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SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT FOR THE SITEWIDE ECOLOGICAL RISK ASSESSMENT AUGUST 1993 DRAFT

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

AUGUST 1993

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

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LIST OF ACRONYMS

ACA	Amended Consent Agreement
AEC	U.S. Atomic Energy Commission
BTAG	Biological Technical Assistance Group
BTV	Benchmark Toxicity Value
CAWQC	Chronic Ambient Water Quality Criteria
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant(s) of Concern
DCF	Dose Conversion Factor
DOC	Dissolved Organic Carbon
DOE	U.S. Department of Energy
DOE-FN	U.S. Department of Energy - Fernald Site Office
EEC	Estimated Environmental Concentrations
EP	Equilibrium Partitioning
EPA	U.S. Environmental Protection Agency
ER-L	Effects Range-Low
ER-M	Effects Range-Median
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FMPC	Feed Materials Production Center
FWS	U.S. Fish and Wildlife Service

ICRP	International Commission on Radiological Protection
MCL	Maximum Concentration Limit
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OU5	Operable Unit 5
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
SERA	Sitewide Ecological Risk Assessment
SLERA	Screening Level Ecological Risk Assessment
SSOD	Storm Sewer Outfall Ditch
SWCR	(Draft) Site-Wide Characterization Report
T&E	Threatened and Endangered
TV	Toxicity Value
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WEMCO	Westinghouse Environmental Management Company of Ohio

EXECUTIVE SUMMARY

Following guidance provided by Region V of the U.S. Environmental Protection Agency (EPA), a Screening Level Ecological Risk Assessment (SLERA) was prepared to determine if radiological and non-radiological contaminants associated with actions at the Fernald Environmental Management Project (FEMP) represent a threat to ecological receptors inhabiting this facility and nearby off-site areas. Contaminant concentration data evaluated in this SLERA were collected during the Remedial Investigation/Feasibility Study (RI/FS). In addition, the results of existing ecological and biological studies conducted on the FEMP were also considered.

The focus of this SLERA was on-site areas not likely to be remediated based on human-health concerns, and off-site areas, including the Great Miami River. Contaminants may have entered soil, sediments, and surface waters as airborne contamination from production or incinerator stacks, the flyash piles, waste pits, or the landfill, as runoff from contaminated soil, or in effluent discharged to the Great Miami River.

A review of information in previous studies conducted on the FEMP indicated that the vegetation on the site was typical of the Western Mesophytic forest region and that population levels of wildlife species on the site appeared normal for southwestern Ohio. No species or group was conspicuously low or absent in any available habitat niches, and the ecological communities on the FEMP were typical of those found in the region where similar land-use practices occur. The presence of threatened and/or endangered species has yet to be established on the FEMP. No studies have identified any major adverse ecological impacts — such as fish kills or vegetation die-off — at the site.

The mean and maximum concentrations of media-specific non-radiological contaminants were compared to benchmark values that are protective of ecological receptors. The results of these comparisons indicated that none of the soil contaminants represent a risk to ecological receptors. Lead, mercury, and silver were identified as contaminants that could adversely impact aquatic organisms in both Paddys Run and the Great Miami River. Selenium detected in water samples collected from Paddys Run and cadmium present in samples collected from the Great Miami River

may also represent a hazard to aquatic biota or to terrestrial organisms ingesting these surface waters. None of the contaminants identified in samples collected from the Great Miami River appear to be associated with activities at the FEMP. Mercury was the only contaminant detected in sediment samples collected on-site (Paddys Run) that was present in concentrations that could adversely impact both aquatic and terrestrial ecoreceptors.

With the exception of very conservative dose calculations based on the maximum level of radiological contaminants present in samples collected from the area immediately east of the production area, the methodology and assumptions used to model the available RI/FS data indicate that the doses absorbed by receptor organisms fall below levels determined to be protective of ecological receptors. It can be concluded that, based on the measured levels of radioactivity on and around the FEMP site, adverse impacts on populations of terrestrial or aquatic biota are unlikely.

Additional samples (soil, surface water, and sediment) are currently being collected from on-site locations. These samples will be analyzed for both radiological and non-radiological constituents, and the results will be used to supplement the data analyzed in this SLERA. Because of the limited number of non-radiological analyses available for review, the additional analytical data are necessary to confirm the extent of contamination by lead, mercury, silver, and selenium and to verify that these contaminants actually represent a risk to ecological receptors. Results of these additional analyses will be included in the Sitewide Ecological Risk Assessment as part of the OU5 Remedial Investigation Report.

The results of the SLERA indicate that, with the exception of lead, mercury, silver, and selenium, contaminants associated with activities occurring at the FEMP are not present in concentrations that are likely to adversely impact on-site or off-site ecological receptors. The results of analyses of additional media samples being collected from the FEMP will permit the nature and extent of contamination by these four metals to be better defined. The results of the SLERA are consistent with those of past studies which have indicated that neither the terrestrial nor aquatic biota associated with the site have been adversely impacted, and that these populations are typical of those found in southwestern Ohio.

1.0 INTRODUCTION

The primary purpose of the Screening Level Ecological Risk Assessment (SLERA) is to use contaminant concentration data collected during the Remedial Investigation/Feasibility Study (RI/FS) to determine if contaminants represent a threat to ecological receptors inhabiting the Fernald Environmental Management Project (FEMP) and nearby off-site areas, including the Great Miami River. Guidance provided by Region V of the U.S. Environmental Protection Agency (EPA) served as the basis for preparing this analysis. The EPA will review the SLERA to determine if there is a need for additional studies to support the Sitewide Ecological Risk Assessment (SERA). If they are not necessary, information in the SLERA and a summary of the reasoning for the decision not to conduct additional studies will form the basis for the SERA. If additional studies are necessary, the results of these studies will be added to the information summarized in this document and incorporated into the SERA.

As stipulated in the Amended Consent Agreement (ACA) between the U.S. Department of Energy (DOE) and the EPA (September 1991), Operable Unit 5 must prepare the Sitewide Ecological Risk Assessment as part of the OU5 RI. Operable Unit 5 representatives from the Fernald Environmental Restoration Management Corporation (FERMCO) and the DOE Fernald Site Office (DOE-FN) discussed the EPA Region V guidelines for conducting ecological assessments with a representative of EPA's Biological Technical Assistance Group (BTAG) during a meeting at the FEMP on February 17, 1993. Region V's guidelines emphasize that factors such as the nature and extent of contamination, the physical and toxicological properties of contaminants, the quantity and quality of ecological resources, and an understanding of the areas that will be remediated to meet human-health concerns be considered in the development of ecological risk assessments.

During the February meeting, FEMP personnel also briefed the BTAG representative on the status of the ongoing RI/FS investigation at the FEMP, including the site's remediation plans, driven by human-health concerns. Based on these discussions, participants at the meeting came to the understanding that the Sitewide Ecological Risk Assessment and the SLERA would evaluate the possible risks of site contaminants to ecological receptors inhabiting on-site and off-site areas not likely to be remediated based on human-health concerns. This means that more than 80 percent of the

FEMP's 1050 acres will be evaluated. In general, the areas of the FEMP which will be remediated to meet human-health concerns are those that were used for production and/or storage of wastes generated during facility operations.

Discussions during the February 1993 meeting also led to an understanding that habitat (for example, grassland) and the size of the home range of receptor species used in the models developed to quantify total radiation doses would be used to determine on-site study areas. This approach provides for a more meaningful evaluation of potential risks to ecological receptors than does examining risks associated with the entire site. These study areas, listed below, are also shown in Figure 1-1 and described in detail in Section 1.1.3:

- Study Area A — Woodlot/Jurisdictional Wetland
- Study Area B — Northern Pine Plantation
- Study Areas C, D, and E — Grasslands
- Study Area F — Paddys Run and Paddys Run Corridor.
- Study Area G — Southern Pine Plantation

In addition to these study areas, OU5 evaluated contaminant concentrations in soil in four off-site study areas, and sediment and surface water contaminant concentrations from the Great Miami River. Operable Unit 5 assessed surface soil contamination in all study areas with the exception of the Great Miami River, and assessed contamination in surface water and sediment collected from the Great Miami River, Paddys Run, and several small, on-site bodies of water (typically drainage ditches). Although the FEMP is located above the Great Miami Aquifer, groundwater was not considered to be a specific medium of concern. While it is known that the relationship between Paddys Run and this aquifer is dynamic, direct exposure of biota to groundwater is unlikely. Ecological risks associated with potential contaminants of concern (COCs) present in the groundwater were indirectly evaluated when the potential COCs detected in the surface water were examined.

The FEMP, established by the Atomic Energy Commission as the Feed Materials Production Center (FMPC), began processing uranium ore and recycled uranium residues into pure uranium metal in 1951. Production and its support functions have always been located within the 136-acre production area (Figure 1-1). Chemicals used in the process were stored in this area as well. Uranium was the

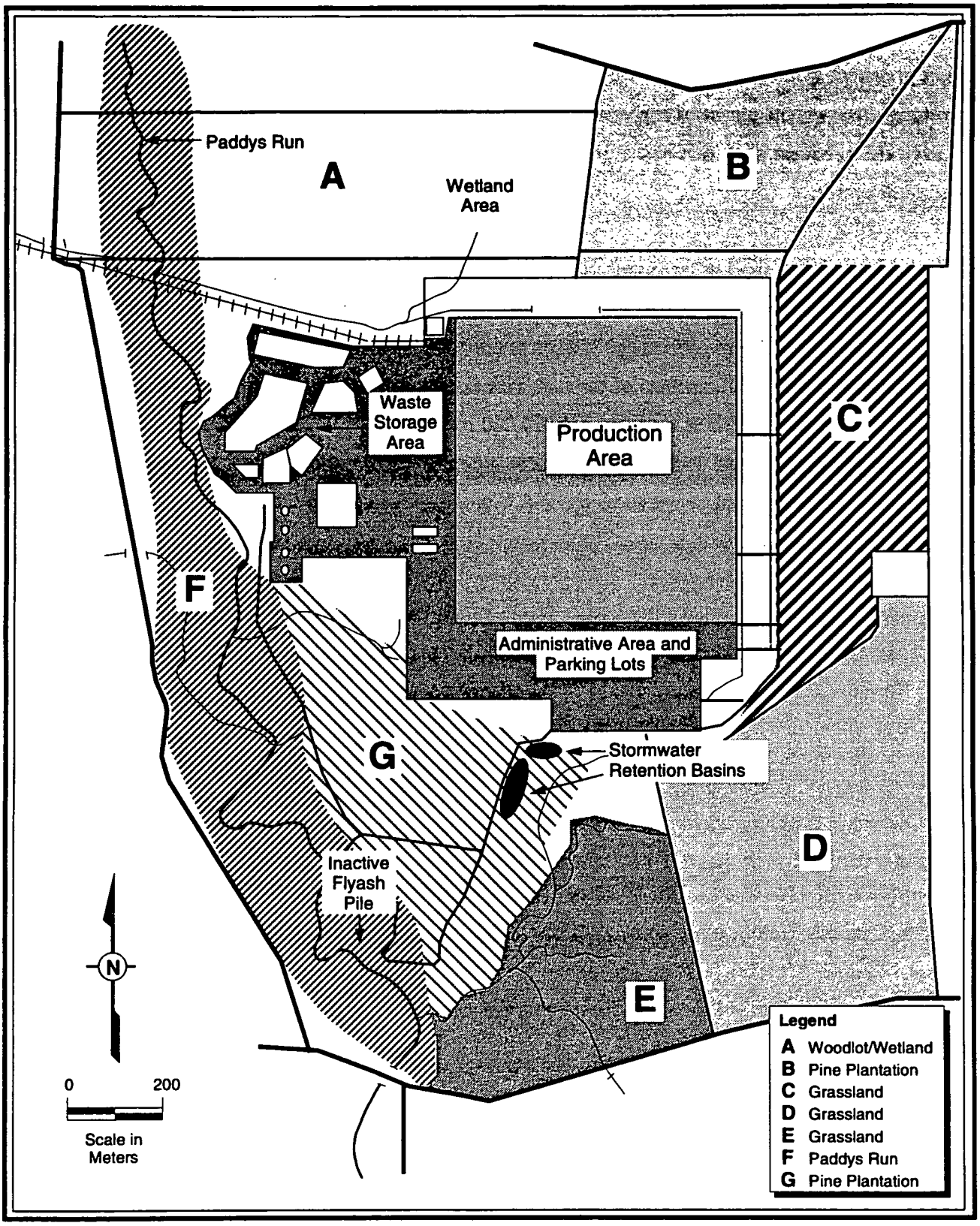

Figure 1-1. Study Areas for the Screening Level Ecological Risk Assessment

most prevalent material processed at the FMPC. Consequently, uranium in various forms, is the most significant contaminant of concern at the FEMP. An incinerator operated for several years near the sewage treatment plant east of the production area. Several waste pits and other waste units were also built on site.

Most of the uranium used in the production process was depleted, that is, it contained a lower percentage of the uranium-235 isotope than is found in natural uranium. Enriched uranium was also processed, but the uranium-235 isotope was generally not enriched to more than 2 or 3 percent. In addition to uranium, small amounts of thorium were occasionally processed from 1954 through 1975. Uranium production peaked at approximately 10,000 metric tons in 1960, and declined throughout the remainder of the 1960s and 1970s. The early 1980s saw some increase in production, but increasing demands for environmental compliance, coupled with the lessening demand for uranium, resulted in an end to production in 1989.

Even before production ended, DOE agreed in 1986 to conduct an RI/FS at the FEMP. As additional information about the nature and extent of contamination became available, the scope of the RI/FS was modified accordingly. For purposes of the RI/FS, the FEMP was divided into five operable units, based in part on an understanding of the historical functions of the various areas of the site (Figure 1-2). The scope of the five operable units was redefined in the 1991 ACA; general descriptions of the operable units are:

- Operable Unit 1: waste pit area
- Operable Unit 2: other waste units (the active and inactive fly ash piles, the solid waste landfill, the lime sludge ponds, and the South Field)
- Operable Unit 3: Production Area buildings
- Operable Unit 4: the four silos in the waste pit area (this includes the K-65 silos)
- Operable Unit 5: environmental media (soil, groundwater, surface water, sediment, flora, and fauna)

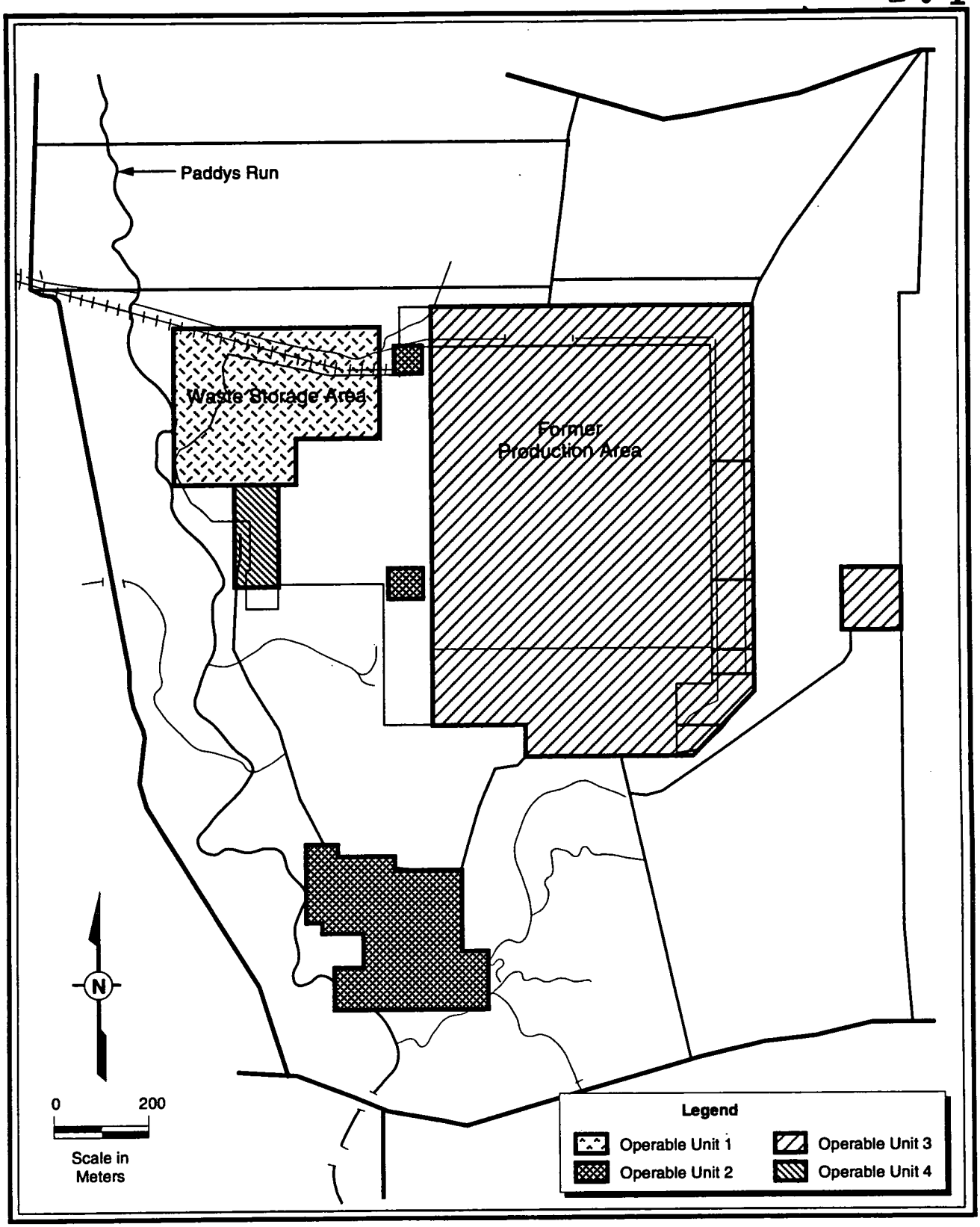

Figure 1-2. Operable Units for the FEMP Remedial Investigation/Feasibility Study

As OU5 began preparing the SLERA, several factors related to the status of the RI/FS database and their impact on this screening level document became significant. First, analytical data used to prepare this document are from the sitewide RI/FS database, which is currently being validated. EPA Region V has been informed that neither the radiological nor the non-radiological data would be validated prior to preparation of the screening level document. A second factor that OU5 considered important is that not all the RI/FS data for the areas being evaluated for the screening level document included sufficient information for proper identification of the sample (e.g., sample type, depth, location). In these cases, the data were not used in the SLERA. The third factor is that OU5 used only positive analytical results in this assessment. If analytical results for a parameter were reported at less than its method detection limit, they were not used. Finally, since unvalidated data were used for this SLERA, OU5 did not perform any preliminary statistical evaluation of these data (distribution, confidence limits, etc.). Rather, OU5 considered all contaminants present in concentrations greater than their method detection limit as potential COCs. It is possible that the conclusions and recommendations presented in this SLERA may be modified in the Sitewide Ecological Risk Assessment following completion of the RI/FS database validation task.

The maximum and arithmetic mean contaminant concentrations for each medium in each study area were determined. Throughout this SLERA, both values are used to evaluate exposure. In many risk assessments, the upper 95 percent confidence limit, rather than the maximum concentration, is used to evaluate exposure. However, use of the maximum measured concentration is a very conservative approach that estimates the maximum possible exposure. In contrast, the use of mean concentrations permits a more probable estimate of exposure.

The remaining sections of Section 1.0 focus on site characterization and the fate and transport of contaminants at the FEMP. Sections 2.0 and 3.0 both include data and supporting information that quantifies the concentrations of potential contaminants present in various media (Exposure Assessment). In Section 2.0, the exposure concentration of a potential COC is compared to appropriate criteria/dose-response information. For ecological risks associated with exposure to radionuclides, models using site-specific ecological receptors were developed to quantify total dose in Section 3.0. These values were then compared to benchmark criteria developed by the International Atomic Energy Agency (IAEA 1992) for ecological receptors.

Because exposure to radioactive metals such as uranium and thorium can impact ecoreceptors both chemically and radiologically, the chemical toxicity of these two metals is evaluated in Section 2.0, while Section 3.0 summarizes the risk to ecological receptors due to radiation effects. Finally, a summary of the toxic effects and conclusions derived thereof are presented in Section 4.0.

1.1 SITE CHARACTERIZATION

This section of the SLERA includes a description of the general ecology as well as a more in-depth description of the study areas developed for the Sitewide Ecological Risk Assessment and this screening document. Throughout the operation of the site, several organizations and universities have conducted ecological or biological studies at the FEMP, and these are noted in this section. The most comprehensive study of plant and animal communities of the FEMP was conducted by Facemire et al. (1990) in 1986-1987 and much of the information on flora and fauna presented here is a summary of that study. A brief summary of threatened and endangered species is also provided in this section; a detailed review is included in Appendix A. None of these studies have identified any major adverse ecological impacts — such as fish kills or vegetation die-off — at the site.

1.1.1 General Ecology

The FEMP and surrounding areas lie in the Eastern Deciduous Forest Province characterized by oak-hickory and beech-maple forests, which provide a continuous, dense summer canopy. Nearly all indigenous forest stands in southwestern Ohio have been cleared, cut, or altered for agriculture or urban development.

Vegetation communities within FEMP boundaries reflect land use practices typical of an industrial facility. The area outside the production and waste storage areas is predominantly open pasture, which continues to be used extensively for grazing by cattle. The milk produced by cattle grazing in the FEMP is analyzed for radionuclides on a routine basis. Forest woodlots occupy drainage ditches or are used as natural fence rows or hedges. This has led to the development of a number of distinct terrestrial habitats, described by Facemire et al. (1990) as introduced (nonnative) grasslands, pine plantations, deciduous woodlands, and the inactive flyash pile.

Facemire et al. (1990) identified and recorded the following flora and fauna on the site: 47 species of trees or shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians or reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates.

The white-footed mouse (*Peromyscus leucopus*) was the most abundant of the five nongame small mammal species recorded, while the short-tailed shrew (*Blarina brevicauda*) occurred in the widest variety of habitats. The meadow vole (*Microtus pennsylvanicus*), meadow jumping mouse (*Zapus hudsonius*), and eastern chipmunk (*Tamias striatus*) were also collected within FEMP boundaries. Medium-sized mammals common on the FEMP include the coyote (*Canis latrans*), red fox (*Vulpes vulpes*), opossum (*Diadelphis virginianus*), raccoon (*Procyon lotor*), groundhog (*Marmota monax*), and fox squirrel (*Sciurus niger*) (Facemire et al. 1990).

Ninety-eight species of birds were identified on the FEMP, including breeding birds, wintering birds, and spring migrants (Facemire et al. 1990). Raptor species which have been observed at the FEMP include the northern harrier (*Circus cyaneus*), red-shouldered hawk (*Buteo lineatus*), Cooper's hawk (*Acciptier cooperii*), red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), eastern screech owl (*Otus asio*), and great horned owl (*Bubo virginianus*).

1.1.2 Threatened and Endangered Species

A detailed review of threatened and endangered species that could occur on or in the vicinity of the FEMP is included in Appendix A. Information obtained from the U.S. Fish and Wildlife Service, the Ohio Department of Natural Resources, and Sitewide Characterization Report (DOE 1992a) was used to compile this review.

Because the Federally endangered Indiana bat (*Myotis sodalis)* has been recorded on Banklick Creek east of the FEMP, a survey of suitable habitats was taken in 1988. Mist netting failed to collect any Indiana bats on the FEMP. Sloan's crawfish (*Orconoctes sloanii*; state threatened) was recorded as common in Paddys Run during the winter of 1986-1987. The bigeye shiner (*Notropis boops*; state endangered) was found at the mouth of Paddys Run in 1973 but has not been observed in this stream since then. Recent surveys indicate that suitable habitat for the cave salamander (*Eurycea lucifuga*;

state endangered) does not occur on the FEMP, and cave salamanders were not found on the FEMP during a 1989 survey. Slender finger-grass (*Digitaria filiformis*; state endangered) and mountain bindweed (*Polygonum cilinode*; state endangered) have been reported on the FEMP. Running buffalo clover (*Trifolium stoloniferum*; Federally endangered) and spring coral-root (*Corallorhiza wisteriana*; state threatened) have not been identified on the FEMP. However, both species occur nearby in Miami Whitewater Forest County Park, and the FEMP has suitable habitat for running buffalo clover. The northern harrier (state endangered), northern waterthrush (*Seiurus noveboracensis*; state endangered), and dark-eyed junco (*Junco hyemalis*; state endangered) migrate through the area but do not nest in southwestern Ohio.

1.1.3 Study Areas Developed for the Sitewide Ecological Risk Assessment

As discussed in Section 1.0 and shown in Figure 1-1, the area of the FEMP outside Operable Units 1-4 was divided into study areas based on habitat type and, to a lesser extent, on home-range size of potential ecological receptors. This approach enabled OU5 to quantify media-specific contaminant concentrations within a given habitat, thus resulting in evaluation of habitats that with greater amounts of contamination separate from less contaminated study areas.

1.1.3.1 Study Area A - Woodlot/Jurisdictional Wetland

The northwestern portion of the FEMP is characterized by wooded areas in various stages of succession. The westernmost portion this area is represented by mature forest while the remainder of the area is a successional woodlot disturbed by grazing. Species common to these woodlands are American elm (*Ulmus americana*), hackberry (*Celtis occidentalis*), and wild black cherry (*Prunus serotina*), a species typical of disturbed areas characterized by gaps in the forest canopy. Facemire et al. (1990) provides an in-depth description of this habitat.

Fauna recorded as abundant or common by Facemire et al. (1990) in the woodland communities in Study Area A include 29 species of birds, the short-tailed shrew, the deer mouse (*Peromyscus maniculatus*), white-tailed deer (*Odocoileus virginianus*), and the eastern cottontail (*Sylvilagus floridanus*). Incidental sightings of the black rat snake (*Elaphe obsoleta*) and the box turtle (*Terrapene carolina*) were also been recorded.

The eastern portion of the woodlot area is characterized by hydric soils which, along with the vegetation and hydrologic characteristics documented in this area, indicate jurisdictional wetlands. The other soils in Study Area A are somewhat poorly drained and upland (DOE 1992a).

1.1.3.2 Study Area B - Northern Pine Plantation and Study Area G - Southern Pine Plantation

Two pine plantations — one in the northeast area of the site and the other in the southwest area of the site — were planted in 1972 as part of an environmental improvement project and to serve as buffer zones between the FEMP and the surrounding area. They were planted in alternating rows of white pine (*Pinus strobus*) and Austrian pine (*Pinus nigra*). Norway spruce (*Picea excelsa*) occurs only occasionally. The trees are very overcrowded and infested with *Diplodia* tip blight. Dominant herbaceous species in the pine plantations include red fescue (*Festuca rubra*), brome grass (*Bromus sp.*), Kentucky bluegrass (*Poa pratensis*), and goldenrod (*Solidago sp.*).

Soils in the northern part of Study Area B are upland, while soils in the southern part of Study Area B are hydric (Ragsdale silty clay loam) and somewhat poorly drained (Fincastle silt loam). Soils in the southern pine plantation are somewhat poorly drained Idenshaw silt loam.

The pine plantations are a preferred habitat for white-tailed deer and the eastern cottontail. Other species listed as common or abundant in the pine plantations include 17 species of birds and the deer mouse. Cooper's hawks were frequently observed in the pine plantations along with incidental sightings of the American toad (*Bufo americanus*) and Butler's garter snake (*Thamnophis butleri*) (Facemire et al. 1990). Coyotes are also periodically observed in this area.

1.1.3.3 Study Areas C, D, and E - Grasslands

The grassland habitat on the FEMP consists of approximately 425 acres of open pasture and mown grass maintained between the riparian woodland and the pine plantations. The mowing, grazing, and brush clearing account for the predominance of introduced grasses and old-field vegetation. Dominant herbaceous species include orchard grass (*Dactylis glomerata*), red fescue, and Kentucky bluegrass. Other common species are listed in Facemire et al. (1990). Soils in these areas range from somewhat poorly drained to well-drained.

Fauna recognized as common or abundant in the grassland communities include eight species of neotropical migrants, white-tailed deer, bobwhite quail (*Colinus virginianus*), and the eastern cottontail (Facemire et al. 1990).

Although predominantly grassland, Study Area E also includes the storm sewer outfall ditch (SSOD) which is a tributary of Paddys Run. It originates east of the production area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property. The corridor bordering the SSOD is dominated by riparian vegetation. Prior to the 1986 completion of the storm water retention basin, the SSOD carried uranium-contaminated runoff from the production area following heavy rains. Currently, the ditch drains nearly all of the area east of the production area (essentially open pasture), but receives storm water from the production area only if the storm water retention basin overflows. During its years of operation, the retention basin has overflowed five times. However, no overflow has occurred since May 1990. The amount of water discharged is minimal compared to the amount of stormwater captured in the basin. Because the bed of the SSOD is highly permeable sand and gravel, it is typically dry.

1.1.3.4 Study Area F - Paddys Run and Paddys Run Corridor

Paddys Run, which originates north of the FEMP, flows southward along the western boundary of the facility and enters the Great Miami River approximately 1.5 miles south of the southwest corner of the FEMP property (Figure 1-3). The stream is about 9 miles long and drains an area of approximately 16 square miles, including the FEMP site. Nearly all the uncontrolled runoff from the FEMP flows into Paddys Run.

Paddys Run is an intermittent stream flowing primarily from January through May. During these months, flow is generally continuous throughout its length. However, the stream has eroded through the glacial overburden and into the top of the Great Miami aquifer from an area beginning just south of the railroad tracks crossing the FEMP to the Great Miami River. Here the flow is slight or absent from June through December except during and immediately following a heavy rain. The wide range of flow conditions in Paddys Run significantly influenced the composition of the aquatic community inhabiting the stream. Paddys Run is steep-sided, and erosion is severe during high flows. Its course has been manually changed twice to prevent erosion into the waste pit area and Paddys Run Road

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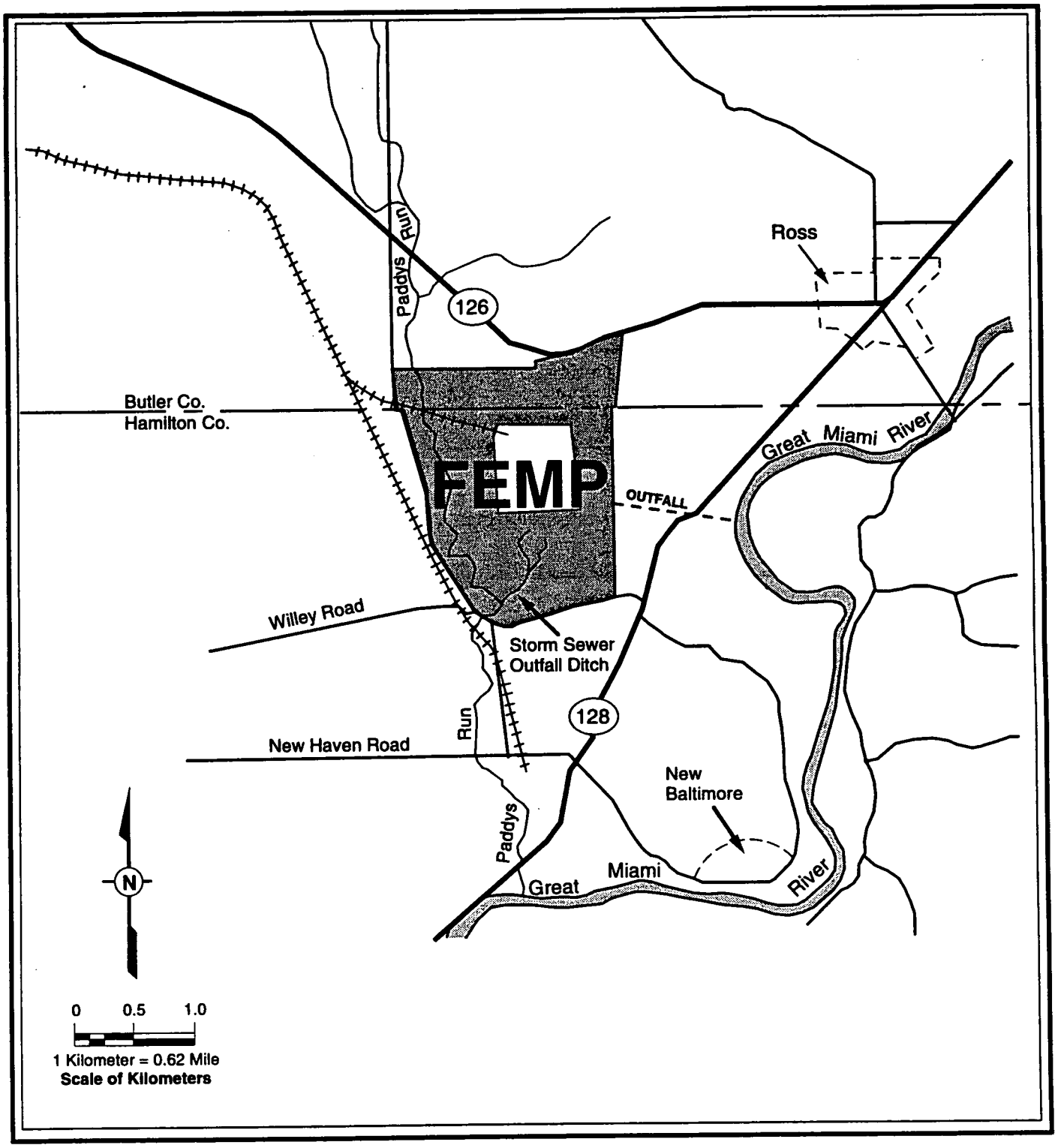

Figure 1-3. FEMP and Surrounding Area

(WMCO 1987). Soils along Paddys Run are categorized as Fox-Genesee loams, characterized as deep, gently sloping, and well drained.

The riparian woodland bordering Paddys Run resembles a maple-cottonwood-sycamore floodplain forest (Anderson 1982). The dominant species present include eastern cottonwood (*Populus deltoides*), hackberry, American elm, and box elder (*Acer negundo*). The streambed alterations resulted in the colonization of other species in the floodplain area. Facemire et al. (1990) compiled an extensive list of the species identified in this area.

Twenty-three species of fish were recorded in Paddys Run by Facemire et al. (1990). The most abundant species were the bluntnose minnow (*Pimephales notatus*), creek chub (*Semotilus atromaculatus*), stoneroller minnow (*Campostroma anomalum*), and several species of shiner (*Notropis sp.*). Paddys Run supports a typical benthic macroinvertebrate community, and includes approximately 70 different benthic taxa (DOE 1992a).

