and radon progeny as a confounding factor. The studies of humans sometimes lack information concerning uranium exposure, potential uranium exposure through previous employment, concurrent smoking patterns, or concurrent radon exposure levels that 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 (if any) above the natural risk. These facts weaken the power of the human studies to detect any excess risk. These uncertainties are not easily or well known.

Although many factors affect the incidence of lung cancer among miners exposed to radon progeny, the BEIR IV Committee concentrated its efforts on investigating the following factors: (1) cumulative exposure; (2) duration of exposure; (3) the age at which risk is being estimated; (4) the age at first exposure; (5) the duration since exposure ended; and (6) the duration since each exposure period. Sources of uncertainty in the BEIR IV model include:

- Gender - The epidemiological data address male cohorts; epidemiological data on females are not available. The BEIR IV Committee assumed that the relative risk (risk relative to baseline risk) is the same for females as for males.

- Age at Exposure - Exposure at an early age could result in a greater risk than exposure beginning at later ages. The committee did not find many data on young miners; therefore, it is assumed that age at exposure does not affect the risk.

- Cigarette Smoking - The miner data provide little information on patterns of tobacco use among the cohorts; therefore, a precise description of the interaction between smoking and radon progeny exposure is not possible. The committee selected a multiplicative model to describe interaction, based on their review of the data.

- Temporal Expression of Risk - The data available primarily address a limited period of observation rather than a lifetime period; therefore, follow-up periods are shorter than desirable. This means that risks are projected through time using models, which require assumptions about the variations in lung cancer risk expression as a function of time.

- Extrapolating from Occupational Exposure of Miners to Exposure of Public in Indoor and Outdoor Environments - Several factors vary between exposures in the mines and exposures in homes: breathing patterns, ventilation patterns, the fraction of unattached progeny in inhaled air, particle size distribution in inhaled air, and the degree of equilibrium between radon and progeny.

An understanding of the dosimetry of alpha particles from radon progeny damaging the cells of the bronchial epithelium is necessary when extrapolating risk estimates based on occupational exposures in underground mines to exposures in homes and other environments. This is because of differences in the circumstances of exposure. Factors that influence the dose to the bronchial epithelium from radon progeny include the quality of the air inhaled (levels of particulates, particle size distribution), breathing patterns, and morphological characteristics of the lung passageways (sizes and branching patterns of airways). In a mine, the exposure concentrations and levels of airborne particulates to which radon progeny can attach are likely to be considerably higher than in other environments. Miners are also likely to exhibit higher breathing rates than persons in the home and other environments.

The BEIR IV Committee cautions that users of the model should be aware of uncertainties, including sampling variation in the primary data, random and possibly systematic errors in the original data on exposure and lung cancer occurrence, potentially inappropriate statistical models used for data analysis or misspecification of the components of the statistical models, and incorrect description of the interaction between radon progeny exposure and cigarette smoking.

Thorotrast studies represent the largest compilation of information that is available. The BEIR IV Committee has emphasized that because of the different characteristics and properties of Thorotrast solutions used historically for medical diagnostic purposes, and thorium in forms in which it is likely to be taken into the body during exposure scenarios, the risk estimates presented in their report strictly speaking apply to Thorotrast exposure, not thorium exposure. Nevertheless, the conclusions presented in the report support the contention that Thorotrast induces cancer 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).

4.4 SUMMARY OF TOXICITY ASSESSMENT

The toxicity assessment presents a review of health effects studies for principal constituents of concern at the FEMP site. These are the primary constituents of concern in existing environmental contamination at the FEMP site. The assessment details the studies of the toxic effects of uranium and the radiocarcinogenic effects of radioisotopes of uranium, thorium, radium, and radon and radon progeny.

Uranium is known to be a chemical toxicant, exposure to which leads to nephritis of the kidney, which is considered a more limiting effect than the carcinogenicity of uranium. The BEIR IV Committee recommends that uranium exposure be controlled on the basis of nephrotoxicity rather than radiocarcinogenicity from alpha particle emissions (NAS 1988). The most probable radiocarcinogenic effect of uranium is expressed as excess bone cancers. The likelihood of induction of excess bone cancers from exposure to naturally occurring uranium is considered low and only demonstrable if a linear dose-response relationship is assumed (Mays et al. 1985). The radiocarcinogenic effect of radon and radon progeny is the induction of excess lung cancers. The BEIR IV Committee estimates the lifetime risk of fatal lung cancer due to lifetime exposure (NAS 1988) while the EPA estimates the age-averaged lifetime total excess cancer risk (cancers induced) (EPA 1991b). The radiocarcinogenic effect of radium exposure is induction of excess bone cancers as a result of the long-term deposition of radium on endosteal bone surfaces (NAS 1988). The paranasal sinuses and the mastoid air cells of the head region are an additional site of excess cancer induction resulting from intake of radium. This effect is attributed to the alpha radiation dose delivered by Rn-222 and progeny following migration to those sites from the sites of radium deposition in the bone tissue. The radiocarcinogenic effect of thorium is induction of excess cancer of the liver and leukemia (NAS 1988).

As discussed in Section 4.1, the toxicity and carcinogenicity values used to estimate toxic and carcinogenic health effects are obtained from the HEAST and the Integrated Risk Information System (IRIS) databases compiled by EPA (EPA 1992, 1991c). These values are presented in Tables 4-1, 4-2, and 4-3.

5.0

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5.0 RISK CHARACTERIZATION

This section describes the final step of the baseline risk assessment process. Section 5.1 describes the methodology used to quantitatively characterize health risks involving exposure to contamination in or from source areas at the FEMP. This methodology is consistent with the methodology presented in the Addendum (DOE 1992a) and EPA guidance for conducting baseline risk assessments for Superfund sites (EPA 1989b). Calculated risks for current land-use conditions with and without access controls are presented in Section 5.2. Calculated risks for potential future land-use conditions are presented in Section 5.3. Uncertainties associated with the risk characterization are discussed in Section 5.4. A brief summary of the risk assessment results is given in Section 5.5.

5.1 METHODOLOGY

There are two steps to characterize the risk posed by a constituent of concern through a given exposure pathway. The first step is to estimate the intake of the constituent via the given exposure pathway. Intake quantities are calculated for specific exposure pathways according to the models given in the Addendum (DOE 1992a). The generic equation for calculating the intake of a constituent for an exposure pathway is:

(radionuclides) $$I = (C)(CR)(EF)(ED) \quad (5\text{-}1)$$

(chemicals) $$I = (C)(CR)(EF)(ED)/(BW)(AT) \quad (5\text{-}2)$$

where

I	=	Intake quantity of specific chemical or radionuclide
C	=	Exposure point concentration of the constituent (determined by measurement or modeling)
CR	=	Contact rate or rate of intake
EF	=	Exposure frequency
ED	=	Exposure duration
BW	=	Body weight
AT	=	Averaging time

The cancer risk is calculated by multiplying the intake by the lifetime risk of cancer incidence per unit intake, or slope factor (SF), described in Section 4.0. This calculation formula is given by:

$$\text{Risk} = (I)(SF) \quad (5\text{-}3)$$

Therefore, it is common practice to calculate the intake of each constituent via a specific exposure pathway and exposure point concentration, and multiply the intake by the slope factor.

This method of calculating risks does not easily allow for calculating risks from different exposure point concentrations without first calculating the intake.

To derive a more useful calculation relationship, Equations 5-1 and 5-2 are combined with Equation 5-3 to have:

(radionuclides) $$\text{Risk} = (C)(CR)(EF)(ED)(SF) \quad (5\text{-}4)$$

(chemicals) $$\text{Risk} = [(C)(CR)(EF)(ED)/(BW)(AT)](SF) \quad (5\text{-}5)$$

Equations 5-4 and 5-5 show that the risk for a specific constituent and a specific exposure pathway is proportional to the concentration of the constituent in the exposure medium. The proportionality constant for this relationship is the risk per unit concentration, and is referred to as the "unit risk factor" or URF. The analogous term for non-carcinogens is the "unit toxicity factor" or UTF. These factors are generically represented as:

(radionuclides) $$\text{URF} = (CR)(EF)(ED)(SF) \quad (5\text{-}6)$$

(chemicals) $$\text{UTF} = [(CR)(EF)(ED)/(BW)(AT)](SF) \quad (5\text{-}7)$$

URF and UTF for the constituents of concern and exposure pathways at the FEMP are listed in Appendix S. These factors are constituent-, pathway-, scenario-, and medium-specific. Use of the URF allows for rapid calculation of risks via a specific exposure pathway once the measured or modeled concentration of the constituent in the exposure medium is determined. The risk associated with a particular exposure pathway, or combination of pathways in an exposure scenario, for a carcinogenic constituent of concern in a given medium is calculated by multiplying the measured or modeled constituent concentration by the appropriate URF.

The total cancer risk associated with a specific exposure pathway or scenario for a specific medium or source area can be estimated (since they may not be additive) as the sum of the risks from all carcinogens of potential concern that are identified in that medium or source area. Similarly, the total risk for a carcinogen at the site can be calculated as the sum of the risks for that carcinogen through all exposure pathways.

Toxic effects for noncarcinogens are determined by dividing the estimated intake (I) by the reference dose (RfD), to determine the hazard quotient (HQ):

$$HQ = I/RfD \quad (5\text{-}8)$$

Pathway-specific HQs for a single chemical are added to produce a chemical-specific hazard index (HI). HIs are individual chemicals and are not added in the presentation of effects. As with carcinogens, HIs can be calculated by first developing a unit toxicity factor (UTF).

Section 3.3 presents exposure point concentrations for noncarcinogens of potential concern in source areas and environmental media at the FEMP. UTFs are determined according to the methodology described in the Addendum (DOE 1992a).

In conclusion, the risk characterization method combines two key elements: (1) exposure point concentrations, and (2) URF values for carcinogens and UTF values for noncarcinogens. This method is used for quantified exposure pathways for constituents of concern identified in the source areas and environmental media at the FEMP. The methods of these risk calculations are given in the following sections. This methodology is not applicable to direct external exposure to radiation from gamma-emitting radionuclides. The methodology for calculating risks via this exposure pathway is presented in Section 5.1.5.3.

5.1.1 Air Pathways

The methodology used to quantitatively characterize human health risks from pathways involving exposure to airborne contaminants is addressed in this section. Silos 1 and 2 (K-65 silos) are the predominant source of radon to the atmosphere at the FEMP. Resuspension of residual surface contamination potentially contributes to airborne particulate contamination. The quantitative characterization of risks from air pathways under current and future land-use scenarios are discussed separately below.

5.1.1.1 Current Land-Use Exposure Scenarios

The methodology for estimating risks from air pathways for current land use includes consideration of two possibilities specified in the Addendum (DOE 1992a): current land use assuming current access controls continue, and current land use assuming access controls are discontinued.

Off-property residents and visitors are potential receptors under both current land-use conditions. As specified in Section 5.1.4.2 of the Addendum (DOE 1992a), any activities requiring development time, such as home building on the property, are not considered for any of the current land-use conditions. They are addressed as future land-use scenarios. Therefore, the scenario that assumes that individuals continuously inhale contaminated air by residing on the property is not applicable to either of the two current land-use conditions.

The risks associated with air exposure pathways from both radon and contaminated particulates for current land-use conditions are calculated by multiplying the modeled concentrations of airborne contaminants presented in Table 3-2 by the URF and unit toxicity factor values given in Appendix S.

5.1.1.2 Future Land-Use Exposure Scenarios

For future land-use scenarios, sources of contaminated air and the potential exposure pathways are identical with those for the current land-use scenario, with or without access controls. However, potential receptors identified for the future land-use scenario include on-property residents in addition to off-property residents.

The risks associated with air exposure pathways for future land-use conditions are calculated by multiplying the modeled future concentrations of airborne contaminants presented in Table 3-3 by the URF and unit toxicity factor values given in Appendix S.

5.1.2 Groundwater Pathways

The methodology used to quantitatively characterize human health risks from pathways involving exposure to contaminated groundwater is addressed in this section. The quantitative characterization of risks from groundwater pathways under the current land-use scenarios and under future land-use scenarios are addressed separately below.

5.1.2.1 Current Land-Use Exposure Scenarios

The methodology for quantitatively characterizing risks from groundwater pathways under current land use includes consideration of two scenarios specified in the Addendum (DOE 1992): current land use assuming current access controls continue, and current land use assuming current access controls are discontinued.

The receptor exposures associated with these two scenarios are the same for groundwater exposure pathways; therefore, the methodology is presented once. No difference exists between the quantified exposures from groundwater pathways under current land use, with and without current access controls, because exposure to current groundwater contamination is limited to off-property well locations under both scenarios. There are currently no on-property drinking water wells or residential use wells. Section 5.1.4.2 of the Addendum (DOE 1992a), which addresses potential current exposures with and without current access controls, considers the current unimproved condition of the property. Any activities requiring development time such as home building, well installation, and planting and harvesting crops are addressed as future land-use scenarios.

Exposure point concentrations for radionuclides and chemicals in groundwater presented in Tables 3-5 and 3-6, respectively, are multiplied by the corresponding URF and unit toxicity factor values from Appendix S to yield the risks associated with groundwater exposure pathways for current land use.

5.1.2.2 Future Land-Use Exposure Scenarios

The methodology for quantitatively characterizing risks from groundwater pathways under future land-use scenarios is the same as the methodology presented above under current land-use scenarios except that modeled potential future contaminant concentrations in groundwater are used for the contaminant exposure point concentrations.

Potential receptor exposures identified in the Exposure Assessment include a construction intruder and the resident farmer under the future land-use scenario. Detailed descriptions of these receptor exposures are included in the Addendum (DOE 1992a).

Maximum exposure point concentrations for radionuclides and chemicals in groundwater under future land-use conditions are presented in Table 3-7. These concentrations are multiplied by the URF or unit toxicity factor values from Appendix S to yield the maximum risks associated with future groundwater exposure pathways. In addition, the URF or unit toxicity factor values were incorporated into groundwater model calculations to generate risk contours for future exposure pathways. The results of these calculations are presented in Section 5.3.

5.1.3 Surface Water Pathways

The methodology used to quantitatively characterize human health risks from pathways involving exposure to contaminated surface water is addressed in this section. The Great Miami River could be a source of potentially contaminated water. In addition, Operable Unit 1 contains ponds of standing water (Waste Pit 5, Waste Pit 6, and Clearwell) that can also serve as future potential sources of stock water. The quantitative characterization of risks from surface water pathways under current and future land-use scenarios are discussed separately below.

5.1.3.1 Current Land-Use Exposure Scenarios

The methodology for estimating risks from surface water pathways under current land use includes consideration of two possibilities specified in the Addendum (DOE 1992): current land use assuming current access controls continue, and current land use assuming current access controls are discontinued.

Measured exposure point concentrations for radionuclides and chemicals in the Great Miami River are presented in Table 3-8. These concentrations are multiplied by the URF or unit

toxicity factor values in Appendix S to yield the risks associated with a farm family using the Great Miami River as their primary source of water. Operable Unit 1 contains Waste Pits 5, 6, and the Clearwell. These three pits are open pits with standing water in them. It is assumed that these pits could be used to water stock if access controls were removed. Measured concentrations of surface water in Waste Pits 5, 6, and the Clearwell are presented in Table 3-8. These concentrations are multiplied by the URF and unit toxicity factor values for the off-property user of meat and milk in Appendix S to yield the risks associated with using animal products grown with on-property surface water.

5.1.3.2 Future Land-Use Exposure Scenarios

Contaminant concentrations in surface water bodies are estimated by modeling contaminant migration from the waste areas of the FEMP. Estimated exposure point concentrations for radionuclides and chemicals in the Great Miami River for future land use are presented in Table 3-9. These concentrations are multiplied by the URF or unit toxicity factor values in Appendix S to yield the risks associated with future surface water exposure pathways.

5.1.4 Sediment Pathways

The methodology used to quantitatively characterize human health risks from pathways involving exposure to contaminated sediment is addressed in this section. The principal receptor of concern for this pathway is the child trespassing on property. Sources of contaminated sediment near the FEMP are from Paddys Run, the SSOD, and drainage ditches leading to Paddys Run or the SSOD.

5.1.4.1 Current Land-Use Exposure Scenarios

The methodology for estimating risks from sediment pathways under current land use includes consideration of two possibilities specified in the Addendum (DOE 1992a): current land use assuming current access controls continue, and current land use assuming current access controls are discontinued. The principal differences between these two scenarios are the exposure point concentrations the child can access (Table 3-12), and the frequency of visitation (Table 3-15). The estimated risks and HI's from exposures to sediments are calculated by multiplying each constituent's exposure point concentrations (Table 3-12) by the corresponding URFs or UTFs (Appendix S). Care must be taken to multiply a given concentration by the appropriate URF or unit toxicity factor in Appendix S, since the URFs and UTFs for different access scenarios incorporate different scenario-specific exposure frequencies.

5.1.4.2 Future Land-Use Exposure Scenarios

A trespassing child is a potential receptor identified for future land-use scenarios. Contaminant concentrations in sediment in Paddys Run and the SSOD are estimated by modeling contaminant

transport from the waste areas of the FEMP. As noted in Section 3.3.5.2, results of modeling of future concentrations of sediment indicated that the concentrations of sediment are less than future soil concentrations. Since future exposure pathways consider exposure to soil/sediment, soil concentrations are used as exposure point concentrations for future soil/sediment pathways.

5.1.5 Soil/Waste Pathways

The methodology used to quantitatively characterize human health risks from pathways involving exposure to contaminated soil/waste is addressed in this section. The quantitative characterization of risks from soil/waste pathways under current land-use scenarios and under future land-use scenarios are addressed separately below.

5.1.5.1 Current Land-Use Exposure Scenarios

The methodology for quantitatively characterizing risks from soil/waste pathways under current land use includes considerations of two scenarios specified in the Addendum (DOE 1992a). Under one of these current land-use scenarios, it is assumed that current access controls continue. The second current land-use scenario assumes current access controls are discontinued.

Contaminant concentrations of radionuclides and chemicals in soil in off-property areas in the vicinity of the FEMP are at background levels for all constituents except uranium. Off-property areas having levels of uranium more than approximately ten times background are adjacent to the FEMP boundary to the east. The areal extent of contaminated soil does not present a significant health risk under current land-use scenarios with current access controls in place.

Concentrations of contaminants in soil/waste at the FEMP are given in Table 3-10. Access to these areas could occur if current access controls are removed. It is assumed that receptors have access to soil in areas proximal to the FEMP property boundary and in open areas on property. The soil/waste concentrations given in Table 3-10 are multiplied by the URF or unit toxicity factor values in Appendix S to yield the risks associated with current soil/waste exposure pathways.

5.1.5.2 Future Land-Use Exposure Scenarios

The methodology for characterizing risks from soil/waste pathways under future land-use scenarios is the same as the methodology presented for current land use, except that subsurface soil may also be the exposure medium.

Exposure point concentrations of radionuclides and chemicals in soil/waste for future land use are given in Table 3-11. These concentrations are listed for all areas of the FEMP. The soil/waste concentrations given in Table 3-11 are multiplied by the URF or unit toxicity factor values in

Appendix S to yield the risks associated with future soil/waste exposure pathways. Access to soil at the site is assumed to be unrestricted under the future land-use scenario.

5.1.5.3 Direct and Indirect External Radiation Exposure From Soil/Waste

The risks from external radiation exposure from soil/waste and from surface water and sediment following the migration of contaminants from soil/waste to surface water courses require quantification using different approaches. The EPA slope factor method developed for quantifying the risk from external radiation exposure from surface soil is used to quantify risk from soil or from sediment following the migration of contaminants from soil/waste to surface water courses. The risk from external radiation exposure from contaminated materials other than surface soil (i.e., the K-65 waste) cannot be performed using the EPA slope factor method. Instead, a radiation dose equivalent is estimated for the pathway and the cancer risk coefficient for external radiation (6.2×10^{-7} $mrem^{-1}$) is used to quantify risk. The choice of this risk coefficient is explained in detail in the Addendum (DOE 1992a).

The dose equivalent is estimated for the potential receptors using dose equivalent rates calculated with the MICROSHIELD computer code and parameter values for exposure time specified in Section 3.0. The risk is quantified as the product of the estimated dose equivalent and the risk coefficient, or:

$$\text{Risk} = (DE)(RC) \qquad (5\text{-}9)$$

where

Risk	=	Risk of cancer incidence, expressed as a unitless probability
DE	=	Total pathway dose equivalent (mrem)
RC	=	Cancer risk coefficient (6.2×10^{-7} $mrem^{-1}$)

5.1.6 Structures

The methodology used to quantitatively characterize human health risks from pathways involving receptors who enter structures is addressed in this section. The quantitative characterization of risks from structure pathways under current land-use scenarios and under future land-use scenarios are addressed separately below.

5.1.6.1 Current Land-Use Exposure Scenarios

It is assumed that scavengers enter FEMP buildings to salvage AIP equipment when access controls fail. A scavenger is considered to spend a limited amount of time inside structures salvaging and resting. For the purpose of estimating risks under current land-use scenarios, a total of 100 days is assumed for the time period for a scavenger to salvage in the FEMP buildings. This length of time is listed in Table 3-17. In addition, a scavenger is assumed to spend twelve

hours a day salvaging in a process building. The scavenger spends the remaining twelve hours resting in the same building. Inhalation of airborne contaminants, and ingestion of contaminated dust are the primary exposure pathways. Since this scenario puts people into direct contact with the most concentrated levels of contamination in the buildings, these scavengers constitute the RME receptors for exposure pathways from contamination inside structures. The methodology of estimating risks from inhalation and ingestion are presented as follows:

Ingestion Risk

An adult ingests approximately 0.1 gram of dust or soil per day. Assume that the 0.1 gram of dust or soil ingested by the scavenger directly comes from the contaminants in the building where he works and rests. The measured plant-specific uranium concentration in dust was used to calculate the risk from ingestion of uranium using Equations 5-1 and 5-3.

In 1985, measurements of fission and activation products in particulate material trapped in scrub liquor and by dust collectors were performed for some of the processing plants (Boback et al. 1987). The results of these measurements are presented as radionuclides concentrations per kilogram of uranium (μCi/kg-uranium). By combining these results with the plant-specific uranium concentration in dust, the concentration of radionuclides other than uranium in the dust can then be estimated. The risk from ingestion of these radionuclides was also calculated using Equations 5-1 and 5-3.

Inhalation Risk - Salvaging

A scavenger is assumed to spend half of the day salvaging and half of the day resting in a given processing plant. During the salvaging, the scavenger stirs up any removable contamination on the equipment during the working period. A resuspension factor of 7.0×10^{-5} m^{-1} was used to convert surface contamination levels to an airborne concentration (Healy 1980). From available data, the geometric mean of the maximum removable alpha activity found on the equipment was the value used as the surface contamination level. Since maximum contamination values were used, there was no need to consider an upper confidence limit estimate to describe contamination.

All alpha activity in the removable contamination on the equipment was assumed to be uranium (isotopes of uranium are the predominant alpha-emitting radionuclides at the FEMP). The risk from inhalation of alpha-emitting radionuclides during salvaging was then estimated using Equations 5-1 and 5-3.

No removable contamination measurements on the equipment were available for Plant 9 as of December 1, 1991. Uranium concentration in the dust for this plant, however, was available. A dust loading rate of 100 $\mu g/m^3$ (DOE 1992a) was used to convert uranium concentration in dust

to the uranium concentration in the air. Once the airborne concentration was estimated, the risk from inhalation of alpha-emitting radionuclides (or uranium, approximately) during salvaging was determined as described above.

Specific beta particle emitter data were used if they were available from the study of Boback et al (1987). Concentrations for beta-emitting radionuclides can then be approximated. The risk from inhalation of beta particle emitters during salvaging can also be evaluated using Equations 5-1 and 5-3.

Therefore, the inhalation risk from salvaging the AIP equipment is the sum of the risk from inhalation of alpha- and beta-emitting radionuclides.

Inhalation Risk - Resting

During resting periods, the monitored airborne alpha and beta radioactivity levels, which were measured under no disturbance conditions, were used to estimate inhalation intakes. Equations 5-1 and 5-3 were used for the risk calculation. The inhalation risk from resting in a given plant is the sum of the risk associated with these airborne alpha and beta emitters.

Finally, the total risk for the scavenger from working and resting in a plant is the sum of the ingestion risk, the inhalation risk during salvaging, and the inhalation risk during resting.

5.1.6.2 Future Land-Use Exposure Scenarios

New residents are assumed to live in the structures and also to use abandoned-in-place equipment, either as part of their work or for salvage.

The methodology for calculating total risk from structures under the future land-use scenarios is the same as that for the current land-use scenario without access controls, except that the parameter for exposure duration was considered to be greater for the future land-use scenarios.

For the purpose of estimating risks, a thirty-year time period living in the structure for the new resident was assumed. The new resident is also assumed to work 8 hours a day, 5 days a week, and 50 weeks a year on salvaging AIP equipment. During these 50 weeks, he rests in the buildings if he is not working.

5.2 RISKS UNDER CURRENT LAND-USE SCENARIOS

Risks are estimated for radionuclides and chemicals of potential concern in air, groundwater, surface water, meat and dairy products produced with surface water, sediment and soil. Risks from external gamma radiation are also evaluated. These are evaluated under the two land-use

scenarios in this section: current with access controls and current without access controls. Radionuclides and chemicals with an ILCR exceeding 1×10^{-6} are noted and discussed. The HI indicates the numerical proximity to acceptable limits of exposure or the degree to which acceptable exposure levels are exceeded. As the HI approaches unity, concern for the potential hazard of the constituent increases. It is assumed that the toxic effects, and thus HIs, are additive across pathways from the same chemical. HIs representing different chemicals are not added in the presentation of effects.

In developing MCLs for toxic effects, the EPA Office of Drinking Water routinely applies a factor of 0.2 to the acceptable HI of 1.0 to account for exposures from "other" sources. Chemicals with an HI greater than or equal to 0.2 are discussed.

5.2.1 Current Land-Use Scenario With Access Controls

5.2.1.1 Air

Air exposure pathways evaluated quantitatively include:

- Inhalation of resuspended particulates
- Inhalation of volatile or gaseous compounds
- Ingestion of fruits, vegetables, beef, and milk contaminated by deposition of airborne particulates on plants

The receptors evaluated quantitatively under this current scenario include the off-property farmer and a visitor. Table 5-1 presents the ILCRs from contaminants of concern in particulate and gaseous forms for exposure of the off-property farmer under the current scenario with access controls. The risks associated with exposures of the off-property farmer from these radionuclides range from 1×10^{-8} to 2×10^{-5} at the off-property locations included in Table 5-1. In each case, the greatest risk is contributed by radon (Table 5-1). ILCRs for the farmer from airborne particulates, airborne radon, and particulates and radon combined are presented in risk contour plots in Figure 5-1, Figure 5-2, and Figure 5-3, respectively. Modeled risks from airborne contaminants exceed 1×10^{-5} immediately outside the property boundary to the east of the Incinerator/WWTP area (Figure 5-3).

Table 5-2 presents the ILCRs from contaminants of concern in particulate and gaseous forms for exposure of the visitor on property. The risks associated with exposure of the visitor range from 7×10^{-6} from particulates to 5×10^{-5} from airborne radon, which dominates the risk to the visitor (Table 5-2).

TABLE 5-1

INCREMENTAL LIFETIME CANCER RISK TO THE OFF-PROPERTY FARMER FROM AIRBORNE RADIONUCLIDES UNDER THE CURRENT LAND-USE SCENARIO[a]

Radionuclide[b]	Highest Off-Site Risk	Risk at Elda School	Risk at Township School
Particulates			
Th-230	6.8E-07	1.6E-08	4.1E-08
Th-232	1.4E-07	4.4E-09	7.0E-08
Ra-226	1.0E-08	2.1E-10	4.2E-10
U-234	3.3E-06	6.0E-08	8.1E-08
U-235	2.5E-07	2.8E-09	3.5E-09
U-238	9.0E-06	1.4E-07	1.8E-07
Sum of Particulate Risks	1.3E-05	2.2E-07	3.8E-07
Gases			
Radon	1.4E-05	6.5E-07	3.2E-07
Total (particulates + radon)	3E-05	9E-07	7E-07

[a] Includes risks from inhalation and ingestion of fruits, vegetables, beef, and dairy products.
[b] Risks include contribution from daughters.

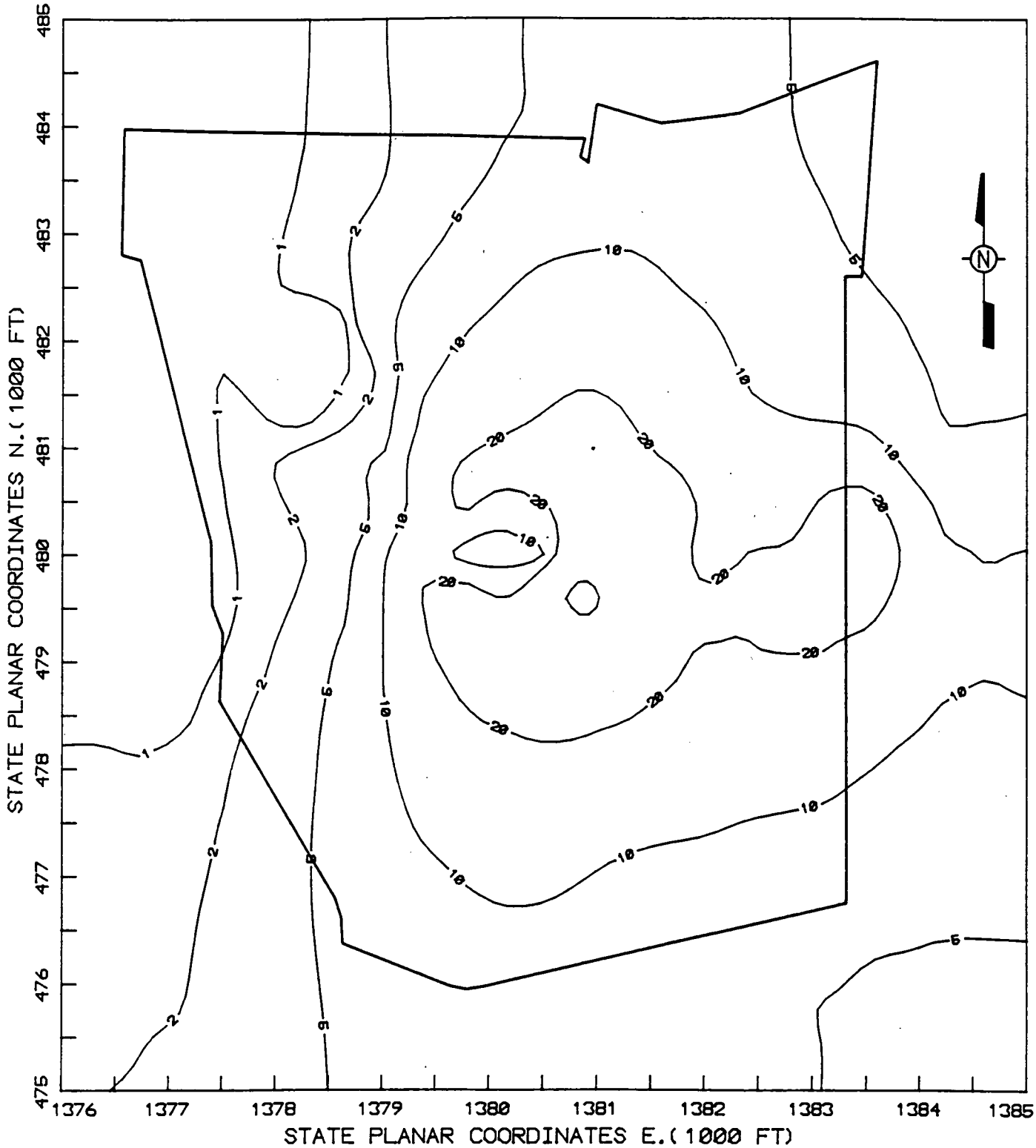

FIGURE 5-1 CONTOUR PLOT OF ILCR (PER 10^{-6}) TO THE HYPOTHETICAL FARMER FROM AIRBORNE PARTICULATES WITH CAPS IN PLACE

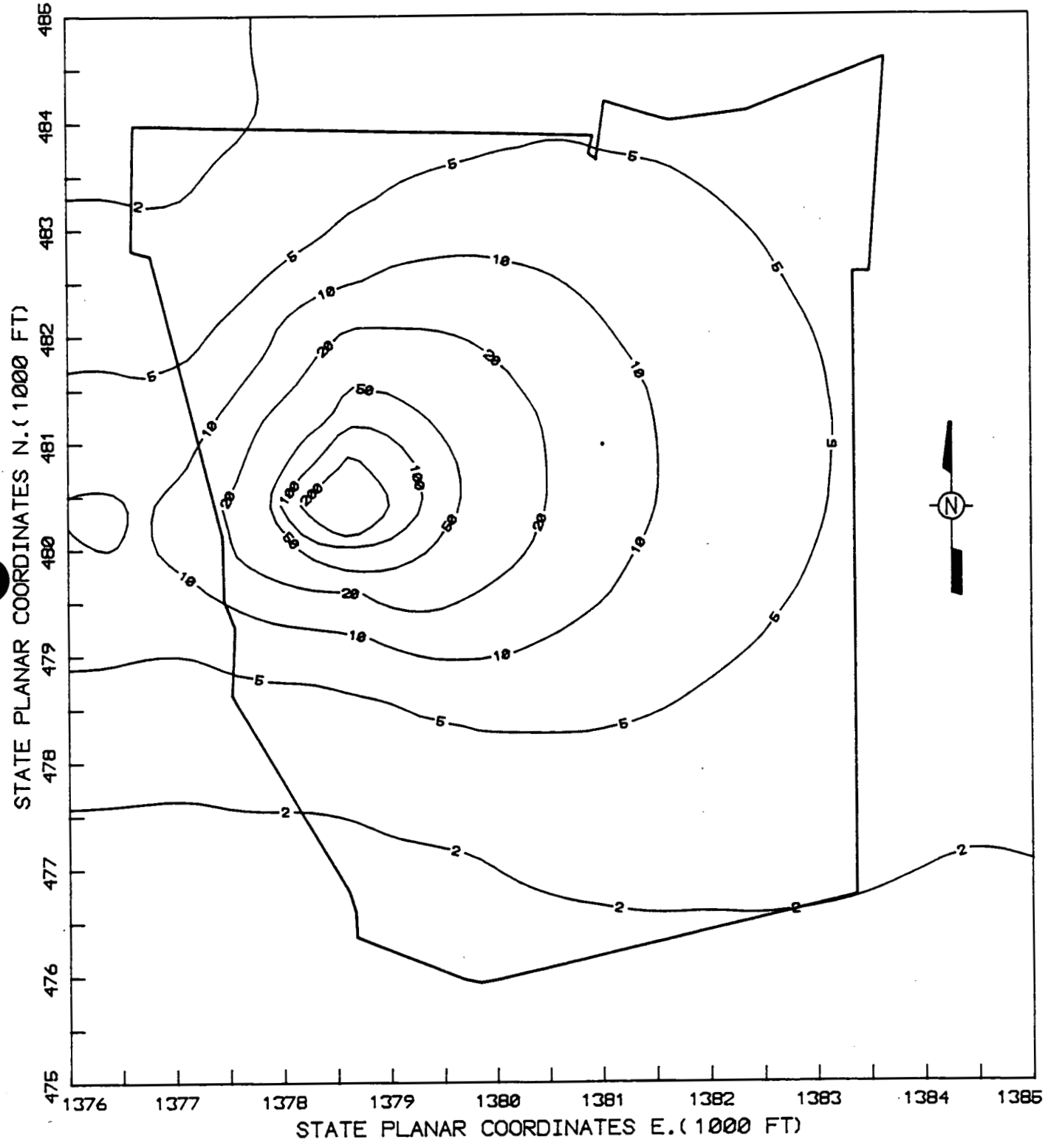

FIGURE 5-2 CONTOUR PLOT OF ILCR (PER 10^{-6}) TO THE HYPOTHETICAL FARMER FROM RADON WITH CAPS IN PLACE

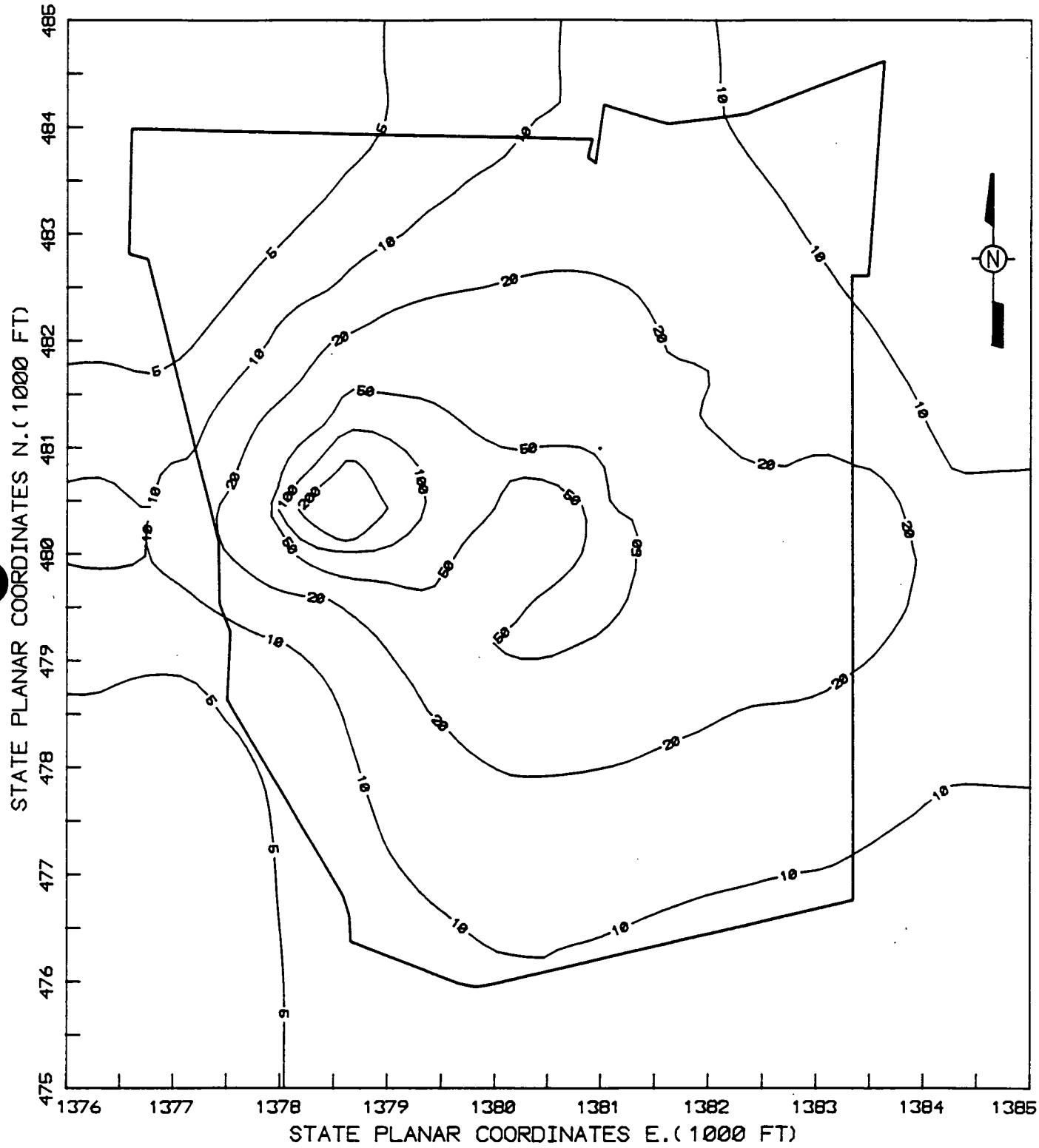

FIGURE 5-3 CONTOUR PLOT OF ILCR (PER 10^{-6}) TO THE HYPOTHETICAL FARMER FROM ALL AIRBORNE CONSTITUENTS WITH CAPS IN PLACE

TABLE 5-2

INCREMENTAL LIFETIME CANCER RISK TO VISITOR FROM AIRBORNE RADIONUCLIDES UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Radionuclide[b]	Risk
Particulates	
Th-230	2.5E-07
Th-232	1.6E-07
Ra-226	1.8E-08
U-234	1.9E-06
U-235	9.4E-08
U-238	4.1E-06
Sum of Particulate Risks	6.5E-06
Gases	
Radon	5.0E-05
Total (particulates + radon)	5.6E-05

[a] Includes risks from inhalation.
[b] Risks include contribution from daughters. Exposure point concentration for the visitor is the maximum modeled on-property air concentration from Table Q.4-1.

Modeled air concentrations for hazardous chemicals under current and future land-use scenarios are extremely low, at picogram/m^3 levels. Assuming a 70-kg person inhales 0.83 m^3 of air per hour, 24 hours a day, and 350 days per year for 70 years, the hazard index (HI) for lead associated with the modeled concentrations would be 0.000001. Because of the low estimated values, the air pathway will not be considered as a viable pathway for current land-use scenarios in the risk characterization for chemicals.

5.2.1.2 Groundwater

The pathways that were evaluated include:

- Ingestion of drinking water
- Inhalation of volatiles released from household water use
- Dermal exposure while bathing
- Ingestion of fruit and vegetables irrigated with groundwater
- Ingestion of milk/dairy products
- Ingestion of beef

The receptor evaluated under this scenario is an adult off-property farmer. The adult farmer is evaluated because the exposure factors selected for this receptor (Table 3-15) ensure that the farmer receives the highest total exposure from a given concentration in groundwater under the current land-use scenario.

Table 5-3 lists the results of these risk calculations for water and food ingestion pathways by radionuclide for 8 wells located along the off-property plume's center line. In nearly all cases, risks from uranium isotopes in water drawn from these wells dominates the risks received from other detected radionuclides. To illustrate the spatial distribution of these 8 wells and the aggregate risks associated with groundwater drawn from them, they are depicted in Figures 5-4 and 5-5.

Figures 5-4 and 5-5 present the combined radiological risks from groundwater in parentheses beside each well. Examination of Figure 5-4 (2000 series wells) reveals that the group of wells producing the highest lifetime risks (2015, 2060, 2061, and 2095) are located just south of the southern FEMP property boundary. These wells are associated with the South Plume, and over 60 percent of this risk is attributable to isotopes of uranium (Table 5-3). The remaining wells further south of the FEMP property and the wells in Figure 5-5 (3000 series wells) produce estimated lifetime risks in the 10^{-4} to 10^{-5} ILCR range.

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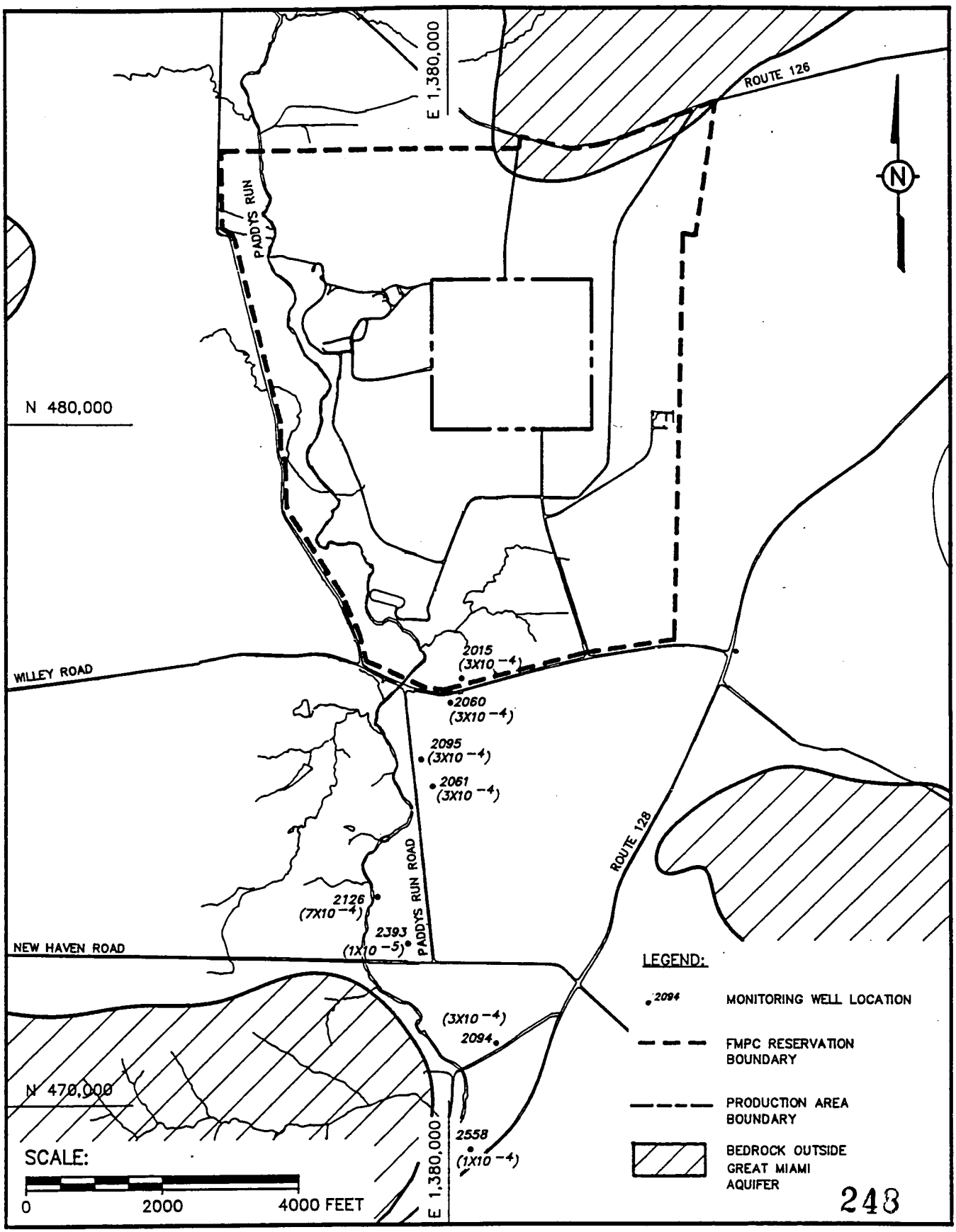
TABLE 5-3

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES IN GROUNDWATER TO THE OFF-PROPERTY FARMER UNDER THE CURRENT LAND-USE SCENARIO[a]

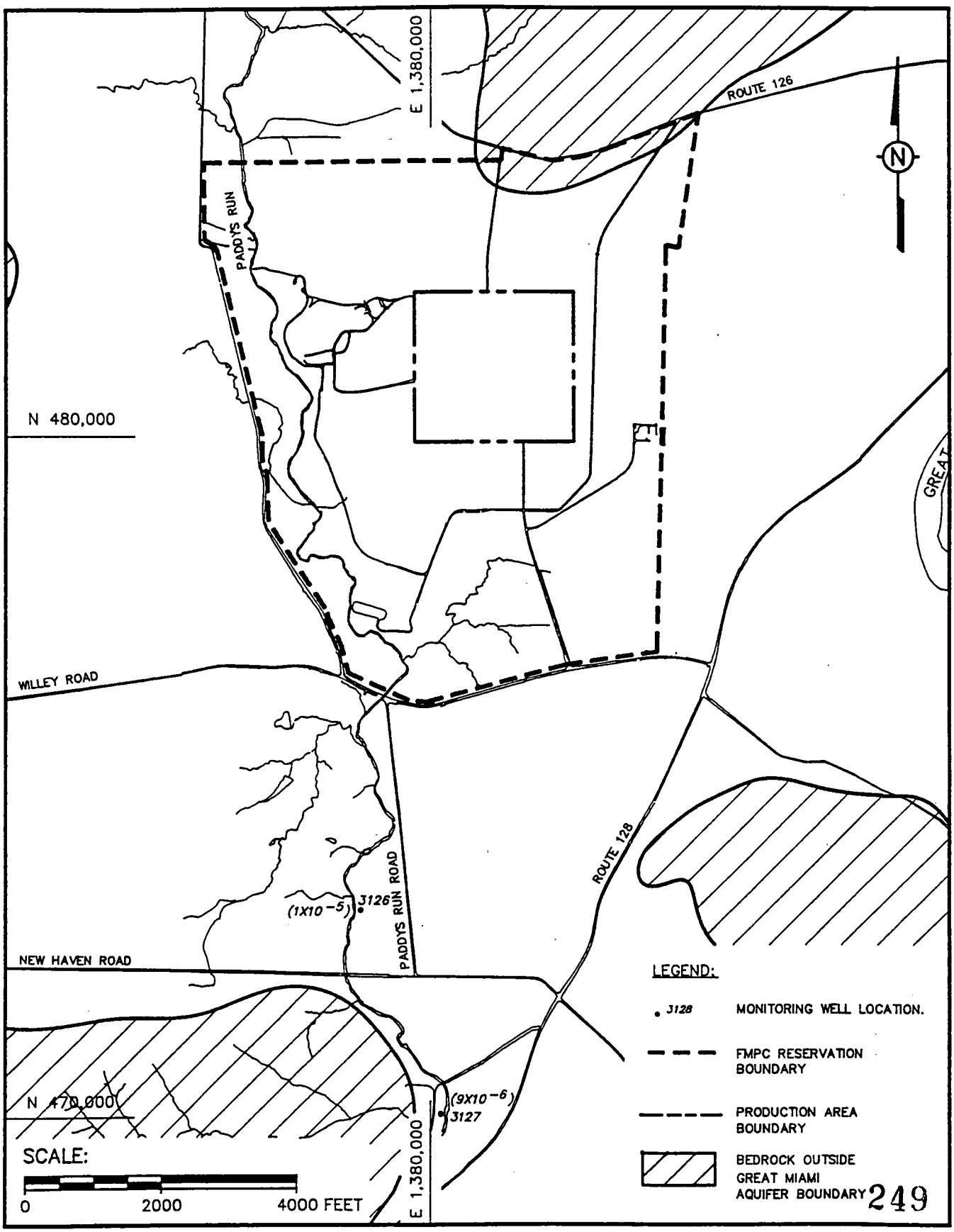
	Radionuclide[b]										
Well	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234	U-235	U-238	Sr-90	Tc-99	Well Sum
Bkgnd	2.7E-05	3.3E-06	1.8E-06	4.2E-07	5.5E-06	5.5E-07	5.5E-07	9.5E-07	0	0	4.0E-05
2015	5.4E-05	2.4E-05	2.7E-06	NA[c]	NA	6.8E-05	3.5E-06	1.2E-04	NA	NA	2.7E-04
2060	NA	1.7E-05	5.3E-06	9.1E-07	NA	8.8E-05	4.8E-06	1.6E-04	NA	NA	2.8E-04
2061	NA	NA	NA	NA	NA	1.1E-04	5.7E-06	1.9E-04	NA	NA	3.1E-04
2094	2.2E-04	1.8E-05	5.6E-06	7.6E-07	NA	3.8E-06	1.2E-06	6.6E-06	NA	NA	2.6E-04
2095	8.1E-05	NA	3.5E-06	9.1E-07	NA	5.9E-05	2.9E-06	1.1E-04	NA	NA	2.6E-04
2558	7.5E-05	1.9E-05	4.9E-06	NA	NA	2.2E-06	NA	3.6E-06	NA	NA	1.0E-04
3126	NA	NA	5.3E-06	NA	NA	1.5E-06	NA	2.8E-06	NA	NA	9.6E-06
3127	NA	NA	3.0E-06	NA	NA	2.1E-06	NA	3.4E-06	NA	NA	8.5E-06

a Includes risks from drinking water and ingestion of fruit, vegetables, beef, and dairy products grown with water.
b Risks include contribution from daughters.
c NA signifies that the radionuclide is not a contaminant of concern in the well.



SITE WIDE BASELINE RISK ASSESSMENT
31332735/SWBRA/KNOX

FIGURE 5–4 INCREMENTAL LIFETIME CANCER RISK FROM RADIONUCLIDES IN GROUNDWATER AT 2000 SERIES WELL LOCATIONS UNDER CURRENT LAND USE



SITE WIDE BASELINE RISK ASSESSMENT
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FIGURE 5-5 INCREMENTAL LIFETIME CANCER RISK FROM RADIONUCLIDES IN GROUNDWATER AT 3000 SERIES WELL LOCATIONS UNDER CURRENT LAND USE

Radon gas is the only radionuclide of concern at the FEMP that may be expected to volatilize from water used for domestic purposes (e.g., showering). Since measurements of radon concentrations in the water from these wells are not available, risks from radon in groundwater must be determined using estimated radon concentrations. Radon concentration is estimated by assuming that Rn-222 is present in equilibrium with Ra-226 in the well. Using the lifetime risk coefficient of 8.1×10^{-7} per pCi/ℓ presented by EPA as the risk from all uses of water in the home (EPA 1991e), and the highest calculated 95 percent confidence interval value Ra-226 concentration, a lifetime risk of approximately 3×10^{-6} is estimated.

Table 5-3 also presents background risks from the radionuclides reported in water from the aquifer beneath the FEMP. Table 5-4 breaks these background risks (4×10^{-5} from all radionuclides) down by pathway and radionuclide. The dominant radionuclides are U-238, Th-232, Th-228, Ra-228, Ra-226, and the dominant pathways are the drinking water pathway, followed by the fruit/vegetable ingestion pathway.

Table 5-5 presents ILCRs for chemical carcinogens associated with groundwater in the 8 wells evaluated. No carcinogens were found in wells 2061, 2558, or 3127. The following constituents had ILCRs above 1×10^{-6}: benzene (wells 2094, 3126), beryllium (wells 2095 and 3126), chloroform (well 2015), and methylene chloride (wells 2015, 2094, 2095, 2060 and 3126). Well 2094 had the highest ILCRs overall, with benzene being the dominant contributor to risk. It should be noted that two of the carcinogens are common laboratory contaminants that may be artifacts of sampling and analysis (e.g., methylene chloride and bis(2-ethylhexyl)phthalate).

HIs for this scenario are presented in Table 5-6. Most of the constituents produced an HI of 0.2 or greater. All wells had constituents with HIs above one. Those constituents with HIs greater than one include: 2-butanone (well 2015), arsenic (wells 2061, 2094), barium (wells 2094, 3127), cadmium (well 3127), chromium (well 3127), lead (well 3127), manganese (well 3127), mercury (wells 2094, 2095, 2060, 3126, 3127), silver (well 3127), thallium (well 3126), uranium (wells 2015, 2061, 2095, 2060), vanadium (well 3127), and zinc (wells 2015, 2060, 2558). The highest HIs were from well 3127, with HIs over 100 for cadmium, chromium, lead and silver.

Wells 2094 or 3127 are the RME locations for groundwater under current conditions with and without access controls. These two wells are located close to the edge of the aquifer.

TABLE 5-4

INCREMENTAL LIFETIME CANCER RISKS TO THE OFF-PROPERTY FARMER FROM BACKGROUND RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER

Radionuclide	Water Concentration[a] (pCi/ℓ)	Direct Ingestion	Fruit/ Vegetable Ingestion	Beef/Milk Ingestion	Total Ingestion
Ra-226	5.0E-01	1.9E-05	6.5E-06	6.3E-07	2.6E-05
Ra-228[b]	5.0E-01	2.5E-06	7.5E-07	5.7E-08	3.3E-06
Th-228	5.0E-01	1.4E-06	3.9E-07	3.8E-10	1.8E-06
Th-230	5.0E-01	3.2E-07	9.5E-08	9.6E-11	4.2E-07
Th-232	5.0E-01	4.1E-06	1.3E-06	1.2E-09	5.4E-06
U-234	5.0E-01	3.9E-07	1.5E-07	1.4E-08	5.5E-07
U-235	5.0E-01	3.9E-07	1.5E-07	1.4E-08	5.5E-07
U-238	5.0E-01	7.0E-07	2.6E-07	2.5E-08	9.9E-07
Sum:		2.9E-05	9.6E-06	7.4E-07	3.9E-05

[a] A background concentration of zero is assumed for fission product and transuranic radionuclides in groundwater; and a background concentration equal to one-half of the detection limit is assumed for naturally-occurring radionuclides.
[b] Ra-228 is assumed to be in equilibrium with the Th-232 chain.

TABLE 5-5

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS TO THE OFF-PROPERTY FARMER FROM GROUNDWATER UNDER THE CURRENT LAND-USE SCENARIO[a]

Chemical	Well 2015	Well 2061	Well 2094	Well 2095	Well 2060	Well 2558	Well 3126	Well 3127
Benzene	NA	NA	1.2E-03	NA	NA	NA	7.8E-06	NA
Beryllium	NA	NA	1.6E-04	NA	NA	NA	3.1E-04	NA
Bis(2-ethylhexyl)phthalate	6.5E-7	NA	NA	NA	NA	NA	NA	NA
Chloroform	3.8E-6	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	2.7E-4	NA	4.5E-05	1.1E-05	2.8E-05	NA	1.1E-05	NA
Sum	3E-04	NA	1E-03	1E-05	3E-05	NA	3.3E-04	NA

[a] The pathways that were evaluated include: ingestion of drinking water, inhalation of volatiles released from household water use, dermal exposure while bathing, ingestion of vegetables irrigated with groundwater, ingestion of milk/dairy products, and ingestion of beef.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-6

HAZARD INDICES FROM CHEMICALS TO THE OFF-PROPERTY FARMER FROM GROUNDWATER UNDER THE CURRENT LAND-USE SCENARIO[a]

Chemical	Well 2015	Well 2061	Well 2094	Well 2095	Well 2060	Well 2558	Well 3126	Well 3127
1,1,1-Trichloroethane	1.2E-02	NA[b]	NA	2.0E-03	1.2E-02	NA	NA	NA
2-Butanone	1.8E+00	NA	NA	3.1E-01	3.1E-01	NA	2.1E-01	NA
Acetone	2.1E-01	NA	5.8E-01	1.1E-01	1.6E-01	NA	3.7E-01	NA
Antimony	3.6E-01	NA	NA	NA	NA	NA	NA	NA
Arsenic	NA	9.9E+00	9.4E+00	NA	NA	NA	NA	NA
Barium	NA	NA	1.0E+00	4.2E-02	4.4E-02	NA	NA	1.3E+01
Beryllium	NA	NA	7.2E-03	NA	NA	NA	1.4E-02	NA
Bis(2-ethylhexyl) phthalate	2.3E-03	NA	NA	NA	NA	NA	NA	NA
Cadmium	1.6E-01	2.8E-01	6.0E-01	2.2E-01	1.1E-01	2.8E-01	4.4E-01	1.1E+02
Chloroform	6.2E-02	NA	NA	NA	NA	NA	NA	NA
Chromium	3.3E-01	2.4E-01	2.2E-01	1.9E-01	2.2E-01	1.9E-01	3.6E-01	1.2E+02
Di-n-butyl phthalate	NA	NA	1.5E-03	NA	NA	NA	NA	NA
Ethylbenzene	NA	NA	9.5E-03	NA	NA	NA	NA	NA
Lead	8.8E-01	2.2E-01	2.2E-01	6.6E-01	NA	NA	3.3E-01	1.2E+02
Manganese	NA	8.1E-03	1.1E-01	7.6E-03	NA	1.4E-02	9.2E-02	2.3E+01
Mercury	NA	NA	3.6E+01	1.5E+01	7.3E+00	NA	2.2E+01	3.6E+01
Methylene chloride	5.9E-01	NA	1.0E-01	2.5E-02	6.3E-02	NA	2.5E-02	NA
Molybednum	NA	2.0E-01	1.3E-01	9.6E-02	2.7E-01	NA	NA	NA
Nickel	NA	NA	1.0E-01	3.0E-02	NA	NA	7.0E-02	3.2E-02
Selenium	NA	2.2E-02	NA	NA	NA	NA	NA	9.8E-02
Silver	NA	2.1E-01	NA	2.8E-01	2.8E-01	5.6E-01	5.1E-01	2.8E+02

TABLE 5-6
(Continued)

Chemical	Well 2015	Well 2061	Well 2094	Well 2095	Well 2060	Well 2558	Well 3126	Well 3127
Thallium	NA	NA	NA	NA	NA	NA	1.5E+00	NA
Toluene	NA	NA	2.8E-03	NA	NA	NA	3.5E-03	NA
Uranium	2.9E+00	3.7E+00	1.1E-01	2.2E+00	3.5E+00	8.6E-02	6.2E-02	2.5E-02
Vanadium	1.0E-01	8.9E-02	5.8E-02	8.4E-02	NA	6.3E-02	1.8E-01	4.6E+01
Xylenes	NA	NA	2.7E-03	NA	NA	NA	NA	NA
Zinc	2.5E+00	NA	1.8E-01	3.9E-01	1.0E+00	2.4E+01	3.1E-01	NA

[a] The pathways that were evaluated include: ingestion of drinking water, inhalation of volatiles released from household water use, dermal exposure while bathing, ingestion of vegetables irrigated with groundwater, ingestion of milk/dairy products, and ingestion of beef.

[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

5.2.1.3 Surface Water

The pathways that were evaluated for the off-property farmer scenario include:

- Ingestion of drinking water
- Inhalation of volatiles released from household water use
- Dermal exposure while bathing
- Dermal exposure while swimming
- Incidental ingestion of water while swimming
- Ingestion of fish
- Ingestion of vegetables irrigated with surface water
- Ingestion of milk/dairy products
- Ingestion of beef

The receptor evaluated under this scenario is an adult off-property farmer who also uses the river for recreational purposes and as a source of household water. The Great Miami River is the only water body with sufficient volume to support the activities associated with these pathways. The Great Miami River is considered in three segments: upstream of the main FEMP effluent line (upstream), between the effluent line and Paddys Run (middle), and downstream of Paddys Run (downstream). The upstream results should be considered to characterize the Great Miami River prior to any site influence.

Table 5-7 presents pathway-specific ILCRs from radionuclides of potential of concern in the Great Miami River for this scenario. Table 5-7 addresses the radionuclide ILCRs only for a farmer using the Great Miami River as the primary source of water. Radionuclide ILCRs for the upstream segment and downstream segment are comparable and are about 10^{-5}. The middle segment of the Great Miami River is estimated to pose ILCRs approximately six times higher than the other two segments, in which Tc-99 predominates.

There were no chemical carcinogens among the constituents of potential concern in the Great Miami River. Hence, there is no cancer risk associated with chemicals for this media-specific RME. Hazard indices for this scenario are presented in Table 5-8. Chemicals producing an HI (across pathways) in the middle or downstream segments greater than 0.2 include: cadmium, lead, and mercury. HIs for cadmium and mercury are higher upstream than in the middle or downstream segments, potentially influenced by the site. Lead HIs for upstream segments and lower segments are comparable. Only arsenic did not have a comparable or higher HI in the upstream segment of the Great Miami River. Overall, the HIs for the middle segment are slightly higher than the downstream segment of the Great Miami River.

TABLE 5-7

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES TO FARMER USING GREAT MIAMI RIVER WATER UNDER THE CURRENT LAND-USE SCENARIO[a]

	Great Miami River		
Radionuclide[b]	Upstream	Middle	Downstream
Ra-226	4.9E-05	NA[c]	NA
Ra-228	4.6E-06	4.9E-06	1.6E-05
Sr-90	NA	NA	NA
Tc-99	NA	3.1E-04	NA
Th-228	2.5E-06	2.6E-06	3.5E-06
Th-230	NA	NA	5.7E-07
U-234	6.9E-07	1.3E-06	1.2E-06
U-235/236	NA	NA	NA
U-238	NA	2.1E-06	2.1E-06
Sum	5.7E-05	3.2E-04	2.3E-05

[a] Includes risks from drinking water, ingestion while swimming, volatilized radon, and ingestion of fruit, vegetables, fish, beef, and dairy products grown with Great Miami River water.
[b] Risks include contribution from daughters.
[c] Not a constituent of potential concern in this stretch of the Great Miami River.

TABLE 5-8

HAZARD INDICES TO FARMER USING GREAT MIAMI RIVER WATER UNDER THE CURRENT LAND-USE SCENARIOS[a]

	Great Miami River		
Chemical	Upstream	Middle	Downstream
Arsenic	NA	1.4E-01	NA
Barium	3.9E-02	3.8E-02	3.1E-02
Cadmium	2.3E+00	NA	4.6E-01
Chromium	5.8E-02	3.9E-02	NA
Lead	5.3E-01	3.2E-01	6.4E-01
Manganese	4.3E-03	3.9E-03	5.2E-03
Mercury	1.4E+02	1.4E+01	2.8E+01
Molybdenum	7.2E-02	NA	NA
Nickel	5.0E-02	4.2E-02	2.7E-02
Uranium	NA	3.6E-02	3.6E-02
Selenium	NA	NA	2.1E-02

[a] The pathways that were evaluated include: ingestion of drinking water, inhalation of volatiles released during household water use, dermal exposure while bathing, incidental ingestion of water while swimming, dermal exposure while swimming, ingestion of fish, ingestion of vegetables irrigated with surface water, ingestion of milk/dairy products and ingestion of beef.

[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

5.2.1.4 Sediment

The pathways that were evaluated include:

- Dermal contact with sediment
- Incidental ingestion of sediment
- External exposure to gamma radiation

The receptor evaluated under this scenario is a child trespassing on-property, ages 7 to 18. It is assumed that the child has access to Paddys Run.

Table 5-9 presents ILCRs for this scenario from radionuclides in sediments. Risks in Paddys Run are calculated to approach 5×10^{-5}. Radium isotopes of the thorium chain contribute over 90 percent of these estimated risks.

ILCRs for chemical carcinogens for this scenario are presented in Table 5-10. Bis(2-ethylhexyl)phthalate and methylene chloride, both common laboratory contaminants, are the only carcinogens detected in the sediment from Paddys Run. These chemicals may be laboratory-introduced contaminants rather than site-related constituents. However, since analytical data for these laboratory blanks were not available as of December 1, 1991, the two common laboratory contaminants are currently included as chemicals of potential concern. Paddys Run was divided into three segments for evaluation (upstream of the FEMP, between the FEMP northern boundary and the SSOD, and downstream of the SSOD). ILCRs in Paddys Run ranged from 9×10^{-13} to 1×10^{-9}. The risks associated with the upstream, middle, and downstream segments of Paddys Run are very similar and are well below the 1×10^{-6} point of departure.

HIs for this scenario are presented in Table 5-11. The HIs range from 1×10^{-8} to 2×10^{-5}, all well below the level of concern.

5.2.1.5 Soil

The pathways that were evaluated include:

- Incidental ingestion of soil
- Dermal contact with soil
- Ingestion of milk/dairy products
- Ingestion of beef
- External exposure to gamma radiation

TABLE 5-9

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES TO A TRESPASSING CHILD FROM SEDIMENT UNDER THE CURRENT LAND-USE SCENARIO[a]

	With Controls			Without Controls			
	Paddys Run			Paddys Run			
Radionuclides[b]	Upstream from FEMP	Middle	Downstream of SSOD	Upstream From FEMP	Middle	SSOD	Downstream of SSOD
Pu-238	No Data Available as of Dec. 1, 1991	NA[c]	2.6E-12	No Data Available as of Dec. 1, 1991	NA	7.4E-11	< 1E-08
Pu-239/240		NA	1.1E-12		NA	9.9E-11	< 1E-08
Ra-224		NA	NA[b]		NA	1.5E-06	NA
Ra-226		NA	NA		NA	1.7E-06	NA
Ra-228		NA	NA		NA	7.7E-07	NA
Sr-90		NA	NA		NA	NA	NA
Tc-99		NA	3.0E-13		NA	NA	< 1E-08
Th-230		NA	4.9E-12		NA	3.2E-10	< 1E-08
U-234		NA	6.2E-12		NA	1.8E-09	< 1E-08
U-235		NA	NA		NA	5.5E08	NA
U-238		NA	3.6E-10		NA	1.2E-07	1.1E-8
Sum		NA	3.8E-10		NA	2.6E-06	1.1E-8

[a] Includes risks from incidental ingestion of sediment and external gamma exposures.
[b] Risks include contribution from daughters.
[c] Not a constituent of potential concern for a given surface water body.

TABLE 5-10

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS TO A TRESPASSING CHILD FROM SEDIMENT UNDER THE CURRENT LAND-USE SCENARIO[a]

	With Controls			Without Controls			
	Paddys Run			Paddys Run			
Radionuclides	Upstream from FEMP	Middle	Downstream of SSOD	Upstream From FEMP	Middle	Downstream of SSOD	SSOD
Bis(2-ethylhexyl) phthalate	8.3E-10	1.1E-9	7.2E-10	2.5E-08	3.2E-08	2.2E-08	NA
Methylene chloride	6.7E-12	1.9E-11	9.5E-13	2.0E-10	5.6E-10	2.8E-11	NA

[a] The pathways that were evaluated include dermal contact with sediment and incidental ingestion of sediment.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-11

HAZARD INDICES TO A TRESPASSING CHILD FROM SEDIMENT UNDER THE CURRENT LAND-USE SCENARIO[a]

	With Controls			Without Controls			
	Paddys Run			Paddys Run			
Radionuclides	Upstream from FEMP	Middle	Downstream of SSOD	Upstream From FEMP	Middle	Downstream of SSOD	Downstream of SSOD
Acetone	1.5E-07	5.9E-08	7.4E-08	4.4E-06	1.8E-06	1.8E-06	NA[b]
Bis(2-ethylhexyl)phthalate	1.7E-05	2.2E-05	1.5E-05	5.1E-04	6.5E-04	4.4E-04	NA
2-Butanone	NA	NA	1.5E-08	NA	NA	4.4E-06	NA
Di-n-butylphthalate	2.9E-07	4.4E-07	NA	8.5E-06	1.3E-05	NA	NA
Methylene chloride	8.4E-08	2.4E-07	1.2E-08	2.5E-06	7.4E-06	3.7E-07	NA
Uranium	NA	2.6E-06	2.6E-06	NA	7.6E-05	7.5E-05	2.2E-04

[a] The pathways that were evaluated include dermal contact with sediment and incidental ingestion of sediment.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

The receptors evaluated under this scenario are a trespassing child, ages 7 to 18 (soil ingestion and dermal contact pathways), and the farmer grazing cattle on property (ingestion of milk/dairy and beef pathways). Under the current land-use scenario with access controls in place, access to soil is limited to the following areas:

- Active Flyash Pile
- Inactive Flyash Pile
- South Field
- Various less contaminated areas of the site (addressed by considering all soil data for the remainder of the site).

It was assumed that cattle do not graze on the Active Flyash Pile because of the lack of vegetative cover.

ILCRs for radionuclide contaminants associated with the trespassing child scenario are presented in Table 5-12. The risks to the trespassing child receptor from all radionuclides combined in the Active Flyash Pile, Inactive Flyash Pile, South Field, and remaining areas are approximately 2×10^{-7}, 4×10^{-6}, 4×10^{-6}, and 3×10^{-6}, respectively. Radium-226 contributes the greatest radionuclide risk for three of these four waste areas (Table 5-12).

ILCRs for chemical carcinogens associated with exposure of a trespassing child are listed in Table 5-13. Chemical carcinogens were not detected in the Active or Inactive Flyash Piles or the South Field. B(a)P, Aroclor-1254, and Aroclor-1260 in the remainder of the site had ILCRs above 1×10^{-6}.

HIs for exposure of a trespassing child are presented in Table 5-14. Only uranium data were available for the Active and Inactive Flyash Piles and the South Field. Uranium HIs in those areas were all below 0.2. There were also no chemicals with an HI greater than 0.2 for soil on the remainder of the site.

The ILCRs for radionuclide contaminants associated with exposures from using beef and dairy products from cattle grazing on property are presented in Table 5-15. The risks from using beef and dairy products from cattle grazing on property in the Inactive Flyash Pile, South Field, and remaining areas are approximately 1.2×10^{-4}, 8.5×10^{-5}, and 1.8×10^{-4}, respectively. Again, Ra-226 contributes the greatest radionuclide risk in these areas.

ILCRs for the consumer of the meat and dairy products are presented in Table 5-16.

TABLE 5-12

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES TO A TRESPASSING CHILD FROM ON-PROPERTY SOIL UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Radionuclide	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Cs-137	NA[b]	1.5E-08	1.0E-08	1.4E-08
Np-237	NA	NA	NA	NA
Pu-238	NA	NA	NA	3.7E-11
Pu-239/240	NA	NA	NA	3.7E-11
Ra-226	4.6E-08	3.2E-06	1.9E-06	2.6E-06
Ra-228	3.2E-08	5.8E-08	6.1E-08	6.4E-08
Sr-90	NA	NA	NA	1.4E-11
Tc-99	NA	NA	NA	4.0E-13
Th-228	6.1E-08	5.5E-08	1.3E-06	1.2E-07
Th-230	NA	4.1E-11	8.8E-10	1.1E-10
Th-232	6.0E-12	1.1E-11	1.1E-11	7.8E-12
U-234	NA	6.6E-10	4.2E-09	1.1E-10
U-235	NA	4.9E-09	8.8E-08	1.4E-09
U-238	1.2E-09	1.5E-08	5.7E-09	7.8E-09
Sum	1.4E-07	3.4E-06	3.3E-06	2.8E-06

[a] Includes risks from ingestion of soil and external gamma exposures.
[b] NA indicates this radionuclide is not a constituent of potential concern in this area.