For the SLERA, analytical data collected from Paddys Run were grouped into three reaches in order to make more meaningful comparisons of the data. Reach 1 encompassed areas upstream of the FEMP and consisted of one sampling station (W5). Reach 2 was comprised of five sampling stations (W10 - W14) adjacent to and immediately downstream of the waste storage and production areas. Reach 3 included two sampling stations (W7 and W8) south of the site and downstream of the confluence of Paddys Run and the SSOD (Figure 1-4).

1.1.3.5 Great Miami River

The Great Miami River is the main off-site surface water body in the vicinity of the FEMP. It flows within one mile of the site's eastern boundary, and is the receiving water for the site's effluent (Figure 1-3). The river generally flows to the southwest, but exhibits meandering patterns that result in sharp directional changes. Its drainage area is approximately 3360 square miles at the Hamilton gage, located about 10 miles upstream from the FEMP discharge outfall. The FEMP is located within the Great Miami River drainage basin but the majority of the site lies above the river's present day floodplain.

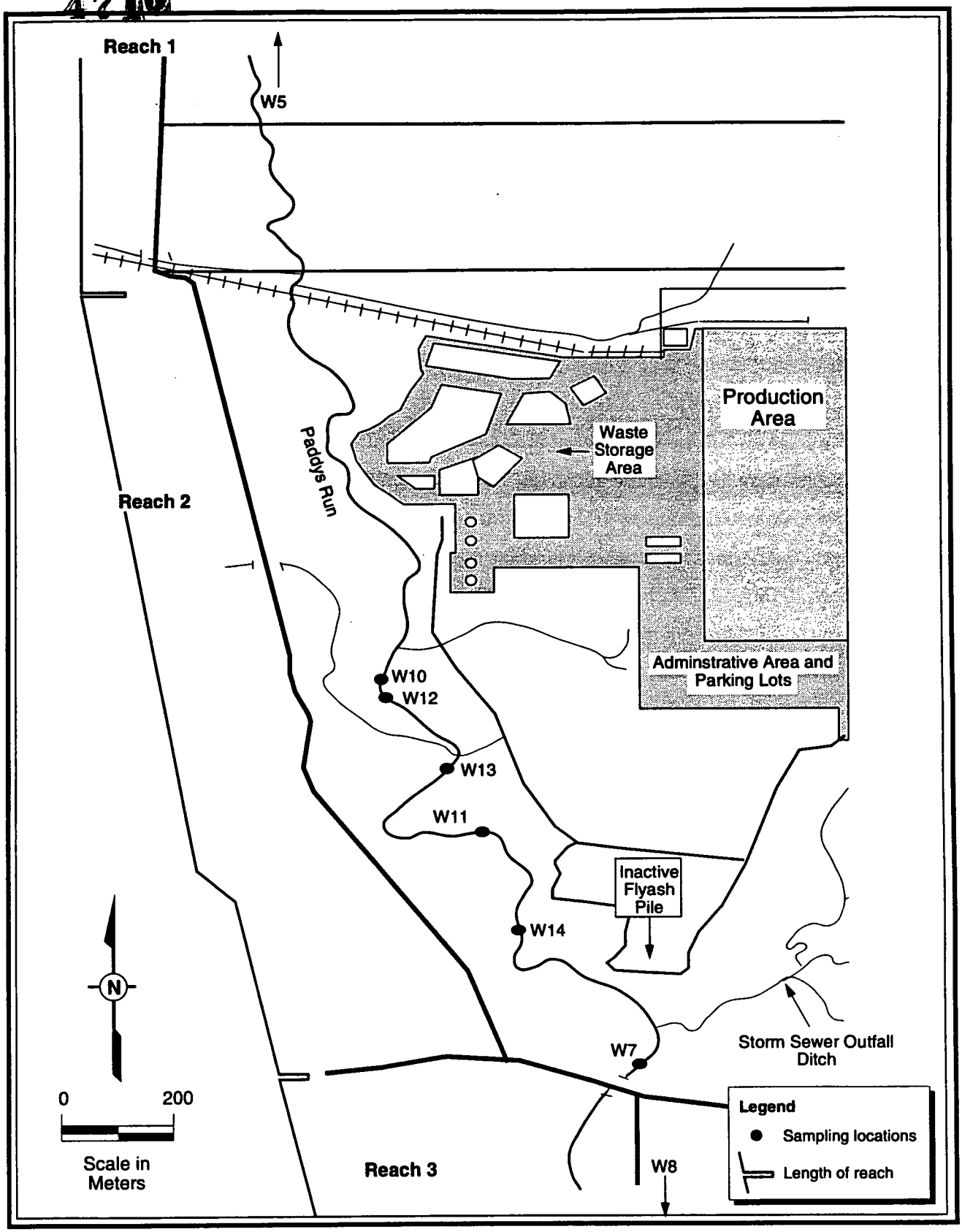

Figure 1-4. Sampling Reaches along Paddys Run

The Ohio Environmental Protection Agency (OEPA) classifies the Great Miami River as a warm-water habitat capable of supporting balanced, reproducing populations of warm-water fish and associated vertebrates, invertebrates, and plants on an annual basis (OEPA 1992). A total of 106 species of fish, including six hybrids, was recorded from the Great Miami River from 1900 to 1978 (Trautman 1957; 1981). The OEPA conducted intensive fisheries surveys along 92 miles of the Great Miami River and the lower reaches of five tributary streams in 1980 and 1989 (OEPA 1982; 1989); 63 and 76 species of fish, respectively, were collected during these surveys. Eighty genera of phytoplankton have been recorded by the U.S. Geological Survey (USGS) in samples taken at New Baltimore (downriver of the FEMP discharge outfall; Figure 1-3) between 1974 and 1982 (USGS 1990). These genera include green algae, diatoms, and blue-green algae. Although not specifically characterized, aquatic macrophytes such as *Myriophyllum sp.* and *Potomogeton sp.* have been observed above and below the FEMP outfall (Miller et al. 1990; 1992). The Great Miami River also supports a diverse benthic macroinvertebrate community. Approximately 60 taxa have been identified in samples taken from the river in the vicinity of the FEMP (DOE 1992a).

For this report, analytical data for the Great Miami River were grouped into five reaches (Figure 1-5). Reach 1 originated north of FEMP property, extended to a point immediately upstream of the outfall, and consisted of samples taken at three sampling stations (W1, GMR1, and ZI7). Reach 2 consisted of four sampling stations (GMR2, ZI4, ZI5, ZI6) immediately downstream of the outfall and extending through half of the westerly bend in the river. Reach 3 included four sampling stations (GMR3, ZI1, ZI2, ZI3) and encompassed the section of the river running southward, downstream of the FEMP property. Reach 4 consisted of the section of river downstream of the easterly curve and included one sampling station (W3). Reach 5 was comprised of two sampling stations (GMR4 and W4) located downstream of the mouth of Paddys Run.

1.1.3.6 Terrestrial Off-site Areas

To help in the evaluation of potential risk to ecological receptors living near but not on the FEMP, off-site soil samples collected for the RI/FS were grouped into one of four quadrants (northwest, northeast, southwest, or southeast) based on their direction from the FEMP. The mean and maximum concentrations of potential COCs for each quadrant were evaluated in this SLERA.6

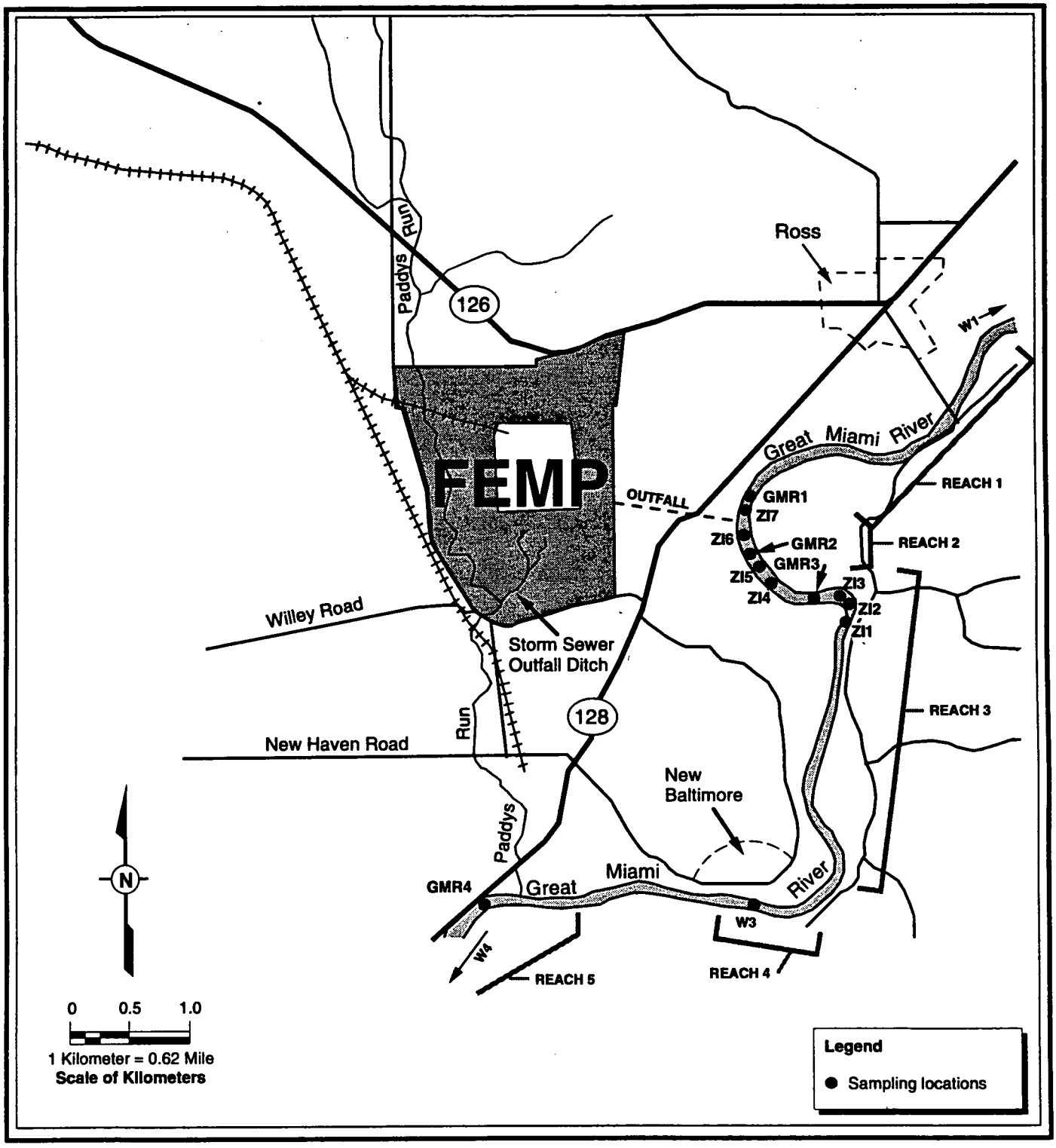

Figure 1-5. Sampling Reaches along the Great Miami River

1.1.4 Other Environmental Surveys and Studies Conducted for the FEMP

In addition to the report completed by Facemire et al. (1990), several other surveys and studies have been conducted at the FEMP throughout its operation. These studies are brief summarized in the following section.

1.1.4.1 Tarzwell 1952

Tarzwell (1952) collected samples from Paddys Run in July, August, and early September 1951 (prior to initiation of operations at the FEMP) to characterize the vertebrate community. This study concluded that fish suitable for sport fishing were largely confined to the area of the stream above the site. Fish below the site, while abundant, were largely forage species.

1.1.4.2 Batelle 1977

This report determined that vegetation occurring on the site was typical of the Western Mesophytic forest region. Population levels of wildlife species on the site appeared normal for southwestern Ohio. No species or group was conspicuously low or absent in any available habitat niches. No threatened or endangered species were present on the site. The ecological communities on the FMPC site were typical of those found in the region where similar land-use practices occur. Fish and benthic invertebrates collected from Paddys Run indicated that the intermittent stream is of good to high quality in areas of permanent water and that clean-water fish species (chubs and darters) were dominant. Fish and benthos from the Great Miami River suggested that the river was of low to good quality and had characteristics of a stressed aquatic system both above and below the FMPC outfall.

1.1.4.3 Miller et al. 1992

This report summarized the work Dr. Miller and his students from the University of Cincinnati conducted on the Great Miami River from 1984 through 1991. The report concluded that the fishery of the Great Miami River has been stable over the eight years, 1984-1991, and 49 species were recorded.

1.1.4.4 Benthic Macroinvertebrate Survey, (DOE 1992a)

The data collected and analyzed in this study indicate that the operation of the FEMP has resulted in nothing more than minor enrichment of the waters of the Great Miami River and Paddys Run. No

deleterious effect on the benthic macroinvertebrate communities of either water body was demonstrated. Rather, factors unrelated to the FEMP exerted a significant controlling influence on the benthos. These factors included the seasonal intermittent nature of Paddys Run and the high sediment loads carried by the Great Miami River during periods of heavy precipitation. These factors reduced the quality of Paddys Run and the Great Miami River as habitat for macroinvertebrates and other aquatic life. Invertebrate Community Index values estimated for these waters were consistent with ranges considered by OEPA (1988) to represent fair to good water quality.

1.2 CONCEPTUAL MODEL

This section evaluates the major fate and transport processes at the FEMP of relevance to the SLERA. As discussed previously, all production activities occurred within the 136-acre production area. Chemicals used to support uranium processing were all stored within this area and all maintenance and garage facilities were located here as well. To comply with DOE orders for estimating radiation dose to off-site residents, the FEMP has been operating 24-hour continuous air monitoring stations along the site perimeter since the 1970s. In addition, the site monitors its liquid effluent for radionuclides as well as for compliance with its NPDES permit. These data have demonstrated that uranium is the primary contaminant associated with the FEMP.

1.2.1 Principal Pathways and Contaminants

The two principal pathways for contaminants to reach the surrounding environment (that is, the study areas being evaluated for this SLERA) during the years of production were airborne emissions from the production stacks and from an incinerator located on the eastern border of the site (Figure 1-6), and liquid effluent collected by various sumps located in the production area and then discharged into the Great Miami River.

Although potential secondary pathways include airborne resuspension of contaminated surface soil and surface water runoff, airborne resuspension is limited because surface soils at the FEMP are generally well developed and highly vegetated. These same features also reduce the loss of soil particles to surface waters. While erosion occurs to some degree at the FEMP (in particular, along some portions of Paddys Run), the site is located on a plateau that is not prone to significant amounts of soil

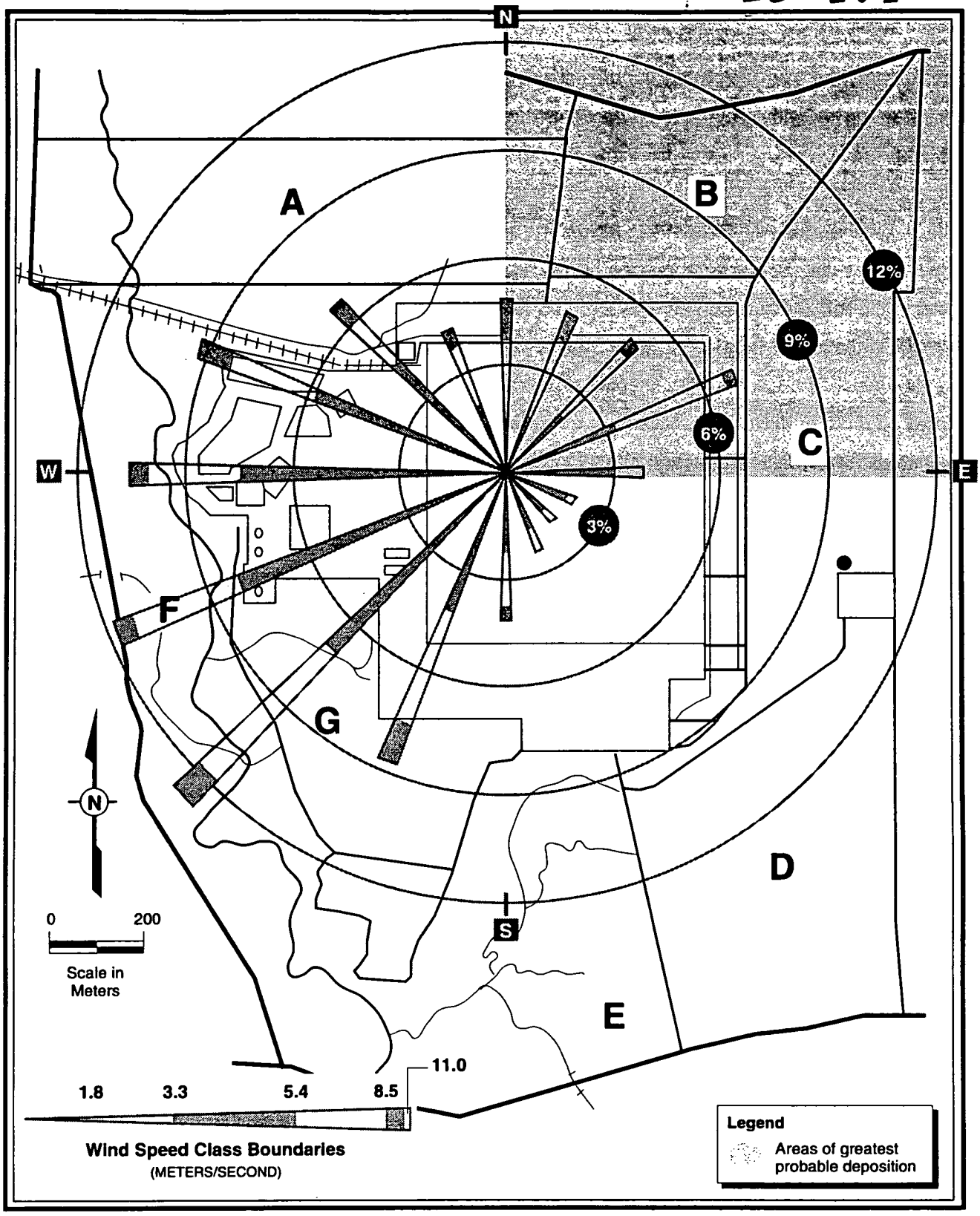

Figure 1-6. Areas of Greatest Probable Deposition of Airborne Particulates Based on Wind Data

erosion, thus limiting the probability of contaminant releases. Almost all uncontrolled storm water runoff flows to Paddys Run, either directly or through various on-site drainage ditches (including the SSOD).

Other contaminants (see DOE 1992a for the list of potential contaminants of concern) associated with the activities that supported production include various metals and organic materials. These may have entered the soil and surface waters as airborne contamination from the flyash piles, waste pits, or the landfill, or as runoff from contaminated soil in various locations on-site.

Based on the manufacturing processes that occurred at the FEMP, uranium was released into the air in various forms, including uranyl nitrate, uranium oxide, metallic uranium, and uranium tetrafluoride. Airborne emissions settled on surface soil within the boundaries of the FEMP as well as on off-site areas. Prevailing winds are from the southwest and west-southwest, and soil samples collected from off-site areas northeast of the FEMP as part of the routine environmental monitoring program have been found to contain uranium concentrations that are slightly above background (WMCO 1990). Figure 1-6 includes areas both on and off-site where airborne emissions were likely to have settled, based on the direction of the prevailing winds.

The following sections will discuss how potential COCs at the FEMP react with soil and water. Chemical interactions occurring with surface soil, water, and sediment may retard the movement of contaminants, increase the pathway travel time to ecological receptors, and decrease or attenuate contaminant concentrations at the receptor location. Ecological receptors in the study areas may be affected by direct uptake of contaminated interstitial waters, by consuming contaminated surface waters, by being directly exposed to contaminated soils, or by consuming vegetation or terrestrial organisms living in these media. Predators may also be impacted by consuming contaminated prey.

1.2.2 Contaminants in Surface Soils

At the FEMP, uranium in the soil may be present in a variety of forms, including uranyl nitrate, uranium oxide, metallic uranium, and uranium tetrafluoride. Metals such uranium can react with soils in a variety of ways including ion exchange, absorption, precipitation, or complexation. Ion exchange tends to be reversible, but is highly dependent on the type of clay mineral present, the

composition of ions occupying the exchange sites, and soil pH. Metal ions, including radionuclides, form complexes with dissolved ligands such as chloride, phosphate, carbonate, and sulfate that change the size and charge of the species, ultimately influencing bioavailability. Adsorption of metals is affected not only by the presence of ligands but also by type of surface soil. Clay minerals have different affinities for the adsorption of charged species due to geometric and chemical factors. This affinity is expressed as the cation exchange capacity (CEC) and relates to the molecular structure and chemical composition of the mineral lattice and the particle size distribution.

The fate and transport of contaminants from the source in the soils to vegetation is controlled by both the leaching rate of contaminants from the soils by infiltrating water and species-specific rates of uptake by the vegetation. These processes are difficult to quantify on a site-specific basis. The leachability of surface soils by infiltrating water depends primarily on the geochemical properties of the soil and the specific COC. Consequently, there is no general statement that would apply to the entire FEMP site. Positively charged forms of uranium tend to sorb to many different soil types, form rigorous complexes with insoluble organic matter, and adsorb to iron-manganese (Fe-Mn) oxides; these factors limit its movement through the environment. However, negatively charged or neutral carbonate and hydroxide uranium complexes formed in carbonate solutions can be highly mobile (Sheppard and Thibault 1992).

The mobility of organic contaminants in soils and other media is affected by chemical processes that in part depend on their volatility, the octanol-water partition coefficient (K_{ow}), water solubility, and chemical concentration. In general, the more water-insoluble an organic compound is, the more hydrophobic it is and the more likely it is to be adsorbed onto soil or organic structures. Water insoluble organics also have a tendency toward self-association in a polar medium such as water. Hydrophobic compounds tend to have higher K_{ow}s and a greater affinity to organic matter contained within the soil matrix. Conversely, compounds with high aqueous solubilities have relatively low K_{ow}s.

Terrestrial receptors can come in contact with contaminants via a number of pathways. At this site, particularly in areas immediately downwind of the production area (Figure 1-6), direct contact with contaminated soil (e.g., burrowing, grooming, or incidental ingestion while browsing), or ingestion of

contaminated vegetation by herbivores, represent likely routes of exposure. Other possible exposure routes include ingestion of contaminated surface water and/or prey items. While exposure to contaminants via inhalation is possible, the heavy vegetation at this site reduces the probability that this represents a significant route of exposure.

1.2.3 Contaminants in Surface Waters

Although uranium and other contaminants may enter the Great Miami River, Paddys Run, or on-site drainage ditches as free ions, it is more likely that they would be bound to either particulate organic matter or soil. Sediment particle size and composition influence how "tightly" bound contaminants are, and, therefore, the biological availability of uranium and other metals and the manner in which they are transported through an aquatic system. Small colloidal particles tend to have a higher affinity for most metals and other contaminants than do large particles, and clays generally exhibit a greater capacity to bind metal ions than do other soil types. Once in the system, metal ions are either deposited in bottom sediments, remain in suspension, or are absorbed directly from water by aquatic organisms (e.g., ingestion or absorption through gill epithelia). The hydrodynamic processes that dictate flow through a system (advection) and the disruptive events like storms and floods (dispersion) will govern the transport of dissolved chemicals through an aquatic system, while sediment transport of bound contaminants will determine rates and areas of contaminant deposition (Burns and Baughman 1985).

In general, sediments can represent a sink and a potential source for contaminants if environmental conditions such as temperature, pH, microbial activity, dissolved oxygen, and acid volatile sulfide concentrations are conducive to their release into interstitial water. Sediments also play an important role in contaminant transport because many contaminants are readily adsorbed onto and transported with sediment particles. Once released from the sediments, contaminants can be absorbed directly by benthic organisms, generally through gill epithelia. In addition to direct absorption, numerous benthic organisms ingest sediments when they feed. In this instance, contaminants may be absorbed through the intestinal wall or can become available to predators if the benthic organisms are consumed prior to gut evacuation.

As discussed earlier, Paddys Run is a dynamic, highly erosional stream. Water level and current velocity rise rapidly after heavy rain, resulting in bank erosion, shifts in the stream's channel, and movement of sediment. Under these conditions, sediments are not likely to represent a long-term sink for contaminants. However, sediment contamination was evaluated in this SLERA.

1.3 SUMMARY

During the years of production, airborne emissions deposited uranium on the site and nearby surrounding areas. With the end of production, transport of airborne contaminants by air is minimal. The site is well vegetated and relatively level, limiting the amount of run-off to surface waters. In addition, storm water runoff control projects have reduced the area of the site draining to Paddys Run. Although contaminated particles entered Paddys Run and on-site drainage ditches, it is unlikely that sediments represent a long-term sink for contaminants because of the dynamic environment of the streams.

Ecological receptors may come in contact with contaminants via a number of pathways. Terrestrial receptors may be exposed to direct radiation from contaminated soil, ingest radionuclides and other contaminants contained in water and various food items, or incidentally ingest contaminated soil during grooming or burrowing. Aquatic receptors may come in contact with contaminants that are dissolved in solution, adsorbed to sediment particles, or through consumption of contaminated prey. However, previous studies and routine observations to date have not identified any major impacts on the flora and fauna at the FEMP.

The next two sections of the SLERA evaluate the potential risk to ecoreceptors associated with RI/FS identified nonradiological and radiological contaminants present in the study areas of the FEMP.

2.0 ASSESSMENT OF NON-RADIOLOGICAL CONTAMINANTS

This section of the SLERA evaluates the possible risks to ecological receptors due to exposure to nonradiological contaminants detected in FEMP on-site and off-site study areas. The mean and maximum concentrations of media-specific contaminants were compared to media-specific benchmark values that are protective of ecological receptors. Contaminants exceeding these values were regarded as final COCs and their toxicological properties summarized. Finally, the relative risks that each of these final COCs might pose to FEMP ecoreceptors was evaluated.

As a result of this process, lead, mercury, and silver were identified as contaminants that may be adversely impacting aquatic organisms in both Paddys Run and the Great Miami River. Selenium detected in water samples collected from Paddys Run and levels of cadmium in samples collected from the Great Miami River may also represent a hazard to aquatic biota or to terrestrial organisms drinking these surface waters. Mercury, detected in sediment samples collected from Paddys Run, may be adversely impacting both aquatic and terrestrial ecoreceptors. The results of this assessment indicated that none of the soil contaminants represent a risk to ecological receptors. This assessment process is described in the sections that follow.

2.1 EXPOSURE ASSESSMENT

As described in the EPA Region V Guidelines, the major objective of the exposure assessment is to estimate, as accurately as possible, the media-specific chemical concentrations to which ecological receptors in each study area might be exposed. Estimated environmental concentrations are most appropriately based on measured site-specific data, and should reflect the bioavailable, or potentially bioavailable, portion of the total media-specific chemical concentration. The bioavailable concentration of a chemical is that portion of the chemical known or likely to cause adverse effects to biota under probable exposure scenarios.

As discussed in Section 1.0, the FEMP and off-site areas were subdivided into smaller study areas, based on habitat type and the size of the home ranges of receptor species used to quantify total potential radiation dose in Section 3.0. The total number of soil, surface water, and sediment RI/FS samples (both radiological and non-radiological) used in the SLERA is listed by study area in

Appendix B. The environmental concentrations to which ecological receptors might be exposed are based on an arithmetic mean and maximum concentrations of media-specific potential COCs collected within a given study area. Environmental concentrations of some sediment potential COCs are estimated using equilibrium partitioning, which is described in Section 2.1.2.

2.1.1 Surface Water

This assessment evaluated the potential impact of surface water contaminants to both freshwater biota and terrestrial receptors that may utilize these bodies of water as sources of drinking water. The surface water exposure assessment is based on both the maximum and the mean concentrations of potential COCs measured in the surface water samples. As described in Section 1.1.3.4 and 1.1.3.5, samples collected from Paddys Run and the Great Miami River were grouped according to reach, with Reach 1 representing upstream areas in both instances. It should be noted that the analytical results determined for samples collected from Reach 1 on the Great Miami River do not represent the same set of analytical data evaluated in the recently released draft report characterizing the background water quality of streams and groundwater for the FEMP (DOE 1993a). In addition, data used in this SLERA to characterize Reach 1 on Paddys Run represent unvalidated analytical results for samples collected in March 1993.

Because the number of surface water samples collected from any given study area was limited, no attempt was made to eliminate contaminants from further consideration by comparing contaminant concentrations present in samples collected from downstream locations with concentrations from upstream locations. Instead, a conservative approach was followed and all contaminants detected in one or more surface water samples were considered to represent potential surface water COCs.

Concentrations of metals present in surface water samples were reported in terms of total metals. As discussed in Section 1.0, the potential impact of uranium and thorium on ecological receptors was examined from the standpoint of heavy metal toxicity (this section) and as radionuclides (Section 3.0). For this portion of the SLERA, the mass concentrations of thorium and uranium (mg/l) were determined by converting the activity concentrations (pCi/l) of the principal isotopes (DOE 1993a). The equations utilized for the conversion are presented in Appendix C.

The mean and maximum concentrations of the RI/FS potential surface water COCs used for this SLERA are summarized in Appendix D, Tables D-1 through D-11. These values were compared directly to concentrations of these same chemicals that are known to be potentially hazardous to aquatic and terrestrial biota (Section 2.2.1).

2.1.2 Sediments

The sediment exposure assessment is based on both the maximum and mean concentrations of potential COCs in sediments. Exposures to sediment contaminants can be evaluated either by examining sediment concentrations (μg/kg, dry weight) or by employing partitioning coefficients to determine the concentrations of potential COCs present in the interstitial water.

Interstitial water concentrations provide estimates of actual bioavailable concentrations of chemicals associated with contaminated sediments. Most modeling methods for determining interstitial water concentrations [e.g., equilibrium partitioning (EP)] are limited to nonionic organic chemicals, and are not applicable to metals because of their complex partitioning behavior. Metal adsorption-desorption from sediments is the result of numerous interrelated processes that depend on ionic strength, pH, Eh, and, for at least some metals, the concentration of acid volatile sulfide present in the sediment (DiToro et al. 1986; 1989). Methods for estimating the interstitial water concentration of metals are still undergoing development.

Because of these limitations, this assessment employed separate methodologies for determining exposure concentrations for organic and inorganic sediment potential COCs. For inorganic potential COCs, exposures were simply based on concentrations of contaminants measured in sediment samples without extrapolation to interstitial water (e.g., μg/kg). The mass concentrations of thorium and uranium (μg/kg) present in sediments were determined by converting the activity concentrations (pCi/g) of the principal isotopes. The maximum and mean concentrations of potential inorganic COCs present in sediment samples are summarized in Appendix E, Tables E-1 through E-9.

For organic potential COCs, equilibrium partitioning (EP) was used to extrapolate from contaminant concentrations in sediment (μg/kg, dry weight) to concentrations present in interstitial water (μg/l). Estimates of interstitial water concentrations are based on concentrations of potential COCs and

organic carbon in sediments. Partitioning coefficients used include f_{oc} (fraction organic carbon), K_{ow} (octanol/water partitioning coefficient), K_{oc} (organic carbon/chemical partitioning coefficient), and Kd (sediment/water partitioning coefficient). These coefficients are defined as follows (EPA 1988a):

$$Kd = K_{oc} \bullet f_{oc}$$

where

$$Kd = \frac{\text{concentration of chemical in soil or sediment}}{\text{concentration of chemical in water}}$$

and

K_{oc} = partitioning coefficient for chemical/organic carbon

f_{oc} = fraction of organic carbon in sediment/soil

Kd values are often estimated from published K_{oc} values and from site-specific f_{oc} values. Site-specific sediment organic carbon data were not present in the RI/FS data base. Therefore, a value of 1.0 percent (f_{oc} = 0.01) was chosen to determine interstitial water concentrations of potential organic COCs. Although arbitrary, this value is believed to be a reasonable assumption based on previously published sediment organic carbon data (EPA 1989).

K_{oc} values were unavailable for the organic chemicals of concern and were instead estimated from the octanol/water partition coefficient, K_{ow}, as follows:

$$K_{ow} = \frac{\text{concentration of chemical in octanol}}{\text{concentration of chemical in water}}$$

Regression equations relate K_{ow} to K_{oc}, and are chemical-class specific. The following equation was used to estimate K_{oc} for the potential sediment organic COCs (EPA 1988a):

$$\text{Log } K_{oc} = 0.544 \log K_{ow} + 1.377$$

Applying equilibrium partitioning, the maximum and mean interstitial water concentrations of potential sediment organic COCs were estimated and summarized in Appendix E, Table E-10. These

estimated concentrations were compared directly to aqueous concentrations of these same chemicals that are known to be potentially hazardous to aquatic biota (Section 2.2.2).

2.1.3 Surface Soils

The surface soil exposure assessment is based on both the maximum and mean concentration of potential COCs present in surface soil samples collected from each study area. The RI/FS data base contained the results of analyses performed on soil samples representing a wide range of sample depths. However, the "CERCLA/RCRA Background Soil Study" (DOE 1993b) calculated mean concentration for various elements present in surface soil samples collected from the 0 - 6 inch depth. However, in some of the study areas, no samples were collected from the 0 - 6 inch depth. If the evaluation of surface soil contamination was restricted to only those RI/FS samples collected at the 0 - 6 inch depth, the assessment of surface soil from a number of the FEMP study areas would not have been possible. Therefore, for the purposes of this SLERA, all RI/FS soil samples collected between 0 - 2 feet were considered "surface soil" samples.

The concentrations of thorium and uranium (mg/kg) present in soil samples were determined by converting the activity concentrations (pCi/g) of the principal isotopes.

Unlike surface water and some sediment potential COCs, only limited data are available for evaluating the bioavailability of surface soil potential COCs. Therefore, the concentrations of potential surface soil COCs used in this exposure assessment were based on individual contaminant concentrations per unit of soil (mg COC/kg, dry weight) without adjustment for bioavailability. These values are listed in Appendix F.

2.1.4 Uncertainty Associated with Exposure Assessment

General areas of potential concern that are expected to contribute to uncertainty are summarized in Table 2-1.

TABLE 2-1

FACTORS THAT ARE EXPECTED TO CONTRIBUTE TO UNCERTAINTY IN EXPOSURE ASSESSMENT

General Factors Contributing to Uncertainty	Site-Specific Factors That May Have Contributed to Uncertainty
1. Sufficient quantities of environmental samples should be collected using appropriate sampling design.	In general, sufficient quantities of radiological samples were collected for this assessment; however, number of non-radiological samples is limited, increasing uncertainty associated with interpreting these data.
2. Methods selected for analyzing environmental samples should be appropriate to the analyte and sufficiently sensitive and specific for the needs of the assessment.	In-laboratory quality control (QC) and quality assurance (QA) programs are expected to limit uncertainty associated with sample analysis. Detection limits (DLs) for a number of water constituents (DDT, Arochlor, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, hexachlorobutadiene, mercury, methoxychlor, phenanthrene, silver, and toxaphene) exceeded CAWQC; the effect of DL on interpreting contamination in other media unknown.
3. Appropriate and reasonable assumptions should be made concerning exposure pathways (sources, points, routes).	All major pathways were considered for the ecological resources potentially at risk. Minor pathways were not considered if they were associated with insignificant contributions to overall exposure.
4. Selection of COCs for each media should not eliminate potentially hazardous chemicals from consideration for full assessment.	Chemicals that were eliminated from further consideration were those that were considered to be non-toxic or occurred in concentrations considered to be nontoxic, and those that did not exceed background concentrations. Concentrations of uranium, thorium and radiological isotopes were based on RI/FS samples collected at depths up to 2 feet. These data were compared to background samples collected at 0 - 6" depth; impact of this comparison on assessment unknown.
5. Appropriate and accepted sources of physical and chemical data should be used for evaluating fate and transport of COCs.	Organic carbon content of sediment assumed to be 1 percent due to unavailability of site-specific K_{oc} values, thereby increasing the uncertainty of exposure assessments based on this parameter. Physical and chemical data used for this exposure assessment were primarily from sources such as the U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Fish and Wildlife Service (FWS). Insufficient data from these sources was supplemented with data from peer-reviewed journals and books in the specific subject areas, where possible.

2.2 TOXICITY SCREENING

The benchmark values used to determine media-specific final COCs are summarized in Table 2-2 and are discussed in greater detail in the sections that follow.

TABLE 2-2

BENCHMARK VALUES USED TO DETERMINE MEDIA-SPECIFIC FINAL CONTAMINANTS OF CONCERN

Media	Benchmark Values Used to Select Media-Specific Final COCs
Surface Water	Detected in at least one sample Chronic Ambient Water Quality Criteria or surrogate values to protect aquatic biota; review of available data on toxicity in drinking water for terrestrial fauna
Sediment	Detected in at least one sample Long and Morgan's Apparent Effects Data Base (ER-L) for inorganics; Equilibrium Partitioning and toxicity data for organics
Soils	Detected in at least one sample Comparison to background soil concentrations (DOE 1993b); comparisons to soil threshold values

2.2.1 Identification of Final Surface Water COCs

As noted in Section 2.1.1, contaminants detected at least once were considered to be surface water potential COCs. The maximum and mean concentrations of potential COCs were determined for Paddys Run, the storm sewer outfall ditch in Study Area E, an unnamed tributary to Paddys Run in Study Area F, drainage from the inactive flyash pile in Area G, and the Great Miami River. The list of final surface water COCs for each study area was compiled by comparing mean and maximum contaminant concentrations to values that are protective of aquatic biota. The potential hazard to terrestrial organisms that may utilize these surface waters as a source of drinking water was also evaluated (Table 2-2). The process used to derive benchmark values and to select final surface water COCs is described below.

For this SLERA, the benchmark values used to identify final surface water COCs were chronic ambient water quality criteria (CAWQC). Actual exposures expected to occur at the FEMP to

potential ecological receptors to COCs are assumed to be primarily chronic (long-term) exposures, usually at sublethal concentrations. CAWQCs are developed to protect sensitive species from exposures to sublethal contaminant concentrations. These CAWQCs were selected as conservative and appropriate screening criteria. However, chronic toxicity data are not uniformly available. Chronic values were therefore estimated from acute toxicity data in some instances. Acute toxicity is generally expressed as the LC50 which represents the aqueous concentration of contaminant lethal to 50 percent of the test population. For this SLERA, CAWQC values were derived by dividing available LC50 values by 100.

The use of LC50/100 is based on the assumption that this ratio provides a reasonable and adequate level of protection for sensitive, untested species. This ratio has been employed by the Office of Pesticide Programs of the EPA to protect sensitive wildlife species (Urban and Cook 1986). The 1972 water quality criteria suggested that the LC50 value be divided by factors of 10 or 100, depending on persistence and potential to bioaccumulate (National Research Council 1972). More recently, examination of the results of acute and chronic toxicity tests performed on effluents has indicated that the ratios of acute - to - chronic toxicity values seldom exceeded 10 (i.e., LC50/10 = chronic value) and ratios above 20 (LC50/20) had not been observed (EPA 1991). The LC50/100 value therefore provides a conservative estimate of CAWQCs.

The calculation of CAWQC for those metals whose toxicity is hardness-dependent was based on study area-specific surface water hardness values (mg $CaCO_3$/l). Site-specific hardness values were calculated for each body of water using the equation provided in Method 314A of Standard Methods (APHA 1985). This formula is listed in Appendix C. Calculated hardness values for the Great Miami River, Paddys Run, the storm sewer outfall ditch (Study Area E), the unnamed tributary for Paddys Run (Study Area F), and the water sample collected from Study Area G are 283.28, 284.75, 400.25, 319.42, and 137.23 mg $CaCO_3$/l, respectively.

Parkhurst et al. (1984) determined that the toxicity of uranium was a function of both water hardness and alkalinity. Alkalinity values were not reported in the RI/FS data base for samples collected from the Great Miami River. However, data collected between 1984 and 1991 by the USGS from the New Baltimore gaging station on the Great Miami River (see Figure 1-3) were used to determine the mean

alkalinity. The alkalinity of the sample collected from Reach 1 on Paddys Run in March 1993 was measured and used in these calculations. Alkalinity and hardness values were then used in the equation provided by Parkhurst et al. (1984) to calculate site-specific CAWQC for uranium. This equation is listed in Appendix C.

Several of the chemicals under preliminary consideration as final surface water COCs (e.g., calcium, magnesium, manganese, and potassium) are essential nutrients and are usually considered to be nontoxic. These chemicals were therefore eliminated from further consideration as final surface water COCs.

Exposures of terrestrial (mammalian) and avian receptors to contaminants in surface water is primarily through drinking water. Currently, no surface water criteria have been established for the protection of avian and terrestrial species. This assessment therefore evaluates the potential hazards of surface water contamination to such species based on the following comparisons:

- benchmark values presented for the aquatic life assessment
- drinking water maximum concentration limits (MCLs) for the protection of human health
- available toxicity data for avian and terrestrial drinking water exposures.

Toxicity data for avian and terrestrial drinking water exposures are summarized in Appendix D, Table D-12. In a few cases, "no effect" toxicity concentrations reported for some species under a set of exposure conditions exceed concentrations at which effects were reported for other species or for the same species under a different set of exposure conditions. This can be attributed to the differing sensitivities of the species exposed or the type of effect reported by the investigator. For example, dogs exposed to 6 μg Cr^{6+}/l exhibited no measurable effects (Steven et al. 1976); however, slight growth retardation and tumor formation occurred in mice exposed to 5 μg Cr^{6+}/l (Schroeder and Michener 1971; Schroeder et al. 1965). DeMayo et al. (1982) reported that 1,000,000 μg Pb/l in drinking water did not affect survival or fertility in mice; however, effects were observed on litter size, pup survival, and birth weight at 800,000 μg Pb/l (Sharma and Kanwar 1985). The variability in response illustrated by these two examples indicates the difficulty in applying nonstandardized toxicity data to a risk assessment.

Information regarding the toxicity of silicon is unavailable and it is eliminated from further consideration. Fluoride in water is considered beneficial to humans at low levels, therefore primary MCL value of 4000 µg/l has been established for this element (EPA 1992). Although sulfate toxicity is primarily associated with inhalation exposures (Klaassen et al. 1986), a primary MCL of 4,500,000 µg/l has been established (EPA 1992). The concentrations of these two potential COCs were compared to benchmark values for these chemicals. In both instances, measured concentrations of sulfate and fluoride in media, were less than benchmark values, and these contaminants were excluded from further consideration.

Tables D-13 to D-22 in Appendix D present a compilation of the toxicity data provided in Table D-12, Appendix D (described above), the benchmark values and MCL, and the maximum and mean surface water contaminant concentrations for each study area. Contaminant concentrations determined to be toxic (avian and mammalian drinking water exposures) exceed surface water contamination levels. These data also greatly exceed the MCL and benchmark values. When comparing the MCLs and benchmark values (CAWQC), it is evident that all but the MCL for lead exceed the benchmark values established for the protection of aquatic biota. Therefore, with the exception of lead, the benchmark values established to be protective of aquatic life are also the most conservative values for this exposure pathway. The primary MCL for lead and CAWQC (or surrogate values) were used to select final surface water COCs; these values are listed in Appendix D. This screening process identified the following contaminants as final surface water COCs:

- Aluminum
- Ammonia
- Cadmium
- Chloride
- Lead
- Mercury
- Phenols
- Selenium
- Silver

2.2.2 Identification of Final Sediment COCs

As was the case for the selection of surface water COCs, chemicals detected in at least one sediment sample were considered to be potential sediment COCs. These potential contaminants of concern

were then compared to appropriate benchmark values (Table 2-2) and final sediment COCs identified. This process is described below in greater detail.

This SLERA employed separate methodologies for identifying sediment organic and inorganic COCs. Several of the inorganic chemicals detected in sediment samples (e.g., calcium, magnesium, potassium, and sodium) are considered to be nontoxic. These chemicals were eliminated from further consideration. The remaining inorganic and organic chemicals were then compared to benchmark criteria. Whenever possible, "apparent effects data" developed by Long and Morgan (1991) were used to identify final inorganic COCs. Long and Morgan developed apparent effects data sets for various sediment toxicants by compiling biological effects data for a specific toxicant. These data were then placed in ascending order (toxicant concentration producing no effect to toxicant concentration producing the greatest effect). The 10th and 50th percentile of these ordered data were then identified. Long and Morgan defined the 10th and 50th percentiles as the "Effects Range-Low" (ER-L) and the "Effects Range-Median" (ER-M), respectively, for each chemical considered. Although the apparent effects data base is founded predominantly on the effects of toxic materials on marine life, ER-L and ER-M values have been adopted by various agencies as appropriate screening criteria for marine, estuarine, and freshwater sediments. Therefore, Long and Morgan's entire data base (containing both freshwater and saltwater data) was considered appropriate for selecting sediment inorganic COCs.

ER-L values have not been derived for several inorganic chemicals measured in RI/FS sediment samples. For these contaminants, surrogate values were selected, including sediment quality criteria established by various government agencies. In several other instances, sediment-specific criteria could not be identified; these potential inorganic sediment COCs were compared instead to mean background soil concentrations (e.g., aluminum, barium, iron, and uranium) (DOE 1993b) or to published soil concentrations that are indicative of contamination (e.g., cobalt).

Chemicals measured in sediments at concentrations greater than the ER-L (or surrogate) values were considered to be sediment inorganic COCs. The results of this screening process are summarized in Appendix E. This process identified the following as final inorganic sediment contaminants of concern:

- Aluminum
- Ammonia
- Cadmium
- Mercury
- Uranium

As described in Section 2.1.2, equilibrium partitioning was used to convert concentrations of organic contaminants present in the sediments to interstitial water concentrations (μg/l). The interstitial water concentrations were then compared to appropriate benchmark criteria. Paddys Run Reach 3 was the only location with sediments containing detectable concentrations of organics (e.g., 2-butanone and 2-hexanone). The equilibrium partitioning method was used to derive the interstitial water concentrations of these contaminants; these concentrations were then compared to benchmark criteria. This process is summarized in Table E-6 of Appendix E. Because the calculated interstitial water concentrations were less than the benchmark values, these potential organic COCs were not considered as final COCs.

2.2.3 Identification of Final Soil COCs

As noted in Section 2.1.3, final surface soil COCs were identified by comparing those inorganic potential COCs present in concentrations that exceeded background concentrations and all organic potential COCs to benchmark values (Table 2-2). Those contaminants exceeding these values represented final surface soil COCs. This process is described below.

A comparison of potential COCs to mean background soil concentrations was used as the initial criterion for the selection of study area-specific final surface soil inorganic COCs. The "CERCLA/RCRA Background Soil Study" (DOE 1993b) served as the source of background soil concentrations for both inorganics and radionuclides. As discussed in Section 2.1.3, all RI/FS soil samples collected between 0 - 2 feet were considered surface soil samples and compared to 0 - 6 inch mean background surface soil concentrations summarized in the DOE (1993b) report.

Inorganic chemicals whose concentrations exceeded mean background concentrations and all organic chemicals detected in soil were then compared to soil threshold values (concentrations considered to represent a hazard). Contaminant threshold values were obtained from a number of sources, including:

- those established by the Quebec Ministry of the Environment for soils (Direction des Substances Dangereuses 1988)
- maximum allowable concentrations established by various regulatory agencies for amending farm soil with sewage sludge
- proposed action levels for contaminated soils at Resource Conservation and Recovery Act (RCRA) sites (EPA 1990)

Chemicals generally considered nontoxic in soils include aluminum, barium, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, and vanadium (Direction des Substances Dangereuses 1988). Calcium, iron, magnesium, manganese, potassium, sodium, and vanadium were eliminated from further consideration as surface soil COCs. Although generally considered nontoxic, benchmark criteria were available for aluminum, barium and cobalt. These three contaminants were therefore retained for assessment.

The only benchmark criterion identified for thorium was that established by the Quebec Ministry of the Environment. However, this value (3.0 mg thorium/kg) was less than the mean background soil concentration (9.7 mg thorium/kg) (DOE 1993b). In most instances, the maximum thorium concentrations detected in soil samples exceeded 9.7 mg thorium/kg. Because of the absence of an alternate criterion, thorium was retained as a final soil COC and its toxicity summarized in Section 2.3.11.

The concentrations of organic chemicals detected in the surface soil samples evaluated in this SLERA were all below the benchmark criteria and were therefore excluded from further evaluation. Thus, only those inorganic chemicals that passed both screens (e.g., exceeded background concentrations and were greater than threshold values) were identified as final surface soil COCs. This screening process is summarized in Appendix F. The following contaminants represent final surface soil COCs;

- Aluminum
- Cadmium
- Molybdenum
- Thorium
- Uranium

2.2.4 Uncertainty Associated with Toxicity Screening

Because complete toxicological data bases do not exist for most chemicals, there are many opportunities for uncertainty to impact the toxicological screening process. Specific areas of concern and methods used to reduce uncertainty are summarized in Table 2-3.

2.3 TOXICOLOGICAL PROPERTIES OF FINAL CONTAMINANTS OF CONCERN

Aluminum, cadmium, molybdenum, thorium and uranium were all present in soil in concentrations that exceeded the soil benchmark criteria used in this SLERA. Sediment contaminants present in concentrations exceeding benchmark criteria included aluminum, ammonia, cadmium, and mercury. These same four elements also exceeded surface water benchmark criteria, as did chloride, lead, phenols, selenium, and silver. The toxicological properties of these contaminants are summarized below.

2.3.1 Aluminum

Although present in food in varying amounts, aluminum (Al) is not an essential element for mammals. The aluminum content of plants typically depends on the soil aluminum concentration and ranges from 10 to 30 mg/kg fresh weight; studies have indicated that this element stimulates the growth of several pasture plant species (Hackett 1962). As summarized in Venugopal and Luckey (1978), aluminum is not readily absorbed through the skin and gastrointestinal absorption of ingested aluminum is poor due to the transformation of aluminum salts into insoluble aluminum phosphate. The lack of accumulation of aluminum in animals with age, or of any increase in tissue levels of aluminum following fairly high dietary intake, suggests that mammals posses a homeostatic mechanism for this element. For most terrestrial organisms, aluminum compounds are generally not harmful and are considered to be toxicologically inert, except in cases of high experimental doses or prolonged inhalation (Venugopal and Luckey 1978).

Data on the toxicity of aluminum to aquatic organisms is somewhat limited. EPA (1988b) stated that freshwater organisms should not be adversely affected if aluminum concentrations do not exceed

TABLE 2-3

FACTORS THAT ARE EXPECTED TO CONTRIBUTE TO UNCERTAINTY IN TOXICITY SCREENING AND METHODS USED TO REDUCE THAT UNCERTAINTY

Factors Contributing to Uncertainty	Approach Used to Reduce Uncertainty
1. Species tested should be representative of site species.	EPA considers tested aquatic species used to derive water quality criteria to be representative of species found throughout the nation. Site-specific species are not expected to be more or less sensitive to contaminants than those comprising the national aquatic data base.
2. Laboratory toxicity tests should be representative of the site (field) environment.	In general, laboratory-to-field extrapolations of toxicity data are considered to be acceptable under most conditions.
3. Extrapolations (acute-to-chronic, species-to-species, chemical-to-chemical) should be reasonable and appropriate for the chemicals and species selected.	Direct testing with local species and site-specific COCs is the best approach for defining potential toxicities of COCs at a given site. However, such data are generally unavailable or incomplete; this document provides equations or other support for extrapolations, where appropriate.
4. Single-point toxicity values such as LC50s, compared to dose/response relationships (e.g., describing the entire toxicity curve), might or might not adequately depict potential toxicity.	Although considered to be a limitation, the use of single-point toxicity values is still expected to provide an adequate description of the relative toxicity between chemicals and between test species.
5. Accepted toxicity data should be based on standardized, accepted test protocols.	All aquatic toxicity data used throughout this assessment were based on tests that followed acceptable experimental designs, conditions, and endpoints as defined by EPA.

87 μg/l when pH is between 6.5 and 9.0. As summarized in EPA (1988b), some studies have shown that the acute toxicity of aluminum increases with pH, whereas other studies found the opposite to be true (EPA 1988b).

Sublethal effects were also reviewed by EPA (1988b). It was found that 169 μg Al/l at a pH of 6.5 to 6.6 caused a 24 percent reduction in the growth of young brook trout (*Salvelinus fontinalis*). Cleveland et al. (1991) determined that brook trout accumulated significantly higher aluminum residues at pH 5.3 than at pH 6.1 or pH 7.2. They also determined that elimination of aluminum during depuration was more rapid at pH 5.3 than at pH 6.1 or pH 7.2. Data reported in EPA (1988b) indicated this metal does not bioconcentrate; bioconcentration factors range from 50 to 231 for brook trout (geometric mean value = 82).

2.3.2 Ammonia

The un-ionized species of ammonia is considered to be the form most toxic to aquatic organisms (EPA 1985a) with NH_4^+ being relatively less toxic (Thurston et al. 1981). Acute exposure of fish to high concentrations of ammonia results in an increase in the rate of gill ventilation, followed by hyperexcitability, convulsions, and then death (Russo 1985). Results of chronic exposures include deleterious histological effects (swelling and diminished numbers of erythrocytes; inflammation and degeneration of gills and kidneys: Reichenbach-Klinke 1967; Flis 1968; Smart 1976; Thurston et al. 1978) and a decrease in reproductive capacity due to a reduction in egg production, egg viability, and/or a delay in spawning. Additional chronic effects include a decrease in growth and morphological development and increased susceptibility to disease (Russo 1985). Although research on the toxicity of ammonia to invertebrates is more limited than that performed on fish, test results indicate that invertebrates, including insects, are also adversely affected by exposure to ammonia (EPA 1985a). Additional information on the toxicity of ammonia is contained in Appendix G.

2.3.3 Cadmium

To date, no evidence exists to suggest that cadmium (Cd) is either biologically essential or beneficial (Venugopal and Luckey 1978; FWS 1985a). Freshwater biota are particularly sensitive to this heavy metal; concentrations as low as 0.8 to 9.9 μg Cd/l produce lethality among insects, crustaceans, and fish (FWS 1985a; EPA 1985b). This heavy metal does not bioconcentrate to an appreciable extent;

bioconcentration data listed in EPA (1985b) for freshwater species range from 3 (brook trout) to 4190 (caddisfly; *Hydropsyche betteni*) with a geometric mean value of 404.

Compared to aquatic biota, mammals and birds are relatively less sensitive to Cd exposure. Adult mallards fed a diet containing up to 200 mg Cd/kg survived and exhibited no loss in body weight, although egg production of laying hens was suppressed (White and Finely 1978). The lowest oral doses producing lethality among mammals were 250 and 150 mg Cd/kg body weight in rats and guinea pigs, respectively (EPA 1985b). Factors affecting the bioavailability of Cd are summarized in Appendix G.

2.3.4 Chloride

According to Hem (1970), chloride (Cl) ions in natural water do not enter significantly into either oxidation or reduction reactions, form no important solute complexes with other ions, tend to form soluble salts, do not adsorb extensively to mineral surfaces, and play few important biochemical roles. Major anthropogenic sources of Cl include deicing, urban and agricultural run-off, and discharges from municipal and industrial plants (EPA 1988c). Although potassium, magnesium, and calcium chlorides are generally more acutely toxic to freshwater organisms than sodium chloride, sodium chloride tends to dominate anthropogenic chloride (EPA 1988c). The acute toxicity of sodium Cl is not apparently influenced by pH, alkalinity, or hardness.

According to EPA (1988c), invertebrates exhibit greater sensitivity to chloride than do vertebrates. Acute toxicity values range from 1479 mg Cl/l for *Daphnia pulex* to 11,940 mg Cl/l for the American eel (*Anguilla anguilla*). Chloride concentrations producing chronic toxicity ranged from 372.1 mg/l for *Daphnia pulex* to 922.7 mg/l for rainbow trout (*Salmo gairdneri*; EPA 1988c).

2.3.5 Lead

As summarized in FWS (1988), research to date has determined that lead (Pb) is neither essential nor beneficial and that all measured effects are adverse. Invertebrates exhibit a wide range of sensitivities to Pb, and the toxicity of Pb to fish has been found to be greater in soft water than in hard water. Organolead compounds are typically more toxic than inorganic compounds, food chain biomagnification is generally negligible, and younger organisms tend to be more sensitive to lead

exposure than older individuals (FWS 1988). Reported bioconcentration factors are relatively low, ranging from 42 for brook trout to 1700 for a gastropod (*Lymnaea palustris*); the geometric mean value of data listed in EPA (1985c) for freshwater species is 403.

As with a number of other metals, hardness has a major effect on the bioavailability of Pb, although the observed effect is probably due to the presence of one or more interrelated ions such as hydroxide, carbonate, calcium, or magnesium (EPA 1985c).

2.3.6 Mercury

In a recent review of the hazards of mercury to fish, wildlife, and invertebrates, FWS (1987) noted that mercury (Hg) and its compounds have no known biological function; its presence is regarded as undesirable and potentially hazardous, and it is a mutagen, teratogen, and carcinogen. Forms of Hg with relatively low toxicity can be transformed into forms with very high toxicity through biological and other processes. Methylmercury can be bioconcentrated in organisms and biomagnified through food chains, returning mercury to upper trophic level consumers in a concentrated form. Bioconcentration factors for methylmercury range from 10,000 for brook trout to 81,670 for fathead minnows (*Pimephales promelas*); the geometric mean value of bioconcentration values listed in EPA (1985d) for freshwater organisms is 25,400. For all organisms tested, early developmental stages were the most sensitive, and organomercury compounds — especially methylmercury — were more toxic than inorganic forms. Numerous biotic and abiotic factors modify the toxicity of Hg compounds, sometimes by an order of magnitude or more, but mechanisms of action are unclear (FWS 1987). Additional factors influencing the toxicity of Hg are summarized in Appendix G.

2.3.7 Molybdenum

Molybdenum (Mo) is an essential micronutrient, involved primarily with flavin-based metalloenzymes (FWS 1989; Venugopal and Luckey 1978). Industrial use of Mo stems largely from the manufacture of steel alloys, fertilizers, pigments, and coatings for glass.

According to Venugopal and Luckey (1978), the toxicity of Mo is low compared to other industrially important chemicals and it is not generally regarded as an industrial hazard. The chemistry of Mo is complex and not well-understood. Its toxicity to mammals, and ruminants in particular, is

significantly impacted by interactions with copper and sulfur. Cattle are prone to Mo poisoning when copper and inorganic sulfate are deficient (FWS 1989). Mo is less toxic to monogastric animals than to ruminants; the resistance of other mammals, including domestic non-ruminants and laboratory animals, is at least ten times that of cattle (Venugopal and Luckey 1978; FWS 1989). Data on the sensitivity of avian and mammalian wildlife to Mo are limited. Aquatic species are not particularly sensitive to Mo and concentrations of this element are usually lower in fish and wildlife than in macrophytes (FWS 1989).

2.3.8 Phenol

As summarized in EPA (1980a), phenol is predominantly used as an intermediate in a wide variety of chemical processes including production of epoxy and phenolic resins, pharmaceuticals, pesticides, dyes, and numerous industrially-important acids. The phenol molecule easily substitutes in the environment to form compounds such as halophenols, which may be more toxic than the parent compound. The acute toxicity of phenols to aquatic organisms has been characterized but information on chronic toxicity is limited. Acute toxicity of phenol to freshwater species has been expressed over 2 to 3 orders of magnitude. Test results have indicated that cladocerans are the most sensitive invertebrate species examined (*Daphnia pulex* LC50 = 5000 μg/l) while rainbow trout are among the most sensitive fish species tested (LC50 =5020 μg/l). Bioconcentration factors range from 1.2 to 2.3 for goldfish (*Carassius auratus*), indicating that phenol is not likely to bioconcentrate or biomagnify (EPA 1980a).

2.3.9 Selenium

Selenium (Se) chemistry is complex, and additional research is warranted on chemical and biochemical transformations among valence states, allotropic forms, and isomers of selenium (FWS 1985b). Selenium metabolism and degradation is significantly modified by interaction with heavy metals, agricultural chemicals, microorganisms, and a variety of physicochemical factors. Results of laboratory studies and field investigations with fish, mammals, and birds have led to the general agreement that elevated concentrations of Se in diet or water are associated with reproductive abnormalities, including congenital malformations, selective bioaccumulation by the organisms and growth retardation (FWS 1985b).

It has been suggested that selenite is more toxic than selenate, particularly to early life stages and that these effects are most pronounced at elevated temperatures. Also, Se salts may be converted to methylated forms by microorganisms, and these forms are readily accumulated by freshwater vertebrates (EPA 1987).

Accumulation of Se by aquatic organisms is highly variable. In short-term tests, exposures to concentrations ranging from 0.015 to 3.3 μg Se/l, resulted in biological concentration factors of 460 for the mosquito fish (*Gambusia* sp.) to 32,000 for a freshwater gastropod (Nassos et al. 1980). Selenium accumulation is modified by water temperature, age of the organism, organ or tissue specificity, mode of administration, and other factors. Data supplied by EPA (1987) for selenium (IV) were used to calculate a geometric mean bioconcentration factor of 120 for freshwater organisms. Additional information on the sources and biological impacts of exposure to Se is contained in Appendix G.

2.3.10 Silver

Numerous studies have indicated that free soluble silver (Ag) is among the most toxic metals to freshwater organisms. In most natural waters, the monovalent form of Ag is of greatest concern. Silver may exist as a simple hydrated monovalent ion, or it may exist in various degrees of association with inorganic ions such as sulfate, bicarbonate, or nitrate (EPA 1980b). Silver is more toxic in soft water than in hard water (EPA, 1980b). The sorption of silver by manganese dioxide, various ferric compounds, and clay minerals, and its subsequent partitioning by the sediment layer is strongly pH-dependent (Dyck 1968).

Silver exhibits a limited ability to bioconcentrate. Biconcentration factors for freshwater species reported by EPA (1980b) ranged from <1 for bluegill sunfish (*Lepomis macrochirus*) to 240 for a mayfly (*Ephemeralla grandis)* with a geometric mean bioconcentration factor of 57.

2.3.11 Thorium

Venugopal and Luckey (1978) provide the following synopsis on the bioavailability and toxicity of thorium (Th):

Although the metabolism of thorium is not well studied, current information suggests that its metabolic behavior is not analogous to any normal body constituent. Thorium and its isotopes are toxic radiologically, but the chemical toxicity of Th is low and depends on the nature of the Th salt. Reports about the chemical toxicity of Th compounds and their involvement in any physiological and biochemical functions in living tissues are scarce and fragmentary. It is known that gastrointestinal absorption of Th salts is very poor, owing to olation of Th salts in the intestine, and depends upon Th solubility and dose of the compound. Poor gastrointestinal absorption and the formation of particulate or colloidal forms of Th following absorption, and their subsequent removal through phagocytosis by the reticuloendothelial system, may partially account for the comparatively low chemical toxicity of Th salts.

According to Venugopal and Luckey (1978), chronic subcutaneous administration, prolonged feeding, or inhalation of Th compounds such as ThO_2 at low levels, has no adverse effects in animals. Reported thorium nitrate LD50s for mice ranged from 620 to 1680 mg Th/kg (method of exposure = gavage). Additional information on thorium is provided in Appendix G.

As discussed in Section 2.2.3, thorium was retained as a final soil COC only because the maximum detected thorium soil concentrations exceeded the mean background soil concentration (DOE 1993b). However, with the exception of Study Areas C, E, and G, mean thorium concentrations were less than the mean background soil concentrations. This information, coupled with the limited bioavailability and low toxicity associated with this contaminant, was used to exclude thorium from further consideration as a non-radiological COC. However, the contribution of thorium-contaminated media to total radiological dose was considered in Section 3.0.

2.3.12 Uranium

Venugopal and Luckey (1978) provided the following summary of mammalian uranium toxicity:

Gastrointestinal absorption of soluble uranyl salts is about 10 percent; insoluble salts are poorly absorbed. Approximately 60 percent of absorbed uranyl compounds deposited in the kidneys is

excreted in about 24 hours; uranyl compounds bound in skeletal material are mobilized much more slowly.

The comparative acute toxicity of some uranium salts is as follows:
$UF_2 > UO_2F_2 > UCl_4 > UO_2(NO_3)_2$; UO_2 and U_3O_8 are the least toxic uranium salts. The toxicity of orally ingested uranium salts is low because they are poorly absorbed. Insoluble salts are the least toxic chemically. When given orally to cats and dogs in the form of soluble uranyl nitrate, LD100s were 100 and 600 mg U/kg body weight, respectively.

Sheppard et al. (1992) performed a series of tests to determine the toxicity of uranium in soil to three species of plants and the earthworm, *Lumbricus* sp. The authors concluded that toxic effects were not consistently observed below 1000 mg U/kg and that none of the measurements indicated that detrimental effects were occurring below 300 mg U/kg. These tests are discussed in greater detail in Appendix G. Sheppard et al. (1992) also demonstrated that the bioavailability and toxicity of uranium in soil is a function of the soil's sorptive capacity (see Appendix G) and that uranium does not bioaccumulate. Mahon (1982) examined the transfer of uranium through three different food chains, one aquatic and two terrestrial. Data examined during this study indicated that uranium is not accumulated to any great extent by terrestrial herbivores, that there was no indication of biomagnification in top predators, and that the movement of "naturally occurring radionuclides from undisturbed ore bodies to aquatic systems does not appear to result in high levels of contamination in fish." According to Mahon, study results indicated that a drop in body burden of one order of magnitude occurred at each successive trophic level. Additional information on radionuclides and aquatic food chains is summarized in Appendix G.

Studies completed by Parkhurst et al. (1984) also indicate that uranium is not readily absorbed by aquatic organisms; bioconcentration factors calculated during the 1984 study were low, ranging from 1.9 to 4.3. Based on the results of acute and chronic (embryo-larval) toxicity tests conducted on brook trout, Parkhurst et al. (1984) calculated a 48 hour LC50 of 59,000 μg U/l and chronically toxic concentrations were estimated to exceed 9000 μg U/l. Studies performed by Tarzwell and Henderson (1960) and Holdway (1992) documented the relationship between increasing water hardness and decreasing acute toxicity of uranium. Although EPA has not developed ambient water quality criteria

for uranium, the Canadian government has adopted 300 μg total U/l as a guideline value for the protection of aquatic life and wildlife (Inland Waters Directorate 1987).

2.4 RISK CHARACTERIZATION OF FINAL COCS

Risk characterization relates exposure concentrations of final COCs to concentrations of COCs that are known to cause adverse effects; it essentially is the integration of exposure and toxicity. The "toxicity quotient method" was selected to characterize risks associated with the final COCs. Toxicity quotient values are derived by dividing the mean and the maximum estimated environmental concentrations for each final COC by the same benchmark toxicity criteria used to identify media-specific COCs. For this SLERA, a toxicity quotient value of less than 1.0 is considered to be associated with insignificant risk. The resulting toxicity quotients for media- and study area-specific final COCs are listed in Appendices D - F and all quotient values $\geq$ 1.0 are summarized in Tables 2-4 to 2-6.

The toxicity quotient method is probably the most common method for risk characterization used in ecological risk assessments. Advantages of this method, according to Barnthouse et al. (1986), include the following:

- the toxicity quotient method is relatively easy to implement, is generally accepted, and can be applied to any data
- this method is useful when a large number of chemicals must be screened.

The toxicity quotient method has some inherent limitations. One primary limitation is that the quotient method is a "yes/no" method for relating toxicity to exposure. That is, it utilizes single values for exposure concentrations and toxicity values, and does not account for incremental or cumulative toxicity. However, cumulative toxicity can be evaluated by employing the method of Barnthouse et al. (1986). This method simply sums the individual mean concentration/TV quotients for various COCs. Although all final surface water COCs with toxicity quotient values > 1.0 were assumed to pose a potential risk to ecoreceptors, those contaminants with quotient values > 0.3 (see Appendix D) were included in this assessment of cumulative risk because they may contribute to chronic effects resulting from additivity or synergism (Cardwell et al. 1993). Toxicant additivity best

TABLE 2-4

SURFACE WATER TOXICITY QUOTIENT VALUES FOR STUDY AREAS ON THE FEMP

Location		Final Contaminants of Concern									Cumulative Risk[a]
		Aluminum	Ammonia	Cadmium	Chloride	Lead[b]	Mercury	Phenols	Selenium	Silver	
Area E	Max.	1.00	c				1.30				2.30
	Mean	1.00					1.30				2.78
Area F	Max	2.67					3.00				6.27
	Mean	2.67					3.00				5.67
Paddys Run											
Reach 1	Max										0.51
	Mean										0.51
Reach 2	Max	5.18		1.26		1.20	1.45		3.38	14.62	28.81
	Mean	1.93		1.11			1.45		3.38	12.46	21.84
Reach 3	Max			1.58		1.48	1.00	6.16		14.62	26.37
	Mean			1.37			1.00	3.11		12.56	20.07
Area G	Max.					1.66	4.00				7.06
	Mean					1.66	4.00				7.06

[a]Cumulative Risk = sum of Quotient Values > 0.3. Quotient values > 0.3 are reported in Appendix D. This determination is restricted to surface water COCs; no equivalent method exists for determining cumulative risks associated with contaminated soils or sediments.
[b]Toxicity Quotient Value for lead based on human health values; all others based on Chronic Ambient Water Quality Criteria or equivalent.
[c]An empty cell indicates that the compound was not a contaminant of concern.