TABLE 5-13

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS TO A TRESPASSING CHILD FROM ON-PROPERTY SOIL UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Chemical	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Aroclor-1254	NA[b]	NA	NA	1.5E-06
Aroclor-1260	NA	NA	NA	1.9E-06
Benzo(a)pyrene	NA	NA	NA	4.9E-06
Beryllium	NA	NA	NA	6.9E-09
Bis(2-ethylhexyl) phthalate	NA	NA	NA	1.3E-09
Chloroform	NA	NA	NA	4.7E-12
Methylene chloride	NA	NA	NA	2.1E-11
N-Nitrosodiphenylamine	NA	NA	NA	1.2E-10
Tetrachloroethene	NA	NA	NA	2.6E-11
Trichloroethene	NA	NA	NA	9.8E-12
Sum	NA	NA	NA	8.3E-06

[a] Pathways evaluated include incidental ingestion of soil and dermal contact with soil.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-14
HAZARD INDICES TO A TRESPASSING CHILD FROM ON-PROPERTY SOIL UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Chemical	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
1,1,1-Trichloroethane	NA[b]	NA	NA	3.3E-08
2-Butanone	NA	NA	NA	2.3E-07
Acenaphthene	NA	NA	NA	3.1E-08
Acetone	NA	NA	NA	1.2E-07
Anthracene	NA	NA	NA	2.0E-06
Antimony	NA	NA	NA	6.1E-04
Arsenic	NA	NA	NA	2.4E-04
Barium	NA	NA	NA	3.0E-05
Benzoic acid	NA	NA	NA	4.6E-08
Beryllium	NA	NA	NA	1.9E-06
Bis(2-ethylhexyl)phthalate	NA	NA	NA	2.6E-05
Carbon disulfide	NA	NA	NA	2.2E-08
Chlorobenzene	NA	NA	NA	3.7E-09
Chloroform	NA	NA	NA	4.4E-07
Cobalt	NA	NA	NA	5.0E-05
Cyanide	NA	NA	NA	7.1E-08
Dibenzofuran	NA	NA	NA	5.6E-05
Fluoranthene	NA	NA	NA	6.1E-04
Fluorene	NA	NA	NA	2.3E-05
Lead	NA	NA	NA	7.0E-04
Mercury	NA	NA	NA	5.5E-06
Methylene chloride	NA	NA	NA	2.6E-07
Naphthalene	NA	NA	NA	1.1E-05
Nickel	NA	NA	NA	1.6E-05
Pyrene	NA	NA	NA	1.8E-04
Silver	NA	NA	NA	1.6E-05
Tetrachloroethene	NA	NA	NA	3.0E-07

TABLE 5-14
(Continued)

Chemical	Active Flyash Area	Inactive Flyash Area	South Field	Remainder of Site
Toluene	NA	NA	NA	1.1E-08
Uranium	7.1E-06	9.5E-05	4.9E-05	2.6E-04
Zinc	NA	NA	NA	5.0E-06
Total	7E-06	1E-04	5E-05	3E-03

[a] Pathways evaluated include: incidental ingestion of soil and dermal contact with soil.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-15

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES IN SOIL TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS FROM CATTLE GRAZING ON-PROPERTY UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Radionuclide	Remainder of Site	Inactive Flyash Pile	South Field
Cs-137	6.1E-06	6.9E-06	4.6E-06
Np-237	NA[b]	NA	NA
Pu-238	2.7E-12	NA	NA
Pu-239/240	2.9E-12	NA	NA
Ra-226	8.6E-05	1.1E-04	6.2E-05
Ra-228	5.9E-07	4.9E-07	5.1E-07
Sr-90	4.6E-05	NA	NA
Tc-99	3.5E-05	NA	NA
Th-228	1.9E-10	8.4E-11	2.0E-09
Th-230	4.2E-10	1.6E-10	3.4E-09
Th-232	3.1E-11	4.3E-11	4.6E-11
U-234	4.5E-07	2.6E-06	1.7E-05
U-235	1.8E-08	6.1E-08	1.1E-06
U-238	1.1E-06	2.1E-06	8.0E-07
Sum	1.8E-04	1.2E-04	8.6E-05

[a] Includes soil ingestion, external gamma exposures, and ingestion of meat and dairy products.
[b] NA indicates this nuclide is not a constituent of concern in this area.

TABLE 5-16

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS IN SOIL TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS FROM CATTLE GRAZING ON-PROPERTY UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Chemical	Remainder of Site	Inactive Flyash Pile	South Field
Beryllium	3.2E-06	NA[b]	NA
Aroclor-1254	9.6E-04	NA	NA
Aroclor-1760	8.8E-04	NA	NA
Benzo(a)pyrene	1.9E-03	NA	NA
Bis(2-ethythexyl)	1.5E-07	NA	NA
Chloroform	1.4E-11	NA	NA
Methylene chloride	3.2E-11	NA	NA
N-nitrosodiphenyla	1.7E-09	NA	NA
Tetrachloroethene	2.6E-10	NA	NA
Trichlorethene	5.8E-11	NA	NA

[a] Includes beef and dairy ingestion.
[b] NA indicates this nuclide is not a constituent of concern in this area.

Beryllium, Aroclor-1254, Aroclor-1260 and benzo(a)pyrene had ILCRs above 1×10^{-6}. Benzo(a)pyrene was a major contributor to the risks with ILCRs of 1×10^{-3}.

HIs for this scenario are presented in Table 5-17. Two chemicals in the remainder of the site had HIs greater than 0.2: mercury (3), and zinc (3). His for uranium in the three sites evaluated were all less than 0.2.

5.2.1.6 External Gamma

Above-background human health risks from external radiation exposure are quantified using the methodology presented in Section 9.2.2.2 of the Addendum (DOE 1992a), and exposure point radiation dose rates estimated using the MICROSHIELD computer code.

Estimated risks for the external radiation exposure pathway from the waste pits and waste storage silos are tabulated separately for a trespassing child exposed under current land-use scenarios with and without access controls. Assumptions concerning exposure time for each case are addressed in Table 3-15.

Estimated risks from external radiation exposure from the waste pits and waste storage silos under the current land-use scenario assuming current access controls continue are presented in Table 5-18. Examination of Table 5-18 reveals that the risks associated with exposure of the trespassing child are approximately 3×10^{-4} on the waste silos, but 1×10^{-6} or less on the waste pits. At a distance of about 100 meters from Silo 3 or the K-65 berm the risk from the estimated annual dose is less than 1×10^{-6} (Table 5-18).

5.2.2 Current Land-Use Scenario Without Access Controls

5.2.2.1 Air

The assessments of exposure and risk for air pathways presented in Section 5.2.1 under the current land-use scenario without access controls include two of the same receptors as the current land use scenario with access controls, the adjacent off-property farmer and the farmer using the Great Miami River as the primary source of water. These exposure scenarios are not effected by the presence or absence of access controls and the estimated risks from them have already been discussed in Section 5.2.1.1. Risks from exposure via air pathways for the three remaining receptors (trespassing child, hunter, and scavenger) were not presented because the combination of low measured air concentration (WEMCO, 1990) and short exposure times were determined to produce a fraction of the risk estimated for a 70-year exposure by the adjacent off property farmer.

TABLE 5-17

HAZARD INDICES FROM CHEMICALS IN SOIL
TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS
FROM CATTLE GRAZING ON-PROPERTY
UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS[a]

Chemical	Remainder of Site	Inactive Flyash Pile	South Field
Antimony	4.4E-02	NA[b]	NA
Arsenic	8.2E-02	NA	NA
Barium	2.0E-02	NA	NA
Beryllium	1.5E-04	NA	NA
Cobalt	1.4E-01	NA	NA
Lead	1.5E-01	NA	NA
Mercury	3.3E+00	NA	NA
Nickel	3.4E-02	NA	NA
Silver	6.8E-02	NA	NA
Zinc	2.73+00	NA	NA
1,1,1-Trichoroeth	2.9E-08	NA	NA
2-Butanone	2.2E-08	NA	NA
Acetone	7.2E-09	NA	NA
Anthracene	1.4E-05	NA	NA
Benzoic Acid	2.2E-08	NA	NA
Bis(2-ethyhexyl)	5.5E-04	NA	NA
Carbon disulfide	1.4E-05	NA	NA
Chlorobenzene	4.5E-09	NA	NA
Chloroform	2.3E-07	NA	NA
Cyanide	5.7E-07	NA	NA
Dibenzofuran	2.6E-04	NA	Na
Fluoranthene	1.3E-02	NA	NA
Fluorene	1.2E-04	NA	NA
Methylene Chloride	7.0E-08	NA	NA

Chemical	Remainder of Site	Inactive Flyash Pile	South Field
Pyrene	3.3E-03	NA	NA
Tetrachloroethane	5.0E-07	NA	NA
Toluene	1.2E-08	NA	NA
Uranium	1.9E-01	7.1E-02	3.6E-02

[a] Includes beef and dairy ingestion.

[b] NA indicates this chemical is not a constituent of concern in this area.

TABLE 5-18

RISKS FROM EXTERNAL RADIATION EXPOSURE FOR THE WASTE STORAGE AREA UNDER THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS

	Visitor	Off-Property Farmer	On Silo or Pit Trespassing Child	Adjacent to K-65 Berm/Silo 3 Trespassing Child	100 Meters from K-65 Berm/Silo 3 Trespassing Child
Silo 1 or 2	NA[a]	NA	3.6E-04 (2.8E-04)[b]	0[c]	0[c]
Silo 3	NA	NA	2.2E-04	2.3E-04	8.7E-07
Pit 1	NA	NA	NM[d]	NM	NM
Pit 2	NA	NA	NM	NM	NM
Pit 3	NA	NA	NM	NM	NM
Pit 4	NA	NA	NM	NM	NM
Burn Pit	NA	NA	NM	NM	NM
Composite[e]	NA	NA	NM	NM	NM

[a] Not applicable, assuming the visitor (delivery person), the off-property farmer, and the building user/scavenger are not exposed at the waste pits or silos.
[b] The first value is based on the model result (MICROSHIELD) and the value in parentheses is based on a measured dose rate.
[c] Modeled dose rate is essentially indistinguishable from zero.
[d] Risks not modeled because modeled dose rates on top of the pits are close to background.
[e] Results in the row labeled "Composite" are based on an area-weighted average dose rate calculated by multiplying each modeled dose rate by the relative surface area of the pit.

5.2.2.2 Groundwater

The receptor pathways and areas evaluated for groundwater under current land-use without access controls are identical to current land-use with access controls because the use of groundwater near the FEMP does not include the use of on-property wells. The use of groundwater from wells located on property is assumed to involve development time for improvement of the property by on-property residents (i.e., home building, well drilling, planting, harvesting). These activities are included in the future land-use scenario.

5.2.2.3 Surface Water

Exposures received by the farmer using surface water from the Great Miami River are not affected by the presence or absence of access. Risks to this farmer are presented in Section 5.2.1.3.

5.2.2.4 Meat and Dairy Products Produced with Surface Water

The receptor evaluated under this scenario is an adult off-property user of meat and dairy products. Without access controls it is assumed that cattle can access and drink from Waste Pit 5, Waste Pit 6, and the Clearwell, in addition to those areas discussed in the previous section. The pathways that were evaluated include:

- Ingestion of milk /dairy products
- Ingestion of beef

Tables 5-19 through 5-21 present the estimated risks to humans from this behavior. Table 5-20 illustrates that the cattle on the property were the primary source of beef and dairy products to an off-property resident, the risks from the radiological constituents would range from 10^{-5} to 10^{-4}. Using Clearwell water as the stock water would potentially pose the highest radionuclide ILCRs via these exposure pathways. Uranium-238 and U-234 contribute approximately 57 percent and 10 percent, respectively, of the estimated ILCRs for the Clearwell, while Tc-99 contributes 31 percent.

The ILCRs for chemical constituents are presented in Table 5-20. Only bis(2-ethylhexyl) phthalate in Waste Pit 6 resulted in an ILCR above 1×10^{-6}.

HIs for this scenario are presented in Table 5-21. Mercury, uranium and zinc had HI values above 0.2. The highest HIs were in the Clearwell for mercury (5) and uranium (6).

TABLE 5-19

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES TO THE OFF-PROPERTY BEEF AND DAIRY PRODUCTS PRODUCED WITH ON-PROPERTY SURFACE WATER UNDER THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS[a]

Radionuclide	Waste Pit 5	Waste Pit 6	Clearwell
Ra-226	NA[b]	NA	1.3E-07
Ra-228	NA	2.6E-07	2.6E-07
Sr-90	1.2E-06	NA	NA
Tc-99	2.1E-06	4.0E-06	2.7E-05
Th-228	NA	1.8E-09	1.8E-09
Th-230	1.0E-08	1.0E-08	1.0E-08
U-234	1.9E-06	3.5E-07	8.6E-06
U-235/236	8.6E-08	4.0E-08	5.4E-07
U-238	3.2E-06	3.6E-06	4.9E-05
Sum	8.5E-06	8.3E-06	8.6E-05

[a] Includes risks from ingesting beef and dairy products produced with on-property surface water.
[b] Not a constituent of potential concern for a given surface water body.

TABLE 5-20

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS PRODUCED WITH ON-PROPERTY SURFACE WATER UNDER THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS[a]

Chemical	Waste Pit 5	Waste Pit 6	Clearwell
Benzene	5.1E-08	NA[b]	NA
Bis(2-ethylhexyl)phthalate	NA	9.5E-05	3.7E-07
Chloroform	NA	5.5E-12	1.3E-11
Methylene chloride	NA	2.0E-09	1.0E-09
N-nitroso-di-phenylamine	NA	NA	NA
Tetrachloroethene	NA	5.9E-10	NA

[a] The pathways that were evaluated include: ingestion of milk/dairy products, and ingestion of beef.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

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TABLE 5-21

HAZARD INDICES FROM CHEMICALS TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS PRODUCED WITH ON-PROPERTY SURFACE WATER UNDER THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS[a]

Chemical	Waste Pit 5	Waste Pit 6	Clearwell
Acetone	NA	4.8E-07	8.0E-07
Bis(2-ethylhexyl)phthalate	NA	3.3E-03	1.3E-03
Chlorobenzene	NA	NA	NA
Chloroform	NA	NA	2.1E-07
Di-n-butyl-phthalate	6.1E-05	3.7E-11	6.1E-05
1,1-Dichloroethene	NA	NA	NA
Diethylphthalate	NA	NA	NA
Methylene chloride	NA	4.4E-06	2.2E-06
Phenol	NA	NA	NA
Tetrachloroethene	NA	NA	NA
Toluene	1.4E-06	2.8E-06	NA
Antimony	NA	NA	NA
Arsenic	NA	NA	NA
Barium	NA	NA	NA
Beryllium	NA	NA	NA
Cadmium	NA	NA	NA
Chromium	NA	NA	NA
Cobalt	NA	NA	NA
Cyanide	NA	NA	NA
Lead	NA	NA	NA
Manganese	NA	NA	1.4E-03
Mercury	NA	1.8E+00	5.1E+00
Molybdenum	NA	NA	NA
Nickel	NA	NA	NA
Selenium	NA	NA	0.00
Silver	NA	NA	8.2E-02

TABLE 5-21
(Continued)

Chemical	Waste Pit 5	Waste Pit 6	Clearwell
Uranium	4.0E-01	4.5E-01	6.1E+00
Zinc	8.1E-01	1.1E+00	NA

[a] The pathways that were evaluated include: ingestion of milk/dairy products, and ingestion of beef.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

5.2.2.5 Sediment

Risks to the trespassing child (ages 6 through 17) from sediment are evaluated using the same pathways considered in Section 5.2.1.5. However, assuming access controls are discontinued, the child may have easier, more frequent access to the same areas listed in Section 5.2.1.5, as well as the SSOD. Thus, the scenario-specific risks are higher for the scenario.

Table 5-9 also presents ILCRs for this scenario from radionuclides in sediment. Risks in Paddys Run are calculated to be less than 10^{-8}. Uranium isotopes contribute over 90 percent of these estimated risks. In the SSOD, radium isotopes dominate the risks, contributing just over 95 percent of the total 1.1×10^{-8} risk.

ILCRs for the scenario are presented in Table 5-10. Results for the two carcinogens are all below 1×10^{-7}. No chemical carcinogens were found in the SSOD. The HI for uranium in the SSOD was 2×10^{-4} (Table 5-11). No HIs were above 0.2.

5.2.2.6 Soil

The pathways that were evaluated include:

- Incidental ingestion of soil
- Dermal contact with soil
- Ingestion of milk/dairy products
- Ingestion of beef

The receptors evaluated under this exposure scenario are a trespassing child (incidental ingestion and dermal contact), an off-property user of beef and dairy products grown on property, a hunter and a scavenger. Risks to the hunter were not quantified, because measured concentrations in on-property game meat are below detection limits (Section 3.2.1). Risks to a scavenger are presented in Section 5.2.2.8.

The following areas were addressed for this scenario:

- Southwest quadrant of the former Production Area
- Southeast quadrant of the former Production Area
- Northwest quadrant of the former Production Area
- Northeast quadrant of the former Production Area
- Waste Storage Area
- Waste Pit 5
- Incinerator Area
- Active Flyash Pile
- Inactive Flyash Pile
- South Field
- The site as a whole.

Soil exposure pathways for other areas on property are quantified in Section 5.2.1.5.

ILCRs for radionuclides associated with the trespassing child exposure scenario are presented in Table 5-22. The risks to the trespassing child receptor from all radionuclides in the former Production Area quadrants, the waste storage area, Waste Pit 5, and the Incinerator Area range from approximately 8×10^{-7} to 4×10^{-5}. The greatest risk is associated with the northwestern quadrant of the former Production Area. No one radionuclide consistently dominates the pathway risks in Table 5-22.

Table 5-23 presents ILCRs for chemical carcinogens for the trespassing child scenario. No chemical carcinogens were detected in the SE quadrant, Active Flyash Pile or Inactive Flyash Pile, the Incinerator Area, or the South Field. The following chemicals had ILCRs above 1×10^{-6}: Aroclor-1248 (Waste Pit 5), Aroclor-1254 (NW, NE, SW quadrants, waste storage area, Waste Pit 5 and remainder of the site), benzo(a)pyrene (NE and SW quadrants, and remainder of the site), beryllium (Waste Pit 5).

HIs for this scenario are presented in Table 5-24. HI values for the Active Flyash Pile and South Field are all below 0.2. The HI values for soil on the remaining site are the same as for current land use with access controls (Section 5.2.1.6). The following chemicals have HI values greater than one: arsenic, barium, cadmium, lead, mercury, uranium, vanadium, and zinc. The areas with chemical-specific HIs greater than one include: northwest, northeast, southeast, and southwest quadrants of the former Production Area, waste storage area, and Waste Pit 5.

Cattle might graze in the waste storage area or the former Production Areas if access controls are removed. Tables 5-25 through 5-27 present the estimated risks to humans from this behavior. Table 5-25 illustrates that the cattle on the property were the primary source of beef and dairy products to an off-property resident, the risks from radiological constituents in FEMP soils would range from 10^{-6} to 10^{-1}. The highest risks are produced by using animal products from cattle grazing on the exposed area of Waste Pit 5, and do not appear reasonable for two reasons. First, if the migratory behavior of cattle is considered, a given cow can be expected to roam over the entire property, and not stay in just one area. Thus, it is unlikely that it would be exposed to conditions in Waste Pit 5 for protracted periods of its life. Second, even if cattle were confined to the Waste Pit 5 area it is doubtful whether humans could obtain a lifetime supply of beef and dairy products from such a small land area. Therefore, this calculated risk (10^{-1}) should be treated as an upper bound risk for this exposure pathway. A more reasonable risk range, based on this information is 10^{-6} to 10^{-3}.

TABLE 5-22

INCREMENTAL LIFETIME CANCER RISK TO TRESPASSING CHILD FROM RADIONUCLIDES IN SOIL UNDER THE CURRENT LAND-USE SCENARIOS WITH ACCESS CONTROLS[a,b]

Radionuclide	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator
Cs-137	1.5E-08	1.1E-08	2.4E-08	6.4E-08	9.5E-09	5.1E-08	1.4E-08
Np-237	NA	NA	NA	NA	6.7E-10	9.1E-08	NA
Pu-238	NA	NA	3.3E-10	NA	2.3E-11	4.0E-10	5.1E-11
Pu-239/240	NA	NA	1.2E-10	5.0E-11	2.4E-11	1.1E-09	4.8E-11
Ra-226	3.4E-05	1.5E-07	1.1E-07	1.2E-07	1.6E-07	7.9E-06	1.5E-06
Ra-228	1.4E-06	1.9E-06	5.1E-06	7.7E-08	1.0E-06	1.5E-06	1.4E-07
Ru-106	NA	NA	NA	NA	1.4E-11	NA	NA
Sr-90	1.1E-11	1.1E-13	1.7E-11	1.2E-11	5.6E-12	1.7E-10	3.1E-11
Tc-99	5.2E-13	6.9E-07	2.4E-11	6.3E-13	1.5E-12	1.1E-09	1.6E-12
Th-228	9.8E-07	2.3E-09	1.9E-05	1.8E-07	6.7E-07	7.3E-06	1.6E-07
Th-230	3.6E-09	5.7E-06	1.9E-09	1.2E-10	1.1E-08	1.0E-07	1.1E-09
Th-232	1.9E-10	1.6E-10	1.7E-09	2.1E-11	1.7E-11	2.8E-10	3.8E-11
U-234	1.4E-08	1.2E-09	1.0E-07	4.8E-09	1.7E-09	7.0E-09	6.3E-08
U-235	2.6E-07	1.3E-08	1.3E-06	9.1E-08	6.2E-08	8.3E-08	1.9E-06
U-238	7.8E-07	3.2E-07	5.7E-06	2.9E-07	1.1E-07	1.0E-07	4.1E-06
Sum	3.7E-05	2.6E-06	3.1E-05	8.3E-07	2.0E-06	1.7E-05	7.9E-06

a Areas listed in Table 5-XX are also accessible under this scenario and the risk listed under those areas supplement the risk information provided in this table.
b Includes risks from ingestion of soil and exposure to internal gamma radiation.

TABLE 5-23

INCREMENTAL LIFETIME CANCER RISKS TO TRESPASSING CHILD FROM CHEMICALS IN SOIL UNDER CURRENT LAND-USE SCENARIOS WITHOUT ACCESS CONTROLS[a]

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator
Aroclor-1248	NA[b]	NA	NA	NA	NA	1.6E-05	NA
Aroclor-1254	4.4E-05	3.5E-05	2.6E-05	NA	2.1E-05	2.2E-05	NA
Benzo(a)pyrene	NA	5.3E-04	1.1E-04	NA	NA	NA	NA
Beryllium	NA	NA	4.4E-07	NA	NA	2.9E-06	NA
Bis(2-ethylhexyl) phthalate	1.1E-07	4.3E-08	9.9E-09	NA	NA	6.8E-08	NA
Chloroform	NA	2.3E-10	NA	NA	NA	NA	NA
Methylene chloride	NA	7.3E-10	5.9E-10	NA	NA	1.1E-08	NA
N-Nitrosodiphenylamine	NA	3.7E-09	1.9E-09	NA	NA	NA	NA
Tetrachloroethene	NA	1.4E-09	3.9E-10	NA	NA	NA	NA
Trichloroethene	NA	4.6E-10	1.7E-10	NA	NA	NA	NA

TABLE 5-23
(Continued)

Chemical	Active Flyash	Inactive Flyash	SouthField	Remainder of Site
Aroclor-1254	NA	NA	NA	4.4E-05
Benzo(a)pyrene	NA	NA	NA	1.5E-04
Beryllium	NA	NA	NA	2.1E-07
Bis(2-ethylhexyl) phthalate	NA	NA	NA	7.6E-08
Chloroform	NA	NA	NA	1.4E-10
Methylene chloride	NA	NA	NA	1.3E-09
N-Nitrosodiphenylamine	NA	NA	NA	3.7E-10
Tetrachloroethene	NA	NA	NA	7.8E-10
Trichloroethene	NA	NA	NA	2.9E-10

[a] The pathways that were evaluated include: incidental ingestion of soil, dermal contact with soil, ingestion of milk/dairy products, and ingestion of beef.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-24

HAZARD INDICES TO TRESPASSING CHILD FROM SOIL
UNDER THE CURRENT LAND-USE SCENARIOS WITHOUT ACCESS CONTROLS[a,b]

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator Area
1,1,1-Trichloroethane	NA[c]	1.2E-06	NA	NA	NA	NA	NA
1,2-Dichloroethene	NA	NA	NA	NA	NA	NA	NA
2-Butanone	NA	7.0E-06	4.0E-06	NA	NA	NA	NA
Acenaphthene	NA	3.3E-06	1.4E-06	NA	NA	NA	NA
Acetone	NA	3.5E-06	4.6E-06	NA	NA	1.4E-04	NA
Anthracene	NA	2.4E-04	1.4E-04	NA	NA	NA	NA
Antimony	2.3E-02	4.8E-03	NA	NA	2.0E-02	2.1E-02	NA
Arsenic	NA	1.4E-02	NA	NA	NA	1.5E+00	NA
Barium	1.7E-03	NA	NA	NA	NA	1.2E-01	NA
Benzoic acid	NA	1.4E-06	NA	NA	NA	NA	NA
Beryllium	NA	NA	1.2E-04	NA	NA	8.0E-04	NA
Beta-BHC	NA	NA	NA	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	NA	8.6E-04	2.0E-04	NA	NA	1.4E-03	NA
Cadmium	NA	NA	NA	NA	NA	5.1E-02	NA
Carbon disulfide	NA	6.7E-07	NA	NA	NA	NA	NA
Chlorobenzene	NA	1.1E-07	NA	NA	NA	NA	NA
Chloroform	NA	2.2E-05	NA	NA	NA	NA	NA
Chromium	NA	NA	NA	NA	NA	1.1E-02	NA
Cobalt	2.4E-03	NA	NA	NA	NA	5.0E-03	NA
Cyanide	3.3E-06	2.1E-04	5.7E-06	NA	2.3E-06	NA	NA
Di-n-butyl phthalate	NA	NA	NA	NA	NA	5.5E-05	NA

TABLE 5-24
(Continued)

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator Area
Dibenzofuran	NA	2.6E-03	1.3E-03	NA	NA	NA	NA
Fluoranthene	NA	9.5E-03	3.6E-03	NA	NA	NA	NA
Fluorene	NA	1.0E-03	6.4E-04	NA	NA	NA	NA
Lead	2.4E-02	5.4E-02	1.3E-01	NA	NA	8.8E-02	NA
Manganese	NA	NA	NA	NA	NA	9.7E-03	NA
Mercury	NA	4.1E-04	9.7E-04	NA	NA	1.5E-03	NA
Methylene chloride	NA	8.6E-06	7.8E-06	NA	NA	1.4E-04	NA
Naphthalene	NA	4.8E-04	NA	NA	NA	NA	NA
Nickel	5.7E-04	8.8E-04	7.5E-04	NA	4.3E-04	3.0E-03	NA
Pyrene	NA	8.7E-03	4.8E-03	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	4.5E-04	NA
Silver	5.3E-04	NA	6.6E-04	NA	5.3E-04	5.6E-04	NA
Tetrachloroethene	NA	1.6E-05	4.4E-06	NA	NA	NA	NA
Toluene	NA	3.3E-07	2.2E-07	NA	NA	NA	NA
Uranium	3.0E-03	7.8E-03	4.3E-01	7.7E-02	5.1E-02	1.9E-02	5.8E-01
Vanadium	NA	NA	NA	NA	NA	1.9E-01	NA
Zinc	1.5E-04	5.0E-04	4.7E-04	NA	NA	3.1E-04	NA

TABLE 5-24
(Continued)

Chemical	Acitve Flyash	Inactive Flyash	SouthField	Remainder of Site
1,1,1-Trichloroethane	NA	NA	NA	9.9E-07
1,2-Dichloroethene	NA	NA	NA	NA
2-Butanone	NA	NA	NA	6.6E-06
Acenaphthene	NA	NA	NA	9.4E-07
Acetone	NA	NA	NA	3.5E-06
Anthracene	NA	NA	NA	6.0E-05
Antimony	NA	NA	NA	1.8E-02
Arsenic	NA	NA	NA	7.1E-03
Barium	NA	NA	NA	8.9E-04
Benzoic acid	NA	NA	NA	1.4E-06
Beryllium	NA	NA	NA	5.6E-05
Beta-BHC	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	NA	NA	NA	7.8E-04
Cadmium	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	6.7E-07
Chlorobenzene	NA	NA	NA	1.1E-07
Chloroform	NA	NA	NA	1.3E-05
Chromium	NA	NA	NA	NA
Cobalt	NA	NA	NA	1.5E-03
Cyanide	NA	NA	NA	2.1E-06
Di-n-butyl phthalate	NA	NA	NA	NA
Dibenzofuran	NA	NA	NA	1.7E-03

TABLE 5-24
(Continued)

Chemical	Acitve Flyash	Inactive Flyash	SouthField	Remainder of Site
Fluoranthene	NA	NA	NA	1.8E-02
Fluorene	NA	NA	NA	6.9E-04
Lead	NA	NA	NA	2.1E-02
Manganese	NA	NA	NA	NA
Mercury	NA	NA	NA	1.7E-04
Methylene chloride	NA	NA	NA	8.1E-06
Naphthalene	NA	NA	NA	3.3E-04
Nickel	NA	NA	NA	4.9E-04
Pyrene	NA	NA	NA	5.4E-03
Selenium	NA	NA	NA	NA
Silver	NA	NA	NA	4.7E-04
Tetrachloroethene	NA	NA	NA	8.9E-06
Toluene	NA	NA	NA	3.3E-07
Uranium	2.1E-04	2.8E-03	1.4E-03	7.7E-03
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	1.5E-04

[a] Areas listed in Table 5-18 are also accessible under this scenario, and the HIs listed under those supplement the risk information provided in this table.
[b] The pathways that were evaluated include: incidental ingestion of soil, dermal contact with soil, ingestion of milk/dairy products, and ingestion of beef.
[c] Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-25

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES IN SOIL TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS FROM CATTLE GRAZING ON PROPERTY UNDER THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS[a,b]

Radionuclide	NW Quad	NE Quad	SW Quad	SE Quad	Waste Pit Area	Exposed Pit 5	Incinerator	Active Flyash Pile
Cs-137	6.9E-06	5.0E-06	1.1E-05	2.8E-05	4.2E-06	2.3E-05	6.1E-06	NA
Np-237	NA[c]	NA	NA	NA	2.2E-08	2.9E-06	NA	NA
Pu-238	NA	NA	2.4E-11	NA	1.7E-12	3.0E-11	3.7E-12	NA
Pu-239/240	NA	NA	9.6E-12	3.8E-12	1.8E-12	8.4E-11	3.8E-12	NA
Ra-226	1.1E-03	5.1E-06	3.5E-06	4.0E-06	5.2E-06	2.6E-04	4.9E-05	1.5E-06
Ra-228	1.2E-05	1.6E-05	4.3E-05	6.4E-07	8.6E-06	1.2E-05	1.2E-06	2.8E-07
Ru-106	NA	NA	NA	NA	2.7E-07	NA	NA	NA
Sr-90	3.1E-05	3.2E-05	5.1E-05	3.7E-05	1.7E-05	5.1E-04	9.2E-05	NA
Tc-99	4.5E-05	6.1E-05	2.1E-03	5.5E-05	1.3E-04	9.9E-02	1.4E-04	NA
Th-228	1.5E-09	3.5E-10	2.9E-08	2.7E-10	1.0E-09	1.1E-08	2.5E-10	9.3E-11
Th-230	1.4E-08	2.2E-08	7.3E-09	4.7E-10	4.1E-08	3.9E-07	4.2E-09	NA
Th-232	7.4E-10	6.5E-10	6.7E-09	8.4E-11	7.0E-11	1.1E-09	1.5E-10	2.4E-11
U-234	5.4E-05	4.8E-06	4.3E-04	1.9E-05	6.7E-06	2.8E-05	2.5E-04	NA
U-235	3.3E-06	1.6E-07	1.6E-05	1.1E-06	7.8E-07	1.0E-06	2.3E-05	NA
U-238	1.1E-04	4.4E-05	8.0E-04	4.0E-05	1.5E-05	1.4E-05	5.7E-04	1.6E-07
Sum	1.4E-03	1.7E-04	3.5E-03	1.8E-04	1.9E-04	1.0E-01	1.1E-03	1.9E-06

[a] Includes ingestion of meat and dairy products
[b] Areas listed in Table 5-16 are also accessible under this scenario, and the risk listed under those areas supplement the risk information provided in this table.
[c] NA indicates this radionuclide was not a constituent of concern in this area.

TABLE 5-26

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS IN SOIL TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS FROM CATTLE GRAZING ON PROPERTY UNDER THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS[a,b]

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator
Aroclor-1248	NA[c]	NA	NA	NA	NA	3.0E-04	NA
Aroclor-1254	1.4E-03	1.1E-03	8.5E-04	NA	6.9E-04	7.2E-04	NA
Benzo(a)pyrene	NA	2.5E-02	5.3E-03	NA	NA	NA	NA
Beryllium	NA	NA	2.3E-05	NA	NA	1.5E-04	NA
Beta-BHC	NA	7.9E-06	1.2E-05	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	NA	6.2E-07	1.4E-07	NA	NA	9.8E-07	NA
Chloroform	NA	2.5E-09	NA	NA	NA	NA	NA
Methylene chloride	NA	8.1E-09	6.5E-09	NA	NA	1.2E-07	NA
N-Nitrosodiphenylamine	NA	4.0E-08	2.0E-08	NA	NA	NA	NA
Tetrachloroethene	NA	1.5E-08	4.4E-09	NA	NA	NA	NA
Trichloroethene	NA	5.1E-09	1.8E-09	NA	NA	NA	NA
Sum	1.4E-03	2.6E-02	6.2E-03	NA	6.9E-04	1.2E-03	NA

[a] Areas listed in Table 5-17 are also accessible under this scenario and the risks listed under those areas supplement the risk information provided in this table.
[b] The pathways that were evaluated include: ingestion of milk/dairy products and ingestion of beef.
[c] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-27

HAZARD INDICES FROM CHEMICALS IN SOIL TO THE OFF-PROPERTY USER OF BEEF AND DAIRY PRODUCTS FROM CATTLE GRAZING ON PROPERTY UNDER THE CURRENT LAND-USE SCENARIOS WITHOUT ACCESS CONTROLS[a,b]

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator Area
1,1,1-Trichloroethane	NA[c]	2.33E-06	NA	NA	NA	NA	NA
1,2-Dichloroethene	NA	2.76E-06	NA	NA	NA	NA	NA
2-Butanone	NA	1.32E-05	7.43E-06	NA	NA	NA	NA
Acenaphthene	NA	1.79E-03	7.51E-04	NA	NA	NA	NA
Acetone	NA	6.60E-06	8.67E-06	NA	NA	2.60E-04	NA
Anthracene	NA	5.04E-04	2.85E-04	NA	NA	NA	NA
Antimony	2.03E-01	4.20E-02	NA	NA	1.77E-01	1.83E-01	NA
Arsenic	NA	7.78E-02	NA	NA	NA	7.79E+00	NA
Barium	7.05E-02	NA	NA	NA	NA	4.96E+00	NA
Benzoic acid	NA	2.60E-06	NA	NA	NA	NA	NA
Beryllium	NA	NA	1.07E-03	NA	NA	7.13E-03	NA
Beta-BHC	NA	1.47E-02	2.14E-02	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	NA	2.21E-03	5.10E-04	NA	NA	3.51E-03	NA
Cadmium	NA	NA	NA	NA	NA	1.16E+00	NA
Carbon disulfide	NA	1.25E-06	NA	NA	NA	NA	NA
Chlorobenzene	NA	2.11E-06	NA	NA	NA	NA	NA
Chloroform	NA	4.16E-05	NA	NA	NA	NA	NA

TABLE 5-27
(Continued)

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator Area
Chromium	NA	NA	NA	NA	NA	3.59E-01	NA
Cobalt	2.46E-01	NA	NA	NA	NA	5.19E-01	NA
Cyanide	2.15E-05	1.42E-03	3.73E-05	NA	1.53E-05	NA	NA
Di-n-butyl phthalate	NA	NA	NA	NA	NA	1.41E-04	NA
Dibenzofuran	NA	5.30E-03	2.27E-03	NA	NA	NA	NA
Fluoranthene	NA	2.46E-02	9.34E-03	NA	NA	NA	NA
Fluorene	NA	2.09E-03	1.30E-03	NA	NA	NA	NA
Lead	3.33E-01	7.29E-01	1.75E+00	NA	NA	1.20E+00	NA
Manganese	NA	NA	NA	NA	NA	4.67E-01	NA
Mercury	NA	8.04E+00	1.92E+01	NA	NA	2.94E+01	NA
Methylene chloride	NA	1.79E-05	1.45E-05	NA	NA	2.68E-04	NA
Naphthalene	NA	8.77E-03	NA	NA	NA	NA	NA
Nickel	4.28E-02	6.61E-02	5.61E-02	NA	3.27E-02	2.27E-01	NA
Pyrene	NA	2.14E-02	1.19E-02	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	NA	5.64E-02	NA
Silver	1.32E-01	NA	1.65E-01	NA	1.32E-01	1.40E-01	NA
Tetrachloroethene	NA	2.97E-05	8.49E-06	NA	NA	NA	NA
Toluene	NA	6.30E-07	4.20E-07	NA	NA	NA	NA

TABLE 5-27
(Continued)

Chemical	NW Quadrant	NE Quadrant	SW Quadrant	SE Quadrant	Waste Storage Area	Waste Pit 5	Incinerator Area
Uranium	1.52E-01	1.39E-01	2.19E+01	3.88E+00	2.67E+00	9.80E-01	2.91E+01
Vanadium	NA	NA	NA	NA	NA	2.22E+00	NA
Zinc	2.73E+00	9.16E+00	8.64E+00	NA	NA	5.59E+00	NA

[a] Areas listed in Table 5-18 are also accessible under this scenario, and the HIs listed under those supplement the risk information provided in this table.
[b] The pathways that were evaluated include: incidental ingestion of soil, dermal contact with soil, ingestion of milk/dairy products, and ingestion of beef.
[c] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

Table 5-26 indicates that ILCRs for chemicals in soils range from 10^{-9} to 10^{-2}. The combined risks from these constituents range from 10^{-4} to 10^{-2}, with risks from benzo(a)pyrene and PCB's dominating.

Table 5-27 contains HIs for this pathway. These HIs range from 4×10^{-7} for toluene to $3 \times 10^{+1}$ for mercury. Concentrations of antimony, arsenic, barium, cadmium, chromium, cobalt, lead, manganese, nickel, silver, uranium, vanadium, and zinc all yield HIs greater than 0.2 in at least one location.

5.2.2.7 External Gamma

External radiation exposures are quantified using radiation dose rates obtained from measurements or estimated using the MICROSHIELD computer code. Assumptions concerning exposure time for each receptor are addressed in Table 3-16.

Estimated risks from external radiation exposure from locations on the waste pits and locations on and adjacent to the waste storage silos under the current land-use scenario assuming access controls are discontinued are presented in Table 5-28. Examination of Table 5-28 reveals that the greatest risk is approximately 1×10^{-2} from exposure of the trespassing child on top of one of the K-65 silo domes. If the trespasser is exposed adjacent to the K-65 berm, the shielding provided by the berm soil results in a modeled risk that is indistinguishable from background contributions. A trespassing child located on top of or adjacent to Silo 3 is exposed to modeled risks of about 7×10^{-3} (Table 5-28). Finally, a trespasser located on the waste pits is exposed to modeled risks of up to 4×10^{-5} per year.

5.2.2.8 Structures

Using the methodology described in Section 5.1.6, risks to scavengers can only be performed for the following three buildings using data available as of December 1, 1991 (see also Section 3.3.6 of Part II)

- Plant 1 (Preparation Plant, Storage and Silos)
- Plant 4 (Green Salt Plant, Warehouse and Maintenance)
- Plant 9 (Special Products).

The results of the risk characterization for ingestion and inhalation by building are shown in Table 5-29. Risks range from 10^{-6} to 10^{-5}.

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TABLE 5-28

RISKS FROM EXTERNAL RADIATION EXPOSURE FOR THE WASTE STORAGE AREA UNDER THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS

	Building User/ Scavenger	On Silo or Pit Trespassing Child	Adjacent to K-65 Berm/Silo 3 Trespassing Child	100 Meters from K-65 Berm/Silo 3 Trespassing Child
Silo 1 or 2	NA[a]	1.1E-02 (8.4E-03)[b]	0[c]	0[c]
Silo 3	NA	6.6E-03	6.8E-03	2.6E-05
Pit 1	NA	NM[d]	NM	NM
Pit 2	NA	NM	NM	NM
Pit 3	NA	NM	NM	NM
Pit 4	NA	NM	NM	NM
Burn Pit	NA	NM	NM	NM
Composite[e]	NA	NM	NM	NM

[a] Not applicable, assuming the visitor (delivery person), the off-property farmer, and the building user/scavenger are not exposed at the waste pits or silos.
[b] The first value is based on the model result (MICROSHIELD) and the value in parentheses is based on a measured dose rate.
[c] Modeled dose rate is essentially indistinguishable from zero.
[d] Risks not modeled because modeled dose rates on top of the pits are close to background.
[e] Results in the row labeled "Composite" are based on an area-weighted average dose rate calculated by multiplying each modeled dose rate by the relative surface area of the pit.

TABLE 5-29

RISK CHARACTERIZATION FOR SCAVENGERS UNDER THE CURRENT LAND-USE SCENARIO

Building Number	Inhalation Risk	Ingestion Risk	Total Risk
1	4.5E-5	4.6×10^{-5}	9.1×10^{-5}
4	6.6E-5	$1.3E \times 10^{-4}$	2.0×10^{-4}
9	9.7E-4	3.7×10^{-4}	1.3×10^{-3}

5.3 RISKS UNDER FUTURE LAND-USE SCENARIOS

Risks are estimated for radionuclides and chemicals of potential concern in air, groundwater, surface water, meat and dairy products produced with surface water, sediment, and soil. Risks are also estimated for external gamma radiation and contamination in structures. Radionuclides and chemicals with an estimated ILCR exceeding 1×10^{-6} are noted and individually discussed. Chemicals with an HI greater than or equal to 0.2 are individually discussed. Radiological risks from direct radiation exposure and exposures associated with existing structures are also evaluated for the future land-use scenario.

5.3.1 Air

The air exposure pathways quantitatively evaluated for the future land-use scenario include:

- Inhalation of resuspended particulates
- Inhalation of volatile or gaseous compounds
- Ingestion of vegetables, meat, and milk contaminated by deposition of airborne particulates on plants

Four receptors were quantitatively evaluated for the airborne exposure pathways. The results from the assessment for one of these receptors, the on-property resident farmer, are presented here. Results of exposures to the home builder, resident child, and home building scenarios are presented in the Site-wide RME discussion in Section 5.5.4.2. It is conceivable the erosion of soil at the FEMP could uncover waste which is presently buried beneath protective caps. In addition, containers could fail, spill their contents on the soil surface. In both of these cases, additional sources of aerial emissions could be added to those sources already presented. Since it is difficult to predict the extent of erosion or container failure over the next 1000 years, a scenario was constructed in which all caps eroded, and all containers lose their integrity. This extremely conservative assumption will provide an upper bound on the potential future exposures associated with contaminated dust and gases from the FEMP. This approach lead to the use of data from subsurface soils as exposure point concentrations (Table 3-11).

Table 5-30 presents the ILCRs from contaminants of concern in particulate and gaseous forms for exposure of the on-property resident farmer. ILCRs from airborne particulates, airborne radon, and all airborne contaminants modeled are presented in risk contour plots in Figure 5-6, Figure 5-7, and Figure 5-8. The risks on property from all airborne particulates reach the 10^{-1} order of magnitude in the vicinity of the waste storage silos (Figure 5-8). The risk associated with exposure

TABLE 5-30

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES IN AIR TO FARMER UNDER THE FUTURE LAND-USE SCENARIO

Radionuclide[a]	Risks To On-Property Resident Farmer	Risks To Farmer Near Elda School	Risks To Farmer Near Township School
Particulates			
Pa-231	4.6E-07	6.9E-11	3.2E-10
Ra-226	4.3E-06	1.1E-09	3.4E-09
Th-230	2.1E-05	2.0E-08	7.5E-08
Th-232	1.4E-04	2.6E-08	1.3E-08
U-233	9.9E-06	9.6E-10	8.0E-11
U-234	2.5E-05	5.4E-08	9.0E-08
U-235	1.1E-06	2.9E-09	5.8E-09
U-238	5.2E-05	1.3E-07	2.1E-07
Sum of particulates	2.5E-04	2.3E-07	4.0E-07
Gases			
Radon	2.2E-02	2.1E-05	1.1E-05
Total (particulates + radon)	2.2E-02	2.1E-05	1.1E-05

[a] Risks include contribution from daughters.

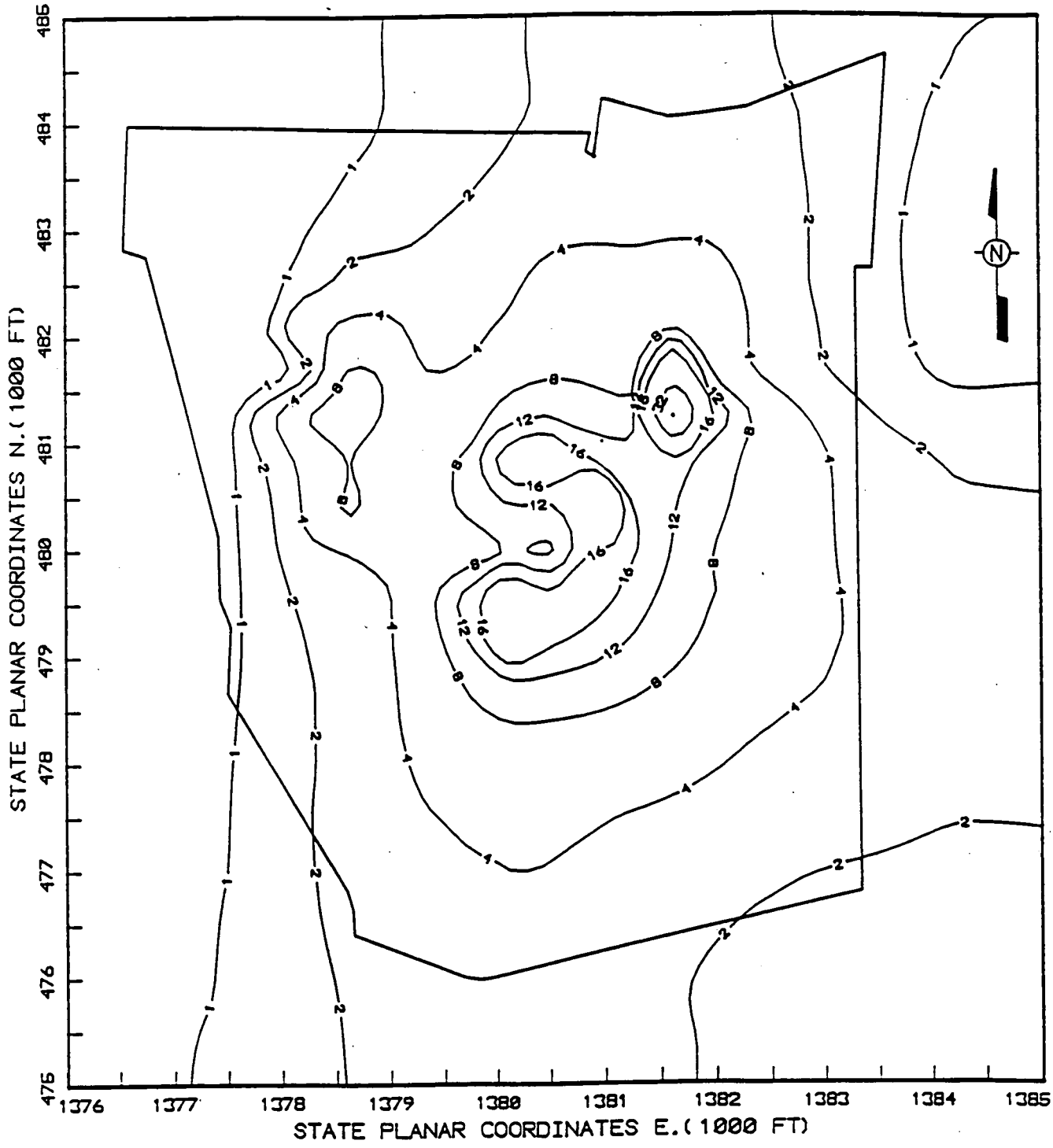

FIGURE 5-6 CONTOUR PLOT OF ILCR (PER 10^{-6}) TO THE HYPOTHETICAL FARMER FROM AIRBORNE PARTICULATES ASSUMING CAPS FAIL

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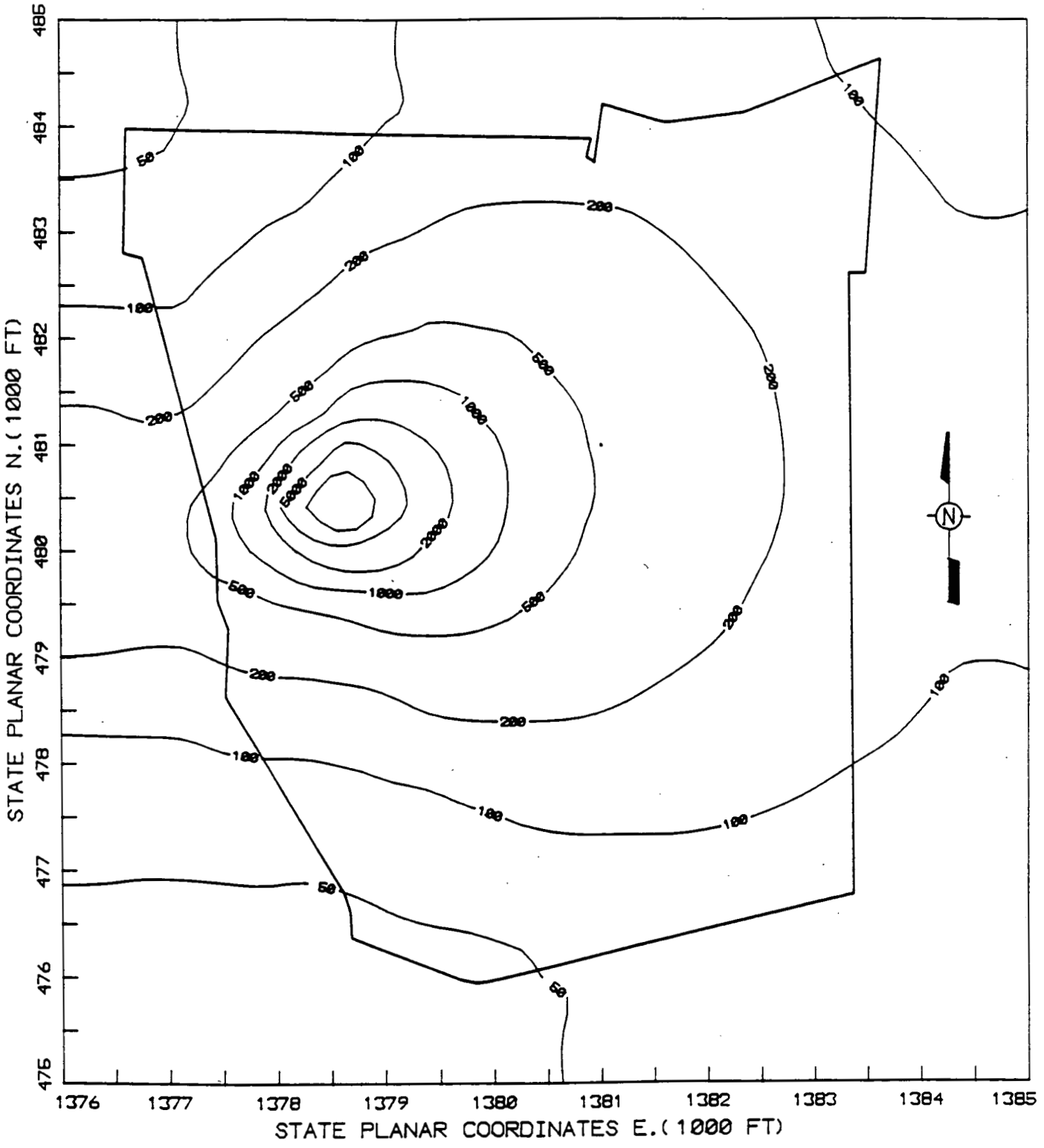

FIGURE 5-7 CONTOUR PLOT OF ILCR (PER 10^{-6}) TO THE HYPOTHETICAL FARMER FROM RADON ASSUMING CAPS FAIL

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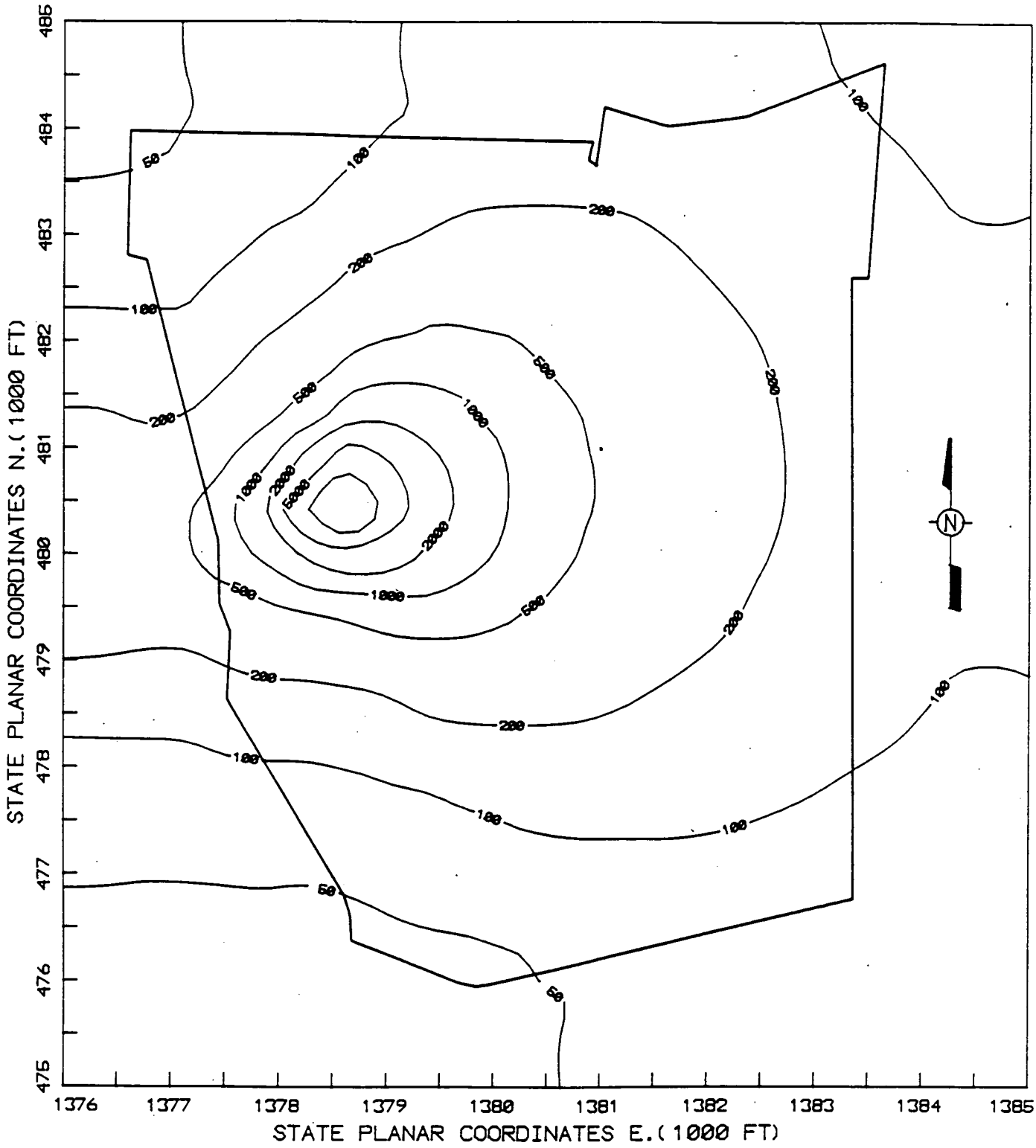

FIGURE 5-8 CONTOUR PLOT OF ILCR (PER 10^{-6}) TO THE HYPOTHETICAL FARMER FROM ALL AIRBORNE CONSTITUENTS ASSUMING CAPS FAIL

of the on-property resident farmer is approximately 2 x 10^{-2}. Risks at two off-property locations are also included in Table 5-31. These off-site risks to farmers living near the Elda and Township schools are approximately 10^{-5}. The greatest risks are contributed by modeled releases of airborne radon from the K-65 silos.

Modeled air concentrations for hazardous chemicals under current and future land-use scenarios are extremely low, at picogram/m^3 levels. Assuming a 70-kg person inhales 0.83 m^3 of air per hour, 24 hours a day, and 350 days per year for 70 years, the hazard index (HI) for lead associated with the modeled concentrations would be 0.000001. Concentrations for future receptors are approximately 100 times higher than off-property concentrations. Again, using the lead example, estimated intakes and corresponding risks would be several orders of magnitude below toxic threshold levels. Because of the low estimated values, the air pathway is not considered a viable pathway for the future land-use scenario in the risk characterization for chemicals.

5.3.2 Groundwater

The pathways that were evaluated include:

- Ingestion of drinking water
- Inhalation of volatiles released from household water use
- Dermal exposure while bathing
- Ingestion of vegetables irrigated with groundwater
- Ingestion of beef
- Ingestion of milk and dairy products

The receptor evaluated under this scenario is an adult resident farmer.

Future exposure point concentrations for groundwater are determined by using transport models to predict the migration of contaminants from potential source terms through the glacial overburden and the regional aquifer (Appendix O). A constituent's modeled concentrations are then multiplied by the appropriate URF in Appendix S to calculate each constituent's risks for each cell in the aquifer model. The maximum risks for each constituent at any location beneath the FEMP are reported in Table 5-31. The results in this table demonstrate that risks from uranium in groundwater beneath the southern portions of the former production area dominate risks from all other nuclides and locations.

The individual risks from each radiological constituent in each cell are then added to the risks from other radionuclides in that cell. The sum of these risks in each cell sum is stored by location in a new array containing the cumulative radiological risks from groundwater. Since each cell corresponds to a unique location at the FEMP, the risks in this array are then plotted on a map

TABLE 5-31

MAXIMUM INCREMENTAL LIFETIME CANCER RISKS TO THE RESIDENT FARMER FROM GROUNDWATER UNDER THE FUTURE LAND-USE SCENARIO

Constituent	Risk	Location
Np-237	1.6E-06[a]	OU1
Sr-90	2.9E-06[a]	OU1
Tc-99	1.7E-07[a]	OU1
Uranium	1.1E-02[a,b]	OU3
Vinyl Chloride	8.7E-04[c]	OU1

[a] Includes risks from drinking water, volatilization of radon, and ingestion of fruit and vegetables, beef and dairy products produced with groundwater.
[b] Evaluated as U-238.
[c] The pathways evaluated include ingestion of drinking water, inhalation of volatiles released from household water use, dermal exposure while bathing, ingestion of fruit and vegetables irrigated with groundwater, ingestion of milk/dairy products, and ingestion of beef.

of the FEMP. This plot is presented as Figure 5-9. Examination of Figure 5-9 reveals that maximum lifetime risks of a 10^{-2} magnitude are associated with the aquifer beneath the waste storage silos and the southern portion of the former production area at 250 years in the future.

The maximum total risk in this array was then found and the location, depth, time, concentration, and total risk were reported as the point of maximum groundwater risk at the FEMP. The estimated risks over time at this location are shown in Figure 5-10. At the maximum risk point, the lifetime risk attained is 1.1×10^{-2}. Note that the risk at this location is zero for the first 100 years, but rises very rapidly to the maximum risk after 100 years. This 100 year lag time is the time required for constituents to move through the mathematical representation of the conceptual model. Once the inputs and outputs of the vadose zone portion of the model have come to equilibrium, the loading rate of the vadose zone model to the aquifer model reaches steady-state conditions. Thus, this lag time in the vadose zone will effect the arrival time of the constituent being modeled at the receptor location, but not its maximum predicted concentration.As plumes of different constituents from various sources pass beneath this location, they add to the cumulative risk. As these plumes are flushed down gradient, the risks decrease. Due to a mathematical artifact of the model, this decrease is step-wise (Figure 5-10).

The constituents contributing most of the radiological risk at this location are uranium and neptunium. Figures 5-11 and 5-12 present plots of the predicted concentrations of these two nuclides over time at the point of maximum risk from groundwater at the FEMP. The shape of the uranium concentration curve coincides with the corresponding plot of risk at the same location, and the magnitude of the predicted uranium concentrations indicates that uranium accounts for nearly all of the estimated risk at the maximum risk point. The next greatest contribution to risk at the maximum risk point is from neptunium. Figure 5-12 presents estimated neptunium concentrations at the maximum risk point plotted versus time to 1000 years in the future.

ILCRs for chemical carcinogens under this scenario are presented in Table 5-32. The only chemical carcinogen that was predicted by groundwater modeling to reach the groundwater from a soil/waste source was vinyl chloride. At the maximum modeled concentration, the resulting ILCR was 8.7×10^{-4}.

Groundwater modeling predicts two areas of vinyl chloride contamination in the aquifer. The first area to appear is centered around Plant 6 in the southwest quadrant of the Product Area. The second appears about 20 years later and originates in the Waste Pit 2 region of the waste storage

3578

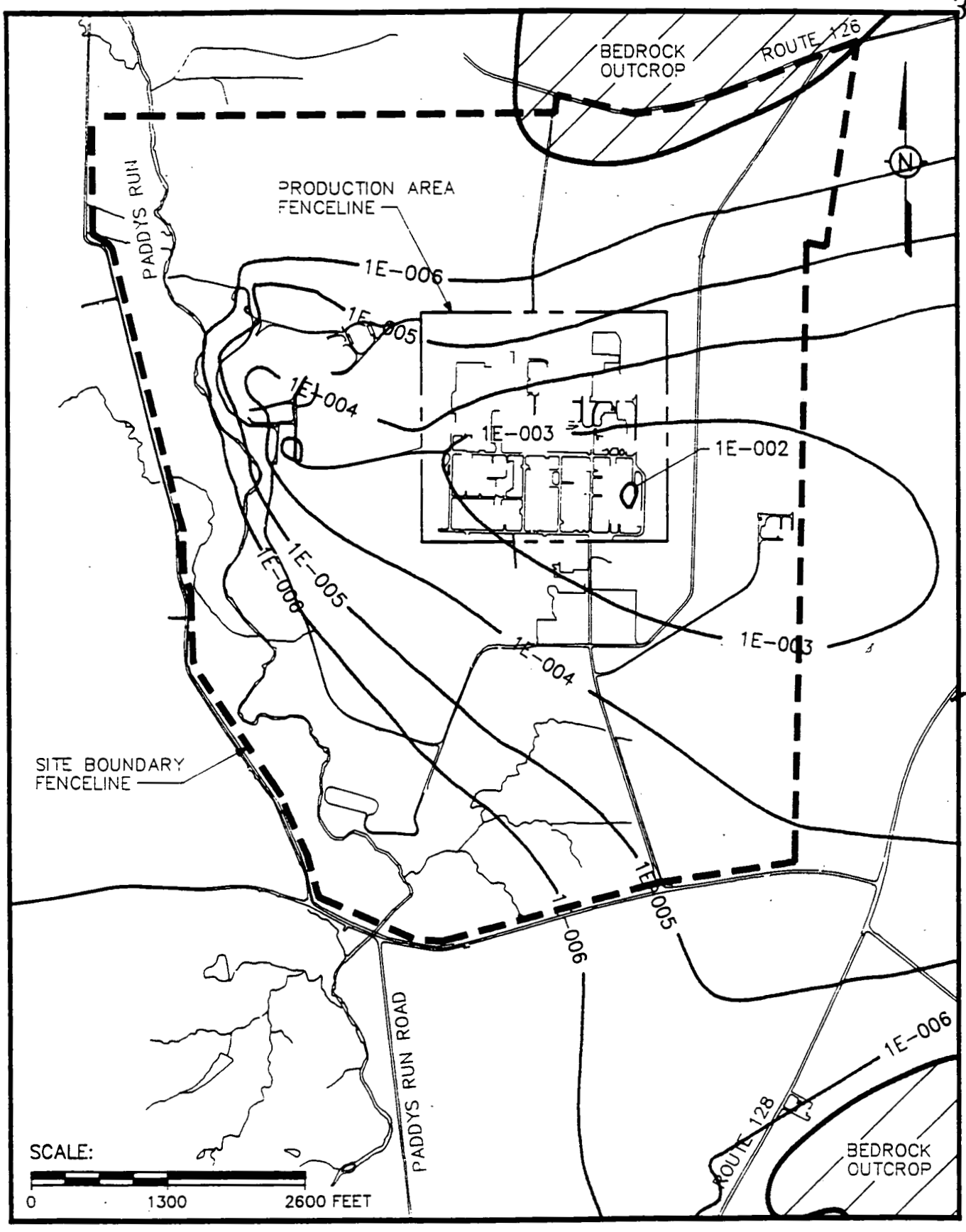

FIGURE 5-9 ESTIMATED RISK TO FARMER RME FROM GROUNDWATER BENEATH THE FEMP AFTER 250 YEARS

303

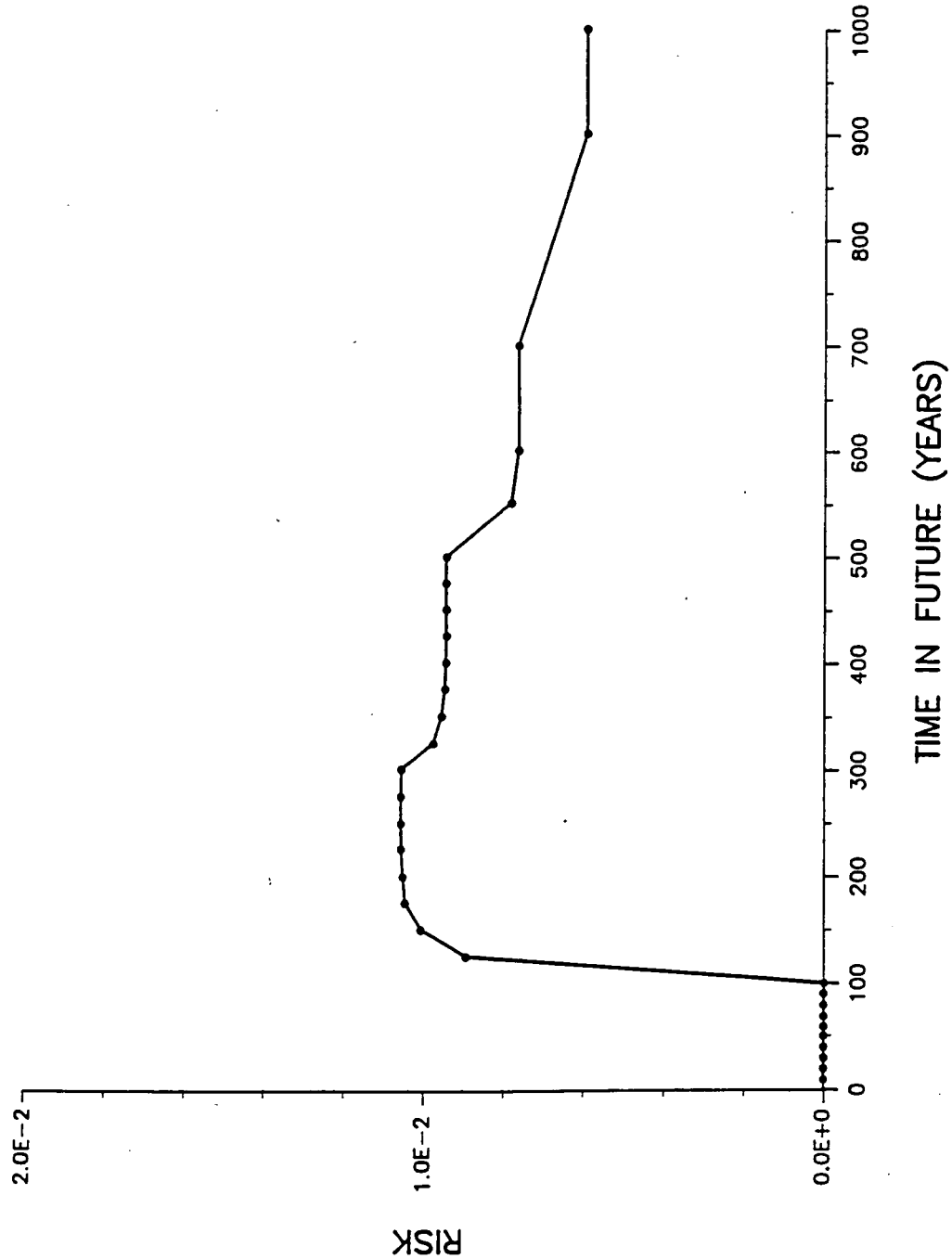

FIGURE 5-10 RISK TO FARMER USING GROUNDWATER AT THE LOCATION OF MAXIMUM GROUNDWATER RISK FROM ALL CONSTITUENTS

SITE WIDE BASELINE RISK ASSESSMENT
31332766/SWBRA/KNOX

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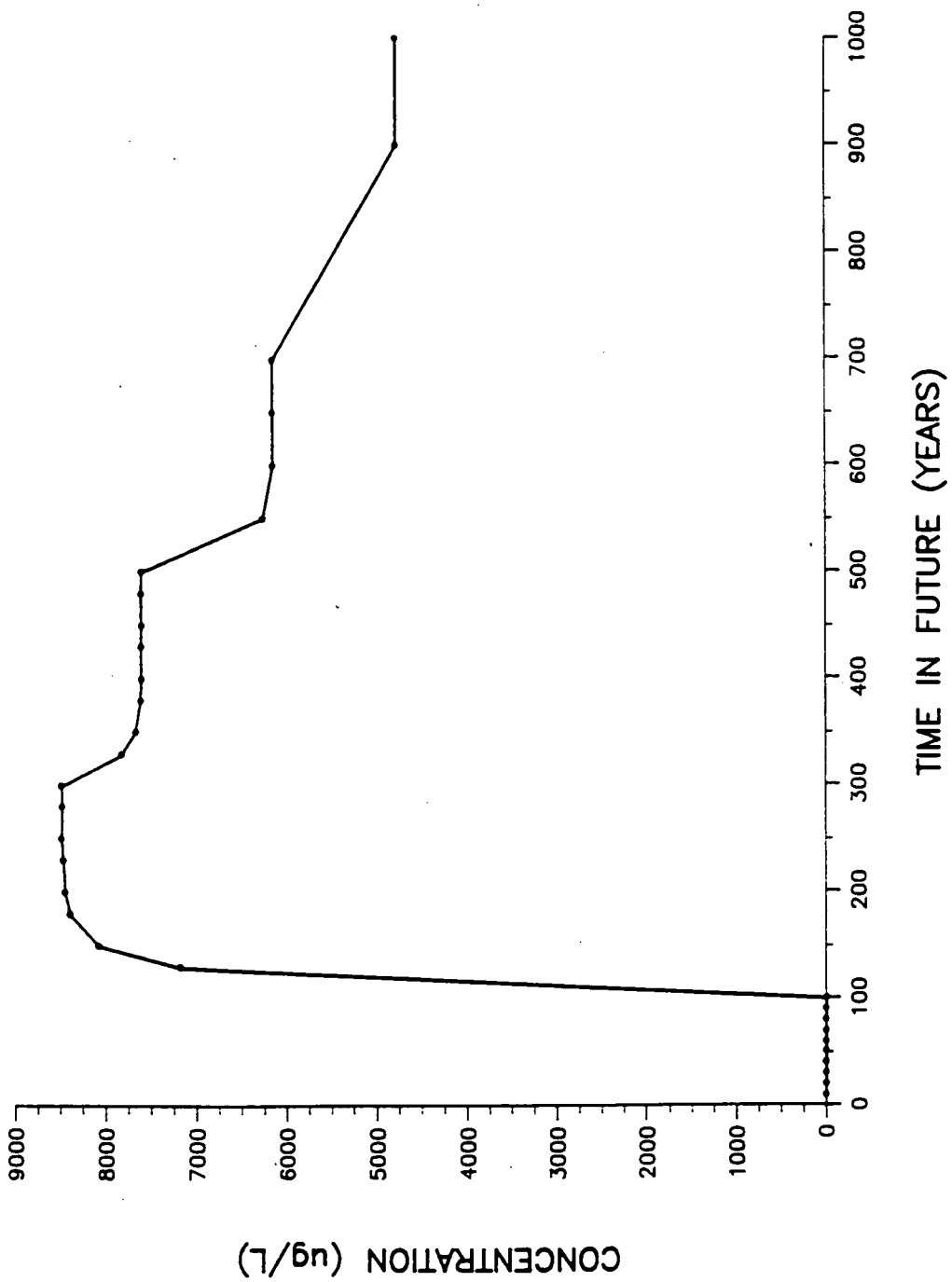

FIGURE 5-11 ESTIMATED URANIUM CONCENTRATION IN GROUNDWATER VERSUS TIME AT THE LOCATION OF MAXIMUM GROUNDWATER RISK FROM ALL CONSTITUENTS

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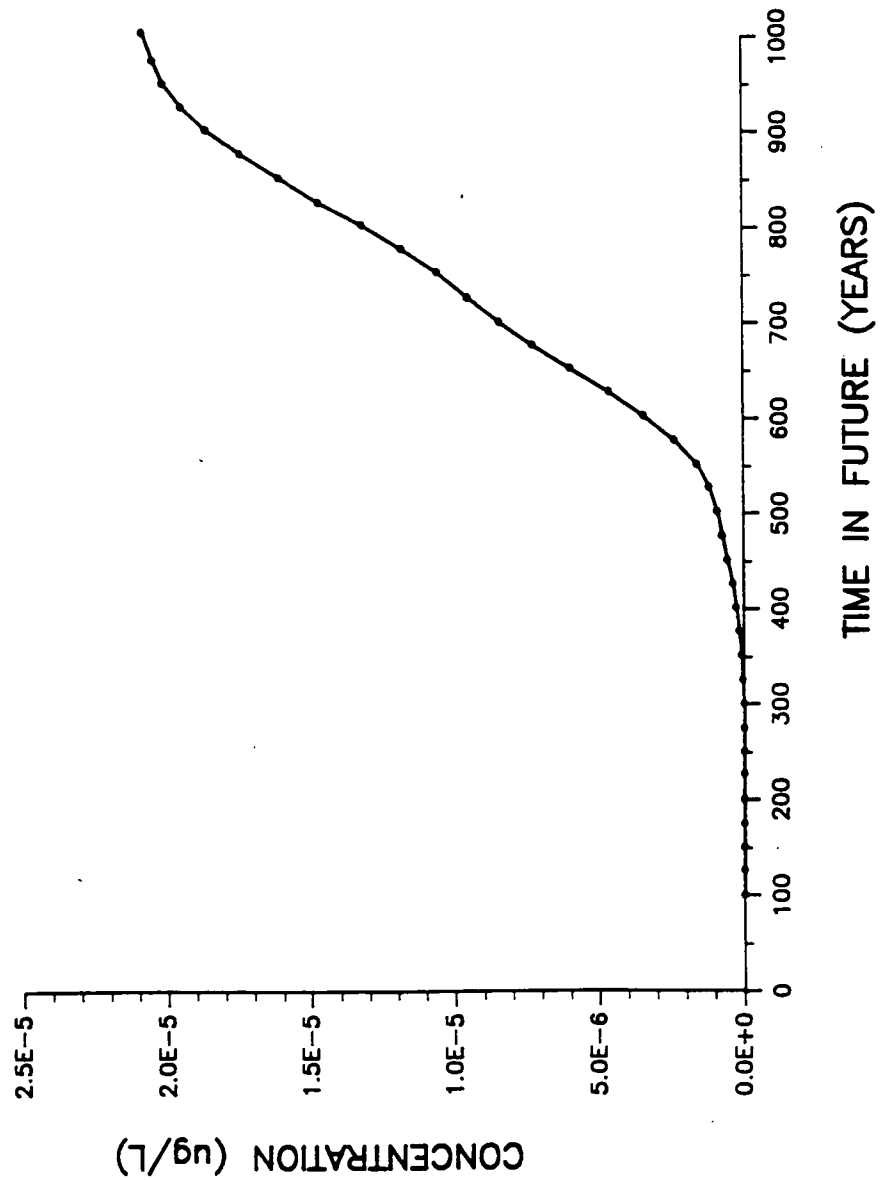

FIGURE 5-12 ESTIMATED NEPTUNIUM CONCENTRATION IN GROUNDWATER VERSUS TIME AT THE LOCATION OF MAXIMUM GROUNDWATER RISK FROM ALL CONSTITUENTS

SITE WIDE BASELINE RISK ASSESSMENT
31332768/SWBRA/KNOX

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TABLE 5-32

HAZARD INDICES FROM CHEMICALS IN GROUNDWATER TO FARMER UNDER THE FUTURE LAND-USE SCENARIO[a]

Chemical	Hazard Indices
Boron	2.3E-03
Molybdenum	2.8E-01
Uranium	1.0E+02

[a] The pathways that were evaluated include: Ingestion of drinking water, inhalation of volatiles released from household water use, dermal exposure while bathing, ingestion of vegetables irrigated with groundwater, ingestion of milk/dairy products, and ingestion of beef.

area. See Appendix O for additional details. Risks due to radionuclides outweigh the risk from vinyl chloride, as shown in Table 5-31.