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TABLE 2-4

(Continued)

Location		Final Contaminants of Concern									Cumulative Risk[a]
		Aluminum	Ammonia	Cadmium	Chloride	Lead[b]	Mercury	Phenols	Selenium	Silver	
Great Miami River											
Reach 1	Max		1.20	3.10	1.41	1.86	47.55			76.92	134.00
	Mean			2.04		1.04	13.34			76.92	95.90
Reach 2	Max		1.40	1.08						15.38	20.06
	Mean			1.08						15.38	19.07
Reach 3	Max				1.10	16.00	4.85				25.08
	Mean					5.80	4.85				13.73
Reach 4	Max		1.10			10.00					13.51
	Mean					5.30					8.09
Reach 5	Max					10.00	9.25			100.00	122.44
	Mean					4.06	6.10			100.00	112.62

[a]Cumulative Risk = sum of Quotient Values > 0.3. Quotient values > 0.3 are reported in Appendix D. This determination is restricted to surface water COCs; no equivalent method exists for determining cumulative risks associated with contaminated soils or sediments.
[b]Toxicity Quotient Value for lead based on human health values; all others based on Chronic Ambient Water Quality Criteria or equivalent.
[c]An empty cell indicates that the compound was not a contaminant of concern.

TABLE 2-5

SEDIMENT TOXICITY QUOTIENT VALUES FOR STUDY AREAS ON THE FEMP

Location		Final Contaminants of Concern				
		Aluminum	Ammonia	Cadmium	Mercury	Uranium
Area E	Max	1.12	a		8.67	4.52
	Mean	1.12			8.67	3.59
Area F	Max		1.25		11.33	
	Mean		1.25		11.33	
Paddys Run						
Reach 1	Max	No non-radiological analytical results present in RI/FS data base.				
	Mean					
Reach 2	Max					
	Mean					
Reach 3	Max			1.10		
	Mean			1.10		
Area G	Max					1.70
	Mean					1.70
Great Miami River						
Reach 1	Max	No non-radiological analytical results present in RI/FS data base.				
	Mean					
Reach 2	Max	No non-radiological analytical results present in RI/FS data base.				
	Mean					
Reach 3	Max	No non-radiological analytical results present in RI/FS data base.				1.05
	Mean					1.05
Reach 4	Max	No non-radiological analytical results present in RI/FS data base.				
	Mean					
Reach 5	Max	No non-radiological analytical results present in RI/FS data base.				
	Mean					

*An empty cell indicates that the compound was not a contaminant of concern.

TABLE 2-6

SOIL TOXICITY QUOTIENT VALUES FOR STUDY AREAS ON THE FEMP

Location		Final Contaminants of Concern			
		Aluminum	Cadmium	Molybdenum	Uranium
Area A	Max	1.22	a	1.33	3.24
	Mean			1.03	1.22
Area B	Max	1.26		1.24	5.26
	Mean				2.03
Area C	Max				712.85
	Mean				57.93
Area D	Max			1.06	4.74
	Mean				1.27
Area E	Max	No non-radiological analytical results present in RI/FS data base.			4.96
	Mean				1.99
Area F	Max		1.16		6.28
	Mean				1.49
Area G	Max	No non-radiological analytical results present in RI/FS data base.			4.58
	Mean				2.19
Off-Site Areas					
Off-site SW	Max				1.81
	Mean				
Off-site NW	Max				
	Mean				
Off-site SE	Max				2.80
	Mean				1.09
Off-site NE	Max				
	Mean				

[a]An empty cell indicates that the compound was not a contaminant of concern.

describes the majority of toxicant interactions, and, therefore, is consistent with this approach for estimating cumulative toxicity. Other types of interactions, including synergistic and antagonistic interactions, have been insufficiently documented for most of the chemical mixtures studied. This method for determining cumulative risk values is intended only for aquatic systems; at present, no equivalent method exists for estimating cumulative toxicity for terrestrial or avian biota. The cumulative risk values calculated for surface waters examined in this study are summarized in Table 2-4.

The following sections summarize estimated risks based on media-specific mean and maximum exposure concentrations. It should be emphasized that the individual toxicity quotient values presented do not represent the absolute probability of risk in themselves, but are representative of the *relative* probability of risk; that is, the greater the toxicity quotient value the greater the likelihood that ecoreceptors coming in contact with a given contaminant may be adversely affected.

2.4.1 Risk Associated with Final Surface Water COCs

The toxicity quotient values of the following on-site surface water COCs exceeded 1.0: aluminum (Study Areas E and F; Reach 2 on Paddys Run), cadmium (Reaches 2 and 3 on Paddys Run), lead (Reaches 2 and 3 on Paddys Run, Study Area G), mercury (Study Areas E, F, and G; Reaches 2 and 3 on Paddys Run), phenols (Reach 3 on Paddys Run), selenium (Reach 2 on Paddys Run), and silver (Reaches 2 and 3 on Paddys Run). Water samples collected from the Great Miami River contained elevated concentrations (i.e., quotient values > 1.0) of ammonia (Reaches 1, 2, and 4), cadmium (Reaches 1 and 2), chloride (Reaches 1 and 3), lead (Reaches 1, 3, 4, and 5), mercury (Reaches 1, 3, and 5), and silver (Reaches 1, 2, and 5) (Table 2-4).

The concentration of aluminum present in water samples collected in Study Areas E, F, and Paddys Run Reach 2 exceeded the benchmark criterion (CAWQC). Quotient values ranged from 1.0 (Study Area E) to 5.18 (Reach 2 on Paddys Run, based on maximum measured value). However, it should be remembered that, as noted in Section 2.1.1, the concentrations of all metals measured in water samples collected for this study are based on concentrations of total, rather than dissolved metals. Expressing concentrations in terms of total metals is conservative and may overestimate the amount of metal that is biologically available and capable of producing a toxic effect. Therefore, it is probable

that the concentration of biologically available Al present in these three locations is less than the CAWQC, reducing the likelihood that Al is adversely impacting aquatic biota.

Quotient values for ammonia exceeded 1.0 in water collected from Reaches 1, 2, and 4 on the Great Miami River. These quotient values are based on the maximum measured ammonia concentration; mean concentrations for this contaminant did not exceed the conservative benchmark criterion (1000 $\mu g\ NH_4^+/l$) used in this SLERA. Therefore, it is unlikely that ammonia is adversely impacting aquatic biota inhabiting this river.

The mean and maximum quotient values for cadmium were only slightly > 1.0 for samples collected from Reaches 2 and 3 on Paddys Run and Reach 2 on the Great Miami River (Table 2-4). Because these quotient values are based on total, rather than dissolved concentrations of cadmium, the risks posed by this metal to aquatic biota inhabiting Paddys Run and Reach 2 on the Great Miami River are likely to be less than suggested by these values. The mean and maximum quotient values calculated for Reach 1 on the Great Miami River equaled 2.04 and 3.10, respectively. Although risks associated with cadmium present in samples collected from Reach 1 on the Great Miami River are probably also overestimated, it is possible that this metal may be adversely affecting aquatic biota inhabiting this area. The cadmium detected in the Great Miami River does not appear to be associated with activities at the FEMP.

Maximum concentrations of chloride exceeding the benchmark criterion were detected in water samples collected from Reaches 1 and 3 on the Great Miami River (quotient values = 1.41 and 1.10, respectively). The presence of elevated chloride concentrations in the upstream samples collected from the Great Miami River (Reach 1) indicates that this contaminant is not related to activities occurring at the FEMP. In addition, this contaminant is unlikely to be adversely impacting aquatic biota, in that the mean chloride concentrations measured in these samples were less than the benchmark criterion (see Appendix D).

As described in Section 2.2.1, the proposed MCL for lead (5 μg Pb/l) was used to conservatively evaluate risks posed to terrestrial biota that may use these surface waters as sources of drinking water. This value is significantly lower than the chronic ambient water quality criterion for this metal and is

therefore also protective of aquatic biota. Lead quotient values > 1.0 were determined for Reaches 2 and 3 on Paddys Run and Study Area G. However, the quotient values reported for Reaches 2 and 3 are based only on the maximum measured concentration; mean lead concentrations did not exceed the MCL. These data suggest that neither terrestrial nor aquatic biota utilizing Reaches 2 and 3 on Paddys Run are being adversely impacted by lead. Because the lead quotient value determined for Study Area G is based on a single analysis, it is difficult to determine if lead is present in concentrations that may adversely impact ecoreceptors.

The mean and maximum lead quotient values (1.04 and 1.86, respectively) determined for Reach 1 on the Great Miami River indicate that this metal may possibly pose a hazard to terrestrial biota utilizing this portion of the river as a drinking water source. Concentrations of lead measured in Reach 2 (immediately downstream of the outfall) did not exceed the benchmark criterion (Table 2-4). Both the mean and maximum lead quotient values determined for Reaches 3 - 5 were substantially greater than 1.0, indicating that this metal may have an adverse impact on terrestrial biota. Lead concentrations in these three reaches also exceeded the chronic ambient water quality criterion (26.2 μg Pb/l). However, it is probable that the concentrations of dissolved lead are less than the concentrations of total metal, thus reducing the impact that lead may have on aquatic biota.

With the exception of Reach 1 on Paddys Run, concentrations of mercury exceeding the benchmark criterion were detected in all surface water samples collected on-site as well as in water samples collected from Reaches 1, 3, and 5 on the Great Miami River (Table 2-4). Although the source of mercury in the samples collected from on-site locations is not known, the data do suggest that the mercury present in the Great Miami River is attributable to sources (point and/or nonpoint sources) upstream from the FEMP; mercury concentrations were greatest in samples collected from Reach 1, upstream of the FEMP outfall. As is the case for all other metals, the concentration of mercury is expressed as total mercury, and the elevated quotient values may overestimate the risk associated with this metal. However, because of mercury's ability to bioaccumulate (geometric mean bioconcentration factor = 25,400; see Section 2.3.6), relatively small quantities can pose a risk to both aquatic and terrestrial ecoreceptors. However, because the quotient values calculated for on-site locations were based on single samples, additional data are necessary to assess the possible risks associated with this metal.

Concentrations of phenols exceeding the benchmark criterion were detected at one location only - Reach 3 on Paddys Run. Phenol exceeded the benchmark criterion in water samples but was not present in sediments collected from this location. Bioconcentration factors determined for phenol ranged from 1.2 to 2.3 (EPA 1980a). Bioconcentration factors this low indicate that no residue problem should occur from exposure to phenol. Phenol is degradable by both bacteria and fungi. Based on aerobic biodegradation rates and aqueous photolysis, the half-life of phenol in surface waters has been estimated to range from 5.3 to 56.5 hours (Howard et al. 1991). This information suggests that although phenol was present in water in concentrations that exceeded the benchmark criterion, the rapid degradation and short half-life limits the hazard that phenol may pose to ecoreceptors.

A quotient value 3.38 was recorded for selenium in Reach 2 of Paddys Run. However, only one sample collected from this location was analyzed for this element. Selenium was not found in concentrations exceeding benchmark criteria collected from any other on-site or off-site location. Because total, rather than dissolved, concentrations were measured, the risks associated with selenium may be overestimated. Additional samples are necessary to confirm that selenium poses a risk to ecoreceptors.

Concentrations of silver greatly exceeding benchmark criteria were detected in water samples collected from Reaches 2 and 3 on Paddys Run as well as Reaches 1, 2, and 5 on the Great Miami River. The presence of silver in upstream samples collected from the Great Miami River indicate that the presence of this metal in this river is not solely related to activities at the FEMP. Although based on total metal concentrations, the magnitude of the quotient values (12.42 to 100.00) indicates that this metal may be adversely impacting aquatic biota inhabiting both Paddys Run and the Great Miami River.

As described in Section 2.4, the sum of final surface water COCs quotient values > 0.3 represented the potential cumulative risk posed to aquatic biota inhabiting the water bodies examined in this study. The highest cumulative risk values for on-site locations were calculated for Reaches 2 and 3 on Paddys Run (Table 2-4). Silver was the single largest source of risk associated with these two sections of stream, accounting for approximately 50 percent of the total value.

Silver was also the single greatest contributor to cumulative risk for Reaches 1, 2, and 5 on the Great Miami River. Lead accounted for most of the cumulative risk associated with Reaches 3 and 4 on this river. As previously discussed, lead quotient values were based on the proposed MCL value (5 μg Pb/l), which was protective of both terrestrial and aquatic ecoreceptors. Although a number of contaminants are present in this section of the river in concentrations that may adversely impact ecoreceptors, none of the contaminants appear to be associated with activities at the FEMP.

2.4.2 Risk Associated with Final Sediment COCs

As summarized in Table 2-5, the following final sediment COCs had quotient values greater than one; aluminum (Study Area E), ammonia (Study Area F), cadmium (Reach 3 on Paddys Run), mercury (Study Areas E and F), and uranium (Study Areas E and G; Reach 3 on the Great Miami River). No sediment samples had been collected from the Great Miami River for analysis of non-radiological contaminants at the time that this document was being prepared. However, additional samples were collected this spring for analyses to determine if radiological and non-radiological contaminants are present in this river. The results of these analyses will be assessed in the final baseline risk assessment.

No sediment benchmark criteria were available for aluminum; instead the benchmark criterion used in this instance was the mean background concentration for soil (DOE 1993b). Although aluminum concentrations present in Study Area E were greater than the mean background soil concentration (quotient value = 1.12), they were far less than the upper 95 percent confidence limit for this metal (13,724 mg/kg) (DOE 1993b). This information suggests that concentrations of aluminum present in this sample were well within the normal range of concentrations for this metal and it is therefore unlikely that aluminum represents a risk to ecoreceptors.

Study Area F was the only location that the sediment concentrations of ammonia exceeded the benchmark criterion (quotient value = 1.25; Table 2-5). This slight exceedance suggests that this contaminant is unlikely to pose a risk to ecoreceptors.

Only one sediment sample contained cadmium in concentrations greater than the ER-L (Paddys Run Reach 3; quotient value = 1.10). The fact that cadmium was only detected in one sample from

Paddys Run, coupled with the conservative nature of this benchmark value, suggests that the concentrations of cadmium present in the sediment sample collected from Reach 3 on Paddys Run poses a minimal threat to benthic organisms inhabiting this stream.

Mercury was found in sediment samples collected from Study Areas E and F in concentrations that greatly exceeded the ER-L (quotient values = 8.67 and 11.33, respectively). Concentrations of mercury exceeding benchmark values were also recorded in surface water samples collected from these same locations (Table 2-4). As previously discussed, this metal readily biomagnifies and small concentrations can represent a significant hazard to ecoreceptors. Therefore, based on currently available data, the presence of this contaminant may represent a hazard to ecoreceptors. However, collection of additional water and sediment samples is necessary in order to fully assess the potential risk associated with this metal.

No specific benchmark values were available to assess the risk posed by uranium in sediments. Instead, this contaminant was compared to the mean background soil concentration (DOE 1993b) and retained for consideration as a final sediment COC. Sediment samples collected from Study Areas E and G and Reach 3 on the Great Miami River contained uranium in concentrations exceeding the mean soil value. However, as summarized in Section 2.3.12, studies conducted on various uranium-contaminated aquatic systems suggest that this metal does not biomagnify and that it is not generally bioavailable. Therefore, although the concentrations of uranium present in these samples are greater than mean background soil values, it is unlikely that the uranium detected in these samples represents a risk to aquatic biota.

2.4.3 Risk Associated with Final Soil COCs

Quotient values derived from the surface soil concentration/Quebec threshold values (or other soil threshold values) for surface soils can only be applied in a broad sense (i.e., potentially hazardous or nonhazardous) because information on the effects of contaminated soils on ecoreceptors is limited. Although specific effects to soil-dwelling species cannot be predicted from these quotient values, values substantially less than 1.0 should be associated with relatively little risk.

In contrast, quotient values that substantially exceed 1.0 imply that a given soil contaminant may represent a risk for at least some species. Table 2-6 lists values $\geq$ 1.0 for final surface soil COCs. Quotient values for uranium exceeded 1.0 for all on-site sampling areas and the off-site, southwest and southeast quadrants. Other soil contaminants with quotient values > 1.0 were aluminum in Study Areas A and B; molybdenum in Study Areas A, B, and D; and cadmium in Study Area F.

Only the maximum concentration of aluminum present in soil samples collected from Study Areas A and B exceeded both the mean background soil concentration and the benchmark value; mean aluminum concentrations were less than the benchmark value (Table 2-6). This suggests that aluminum is not likely to represent a significant hazard to terrestrial ecoreceptors inhabiting these two areas.

Like aluminum, only the maximum concentration of cadmium present in soil samples collected from Study Area F exceeded the benchmark value used to screen for this contaminant in soil (quotient value = 1.16; Table 2-6). It is therefore unlikely that cadmium represents a hazard to ecoreceptors inhabiting Study Area F.

Molybdenum (Mo) was present in concentrations that exceeded the benchmark value in soil samples collected from Study Areas A, B, and D. Quotient values ranged from 1.06 to 1.33 (Table 2-6). Although molybdenum concentrations in soils collected from these study areas exceeded the benchmark criterion selected for this SLERA, these relatively low quotient values and molybdenum's limited toxicity suggest that this element does not represent a hazard to ecoreceptors.

Mean surface soil uranium (U) concentrations determined for the on-site study areas exceeded the benchmark criterion used to screen these data (10 mg U/kg; Direction des Substances Dangereuses 1988) as did the mean uranium concentrations determined for the off-site, southeast quadrant. Mean concentrations of uranium present in off-site surface soils ranged from 3.3 to 10.9 mg U/kg while on-site soils mean concentrations ranged from 12.2 mg U/kg (Study Area A) to 579.3 mg U/kg (Study Area C). The high mean soil concentration calculated for Study Area C are primarily attributable to four soil samples that contained uranium in excess of 4000 mg/kg. If these four samples are

eliminated from the calculations, the re-calculated mean soil concentration for Study Area C equals 78.82 mg U/kg.

Despite the fact that the prevailing winds are from the south and southwest, neither the mean nor the maximum soil uranium concentrations determined for the RI/FS soil samples collected from the northwest and northeast off-site quadrants exceeded the mean surface soil background concentration for uranium.

Although the mean soil concentrations of uranium determined for the various on-site areas exceed the mean background soil concentrations and the criterion established by the province of Quebec, they are well below the concentrations (300 mg U/kg) that Sheppard et al. (1992) associated with phytotoxicity and reduced earthworm survival. As discussed in Section 2.3.12, the toxicity of uranium is associated with solubility; insoluble forms exhibit low toxicity in standard laboratory test animals (both aquatic and terrestrial animals). Uranium is not generally biologically available; transfer coefficients through various food chains indicate an order of magnitude decline at every trophic level. Based on the results of several recent studies (see Section 2.3.12 and Appendix G), concentrations of uranium present in surface soils collected from on-site and off-site locations are well below concentrations associated with adverse biological effects (e.g., phytotoxicity, decreased earthworm survival, chronic aquatic toxicity). This information indicates that concentrations of uranium, although greater than the mean background soil concentrations and the benchmark criterion developed by the Quebec Ministry of the Environment, are less than values reported to adversely impact terrestrial ecoreceptors. Therefore, it is not likely that uranium is having an adverse impact on organisms inhabiting the FEMP.

2.4.4 Uncertainty Associated with Risk Characterization

Because risk characterization is essentially the integration of the exposure assessment and toxicity screening, sources of uncertainty associated with either of these two processes should also contribute to uncertainty in the risk characterization. In addition, elements of the risk characterization procedure itself should contribute to overall uncertainty. The toxicity quotient method was selected to characterize risk. The advantages of this method, and one of the primary limitations, were previously addressed. Areas of uncertainty associated with this risk characterization, and efforts to reduce

uncertainty, are summarized in Table 2-7.

2.5 SUMMARY

The results of this assessment indicate that none of the soil contaminants, including uranium, represent a risk to ecological receptors. However, lead, mercury and silver were identified as surface water contaminants that may be adversely impacting aquatic organisms in both Paddys Run and the Great Miami River. Surface water concentrations of selenium in Paddys Run, and cadmium in the Great Miami River, may also represent a hazard to aquatic biota or terrestrial organisms ingesting these waters. Finally, mercury detected in sediment samples from Paddys Run may be adversely impacting both aquatic and terrestrial ecological receptors.

TABLE 2-7

FACTORS THAT ARE EXPECTED TO CONTRIBUTE TO UNCERTAINTY IN THE RISK CHARACTERIZATION AND METHODS USED TO DECREASE THAT UNCERTAINTY

Factors Contributing to Uncertainty	Approach Used to Reduce Uncertainty
1. EPA-reviewed toxicity data are available for only a limited number of chemicals.	The use of acceptable chemical quantitative structure activity relationships should provide reasonable estimates of toxicity data for untested chemicals.
2. Chronic toxicity endpoint data can be inconsistent.	Chronic toxicity test results based only on appropriate endpoints (e.g., effects on mortality, growth, and reproduction); test design and test durations should decrease the uncertainty associated with chronic test results.
3. Toxicity data are sparse for media other than surface waters.	Sufficient toxicity data for media other than surface waters generally exist; when combined with extrapolations based on chemical structure activity relationships or interspecies correlations, reasonable estimates of required data are possible.
4. Analytical detection limits commonly exceed toxicity benchmark values (i.e., criteria).	Relatively high detection limits (DLs) were noted for several analyses in water samples. Benchmark criteria employed for other media believed to be reasonably conservative, reducing influence of method DL.

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3.0 ASSESSMENT OF RADIOLOGICAL CONTAMINANTS

This section of the SLERA evaluates the potential risks to ecological receptors due to chronic exposure to low-levels of radiological contaminants present in the FEMP study areas. To calculate the internal and external doses, media- and site-specific data are evaluated in a model, and the results are compared to a target level dose published in 1992 by the International Atomic Energy Agency (IAEA). The basis for the target level dose is presented in the publication, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*. Among the conclusions reached in the report is that there is no convincing evidence from the scientific literature that chronic radiation dose rates below 1 mGy/day (36.5 rad/year) will harm animal or plant populations.

With the exception of very conservative dose calculations based on the maximum level of radiological contaminants present in Study Area C, the methodology and assumptions used to model the available RI/FS data indicate that the absorbed doses to receptor organisms fall below the target level dose (36.5 rad/year). It can be concluded that, based on the measured levels of radioactivity on and around the FEMP site, there is no threat of adverse effects to populations of terrestrial or aquatic biota. The methodology, assumptions, and calculations used in this determination are presented in the following sections.

3.1 METHODOLOGY AND ASSUMPTIONS

This section presents information on the selection of receptor organisms (mammals, plant, and fish), the most likely pathways by which radiological contaminants could reach the receptor organisms, and the parameters (e.g., ingestion and inhalation rates) used in the calculations.

3.1.1 Selection of Receptor Organisms

White-footed deer mice (*Peromyscus leucopus noveborensis*) and western meadow voles (*Microtus pennsylvanicus*) were selected as the reference mammals for several reasons. First, they are known to occur on the FEMP, and the small size of their home ranges makes it likely that individuals would spend their entire life on the site. These mammals live in direct contact with the soil, increasing the probability that they will come in contact with contaminants in this particular medium. In addition,

mice and meadow voles are potential prey for a number of species that feed at the FEMP. Finally, studies have documented that they are sensitive to radioactivity (IAEA 1992).

The white-footed deer mouse is common to the eastern and central United States. It is the only subspecies of deer mouse known to occur in Ohio (Gottschang 1981; Facemire et al. 1990 and references therein). Deer mice comprised 60 percent of the animals trapped in the Butler County, Ohio woodlots in July and August, 1986 (Facemire et al. 1990). These mice reach the highest densities in brushy fields and in woodlots dominated by deciduous trees, and their average home range size is approximately 0.1 hectares (Lackey et al. 1985). Their diet generally consists of insects, fruit, starchy matter, green vegetation, and seeds. The frequency of each of these items in the diet is season-dependent, due to availability (Brown 1964).

The meadow vole is primarily a northern species whose range extends down the Atlantic Coast into South Carolina. This microtine rodent is most commonly found in grasslands, preferring moister areas, but also may be found in woodlands (Reich 1981 and references therein). Meadow voles comprised approximately six percent of the animals trapped in Butler County in July and August, 1986 (Facemire et al. 1990). The home range for the meadow vole ranges from 0.04 to 0.47 hectares and 0.016 to 0.31 hectares for males and females, respectively (Reich 1981 and references therein). This species is herbivorous with a diet of fresh stems and leaves, shifting to seeds, stembases, and roots as plants age (Batzli 1977). Insects and animal remains also comprise part of this species' diet (Reich 1981).

A generic pine was selected as the indicator plant for two reasons. First, studies of terrestrial vegetation have shown that pine trees are among the most sensitive plant species to radiation, and secondly, because of the large number of white pines (*Pinus strobus*) and Austrian pines (*Pinus nigra*) on the FEMP. Some Norway spruce (*Picea excelsa*) also occur on site.

Shiners (*Notropis* sp.) were selected as the indicator fish species because the genus is common in the Great Miami River and comprises more than 50 percent of the fish community in Paddys Run. In addition, there is adequate information in the literature to characterize their sensitivity to radiation. Although most species grow to a maximum of two to five inches, a few species do reach up to eight

inches in length. Shiner diets commonly include insects and plankton, but some consume plant material (Tomelleri and Eberle 1990). Usually two or more species of *Notropis* occur in the same area, but occupy slightly different niches. Niche differences include feeding in different microhabitats or consuming different sizes or types of food (Moyle and Cech 1982).

3.1.2 Selection of Pathways

This section lists the exposure pathways used for calculating absorbed dose to the receptor organisms in the appropriate study areas. First, for mammals inhabiting each of the terrestrial study areas, including the four off-site locations, the exposure pathways are:

- Direct irradiation from soil
- Inhalation of resuspended soil
- Ingestion of insects
- Incidental ingestion of soil (e.g., through grooming)
- Ingestion of vegetation
- Ingestion of water (only for study areas where water monitoring results were available).

Second, for aquatic animals in Paddys Run and the Great Miami River, the exposure pathways are:

- Direct irradiation from sediment
- Uptake of contaminants from water (all pathways)
- Direct irradiation from submersion in water.

Third, for pine trees in all study areas, the exposure pathways are:

- Direct irradiation from soil
- Uptake of contaminants from soil.

Several additional pathways were considered for evaluation, but were eliminated for a number of reasons

- Pine tree uptake of contaminants from groundwater
- Soil resuspension — interception (pine tree) — direct irradiation
- Air — interception (pine tree) — direct irradiation.

The groundwater pathway was eliminated because available information indicate that the groundwater at Fernald is deeper than the depth of pine tree tap root penetration. The interception pathways were eliminated because there are no active mechanisms for transport of contaminants (other than carbon-14 or tritium, which are not present in the FEMP environment) from the tree needles to the tree core.

In addition, for mammalian pathways, the soil — skin — ingestion and water — skin — ingestion pathways were not separately determined because it was assumed that the soil and vegetation ingestion rate values included contributions from indirect ingestion. The sediment ingestion pathway for aquatic animal exposure was not calculated because the sediment ingestion rate for shiners is negligible.

The selected pathways include the internal pathways described in the Risk Assessment Work Plan (DOE 1992b), as well as additional external pathways to ensure that the actual dose received by the organisms would not exceed the calculated values. Mathematical equations used to calculate absorbed dose through each of these pathways are provided in Appendix H.

3.1.3 Selection of Calculation Parameters

Parameters used in the calculations and their source(s) are listed in Tables 3-1 through 3-3. Plant to soil concentration ratios for grasses were used to calculate uptake of contaminants by pine trees due to the lack of tree-specific data (Till and Meyer 1983). Soil to insect concentration factors were assumed to be equal to 1.0 in the absence of radionuclide-specific data. This should be a conservative assumption, as the only published soil to insect value which could be located was a 0.01 established for radium (Clulow et al. 1988).

Soil to air transfer factors (T_{ma}) were calculated by the methodology provided in NUREG/CR-4370 (Oztunali and Roles 1986), using the average wind velocity and percent silt in soil values listed in the tables, and the precipitation-evaporation index of 103 provided in Figure C-16 of NUREG/CR-4370. These T_{ma} values are presented in Table 3-4.

3.2 CALCULATION OF ABSORBED DOSE DUE TO EXTERNAL EXPOSURE

The maximum and mean concentration values for each radionuclide and medium in each study area were derived from the RI/FS data base and are presented in Appendix I. The calculations for absorbed dose to the white-footed deer mouse, the meadow vole, pine trees, and shiners were performed using the computer program MicroShield™ (Grove Engineering 1988). While this program is designed primarily for use as a shielding calculational tool, it provides estimates for external exposure scenarios where attenuating media are involved. Following the entry of data

regarding source and shield materials and geometry, the program determines the exposure rate in milliroentgens per hour, which is converted to milliroentgens per year.

TABLE 3-1

GENERAL CALCULATION PARAMETERS FOR RADIATION DOSE EXPOSURE PATHWAYS FOR TERRESTRIAL AND AQUATIC ORGANISMS

Parameter	Symbol	Value (units)	Source
Average wind velocity	v	4.02 (m/s)	DOE 1992b
Precipitation-Evaporation Index	PE	103 (unitless)	Oztunali and Roles 1986
Deer mouse inhalation rate	R_m	1.93 (m^3/yr)	Hill 1975
Deer mouse soil ingestion rate	IR_{ms}	0.01825 (kg/yr)	Beyer 1993
Soil to grub concentration factors	BF_g	1.00 (unitless)	Assumed value (see text)
Deer mouse insect ingestion rate	IR_{mg}	0.292 (kg/yr)	Brown 1964
Deer mouse vegetation ingestion rate	IR_{mv}	0.675 (kg/yr)	Brown 1964
Deer mouse water ingestion rate	IR_{mw}	1.504 (L/yr)	Brown 1964
Deer mouse mass	m_m	0.023 (kg)	Deavers and Hudson 1981
Deer mouse effective radius	r_m	0.0314 (m)	Lackey et al. 1985
Meadow vole inhalation rate	R_v	5.753 (m^3/yr)	Reich 1981
Meadow vole soil ingestion rate	IR_{vs}	0.0767 (kg/yr)	Beyer 1993
Meadow vole insect ingestion rate	IR_{vg}	0.062 (kg/yr)	Batzli 1977
Meadow vole vegetation ingestion rate	IR_{vv}	2.905 (kg/yr)	Batzli 1977
Meadow vole water ingestion rate	IR_{vw}	3.45 (L/yr)	Ernst 1968
Meadow vole mass	m_v	0.045 (kg)	Reich 1981
Meadow vole effective radius	r_v	0.0309 (m)	Reich 1981
Shiner mass	m_{mi}	0.0206 (kg)	Scott and Crossman 1973
Shiner effective radius	r_{mi}	0.0070 (m)	Scott and Crossman 1973

TABLE 3-2

ELEMENT-SPECIFIC CALCULATION PARAMETERS FOR RADIATION DOSE EXPOSURE PATHWAYS FOR TERRESTRIAL AND AQUATIC ORGANISMS

Parameter	Element	Value	Reference
Plant to soil concentration ratio (B_s) (unitless)	Sr	1.25	Till and Meyer 1983
	Tc	0.25	Till and Meyer 1983
	Cs	0.048	NRC 1977
	Ra	0.04	Till and Meyer 1983
	Th	0.002	Till and Meyer 1983
	U	0.005	Till and Meyer 1983
Shiner bioconcentration factor (BF_s) (liter/kg)	Sr	40	Jorgenson et al. 1991
	Tc	3.206	Jorgenson et al. 1991
	Ra	322.5	Swanson 1985
	Th	190	Jorgenson et al. 1991
	U	2.06	Parkhurst et al. 1984

TABLE 3-3

STUDY AREA-SPECIFIC CALCULATION PARAMETERS FOR RADIATION DOSE EXPOSURE PATHWAYS FOR TERRESTRIAL AND AQUATIC ORGANISMS

Parameter	Symbol	Study Area	Value	Source
Percent silt in soil (%)	s	A	81	USDA 1976 and USDA 1980
		B	85	USDA 1976 and USDA 1980
		C	88	USDA 1976 and USDA 1980
		D	87	USDA 1976 and USDA 1980
		E	85	USDA 1976 and USDA 1980
		F	69	USDA 1976 and USDA 1980
		G	87	USDA 1976 and USDA 1980
		Off-site NE	83	Average of all on-site study areas
		Off-site NW	83	Average of all on-site study areas
		Off-site SE	83	Average of all on-site study areas
		Off-site SW	83	Average of all on-site study areas
Soil density (km^{-3})	ρ	A	1430	Average value from USDA 1976 and USDA 1980
		B	1455	Average value from USDA 1976 and USDA 1980
		C	1470	Average value from USDA 1976 and USDA 1980
		D	1460	Average value from USDA 1976 and USDA 1980
		E	1395	Average value from USDA 1976 and USDA 1980
		F	1379	Average value from USDA 1976 and USDA 1980
		G	1320	Average value from USDA 1976 and USDA 1980
		Off-site NE	1416	Average of all on-site study areas
		Off-site NW	1416	Average of all on-site study areas
		Off-site SE	1416	Average of all on-site study areas
		Off-site SW	1416	Average of all on-site study areas

TABLE 3-4

SOIL-TO-AIR TRANSFER FACTOR (T_{sa}) FOR RADIATION DOSE EXPOSURE PATHWAY

Study Area	(T_{sa})	Study Area	(T_{sa})
A	4.01E-10	G	4.31E-10
B	4.21E-10	Off-site NE	4.11E-10
C	4.35E-10	Off-site NW	4.11E-10
D	4.31E-10	Off-site SE	4.11E-10
E	4.21E-10	Off-site SW	4.11E-10
F	3.41E-10		

3.2.1 White-footed Deer Mouse/Meadow Vole

It was assumed that both of these mammals reside at a height of 3 cm above ground level for their entire lives. The ground beneath the animals was represented as a cylinder with a radius of 100 meters and a thickness of 150 cm (approximately 5 feet). The choice of five feet as the depth is based on the degree of gamma-ray attenuation provided by soil, and will approximate a semi-infinite soil thickness. The animal was assumed to be placed along the central axis of the cylinder. The soil along the entire distance between source and dose point was assumed to be composed solely of carbon with a density of 1.3 grams per cubic centimeter. While natural soil would contain other elements, most of these elements would have a higher atomic number, resulting in a greater shielding effect, particularly at low photon energies. Therefore, choosing pure carbon as the source volume while maintaining the appropriate measured density of soil surrounding the FEMP site is conservative. The photon flux is taken into account via the geometric progression approximation that is incorporated into MicroShield™.

Following standard assumptions, both animals are considered equivalent in tissue composition to humans, such that the approximation of 1 roentgen leading to an absorbed dose of 1 rad is valid over the photon energies of interest. In addition, the absorbed dose from the soil is assumed to be attributable only to gamma rays from the isotopes in the soil. The dose from beta particles and alpha particles is assumed to be zero, since both particle types would be fully attenuated by the soil before reaching the animal.

3.2.2 Pine Trees

The absorbed dose to pine trees is calculated in much the same manner as that for the mouse and vole: that is, the pine tree is assumed to be irradiated by a cylindrical slab of material with a radius of 100 meters and a thickness of 150 cm. The composition of the ground is the same as before, and the absorbed dose is assumed again to be due entirely to photon radiation. All pertinent calculations were carried out using MicroShield™.

Calculation of the absorbed dose to the pine tree is complicated by several factors, such as its height above the ground, the composition of the tree material, and the attenuating effects of the outer layers of the tree itself. For purposes of this calculation and to maintain the approximation that 1 roentgen leads to an absorbed dose of 1 rad, the conservative assumption is made that the tree has a similar isotopic makeup as mammalian tissue. In addition, attenuation of photons in the outer layers of the tree is neglected, and the reported doses are calculated at a height of 3 cm above the ground just as for the mouse and vole, since this would represent a conservative absorbed dose. This absorbed dose is assumed to be the same at all points within the tree, regardless of position, again resulting in an overestimate of the true absorbed dose rate.

3.2.3 Shiners

The external dose to shiners in streams is assumed to result from two sources: the water surrounding the shiner and the sediment beneath the shiner. For purposes of the submersion dose calculation, the shiner is assumed to be surrounded by an infinite body of water with a uniform distribution of radioactive material at all times in its lifespan. As with the external dose calculations for the terrestrial animals, the external dose is assumed to arise entirely from photon radiation. In addition, the physical dimensions of the shiner are such that it can be represented in water as a point receptor; that is, its presence in the water does not affect the ambient photon radiation field. While this may seem to oversimplify the problem, the effective radius of the shiner (0.7 cm) (Scott and Crossman 1978) is less than 1/8 of the mean free path of a 100 keV photon. Thus, assuming the shiner to be a point receptor will tend to overestimate the dose slightly. Under this assumption, the absorbed dose received by the shiner would be equal to the absorbed dose received by any other mass of water in the waterway. Since an infinite body of water is assumed, radiation equilibrium exists, and the

energy deposited in any mass is equal to the energy emitted in the same mass. Thus, the absorbed dose to the shiner is assumed to be equal to the photon energy emitted per unit mass of water.

For calculating the absorbed dose to the shiner as a result of exposure to sediment on the bottom of the waterway, the shiner is assumed to reside 3 cm above the sediment at all times. As with the soil, the sediment is assumed to be composed solely of carbon with a density of 1.3 grams per cubic centimeter. The shiner is presumably irradiated by a cylinder of sediment measuring 10 meters in radius and 30.5 centimeters in thickness. The choice of 10 meters for the radius is sufficient since the photons will be attenuated severely by water so that less than 1E-26 of primary gamma rays originating from distances greater than 10 meters will penetrate to the dose point. Attenuation is taken into account in the intervening water medium, and, as for terrestrial animals, the geometric progression calculation technique is used to estimate the effect of buildup within the medium.

3.3 CALCULATION OF ABSORBED DOSE DUE TO INTERNAL EXPOSURE

To calculate absorbed dose due to ingested or inhaled radioactive contaminants, dose conversion factors (DCFs) were derived using methodology similar to that in Sections 7.4.2 and 7.4.3 of the Risk Assessment Work Plan Addendum (DOE 1992b). Doses were calculated for maximum and mean environmental concentrations to represent maximum and mean doses to individual organisms in each study area. Data used in the calculation of DCFs are listed in Tables 3-5 through 3-7.

3.3.1 White-footed Deer Mouse/Meadow Vole

The calculation of DCFs for inhalation and ingestion for both of these mammals is similar (Table 3-8). For purposes of these calculations, the animals are assumed to have the same metabolic processes as humans with regard to retention and excretion of radioisotopes, and the chemistry of radioisotopes in the animals' bodies is assumed to be the same as that of humans. Equations from the International Commission on Radiological Protection (ICRP) Publication 2 (1959) were used to predict the uptake rate and body burden of radioactive material over the lifespan of the animals, which is assumed to be one year. All isotopes were assumed to be uniformly distributed throughout the body of the animal.

The overwhelming majority of the absorbed dose due to the internal emitters is due to particulate radiation (i.e., beta and alpha particles). For purposes of this calculation, the entire alpha and beta

particle energies are assumed to be absorbed within the body of the animals. Although only a small fraction of the energy emitted by the isotopes of concern is due to gamma rays, their contribution to the absorbed dose is taken into account by assuming both animals to have an effective radius of 3 centimeters. Tabulated values of absorbed energy per disintegration were utilized. The mass of the

TABLE 3-5

TERRESTRIAL MAMMAL DATA USED TO CALCULATE DOSE CONVERSION FACTORS

Isotope	Inhalation uptake fraction (f_a)[a]	Ingestion uptake fraction (f_w)[a]	Average Energy per decay (ϵ)(MeV)[b]	Biological half-life T_b (d)	Effective half-life (T_r)(d)[c]
Sr-90/Y-90	4.00E-01	3.00E-01	1.14E+00	1.30E+04	1.06E+04
Tc-99	5.00E-01	5.00E-01	8.40E-02	1.00E+00	7.77E+07
Cs-137	7.50E-01	1.00E+00	2.84E-01	7.00E+01	1.10E+04
Ra-224	4.00E-01	3.00E-01	5.79E+00[d]	8.10E+03	3.66E+00
Ra-226	4.00E-01	3.00E-01	4.87E+00[d]	8.10E+03	5.84E+05
Ra-228	4.00E-01	3.00E-01	1.69E-02[d]	8.10E+03	2.10E+03
Th-228	2.50E-01	1.00E-04	5.52E+00[d]	5.70E+04	6.98E+02
Th-230	2.50E-01	1.00E-04	4.76E+00[d]	5.70E+04	2.75E+07
Th-232	2.50E-01	1.00E-04	4.08E+00[d]	5.70E+04	5.11E+12
U-234	2.50E-01	5.00E-02[e]	4.90E+00	1.00E+02	8.98E+07
U-235	2.50E-01	5.00E-02[e]	4.60E+00	1.00E+02	2.57E+11
U-238	2.50E-01	5.00E-02[e]	4.30E+00	1.00E+02	1.63E+12

[a]ICRP 1959
[b]Baker and Soldat 1992
[c]GE 1989
[d]ICRP 1983
[e]ICRP 1978

TABLE 3-6

SHINER DATA USED TO CALCULATE DOSE CONVERSION FACTORS[a]

Isotope	Internal energy per disintegration (ϵ_i) (MeV)	Submersion energy per disintegration (ϵ_i) (MeV)
Sr-90/Y-90	1.14E+00	0.00E+00
Tc-99	8.40E-02	0.00E+00
Cs-137	2.57E-01	5.68E-01
Ra-224	5.79E+00	1.00E-02
Ra-226	4.87E+00	6.75E-03
Ra-228	1.69E-02	0.00E+00
Th-228	5.52E+00	3.07E-03
Th-230	4.76E+00	1.40E-03
Th-232	4.08E+00	1.19E-03
U-234	4.90E+00	1.47E-03
U-235	4.60E+00	1.53E-01
U-238	4.30E+00	1.20E-03

[a]Baker and Soldat 1992 and ICRP 1983

TABLE 3-7

PINE TREE DATA USED TO CALCULATE DOSE CONVERSION FACTORS

Isotope	Particulate energy per disintegration (ϵ)(MeV)[a]
Sr-90/Y-90	1.13E+00
Tc-99	1.01E-01
Cs-137	8.15E-01
Ra-224	5.79E+00
Ra-226	4.87E+00
Ra-228	1.69E-02
Th-228	5.52E+00
Th-230	4.76E+00
Th-232	4.08E+00
U-234	4.86E+00
U-235	4.67E+00
U-238	4.28E+00

[a]ICRP 1983

TABLE 3-8

DOSE CONVERSION FACTORS

Dose Conversion Factors (mrad/pCi)													
Isotope		Sr-90/Y-90	Tc-99	Cs-137	Ra-224	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234	U-235	U-238
Deer Mouse	Inhalation ($DCF_{m,in}$)	3.62E-01	1.35E-04	4.65E-02	2.68E-02	1.56E+00	5.13E-03	9.38E-01	9.64E-01	8.26E-01	3.62E-01	3.40E-01	3.17E-01
	Ingestion (DCF_{mi})	2.71E-01	1.35E-04	6.21E-02	2.01E-02	1.17E+00	3.85E-03	3.75E-04	3.85E-04	3.30E-04	7.23E-02	6.79E-02	6.35E-02
Meadow Vole	Inhalation ($DCF_{v,in}$)	1.85E-01	6.89E-05	2.38E-02	1.37E-02	7.95E-01	2.62E-03	4.79E-01	4.93E-01	4.22E-01	1.85E-01	1.74E-01	1.62E-01
	Ingestion (DCF_{vi})	1.39E-01	6.89E-05	3.17E-02	1.03E-02	5.97E-01	1.97E-03	1.92E-04	1.97E-04	1.69E-04	3.70E-02	3.47E-02	3.24E-02
Pine Tree[a]	Uptake (DCF_{tu})	2.11E-02	1.89E-03	1.52E-02	1.08E-01	9.10E-02	3.16E-04	1.03E-01	8.89E-02	7.62E-02	9.08E-02	8.72E-02	8.00E-02
Shiner[a]	Uptake (DCF_{su})	2.13E-02	1.57E-03	4.80E-03	1.08E-01	9.10E-02	3.16E-04	1.03E-01	8.89E-02	7.62E-02	9.15E-02	8.59E-02	8.03E-02

[a]mrad kg/pCi yr

086

42710

meadow vole is assumed to be 45 grams (Reich 1981), and the white-footed deer mouse is assumed to have a mass of 23 grams (Deavers and Hudson 1981). The formulas used to calculate the dose conversion factors for inhalation and ingestion are listed in Appendix J.

3.3.2 Pine Trees

Dose conversion factors for pine trees are calculated by assuming a steady-state concentration of radioactive material within the tree (Table 3-8). As with the vole and mouse, almost all of the absorbed dose is due to particulate radiation. Because of its negligible contribution to the overall absorbed dose, the absorbed fraction for photon radiation is assumed to be unity. This results in a slight overestimation that is virtually unnoticeable in the presence of the relatively large absorbed dose from particulate radiation. As was the base for the terrestrial animals, the absorbed fractions for particulate radiation are assumed to be unity. The formula for the dose conversion factor is provided in Appendix J.

3.3.3 Shiners

Dose conversion factors for shiners are calculated by assuming a steady-state concentration of radioactive material within the tissues of the animal (Table 3-8). The absorbed dose due to particulate radiation is calculated as described for the pine tree, mouse, and vole. For photon radiation, however, the small physical dimensions of the shiner (effective radius of 0.7 cm) (Scott and Crossman 1973) are such that very little of the energy would be absorbed in the tissues of the shiner. However, for conservatism, the absorbed fractions are assumed to be equal to that for a sphere of water with an effective radius of 1.4 cm (Baker and Soldat 1992). The uptake dose conversion factor is provided in Appendix J.

3.4 ANALYSIS OF RESULTS

Calculated absorbed (internal and external) doses to the receptor organisms in each study area, the Great Miami River, and other off-site locations are provided in Table 3-9. The results of the intermediate calculations are presented in Appendix K. The final calculated absorbed doses to the receptor organisms were compared to the trigger level dose of 36.5 rad per year, which was selected after review of the literature relating to the effects of ionizing radiation on plants and animals (IAEA

TABLE 3-9

DOSE ABSORBED BY RECEPTOR ORGANISMS IN EACH APPROPRIATE STUDY AREA (RAD/YR)[a]

	Study Areas											
	A	B	C	D	E	F	G	Great Miami River	Off site NE	Off site NW	Off site SE	Off site SW
Mouse												
Max	1.54E+00	1.71E+00	1.37E+02	1.82E+00	1.61E+00	1.82E+00	1.66E+00	b	9.00E-02	6.30E-01	1.03E+00	7.30E-01
Mean	9.50E-01	8.80E-01	9.93E+00	7.90E-01	1.13E+00	7.80E-01	1.18E+00	b	6.00E-02	4.80E-01	6.30E-01	4.60E-01
Vole												
Max	1.14E+00	7.70E-01	3.40E+01	6.80E-01	9.50E-01	9.40E-01	1.18E+00	b	2.00E-02	1.50E-01	2.40E-01	1.70E-01
Mean	9.20E-01	4.90E-01	3.44E+00	4.00E-01	7.70E-01	5.20E-01	9.00E-01	b	1.00E-02	1.10E-01	1.50E-01	1.70E-01
Pine Tree												
Max	9.00E-02	1.30E-01	3.14E+00	1.40E-01	6.00E-02	8.00E-02	5.00E-02	b	0.00E+00	2.00E-02	2.00E-02	2.00E-02
Mean	4.00E-02	6.00E-02	2.60E-01	5.00E-02	5.00E-02	4.00E-02	4.00E-02	b	0.00E+00	1.00E-02	1.00E-02	1.00E-02
Shiner												
Max	b	b	b	b	b	2.39E-01	b	7.00E-02	b	b	b	b
Mean	b	b	b	b	b	1.17E-01	b	6.00E-02	b	b	b	b

[a]Benchmark Criterion = 3.65E+01.
[b]An empty cell indicates that there was no appropriate data.

1992). The IAEA (1992) has concluded that, "There is no convincing evidence from the scientific literature that chronic radiation dose rates below 1 mGy/day (36.5 rad/year) will harm animal or plant populations."

All calculated doses are below the trigger level dose of 36.5 rad per year, with the exception of the dose to the mouse using the maximum concentrations in Study Area C. Approximately 93 percent of this dose is due to the insect ingestion pathway, which, as noted in Section 3.1.3, uses the conservative assumption that the soil-to-insect concentration factor is equal to 1.0. If the soil-to-insect concentration factor for uranium (most of the dose is due to isotopes of uranium) is assumed to be similar to the published value for radium (0.01), the calculated dose would drop by a factor of approximately 100 and would then be well below the trigger level dose. In addition, the calculated dose to mice from average concentrations in Study Area C is approximately 9.9 rad per year, which is less than the trigger level dose. This is a more accurate measure of potential adverse population effects.

It can be concluded that, based on the measured levels of radioactivity on and around the FEMP site, there is no threat of adverse effects to populations of terrestrial plants or terrestrial or aquatic animals.

4.0 SUMMARY AND CONCLUSIONS

The primary purpose of the SLERA was to use available information to determine if radiological and non-radiological contaminants associated with actions at the FEMP represent a threat to ecological receptors inhabiting this facility and nearby off-site areas. Contaminant concentration data evaluated in this SLERA were collected during the RI for OU5. In addition, the results of ecological and biological studies conducted on the FEMP were also considered. This document was prepared by following guidance provided by EPA Region V.

The focus of this SLERA was on-site and off-site areas not likely to be remediated based on human-health concerns. On-site study areas were defined by habitat type (for example, grassland) and the size of the home range of receptor species used in the models developed to quantify total radiation doses. In addition to these study areas, hazards associated with contaminant concentrations in soil in four off-site study areas, and sediment and surface water contaminant concentrations from the Great Miami River were assessed.

Uranium represented the major contaminant at the FEMP. Airborne emissions of uranium from production stacks and from an incinerator located on the eastern border of the site as well as effluent discharged into the Great Miami River represented the principal pathways for contaminants to reach the surrounding environment. Other contaminants associated with the activities that supported uranium production include various metals and organic materials. These may have entered the soil and surface waters as airborne contamination from the flyash piles, waste pits, or the landfill, or as runoff from contaminated soil in various on-site locations.

A review of information contained in previous studies conducted on the FEMP indicated that the vegetation on the site was typical of the Western Mesophytic forest region and that population levels of flora and fauna on the site appeared normal for southwestern Ohio. No species or group was conspicuously low or absent in any available habitat niches and the ecological communities on the FEMP were typical of those found in the region where similar land-use practices occur.

Fish and benthic invertebrates collected from Paddys Run indicated that the intermittent stream is of good to high quality in areas of permanent water and that clean water fish species were dominant. Studies conducted on the Great Miami River from 1984 through 1991 concluded that the fishery in the river is stable. Studies of fish and benthos in the Great Miami River suggested that the river was of low to good quality and had characteristics of a stressed aquatic system both above and below the FEMP outfall. Results of studies of the macroinvertebrate communities in Paddys Run and the Great Miami River have concluded that the operation of the FEMP has resulted in nothing more than minor nutrient enrichment and no deleterious effects on the benthic macroinvertebrate communities of either water body were demonstrated. However, studies have indicated that factors unrelated to the FEMP exerted a significant controlling influence on the benthos. These factors included the seasonal intermittent nature of Paddys Run and the loads carried by the Great Miami River following periods of heavy precipitation. Despite these physical stresses, Invertebrate Community Index values estimated for these waters were consistent with ranges considered by OEPA (1988) to represent fair to good water quality. No threatened or endangered species were present on the FEMP. No studies have identified any major adverse ecological impacts — such as fish kills or vegetation die-off — at the site.

The mean and maximum concentrations of media-specific non-radiological contaminants were compared to media-specific benchmark values that are protective of ecological receptors. Contaminants exceeding these values were regarded as final COCs and their toxicological properties summarized. The relative risks that each of these final COCs might pose to FEMP ecoreceptors was then evaluated.

Potential risks to ecological receptors due to chronic exposure to low-levels of radiological contaminants present in the FEMP study areas were also addressed. To calculate the internal and external doses, media- and site-specific data are evaluated in a model, and the results are compared to a target level dose (36.5 rad/year) published in 1992 by the International Atomic Energy Agency (IAEA).

The results of this assessment indicated that none of the soil contaminants, including uranium, represent a risk to ecological receptors. Lead, mercury, and silver were identified as contaminants

that may be adversely impacting aquatic organisms in both Paddys Run and the Great Miami River. Selenium detected in water samples collected from Paddys Run and cadmium present in samples collected from the Great Miami River may also represent a hazard to aquatic biota or to terrestrial organisms drinking these surface waters. None of the contaminants identified in samples collected from the Great Miami River appear be to associated with the FEMP. Mercury was the only contaminant detected in sediment samples collected from Paddys Run that may be adversely impacting both aquatic and terrestrial ecoreceptors.

With the exception of very conservative dose calculations based on the maximum level of radiological contaminants present in Study Area C, the methodology and assumptions used to model the available RI/FS data indicate that the absorbed doses to receptor organisms fall below the target level dose (36.5 rad/year). It can be concluded that, based on the measured levels of radioactivity on and around the FEMP site, there is no threat of adverse effects to populations of terrestrial or aquatic biota.

Additional samples (soil, water, and sediment) are currently being collected from on-site locations. These samples will be analyzed for both radiological and non-radiological constituents. The results of these analyses will be used to supplement the data analyzed in this SLERA. Because of the limited number of non-radiological analyses available for review, the additional analytical data are particularly necessary to confirm the extent of contamination by mercury and silver and to verify that these contaminants represent a risk to ecological receptors. The results of these additional analyses will be included in the Sitewide Ecological Assessment as part of the OU5 Report.

The results of the SLERA indicate that, with few exceptions, contaminants associated with activities occurring at the FEMP are not adversely impacting on-site or off-site ecological receptors. These results are consistent with results of past studies that have indicated that neither the terrestrial nor aquatic biota associated with the site have been adversely impacted and that these populations are typical of those found in southwestern Ohio.

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APPENDIX A

THREATENED AND ENDANGERED SPECIES OF THE FEMP

4710

THREATENED AND ENDANGERED SPECIES
THAT OCCUR OR MIGHT OCCUR ON
THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
HAMILTON AND BUTLER COUNTIES, OHIO

PREPARED BY
HALLIBURTON NUS CORPORATION
900 TRAIL RIDGE ROAD
AIKEN, SC 29803

MAY 1993

PREPARED FOR

FERNALD ENVIRONMENTAL RESTORATION MANAGEMENT CORPORATION
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1.0 PROJECT SITE DESCRIPTION

The Fernald Environmental Management Project (FEMP) site, located on 1,050 acres in a rural area of Hamilton and Butler Counties, is approximately 18 miles northwest of Cincinnati, Ohio (Figure 1). The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the site.

The FEMP and surrounding areas lie in a transition zone between two distinct sections of the Eastern Deciduous Forest Province: the Oak-Hickory and the Beech-Maple (Bailey, 1978). The region is characterized by a mosaic of these forest types. The Eastern Deciduous Forest was historically dominated by tall, broadleaf trees which provided a continuous, dense summer canopy. Nearly all indigenous forest stands in southwestern Ohio have been cleared, cut, or altered for agriculture or urban development. Vegetative communities within and surrounding FEMP is predominantly agricultural, resulting in a landscape of open pasture and plowed fields dissected by forests occupying drainages, steep slopes, and ditch banks. There are several distinct terrestrial habitats including plowed fields, pasture and lawn, floodplain forest, and upland forest.

Upland forested habitats are characterized by American elm (*Ulmus americana*), eastern cottonwood (*Populus deltoides*), black locust (*Robinia pseudo-acacia*), black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), black walnut (*Juglans nigra*), box elder (*Acer negundo*), honey locust (*Gleditsia triacanthos*), and several species of oak (*Quercus sp.*).

The floodplain forests along the Great Miami River and Paddys Run are dominated by American sycamore (*Platanus occidentalis*), hackberry (*Celtis occidentalis*), red maple (*Acer rubrum*), eastern cottonwood, American elm, and box elder.

Inclusion of threatened and endangered (T&E) species in this report was based on the following three sources.

(1) Ken Multerer, a biologist with the U.S. Fish and Wildlife Service (FWS), stated that there were only two Federally listed T&E species in the area (pers. comm.).

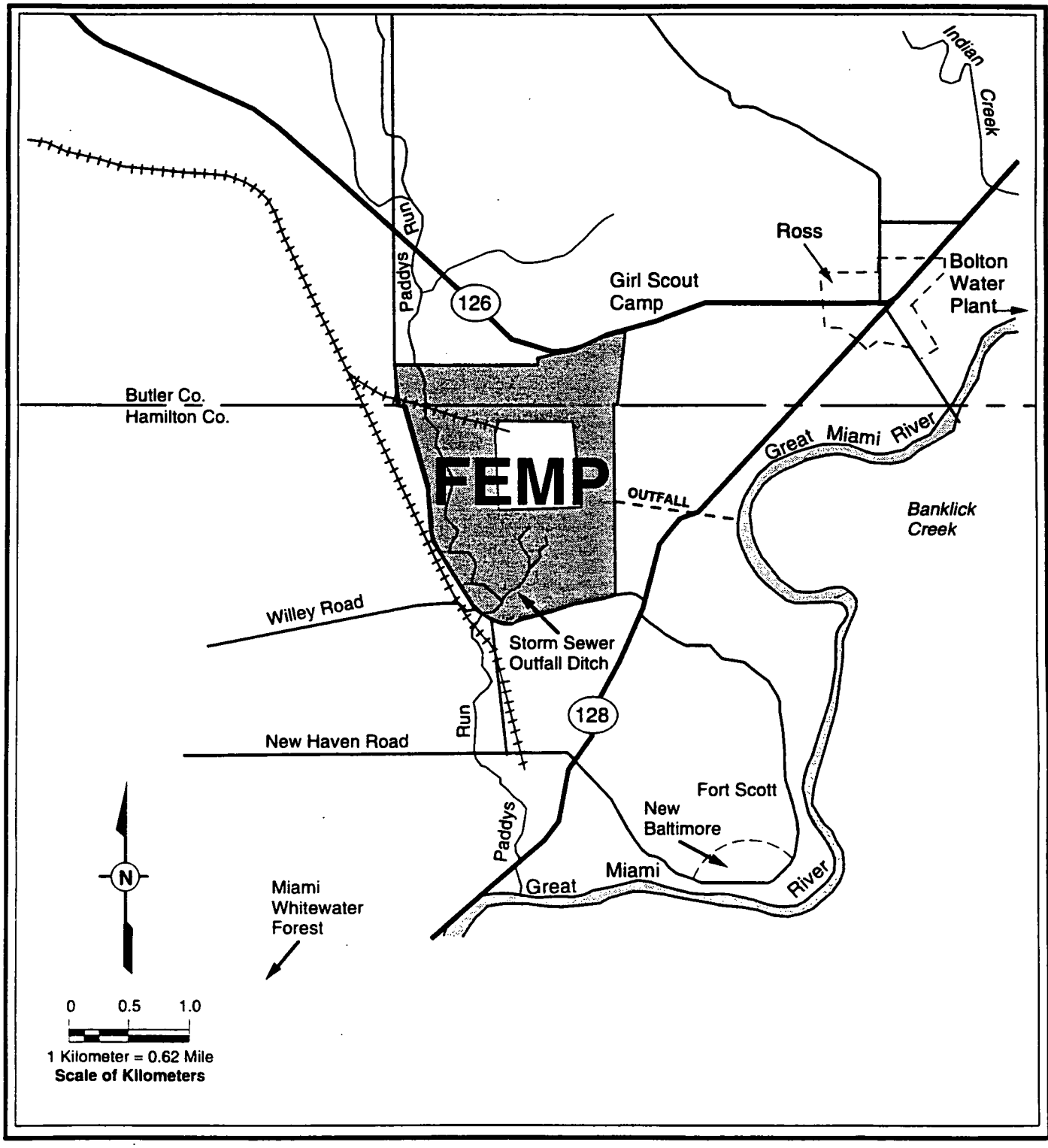

Figure A-1. FEMP and Surrounding Area

He suggested that the Indiana bat (*Myotis sodalis*) and running buffalo clover (*Trifolium stoloniferum*) be included.

(2) Patricia D. Jones, Ohio Department of Natural Resources (ODNR), provided information from the state's Natural Heritage Database (NHD; pers. comm.). While no records were found for the FEMP (see Exhibit A), this report includes records from the southern half of the Shandon, Ohio quadrangle, and the western half of the Greenhills, Ohio quadrangle for the following species: Sloan's crawfish (*Orconectes sloanii*), bigeye shiner (*Notropis boops*), cave salamander (*Eurycea lucifuga*), running buffalo clover, and spring coral-root (*Corallorhiza wisteriana*).

(3) The 1992 Site-Wide Characterization Report of FEMP identified cobblestone tiger beetle (*Cicendela margipennis*), Sloan's crawfish, cave salamander, northern harrier (*Circus cyaneus*), red-shouldered hawk (*Buteo lineatus*), northern waterthrush (*Seiurus noveboracensis*), dark-eyed junco (*Junco hyemalis*), Indiana bat, running buffalo clover, slender finger-grass (*Digitaria filiformis*), and mountain bindweed (*Polygonum cilinode*) as occurring or having the potential to occur on the FEMP (DOE, 1992). The red-shouldered hawk and cobblestone tiger beetle are listed as "special interest" and were not included in this document.

2.0 FEDERALLY-LISTED THREATENED AND ENDANGERED SPECIES THAT MIGHT OCCUR ON THE FEMP

2.1 INDIANA BAT (*Myotis sodalis*)

The Indiana bat, listed as endangered in 1967, usually hibernates in limestone caves characterized by floors covered with standing water. During the summer, females form maternity colonies in hollow trees and under loose bark. Most summer roosts are near streams and small rivers and the bats forage at night for moths, mayflies, and other flying insects near the tops of trees and over streams (Webster et al., 1985). The Indiana bat is found from New York south to northern Georgia, and west to eastern Oklahoma and eastern Iowa (FWS, 1983).

Indiana bats were mist netted on 13 nights between June 24, 1988, and August 10, 1988, along the Great Miami River from the I-275 bridge upstream to the Cincinnati Water Works (CWW) Bolton Water Plant and along Paddys Run from the State Route 126 bridge to its confluence with the Great Miami River (DOE, 1992). In addition, potential habitat for the bats was also surveyed. Excellent habitat, defined as mature woodland with dead trees extending more than 30 yards beyond the stream edge on one or both banks, was noted on one area of Paddys Run at the Butler/Hamilton County line. Good habitat, defined as mature woodland on one or both banks but not extending far beyond the stream edge, was noted on Paddys Run at the New Haven and the Willey Road bridges and along portions of the Great Miami River near the CWW Bolton Water Plant. While five mist net sites on Paddys Run on or adjacent to the FEMP produced 48 bats of 3 species, none were Indiana bats. Eight Indiana bats were trapped on Banklick Creek near the East Miami River Road bridge approximately 3 miles east of the FEMP in late July and early August 1988 (DOE, 1992). While the results of the 1988 survey and the limited suitable habitat suggest that it is unlikely that the Indiana bat utilizes the FEMP, additional studies are necessary to confirm that this species does not occur on this site.

2.2 RUNNING BUFFALO CLOVER (*Trifolium stoloniferum*)

Running buffalo clover habitat consists of mesic ravines on tributaries of the Little Miami River in Clermont and Warren counties and in western sections of Butler and Hamilton counties (McCance et al., 1984). When the running buffalo clover was listed as endangered on June 5, 1987, the species

was known to occur at only one location in West Virginia (DOI, 1987). This species has since been reported in disturbed areas of Hamilton County, Ohio.

The 1986 and 1987 botanical surveys did not record this species on the FEMP (Facemire et al., 1990). However the ODNR NHD indicates that running buffalo clover exists in the Miami Whitewater Forest County Park on the south shore of Miami Whitewater Lake (P.D. Jones, pers. comm.). The flora of the park was surveyed by the Hamilton County Parks Department during the summer of 1992 and no running buffalo clover populations were located (Conover, 1992). A limited survey of habitats suitable for buffalo clover was conducted in 1992 on the FEMP failed to identify any populations of this plant. While no running buffalo clover populations have been located on the FEMP, its occurrence on Miami Whitewater Forest County Park indicates that it is present in the general area and could occur on the FEMP.

3.0 STATE-LISTED THREATENED AND ENDANGERED SPECIES THAT OCCUR OR MIGHT OCCUR ON THE FEMP

3.1 SLOAN'S CRAWFISH (*Orconectes sloanii*)

This species is listed as threatened by ODNR but is not listed by the FWS. The ODNR NHD records it in Indian Creek at the SR 128 bridge (P.D. Jones, pers. comm.).

Sloan's Crawfish was recorded as common in Paddys Run during the winter of 1986-1987 (DOE, 1992; Facemire et al., 1990). It is likely that it also occurs in other streams in the surrounding area.

3.2 BIGEYE SHINER (*Notropis boops*)

This species is listed as endangered by ODNR but is not listed by the FWS. It prefers the clearest of streams with stream bottoms of sand, gravel, bedrock, and small amounts of organic matter. This species was common in western Ohio prior to 1900 but has disappeared from much of its range with the clearing of the forests and the subsequent increased siltation of the streams (Trautman, 1957).

The ODNR NHD has recorded this species at the mouth of Paddys Run (P.D. Jones, pers. comm.). This record is based on a survey conducted in 1973 (Bauer et al., 1978). The authors concluded that this species may have moved into Paddys Run from the Great Miami River, where its occurrence was more common. Subsequent surveys in the Great Miami River from 1980 - 1991 failed to locate this species (Miller et al., 1990; 1992;
OEPA, 1989). In addition, a 1986 stream survey in Paddys Run did not indicate its presence (Facemire et al., 1990). Since the species has not been observed since 1973, it appears that the bigeye shiner no longer inhabits Paddys Run or the Great Miami River.

3.3 CAVE SALAMANDER (*Eurycea lucifuga*)

The cave salamander is listed as endangered by the State of Ohio and is not listed by the FWS (ODNR, 1992). Its favorite habitat is the dimly lit entrance to limestone caves; however, it may also be found in forested areas or along streams removed from any known caves (Denny, 1990). Streams favored by this species are commonly narrow (less than 3 feet wide) and intermittent, often disappearing underground and reappearing some distance down the slope (J. Davis, pers. comm.).

The three known cave salamander sites on the Miami Whitewater Forest County Park are all small, steep ravines in deciduous woodlots (Juterbock, 1987).

A 1988 survey of T&E species on and around the FEMP searched for cave salamander populations along Paddys Run, Ross Trails Girl Scout Camp, and Camp Fort Scott (DOE, 1992). A population of cave salamanders was located on Ross Trails Girl Scout Camp north of the FEMP on May 25, 1988. Potential habitat exists on Camp Fort Scott north of New Baltimore and near Paddys Run downstream of New Haven Road. This study also listed previously discovered populations near Banklick Creek and north of New London Road. The ODNR NHD recorded three locations on Miami Whitewater Forest County Park (P.D. Jones, pers. comm.). The species was also recorded north of Day Road on the east side of the Great Miami River. Surveys conducted by J. Davis during the summer of 1989 located another previously discovered population 25 yards south of East Miami River Road near its junction with Stone Mill Road (J. Davis, pers. comm.). A small, intermittent limestone stream flowing under East Miami River Road adjacent to Stone Mill Road contains suitable habitat for cave salamanders on both sides of the road. This stream was searched by J. Davis during a 1989 survey for Richardson Forest Preserve County Park, and no cave salamanders were located (J. Davis, pers. comm.). No populations were located in Banklick Creek or Paddys Run. These streams are too large and contain unsuitable habitat (J. Davis, pers. comm.; Juterbock, 1987). No cave salamander populations have been located on the FEMP. Extensive, unproductive searches for the species and the lack of suitable habitat on the FEMP suggest that the possibility that these salamanders occur on the FEMP is remote.

3.4 NORTHERN HARRIER (*Circus cyaneus*)

This rare summer resident is classified as endangered by ODNR due to limited nesting records in Ohio but is not listed by FWS. The northern harrier was a common nester in the wetlands and pastures of northern Ohio as late as the 1920s. Populations have declined so that only 5 to 15 pairs are estimated to be nesting in the entire state. Nesting records in the southwestern portion of the state have always been rare. The species, common during migration, is most often seen near meadows and wetlands (Peterjohn, 1989).