HIs for this scenario are presented in Table 5-32. Molybdenum (0.3) and uranium (100) exceeded an HI of 0.2. The other chemical predicted to reach the groundwater from a soil/waste source was boron, with an HI below 0.2. Figure 5-13 presents HI contours for an on-property resident farmer using the groundwater 250 years in the future. HIs above 100 are shown in the southeast quadrant of the former Production Area. HIs above one extend off property to the east. The modeled results for 500 years indicate these elevated HIs will extend off property further to the east. Figure 5-14 presents a plot of the HI versus time at the point of maximum uranium concentration. The HI is shown to reach a peak (around 120) 200 to 300 years in the future, then gradually decrease to approximately 65 in the future, 900 to 1000 years from now.

5.3.3 Surface Water

The pathways that were evaluated include:

- Ingestion of drinking water
- Inhalation of volatiles released from household water use
- Dermal exposure while bathing
- Dermal exposure while swimming
- Incidental ingestion of water while swimming
- Ingestion of fish
- Ingestion of vegetables irrigated with surface water
- Ingestion of milk/dairy products
- Ingestion of beef

The receptor evaluated under this scenario is an adult resident farmer. As in the current scenario, in the future the Great Miami River should be the only water body capable of supporting the pathways considered for this scenario. No distinction was made in modeling future surface water concentrations between middle and lower segments of the Great Miami River. The upstream segment was not considered under this scenario.

Table 5-33 presents the ILCRs for the radionuclides from the FEMP predicted to be present in the Great Miami River. The risks via this exposure pathway approach 10^{-4}, with uranium isotopes contributing over 95 percent of the total.

ILCRs for chemical carcinogens for this scenario are presented in Table 5-34. The total ILCR from chemicals via these pathways estimated for the future is 1×10^{-5}. Aroclor-1254 is the major contributor to risk with an ILCR of 1.2×10^{-5}.

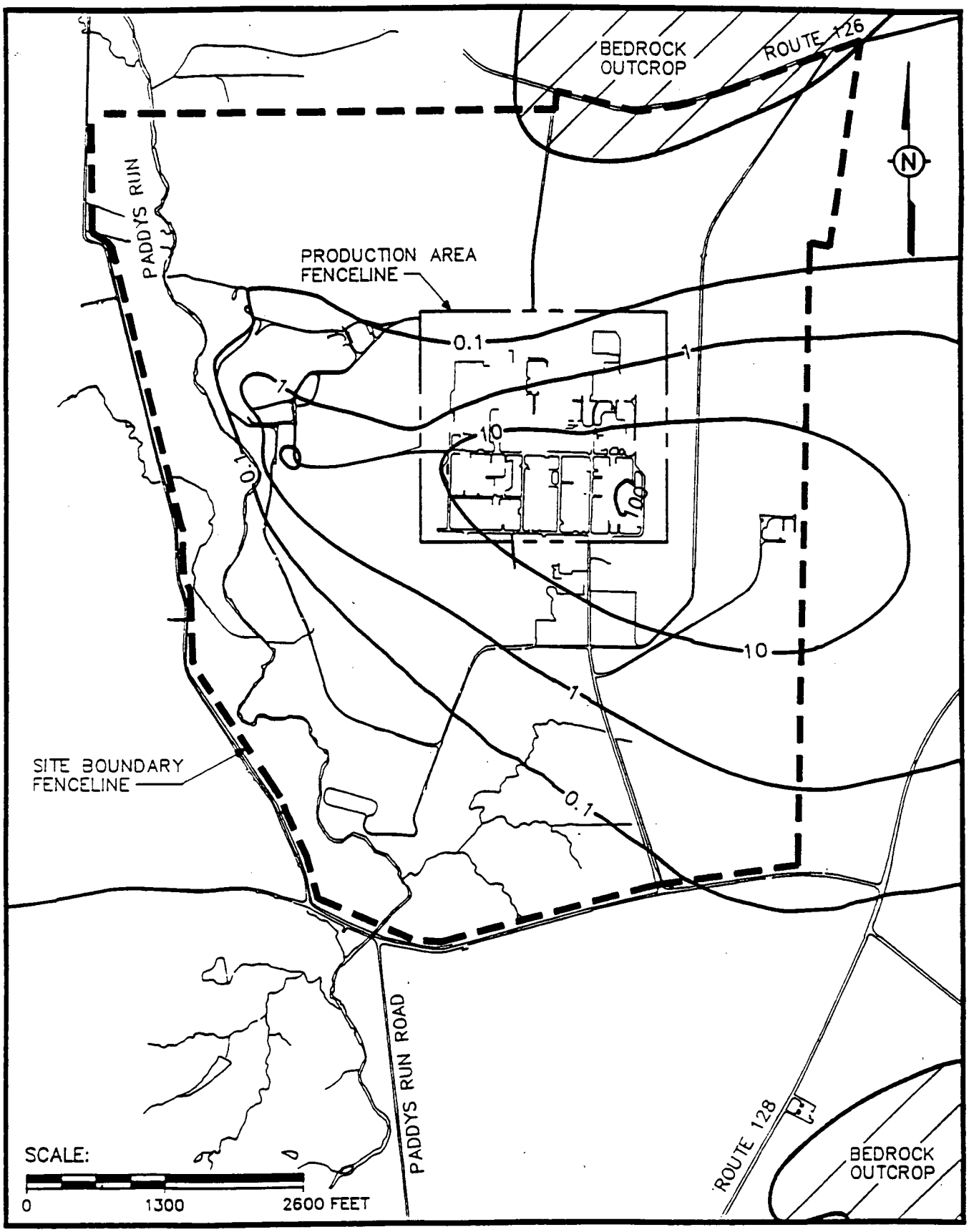

FIGURE 5-13 ESTIMATED HI OF FARMER RME USING GROUNDWATER BENEATH THE FEMP AFTER 250 YEARS 309

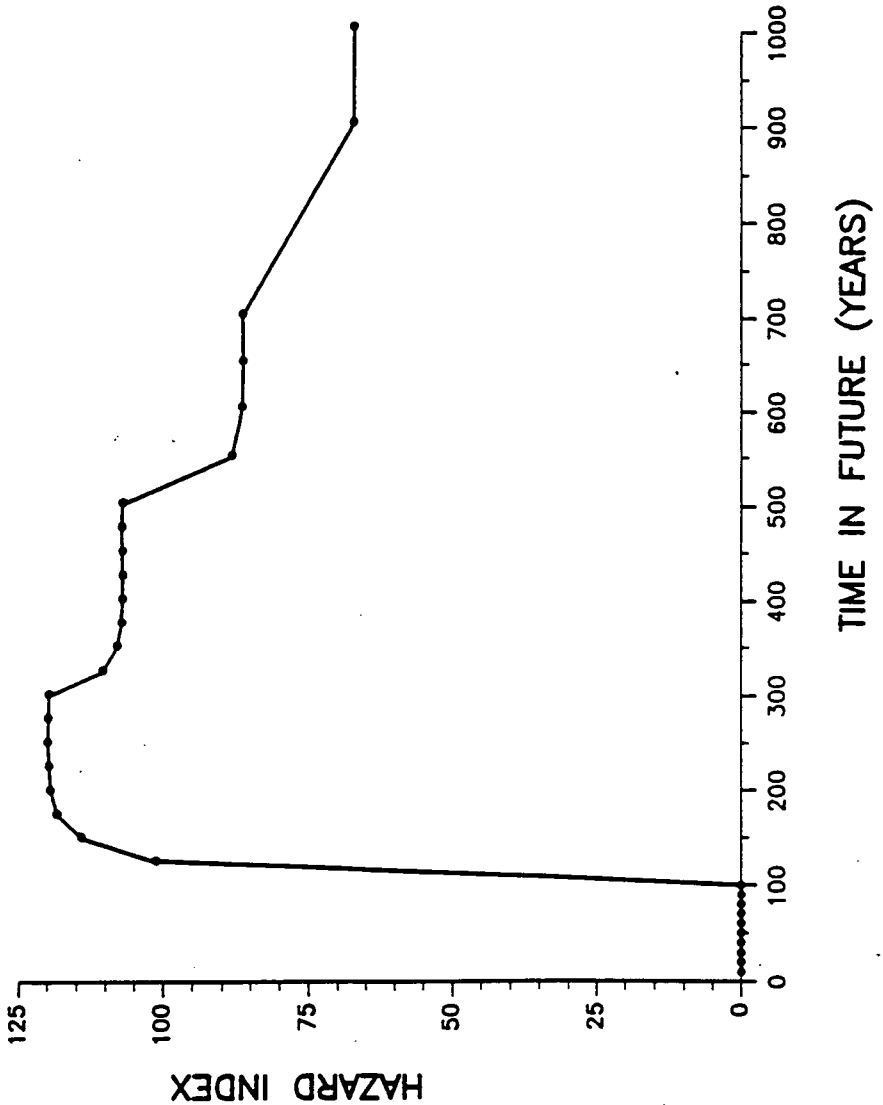

FIGURE 5-14 HAZARD INDEX TO FARMER USING GROUNDWATER AT GROUNDWATER RME LOCATION

SITE WIDE BASELINE RISK ASSESSMENT
31332767/SWBRA/KNOX

TABLE 5-33

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES TO FARMER USING GREAT MIAMI RIVER WATER UNDER THE FUTURE LAND-USE SCENARIO [a]

Radionuclide	Great Miami River
Cs-137	1.1E-08
Np-237	2.1E-10
Pu-238	2.7E-09
Pu-239/240	3.0E-09
Ra-226	1.4E-06
Ra-228	1.9E-08
Ru-106	1.3E-11
Sr-90	2.0E-08
Tc-99	2.5E-06
Th-228	4.8E-09
Th-230	1.0E-08
Th-232	7.6E-10
U-234	2.7E-05
U-235/236	1.4E-06
U-238	5.6E-05
Sum	8.8E-05

[a] Includes risk from drinking water, volatilization of radon, incidental ingestion while swimming, ingestion of fruit and vegetables, fish, beef, and dairy products grown with Great Miami River water.

TABLE 5-34

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS TO FARMER USING GREAT MIAMI RIVER WATER UNDER THE FUTURE LAND-USE SCENARIO[a]

Chemical	Great Miami River
Aroclor-1254	1.2E-05
Aroclor-1260	2.3E-07
Benzo(a)pyrene	2.8E-07
Bis(2-ethylhexyl) phthalate	3.5E-12
Chloroform	2.9E-11
Methylene chloride	1.1E-09
N-nitrosodiphenylamine	2.7E-11
Tetrachloroethene	1.6E-11
Trichloroethene	2.1E-12
Beryllium	7.1E-08

[a] The pathways that were evaluated include: ingestion of drinking water, inhalation of volatiles released from household water use, dermal exposure while bathing, dermal exposure while swimming, incidental ingestion of water while swimming, ingestion of fish, ingestion of fruit and vegetables irrigated with surface water, ingestion of milk/dairy products, and ingestion of beef.

HIs for this scenario are presented in Table 5-35. The estimated hazard indices from chemicals in the future are all less than 0.2, except for uranium with an HI of 1.0.

5.3.4 Soil

The pathways that were evaluated include:

- Incidental ingestion of soil
- Dermal contact with soil
- Ingestion of vegetables grown in contaminated soil
- Ingestion of milk/dairy products
- Ingestion of beef
- External exposure to gamma radiation

The receptor evaluated under this scenario is an adult resident farmer, scavenger, home builder, and resident child. The scavenger is discussed in Section 5.3.7, while the home builder and resident child are presented in Section 5.5. The following areas were evaluated for this scenario:

- Waste Pits 1 through 6
- Burn Pit
- Incinerator Area
- Active Flyash Pile
- Inactive Flyash Pile
- South Field
- Solid Waste Landfill
- Clearwell
- North and South Lime Sludge Ponds
- Plants 2/3, 6, 9 and the Pilot Plant in the former Production Area

ILCRs for radionuclide contaminants associated with the resident farmer under the future land-use scenario are presented in Table 5-36. The risks from all radionuclides range from 5×10^{-5} for the South Lime Sludge Pond to 3×10^{-1} for Waste Pit 3. Contributions to risks in each of the areas included in Table 5-36 are dominated by Ra-226, Th-232 plus associated decay products, Tc-99, and isotopes of uranium plus the two immediate decay products of U-238.

The ILCRs for chemical carcinogens associated with this scenario are presented in Table 5-37. The highest ILCRs were in Waste Pit 2. The following chemicals had ILCR values above 1×10^{-6} in one or more of the areas evaluated: 4,4 DDT; Aroclor-1248; Aroclor-1254; Aroclor-1260; benzo(a)pyrene; beryllium; bis(2-ethylhexyl) phthalate; chloroform; methylene chloride; pentachlorophenol; tetrachloroethene; trichloroethane; vinyl chloride; 1,1 dichloroethene and bromodichloromethane. B(a)P and vinyl chloride were the primary contributors to the risk in Waste Pit 2.

TABLE 5-35

HAZARD INDICES FROM CHEMICALS
TO FARMER USING GREAT MIAMI RIVER WATER
UNDER THE FUTURE LAND-USE SCENARIO[a]

Chemical	Great Miami River
1,1,1-Trichloroethane	5.6E-09
2-Butanone	8.9E-06
Acenaphthene	3.2E-08
Acetone	1.3E-05
Anthracene	1.0E-07
Benzoic acid	6.4E-08
Bis(2-ethylhexyl) phthalate	2.7E-08
Carbon disulfide	2.1E-08
Chloroform	4.7E-07
Chlorobenzene	9.4E-10
Cyanide	1.3E-02
Dibenzofuran	1.3E-06
Fluoranthene	4.0E-08
Methylene chloride	2.4E-06
Pyrene	2.8E-08
Tetrachloroethene	3.2E-08
Antimony	5.0E-03
Arsenic	1.2E-03
Barium	2.2E-05
Beryllium	3.9E-06
Cobalt	1.1E-04
Lead	1.6E-03
Mercury	8.0E-03
Nickel	6.2E-05
Silver	2.3E-03
Zinc	2.7E-05

TABLE 5-35
(Continued)

Chemical	Great Miami River
Uranium	1.0E+00

[a] The pathways that were evaluated include: ingestion of drinking water, inhalation of volatiles released from household water use, dermal exposure while bathing, dermal exposure while swimming, incidental ingestion of water while swimming, ingestion of fish, ingestion of fruit and vegetables irrigated with surface water, ingestion of milk/dairy products, and ingestion of beef.

TABLE 5-36

INCREMENTAL LIFETIME CANCER RISKS FROM RADIONUCLIDES IN SOIL TO FARMER UNDER THE FUTURE LAND-USE SCENARIO[a]

Radionuclide[b]	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Am-241	NA[c]	NA	4.9E-05	NA	NA	NA
Cs-137	1.1E-04	2.4E-04	1.6E-04	NA	2.3E-04	NA
Np-237	NA	NA	1.1E-05	9.2E-06	4.8E-04	1.1E-05
Pu-238	NA	6.0E-08	1.5E-07	3.1E-07	2.3E-06	1.3E-07
Pu-239/240	NA	1.5E-07	1.2E-06	2.4E-07	6.3E-06	1.2E-07
Ra-226	1.7E-02	1.1E-01	1.1E-01	8.1E-03	3.1E-02	6.8E-04
Ru-106	6.2E-06	1.4E-05	NA	1.2E-05	NA	NA
Sr-90	NA	NA	1.6E-04	NA	7.9E-04	NA
Tc-99	3.0E-04	8.5E-03	1.3E-01	1.3E-02	1.1E-01	4.3E-03
Th-230	1.1E-04	1.4E-04	7.0E-04	2.3E-05	6.2E-04	3.6E-06
Th-232	7.7E-03	3.5E-02	8.4E-03	2.0E-02	1.6E-02	2.0E-03
U-234	2.6E-04	1.3E-03	1.1E-04	5.6E-04	2.7E-04	7.8E-05
U-235	9.1E-04	1.4E-02	7.5E-04	3.3E-03	3.2E-04	1.6E-04
U-238	2.3E-03	1.2E-02	4.8E-04	9.2E-03	5.0E-04	3.6E-04
Sum	2.9E-02	1.8E-01	2.5E-01	5.4E-02	1.6E-01	7.6E-03

TABLE 5-36
(Continued)

Radionuclide	Solid Waste Landfill	Active Flyash	Inactive Flyash	South Lime Sludge Pond	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant
Am-241	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cs-137	NA	NA	NA	3.3E-05	NA	1.6E-05	NA	1.3E-05	3.5E-05
Np-237	NA	NA	NA	NA	NA	1.7E-05	NA	1.0E-05	NA
Pu-238	6.2E-08	NA	NA	NA	NA	2.2E-07	2.7E-07	NA	4.1E-07
Pu-239/240	NA	NA	NA	NA	NA	2.5E-07	2.4E-07	NA	3.1E-07
Ra-226	2.5E-04	6.1E-04	6.3E-03	NA	5.8E-04	1.2E-03	2.1E-04	2.1E-04	2.9E-03
Ru-106	NA	NA	NA	NA	2.2E-06	NA	NA	NA	NA
Sr-90	8.9E-05	1.6E-04	9.9E-05	NA	NA	8.9E-05	4.9E-05	6.1E-05	4.1E-05
Tc-99	NA	NA	NA	NA	NA	7.1E-05	6.6E-05	8.8E-05	1.5E-04
Th-230	1.7E-07	1.6E-07	2.8E-07	2.9E-07	7.8E-07	1.3E-06	9.5E-08	5.1E-07	3.1E-07
Th-232	8.1E-04	6.3E-04	7.4E-04	NA	1.6E-03	4.5E-04	3.3E-04	4.3E-03	9.8E-04
U-234	8.7E-06	1.5E-06	8.5E-06	9.6E-07	4.6E-06	4.1E-04	3.5E-04	2.6E-05	4.2E-05
U-235	1.0E-05	2.0E-06	1.2E-05	3.0E-06	8.0E-06	6.9E-04	2.2E-05	3.6E-04	1.7E-04
U-238	2.9E-05	1.1E-05	2.3E-05	8.4E-06	2.1E-05	2.6E-03	2.6E-03	1.5E-04	5.4E-04
Sum	1.2E-03	1.4E-03	1.5E-03	4.6E-05	2.2E-03	5.5E-03	3.6E-03	5.2E-03	4.9E-03

[a] Included risks from soil ingestion, direct gamma exposures, and ingestion of fruit and vegetables, meat and milk produced on soil.
[b] Includes risks from daughter nuclides.
[c] Not a constituent of potential concern for a given waste area.

TABLE 5-37

INCREMENTAL LIFETIME CANCER RISKS FROM CHEMICALS IN SOIL TO FARMER UNDER THE FUTURE LAND-USE SCENARIO[a]

Chemicals	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
1,1,2-Trichloroethane	NA[b]	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA
4,4-DDT	7.0E-05	6.1E-05	NA	NA	NA	NA
Aroclor-1242	NA	NA	NA	NA	NA	NA
Aroclor-1248	2.9E-03	2.7E-04	NA	7.1E-04	4.6E-04	1.7E-04
Aroclor-1254	9.6E-03	3.4E-04	2.6E-04	1.1E-03	7.8E-04	2.8E-03
Aroclor-1260	6.3E-03	1.6E-03	NA	NA	NA	NA
Benzene	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	9.1E-05	9.1E-02	NA	3.6E-04	NA	1.0E-04
Beryllium	NA	2.6E-04	5.2E-04	3.9E-04	4.0E-04	4.9E-04
Bis(2-ethylhexyl) phthalate	3.1E-06	6.5E-07	1.4E-06	4.9E-07	2.2E-06	3.4E-06
Bromodichloromethane	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA
Chlordane	NA	NA	NA	NA	NA	NA
Chloroform	5.9E-06	NA	NA	3.8E-05	NA	NA
Methylene chloride	1.2E-05	1.8E-05	3.9E-05	2.1E-05	3.6E-05	1.1E-05
N-Nitrosodiphenylamine	NA	NA	NA	NA	NA	NA
Pentachlorophenol	NA	NA	2.0E-05	NA	NA	4.0E-05
Tetrachloroethene	8.0E-06	NA	NA	1.1E-03	NA	5.9E-06
Trichloroethene	6.5E-07	NA	NA	1.0E-05	NA	NA

TABLE 5-37
(Continued)

Chemicals	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Uranium	NA	NA	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA	NA	NA
Vinyl chloride	NA	1.3E-02	NA	NA	NA	5.90E-05

TABLE 5-37
(Continued)

Chemical	Sanitary Landfill	Active Fly Ash	Inactive Fly Ash	South Lime Sludge	Southfield	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant	Incinerator Area
1,1,2,2-Tetrachloroethane	NA	NA	NA	NA	NA	NA	NA	NA	1.3E-07	NA
1,1-Dichloroethene	NA	1.1E-05	NA	NA	NA	1.1E-05	4.9E-05	2.2E-05	3.8E-05	NA
4,4-DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1242	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1248	4.7E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1254	7.5E-04	NA	3.0E-04	NA	6.5E-04	3.8E-04	NA	NA	7.1E-04	NA
Aroclor-1260	NA	3.4E-05	NA	NA	3.8E-04	NA	NA	NA	8.7E-04	NA
Benzene	NA	NA	NA	NA	NA	NA	NA	NA	5.6E-07	NA
Benzo(a)pyrene	4.3E-03	NA	NA	NA	NA	NA	NA	NA	2.3E-03	NA
Beryllium	NA	1.0E-04	1.7E-04	NA	NA	7.1E-05	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	2.7E-07	1.0E-06	NA	5.6E-07	NA	3.2E-07	4.4E-07	5.8E-07	8.8E-07	NA
Bromodichloromethane	NA	1.4E-06	NA	NA	NA	NA	NA	2.8E-06	NA	NA
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlordane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	NA	1.7E-07	NA	NA	NA	NA	8.7E-08	1.7E-07	5.8E-08	NA
Methylene chloride	1.2E-05	NA	NA	2.2E-05	1.0E-05	3.4E-06	1.6E-06	1.6E-06	1.8E-04	NA
N-Nitrosodiphenylamine	NA	NA	NA	NA	NA	9.51E-10	NA	NA	NA	NA
Pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	3.7E-06	NA	NA	NA	NA	NA	1.1E-07	1.9E-07	3.2E-06	NA
Trichloroethene	NA	NA	NA	NA	NA	NA	2.7E-07	3.8E-07	9.6E-07	NA

TABLE 5-37
(Continued)

Chemical	Sanitary Landfill	Active Fly Ash	Inactive Fly Ash	South Lime Sludge	Southfield	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant	Incinerator Area
Uranium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	NA	NA	NA	5.9E-05	NA	1.2E-04	NA

[a] The pathways that were evaluated include: incidental ingestion of soil, dermal contact with soil, ingestion of vegetables grown in contaminated soil, ingestion of milk/dairy products, and ingestion of beef.
[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

HIs for this scenario are presented in Table 5-38. Chemicals with HIs over one include: 2-butanone, antimony, arsenic, barium, boron, cobalt, cyanide, dibenzofuran, lead, manganese, mercury, methyl parathion, nickel, selenium, silver, tetrachloroethene, uranium, vanadium, and zinc. All waste areas evaluated, except the Incinerator Area, had chemical-specific HIs greater than one. The waste areas with the highest HIs are Waste Pit 3 and Waste Pit 5.

5.3.5 External Gamma

Estimated risks for the external radiation exposure pathway from the waste pits and the waste storage silos are tabulated for the typical resident, the RME resident farmer, a resident child, and a temporary home builder exposed under the future land-use scenario in Table 5-39. Assumptions concerning exposure time for each case are addressed in Table 3-18.

Examination of Table 5-39 reveals that the greatest risk for the future land-use scenario on the waste pits is approximately 6×10^{-3} from lifetime exposure of the on-property resident farmer on Waste Pit 2. If the on-property resident farmer is located adjacent to or 100 meters distant from the K-65 berm, the shielding provided by the berm soil results in a modeled dose and corresponding risk that are indistinguishable from background contributions. An on-property resident farmer located adjacent to, or 100 meters distant from Silo 3 is exposed to modeled doses that correspond to lifetime risks of 9×10^{-1} and 3×10^{-3}, respectively (Table 5-39). An on-property resident farmer located on the waste pits may be exposed to modeled doses that correspond to a lifetime risk of up to 6×10^{-3} (Table 5-39).

Background risks for the external radiation exposure pathway may be calculated for comparison with the modeled results presented for the on-property resident farmer under the future land-use scenario. Using the risk calculation methodology presented in Section 9.2.2.2 of the Addendum (DOE 1992a), and external radiation dose rates measured at background locations (6.3 μrem/hr) presented in the Annual Environmental Monitoring Report for 1990 (WMCO 1991) a lifetime risk from background external radiation exposure of 2×10^{-3} is calculated. Alternatively, the National Council on Radiation Protection and Measurements (NCRP) cites an average annual effective dose equivalent in the U.S. population of 100 mrem from natural sources other than radon (NCRP 1987), which corresponds to a lifetime risk of about 4×10^{-3}.

5.3.6 Structures

The results of the risk characterization for ingestion and inhalation from structures under the future land-use scenarios is shown in Table 5-40.

TABLE 5-38

HAZARD INDICES TO RME FARMER FROM SOIL UNDER THE FUTURE LAND-USE SCENARIO[a]

Chemical	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
1,1,2-Trichloro-1,2,2-trifluoroethene	NA[b]	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	3.0E-03	4.0E-03	NA	3.2E-03	NA	5.3E-05
1,1-Dichloroethane	NA	NA	NA	NA	NA	6.6E-03
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA
1,2-Dichloroethene	NA	NA	NA	NA	NA	NA
2,4-Dimethylphenol	NA	1.8E-02	NA	NA	NA	NA
2-Butanone	2.0E+00	2.4E+00	3.2E+00	7.0E+00	NA	5.9E-02
2-Chlorophenol	NA	NA	NA	NA	NA	NA
4,4-DDT	4.1E-01	3.6E-01	NA	NA	NA	NA
Acenaphthene	NA	1.2E-03	NA	4.2E-06	NA	NA
Acetone	2.0E-01	4.8E-01	2.2E-01	4.6E-01	5.6E-01	2.1E-01
Anthracene	5.4E-05	8.8E-02	NA	3.7E-04	NA	NA
Antimony	NA	NA	NA	NA	1.1E+02	5.1E+01
Arsenic	NA	NA	1.5E+02	NA	1.1E+02	NA
Barium	NA	NA	6.4E+00	5.1E+00	2.5E+01	9.7E-01
Benzoic acid	NA	NA	NA	NA	NA	NA
Beryllium	NA	1.2E-02	2.4E-02	1.8E-02	1.9E-02	2.3E-02
Bis(2-ethylhexyl) phthalate	1.3E-02	2.3E-03	5.0E-03	1.7E-03	8.0E-03	1.2E-02
Boron	NA	NA	NA	NA	NA	2.4E+00
Bromodichloromethane	NA	NA	NA	NA	NA	NA
Butyl benzyl phthalate	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	1.8E-02	5.5E-02	3.2E-02	NA

TABLE 5-38
(Continued)

Chemical	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	NA	NA	4.6E-05
Chlordane	NA	NA	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	NA	NA	1.5E-05
Chloroform	9.6E-02	NA	NA	6.2E-01	NA	NA
Chromium	NA	NA	4.3E-01	NA	6.5E-01	NA
Cobalt	4.8E-01	5.9E+00	NA	1.5E+00	7.6E-01	1.8E+00
Cyanide	NA	NA	NA	NA	NA	NA
Di-n-butyl phthalate	1.6E-04	6.7E-04	1.5E-04	8.7E-04	4.4E-04	3.7E-04
Dibenzofuran	NA	1.1E+00	NA	5.0E-03	NA	NA
Ethylbenzene	3.8E-03	4.9E-03	NA	NA	NA	1.9E-02
Fluoranthene	1.1E-03	5.4E-01	6.4E-04	6.1E-03	NA	9.4E-04
Fluorene	NA	4.6E-01	NA	2.3E-03	NA	NA
Lead	2.2E+00	6.6E+00	1.6E+01	2.4E+00	7.8E+00	1.1E+01
Manganese	3.3E+00	NA	5.0E+00	5.0E+00	4.5E+00	2.4E+00
Mercury	7.7E+00	1.5E+01	7.3E+01	1.3E+01	3.2E+01	1.9E+01
Methyl parathion	NA	NA	NA	3.6E+00	NA	NA
Methylene chloride	2.7E-02	4.1E-02	8.6-02	4.7E-02	8.0E-02	2.3E-02
Molybednum	NA	NA	NA	NA	NA	3.6E-01
Naphthalene	5.4E-05	1.6E-02	NA	1.1E-04	NA	NA
Nickel	3.7E-01	2.8E+00	1.4E+00	3.1E-01	1.2E+00	4.2E-01
Pentachlorophenol	NA	NA	5.6E-03	NA	NA	1.1E-02
Phenol	NA	5.1E-03	NA	1.3E-02	3.1E-03	1.0E-02

TABLE 5-38
(Continued)

Chemical	Waste Pit 1	Waste Pit 2	Waste Pit 3	Waste Pit 4	Waste Pit 5	Burn Pit
Pyrene	1.1E-03	4.9E-01	7.0E-04	5.1E-03	NA	7.5E-04
Selenium	NA	1.6E-01	1.4E+00	NA	1.2E-01	NA
Silver	1.3E+00	8.9E-01	NA	1.7E+01	3.6E-01	1.9E+01
Tetrachloroethene	1.6E-02	NA	NA	2.2E+00	NA	1.1E-02
Toluene	4.8E-04	NA	NA	5.9E-04	NA	3.7E-04
Trans-1,2-dichloroethene	NA	NA	NA	2.7E-02	NA	NA
Uranium	1.3E+01	6.9E+01	2.8E+00	5.1E+01	2.8E+00	2.0E+00
Vanadium	NA	NA	6.9E+00	3.1E-01	5.7E+00	1.8E-01
Xylenes	1.1E-05	1.3E-04	NA	NA	NA	3.8E-04
Zinc	NA	6.7E+01	7.8E+00	NA	7.2E+00	1.8E+01
Beta-BHC	NA	NA	NA	NA	NA	NA

TABLE 5-38
(Continued)

Chemical	Sanitary Landfill	Active Flyash	Inactive Flyash	South Lime Sludge Pond	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant	Incinerator Area
1,1,2-Trichloro-1,2,2-trifluoroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	8.3E-04	6.4E-04	NA	NA	1.1E-04	5.3E-05	2.7E-04	8.3E-04	NA
1,1-Dichloroethane	7.8E-03	NA	NA	NA	NA	9.6E-04	NA	NA	1.6E-03	NA
1,1-Dichloroethene	NA	2.0E-03	NA	NA	NA	2.0E-03	9.1E-03	4.0E-03	7.1E-03	NA
1,2-Dichloroethene	NA	NA	NA	NA	NA	NA	5.3E-03	NA	NA	NA
2,4-Dimethylphenol	2.8E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone	1.1E-01	3.5E-03	NA	1.6E+00	NA	4.9E-02	1.2E-02	6.2E-03	2.1E+00	NA
2-Chlorophenol	NA	3.6E-02	NA	NA	NA	NA	NA	NA	NA	NA
4,4-DDT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	2.1E-04	NA	NA	NA	NA	NA	NA	NA	1.3E-05	NA
Acetone	1.7E-01	5.4E-02	3.7E-02	1.2E-01	2.2E-01	7.5E-02	7.0E-02	1.4E-02	5.4E-02	NA
Anthracene	1.8E-03	NA	NA	NA	NA	NA	NA	NA	2.8E-04	NA
Antimony	NA	3.5E+01	4.1E+01	NA	NA	NA	7.2E+01	7.2E+01	3.5E+01	NA
Arsenic	NA	4.9E+00	2.6E+00	NA	NA	2.0E+00	NA	NA	NA	NA
Barium	NA	NA	NA	NA	NA	NA	NA	NA	3.1E+00	NA
Benzoic acid	NA	9.9E-05	2.0E-04	2.2E-04	NA	1.2E-04	NA	NA	8.0E-05	NA
Beryllium	NA	4.7E-03	8.0E-03	NA	NA	3.3E-03	NA	NA	NA	NA
Bis(2-ethylhexyl) phthalate	9.6E-04	3.7E-03	NA	2.0E-03	NA	1.2E-03	1.6E-03	2.1E-03	3.1E-03	NA
Boron	1.3E+00	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bromodichloromethane	NA	5.3E-04	NA	NA	NA	NA	NA	1.1E-03	NA	NA
Butyl benzyl phthalate	2.2E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-38
(Continued)

Chemical	Sanitary Landfill	Active Flyash	Inactive Flyash	South Lime Sludge Pond	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant	Incinerator Area
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	1.4E-04	NA	NA	NA	NA	1.8E-04	1.8E-04	NA
Chlordane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	NA	NA	NA	NA	NA	3.8E-05	NA
Chloroform	NA	2.8E-03	NA	NA	NA	NA	1.4E-03	2.8E-03	9.5E-04	NA
Chromium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	NA	NA	NA	NA	3.6E-01	NA	NA	NA	NA	NA
Cyanide	1.6E+00	5.7E-01	1.4E+00	NA	NA	NA	9.2E-01	NA	NA	NA
Di-n-butyl phthalate	4.9E-04	NA	NA	1.3E-04	NA	NA	NA	NA	1.2E-03	NA
Dibenzofuran	5.4E-02	NA	NA	NA	NA	NA	NA	NA	9.9E-03	NA
Ethylbenzene	9.3E-03	NA	NA	NA	NA	3.1E-04	2.0E-04	NA	1.0E-04	NA
Fluoranthene	3.6E-03	NA	NA	NA	NA	2.2E-04	NA	NA	1.8E-02	NA
Fluorene	1.6E-02	NA	NA	NA	NA	NA	NA	NA	4.1E-03	NA
Lead	2.4E+00	1.7E+00	2.6E+00	NA	NA	1.7E+01	NA	NA	1.7E+00	NA
Manganese	NA	NA	NA	NA	1.1E+00	NA	NA	NA	8.3E-01	NA
Mercury	NA	4.2E+00	3.9E+00	NA	1.8E+01	2.8E+01	NA	NA	1.8E+01	NA
Methyl parathion	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	2.8E-02	NA	NA	4.9E-02	2.3E-02	7.6E-03	3.5E-03	3.5E-03	3.9E-01	NA
Molybednum	2.1E-01	3.0E-01	1.8E-01	NA	NA	NA	NA	NA	NA	NA
Naphthalene	1.6E-02	8.2E-05	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	2.0E-01	2.0E-01	NA	NA	2.1E-01	3.1E-01	NA	NA	1.8E-01	NA

TABLE 5-38
(Continued)

Chemical	Sanitary Landfill	Active Flyash	Inactive Flyash	South Lime Sludge Pond	South Field	Production Area Plants 2/3	Production Area Plant 6	Production Area Plant 9	Production Area Pilot Plant	Incinerator Area
Nitrate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenol	4.8E-03	9.0E-04	4.8E-01	1.4E-03	NA	NA	NA	NA	1.1E-03	NA
Pyrene	6.9E-03	NA	NA	NA	NA	NA	NA	NA	2.9E-03	NA
Selenium	NA	8.6E-02	4.1E-02	NA	NA	NA	NA	NA	NA	NA
Silver	4.8E-01	1.7E-01	NA	NA	NA	6.6E-01	NA	NA	1.7E-01	NA
Tetrachloroethene	7.2E-03	NA	NA	NA	NA	NA	2.2E-04	3.7E-04	6.3E-03	NA
Toluene	1.6E-03	5.3E-05	2.6E-05	NA	NA	1.2E-04	3.5E-05	1.8E-05	8.8E-05	NA
Trans-1,2-dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium	5.5E-01	7.9E-02	2.2E+00	4.6E-02	1.2E-01	9.3E-01	1.4E+00	3.6E-01	2.6E+00	2.41E-01
Vanadium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylenes	1.6E-04	NA	NA	NA	NA	6.1E-06	2.0E-06	NA	2.2E-05	NA
Zinc	3.5E+00	2.9E+00	NA	NA	NA	8.8E+00	NA	NA	6.2E+00	NA
Beta-BHC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] The pathways that were evaluated include: incidental ingestion of soil, dermal contact with soil, ingestion of fruit and vegetables grown in contaminated soil, ingestion of milk/dairy products, and ingestion of beef.

[b] NA = Results not calculated because chemical was not a constituent of potential concern in this area.

TABLE 5-39

RISKS FROM EXTERNAL RADIATION EXPOSURE FOR THE WASTE STORAGE AREA UNDER THE FUTURE LAND-USE SCENARIO

	Typical Resident	RME Farmer	Resident Child	Home Builder	Building User/Scavenger
	On Waste Pit or Silo				
Silo 1 or 2	NA[a]	NA[a]	NA[a]	NA[a]	NA[b]
Silo 3	NA	NA	NA	NA	NA
Pit 1	4.9E-04	3.8E-03	2.9E-04	4.0E-06	NA
Pit 2	7.0E-04	5.5E-03	4.1E-04	5.6E-06	NA
Pit 3	4.4E-10	3.4E-09	2.6E-10	3.5E-12	NA
Pit 4	2.3E-07	1.8E-06	1.4E-07	1.9E-09	NA
Burn Pit	1.2E-05	9.0E-05	6.8E-06	9.3E-08	NA
Composite[c]	8.9E-05	6.9E-04	5.2E-05	7.2E-07	NA
	Adjacent to K-65 Berm or Silo 3				
Silo 1 or 2	≈0[d]	≈0[d]	≈0[d]	≈0[d]	NA[b]
Silo 3	1.1E-01	8.6E-01	6.5E-02	8.9E-04	NA
Pit 1	NM[e]	NM[e]	NM[e]	NM[e]	NA
Pit 2	NM	NM	NM	NM	NA
Pit 3	NM	NM	NM	NM	NA
Pit 4	NM	NM	NM	NM	NA
Burn Pit	NM	NM	NM	NM	NA
Composite[c]	NM	NM	NM	NM	NA

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Table 5-39
(Continued)

	Typical Resident	RME Farmer	Resident Child	Home Builder	Building User/Scavenger
	100 Meters from K-65 Berm or Silo 3				
Silo 1 or 2	≈0[d]	≈0[d]	≈0[d]	≈0[d]	NA
Silo 3	4.2E-04	3.3E-03	2.5E-04	5.7E-05	NA
Pit 1	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Pit 2	NA	NM	NM	NM	NM
Pit 3	NA	NM	NM	NM	NM
Pit 4	NA	NM	NM	NM	NM
Burn Pit	NA	NM	NM	NM	NM
Composite[c]	NA	NM	NM	NM	NM

[a] Not applicable, assuming a residence will not be established on top of a silo.
[b] Not applicable, assuming the visitor (delivery person), the off-property farmer, and the building user/scavenger are not exposed at the waste pits or silos.
[c] Results in the row labeled "Composite" are based on an area-weighted average dose rate calculated by multiplying each modeled dose rate by the relative surface area of the pit.
[d] Modeled dose rate is essentially indistinguishable from zero.
[e] Dose rates not modeled because modeled dose rates on top of the pits are close to background.

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TABLE 5-40

RISK CHARACTERIZATION FOR BUILDING RESIDENTS UNDER THE FUTURE LAND-USE SCENARIO

Building Number	Inhalation Risk	Ingestion Risk	Total Risk
1	3.4E-03	4.8E-03	8.2E-03
4	4.8E-03	1.4E-02	1.9E-02
9	6.7E-02	3.8E-02	1.1E-01

Unlike the current land-use scenarios, a building user is assumed to live in the former Production Area for 30 years and may move from plant to plant during this period of time. It is assumed that a new resident is equally likely to reside in each of the three plants (Plants 1, 4, and 9) for which risk characterization can be performed. The average risk after a 30-year exposure is estimated to be about 5×10^{-2}.

5.4 UNCERTAINTIES

Uncertainties relating to each aspect of the exposure assessment were discussed in Section 3.5. These uncertainties were not presented quantitatively due to the nature and scope of this CERCLA risk assessment. Each step of the exposure assessment (i.e., determination of constituents of concern, exposure point concentrations, and exposure duration and frequency) can have an uncertainty of a factor of ten or more. Nearly all of these uncertainties are intended to overestimate the exposure and hence the risk.

Major uncertainties associated with the risk assessment results are summarized in Table 5-43. It is important to note that uncertainties associated with early stages of the risk assessment, e.g., with the data evaluation stage, are propagated through the subsequent stages of the risk assessment. The uncertainty analysis is not highly quantitative due to the nature and scope of an RI/FS risk assessment. Of major importance in understanding risk results is that the risks presented in this document are not intended as a reconstruction of actual risks resulting from past practices at the FEMP. The risks in the PBRA are intended to be used in the CERCLA process, and application of the future land-use scenario may significantly overestimate actual future risks. The resident farmer scenario is highly unlikely, although plausible. Most of the waste areas at the site are too small to support a resident farmer, who is assumed to live, farm, and raise livestock and vegetables on top of the waste area for 70 years. This assumption leads to a significant overestimation of the risk since the great majority of contaminants are located in these relatively small waste areas. Nevertheless, the assumption of the resident farmer for future land use provides the upper-bound values for the risk assessment.

For calculation of future exposure to groundwater, several aspects of the effort to model vertical flow through the glacial overburden to the till produce major uncertainties. First, calculation of the source term is based on the UCL concentrations of contaminants. As a consequence of the conservative approach, abnormally high data values have been treated as valid measurements of contamination throughout the assessment, although the contamination may not exist. Many of the UCLs were developed using apparent data outliers, which likely result in an overestimation of the concentrations for calculating the total contaminant mass. Total mass of each contaminant was

TABLE 5-41

UNCERTAINTY ESTIMATES

Assumption	Effect on Risk Estimation: Potential Magnitude for Over-Estimation of Risk	Potential Magnitude for Under-Estimation of Risk	Potential Magnitude for Over- or Under-Estimation of Risk
Source Terms			
Sufficient data may not have been collected to characterize source media			Low (radionuclides) High (chemicals)
Biased sampling design	High (radionuclides)		Low (chemicals)
Inclusion of outliers to calculate UCLs for contaminant concentrations	Moderate (radionuclides) High (chemicals)		
Variation in QA/QC for data acquired other than from the RI/FS field investigation			Low (radionuclides and chemicals)
Land-Use Assumptions/ Exposure Scenarios			
Assumption of loss of access controls in the future	High (radionuclides and chemicals)		
Placement of future resident farmer on top of waste areas	High (radionuclides and chemicals)		
Fate and Transport Models			
Geochemical Models and Parameters	Moderate to High (radionuclides)		Moderate (chemicals)
Vadose Zone and Regional Aquifer Models and Parameters			Low (radionuclides and chemicals)
Surface Water/Sediment Models and Parameters			Moderate (radionuclides and chemicals)
Air Models and Parameters			Low (radionuclides and chemicals)
Exposure Assessment Parameters			
Exposure frequencies and duration	Moderate (radionuclides and chemicals)		
The standard assumptions regarding body weight, period exposed, life expectancy, population characterization and life style are representative of sensitive subpopulations (usually 5% of the total population)	Moderate (radionuclides and chemicals)		

TABLE 5-41
(Continued)

Assumption	Effect on Risk Estimation: Potential Magnitude for Over-Estimation of Risk	Potential Magnitude for Under-Estimation of Risk	Potential Magnitude for Over- or Under-Estimation of Risk	
Intake of media is assumed to be constant over an entire lifetime	Moderate (radionuclides and chemicals)			1 2
Use of biotransfer factors to predict contaminant concentrations	Moderate to High (radionuclides and chemicals)			3 4
Assumption that receptor is exposed to all contaminants simultaneously via all pathways	Moderate to High (radionuclides and chemicals)			5 6 7
Toxicity Assessment				8
Use of slope factors for ingestion or inhalation	Moderate (radionuclides and chemicals)			9 10
Use of slope factors for external exposure to radionuclides in surface soil	Moderate (radionuclides)			11 12 13
Use of RfD values with uncertainty factors ranging from 10 to 10,000 to estimate noncarcinogenic effects associated with the exposure	Moderate to High (chemicals)			14 15 16 17
Risk Characterization				18
Combination of risks from multiple pathways and multiple constituents	Low (radionuclides) Moderate to High (chemicals)			19 20

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. Although the data outliers may represent actual concentrations of contaminants, the infrequent detection of outlier concentrations indicates high concentrations in limited areas. Adjusted methodology to determine more realistic risk values will be presented in the individual Operable Unit baseline risk assessments.

Parameters used to calculate transport of the waste mass were chosen to calculate the upper bound of possible exposure point concentrations. For air, it was assumed that there was limited vegetative cover to inhibit fugitive dust emissions. Additionally, modeled concentrations of airborne contaminants were assumed to be the same indoors as outdoors. For groundwater modeling, assumptions regarding the mineralogy of the waste areas and the underlying glacial materials led to differences of orders of magnitude for the groundwater concentrations from one waste area to the next. This uncertainty will be reduced as additional field data are incorporated into groundwater fate and transport modeling.

The following factors contribute to uncertainty:

- Use of the upper 95-percent sampling concentrations and maximum modeled concentrations for exposure point concentrations while including data outliers that suggest only isolated areas of elevated concentrations

- Fate and transport modeling parameters, such as retardation factors, and biotransport factors. For example, soil-to-vegetable transfer factors suggest high levels of plant uptake. If background concentrations of metals are run through the future resident farmer scenario, resulting HIs are high. For example, the UTL background soil concentration for mercury results in an HI of 3.5. These results suggest one of two things: 1) background concentrations of metals may cause toxic effects, or 2) the model used to estimate intakes and risks significantly overestimate the true effect.

- Soil-to-plant transfer factors (B_{iv} values) that are used are generally conservative, meaning that the value represents near the maximum amount of contaminant transfer that may occur. In reality, the contaminant transfer is quite dependent on the metal species, in the same way soil sorption is dependent on metal solubility.

- Intake assessment parameters, which generally represent the habits of a small percentage of the population (usually 5 or 10 percent). The effect of these parameters on the intake and risk calculations is presented in Tables 5-42 and 5-43. In general, a change in an exposure parameter results in linear changes in risks.

TABLE 5-42

ANALYSIS OF THE SENSITIVITY OF SELECTED EXPOSURE PARAMETERS FOR EXPOSURES TO CHEMICALS IN GROUNDWATER

Parameter Varied:			
Ingestion Rate (ℓ/day)	1.8	2.0	2.2
Percent Variation	-10	0	+10
Resulting Variation:			
Intake of Chemical (mg/kg/day)	2.5×10^{-2}	2.7×10^{-2}	3.0×10^{-2}
Percent Variation	-10	0	10
Parameter Varied:			
Exposure Duration (years)	63	70	77
Percent Variation	-10	0	10
Resulting Variation:			
Intake of Chemical (mg/kg/day)	2.5×10^{-2}	2.7×10^{-2}	3.0×10^{-2}
Percent Variation	-10	0	10
Parameter Varied:			
Concentration of Chemical	0.9	1.0	1.1
Percent Variation	-10	0	10
Resulting Variation:			
Intake of Chemical (mg/kg/day)	2.5×10^{-2}	2.7×10^{-2}	3.0×10^{-2}
Percent Variation	-10	0	10

TABLE 5-43

ANALYSIS OF THE SENSITIVITY OF SELECTED EXPOSURE PARAMETERS FOR EXPOSURES TO CHEMICALS IN SOIL

Parameter Varied:		
Diet Fraction (unitless)	0.9	1.0
Percent Variation	-10	0
Resulting Variation:		
Intake of Chemical (mg/kg/day)	1.34×10^{-6}	1.49×10^{-6}
Percent Variation	-10	0
Parameter Varied:		
Exposure Frequency (days/yr)	315	350
Percent Variation	-10	0
Resulting Variation:		
Intake of Chemical (mg/kg/day)	1.34×10^{-6}	1.49×10^{-6}
Percent Variation	-10	0

Uncertainties in toxicity and risk characterization are present as a consequence of the assumptions used for derivation of toxicity and risk characterization factors. Much of the data are based on extrapolation to humans from limited data on laboratory animals. These extrapolations include an additional uncertainty (positive bias) of a factor of 10 to 10,000. Some toxicity risk characterization data are also based on assumptions for "similar compounds". For example, the application of available toxicity data for PCBs, PAHs, and dioxins is very uncertain. The only PCB with positive carcinogenicity results is Aroclor-1260. Statistically significant cancer results were not seen for other isomers. Application of the Aroclor-1260 carcinogenicity to other isomers may result in a calculated risk being significant when it is more likely a "zero PCB cancer risk".

In almost all cases where calculated risks are high, systematic uncertainties with the available risk assessment methods appear to contribute significantly to the high risk values. This overestimation is a direct consequence of pervasive use of upper-bound values of each risk assessment parameter.

The goal of the evaluation of uncertainties is to provide the complete spectrum of information concerning the uncertainty of calculated risks. For the PBRA, it can be concluded that calculated risks represent not only the "upper-bound", but a level perhaps several orders of magnitude above the risk that would be calculated for a "reasonable maximum exposure" using reasonable exposure scenarios and intake parameters.

5.5 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

5.5.1 DATA EVALUATION AND SELECTION OF CONSTITUENTS OF CONCERN

The first portion of the risk assessment involves compilation and evaluation of data that characterize the site and the selection of constituents of concern. In this portion of the risk assessment the sources of data that characterize the site are summarized, the methods for evaluating analytical results are described, and the selection of constituents of concern is defined.

The description of the sources of data that characterize the site includes consideration of those data that characterize the FEMP property and site-influenced environmental media, and those data used to characterize background levels that are not attributable to the site. The presentation of the methodology for evaluating data includes a summary of statistical approaches used to compare site-related data to background data, determine distributions of data, and summarize the distributions with statistical parameters. The selection of constituents of concern is presented and is based on the statistical data evaluation methods described and additional nonstatistical considerations from EPA risk assessment guidance.

Selected constituents of concern are presented in summary form in Section 2.0 (Tables 2-3 through 2-29) by waste area and environmental medium. Statistical summary parameters presented include background upper tolerance limit values, and mean and UCL site-related values. UCL values are used in the exposure assessment to calculate source terms for environmental transport modeling of constituents of concern and to estimate potential receptor exposure point concentrations.

5.5.2 EXPOSURE ASSESSMENT

The second portion of the risk assessment involves assessing potential exposures to selected constituents of concern that could impact potential human receptors. In this portion of the risk assessment the exposure setting is characterized, potential exposures scenarios are investigated and selected for quantitative evaluation, and potential exposures are quantified for the selected site-specific exposure pathways.

Characterization of the exposure setting includes description of the physical setting, potentially exposed receptors, and the land-use assumptions employed to quantify potential exposures. The exposure pathway selection process begins with development of all reasonable quantifiable exposure pathways by medium, land use type, and potentially exposed receptor. Each pathway that is quantitatively evaluated is described in detail and the basis for selecting or excluding each pathway for quantitative assessment is presented. The presentation of exposure quantification for the selected pathways and receptors includes the methods used to estimate receptor exposure point concentrations, including consideration of methods for estimating concentrations by using transport models. Estimated constituent exposure point concentrations, and parameter values are presented for each exposure pathway that is quantitatively evaluated.

5.5.3 TOXICITY ASSESSMENT

The third portion of the risk assessment involves assessing the toxicity or health impact of the constituents of concern selected in Section 2.0. The toxicity assessment presents available information on the health effects of constituents of concern. Detailed assessments of toxicity information are presented for primary constituents of concern at the site, and quantitative estimates of toxicity values are tabulated for all constituents of concern including the basis for quantitative toxicity estimates. Radionuclides, carcinogenic chemicals, and noncarcinogenic chemicals are addressed separately. The toxicity assessment includes identification of a number of uncertainties inherent in the quantitative toxicity estimates. These are important considerations because these estimates are used to characterize the risk to human health from exposure estimates quantified in Section 3.0.

5.5.4 RISK CHARACTERIZATION

The forth portion of the risk assessment involves characterizing the risks associated with the exposure pathways selected in the exposure assessment. During risk characterization, the methodology used to quantify the risks and hazard indices are presented, the quantitative risk results are presented in tabular form or in figures by land use scenario and exposure medium, the contributions to uncertainties in the risks are identified and their impacts discussed, and the risk results are discussed. Section 5.5.4.1 summarizes the risk characterization results. Section 5.5.4.2 uses the risk information generated by this assessment to determine the preliminary site-wide RME individual and location. Section 5.5.4.3 presents the risks calculated from background concentrations of site related constituents to provide perspective on both the methodology employed and the results.

5.5.4.1 SUMMARY RISK TABLES

The results of the preliminary site-wide baseline risk assessment have been summarized in Tables 5-44 through 5-46. These tables present the RME individual, RME location, and ILCR/HI for each exposure pathway quantified in the three land-use scenarios investigated.

Under the current land use scenario (with access controls) the radiological ILCRs exceed 1 x10^{-6} for each exposure medium (Table 5-44). The highest ILCRs associated with radionuclides are about 3 x 10^{-4} for the off-property farmer (either surface or groundwater use) and the trespassing child (external radiation exposures). Chemical ILCR's, presented in Table 5-44, indicate that risks from chemical carcinogens exceed 10^{-6} for exposure pathways associated with surface water, groundwater, and soil/waste. The ILCRs calculated for the off-property farmer's exposures via groundwater is about 10^{-3}. ILCR's associated with the use of beef and dairy products grown with Great Miami River water or grazed on-property are 1 x 10^{-4} and 3 x 10-^{3}, respectively. The HIs presented in Table 5-44 for the off-property farmer using ground water is 280 (associated with intake of silver). The hazard indices of the off-property user of beef and dairy products produced using surface water from the Great Miami River and contaminated grazing land are 28 (associated with the intake of mercury) and 3.3, respectively.

Under the hypothetical current land-use scenario without access controls radiological ILCRs exceed 1 x10^{-6} for each exposure medium (Table 5-45). The highest ILCRs for radionuclides in this scenario are 8 x10^{-3} for external radiation exposure of the trespassing child, 4 x 10^{-3} from using beef and dairy products from cattle raised on property, 3 x 10^{-3} for aerial exposures to the off-property farmer, 1 x 10^{-3} for scavenging activities, and 3 x 10^{-4} for the farmer using Great Miami River water and the for the off-property farmer using groundwater, respectively. Table 5-45 also summarizes ILCRs and HIs from chemical carcinogens for pathways associated with soil

TABLE 5-44

SUMMARY OF RISK ASSESSMENT RESULTS
FOR THE CURRENT LAND-USE SCENARIO WITH ACCESS CONTROLS

Medium	RME Receptor	TOTAL ILCR	ILCR Location	High HI	HI Location
Air (rad)	Visitor	5.6E-05	Former Prod. Area	NA[a]	NA
Groundwater (rad)	Resident farmer	3.1E-04	So. Plume, well 2061	NA	NA
Groundwater (chem)	Resident farmer	1.0E-03	So. Plume, well 2094	280	S. Plume, well 3127
Surface water (rad)	GM River user	3.2E-04	GMR, below P. Run	NA	NA
Surface water (chem)	Beef & Dairy User	1.0E-04	Waste Pit 6	28	GM River, below P. Run
Sediment (rad)	Trespassing child	<1.0E-08	P. Run, below SSOD	NA	NA
Sediment (chem)	Trespassing child	1.0E-09	Mid. Paddys Run	2.0E-05	Mid. Paddys Run
Soil/waste (rad)	Beef & dairy user	2.0E-04	Site-wide soils	NA	NA
Soil/waste (chem)	Beef & dairy user	4.0E-03	Site-wide soils	3.3	Site-wide soils
External exposure (rad)	Trespassing child	3.0E-04	Near K-65 silos	NA	NA
Structures (rad)	NA	NA	NA	NA	NA

[a] Not Applicable

TABLE 5-45

SUMMARY OF RISK ASSESSMENT RESULTS
FOR THE CURRENT LAND-USE SCENARIO WITHOUT ACCESS CONTROLS

Medium	REM Receptor	Total ILCR	ILCR Location	High HI	HI Location
Air (rad)	Resident farmer	3.0E-03	East of FEMP	NA[a]	NA
Groundwater (rad)	Resident farmer	3.1E-04	S. Plume, well 2061	NA	NA
Groundwater (chem)	Resident farmer	1.0E-03	S. Plume, well 2094	280	S. Plume, well 3127
Surface water (rad)	GM River user	3.2E-04	GMR, below Outfall	NA	NA
Surface water (chem)	Beef & dairy user	1.0E-04	Waste Pit 6	28	GM River, below P. Run
Sediment (rad)	Trespassing child	2.6E-06	SSOD	NA	NA
Sediment (chem)	Trespassing child	3.0E-08	Mid. Paddys Run	6.0e-04	Mid. Paddys Run
Soil/waste (rad)	Beef & dairy user	3.5E-03	SW Quad of Prod. Area	NA	NA
Soil/waste (chem)	Trespassing child	6.0E-04	NE Quad of Prod. Area	1.5	Waste Pit 5
External exposure (rad)	Trespassing child	8.4E-03	Near K-65 silos	NA	NA
Structures (rad)	Scavenger	1.3E-03	Plant 9	NA	NA

[a] Not Applicable

TABLE 5-46

SUMMARY OF RISK ASSESSMENT RESULTS
FOR FUTURE LAND-USE SCENARIOS

Medium	RME Receptor	Total ILCR	ILCR Location	HI	HI Location
Air (rad)	Resident farmer	2.2E-02	Near Plant 2/3	NA[a]	NA
Groundwater (rad)	Resident farmer	1.1E-02	Near Plant 9	NA	NA
Groundwater (chem)	Resident farmer	9.0E-04	Near Plant 9	100	Near Plant 9
Surface water (rad)	GM River user	8.8E-05	GM River, below P. Run	NA	NA
Surface water (chem)	GM River user	1.0E-05	GM River, below P. Run	1	GM River, below P. Run
Soil/waste (rad)	Resident farmer	2.5E-01	Waste Pit 3	NA	NA
Soil/waste (chem)	Resident farmer	1.0E-01	Waste Pit 2	150	Waste Pit 3
External exposure (rad)	Resident farmer	3.3E-03	Near Silo 3	NA	NA
Structures (rad)	Building user	1.1E-01	Building 9	NA	NA

[a] Not Applicable

and waste. The trespassing child scenario yields a ILCR of about 6 x 10^{-4}, and HI of 1.5 (associated with arsenic). 3578

Under the future land-use scenario (Table 4-46), the radiological ILCRs exceed 10^{-6} for all media. The radiological risk to the on-property farmer from exposure pathways associated with air, groundwater, soil/waste, and external radiation exposure are 2 x 10^{-2}, 1 x 10^{-2}, 3 x 10^{-1}, and 3 x 10^{-3}, respectively. The ILCRs for the hypothetical farmer using the Great Miami River is about 10^{-4} and the risk to an inhabitant of buildings and structures in the former production area is about 10^{-1}. ILCRs from chemical carcinogens in Table 5-46 reveal that the risks for the on-property farmer using groundwater and residing on contaminated soil/waste are approximately 10^{-3} and 10^{-1}, respectively. Hazard indices for the on-property farmer using groundwater and residing on contaminated soil/waste are 100 (uranium) and 150 (arsenic), respectively. The hazard index for an off-property user of surface water from the Great Miami River is 1.0 (associated with uranium).

5.5.4.2 SITE-WIDE RME

The site-wide RME location is selected as the location which produces the greatest risks from all constituents, all sources, and all pathways. The information in Sections 5.2 and 5.3 will be used to determine this location for the current scenarios, and information in Section 5.4 will be used to determine this location for the future scenarios.

Current Site-wide RME Location

Examining the radiological results presented in Tables 5-1 through 5-18, and Figures 5-1 and 5-5, it can be demonstrated that the highest CERCLA risks for radionuclides under current land use conditions (with access controls) are associated with groundwater wells to the south of the property. The estimated risks to the hypothetical off-property adjacent farmer from radionuclides exceed 3 x 10^{-4} for well 2061. Risks from exposures to airborne constituents are calculated to be 20% of these risks and extend to the east of the silos. Thus the adjacent off-property farmer using groundwater is the current preliminary site-wide RME individual. Due to prevailing weather patterns, the risks to this receptor (south of the FEMP) from air pathways are minor compared to those associated with groundwater use.

It is conceivable that the off-property farmer could use meat and dairy products from cattle raised on property. The presence of access controls limits additional risks to this hypothetical receptor from this pathway to about 2 x 10^{-4} (Table 5-15).

Without existing access controls, the estimated CERCLA risks to the current hypothetical off-property receptor could increase to 1 x 10^{-1} from grazing on Pit 5 wastes (Tables 5-19 and 5-25). A closer examination of Pit 5 reveals that the surface area of the exposed pit wastes is too small to allow sustained grazing, and that it is not currently covered with vegetation. If this pit is removed from consideration for these reasons, risks for the off-property resident could approach 4 x 10^{-3} for this pathway. Thus, if access controls were removed, the current RME individual would shift to the off-property user of beef and dairy products grown on site.

Future Site-wide RME Location

Examining Tables 5-30 through 5-38, and Figures 5-6 and 5-10, it can be demonstrated that CERCLA risks from radionuclides in soils within Pits 3 and 5 are in excess of 10^{-1}. This is the location of maximum on-property risk. Both air and water exposures are estimated to produce risks which approach 10-2. These risks are approximately 10% of the risks from Pit 3 soils. Therefore, risks from these soils dominate all other risks in the future scenario, and these locations must be carefully considered when locating the site-wide RME.

It is possible that a number of media could combine and produce a new aggregate risk exceeding the risks from waste pit soils. To investigate this, the magnitude and spatial distribution of risks from the air and groundwater plumes are examined, and compared to the magnitude and spatial distribution of risks associated with soils at the FEMP.

This comparison reveals a receptor in the SW Quadrant of the former production area could be exposed to risks in excess of 10^{-3} from soil, air and water pathways at the same time. The Plant 2/3 area is associated with some of the highest risks from soil pathways, outside of the waste pit area. These soil related risks are about 5 x 10^{-3}. If the silo caps fail in the next 1000 years, the center of the plume from the silos is predicted to pass over Plant 2/3 in the SW quadrant of the former production area. Risks from airborne contamination (both particulates and radon) in this area of the former production area could approach 10^{-3}. The use of groundwater beneath the southern portion of the former production area by a resident farmer could produce risks in excess of 10^{-3}.

Using information on the exposure point concentrations of the various media within the Plant 2/3 area, the risks from radionuclides were calculated for a variety of receptors. Table 5-47 illustrates the relative importance of various nuclides in each media, and provides a quantitative assessment of the relative sensitivities of four different receptors to radionuclides predicted to be present in air, water, and soil. It also demonstrates that the combined risks from all media at this location do not approach those risks estimated for a farmer on waste pit soils. Therefore, this area is not considered further in the search for the RME location.

TABLE 5-47

ILCRs FROM RADIONUCLIDES IN THE SOUTHERN PORTION OF THE FORMER PRODUCTION AREA FOR FOUR FUTURE HYPOTHETICAL RECEPTORS

Medium Radionuclide	Resident RME Farmer	Typical On-property Resident	Resident RME Child	Home Builder
Soil (Plant 2/3 subsoils)				
U-238	2.6E-03	3.3E-04	2.3E-04	2.2E-06
U-235	7.1E-04	9.0E-05	5.4E-05	7.1E-07
U-234	4.1E-04	4.6E-05	5.0E-05	1.1E-07
Ra-226	1.2E-03	1.5E-04	9.3E-05	1.2E-06
Tc-99	7.1E-05	9.1E-06	1.5E-05	7.6E-12
Th-230	1.2E-06	3.6E-08	1.8E-07	2.1E-09
Th-232	4.6E-04	5.9E-05	3.4E-05	4.7E-07
Air				
Th-232	1.4E-04	1.8E-05	4.3E-06	2.5E-07
Rn-222	2.2E-02	2.8E-03	6.6E-04	3.9E-05
Groundwater				
U-238	1.1E-02	1.4E-03	3.9E-03	NA
Np-237	2.7E-07	3.5E-08	1.1E-07	NA
Combined	4E-02	5E-03	5E-03	4E-05

Returning to the waste area, examination of the radiological risks from Pit 3 soils reveals a major portion of these risks can be attributed to gamma risks from Ra-226 and its daughters (Table 5-48). In addition, the risks from Pit 3 soils contain a sizable contribution from Tc-99 via the dairy product pathway. However, the data upon which the Tc-99 numbers are based may be suspect. These are unvalidated data available as of Dec 1, 1991, and yield exposure point concentrations well in excess of what may reasonably be suspected to be present, based on process history and data made available after December 1. This additional data, collected since December 1, 1991, will be presented in the OU1 RI to clarify this point. Additional contributors include Pb-210 (vegetable and fruit), and Th-232 (gamma). Even discounting the risks associated with Tc-99, risks in the waste area exceed 10^{-1} in places. Thus the farmer on the OU1 waste pits appears to be the leading candidate for the preliminary site-wide maximally exposed individual for radionuclides.

5.5.4.3 Background Risks

ILCRs and HIs were calculated under the RME resident farmer scenario using the upper 95% confidence interval on the mean for regional background data as exposure point concentrations. This was the only data available as of December 1, 1991). Tables 5-49 through 5-51 present the results. These results should be used as a point of reference when interpreting risk results from radionuclides and inorganic chemicals in soils under this scenario.

Background concentrations of radionuclides in air, water, and soil yield ILCRs ranging from 10^{-7} to 10^{-4} (Table 5-49). The aggregate radiological risks from background are calculated to be about 10^{-3}. The highest risk from a single radionuclide and pathway is about 10^{-3} from Rn-222 in air. Background levels of beryllium are calculated to produce an ILCR of approximately 3×10^{-5} (Table 5-50).

Table 5-51 presents Hazard Indices for 20 site related constituents. Background concentrations of nine constituents in soil yield HIs greater than 0.2: arsenic (0.9), barium (0.5), chromium (0.2), cobalt (0.2), lead (0.9), manganese (1), mercury (3), thallium (5), and zinc (3).

TABLE 5-48

FRACTIONAL CONTRIBUTION OF EXPOSURE PATHWAYS TO THE ON-PROPERTY RESIDENT FARMER'S RISK FROM RADIONUCLIDES IN PIT 3 SOILS*

Nuclide	External Exposure from Soil	Soil Ingestion	Vegetable & Fruit Ingestion	Beef Ingestion	Dairy Product Ingestion
Am-241	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Cs-137 + dtr	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Np-237 + dtr	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Pa-231+ 8 dtrs	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
Pb-210 + 2 dtrs	<0.1%	0%	3%	0%	1%
Pu-239/240	0%	<0.1%	<0.1%	<0.1%	<0.1%
Ra-226 + 5 dtrs	41%	<0.1%	<0.1%	<0.1%	<0.1%
Sr-90 + dtr	na	<0.1%	<0.1%	<0.1%	<0.1%
Tc-99	<0.1%	<0.1%	5%	8%	38%
Th-230	<0.1%	0%	<0.1%	<0.1%	<0.1%
Th-232 + 10 dtrs	3%	<0.1%	<0.1%	<0.1%	<0.1%
U-234	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
U-235 + 1 dtr	0%	<0.1%	<0.1%	<0.1%	<0.1%
U-238 + 2 dtrs	0%	<0.1%	<0.1%	<0.1%	<0.1%

*The number of signficant figures presented is provided to lessen the impacts of rounding errors, and is not indicative of a value's accuracy.

TABLE 5-49

ILCRs FOR THE RESIDENT FARMER
FROM BACKGROUND CONCENTRATIONS OF RADIONUCLIDES

Medium	Radionuclide	UCL Background Concentrations	Resident On-property Farmer	ILCR
Soil		(pCi/g)	(ILCR-g/pCi)	
	U-238	1.6E+00	2.0E-06	3.2E-06
	U-235	7.0E-02	1.0E-05	7.2E-07
	U-234	1.6E+00	3.1E-07	4.9E-07
	Ra-226	1.7E+00	2.6E-04	4.3E-04
	Th-230	1.6E+00	4.1E-08	6.5E-08
	Th-232	1.1E+00	3.5E-04	3.7E-04
Air		(pCi/m3)	(ILCR-m3/pCi)	
	Rn-222	6.3E+02	8.9E-07	5.6E-04
Groundwater		(pCi/L)	(ILCR-L/pCi)	
	U-238	1.0E+00	1.9E-06	1.9E-06
	Th-232	1.0E+00	1.1E-05	1.1E-05
	Ra-226	1.0E+00	8.8E-06	8.8E-06
Combined				1E-03

TABLE 5-50

ILCR FOR BACKGROUND

Chemical Name	Background Concentration (mg/kg)	Unit Toxicity Factor	Hazard Index
Beryllium	1.05	3.0E-05	3.15E-05

TABLE 5-51

HAZARD INDEX FOR BACKGROUND

Chemical Name	Background Concentration (mg/kg)	Unit Toxicity Factor	Hazard Index
Antimony		3.8E+00	0.0
Arsenic	12.361	7.4E-02	9.1E-01
Barium	533.52	8.7E-04	4.7E-01
Beryllium	1.05	1.4E-03	1.5E-03
Boron		4.9E-02	0.0
Cadmium (food)	4.159	1.9E-03	7.9E-03
Chromium	59.043	3.6E-03	2.1E-01
Cobalt	13.146	1.7E-02	2.2E-01
Cyanide		2.0E+00	0.0
Lead	23.422	3.8E-02	8.9E-01
Manganese	679.541	1.4E-03	9.5E-01
Mercury	0.166	2.1E+01	3.5E+00
Molybdenum	4.187	1.9E-02	8.0E-02
Nickel	25.698	6.1E-03	1.6E-01
Selenium	0.568	1.6E-02	9.1E-03
Silver	3.947	3.8E-02	1.5E-01
Thallium	10.94	4.7E-01	5.1E+00
Uranium	3.23	3.7E-03	1.2E-02
Vanadium	95.026	1.3E-03	1.2E-01
Zinc	73.965	3.5E-02	2.6E+00

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6.0 ECOLOGICAL ASSESSMENT

6.1 INTRODUCTION

The purpose of the ecological assessment is to estimate the potential present and future baseline risks of FEMP contaminants to ecological receptors. These receptors include all organisms, exclusive of humans and domestic animals, potentially exposed to FEMP contaminants. It is not possible to evaluate all potential effects on all potential ecological receptors which may be exposed to FEMP contaminants. This assessment therefore focuses on a group of indicator species selected to represent a variety of exposure pathways and trophic positions, as described in the Risk Assessment Work Plan Addendum (DOE 1992) and briefly reiterated below. The scope of the PBRA, the entire FEMP site, allows for a large number of potential exposure scenarios for each receptor evaluated, for example, exposure to surface soils within each operable unit or suboperable unit at the FEMP. However, in accordance with the focus of the PBRA on site-wide risks, this preliminary assessment examines risks to terrestrial organisms associated with contaminants in two environmental media -- surface soils, summarized for the entire site, and surface water in Paddys Run from the northern boundary of the FEMP to the confluence with the storm sewer outfall ditch, that is, the primary on-property soil and surface water exposures likely to occur. Risks to aquatic organisms are evaluated for exposure to contaminants in Paddys Run, the Great Miami River, and in runoff into the storm sewer outfall ditch. Both terrestrial and aquatic assessments use a combination of modeling and field data, and both evaluate risks of exposure to inorganic, organic, and radiological constituents. The analyses presented below will be updated via a Site-Wide Ecological Assessment in the Operable Unit 5 RI report, which will incorporate data and field studies not available on December 1, 1991, the cutoff date for data presented in the SWCR.

6.2 ECOLOGICAL SETTING

The regional and site-specific ecology of the FEMP is described in detail in Part I, Section 2.0. RI/FS studies of threatened and endangered species, wetlands, and macroinvertebrate communities are detailed in Appendices G, B, and D, respectively. This section briefly summarizes this information to provide a context for the ecological assessment data which follow.

The FEMP lies in the Oak-Hickory Forest Section of the Eastern Deciduous Forest, as described by Bailey (1978). Ecological communities consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the Inactive Flyash Pile/South Field ("reclaimed fly ash pile area") (Facemire et al. 1990). Facemire et al. (1990) considered the latter to be a separate habitat because of its distinct flora and fauna composition. 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 have been recorded at 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. The Inactive Flyash Disposal Area/Southfield is dominated by American elm, eastern cottonwood, and black locust.

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, while less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Forested jurisdictional wetlands, as defined by federal guidance (FICWD 1989) occupy approximately 50 acres north of the production area. Emergent jurisdictional wetlands occur along the railroad spur and various drainageways on the FEMP. Paddys Run and adjacent aquatic habitats harbor small fish, amphibians, and a variety of benthic macroinvertebrates.

The most common fish are the bluntnose minnow, creek chub, and stoneroller minnow. The most common benthic macroinvertebrates are nonbiting midges, riffle beetles, mayflies, and stoneflies.

No federally listed threatened or endangered species have been observed on the FEMP or in its immediate vicinity. Suitable habitat for one species of mammal listed as federally endangered, the Indiana bat, occurs along Paddys Run; however, the Indiana bat was not found on site.

6.3 METHODOLOGY

As described previously in Section 6.1, several species were selected for detailed evaluation as indicators of potential effects of FEMP contaminants at various levels of the food chain. The selection of these species and the methods used to estimate exposures and characterize resulting risks are briefly summarized below. Details of methodology may be found in DOE (1992).

6.3.1 Constituents of Potential Concern

All nonradioactive and radioactive constituents identified as of potential concern in the human health risk assessment before screening of constituents of greatest human health risk were considered to be of concern for the ecological risk assessment. The methods and results of this selection are described in Part II, Section 2.0. Because ecological receptors currently have access to the FEMP site, no distinction was made between present and future constituents of potential concern, except for potential future exposure of aquatic organisms to contaminants eroded from waste units and soils. Appendix R lists constituents of concern for all media at the FEMP and for a variety of subdivisions of the FEMP. The exposure concentrations selected for evaluation of effects on terrestrial organisms were the mean surface soil (0 to 6 inches) concentrations for the entire site, based on RI/FS sampling, and the mean surface water concentrations in Paddys Run from the northern boundary of the FEMP to the confluence with the storm sewer outfall ditch. The exposure concentrations examined for effects on aquatic organisms were the upper 95 percent confidence limits of concentrations in Paddys Run and the Great Miami River, and modeled concentrations in runoff into the storm sewer outfall ditch.

6.3.2 Exposure Assessment and Risk Characterization

The ecological assessment focuses on potential noncarcinogenic effects on vegetation, wildlife, and aquatic organisms as a result of exposure to radioactive and nonradioactive constituents of potential concern. Terrestrial vegetation is represented by a generic plant species. Terrestrial wildlife species to be evaluated were selected based on species abundance on the FEMP, trophic level position, and habitat requirements. The species selected were the white-tailed deer (*Odocoileus virginianus*), white-footed mouse (*Peromyscus leucopus*), raccoon (*Procyon lotor*), red fox (*Vulpes*), muskrat (*Ondatra zibethica*), American robin (*Turdus migratorius*), and red-tailed hawk (*Buteo jamaicensis*). The major route of exposure of plants to FEMP nonradioactive contaminants is assumed to be the direct uptake of constituents in soil or sediment. Ingestion was assumed to be the major route of exposure of wildlife species to nonradioactive contaminants and was consequently the only route of exposure evaluated for mammals and birds. Concentrations measured and estimated in plants were compared to toxic and background levels reported in the literature. Risk to wildlife was assessed by comparisons of tissue residue concentrations in wildlife and intake concentrations with toxicity information from the

literature and from EPA guidance on human health effects, for example HEAST and IRIS. Hazard indices for nonradioactive contaminants were calculated as the ratio of the exposure concentration or intake rate to the no observed effects level (NOEL). The NOEL for wildlife is directly analogous to the reference dose (R_fD) used in human health risk assessment, and in some cases, NOELs were calculated from R_fDs, as described below. Population effects were qualitatively assessed based on potential impacts on individual organisms, supplemented by the ecological characterization of Facemire et al. (1990).

6.3.2.1 Intake of Constituents of Concern by Terrestrial Organisms

This section describes the methods used to estimate intake of constituents of concern in surface soils and waters by terrestrial organisms at the FEMP.

Plants

The mean concentration of each constituent of concern in a generic plant growing in FEMP soil was estimated from RI/FS surface soil data for the whole FEMP site. These estimates were supplemented with RI/FS data on constituent concentrations in FEMP vegetation. Direct uptake from soil or sediment was assumed to be the major route of exposure of plants to FEMP contaminants, with exposure to wind-blown soil and associated contaminants assumed to be a minor route of exposure. Soil to plant transfer factors for radionuclides and inorganic chemicals in both vegetative plant parts and fruits were obtained from Baes et al. (1984) (Table 6-1). Soil to plant (vegetative plant parts only) transfer coefficients for organic compounds of potential concern were estimated using the equations of Travis and Arms (1988) (Table 6-2). These transfer factors are conservative and do not consider such factors as the bioavailability of a chemical in soil, the biodegradation rate of a compound in soil or the metabolic transformation of compounds in plants.

Wildlife

Intake of contaminants by each of the terrestrial wildlife indicator species was estimated using intake parameters obtained from either published literature or derived from EPA formulas (EPA 1988) (Table 6-3). Intake of contaminants in vegetation was estimated using an equation adapted from EPA's Human Health Evaluation Manual (1989a) in which

$$I_v = (C_v)(Q_v)(FI)(EF)(ED)/(BW)(AT)$$

where

I_v = intake of chemical in vegetation (mg/kg/day)
C_v = concentration in vegetation (mg/kg)
Q_v = ingestion rate (kg/day)
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (days/year)
ED = exposure duration (years)

TABLE 6-1
SOIL-TO-PLANT TRANSFER COEFFICIENTS USED FOR RADIONUCLIDES AND INORGANIC CHEMICALS OF POTENTIAL CONCERN IN FEMP SOILS

Chemical	Transfer Coefficient[a]	
	Soil-to-Vegetative Plant Parts	Soil-to-Fruits
Radionuclides		
Cesium	0.080	0.03
Plutonium	4.5×10^{-4}	4.5×10^{-5}
Radium	0.015	1.5×10^{-3}
Strontium	2.5	0.25
Technetium	9.5	1.5
Thorium	0.00085	8.5×10^{-5}
Uranium	0.0085	4×10^{-3}
Inorganic Chemicals		
Arsenic	0.04	6×10^{-3}
Barium	0.15	0.015
Beryllium	0.010	1.5×10^{-3}
Cadmium	0.55	0.15
Chromium	0.0075	4.5×10^{-3}
Cobalt	0.020	7×10^{-3}
Copper	0.40	0.25
Lead	0.045	9×10^{-3}
Magnesium	1.0	0.55
Manganese	0.25	0.05
Mercury	0.90	0.20
Nickel	0.060	0.06
Selenium	0.025	0.025
Silver	0.40	0.10
Thallium	0.004	4×10^{-4}
Vanadium	0.0055	3×10^{-3}
Zinc	1.5	0.90

[a]Soil-to-plant elemental transfer factors assume dry plant and soil weights.
SOURCE: Baes et al. (1984)

TABLE 6-2
SOIL-TO PLANT AND PLANT-TO-BEEF TRANSFER COEFFICIENTS USED FOR ORGANIC COMPOUNDS OF POTENTIAL CONCERN IN FEMP SOILS

Compound	Log k_{ow}	Transfer Coefficients	
		Soil-to-Plant[a]	Plant-to-Beef[b]
Polycyclic Aromatic Hydrocarbons			
Acenapthene	4.13	0.16	3.0×10^{-4}
Anthracene	4.45	0.104	7.0×10^{-4}
Benzo(a)anthracene	5.61	0.022	0.010
Benzo(a)pyrene	6.04	0.013	0.0275
Benzo(b)fluoranthene	6.57	6.2×10^{-3}	0.093
Benzo(g,h,i)perylene	7.23	2.6×10^{-3}	0.427
Benzo(k)fluoranthene	6.85	4.3×10^{-3}	0.178
Chrysene	5.61	0.022	0.010
Dibenzo(a,h)anthracene	5.79	0.017	0.0155
Fluoranthene	5.33	0.032	5.4×10^{-3}
Fluorene	4.18	0.149	4.0×10^{-4}
Indeno(1,2-cd)pyrene	7.66	1.4×10^{-3}	1.15
2-Methylnapthalene	3.86	0.228	1.82×10^{-4}
Naphthalene	3.3	0.479	1.0×10^{-4}
Phenanthrene	4.46	0.102	7.0×10^{-4}
Pyrene	5.32	0.033	0.0052
Monocyclic Aromatics			
Benzene	2.13	2.27	3.4×10^{-6}
Benzoic Acid	1.87	3.21	1.9×10^{-6}
Chlorobenzene	2.84	0.88	1.7×10^{-5}
2,4-Dimethylphenol	2.5	1.39	7.9×10^{-6}
Ethylbenzene	3.15	0.585	3.6×10^{-5}
2-Methylphenol	1.95	2.89	2.2×10^{-6}
4-Methylphenol	1.94	2.93	2.2×10^{-6}
Pentachlorophenol	5.06	0.046	2.9×10^{-3}
Phenol	1.46	5.55	7.2×10^{-7}
Toluene	2.73	1.02	1.35×10^{-5}

TABLE 6-2
(Continued)

Compound	Log k_{ow}	Transfer Coefficients	
		Soil-to-Plant[a]	Plant-to-Beef[b]
Xylenes, total	3.15	0.585	3.55×10^{-5}
Phthalate Esters			
Bis(2-ethylhexyl)phthalate	5.11	0.043	3.2×10^{-3}
Butyl benzyl phthalate	4.91	0.056	2.0×10^{-3}
Di-n-butyl phthalate	4.72	0.072	1.3×10^{-3}
Di-n-octyl phthalate	9.2	2.0×10^{-4}	39.8
Polychlorinated Biphenyls			
Aroclor-1016	4.38	0.11	6.0×10^{-4}
Aroclor-1242	4.11	0.16	3.0×10^{-4}
Aroclor-1248	5.6	0.022	0.01
Aroclor-1254	6.47	7.1×10^{-3}	0.074
Aroclor-1260	6.11	0.011	0.032
Halogenated Aliphatic Hydrocarbons			
Chloroform	1.97	2.81	2.3×10^{-6}
1,1-Dichloroethane	1.79	3.58	1.55×10^{-6}
1,1-Dichloroethene	1.48	5.40	7.6×10^{-7}
1,2-Dichloroethene	2.06	2.5	2.9×10^{-6}
Methylene chloride	1.25	7.34	4.5×10^{-7}
1,1,2,2-Tetrachloroethane	3.4	0.42	1.0×10^{-4}
Tetrachloroethene	3.4	0.42	1.0×10^{-4}
1,1,1-Trichloroethane	2.49	1.41	7.8×10^{-6}
Trichloroethene	2.29	1.84	4.9×10^{-6}
1,1,2-Trichloro-1,2,2-trifluoroethane	3.16	0.578	3.6×10^{-5}
Vinyl chloride	1.38	6.17	6.0×10^{-7}
Nonhalogenated Aliphatic Hydrocarbons			
Acetone	-0.24	53.3	1.45×10^{-8}
2-Butanone	0.29	26.3	4.9×10^{-8}
4-Methyl-2-pentanone	1.19	7.95	3.9×10^{-7}

TABLE 6-2
(Continued)

Compound	Log k_{ow}	Transfer Coefficients	
		Soil-to-Plant[a]	Plant-to-Beef[b]
Pesticides			
Beta-BHC	3.8	0.246	2.0×10^{-4}
Chlordane	6	0.013	0.025
4,4-DDT	5.76	0.018	0.0145
Malathion	2.89	0.827	1.95×10^{-5}
Methyl parathion	2.04	0.107	2.8×10^{-6}
Ethyl parathion	3.1	0.24	3.2×10^{-4}
Miscellaneous Compounds			
Carbon disulfide	1.84-2.16	2.19-3.35	1.7×10^{-6}-3.6 x
N-Nitrosodiphenylamine	2.57	1.27	9.3×10^{-6}
3,3-Dichlorobenzidine	3.02	0.70	2.6×10^{-5}
Cyanide	0.35	61.7	5.63×10^{-8}
Dibenzofurans	4.12	0.16	3.31×10^{-4}

[a]Soil-to-plant transfer coefficient estimated by calculating log Biotransfer Factor = 1.588 - 0.578 log k_{ow} (Travis, C.C. and A.D. Arms, 1988. "Bioconcentration of Organics in Beef, Milk, and Vegetation," Environmental Science and Technology, Vol. 22, pp. 271-274). It is based on a dry plant weight and dry soil weight.

[b]Plant-to-beef transfer coefficient assumes meat is 25 percent fat and is estimated by calculating log Biotransfer Factor = -7.6 + log k_{ow} (Travis, C.C. and A.D. Arms, 1988, "Bioconcentration of Organics in Beef, Milk, and Vegetation," Environmental Science and Technology, Vol. 22, pp. 271-274).

TABLE 6-3
WILDLIFE EXPOSURE PARAMETERS USED
IN THE FEMP ECOLOGICAL RISK ASSESSMENT

Species	Weight (kg)	Ingestion Rate Food (kg/day) wet wt.	Diet Composition (% Volume)		Ingestion Rate Soil/Sediment (g/day) dry wt.	Water Consumption (ℓ/day)	Fraction Ingested From Contaminated Source
			Animal	Plant			
White-tailed deer	59.1[a]	4.39[b]	NA[c]	100[d]	18.9[e]	2.73[f]	0.5[g]
White-footed mouse	0.021[h]	0.0327	69.9[i]	30.1[i]	NA	.00357[i]	0.75
Raccoon	5.8[j]	1.14	30[j]	70[j]	NA	0.44[f]	0.5
Red fox	4.7[k]	1.0	89.4[l]	10.6[l]	NA	0.37[i]	0.5
Muskrat	1.23[m]	0.46	NA	100[n]	NA	0.13[f]	0.5
American robin	0.084[o]	0.12	48[o]	52[o]	NA	0.02[p]	0.5
Red-tailed hawk	1.13[q]	0.49	100[r]	NA	NA	0.14[p]	0.5

[a]Weighted mean of data on male and female deer from populations in the northwest and Hill counties of Ohio (Nixon et al. 1970).
[b]Ingestion rate estimated using equation 7-2a in EPA (1988) and the water consumption value presented in this table. The rate is specific to the body weight listed in the table.
[c]Not available.
[d]Deer assumed to be exclusively herbivorous.
[e]Soil ingestion rate assumed to be 1.35% of the total daily dry matter intake as reported for mule deer (Arthur and Alldredge 1979).
[f]Water consumption rate estimated using equation 5-2 in EPA (1988a) and the body weight presented in this table.
[g]The fraction ingested from a contaminated source was based on the animal's home range and the amount of food and water expected to be consumed from contaminated area(s).
[h]Weight presented as a weighted mean of data on male and female white-footed mice collected in Indiana (Mumford 1969).

TABLE 6-3
(Continued)

[i]Water consumption rate and food habits data (average from March through December) for white-footed mice collected in southern Missouri (Brown 1964).
[j]Body weight and food habits data for raccoons were obtained from animals collected in Michigan (Stuewer 1943). The weight presented is a weighted mean of data on male and female raccoons collected over a one-year period. Food habits data are presented as mean percent volumes of items within raccoon scat collected over a one-year period.
[k]Weighted mean of data on male and female red fox collected in Indiana (Hoffman and Kirkpatrick 1954).
[l]Food habits data for red fox were obtained from fall and winter data on animals collected in Maryland (Hockman and Chapman 1983). Data are reported in percent weight.
[m]Body weight of the muskrat is an average weight of Indiana muskrats (Brooks 1959).
[n]Food habits data for muskrats were obtained from animals collected in Maryland (Willner 1975).
[o]Body weight and food habits data for American robins were obtained from birds collected in New York and the central region of North America, respectively (Wheelwright 1986). The weight presented is an average of weighted mean body weights of male and female robins during the breeding season (two months) and during the nonbreeding season (ten months). Food habits data are presented as mean percent volumes of items within the stomachs of robins collected over a one-year period.
[p]Water consumption rate for American robin and red-tailed hawk were estimated using the equation presented for chickens in Table 5-2 in EPA (1988) and the whole body weight for each species as presented in this table.
[q]The body weight of a red-tailed hawk is an average of adult male and females (Snyder and Wiley 1976).
[r]Food habits data on red-tailed hawks were obtained from hawks collected in Alberta, Canada (Adamirk et al. 1979) and Oregon (Janes 1984).

BW = body weight (kg)
AT = averaging time, (ED)(365 days/year)

This equation was used to predict the intake of contaminants in vegetation by the indicator species. Because all organisms were assumed to spend their entire lives on the FEMP, averaging time, exposure duration, and exposure frequency can be eliminated from all intake equations. Species specific values for parameters such as ingestion rate and body weight are presented in Table 6-3. The fraction ingested from a contaminated source was based on the animal's home range and the amount of food and water expected to be consumed from contaminated areas. Feeding rates and NOELs are typically reported on a wet weight basis, while contaminant concentrations in soils and biota are reported on a dry weight basis. Dry weight to wet weight conversion factors used to account for this difference are listed in Table 6-4.

In order to evaluate the potential exposure of resident red fox and red-tailed hawk to FEMP contaminants, estimates were made of the concentrations of metals and organic compounds in the muscle tissues of prey species. Concentrations of metals and organics in muscle tissue of white-footed mice were calculated using plant to beef transfer factors (Baes et al. 1984). Plant to muscle transfer factors were used instead of plant to whole animal transfer factors, due to the scarcity of such values in the literature. Use of plant to muscle transfer factors may underestimate the concentration of a contaminant in a prey species for some constituents that can be biomagnified through food chains and which concentrate in specific tissue (i.e., chlorinated organics in fat, lead and strontium in bone, and mercury in kidney and liver). Use of these factors assumes that (1) the fat content in white-footed mice is minimal, (2) if bones of the prey species are ingested, most of the ingested bone will not be digested, (3) and concentrations of metals in a whole white-footed mouse are expected to be similar to that in muscle. This is supported by data on omnivorous rodents in which whole body concentrations did not differ from that in muscle by more than an order of magnitude (dry weight basis) as reported for cadmium (<1 to 2.25), lead (0.4 to 6.5), and zinc (1.3 to 1.7) (Talmage and Walton 1991). With these assumptions in mind, metal transfer factors for plant to beef were obtained from Baes et al. (1984) and are presented in Table 6-5. Transfer factors for organic compounds were estimated according to Travis and Arms (1988) (Table 6-2).

The concentration of a chemical in muscle was estimated using the following equation:

$$C_a = B_b(C_v \times Q_v)(FI)$$

where

C_a = concentration in muscle (mg/kg)
B_b = plant to beef transfer factor (day/kg)
C_v = concentration in vegetation (mg/kg)

TABLE 6-4
DRY WEIGHT TO WET WEIGHT CONVERSION FACTORS[a]

Item	Conversion Factor
Grass	0.32[b]
Fruits	0.17[c]
Mammal - whole body	0.32[d]
Mammal - soft tissue	0.29[d]
Earthworms	0.22[d]
Fish	0.29[e]

[a]To obtain wet weight ppm, multiply the dry weight ppm by the conversion factor.
[b]The value for grass is an average of conversion factors for wild bromegrass, meadow fescue, Kentucky bluegrass, and orchard grass reported in Morrison (1959).
[c]The value for fruits is an average of conversion factors for cowpea and corn, grapefruits, oranges, apples, and peas reported in Morrison (1959).
[d]Mammal and earthworm values are from Talmage and Walton (1991).
[e]Conversion factor for fish is that for fish muscle and/or skin as reported in Meeks (1968).

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TABLE 6-5
PLANT-TO-BEEF TRANSFER COEFFICIENTS USED FOR RADIONUCLIDES AND INORGANIC CHEMICALS OF POTENTIAL CONCERN IN FEMP SOILS

Chemical	Plant-to-Beef Transfer Coefficient
Radionuclides	
Cesium	0.020
Plutonium	5.0×10^{-7}
Radium	2.5×10^{-4}
Strontium	3.0×10^{-4}
Technetium	8.5×10^{-3}
Thorium	6.0×10^{-6}
Uranium	2.0×10^{-4}
Inorganic Chemicals	
Arsenic	2.0×10^{-3}
Barium	1.5×10^{-4}
Beryllium	1.0×10^{-3}
Cadmium	5.5×10^{-3}
Chromium	5.5×10^{-3}
Cobalt	0.020
Copper	0.010
Lead	3.0×10^{-4}
Magnesium	5.0×10^{-3}
Manganese	4.0×10^{-4}
Mercury	0.25
Nickel	6.0×10^{-3}
Selenium	0.015
Silver	3.0×10^{-3}
Thallium	0.040
Vanadium	2.5×10^{-3}
Zinc	0.10

SOURCE: Baes et al. (1984). The ratio assumes dry weight in plants and a fresh weight in beef.

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Q_v = consumption rate of vegetation by animal (kg/day)

FI = fraction ingested from contaminated source

Parameters used in estimating the concentration of a contaminant in the muscle of white-footed mice as a result of uptake via grazing include the parameters listed in Table 6-3 and concentrations of chemicals in vegetation, estimated as described previously. It was also necessary to estimate transfer of contaminants from earthworms to mouse muscle in order to evaluate contaminant transfer to the mouse predators, the red fox and the red-tailed hawk. The default muscle-to-muscle transfer factor used was 1.0, due difficulty in locating such factors in the literature. Muscle-to-muscle transfer was also estimated using the plant-to-beef transfer coefficients presented in Tables 6-2 and 6-5, in order to provide a lower bound for contaminant uptake via predation.

Equations used to determine the intake of contaminants by herbivores were modified for the red fox and red-tailed hawk by substituting the concentration of a chemical in herbivore muscle for that in vegetation.

Like white-footed mice, raccoons were assumed to be omnivores. Intake of contaminants in fruits was estimated by the methodology presented for herbivores. Actual concentrations of contaminants measured in fish from Paddys Run during RI/FS sampling were used to evaluate the exposure of raccoons to metals and organics in FEMP fish.

In addition to plant matter, white-tailed deer were assumed to ingest soil. Soil intake was evaluated by estimating intake in the same manner as described above for intake of vegetation by an herbivore with the concentration in soil/sediment substituted for the concentration in vegetation.

A substantial portion of the diets of American robins and white-footed mice is composed of earthworms and or insects. Because of limited data on soil to earthworm/insect transfer factors in the literature (Table 6-6), it was necessary to make assumptions in order to estimate exposure of robins and mice to contaminants in FEMP invertebrates. These include, a default value of one for the soil to earthworm transfer coefficient. In addition, invertebrates in the diet of white-footed mice were assumed to be exclusively earthworms. This is a conservative assumption because earthworms are expected to contain higher concentrations of FEMP soil contaminants than insects. Intake of contaminants in earthworms by robins and mice was estimated using the same equation used to estimate soil intake by deer.

TABLE 6-6
SOIL-TO-EARTHWORM TRANSFER FACTORS

Chemical	Transfer Factor[a]
Cadmium	4.68
Chromium	0.73
Copper	0.56
Lead	0.44
Nickel	0.40
Zinc	1.28
DDT	0.18

[a]All soil-to-earthworm transfer factors are based on the concentration in whole undepurated earthworms and dry soil and earthworm weights. Transfer factors for metals were calculated from data in Stafford and Edwards (1985) for a site containing 4.3% organic carbon in soil (The highest value comparable to the 5 to 8.6% reported in FEMP soils) (USDA 1980, 1982). The transfer factor for DDT was calculated from data presented in Beyer and Gish (1980).

All FEMP indicator species were assumed to consume water from Paddys Run. Intake of water by each species was estimated by utilizing the mean concentration of a given contaminant measured in FEMP surface water. The following equation was used to estimate intake of a contaminant in water:

$$I_w = (C_w)(Q_w)(FI)/(BW)$$

where

I_w = intake of chemical in water (mg/kg/day)
C_w = concentration in water (mg/l)
Q_w = ingestion rate (l/day)
FI = fraction ingested from contaminated source (unitless)
BW = body weight (kg)

Species specific parameters used in the equation are presented in Table 6-3.

Exposure of each indicator wildlife species to FEMP contaminants involves more than one pathway of exposure. It was therefore necessary to sum intakes across all pathways for a given indicator species to obtain a total intake value. For instance, intake of contaminants by white-tailed deer was estimated by adding the intake via ingestion of vegetation and soil. Water intake was not added, but evaluated separately because the constituents of concern for water were different than those for soil.

To evaluate the toxicity of chemicals to each wildlife indicator species, intake values for a given contaminant were compared to the NOEL or LOEL. Toxicity information for terrestrial organisms relied on animal studies that support the IRIS (EPA 1991) and the Health Effects Assessment Summary Table (EPA 1990, fourth quarter) databases, and on U.S. Fish and Wildlife Service studies (e.g., Eisler 1987). As a screening tool, NOELs and LOELs presented in the IRIS (EPA 1991b) or when absent in the HEAST database (EPA 1990) were used for mammals. Uncertainty factors were applied to the animal toxicity data to correct for differences between species, to modify LOEL values to NOEL, and to adjust data obtained through short-term studies to that which would be expected in long-term studies. Literature obtained avian toxicity values were used for the robin and hawk. LD_{50} values were adjusted with uncertainty factors to obtain an estimated NOEL. In the absence of avian toxicity data, available mammalian data was substituted and appropriate uncertainty factors used. Uncertainty factors used to modify toxicity values include:

- Short-term (<30 days) (Newell et al. 1987) effect levels were multiplied by 0.1 to estimate chronic, long-term effects.

- LOELs were converted to NOELs by multiplying the effect concentration by 0.2 (Newell et al. 1987).

- Oral LD_{50} values were converted to acute NOEL values by multiplying the effect concentration by 0.2.

- Interspecies adjustments were made by multiplying the effect concentration by 0.1 (Newell et al. 1987). For species of different phylogenetic classes (e.g., mammal to bird), 0.05 was used as the uncertainty factor.

Estimated NOELS and data sources for the FEMP indicator species are listed in Tables 6-7A, B and 6-8A, B. When available, wildlife-specific dietary toxicity values were compared to concentrations of specific constituents in the diet of the animal.

To estimate the risk of chemical exposure to wildlife, modified effect levels were compared to calculated intake values for each chemical and animal species. As with the hazard quotient in human health risk assessments, if the quotient of the intake divided by the modified effect level exceeds unity, it is concluded that the indicator species may be exposed to hazardous concentrations of a given contaminant at the FEMP.

6.3.2.2 Estimation of Radiation Dose to Terrestrial Organisms

Uptake of radionuclides from soils, plants, and predation was estimated in the same way as uptake of nonradioactive constituents, described previously. Radiation doses to terrestrial organisms were estimated by assuming uniform radionuclide distribution in the organism, and converting the resulting whole body concentrations to dose using the equation

$$D(\text{rad/yr}) = 0.01867(E_i)(C_i)$$

where

D = internal whole body dose rate
E_i = average energy of decay (MeV) for isotope i
C_i = radionuclide concentration in the organism (pCi/g dry weight)

The decay energies of the radionuclides of concern are stated in Table 6-9. The tissue concentration, C_{iA}, resulting from intake via water was calculated from the equation

$$C_{iA}(\text{pCi/g}) = (I)(R_{avg})(F)(T)[(365)/(W)$$

where

I = water intake (ℓ/d)
R_{avg} = average radionuclide concentration in ingested water (pCi/ℓ)
F = fraction of water ingested which is contaminated
T = ingestion-to-beef transfer coefficient from Baes et al. (1984).
W = weight of organism (g)

TABLE 6-7A
DERIVATION OF WILDLIFE NOELS FOR INORGANIC CHEMICALS

Chemical	Oral LD50 (mg/kg/day)	LD50-to-Acute NOEL Factor	Rat NOEL (mg/kg/day)	Human Reference Dose (mg/kg/day)	Human Uncertainty Factor	Species/Class Factor	Acute-to-Chronic Factor	Wildlife NOEL (mg/kg/day)
Antimony	--	--	--	0.0004[a]	1000	0.1	--	0.04
Arsenic	--	--	--	0.0008[a]	--	0.1	--	0.00008
Barium	--	--	--	0.21[b]	--	0.1	--	0.02
Beryllium	--	--	0.54[b]	--	--	0.1	--	0.05
Cadmium	--	--	--	0.001[a]	10	0.1	--	0.001
Chromium	--	--	2.4[a]	--	--	0.1	--	0.2
Cobalt	--	--	0.0026[c]	--	0.1	--	0.00026	--
Lead	--	--	--	0.00069[d]	--	0.1	--	0.000069
Manganese	--	--	--	0.14[a]	--	0.1	--	0.01
Mercury	12.6[a]	0.2	--	--	--	0.1	0.1	0.03
Molybdenum	--	--	--	0.004[a]	--	0.1	--	0.0004
Nickel	--	--	5[b]	--	--	0.1	--	0.5
Selenium	--	--	--	0.015[a]	--	0.1	--	0.0015
Silver	--	--	--	0.0052[b]	--	0.1	--	0.0005
Vanadium	--	--	0.7[a]	--	--	0.1	--	0.07
Zinc	--	--	--	0.2[a]	10	0.1	--	0.2

NOTE: The wildlife NOEL for each chemical is the product of the factors listed for that chemical.

SOURCES: [a] HEAST Annual, 1991
[b] IRIS, 1990, 1991
[c] Schroeder et al., 1967 J. Chron. Dis., 20:869-890 (See Part II, Table 4-1 for full reference)
[d] Pocock et al., 1983 J. Epidem. Comm. Health, 37:1-7 (See Part II, Table 4-1 for full reference)

TABLE 6-7B
DERIVATION OF AVIAN NOELS FOR INORGANIC CHEMICALS

Chemical	Oral LD50 (mg/kg/day)	LD50-to-Acute NOEL Factor	Rat NOEL (mg/kg/day)	Human Reference Dose (mg/kg/day)	Human Uncertainty Factor	Species/Class Factor	Acute-to-Chronic Factor	Avian NOEL (mg/kg/day)
Antimony	--	--	--	0.0004[a]	1000	0.05	--	0.04
Arsenic	47.6[b]	0.2	--	--	--	0.1	0.1	0.0952
Barium	--	--	--	0.21[c]	--	0.05	--	0.01
Beryllium	--	--	0.54[c]	--	--	0.05	--	0.025
Cadmium	--	--	--	0.01[a]	10	0.05	--	0.0005
Chromium	--	--	2.4[c]	--	--	0.05	--	0.1
Cobalt	--	--	0.0026[d]	--	0.05	--	0.00013	--
Lead	24.6[b]	0.2	--	--	--	0.1	0.1	0.0492
Manganese	--	--	--	0.14[c]	--	0.05	--	0.005
Mercury	12.6[e]	0.2	--	--	--	0.1	0.1	0.0252
Molybdenum	--	--	--	0.004[a]	--	0.05	--	0.0002
Nickel	--	--	5[c]	--	--	0.05	--	0.25
Selenium	--	--	--	0.015[f]	--	0.05	--	0.00075
Silver	--	--	--	0.0052[c]	--	0.05	--	0.00025
Vanadium	--	--	0.7[a]	--	--	0.05	--	0.035
Zinc	--	--	--	2.14[a]	--	0.05	--	0.1

NOTE: The avian NOEL for each chemical is the product of the factors listed for that chemical.
SOURCES: [a] HEAST Annual, 1991
[b] Hudson et al., (1984) quail
[c] IRIS, 1990, 1991
[d] Schroeder et al., 1967 J. Chron. Dis., 20:869-890
[e] Eisler (1987) sparrow
[f] Heinz et al., 1989

TABLE 6-8A
DERIVATION OF WILDLIFE NOELS FOR ORGANIC CHEMICALS

Chemical	Mouse LOEL/NOEL (mg/kg/day)	Human Reference Dose (mg/kg/day)	Human Uncertainty Factor	Species/Class Factor	LOEL-to-NOEL Factor	Wildlife NOEL (mg/kg/day)
Polycyclic aromatic hydrocarbons						
Acenaphthene	175[a,c]	--	--	0.1	--	6
Anthracene	1000[a,c]	--	--	0.1	--	33
Fluoranthene	125[a,c]	--	--	0.1	0.2	3
Fluorene	125[b,d]	--	--	0.1	0.2	3
Naphthalene	35.7[d]	--	--	0.1	0.2	0.7
Phenanthrene	--	--	--	--	--	ND
Pyrene	75[a,c]	--	--	0.1	--	2
Monocyclic aromatics						
Benzoic acid	--	4.4[e]	--	0.1	--	0.4
Chlorobenzene	28[e]	--	--	0.1	--	3
Toluene	223[e]	--	--	0.1	--	22
Phthalate esters						
Bis(2-ethylhexyl) phthalate	19[e]	--	--	0.1	0.2	0.4
Halogenated Aliphatic Hydrocarbons						
Chloroform	15[e]	--	--	0.1	0.2	0.3
Methylene chloride	6.16[e]	--	--	0.1	--	0.6
Tetrachloroethene	20[e]	--	--	0.1	--	2
1,1,1-trichloroethane	90[e]	--	--	0.1	--	9

Chemical	Mouse LOEL/NOEL (mg/kg/day)	Human Reference Dose (mg/kg/day)	Human Uncertainty Factor	Species/Class Factor	LOEL-to-NOEL Factor	Wildlife NOEL (mg/kg/day)
Nonhalogenated Aliphatic Hydrocarbons						
Acetone	100[c]	--	--	0.1	--	10
2-butanone	--	0.05[d]	1000	0.1	--	5
Miscellaneous Compounds	--	--	--	--	--	--
Carbon disulfide	11[d]	--	--	0.1	--	1
Dibenzofurans	--	0.01[d]	--	0.1	--	0.001

NOTE: The wildlife NOEL for each chemical is the product of the factors listed for each chemical.

[a]IRIS recommends an additional factor of 0.33 for inadequacies in the study.
[b]HEAST recommends an additional factor of 0.13 for inadequacies in the study.

SOURCES: [c]IRIS, 1990, 1991
[d]HEAST Annual, 1991

TABLE 6-8B
DERIVATION OF AVIAN NOELS FOR ORGANIC CHEMICALS

Chemical	Oral LD50 (mg/kg/day)	LD50-to-Acute NOEL Factor	Mouse LOEL/NOEL (mg/kg/day)	Human Reference Dose (mg/kg/day)	Human Uncertainty Factor	Species/Class Factor	Acute-to-Chronic Factor	LOEL-to-NOEL Factor	Avian NOEL (mg/kg/day)
Polycyclic aromatic hydrocarbons									
Acenaphthene	101[c]	0.2	--	--	--	0.1	0.1	--	0.202
Anthracene	--	--	1000[d]	--	--	0.05	--	--	16.5
Fluoranthene	--	--	125[e]	--	--	0.05	--	0.2	1.5
Fluorene	113[c]	0.2	--	--	--	0.1	0.1	--	0.226
Naphthalene	--	--	35.7[b]	--	--	0.05	--	0.2	0.35
Phenanthrene	101[c]	0.2	--	--	--	0.1	0.1	--	0.202
Pyrene	--	--	75[d]	--	--	0.05	--	--	1
Monocyclic aromatics									
Benzoic acid	100[c]	0.2	--	--	--	0.1	0.1	--	0.2
Chlorobenzene	--	--	28[a]	--	--	0.05	--	--	1.5
Toluene	--	--	223[a]	--	--	0.05	--	--	11
Phthalate esters									
Bis(2-ethylhexyl) phthalate	--	--	19[a]	--	--	0.05	--	0.2	0.2
Halogenated Aliphatic Hydrocarbons									
Chloroform	--	--	15[a]	--	--	0.05	--	0.2	0.15
Methylene chloride	--	--	6.16[a]	--	--	0.05	--	--	0.3
Tetrachloroethene	--	--	20[a]	--	--	0.05	--	--	1
1,1,1-trichloroethane	--	--	90[a]	--	--	0.05	--	--	4.5

TABLE 6-8B (Continued)

Chemical	Oral LD50 (mg/kg/day)	LD50-to-Acute NOEL Factor	Mouse LOEL/NOEL (mg/kg/day)	Human Reference Dose (mg/kg/day)	Human Uncertainty Factor	Species/Class Factor	Acute-to-Chronic Factor	LOEL-to-NOEL Factor	Avian NOEL (mg/kg/day)
Nonhalogenated Aliphatic Hydrocarbons									
Acetone	--	--	100[a]	--	--	0.05	--	--	5
2-butanone	--	--	--	0.05[b]	1000	0.05	--	--	2.5
Miscellaneous Compounds									
Carbon disulfide	--	--	11[b]	--	--	0.05	--	--	0.5
Dibenzofurans	--	--	--	0.01[b]	ND	0.05	--	--	0.0005

NOTE: The avian NOEL for each chemical is the product of the factors listed for that chemical.

[a]IRIS recommends an additional factor of 0.33 for inadequacies in the study.
[b]IRIS recommends an additional factor of 0.13 for inadequacies in the study.

SOURCES: [a]IRIS FY 1990, 1991
[b]HEAST Annual FY 1991
[c]Schafer et al. (1983)

TABLE 6-9
RADIONUCLIDE DECAY ENERGIES USED TO CALCULATE RADIATION DOSES TO ECOLOGICAL RECEPTORS

Element	Weighted Average Decay Energy (MeV)[a]
Cesium-137	1.11
Plutonium-238	5.49
Plutonium-239/240[b]	5.158
Radium-226	4.78
Radium-228	0.014
Strontium-90	0.54
Technetium-99	0.292
Thorium-228	5.350
Thorium-230	4.658
Thorium-232	4.00
Uranium-234	4.762
Uranium-235/236[c]	3.88
Uranium-238	4.19
Total Uranium	4.5

[a] Assumptions include: 1) Energies will be used to calculate whole body dose only; 2) 100% energy absorption assumed.

[b] Analysis results were undifferentiated between these two isotopes. Therefore, it was assumed that the detected material is Pu-240, which has a higher specific activity and undergoes more energetic decay, and would therefore deliver a higher dose.

[c] Analysis results were undifferentiated between these two isotopes. Therefore, it was assumed that the detected material is U-235, which has the higher specific activity, and would therefore deliver a higher dose.

The ingestion-to-beef transfer factor was used in the absence of factors specific for water-to-beef. The calculated doses were then compared with those reported in the literature to cause chronic or acute effects.

6.3.2.3 Exposures of Aquatic Organisms

Current exposures of aquatic organisms to potential FEMP contaminants were estimated from surface water concentrations as described above. This information was supplemented with observations from macroinvertebrate surveys of Paddys Run and the Great Miami River, reported in Part I, Section 4.1.7 and Appendix D, and with toxicity tests of FEMP effluent, reported in Part I, Section 4.1.7 and Appendix E. Potential future exposures of aquatic organisms as a result of runoff from the FEMP were estimated using EPA's USLE and MUSLE runoff models, as described in Part II, Section 3.0. Concentrations of nonradioactive constituents were compared to Ohio Water Quality Standards or EPA Ambient Water Quality Criteria if they were available. If they were not, the NOEL or LOEL available from the literature was used for comparison. The ratio of the exposure concentration to the effect concentration was calculated to estimate a hazard index for each constituent of potential concern. Radiation doses to aquatic organisms were estimated from water concentrations using the constants of Killough and McKay (1976) and comparing the dose to literature values reported to have no chronic or acute effects. The primary information source used was "Effects of Ionizing Radiation on Aquatic Organisms" (NCRP 1991).

6.4 ECOLOGICAL EXPOSURE ASSESSMENT

This section estimates the exposures of the selected indicator species to each constituent of potential concern for each pathway considered. The resulting risks are reported in Section 6.5, Ecological Risk Characterization.

6.4.1 Vegetation

Predicted concentrations in plants of inorganic, organic, and radionuclide constituents of potential concern in FEMP surface soils are presented in Tables 6-10, 6-11, and 6-12, respectively.

6.4.1.1 Plant Exposures to Inorganic and Organic Chemicals

The only inorganic chemical for which the estimated concentration exceeded the highest background concentration reported was zinc (Table 6-13). However, arsenic and mercury concentrations recorded in FEMP vegetation samples during RI/FS sampling exceeded estimated concentrations and background concentrations by as much as an order of magnitude (Table 6-14). These discrepancies can be primarily attributed to uncertainties associated with the lack of site-specific soil to plant transfer factors for the chemicals of potential concern. Organic compounds estimated in FEMP plants at concentrations exceeding 1 mg/kg (dry weight) phenanthrene, acetone, and cyanide. Vegetation samples from the FEMP were analyzed for a variety of organic compounds, but none were detected,as described in Part I, Section 4.1.7. Estimated concentrations of uranium in FEMP vegetation were

TABLE 6-10
ESTIMATED INORGANIC CHEMICAL CONCENTRATIONS IN FEMP GRASS AND FRUIT

Chemical	Mean Soil Concentration[a] (mg/kg)	Concentrations (Dry Weight)	
		Grass[b] (mg/kg)	Fruits[c] (mg/kg)
Antimony	22.3	4.46	0.669
Arsenic	6.5	0.26	0.039
Barium	141.1	21.165	2.1165
Beryllium	0.87	0.0087	0.001305
Cobalt	11.8	0.236	0.0826
Copper	34.8	13.92	8.7
Lead	33	1.485	0.297
Mercury	0.12	0.108	0.024
Nickel	30.3	1.818	1.818
Silver	7.3	2.92	0.73
Zinc	82	123	73.8

[a]RI/FS soil samples from 0-6 inches, averaged for the entire site.
[b]Calculated using soil-to-vegetative plant parts transfer coefficients of Baes et al. (1984) (See Table 6-1).
[c]Calculated using soil-to-fruits transfer coefficients of Baes et al. (1984) (See Table 6-1).

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TABLE 6-11
ESTIMATED ORGANIC CONCENTRATIONS IN PLANTS
USING MEAN FEMP SURFACE SOIL CONCENTRATIONS (0-6 INCHES)

	Soil Concentration (mg/kg)[a]	Plant Concentration (mg/kg)
Polycyclic Aromatic Hydrocarbons		
Acenapthene	0.41	0.768
Anthracene	0.42	0.6448
Benzo(a)anthracene	0.59	0.418
Benzo(a)pyrene	0.89	0.312
Benzo(b)fluoranthene	0.6	0.2418
Benzo(g,h,i)perylene	0.69	0.0312
Benzo(k)fluoranthene	1.3	0.0215
Chrysene	0.71	0.396
Dibenzo(a,h)anthracene	0.46	0.1173
Fluoranthene	4.5	1.056
Fluorene	0.71	0.4917
Indeno(1,2,-cd)pyrene	0.64	0.0182
2-methyl napththalene	0.27	0.1748
Naphthalene	0.4	0.6227
Phenanthrene	3.4	2.244
Pyrene	3.6.	0.726
Monocyclic Aromatics		
Benzoic acid	0.25	0.8025
Chlorobenzene	0.003	0.00088
Toluene	0.002	0.00408
Phthalate Esters		
Bis(2-ethylhexyl)phthalate	0.44	0.03354
Polychlorinated Biphenyls		
Aroclor-1254	0.37	0.01065
Aroclor-1260	0.88	0.0308

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TABLE 6-11
(Continued)

	Soil Concentration (mg/kg)[a]	Plant Concentration (mg/kg)
Pesticides		
Beta-BHC	0.02	0.05412
Halogenated Aliphatic Hydrocarbons		
Chloroform	0.004	0.0281
1,2-Dichloroethane	0.001	0.0025
Methylene chloride	0.018	0.20552
Tetrachloroethene	0.003	0.0042
1,1,1-Trichloroethane	0.003	0.00987
Trichloroethene	0.004	0.03312
Nonhalogenated Aliphatic		
Acetone	0.012	1.4391
2-Butanone	0.007	0.6838
4-Methyl-2-pentanone	0.27	0.02385
Tributyl phosphate	1.2	
Miscellaneous Compounds		
Carbon disulfide	0.003	0.0134
Carbon disulfide	0.003	0.00876
Dibenzofurans	0.46	0.32
1-Nitrosodiphenylamine	0.2	0.254
Cyanide	0.112	6.9104

[a] Dry weight

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TABLE 6-12
ESTIMATED RADIATION DOSES TO GRASS AND FRUITS RESULTING FROM UPTAKE OF RADIONUCLIDES FROM FEMP SURFACE SOILS

Radionuclide	Mean Soil Activity (pCi/g)[a]	Mean Grass Activity (pCi/g)[b]	Estimated Annual Dose Grass (rad)	Mean Fruit Activity (pCi/g)[b]	Estimated Annual Dose Fruit (rad)
Cesium-137	0.574	1.47E-02	1.11E-01	2.93E-03	2.21E-02
Plutonium-238	0.336	4.84E-05	1.81E-03	2.57E-06	9.62E-05
Plutonium-239/240	0.323	4.65E-05	1.63E-03	2.47E-06	8.69E-05
Radium-226	18.670	8.96E-02	2.92E+00	4.76E-03	1.55E-01
Radium-228	9.399	4.51E-02	4.30E-03	2.40E-03	2.29E-04
Strontium-90	0.868	6.94E-01	2.56E+00	3.69E-02	1.36E-01
Technetium-99	0.709	2.16E+00	4.29E+00	1.81E-01	3.60E-01
Thorium-228	4.651	1.27E-03	4.61E-02	6.72E-05	2.45E-03
Thorium-230	48.397	1.32E-02	4.18E-01	6.99E-04	2.22E-02
Thorium-232	5.496	1.49E-03	4.07E-02	7.94E-05	2.16E-03
Uranium-234	58.428	1.59E-01	5.16E+00	3.97E-02	1.29E+00
Uranium-235/236	0.868	2.36E-03	6.24E-02	5.90E-04	1.56E-02
Uranium-238	72.051	1.96E-01	5.60E+00	4.90E-02	1.40E+00
Total			2.12E+01		3.40E+00

[a] Dry weight
[b] Wet weight

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TABLE 6-13
COMPARISON OF ESTIMATED INORGANIC CHEMICAL CONCENTRATIONS IN FEMP GRASS SAMPLES WITH BACKGROUND CONCENTRATIONS REPORTED IN THE LITERATURE

Chemical	Concentration in Grass[a] (mg/kg)	Background Concentration[b] (mg/kg)
Antimony	4.46	NA[c]
Arsenic	0.26	0.009-1.5
Barium	21.165	1-198
Beryllium	0.0087	0.001-0.4
Cobalt	0.236	<0.04-0.39
Copper	13.92	1.5-29
Lead	1.485	<0.8-15
Mercury	0.108	0.02-0.3
Nickel	1.818	<0.07-5
Silver	2.92	0.03-5
Zinc	123	12-47

[a]Dry weight.
[b]Arsenic, barium, beryllium, and silver are in whole plants. Cobalt, copper, lead, mercury, nickel, and zinc are in immature grass and clover collected in the United States.
[c]Not available.

SOURCE: Kabata-Pendias and Pendias (1982)

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TABLE 6-14
COMPARISON OF ESTIMATED INORGANIC CHEMICAL CONCENTRATIONS IN FEMP VEGETATION WITH CONCENTRATIONS MEASURED DURING RI/FS SAMPLING

Chemical	Estimated Concentration in Grass (mg/kg)[a]	RI/FS Sampling Range (Mean)
Arsenic	0.26	5 - 13 (9)
Barium	21.2	2.6 - 12.5 (6)
Lead	1.5	3U[b] (3U)
Mercury	0.11	0.5 - 15.3 (5.2)
Silver	2.92	0.5U (0.5U)
Zinc	123	4.4 - 13 (8.9)

[a] Dry weight
[b] U, not detected. Value is detection limit.

lower than those recorded during RI/FS sampling. The RI/FS samples were collected in 1987-1988, when the FEMP was still in operation, and probably include contributions from airborne deposition, while the estimated concentrations include only direct uptake from soil. The estimated concentrations would likely be a better estimate of plant radionuclide concentrations under the no action alternative in the absence of significant soil disturbance which could cause renewed airborne uranium deposition.

6.4.1.2 Plant Exposures to Radionuclides

The primary contributor to plant radiation dose was uranium, as U-234 and U-238 (Table 6-12). The sum of these two accounted for 50 and 79 percent of the estimated dose to vegetative and reproductive portions of plants, respectively. Other radionuclides contributing more than one percent to the total were radium-226, strontium-90, technetium-99, and thorium-230. As described in Section 6.5.1.2, however, the total estimated dose was low compared to levels known to affect plant growth and reproduction.

6.4.2 Terrestrial Wildlife

This section describes exposure pathways and parameters evaluated for terrestrial wildlife at the FEMP. Details of exposure parameters are presented, followed by data on exposures to nonradioactive and radioactive constituents, respectively.

6.4.2.1 Exposure Pathways and Parameters

Because data on concentrations of contaminants in FEMP mammals and birds are limited (Facemire et al. 1990), exposure of wildlife to contaminants was estimated by evaluation of the uptake of contaminants via food chain interactions. Terrestrial indicator species selected for the FEMP ecological assessment, as described above, were the white-tailed deer, white-footed mouse, raccoon, red fox, muskrat, American robin, and red-tailed hawk. A brief description of the relevant natural history characteristics of each of these species is presented below. Exposure pathways evaluated for each indicator species are listed in Table 6-15, and exposure parameters used to model uptake are listed in Table 6-3. Diagrams illustrating each of the exposure pathways and interactions between species are presented in Figure 6-1.

White-tailed deer are common to most of the contiguous United States. The deer was noted as an abundant species in introduced grasslands, pine plantations, riparian habitats, and deciduous wetlands on the FEMP property (Facemire et al. 1990). The home range of white-tailed deer usually does not exceed 1.6 km (Burt and Grossenheider 1976). White-tailed deer are herbivorous and like many grazing species, are assumed to ingest some soil. Based on information on mule deer (Arthur and Alldredge 1979), white-tailed deer were assumed to ingest a quantity of soil comparable to 1.35 percent of the total daily dry matter intake (the percentage of soil in the mule deer diet was reported to range between 0.6 to 2.1 percent). The species may live up to 16.5 years in the wild (Burt and Grossenheider 1976).

TABLE 6-15
EXPOSURE PATHWAYS EVALUATED FOR TERRESTRIAL WILDLIFE INDICATOR SPECIES

Indicator Species	Pathways Evaluated
White-tailed deer	Plant ingestion Soil ingestion Water ingestion
White-footed mouse	Plant ingestion Insect ingestion[a] Water ingestion
Raccoon	Fruit ingestion Fish ingestion[b] Water ingestion
Red fox	Mouse ingestion[c] Fruit ingestion Water ingestion
Muskrat	Plant ingestion Water ingestion
American robin	Fruit ingestion Earthworm ingestion[d] Water ingestion
Red-tailed hawk	Mouse ingestion[c] Water ingestion

[a] Earthworm ingestion used as a surrogate, assuming soil-to-earthworm transfer coefficients of 1.0.
[b] Based on inorganic chemical concentrations measured a single RI/FS sample from Paddys Run.
[c] Evaluated using two different assumptions about muscle-to-muscle transfer coefficients: (1) muscle-to-muscle transfer equal to plant-to-beef transfer coefficients (See Tables 6-2, 6-5) and (2) muscle-to-muscle transfer equal to 1.0. This was done for consumption of earthworms by mice and for consumption of mice by red fox and red-tailed hawks.
[d] See footnote c, but separate evaluations were necessary only for radiation dose estimation, because evaluation of chemical hazard was based only on intake, rather than assimilation.

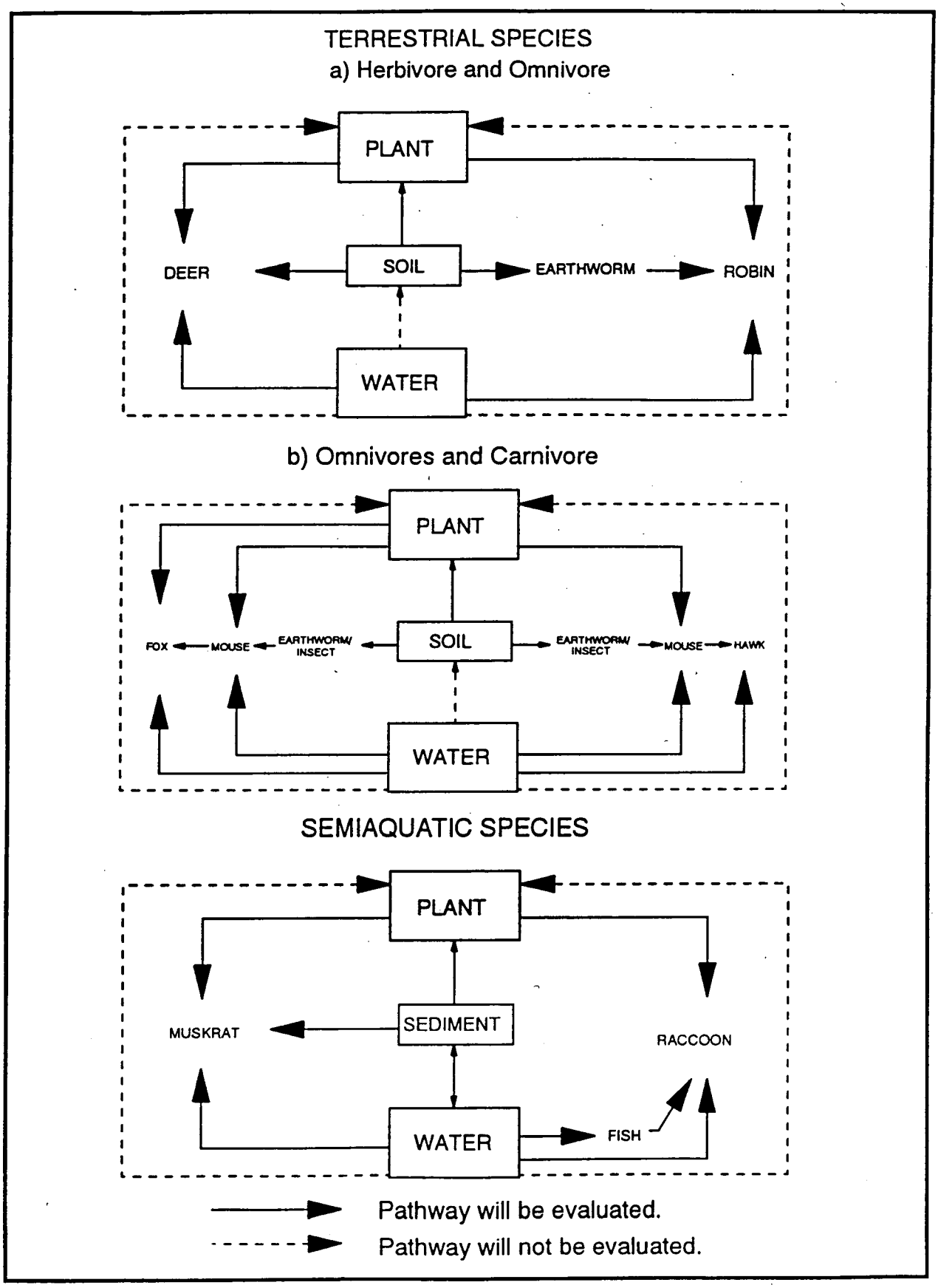

FIGURE 6-1. ECOLOGICAL RISK ASSESSMENT EXPOSURE PATHWAYS

The white-footed mouse is a small rodent common to the eastern and central United States. It was reported as common in deciduous woodlands, riparian habitats, and in the Inactive Flyash Disposal Area of the FEMP (Facemire et al. 1990). The home range usually ranges between 0.2 to 0.6 ha (Burt and Grossenheider 1976). Population densities have been reported to range from 10 to 30 mice per hectare (Burt and Grossenheider 1976). The species is omnivorous, with mice from southern Missouri reported to ingest approximately 70 percent (by volume) animal matter and 30 percent plant matter (Brown 1964). White-footed mice live from 2 to 3 years in the wild (Burt and Grossenheider 1976).

Raccoons are found throughout most of the continental United States. Although they frequent streams and wooded areas (Burt and Grossenheider 1976), only an incidental sighting of the species was reported by Facemire et al. (1990) on the FEMP. This may be due to the nocturnal nature of raccoons and the absence of specific efforts to trap medium to large sized mammals on the FEMP (Facemire et al. 1990). The home range of a raccoon is usually less than 1.6 km across with population densities reaching as high as 3 animals per hectare (Burt and Grossenheider 1976). Animals are omnivorous, ingesting 30 percent (percent volume in scat) animal matter, 65 percent plant matter, and 5 percent miscellaneous material (Stuewer 1943). Raccoons may live up to 14 years in captivity (Burt and Grossenheider 1976).

The red fox, which is found throughout most of North America, was occasionally observed on the FEMP property (Facemire et al. 1990). The home range of the red fox ranges from 259 to 518 ha (Burt and Grossenheider 1976). The species ingests primarily animal matter (89.4 percent weight), but fruits and berries are also consumed (10.6 percent) (Hockman and Chapman 1983).

Muskrats, found throughout most of North America, were occasionally sighted in riparian habitats on the FEMP property (Facemire et al. 1990). The species is primarily an herbivore (Willner et al. 1975), although it has been known to consume animal prey such as clams, crayfish, and fish (Convey et al. 1989). Animals have home ranges of from 0.06 to 0.095 ha (Neal 1968) with population densities of 2.8 to 64.2 animals per hectare (Perry 1982). The mean life span for muskrats is from 4 to 5 years (Godin 1977).

American robins are common throughout North America and were abundant in both the winter and summer bird surveys conducted on the FEMP by Facemire et al. (1990). FEMP habitats frequented by robins include introduced grasslands, pine plantations, woodlands and woodlots, riparian habitats, and the inactive fly ash disposal area (Facemire et al. 1990). Birds collected from New York and the central regions of the United States consume a diet consisting of both fruits and berries (52 percent by volume) and earthworms and insects (48 percent by volume) (Wheelwright 1986).

Red-tailed hawks are common in the continental United States and Canada and were regularly observed in introduced grasslands, pine plantations, woodlands and woodlots, riparian habitats, and the

Inactive Flyash Pile (Facemire et al. 1990). Hawks are carnivores and consume primarily mammals (Janes 1984, Adamkirk et al. 1979). Adult hawks in Wisconsin occupy a home range of approximately 165 ha (Petersen 1979). Population densities of red-tailed hawks in Ohio have been reported as 0.0016 pairs/ha (Rothfels and Lein 1983).

6.4.2.2 Exposures to Inorganic and Organic Chemicals

The estimated intake of nonradioactive chemicals and associated hazard indices for each constituent of concern is summarized for each indicator species in Tables 6-16A to 6-23. The implications of the intake data with respect to risk are discussed below in Section 6.5.2.1.

Total intake of inorganic chemicals on a mg/kg body weight/day basis was highest for the white-footed mouse and the American Robin. This is primarily attributed to the ingestion of earthworms by the two species and the associated soil to earthworm transfer factors. The white-footed mouse was also assumed to consume 75 percent of its food resources from the contaminated area. White-tailed deer, raccoons, and muskrats had lower intake rates, with the fox and hawk the lowest. However, when muscle-to-muscle transfer coefficients were assumed to be 1.0, fox and hawk intakes were among the highest estimated intakes. These groupings were similar with respect to risk, as described below, and are a result of the relative trophic positions of the various organisms. Beryllium and mercury had the lowest intake rates, while zinc and barium had the highest.

For the white-tailed deer, intake from vegetation was the primary pathway for intake of inorganics, except for beryllium (Table 6-16A), which has a relatively low soil-to-plant transfer coefficient (Table 6-1).

Intake via insect ingestion, using earthworms as a surrogate, dominated inorganic uptake by the white-footed mouse, contributing 58-99% of total intake (Table 6-17A). This is primarily due to the much higher transfer coefficient (1.0) assumed for soil-to-earthworm transfer than for soil-to-plant transfer (Table 6-1). However, the assumption of 1:1 transfer to earthworms appears reasonable, given the literature values reported in Table 6-6.

Raccoon intake of inorganic chemicals from fish could be estimated for four of the constituents of concern evaluated for fruits -- arsenic, barium, mercury, and zinc (Table 6-18A). Intake via fish would dominate for arsenic and mercury, while intake via fruit would dominate for barium and zinc. Eliminating the fish data had no effect on the specific chemicals with hazard indices greater than 1.0.

For the red fox, intake from mouse ingestion dominated uptake of two of the inorganics with HIs greater than 1.0 -- arsenic and cobalt (Table 6-19A). Fruit intake was the primary pathway for the other two, lead and silver. Mouse intake was dominant for all four when conservative muscle-to-muscle transfer factors were used (Table 6-19C).