This species was observed during the 1986 summer survey (Facemire et al., 1990). It is likely that the species migrates through the area during the fall and spring but doubtful that the species nests on the FEMP.

3.5 NORTHERN WATERTHRUSH (*Seiurus noveboracensis*)

This common migrant is listed as endangered by the ODNR due to limited nesting records in Ohio and is not listed by the FWS. It is a rare summer resident in northeastern Ohio and prefers quiet backwaters and wooded swamps. A related species, the Louisiana waterthrush, is common throughout Ohio and prefers shaded streams with adjacent, mature deciduous woods (Peterjohn, 1989).

This species was reported on the FEMP during the spring of 1987 but not during the summer of 1986 or the winter of 1986 - 1987 (Facemire et al., 1990). It is probable that this species is locally common during migration and doubtful that it nests further south than northern Ohio.

3.6 DARK-EYED JUNCO (*Junco hyemalis*)

This common migrant is listed as endangered by the ODNR due to limited nesting records in Ohio and is not listed by the FWS. It is a rare summer resident in northern Ohio and prefers to nest in cool hemlock ravines and mature beech-maple forests (Peterjohn, 1989).

This species was reported on the FEMP during the winter of 1986-1987 (Facemire et al., 1990). It is probable that this species is locally common during migration and over winters in southwestern Ohio, but it is doubtful that it nests further south than northern Ohio.

3.7 SLENDER FINGER-GRASS (*Digitaria filiformis*)

This rare crab grass is classified as endangered by ODNR but is not listed by FWS. The plant blooms from August to October and prefers full sun in sterile, sandy soils (McCance et al., 1984). The species in Ohio is confined to dry, sandy native prairie habitat (J. McCormick, pers. comm.).

This plant was located during the 1986 botanical survey of the area. It was recorded as being rare in the riparian habitats of the FEMP (Facemire et al., 1990). The 1992 survey at Miami Whitewater Forest County Park failed to locate the species (Conover, 1992). J. McCormick, Staff Botanist with

ODNR, stated that the species is largely confined to dry, sandy native prairie (pers. comm.). The presence of this species in riparian habitats is unusual and warrants further investigation to determine the extent of its occurrence on the FEMP.

3.8 SPRING CORAL-ROOT (*Corallorhiza wisteriana*)

This rare orchid is classified as threatened by ODNR but is not listed by FWS. The plant blooms in April and May and is found in swamp forests and wooded ravines (Radford et al., 1968).

This plant was not located during the botanical surveys of the area in 1986 and 1987 (Facemire et al., 1990); however, ODNR NHD reports a population on the Miami Whitewater Forest approximately 1,500 feet southwest of Miami Whitewater Lake (P.D. Jones, pers. comm.). The 1992 survey of Miami Whitewater Forest failed to locate the species (Conover, 1992). The habitat for this species does not occur on the FEMP and it is unlikely that the species occurs on the FEMP.

3.9 MOUNTAIN BINDWEED (*Polygonum cilinode*)

This rare smartweed or climbing buckwheat is classified as endangered by ODNR but is not listed by FWS. The plant blooms from June through September and is found in openings and clearings in forested areas (Radford et al., 1968). This species has been reported (post-1960) in Portage and Summit Counties in northeastern Ohio (McCance, 1984).

This plant was not mentioned in the 1988 T&E species survey of the area; however, it was reported as being rare in the riparian woodlands and pine plantations on the FEMP during the 1986 botanical survey (Facemire et al., 1990). The 1992 survey of Miami Whitewater Forest failed to locate this species (Conover, 1992). The presence of this species in southwestern Ohio is unusual and warrants further investigation to determine the extent of its occurrence on the FEMP.

4.0 SUMMARY OF T&E SPECIES THAT OCCUR OR MIGHT OCCUR ON THE FEMP

A survey of bat habitat and bat mist netting in 1988 failed to locate the Indiana bat on the FEMP. However, the Indiana bat was recorded on Banklick Creek east of the FEMP. Sloan's crawfish was recorded as common in Paddys Run during the winter of 1986 - 1987. The bigeye shiner was found at the mouth of Paddys Run in 1973 but has not been located since then. Suitable habitat for the cave salamander does not occur on the FEMP and no cave salamanders were located on the FEMP during a 1989 survey. Slender finger-grass and mountain bindweed have been reported on the FEMP. Running buffalo clover and spring coral-root have not been identified on the FEMP. Both species occur on Miami Whitewater Forest County Park and running buffalo clover might occur on the FEMP. The northern harrier, northern waterthrush, and dark-eyed junco migrate through the area but do not nest in southwestern Ohio. Table 1 summarizes the Federally- and State-listed T&E species that occur or might occur on the FEMP.

TABLE 1

SUMMARY TABLE OF THREATENED AND ENDANGERED SPECIES THAT OCCUR OR MIGHT OCCUR ON THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

Species	Status	Occurrence on the FEMP
Federally-listed		
Indiana Bat	Endangered	Not likely to occur
Running Buffalo Clover	Endangered	Not found but might occur
State-listed		
Sloan's Crawfish	Threatened	Found in Paddys Run on FEMP
Bigeye Shiner	Endangered	Not likely to occur
Cave Salamander	Endangered	Not likely to occur
Northern Harrier	Endangered	Not likely to nest (migratory)
Northern Waterthrush	Endangered	Not likely to nest (migratory)
Dark-Eyed Junco	Endangered	Not likely to nest (migratory)
Slender Finger-Grass	Endangered	Found in riparian habitat on FEMP
Spring Coral-Root	Threatened	Not likely to occur
Mountain Bindweed	Endangered	Found in riparian habitat on FEMP

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EXHIBIT A

OHIO
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George V. Voinovich • Governor
Frances S. Buchholzer • Director

4710

April 6, 1993

Robert K. Abernethy
Halliburton NUS Corporation
Savannah River Center
900 Trail Ridge Road
Aiken, SC 29803

Dear Mr. Abernethy:

After reviewing our maps and files, I find the Division of Natural Areas & Preserves has no records of rare and endangered species in the Hamilton County Water Supply and Fernald Environmental Management project area.

There are no existing or proposed nature preserves or scenic rivers in the project area, and we are unaware of any other unique ecological sites in the vicinity of the Colerain and Crosby townships, Hamilton County and Ross Township, Butler County site.

Because our inventory program relies on information supplied by a number of individuals and organizations, a lack of records for any particular area is not a statement that special plant or animal species are absent from a site. Please note that we inventory only high-quality plant communities and do not maintain an inventory of all Ohio wetlands.

Please contact me if I can be of further assistance.

Sincerely,

Jennifer A Hillmer

Jennifer Hillmer, Ecological Analyst
Division of Natural Areas & Preserves

JH/ks

120

Fountain Square • Columbus, Ohio 43224-1387

APPENDIX B

TOTAL NUMBER OF ON- AND OFF-SITE RI/FS DATA BASE SAMPLES EVALUATED IN THE SLERA

TABLE B-1

TOTAL NUMBER OF ON- AND OFF-SITE RI/FS DATA BASE WATER SAMPLES EVALUATED IN THE SLERA

Area	Non-Radiological Samples	Radiological Samples
A	a	
B		
C		
D		
E	2	10
F	1	5
Paddys Run - Reach 1		
Paddys Run - Reach 2	8	17
Paddys Run - Reach 3	5	13
G	1	2
Offsite NE		
Offsite NW		
Offsite SE		
Offsite SW		
Great Miami River - Reach 1	7	15
Great Miami River - Reach 2	3	24
Great Miami River - Reach 3	3	14
Great Miami River - Reach 4		7
Great Miami River - Reach 5	5	14

[a]An empty cell indicates that no samples were collected.

TABLE B-2

TOTAL NUMBER OF ON- AND OFF-SITE RI/FS DATA BASE SEDIMENT SAMPLES EVALUATED IN THE SLERA

Area	Non-Radiological Samples	Radiological Samples
A	a	
B		
C		
D		
E	1	
F	1	3
Paddys Run - Reach 1	1	3
Paddys Run - Reach 2	1	5
Paddys Run - Reach 3	1	3
G		1
Offsite NE		
Offsite NW		
Offsite SE		
Offsite SW		
Great Miami River - Reach 1		
Great Miami River - Reach 2		3
Great Miami River - Reach 3		3
Great Miami River - Reach 4		3
Great Miami River - Reach 5		6

*An empty cell indicates that no samples were collected.

TABLE B-3

TOTAL NUMBER OF ON- AND OFF-SITE RI/FS DATA BASE SOIL SAMPLES EVALUATED IN THE SLERA

Area	Non-Radiological Samples	Radiological Samples
A	5	25
B	2	28
C	3	51
D	4	26
E	2	7
F	4	24
Paddys Run - Reach 1	a	
Paddys Run - Reach 2		
Paddys Run - Reach 3		
G		7
Offsite NE		9
Offsite NW		43
Offsite SE		9
Offsite SW		9
Great Miami River - Reach 1		
Great Miami River - Reach 2		
Great Miami River - Reach 3		
Great Miami River - Reach 4		
Great Miami River - Reach 5		

[a]An empty cell indicates that no samples were collected.

APPENDIX C

CALCULATIONS USED IN THE NON-RADIOLOGICAL ASSESSMENT

CALCULATIONS USED IN THIS STUDY

1.0 HARDNESS

Hardness (mg $CaCO_3$/l) = 2.497 [Ca mg/l] + 4.118 [Mg mg/l]

2.0 CONVERSION OF URANIUM ISOTOPIC ACTIVITY CONCENTRATIONS TO MASS CONCENTRATIONS:

$$M_U = A_{U\text{-}238}/SpA_{U\text{-}238} + A_{U\text{-}235}/SpA_{U\text{-}235} + A_{U\text{-}234}/SpA_{U\text{-}234}$$

Where:

M_U is the mass concentration of uranium in the soil in units of micrograms of uranium per gram (μg/g) of soil.

$A_{U\text{-}238}$ is the activity concentration of U-238 in the sample by isotopic analysis in units of picocuries per gram (pCi/g) of soil.

$SpA_{U\text{-}238}$ is the specific activity of U-238 (0.336 picocuries per microgram [pCi/μg] of U-238).

$A_{U\text{-}235}$ is the activity concentration of U-235 in the sample by isotopic analysis in units of pCi/g of soil.

$SpA_{U\text{-}235}$ is the specific activity of U-235 (2.16 pCi/μg of U-235).

$A_{U\text{-}234}$ is the activity concentration of U-234 in the sample by isotopic analysis in units of pCi/g of soil.

$SpA_{U\text{-}234}$ is the specific activity of U-234 (6.25×10^3 pCi/μg of U-234).

3.0 CONVERSION OF THORIUM ISOTOPIC ACTIVITY CONCENTRATIONS TO MASS CONCENTRATIONS:

$$M_U = A_{Th\text{-}232}/SpA_{Th\text{-}232} + A_{Th\text{-}230}/SpA_{Th\text{-}230} + A_{Th\text{-}228}/SpA_{Th\text{-}228}$$

Where:

M_U is the mass concentration of uranium in the soil in units of micrograms of uranium per gram (μg/g) of soil.

$A_{Th\text{-}232}$ is the activity concentration of Th-232 in the sample by isotopic analysis in units of picocuries per gram (pCi/g) of soil.

$SpA_{Th\text{-}232}$ is the specific activity of Th-232 (0.11 picocuries per microgram [pCi/μg] of Th-232).

$A_{Th\text{-}230}$ is the activity concentration of Th-230 in the sample by isotopic analysis in units of pCi/g of soil.

$SpA_{Th\text{-}230}$ is the specific activity of Th-230 (20,200 pCi/μg of Th-230).

$A_{Th\text{-}228}$ is the activity concentration of Th-228 in the sample by isotopic analysis in units of pCi/g of soil.

$SpA_{Th\text{-}228}$ is the specific activity of Th-228 (8.2×10^8 pCi/μg of Th-228).

4.0 CALCULATION OF THE LC50 FOR URANIUM

$$LC50 = -2.84 + 0.337(\text{Hardness, mg } CaCO_3/l) + 0.0406(\text{Alkalinity, mg } CaCO_3/l)$$

APPENDIX D

SURFACE WATER CONTAMINANTS OF CONCERN

TABLE D-1

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA E BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	1	87.0	1	86.6	1.00	Y	86.6	1.00	Y
Ammonia	2	1000.0	2	162.0	0.16	b	144.0	0.14	
Arsenic		190.0	2	b					
Barium	2	145.0	3	39.9	0.28		33.5	0.23	
Cadmium[c]		4.1	2						
Chloride	2	230000.0	1	34000.0	0.15		31500.0	0.14	
Chromium[c]	1	644.5	2	7.2	0.01		7.2	0.01	
Copper[c]	1	42.4	2	10.5	0.25		10.5	0.25	
Fluoride	2			210.0			200.0		
Iron	2	1000.0	2	292.0	0.29		179.0	0.18	
Lead	2	5.0	4	0.52	0.06		2.4	0.48	
Manganese	2			9.7			9.1		
Mercury	1	0.2	2	0.3	1.30	Y	0.3	1.30	Y
Molybdenum									
Nickel[c]		580.0	2						
Nitrate	2			5440.0			3075.0		
Selenium		5.0	2						
Silicon	1			3890.0			3890.0		
Silver		1.3	2						
Sulfate	2			51300.0			49450.0		
Uranium[c]	2	1171.6	5	47.3	0.04		25.6	0.02	
Acetone		78000.0	2						
Phenols		370.0	2						
Cumulative Risk			6		2.30			2.78	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:
CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-2

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA F BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (μg/l)	Notes[a]	Max SW Conc(μg/l)	Based on Maximum SW Concentration		Mean SW Conc(μg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	1	87.0	1	232.0	2.67	Y	232.0	2.67	Y
Ammonia	b	1000.0	2						
Arsenic		190.0	2						
Barium		145.0	3						
Cadmium[c]		3.5	2						
Chloride	1	230000.0	1	7000.0	0.03		7000.0	0.03	
Chromium[c]	1	535.8	2	19.9	0.04		19.9	0.04	
Copper[c]		34.4	2						
Fluoride	1			440.0			440.0		
Iron	1	1000.0	2	168.0	0.17		168.0	0.17	
Lead		5.0	4						
Manganese	1			24.2			24.2		
Mercury	1	0.2	2	0.6	3.00	Y	0.6	3.00	Y
Molybdenum									
Nickel[c]		476.6	2						
Nitrate	1			2300.0			2300.0		
Selenium		5.0	2						
Silicon									
Silver		1.3	2						
Sulfate	1			129000.0			129000.0		
Uranium[c]	5	929.3	5	561.5	0.60		221.6	0.24	
Acetone	1	78000.0	2	4.0	0.00005		4.0	0.00005	
Phenols		370.0	2						
Cumulative Risk			6		6.27			5.67	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:

CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-3

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF PADDYS RUN REACH 1 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Comparison Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Comparison Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	b	87.0	1						
Ammonia	1	1000.0	2	100.0	0.10		100.0	0.10	
Arsenic		190.0	2						
Barium		145.0	3						
Cadmium[c]		3.2	2						
Chloride	1	230000.0	1	2780.0	0.01		2780.0	0.01	
Chromium[c]		487.7	2						
Copper[c]		31.0	2						
Fluoride	1			166.0			166.0		
Iron	1	1000.0	2	513.0	0.51		513.0	0.51	
Lead		5.0	4						
Manganese	1			35.0			35.0		
Mercury		0.2	2						
Molybdenum									
Nickel[c]		431.2	2						
Nitrate	1			166.0			166.0		
Selenium		5.0	2						
Silicon	1			3360.0			3360.0		
Silver		1.3	2						
Sulfate	1			5565.0			5565.0		
Uranium[c]		880.2	5						
Acetone		78000.0	2						
Phenols	1	370.0	2	10.0	0.03		10.0	0.03	
Cumulative Risk			6		0.51			0.51	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:
CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-4

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF PADDYS RUN REACH 2 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Comparison Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Comparison Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	4	87.0	1	451.0	5.18	Y	167.8	1.93	Y
Ammonia	3	1000.0	2	452.0	0.45	b	320.3	0.32	
Arsenic	1	190.0	2	18.8	0.10		18.8	0.10	
Barium	6	145.0	3	47.0	0.32		41.6	0.29	
Cadmium[c]	6	3.2	2	4.0	1.26	Y	3.5	1.11	Y
Chloride	8	230000.0	1	20260.0	0.09		14375.0	0.06	
Chromium[c]	8	487.7	2	26.0	0.05		19.4	0.04	
Copper[c]	3	31.0	2	12.0	0.39		11.3	0.37	
Fluoride	8			300.0			243.8		
Iron	8	1000.0	2	556.0	0.56		166.8	0.17	
Lead	2	5.0	4	6.0	1.20	Y	4.1	0.82	
Manganese	8			29.0			21.3		
Mercury	1	0.2	2	0.3	1.45	Y	0.3	1.45	Y
Molybdenum									
Nickel[c]	1	431.2	2	25.0	0.06		25.0	0.06	
Nitrate	8			12100.0			4712.5		
Selenium	1	5.0	2	16.9	3.38	Y	16.9	3.38	Y
Silicon	5			4610.0			4352.0		
Silver	5	1.3	2	19.0	14.62	Y	16.2	12.46	Y
Sulfate	8			52200.0			43970.0		
Uranium[c]	16	880.2	5	20.2	0.02		9.8	0.01	
Acetone		78000.0	2						
Phenols	2	370.0	2	20.0	0.05		15.0	0.04	
Cumulative Risk			6		28.81			21.84	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:

CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-5

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF PADDYS RUN REACH 3 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	2	87.0	1	71.0	0.82	b	71.0	0.82	
Ammonia	1	1000.0	2	163.0	0.16		163.00	0.16	
Arsenic	2	190.0	2	3.0	0.02		2.5	0.01	
Barium	4	145.0	3	47.0	0.32		42.6	0.29	
Cadmium[c]	3	3.2	2	5.0	1.58	Y	4.3	1.37	Y
Chloride	5	230000.0	1	19100.0	0.08		14702.0	0.06	
Chromium[c]	3	487.7	2	20.0	0.04		18.3	0.04	
Copper[c]	2	31.0	2	12.0	0.39		12.0	0.39	
Fluoride				300.0			251.0		
Iron	4	1000.0	2	28.6	0.03		23.4	0.02	
Lead	3	5.0	4	7.4	1.48	Y	4.1	0.82	
Manganese	3			32.0			18.4		
Mercury	2	0.2	2	0.2	1.00	Y	0.2	1.00	Y
Molybdenum									
Nickel[c]		431.2	2						
Nitrate	5			11300.0			4359.6		
Selenium		5.0	2						
Silicon	4			4650.0			3685.0		
Silver	3	1.3	2	19.0	14.62	Y	16.3	12.56	Y
Sulfate	5			57360.0			43542.0		
Uranium[c]	12	880.2	5	18.2	0.02		11.8	0.01	
Acetone		78000.0	2						
Phenols	2	370.0	2	2280.0	6.16	Y	1150.0	3.11	Y
Cumulative Risk			6		26.37			20.07	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:
CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-6

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA G BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (μg/l)	Notes[a]	Max SW Conc (μg/l)	Based on Maximum SW Concentration		Mean SW Conc (μg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	b	87.0	1						
Ammonia	1	1000.0	2	162.6	0.16		162.6	0.16	
Arsenic		190.0	2						
Barium	1	145.0	3	26.7	0.18		26.7	0.18	
Cadmium[c]	1	1.8	2	1.6	0.89		1.6	0.89	
Chloride	1	230000.0	1	3500.0	0.02		3500.0	0.02	
Chromium[c]		268.2	2						
Copper[c]	1	15.8	2	8.1	0.51		8.1	0.51	
Fluoride	1			300.0			300.0		
Iron	1	1000.0	2	284.0	0.28		284.0	0.28	
Lead	1	5.0	4	8.3	1.66	Y	8.3	1.66	Y
Manganese	1			46.2			46.2		
Mercury	1	0.2	2	0.8	4.00	Y	0.8	4.00	Y
Molybdenum									
Nickel[c]	1	228.3	2	8.0	0.04		8.0	0.04	
Nitrate	1			140.0			140.0		
Selenium		5.0	2						
Silicon									
Silver		1.3	2						
Sulfate	1			171000.0			171000.0		
Uranium[c]	5	383.0	4						
Acetone		78000.0	2						
Phenols		370.0	2			Y			
Cumulative Risk			6		7.06			7.06	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:

CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-7

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 1 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	1	87.0	1	76.4	0.88	b	76.4	0.88	
Ammonia	5	1000.0	2	1200.0	1.20	Y	345.8	0.35	
Arsenic		190.0	2						
Barium	6	145.0	3	100.0	0.69		69.9	0.48	
Cadmium[c]	2	3.2	2	9.8	3.10	Y	6.5	2.04	Y
Chloride	6	230000.0	1	325000.0	1.41	Y	116161.7	0.51	
Chromium[c]	1	485.6	2	6.1	0.01		6.1	0.01	
Copper[c]	2	30.8	2	11.9	0.39		10.5	0.34	
Fluoride	6			900.0			561.7		
Iron	4	1000.0	2	216.0	0.22		107.9	0.11	
Lead	4	5.0	4	9.3	1.86	Y	5.2	1.04	Y
Manganese	3			12.1			10.4		
Mercury	4	0.2	2	9.5	47.55	Y	2.7	13.34	Y
Molybdenum	2			24.0			15.5		
Nickel[c]	3	429.3	2	20.0	0.05		14.5	0.03	
Nitrate	6			8270.0			4010.0		
Selenium		5.0	2						
Silicon	1			2250.0			2250.0		
Silver	1	1.3	2	100.0	76.92	Y	100.0	76.92	Y
Sulfate	6			4310000.0			798080.0		
Uranium[c]	11	820.9	5	3.3	0.004		3.3	0.004	
Acetone		78000.0	2						
Phenols	2	370.0	2	10.0	0.03		10.0	0.03	
Cumulative Risk			6		134.00			95.90	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:

CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
LEAD: e (1.279 [ln (HARDNESS mg $CaCO_3$)]-3.956)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-8

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 2 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Comparison Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Comparison Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	b	87.0	1						
Ammonia	2	1000.0	2	1400.0	1.40	Y	814.5	0.81	
Arsenic	1	190.0	2	2.1	0.01		2.1	0.01	
Barium	3	145.0	3	100.0	0.69		79.2	0.55	
Cadmium[c]	1	3.2	2	3.4	1.08	Y	3.4	1.08	Y
Chloride	3	230000.0	1	139000.0	0.60		97330.0	0.42	
Chromium[c]	1	485.6	2	3.7	0.01		3.7	0.01	
Copper[c]	1	30.8	2	9.7	0.31		9.7	0.31	
Fluoride	3			880.0			670.0		
Iron	2	1000.0	2	175.0	0.18		102.5	0.10	
Lead	2	5.0	4	3.0	0.60		2.6	0.52	
Manganese	2			8.5			5.3		
Mercury		0.2	2						
Molybdenum									
Nickel[c]	1	429.3	2	11.4	0.03		11.4	0.03	
Nitrate	3			7680.0			3760.0		
Selenium		5.0	2						
Silicon									
Silver	1	1.3	2	20.0	15.38	Y	20.0	15.38	Y
Sulfate	3			132000.0			103173.3		
Uranium[c]	11	820.9	5	5.7	0.01		4.3	0.01	
Acetone		78000.0	2						
Phenols	2	370.0	2	20.0	0.05		20.0	0.05	
Cumulative Risk			6		20.06			19.07	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:
CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-9

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 3 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	b	87.0	1						
Ammonia	1	1000.0	2	600.0	0.60		600.0	0.60	
Arsenic		190.0	2						
Barium	3	145.0	3	90.0	0.62		76.0	0.52	
Cadmium[c]	1	3.2	2	2.7	0.85		3.0	0.95	
Chloride	3	230000.0	1	252000.0	1.10	Y	129663.0	0.56	
Chromium[c]		485.6	2						
Copper[c]	1	30.8	2	14.2	0.46		14.0	0.45	
Fluoride	3			880.0			680.0		
Iron	3	1000.0	2	600.0	0.60		270.0	0.27	
Lead	3	5.0	4	80.0	16.00	Y	29.0	5.80	Y
Manganese	1			7.8			8.0		
Mercury	1	0.2	2	1.0	4.85	Y	1.0	4.85	Y
Molybdenum	1			40.0			40.0		
Nickel[c]	1	429.3	2	11.3	0.03		11.0	0.03	
Nitrate	3			7060.0			3787.0		
Selenium		5.0	2						
Silicon									
Silver		1.3	2						
Sulfate	3			112000.0			104067.0		
Uranium[c]	9	820.9	5	3.6	0.004		4.5	0.01	
Acetone		78000.0	2						
Phenols	1	370.0	2	30.0	0.08		30.0		
Cumulative Risk			6		25.08			13.73	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:
CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-10

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 4 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Comparison Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Comparison Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	b	87.0	1						
Ammonia	4	1000.0	2	1100.0	1.10	Y	647.0	0.65	
Arsenic		190.0	2						
Barium	5	145.0	3	91.0	0.63		79.0	0.54	
Cadmium[c]	1	3.2	2	2.5	0.79		2.5	0.79	
Chloride	4	230000.0	1	149000.0	0.65		109000.0	0.47	
Chromium[c]		485.6	2						
Copper[c]	1	30.8	2	10.5	0.34		10.5	0.34	
Fluoride	4			900.0			707.5		
Iron	3	1000.0	2	194.0	0.19		114.7	0.11	
Lead	2	5.0	4	50.0	10.00	Y	26.5	5.30	Y
Manganese	2			11.0			10.2		
Mercury		0.2	2						
Molybdenum	1			30.0			30.0		
Nickel[c]	1	429.3	2	10.7	0.02		10.7	0.02	
Nitrate	4			6760.0			2690.0		
Selenium		5.0	2						
Silicon									
Silver		1.3	2						
Sulfate	4			111000.0			103700.0		
Uranium[c]	1	820.9	5	5.4	0.01		5.4	0.01	
Acetone		78000.0	2						
Phenols	2	370.0	2	10.0	0.03		10.0	0.03	
Cumulative Risk			6		13.51			8.09	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:

CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

TABLE D-11

SURFACE WATER (SW) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 5 BASED ON TOXICITY

Potential Surface Water (SW) COCs	Number of SW Samples	Benchmark Toxicity Value (BTV) (µg/l)	Notes[a]	Max SW Conc (µg/l)	Based on Maximum SW Concentration		Mean SW Conc (µg/l)	Based on Mean SW Concentration	
					Conc/BTV Ratio	Toxic SW COC		Conc/BTV Ratio	Toxic SW COC
Aluminum	b	87.0	1						
Ammonia	4	1000.0	2	800.0	0.80		626.8	0.63	
Arsenic		190.0	2						
Barium	5	145.0	3	91.0	0.63		69.2	0.48	
Cadmium[c]	2	3.2	2	1.8	0.57		1.8	0.55	
Chloride	5	230000.0	1	154000.0	0.67		92800.0	0.40	
Chromium[c]		485.6	2						
Copper[c]	2	30.8	2	6.9	0.22		6.3	0.20	
Fluoride	5			900.0			598.0		
Iron	5	1000.0	2	522.0	0.52		228.4	0.23	
Lead	3	5.0	4	50.0	10.00	Y	20.3	4.06	Y
Manganese	3			11.7			9.4		
Mercury	2	0.2	2	1.9	9.25	Y	1.2	6.10	Y
Molybdenum	2			30.0			30.0		
Nickel[c]	1	429.3	2	7.2	0.02		7.2	0.02	
Nitrate	4			4120.0			2945.0		
Selenium	1	5.0	2	2.0	0.04		2.0	0.40	
Silicon									
Silver	1	1.3	2	130.0	100.00	Y	130.0	100.00	Y
Sulfate	5			191900.0			141120.0		
Uranium[c]	2	820.9	5	6.0	0.01		4.5	0.01	
Acetone		78000.0	2						
Phenols	1	370.0	2	20.0	0.05		20.0	0.05	
Cumulative Risk			6		122.44			112.62	

[a]All notes appear after Table D-11.
[b]An empty cell indicates that the contaminant was below the detection limit or the sample was not analyzed for the contaminant.
[c]Hardness-Dependent Criteria Equations:
CADMIUM: e (0.7852 [ln (HARDNESS mg $CaCO_3$)]-3.283)
CHROMIUM: e (0.8190 [ln (HARDNESS mg $CaCO_3$)]+1.561)
COPPER: e (0.9231 [ln (HARDNESS mg $CaCO_3$)]-1.784)
NICKEL: e (0.8710 [ln (HARDNESS mg $CaCO_3$)]+1.144)
URANIUM: (((0.337(ALK)+0.0406(HARD))-2.84)/100)1000

Notes for Appendix D, Tables 1-11

1: BTV = Chronic Ambient Water Quality Criteria (EPA, all references, 1980-91). Based on hardness (Study Area E: 400.245 mg $CaCO_3$/l, Study Area F: 319.418 mg $CaCO_3$/l, Study Area G: 137.227 mg $CaCO_3$/l, Great Miami River Area: 283.281 mg $CaCO_3$/l, Paddys Run: 284.749 mg $CaCO_3$/l).
2: Warmwater (OEPA 1992).
3: BTV = 48 HR LC50 for *Daphnia magna*/100 (Jorgensen et al. 1988).
4: BTV = the proposed MCL value.
5: Parkhurst et al. (1984).
6: Cumulative Risk = sum of all Conc./BTV ratios > 0.3.

4710

EXISTING DRINKING WATER TOXICITY DATA FOR CONTAMINANTS OF CONCERN

Contaminant	Species Group	Concentration	Effect	Species and Exposure Conditions	Notes[a]
Aluminum	b				
Ammonia					
Arsenic	Mammalian	500 mg As/l as sodium arsenite	Lethal 100 to 200 mg/kg body weight	Pig *Sus* sp.	1
Barium	Mammalian No Effect	5 mg/l	No measurable effects	Mouse *Mus* sp. long-term feeding studies	2
Cadmium	Avian	600 ppb	Cardiovascular disease	Domestic pigeons *Columbia livia*	3
	Mammalian	10 ppm	No symptoms; reduced longevity	Rat *Rattus* sp. Lifetime exposure	4
Chloride					
Chromium	Mammalian No Effect	6 ppm	No measurable effect	Dog *Canis familiaris* exposed to Cr^{+6} over 4 years	5
		11.2 ppm	Not lethal	Dog *Canis familiaris* exposed to Cr^{+6} over 4 years	5
		134 ppm	Not lethal	Rat *Rattus* sp. exposed to Cr^{+6} over 3 months	5
	Mammalian	5 ppm	Slight growth retardation; formation of malignant tumors	Mouse *Mus* sp. lifetime exposure	6, 7
Copper					

[a]All notes appear at end of table.
[b]An empty cell indicates no appropriate data.

42 1 0

TABLE D-12

(Continued)

Contaminant	Species Group	Concentration	Effect	Species and Exposure Conditions	Notes[a]
Fluoride	b				
Iron					
Lead	Avian	100 μg/l	Reduced testicle weight	Ringed turtle-dove *Streptopelia risoria* 2 weeks before pairing and during breeding cycle	8
	Mammalian No Effect	1000 mg/l	No effect on survival or fertility	Mouse *Mus* sp. for 9 months	9
		1.5 mg/l	Disturbed sleep patterns	Rat *Rattus* sp. over several days	10
		5 mg/l	Lowered survival and reduced longevity	Rat *Rattus* sp. lifetime exposure	9
	Mammalian Minimum	800 mg Pb/l	Decreased litter size, pup survival, birth weight	Mouse *Mus* sp. exposed to lead acetate for 11 weeks	11
	Mammalian Maximum	4000 mg/l	Depressed serum testosterone, Leydig cell lesions	Rat *Rattus* sp. for 130 days	12
Manganese	Mammalian No Effect	about 1000 ppm	Tolerate	Mice, rats, and rabbits	13
	Mammalian Minimum	81.6 - 252.6 μg/l	Neurological response	Human epidemiology study	14
	Mammalian Maximum	approximately 28 mg/l	Symptoms of manganese toxicity	Human epidemiology study	15

[a]All notes appear at end of table.
[b]An empty cell indicates no appropriate data.

(Continued)

Contaminant	Species Group	Concentration	Effect	Species and Exposure Conditions	Notes[a]
Mercury	Avian	500 mg/l	Mortality, decreased growth rate	Chicken *Gallus domesticus* exposed to inorganic mercury for 3 days	16
	Mammalian	6 ppm	Growth reduction	Mouse *Mus* sp.	17
Molybdenum	Mammalian No Effect	1 or 10 mg Mo/l	No significant effect observed	Cattle *Bos* sp. exposed to ammonium molybdenate for 21 days	18
	Mammalian Minimum	10 mg/l	Decreased survival of F2 and F3 generations	Mouse *Mus* sp. breeding mice	19
	Mammalian Maximum	1000 mg/l	Stunted sterile offspring with behavioral abnormalities	Rats *Rattus* sp. (adults and offspring) lifetime exposure	20
Nickel	b				
Nitrate					
Selenium	Mammalian	3 ppm (selenite)	Reduced litter numbers and reproductive capacity	F3 Mice *Mus* sp.	21
Silicon					
Silver					
Sulfate					
Thorium					

[a]All notes appear at end of table.
[b]An empty cell indicates no appropriate data.

TABLE D-12

(Continued)

Contaminant	Species Group	Concentration	Effect	Species and Exposure Conditions	Notes[a]
Uranium	b				
Acetone					
Phenols					

[a]1: National Academy of Science 1977
2: Schroeder and Mitchener 1975
3: Revis et al. 1981
4: Schroeder et al. 1963
5: Steven et al. 1976
6: Schroeder and Mitchener 1971
7: Schroeder et al. 1965
8: Kendall and Scanlon 1982
9: Demayo et al. 1982
10: Nraigu 1978
11: Sharma and Kanwar 1985
12: Zirkin et al. 1985
13: Venugopal and Luckey 1978
14: Kondakis et al. 1989
15: Kawamura et al. 1941
16: Grissom and Thaxon 1985
17: Schroeder 1973
18: Kinkaid 1980
19: Earl and Vish 1979
20: Chappell et al. 1979
21: Schroeder and Mitchener 1972

[b]An empty cell indicates no appropriate data.