TABLE 6-16A

WHITE-TAILED DEER ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS

Chemical	Daily Intake From Vegetation (mg/kg)[a]	Daily Intake From Soil (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	5.30E-02	3.57E-03	5.66E-02	0.04	1.41E+00	Yes
Arsenic	3.09E-03	1.04E-03	4.13E-03	0.00008	5.16E+01	Yes
Barium	2.52E-01	2.26E-02	2.74E-01	0.02	1.37E+01	Yes
Beryllium	1.03E-04	1.39E-04	2.43E-04	0.05	4.85E-03	No
Cobalt	2.80E-03	1.89E-03	4.69E-03	0.00026	1.80E+01	Yes
Copper	1.65E-01	5.56E-03	1.71E-01	NA[b]	NA	NA
Lead	1.76E-02	5.28E-03	2.29E-02	0.000069	3.32E+02	Yes
Mercury	1.28E-03	1.92E-05	1.30E-03	0.03	4.34E-02	No
Nickel	2.16E-02	4.84E-03	2.65E-02	0.5	5.29E-02	No
Silver	3.47E-02	1.17E-03	3.59E-02	0.0005	7.17E+01	Yes
Zinc	1.46E+00	1.31E-02	1.47E+00	0.2	7.37E+00	Yes

[a] Wet weight

[b] Not available

TABLE 6-16B

WHITE-TAILED DEER INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Daily Intake From Soil (mg/kg)[a]	Daily Intake From Grass (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	6.56E-05	2.44E-03	2.50E-03	6	4.17E-04	No
Anthracene	6.72E-05	1.62E-03	1.69E-03	33	5.12E-05	No
Benzo(a)anthracene	9.43E-05	4.82E-04	5.76E-04	NA[b]	NA	NA
Benzo(a)pyrene	1.42E-04	4.30E-04	5.72E-04	NA	NA	NA
Benzo(b)fluoranthene	9.59E-05	1.38E-04	2.34E-04	NA	NA	NA
Benzo(g,h,i)perylene	1.10E-04	6.66E-05	1.77E-04	NA	NA	NA
Benzo(k)fluoranthene	2.08E-04	2.08E-04	4.15E-04	NA	NA	NA
Chrysene	1.14E-04	5.80E-04	6.94E-04	NA	NA	NA
Dibenzo(a,h)anthracene	7.36E-05	2.90E-04	3.64E-04	NA	NA	NA
Fluoranthene	7.20E-04	5.35E-03	6.07E-03	3	2.02E-03	No
Fluorene	1.14E-04	3.93E-03	4.04E-03	3	1.35E-03	No
Indeno(1,2,3-cd)pyrene	1.02E-04	3.33E-05	1.36E-04	NA	NA	NA
2-methyl naphthalene	4.32E-05	2.31E-03	2.35E-03	NA	NA	NA
Naphthalene	6.40E-05	7.12E-03	7.18E-03	0.7	1.03E-02	No
Phenanthrene	5.44E-04	1.29E-02	1.34E-02	NA	NA	NA
Pyrene	5.76E-04	4.41E-03	4.99E-03	2	2.49E-03	No
Monocyclic aromatics						
Benzoic acid	4.00E-05	2.98E-02	2.98E-02	0.4	7.46E-02	No
Chlorobenzene	4.80E-07	9.81E-05	9.85E-05	3	3.28E-05	No
Toluene	3.20E-07	7.58E-05	7.61E-05	22	3.46E-06	No
Phthalate Esters						
Bis(2-ethylhexyl)phthalate	7.04E-05	7.03E-04	7.73E-04	0.4	1.93E-03	No
Polychlorinated biphenyls						
Arochlor 1254	5.92E-05	9.76E-05	1.57E-04	NA	NA	NA
Arochlor 1260	1.41E-04	3.60E-04	5.00E-04	NA	NA	NA
Pesticides						
Beta-BHC	3.20E-06	1.83E-04	1.86E-04	NA	NA	NA

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TABLE 6-16B
(Continued)

Chemical	Daily Intake From Soil (mg/kg)[a]	Daily Intake From Grass (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Halogenated Aliphatic Hydrocarbons						
Chloroform	6.40E-07	4.17E-04	4.18E-04	0.3	1.39E-03	No
1,2-dichloroethylene	1.60E-07	9.29E-05	9.30E-05	NA	NA	NA
Methylene chloride	2.88E-06	4.91E-03	4.91E-03	0.6	8.18E-03	No
Tetrachloroethene	4.80E-07	4.68E-05	4.73E-05	2	2.36E-05	No
1,1,1-trichloroethane	4.80E-07	1.57e-04	1.58E-04	9	1.75E-05	No
Trichloroethene	6.40E-07	2.73E-04	2.74E-04	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons						
Acetone	1.92E-06	2.38E-02	2.38E-02	10	2.38E-03	No
2-butanone	1.12E-06	6.84E-03	6.84E-03	NA	NA	NA
4-methyl-2-pentanone	4.32E-05	7.97E-02	7.98E-02	NA	NA	NA
Tributyl phosphate	1.92E-04	0.00	1.92E-04	NA	NA	NA
Miscellaneous Compounds						
Carbon disulfide	4.80E-07	3.73E-04	3.74E-04	1	3.74E-04	No
Carbon disulfide	4.80E-07	2.44E-04	2.44E-04	1	2.44E-04	No
Dibenzofurans	7.36E-05	2.73E-03	2.81E-03	0.001	2.81	Yes
N-nitrosodiphenyamine	3.20E-05	9.43E-03	9.47E-03	NA	NA	NA

[a] Not available

[b] Wet weight

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TABLE 6-17A

WHITE-FOOTED MOUSE ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS

Chemical	Daily Intake From Grass (mg/kg)[a]	Daily Intake From Earthworms (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	5.02E-01	4.00E+00	4.51E+00	0.04	1.13E+02	Yes
Arsenic	2.92E-02	1.17E+00	1.20E+00	0.00008	1.50E+04	Yes
Barium	2.38E+00	2.53E+01	2.77E+01	0.02	1.39E+03	Yes
Beryllium	9.79E-04	1.56E-01	1.57E-01	0.05	3.14E+00	Yes
Cobalt	2.65E-02	2.12E+00	2.15E+00	0.00026	8.25E+03	Yes
Copper	1.57E+00	3.50E+00	5.07E+00	NA[b]	NA	NA
Lead	1.67E-01	2.61E+00	2.77E+00	0.000069	4.02E+04	Yes
Mercury	1.21E-02	2.16E-02	3.37E-02	0.03	1.12E+00	Yes
Nickel	2.05E-01	2.18E+00	2.38E+00	0.5	4.76E+00	Yes
Silver	3.28E-01	1.31E+00	1.64E+00	0.0005	3.28E+03	Yes
Zinc	1.38E+01	1.89E+01	3.27E+01	0.2	1.63E+02	Yes

[a] Wet weight

[b] Not available

TABLE 6-17B
WHITE-FOOTED MOUSE ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Daily Intake Through Grass (mg/kg)[a]	Daily Intake From Worms (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	2.31E-02	7.38E-02	9.68E-02	6	1.61E-02	No
Anthracene	1.54E-02	7.56E-02	9.09E-02	33	2.76E-03	No
Benzo(a)anthracene	4.56E-03	1.06E-01	1.11E-01	NA[b]	NA	NA
Benzo(a)pyrene	4.07E-03	1.60E-01	1.64E-01	NA	NA	NA
Benzo(b)fluoranthene	1.31E-03	1.08E-01	1.09E-01	NA	NA	NA
Benzo(g,h,i)perylene	6.30E-04	1.24E-01	1.25E-01	NA	NA	NA
Benzo(k)fluoranthene	1.96E-03	2.34E-01	2.36E-01	NA	NA	NA
Chrysene	5.49E-03	1.28E-01	1.33E-01	NA	NA	NA
Dibenzo(a,h)anthracene	2.75E-03	8.28E-02	8.55E-02	NA	NA	NA
Fluoranthene	5.06E-02	8.10E-01	8.60E-01	3	2.87E-01	No
Fluorene	3.72E-02	1.28E-01	1.65E-01	3	5.50E-02	No
Indeno(1,2,3-cd)pyrene	3.15E-04	1.15E-01	1.15E-01	NA	NA	NA
2-methyl naphthalene	1.97E-02	4.86E-02	4.86E-02	NA	NA	NA
Naphthalene	6.73E-02	7.20E-02	1.39E-01	0.7	1.99E-01	No
Phenanthrene	1.22E-01	6.12E-01	7.34E-01	NA	NA	NA
Pyrene	4.17E-02	6.48E-01	6.89E-01	2	3.45E-01	No
Monocyclic Aromatics						
Benzoic acid	2.82E-01	4.50E-02	3.27E-01	0.4	8.18E-01	No
Chlorobenzene	9.28E-04	5.40E-04	1.47E-03	3	4.89E-04	No
Toluene	7.17E-04	3.60E-04	1.08E-03	22	4.89E-05	No
Phthalate Esters						
Bis(2-ethylhexyl)phthalate	6.65E-03	7.92E-02	8.58E-02	0.4	2.15E-01	No
Polychlorinated Biphenyls						
Arochlor 1254	9.23E-04	6.66E-02	6.75E-02	NA	NA	NA
Arochlor 1260	3.40E-03	1.58E-01	1.62E-01	NA	NA	NA

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TABLE 6-17B
(Continued)

Chemical	Daily Intake Through Grass (mg/kg)[a]	Daily Intake From Worms (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Halogenated Aliphatic Hydrocarbons						
Chloroform	3.95E-03	7.20E-04	4.67E-03	0.3	1.56E-02	No
1,2-dichloroethylene	8.79E-04	1.80E-04	1.06E-03	NA	NA	NA
Methylene chloride	4.64E-02	3.24E-03	4.97E-02	0.6	8.28E-02	No
Tetrachloroethene	4.43E-04	5.40E-04	9.83E-04	2	4.91E-04	No
1,1,1-trichloroethane	1.49E-03	5.40E-04	2.03E-03	9	2.25E-04	No
Trichloroethene	2.59E-03	7.20E-04	3.31E-03	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons						
Acetone	2.38E-02	2.16E-03	2.59E-02	10	2.59E-03	No
2-butanone	6.84E-03	1.26E-03	8.10E-03	5	1.62E-03	No
4-methyl-2-pentanone	7.97E-02	4.86E-02	1.28E-01	NA	NA	NA
Tributyl phosphate				NA	NA	NA
Pesticides						
Beta-BHC	1.83E-04	3.60E-03	3.78E-03	NA	NA	NA
Miscellaneous Compounds						
Carbon disulfide	3.73E-04	5.40E-04	9.13E-04	1	9.13E-04	No
Carbon disulfide	2.44E-04	5.40E-04	7.84E-04	1	7.84E-04	No
Dibenzofurans	3.80E.03	8.28E-02	8.66E-02	0.001	8.66E+01	Yes
N-nitrosodiphenyamine	9.43E-03	3.60E-02	4.54E-02	NA	NA	NA

[a] Not available
[b] Wet weight

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TABLE 6-18A
RACCOON ESTIMATED INTAKE AND HAZARD
DUE TO INGESTION OF INORGANIC CHEMICALS

Chemicals	Daily Intake From Fruits (mg/kg)[a]	Daily Intake From Fish (mg/kg)[b]	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	7.84E-03	NA[c]	7.84E-03	0.04	1.96E-01	No
Arsenic	4.57E-04	0.051	5.15E-02	0.00008	6.43E+02	Yes
Barium	2.48E-02	0.0085	3.33E-02	0.02	1.67E+00	Yes
Beryllium	1.53E-05	NA	1.53E-05	0.05	3.06E-04	No
Cobalt	9.68E-04	NA	9.68E-04	0.00026	3.72E+00	Yes
Copper	1.02E-01	NA	1.02E-01	NA	NA	No
Lead	3.48E-03	NA	3.48E-03	0.000069	5.05E+01	Yes
Mercury	2.81E-04	0.00255	2.83E-03	0.03	9.44E-02	No
Nickel	2.13E-02	NA	2.13E-02	0.5	4.26E-02	No
Silver	8.56E-03	NA	8.56E-03	0.0005	1.71E+01	Yes
Zinc	8.65E-01	0.282	1.15E+00	0.07	1.64E+01	Yes

[a] Wet weight

[b] RI/FS data for a fish sample from Paddys Run

[c] Not available

TABLE 6-18B
RACCOON ESTIMATED INTAKE AND HAZARD
DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	1.45E-03	6	2.41E-04	No
Anthracene	9.64E-04	33	2.92E-05	No
Benzo(a)anthracene	2.86E-04	NA[a]	NA	No
Benzo(a)pyrene	2.55E-04	NA	NA	No
Benzo(b)fluoranthene	8.21E-05	NA	NA	No
Benzo(g,h,i)perylene	3.96E-05	NA	NA	No
Benzo(k)fluoranthene	1.23E-04	NA	NA	No
Chrysene	3.45E-04	NA	NA	No
Dibenzo(a,h)anthracene	1.73E-04	NA	NA	No
Fluoranthene	3.18E-03	3	1.06E-03	No
Fluorene	2.33E-03	3	7.78E-04	No
Indeno(1,2,3-cd)pyrene	1.98E-05	NA	NA	No
2-methyl naphthalene	1.37E-03	NA	NA	No
Naphthalene	4.23E-03	0.7	6.04E-03	No
Phenanthrene	7.65E-03	NA	NA	No
Pyrene	2.62E-03	2	1.31E-03	No
Monocyclic Aromatics				
Benzoic acid	1.77E-02	0.4	4.43E-02	No
Chlorobenzene	5.83E-05	3	1.94E-05	No
Toluene	4.50E-05	22	2.05E-06	No
Phthalate Esters				
Bis(2-ethylhexyl)phthalate	4.18E-04	0.4	1.04E-03	No

TABLE 6-18B
(Continued)

Chemical	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polychlorinated Biphenyls				
Arochlor 1254	5.80E-05	NA	NA	No
Arochlor 1260	2.14E-04	NA	NA	No
Pesticides				
Beta-BHC	1.09E-04	NA	NA	No
Halogenated Aliphatic Hydrocarbons				
Chloroform	2.48E-04	0.3	8.27E-04	No
1,2-dichloroethylene	5.52E-05	NA	NA	No
Methylene chloride	2.92E-03	0.6	4.86E-03	No
Tetrachloroethene	2.78E-05	2	1.39E-05	No
1,1,1-trichloroethane	9.34E-05	9	1.04E-05	No
Trichloroethene	1.62E-04	NA	NA	No
Nonhalogenated Aliphatic Hydrocarbons				
Acetone	1.41E-02	10	1.41E-03	No
2-butanone	4.06E-03	5	8.13E-04	No
4-methyl-2-pentanone	4.74E-02	NA	NA	No
Tributyl phosphate		NA	NA	No
Miscellaneous Compounds				
Carbon disulfide	2.22E-04	1	2.22E-04	No
Carbon disulfide	1.45E-04	1	1.45E-04	No
Dibenzofurans	1.62E-03	0.001	1.62	Yes
N-nitrosodiphenyamine	5.61E-03	NA	NA	NA

[a] Not available

TABLE 6-19A
RED FOX INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS

Chemical	Daily Intake From Mice (mg/kg)[a]	Daily Intake From Fruits (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	4.29E-04	1.28E-03	1.71E-03	0.04	4.28E-02	No
Arsenic	2.28E-04	7.48E-05	3.03E-04	0.00008	3.78E+00	Yes
Barium	3.96E-04	4.06E-03	4.45E-03	0.02	2.23E-01	No
Beryllium	1.50E-05	2.50E-06	1.75E-05	0.05	3.50E-04	No
Cobalt	4.09E-03	1.58E-04	4.25E-03	0.00026	1.63E+01	Yes
Copper	4.82E-03	1.67E-02	2.15E-02	NA[b]	NA	NA
Lead	7.93E-05	5.69E-04	6.49E-04	0.000069	9.40E+00	Yes
Mercury	8.02E-04	4.60E-05	8.48E-04	0.03	2.83E-02	No
Nickel	1.36E-03	3.49E-03	4.85E-03	0.5	9.69E-03	No
Silver	4.68E-04	1.40E-03	1.87E-03	0.0005	3.74E+00	Yes
Zinc	3.11E-02	1.41E-01	1.73E-01	0.2	8.63E-01	No

[a]Wet weight
[b]Not available

TABLE 6-19B
RED FOX ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Daily Intake From Mice (mg/kg)[a]	Daily Intake From Plants (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	3.32E-06	2.77E-03	2.77E-03	6	4.62E-04	No
Anthracene	1.66E-06	2.33E-03	2.33E-03	33	7.05E-05	No
Benzo(a)anthracene	6.92E-05	1.51E-03	1.58E-03	NA[b]	NA	NA
Benzo(a)pyrene	2.39E-04	1.13E-03	1.36E-03	NA	NA	NA
Benzo(b)fluoranthene	1.31E-03	8.73E-04	2.19E-03	NA	NA	NA
Benzo(g,h,i)perylene	1.85E-03	1.13E-04	1.96E-03	NA	NA	No
Benzo(k)fluoranthene	3.21E-04	7.76E-05	3.98E-04	NA	NA	NA
Chrysene	6.55E-05	1.43E-03	1.49E-03	NA	NA	No
Dibenzo(a,h)anthracene	3.88E-05	4.23E-04	4.62E-04	NA	NA	No
Fluoranthene	6.52E-05	3.81E-03	3.88E-03	3	1.27E-03	No
Fluorene	5.18E-07	1.77E-03	1.77E-03	3	5.91E-04	No
Indeno(1,2,3-cd)pyrene	5.37E-03	6.57E-05	5.44E-03	NA	NA	NA
2-Methyl naphthalene	0.019872	2.24E-04	2.01E-02	NA	NA	NA
Naphthalene	3.73E-06	2.25E-03	2.25E-03	0.7	3.21E-03	No
Phenanthrene	5.89E-06	8.10E-03	8.10E-03	NA	NA	NA
Pyrene	4.19E-05	2.62E-03	2.66E-03	2	1.31E-03	No
Monocyclic Aromatics						
Benzoic Acid	3.28E-10	2.90E-03	2.90E-03	0.4	7.24E-03	No
Chlorobenzene	4.74E-11	3.18E-06	3.18E-06	3	1.06E-06	No
Toluene	3.49E-09	1.47E-05	1.47E-05	22	6.69E-07	No
Phthalate Esters						
Bis(2-Ethylhexyl)Phthalate	2.71E-06	1.21E-04	1.24E-04	0.4	3.03E-04	No
Polychlorinated Biphenyls						
Aroclor 1254	2.67E-04	3.84E-05	3.06E-04	NA	NA	NA
Aroclor 1260	8.10E-05	1.11E-04	1.92E-04	NA	NA	NA

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TABLE 6-19B
(Continued)

Chemical	Daily Intake From Mice (mg/kg)[a]	Daily Intake From Plants (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Pesticides						
Beta-BHC	1.83E-08	1.95E-04	1.95E-04	NA	NA	NA
Halogenated Aliphatic Hydrocarbons						
Chloroform	3.85E-09	1.01E-04	1.01E-04	0.3	3.38E-04	No
1,2-Dichloroethylene	4.27E-09	9.02E-06	9.03E-06	NA	NA	NA
Methylene cloride	9.99E-10	7.42E-04	7.42E-04	0.6	1.24E-03	No
Tetrachloroethene	1.36E-06	1.52E-05	1.65E-05	2	7.58E-06	No
1,1,1-Trichloroethane	2.22E-09	3.56E-05	3.56E-05	9	3.96E-06	No
Trichloroethene	5.68E-07	1.20E-04	1.20E-04	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons						
Acetone	5.73E-10	5.19E-03	5.19E-03	10	5.19E-04	No
2-Butanone	8.29E-10	2.47E-03	2.47E-03	5	4.93E-04	No
4-Methyl-2-pentanone	1.43E-11	8.61E-05	8.61E-05	NA	NA	NA
Tributyl Phosphate	0.00	0.00	0.00	NA	NA	NA
Miscellaneous Compounds						
Carbon disulfide	2.99E-11	4.84E-05	4.84E-05	1	4.84E-05	No
Carbon Disulfide	1.91E-11	3.16E-05	3.16E-05	1	3.16E-05	No
Dibenzofurans	0.00	2.66E-04	2.66E-04	0.001	2.66E-01	No
N-Nitrosodiphenyamine	3.78E-09	9.17E-04	9.17E-04	NA	NA	NA

[a] Wet weight.
[b] Not available.

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TABLE 6-19C
RED FOX ESTIMATED INTAKE
AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS
ASSUMING 1:1 MUSCLE TO MUSCLE TRANSFER

Chemical	Daily Intake From Mice (mg/kg)[a]	Daily Intake From Fruit (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	3.82E-01	1.28E-03	3.83E-01	0.04	9.57E+00	Yes
Arsenic	1.11E-01	7.48E-05	1.11E-01	0.00008	1.39E+03	Yes
Barium	2.41E+00	4.06E-03	2.42E+00	0.02	1.21E+02	Yes
Beryllium	1.49E-02	2.50E-06	1.49E-02	0.05	2.98E-01	No
Cobalt	2.02E-01	1.58E-04	2.02E-01	0.00026	7.77E+02	Yes
Copper	3.35E-01	1.67E-02	3.52E-01	NA[b]	NA	NA
Lead	2.48E-01	5.69E-04	2.49E-01	0.000069	3.61E+03	Yes
Mercury	2.34E-03	4.60E-05	2.39E-03	0.03	7.96E-02	No
Nickel	2.08E-01	3.49E-03	2.11E-01	0.5	4.22E-01	No
Silver	1.25E-01	1.40E-03	1.26E-01	0.0005	2.53E+02	Yes
Zinc	1.81E+00	1.41E-01	1.95E+00	0.2	9.75E+00	Yes

[a]Wet weight
[b]Not Available

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TABLE 6-19D
RED FOX ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS ASSUMING 1:1 MUSCLE: MUSCLE TRANSFER

Chemical	Daily Intake From Mice (mg/kg)[a]	Daily Intake From Plants (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	2.76E-06	2.77E-03	2.77E-03	6	4.62E-04	No
Anthracene	6.05E-06	2.33E-03	2.33E-03	33	7.07E-05	No
Benzo(a)anthracene	1.05E-04	1.51E-03	1.61E-03	NA[b]	NA	NA
Benzo(a)pyrene	4.29E-04	1.13E-03	1.56E-03	NA	NA	NA
Benzo(b)fluoranthene	9.66E-04	8.73E-04	1.84E-03	NA	NA	NA
Benzo(g,h,i)perylene	5.07E-03	1.13E-04	5.18E-03	NA	NA	NA
Benzo(k)fluoranthene	3.99E-03	7.76E-05	4.07E-03	NA	NA	NA
Chrysene	1.27E-04	1.43E-03	1.56E-03	NA	NA	NA
Dibenzo(a,h)anthracene	1.26E-04	4.23E-04	5.49E-04	NA	NA	NA
Fluoranthene	4.42E-04	3.81E-03	4.25E-03	3	1.42E-03	No
Fluorene	6.27E-06	1.77E-03	1.78E-03	3	5.94E-04	No
Indeno(1,2,3-cd)pyrene	1.26E-02	6.57E-05	1.27E-02	NA	NA	NA
2-Methyl naphthalene	0.00	2.24E-04	2.24E-04	NA	NA	NA
Naphthalene	1.32E-06	2.25E-03	2.25E-03	0.7	3.21E-03	No
Phenanthrene	4.88E-05	8.10E-03	8.15E-03	NA	NA	NA
Pyrene	3.41E-04	2.62E-03	2.96E-03	2	1.48E-03	No
Monocyclic Aromatics						
Benzoic Acid	5.91E-08	2.90E-03	2.90E-03	0.4	7.24E-03	No
Chlorobenzene	2.37E-09	3.18E-06	3.18E-06	3	1.06E-06	No
Toluene	1.38E-09	1.47E-05	1.47E-05	22	6.69E-07	No
Phthalate Esters						
Bis(2-ethylhexyl)phthalate	2.61E-05	1.21E-04	1.47E-04	0.4	3.68E-04	No
Polychlorinated Biphenyls						
Arochlor 1254	4.75E-04	3.84E-05	5.13E-04	NA	NA	NA
Arochlor 1260	4.92E-04	1.11E-04	6.03E-04	NA	NA	NA

TABLE 6-19D
(Continued)

Chemical	Daily Intake From Mice (mg/kg)[a]	Daily Intake From Plants (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Pesticides						
Beta-BHC	1.01E-07	1.95E-04	1.95E-04	NA	NA	NA
Halogenated Aliphatic Hydrocarbons						
Chloroform	1.02E-09	1.01E-04	1.01E-04	0.3	3.38E-04	No
1,2-Dichloroethylene	1.56E-10	9.02E-06	9.02E-06	NA	NA	NA
Methylene chloride	2.13E-09	7.42E-04	7.42E-04	0.6	1.24E-03	No
Tetrachloroethene	9.35E-09	1.52E-05	1.52E-05	2	7.58E-06	No
1,1,1-Trichloroethane	1.50E-09	3.56E-05	3.56E-05	9	3.96E-06	No
Trichloroethene	1.54E-09	1.20E-04	1.20E-04	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons						
Acetone	3.13E-10	5.19E-03	5.19E-03	10	5.19E-04	No
2-Butanone	3.07E-10	2.47E-03	2.47E-03	5	4.93E-04	No
4-Methyl-2-pentanone	2.98E-08	8.61E-05	8.61E-05	NA	NA	NA
Tributyl phosphate	0.00	0.00	0.00	NA	NA	NA
Miscellaneous Compounds						
Carbon disulfide	1.30E-09	4.84E-05	4.84E-05	1	4.84E-05	No
Carbon disulfide	5.58E-10	3.16E-05	3.16E-05	1	3.16E-05	No
Dibenzofurans	0.00	2.66E-04	2.66E-04	0.001	2.66E-01	No
N-Nitrosodiphenylamine	1.11E-07	9.17E-04	9.17E-04	NA	NA	NA

[a] Wet weight

[b] Not available

TABLE 6-20A
MUSKRAT ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS

Chemical	Daily Ingestion of Vegetation (mg/kg)[a]	Adjusted Wildlife NOEL (mg/kg)	Hazard Index (HI)	Exceeds HI of 1
Antimony	2.67E-01	4.00E-02	6.67E+00	Yes
Arsenic	1.56E-02	8.00E-05	1.94E+02	Yes
Barium	1.27E+00	2.00E-02	6.33E+01	Yes
Beryllium	5.21E-04	5.00E-02	1.04E-02	No
Cobalt	1.41E-02	2.60E-04	5.43E+01	Yes
Copper	8.33E-01	NA[b]	NA	NA
Lead	8.89E-02	6.90E-05	1.29E+03	Yes
Mercury	6.46E-03	3.00E-02	2.15E-01	No
Nickel	1.09E-01	5.00E-01	2.18E-01	No
Silver	1.75E-01	5.00E-04	3.49E+02	Yes
Zinc	7.36E+00	2.00E-01	3.68E+01	Yes

[a] Wet weight
[b] Not available

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TABLE 6-20B
MUSKRAT ESTIMATED INTAKE
AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Daily Intake From Vegetation (mg/kg)[a]	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	4.60E-02	6	7.66E-03	No
Anthracene	3.86E-02	33	1.17E-03	No
Benzo(a)anthracene	2.50E-02	NA[b]	NA	NA
Benzo(a)pyrene	1.87E-02	NA	NA	NA
Benzo(b)fluoranthene	1.45E-02	NA	NA	NA
Benzo(g,h,i)perylene	1.87E-03	NA	NA	NA
Benzo(k)fluoranthene	1.29E-03	NA	NA	NA
Chrysene	2.37E-02	NA	NA	NA
Dibenzo(a,h)anthracene	7.02E-03	NA	NA	NA
Fluoranthene	6.32E-02	3	2.11E-02	No
Fluorene	2.94E-02	3	9.81E-03	No
Indeno(1,2,3-cd)pyrene	1.09E-03	NA	NA	NA
2-Methyl naphthalene	1.05E-02	NA	NA	NA
Naphthalene	3.73E-02	0.7	5.32E-02	No
Phenanthrene	1.34E-01	NA	NA	NA
Pyrene	4.34E-02	2	2.17E-02	No
Monocyclic Aromatics				
Benzoic acid	4.80E-02	0.4	1.20E-01	No
Chlorobenzene	5.27E-05	3	1.76E-05	No
Toluene	2.44E-04	22	1.11E-05	No
Phthalate Esters				
Bis(2-ethylhexyl)phthalate	2.01E-03	0.4	5.02E-03	No
Polychlorinated Biphenyls				
Arochlor 1254	6.37E-04	NA	NA	NA
Arochlor 1260	1.84E-03	NA	NA	NA

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TABLE 6-20B
(Continued)

Chemical	Daily Intake From Vegetation (mg/kg)[a]	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1
Pesticides				
Beta-BHC	3.24E-03	NA	NA	NA
Halogenated Aliphatic Hydrocarbons				
Chloroform	1.68E-03	0.3	5.60E-03	No
1,2-Dichloroethylene	1.50E-04	NA	NA	NA
Methylene chloride	1.23E-02	0.6	2.05E-02	No
Tetrachloroethene	2.51E-04	2	1.26E-04	No
1,1,1-Trichloroethane	5.91E-04	9	6.56E-05	No
Trichloroethene	1.98E-03	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons				
Acetone	8.61E-02	10	8.61E-03	No
2-Butanone	4.09E-02	5	8.18E-03	No
4-Methyl-2-pentanone	1.43E-03	NA	NA	NA
Tributyl phosphate	NA	NA	NA	NA
Miscellaneous Compounds				
Carbon disulfide	8.02E-04	1	8.02E-04	No
Carbon disulfide	5.24E-04	1	5.24E-04	No
Dibenzofurans	1.91E-02	0.001	1.91E+01	Yes
N-Nitrosodiphenylamine	1.52E-02	NA	NA	NA

[a] Wet weight
[b] Not available

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TABLE 6-21A
AMERICAN ROBIN ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS

Inorganics	Daily Intake From Earthworms (mg/kg)	Daily Intake From Fruits (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Avian/Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	1.68E+00	4.22E-02	1.72E+00	0.02	8.62E+01	Yes
Arsenic	4.90E-01	2.46E-03	4.93E-01	0.0952	5.18E+00	Yes
Barium	1.06E+01	1.34E-01	1.08E+01	0.01	1.08E+03	Yes
Beryllium	6.56E-02	8.24E-05	6.57E-02	0.025	2.63E+00	Yes
Cobalt	8.90E-01	5.22E-03	8.95E-01	0.00013	6.88E+03	Yes
Copper	1.47E+00	5.49E-01	2.02E+00	NA[a]	NA	No
Lead	1.10E+00	1.88E-02	1.11E+00	0.0492	2.26E+01	Yes
Mercury	9.05E-03	1.52E-03	1.06E-02	0.0252	4.19e-01	No
Nickel	9.14E-01	1.15E-01	1.03E+00	0.25	4.12E+00	Yes
Silver	5.51E-01	4.61E-02	5.97E-01	0.00025	2.39E+03	Yes
Zinc	7.92E+00	4.66E+00	1.26E+01	0.1	1.26E+02	Yes

[a] Not available

TABLE 6-21B
AMERICAN ROBIN ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Daily Intake From Earthworms (mg/kg)	Daily Intake From Fruits (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Avian/Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	3.09E-02	7.80E-03	3.87E-02	0.202	1.92E-01	No
Anthracene	3.17E-02	5.19E-03	3.69E-02	16.5	2.23E-03	No
Benzo(a)anthracene	4.45E-02	1.54E-03	4.60E-02	NA[a]	NA	NA
Benzo(a)pyrene	6.71E-02	1.38E-03	6.85E-02	NA	NA	NA
Benzo(b)fluoranthene	4.53E-02	4.42E-04	4.57E-02	NA	NA	NA
Benzo(g,h,i)perylene	5.20E-02	2.13E-04	5.23E-02	NA	NA	NA
Benzo(k)fluoranthene	9.81E-02	6.64E-04	9.87E-02	NA	NA	NA
Chrysene	5.36E-02	1.86E-03	5.54E-02	NA	NA	NA
Dibenzo(a,h)anthracene	3.47E-02	9.29E-04	3.56E-02	NA	NA	NA
Fluoranthene	3.39E-01	1.71E-02	3.57E-01	1.5	2.38E-01	No
Fluorene	5.36E-02	1.26E-02	6.61E-02	0.226	2.93E-01	No
Indeno(1,2,3-cd)pyrene	4.83E-02	1.06E-04	4.84E-02	NA	NA	NA
2-Methyl naphthalene	2.04E-02	7.38E-03	2.77E-02	NA	NA	NA
Naphthalene	3.02E-02	2.28E-02	5.29E-02	0.35	1.51E-01	No
Phenanthrene	2.56E-01	4.12E-02	2.98E-01	0.202	1.47E+00	Yes
Pyrene	2.72E-01	1.41E-02	2.86E-01	1	2.86E-01	No
Monocyclic Aromatics						
Benzoic acid	1.89E-02	9.54E-02	1.14E-01	0.2	5.71E-01	No
Chlorobenzene	2.26E-04	3.14E-04	5.40E-04	1.5	3.60E-04	No
Toluene	1.51E-04	2.42E-04	3.93E-04	11	3.58E-05	No
Phthalate Esters						
Bis(2-ethylhexyl)phthalate	3.32E-02	2.25E-03	3.54E-02	0.2	1.77E-01	No
Polychlorinated Biphenyls						
Arochlor 1254	2.79E-02	3.12E-04	2.82E-02	NA	NA	NA
Arochlor 1260	6.64E-02	1.15E-03	6.75E-02	NA	NA	NA
Pesticides						
Beta-BHC	1.51E-03	5.85E-04	2.09E-03	NA	NA	NA

TABLE 6-21B
(Continued)

Chemical	Daily Intake From Earthworms (mg/kg)	Daily Intake From Fruits (mg/kg)	Total Daily Intake (mg/kg)	Adjusted Avian/Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Halogenated Aliphatic Hydrocarbons						
Chloroform	3.02E-04	1.34E-03	1.64E-03	0.15	1.09E-02	No
1,2-Dichloroethylene	7.54E-05	2.97E-04	3.73E-04	NA	NA	NA
Methylene chloride	1.36E-03	1.57E-02	1.71E-02	0.3	5.69E-02	No
Tetrachloroethene	2.26E-04	1.50E-04	3.76E-04	1	3.76E-04	No
1,1,1-Trichloroethane	2.26E-04	5.03E-04	7.29E-04	4.5	1.62E-04	No
Trichloroethene	3.02E-04	8.75E-04	1.18E-03	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons						
Acetone	9.05E-04	7.60E-02	7.69E-02	5	1.54E-02	No
2-Butanone	5.28E-04	2.19E-02	2.24E-02	2.5	8.96E-03	No
4-Methyl-2-pentanone	2.04E-02	2.55E-01	2.75E-01	NA	NA	NA
Tributyl phosphate	9.05E-02	0.00	9.05E-02	NA	NA	NA
Miscellaneous Compounds						
Carbon disulfide	2.26E-04	1.19E-03	1.42E-03	0.5	2.84E-03	No
Carbon disulfide	2.26E-04	7.81E-04	1.01E-03	0.5	2.01E-03	No
Dibenzofurans	3.47E-02	8.75E-03	4.34E-02	0.0005	8.69E+01	Yes
N-Nitrosodiphenylamine	1.51E-02	3.02E-02	4.53E-02	NA	NA	NA

[a] Not available

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TABLE 6-22A
RED-TAILED HAWK ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS

Chemical	Daily Intake From Mice by Hawk (mg/kg)[a]	Adjusted Avian/Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	9.79E-04	0.02	4.90E-02	No
Arsenic	5.20E-04	0.0952	5.46E-03	No
Barium	9.03E-04	0.01	9.03E-02	No
Beryllium	3.42E-05	0.025	1.37E-03	No
Cobalt	9.32E-03	0.00013	7.18E+01	No
Copper	1.10E-02	NA[b]	NA	NA
Lead	1.81E-04	0.0492	3.67E-03	No
Mercury	1.83E-03	0.0252	7.26E-02	No
Nickel	3.10E-03	0.25	1.24E-02	No
Silver	1.07E-03	0.00025	4.27E+00	No
Zinc	7.09E-02	0.1	7.09E-01	No

[a] Wet weight
[b] Not available

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TABLE 6-22B
RED-TAILED HAWK ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS

Chemical	Daily Intake From Mice (mg/kg)[a]	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	6.30E-06	0.202	3.12E-05	No
Anthracene	1.38E-05	16.5	8.36E-07	No
Benzo(a)anthracene	2.40E-04	NA[b]	NA	NA
Benzo(a)pyrene	9.79E-04	NA	NA	NA
Benzo(b)fluoranthene	2.20E-03	NA	NA	NA
Benzo(g,h,i)perylene	1.16E-02	NA	NA	NA
Benzo(k)fluoranthene	9.10E-03	NA	NA	NA
Chrysene	2.89E-04	NA	NA	NA
Dibenzo(a,h)anthracene	2.87E-04	NA	NA	NA
Fluoranthene	1.01E-03	1.5	6.71E-04	No
Fluorene	1.43E-05	0.226	6.33E-05	No
Indeno(1,2,3-cd)pyrene	2.88E-02	NA	NA	NA
2-Methyl naphthalene	1.92E-06	NA	NA	NA
Naphthalene	3.02E-06	0.35	8.63E-06	No
Phenanthrene	1.11E-04	0.202	5.51E-04	No
Pyrene	7.77E-04	1	7.77E-04	No
Monocyclic Aromatics				
Benzoic acid	1.35E-07	0.2	6.74E-07	No
Chlorobenzene	5.41E-09	1.5	3.61E-09	No
Toluene	3.15E-09	11	2.87E-10	No
Phthalate Esters				
Bis(2-ethylhexyl)phthalate	5.95E-05	0.2	2.98E-04	No
Polychlorinated Biphenyls				
Arochlor 1254	1.08E-03	NA	NA	NA
Arochlor 1260	1.12E-03	NA	NA	NA
Pesticides				
Beta-BHC	2.31E-07	NA	NA	NA

TABLE 6-22B
(Continued)

Chemical	Daily Intake From Mice (mg/kg)[a]	Adjusted Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Halogenated Aliphatic Hydrocarbons				
Chloroform	2.32E-09	0.15	1.55E-08	No
1,2-Dichloroethylene	3.56E-10	NA	NA	NA
Methylene chloride	4.85E-09	0.3	1.62E-08	No
Tetrachloroethene	2.13E-08	1	2.13E-08	No
1,1,1-Trichloroethane	3.43E-09	4.5	7.62E-10	No
Trichloroethene	3.51E-09	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons				
Acetone	7.13E-10	5	1.43E-10	No
2-Butanone	7.01E-10	2.5	2.80E-10	No
4-Methyl-2-pentanone	6.79E-08	NA	NA	NA
Tributyl phosphate	NA	NA	NA	NA
Miscellaneous Compounds				
Carbon disulfide	2.96E-09	0.5	5.91E-09	No
Carbon disulfide	1.27E-09	0.5	2.54E-09	No
Dibenzofurans	2.21E-02	0.0005	4.42E+01	Yes
N-nitrosodiphenylamine	2.53E-07	NA	NA	No

[a] Wet weight

[b] Not available

TABLE 6-22C
RED-TAILED HAWK ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF INORGANIC CHEMICALS ASSUMING 1:1 MUSCLE TO MUSCLE TRANSFER

Chemical	Daily Intake From Mice (mg/kg)[a]	Adjusted Avian/Wildlife NOEL (mg/kg-day)	Hazard Index (HI)	Exceeds HI of 1
Antimony	8.70E-01	0.02	4.36E+01	Yes
Arsenic	2.54E-01	0.0952	2.66E+00	Yes
Barium	5.50E+00	0.01	5.50E+02	Yes
Beryllium	3.39E-02	0.025	1.36E+00	Yes
Cobalt	4.60E-01	0.00013	3.54E+03	Yes
Copper	7.64E-01	NA[b]	NA	NA
Lead	5.66E-01	0.0492	1.15E+01	Yes
Mercury	5.34E-03	0.0252	2.12E-01	No
Nickel	4.73E-01	0.25	1.89E+00	Yes
Silver	2.85E-01	0.00025	1.14E+03	Yes
Zinc	4.12E+00	0.1	4.12E+01	Yes

[a] Wet weight

[b] Not available

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TABLE 6-22D

RED-TAILED HAWK ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF ORGANIC CHEMICALS ASUMING 1:1 MUSCLE TO MUSCLE TRANSFER

Chemical	Daily Intake From Mice (mg/kg)[a]	Adjusted Wildlife NOEL (mg/kg/day)	Hazard Index (HI)	Exceeds HI of 1
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	1.60E-02	0.202	7.92E-02	No
Anthracene	1.64E-02	16.5	9.93E-04	No
Benzo(a)anthracene	2.30E-02	NA[b]	NA	NA
Benzo(a)pyrene	3.47E-02	NA	NA	NA
Benzo(b)fluoranthene	2.34E-02	NA	NA	NA
Benzo(g,h,i)perylene	2.70E-02	NA	NA	NA
Benzo(k)fluoranthene	5.08E-02	NA	NA	NA
Chrysene	2.77E-02	NA	NA	NA
Dibenzo(a,h)anthracene	1.80E-02	NA	NA	NA
Fluoranthene	1.76E-01	1.5	1.17E-01	No
Fluorene	2.77E-02	0.226	1.23E-01	No
Indeno(1,2,3-cd)pyrene	2.50E-02	NA	NA	NA
2-Methyl naphthalene	1.05E-02	NA	NA	NA
Naphthalene	1.56E-02	0.35	4.46E-02	No
Phenanthrene	1.33E-01	0.202	6.57E-01	No
Pyrene	1.40E-01	1	1.40E-01	No
Monocyclic Aromatics				
Benzoic acid	9.75E-03	0.2	4.88E-02	No
Chlorobenzene	1.17E-04	1.5	7.80E-05	No
Toluene	7.80E-05	11	7.09E-06	No
Phthalate Esters				
Bis(2-ethylhexyl)phthalate	1.72E-02	0.2	8.58E-02	No

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TABLE 6-22D
(Continued)

Chemical	Daily Intake From Mice (mg/kg)[a]	Adjusted Wildlife NOEL (mg/kg/day)	Hazard Index (HI)	Exceeds HI of 1
Polychlorinated Biphenyls				
Arochlor 1254	1.44E-02	NA	NA	NA
Arochlor 1260	3.44E-02	NA	NA	NA
Pesticides				
Beta-BHC	7.80E-04	NA	NA	NA
Halogenated Aliphatic Hydrocarbons				
Chloroform	1.56E-04	0.15	1.04E-03	No
1,2-Dichloroethylene	3.90E-05	NA	NA	NA
Methylene chloride	7.02E-04	0.3	2.34E-03	No
Tetrachloroethene	1.17E-04	1	1.17E-04	No
1,1,1-Trichloroethane	1.17E-04	4.5	2.60E-05	No
Trichloroethene	1.56E-04	NA	NA	NA
Nonhalogenated Aliphatic Hydrocarbons				
Acetone	4.68E-04	5	9.36E-05	No
2-Butanone	2.73E-04	2.5	1.09E-04	No
4-Methyl-2-pentanone	1.05E-02	NA	NA	NA
Tributyl phosphate		NA	NA	NA
Miscellaneous Compounds				
Carbon disulfide	1.17E-04	0.5	2.34E-04	No
Carbon disulfide	1.17E-04	0.5	2.34E-04	No
Dibenzofurans	7.80E-03	0.0005	1.56E+01	Yes
N-nitrosodiphenylamine	2.53E-07	NA	NA	NA

[a] Wet weight
[b] Not available

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TABLE 6-23
WILDLIFE ESTIMATED INTAKE AND HAZARD DUE TO INGESTION OF PADDYS RUN SURFACE WATER

	White-Tailed Deer				White-Footed Mouse			
Chemical	Daily Water Intake (mg/kg)[a]	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1	Daily Water Intake (mg/kg)	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1
Inorganic Chemical								
Antimony	6.93E-05	0.04	1.73E-03	No	3.83E-04	0.04	9.56E-03	No
Arsenic	4.62E-05	0.00008	5.77E-01	No	2.55E-04	0.00008	3.19E+00	Yes
Barium	1.06E-03	0.02	5.31E-02	No	5.87E-03	0.02	2.93E-01	No
Beryllium	2.31E-05	0.05	4.62E-04	No	1.28E-04	0.05	2.55E-03	No
Cadmium	6.93E-05	0.001	6.93E-02	No	3.83E-04	0.001	3.83E-01	No
Chromium	4.16E-04	0.2	2.08E-03	No	2.30E-03	0.2	1.15E-02	No
Copper	1.62E-04	NA[b]	NA	NA	8.93E-04	NA	NA	NA
Lead	6.93E-05	0.000069	1.00E+00	Yes	3.83E-04	0.000069	5.54E+00	Yes
Manganese	4.16E-04	0.01	4.16E-02	No	2.30E-03	0.01	2.30E-01	No
Mercury	3.93E-06	0.03	1.31E-04	No	2.17E-05	0.03	7.23E-04	No
Molybdenum	1.85E-04	0.0004	4.62E-01	No	1.02E-03	0.0004	2.55E+00	Yes
Nickel	3.00E-04	0.5	6.01E-04	No	1.66E-03	0.5	3.32E-03	No
Nitrate	9.86E-02	NA	NA	NA	5.44E-01	NA	NA	NA
Selenium	4.62E-05	0.0015	3.08E-02	No	2.55E-04	0.0015	1.70E-01	No
Silicon	8.72E-02	NA	NA	NA	4.82E-01	NA	NA	NA
Silver	1.39E-04	0.0005	2.77E-01	No	7.65E-04	0.0005	1.53E+00	Yes
Vanadium	2.77E-04	0.07	3.96E-03	No	1.53E-03	0.07	2.19E-02	No
Zinc	8.55E-04	0.2	4.27E-03	No	4.72E-03	0.2	2.36E-02	No
Organic Chemicals								
Diethyl Phthalate	4.62E-05	NA	NA	NA	2.55E-04	NA	NA	NA
N-Nitrosodiphenylamine	9.24E-05	NA	NA	NA	5.10E-04	NA	NA	NA
Phenols	1.85E-04	6	3.08E-05	No	1.02E-03	6	1.70E-04	No
bis(2-ethylhexyl)phthalate	9.24E-05	0.4	2.31E-04	No	5.10E-04	0.4	1.28E-03	No
Other								
Ammonia	4.27E-03	NA	NA	NA	2.36E-02	NA	NA	NA

TABLE 6-23
(Continued)

Chemical	Raccoon				Red Fox			
	Daily Water Intake (mg/kg)[a]	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1	Daily Water Intake (mg/kg)	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1
Inorganic Chemicals								
Arsenic	7.59E-05	0.00008	9.48E-01	No	1.18E-04	0.04	2.95E-03	No
Barium	1.74E-03	0.02	8.72E-02	No	7.87E-05	0.00008	9.84E-01	No
Beryllium	3.79E-05	0.05	7.59E-04	No	1.81E-03	0.02	9.05E-02	No
Cadmium	1.14E-04	0.001	1.14E-01	No	3.94E-05	0.05	7.87E-04	No
Chromium	6.83E-04	0.2	3.41E-03	No	1.18E-04	0.001	1.18E-01	No
Copper	2.66E-04	NA	NA	NA	7.09E-04	0.2	3.54E-03	No
Lead	1.14E-04	0.000069	1.65E+00	Yes	2.76E-04	NA	NA	NA
Manganese	6.83E-04	0.01	6.83E-02	No	1.18E-04	0.000069	1.71E+00	Yes
Mercury	6.45E-06	0.03	2.15E-04	No	7.09E-04	0.01	7.09E-02	No
Molybdenum	3.03E-04	0.0004	7.59E-01	No	6.69E-06	0.03	2.23E-04	No
Nickel	4.93E-04	0.5	9.86E-04	No	3.15E-04	0.0004	7.87E-01	No
Nitrate	1.62E-01	NA	NA	NA	5.12E-04	0.5	1.02E-03	No
Selenium	7.59E-05	0.0015	5.06E-02	No	7.87E-05	0.0015	5.25E-02	No
Silicon	1.43E-01	NA	NA	NA	1.49E-01	NA	NA	NA
Silver	2.28E-04	0.0005	4.55E-01	No	2.36E-04	0.0005	4.72E-01	No
Vanadium	4.55E-04	0.07	6.50E-03	No	4.72E-04	0.07	6.75E-03	No
Zinc	1.40E-03	0.2	7.02E-03	No	1.46E-03	0.2	7.28E-03	No
Organic Chemicals								
Diethyl Phthalate	7.59E-05	NA	NA	NA				
N-Nitrosodiphenylamine	1.52E-04	NA	NA	NA	7.87E-05	NA	NA	NA
Phenols	3.03E-04	6	5.06E-05	No	1.57E-04	NA	NA	NA
bis(2-ethylhexyl)phthalate	1.52E-04	0.4	3.79E-04	No	3.15E-04	6	5.25E-05	No
Other								
Ammonia	7.02E-03	NA	NA	NA	7.28e-03	NA	NA	NA

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TABLE 6-23
(Continued)

Chemical	American Robin				Red-Tailed Hawk			
	Daily Water Intake (mg/kg)[a]	Adjusted Avian NOEL	Hazard Index (HI)	Exceeds HI of 1	Daily Water Intake (mg/kg)	Adjusted Aviane NOEL	Hazard Index (HI)	Exceeds HI of 1
Inorganic Chemicals								
Antimony	3.57E-04	0.02	1.79E-02	No	1.86E-04	0.02	9.29E-03	No
Arsenic	2.38E-04	0.0952	2.50E-03	No	1.24E-04	0.0952	1.30E-03	No
Barium	5.48E-03	0.01	5.48E-01	No	2.85E-03	0.01	2.85E-01	No
Beryllium	1.19E-04	0.025	4.76E-03	No	6.19E-05	0.025	2.48E-03	No
Cadmium	3.57E-04	0.0005	7.14E-01	No	1.86E-04	0.0005	3.72E-01	No
Chromium	2.14E-03	0.1	2.14E-02	No	1.12E-03	0.1	1.12E-02	No
Copper	8.33E-04	NA	NA	NA	4.34E-04	NA	NA	NA
Lead	3.57E-04	0.0492	7.26E-03	No	1.86E-04	0.0492	3.78E-03	No
Manganese	2.14E-03	0.005	4.29E-01	No	1.12E-03	0.005	2.23E-01	No
Mercury	2.02E-05	0.0252	8.03E-04	No	1.05E-05	0.0252	4.18E-04	No
Molybdenum	9.52E-04	0.0002	4.76E+00	Yes	4.96E-04	0.0002	2.48E+00	Yes
Nickel	1.55E-03	0.25	6.19E-03	No	8.05E-04	0.25	3.22E-03	No
Selenium	2.38E-04	0.00075	3.17E-01	No	1.24E-04	0.00075	1.65E-01	No
Silicon	4.50E-01	NA	NA	NA	2.34E-01	NA	NA	NA
Silver	7.14E-04	0.00025	2.86E+00	Yes	3.72E-04	0.00025	1.49E+00	Yes
Vanadium	1.43E-03	0.035	4.08E-02	No	7.43E-04	0.035	2.12E-02	No
Zinc	4.40E-03	0.2	2.20E-02	No	2.29E-03	0.2	1.15E-02	No
Organic Chemicals								
Diethyl Phthalate	2.38E-04	NA	NA	NA	1.24E-04	NA	NA	NA
N-Nitrosodiphenylamine	4.76E-04	NA	NA	NA	2.48E-04	NA	NA	NA
Phenols	9.52E-04	3	3.17E-04	No	4.96E-04	3	1.65E-04	No
bis(2-ethylhexyl)phthalate	4.76E-04	0.2	2.38E-03	No	2.48E-04	0.2	1.24E-03	No
General Chemical								
Ammonia	2.20E-02	NA	NA	NA	1.15E-02	NA	NA	NA
Nitrate	5.08E-01	NA	NA	NA	2.65E-01	NA	NA	NA

TABLE 6-23
(Continued)

Chemical	Muskrat			
	Daily Water Intake (mg/kg)[a]	Adjusted Wildlife NOEL	Hazard Index (HI)	Exceeds HI of 1
Inorganic Chemical				
Antimony	1.59E-04	0.04	3.96E-03	No
Arsenic	1.06E-04	0.00008	1.32E+00	Yes
Barium	2.43E-03	0.02	1.22E-01	No
Beryllium	5.28E-05	0.05	1.06E-03	No
Cadmium	1.59E-04	0.001	1.59E-01	No
Chromium	9.51E-04	0.2	4.76E-03	No
Copper	3.70E-04	NA	NA	NA
Lead	1.59E-04	0.000069	2.30E+00	Yes
Manganese	9.51E-04	0.01	9.51E-02	No
Mercury	8.98E-06	0.03	2.99E-04	No
Molybdenum	4.23E-04	0.0004	1.06E+00	Yes
Nickel	6.87E-04	0.5	1.37E-03	No
Nitrate	2.26E-01	NA	NA	NA
Selenium	1.06E-04	0.0015	7.05E-02	No
Silicon	2.00E-01	NA	NA	NA
Silver	3.17-04	0.0005	6.34E-01	No
Vanadium	6.34E-04	0.07	9.06E-03	No
Zinc	1.96E-03	0.2	9.78E-03	No
Organic Chemicals				
Diethyl Phthalate	1.06E-04	NA	NA	NA
N-Nitrosodiphenylamine	2.11E-04	NA	NA	NA
Phenols	4.23E-04	6	7.05E-05	No
bis(2-ethylhexyl)phthalate	2.11E-04	0.4	5.28-04	No
Other				
Ammonia	9.78E-03	NA	NA	NA

[a] Wet weight

[b] Not available

Muskrats were assumed to receive all of their exposure to constituents of concern in FEMP surface soils from intake of vegetation (Table 6-20A, B).

Earthworms contributed 63-99% of the inorganic chemical uptake by robins (Table 6-21A), emphasizing the importance of the soil-to-earthworm pathway relative to soil-to-fruit or vegetation.

Red-tailed hawks were assumed to receive all of their exposure to constituents of concern in FEMP surface soils by preying on mice. Using a conservative muscle-to-muscle transfer factor of 1.0 increased estimated intakes by one to three orders of magnitude and increased the chemicals with HIs greater than 1.0 from cobalt and silver to all but mercury (Tables 6-22A, 6-22C). This indicates muscle-to-muscle transfer is an important source of uncertainty in evaluating hazards to predators. In the case of the hawk, the use of the conservative transfer factors is equivalent to having the hawk directly consume soil in the same proportion as the mouse consumes insects (70%).

Intake of organic compounds was generally lower than that of inorganic chemicals, and only a few of those organic chemicals for which toxicity data was located had hazard indices greater than 1.0, as discussed below. As with the metals, total intake values were highest for the white-footed mouse and American robin.

The relative importances of the various pathways of organic chemical intake were similar to those inorganic chemicals. The exceptions to this were for organic chemicals with soil-to-plant transfer coefficients greater than 1.0 (Table 6-2). For these compounds, the relative importance of plant intake in omnivorous species, for example the white-footed mouse and red fox, increased relative to earthworm or mouse intake, due to the assumption that muscle-to-muscle transfer was equal to 1.0 under worst-case conditions. Given the small number of organic chemicals with HIs greater than 1.0, and the lack of any detections of organic chemicals in FEMP biota (Part I, Section 4.1.7), intake via the food chain dos not appear to be a significant pathway for exposure of ecological receptors to organic chemicals from the FEMP. This does not exclude the possibility of higher exposures at localized areas of contamination such as the waste pits.

Estimated intake of inorganic and organic chemicals via water ingestion was limited, with only four inorganic (arsenic, lead, molybdenum, and silver) and no organic chemicals with HIs greater than 1.0 (Table 6-23). The water pathway thus contributes only a small fraction of the total estimated exposure of the terrestrial indicator species to chemical constituents of potential concern at the FEMP.

6.4.2.3 Exposures to Radionuclides

The estimated muscle concentrations resulting from intake of radionuclides and associated radiation doses for each radionuclide constituent of concern is summarized for each indicator species in Tables 6-24 to 6-31. The implications of the estimated radiation doses with respect to risk are discussed below in Section 6.5.2.2.

The soil ingestion pathway was responsible for nearly all the estimated radiation dose to white-tailed deer (Table 6-24). This appears to differ from the estimates for inorganic chemical intake. However, chemical hazard estimates are based on intake only, while radiation doses were estimated following assimilation. Deer ingesting soil were assumed to assimilate radionuclides into muscle at the plant-to-beef transfer coefficients. Deer ingesting vegetation were assumed to assimilate radionuclides already attenuated by the intervening soil-to-plant transfer coefficients, the highest of which (cesium) is only 0.02 (Table 6-5). The total dose to deer was estimated to be less than one rad per day (Table 6-24). Technetium-99 dominated the dose via grass intake, with 86 percent, while uranium-234 and -238 contributed 75 percent of the dose via soil intake (Table 6-24).

These same patterns were observed for the white-footed mouse (Table 6-25A), with radiation dose dominated by the insect (earthworm) pathway, as was inorganic chemical intake (Table 6-17A). The total dose to the mouse was estimated at approximately 0.1 one rad per day, assuming muscle-to-muscle transfer equal to plant-to-beef (Table 6-24). Assuming muscle-to-muscle transfer equal to 1.0, this increased to 3 rad per day (Table 6-25B). Similar to the deer, technetium-99 accounted for most of the dose via grass intake, while uranium dominated the earthworm intake pathway.

Total estimated radiation doses to raccoons from fruit intake were less than 1 mrad per day (Table 6-26). Similarly to grass intake by the white-tailed deer and white-footed mouse, technetium-99 accounted for the majority of radiation dose via fruit intake (Table 6-26).

The total dose to the red fox was approximately 0.1 mrad per year, assuming muscle-to-muscle transfer equal to plant-to-beef (Table 6-27A). Assuming muscle-to-muscle transfer equal to 1.0, this increased by a factor of million to approximately 100 rad per year (Table 6-27B). Fruit and mouse intake contributed equally to the first estimate, with mouse intake accounting for essentially all of the second. Technetium-99 accounted for most of the radiation dose via fruit intake, and cesium-137 and technetium-99 accounted for most of the dose via mouse intake assuming muscle-to-muscle transfer equal to plant-to-beef (Table 6-27A). When muscle-to-muscle transfer was assumed to be 1.0, uranium isotopes, thorium-230, and radium-226 were the primary contributors to radiation dose (Table 6-27B).

TABLE 6-24
WHITE-TAILED DEER RADIATION DOSES
FROM INGESTION OF GRASS AND SOIL

Radionuclide	Concentration in Muscle From Ingestion of Grass (pCi/g)[a]	Estimated Annual Dose From Ingestion of Grass (rad)	Concentration in Muscle From Ingestion of Soil (pCi/g)	Estimated Annual Dose From Ingestion of Soil (rad)
Cesium-137	1.09E-05	8.26E-05	1.08E-01	8.21E-01
Plutonium-238	8.99E-13	3.36E-11	1.59E-06	5.94E-05
Plutonium-239/240	8.64E-13	3.04E-11	1.53E-06	5.36E-05
Radium-226	8.32E-07	2.71E-05	4.41E-02	1.44E+00
Radium-228	4.19E-07	4.00E-08	2.22E-02	2.12E-03
Strontium-90	7.74E-06	2.85E-05	2.46E-03	9.06E-03
Technetium-99	6.80E-04	1.35E-03	5.70E-02	1.13E-01
Thorium-228	2.82E-10	1.03E-08	2.64E-04	9.61E-03
Thorium-230	2.93E-09	9.31E-08	2.74E-03	8.71E-02
Thorium-232	3.33E-10	9.08E-09	3.12E-04	8.49E-03
Uranium-234	1.18E-06	3.83E-05	1.10E-01	3.58E+00
Uranium-235/236	1.75E-08	4.64E-07	1.64E-03	4.34E-02
Uranium-238	1.46E-06	4.16E-05	1.36E-01	3.89E+00
Total Annual Dose		1.57E-03		1.00E+01

[a] Wet weight

TABLE 6-25A
WHITE-FOOTED MOUSE RADIATION DOSES FROM INGESTION OF GRASS AND EARTHWORMS

Radionuclide	Concentration in Muscle From Grass Ingestion (pCi/g)[a]	Estimated Annual Dose From Ingestion of Grass (rad)	Concentration in Muscle From Worm Ingestion (pCi/g)[a]	Estimated Annual Dose From Ingestion of Worms (rad)
Cesium-137	1.03E-04	7.81E-04	2.07E-03	1.56E-02
Plutonium-238	8.50E-12	3.18E-10	3.02E-08	1.13E-06
Plutonium-239/240	8.17E-12	2.87E-10	2.91E-08	1.02E-06
Radium-226	7.87E-06	2.56E-04	8.40E-04	2.74E-02
Radium-228	3.96E-06	3.78E-07	4.23E-04	4.03E-05
Strontium-90	7.32E-05	2.69E-04	4.69E-05	1.72E-04
Technetium-99	6.44E-03	1.28E-02	1.08E-03	2.16E-03
Thorium-228	2.67E-09	9.73E-08	5.02E-06	1.83E-04
Thorium-230	2.78E-08	8.81E-07	5.22E-05	1.66E-03
Thorium-232	3.15E-09	8.59E-08	5.93E-06	1.62E-04
Uranium-234	1.12E-05	3.62E-04	2.10E-03	6.82E-02
Uranium-235/236	1.66E-07	4.39E-06	3.12E-05	8.26E-04
Uranium-238	1.38E-05	3.93E-04	2.59E-03	7.40E-02
Total Annual Dose		1.49E-02		1.90E-01

[a] Wet weight

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TABLE 6-25B
WHITE-FOOTED MOUSE RADIATION DOSES FROM INGESTION OF GRASS AND EARTHWORMS ASSUMING 1:1 MUSCLE TO MUSCLE TRANSFER

Radionuclide	Concentration in Muscle from Ingestion of Grass (pCi/g)[a]	Estimated Annual Dose From Ingestion of Grass (rad)	Concentration in Muscle From Ingestion of Worms (pCi/g)	Estimated Annual Dose From Ingestion of Worms (rad)
Cesium-137	1.03E-04	7.81E-04	1.03E-01	7.81E-01
Plutonium-238	8.50E-12	3.18E-10	6.05E-02	2.26E+00
Plutonium-239/240	8.17E-12	2.87E-10	5.81E-02	2.04E+00
Radium-226	7.87E-06	2.56E-04	3.36E+00	1.09E+02
Radium-228	3.96E-06	3.78E-07	1.69E+00	1.61E-01
Strontium-90	7.32E-05	2.69E-04	1.56E-01	5.75E-01
Technetium-99	6.44E-03	1.28E-02	1.28E-01	2.54E-01
Thorium-228	2.67E-09	9.73E-08	8.37E-01	3.05E+01
Thorium-230	2.78E-08	8.81E-07	8.71E+00	2.76E+02
Thorium-232	3.15E-09	8.59E-08	9.89E-01	2.70E+01
Uranium-234	1.12E-05	3.62E-04	1.05E+01	3.41E+02
Uranium-235/236	1.66E-07	4.39E-06	1.56E-01	4.13E+00
Uranium-238	1.38E-05	3.93E-04	1.30E+01	3.70E+02
Total Annual Dose		1.47E-02		1.16E+03

[a] Wet weight

423

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TABLE 6-26
RACCOON RADIATION DOSES
FROM INGESTION OF FRUIT

Radionuclide	Concentration in Muscle From Ingestion of Fruit (pCi/g)[a]	Estimated Annual Dose From Ingestion of Fruit (rad)
Cesium-137	4.03E-06	3.05E-05
Plutonium-238	8.84E-14	3.31E-12
Plutonium-239/240	8.50E-14	2.99E-12
Radium-226	8.19E-08	2.67E-06
Radium-228	4.12E-08	3.93E-09
Strontium-90	7.61E-07	2.80E-06
Technetium-99	1.06E-04	2.10E-04
Thorium-228	2.77E-11	1.01E-09
Thorium-230	2.89E-10	9.16E-09
Thorium-232	3.28E-11	8.94E-10
Uranium-234	5.47E-07	1.77E-05
Uranium-235/236	8.12E-09	2.15E-07
Uranium-238	6.74E-07	1.92E-05
Total Annual Dose		2.84E-04

[a] Wet weight

424

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TABLE 6-27A
RED FOX RADIATION DOSES FROM INGESTION OF FRUIT AND MICE

Radionuclide	Concentration in Muscle From Ingestion of Fruit (pCi/g)[a]	Estimated Annual Dose From Ingestion of Fuit (rad)	Concentration in Muscle From Ingestion of Mice (pCi/g)	Estimated Annual Dose From Ingestion of Mice (rad)
Cesium-137	6.60E-07	4.99E-06	4.13E-06	3.12E-05
Plutonium-238	1.45E-14	5.42E-13	1.44E-15	5.38E-14
Plutonium-239/240	1.39E-14	4.90E-13	1.38E-15	4.86E-14
Radium-226	1.34E-08	4.37E-07	2.02E-08	6.57E-07
Radium-228	6.76E-09	6.45E-10	1.01E-08	9.68E-10
Strontium-90	1.25E-07	4.59E-07	3.43E-09	1.26E-08
Technetium-99	1.73E-05	3.45E-05	6.08E-06	1.21E-05
Thorium-228	4.55E-12	1.66E-10	2.87E-12	1.05E-10
Thorium-230	4.73E-11	1.50E-09	2.98E-11	9.47E-10
Thorium-232	5.37E-12	1.46E-10	3.39E-12	9.23E-11
Uranium-234	8.96E-08	2.91E-06	4.02E-08	1.30E-06
Uranium-235/236	1.33E-09	3.52E-08	5.97E-10	1.58E-08
Uranium-238	1.10E-07	3.16E-06	4.96E-08	1.42E-06
Total Annual Dose		4.65E-05		4.67E-05

[a] Wet weight

TABLE 6-27B
RED FOX RADIATION DOSES FROM INGESTION OF FRUIT AND MICE ASSUMING 1:1 MUSCLE TO MUSCLE TRANSFER

Radionuclide	Concentration in Muscle From Ingestion of Fruit (pCi/gw)[a]	Estimated Annual Dose From Ingestion of Fruit (rad)	Concentration in Muscle From Ingestion of Mice (pCi/g)	Estimated Annual Dose From Ingestion of Mice (rad)
Cesium-137	6.60E-07	4.99E-06	9.83E-03	7.44E-02
Plutonium-238	1.45E-14	5.42E-13	5.75E-03	2.15E-01
Plutonium-239/240	1.39E-14	4.90E-13	5.53E-03	1.94E-01
Radium-226	1.34E-08	4.37E-07	3.19E-01	1.04E+01
Radium-228	6.76E-09	6.45E-10	1.61E-01	1.53E-02
Strontium-90	1.25E-07	4.59E-07	1.49E-02	5.47E-02
Technetium-99	1.73E-05	3.45E-05	1.21E-02	2.41E-02
Thorium-228	4.55E-12	1.66E-10	7.96E-02	2.90E+00
Thorium-230	4.73E-11	1.50E-09	8.28E-01	2.63E+01
Thorium-232	5.37E-12	1.46E-10	9.40E-02	2.56E+00
Uranium-234	8.96E-08	2.91E-06	1.00E+00	3.24E+01
Uranium-235/236	1.33E-09	3.52E-08	1.49E-02	3.93E-01
Uranium-238	1.10E-07	3.16E-06	1.23E+00	3.52E+01
Total Annual Dose		5.67E-05		1.00E+02

[a] Wet weight

TABLE 6-28
MUSKRAT RADIATION DOSES FROM INGESTION OF GRASS

Radionuclide	Concentration in Muscle From Ingestion of Grass (pCi/g)[a]	Estimated Annual Dose From Ingestion of Grass (rad)
Cesium-137	5.50E-05	4.16E-04
Plutonium-238	4.52E-12	1.69E-10
Plutonium-239/240	4.35E-12	1.53E-10
Radium-226	4.19E-06	1.36E-04
Radium-228	2.11E-06	2.01E-07
Strontium-90	3.90E-05	1.43E-04
Technetium-99	3.43E-03	6.82E-03
Thorium-228	1.42E-09	5.17E-08
Thorium-230	1.48E-08	4.69E-07
Thorium-232	1.68E-09	4.57E-08
Uranium-234	5.94E-06	1.93E-04
Uranium-235/236	8.83E-08	2.33E-06
Uranium-238	7.33E-06	2.09E-04
Total Annual Dose		7.92E-03

[a]Wet weight

TABLE 6-29A
ROBIN RADIATION DOSES FROM INGESTION OF FRUIT AND EARTHWORMS

Radionuclide	Concentration in Muscle From Ingestion of Fruit (pCi/g)[a]	Estimated Annual Dose From Ingestion of Fruit (rad)	Concentration in Muscle From Ingestion of Earthworms (pCi/g)[a]	Estimated Annual Dose From Ingestion of Earthworms (rad)
Cesium-137	2.17E-05	1.64E-04	8.66E-04	6.55E-03
Plutonium-238	4.77E-13	1.79E-11	1.27E-08	4.74E-07
Plutonium-239/240	4.59E-13	1.61E-11	1.22E-08	4.28E-07
Radium-226	4.42E-07	1.44E-05	3.52E-04	1.15E-02
Radium-228	2.23E-07	2.12E-08	1.77E-04	1.69E-05
Strontium-90	4.11E-06	1.51E-05	1.96E-05	7.23E-05
Technetium-99	5.71E-04	1.14E-03	4.55E-04	9.05E-04
Thorium-228	1.50E-10	5.46E-09	2.10E-06	7.67E-05
Thorium-230	1.56E-09	4.95E-08	2.19E-05	6.95E-04
Thorium-232	1.77E-10	4.82E-09	2.49E-06	6.78E-05
Uranium-234	2.95E-06	9.58E-05	8.81E-04	2.86E-02
Uranium-235/236	4.38E-08	1.16E-06	1.31E-05	3.46E-04
Uranium-238	3.64E-06	1.04E-04	1.09E-03	3.10E-02
Total Anuual Dose		1.5E-03		7.98E-02

[a]Wet Weight

TABLE 6-29B
ROBIN RADIATION DOSES FROM INGESTION OF GRUIT AND EARTHWORMS ASSUMING A 1:1 MUSCLE TO MUSCLE TRANSFER

Radionuclide	Concentration in Muscle From Ingestion of Fruit (pCi/g)[a]	Estimated Annual Dose From Ingestion of Fruit (rad)	Concentration in Muscle From Ingestion of Earthworms (pCi/g)[a]	Estimated Annual Dose From Ingestion of Earthworms (rad)
Cesium-137	2.17E-05	1.64E-04	4.33E-02	3.27E-01
Plutonium-238	4.77E-13	1.79E-11	2.53E-02	9.48E-01
Plutonium-239/240	4.59E-13	1.61E-11	2.44E-02	8.56E-01
Radium-226	4.42E-07	1.44E-05	1.41E+00	4.59E+01
Radium-228	2.23E-07	2.12E-08	7.09E-01	6.76E-02
Strontium-90	4.11E-06	1.51E-05	6.55E-02	2.41E-01
Technetium-99	5.71E-04	1.14E-03	5.35E-02	1.06E-01
Thorium-228	1.50E-10	5.46E-09	3.51E-01	1.28E+01
Thorium-230	1.56E-09	4.95E-08	3.65E+00	1.16E+02
Thorium-232	1.77E-10	4.82E-09	4.15E-01	1.13E+01
Uranium-234	2.95E-06	9.58E-05	4.41E+00	1.43E+02
Uranium-235/236	4.38E-08	1.16E-06	6.55E-02	1.73E+00
Uranium-238	3.64E-06	1.04E-04	5.43E+00	1.55E+02
Total Annual Dose		1.53E-03		4.88E+02

[a] Wet weight

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TABLE 6-30A
RED-TAILED HAWK RADIATION DOSES
FROM INGESTION OF MICE

Radionuclide	Concentration in Muscle From Ingestion of Mice (pCi/g)[a]	Estimated Annual Dose From Ingestion of Mice (rad)
Cesium-137	9.40E-06	7.11E-05
Plutonium-238	3.28E-15	1.23E-13
Plutonium-239/240	3.15E-15	1.11E-13
Radium-226	4.59E-08	1.50E-06
Radium-228	2.31E-08	2.21E-09
Strontium-90	7.81E-09	2.87E-08
Technetium-99	1.39E-05	2.76E-05
Thorium-228	6.54E-12	2.38E-10
Thorium-230	6.80E-11	2.16E-09
Thorium-232	7.72E-12	2.11E-10
Uranium-234	9.17E-08	2.97E-06
Uranium-235/236	1.36E-09	3.60E-08
Uranium-238	1.13E-07	3.23E-06
Total Annual Dose		1.06E-04

[a]Wet weight

430

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TABLE 6-30B
RED-TAILED HAWK RADIATION DOSES FROM INGESTION OF MICE ASSUMING A 1:1 MUSCLE TO MUSCLE TRANSFER

Radionuclide	Concentration in Muscle From Ingestion of Mice (pCi/g)[a]	Estimated Annual Dose From Ingestion of Mice (rad)
Cesium-137	2.24E-02	1.70E-01
Plutonium-238	1.31E-02	4.90E-01
Plutonium-239/240	1.26E-02	4.43E-01
Radium-226	7.28E-01	2.37E+01
Radium-228	3.67E-01	3.50E-02
Strontium-90	3.39E-02	1.25E-01
Technetium-99	2.77E-02	5.50E-02
Thorium-228	1.81E-01	6.61E+00
Thorium-230	1.89E+00	5.99E+01
Thorium-232	2.14E-01	5.84E+00
Uranium-234	2.28E+00	7.40E+01
Uranium-235/236	3.39E-02	8.95E-01
Uranium-238	2.81E+00	8.03E+01
Total Annual Dose		2.53E+02

[a]Wet weight

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TABLE 6-31
INTAKE OF RADOINUCLIDES THROUGH WATER

	White-Footed Mouse		Racoon		Red Fox	
Radionuclide	Concentration in Muscle from Water Intake (pCi/g)[a]	Estimated Annual Dose from Water Intake (rad)	Concentration in Muscle from Water Intake (pCi/g)[a]	Estimated Annual Dose from Water Intake (rad)	Concentration in Muscle from Water Intake (pCi/g)[a]	Estimated Annual Dose from Water Intake (rad)
Strontium-90	1.27E-07	4.67E-07	3.77E-08	1.39E-07	5.26E-08	1.94E-07
Thorium-230	8.78E-10	2.79E-08	2.61E-10	8.29E-09	3.64E-10	1.16E-08
Uranium-234	7.89E-08	2.56E-06	2.35E-08	7.62E-07	3.27E-08	1.06E-06
Uranium-238	9.19E-08	2.62E-06	2.73E-08	7.81E-07	3.81E-08	1.09E-06
Total Annual Radionuclide Dose from Water Intake		5.68E-06		1.69E-06		2.35E-06

TABLE 6-31
(Continued)

Radionuclide	Muskrat		American Robin		Red-Tailed Hawk	
	Concentration in Muscle from Water Intake (pCi/g)[a]	Estimated Annual Dose from Water Intake (rad)	Concentration in Muscle from Water Intake (pCi/g)[a]	Estimated Annual Dose from Water Intake (rad)	Concentration in Muscle from Water Intake (pCi/g)[a]	Estimated Annual Dose from Water Intake (rad)
Strontium-90	5.26E-08	1.94E-07	1.18E-07	4.36E-07	6.16E-08	2.27E-07
Thorium-230	3.64E-10	1.16E-08	8.20E-10	2.60E-08	4.27E-10	1.35E-08
Uranium-234	3.27E-08	1.06E-06	7.36E-08	2.39E-06	3.83E-08	1.24E-06
Uranium-238	3.81E-08	1.09E-06	8.58E-08	2.45E-06	4.47E-08	1.28E-06
Total Annual Radionuclide Dose from Water Intake		2.36E-06		5.30E-06		2.76E-06

TABLE 6-31
(Continued)

Radionuclide	White-Tailed Deer	
	Concentration in Muscle From Water Intake (pCi/g)[a]	Estimated Annual Dose From Water Intake (rad)
Strontium-90	2.30E-08	8.46E-08
Thorium-230	1.59E-10	5.05E-09
Uranium-234	1.43E-08	4.64E-07
Uranium-238	1.67E-08	4.75E-07
Total Annual Radionuclide Dose from Water Intake		1.03E-06

[a] Wet weight

The earthworm intake pathway dominated estimated radiation doses to robins for both sets of muscle-to-muscle transfer assumptions (Tables 6-29A, B). As described for other indicator species, technetium-99 was the primary contributor to dose via fruit intake, while uranium, thorium, and radium accounted for the majority of the dose via earthworm intake. The two sets of transfer assumptions yielded estimated total doses of approximately 0.1 and 500 rad per year, respectively.

Estimated radiation dose to the red-tailed hawk was primarily due to cesium-137 and technetium-99 when muscle-to-muscle transfer was assumed equal to plant-to-beef (Table 6-30A), and shifted to uranium, thorium, and radium when the transfer coefficients were assumed equal to 1.0 (Table 6-30B). Similarly to the red fox, the estimated total dose differed by approximately a factor of a million (Tables 6-30A, B).

Estimated radiation doses to terrestrial indicator species from water intake were all less than 10^{-5} rad per year (Table 6-31).

6.4.3 Aquatic Organisms

This section describes exposure pathways and parameters evaluated for aquatic organisms at the FEMP. A description of exposure pathways is followed by data on exposures to nonradioactive and radioactive constituents, respectively.

6.4.3.1 Exposure Pathways

Exposure of aquatic biota inhabiting the FEMP may occur via several different pathways. They are a) direct ingestion, b) uptake by aquatic plants, c) external exposure to aquatic organisms from the water and sediments, and d) indirect exposure via uptake through the food chain. Chronic exposures of aquatic organisms to contaminants in surface water and sediments were determined for fish, benthic macroinvertebrates, muskrats, and wetland emergent plants. The fish species considered include minnows, bluegill, shad, catfish, drum, bass and sunfish, encompassing the entire trophic structure. Benthic macroinvertebrates include insects and their larvae, worms, snails, and crayfish. The aquatic plants considered are primarily riparian (wetland) vegetation and filamentous algae. Because muskrats are semi-aquatic, estimated radiation doses and toxic effects on them are conservative, since the criteria are established for strictly aquatic species.

The primary water bodies of concern considered are Paddys Run within the boundaries of the FEMP, the storm sewer outfall ditch (SSOD), and the Great Miami River from the effluent discharge to downstream of the confluence with Paddys Run (Part I, Figure 2-8). Present exposures were estimated from contaminant concentrations measured in the SSOD, Paddys Run, and the Great Miami River during RI/FS sampling. Future exposures were estimated by modeling runoff from the FEMP as described in Section 3.0. Contaminant concentrations in runoff were modeled for both low and high flow conditions. The maximum values considered in the estimation of internal and external

(radionuclides only) exposures corresponded to the concentrations calculated in the SSOD under low flow conditions.

6.4.3.2 Exposures to Inorganic and Organic Chemicals

Hazardous chemicals were analyzed for approximately 15 organisms collected from the FEMP, including wetland plants and minnows. Organic chemicals, pesticides and PCBs were not detected in any of the samples. The metals arsenic, aluminum, barium, cadmium, mercury, and zinc were detected in minnows from Paddys Run at the control site north of the influence from the FEMP. These metals, except for cadmium, were also detected in wetland grass leaves.

Surface water concentrations of priority chemical pollutants of potential concern from each site were compared to the OEPA Water Quality Standards (OEPA 1990) for warmwater biota outside the mixing zone. For those contaminants that did not have OEPA criteria, the EPA (1986) Ambient Water Quality Criteria were used, or were gathered from literature sources. Measured mercury concentrations in the water exceeded the criterion in all three sites, and cadmium exceeded the standards in Paddys Run and the Great Miami River (Tables 6-32, 6-33, 6-34). The silver concentration in Paddys Run was almost seven times higher than the criterion (Table 6-33), and copper concentrations in the Great Miami River only slightly exceeded the criterion (Table 6-34).

Benthic macroinvertebrates and bottom-dwelling fish are exposed to contaminants primarily in the aqueous phase of the sediments, rather than the sediments as a whole. Therefore, in lieu of site-specific data, it is necessary to determine the interstitial water concentration of the chemicals of concern. For organic chemicals, the pore water concentration can be estimated by assuming equilibrium partitioning between the organic portion of the sediments and the water (Suter 1991). The octanol/water coefficient (K_{ow}) approximates the partitioning between the two. The product of the K_{ow} and the organic fraction of the sediment, assumed to be one percent, divided into the sediment concentration will give the pore water concentration, that is

$$\text{sediment concentration (mg/kg)} / (K_{ow} \times 0.01) = \text{pore water concentration (mg/}\ell\text{)}$$

Although metals partition as well, determining the pore water concentration of metals is not feasible due to the lack of adequate information on partitioning between different fractions of the sediment. It is assumed for this assessment that they are 100 percent available. Partitioning lowers the available concentrations, thus reducing potential toxic effects. The same water quality criteria can be applied to the pore water concentrations, since most were derived for surface waters (Suter 1991).

The chemicals and metals in FEMP surface waters resulting from surface soil runoff that exceeded the criteria were cyanide, aluminum, cadmium, cobalt, iron, lead, mercury, and silver (Table 6-35A, B). There were no potential toxic effects estimated from exposure to the sediments (Table 6-35A, B).

TABLE 6-32
UPPER 95% CONFIDENCE INTERVAL FOR SURFACE WATER CONSTITUENTS OF CONCERN FROM RI/FS SAMPLING OF THE STORM SEWER OUTFALL DITCH, CRITERIA AND TOXICITY QUOTIENTS

Chemical	Upper 95% CI on Mean (µg/ℓ)	Criteria (µg/ℓ)	Toxicity Quotient
Ammonia	162	3300	4.9E-02
Barium[a]	40	50,000	8.0E-04
Chromium[b]	7	210	3.3E-02
Copper[b]	11	12	9.2E-01
Lead[b]	3	6.9	4.3E-01
Manganese	10	1500	6.7E-03
Mercury	0.3	0.2	1.5E+00
Nitrate[a]	5,440	400,000	1.36E-02

[a] Criteria from USEPA (1986)
[b] Assuming a water hardness of 100 mg/ℓ

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TABLE 6-33
ESTIMATED HAZARD TO AQUATIC ORGANISMS EXPOSED TO CONSTITUENTS OF CONCERN BASED ON RI/FS SAMPLING IN PADDYS RUN

Chemical	Upper 95% CI on Mean (mg/ℓ)	Criterion (µg/ℓ)	Hazard Index
Ammonia	0.343	3300	1.0E-01
Antimony	0.003	190	1.6E-02
Arsenic	0.004	190	2.1E-02
Barium[a]	0.057	50,000	1.1E-03
Beryllium[b]	0.001	23	4.3E-02
Cadmium[b]	0.003	1.4	2.1E+00
Chromium[b]	0.025	210	1.2E-01
Copper[b]	0.011	12	9.2E-01
Diethyl phthalate	0.002	120	1.7E-02
Lead[b]	0.006	6.9	8.7E-01
Manganese	0.025	1500	1.7E-02
Mercury	0.00027	0.2	1.35E+00
Molybdenum	0.014	2350	6.1E-03
N-Nitrosodiphenylamine	0.004	13	3.1E-01
Nickel[b]	0.018	170	1.1E-01
Nitrate[a]	7.803	400,000	1.9E-02
Selenium	0.005	5	1.0E+00
Silver	0.019	1.3	7.7E+00
Vanadium[c]	0.01	80	2.0E-01
Zinc[b]	0.037	110	3.4E-01
bis(2-Ethylhexyl) phthalate	0.004	8.4	4.8E-01

[a] USEPA (1986)
[b] Assuming a water hardness of 100 mg/ℓ
[c] Suter (1991)

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TABLE 6-34
ESTIMATED HAZARD TO AQUATIC ORGANISMS EXPOSED TO CONSTITUENTS OF CONCERN BASED ON RI/FS SAMPLING IN THE MIAMI RIVER

Chemical	Upper 95% CI on Mean (mg/ℓ)	Criterion (µg/ℓ)	Hazard Index
Ammonia	0.799	3300	2.42E-04
Arsenic	0.002	190	1.1E-02
Barium[a]	0.049	50,000	9.8E-07
Cadmium[b]	0.003	1.4	2.14E+00
Chromium[b]	0.004	210	1.9E-02
Copper[b]	0.014	12	1.2E+00
Lead[b]	0.003	6.9	4.3E-01
Manganese	0.009	1500	6.0E-03
Mercury	0.001	0.2	5.0E+00
Nickel[b]	0.011	170	6.5E-02
Nitrate[a]	7.68	400,000	1.9E-02

[a] USEPA (1986)
[b] Assuming a water hardness of 100 mg/ℓ

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TABLE 6-35A
ESTIMATED HAZARD TO AQUATIC ORGANISMS FROM EXPOSURE TO ORGANIC CHEMICALS AS A RESULT OF SURFACE SOIL RUNOFF DURING LOW FLOW

	Water Factors			Sediment Factors			
Chemical	Water Criteria (mg/ℓ)	Estimated Water Concen. (mg/ℓ)	Hazard Index	Estimated Sediment Concen. (mg/kg)	log K_{ow}	Pore Water Concen. (mg/ℓ)	Hazard Index
1,1,1-Trichloroethane[a]	0.088	3.15E-06	0.0000358	1.71E-04	2.48	0.0000566	0.000648
1,2-Dichloroethene	NA[b]	1.38E-06	NA	3.12E-05	2.09	0.0000254	NA
2-Butanone	7.1	1.97E-04	0.0000277	6.19E-05	NA	NA	NA
2-Methylnaphthalene	NA	1.53E-05	NA	2.04E-02	NA	NA	NA
4-Methyl-2-pentanone[c]	57	1.78E-05	0.000000312	4.03E-05	NA	NA	NA
Acenaphthene	0.067	8.15E-05	0.00122	1.19E-01	3.92	0.00143	0.0213
Acetone	78	2.90E-04	0.00000372	3.74E-04	-0.24	0.065	0.000833
Anthracene[d,e]	0.00056	3.29E-05	0.0588	1.60E-01	4.45	0.000568	1
Aroclor-1254[g]	0.00052	3.00E-05	0.0577	1.98E-01	6	0.0000198	0.0381
Aroclor-1260[g]	0.0001	5.47E-07	0.000547	1.25E-01	6	0.0000125	0.1
Benzo(a)anthracene[d,e]	0.002	9.71E-06	0.00486	6.91E-01	5.91	0.000085	0.0425
Benzo(a)pyrene[d,e]	0.001	5.79E-06	0.00579	9.91E-01	6.19	0.000064	0.064
Benzo(b)fluoranthene	NA	1.92E-06	NA	1.29E+00	6.12	0.0000979	NA
Benzo(g,h,i)perylene	NA	1.48E-07	NA	4.45E-01	6.58	0.0000117	NA
Benzo(k)fluoranthene	NA	1.66E-07	NA	1.90E-01	6.84	0.0000145	NA
Benzoic acid[d,e]	36	5.22E-04	0.0000145	7.11E-03	1.9	0.009	0.00025
Beta-BHC	NA	6.57E-06	NA	6.88E-03	3.8	0.000109	NA
Bis(2-ethylhexyl)phthalate	0.0084	9.09E-07	0.000108	3.25E-02	4.2	0.000205	0.0244
Carbondisulfide	NA	3.59E-06	NA	9.57E-05	0	NA	NA
Chloroform	0.079	1.74E-05	0.00022	2.98E-04	1.94	0.000342	0.00433
Cholorobenzene	0.026	2.79E-07	0.0000107	3.55E-05	2.65	0.00000795	0.000306
Chrysene	NA	9.86E-06	NA	6.94E-01	5.91	0.0000854	NA
Cyanide[d,f]	0.012	1.26E-01	10.5	6.06E-02	NA	NA	NA
Dibenzofuran	NA	2.36E-05	NA	5.46E-02	NA	NA	NA
Dibenzo(a,h)anthracene	NA	1.45E-06	NA	2.42E-01	6.5	0.00000765	NA
Fluoranthene	0.0089	2.04E-05	0.0023	7.71E-01	5.22	0.000465	0.0522
Fluorene	0.12	3.60E-05	0.0003	9.34E-02	4.18	0.000617	0.00514
Ideno(1,2,3-cd)pyrene	NA	5.61E-08	NA	4.59E-01	6.58	0.0000121	NA
Methylene chloride[g]	4	0.000216	0.000054	0.0106	1.25	0.1	0.025
Napthalene	0.044	0.0000729	0.00166	0.0308	3.33	0.00144	0.0327
N-nitrosodiphenyl amine[d,f]	1.17	0.0000398	0.000034	0.00939	2.57	0.00253	0.00216
Phenanthrene[d,f]	0.074	1.15E-04	0.00155	5.78E-01	4.57	0.00156	0.0211
Pyrene[g]	0.84	2.18E-05	0.000026	5.73E-01	5.18	0.000379	0.000451
Tetrachloroethene	0.073	4.69E-06	0.0000642	2.83E-04	3.4	0.00001127	0.000154
Toluene	1.7	1.75E-06	0.00000103	1.48E-04	2.58	0.0000389	0.0000229
Tributyl phosphate	NA	1.78E-05	0.000103	2.66E-02	NA	NA	NA
Trichloroethene	0.075	7.73E-06	0.000237	4.62E-04	2.4	0.0001839	0.0024

[a] Unless otherwise noted, water quality criteria are from OEPA (1990)
[b] Not available
[c] Water quality criteria from Barnthouse, et al. (1986)
[d] Water quality criteria is the LC50 multiplied by an uncertainty factor of 2
[e] Water quality criteria from USEPA (1988)
[f] Water quality criteria from Suter (1991)
[g] Water quality criteria from USEPA (1986)

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TABLE 6-35B
ESTIMATED HAZARD TO AQUATIC ORGANISMS FROM EXPOSURE TO INORGANIC CHEMICALS AS A RESULT OF SURFACE SOIL RUNOFF DURING LOW FLOW

Chemical	Water Criteria (mg/ℓ)	Estimated Surface Water Concen. (mg/ℓ)	Hazard Index (HI)	Exceeds HI of 1
Aluminum[a]	0.087	2.71E+00	31	Yes
Antimony	0.19	[b]	0.042	No
Arsenic	0.19	3.12E-03	0.016	No
Barium[a]	5.8	2.36E-02	0.0041	No
Beryllium	0.023	2.33E-04	0.010	No
Cadmium	0.0014	1.54E-03	1.1	Yes
Calcium	[b]	4.57E+01	[b]	NA[c]
Chromium	0.21	5.22E-03	0.025	No
Cobalt[a]	0.0001	3.31E-03	33	Yes
Copper	0.012	1.08E-02	0.9	No
Iron	1	6.90E+00	6.9	Yes
Lead	0.0069	8.73E-03	1.27	Yes
Magnesium[d]	82	6.95E+01	0.85	No
Manganese[a]	1.5	1.73E-01	0.121	No
Mercury	0.0002	4.42E-04	2.21	Yes
Molybdenum[d]	2.35	1.58E-03	0.0007	No
Nickel	0.17	8.83E-03	0.0521	No
Potassium[a]	53	4.75E-01	0.009	No
Selenium	0.005	3.44E-10	0.000000068	No
Silver	0.0013	2.95E-03	2.271	Yes
Sodium[a]	68	1.55E-01	0.0023	No
Thallium	0.016	8.07E-05	0.005	No
Vanadium	0.08	7.04E-03	0.088	No
Zinc	0.11	1.57E-02	0.14	No

[a] Water quality criteria from USEPA (1986)
[b] No criterion exists
[c] Not applicable
[d] Water quality criteria from Suter (1991)

SOURCE: Unless otherwise noted, OEPA (1990)

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6.4.3.3 Exposures to Radionuclides

Radionuclide concentrations measured in aquatic biota from Paddys Run and the Great Miami River are relatively low (Table 6-36). Cesium-137, strontium-90 and technetium-99 were not detected in any of the samples collected, except for 1.9 pCi/g technetium-99 in one grass leaf sample. The primary radionuclide of concern is uranium. Uranium concentrations in fish from Paddys Run ranged from <0.6 to 3.7 pCi/g. Uranium was not measured in fish above the detection limit of 0.6 pCi/g for both the RI/FS and WEMCO (1990) sampling efforts in the Great Miami River. Uranium activity was measured in benthic macroinvertebrates from both sites, however, at a maximum concentration of 6.5 pCi/g (Table 6-36). Although benthic macroinvertebrates are continuously exposed to the sediments, where concentrations are typically much higher than the water, their radionuclide content is not significantly different from that of fish. Concentrations in the roots of wetland plants were higher than that measured in the above-ground shoots (Table 6-36).

The internal dose calculated to the aquatic organisms inhabiting Paddys Run and the Great Miami River (calculated from the internal dose conversion factors in Killough and McKay (1976) (Table 6-37) from exposure to the water were relatively low (Table 6-38). The concentrations of the radionuclide constituents of concern in the surface water at each site were the upper 95% confidence interval (CI) on the mean. The highest doses were to the organisms residing in Paddys Run, due to the greater water concentrations (Table 6-38). The highest dose at both sites is to aquatic plants. The lowest doses estimated were to muskrats, with lower value of 14 mrad per year comparable to the 7.9 mrad per year estimated for muskrats feeding on FEMP vegetation (Table 6-28). Doses to fish were approximately 200-400 mrad/y, and the invertebrate doses were an order of magnitude higher (Table 6-37). The major contributor to internal dose was thorium-228 for all organisms at both sites, except for muskrats in Paddys Run which received a higher dose from strontium-90.

Aquatic organisms also receive external exposure from water immersion and sediments. Consideration of the exposure from sediments is particularly significant to benthic invertebrates and bottom-dwelling fish. Exposure to all biota from external gamma and beta radiation is very small at the low concentrations measured in the water and sediments in Paddys Run and the Great Miami River (Table 6-39). External exposures were calculated only for the sediments in the SSOD. The highest external dose received by an organism was from uranium-238 at about 0.4 mrad/y. This dose is conservative for the fish, because it is assumed that the fish spend 100% of their time residing at the sediment-water interface. However, the developmental embryonic stages of fish that reside in the sediments are the most sensitive, and external irradiation of them is more realistic. External exposure to alpha radiation was not considered because it does not significantly contribute to whole-body dose. However, it may cause damage to the skin and digestive track lining to organisms that inadvertently ingest sediment (NCRP 1991). The calculation of internal dose to aquatic organisms does, however, consider exposure from alpha emitters.

TABLE 6-36
RADIONUCLIDES IN AQUATIC FLORA AND FAUNA
(RI/FS SAMPLING)

Sample	Location	Radionuclide Type and Concentration Range (pCi/g)						
		Cs-137	Sr-90	Tc-99	U-234	U-235, U-236	U-238	Sum of U Activity
Benthic Macroinvertebrates[a] (Crayfish)	Paddy's Run	<0.2[b]-<2.0	<0.5-<3.7	<0.9	<0.3-3.6	<0.6-<1.5	<0.6-2.8	<0.6-6.4
	Paddy's Run	<0.24-<4.00	<1.2-<2.6	NA	1.5-3.6	<0.6-<1.1	<0.6-1.5	1.5-5.1
	Great Miami River	<0.2-<2.1	<1.1-<4.7	<0.9	<0.6-3.4	<0.6-<2.2	<0.6-3.1	<0.6-6.5
Fish								
Minnow	Paddy's Run	<0.2-<0.42	<0.5	<0.6-<1.6	<0.6	<0.6	<0.6	-[c]
White sucker	Paddy's Run	<0.17-0.20	<0.5	NA[d]	<0.6-0.6	<0.6	<0.6	<0.6-0.69
Creek chub	Paddy's Run	<0.22-<1.90	<0.5-<0.7	NA	<0.6-1.0	<0.6	<0.6-0.7	<0.6-1.7
Bluegill	Paddy's Run	<0.19-<1.23	<0.5-<3.32	NA	<0.6-2.4	<0.6-<1.1	<0.6-1.3	<0.6-3.7
Gizzard shad	Great Miami River	<0.2-<0.3	<0.5	NA	<0.6	<0.6	<0.6	-
Channel catfish	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	-
Minnow	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	-
Catfish (fillets)	Great Miami River	<0.3-<0.7	<0.5	NA	<0.6	<0.6	<0.6	-
Catfish (bones and entrails)	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	-
Freshwater drum	Great Miami River	<0.2	<0.5	NA	<0.6	<0.6	<0.6	-
Smallmouth bass	Great Miami River	<0.3	LIA[e]	NA	LIA	LIA	LIA	-
Green sunfish	Great Miami River	<0.3	<0.5	NA	<0.6	<0.6	<0.6	-
Longear sunfish	Great Miami River	<0.3	<0.5	NA	<0.6	<0.6	<0.6	-
Aquatic Plants								
Algae	FEMP Wetlands	<0.2	<0.5-0.9	<0.9	<0.6	<0.6	<0.6	-
Cattail leaf	FEMP Wetlands	<0.2-<0.6	<0.5-<1.0	NA[c]	<0.6-1.4	<0.6	<0.6-1.9	<0.6-3.3
Cattail root	FEMP Wetlands	<0.2-<0.6	<0.5-<0.9	NA	<0.6-2.6	<0.6	<0.6-3.8	<0.6-6.4
Sedge leaf	FEMP Wetlands	<0.2	<0.7-<1.3	NA	<0.6	<0.6	<0.6	-
Grass leaf	FEMP Wetlands	<0.2-<0.3	<0.5-<0.6	1.9	<0.6	<0.6	<0.6	-
Grass root	FEMP Wetlands	<0.2	<0.5	<0.9	0.9-7.7	<0.6-1.3	4.2-22.3	5.1-31.3

[a] Benthic macroinvertebrates are aquatic organisms, including insects, insect larvae, annelid worms, and snails.
[b] Concentration less than the stated detection limit.
[c] All uranium isotopes below detection limit.
[d] Not analyzed.
[e] Lost in analysis.

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TABLE 6-37
INTERNAL AND EXTERNAL DOSES (MRAD/Y) TO FRESHWATER BIOTA EXPOSED TO 1.0 pCi/ℓ

		Receptor			
Radionuclide	External	Aquatic Plants	Invertebrates	Fish	Muskrat
Cesium-137	0.012	0.88	1.1	4.4	6.2
Ruthenium-106	0.017	5.2	7.9	.26	.16
Radium-226	0.00025	5100	510	100	22,000
Strontium-90	0.01	10	2.1	0.1	44
Technetium-99	.0009	.07	.0088	.026	.0051
Thorium-228	0.08	6500	2200	130	9.7
Thorium-230	0.00017	1300	450	27	1.9
Uranium-234	0.00016	920	92	9.2	1.3
Uranium-235	0.0054	860	86	8.6	1.2
Uranium-236	0.00013	880	88	8.8	1.3
Uranium-238	.074	800	80	8.0	1.2
Plutonium-238	0.00013	370	110	370	.16
Plutonium-239/240	0.000083	350	99	350	.15
Neptunium-237	0.0073	920	370	9.2	1.3

[a] Adapted from Killough and McKay (1976)

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TABLE 6-38
MAXIMUM WATER CONCENTRATIONS FOR RADIONUCLIDES OF CONCERN IN PADDYS RUN AND THE GREAT MIAMI RIVER, AND THE INTERNAL DOSE TO AQUATIC RECEPTOR ORGANISMS AT EACH SITE

	Maximum Value of Upper 95% CI[a] on Mean		Internal Dose to Receptor[b] (mrad/y)							
			Paddys Run				Great Miami River			
Radionuclide	Paddys Run (pCi/ℓ)	Great Miami River (pCi/ℓ)	Fish	Aquatic Plants	Invertebrates	Muskrats	Fish	Aquatic Plants	Invertebrates	Muskrats
Tc-99	NA	27.51	NA	NA	NA	NA	0.7	2	0.2	0.1
Th-228	1.67	0.99	217	10,855	3674	16	129	6435	2178	10
Th-230	2.26	0.69	61	2938	1017	4	19	897	311	1
U-234	3.95	1.22	36	3634	363	5	11	1122	112	2
U-238	5.25	1.09	42	4200	420	6	9	872	87	1
Sr-90	5.67	NA	0.6	57	12	249	NA	NA	NA	NA
Total Dose			357	22,000	5486	280	169	9328	2688	14.1

[a] Confidence interval

[b] Dose conversion factors from Killough and McKay (1976)

[c] Not analyzed

TABLE 6-39
ESTIMATED EXTERNAL RADIATION DOSES TO AQUATIC ORGANISMS EXPOSED TO FEMP SEDIMENTS AND SURFACE WATERS

	Maximum Value of Upper 95% CI[a] on Mean					External Dose to Organism				
	Paddys Run		Great Miami River		SSOD[b]	Paddys Run		Great Miami River		SSOD
Radionuclide	Sediments (pCi/g)	Water (pCi/ℓ)	Sediments (pCi/g)	River Water (pCi/ℓ)	Sediments (pCi/g)	Sediments (mrad/y)[c]	Water (mrad/y)	Sediments (mrad/y)	Water (mrad/y)	Sediments (mrad/y)
U-234	0.778	3.95	NA	1.22	7.81	6.2E-05	6.3E-04	NA	2.0E-04	6.2E-04
U-238	0.689	5.25	NA	1.09	10.52	2.5E-02	3.9E-01	NA	8.1E-02	3.9E-01
Tc-99	0.476	NA	NA	27.51	NA	2.1E-04	NA	NA	2.5E-02	NA
Th-228	0.608	1.67	NA	0.99	NA	2.4E-02	1.3E-01	NA	7.9E-02	NA
Th-230	0.719	2.26	1.462	0.69	2.6	6.11E-05	3.8E-04	1.2E-04	1.2E-04	2.2E-04
Sr-90	NA	5.67	0.565	NA	NA	NA	5.7E-02	2.8E-03	NA	NA
Pu-238	0.024	NA	NA	NA	0.071	1.61E-06	NA	NA	NA	4.6E-06
Pu-238/240	0.011	NA	NA	NA	0.081	4.6E1-07	NA	NA	NA	3.4E-06

[a] Confidence interval
[b] Storm sewer outfall ditch
[c] Dose conversion factors from Killough and McKay (1976)
[d] Not a Constituent of Concern

Internal doses to aquatic receptors from surface water exposure to radionuclides in runoff were significantly higher than the doses received from the current water concentrations (Table 6-40). The primary contributor to internal dose to fish, aquatic plants, invertebrates and muskrats was from uranium, with doses on the order of 10^3 to 10^7 mrad/y (Table 6-40). The doses from radium-226 were within the same range, with muskrats receiving the largest dose. The isotopes of thorium contributed a substantial dose to aquatic plants and invertebrates, but not to fish and muskrats. The total dose from all the radionuclides combined ranged from 3.5×10^5 in muskrats to 5.1×10^7 mrad/y in aquatic plants (Table 6-40). This is equivalent to approximately 1 to 140 rad/d, respectively. The sum of the total external sediment exposure to all aquatic biota resulted in doses about eight times greater than doses from water immersion (Table 6-41).

6.5 TOXICITY ASSESSMENT AND RISK CHARACTERIZATION

This section describes potential risks to vegetation, terrestrial wildlife, and aquatic organisms resulting from exposure to constituents of potential concern in FEMP surface soils and surface waters. This evaluation relies on the estimated exposures and hazard indices presented previously, as well as number of FEMP-specific ecological field studies. Details of these studies may be found in the references cited and in this report, Appendices B and D-H.

6.5.1 Vegetation

6.5.1.1 Risks of Exposure to Inorganic and Organic Chemicals

Risk to vegetation as a result of exposure to constituents of concern in FEMP soils was evaluated by comparisons of concentrations measured and estimated in FEMP vegetation to plant toxicity data published in the literature. Mean estimated concentrations and the range and mean of concentrations in FEMP vegetation were compared to NOELs and LOELs (Table 6-42).

Estimated concentrations of copper and zinc exceed the minimum reported toxic concentrations (Table 6-42). Concentrations of aluminum, arsenic, and mercury measured in FEMP grass leaves were higher than those reported to be toxic or cause a yield loss. Arsenic and mercury concentrations recorded in FEMP grass leaves were also higher than those predicted, while the other values were lower. Discrepancies between predicted and measured concentrations in FEMP plants can be attributed to uncertainties associated with the literature obtained soil to plant transfer factors and to the fact that plants were only sampled from five on-property locations (Part I, Section 3.1.7). Data relating concentrations of organic chemicals in plants to toxic effects were not located in the literature. However, the relatively low levels estimated and the lack of any detections of organic compounds in RI/FS samples suggests that hazards to plants due to organic chemicals are likely to be low.

TABLE 6-40

INTERNAL RADIATION DOSE TO AQUATIC ORGANISMS FROM EXPOSURE TO RADIONUCLIDES IN FEMP SURFACE WATERS RESULTING FROM SURFACE SOIL RUNOFF DURING LOW FLOW

Radionuclide	Water Concentration (pCi/ℓ)	Internal Dose to Receptor (mrad/y)			
		Fish	Aquatic Plant	Invertebrates	Muskrats
Cesium-137	1.81E-01	8.0E-01	1.6E-01	2.0E-01	1.12E+00
Nepunium-237	1.48E-02	1.36E-01	1.36E+01	5.5E+00	1.2E-02
Plutonium-238	9.56E-02	3.54E+01	3.54E+01	1.05E+01	1.53E-02
Plutonium-239/240	9.79E-02	3.43E+01	3.43E+01	9.69+00	1.47E-02
Radium-226	1.24E+01	6.32E+04	6.32E+03	1.24E+03	2.73E+05
Radium-228	1.73E+00	NA[a]	NA	NA	NA
Ruthenium-106	2.18E-02	5.67E-03	1.13E-01	1.72E-01	3.49E-03
Strontium-90	1.47E+00	1.47E-01	1.47E+01	3.09E+00	6.47E+01
Technetium-99	2.31E+02	6.00E+00	1.62E+01	2.03E+00	1.18E+00
Thorium-228	7.13E-01	9.23E+01	4.63E+03	1.57E+03	6.92E+00
Thorium-230	5.55E+00	1.5E+02	7.22E+03	2.5E+03	1.05E+01
Thorium-232	5.44E-01	NA	NA	NA	NA
Uranium-234	2.66E+04	2.44E+05	2.44E+07	2.44E+06	3.46E+04
Uranium-235/236	1.37E+03	1.18E+04	1.18E+06	1.18E+05	1.64E+03
Uranium-238	3.16E+04	2.53E+05	2.53E+07	2.53E+06	3.8E+04
Total Dose		5.7E+05	5.1E+07	5.1E+06	3.5E+05

[a] Not available

3578

TABLE 6-41
EXTERNAL RADIATION DOSE TO AQUATIC BIOTA FROM WATER IMMERSION AND SEDIMENT EXPOSURE TO RADIONUCLIDES IN FEMP SURFACE WATERS RESULTING FROM SURFACE SOIL RUNOFF DURING LOW FLOW

			External Dose (mrad/y)	
Radionuclide	Water Concentration (pCi/ℓ)	Sediment Concentration (pCi/g)	Water Immersion	Sediments
Cesium-137	18.1	0.691	2.2E-01	E+00
Neptunium-237	0.0148	0.00619	1.1E-04	2.3E-02
Plutonium-238	0.0956	0.354	1.2E-05	2.3E-02
Plutonium-239/240	0.0979	0.341	8.1E-06	1.4E-0215
Radium-226	12.4	46.6	3.1E-03	5.8E+00
Radium-228	1.73	8.77	NA[a]	NA
Ruthenium-106	0.0218	0.133	3.7E-04	1.1E+00
Strontium-90	1.47	0.861	1.5E-02	4.3E+00
Technetium-99	231	0.344	2.1E-01	1.5E-01
Thorium-228	0.713	9.38	5.7E-02	3.8E+02
Thorium-230	5.55	68.4	9.4E-04	5.8E+00
Thorium-232	0.544	9.59	NA	NA
Uranium-234	26,600	397	4.3E+00	31.7E+00
Uranium-235	1370	20.7	7.4E+00	55.9E+00
Uranium-238	31,600	478	2.3E+03	1.8E+04
Total Dose			2.4E+03	1.8E+04

[a] Not available

TABLE 6-42
COMPARISON OF INORGANIC CHEMICAL CONCENTRATIONS IN FEMP GRASSES TO REPORTED TOXIC CONCENTRATIONS[a]

Chemical	Concentration Measured in FEMP Plants Range/(Mean) (µg/g)	Estimated Maximum Concentration in FEMP Plants (µg/g)[b]	Excessive or Toxic Concentrations (µg/g)[c]	10% Yield Loss (µg/g)[d]
Aluminum	25-4950/(1577)	[e]	25-280	25-280
Antimony	NA[f]	4.46	150	NA
Arsenic	5-13/(9)	0.26	5-20	1-20
Barium	2.6-12.5/(6)	21.165	500	500
Beryllium	NA	0.0087	10-50	NA
Cadmium	0.5U[g]/(0.5U)	[e]	5-30	10-20
Cobalt	NA	0.236	15-50	20-40
Copper	NA	13.92	20-100	10-30
Lead	3U/(3U)	1.485	30-300	NA
Mercury	0.5-15.3/(5.2)	0.108	1-3	1-8
Nickel	NA	1.818	10-100	10-30
Silver	0.5U/(0.5U)	2.92	5-10	NA
Vanadium	1U-1	[e]	5-10	NA
Zinc	4.4-13/(8.9)	123	100-400	100-500

[a] A comparison of dry weight concentrations in leaf tissue only.
[b] Maximum concentrations in FEMP plants were estimated using maximum FEMP soil concentrations and transfer factors presented in Baes et al. (1984).
[c] Excessive or toxic concentrations for all metal except aluminum reported in Kabata-Pendias and Pendias (1992). As stated in the source, values do not include those for sensitive or highly tolerant plants.
[d] Concentrations resulting in a 10% loss in crop yield were obtained from Macnicol and Beckett (1985).
[e] Not a contaminant of concern
[f] Not available
[g] Not detected, value is detection limit

6.5.1.2 Risks of Exposure to Radionuclides

Total estimated radiation dose to vegetative and reproductive portions of FEMP plants were 21.2 and 3.4 rad per year, respectively (Table 6-12). The maximum radionuclide concentration in vegetation collected during RI/FS sampling was 35.5 pCi/g total isotopic uranium in forb roots (Appendix H), which yields an estimated dose of approximately 3 rad per year. These estimates are less than one percent of the radiation dose of 1460 rad per year reported to reduce the growth of conifers, plants which are particularly sensitive to radiation (Klechkovskii et al. 1973). This suggests that radiation doses due to uptake are not likely to cause detectable effects on plants exposed to radionuclides in FEMP soils. This does not dismiss the possibility of long-term chronic effects, but the effects of low-level radiation on plants have not been extensively studied and cannot be addressed here.

6.5.1.3 Field Studies

Although estimates of inorganic chemical uptake suggest potential adverse impacts on FEMP vegetation, data from field studies are inconclusive. Ecological surveys indicated differences between on and off-property vegetation (Facemire et al. 1990). Several woody species were expected but were either absent (e.g., American beech (Fagus grandifolia), and American hornbeam (Carpinus caroliniana) or present in extremely low abundance (e.g., honeysuckle (Lonicera sp.). A spring 1986 survey revealed the presence of saplings for only 16 of the 34 tree species observed on the FEMP. This ratio was, however, exceeded in the area along the northern section of Paddys Run and in a woodlot north of the production area. In addition, comparisons with an off-property reference location indicated FEMP woodlots contained 32 to 43 percent fewer herbaceous species. Among herbaceous plant species recorded on property, 50 percent were considered rare in occurrence in the Spring 1986 survey. Ten species of herbaceous plants common in off-property woodlots that were either in extremely low abundance or were absent from the FEMP included squirrel-corn (Dicentra canadensis), and Dutchman's breeches (Dicentra cucullaria). These unexpected differences between reference and FEMP plant populations may be attributed to differences in land use and/or differences in contaminant concentrations.

Population genetics studies were conducted on common dandelion (Taraxacum officinale) and common milkweed (Asclepias syriaca) plants as part of the biological and ecological characterization of the FEMP (Facemire et al. 1990). Dandelions collected in 1986 from 13 locations within the FEMP property boundaries and one off-property reference site showed statistically significant differences among samples from different habitats attributable to land management practices (i.e., mowing, grazing). The lowest genetic diversity observed on-property was from samples collected north of the sewage treatment plant. The population genetics study of common milkweeds involved the collection of 20 plants from four on-property locations and one off-property reference site. Off-property milkweed samples were found to exhibit genetic variability similar to that detected in FEMP milkweeds. Because only one reference population was used in each study, conclusions cannot be

made as to the significance of differences in genetic variability in the dandelion study or lack of differences in genetic variability in the milkweed study.

6.5.2 Wildlife

This section describes potential risks to terrestrial indicator species of exposure to FEMP constituents of potential concern. Risks due to nonradioactive chemicals are presented first, followed by risks due to radiation.

6.5.2.1 Risks of Exposure to Inorganic and Organic Chemicals

Inorganic Chemicals

As described previously, risks to wildlife resulting from exposure to nonradioactive constituents of concern were assessed by the quotient (HI) method. Table 6-43 summarizes the hazard indices calculated for intake of inorganic chemicals of potential concern in FEMP surface soils.

There are a number of sources of uncertainty in estimating HIs, as discussed below, which suggests that rather than focusing on the absolute magnitude of the values, it is more appropriate to examine the patterns in the data and the relative magnitudes, assuming that levels of uncertainty are comparable among chemicals and indicator species. HIs exceeded 1.0 for at least one indicator species for every chemical for which NOELs could be calculated except copper. Cobalt and silver HIs were greater than 1.0 for all indicator species, and arsenic and lead were greater than 1.0 for all but the hawk. The remaining six chemicals were of narrower significance, with mercury of borderline significance and only to the white-footed mouse. HIs of specific chemicals varied by several orders of magnitude among species, consistent with the relative attenuation of chemicals up the food chain, as described below.

Overall, the indicator species fell into three groups consistent with their relative trophic status. The white-footed mouse and the robin had HIs greater than 1.0 for all ten and for nine out of ten chemicals respectively. This resulted in both cases from the fact that they were both consumers of earthworms, which contributed a high fraction of total intake (Tables 6-17A, 6-21A). (It should be remembered, however, that in the case of the mouse, earthworms are a surrogate for insects.) Since soil-to-earthworm transfer factors are assumed to be 1.0, earthworm ingestion and soil ingestion are equivalent. Estimated HIs for the mouse were also higher than those for the robin, consistent with the higher assumed percent composition of earthworms in the diet (70 percent compared to 48 percent) (Table 6-3).

The second group consists of the white-tailed deer, the raccoon, and the muskrat, with HIs greater than 1.0 for 7 of 10, 6 of 10, and 7 of 10 chemicals, respectively. Further, the specific chemicals were the same, with antimony not included in the raccoon list. The deer and the muskrat were both assumed to meet all their food requirements by ingesting vegetation, although the deer also ingested soil. The

TABLE 6-43
WILDLIFE HAZARD INDICES FOR EXPOSURE TO INORGANIC CHEMICALS OF CONCERN IN FEMP SURFACE SOILS

Chemical	Deer HI[b]	Mouse HI	Raccoon HI	Red Fox[a] HI	Muskrat HI	Robin HI	Hawk[a] HI
Antimony	1.41E+00	1.13E+02	1.96E-01	4.28E-02	6.67E+00	8.62E+01	4.89E-02
Arsenic	5.16E+01	1.50E+04	6.43E+02	3.78E+00	1.94E+02	5.18E+00	5.46E-03
Barium	1.37E+01	1.39E+03	1.67E+00	2.23E-01	6.33E+01	1.08E+03	9.03E-02
Beryllium	4.85E-03	3.14E+00	3.06E-04	3.50E-04	1.04E-02	2.63E+00	1.37E-03
Cobalt	1.80E+01	8.25E+03	3.72E+00	1.63E+01	5.43E+01	3.44E+03	3.59E+01
Copper	NA[c]	NA	NA	NA	NA	NA	NA
Lead	3.32E+02	4.02E+04	5.05E+01	9.40E+00	1.29E+03	2.26E+01	3.67E-03
Mercury	4.34E-02	1.12E+00	9.44E-02	2.83E-02	2.15E-01	4.19E-01	7.26E-02
Nickel	5.29E-02	4.76E+00	4.26E-02	9.69E-03	2.18E-01	4.12E+00	1.24E-02
Silver	7.17E+01	3.28E+03	1.71E+01	3.74E+00	3.49E+02	2.39E+03	4.27E+00
Zinc	7.37E+00	1.63E+02	5.74E+00	8.63E-01	3.68E+01	1.26E+02	7.09E-01

[a] Assuming muscle-to-muscle transfer equal to plant-to-beef transfer
[b] Hazard Index
[c] Not available

raccoon consumed 70 percent fruits and 30 percent fish, but estimates of fish intake were available only for four of the inorganics. Exposure to soil concentrations of inorganics was filtered by the soil-to-plant transfer coefficients, which were all less than 1.0 except for zinc.

The third group consists of the red fox, primarily a carnivore, and the red-tailed hawk, which is solely carnivorous. The fox and hawk had HIs greater than 1.0 for 4 of 10 and 2 of 10 inorganic chemicals, respectively. This was a result of their consuming mice which were assumed to assimilate chemicals from earthworms at the same ratio as plant-to-beef. These coefficients are all low (Table 6-5), and therefore greatly reduced estimated intake by predators. The importance of this assumption is illustrated by Tables 6-19C and 6-22C, which provide the respective HIs assuming muscle-to-muscle transfer coefficients of 1.0. The fox had HIs greater than 1.0 for all inorganics except beryllium, mercury, and nickel, and the hawk for all except mercury.

Only four inorganic chemicals of potential concern in surface water had HIs greater than 1.0 for any indicator species - lead, molybdenum, silver, and arsenic, in order of the number of species potentially affected (Table 6-44). HIs were less than 10 in all cases, suggesting that water intake would contribute only a small fraction to the total inorganic chemical hazard faced by the indicator species.

Concentrations of inorganic chemicals measured in several FEMP wildlife samples were also compared with background concentrations reported in the literature. This limited comparison suggested that arsenic levels in FEMP wildlife exceeded background (Table 6-45).

Concentrations of arsenic in FEMP wildlife ranged from 8 to 20 mg/kg (dry weight) and were less than an order of magnitude greater than the estimated background concentration of less than 3.1 mg/kg (dry weight) (Table 6-45). A liver arsenic concentration that resulted in the death of a white-tailed deer was 19 mg/kg wet weight (Eisler 1988), approximately 59 mg/kg dry weight. This concentration is three times greater than that measured in the liver of the FEMP deer. Dietary concentrations of 5 to 50 mg arsenic/kg diet can induce toxic responses in animals (Eisler 1988). This is equal to an intake of 0.19 to 1.9 mg/kg/day using the intake parameters in Table 6-3. This suggests that the NOEL used to evaluate wildlife hazards here may be overly conservative. However, a deer consuming grass containing the maximum concentration measured in FEMP grass leaves (11 mg/kg dry weight, or approximately 3.52 mg/kg wet weight) would consume 0.13 mg/kg/day, which still suggests potential exposure to excessive arsenic levels by white-tailed deer at the FEMP.

Organic Chemicals

NOELS were located for only about half the organic chemicals of potential concern in FEMP surface soils. Of these, only two, phenanthrene and dibenzofurans had HIs greater than 1.0 for any of the terrestrial indicator species (Table 6-46). The general pattern of HIs related to trophic position persisted, although the maximum HIs estimated were much lower than those for inorganic chemicals.

TABLE 6-44
HAZARD INDICES FOR WILDLIFE EXPOSED TO INORGANIC CHEMICALS OF POTENTIAL CONCERN IN PADDYS RUN SURFACE WATER

Chemical	Mean (mg/ℓ)	Deer HI[a]	Mouse HI	Raccoon HI	Fox HI	Muskrat HI	Robin HI	Hawk HI
Antimony	0.003	1.73E-03	9.56E-03	2.84E-03	2.95E-03	3.96E-03	1.79E-02	9.29E-03
Arsenic	0.002	5.77E-01	3.19E+00	9.48E-01	9.84E-01	1.32E+00	2.50E-03	1.30E-03
Barium	0.046	5.31E-02	2.93E-01	8.72E-02	9.05E-02	1.22E-01	5.48E-01	2.85E-01
Beryllium	0.001	4.62E-04	2.55E-03	7.59E-04	7.87E-04	1.06E-03	4.76E-03	2.48E-03
Cadmium	0.003	6.93E-02	3.83E-01	1.14E-01	1.18E-01	1.59E-01	7.14E-01	3.72E-01
Chromium	0.018	2.08E-03	1.15E-02	3.41E-03	3.54E-03	4.76E-03	2.14E-02	1.12E-02
Copper	0.007	NA[b]	NA	NA	NA	NA	NA	NA
Lead	0.003	1.00E+00	5.54E+00	1.65E+00	1.71E+00	2.30E+00	7.26E-03	3.78E-03
Manganese	0.018	4.16E-02	2.30E-01	6.83E-02	7.09E-02	9.51E-02	4.29E-01	2.23E-01
Mercury	0.00017	1.31E-04	7.23E-04	2.15E-04	2.23E-04	2.99E-04	8.03E-04	4.18E-04
Molybdenum	0.008	4.62E-01	2.55E+00	7.59E-01	7.87E-01	1.06E+00	4.76E+00	2.48E+00
Nickel	0.013	6.01E-04	3.32E-03	9.86E-04	1.02E-03	1.37E-03	6.19E-03	3.22E-03
Nitrate	4.27	NA	NA	NA	NA	NA	NA	NA
Selenium	0.002	3.08E-02	1.70E-01	5.06E-02	5.25E-02	7.05E-02	3.17E-01	1.65E-01
Silicon	3.777	NA	NA	NA	NA	NA	NA	NA
Silver	0.006	2.77E-01	1.53E+00	4.55E-01	4.72E-01	6.34E-01	2.86E+00	1.49E+00
Vanadium	0.012	3.96E-03	2.19E-02	6.50E-03	6.75E-03	9.06E-03	4.08E-02	2.12E-02
Zinc	0.037	4.27E-03	2.36E-02	7.02E-03	7.28E-03	9.78E-03	2.20E-02	1.15E-02

[a] Hazard Index
[b] Not available

TABLE 6-45
COMPARISON OF CONCENTRATIONS OF INORGANIC CHEMICALS DETECTED IN FEMP MAMMALS TO BACKGROUND CONCENTRATIONS

Chemical	Small Mammal Carcass (mg/kg)[a]	Cottontail Rabbit Muscle (mg/kg)	White-Tailed Deer Kidney (mg/kg)	White-Tailed Deer Liver (mg/kg)	Background (mg/kg)
Aluminum	42	4U[b]	4U	8	NA[c]
Arsenic	13	8	17	20	<1[d]-<3.1
Barium	1	0.2U	0.2U	0.2U	NA[c]
Mercury	0.24	0.2	0.1U	0.1U	<1[e]-<3.1
Zinc	38.3	10.9	32.3	51.8	67-120[f]

[a] Dry weight.
[b] U, not detected. Value is detection limit.
[c] Not available.
[d] Background concentrations of arsenic in biota obtained from Eisler (1988). Wet weight of <1 mg/kg converted to dry weight by dividing by 0.32 (Talmage and Walton 1991).
[e] Background concentrations of mercury in biota was obtained from Eisler (1987).
[f] Range of background concentrations of zinc in animals was obtained from Beardsley et al. (1978).

TABLE 6-46
HAZARD INDICES FOR WILDLIFE EXPOSED TO ORGANIC CHEMICALS OF POTENTIAL CONCERN IN FEMP SURFACE SOILS[a]

Chemical	Deer HI[b]	Mouse HI	Raccoon HI	Red Fox[c] HI	Muskrat HI	Robin HI	Hawk[c] HI
Polycyclic Aromatic Hydrocarbons							
Acenaphthene	4.17E-04	1.61E-02	2.41E-04	4.62E-04	7.66E-03	1.92E-01	3.12E-05
Anthracene	5.12E-05	2.76E-03	2.92E-05	7.07E-05	1.17E-03	2.23E-03	8.36E-07
Fluoranthene	2.02E-03	2.87E-01	1.06E-03	1.42E-03	2.11E-02	2.38E-01	6.71E-04
Fluorene	1.35E-03	5.50E-02	7.78E-04	5.94E-04	9.81E-03	2.93E-01	6.33E-05
Naphthalene	1.03E-02	1.99E-01	6.04E-03	3.21E-03	5.32E-02	1.51E-01	8.63E-06
Phenanthrene	NA[d]	NA	NA	NA	NA	1.47E+00	5.51E-04
Pyrene	2.49E-03	3.45E-01	1.31E-03	1.48E-03	2.17E-02	2.86E-01	7.77E-04
Monocyclic Aromatics							
Benzoic acid	7.46E-02	8.18E-01	4.43E-02	7.24E-03	1.20E-01	5.71E-01	6.74E-07
Chlorobenzene	3.28E-05	4.89E-04	1.94E-05	1.06E-06	1.76E-05	3.60E-04	3.61E-09
Toluene	3.46E-06	4.89E-05	2.05E-06	6.69E-07	1.11E-05	3.58E-05	2.87E-10
Phthalate Esters							
Bis(2-ethylhexyl)phthalate	1.93E-03	2.15E-01	1.04E-03	3.68E-04	5.02E-03	1.77E-01	2.98E-04
Halogenated Aliphatic Hydrocarbons							
Chloroform	1.39E-03	1.56E-02	8.27E-04	3.38E-04	5.60E-03	1.09E-02	1.55E-08
Methylene chloride	8.18E-03	8.28E-02	4.86E-03	1.24E-03	2.05E-02	5.69E-02	1.62E-08
Tetrachloroethene	2.36E-05	4.91E-04	1.39E-05	7.58E-06	1.26E-04	3.76E-04	2.13E-08
1,1,1-Trichloroethane	1.75E-05	2.25E-04	1.04E-05	3.96E-06	6.56E-05	1.62E-04	7.62E-10

See footnotes at end of table.

TABLE 6-46
(Continued)

Chemical	Deer HI[b]	Mouse HI	Raccoon HI	Red Fox[c] HI	Muskrat HI	Robin HI	Hawk[c] HI
Nonhalogenated Aliphatic Hydorcarbons							
Acetone	2.38E-03	2.59E-03	1.41E-03	5.19E-04	8.61E-03	1.54E-02	1.43E-10
2-Butanone	1.37E-03	1.62E-03	8.13E-04	4.93E-04	8.18E-03	8.96E-03	2.80E-10
Miscellaneous Compounds							
Carbon disulfide	3.74E-04	9.13E-04	2.22E-04	4.84E-05	8.02E-04	2.84E-03	5.91E-09
Carbon disulfide	2.44E-04	7.84E-04	1.45E-04	3.16E-05	5.24E-04	2.01E-03	2.54E-09
Dibenzofurans	2.81E+00	8.66E+01	1.66E+00	9.97E-00	1.91E+01	8.69E+01	4.42E+01

[a] Compounds for which NOELs were unavailable are not included in the table.
[b] Hazard Index
[c] Based on assumption of muscle-to-muscle transfer equal to plant-to-beef transfer
[d] Not available.

HIs for organic chemicals of concern in surface waters were much less than 1.0 for the two for which NOELs were located (Table 6-23).

6.5.2.2 Risks of Exposure to Radionuclides

Radiation exposures causing detectable chronic to acute effects in mammals and birds are several hundred rads (e.g., Iverson and Turner 1976, Snyder et al. 1976, Tester et al. 1968). As with plants, the effects on animals of exposure to chronic low-level radiation are unknown. Estimated radiation doses to white-tailed deer, raccoons, and muskrats were orders of magnitude lower than this range, indicating that radiation effects on these species associated with exposure to FEMP radionuclides are not likely to be detectable. Estimated radiation doses to the white-footed mouse, red fox, American robin, and red-tailed hawk were highly dependent on the assumption used about muscle-to-muscle transfer. If muscle-to-muscle transfer is similar to that of plant-to-beef, the estimated radiation doses would not be expected to cause detectable effects. If, however, radionuclides are transferred from prey to predators with perfect efficiency (i.e. transfer factor equals 1.0), predators feeding on prey exposed to FEMP radionuclides could be exposed to potentially harmful levels of radiation. In this context, the observation that uranium was the primary contributor to estimated dose via the soil-earthworm-mouse-predator pathways may be important. Uranium is generally less mobile and less bioavailable than radionuclides such as technetium-99 and cesium-137, and might be expected to have relatively transfer efficiency from prey to predators. For example, uranium soil-to-vegetation and plant-to-beef transfer factors are 10 to 1000 times lower than those of technetium-99 (Tables 6-1, 6-5). If this holds true for muscle-to-muscle transfer, the more conservative radiation dose estimates would be overestimates. If more realistic muscle-to-muscle transfer factors were approximately 0.1, the estimated radiation doses would fall below the range likely to result in visible chronic to acute effects. As described below, such effects have not been observed in the field at the FEMP.

6.5.2.3 Field Studies

Although modeling suggests that FEMP wildlife may be exposed to chemical intakes or radiation doses hazardous to individual organisms, field collected data do not indicate, for the most part, that the animals are adversely impacted at the population level. Discrepancies between the predicted and the observed are primarily attributed to the conservative assumptions that were used in the model and to the limited amount of site-specific data. Ecological studies on the FEMP wildlife include mammalian diversity and abundance, rabbit and treefrog population genetics, avian diversity and abundance, robin growth and reproduction, and dove growth studies.

Mammals were censused on-property during the summer of 1986 (Facemire et al. 1990). In general, the species found were comparable to that reported in off-property studies. Exceptions include the prairie vole (Microtus ochrogaster) and woodland vole (Microtus pintorum) which were absent from the FEMP. No explanation was given as to the absence of these species form the FEMP. A game wildlife census conducted on the FEMP during the same time period indicated 38 white-tailed deer

(Odocoileus virginianus) per square kilometer. According to Nixon (1968), Ohio has the lowest white-tailed deer production in the midwest, with about 0.24 deer/km^2. Deer densities in the western part of the state have been reported as very low, less than 1 deer/km^2 (Nixon et al. 1970). Deer densities at the FEMP therefore appear to be greater than expected. This may be a result of the protection from hunting afforded by the FEMP. Cottontail rabbit (Sylvilagus floridanus) densities on-property were, however, lower than that reported for the off-property populations (Facemire et al. 1990). This was attributed by the investigators to either current land management practice on-property and/or to predation by owls.

A study was performed in 1987 to determine whether mammals on-property were exposed to stressors that could induce genetic change (Facemire et al. 1990). Ten rabbits were collected from the northern pine stand and six from off-site areas. Rabbits from the FEMP and off property locations were found to possess the same level of genetic variation. Because the rabbits within the pine plantation may have been transients, the investigators felt the results of the study were inconclusive.

FEMP data on avian species diversity and abundance were compared to data published in the literature for similar habitat types (Facemire et al. 1990). Eighty-two species of breeding birds were recorded on property with the highest species diversity and abundance observed in riparian habitats during the summer of 1986. Summer avian densities at the FEMP were slightly less than those reported in the literature. The summer census revealed that eleven species normally present in similar habitat types were absent from the FEMP. Nine of these were insectivores (e.g., common night hawk, Chordeiles minor). Factors that could contribute to the absence of these species include the limited amount of suitable habitat present, errors in sampling, and normal FEMP operations. Species richness was lower in winter than in summer. Fourteen species common to the Cincinnati area during the winter were absent from the FEMP. Among these species were the white-crowned sparrow (Zonotrichia leucophyrus), swamp sparrow (Melospiza georgiana), and cedar waxwing (Bombycilla cedrorum). Because sufficient habitat were believed to be available, the absence of these species may have been associated with factors such as food limitations, climate, or other environmental perturbations. The FEMP was found to support relatively high densities of two predatory bird species- eastern screech owl (Otus asio) and great horned owl (Bubo virginianus). With reference to game birds on the FEMP property, bobwhite quail (Colinus virginianus) densities estimated in the summer of 1986 were within the ranges of that reported in Iowa and Wisconsin on unmanaged lands. This information suggests that deficiencies in habitat type and food availability may be the greatest factor determining the avian species found on the FEMP.

Studies were conducted on the FEMP property to determine whether birds present were exposed to stressors in the environment (Facemire et al. 1990). A study of morning dove (Zenaida macroura) populations conducted in 1987 did not reveal statistically significant differences in any of the five growth parameters measured in nestlings located on the FEMP as compared to off-property

populations. Hatching success, however, was significantly lower in northern on-property pine plantations than in southern on-property pine plantations.

Reproduction and growth studies were conducted on American robin populations both on the FEMP property and off-property (Facemire et al. 1990, Osborne and Jones 1990). These studies indicated stunted growth in FEMP robins. Clutch size, embryo size, and number of fledglings were all normal (Osborne and Jones 1990). Recent data from ongoing studies show no difference in growth between FEMP and off-property robins, suggesting that either the stressor has disappeared or that factors other than stress (e.g., natural variability or sample size) may have explained the previously observed differences.

Population genetics studies were conducted in 1986, 1987 (Facemire et al. 1990), 1990 (Guttman 1990), and 1991 (Guttman 1992) on treefrogs (Hyla crucifer) collected both on and off the FEMP property. These studies noted the presence of a unique allele at the glucose phosphate isomerase locus which was at one time thought to be inversely correlated with the distance from the FEMP (Guttman 1990). Later studies, however, revealed the presence of the allele in higher frequency over a much wider distribution than was previously indicated, and the range of the allele is now considered too extensive to be attributable to a FEMP origin (Guttman 1992).

6.5.3 Aquatic Organisms

This section describes risks to aquatic organisms associated with exposure to radionuclides and summarizes conclusions of field studies of aquatic organisms in Paddys Run and the Great Miami River. The relative risks associated with exposure to nonradioactive chemicals are correlated with the degree to which exposures exceed water quality standards. These data were summarized previously in Section 6.4.3.2.

6.5.3.1 Risks of Exposure to Radionuclides

A chronic dose rate of 1 rad/d or 3.65 x 10^5 mrad/y or less to the maximally exposed member of a population of aquatic organisms would ensure that there were no deleterious effects from radiation on the population (NCRP 1991). The maximally exposed individual could be a sensitive species, including developmental stages of fish. Therefore, this upper limit is somewhat conservative. The sum of internal and external doses estimated from measured surface water concentrations at the three sites considered are far below this criterion. The maximum dose calculated to aquatic plants was 2.2 x 10^4 mrad/y. These dose rates were derived using generic bioaccumulation factors (Killough & McKay 1976) that are not site-specific, and other non-site-specific assumptions. As a result, the doses calculated are likely to overestimate true exposures at the site. This is supported by the fact that the maximum uranium concentration measured in a benthic macroinvertebrate sample, 6.5 pCi/g, would only result in a yearly dose of 540 mrads. Therefore, under current conditions, the surface waters adjacent to the FEMP do not pose any risk to the aquatic organisms residing there.

The activity in the surface waters resulting from surface soil runoff into the SSOD or Paddys Run during low flow would produce doses in all the aquatic receptors that exceeded the 1 rad/d limit. Internal doses exceeded the criteria for all organisms except for muskrats. The sum of the doses from all radionuclides from exposure to the water and sediments is 2.0 x 10^4 mrad/y. The combined internal and external doses in muskrats would then exceed 1 rad/d. The maximum concentrations in the water and sediments used in the calculations were for the low flow conditions in the SSOD. The doses to organisms residing in Paddys Run and the Great Miami River would be lower than that indicated in the SSOD. However, low flow does occur for most of the year and this assessment can be considered a potential worst-case scenario.

6.5.3.2 Field and Toxicity Studies

Studies focusing on potential effects of the FEMP on aquatic organisms include sampling of Paddys Run organisms by Facemire et al. (1990), macroinvertebrate surveys of Paddys Run and the Great Miami River, toxicity tests of the FEMP effluent discharge into the Great Miami River, and toxicity tests of water-soluble extracts of FEMP soils and sediments. The latter three studies were conducted specifically for the RI/FS and are summarized in Part I, Section 4.1.7. Complete reports are provided as Appendices D, E, and F, respectively.

Benthic macroinvertebrate community structure is a sensitive indicator of water quality. RI/FS surveys of macroinvertebrates in the Great Miami River indicate no negative effects of the FEMP. There was some evidence of net enrichment just downstream from the effluent discharge, probably due to nutrients present in the effluent. Community structure in Paddys Run shows a general decline in diversity and the OEPA Invertebrate Community Index downstream from Silos 1 and 2. However, this coincides with the portion of Paddys Run subjected to intermittent flow, and the effect may be due to physical stress, rather than exposure to FEMP contaminants.

FEMP effluent was tested for toxicity five times over two years, using standard acute and chronic tests developed by EPA (Appendix E). Acute toxicity was not observed and chronic toxicity was observed only three times. Under worst-case assumptions (10-year low river flow and annual high effluent flow), the estimated in-stream effluent concentration was 0.03 percent, far below the 6.25 to 25 percent effluent concentration associated with the lowest observed toxicities (Appendix E).

Water soluble extracts of two soil and two sediment samples from the FEMP showed no acute toxicity to chironomid worms, fathead minnows, or water fleas (Appendix F).

6.6 Conclusions and Uncertainties

Estimated ecological risks associated with exposure to FEMP constituents of concern are primarily due to nonradioactive inorganic chemicals in soils, rather than to organic chemicals or radionuclides. This is true for both terrestrial and aquatic organisms and for plants as well as wildlife. In particular,

estimated intakes of arsenic, cobalt, lead, and silver from FEMP soils were all higher than NOELs for at least six of the seven indicator species selected for this assessment. The relative hazards to individual species varied, but the white-footed mouse consistently had the highest hazard indices for these chemicals. This can be attributed to the assumed intake by the mouse of insects (earthworms), which in turn were assumed to assimilate chemicals from soil with a transfer coefficient of 1.0. The American robin was also exposed to relatively high levels of soil contaminants via this pathway. Contaminant intake and associated hazard indexes for the top carnivores among the indicator species, the red fox and the red-tailed hawk, were sensitive to assumptions about muscle-to-muscle transfer factors, as described above. If muscle-to-muscle transfer is comparable to plant-to-beef transfer, the estimated hazard was relatively low, but increased dramatically when assumed to be 1.0.

Estimated hazards to terrestrial organisms of exposure to constituents of concern in FEMP surface waters were relatively low, with HIs greater than one only for arsenic, lead, molybdenum, and silver. These chemicals presented hazards to two, five, four, and three species, respectively, and the highest HI estimated was 5.0 for lead intake by the mouse. Surface water exposure is therefore unlikely to be a significant source of risk to terrestrial ecological receptors at the FEMP.

Estimated radiation doses to terrestrial organisms at the FEMP, originating from soil uptake by plants and earthworms, were below levels expected to cause detectable effects. However, as with inorganic chemicals, this conclusion is sensitive to assumptions about muscle-to-muscle transfer of radionuclides. Highly efficient transfer or biomagnification of uranium, in particular, could expose terrestrial wildlife at the FEMP to potentially harmful radiation levels. Radiation doses due to water intake were insignificant.

Exposure to radiological contaminants does not appear to pose a risk to aquatic organisms at the measured concentrations in the surface waters and sediments impacted by the FEMP. However, radionuclides in runoff sources into surface water would cause estimated exposures to exceed the upper limit of 1 rad/d for all aquatic organisms, except for muskrats. The most affected organisms would be aquatic plants, receiving a total dose from internal and external exposure of about 140 rad/d. The total dose to fish is minimally over the limit, at 1.6 rad/d, and the total dose to benthic macroinvertebrates is about 14 rad/d. Although the maximum concentrations at low flow were used in the source runoff calculations, the minimum values in the SSOD and Paddys Run are within the same magnitude of values. Doses to aquatic organisms in the Great Miami River would be well below 1 rad/d.

The measured concentrations of cadmium, copper, mercury and silver in surface water exceeded the chronic toxicity criteria for the protection of freshwater organisms. Of the tested mercury compounds, methylmercury is the most chronically toxic. Levels of methylmercury greater than 0.07 ug/ℓ produced chronic toxic effects on Daphnia magna, and the chronic value for mercury (II) for the same

species was reported at 1.1 ug/ℓ (EPA 1986). The OEPA standard is 0.0002 ug/ℓ, a very conservative value.

Field studies on the impact of the FEMP on terrestrial and aquatic communities do not indicate any effects consistent with contaminant impacts, except for above-background levels of arsenic and mercury recorded in RI/FS plant samples. In addition, although potential impacts at the individual level were predicted for wildlife species, detrimental or adverse impacts have not been observed in the field. This suggests that the potential exposures predicted by modeling may not occur in the field or that the resulting potential effects may not occur. A comparison of the concentrations of inorganic chemical concentrations in FEMP soils to regional background values (Table 2-18) indicates that mean FEMP concentrations may be similar to the upper 95 percent confidence levels of background values. This suggests that ecological risks estimated using background values of inorganics would be comparable to those estimated for the FEMP, and emphasizes the conservative nature of the method used. Additional important sources of uncertainty include 1) the efficiency of contaminant transfer among trophic levels, in particular muscle-to-muscle transfer described previously, 2) the use of laboratory toxicity data to predict effects on species in the field, and 3) the assumptions and uncertainty factors incorporated into estimates of NOELs, for example multiplying by 0.1 to account for interspecies differences. Uncertainty associated with radiation dose assessment includes the assumptions that the dose is completely absorbed and that the radionuclides are uniformly distributed in tissue. Departures from these two assumptions would tend to decrease and increase tissue-specific doses, respectively.

Many uncertainties exist in the assessment of toxic effects to aquatic biota. Examples are the complex chemical speciations and interactions not directly accounted for, the assumption of water hardness (100 mg/ℓ), sediment organic content (1%), and differences in species and sensitivities. Overall, the consideration of these uncertainties will tend to overpredict the potential for adverse effects rather than underpredict.

In summary, despite the fact that radionuclides are the most ubiquitous contaminants at the FEMP, estimated ecological risks to both terrestrial and aquatic organisms are primarily associated with nonradioactive inorganic chemicals. Although estimated risks are substantial in some instances, they are based on soil inorganic chemical concentrations comparable to background levels, and deleterious effects have not been observed in the field. This suggests that current FEMP-specific ecological risks are low, but that remedial actions are appropriate to prevent potential future ecological harm as well as to limit human exposures to FEMP contaminants.

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7.0 NEPA IMPACT ANALYSIS OF THE NO ACTION ALTERNATIVE

It is the intent of the Fernald Environmental Management Project to fully satisfy the requirements of NEPA and CERCLA by integrating the data collection and analysis, document preparation and alternative selection in the RI/FS process as required by DOE Order 5400.4. The SWCR is a key document in the NEPA integration process and provides the following components: Part I, Section 2 (Site Setting) and Appendices A through H contain the regional and site description of the "existing environment" as required by NEPA and CERCLA guidelines. The analytical results for groundwater, surface water, sediments, soils, flora and fauna, and contaminant sources are presented in Part I, Section 4 (Data Summary). This section provides the data necessary to support the analysis of the no action alternative in the PBRA and in the NEPA impact analysis presented below. All of the data and analyses described above will provide the "baseline" for the analysis of cumulative impacts resulting from remedial alternatives in each operable unit feasibility study, and will be referenced as required.

Figure 7-1 highlights the NEPA components of the SWCR and the initial operable unit RI/FS-environmental impact statement (EIS). Overall, the SWCR presents a baseline analysis of the entire site which will lead to a specific analysis of each operable unit and its remedial alternatives in the operable unit-specific RI and FS reports. Operable Unit 2 is scheduled to be the first RI/FS completed for EPA and public review as described in Part I, Section 1.2.4 of this report. It will contain the EIS and will reference site-wide information contained in the SWCR.

The definition of the no action alternative below has been developed based on the NEPA no action approach and is consistent with the definition outlined in the Amended Consent Agreement and the Risk Assessment Work Plan Addendum (DOE 1992). For the purposes of NEPA impact analysis, it is necessary to define the no action alternative in terms of the following factors:

- Status of production at the facility
- Definition of current and future impacts
- Completion status of specific removal actions and RCRA corrective actions at the site
- Future deterioration of containment systems and migration of contaminants
- Utilization of institutional controls
- Anticipated future land use in the vicinity of the FEMP

Status of Production at the Facility In July 1989, WMCO announced that a decision had been made to suspend production at the FEMP. In October 1990, DOE headquarters announced that management oversight of the FEMP was to be transferred from the Defense Programs Office to the Environmental Restoration Office. Based on the announcement on August 23, 1991 of "no future production" at the FEMP, the NEPA analysis will assume no production at the facility.

SITE-WIDE CHARACTERIZATION REPORT

- Description of existing environment
- No action definition
- No action impact analysis
- Leading remedial alternatives for Operable Units 1 - 5

OPERABLE UNIT 2 RI/FS-EIS[a]

- Description of Operable Unit 2 study area existing environment
- Impact analysis of alternatives for Operable Unit 2

- NEPA cumulative impact analysis of all operable unit leading alternatives
- CERCLA comprehensive response action risk evaluation

[a] Each operable unit RI/FS will contain the same components.

FIGURE 7-1. NEPA COMPONENTS OF CERCLA REPORTS

Definition of Current and Future Impacts To remain consistent with risk assessment definitions as specified in the Risk Assessment Work Plan (DOE 1992), the risk assessment terms "current" and "future" shall be substituted for the NEPA phrases "short-" and "long-term". Each specific discipline will determine its own definition of current and future based on specific anticipated events related to its technical analysis. For example, for the risk assessment, "current" land use scenarios consider "only the current, unimproved condition of the property", while future land use of the property involves "any activities requiring development time (i.e., home building, planting and harvesting crops, etc.)."

Completion of Removal Actions RI/FS activities at the FEMP have led to the development and implementation of a number of removal actions. Removal actions, as defined in CERCLA, are intended to abate, minimize, stabilize, mitigate, or eliminate the release or threat of release of hazardous substances, pollutants, contaminants, or hazardous constituents at or from the site. Eighteen removal actions were defined in the Amended Consent Agreement for the FEMP and 24 have been approved by EPA and are at various levels of completion. The following removal actions have been completed:

- K-65 Decant Sump Tank - was completed in April 1991, when approximately 8,000 gallons of contaminated water were pumped from the K-65 Decant Sump Tank and transferred to the holding tanks in Plant 2/3.

- Silos 1 and 2 - as described in the K-65 Silos Removal Action Engineering Evaluation/Cost Analysis (EE/CA), this involved the placement of bentonite clay over the silo residues to reduce radon levels in the silos and to reduce the magnitude of a potential release to the environment in the event of silo dome collapse (DOE 1990a). Completed in late November of 1991, this removal action has decreased routine emissions of radon gas from the silos considerably. (See Part I, Section 4.2)

- Waste Pit 6 Residues - was designed to decrease radioactive dust and particles released from Waste Pit 6 into the air. A mound of exposed waste protruding above standing water in the shallow end of the pit was submerged under water in the deeper end of the pit during December of 1990. The only remaining activity involves the placement of air monitors to augment the site requirements for estimating the off-site releases of potentially harmful contaminants. Installation is expected in early 1992.

The K-65 Decant Tank, Silos 1 and 2, and Waste Pit 6 removal actions are to be considered in the NEPA analysis of no action.

RCRA Actions at the FEMP The FEMP is a regulated hazardous waste facility as defined under RCRA. Characteristic and listed wastes generated at the FEMP are containerized in tanks or drums. Wastes anticipated or observed to contain free liquids are stored in locations with appropriate secondary containment. There is no land treatment of RCRA-regulated wastes at the FEMP. RCRA wastes are disposed of at commercial facilities in accordance with all applicable regulations. All

wastes are being characterized to determine RCRA status. Mixed wastes (hazardous and radioactive) are stored on-property. The no action alternative will assume that mixed wastes remain on-property and contribute to the current and potential future contamination of environmental media.

Future Deterioration of Containment Systems and Migration of Contaminants The containment systems included in this discussion are the silos, waste pits, lime sludge ponds, flyash piles, the South Field, the solid waste landfill, and other storage areas such as the Plant 1 Pad. For the purposes of "no action," the future deterioration of these containment systems will be considered to result in a gradual leakage of contaminants into the environment over a long period of time rather than a catastrophic release, for example, a tornado-induced or spontaneous Silo 1 or 2 dome failure.

A number of removal actions have been initiated to control contaminant migration through the elimination or minimization of contaminant pathways. Other potential contaminant pathways still exist under a no action scenario. For example, if there is silo leakage underground, the bentonite layer installed above the residue would still reduce radon diffusion upward, but would not affect the downward migration of contaminants. New contaminant pathways could also develop over time possibly associated with structural failure. The no action alternative assumes that a gradual leakage of contaminants could occur.

Use of Institutional Controls These include monitoring systems and land use or access restrictions. The monitoring well networks currently installed are used to monitor the performance of collection and/or treatment systems for groundwater, for detecting releases from the site, or for compliance monitoring. Land use or access restrictions include fencing, security systems and deed restrictions. For the no action alternative, it is assumed that the existing and proposed monitoring systems and existing land use or access restrictions (FEMP security systems) will not continue in operation.

Anticipated Future Land Use The two risk assessment land use scenarios for future land use at the FEMP include a resident farm family and a construction intruder. The future resident farm family is assumed to reside on-property, eating food grown on-property, drinking from the Miami Valley Aquifer, and inhaling dust and gases generated at the property. The construction intruder is assumed to enter the property, dig a basement and a well, build a home, and leave. Potential exposure could be through inhalation of gases and dust and/or direct contact with contaminated waste or soil. Completion of the construction ends the scenario, at which point the resident will be considered under the resident farm family scenario. Both of these scenarios are consistent with expected growth in the vicinity of the FEMP. Based on information included in Part I, Section 2.2.6.3, it is projected that land use adjacent to the FEMP will remain predominantly agricultural for the next 10 to 20 years with the majority of metropolitan residential growth continuing to the north and east of Cincinnati rather than in the vicinity of the FEMP.

Key Assumptions for the No Action Alternative NEPA analysis of the no action alternative will be based on the following assumptions:

- There will be no production at the facility.
- Removal actions to be considered in the NEPA analysis of current impacts include the K-65 Decant Sump Tank, Silos 1 and 2, and Waste Pit 6 removal actions.
- Mixed wastes remain on-property and contribute to the current contamination of environmental media. RCRA wastes are shipped off-property and disposed of commercially.
- A gradual leakage of contaminants may occur and implemented removal actions may not eliminate all future migration of contaminants.
- Existing FEMP monitoring systems and existing land use or access restrictions (FEMP security systems) will not continue in operation.
- Anticipated land use scenarios include on-property residential use. It is projected that land use adjacent to the FEMP will remain predominantly agricultural for the next 20 years with the majority of metropolitan residential growth continuing to the north and east of Cincinnati rather than in the Fernald area.

7.1 Impacts to Air Quality

This section discusses current and future air quality under the no action alternative with respect to criteria pollutants (regulated under the Clean Air Act), air toxics, and airborne radionuclides. A description of the methodologies used in the evaluation of current and future air quality is also included. Existing air quality provides a baseline for comparison to environmental consequences in the current and future scenarios of the no action alternative.

Air quality in the vicinity of the FEMP is generally regarded as "good," with respect to National Ambient Air Quality Standards (NAAQS). These nationally-adopted health-protective standards apply to six pollutants regulated under the Clean Air Act: inhalable (PM10) particulates, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead. Historically, none of these has been monitored in the immediate vicinity of the FEMP, because there are few sources in the vicinity. Extensive monitoring has been performed by the Southwestern Ohio Air Pollution Control Agency (SWOAPCA) in urban locations where the highest concentrations within its four-county jurisdiction are found. With the exception of ozone, pollutant concentrations in these locations meet the NAAQS. Ozone is a widespread problem that will require regional control and abatement measures, such as the long-range measures mandated by the Clean Air Act Amendments of 1990.

Air quality standards for toxic compounds not regulated under the Clean Air Act are defined by individual states. The State of Ohio, acting through the SWOAPCA, has established standards for chemically toxic compounds including ammonia, hydrogen fluoride, and nitric acid, all of which have been released from the FEMP in relatively small amounts. Estimates of the air quality impact of the

amounts released have been made by dispersion modeling and indicate that concentrations in recent years are well within the limits set by the State of Ohio.