TABLE D-13

SUMMARY OF STUDY AREA E DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	86.6	86.6	pH dependent	87.0	a	
Ammonia	162.0	144.0	pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium	39.9	33.5	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium			5	4.2	Avian	600
					Mammalian	10,000
Chloride	34000.0	31500.0		230000.0		
Chromium	7.2	7.2	100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	10.5	10.5	/p/1300[b]	42.4		
Fluoride	210.0	200.0				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-13

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	292.0	179.0	a	1000.0		
Lead	2.6	2.4	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	9.7	9.0			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	0.3	0.3	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum					Mammalian	10000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel				580.0		
Nitrate	5440.0	3075.0	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-13

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon	3890.0	3890.0				
Silver				1.3		
Sulfate	51300.0	49450.0				
Thorium				565.0		
Uranium	47.3	25.6		1171.6		
Acetone				78000.0		
Phenols				370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-14

SUMMARY OF STUDY AREA F DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	232.0	232.0	pH dependent	87.0	a	
Ammonia			pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium			/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium			5	4.2	Avian	600
					Mammalian	10,000
Chloride	7000.0	7000.0		230000.0		
Chromium	19.9	19.9	100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper			/p/1300[b]	42.4		
Fluoride	440.0	440.0				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-14

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	168.0	168.0	a	1000.0		
Lead			/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	24.2	24.2			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	0.6	0.6	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum					Mammalian	10000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel				580.0		
Nitrate	2300.0	2300.0	10000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-14

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon						
Silver				1.3		
Sulfate	129000.0	129000.0				
Thorium				565.0		
Uranium	61.5	221.5		1171.6		
Acetone	4.0	4.0		78000.0		
Phenols				370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-15

SUMMARY OF PADDYS RUN REACH 2 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	451.0	167.8	pH dependent	87.0	a	
Ammonia	452.0	320.3	pH and temperature dependent	30.0		
Arsenic	18.8	18.8		190.0	Mammalian	500,000
Barium	47.0	41.6	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	4.0	3.5	5	4.2	Avian	600
					Mammalian	10,000
Chloride	20260.0	14375.0		230000.0		
Chromium	26.0	19.4	100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	12.0	11.3	/p/1300[b]	42.4		
Fluoride	300.0	243.8				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-15

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	556.0	166.8	a	1000.0		
Lead	6.0	4.0	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	29.0	21.3			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	0.3	0.3	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum					Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	25.0	25.0		580.0		
Nitrate	12100.0	4712.5	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-15

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	16.9	16.9	50	5.0	Mammalian	3000
Silicon	4610.0	4352.0	a			
Silver	19.0	16.2		1.3		
Sulfate	52200.0	43970.0				
Thorium				565.0		
Uranium	20.2	9.8		1171.6		
Acetone				78000.0		
Phenols	20.0	15.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-16

SUMMARY OF PADDYS RUN REACH 3 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	71.0	71.0	pH dependent	87.0	a	
Ammonia	163.0	163.0	pH and temperature dependent	30.0		
Arsenic	3.0	2.5		190.0	Mammalian	500,000
Barium	47.0	42.6	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	5.0	4.3	5	4.2	Avian	600
					Mammalian	10,000
Chloride	19100.0	14702.0		230000.0		
Chromium	20.0	18.3	100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	12.0	12.0	/p/1300[b]	42.4		
Fluoride	300.0	251.0				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-16

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	28.6	23.4	a	1000.0		
Lead	7.4	4.1	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	32.0	18.4			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	0.2	0.2	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum					Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel				580.0		
Nitrate	11300.0	4359.6	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-16

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon	4650.0	3685.0				
Silver	19.0	16.3		1.3		
Sulfate	57360.0	43542.0				
Thorium				565.0		
Uranium	18.2	11.8		1171.6		
Acetone				78000.0		
Phenols	2280.0	1150.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-17

SUMMARY OF STUDY AREA G DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	a		pH dependent	87.0		
Ammonia	162.6	162.6	pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium	26.7	26.7	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	1.6	1.6	5	4.2	Avian	600
					Mammalian	10,000
Chloride	3500.0	3500.0		230000.0		
Chromium			100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	8.1	8.1	/p/1300[b]	42.4		
Fluoride	300.0	300.0				
Iron	284.0	284.0		1000.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-17

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Lead	8.3	8.3	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	46.2	46.2			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	0.8	0.8	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum					Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	8.0	8.0		580.0		
Nitrate	140.0	140.0	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-17

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon						
Silver				1.3		
Sulfate	171000.0	171000.0				
Thorium				565.0		
Uranium				1171.6		
Acetone				78000.0		
Phenols				370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-18

SUMMARY OF GREAT MIAMI RIVER REACH 1 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	76.4	76.4	pH dependent	87.0	a	
Ammonia	1200.0	345.8	pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium	100.0	69.7	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	9.8	6.4	5	4.2	Avian	600
					Mammalian	10,000
Chloride	325000.0	116161.7		230000.0		
Chromium	6.1	6.1	100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	11.9	10.5	/p/1300[b]	42.4		
Fluoride	900.0	561.7				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-18

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	216.0	107.9	1000	a		
Lead	9.3	5.2	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	12.1	10.4			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	9.5	2.7	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum	24.0	15.5			Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	20.0	14.5		580.0		
Nitrate	8270.0	4010.0	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-18

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon	2250.0	2250.0				
Silver	100.0	100.0		1.3		
Sulfate	4310000.0	798080.0				
Thorium				565.0		
Uranium	3.3	3.3		1171.6		
Acetone				78000.0		
Phenols		10.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-19

SUMMARY OF GREAT MIAMI RIVER REACH 2 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum			pH dependent	87.0	a	
Ammonia	1400.0	814.5	pH and temperature dependent	30.0		
Arsenic	2.1	2.1		190.0	Mammalian	500,000
Barium	100.0	79.2	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	3.4	3.4	5	4.2	Avian	600
					Mammalian	10,000
Chloride	13900.0	97330.0		230000.0		
Chromium	3.7	3.7	100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	9.7	9.7	/p/1300[b]	42.4		
Fluoride	880.0	670.0				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-19

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	175.0	102.5		1000.0		
Lead	3.0	2.6	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	8.5	5.2			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury			2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum					Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	11.4	11.4		580.0		
Nitrate	7680.0	3760.0	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-19

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon						
Silver	20.0	20.0		1.3		
Sulfate	132000.0	103173.3				
Thorium				565.0		
Uranium	5.7	4.3		1171.6		
Acetone				78000.0		
Phenols	20.0	20.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-20

SUMMARY OF GREAT MIAMI RIVER REACH 3 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum			pH dependent	87.0	a	
Ammonia	600.0	600.0	pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium	90.0	76.0	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	2.7	3.0	5	4.2	Avian	600
					Mammalian	10,000
Chloride	252000.0	129663.0		230000.0		
Chromium			100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	14.2	14.0	/p/1300[b]	42.4		
Fluoride	880.0	680.0				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-20

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	600.0	270.0	a	1000.0		
Lead	80.0	29.0	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	7.8	8.0			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	1.0	1.0	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum	40.0	40.0			Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	11.3	11.0		580.0		
Nitrate	7060.0	3787.0	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-20

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon						
Silver				1.3		
Sulfate	112000.0	104067.0				
Thorium				565.0		
Uranium	3.7	4.5		1171.62		
Acetone				78000.0		
Phenols	30.0	30.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-21

SUMMARY OF GREAT MIAMI RIVER REACH 4 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	a		pH dependent	87.0		
Ammonia	1100.0	647.0	pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium	91.0	79.0	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	2.5	2.5	5	4.2	Avian	600
					Mammalian	10,000
Chloride	149000.0	109000.0		230000.0		
Chromium			100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	10.5	10.5	/p/1300[b]	42.4		
Fluoride	900.0	707.5				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-21

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	194.0	114.7	a	1000.0		
Lead	50.0	26.4	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	11.0	10.2			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury			2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum	30.0	30.0			Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	10.7	10.7		580.0		
Nitrate	6760.0	2690.0	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-21

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	a		50	5.0	Mammalian	3000
Silicon						
Silver				1.3		
Sulfate	111000.0	103700.0				
Thorium				565.0		
Uranium	5.4	5.4		1171.6		
Acetone				78000.0		
Phenols	10.0	10.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-22

SUMMARY OF GREAT MIAMI RIVER REACH 5 DRINKING WATER COC CONCENTRATIONS AND COMPARISONS TO EXISTING TOXICITY DATA AND BENCHMARKS

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Aluminum	a		pH dependent	87.0		
Ammonia	800.0	626.8	pH and temperature dependent	30.0		
Arsenic				190.0	Mammalian	500,000
Barium	91.0	69.2	/p/2000[b]	145.0	Mammalian No Effect	5000
Cadmium	1.8	1.8	5	4.2	Avian	600
					Mammalian	10,000
Chloride	154000.0	92800.0		230000.0		
Chromium			100	644.5	Mammalian	5000
					Mammalian No Effect	6000 - 134,000
Copper	6.9	6.2	/p/1300[b]	42.4		
Fluoride	900.0	598.0				

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-22

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Iron	522.0	228.4	a	1000.0		
Lead	50.0	20.3	/p/5[b]	40.8	Avian	100
					Mammalian	800,000 - 4,000,000
					Mammalian No Effect	5000 - 1,000,000
Manganese	11.7	9.4			Mammalian (human)	252.6 - 28,000
					Mammalian No Effect	1,000,000
Mercury	0.8	1.2	2	0.2	Avian	500,000
					Mammalian	6000
Molybdenum	30.0	30.0			Mammalian	10,000 - 1,000,000
					Mammalian No Effect	1000 or 10,000
Nickel	7.2	7.2		580.0		
Nitrate	4120.0	29.4	10,000			

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

TABLE D-22

(Continued)

Contaminant	Surface Water Concentration (μg/l)		Drinking Water Maximum Contaminant Limit (MCL in μg/l)	Benchmark Toxicity Value (BTV in μg/l) (from Table 10)	Water Ingestion Toxicity Data (from Table 11)	
	Maximum	Mean			Species	Concentration (μg/l)
Selenium	2.0	2.0	50	5.0	Mammalian	3000
Silicon	a					
Silver	130.0	130.0		1.3		
Sulfate	191900.0	141120.0				
Thorium				565.0		
Uranium	6.0	4.5		1171.6		
Acetone		2869.5		78000.0		
Phenols	20.0	20100.0		370.0		

[a]An empty cell indicates either there was no appropriate data or concentrations were below detection limits.
[b]Denotes a proposed MCL.

APPENDIX E

SEDIMENT CONTAMINANTS OF CONCERN

TABLE E-1
SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA E BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Sediment Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Aluminum	1	7863000.0	1	8830000.0	1.12	Y	8830000.0	1.12	Y
Ammonia	1	75000.0	2	50400.0	0.67	b	50400.0	0.67	
Arsenic		33000.0	3						
Barium	1	61950.0	1	56700.0	0.92		56700.0	0.92	
Cadmium		5000.0	3						
Chromium	1	80000.0	3	12500.0	0.16		12500.0	0.16	
Cobalt	1	50000.0	4	8100.0	0.16		8100.0	0.16	
Copper	1	70000.0	3	16100.0	0.23		16100.0	0.23	
Iron	1	14465000.0	1	19000000.0	1.31	Y	19000000.0	1.31	Y
Lead		35000.0	3						
Manganese	1	300000.0	2	399000.0	1.33	Y	399000.0	1.33	Y
Mercury	1	150.0	3	1300.0	8.67	Y	1300.0	8.67	Y
Nickel	1	30000.0	3	19100.0	0.64		19100.0	0.64	
Thorium	2	9703.0	1	0.1	0.00001		0.1	0.00001	
Uranium	2	3123.0	1	14107.8	4.52	Y	11220.8	3.59	Y
Zinc	1	120000.0	3	47600.0	0.40		47600.0	0.40	

[a] All notes appear at end of appendix.
[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-2

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA F BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Sediment Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Aluminum	1	7863000.0	1	5460000.0	0.69	b	5460000.0	0.69	
Ammonia	1	75000.0	2	93600.0	1.25	Y	93600.0	1.25	Y
Arsenic		33000.0	3						
Barium	1	61950.0	1	49400.0	0.80		49400.0	0.80	
Cadmium		5000.0	3						
Chromium	1	80000.0	3	6900.0	0.09		6900.0	0.09	
Cobalt		50000.0	4						
Copper	1	70000.0	3	9200.0	0.13		9200.0	0.13	
Iron	1	14465000.0	1	10000000.0	0.69		10000000.0	0.69	
Lead	1	35000.0	3	18400.0	0.53		18400.0	0.53	
Manganese	1	300000.0	2	500000.0	1.67	Y	500000.0	1.67	Y
Mercury	1	150.0	3	1700.0	11.33	Y	1700.0	11.33	Y
Nickel	1	30000.0	3	9400.0	0.31		9400.0	0.31	
Thorium		9703.0	1						
Uranium		3123.0	1						
Zinc	1	120000.0	3	37300.0	0.31		37300.0	0.31	

[a] All notes appear at end of appendix.

[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-3

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF PADDY'S RUN REACH 1 BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Sediment Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Aluminum	b	7863000.0	1						
Ammonia		75000.0	2						
Arsenic	1	33000.0	3	7000.0	0.21		7000.0	0.21	
Barium		61950.0	1						
Cadmium	1	5000.0	3	3700.0	0.74		3700.0	0.74	
Chromium	1	80000.0	3	18300.0	0.23		18300.0	0.23	
Cobalt		50000.0	4						
Copper		70000.0	3						
Iron	1	14465000.0	1	6700000.0	0.46		6700000.0	0.46	
Lead	1	35000.0	3	9300.0	0.27		9300.0	0.27	
Manganese	1	300000.0	2	411000.0	1.37	Y	411000.0	1.37	Y
Mercury		150.0	3						
Nickel	1	30000.0	3	13700.0	0.46		13700.0	0.46	
Thorium		9703.0	1						
Uranium		3123.0	1						
Zinc	1	120000.0	3	13500.0	0.11		13500.0	0.11	

[a] All notes appear at end of appendix.

[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-4

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF PADDY'S RUN REACH 2 BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Sediment Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Aluminum	b	7863000.0	1						
Ammonia		75000.0	2						
Arsenic	1	33000.0	3	2700.0	0.08		2700.0	0.08	
Barium		61950.0	1						
Cadmium	1	5000.0	3	4500.0	0.90		4500.0	0.90	
Chromium	1	80000.0	3	17400.0	0.22		17400.0	0.22	
Cobalt		50000.0	4						
Copper	1	70000.0	3	11700.0	0.17		11700.0	0.17	
Iron	1	14465000.0	1	5940000.0	0.41		5940000.0	0.41	
Lead	1	35000.0	3	4600.0	0.13		4600.0	0.13	
Manganese	1	300000.0	2	362000.0	1.21	Y	362000.0	1.21	Y
Mercury		150.0	3						
Nickel	1	30000.0	3	16400.0	0.55		16400.0	0.55	
Thorium		9703.0	1						
Uranium		3123.0	1						
Zinc	1	120000.0	3	13400.0	0.11		13400.0	0.11	

[a] All notes appear at end of appendix.

[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-5

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF PADDY'S RUN REACH 3 BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogat(μg/kg)	Notes[a]	Max Sediment Conc (μg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (μg/kg)	Based on Mean Sediment Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Aluminum	b	7863000.0	1						
Ammonia		75000.0	2						
Arsenic	1	33000.0	3	2600.0	0.08		2600.0	0.08	
Barium		61950.0	1						
Cadmium	1	5000.0	3	5500.0	1.10	Y	5500.0	1.10	Y
Chromium	1	80000.0	3	16900.0	0.21		16900.0	0.21	
Cobalt		50000.0	4						
Copper	1	70000.0	3	11500.0	0.16		11500.0	0.16	
Iron	1	14465000.0	1	5600000.0	0.39		5600000.0	0.39	
Lead	1	35000.0	3	4600.0	0.13		4600.0	0.13	
Manganese	1	300000.0	2	273000.0	0.91		273000.0	0.91	
Mercury		150.0	3						
Nickel	1	30000.0	3	17900.0	0.60		17900.0	0.60	
Thorium	1	9703.0	1	0.04	0.000004		0.04		
Uranium		3123.0	1						
Zinc	1	120000.0	3	15300.0	0.13		15300.0	0.13	
2-Butanone	1		5	12.0			12.0		
2-Hexanone			5	11.0			11.0		

[a] All notes appear at end of appendix.
[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-6

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA G BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Uranium	1	3123.0	1	5300.0	1.70	Y	5300.0	1.70	Y

[a] All notes appear at end of appendix.

TABLE E-7

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 2 BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Maximum Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Thorium	2	9703.0	1	0.1	0.000008	b	0.1	0.000007	
Uranium	2	3123.0	1	2381.1	0.76		2083.4	0.67	

[a] All notes appear at end of appendix.
[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-8

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 3 BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Thorium	2	9703.0	1	0.1	0.00001	b	0.1	0.00001	
Uranium	1	3123.0	1	3270.0	1.05	Y	3270.0	1.05	Y

[a] All notes appear at end of appendix.
[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

TABLE E-9

SEDIMENT COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF GREAT MIAMI RIVER REACH 5 BASED ON TOXICITY

Potential Sediment COCs	Number of Sediment Samples	ER-L or Surrogate (µg/kg)	Notes[a]	Max Sediment Conc (µg/kg)	Based on Maximum Concentrations		Mean Sediment Conc (µg/kg)	Based on Mean Concentrations	
					Conc/ER-L Ratio	Toxic Sediment COC		Conc/ER-L Ratio	Toxic Sediment COC
Thorium	4	9703.0	1	0.1	0.00001	b	0.1	0.00001	
Uranium	3	3123.0	1	2678.7	0.86		1587.4	0.51	

[a] All notes appear at end of appendix.
[b] An empty cell indicates that the contaminant was below the detection limit or that a sample was not analyzed for the contaminant.

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TABLE E-10

SEDIMENT ORGANIC COCS OF PADDY'S RUN REACH 3 BASED ON INTERSTITIAL WATER CONCENTRATION AND TOXICITY

Sediment Organic COCs	Log K_{ow}	Notes[a]	Log K_{oc}	Mean F_{oc} 0.001 KD	Mean Sediment Conc µg/kg	Max Sediment Conc µg/kg	Mean IWC Conc µg/l	Max IWC Conc µg/l	Benchmark Toxic Value µg/l	Notes	Sediment COC
2-butanone	1.4	6	2.1	0.13	12	12	89.4	89.4	50000	7	N
2-hexanone	0.3	6	1.5	0.03	11	11	333.4	333.4	50000	7	N

[a]1: EPA 1993
2: EPA 1977
3: Long and Morgan 1991
4: TV = threshold level for contaminated soils (Direction des Substances Dangereuses 1988)
5: See Table 10
6: Verschueren 1983
7: Shell Chemie 1975

F_{oc} = FRACTION ORGANIC CARBON
LOG K_{oc} = 0.544 LOG K_{ow} + 1.377
KD = K_{oc} * F_{oc}
IWC = INTERSTITIAL WATER CONCENTRATION = SEDIMENT CONCENTRATION (µg/kg)/KD

APPENDIX F

SURFACE SOIL CONTAMINANTS OF CONCERN

TABLE F-1

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA A BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Aluminum	5	7863.0	10103.0	3	12300.0	Y	1.22	Y	9776.0	Y	0.97	b
Antimony		3.9	395.9	2								
Arsenic	5	5.2	30.0	1	5.8	Y	0.19		4.1		0.14	
Barium	5	62.0	500.0	1	131.0	Y	0.26		98.1	Y	0.20	
Cadmium	1	0.3	5.0	1	1.7	Y	0.34		1.7	Y	0.34	
Calcium	3	1900.0			4520.0	Y			3320.0	Y		
Chromium	5	10.4	250.0	1	19.4	Y	0.08		15.0	Y	0.06	
Cobalt	3	9.7	50.0	1	17.9	Y	0.36		15.4	Y	0.31	
Copper	5	7.3	100.0	1	18.7	Y	0.19		14.1	Y	0.14	
Cyanide	1	0.1	50.0	4	1.7	Y	0.03		1.7	Y	0.03	
Iron	5	14465.0			22200.0	Y			16520.0	Y		
Lead	5	17.2	200.0	1	20.1	Y	0.10		16.0		0.08	
Magnesium	4	1646.0			3300.0	Y			2468.0	Y		
Molybdenum	5	1.3	10.0	1	13.3	Y	1.33	Y	10.3	Y	1.03	Y
Nickel	5	9.7	100.0	1	25.8	Y	0.26		19.4	Y	0.19	
Potassium	1	742.0			1760.0	Y			1760.0	Y		
Selenium		0.4										
Silver		1.3										
Thorium	24	9.7			12.7	Y			9.2			
Uranium	24	3.1	10.0	1	32.4	Y	3.24	Y	12.2	Y	1.22	Y
Vanadium	5	19.8	150.0	5	28.8	Y	0.19		23.2	Y	0.15	
Zinc	5	40.0	500.0	1	61.8	Y	0.12		46.5	Y	0.09	
Aroclor-1254			1.0	1								
2-butanone												
2-chlorophenol			0.5	4								
4-methyl-2-pentanone	1				0.01	Y						
Acetone			8000.0	6								
Benzoic acid												
Phenol			1.0	4								
Pyrene			10.0	4								
Toluene	3		3.0	4	0.004	Y	0.001					

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-2

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA B BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Aluminum	2	7863.0	10103.0	3	12700.0	Y	1.26	Y	9460.0	Y	0.95	b
Antimony		3.9	395.9	2								
Arsenic	2	5.2	30.0	1	3.9		0.13		3.5		0.12	
Barium	2	62.0	500.0	1	114.0	Y	0.23		87.9	Y	0.18	
Cadmium		0.3	5.0	1								
Calcium	2	1900.0			3570.0	Y			2555.0	Y		
Chromium	2	10.4	250.0	1	17.8	Y	0.07		14.1	Y	0.06	
Cobalt	2	9.7	50.0	1	13.2	Y	0.26		13.2	Y	0.26	
Copper	2	7.3	100.0	1	19.2	Y	0.19		15.0	Y	0.15	
Cyanide		0.1	50.0	4		Y						
Iron	2	14465.0			19500.0	Y			15550.0	Y		
Lead	2	17.2	200.0	1	16.2		0.08		15.4		0.08	
Magnesium	2	1646.0			2560.0	Y			1915.0	Y		
Molybdenum	2	1.3	10.0	1	12.4	Y	1.24	Y	9.8	Y	0.98	
Nickel	2	9.7	100.0	1	23.6	Y	0.24		19.7	Y	0.20	
Potassium	1	742.0			1620.0	Y			1620.0	Y		
Selenium		0.4										
Silver		1.3										
Thorium	28	9.7			16.4	Y			9.2			
Uranium	28	3.1	10.0	1	52.6	Y	5.26	Y	20.3	Y	2.03	Y
Vanadium	2	19.8	150.0	5	26.4	Y	0.18		22.5	Y	0.15	
Zinc	2	40.0	500.0	1	57.4	Y	0.11		44.1	Y	0.09	
Aroclor-1254			1.0	1								
2-butanone	1				0.001	Y			0.001	Y		
2-chlorophenol			0.5	4								
4-methyl-2-pentanone												
Acetone			8000.0	6								
Benzoic acid												
Phenol			1.0	4								
Pyrene	1		10.0	4	0.1	Y	0.01		0.1	Y	0.01	
Toluene			3.0	4								

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA C BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (kg/mg)	Based on Maximum SS Concentration			Mean SS Conc (kg/mg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Aluminum	3	7863.0	10103.0	3	7380.0	b	0.73		6980.0		0.69	
Antimony		3.9	395.9	2								
Arsenic	3	5.2	30.0	1	5.9	Y	0.20		4.7		0.16	
Barium	3	62.0	500.0	1	76.9	Y	0.15		73.3	Y	0.15	
Cadmium		0.3	5.0	1								
Calcium	3	1900.0			3590.0	Y			2530.0	Y		
Chromium	3	10.4	250.0	1	11.9	Y	0.05		11.3	Y	0.05	
Cobalt	1	9.7	50.0	1	14.3	Y	0.29		14.3	Y	0.29	
Copper	3	7.3	100.0	1	12.5	Y	0.13		11.1	Y	0.11	
Cyanide		0.1	50.0	4								
Iron	3	14465.0			14500.0	Y			13766.7			
Lead	3	17.2	200.0	1	23.5	Y	0.12		18.4	Y	0.09	
Magnesium	3	1646.0			1850.0	Y			1546.7			
Molybdenum	3	1.3	10.0	1	8.5	Y	0.85		8.2	Y	0.82	
Nickel	3	9.7	100.0	1	13.2	Y	0.13		12.1	Y	0.12	
Potassium		742.0										
Selenium	1	0.4			0.5	Y			0.5	Y		
Silver		1.3										
Thorium	43	9.7			562.8	Y			32.6	Y		
Uranium	45	3.1	10.0	1	7128.5	Y	712.85	Y	579.3	Y	57.93	Y
Vanadium	3	19.8	150.0	5	25.0	Y	0.17		22.6	Y	0.15	
Zinc	3	40.0	500.0	1	63.1	Y	0.13		46.3	Y	0.09	
Aroclor-1254			1.0	1								
2-butanone												
2-chlorophenol	1		0.5	4	0.05	Y	0.09		0.05	Y	0.09	
4-methyl-2-pentanone												
Acetone	1		8000.0	6	0.01	Y	0.000002		0.01	Y	0.000002	
Benzoic acid	2				0.1	Y				Y		
Phenol	1		1.0	4	0.1	Y	0.06		0.05	Y	0.09	
Pyrene			10.0	4								
Toluene	1		3.0	4	0.001	Y	0.0003		0.001	Y	0.0003	

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-4

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA D BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Aluminum	4	7863.0	10103.0	3	7320.0	b	0.72		6655.0		0.66	
Antimony	1	3.9	395.9	2	14.5	Y	0.04		14.5	Y	0.04	
Arsenic	4	5.2	30.0	1	6.7	Y	0.22		4.7		0.16	
Barium	3	62.0	500.0	1	76.5	Y	0.15		67.0	Y	0.13	
Cadmium	1	0.3	5.0	1	1.9	Y	0.38		1.9	Y	0.38	
Calcium	2	1900.0			64900.0	Y			33070.0	Y		
Chromium	4	10.4	250.0	1	23.3	Y	0.09		13.4	Y	0.05	
Cobalt		9.7	50.0	1								
Copper	4	7.3	100.0	1	17.5	Y	0.18		10.8	Y	0.11	
Cyanide		0.1	50.0	4								
Iron	4	14465.0			16300.0	Y			13390.0			
Lead	4	17.2	200.0	1	61.5	Y	0.31		25.7	Y	0.13	
Magnesium	1	1646.0			13800.0	Y			13800.0	Y		
Molybdenum	4	1.3	10.0	1	10.6	Y	1.06	Y	8.4	Y	0.84	
Nickel	4	9.7	100.0	1	22.9	Y	0.23		15.1	Y	0.15	
Potassium		742.0										
Selenium		0.4										
Silver	1	1.3			12.2	Y			12.2	Y		
Thorium	25	9.7			16.4	Y			9.1			
Uranium	25	3.1	10.0	1	47.4	Y	4.74	Y	12.7	Y	1.27	Y
Vanadium	4	19.8	150.0	5	25.8	Y	0.17		21.9	Y	0.15	
Zinc	4	40.0	500.0	1	40.2	Y	0.08		32.6	Y	0.07	
Aroclor-1254			1.0	1								
2-butanone	4				0.01	Y			0.01	Y		
2-chlorophenol			0.5	4								
4-methyl-2-pentanone												
Acetone			8000.0	6								
Benzoic acid												
Phenol			1.0	4								
Pyrene			10.0	4								
Toluene			3.0	4								

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-5

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA E BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Thorium	5	9.7	b		13.6	Y			11.1	Y		
Uranium	5	3.1	10.0	1	49.6	Y	4.96	Y	19.9	Y	1.99	Y

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-6

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA F BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Aluminum	4	7863.0	10103.0	3	8200.0	Y	0.81	b	5920.0		0.59	
Antimony	4	3.9	395.9	2	28.4	Y	0.07		24.7	Y	0.06	
Arsenic	4	5.2	30.0	1	5.7	Y	0.19		4.4		0.15	
Barium	2	62.0	500.0	1	52.9		0.11		51.3		0.10	
Cadmium	4	0.3	5.0	1	5.8	Y	1.16	Y	4.9	Y	0.97	
Calcium	4	1900.0			143000.0	Y			85825.0	Y		
Chromium	4	10.4	250.0	1	19.8	Y	0.08		13.7	Y	0.05	
Cobalt		9.7	50.0	1								
Copper	4	7.3	100.0	1	19.9	Y	0.20		15.2	Y	0.15	
Cyanide		0.1	50.0	4								
Iron	4	14465.0			21300.0	Y			14345.0			
Lead	4	17.2	200.0	1	12.1		0.06		9.3		0.15	
Magnesium	4	1646.0			24800.0	Y			19850.0	Y		
Molybdenum	3	1.3	10.0	1	4.7	Y	0.47		4.3	Y	0.43	
Nickel	4	9.7	100.0	1	41.3	Y	0.41		28.3	Y	0.28	
Potassium		742.0										
Selenium		0.4										
Silver		1.3										
Thorium	21	9.7			47.3	Y			9.5			
Uranium	22	3.1	10.0	1	62.8	Y	6.28	Y	14.9	Y	1.49	Y
Vanadium	4	19.8	150.0	5	23.8	Y	0.16		18.1		0.12	
Zinc	4	40.0	500.0	1	49.6	Y	0.10		39.5		0.08	
Aroclor-1254	1		1.0	1	0.01	Y	0.01		0.01	Y	0.01	
2-butanone												
2-chlorophenol			0.5	4								
4-methyl-2-pentanone												
Acetone			8000.0	6								
Benzoic acid												
Phenol			1.0	4								
Pyrene			10.0	4								
Toluene			3.0	4								

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA G BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean. Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Thorium	5	9.7	b		19.1	Y			11.6	Y		
Uranium	5	3.1	10.0	1	45.8	Y	4.58	Y	21.9	Y	2.19	Y

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-8

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA OFFSITE NW BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Thorium	38	9.7	b		13.8	Y			9.2			
Uranium	43	3.1	10.0	1	6.0	Y	0.60		3.3	Y	0.33	

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-9

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA OFFSITE NE BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Thorium	b	9.7										
Uranium	9	3.1	10.0	1	6.3	Y	0.63		4.5	Y	0.45	

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

TABLE F-10

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA OFFSITE SE BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COC	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value(BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Thorium	2	9.7	b		8.2				7.3			
Uranium	9	3.1	10.0	1	28.0	Y	2.80	Y	10.9	Y	1.09	Y

[a]All notes appear at end of appendix.
[b]An empty cell indicates there was no appropriate data.

SURFACE SOIL (SS) COCS (MAXIMUM AND MEAN CONCENTRATIONS) OF STUDY AREA OFFSITE SW BASED ON COMPARISON TO BACKGROUND CONCENTRATIONS AND TOXICITY CRITERIA

Potential Surface Soil (SS) COCs	Number of SS Samples	Mean Background Conc (mg/kg)	Benchmark Toxicity Value (BTV) (mg/kg)	Notes[a]	Max SS Conc (mg/kg)	Based on Maximum SS Concentration			Mean SS Conc (mg/kg)	Based on Mean SS Concentration		
						Background SS COC	Conc/BTV Ratio	Toxic SS COC		Background SS COC	Conc/BTV Ratio	Toxic SS COC
Thorium	7	9.7	b		12.7	Y			7.7			
Uranium	9	3.1	10.0	1	18.1	Y	1.81	Y	6.0	Y	0.60	

[a]1: BTV = Threshold level for contaminated soils (Direction des Substances Dangereuses 1988)
2: Illinois EPA 1984 (Maximum Cumulative Addition)
3: Missouri DNR 1988 (Maximum Cumulative Addition)
4: Richardson 1987
5: USSR 1984 (Maximum Allowable Concentration)
6: EPA 1990.

[b]An empty cell indicates there was no appropriate data.

APPENDIX G

FACTORS AFFECTING TOXICITY

FACTORS EFFECTING TOXICITY

Ammonia

Aqueous ammonia solutions are typically composed of un-ionized ammonia (NH_3) in equilibrium with the ammonia and hydroxide ions. "Total ammonia" is the sum of the concentration of un-ionized and ionized (NH_4^+) forms present in solution (EPA 1985a). Aqueous ammonia equilibrium is mainly influenced by temperature and pH with the latter parameter exhibiting the greatest effect on concentrations of ammonia; increases in pH result in increased concentrations of NH_3 (EPA 1985a). Ionic strength is another important parameter influencing this equilibrium. Decreases in the percentage of un-ionized ammonia (NH_3) occur as the ionic strength increases in either hard or salt water (Messer et al. 1984; Whitfield 1974).

The effects of temperature on ammonia toxicity are varied. The concentration of NH_3 increases with increases in temperature and some authors have reported an effect of temperature on the toxicity of un-ionized ammonia, independent of the effect of temperature on the aqueous ammonia equilibrium (EPA 1985a). Numerous authors have reported that NH_3 toxicity increases with increasing temperature but several have reported greater NH_3 toxicity at lower ($<5°$ C) temperatures than higher ($>22°$ C) (e.g., Reinbold and Pescitelli 1982). The actual effects of temperature on ammonia toxicity are still not clearly understood and await further investigation (EPA 1985a).

Under aerobic conditions, ammonia is readily oxidized to nitrite by *Nitrosomonas* bacteria. Nitrite is generally very labile and is rapidly converted to nitrate by *Nitrobacter* bacteria (Russo 1985; Wetzel 1983). Although high concentrations of nitrite are toxic to aquatic organisms, the conversion of nitrite to nitrate is so rapid that it is rare for this form of nitrogen to be present in toxic amounts (Wetzel 1983; Russo 1985).

Cadmium

Elemental cadmium (Cd) is insoluble in water, although its chloride and sulfate salts are freely soluble (FWS 1985a). The availability of cadmium to aquatic biota from their immediate physical and chemical environs depends on numerous factors, including adsorption and desorption rates of cadmium from terrigenous materials, pH, Eh, chemical speciation, and many other modifiers. Adsorption and desorption processes are likely to be major factors in controlling the concentration of cadmium in natural waters and tend to counteract changes in the concentration of cadmium ions in

solution (FWS 1985a). Water hardness also alters the bioavailability of cadmium. Adsorption and desorption rates of cadmium are rapid on mud solids and particles of clay, silica, humic material, and other naturally occurring solids. It should be borne in mind that mobility and availability of cadmium, like most heavy metals, is a function of a large number of interrelated factors [e.g., cation exchange capacity (CEC)]. Beyer et al. (1985) demonstrated that only a small portion of all metals measured in the soil become incorporated into plant foliage and suggested that most of the metal contamination detected in biota came from aerial deposition.