Uranium and radon are the principal airborne radionuclides of concern at the FEMP. Before production ceased, uranium emissions were generated by a variety of processes. Radon is a decay product of radium contained in the wastes currently stored in Silos 1 and 2. Historically, both pollutants have been extensively monitored by the FEMP, and there have been no violations of the air quality standards mandated by DOE and EPA. The last full year of production at the FEMP was 1988. Emissions of radionuclides during 1989 and 1990 were substantially reduced, as shown in Part I, Section 4.1.2. The concentration of each radionuclide at each of the 16 air monitoring sites is well within (at the 95% confidence interval) the "derived concentration guide" (DCG), a DOE guideline for a dose to a member of the general public. Monitored concentrations of airborne radon did not change substantially during 1989 and 1990, but were notably lower after the placement of bentonite in Silos 1 and 2 during 1991 (Part I, Sections 4.1 and 4.2).

Because there would be no production or other activities associated with the no action alternative, there would be no additional emissions of any of the pollutants referred to above. Accordingly, there would be no deterioration of air quality during the current time frame.

There is a potential for additional emissions in the future due to gradual deterioration of the containment systems for wastes stored on the FEMP property. In the absence of production activity under the no action alternative, the primary source of airborne contaminants would be resuspension of particles from contaminated areas. During periods of turbulent wind conditions, particles of surface materials (e.g., contaminated soil) can become resuspended in ambient air and thus become subject to inhalation. The amount of particles resuspended depends on wind speed and other site conditions such as soil moisture, particle size range, and the extent of vegetative cover. Once resuspended, particles travel in whatever direction the wind happens to be blowing at the time, dispersing as they migrate downwind and eventually resettling to the ground. Downwind concentrations of the contaminated particles can vary widely, depending on atmospheric conditions. For each resuspended contaminant of concern, a dispersion model was used to project annual average concentrations. Appendix Q describes the dispersion model and the assumptions made to facilitate its use. Four concentrations were of special interest: the highest on-property concentration, the highest off-property concentration, and the highest concentrations at the two nearest "sensitive receptor" sites (Elda Elementary School, near Ross, and Crosby Elementary School, located between Fernald and New Haven).

Current and future estimated concentrations of radionuclides are presented in Tables 7.1 and 7.2, respectively. These concentrations can be compared to the DCGs, also listed in the tables. The DCG is only exceeded in the highest future on-property concentration of radon. As with all maximum concentrations, this occurrence is immediately downwind of the source.

Contamination of ambient air in the immediate vicinity of the FEMP is a direct impact of resuspension. Indirect impacts include adverse health effects which could result from inhalation

TABLE 7-1
ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED AIRBORNE RADIONUCLIDES (CURRENT SCENARIO)

Radionuclide	Highest On-Property Concentration (aCi/m^3)[a]	Highest Off-Property Concentration (aCi/m^3)	Elda School (aCi/m^3)	Crosby School (aCi/m^3)	Derived Concentration Guide (DCG)[b] (aCi/m^3)
Thorium-230	833.87	197.65	4.59	11.94	40,000
Thorium-232	148.56	11.94	0.37	0.58	7,000
Radium-226	254.35	29.16	0.60	1.16	1,000,000
Uranium-234	6,975.23	1,142.62	19.59	26.69	90,000
Uranium-235		85.25	0.98	1.17	100,000
Uranium-238		1,493.65	22.99	30.32	100,000
Radon[c]	6.30E+08	1.58E+07	7.31E+05	3.56E+05	3.0E+09

[a] attoCuries per cubic meter. One Curie = 10^{18} attoCuries.

[b] Airborne concentrations of radionuclides are compared to Derived Concentration Guidelines (DCG) specified in DOE Order 5400.5, Radiation Protection of the Public and the Environment, (DOE 1990).

[c] Because radon is not a resuspended contaminant dependent upon a threshold wind speed, radon emission rates for input to the dispersion model were based on information from prior investigations. The estimated emission rates are shown in Appendix Q, Table Q-2.

TABLE 7-2
ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED AIRBORNE RADIONUCLIDES (FUTURE SCENARIO)

Radionuclide	Highest On-Property Concentration (aCi/m^3)[a]	Highest Off-Property Concentration (aCi/m^3)	Elda School (aCi/m^3)	Crosby School (aCi/m^3)	Derived Concentration Guide (DCG)[b] (aCi/m^3)
Protactinium	31	0.5	4.6E-03	2.1E-02	900
Radium-226	7,584	147	2	6	40,000
Thorium-230	6,271	291	6	22	7,000
Thorium-232	11,028	231	2	1	20,000
Uranium-233	3,080	11	0.3	2.5E-02	90,000
Uranium-234	8,433	646	18	30	90,000
Uranium-235	376	29	1	2	100,000
Uranium-238	8,575	723	21	34	100,000
Radon[c]	2.45E+10	1.81E+08	2.40E+07	1.20E+07	3.0E+09

[a] attoCuries per cubic meter. One Curie = 10^{18} attoCuries.

[b] Airborne concentrations of radionuclides are compared to Derived Concentration Guidelines (DCG) specified in DOE Order 5400.5, Radiation Protection of the Public and the Environment, (DOE 1990).

[c] Because radon is not a resuspended contaminant dependent upon a threshold wind speed, radon emission rates for input to the dispersion model were based on information from prior investigations. The estimated emission rates are shown in Appendix Q, Table Q-2.

of contaminated airborne particles. Direct and indirect impacts, in both current and future time frames, represent a potential threat to on-property workers, nearby residents, and future land use. Based on the comparison of estimated concentrations to the DCGs, presented in Tables 7-1 and 7-2, the only instance of concern pertains to future on-property concentrations of radon.

7.2 Impacts to Surface Water

Surface waters subject to impacts from the FEMP include the Great Miami River, Paddys Run, the storm sewer outfall ditch (SSOD), and wetlands. This section presents an analysis of current and future impacts to these waters under the no action alternative.

7.2.1 Great Miami River

Under the no action alternative, current impacts of the FEMP on the Great Miami River would continue. These impacts, as described in Part I, Section 4 include releases of radionuclides and inorganic chemicals via the FEMP effluent line and Paddys Run. However, the resulting site-related concentrations of these substances in the river are low. Total isotopic uranium concentrations at stations downstream from the FEMP below the FEMP, measured from 1976 to 1990, ranged from 0.3 to 19.0 pCi/ℓ, compared to 0.3 to 25.7 pCi/ℓ at the reference station (Part I, Section 4.1.3). The tentative remediation standard for groundwater at the FEMP is 20 pCi/ℓ. The upper 95% confidence intervals for chemical and radionuclide constituents of concern in the Great Miami River are provided in Tables 6-34 and 6-39, respectively, in Section 6.5.3. Hazardous organic chemicals were not detected in the Great Miami River during RI/FS sampling. The upper 95% confidence interval for cadmium of 3 µg/ℓ exceeds the 30-day average OEPA water quality criterion of 2.4 µg/ℓ (Table 7-3), but not the maximum criterion of 12 µg/ℓ. The upper 95% confidence interval for mercury of 1.0 µg/ℓ exceeds the 30-day average OEPA water quality criterion of 0.2 µg/ℓ, but not the maximum criterion of 1.1 µg/ℓ. Further, the cadmium criterion is hardness-dependent, and would increase from 2.4 µg/ℓ at 200 mg/ℓ $CaCO_3$, the lower limit of water hardness recorded by ORSANCO in the Great Miami River, to 3.3 µg/ℓ at 300 mg/ℓ hardness, a more typical value.

Assuming that runoff collection and water treatment systems continue to function, future direct impacts of no action are similar in nature to current impacts. Indirect adverse impacts could be associated with erosion of contaminated soils and stored wastes into Paddys Run or the SSOD. However, flow from Paddys Run and the SSOD is greatly diluted by the river. Flow in SSOD occurs only as a result of runoff or overflow from the stormwater retention basins, and flow rates in Paddys Run range from 0.2 to 4.0 ft^3/s, compared to the average river flow of over 3,000 ft^3/s. Another indirect adverse impact could result from the future migration of contaminated groundwater in the regional aquifer to the river, but this too would likely be minimized by dilution. The absence of documented ecological impacts on the Great Miami River, as described below, suggests that both current and potential future impacts of the FEMP on river water quality are not likely to be of concern.

TABLE 7-3

OHIO EPA WATER QUALITY CRITERIA FOR CONSTITUENTS OF POTENTIAL CONCERN IN FEMP SURFACE WATERS[a]

Chemical	30-Day Average (mg/ℓ)	Maximum (mg/ℓ)
Organics		
Acetone	78	550
Bis-2-ethylhexylphthalate	0.0084	1.1
Cyanide	0.012	0.046
Di-n-butylphthalate	0.190	0.350
Methylene chloride	0.430	9.7
N-nitrosodiphenylamine	0.013	0.290
PCBs (µg/ℓ)	0.00079	0.001
Toluene	1.7	2.4
1,1,1-Trichloroethane	0.088	2.0
2-Butanone	7.1	160
Metals		
Antimony	0.190	0.650
Arsenic	0.190	0.360
Beryllium[b]	0.071	1.6
Cadmium[b]	0.0024	0.012
Chromium (total)[b]	0.370	3.2
Copper[b]	0.022	0.036
Lead[b]	0.017	0.320
Mercury (µg/ℓ)	0.20	1.1
Nickel[b]	0.320	2.9
Selenium	0.005	0.020
Silver	0.0013	0.0053
Zinc[b]	0.190	0.210

[a] Criteria stated are for warm water habitat, the classification assigned by OEPA to Paddys Run and the Great Miami River.

[b] Hardness-dependent criterion; increases with water hardness. Values stated are for a hardness of 200 mg/ℓ (as $CaCO_3$), approximately the lower limit in the Great Miami River (Part I, Table 4-5).

SOURCE: OEPA (1990)

Current potential impacts of the FEMP on Great Miami River sediments include contamination by radioactive and nonradioactive constituents. Existing impacts of radioactive constituents are not major (Part I, Section 4.0). Mean sediment concentrations for radionuclides of concern in the Great Miami River, with the maximum value of the upper 95% confidence interval applied, are provided in Table 6-39, Section 6.5.3. Data on nonradioactive constituents in river sediments are not available. Future impacts on sediments would be correlated with impacts on surface water and would depend on the water solubility of contaminants, the tendency of contaminants to bind to suspended particulate matter, and uptake of contaminants by biota, with subsequent incorporation into particulates. FEMP impacts on Great Miami River sediments are also unlikely to be of concern due to dilution by the river.

With respect to potential impacts of eroded materials carried from Paddys Run to the river, it is worth noting that the Great Miami River has a drainage area of approximately 3800 square miles at the FEMP, compared to the total drainage area of Paddys Run of 15.8 square miles. This suggests that the relative contribution of Paddys Run to sediment loading in the Great Miami River is likely to be small.

7.2.2 Paddys Run

Under the no action alternative, current impacts of the FEMP on Paddys Run would continue. These impacts include contamination by radioactive and nonradioactive constituents. The site-related concentrations of radionuclides in the stream are generally low, although total isotopic uranium concentrations have occasionally exceeded the tentative FEMP action limit of 20 pCi/ℓ. Low levels of nonradioactive constituents, including phthalates and inorganic chemicals, have been detected in Paddys Run. The upper 95% confidence intervals for chemical and radionuclide constituents of concern in Paddys Run are provided in Tables 6-33 and 6-39, respectively, in Section 6.5.3. The upper 95% confidence intervals for cadmium and mercury slightly exceed the OEPA 30-day average water quality criterion, but not the maximum. As in the Great Miami River, the cadmium criterion for a water hardness of 300 mg/ℓ, 3.3 mg/ℓ, was not exceeded.

Future impacts of no action are similar in nature to current impacts. However, indirect adverse impacts on Paddys Run could result from erosion of contaminated soils or wastes into the stream. Depending on the contaminant levels in eroded soils and the flow rate of the stream, these impacts could range from undetectable to significant. Radionuclide concentrations in FEMP surface waters resulting from surface soil runoff during low flow are provided in Table 6-40, Section 6.5.3. Direct erosion of solid waste by Paddys Run is also a potential future hazard and could result in significant release of radioactive and nonradioactive constituents into the stream.

Current potential impacts of the FEMP on Paddys Run sediments include contamination by radioactive and nonradioactive constituents. Existing impacts of radioactive constituents are minor, with the

possible exception of radium, as described in Part I, Section 4. Low levels of organic and inorganic constituents have been detected in Paddys Run sediments. The upper 95% confidence intervals for radionuclides of concern in Paddys Run sediments are provided in Table 6-39, Section 6.5.3. Future impacts on sediments would be correlated with impacts on surface water. Contamination of sediments at specific sites in Paddys Run is unlikely to be stable, due to the highly variable flow regime in the stream, with consequent frequent flushing out of deposited material.

7.2.3 Storm Sewer Outfall Ditch

Flow exists in the storm sewer outfall ditch only as a result of runoff from adjacent areas or overflow from the stormwater retention basins. The SSOD does not provide aquatic habitat, and direct impacts on surface water and sediments are primarily of concern as sources of indirect impacts on Paddys Run. Under the no action alternative, current impacts would continue. Total uranium concentrations in RI/FS water samples from the SSOD ranged from 2 to 24 µg/ℓ. The upper 95% confidence intervals for chemical constituents of concern in SSOD surface water are provided in Table 6-32 of Section 6.5.3.

Current potential impacts of the FEMP on SSOD sediments include contamination by radioactive and nonradioactive constituents. The upper 95% confidence intervals for radionuclide constituents of concern in SSOD sediments are provided in Table 6-39, Section 6.5.3. The maximum total isotopic uranium concentration recorded from 1986 to 1989 was 77 pCi/g, above the tentative FEMP action level of 35 pCi/g (Part I, Section 4.1.3). Only one sample of SSOD sediments has been analyzed for nonradioactive constituents. Methylene chloride and 2-propane and a number of inorganic constituents were detected.

Future impacts on surface water and sediment would be similar in nature to current impacts. Adverse impacts on water quality could result from erosion of contaminated soils and from the adjacent active flyash pile. Depending on the contaminant levels in eroded soils and flyash and the flow rate of the stream, these impacts could range from undetectable to significant. Estimated radionuclide concentrations in runoff from FEMP surface soils during low flow are provided in Table 6-40, Section 6.5.3.

7.2.4 Floodplains and Wetlands

The no action alternative would have no current or future impacts on floodplains in the Great Miami River and Paddys Run, because no construction or dredge and fill activities would take place. Limited data are available on present impacts of the FEMP on wetlands. Uranium was detected in grass and cattail samples collected from one wetland site at the FEMP and arsenic, aluminum, barium, mercury and zinc were detected in one grass sample (Part 1, Section 4.1.7) . However, these substances were not present at toxicologically significant levels. Aquatic animals in wetlands at the FEMP have not been sampled for contaminants. Uranium was detected at a maximum concentration of 7.07 mg/ℓ in

one sample from a wetland drainage site (ASIT-038) at the FEMP (Part 1, Section 4.1.7), which could have chronic to acute effects on aquatic organisms. However, the average total uranium concentration in samples from FEMP drainages was only 0.7 mg/ℓ. This concentration could have chronic chemical effects on aquatic organisms (Poston et al. 1984), but would not be likely to cause detectable radiation effects (NCRP 1991). These current impacts would continue under no action. Future indirect impacts on wetlands could occur as a result of erosion of wastes or contaminated soils, and could range from undetectable to significant, depending on the contaminant levels in the eroded material. The wetlands primarily affected by runoff and erosion from contaminated soils are in the waste pit area.

7.3 Impacts to Groundwater

Current and potential future sources of groundwater contamination would remain in place under the no action alternative, as no measures would be undertaken to eliminate or isolate them. Existing sources would continue to release contaminants, with the contaminant loading rates of some sources expected to increase in the future. New sources may also develop due to the deterioration of waste storage units over time. Currently contaminated groundwater would not be prevented from migrating to unaffected areas in the future.

Evaluation of groundwater impacts will focus on the sole-source Great Miami Aquifer and site-wide perched groundwater. The hydrogeology of the FEMP study area and the nature and extent of groundwater contamination are discussed in Part I, Sections 2.2.3.3 and 4.1.4, respectively.

7.3.1 Contamination Sources and Pathways

As shown in Figure 7-2, there are three primary pathways by which contaminants could migrate into perched groundwater and the aquifer under the no action alternative. These include the infiltration of contaminated storm water runoff; subsurface leachate releases from waste storage units and other sources; and episodic releases (e.g., spills) that infiltrate perched groundwater and/or the aquifer. Contaminated storm water runoff and leachate can either directly infiltrate the aquifer or infiltrate perched groundwater and subsequently migrate to the aquifer.

Contaminated runoff that collects in Paddys Run or the SSOD could also infiltrate the aquifer, because portions of both streams are subject to leakage to the aquifer. Another pathway, similar to the contaminated storm water runoff pathway, involves the erosion of contaminated soils or wastes into Paddys Run and/or the SSOD.

Contaminated Storm Water Runoff The resuspension of surface contaminants into storm water runoff would continue under the no action alternative. The sources of contaminated storm water runoff include the waste storage area, the former production area, the flyash/South Field area, open fields to the east and south, and suspect areas (Figure 7-2). Another source is perched groundwater that can seep to the surface following heavy or sustained rainfall or discharge through springs.

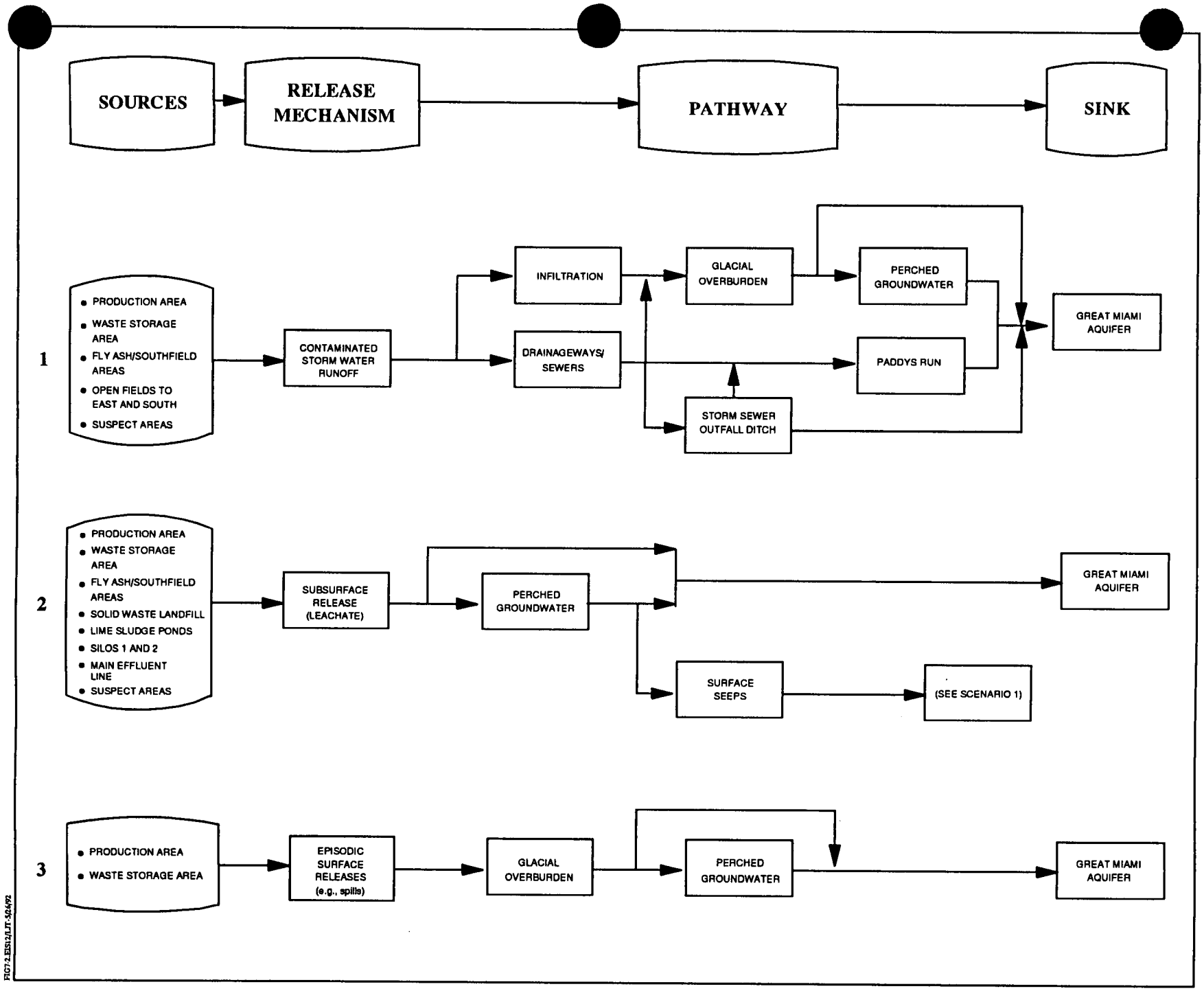

FIGURE 7-2. GROUNDWATER CONTAMINATION SOURCES AND PATHWAYS

FIG7-2.EIS12/JT-5/24/92

Runoff contaminants could be introduced into groundwater via the following pathways:

- Infiltration through glacial overburden to perched groundwater and/or the aquifer
- Migration of contaminants in perched groundwater to the aquifer
- Overland drainage to Paddys Run and leakage through the streambed to the aquifer
- Overland drainage to the SSOD and leakage through the streambed to the aquifer

The South Plume, a uranium-contaminated plume of groundwater extending south of the FEMP, appears to have resulted primarily from historical releases of radioactive materials in FEMP storm water runoff that entered Paddys Run by way of the SSOD and other overland pathways and infiltrated the aquifer through the streambed (Part I, Section 4.1.4). Uranium loading rates to the South Plume would remain relatively low under no action. This is due to the reduced supply of uranium to Paddys Run and the SSOD associated with the cessation of production at the site, recent surface water management practices, and the operation of the storm water retention basins (DOE 1991).

Subsurface Release/Leachate The subsurface release of contaminants to groundwater would continue under the no action alternative. Sources of contamination include the waste pits, the South Field, the solid waste landfill, the flyash piles, the lime sludge ponds, leaking portions of the main effluent line, and contaminated perched groundwater. As shown in Figure 7-2, subsurface releases could introduce contaminants into groundwater via the following pathways:

- Release of leachate from waste units to perched groundwater and/or the aquifer
- Downward migration of contaminants in perched groundwater to the aquifer
- Subsurface leakage along leaking portions of the main effluent line to groundwater

Groundwater fate and transport modeling, discussed in Part I, Section 3.3.1, was used to predict contaminant movement from waste areas to the aquifer through the unsaturated zone (vadose zone) between the land surface and the water table of the aquifer. Loading rates to the Great Miami Aquifer were estimated for each contaminant of concern for each waste area. Appendix O provides a summary of the constituents of concern, the maximum aquifer loading rates over a 1000 year period from each waste area, the technical approach used to model transport by the groundwater pathway, and a summary of the modeling results.

In general, the vadose zone modeling results predict that uranium will, by far, have the highest aquifer loading concentration of any constituent. Neptunium-237, strontium-90, technetium-99, boron, molybdenum, vinyl chloride, and 4-chloro-3-methylphenol are expected to have much lower aquifer loading concentrations, and are the only other constituents that warranted modeling. Waste areas are expected to begin loading uranium to the aquifer in 20 to 160 years, with maximum loading rates generally reached in 100 to 200 years.

Each of the three pathways shown in Figure 7-2 may involve the introduction of contaminants to perched groundwater. Contaminants that reach perched groundwater may also infiltrate the aquifer. Thus, contaminated perched groundwater would remain a continuing source under the no action alternative. The perched groundwater with the highest contamination occurs beneath the former production and waste storage areas. These areas pose a serious future threat to the aquifer.

The main effluent line is leaking along portions of its length. The effects of the leakage on groundwater quality is not known. However, the leaking portions of the line may be a potential source of release to perched groundwater and the aquifer for as long as the effluent line remains in operation.

Episodic Releases Mixed wastes would remain on the FEMP property in drums and facilities in the waste storage and former production areas under the no action alternative. The potential exists for spills to occur as containment vessels deteriorate over time. As shown in Figure 7-2, spills could contribute to the contamination of groundwater via the following pathways:

- Infiltration through glacial overburden to perched groundwater
- Infiltration through glacial overburden to the aquifer

Other potential releases could result from a natural disturbance or failure of containment in the former production area or Silos 1 and 2. The likelihood of such occurrences and their impact on groundwater are difficult to assess but remain a potential source of release under the no action alternative.

Other Pathways The erosion of flyash from the active flyash pile into the SSOD and subsequent leakage of contaminants directly into the aquifer would continue under the no action alternative. Direct erosion of solid waste by Paddys Run and the SSOD is a potential future hazard and could release radioactive and nonradioactive constituents into the streams. This would have an adverse impact on groundwater since both streams are susceptible to leakage directly into the aquifer along portions of their lengths. Both pathways are similar to the contaminated storm water runoff pathway. Depending on the contaminant levels and the flow rate of the streams, impacts on the aquifer could vary.

The discharge of contaminant-bearing surface water into the Great Miami River via the FEMP's main effluent line will not be considered a groundwater contamination source/pathway for the analysis of impacts under no action. The possible impacts of effluent discharge on groundwater quality due to interaction between the river and the aquifer (Part I, Section 2.2.3.3) were evaluated in a 1988 study (IT 1988). This study concluded that the FEMP discharge did not have an observable effect on groundwater quality as most of the induced infiltration occurred upstream from the discharge point. Also, much of the contaminant-bearing surface water that enters the river is diluted and carried downstream from the zone of influence of the SOWC collector wells before it has a chance to

infiltrate the aquifer through the bed of the river. Thus, interaction between the river and aquifer is not considered a pathway for contaminant-bearing effluent to impact groundwater quality (DOE 1990c).

7.3.2 Migration of Contaminants in the Aquifer

Appendix O presents the maximum concentrations for compounds modeled in the aquifer beneath the FEMP by SWIFT III modeling and the expected time of the maximum concentration. The maximum concentrations of uranium and molybdenum are 8,497 µg/ℓ at 300 years from the present and 32 µg/ℓ at 700 years from the present, respectively. The maximum concentrations of the other constituents modeled in the aquifer were all below 1.0 µg/ℓ.

Uranium concentrations in the South Plume are predicted to decrease over time due to dispersion and dilution and fall below levels of concern in approximately 100 years. The maximum predicted uranium concentrations in the plume 10 years, 30 years, and 100 years from the present are 100 µg/ℓ, 30 µg/ℓ, and 3 µg/ℓ, respectively. A large uranium plume is expected to develop beneath the waste storage and production areas between 100 and 300 years. The maximum predicted concentration in the plume in 300 years is 3000 µg/ℓ, with concentration contours up to 1000 µg/ℓ extending beyond the eastern FEMP boundary. At 1000 years from the present, the maximum predicted uranium concentration in the plume is still at 3000 µg/ℓ, and concentration contours up to 300 µg/ℓ extend beyond the eastern FEMP property boundary. Figures showing the predicted concentrations and movement of the uranium plumes discussed above are included in Part II, Section 5.

Other constituents that warranted aquifer modeling include molybdenum, vinyl chloride, and neptunium. However, the estimated concentrations of plumes resulting from these constituents are predicted to be relatively low.

7.4 Impacts to Soils

Soils are an environmental media that play a critical role in the development of the no action alternative. The properties of soils can influence the transport of contaminants to other environmental media such as air and groundwater. Soil can also serve as a reservoir for contaminants. As a result, evaluation of soils must include a thorough understanding of the physical and chemical characteristics of soils both on FEMP property and in the general vicinity of the FEMP. Part I, Section 2.2.4 describes soil series, soil type, and drainage characteristics of FEMP soils. This section discusses the possible impacts that may occur to soils and adjacent environmental media as a result of the no action alternative.

Current impacts on soil under the no action alternative include a combination of those associated with completed removal actions and current environmental conditions. In the future, the addition of contaminants to the soil could occur due to gradual leakage of waste containment systems remaining

on property. Continued on- and off-property monitoring of contaminants would no longer be used to assess whether soil contaminants are migrating to other environmental media. In addition, existing land use or access restrictions would not continue in operation, enabling FEMP land to be used in the same ways local land is used, primarily for residential or agricultural purposes.

Evaluation of the degree of contamination in FEMP soils is based on data collected as of December 1, 1991 and includes data collected while the plant was still in operation. These data do not account for the physical, chemical, and biological processes that have occurred over time which could reduce soil contaminant concentrations. In addition, data on the concentrations of nonradioactive constituents in the soils from some areas within the FEMP were absent. Available data indicate that FEMP soils contain above-background concentrations of the isotopes of uranium, thorium, radium, cesium, strontium, and technetium (Table 7-4). These soils would remain on-property. Arsenic, barium, cadmium, cobalt, lead, mercury, and silver would remain the major nonradioactive metals of potential concern (Table 7-5). Included among the organic contaminants are polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, pesticides, halogenated aliphatic hydrocarbons, halogenated esters, monocyclic aromatics, and phthalate esters (Table 7-6). The primary areas of soil contamination are the waste storage area and the former production area. Concentrations of specific radionuclides and nonradiological constituents in FEMP soils are presented in Part I, Sections 4.1.5 and 4.1.6.

Relationships of soils with other environmental media under the no action alternative include the loss of soils and associated contaminants to air, surface water, and groundwater. The Waste Pit 6 removal action (Part I, Section 1.2.2), the submergence of exposed waste into a deeper area of the pit, should reduce the current release of contaminated soil particles to the air, although confirmatory data are not yet available. Erosion of other areas of the site may, as described in section 7.1, result in the redistribution of soil contaminants into air. This current impact is expected to be minor and primarily for radon. In the future, FEMP soils may be used for agricultural as well as residential development. Physical processes associated with these activities could lead to an expansion of soil and contaminant release through wind suspension, due to the increased exposure of soil to the atmosphere.

Runoff of surface water and surficial soils under the no action alternative would be about the same as present conditions. However, future increases in contamination could occur if contained wastes remaining on-property were to be released to the environment. While this is unlikely to occur in the waste storage areas and near Silos 1 and 2 for several decades, drums of mixed waste remaining on property could conceivably deteriorate within several years. If these drums fail, contaminants could be released into the soils adjacent to the holding areas. Subsequent runoff of surface water and contaminated surficial soils could impact surface water to a somewhat greater extent than in the present.

TABLE 7-4
RANGE OF RADIONUCLIDE CONCENTRATIONS DETECTED IN FEMP SOIL SAMPLES

Radionuclide	Range[a] (pCi/g)	Range[b] (pCi/g)	Background[c] (pCi/g)
Cesium-137	0.2-14.4	0.3-450	NA[d]
Radium-226	0.37-2950	0.2-1668.4	1.5
Radium-228	0.32-558	0.9-2.0	1.0
Strontium-90	0.5-26.3	0.8-26	NA
Technetium-99	0.9-320	2.6-2990	NA
Thorium-228	0.6-581	0.1-191	1.0
Thorium-230	0.634-7901	0.1-30520	1.4
Thorium-232	0.35-761	0.1-580	1.0
Uranium-234	0.6-18093	1.7-18200	1.4
Uranium-235/236	0.126-1730	0.09-8780	0.06
Uranium-238	0.6-25670	1.2-18700	1.4

[a] Data are from RI/FS soil samples (surface and subsurface) available on data base as of December 1, 1991.

[b] Data are from CIS surface and subsurface soil samples available on data base as of December 1, 1991 (Weston, 1987).

[c] Background concentrations are reported in the memorandum "Background Concentrations of Radionuclides in the Environment Around the FMPC, Rev. 3," Michael Littleton, September 13, 1990.

[d] Data not available

TABLE 7-5

RANGE OF INORGANIC CHEMICAL CONCENTRATIONS DETECTED IN FEMP SOIL SAMPLES

Chemical	Range[a] (mg/kg)	Range[b] (mg/kg)	Background[c] (mg/kg)
Arsenic	0.02-81.9	2.75-3049	7.4
Barium	0.089-3610	48.37-36939	420
Cadmium	0.003-8.0	0.6-34.84	1.7
Cobalt	0.014-59.5	9.76-450.56	9.2
Cyanide	0.120-22.8	NA[d]	NA
Lead	0.040-440	2.140-613.21	17
Mercury	0.050-1.9	0.03-4.38	0.12
Silver	0.003-20.4	2.25-506	3.0

[a] Data are from RI/FS soil samples available on data base as of December 1, 1991.

[b] Data are from CIS soil samples available on data base as of December 1, 1991 (Weston, 1987).

[c] Background concentrations are arithmetic mean concentrations from U.S. Geological Survey data (Shacklette and Boerngen 1984).

[d] Data not available

TABLE 7-6
RANGE OF ORGANIC CHEMICAL CONCENTRATIONS DETECTED IN FEMP SOIL SAMPLES

Chemical	Range[a] (µg/kg)	Range[b] (µg/kg)
1,1,2,2-Tetrachloroethane	3-350	29000-29000
1,1,2-Trichloroethane	2-14	NA[c]
1,1-Dichloroethane	12-130	3-3
1,1-Dichloroethene	1-44	NA
1,2-Dichloroethene	1-340	NA
2-Butanone	1-2400	70-7900
2-Hexanone	2-10	NA
2-Methylnaphthalene	56-760	50-11000
4-Methyl-2-pentanone	1-330	NA
Acenaphthene	71-4800	80-50000
Acetone	3-190	58-3200
Anthracene	60-6200	74-120000
Benzene	2-5	NA
Benzo(a)anthracene	48-19000	52-18000
Benzo(a)pyrene	46-24000	100-140000
Benzo(b)fluoranthene	45-39000	55-110000
Benzo(g,h,i)perylene	67-12000	65-52000
Benzo(k)fluoranthene	81-5000	84-120000
Benzoic acid	52-250	160-160
Beta-BHC	16-250	NA
Bis(2-ethylhexyl)phthalate	41-8400	49-2300
Carbon disulfide	1-14	NA
Chlorobenzene	1-5	NA
Chloroform	1-330	40-1300
Chrysene	70-18000	64-180000
Di-n-butylphthalate	46-1400	47-490

TABLE 7-6
(Continued)

Chemical	Range[a] (µg/kg)	Range[b] (µg/kg)
Dibenzo(a,h)anthracene	140-6900	65-16000
Dibenzofuran	50-2000	78-36000
Ethylbenzene	2-28	40-270
Fluoranthene	43-33000	74-460000
Fluorene	44-3300	150-62000
Indeno(1,2,3-cd)pyrene	49-13000	78-52000
Methylene chloride	2-6700	21-700
N-nitrosodiphenylamine	43-200	67-130
PCB-1254	10-3000	39-10000
PCB-1260	35-2800	28-7000
Phenanthrene	37-22000	49-370000
Phenol	58-310	140-830
Pyrene	59-22000	72-6300
Styrene	5-5	NA
Tetrachloroethene	1-17000	75-30000
Toluene	1-200	20-440
Tributyl phosphate	170-1200	NA
Trichloroethene	1-10000	170-300
Xylenes, Total	3-31000	260-890

[a] Data are from RI/FS soil samples available on data base as of December 1, 1991.

[b] Data are from CIS soil samples available on data base as of December 1, 1991 (Weston, 1987).

[c] Data not available

Runoff from other areas on the FEMP could continue in both the current and the future time frames. These include runoff of contaminants from the remaining former production area soils and from the active flyash pile into the SSOD. These impacts are expected to be similar to present conditions. Other future considerations include gradual leaking of waste storage facilities, including the waste pits and Silos 1 and 2, that would ultimately lead to an increase of contaminants to the surrounding soil. In addition, the eventual agricultural and residential use of FEMP soils could lead to increased soil exposure and greater soil and contaminant uptake from surface water runoff, which would lead to a contaminant increase over time compared to present releases.

Under the no action alternative, contaminants would continue to migrate from overlying soil into the Great Miami Aquifer. Current indirect impacts from soil to groundwater would remain as under present conditions for all areas. Future impacts would result from an increase of contaminant migration to the aquifer after the eventual failure of the contaminant containment areas (i.e., drummed waste, silos, clay liners of the waste pits). Contaminant migration through the soil would be modified by physical, chemical, and biological processes that can cause a decrease in the concentration of a particular contaminant in the environment. However, the influx of nonmonitored waste material could result in an overall increase of soil contaminants to groundwater.

7.5 Ecological Impacts

This section summarizes potential impacts of the no action alternative on terrestrial and aquatic organisms at and adjacent to the FEMP. The technical approach and detailed analyses of ecological risks associated with exposures of organisms to FEMP contaminants were described previously in Section 6.0, Ecological Assessment. Overall, current and future ecological impacts are associated primarily with exposure to nonradioactive inorganic chemicals, including arsenic and mercury. Current and future estimated radiation doses are relatively low compared to those reported to have chronic to acute effects on plants and animals. However, exposure to stored wastes, to the most contaminated soils on-property, or to the higher radionuclide concentrations predicted in FEMP runoff could cause radiation doses hazardous to terrestrial and aquatic plants and animals.

7.5.1 Terrestrial Ecology

This section describes potential impacts of the no action alternative on terrestrial plants, animals, and birds, based on the ecological assessment in Section 6.0. Potential impacts of exposure to FEMP contaminants were evaluated for seven wildlife species chosen to represent a variety of potential pathways and positions in the food chain: the white-tailed deer, white-footed mouse, raccoon, red fox, muskrat, American robin, and red-tailed hawk. Potential impacts on vegetation were evaluated based on a generic plant containing both vegetative parts (leaves) and reproductive parts (fruits). Intake of contaminants from surface soil and from Paddys Run surface water was estimated for each indicator species and generic plant. For nonradioactive contaminants, intake rates were compared to literature values for no observed effect levels (NOELs), that is, intake rates having no toxic effect. For

radioactive contaminants, radiation doses due to accumulation of radionuclides in tissue were compared to literature values for chronic to acute effects on organisms.

7.5.1.1 Vegetation

Current and future potential impacts of the no action alternative on vegetation are limited. Aluminum, arsenic and mercury concentrations recorded in FEMP plants during RI/FS sampling exceeded literature background values and levels reported to be toxic or cause a yield loss (Section 6.4.1.1). Other inorganic chemicals were not detected at potentially harmful concentrations. Organic chemicals were not detected in plant samples from the FEMP, and modeled concentrations were low compared to values likely to lead to detectable risks to wildlife via food chain uptake.

Radionuclides have been detected in FEMP vegetation at up to 35.5 pCi/g, which would result in an estimated radiation dose of three rad per year, far below levels reported to have any chronic effects on plants (Klechkovskii et al. 1973). Modeled concentrations of radionuclides in vegetation were much lower than those measured at the FEMP, because the model assumes uptake only from soil, while the measured concentrations probably included airborne deposition. The modeled concentrations are the most representative of future concentrations, assuming that the current air emissions of radionuclides remain low (Section 7.1). Future negative impacts could occur to plants growing in locations such as the waste pit area, where they could take up a variety of radioactive and nonradioactive contaminants to levels which could inhibit growth and reproduction. Future positive impacts of the no action alternative would result from the regrowth of vegetation on areas currently kept mowed or grazed.

7.5.1.2 Wildlife

Similarly to vegetation, current and future potential impacts of the no action alternative on wildlife are primarily associated with exposure to nonradioactive inorganic chemicals. Current impacts are low -- the FEMP supports a variety of wildlife species, with diversity comparable to nearby nonimpacted habitats. Although possible stress effects on American robin reproduction have been reported in the past (Facemire et al. 1990), these effects have not been observed in more recent sampling. Potential impacts, based on the ecological assessment (Section 6.0), could be substantial. Estimated HIs (modeled intake/NOEL) were greater than 1.0 for all ten inorganic chemicals of concern in FEMP soils for which NOELs were located (Table 6-44). These include arsenic, lead, cobalt, and silver. Organic chemicals have not been detected in wildlife samples from the FEMP and modeled intakes are low (Section 6.0).

Potential radionuclide impacts are below levels expected to cause detectable effects. However, this prediction is sensitive to assumptions about the efficiency of transfer of radionuclides up the food chain. In particular, if transfer from prey species to predators, for example, mouse to hawk, is assumed to be highly efficient, predators, including omnivores such as the fox and American robin, could receive radiation doses in the range reported to cause chronic to acute effects. However, as

described previously, such effects have not been observed in the field at the FEMP in the course of a number of ecological studies.

Future negative impacts could occur to animals burrowing into stored wastes or consuming plants growing in locations such as the waste pit area. Potential impacts include direct radiation exposure and intake of a variety of radioactive and nonradioactive contaminants at levels which could inhibit growth and reproduction. Future positive impacts would result from the regrowth of vegetation on the property with a consequent increase in habitat availability and diversity.

7.5.2 Aquatic Ecology

Aquatic environments subject to FEMP effects are the ecosystems of the Great Miami River, Paddys Run, and wetlands within and adjacent to the FEMP property. This section describes potential current and future impacts to these environments from FEMP-related contaminants under the no action alternative.

7.5.2.1 Great Miami River

FEMP contaminants may reach the Great Miami River via inflow from Paddys Run, discharges from the FEMP effluent line at River Mile 24.1, and surface runoff from eastern sections of the FEMP property. These contaminants have the potential to affect aquatic communities of the river, which include phytoplankton (microalgae), attached macroalgae, aquatic vascular plants, invertebrates and fish, as well as several species of amphibians and reptiles.

Low levels of inorganic constituents of concern have been detected in water samples from the Great Miami River, but no organic constituents have been detected. Most inorganic chemicals were orders of magnitude below EPA criteria for the protection of aquatic life (Sections 6.4.3.2, 7.2.1). The upper 95% confidence intervals for cadmium and mercury were above the OEPA average criteria, but not above the maximum. Current impacts of inorganic chemicals therefore appear to be minimal. Estimated radiation doses to organisms in the Great Miami River were below levels expected to cause detectable effects, as described in Section 6.5.3.1. No Great Miami River fish samples have shown detectable radionuclides.

Field surveys of benthic macroinvertebrate communities in the Great Miami River have been conducted by OEPA (1982, 1989) and under the RI/FS. These studies indicate little difference in community structure downstream from the FEMP compared to upstream reference areas (OEPA 1982, 1989; Appendix D). The only effect attributable to the FEMP was possible organic enrichment, which was minor and restricted to the immediate vicinity of the FEMP discharge.

Toxicity testing of FEMP effluent was conducted under the RI/FS (Appendix E). The tests determined both acute (lethality) and chronic (inhibited growth and reproduction) responses of four species of

aquatic organisms to the effluent. The testing, which was performed five times over a period of approximately two years, demonstrated no acute toxicity and only limited chronic toxicity, as described previously in Section 6.5.3.2. There was also no correlation between effluent toxicity and concentrations of radiological or nonradiological contaminants.

Future impacts of the no action alternative could be greater than current. Estimated concentrations of chemicals in runoff from the FEMP are high enough to cause potential impacts to aquatic organisms (Table 6-35A, B). In addition, migration of contaminants and/or deterioration of present containment systems could result in increased exposure of Great Miami River biota to radionuclides and other constituents. However, impacts to organisms of the Great Miami River would be mitigated by distance from the source of contamination and dilution due to the large flow volume of the river.

7.5.2.2 Paddys Run

Under current conditions, Paddys Run receives potentially contaminated stormwater runoff from large areas of the FEMP including the entire waste storage area. This contribution of contaminants would continue under the no action alternative. As described in Section 6.4.3.2, water quality criteria were exceeded for mercury, cadmium, and silver. The total mass loading of uranium to the stream has been estimated at approximately 260 pounds per year (WMCO 1989b), but estimated radiation doses to fish in the stream were below the one rad per day likely to ensure no deleterious effects on aquatic populations (NCRP 1991). No organic chemicals, pesticides or PCBs were detected in surface water, sediments, or aquatic biota of Paddys Run.

Surveys of benthic macroinvertebrate communities in Paddys Run showed a general decline in diversity and in OEPA's Invertebrate Community Index downstream of Silos 1 and 2. However, this apparent decline in community quality was not attributed to FEMP effects but rather to the intermittent nature of the stream at the lower (downstream) sampling stations.

Future impacts, as described in the previous section, could be greater than current impacts, due to additional migration of contaminants or deterioration of present containment systems. As described previously in Section 7.5.2.1, estimated concentrations of chemicals in runoff from the FEMP are high enough to cause potential impacts to aquatic organisms. This could cause toxic effects from inorganic chemicals or radiation doses exceeding the suggested one rad per day limit (NCRP 1991). However, this scenario assumes both high runoff and low flow in Paddys Run, events which are unlikely to occur simultaneously.

7.6 Socioeconomic Impacts

This section discusses the impacts to the local and regional economies resulting from the implementation of a no action alternative at the FEMP. This action might indirectly affect the

following components of the socioeconomic structure: labor force, land use, transportation systems, community services, utilities, natural resources, recreation, housing, and cultural resources.

7.6.1 Economic Activity

If no remedial action were to be initiated at the FEMP, the economy of the six townships comprising the study area should continue in its present form, predominantly influenced by the economy of the greater Cincinnati metropolitan area. The aspects of the local economy under examination include labor force, commercial and industrial activity, and residential development. Under the no action alternative, employment at the FEMP would not continue, assuming there would be no requirement to continue environmental monitoring, to provide security, or to maintain the facility and power plant. This would result in a decrease of 1358 jobs at the FEMP. The present complement of contractors (approximately 250) directly associated with the FEMP would also disperse. Based on the composition of the current workforce at the FEMP (residents of 18 different counties as well as temporary workers from around the country) and the large size of the metropolitan labor force (in excess of 900,000 workers), there should be no direct impact on the local labor market as a result of lowered employment at the FEMP. There should also be no indirect impacts to the service and commercial sectors of the local economy. These types of indirect impacts usually follow major changes in employment and a corresponding migration into or from a region.

Usually, when a large facility is established in a rather isolated location, a number of firms that provide supporting services to the facility locate in the immediate vicinity. In this instance, the FEMP was self-sufficient in some services and purchased other services in the regional and national economy and this type of local FEMP-dependent economy did not develop. The nearby restaurants, retailers, and personal services providers (doctors and dentists, florists) might experience a decline in daytime clientele immediately following the implementation of the no action alternative. For most, this would require a reduction of operations rather than business failures as most have a regular client base from the local residents.

7.6.2 Land Use

Land use in the immediate vicinity of the FEMP is primarily agricultural with concentrations of light industry to the south, as described in Part I, Section 2.2.6.3. There should be no change in existing or projected land use in the immediate vicinity of the FEMP as a result of the implementation of a no action alternative.

Population and economic growth in the Cincinnati metropolitan area has been placing pressure for residential and commercial development on the once predominantly rural areas surrounding the city. Currently this force for residential development is most apparent locally in Ross, northeast of the facility; near Harrison, to the southwest of the FEMP; and adjacent to the Miami Whitewater Forest, south of the FEMP. Given existing conditions, residential development would very slowly move into

the immediate vicinity of the FEMP. Commercial development would probably continue in Ross and would definitely continue in Harrison. The introduction of public water to the presently unserved portions of Crosby Township, included as a part of the South Plume removal action (DOE 1990), might cause residential development, and subsequently commercial development, to accelerate in the presently undeveloped portions of the township. The area near the FEMP would possibly be among the last of the areas to be developed due to the presence of the facility. The majority of development will depend upon the willingness of the property owners to sell or to subdivide.

As discussed in Part I, Section 2.2.6.3, land and property values near the FEMP are comparable to similar properties in the Cincinnati area and follow Cincinnati area market trends with the exception of those properties adjacent to and/or within sight of the FEMP. These properties are generally valued slightly below comparable area properties (RECGC 1987). In the event of no remedial activity occurring at the FEMP, values should continue to reflect these trends. In the event of the announcement of a contaminant release, property values in the vicinity would experience a decline. This decline would most likely be short-lived if the contamination could be fairly easily or quickly contained. Studies of the housing market near Three Mile Island recorded recoveries of housing values to previous levels within four to eight months of the release during a time of high mortgage rates and a slow real estate market (Gamble and Downing, 1982). A more serious release of contaminants might cause a scenario similar to the Love Canal, in which families are moved, homes and property are condemned, and the owners paid a "reasonable market value".

The industrial support services located near the facility would continue to operate with the exception of the environmental consulting offices that are primarily associated with FEMP remediation. It is not unrealistic to predict that in 20 years residential and commercial development might exist on land adjacent to the FEMP at a higher density than exists today (Part I, Section 2.2.6.3). Because there will be no institutional controls, residential development could exist on the FEMP property.

After the 1986 announcement of uranium releases to the atmosphere from the FEMP and the ensuing debate on public health and safety, the Great Rivers Girl Scout Council of Cincinnati closed Camp Ross Trails, located just over one mile northeast of the FEMP. The Council cited concern for the safety of the campers as the cause of the closure of the camp and is presently considering selling the property. Similar activity took place at Camp Fort Scott, a church-affiliated camp just north of New Baltimore. Continued losses of this type might continue under the no action alternative.

7.6.3 Transportation

Reduced employment at the FEMP following the implementation of the no action alternative might beneficially affect current traffic patterns, transportation systems, or road conditions due to fewer commuters on the local roadways as well as fewer trucks with the absence of truck transport to and from the FEMP.

7.6.4 Community Services

Community services such as schools, health care facilities, housing, emergency and protective services, recreational resources, and wastewater treatment systems could be affected by the implementation of a no action alternative.

Recreational use of the Great Miami River would not be affected by the implementation of a no action alternative. Both current and future potential impacts of the FEMP on Great Miami River water quality are not likely to be of concern. Dilution of the uranium-contaminated groundwater in the South Plume when it reaches the river would be reduced to very low levels (described in greater detail in Section 7.4). There should be no impacts to the Miami Whitewater Forest due to its distance from the facility. Additional closures of recreational facilities such as the Camp Ross Trails might continue under the no action alternative.

Impacts to natural resources, discussed in earlier sections on air, surface water, soils, biota, and groundwater, could affect the local community. In both current and future scenarios, contamination of ambient air, surface water, groundwater, and soils in the vicinity of the FEMP is possible through gradual deterioration of waste containment systems or resuspension of contaminated particles caused by turbulence. Additionally, contaminant loading rates of most sources into the aquifer will increase in the future, and many sources will continue releasing contaminants to the aquifer beyond 1000 years. Contaminants present in perched groundwater could also migrate to the aquifer over time, with perched water beneath the waste storage and former production areas posing the most serious threat. Currently contaminated groundwater would not be prevented from migrating to unaffected areas. Modeling results predict future uranium concentrations much higher than those currently measured in the aquifer to occur. Wastes that would remain in the former production and waste storage areas are expected to migrate to the aquifer and form a large and highly concentrated uranium plume that will extend beyond the eastern FEMP property boundary. This plume is expected to remain above levels of concern even after 1000 years.

Aside from the implications of hazards to human health and the environment, negative impacts to the local economy might arise from any accidental releases that are real or even perceived or from contamination of the local water supply as a result of movement of the groundwater. An additional factor to be considered in this area is public acceptance of the no action alternative. The State of Ohio currently has filed a case against DOE in the Ohio Supreme Court concerning alleged environmental damages associated with FEMP production practices. The case is held pending the outcome of the RI/FS. Also a highly vocal, grass-roots coalition involving local residents has evolved and gained recognition in the national press. The implementation of a no action alternative at the FEMP would likely become a target of vigorous local and state opposition.

7.6.5 Cultural Resources

There are a number of historic and archaeological resources in the vicinity of the FEMP (described in detail in Part I, Section 2.2.6.6). No direct impacts to historic or archaeological resources should result from the implementation of the no action alternative. However, if any of these resources are currently being subjected to contamination through releases to the air or groundwater, this damage would continue. For example, if there were an undiscovered Adena village located within the boundaries of the South Plume, the artifacts may be contaminated.

7.7 Summary

Under the no action alternative, the FEMP would effectively be abandoned and left as is. There would be no remedial action to mitigate existing sources of contamination or any media contaminated by previous activities at the site. In both current and future scenarios, the continued release of contaminants to various media is possible. These releases may result from deterioration of waste containment systems, continued air and water erosion of contaminated soils, or the various chemical/physical processes ongoing in groundwater. In addition to the possible threat to human health and the environment associated with no action at the site, the local economy may be impacted by public perceptions of the situation at the FEMP.

Despite the "no production" status of the FEMP, there is a potential for additional emissions to air. Currently, existing areas of contamination may continue to release to the air. In the future, the gradual deterioration of waste containment systems may expose additional contaminants to movement through resuspension in the air. The downwind concentrations of contaminants may vary widely, depending on atmospheric conditions.

Under the no action alternative, current impacts of the FEMP on the Great Miami River, Paddys Run, and the SSOD would continue. Impacts to the Great Miami River include releases of radionuclides and inorganic chemicals via the FEMP effluent line and Paddys Run. However, the existing site-related concentrations of these substances in the Great Miami River are virtually undetectable with the exception of uranium, which is low. Impacts to Paddys Run include radioactive and chemical contamination associated with erosion of contaminated soils from the waste pit area and the erosion of wastes or contaminated soils from the active flyash pile into the SSOD. Current potential impacts of the FEMP on Great Miami River, Paddys Run, and the SSOD sediments include radioactive and chemical contamination. Future impacts on sediments would be correlated with impacts on surface waters. Contamination of sediments at specific sites in Paddys Run is unlikely to be stable, due to the highly variable flow regime in the stream, with consequent frequent transport and redeposition of stream bed material. The no action alternative would likely have no current or future impacts on floodplains in the Great Miami River and Paddys Run. Future indirect impacts on wetlands could vary widely as a result of erosion of wastes or contaminated soils.

Under the no action alternative, existing contaminated groundwater would continue migrating to currently unaffected areas. In the future, contaminant loading rates to the aquifer from most sources will increase. Many of these sources will continue releasing contaminants to the aquifer beyond 1000 years in the future. Contaminated perched groundwater might also migrate to the aquifer over time. The perched groundwater beneath the waste storage and former production areas pose the most serious threat. Under the no action alternative, groundwater modeling predicts future groundwater uranium concentrations much higher than those currently measured. Wastes remaining on the site are expected to migrate to the aquifer to form a large and highly concentrated uranium plume, extending beyond the eastern FEMP boundary. This plume is anticipated to remain above levels of concern beyond 1000 years in the future.

With implementation of the no action alternative, contaminated soils would continue to be lost to air, surface water and groundwater. Future impacts to FEMP soils may be associated with increased releases of contaminants through deterioration of waste containment systems, with related impacts to air, surface water and groundwater. These impacts are expected to be greater than under present conditions due to gradual release of wastes remaining on site, the abandonment of existing environmental monitoring systems, and the removal of existing land use and site access restrictions.

Overall, current and future impacts to the local ecology are associated primarily with exposure to nonradioactive inorganic chemicals, including arsenic and mercury. Current and future estimated radiation doses are relatively low compared to those reported to have chronic to acute effects on plants and animals. However, exposure to stored wastes, to the most contaminated soils on-property, or to the higher of predicted radionuclide concentrations in FEMP runoff could cause radiation doses hazardous to terrestrial and aquatic plants and animals.

The implementation of a no action alternative at the FEMP should not affect the local labor force, transportation systems, community services, utilities, recreation, housing, or cultural resources. Commercial establishments in the immediate vicinity might experience a decline in daytime clientele, however, this should not result in business failures. Land use adjacent to the FEMP should remain predominantly agricultural for the next 20 years. Value of adjacent land should remain slightly below similar properties farther from the site. An important factor to be considered in this area is public acceptance of the no action alternative. The implementation of a no action alternative at the FEMP would likely become a target of vigorous local and state opposition.

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PART III

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SITE-WIDE CHARACTERIZATION REPORT

PART III
FEASIBILITY STUDY SUPPORT

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

AUGUST 1992

DRAFT

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LIST OF ACRONYMS

ACL	alternate concentration limit
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DAF	dilution attenuation factor
EPA	U.S. Environmental Protection Agency
EWMF	engineered waste management facility
FEMP	Fernald Environmental Management Project
FRL	Final remediation level
LRA	leading remedial alternative
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MF	modifying factors
NCP	National Contingency Plan
NESHAP	National Pollutant Discharge Elimination System
ODW	Office of Drinking Water
PEF	particulate emission factor
PRG	preliminary remediation goal
QA	quality assurance
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RFD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RSC	relative source contribution
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
THI	target hazard index
THQ	target hazard quotient
TR	target risk [levels]

PART III SUMMARY

Part III of the Site-Wide Characterization Report presents two types of information necessary to progress from Remedial Investigation (RI) to Feasibility Study (FS). These include development of Preliminary Remediation Goals (PRGs) and selection of Leading Remedial Alternatives (LRAs) for use in the FS/Comprehensive Response Action Risk Evaluations.

PRGs were developed based on the following future land use assumptions. For groundwater exposures, residential land use is assumed. For soil exposures, both residential and recreational. For perched water exposures, PRGs are based on an assumption that shallow water may leach to the regional aquifer.

In addition, PRGs are based on the following:

- For chemical toxicants, a Hazard Index = 0.2
- For chemical and radiation carcinogens, an Incremental Lifetime Cancer Risk = 10^{-6}
- For radionuclides, dose limit ARARs/TBCs
- Pertinent ARARs, where available

Complete lists of PRGs are provided for each environmental medium.

The Amended Consent Agreement defines the LRA as follows:

> the Leading Remedial Alternative shall mean the remedial alternative which, based upon all available data and best professional judgement, consistent with CERCLA, is the most likely to be selected as the response action for an OU. The Leading Remedial Alternative does not represent the pre-selection of a remedy and shall be used only for the purpose of estimating and evaluating the risk presented by the entire Site during the FS/Comprehensive Response Action Risk Evaluations for Operable Units 1-5. The Leading Remedial Alternative shall in no way prescribe or restrict the selection of the remedy for the Operable Units 1-5 RODs.

The LRA for Operable Unit 1 involves the removal and treatment of sufficient waste materials from Waste Pits 1-6, the burn Pit and the Clearwell and/or associated contaminated soils to achieve risk-based PRGs and ARARs. The excavated area will be filled with compacted soils. Any remaining waste and contaminated soils in the Operable Unit 1 area will be stabilized and covered with a closure cap. The excavated materials will be treated and placed within an on-property engineered aboveground disposal facility. This alternative also includes continued federal ownership of the land to control future land use.

The LRA for Operable Unit 2 is capping each of the waste units with a multilayer RCRA-type cap. Regrading of the waste and runoff/run-on controls also would be employed. This alternative would

prevent direct contact with the waste and surface transport of waste. This alternative also includes continued federal, through ownership of the land to control future land use. The drainage north of the Solid Waste Landfill, an emergent wetland area, may require realignment to implement the LRA on this waste unit. For the lime sludge ponds, a shallow-soil mixing technology will be used before capping. For the Flyash/South Field areas, Paddys Run is identified as a floodplain and may require realignment to implement the LRAs.

The LRA selected for Operable Unit 3 involves the removal, treatment/decontamination, and disposal of contaminated materials to reduce the potential for contaminant migration. Decontamination and treatment residues would require further treatment and disposal. Contaminated materials will be disposed of in an on-property engineered aboveground disposal facility and clean materials will be free released for reuse or recycling. The selection of this LRA is based on limited characterization and engineering study data and may change. This alternative also includes continued federal ownership of the land to control future land use.

The LRA for Operable Unit 4 involves the removal of the stored waste inventories from Silos 1, 2, and 3. Contaminated soil and construction material from the silo berms, subsoil and the decant tank will be removed to the extent necessary to achieve risk-based PRGs and ARARs. Removed waste material from Silos 1 and 2 will undergo a contaminant separation process to reduce the concentrations of long-lived alpha emitting radioactive constituents. Treated Silos 1, 2 and 3 waste will be stabilized and placed within an on-property engineered aboveground disposal facility. Concentrated wastes from the contaminant separation process will be stabilized and placed in an interim on-property storage facility pending shipment to an off-site disposal facility. Soil removal, necessary to meet risk-based PRGs and ARARs, will be disposed of in an on-property disposal facility. Silo 4 is an unused facility and will be dispositioned as a no-action alternative. The LRA also includes continued federal ownership of the land to control future land use.

The LRA for Operable Unit 5 involves the extraction of contaminated groundwater, treatment at an on-property facility, and discharge of the treated effluent to the Great Miami River through the newly constructed effluent line. Treatment residuals will be disposed of in an on-property engineered aboveground disposal facility. The LRA also involves the excavation of contaminated sediments/soils necessary to meet risk-based PRGs and ARARs, transport to an on-property location for treatment using a fluidized soil washing technique, and returning the treated materials as backfill. The soil washing fluids will be recycled and the removed contaminants will be stabilized and disposed in the on-property facility. This alternative also includes continued federal ownership of the land to control future land use.

1.0 INTRODUCTION

The purpose of Part III of the Site-Wide Characterization Report is to provide information necessary to make the transition from site characterization to the selection of remedial technologies. Two site-wide tasks support feasibility study work: development of preliminary remediation goals (PRGs), and the selection of leading remedial alternatives (LRA).

1.1 OBJECTIVES

Section 2.0 presents PRGs for the Fernald Environmental Management Project (FEMP). In the early stages of the Remedial Investigation/Feasibility Study (RI/FS), PRGs are used as action levels to determine if concentrations in the environment need to be addressed further. If detected chemical concentrations are greater than PRGs, the FS should address the contaminants. PRGs are not final cleanup levels. They will be further refined based on the results of the operable unit-specific baseline risk assessments and other considerations before they become final remediation goals.

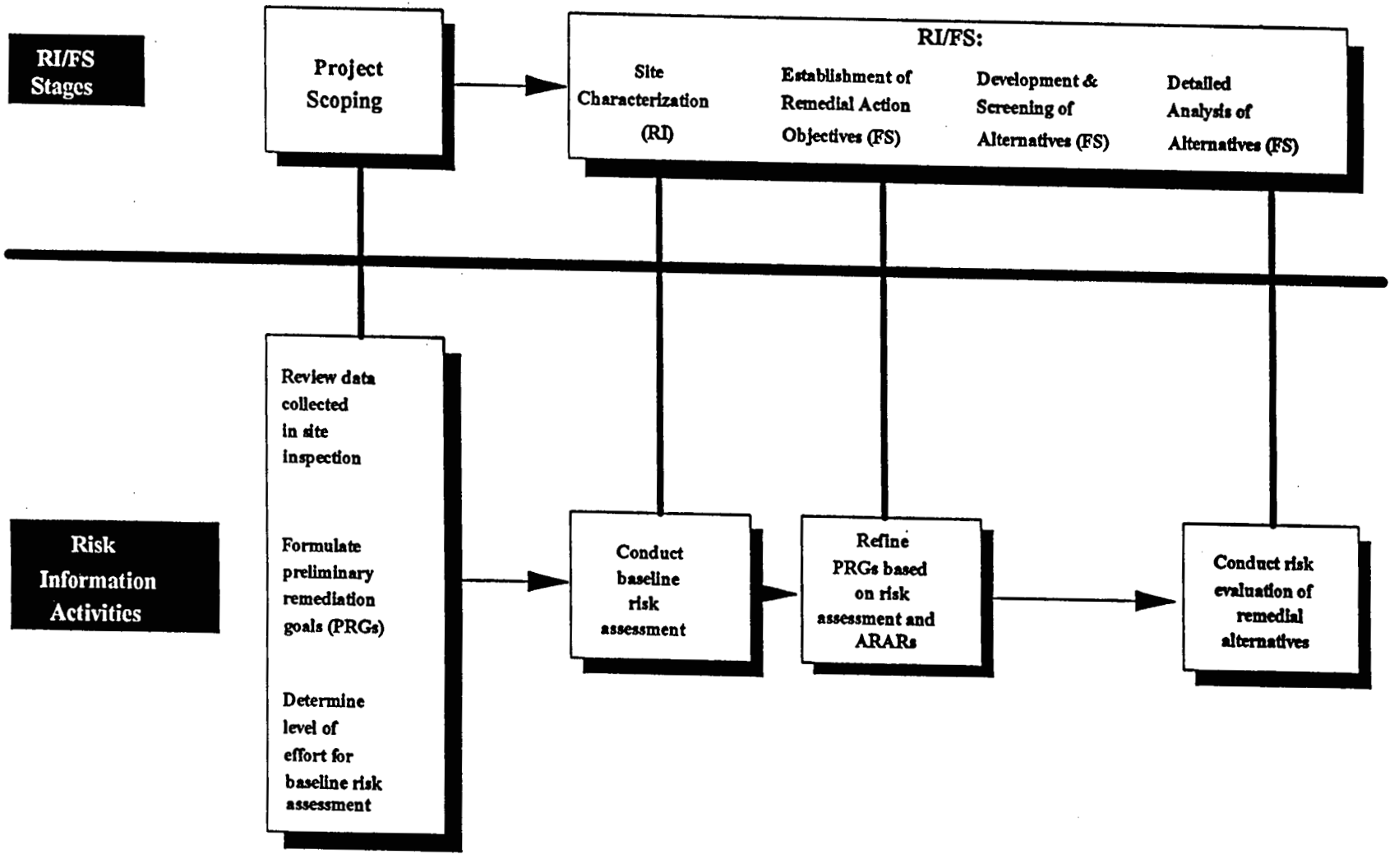
Section 3.0 of Part III presents the selection of the LRAs as defined in the Amended Consent Agreement,

> the Leading Remedial Alternative shall mean the remedial alternative which, based upon all available data and best professional judgement, consistent with CERCLA, is the most likely to be selected as the response action for an OU. The Leading Remedial Alternative does not represent the pre-selection of a remedy and shall be used only for the purpose of estimating and evaluating the risk presented by the entire Site during the FS/Comprehensive Response Action Risk Evaluations for Operable Units 1-5. The Leading Remedial Alternative shall in no way prescribe or restrict the selection of the remedy for the Operable Units 1-5 RODs.

LRAs are required to begin the process of managing and optimizing risks from a site-wide perspective. They will be used in the FS/Comprehensive Response Action Risk Evaluations (CRARE), which are attached to each operable unit-specific FS. The CRARE will estimate the residual risk at the entire site following remediation of all operable units for each operable unit which has completed the FS process, the selected alternative will be used to estimate residual risk associated with that operable unit. For any operable unit which has not completed the FS process, the LRA will be used as a surrogate for a selected alternative. For example, the CRARE for Operable Unit 2 will be based on the selected alternative for Operable Unit 2 and the LRAs for Operable Units 1, 3, 4, and 5.

1.2 TECHNICAL ISSUES

One of the issues of importance to both the development of PRGs and the selection of LRAs is the use of institutional controls in the remedy selection process. One of the first steps in developing PRGs is the selection of a future land use scenario for which appropriate exposure pathways and parameters are selected. A future land use scenario may or may not assume the loss of ownership controls at a site.



Source: Adopted from EPA 1989a

FIGURE 1-1. RISK INFORMATION ACTIVITIES IN THE RI/FS PROCESS

In selecting LRAs for the FEMP, an assumption had to be made concerning future control of the FEMP property, because many of the alternatives require waste management to continue on-property.

For both PRG development and LRA selection, it has been assumed that the government will retain control of the land in the future. Thus, PRGs have been developed based on a future recreational scenario, and each of the selected LRAs requires that the government retain control of the property.

In accordance with the Risk Assessment Work Plan Addendum (WPA) (DOE, 1992) and to be consistent with the U.S. Environmental Protection Agency's, (EPA) guidance "Part B, Development of Risk-Based Preliminary Remediation Goals," PRGs for groundwater are based on residential use of water. Any water deemed "drinkable" should be evaluated for residential use. Also to be consistent with the WPA, PRGs for soil are developed using the future residential land use scenario.

The basis for presenting both residential and recreational PRGs is to provide flexibility to engineers during the preparation of operable unit FSs and to provide PRGs that can be used to support the selected LRAs. While the goal remains to achieve residential-based PRGs, it may be determined that a viable alternative cannot achieve these values, technologically or in a cost-effective manner. EPA (1991a), states:

> In cases where the alternative that represents the best balance of factors is not able to attain cancer risks within the risk range of an HI of 1, institutional controls may be used to supplement treatment.

A second issue of importance is the concept of apportioning allowable site-wide risk among all chemicals for all operable units. In developing PRGs, a target risk of 10^{-6} has been selected, even though the allowable risk range is 1×10^{-4} to 1×10^{-6}. This was selected to avoid exceeding the 10^{-4} allowable cumulative risk. By starting with 10^{-6}, it would take 100 significant additive risks to a single receptor to exceed 10^{-4} and this is not likely to happen. Thus, in selecting LRAs, it can be assumed that if the alternative can meet all PRGs, it is not likely that sitewide risks could be exceeded.

1.3 Deviations from the Risk Assessment Work Plan Addendum

Calculation of PRGs was performed in accordance with the WPA, with the following exceptions:

- Groundwater PRGs for radionuclides are developed from a 10^{-6} target risk level and from applicable, relevant, and appropriate requirements (ARARs) and those to be considered (TBCs). The ARARs/TBCs include maximum contaminant levels (MCLs) and proposed MCLs. In addition, the 4 mrem/year MCL for man-made beta and gamma emitters is interpreted to apply to alpha emitters. In this instance, PRGs are calculated using committed effective dose equivalents (CEDE) to a 4 mrem/year intake assuming a drinking water rate of 730 ℓ/year, and using dose conversion factors (DCF) from EPA's "Federal Guidance Report No. 11" (EPA, 1988b).

- In addition to calculating PRGs for soil based on the residential land use scenario, PRGs have also been calculated assuming the future recreational land use scenario. Values for both the residential and recreational scenarios are calculated using both a 10^{-6} target risk and a 100 mrem dose limit, from 10CFR20, for allowable exposures to the general public.

2.0 PRELIMINARY REMEDIATION GOALS

PRGs are "initial cleanup goals that 1) are protective of human health and the environment and 2) comply with ARARs. They are developed early in the process and are based on readily available information" (EPA 1991a). These goals are used by engineers as design criteria during development and selection of remedial alternatives. PRGs are a subset of remedial action objectives (RAOs), which are site-specific, qualitative goals that define the extent of cleanup required to achieve a CERCLA response action (EPA 1988a). RAOs address contaminants of concern, media of concern, potential exposure pathways and preliminary remediation goals (EPA 1990a). Figure 1-1 shows the relationship between PRGs and the rest of the RI/FS process.

PRGs are chemical-specific, medium-specific numerical concentration limits that should address all contaminants and all pathways found to be of concern during the baseline risk assessment process. Remediation goals are defined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) at 40CFR300.430(e)(2)(i) as:

> (A) Applicable or relevant and appropriate requirements under federal environmental or state environmental or facility citing laws, if available, and the following factors:
>
> 1) For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety
>
> 2) For known or suspected carcinogens, acceptable exposure levels are generally concentration levels representing an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response. The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure
>
> 3) Factors related to technical limitations such as detection/quantification limits for contaminants
>
> 4) Factors related to uncertainty
>
> 5) Other pertinent information
>
> (B) Maximum contaminant level goals (MCLGs) established under the Safe Drinking Water Act, that are set at levels above zero, shall be attained by remedial actions for ground or surface waters that are current or potential sources of drinking water, where the MCLGs are relevant and appropriate under the circumstances of the release based on the factors in § 300.400(g)(2). If an MCLG is determined not to be relevant and appropriate, the corresponding maximum contaminant level (MCL) shall be attained where relevant and appropriate to the circumstances of the release.

(C) Where the MCLG for a contaminant has been set at a level of zero, the MCL promulgated for that contaminant under the Safe Drinking Water Act shall be attained by remedial actions for ground or surface waters that are current or potential sources of drinking water, where the MCL is relevant and appropriate under the circumstances of the release based on the factors in § 300.400(g)(2).

(D) In cases involving multiple contaminants or pathways where attainment of chemical-specific ARARs will result in cumulative risk in excess of 10^{-4}, criteria in paragraph (e)(2)(i)(A) of this section may also be considered when determining the cleanup level to be attained.

(E) Water quality criteria established under sections 303 or 304 of the Clean Water Act shall be attained where relevant and appropriate under the circumstances of the release.

(F) An alternate concentration limit (ACL) may be established in accordance with CERCLA section 121(d)(2)(B)(ii).

(G) Environmental evaluations shall be performed to assess threats to the environment, especially sensitive habitats and critical habitats of species protected under the Endangered Species Act (EPA 1990a).

Ideally, PRGs should comply with ARARs and be protective of human health and the environment. However, many ARARs have not been derived from risk levels that would meet the CERCLA objective of "protectiveness of human health." In other words, PRGs based on ARARs could be less stringent than criteria based on the 10^{-4} to 10^{-6} risk level. This is especially true for radionuclides. Therefore, both ARAR-based and risk-based PRGs have been developed for the FEMP.

At the FEMP, a single set of PRGs has been developed for all operable units. Because the initial PRGs are generic for the site and not operable unit-specific, they are based on generic default exposure pathways and equation assumptions recommended by in EPA (1991a) and the exposure parameters presented in the WPA (DOE 1992a) and are the same parameters used in the baseline risk assessment. The exposure pathways used to develop site-wide PRGs are considered to be "limiting" pathways, viz., pathways that often are responsible for much of the baseline risk.

Initial PRGs may need to be modified as operable unit-specific baseline risk assessments are completed. In using initial PRGs in the early stages of the alternative screening process, engineers should understand that PRGs may be modified and should make the design of alternatives flexible. Chemicals may be added or deleted from the list of chemicals of concern or PRGs may need to be modified based on the identification of additional limiting pathways. Modified PRGs will be presented in the operable unit FS reports.

Modified PRGs are refined into final remediation levels (FRLs) and presented in the Record of Decision. Final remediation levels must meet threshold criteria of "protection of human health and the

environment" and "compliance with ARARs," (EPA 1991a):

> However, the NCP also allows for modification of PRGs during final remedy selection based on the "balancing" and "modifying" criteria and factors relating to uncertainty, exposure and technical feasibility.

Note should be taken that, with the exception of recommending the inclusion of environmental ARARs in the selection of PRGs, EPA (1991a) addresses human health effects only. Available environmental ARARs, for example, ambient water quality criteria (AWQC), are used to develop surface water PRGs.

2.1 METHODS FOR RISK-BASED PRGs

Development of initial risk-based PRGs requires the following information:

- Chemicals of potential concern
- Environmental media of potential concern
- Probable future land use and exposures
- Chemical-specific toxicity information
- Target risk levels

Chemicals of potential concern and environmental media of potential concern for the site are presented in Part II of this report, the Preliminary Baseline Risk Assessment. Probable future land use is also described in Part II. To develop PRGs, it is assumed that the future reasonable maximum exposure scenario is the resident farmer because of the current prevailing farming practices off-property at Fernald. Another "recreational" scenario is evaluated for surface soils. Toxicity data used to develop PRGs are cancer slope factors and reference doses from the IRIS database (EPA 1992) and Health Effects Assessment Summary Tables (EPA 1991b). Target risk levels and future exposure are addressed here in more detail.

2.1.1 Target Risk Levels

In developing risk-based PRGs, target risk levels (TR) must be established for carcinogens and a target hazard quotient (THQ) and target hazard index (THI) (the sum of the THQs) must be established for noncarcinogens. Once these levels are established, they can be used in conjunction with toxicity data and exposure equations to calculate PRGs.

One of the goals of the NCP is to manage total site-wide risks such that the sum of all risks does not exceed 10^{-4}. The default target risk of 10^{-6} suggested by EPA (1991a) will be used as a target risk for the FEMP PRGs. Use of the 10^{-6} target risk helps to insure that cumulative site-wide risk does not exceed 10^{-4}.

EPA indicates that the cumulative site hazard index (HI) should be less than 1. However, while total noncancer effects cannot exceed a HI of 1, no direct guidance is available on apportioning the allowable level among the various chemicals in the various environmental media. The most applicable regulatory guidance comes from the Office of Drinking Water (ODW), which, in calculating MCLGs, uses a relative source contribution (RSC) factor to account for the contribution from other sources of exposure (EPA 1989b). If sufficient data are not available to evaluate the drinking water exposure relative to other exposures, ODW assumes other exposures account for 80 percent of the total, leaving 20 percent for water. Thus, the default RSC is 20 percent (0.20).

This method can be adapted to the development of PRGs for noncarcinogens. Because it is not known what additional sources are contributing to total exposure, the default RSC of 0.20 will be used to develop individual chemical-/media-specific PRGs, helping to insure that the total THI from each exposure does not exceed 1. The THQ for medium-specific, noncarcinogenic effects will be 0.2, helping to insure that the total HI from multi-contaminant/multi-pathway exposures is less than or equal to 1, as recommended by EPA (1991a).

2.1.2 Land Use

A second major requirement in establishing site-related PRGs is to identify the most appropriate future land use for the site and select the appropriate exposure pathways, parameters, and equations that are often significant contributors to risk for each medium.

The WPA requires that the baseline risk assessments at the FEMP evaluate a residential land use scenario to understand potential worst-case exposures. However, the federal government may retain ownership of the property to maintain and monitor proposed caps and/or the engineered waste management facility (EWMF) for waste that is proposed to be managed on-property. In this case, the most likely future land-use scenario is a recreational scenario. An industrial scenario does not apply since the property is not planned to be used for industrial production.

2.1.2.1 Groundwater Exposures

Because the NCP encourages protection of groundwater for its maximum use, and since groundwater in the Great Miami Aquifer is "drinkable," risk-based PRGs will be calculated assuming groundwater as potable water. EPA suggests using the drinking water exposure pathways for determining PRGs (EPA 1991a). Where volatile organic compounds are present in the water, a second pathway, inhalation while showering, should be used. However, with the exception of a few positive detections of 1,1,1-trichloroethane in the groundwater, volatiles do not appear to be of concern in the groundwater at the FEMP. Additionally, they are not present in the aquifer or in the waste unit sources in sufficient quantities to warrant evaluating volatilization from showering. Thus, the drinking water pathway will be the sole exposure pathway used to develop risk-based PRGs for organic compounds, inorganics, and radionuclides.

Site-specific parameters used to developed the PRGs are available in the WPA, Sections 6.0 and 7.0. Equations used are from RAGS (EPA 1991a).

For noncarcinogens, the groundwater exposure equation is:

$$C_w = \frac{(THI)(BW)(AT)(365\ days/yr)}{(EF)(ED)[(1/RfD_o)(IR_w)]} \qquad (2\text{-}1)$$

where

C_w	=	PRG concentration in water (mg/ℓ)
THI	=	Target Hazard Index (0.20)
RfD_o	=	Oral reference dose (mg/kg/day) (chemical specific)
BW	=	Adult body weight (70 kg)
AT	=	Averaging time (70 yr)
EF	=	Exposure frequency (350 days/yr)
ED	=	Exposure duration (70 yr)
IR_w	=	Daily water ingestion rate (2 ℓ/day)

For chemical carcinogens, the exposure equation is:

$$C_w = \frac{(TR)(BW)(AT)(365\ days/year)}{(ED)(EF)[(SF_o)(IRw)]} \qquad (2\text{-}2)$$

where

C_w	=	PRG concentration in water (mg/ℓ)
TR	=	Target risk (1×10^{-6}).
BW	=	Adult body weight (70 kg)
AT	=	Averaging time (70 yr)
EF	=	Exposure frequency (350 days/yr)
ED	=	Exposure duration (70 yr)
SF_o	=	Oral slope factor $(mg/kg/day)^{-1}$ (chemical specific)
IR_w	=	Daily water ingestion rate (2 ℓ/day)

For radionuclides the exposure equation is:

$$C_w = \frac{(TR)}{(EF)(ED)(SF_o)(IR_w)} \qquad (2\text{-}3)$$

where

C_w	=	PRG concentration in water (pCi/ℓ)
TR	=	Target risk (1×10^{-6})
EF	=	Exposure frequency (350 d/yr)
ED	=	Exposure duration (70 yr)

IR_w = Ingestion rate (2 ℓ/d)
SF_o = Oral slope factor (risk/pCi)

For radon, the equation is:

$$C_w = \frac{TR}{(EF)(ED)(SF_o)(IR_w)} \quad (2\text{-}4)$$

where

C_w = PRG concentration in water (pCi/ℓ)
TR = Target risk (1×10^{-6}).
EF = Exposure frequency (350 days/yr)
ED = Exposure duration (70 yr)
SF_o = Oral slope factor (risk/pCi) (chemical specific)
IR_w = Daily water ingestion rate (2 ℓ/day)

Dose based PRGs for groundwater are calculated using Equation 2-3 and an annual dose limit of 4 mrem/yr:

$$C_w = \frac{TD}{(EF)(IR_w)(DCF)} \quad (2\text{-}5)$$

where

C_w = PRG concentration in water (pCi/ℓ)
TD = Target dose (4 mrem/yr)
EF = Exposure frequency (350 d/yr)
IR_w = Ingestion rate (2 ℓ/d)
DCF_o = Oral dose conversion factor (mrem/pCi)

2.1.2.2 Exposures to Perched Water

PRGs for perched water that is deemed usable for potable water will be based on Equations 2-1 through 2-3 for groundwater exposures. However, many of the perched zones at the site are of limited areal extent and have low hydraulic conductivity, leading to low yield rates. These zones cannot be relied upon as year-round potable water sources. In general, typical rates for potable water wells are 200 gallons per day sustained yield (California State Water Resources Control Board) to 400 gallons per day for a family of four (Henderson and Jones 1982; Reid 1965).

For perched water that is not a potential potable water source, PRGs will be developed based on the potential for chemicals in those perched zones to leach into the regional aquifer or a receiving surface water body, thereby equating water in the shallow zones to "leachate." Leachate is regulated by EPA under 40CFR261 with the use of the toxicity characteristic leaching procedure (TCLP). TCLP regulatory levels are based on the acceptable drinking water concentrations multiplied by a dilution

attenuation factor (DAF) which accounts for the degree of attenuation and dilution that a compound is expected to undergo during transport to the drinking water aquifer or receiving stream (EPA 1986a).

Both risk-based and ARAR-based acceptable drinking water concentrations will be used to develop PRGs for the perched waters. These values will be multiplied by the default DAF of 100 (EPA 1986a).

2.1.2.3 Exposures to Soil and Waste Materials

PRGs for soil are developed based on the assumption that people will come into direct contact with soil and waste material, through either residential or recreational activities. EPA is currently evaluating methods for developing soil PRGs based on the potential of soil contaminants to leach to groundwater. This is necessary when no direct contact with contaminants is expected to occur. Methods are available for this purpose (EPA 1989c, Summer et al. 1980) and may be used for operable unit-specific PRGs if deemed necessary.

The same exposure pathways are evaluated for the residential and recreational scenarios. The differences lie in several parameters including exposure duration, exposure frequency, and shielding factors. Equations 2-4 through 2-7 present the methods and parameters used for evaluating residential exposures.

For volatile organic noncarcinogenic effects, the exposure equation is:

$$C_s = \frac{(THI)(BW)(AT)(365 days/yr)}{(EF)(ED)[((1/RfD_o)(CF)(IR_s))+((1/RfD_i)(IR_a)(1/VF+1/PEF))]} \qquad (2\text{-}6)$$

where

C_s	=	PRG concentration in soil (mg/kg)
THI	=	Target Hazard Index (0.20)
RfD_o	=	Oral reference dose (mg/kg/day)
RfD_i	=	Inhalation reference dose (mg/kg/day)
BW	=	Adult body weight (70 kg)
AT	=	Averaging time (70 yr)
EF	=	Exposure frequency (350 days/yr)
ED	=	Exposure duration (70 yr)
IR_s	=	Daily soil ingestion rate (109 mg/day)
IR_a	=	Daily inhalation rate (20 m^3/day)
VF	=	Soil-to-air volatilization factor (m^3/kg)
PEF	=	Particulate emission factor (m^3/kg)
CF	=	Conversion factor (10^{-6} kg/mg)

For nonvolatile organics and inorganic noncarcinogenic effects, Equation 2-6 may be used without the expression for volatilization (1/VF).

For volatile organic chemical carcinogens, the exposure equation is:

$$C_s = \frac{(TR)(BW)(AT)(365 days/yr)}{(EF)(ED)[((SF_o)(CF)(IR_s))+((SF_i)(IR_a)(1/VF+1/PEF))]} \quad (2\text{-}7)$$

where

C_s	=	PRG concentration in soil (mg/kg)
TR	=	Target risk (1×10^{-6}).
BW	=	Adult body weight (70 kg)
AT	=	Averaging time (70 yr)
EF	=	Exposure frequency (350 days/yr)
ED	=	Exposure duration (70 yr)
SF_o	=	Oral slope factor $(mg/kg/day)^{-1}$
SF_i	=	Inhalation slope factor $(mg/kg/day)^{-1}$
IR_s	=	Daily soil ingestion rate (109 mg/day)
IR_a	=	Daily inhalation rate (20 m^3/day)
VF	=	Soil-to-air volatilization factor (m^3/kg)
PEF	=	Particulate emission factor (m^3/kg)
CF	=	Conversion factor (10^{-6} kg/mg)

For nonvolatile organics and inorganic carcinogens, Equation 2-7 may be used without the expression for volatilization (1/VF).

For radionuclides, the exposure equation is:

$$C_s = \frac{TR}{(ED)([(SF_o)(CF)(EF)(IR_s)]+[(SF_e)(1-S_e)(T_e)])} \quad (2\text{-}8)$$

where

C_w	=	PRG concentration in soil (pCi/g)
TR	=	Target risk (1×10^{-6}).
EF	=	Exposure frequency (350 days/yr)
ED	=	Exposure duration (70 yr)
SF_o	=	Oral slope factor (risk/pCi)
SF_e	=	External exposure slope factor (risk/yr per pCi/g)
IR_s	=	Daily soil ingestion rate (0.109 g/day)
S_e	=	Gamma shielding factor (unitless)
T_e	=	Gamma exposure time factor (unitless)
CF	=	Conversion factor (10^{-3})

The equation for estimating soil PRGs using a dose limit is:

$$C_s = \frac{TD}{(IR)(EF)(DCF)+(SF_e)(1-S_e)(T_e)(RDF)} \qquad (2\text{-}9)$$

where

TD	=	Target dose (100 mrem/yr)
C_s	=	PRG in soil (pCi/g)
IR	=	Ingestion rate (0.109 g/day)
EF	=	Exposure frequency (350 d/yr)
S_e	=	Gamma shielding factor (0.25)
ED	=	Exposure duration (70 yr)
T_e	=	Exposure time (14hr/d)(350d/yr)(yr/8760 hr)
DCF	=	Ingestion dose conversion factor (mrem/pCi)
SF_e	=	External slope factor (Risk/yr per pCi/g)
RDF	=	Risk to dose conversion factor from DOE 1992 (mrem/6.2E-7 risk)

The 100 mrem per year target dose is based on single pathway exposure to a single radionuclide. The PRG is divided by 100 to account for multiple pathway exposure to multiple radionuclides.

Methods for evaluating volatilization and particulate emission factors require data input that is not readily available for all chemicals of concern in addition to site-specific data. The volatilization factor is calculated with the following equation (EPA 1991a):

$$VF(m^3/kg) = \frac{(LS \times V \times DH)}{A} \times \frac{(3.14 \times \alpha \times T)^{1/2}}{(2 \times D_{ei}\ E \times K_{as} \times 10^{-3}\ kg/g)} \qquad (2\text{-}10)$$

where

$$\alpha(cm^2/s) = \frac{(D_{ei} \times E)}{E+(p_s)(1-E)/K_{as}} \qquad (2\text{-}11)$$

where

VF	=	Volatilization factor (m^3/kg)
LS	=	Length of side of contaminated area (45 m)
V	=	Wind speed in mixing zone (2.25 m/s)
DH	=	Diffusion height (2 m)
A	=	Area of contamination (20,250,000 cm^2)
D_{ei}	=	$D_i\ E^{0.33}$ Effective diffusivity (cm^2/s)
E	=	True soil porosity (.35 unitless)
K_{as}	=	Soil/air partition coefficient (H/K_d) 41(g soil/cm^3 air)
P_s	=	True soil density or particulate density 2.65(g/cm^3)

T	=	Exposure interval (s) 7.9E+08 s
D_i	=	Molecular diffusivity (cm^2/s)
H	=	Henry's law constant ($atm\text{-}m^3/mol$)
K_d	=	Soil-water partition coefficient (cm^3/g) or K_{oc} OC
K_{oc}	=	Organic carbon partition coefficient (cm^3/g)
OC	=	Organic carbon content of soil (fraction); site specific or 0.02

This model requires chemical-specific data that is difficult to obtain, such as molecular diffusivity. Because of this, the model was run for several site-related chemicals to determine if the pathway contributes significantly to the development of the PRG. Volatilization factors (VF) were developed for acetone, 2-butanone, ethyl benzene, toluene, tetrachloroethene, 1,1,1-trichloroethane and xylenes using data presented in Table 2-1. These chemicals represent Henry's law constants ranging from 2.27 x 10^{-2} to 3.97 x 10^{-5}. The resulting volatilization factors were used in Equation 2-6 along with inhalation reference doses and cancer slope factors.

As presented in Table 2-1, risk-based PRGs for the indicator constituents would range from 9,000 mg/kg for acetone to 500,000 mg/kg for ethylbenzene. These values indicate that exposure to volatiles is likely a minor pathway for developing PRGs, and since this evaluation requires extensive data gathering, it will not be used.

EPA suggests that for evaluating exposure to particulate emissions, a default particulate emission factor (PEF) of 4.63 x 10^9 m^3/kg should be used. Several chemicals were evaluated using this value, inhalation R_fDs, and Equations 2-10 and 2-11. The soil cleanup level for chromium, using the conservative chromium 6 toxicity value of 41 $(mg/kg/day)^{-1}$, would be 400 mg/kg based on inhalation of particulates. In general, as with the volatilization pathway, the pathway does not contribute significantly to the development of chemical PRGs because such a small portion of the contaminant is inhaled by the receptor.

Cleanup levels based on soil ingestion are generally one to two orders of magnitude lower (i.e., more stringent) than levels calculated using fugitive dust or volatilization pathways. Because the contribution from volatilization and fugitive dust emission pathways are generally so low that they get lost in the rounding of the PRG, they are not used as default pathways for developing PRGs.

Equations for evaluating exposures under the recreational land-use scenario are modified versions of the residential equations. The receptor for recreational exposures is a person who plays on the property as a child and uses the property less frequently for recreational activities as an adult, perhaps for baseball games or similar activities. To evaluate cancer risk, both the child and adult exposure period must be evaluated. For toxic effects, the most sensitive exposure, the child, must be evaluated.

TABLE 2-1
RESULTS OF USING VOLATILIZATION PATHWAY TO DETERMINE PRELIMINARY REMEDIATION GOALS

Chemical	Molecular Diffusivity[a] (cm^2/s)	Henry's Law Constant[b] ($atm\text{-}m^3/mol$)	K_{oc}[c] (cm^3/g)	O_c[d]	K_d[e] (cm^3/g)	Effective Diffusivity[f] (cm^2/s)	K_as[g] (cm^3/g)	Alpha[h] (cm^2/s)	VF[i] (m^3/kg)	Preliminary Remediation Goal[j] (mg/kg)
Acetone	0.106	3.97E-05	2.80E-01	0.01	0.0028	0.075	0.58	0.0352	1.31E+05	9.4E+03
2-Butanone	0.092	4.35E-05	9.40E-01	0.01	0.0094	0.065	0.19	0.0146	2.99E+05	1.9E+04
Ethylbenzene	0.074	7.90E-03	6.81E+02	0.01	6.81	0.052	0.05	0.0035	7.32E+05	5.3E+05
Tetrachloroethene	0.076	2.27E-02	6.65E+02	0.01	6.65	0.054	0.14	0.0095	3.95E+05	2.9E+03
Toluene	0.080	6.61E-03	2.59E+02	0.01	2.59	0.057	0.10	0.0079	4.54E+05	1.9E+05
1,1,1-Trichloroethane	0.082	2.76E-02	1.52E+02	0.01	1.52	0.058	0.74	0.0308	1.24E+05	2.6E+04
Total Xylenes	0.074	7.23E-03	2.40E+02	0.01	2.4	0.052	0.12	0.0083	4.32E+05	2.8E+04

[a] Lyman (1982)
[b] EPA (1986b)
[c] K_{oc} = partition coefficient for organic carbon, from U.S. Air Force Systems Command (1990)
[d] O_c = organic carbon, assume organic carbon content of sand
[e] K_d = distribution, taken from EPA (1991a)
[f] $D_i \times E^{0.33}$ (EPA 1991a)
[g] $(H/K_d) \times 41$ (EPA 1991a)
[h] $(D_{ei} \times E)/E + (P_s)(1 - E)/K_as$ (EPA 1991a); E = 0.35
[i] Equation 2-7 (EPA 1991a)
[j] Calculated using exposure parameters given in Equations 2-4 and 2-5, for the inhalation route only.

This is done since the target goal is to limit daily intake (for toxicants) or annual intake (in the case of dose limits) and the child exposure frequency and thus daily or annual intake is greater than the adults. The child scenario will be used to develop the PRG.

The following equation is used for chemical toxicants. It assumes a child aged 6 through 18 plays on-property. Parameters in the equation are consistent with parameters used to evaluate children playing on-property in the baseline risk assessments:

$$C_s = \frac{(THI)(AT)(BW)}{(1/RfD_o)(CF)(FI)(EF)(ED)(IRs)} \qquad (2\text{-}12)$$

where

C_s	=	PRG concentration in soil (mg/kg)
THI	=	Target Hazard Index (0.20)
RfD_o	=	Oral reference dose (mg/kg/day)
BW	=	Child body weight (43 kg)
AT	=	Averaging time (12 yr x 365 days)
EF	=	Exposure frequency (120 days/yr)
ED	=	Exposure duration (12 yr)
IR_s	=	Daily soil ingestion rate (100 mg/day)
FI	=	Fraction of total daily intake ingested from source (10 percent)
CF	=	10^{-6} kg/mg

The following equation is used for chemical carcinogens:

$$C_s = \frac{TR[(BW_c)(AT_c)+(BW_a)(AT_a)]}{[(SF_o)(CF_c)(FI_c)(ED_c)(EF_c)(IR_s)]+[(SF_o)(CF_a)(FI_a)(ED_a)(IR_s)]} \qquad (2\text{-}13)$$

where

C_s	=	PRG concentration in soil (mg/kg)
TR	=	Target Risk (1×10^{-6})
SF_o	=	Oral slope factor $(mg/kg/day)^{-1}$
BW_c	=	Child body weight (43 kg)
BW_a	=	Adult body weight (70 kg)
AT_a	=	Averaging time (70 yr x 365 days)
AT_c	=	Averaging time (70 yr x 365 days)
EF_c	=	Child exposure frequency (120 days/yr)

EF_a	=	Adult exposure frequency (40 days/yr)
ED_c	=	Child exposure duration (12 yr)
ED_a	=	Adult exposure duration (32 yr)
IR_s	=	Daily soil ingestion rate (100 mg/day)
FI_c	=	Fraction child ingests from source (10 percent)
FI_a	=	Fraction adult ingests from source (5 percent)
CF	=	10^{-6} kg/mg

The following equation is used to develop risk based recreational PRGs for radionuclides:

$$C_s = \frac{TR}{SF_o(IR_s)(CF)[(FI_c)(EF_c)(ED_c)+(FI_a)(EF_a)(ED_a)]+SF_e(1-S_e)[(ED_c)(T_{ec})+(ED_a)(T_{ea})]} \qquad (2\text{-}14)$$

where

C_s	=	PRG concentration in (pCi/g)
TR	=	Target risk (1×10^{-6})
SF_o	=	Oral slope factor (risk/pCi)
SF_e	=	External slope factor (risk/yr per pCi/g soil)
T_{ec}	=	Exposure time, child (2 hr/d)(120 d/yr)(yr/8760 hr)
T_{ea}	=	Exposure time, adult (1 hr/d)(40 d/yr)(yr/8760 hr)
EF_c	=	Child exposure frequency (120 days/yr)
EF_a	=	Adult exposure frequency (40 days/yr)
ED_c	=	Child exposure duration (12 yr)
ED_a	=	Adult exposure duration (32 yr)
IR_s	=	Daily soil ingestion rate (100 mg/day)
FI_c	=	Fraction child ingests from source (0.1)
FI_a	=	Fraction adult ingests from source (0.05)
S_e	=	Shielding factor(0)
CF	=	Conversion factor (10^{-3})

The following equation was used to develop dose based PRGs for the recreational scenario:

$$C_s(pCi/g) = \frac{TD}{[(DCF_o)(IR_s)(FI_c)(EF_c) + (SF_e)(1-S_e)(T_{ec})(RDF)]} \qquad (2\text{-}15)$$

where

C_s	=	PRG concentration in soil (mg/kg)
TD	=	Target dose (mrem/yr)
DCF_o	=	Oral dose conversion factor (mrem/pCi)
ED_c	=	Exposure duration, child (12 yr)
EF_c	=	Exposure frequency, child (120 d/yr)
FI	=	Fraction child ingests from source (0.1)
IR_s	=	Daily soil ingestion rate (100 mg/d)
RDF	=	Risk to dose conversion factor from DOE, 1992 (mrem/6.2E-07 risk)
S_e	=	Shielding factor (0)
SF_e	=	External exposure slope factor (risk - yr/pCi-g)
T_{ec}	=	Exposure time, child (2 hr)(340 d/yr)(yr/8760 hr)
TD	=	Target dose limit (100 mrem/yr)

Dose based PRGs are derived from an annual dose limit, so the receptor spending the most time on-property during any on year will be the critical receptor. The recreational scenario assumes that younger park users spend more time on site than older ones (240 hr/yr versus 40 hr/yr). Since the child spends more time on site during any one year, the child was selected as the limiting scenario.

Many of the parameters used in the recreational equation are adopted from the "exploring child" scenario developed in FEMP baseline risk assessments.

2.2 RESULTS - PRELIMINARY REMEDIATION GOALS

Tables 2-2 and 2-3 present preliminary PRGs for potential drinking water (groundwater/surface water), and soils/sediments. In addition to providing risk-based PRGs and ARARs, the tables provide PRGs based on radiological dose limit ARARs/TBCs. These dose-limit PRGs are determined using to exact same pathways and parameters used to calculate risk-based PRG. However, instead of using a target risk of 10^{-6}, a radiological dose limit plus a dose conversion factor from *Federal Report No. 11* is used.

2.2.1 Groundwater

Table 2-2 presents PRGs for groundwater and surface water that may be used in the future for drinking water. Values representing risk-based PRGS and ARARs span several orders of magnitude for

TABLE 2-2
PRELIMINARY REMEDIATION GOALS - GREAT MIAMI AQUIFER
RESIDENT FARMER LAND USE SCENARIO
WATER INGESTION

Chemical	Risk-Based PRGs		ARAR/TBC-Based PRGs		
			Federal Standards		State Standards
	HI=0.20 R_fD-Based PRG[a]	10^{-6} SF-Based PRG, above background[b]	Source[c]	Concentration[d]	Ground-waters[e]
RADIONUCLIDES (pCi/ℓ)					
Ac-227 + 7 daughters		0.06	4 mrem dose limit[f]	0.4	
Am-241		0.09	4 mrem dose	1.5	
Cs-137 + 1 daughter		0.7	MCL[g]	110	
Pb-210 + 2 daughters		0.03	4 mrem dose	1	
Np-237 + 1 daughter		0.09	4 mrem dose	1	
Pa-231		0.2	4 mrem dose	0.5	
Pu-238		0.09	4 mrem dose	1.7	
Pu-239		0.09	4 mrem dose	1.5	
Pu-240		0.09	4 mrem dose	1.5	
Ra-226 + 5 daughters		0.2	PMCL[h]	20	5
Ra-228 + 1 daughter		0.2	PMCL	20	5
Rn-222			PMCL	300	
Ru-106 + 1 daughter		2	MCL	20	
Sr-90 + 1 daughter		0.6	MCL	4	8
Tc-99		16	MCL	3750	
Th-228 + 7 daughters		0.4	4 mrem dose	14	
Th-230		2	4 mrem dose	10	
Th-232		2	4 mrem dose	2	
U-233		1	4 mrem dose	19	
U-234		1	PMCL	7	
U-235 + 1 daughter		1	PMCL	0.3	
U-238 + 2 daughters		1	PMCL	7	

TABLE 2-2
(Continued)

Chemical	Risk-Based PRGs		ARAR/TBC-Based PRGs		
			Federal Standards		State Standards
	HI=0.20 R_fD-Based PRG[a]	10^{-6} SF-Based PRG, above background[b]	Source[c]	Concentration[d]	Ground-waters[e]
INORGANICS (mg/ℓ)					
Aluminum[i]					
Ammonia	7				
Antimony	0.003				
Arsenic	0.007		MCL	0.05	0.05
Barium	0.4		MCL	2	1
Beryllium	0.04	8E-06	PMCL	0.001	
Boron	0.7				
Cadmium	0.004		MCL	0.005	0.01
Chromium	0.04		MCL	0.1	0.05
Cobalt	0.02				
Copper[i]					
Iron[i]					
Lead	0.005		MCL	0.005	0.05
Magnesium[i]					
Manganese	0.7				
Mercury	0.002		MCL	0.002	0.002
Molybdenum	0.03				
Nickel	0.1		PMCL	0.1	
Nitrate[i]					
Selenium	0.04		MCL	0.05	0.01
Silver	0.02		MCL	0.05	0.05
Thallium	0.0005		PMCL	0.002	
Uranium	0.02		MCL	0.02	
Vanadium	0.05				
Zinc	1				

TABLE 2-2
(Continued)

Chemical	Risk-Based PRGs		ARAR/TBC-Based PRGs		
			Federal Standards		State Standards
	HI=0.20 R_fD-Based PRG[a]	10^{-6} SF-Based PRG, above background[b]	Source[c]	Concentration[d]	Ground-waters[e]
Cyanide	0.1		PMCL	0.2	
ORGANICS (mg/ℓ)					
1,1,2-Trichloro-1,2,2-trifluoroethane	20				
1,1,2,2-Tetrachloroethane		0.0002			
1,1,1-Trichloroethane	0.7		MCL	0.2	0.2
1,1-Dichloroethane	0.7				
1,1-Dichloroethene	0.07	0.00006	MCL	0.007	0.007
1,2-Dichloroethane		0.0004	MCL	0.005	0.005
1,2-cis-Dichloroethene	0.07		MCL	0.07	
1,2-trans-Dichloroethene	0.1		MCL	0.1	
1,4-Dioxane		0.003			
2-Butanone	0.4				
2-Hexanone[i]					
2-Methylnaphthalene[i]					
2-Methylphenol[i]					
2-Methyl-4,6-Dinitrophenol[i]					
2-Nitrophenol[i]					
2,3,4,6-Tetrachlorophenol[i]					
2,4-Dimethylphenol	0.1				
3-Nitroaniline[i]					
4-Methyl-2-pentanone	0.4				
4-Methylphenol[i]					
4-Nitrophenol[i]					
Acenaphthene	0.4				
Acenaphthylene[i]					
Acetone	0.7				

TABLE 2-2
(Continued)

Chemical	Risk-Based PRGs		ARAR/TBC-Based PRGs		
			Federal Standards		State Standards
	HI=0.20 R_fD-Based PRG[a]	10^{-6} SF-Based PRG, above background[b]	Source[c]	Concentration[d]	Ground-waters[e]
Aldrin	0.0002	2E-06			
Anthracene	2				
Aroclor-1242		5E-06	MCL	0.0005	
Aroclor-1248		5E-06	MCL	0.0005	
Aroclor-1254		5E-06	MCL	0.0005	
Aroclor-1260		5E-06	MCL	0.0005	
Benzene		0.001	MCL	0.005	0.005
Benzo(a)anthracene[i]			PMCL	0.0001	
Benzo(a)pyrene		3E-06	PMCL	0.0002	
Benzo(b)fluoranthene[i]			PMCL	0.0002	
Benzo(g,h,i)perylene[i]					
Benzo(k)fluoranthene[i]			PMCL	0.0002	
Benzoic acid	29				
Benzyl alcohol	2				
Bis(2-ethylhexyl)phthalate	0.1	0.003			
Bromochloromethane[i]					
Bromodichloromethane		0.0003			
Butanol	0.7				
Butyl benzyl phthalate	1				
Carbon disulfide	0.7				
Carbon tetrachloride	0.005	0.0003	MCL	0.005	0.005
Chlordane	0.0004	0.00003	MCL	0.002	
Chlorobenzene	0.1				
Chloroethane[i]					
Chloroform	0.07	0.006	MLC	0.1	
Chrysene[i]			PMCL	0.0002	

TABLE 2-2
(Continued)

Chemical	Risk-Based PRGs		ARAR/TBC-Based PRGs		
			Federal Standards		State Standards
	HI=0.20 R_fD-Based PRG[a]	10^{-6} SF-Based PRG, above background[b]	Source[c]	Concentration[d]	Ground-waters[e]
Cyclohexane[i]					
DDT	0.004	0.0001			
Di-n-butyl phthalate	0.7				
Di-n-octyl phthalate	0.1				
Dibenzo(a,h)anthracene[i]			PMCL	0.0003	
Dibenzofuran[i]					
Diethylphthalate	6.0				
Dimethylphthalate	70				
Ethyl parathion[i]					
Ethylbenzene	0.07		MCL	0.7	
Fluoranthene	0.3				
Fluorene	0.3				
Heptachlor	0.004	8E-06	MCL	0.0004	
alpha-Hexachlorocyclohexane		6E-06		0.0002	
beta-Hexachlorocyclohexane		0.00002			0.004
Indeno(1,2,3-cd)pyrene[i]			PMCL	0.0004	
Isophorone	1.0				
Methyl parathion	0.02				
Methylene chloride	0.4	0.005	PMCL	0.005	
N-nitrosodiethylamine		2E-07			
N-nitrosodiphenylamine		0.007			
Naphthalene	0.03				
Pentachlorophenol	0.2	0.0003	MCL	0.001	
Phenanthrene[i]					
Phenol	4				
Pyrene	0.2				

TABLE 2-2
(Continued)

Chemical	Risk-Based PRGs		ARAR/TBC-Based PRGs		
			Federal Standards		State Standards
	HI=0.20 R_fD-Based PRG[a]	10^{-6} SF-Based PRG, above background[b]	Source[c]	Concentration[d]	Ground-waters[e]
Tetrachloroethene	0.07	0.0007	MCL	0.005	
Toluene	1		MCL	1	
Trichloroethene		0.003	MCL	0.005	0.0
Vinyl chloride		0.00002	MCL	0.002	0.002
Xylenes (total)	15		MCL	10	

[a] PRGs developed using equations and parameters for drinking water ingestion and RfDs from Health Effects Assessment Summary Tables (EPA, 1992a) and the Integrated Risk Information System (EPA, 1992b).

[b] PRGs developed using equations and parameters for drinking water ingestion and chemical-specific SFs from HEAST and IRIS. Values represent cleanup goal above background values since 10^{-6} target risk represents an **incremental** lifetime cancer risk goal.

[c] ARAR-based PRGs are developed from several sources. The primary source is promulgated or prosed maximum contaminnat levels (MCLs) developed under the Safe Drinking Water Act, 40CFR141, 142. If no MCL exists that strckly applies to the individual radionuclide, a PRG is developed using the 4 mrem dose limit that strckly applies to man-made beta and gamma emitters.

[d] Concentration in pCi/ℓ for radionuclides and mg/ℓ for chemicals, corresponding to MCL or PMCL values.

[e] Based on OAC3745-81-16; for many radionuclides, values are based on an average annual dose of beta particle and photon (e.g., gamma) of 4 mrem/year.

[f] PRG based on interpretation to 4 mrem/year dose limit for beta and gamma emitters may be applicable to alpha emitters. PRG developed using committed effective dose equivalents (CEDE) to 4 mrem/year of intake at a rate of 730 ℓ/yr, using Dose conversion factros (DCFs) from EPA (1988b).

[g] PRG developed using the strickly applicable MCL of 4 mrem/year for man-made beta and gamma emitters (40 CFR 141, 142). Value developed using a CEDE or critical organ dose equivalent (if available or if more conservative) to 4 mrem/yr intake at a rate of 730 ℓ/yr, using DCFs from EPA (1988b).

[h] Proposed MCLs from "Federal Register", Vol. 55, No. 138, p.33050.

[i] No toxicity data available to develop a PRG.

TABLE 2-3
PRELIMINARY REMEDIATION GOALS - SURFACE SOILS AND WASTE MATERIAL
RESIDENTIAL/RECREATIONAL LAND USE SCENARIO
SOIL INGESTION AND EXTERNAL RADIATION

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
RADIONUCLIDES (pCi/g)							
Ac-227 + 7 daughters		0.04	0.9		2	18	
Am-241		1	7		140	22	
Cs-137 + 1 daughter		0.02	0.7		1	11	
Pb-210 + 2daughter		0.6	4.9		70	155	
Np-237 + 1 daughter		0.08	2.2		5	41	
Pa-231		1.0	2.4		70	72	
Pu-238[h]		1.7	8.2		220	260	
Pu-239[h]		1.6	7.4		210	240	
Pu-240[h]		1.6	7.4		210	240	
Ra-226 + 5 daughters[h]		0.006	0.2		0.4	3.8	5[g]
Ra-228 + 1 daughter[h]		0.01	0.5		0.7	7.7	5[g]
Ru-106 + 1 daughter		0.05	2.2		3	34	
Sr-90 + 1 daughter		10	184		1,340	5,900	
Tc-99		290	17,800		36,600	560,000	
Th-228 + 7 daughters[h]		0.006	0.3		0.4	4	

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
Th-230[h]		28	48		3,400	1,520	5[i]
Th-232[h]		30	9.6		3,800	305	5[i]
U-233[h]		23	90		2,800	2,900	35[j]
U-234[h]		23	92		2,900	2,930	35[j]
U-235 + 1 daughter[h]		0.14	5.8		9	92	35[j]
U-238 + 2 daughters[h]		0.9	29		60	527	35[j]
INORGANICS (mg/kg)							
Aluminum[k]							
Ammonia							
Antimony	50			1,050			
Arsenic	130			780			
Barium	6400			183,000			
Beryllium	640	0.2		13,000	16	17	
Boron	11500			235,000			
Cadmium	130			2,600			
Chromium	640			13,000			

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
Cobalt	330			6,800			
Copper[j]							
Iron[j]							
Lead	90			1,800			
Magnesium[j]							
Manganese	12,800			262,000			
Mercury	40			780			
Molybdenum	510			13,000			
Nickel	2,600			52,000			
Nitrate[j]							
Selenium	640			13,000			
Silver	380			13,000			
Thallium	9			180			
Uranium	380			78,500			
Vanadium	900			18,300			
Zinc	25,600			523,000			

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
Cyanide	2,600			780			
ORGANICS (mg/kg)							
1,1,2-Trichloro-1,2,2-trifluoroethane	38,400			7,850,000			
1,1,2,2-Tetrachloroethane		4			690		
1,1,1-Trichloroethane	11,500			235,000			
1,1-Dichloroethane	12,800			262,000			
1,1-Dichloroethene	1,200	1		235,000	230		
1,2-Dichloroethane		8			1500		
1,2-cis-Dichloroethene	1,300			1,050			
1,2-trans-Dichloroethene	2,600			235,000			
1,4-Dioxane		60			12600		
2-Hexanone[j]							
2-Butanone	6,400			134,000			
2-Methylnaphthalene[j]							
2-Methylphenol[j]							
2-Methyl-4,6-Dinitrophenol[j]							

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
2-Nitrophenol[j]							
2,3,4,6-Tetrachlorophenol[j]							
2,4-Dimethylphenol	2,600			52,300			
3-Nitroaniline[j]							
4-Methyl-2-pentanone	6,400						
4-Methylphenol							
4-Nitrophenol[j]							
Acenaphthene	7,700			157,000			
Acenaphthylene[j]							
Acetone	12,800			262,000			
Aldrin					8.0		
Anthracene	38,400			785,000			
Aroclor-1242		0.09			18		10[j]
Aroclor-1248		0.09			18		10[j]
Aroclor-1254		0.09			18		10[j]
Aroclor-1260		0.09			18		10[j]

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
Benzene		200			4,800		
Benzo(a)anthracene[j]							
Benzo(a)pyrene		0.06			24		
Benzo(b)fluoranthene[j]							
Benzo(g,h,i)perylene[j]							
Benzo(k)fluoranthene[j]							
Benzoic acid	512,000			10,460,000			
Benzyl alcohol	38,400			785,000			
Bis(2-ethylhexyl)phthalate	2,600	50		52,000	9,900		
Bromochloromethane[j]							
Bromodichloromethane		5			1,100		
Butanol[j]							
Butyl benzyl phthalate	25,600			523,000			
Carbon disulfide	12,800			262,000			
Carbon tetrachloride	90	5		1,830	1,100		
Chlordane	8	0.5		160	100		

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
Chlorobenzene	2,600			523,000			
Chloroethane[j]							
Chloroform	1,300	100		26,000	22,800		
Chrysene							
Cyclohexane[j]							
DDT	60	2		1,300	400		
Di-n-butyl phthalate	12,800			262,000			
Di-n-octyl phthalate	2,600			52,000			
Dibenzo(a,h)anthracene[j]							
Dibenzofuran							
Diethylphthalate				2,000,000			
Dimethylphthalate							
Ethyl parathion[j]							
Ethylbenzene	1,300			262,000			
Fluoranthene	5,100			105,000			
Fluorene	5,100			105,000			

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
alpha-Hexachlorocyclohexane					20		
beta-Hexachlorocyclohexane		0.4			80		
Isophorone							
Indeno(1,2,3-cd)pyrene[j]							
Isophorone							
Methyl parathion	320			785			
Methylene chloride	7,700	90		160,000	18,500		
N-Nitrosodiethylamine							
N-nitrosodiphenylamine		100			28,300		
Naphthalene	510			105,000			
Pentachlorophenol	3,800	6		78,500	1,200		
Phenanthrene[j]							
Phenol	76,800			1,600,000			
Pyrene	3,800			78,500			
Tetrachloroethene	1,300	10		26,000	2,700		
Toluene	25,600			523,000			

TABLE 2-3
(Continued)

Chemical	Future Land Use Residential			Future Land Use Recreational			Other ARARs/ TBCs[g]
	HI=0.20 R_fD-Based PRG[a]	10^{-6} Risk-Based PRG, above background[b]	Dose Limit-Based PRG[c]	HI=0.20 R_fD-Based PRG[d]	10^{-6} Risk-Based PRG, above background[e]	Dose Limit-Based PRG[f]	
Trichloroethene		60			12,600		
Vinyl chloride		0.04			70		
Xylenes (total)	260			5,232,000			

[a] PRG developed using equation and parameters for soil ingestion and chemical-specific RfDs from Health Effect Assessment Summary Tables (HEAST) (EPA 1992a) and Integrated Risk Information System (IRIS) (EPA 1992b).
[b] PRG developed using equation and chemical-specific SFs from HEAST and IRIS.
[c] PRG based on 100 mrem dose limit for exposures to the general public (10CFR20) and a CEDE DCFs from EPA (1988b). The calculated dose-based PRG has been divided by 100 to account for the fact that the 100 mrem limit is for all exposures, while the PRG is for a single exposure pathway and radionuclide. Exposure pathways and parameters are the same as those used for risk-based residential PRGs.
[d] PRGs developed using parameters for recreational exposures and HEAST.
[e] PRGs developed using parameters for recreational exposures and HEAST and IRIS.
[f] PRG based on 100 mrem dose limit for exposures to the general public (10CFR20) and a CEDE DCFs from EPA (1988b). The calculated dose-based PRG has been divided by 100 to account for the fact that the 100 mrem limit is for all exposures, while the PRG is for a single exposure pathway and radionuclide. Exposure pathways and parameters are the same as those used for risk-based recreational PRGs.
[g] First 15 cm depth (40CFR192).
[h] The methodology used to calculate PRGs results in different values for different isotopes of a given radionuclide. In most cases, this is due to differences in external dose rate factors among isotopes. The lowest value calculated for a given radionuclide will drive the choice of the PRG used in design of remedial alternatives.
[i] First 15 cm depth (DOE Order 5400.5).
[j] Based on Nuclear Regulatory Commission Branch Technical Position on "Disposal or On-site Storage of Residual Thorium or Uranium (either as natural ores or without daughters present) from Past Operations."
[k] No toxicity data available to develop a PRG.

some chemicals. The 10^{-6}-based values for radionuclides are less than the standard deviation of background. These levels are indistinuishable from background using standard statistical techniques. For organics, most PRGs based on the 10^{-6} risk level are below the CRDLs established by the EPA. To date at the FEMP, these CRDLs have been used for the site characterization study. MCLs for many organic carcinogens appear to be equivalent to a 10^{-4} risk level, e.g, for PCBs and vinyl chloride. For noncarcinogens, the MCL appears to be close to the risk-based value. This is not surprising since the method used to developed MCLs is the same method used to develop the risk-based values.

2.2.2 Surface Soils and Waste Materials

Table 2-3 presents the PRGs for soils and waste materials. Site-wide PRGs have not been developed based on contaminant leaching to groundwater because of the operable unit specific characterization requirements needed to develop these values. Risk-based values developed using soil ingestion suggest that cleanup to background levels may not be required.

The daughter isotopes of radionuclides present at the FEMP significantly impact the results of these PRG calculations. For example, U-238 is a radionuclide of concern at the FEMP. If the presence of its two immediate short-lived daughters is neglected, the risk based PRG for a residential farmer exposed to U-238 in soil is approximately 23 pCi/g. Including its two short-lived daughters yields a PRG of 0.9 pCi/g (Table 2-3). In another example Ra-226 (without daughters) would have a PRG of about 1.5 pCi/g for the same scenario. Including its short-lived daughters reduces the PRG in soil to 0.006 pCi/g (Table 2-3). The PRGs presented in Table 2-3 consider the contributions of radioactive daughter products to be and integral part of the total risk from the parent nuclide.

2.2.3 Subsurface Soil

Subsurface soil PRGs can be set by using the Summers Model to model the contaminant infiltration into groundwater. The model however, uses parameters that are site specific such as area of contamination, depth to aquifer, and width of contamination perpendicular to the aquifer flow. Subsurface soil PRGs will therefore, be set separately for each OU within the site as opposed to site wide PRGs.

2.2.4 Surface Water

Table 2-4 lists ambient water quality criteria (AWQC) and State of Ohio regulations that can be used to develop surface water PRGs. AWQC are guidelines for the states to use for developing ambient water quality standards. These guidelines represent level for chemicals that likely will not cause impairment to aquatic populations. These PRGs should be used in conjunction with PRGs listed in Table 2-2. In cases where values in Table 2-4 are lower, they should be used in lieu of the drinking water PRGs.

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TABLE 2-4
PRELIMINARY REMEDIATION GOALS FOR SURFACE WATER BASED ON PROTECTION OF AQUATIC SPECIES

Chemical	ARAR/TBC-Based PRGs		Other Considerations	
	Federal Ambient Water Quality Criteria[a] (acute/chronic) (mg/ℓ)	Ohio State Water Quality Standards[b] (maximum/30-day average) (mg/ℓ)	Background Upper Tolerance Limit[c] (mg/ℓ)	Contract Required Detection Limit[d] (mg/ℓ)
INORGANICS				
Antimony	9/1.6(*)	0.65/0.19		0.06
Arsenic	0.36/.19(*)	0.36/0.19		0.01
Beryllium	0.13/0.0053(*)	3.75/0.17		0.005
Cadmium	0.0039/0.0011(+)	0.02/0.02	0.0002	0.005
Chromium	1.7/0.210	4.92/0.46	0.027	0.01
Copper	0.018/0.012(+)	0.06/0.04	0.01	0.025
Iron	- / 1.0		1.30	0.1
Lead	0.082/0.0032(+)	0.63/0.03	0.002	0.005
Mercury	0.0024/0.000012	0.001/0.0002		0.0002
Nickel	1.4/0.16(+)	4.51/0.50	0.036	0.04
Selenium	0.28/0.036	0.02/0.005		0.005
Silver	0.0041/0.00012(+)	0.01		0.01
Thallium	1.4/0.04(*)			0.01
Zinc	0.12/0.11(+)	0.33/0.30	0.014	0.02
Cyanide	0.022/0.0052	0.046/0.012 (E)		0.01
ORGANICS				
1,1,2-Trichloro-1,2,2-trifluoroethane	2.4/9.02(*)			
1,1,2,2-Tetrachloroethane		1/0.36		
1,1,1-Trichloroethane	31.2/ - (*)	2/0.088		0.005
1,1-Dichloroethene	11.6/ - (*)	1.5/0.078		0.005
1,2-Dichloroethane	118/20(*)	12/3.5		0.005
1,2-cis-Dichloroethene	11.6/ - (*)			

TABLE 2-4
(Continued)

Chemical	ARAR/TBC-Based PRGs		Other Considerations	
	Federal Ambient Water Quality Criteria[a] (acute/chronic) (mg/ℓ)	Ohio State Water Quality Standards[b] (maximum/30-day average) (mg/ℓ)	Background Upper Tolerance Limit[c] (mg/ℓ)	Contract Required Detection Limit[d] (mg/ℓ)
1,2-trans-Dichloroethene	11.6/ - (*)			0.005
2,4-Dimethylphenol	2.12/-(*)			0.01
Acenaphthene	1.7/0.52(*)	0.067/0.067		0.01
Acetone		0.55/0.078		0.01
Aroclor-1242	0.002/0.000014	- /0.001		0.0005
Aroclor-1248	0.002/0.000014	- /0.001		0.0005
Aroclor-1254	0.002/0.000014	- /0.001		0.001
Aroclor-1260	0.002/0.000014	- /0.001		0.001
Benzene	5.3/ - (*)	1.1/0.56		0.005
Bis(2-ethylhexyl)phthalate		1.1/0.0084		0.01
Butyl benzyl phthalate		0.23/0.049		0.01
Carbon Tetrachloride	35.2/ - (*)	1.8.0.28		0.005
Chlordane	0.0024/0.0000043	0.00001/0.0000048		0.0005
Chlorobenzene	0.25/0.05(*)	0.59/0.026		0.005
Chloroform	28.9/1.24(*)	1.8.0.079		0.005
DDT	0.0011/0.000001	0.000001/0.00000024		
Di-n-butyl Phthalate		0.35/0.19		0.01
Ethylbenzene	32/ - (*)	1.4/0.062		0.005
Fluoranthene	3.9/ - (*)	0.2/0.0089		0.01
beta-Hexachlorocyclohexane	0.002/0.00008	- /0.00055		0.00005
Methylene Chloride		9.7/0.43		0.005
N-nitrosodiphenylamine		0.29/0.013		0.01
Naphthalene	2.3/0.620	0.16/0.044		0.01
Pentachlorophenol	0.02/0.013(++)	0.04/0.02		0.05
Phenol	10.2/2.5(*)	5.3/0.37 (E)		0.01

TABLE 2-4
(Continued)

Chemical	ARAR/TBC-Based PRGs		Other Considerations	
	Federal Ambient Water Quality Criteria[a] (acute/chronic) (mg/ℓ)	Ohio State Water Quality Standards[b] (maximum/30-day average) (mg/ℓ)	Background Upper Tolerance Limit[c] (mg/ℓ)	Contract Required Detection Limit[d] (mg/ℓ)
Tetrachloroethene	5.28/0.84(*)	0.54/0.073		0.005
Toluene	17.5/	2.4/1.7		0.005
Trichloroethene	46/21.9(*)	0.0 1.7/0.075		
Vinyl Chloride	0.002	/5.25		0.01
Xylenes (total)	10			0.005

[a] Federal ambient water quality criteria from "Quality Criteria for Water 1986" (EPA, 1986b). Values are for freshwater species. Footnotes as listed in EPA (1986b) include: (*) - hardness dependent criteria (100 mg/ℓ used); (+) - insufficient data to develop criteria, value presented is the LOEL (Lowest Observed Effect Level; (++) - pH dependent criteria (7.8 pH used).

[b] Numerical criteria from Ohio Water Quality Standards, Chapter 3745-1 of the Ohio Adminstrative Code. Values are for modified warm water habitats unless noted by (E), which represent "exceptional" warm water habitat.

Ohio EPA data from the Great Miami River (Ohio Environmental Protection Agency, 1989, "Great Miami River Intensive Stream Survey").

[d] From CLP Statement of Work 3900LM01.08.

3.0 LEADING REMEDIAL ALTERNATIVES

This section describes the LRAs for Operable Units 1 through 5 and explains their selection in terms of effectiveness, implementability, and cost.

3.1 OPERABLE UNIT 1

Operable Unit 1 includes Waste Pits 1 through 6, the Burn Pit, and the Clearwell. The pits and Clearwell contain approximately 570,000 cubic yards of solid/sludge wastes, 800,000 cubic yards of potentially contaminated surrounding soils, and 2.3 million gallons of surface water waste to be remediated. Included in the remediation will be soil between the pits and contaminated soil surrounding the boundary of Operable Unit 1. Perched groundwater within the waste pit area is also within the scope of Operable Unit 1. Pits 1, 2, 3, 6, and the Burn Pit contain hazardous constituents (which do not necessarily cause the material to be a hazardous waste) and radiological substances; Pits 4, 5, and the Clearwell containss mixed waste (classified as a mixture of radiological and hazardous waste).

The LRA for Operable Unit 1 involves the removal and treatment of sufficient waste materials from Waste Pits 1-6, the Burn pit and the Clearwell and/or associated contaminated soils to achieve risk-based PRGs and ARARs. The excavated area will be filled with compacted soils. Any remaining waste and contaminated soils in the Operable Unit 1 area will be stabilized and covered with a closure cap. The excavated materials will be treated and placed within an on-property engineered aboveground disposal facility. This alternative also includes continued federal ownership of the land to control future land use. The following actions will be taken:

- Removal and Treatment of Standing Water - Pits 5 and 6 and the Clearwell have standing water requiring treatment by a wastewater treatment facility. The effluent from this facility will be discharged to the Great Miami River and will meet all surface water PRGs and ARARs.

- Waste Removal and Segregation - Pit wastes and soils will be mechanically or hydraulically removed to attain risk-based PRGs and ARARs. Waste segregation technologies will be employed to facilitate waste handling, treatment, packaging, and disposal.

- Waste Treatment - Excavated waste materials will be processed prior to treatment. Stable waste materials such as concrete construction rubble and debris will be crushed and sent directly for disposal. Other materials including sludges and contaminated soils will be stabilized by vitrification or cement-based solidification prior to disposal. Shallow soil mixing (cement-based) will be used to the extent necessary to stabilize the unexcavated soils and waste materials prior to the backfilling of the excavated area and installation of a capping system.

- On-Property Disposal - Following treatment and/or volume reduction, the resultant stable waste will be transferred from a temporary holding area to an on-property disposal facility at the FEMP. The disposal facility is envisioned to include a series of aboveground reinforced concrete vaults, which will be underlain by a leachate collection and detection system and covered by a multilayered RCRA-type cap.

- Capping - The waste pit area will be backfilled with compacted soils and graded prior to installation of a multilayered RCRA-type cap. Paddys Run will be realigned as necessary to ensure the integrity of the capped area.

- Runoff/Run-on Control - Runoff control features remove stormwater from the operable unit area, and run-on control features direct storm water away from the closed facility. Control can be accomplished by using site contour grading, vegetation, diversion and collection ditches, as well as various physical devices including silt traps and sedimentation basins.

The LRA for Operable Unit 1 was selected for the reasons provided below:

- Effectiveness - A majority of the waste will be removed and treated to an immobile form and then isolated and controlled in the on-property disposal facility. The residual materials and associated contaminated soils will be stabilized as needed and capped. The capacity for direct contact with the residuals will therefore be eliminated, and rainwater infiltration will be decreased, minimizing the potential for leaching. This alternative is expected to meet risk-based PRGs and ARARs as described above. Preliminary engineering estimates indicate that the proposed on-property disposal facility can be designed and constructed to meet risk-based PRGs and ARARs. Further studies are continuing to provide more definitive technical information on the effectiveness of this proposed facility.

- Implementability - Excavation of waste materials is a common practice using widely available equipment. Proposed treatment technologies have either been demonstrated in the field or are being refined through treatability studies. The placement of engineered capping systems is a widely applied remediation technology. The on-property disposal facility employs conventional construction methods and is readily implementable.

- Cost - The cost of this alternative is within the range of those alternatives judged during the screening phase to be effective and implementable.

3.2 OPERABLE UNIT 2

Operable Unit 2, as defined in the Amended Consent Agreement, includes the Flyash Piles, other South Field disposal areas, lime sludge ponds, solid waste landfill, berms, liners, and soil within the operable unit boundary.

Solid Waste Landfill

The Solid Waste Landfill was used for the disposal of wastes from nonprocess areas. Historical aerial photographs show evidence of disposal activity as early as 1954 (EPA 1988c). Some construction rubble placed in the landfill and the soil used to cover exposed wastes may have been contaminated with radionuclides. Site characterization information indicates a high soil to waste volume ratio.

The Solid Waste Landfill is organized into five cells. When filled to capacity, the five existing cells were covered with soil. The maximum depth of fill measured in the landfill is 17 feet. Based on an average depth of 13 feet and an area of 52,000 square feet, the volume of fill in the landfill is estimated at 25,000 cubic yards.

South Lime Sludge Pond

The South Lime Sludge Pond is an unlined pond in the southeast corner of the waste storage area, with approximate surface dimensions of 150 by 250 feet. The South Lime Pond received lime-alum sludge from site water treatment activities as well as sludges from the neutralization of boiler plant blowdown and coal pile storm water runoff. Borehole log information (Weston 1988) indicates the volume of the South Pond to be approximately 16,000 cubic yards. The volume of the berm material is estimated to be 2,800 cubic yards.

North Lime Sludge Pond

The North Lime Sludge Pond is an unlined pond that receives spent lime alum sludge as well as sludges from the neutralization of boiler plant blowdown and coal pile storm water runoff. It is approximately 150 by 250 feet in size and is approximately 90 percent full. This pond is partially covered with water (estimated to be a maximum of 150,000 gallons) that ranges up to 4 feet in depth. The actual volume of water can vary, depending on plant operations and precipitation.

The height of the berm surrounding the North Pond is lower than the height of the South Pond, and the depth of lime sludge in the North Pond ranges from 3.5 to 7 feet. Assuming an average depth of 5.5 feet, the volume of lime sludge contained in the North Pond is estimated to be 7,600 cubic yards. The volume of the berm material is estimated to be 1,100 cubic yards.

Inactive Flyash Pile

Flyash from the coal-fired boiler plant was loaded into dump trucks and transported to the flyash disposal area. It has been reported, but not documented, that contaminated waste oils were sprayed onto both the active and inactive flyash piles as a dust suppressant. This pile, which also received miscellaneous disposal of solid waste materials such as construction rubble is now covered with soil or vegetation. A total of 78,500 cubic yards of flyash is estimated to be present in the Inactive Flyash Pile.

Active Flyash Pile

In current operations, as in the past, flyash from the coal-fired boiler plant is loaded into dump trucks and transported to this disposal site. The estimated volume of flyash in the Active Flyash Pile is 58,800 cubic yards.

South Field

The South Field was reportedly used as a burial site for construction rubble that may have contained low levels of radioactivity; this includes debris from the razing of the old administration building. The boundary of the South Field includes a surface area of approximately 11 acres with a fill volume of 109,000 cubic yards.

The LRA for Operable Unit 2 is capping each of the waste units with a multilayer RCRA-type cap. Regrading of the waste and runoff/run-on controls also would be employed. This alternative would prevent direct contact with the waste and surface transport of waste. This alternative also includes continued federal ownership of the land to control future land use. The drainage north of the Solid Waste Landfill, an emergent wetland area, may require realignment to implement the LRA on this waste unit. For the lime sludge ponds, a shallow-soil mixing technology will be used before capping. For the Flyash/South Field Areas, Paddys Run is identified as a floodplain and may require realignment to implement the LRA.

The following processes will occur:

- Capping - The closure cap may be designed and constructed using a low-permeability clay layer, a flexible membrane layer, a natural drainage layer, and a vegetative cover. All cap units will be contoured to grades that promote drainage while minimizing the effects of waste subsidence and storm water erosion. Shallow soil mixing employing cement and/or may be applied to the materials in the lime sludge ponds to stabilize the waste material before placement of the capping system.

- Runoff/Run-on Control - Runoff control features remove storm water from the operable unit area and run-on control features direct storm water away from the closed facility. Control can be accomplished using site contour grading, vegetation, diversion and collection ditches, as well as various physical devices including weirs, baffles, and lined sedimentation basins.

- Biointrusion barrier - A biointrusion barrier may be added to the cap between the vegetative cover and the drainage layer. This barrier could consist of a two-foot-thick layer of cobbles and would be designed to preclude deep-rooting plants and burrowing animals from damaging the flexible membrane liner and low-permeability clay liner. A filter layer would be placed on top of the biointrusion barrier to limit soil migration into this layer.

The LRA for Operable Unit 2 was selected for the reasons below:

- Effectiveness - The wastes will remain in place and be capped. The capacity for direct contact with the residuals will therefore be eliminated, and rainwater infiltration will be decreased, minimizing the potential for leaching. This alternative is expected to meet risk-based PRGs and ARARs.

- Implementability - Capping, shallow-soil mixing and surface drainage control are common remediation approaches using readily available equipment. The engineered construction of

a cap and drainage control structures is common and widely applied to many remediation projects. The technology of capping landfills has been demonstrated to be implementable in the field.

- Cost - The cost of this alternative is within the range of those alternatives judged during the screening phase to be effective and implementable.

3.3 OPERABLE UNIT 3

Operable Unit 3 consists of the former production area and production-associated facilities and equipment. It incorporates all above- and below-grade improvements including, but not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste product, thorium, effluent lines, K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feed stocks, and coal pile. The former production area occupies about 136 acres near the center of the FEMP and contains many buildings, scrap metal and soil piles, containerized materials, storage pads, a parking lot, roads, railroad tracks, above- and underground tanks, utilities, and equipment. Several impoundments, ponds, and basins are also included.

The LRA selected for Operable Unit 3 involves the removal, treatment/decontamination, and disposal of contaminated materials to reduce the potential for contaminant migration. Decontamination and treatment residues would require further treatment and disposal. Contaminated materials will be disposed of in an on-property engineered aboveground disposal facility and clean materials will be free released for reuse or recycling. The selection of this LRA is based on limited characterization and engineering study data and may change. This alternative also includes continued federal ownership of the land to control future land use.

The following processes will occur:

- Removal - Buildings and structures will be mechanically removed in a health protective fashion and in compliance with ARARs. Waste segregation technologies will be employed to facilitate waste handling, treatment, packaging, and disposition/disposal. Limited in-place decontamination is anticipated for all materials exhibiting gross removable contamination in order to reduce worker exposures and minimize off-property release during demolition/dismantlement. Soils will be removed using mechanical equipment and processed as materials described in the Operable Unit 5 LRA (Section 3.5). Equipment, drums, waste, and product will be removed, treated, and/or packaged to meet risk-based PRGs and ARARs.

- Waste Treatment/Decontamination - Treatment options for containerized waste and bulk soil materials include the application of a wide range of technologies commensurate with the large quantities and types of waste and product materials in Operable Unit 3. Treatment options for containerized waste and bulk material include soil washing, cement-based solidification, and vitrification. Equipment and building materials will be decontaminated employing a range of available technologies including dry concrete scabbling, acid washing, and grit blasting. Soils will be treated as materials described in the Operable Unit 5 LRA. It should be noted that on-going treatability programs for the other four FEMP operable units may provide significant information pertinent to a number of the envisioned Operable Unit 3 waste types. Additional

treatability studies are envisioned to support Operable Unit 3 to demonstrate the effectiveness of specific treatment and decontamination options.

- On-Property Disposal - Following treatment, volume reduction, and/or packaging, the resultant stable waste will be transferred from a temporary holding area to an on-property disposal facility at the FEMP. The disposal facility would include a series of aboveground reinforced concrete vaults, which will be underlain by a leachate collection and detection system and covered by a multilayered RCRA-type cap.

- Free Release/Recycle - Decontamination will be employed to the extent practical to maximize reuse and recycling of materials and minimize the requirement for disposal. Materials meeting free release criteria of DOE Order 5400.5 may be distributed for recycling or reuse to commercial vendors or disposed of at public landfills. Some materials may be released to other DOE facilities for controlled recycling and reuse.

The LRA for Operable Unit 3 was selected for the reasons below:

- Effectiveness - Building and structure wastes will be removed and decontaminated. Remaining contaminated materials will be treated to an immobile form and isolated and controlled in the on-property disposal facility. No residual materials will remain after removal. Limited in-place decontamination will reduce worker exposures and minimize off-property release during demolition/dismantlement. This alternative is expected to meet risk-based PRGs and ARARs as described above. Preliminary engineering estimates indicate that the proposed disposal facility can be designed and constructed to meet risk-based PRGs and ARARs. Further studies are continuing to provide more definitive technical information on the effectiveness of the proposed facility.

- Implementability - Demolition of buildings and structures is a common practice using widely available equipment. Certain intrinsic characteristics of FEMP buildings and structures may require deviations from standard demolition techniques. Suppression techniques may be necessary to prevent creating localized clouds of radioactive particulates. The site-specific demolition process and the decontamination techniques are readily available and implementable. Decontamination techniques may require a dedicated facility for treatment of expected waste forms. The on-property disposal facility employs conventional construction methods and is readily implementable.

- Cost - At this time, no cost estimates have been made, but best professional judgment estimates that the cost of this alternative is expected to be within the range of those alternatives judged to be effective and implementable.

3.4 OPERABLE UNIT 4

Operable Unit 4 includes the physical structures of Silos 1, 2, 3, and 4; the stored waste within them; the soil berms surrounding Silos 1 and 2; the decant tank and associated piping and any contaminated subsoil underlying the silos. Silos 1 and 2 contain approximately 9,500 cubic yards of K-65 residues; Silo 3 contains approximately 5,100 cubic yards of metal oxide residues; and the berms and subsoil contain 40,000 cubic yards of potentially contaminated soil. The K-65 and metal oxide residues contain elevated concentrations of inorganic hazardous constituents and radiological substances.

The LRA for Operable Unit 4 involves the removal of the stored waste inventories from Silos 1, 2, and 3. Contaminated soil and construction material from the silo berms, subsoil and the decant tank will be removed to the extent necessary to achieve risk-based PRGs and ARARs. Removed waste material from Silos 1 and 2 will undergo a contaminant separation process to reduce the concentrations of long-lived alpha emitting radioactive constituents. Treated Silos 1, 2 and 3 waste will be stabilized and placed within an on-property engineered aboveground disposal facility. Concentrated wastes from the contaminant separation process will be stabilized and placed in an interim on-property storage facility pending shipment to an off-site disposal facility. Soil removal, necessary to meet risk-based PRGs and ARARs, will be disposed of in an on-property disposal facility. Silo 4 is an unused facility and will be dispositioned as a no-action alternative. The LRA also includes continued federal ownership of the land to control future land use.

The following processes will occur:

- Removal of Waste Materials - Silos 1 and 2 waste material will be hydraulically removed from the silos as a slurry. Engineering controls will be applied to the removal process to reduce radon release to levels which are protective of human health and the environment. Silo 3 material will be pneumatically removed. The berm material, any contaminated subsoil and the decant tank will be removed by suitable mechanical equipment.

- Waste Treatment - Silos 1 and 2 waste will be treated by chemical separation to remove most of the long-lived alpha-emitting radioactive constituents from the bulk of the material, followed by stabilization of each of the separated material streams. This process will result in a reduced volume of material with higher levels of contamination requiring off-site disposal. Silo 3 waste will be stabilized by vitrification or cement-based solidification before disposal. Any berm and subsoil materials needing treatment will be processed using the same methods as for Silo 3 material. Berm material and the decant tank and piping will be packaged for disposal, if necessary. All water encountered will be treated as required.

- On-Property Disposal - Following treatment, the bulk of the stabilized waste will be transferred from a temporary holding area to an on-property disposal facility. The disposal facility would include a series of aboveground reinforced concrete vaults, which will be underlain by a leachate collection and detection system and covered by a multilayered RCRA-type cap.

- Off-Site Disposal - The reduced volume of material, which contain long-lived alpha-emitting radioactive constituents from the chemical separation process will be stabilized, properly packaged and disposed of in an appropriate off-site disposal facility.

- Runoff/Run-on Control - Runoff control features remove storm water from the operable unit area, and run-on control features direct storm water away from the enclosed process area. Control can be accomplished by using site contour grading, vegetation, diversion and collection ditches, as well as various physical devices including silt traps and sedimentation basins.

The LRA for Operable Unit 4 was selected for the reasons provided below:

- Effectiveness - The waste will be removed and treated, as necessary, to an immobile form and isolated and controlled in the on-property disposal facility. The potential for direct contact with the residuals will therefore be eliminated, and rain water infiltration will be decreased, minimizing the potential for leaching. The reduced volume of material from chemical separation will be stabilized and disposed of in an off-site disposal facility. This alternative is expected to meet risk-based PRGs and ARARs. Further studies are continuing to provide more definitive technical information on the effectiveness of this proposed alternative.

- Implementability - All removal technologies mentioned above are proven, commonly used, and the equipment readily available. Proposed treatment technologies have either been demonstrated in the field or are being refined through treatability studies. The on-property disposal facility employs conventional construction methods and is readily implementable. Packaging of a reduced volume of highly contaminated material and transportation to an off-property disposal facility is readily implementable.

- Cost - The cost of this alternative is within the range of those alternatives judged during the screening phase to be effective and implementable.

3.5 OPERABLE UNIT 5

Operable Unit 5, as defined in the Amended Consent Agreement, includes groundwater, surface water, soil not included in the definitions of Operable Units 1-4, sediments, flora, and fauna. Preliminary estimates are that approximately 366,000 cubic yards of soils and sediments would require remediation under Operable Unit 5.

The LRA for Operable Unit 5 involves the extraction of contaminated groundwater, treatment at an on-property facility, and discharge of the treated effluent to the Great Miami River through the newly constructed effluent line. Treatment residuals will be disposed of in an on-property engineered aboveground disposal facility. The LRA also involves the excavation of contaminated sediments/soils necessary to meet risk-based PRGs and ARARs, transport to an on-property location for treatment using a fluidized soil washing technique, and returning the treated materials as backfill. The soil washing fluids will be recycled and the removed contaminants will be stabilized and disposed in the on-property facility. This alternative also includes continued federal ownership of the land to control future land use.

The following processes will occur:

- Groundwater Extraction - Five recovery wells which will be installed in the regional aquifer as part of the South Plume removal action will be supplemented with several additional wells. Each well is estimated to produce a average flow rate of 650 gallons per minute. Groundwater extraction will continue until risk-based PRGs and ARARs for the regional aquifer are met.

  Perched groundwater will be extracted using french drains, a wellpoint system, and extraction wells. Perched groundwater extraction will continue until risk-based PRGs and ARARs for perched groundwater are met.

- Groundwater Treatment - Groundwater treatment will include a carbon adsorption pretreatment step, followed by precipitation for metals removal, ion exchange for uranium removal, and sludge dewatering. The system may be designed to process up to 8,000 gpm, reducing contaminant concentrations to levels necessary to meet risk-based PRGs and ARARs. The treated water will be discharged to the Great Miami River, and the sludge generated by the treatment system will be stabilized as necessary and disposed of in an on-property disposal facility.

- Soil Removal - Soils will be excavated using traditional heavy construction equipment and techniques. Some deviations from standard excavation techniques may be necessary for excavation around and under facilities that may remain after Operable Unit 3 remediation. Soils in the contaminated zones will be excavated to meet risk-based PRGs and ARARs. Those excavated soils that contain constituents below the remediation goals (based upon analysis) will be separated and used as backfill.

- Waste/Soil Treatment - After removal, the soils may go through solids processing (sorting, shredding, and/or compaction) to facilitate transport and on-property stockpiling for treatment using soil washing. The soil washing process will extract uranium and organic/inorganic contaminants from the sediment/soil using a liquid medium as the washing solution. Following the initial sorting and preparation in a rotating drum or a vibrating screen device, the larger pieces of soil/sediment are placed in a countercurrent chemical extractor, where additional washing fluid is passed countercurrent to the soil/sediment flow, removing the contaminants. The treated solids are then dewatered. The remainder of the process is a multi-step treatment for removal of contaminants from the washing fluid prior to its recycling. Although the treated soils and sediments can be safely backfilled at the FEMP, the treatment sludges will contain concentrated contaminants and will require disposal in an on-property disposal facility.

- On-Property Disposal - Following treatment, volume reduction, and packaging, the resultant stable waste will be transferred from a temporary holding area to an on-property disposal facility. The disposal facility is envisioned to include a series of aboveground reinforced concrete vaults, which will be underlain by a leachate collection and detection system and covered by a multilayered RCRA-type cap.

The LRA for Operable Unit 5 was selected for the reasons provided below:

- Effectiveness - Contaminated groundwater will be extracted, treated, and the treated effluent discharged to the Great Miami River. All PRGs and ARARs for surface water will be met. Treatment residuals will be stabilized and disposed of in an on-property facility. Soils and sediments will be removed and treated to an immobile form and controlled in the on-property disposal facility. This alternative is expected to meet risk-based PRGs and ARARs.

- Implementability - Groundwater extraction is an established technology. The carbon adsorption, precipitation, and ion exchange technologies required for groundwater treatment are established and readily available. Soil washing is an established technology in the mining industry which is being applied to environmental remediation projects. Preliminary treatability studies on FEMP soils show that risk-based PRGs and ARARs for the FEMP are attainable. The on-property disposal facility employs conventional construction methods and is readily implementable.

- Cost - The cost of this alternative is within the range of those alternatives judged during the screening phase to be both effective and implementable.

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