Mercury

The chemical speciation of mercury (Hg) is probably the most important variable influencing ecotoxicology of Hg, but Hg speciation is complicated, especially in natural environments (Boudou and Ribeyre 1983; FWS 1987). Most mercury entering aquatic systems is inorganic (Hg II) although recent studies have measured methylated mercury (CH_3HgH^+) in rain and surface runoff (Bloom and Watras 1989; Lee and Hultberg 1990). Methyl mercury is the major form of mercury in fish; methylation of inorganic mercury takes place in the terrestrial environment, the water column, and in sediments. The net amount of methyl mercury in an aquatic system is the result not only of its rate of formation, but also the result of the rates of those processes that alter the availability of inorganic mercury for methylation, and methyl mercury decomposition (demethylation)(Winfrey and Rudd 1990).

Inorganic mercury readily adsorbs to inorganic and organic particles as well as dissolved organic carbon (DOC)(Benes and Havelik 1979; Rudd and Turner 1983; Rogers et al. 1984). The degree and extent of this binding, while not well understood, will affect the availability of mercury for methylation. Methylation of mercury in most aquatic systems is thought to be primarily a function of microbiological activity in the sediments (Winfrey and Rudd 1990). Rates of methylation peak at the sediment-water interface and decrease in the overlying water and subsurface sediments (Korthals and Winfrey 1987). Reduced pH also appears to increase the availability of methylated mercury by expediting its release from sediments into the water column.

Unlike most heavy metals, mercury tends to bioaccumulate and its excretion tends to be slow and biphasic (i.e., an initial rapid phase followed by slow, gradual excretion), with an estimated half-retention time of 200-days for the first 100-days phase. Subsequent excretion is apparently governed

by the rate of release of methyl mercury from skeletal muscle (Massaro and Giblin 1972). Therefore, it is possible that exposure of fish and/or its prey to mercury may be intermittent, but these periodic exposures result in detectable tissue concentrations of mercury for long periods after sediment deposits are either buried or flushed downstream.

Selenium

Selenium (Se) is the most strongly enriched element in coal, being present as an organoselenium compound, a chelated species, or an adsorbed element. On combustion of coal, the sulfur dioxide formed reduces the selenium to elemental Se. Air and surface waters generally contain nonhazardous concentrations of Se. Significant increases of Se in specific areas are attributed exclusively to industrial sources, and to leaching of groundwater from seleniferous soils (FWS 1985b).

In a lake in North Carolina receiving selenium (as flyash waste from a coal-fired power station), reproduction of green sunfish (*Lepomis cyanellus*) failed and the population declined markedly. In these fish, Se levels were elevated in liver and other tissues; kidney, heart, liver, and gills exhibited altered histopathology and blood chemistry. It is probable that Se uptake by plankton [containing 41-97 parts per million (ppm) dry weight] from the lake water [9-12 parts per billion (ppb)] introduced Se into the food chain where it ultimately reached levels in fish through biomagnification (Cumbie and Van Horn 1978).

Thorium

Thorium (Th) is ubiquitous in nature, and minute quantities are presumed to be present in food and the environment (Venugopal and Luckey 1978). Shacklette and Boerngen (1984) reported that thorium concentrations in surface soils collected in the United States averaged 9.4 mg Th/kg (range = 2.2 - 31 mg Th/kg). Hem (1970) reported that the chemistry of thorium apparently causes the element to be deposited in the hydrolyzable sediments and not to be carried extensively in solution in water. This chemical behavior may account for the absence of detectable thorium in water samples collected during this study. In addition, the lack of detectable thorium in the sediment samples may be the combined result of minimal run-off and periodic scouring of on-site surface bodies, particularly Paddys Run.

Uranium

Uranium (U) is ubiquitous in the environment. Average values for U.S. surface soils equal 2.7 mg U/kg (range = 0.29 - 11 mg U/kg) (Shacklette and Boerngen 1984). Uranium is present in most natural waters in concentrations ranging between 0.1 and 10 μg/l but the element is not soluble enough to be present in large amounts in the ocean (Hem 1970). Sheppard and Evenden (1992) performed a series of tests to determine the toxicity of uranium in 11 different soil types. Three plant species (*Phaseolus vulgaris*, *Lactuca sativa*, and *Brassica rapa*), and the earthworm (*Lumbricus* sp.) served as test species. A wide array of endpoints (e.g., seed germination, number of pods produced, earthworm survival) were used to assess the results of exposure. Concentrations ranged from background to 10,000 mg U/kg. The authors concluded that toxic effects were not consistently observed at concentrations below 1000 mg U/kg, that none of the measurements indicated that detrimental effects were occurring below 300 mg U/kg, and that phytotoxicity due to uranium occurred at concentrations 8- and 3-fold higher than phytotoxic concentrations of arsenic and zinc, respectively. Although Sheppard and Evenden (1992) did not test soils identical to those found on the FEMP, two of the soils tested did possess physical properties similar to those that predominate at the FEMP. The primary differences between the two Sheppard and Evenden (1992) test soils and those found at the FEMP were that FEMP soils generally had higher clay contents and greater ion exchange capacity (sorptive capacity) than did Sheppard soils. This suggests that the elevated concentrations of uranium present in FEMP soils are also associated with low toxicity, particularly when Sheppard and Eveden (1992) were able to demonstrate that uranium bioavailability and the sorptive capacity of a soil are negatively correlated. Studies by Swanson (1983; 1985) on aquatic food chains documented decreasing radionuclide content with successive trophic level, suggesting that actual assimilation of these nuclides (natural U, radium 226, and polonium 210) into tissue at each trophic level is small. Swanson (1985) reported that most ingested radionuclides simply passed through the gut and cycle back into the sediments.

APPENDIX H

EQUATIONS USED TO CALCULATE RADIATION DOSES TO TERRESTRIAL AND AQUATIC ORGANISMS

MOUSE EXPOSURE PATHWAYS

1. Direct irradiation from soil

Calculated using the MicroShield™ code

2. Inhalation of resuspended soil

$D_{s\text{-}in} = C_s \bullet T_{ms} \bullet \rho \bullet R \bullet DCF_{min}$

$D_{s\text{-}in}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]
T_{ms} = soil to air transfer factor [unitless]
ρ = soil density [kg/m^3]
R_m = mouse inhalation rate [m^3/yr]
DCF_{min}= dose conversion factor for inhaled radioactivity [mrad/pCi]

Where:

$T_{ms} = T_{ms0} \bullet 10/v \bullet s/30 \bullet (50/PE)^2$

$T_{ms0} = 2.53 \times 10^{-10}$
v = average wind speed [m/sec]
s = % silt in soil
PE = precipitation - evaporation index

(from Oztunali and Roles 1986)

3. Ingestion of soil

$D_{s\text{-}i} = C_s \bullet IR_{ms} \bullet DCF_{mi}$

$D_{s\text{-}i}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]
IR_{ms} = soil ingestion rate [kg/yr]
DCF_{mi} = dose conversion factor for ingested radioactivity [mrad/pCi]

4. Soil - Insect - Ingestion

$D_{s\text{-}g\text{-}i} = C_s \bullet BF_g \bullet IR_{mg} \bullet DCF_{mi}$

$D_{s\text{-}g\text{-}i}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]
BF_g = insect : soil bioaccumulation factor
IR_{mg} = insect ingestion rate [kg/yr]
DCF_{mi} = dose conversion factor for ingested radioactivity [mrad/pCi]

5. Ingestion of vegetation

$D_{v\to i} = C_v \bullet IR_{mv} \bullet DCF_{mi}$

$D_{v\to i}$ = absorbed dose [mrad/yr]
C_v = radionuclide concentration in vegetation [pCi/kg]
IR_{mv} = vegetation ingestion rate [kg/yr]
DCF_{mi} = dose conversion factor for ingested radioactivity [mrad/pCi]

6. Ingestion of water

$D_{w\to i} = C_w \bullet IR_{mw} \bullet DCF_{mi}$

$D_{w\to i}$ = absorbed dose [mrad/yr]
C_w = radionuclide concentration in water [pCi/L]
IR_{mw} = water ingestion rate [L/yr]
DCF_{mi} = dose conversion factor for ingested radioactivity [mrad/pCi]

MEADOW VOLE EXPOSURE PATHWAYS

1. Direct irradiation from soil

Calculated using the MicroShield™ code

2. Inhalation of resuspended soil

$D_{s\to in} = C_s \bullet T_{sa} \bullet \rho \bullet R \bullet DCF_{vin}$

$D_{s\to in}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]
T_{sa} = soil to air transfer factor [unitless]
ρ = soil density [kg/m^3]
R_v = vole inhalation rate [m^3/yr]
DCF_{vin} = dose conversion factor for inhaled radioactivity [mrad/pCi]

where

$T_{sa} = T_{sa0} \bullet 10/v \bullet s/30 \bullet (50/PE)^2$

$T_{sa0} = 2.53 \times 10^{-10}$
v = average wind speed [m/sec]
s = % silt in soil
PE = precipitation - evaporation index

(from NUREG/CR-4370, vol 1)

3. Ingestion of soil

$D_{s\to i} = C_s \bullet IR_{vs} \bullet DCF_{vi}$

$D_{s\to i}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]
IR_{vs} = soil ingestion rate [kg/yr]
DCF_{vi} = dose conversion factor for ingested radioactivity [mrad/pCi]

4. Soil - Insect - Ingestion

$D_{s\to g\to i} = C_s \bullet BF_g \bullet IR_{vg} \bullet DCF_{vi}$

$D_{s\to g\to i}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]
BF_g = insect : soil bioaccumulation factor
IR_{vg} = insect ingestion rate [kg/yr]
DCF_{vi} = dose conversion factor for ingested radioactivity [mrad/pCi]

5. Ingestion of vegetation

$D_{v\to i} = C_v \bullet IR_{vv} \bullet DCF_{vi}$

$D_{v\to i}$ = absorbed dose [mrad/yr]
C_v = radionuclide concentration in vegetation [pCi/kg]
IR_{vv} = vegetation ingestion rate [kg/yr]
DCF_{vi} = dose conversion factor for ingested radioactivity [mrad/pCi]

6. Ingestion of water

$D_{w\to i} = C_w \bullet IR_{vw} \bullet DCF_{vi}$

$D_{w\to i}$ = absorbed dose [mrad/yr]
C_w = radionuclide concentration in water [pCi/L]
IR_{vw} = water ingestion rate [L/yr]
DCF_{vi} = dose conversion factor for ingested radioactivity [mrad/pCi]

PINE TREE EXPOSURE PATHWAYS

1. Direct irradiation from soil

Calculated using the MicroShield™ code

2. Uptake of contaminants from soil

$D_{s\to u} = C_s \bullet B_s \bullet DCF_{su}$

$D_{s\to u}$ = absorbed dose [mrad/yr]
C_s = radionuclide concentration in soil [pCi/kg]

B_e = element transfer coefficient [unitless]
DCF_{tu} = dose conversion factor [mrad Kg/pCi yr]

SHINER EXPOSURE PATHWAYS

1. Direct irradiation from sediment

Calculated using the MicroShield™ code

2. Uptake of contaminants (all pathways)

$D_{s\to s} = C_w \bullet BF_s \bullet DCF_{si}$

$D_{s\to s}$ = absorbed dose [mrad/yr]
C_w = radionuclide concentration in water [pCi/L]
BF_s = bioconcentration factor [L/kg]
DCF_{si} = dose conversion factor [mrad kg/pCi yr]

3. Direct irradiation from water

$D_{w\to s} = C_w \bullet DCF_{siw}$

$D_{w\to s}$ = absorbed dose [mrad/yr]
C_w = radionuclide concentration in water [pCi/L]
DCF_{sw} = dose conversion factor [mrad L/pCi yr]

APPENDIX I

RADIONUCLIDE CONCENTRATIONS FROM THE RI/FS DATA BASE

TABLE I-1

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA A

Sample Type		Radionuclide (pCi/g)								
		Cs-137	Ra-226	Ra-228	Sr-90	Th-228	Th-230	Th-232	U-234	U-238
Soil	Mean	0.70	0.95	1.08	0.94	1.48	1.72	1.06	3.49	4.09
	Max	1.60	1.20	1.35	2.50	2.74	3.14	1.40	11.00	10.90
Vegetation	Mean	a			0.70				3.25	1.55
	Max				0.70				4.00	1.70
Surface Water[b]	Mean									
	Max									

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.

TABLE I-2

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA B

Sample Type		Radionuclide (pCi/g)									
		Cs-137	Ra-226	Ra-228	Sr-90	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Soil	Mean	0.82	0.81	1.06	1.57	1.19	1.84	1.13	6.31	0.87	6.80
	Max	1.60	1.20	1.40	3.60	1.90	3.20	1.80	16.50	1.70	17.40
Vegetation	Mean	0.40							1.70		1.03
	Max	0.40							2.40		1.20
Surface Water[b]	Mean	a									
	Max										

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.

TABLE I-3

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA C

Sample Type		Radionuclide (pCi/g)										
		Cs-137	Ra-226	Ra-228	Sr-90	Tc-99	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Soil	Mean	0.63	2.90	2.10	1.72	5.10	2.79	42.31	3.76	180.69	12.51	193.05
	Max	1.40	57.40	18.00	5.20	13.00	24.80	806.00	61.90	2899.00	134.00	2376.00
Vegetation	Mean	a			0.90					5.40		3.58
	Max				0.90					12.10		10.80
Surface Water[b]	Mean											
	Max											

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.

TABLE I-4

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA D

Sample Type		Radionuclide (pCi/g)									
		Cs-137	Ra-226	Ra-228	Sr-90	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Soil	Mean	0.51	0.98	0.94	1.49	1.08	1.70	1.09	4.11	0.75	4.25
	Max	0.80	1.80	1.20	4.10	1.60	2.20	1.80	15.70	0.80	15.80
Vegetation	Mean	a							1.15		1.25
	Max								1.30		1.60
Surface Water[b]	Mean										
	Max										

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.

TABLE I-5

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA E

Sample Type		Radionuclide (pCi/g)									
		Cs-137	Ra-226	Ra-228	Sr-90	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Soil	Mean	0.72	1.33	1.00	0.93	1.18	2.32	1.22	5.98	1.80	6.64
	Max	1.10	1.40	1.10	1.20	1.70	3.60	1.50	14.30	1.80	16.40
Vegetation	Mean	a			0.75				1.07		1.50
	Max				0.90				1.10		1.70
Surface Water[b]	Mean								15.90		8.60
	Max								15.90		15.90

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.

TABLE I-6

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA G

Sample Type		Radionuclide (pCi/g)									
		Cs-137	Ra-226	Ra-228	Sr-90	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Soil	Mean	0.83	1.24	1.23	0.70	1.00	2.04	1.60	7.37	1.30	7.29
	Max	1.20	1.30	1.30	0.80	1.10	3.20	2.10	16.00	1.40	15.20
Vegetation	Mean	a			0.60				1.32		3.30
	Max				0.60				3.10		3.30
Surface Water[b]	Mean										
	Max										

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.

TABLE I-7

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY AREA F

Sample Type		Radionuclide (pCi/g)										
		Cs-137	Ra-226	Ra-228	Sr-90	Tc-99	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Soil	Mean	0.68	0.86	0.86	0.97		1.72	2.06	1.15	3.90		5.25
	Max	1.00	1.40	1.20	1.60		13.60	8.40	5.20	21.00		21.10
Vegetation	Mean	a								1.60		1.95
	Max									2.30		3.20
Surface Water[b]	Mean					86.15				42.30	3.85	185.50
	Max					88.50				44.00	4.30	188.00
Paddys Run Water[c]	Mean				24.00		2.88	2.40		3.00	1.83	3.57
	Max				24.00		5.48	6.74		7.04	1.98	6.80
Sediments	Mean		0.69	0.90				0.80				
	Max		1.00	0.90				0.80				

[a]An empty cell indicates no appropriate data was collected.
[b]Surface water available in study area for mammalian pathways.
[c]Paddys Run water available for fish pathways.

TABLE I-8

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM STUDY OF GREAT MIAMI RIVER

Sample Type		Radionuclide (pCi/g)							
		Ra-226	Ra-228	Sr-90	Tc-99	Th-228	Th-230	U-234	U-238
Water	Mean	a	5.00		42.99	1.97	1.30	1.43	1.37
	Max		5.00		95.90	2.60	1.30	2.30	2.00
Sediment	Mean	0.55	0.60	0.67			1.25	0.82	0.82
	Max	0.91	0.60	0.80			2.30	1.40	1.10

[a]An empty cell indicates no appropriate data was collected.

TABLE I-9

CONCENTRATION OF RADIONUCLIDES MEASURED IN VARIOUS MEDIA COLLECTED FROM OFFSITE STUDY AREAS

Sample Type		Radionuclide (pCi/g)									
		Cs-137	Ra-224	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234	U-235/236	U-238
Off Site NE											
Soil	Mean	a							1.47		1.50
	Max								2.20		2.10
Off Site NW											
Soil	Mean	0.39	0.80	1.18	1.06	1.07	1.41	1.01	1.06	0.08	1.10
	Max	0.77	0.93	1.48	1.27	1.43	2.01	1.52	1.60	0.24	2.00
Off Site SE											
Soil	Mean	0.20		1.35	1.10	1.25	1.20	0.80	3.37		3.64
	Max	0.20		1.80	1.10	1.60	1.70	0.90	8.90		9.40
Off Site SW											
Soil	Mean	0.38		1.03	0.89	0.97	1.81	0.85	2.02		2.00
	Max	0.60		1.25	0.99	1.30	3.52	1.40	6.48		6.09

[a]An empty cell indicates no appropriate data was collected.

APPENDIX J

CALCULATION OF DOSE CONVERSION FACTORS FOR INTERNAL EXPOSURE

CALCULATION OF DOSE CONVERSION FACTORS FOR INTERNAL EXPOSURE

MEADOW VOLE/WHITE-FOOTED DEER MOUSE

The dose conversion factor for inhalation is then determined by

$$DCF_{in} = \frac{(1pCi)\bullet(3.7X10^{-2})\bullet(8.64X10^{4})\bullet f_{a}\bullet\epsilon\bullet(1.6X10^{-13})\bullet(1-e^{-\lambda_{eff}\bullet t})}{m\bullet(1.0X10^{-5})\bullet(1.0X10^{-3})\bullet\lambda_{eff}}$$

Where:

DCF_{in} = Inhalation dose conversion factor (mrad/pCi)
f_a = Uptake fraction by inhalation
$3.7X10^{-2}$ = Conversion factor (disintegrations per second/pCi)
$8.64X10^{4}$ = Conversion factor (seconds/day)
ϵ = Mean energy absorbed per disintegration
$1.6X10^{-13}$ = Conversion factor (joule/MeV)
λ_{eff} = Effective elimination constant (day^{-1})
t = Exposure time (365 days)
m = Mass of organism (gram)
$1.0X10^{-5}$ = Conversion factor (J/gram per rad)
$1.0X10^{-3}$ = Conversion factor (rad/mrad)

The dose conversion factor for ingestion is similarly determined by

$$DCF_{i} = \frac{(1pCi)\bullet(3.7X10^{-2})\bullet(8.64X10^{4})\bullet f_{w}\bullet\epsilon\bullet(1.6X10^{-13})\bullet(1-e^{-\lambda_{eff}\bullet t})}{m\bullet(1.0X10^{-5})\bullet(1.0X10^{-3})\bullet\lambda_{eff}}$$

Where:

DCF_{i} = Ingestion dose conversion factor (mrad/pCi)
f_w = Uptake fraction by ingestion
$3.7X10^{-2}$ = Conversion factor (disintegrations per second/pCi)
$8.64X10^{4}$ = Conversion factor (seconds/day)
ϵ = Mean energy absorbed per disintegration (MeV/disintegration)
$1.6X10^{-13}$ = Conversion factor (joule/MeV)
λ_{eff} = Effective elimination constant (day^{-1})
t = Exposure time (365 days)
m = Mass of organism (gram)
$1.0X10^{-5}$ = Conversion factor (J/gram per rad)
$1.0X10^{-3}$ = Conversion factor (rad/mrad)

PINE TREES

The dose conversion factor is then determined by

$$DCF_{tu} = \frac{(1pCi/kg)\bullet(3.7X10^{-2})\bullet(3.154X10^{7})\bullet\epsilon\bullet(1.6X10^{-13})}{(1.0X10^{3})\bullet(1.0X10^{-5})\bullet(1.0X10^{-3})}$$

where:

DCF_{tu} = Uptake dose conversion factor (mrad/year per pCi/kg)
$3.7X10^{-2}$ = Conversion factor (disintegrations per second/pCi)
$3.154X10^{7}$ = Conversion factor (second/year)
ϵ = Energy absorbed per disintegration (MeV/disintegration)
$1.6X10^{-13}$ = Conversion factor (joule/MeV)
$(1.0X10^{3})$ = Conversion factor (g/kg)
$(1.0X10^{-5})$ = Conversion factor (J/gram per rad)
$(1.0X10^{-3})$ = Conversion factor (rad/mrad)

SHINERS

The uptake dose conversion factor is then determined by

$$DCF_{si} = \frac{(1pCi/kg)\bullet(3.7X10^{-2})\bullet(3.154X10^{7})\bullet\epsilon_i\bullet(1.6X10^{-13})}{(1.0X10^{3})\bullet(1.0X10^{-5})\bullet(1.0X10^{-3})}$$

where:

DCF_{si} = Uptake dose conversion factor (mrad/year per pCi/kg)
$3.7X10^{-2}$ = Conversion factor (disintegrations per second/pCi)
$3.154X10^{7}$ = Conversion factor (second/year)
ϵ_i = Internal energy absorbed per disintegration (MeV/disintegration)
$1.6X10^{-13}$ = Conversion factor (joule/MeV)
$(1.0X10^{3})$ = Conversion factor (g/kg)
$(1.0X10^{-5})$ = Conversion factor (J/gram per rad)
$(1.0X10^{-3})$ = Conversion factor (rad/mrad)

APPENDIX K

INTERMEDIATE CALCULATION RESULTS

TABLE K-1

SUMMATION OF ABSORBED DOSE BY AREA AND PATHWAY

Species	Dose (mrad/year)	Pathway 1[a]	Pathway 2	Pathway 3	Pathway 4	Pathway 5	Pathway 6	Total
Area A								
Mouse	Maximum	1.13E+01	1.86E-02	6.65E+01	1.06E+03	3.97E+02	n/a	1.54E+03
	Mean	5.00E+00	9.09E-03	3.47E+01	5.56E+02	3.54E+02	n/a	9.49E+02
Vole	Maximum	1.13E+01	2.84E-02	1.43E+02	1.16E+02	8.72E+02	n/a	1.14E+03
	Mean	5.00E+00	1.39E-02	7.46E+01	6.04E+01	7.77E+02	n/a	9.17E+02
Pine Tree	Maximum	1.13E+01	8.27E+01	n/a	n/a	n/a	n/a	9.41E+01
	Mean	5.00E+00	3.29E+01	n/a	n/a	n/a	n/a	3.79E+01
Area B								
Mouse	Maximum	1.48E+01	2.54E-02	8.89E+01	1.42E+03	1.85E+02	n/a	1.71E+03
	Mean	7.61E+00	1.22E-02	4.30E+01	6.88E+02	1.44E+02	n/a	8.83E+02
Vole	Maximum	1.48E+01	3.87E-02	1.91E+02	1.54E+02	4.08E+02	n/a	7.68E+02
	Mean	7.61E+00	1.86E-02	9.23E+01	7.47E+01	3.17E+02	n/a	4.91E+02
Pine Tree	Maximum	1.48E+01	1.18E+02	n/a	n/a	n/a	n/a	1.33E+02
	Mean	7.61E+00	5.20E+01	n/a	n/a	n/a	n/a	5.96E+01

[a] Pathways:

Mouse & Vole	1 direct irradiation from soil	3 ingestion of soil	5 ingestion of vegetation
	2 inhalation of resuspended soil	4 ingestion of insects/grubs	6 ingestion of water
Pine Tree	1 direct irradiation from soil	2 uptake from soil	
Shiner	1 direct irradiation from sediment	2 uptake from water (all pathways)	3 direct irradiation from immersion in water

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TABLE K-1

(Continued)

Species	Dose (mrad/year)	Pathway 1	Pathway 2	Pathway 3	Pathway 4	Pathway 5	Pathway 6	Total
Area C								
Mouse	Maximum	2.93E+02	3.42E+00	7.98E+03	1.28E+05	1.22E+03	n/a	1.37E+05
	Mean	3.05E+01	2.24E-01	5.48E+02	8.77E+03	5.82E+02	n/a	9.93E+03
Vole	Maximum	2.93E+02	5.22E+00	1.71E+04	1.39E+04	2.68E+03	n/a	3.40E+04
	Mean	3.05E+01	3.42E-01	1.18E+03	9.52E+02	1.28E+03	n/a	3.44E+03
Pine Tree	Maximum	2.93E+02	2.85E+03	n/a	n/a	n/a	n/a	3.14E+03
	Mean	3.05E+01	2.33E+02	n/a	n/a	n/a	n/a	2.63E+02
Area D								
Mouse	Maximum	7.43E+00	2.45E-02	9.90E+01	1.58E+03	1.32E+02	n/a	1.82E+03
	Mean	4.81E+00	1.05E-02	3.98E+01	6.37E+02	1.10E+02	n/a	7.91E+02
Vole	Maximum	7.43E+00	3.74E-02	2.12E+02	1.72E+02	2.90E+02	n/a	6.82E+02
	Mean	4.81E+00	1.59E-02	8.54E+01	6.92E+01	2.41E+02	n/a	4.01E+02
Pine Tree	Maximum	7.43E+00	1.31E+02	n/a	n/a	n/a	n/a	1.38E+02
	Mean	4.81E+00	4.81E+01	n/a	n/a	n/a	n/a	5.30E+01

[a] Pathways:

[a] Mouse & Vole: 1 direct irradiation from soil; 2 inhalation of resuspended soil; 3 ingestion of soil; 4 ingestion of insects/grubs; 5 ingestion of vegetation; 6 ingestion of water

Pine Tree: 1 direct irradiation from soil; 2 uptake from soil

Shiner: 1 direct irradiation from sediment; 2 uptake from water (all pathways); 3 direct irradiation from immersion in water

TABLE K-1

(Continued)

Species	Dose (mrad/year)	Pathway 1	Pathway 2	Pathway 3	Pathway 4	Pathway 5	Pathway 6	Total
Area E								
Mouse	Maximum	1.16E+01	2.24E-02	7.67E+01	1.23E+03	2.92E+02	3.25E+00	1.61E+03
	Mean	8.88E+00	1.31E-02	5.11E+01	8.18E+02	2.54E+02	2.55E+00	1.13E+03
Vole	Maximum	1.16E+01	3.41E-02	1.65E+02	1.33E+02	6.41E+02	3.81E+00	9.54E+02
	Mean	8.88E+00	1.99E-02	1.10E+02	8.88E+01	5.58E+02	2.99E+00	7.69E+02
Pine Tree	Maximum	1.16E+01	5.29E+01	n/a	n/a	n/a	n/a	6.44E+01
	Mean	8.88E+00	3.69E+01	n/a	n/a	n/a	n/a	4.58E+01
Area F								
Mouse	Maximum	7.31E+00	3.78E-02	9.07E+01	1.45E+03	2.50E+02	2.32E+01	1.82E+03
	Mean	4.84E+00	8.38E-03	3.48E+01	5.57E+02	1.62E+02	2.27E+01	7.81E+02
Vole	Maximum	7.31E+00	5.76E-02	1.95E+02	1.58E+02	5.49E+02	2.72E+01	9.36E+02
	Mean	4.84E+00	1.28E-02	7.47E+01	6.05E+01	3.56E+02	2.66E+01	5.22E+02
Pine Tree	Maximum	7.31E+00	7.15E+01	n/a	n/a	n/a	n/a	7.88E+01
	Mean	4.84E+00	3.42E+01	n/a	n/a	n/a	n/a	3.90E+01
Shiner	Maximum	6.10E-02	2.39E+02	6.50E-03	n/a	n/a	n/a	2.39E+02
	Mean	4.20E-02	1.17E+02	5.62E-03	n/a	n/a	n/a	1.17E+02

[a] Pathways:

[a] Mouse & Vole: 1 direct irradiation from soil; 2 inhalation of resuspended soil; 3 ingestion of soil; 4 ingestion of insects/grubs; 5 ingestion of vegetation; 6 ingestion of water

Pine Tree: 1 direct irradiation from soil; 2 uptake from soil

Shiner: 1 direct irradiation from sediment; 2 uptake from water (all pathways); 3 direct irradiation from immersion in water

TABLE K-1

(Continued)

Species	Dose (mrad/year)	Pathway 1	Pathway 2	Pathway 3	Pathway 4	Pathway 5	Pathway 6	Total
Area G								
Mouse	Maximum	1.14E+01	2.10E-02	7.31E+01	1.17E+03	4.03E+02	n/a	1.66E+03
	Mean	8.59E+00	1.29E-02	5.02E+01	8.03E+02	3.16E+02	n/a	1.18E+03
Vole	Maximum	1.14E+01	3.20E-02	1.57E+02	1.27E+02	8.86E+02	n/a	1.18E+03
	Mean	8.59E+00	1.96E-02	1.08E+02	8.72E+01	6.95E+02	n/a	8.99E+02
Pine Tree	Maximum	1.14E+01	4.20E+01	n/a	n/a	n/a	n/a	5.34E+01
	Mean	8.59E+00	3.14E+01	n/a	n/a	n/a	n/a	3.99E+01
Great Miami River								
Shiner	Maximum	5.80E-02	7.27E+01	2.91E-04	n/a	n/a	n/a	7.28E+01
	Mean	3.40E-02	6.01E+01	2.17E-04	n/a	n/a	n/a	6.02E+01

[a] Pathways:

[a] Mouse & Vole: 1 direct irradiation from soil; 2 inhalation of resuspended soil; 3 ingestion of soil; 4 ingestion of insects/grubs; 5 ingestion of vegetation; 6 ingestion of water

Pine Tree: 1 direct irradiation from soil; 2 uptake from soil

Shiner: 1 direct irradiation from sediment; 2 uptake from water (all pathways); 3 direct irradiation from immersion in water

TABLE K-1

(Continued)

Species	Dose (mrad/year)	Pathway 1	Pathway 2	Pathway 3	Pathway 4	Pathway 5	Pathway 6	Total
Off site-NE								
Mouse	Maximum	1.00E-04	1.64E-03	5.34E+00	8.54E+01	n/a	n/a	9.07E+01
	Mean	1.00E-04	1.13E-03	3.68E+00	5.89E+01	n/a	n/a	6.25E+01
Vole	Maximum	1.00E-04	2.50E-03	1.15E+01	9.28E+00	n/a	n/a	2.07E+01
	Mean	1.00E-04	1.72E-03	7.90E+00	6.39E+00	n/a	n/a	1.43E+01
Pine Tree	Maximum	1.00E-04	1.85E+00	n/a	n/a	n/a	n/a	1.85E+00
	Mean	1.00E-04	1.28E+00	n/a	n/a	n/a	n/a	1.28E+00
Off site-NW								
Mouse	Maximum	6.16E+00	9.04E-03	3.70E+01	5.91E+02	n/a	n/a	6.34E+02
	Mean	3.12E+00	6.43E-03	2.82E+01	4.52E+02	n/a	n/a	4.83E+02
Vole	Maximum	6.16E+00	1.38E-02	7.93E+01	6.42E+01	n/a	n/a	1.50E+02
	Mean	3.12E+00	9.80E-03	6.06E+01	4.91E+01	n/a	n/a	1.13E+02
Pine Tree	Maximum	6.16E+00	1.23E+01	n/a	n/a	n/a	n/a	1.85E+01
	Mean	3.12E+00	9.49E+00	n/a	n/a	n/a	n/a	1.26E+01

Pathways:

Mouse & Vole: 1 direct irradiation from soil; 2 inhalation of resuspended soil; 3 ingestion of soil; 4 ingestion of insects/grubs; 5 ingestion of vegetation; 6 ingestion of water

Pine Tree: 1 direct irradiation from soil; 2 uptake from soil

Shiner: 1 direct irradiation from sediment; 2 uptake from water (all pathways); 3 direct irradiation from immersion in water

TABLE K-1

(Continued)

Species	Dose (mrad/year)	Pathway 1	Pathway 2	Pathway 3	Pathway 4	Pathway 5	Pathway 6	Total
Off site-SE								
Mouse	Maximum	1.58E+00	1.43E-02	6.06E+01	9.69E+02	n/a	n/a	1.03E+03
	Mean	1.53E+00	8.27E-03	3.72E+01	5.95E+02	n/a	n/a	6.34E+02
Vole	Maximum	1.58E+00	2.18E-02	1.30E+02	1.05E+02	n/a	n/a	2.37E+02
	Mean	1.53E+00	1.26E-02	7.98E+01	6.46E+01	n/a	n/a	1.46E+02
Pine Tree	Maximum	1.58E+00	1.52E+01	n/a	n/a	n/a	n/a	1.68E+01
	Mean	1.53E+00	8.58E+00	n/a	n/a	n/a	n/a	1.01E+01
Off site-SW								
Mouse	Maximum	4.33E+00	1.33E-02	4.25E+01	6.80E+02	n/a	n/a	7.27E+02
	Mean	2.76E+00	7.01E-03	2.70E+01	4.32E+02	n/a	n/a	4.62E+02
Vole	Maximum	4.33E+00	2.03E-02	9.12E+01	7.39E+01	n/a	n/a	1.69E+02
	Mean	2.76E+00	1.07E-02	1.18E+02	4.69E+01	n/a	n/a	1.68E+02
Pine Tree	Maximum	4.33E+00	1.14E+01	n/a	n/a	n/a	n/a	1.57E+01
	Mean	2.76E+00	6.34E+00	n/a	n/a	n/a	n/a	9.10E+00

[a] Pathways:

[a] Mouse & Vole: 1 direct irradiation from soil; 2 inhalation of resuspended soil; 3 ingestion of soil; 4 ingestion of insects/grubs; 5 ingestion of vegetation; 6 ingestion of water

Pine Tree: 1 direct irradiation from soil; 2 uptake from soil

Shiner: 1 direct irradiation from sediment; 2 uptake from water (all pathways); 3 direct irradiation from immersion in water