PRS-ENM-0045
Volume I

PADUCAH SITE
ANNUAL SITE ENVIRONMENTAL REPORT
2008

EM Environmental Management

safety ❖ performance ❖ cleanup ❖ closure

Fractions and Multiples of Units

Multiple	Decimal Equivalent	Prefix	Symbol	Engineering Format
10^{6}	1,000,000	mega-	M	E+06
10^{3}	1,000	kilo-	k	E+03
10^{2}	100	hecto-	h	E+02
10	10	deka-	da	E+01
10^{-1}	0.1	deci-	d	E-01
10^{-2}	0.01	centi-	c	E-02
10^{-3}	0.001	milli-	m	E-03
10^{-6}	0.000001	micro-	µ	E-06
10^{-9}	0.000000001	nano-	n	E-09
10^{-12}	0.000000000001	pico-	P	E-12
10^{-15}	0.000000000000001	femto-	F	E-15
10^{-18}	0.000000000000000001	atto-	a	E-18

This report is intended to fulfill the requirements of U. S. Department of Energy (DOE) Order 231.1A Change 2. The data and information contained in this report were collected in accordance with the Paducah Site Environmental Monitoring Plan (PRS 2007c; PRS 2009) approved by DOE. This report is not intended to provide the results of all sampling conducted at the Paducah Site. Additional data collected for other site purposes, such as environmental restoration, remedial investigation reports, and waste management characterization sampling, are presented in other documents that have been prepared in accordance with applicable DOE guidance and/or federal or state laws.

PRS-ENM-0045
Volume I

Paducah Site

Annual Site Environmental Report for Calendar Year 2008

July 2010

Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Managed by
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

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Acronyms and Abbreviations

ACM	asbestos-containing material
ACO	Administrative Order by Consent
AEC	Atomic Energy Commission
AIP	Agreement in Principle
^{241}Am	americium-241
AO	Agreed Order
ASER	Annual Site Environmental Report
ASTM	American Society of Testing and Materials
BGOU	Burial Grounds Operable Unit
BHHRA	Baseline Human Health Risk Assessment
BJC	Bechtel Jacobs Company LLC
CAA	Clean Air Act
CAB	Paducah Citizens Advisory Board
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
Ci	curie
COE	U.S. Army Corps of Engineers
^{137}Cs	cesium-137
CSOU	comprehensive sitewide operable unit
CWA	Clean Water Act
CX	categorical exclusion
CY	calendar year
D&D	decontamination and decommissioning
DCG	derived concentration guideline
DMSA	DOE Material Storage Area
DNAPL	dense nonaqueous-phase liquid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOECAP	U.S. Department of Energy Consolidated Audit Program
DQO	data quality objective
DUF_6	depleted uranium hexafluoride
EA	environmental assessment
EDD	electronic data deliverable
EE/CA	engineering evaluation/cost analysis
EIC	Environmental Information Center
EIS	environmental impact statement
EM	environmental management
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
FFA	Federal Facility Agreement
FFC Act	Federal Facilities Compliance Act
FFCA	Federal Facilities Compliance Agreement
FS	feasibility study
ft	foot (feet)
FY	fiscal year
g	gram
GDP	gaseous diffusion plant
GWOU	Ground Water Operable Unit

HAP	hazardous air pollutant
ICRP	International Commission on Radiological Protection
IRA	interim remedial action
KAR	*Kentucky Administrative Regulations*
KCHFS	Kentucky Cabinet for Health and Family Services
KDAQ	Kentucky Division for Air Quality
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KDWM	Kentucky Division of Waste Management
^{40}K	potassium-40
kg	kilogram(s)
km	kilometer(s)
KPDES	Kentucky Pollutant Discharge Elimination System
KYREG	Kentucky regulations
L	liter(s)
LLW	low-level radioactive waste
LPAF	Liquid Pollution Abatement Facility
LRGA	Lower Regional Gravel Aquifer
m	meter(s)
MCL	maximum contaminant level
µg	microgram(s)
mg	milligrams(s)
MGD	million gallons per day
mR	milliRoentgen(s)
mrem	millirem(s)
MW	monitoring well
NCRP	National Council for Radiation Protection
ND	not detected
NEPA	National Environmental Policy Act
NEPCS	Northeast Plume Containment System
NOV	notice of violation
^{237}Np	neptunium-237
NPL	National Priorities List
NR	not reported
NRHP	National Register of Historic Places
NSDD	North-South Diversion Ditch
NWPGS	Northwest Plume Groundwater System
OREIS	Oak Ridge Environmental Information System
OS	outside
OU	operable unit
oz	ounce
PCB	polychlorinated biphenyl
pCi	picoCurie(s)
PEMS	Project Environmental Measurement Systems
PGDP	Paducah Gaseous Diffusion Plant
pH	hydrogen-ion concentration
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PRS	Paducah Remediation Services, LLC
^{239}Pu	plutonium-239
QA	Quality Assurance

QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RDSI	Remedial Design Support Investigation
RGA	Regional Gravel Aquifer
RHTAB	Radiation Health and Toxic Agents Branch
RI	remedial investigation
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
SERA	Screening Ecological Risk Assessment
SI	site investigation
SI/BRA	site investigation/baseline risk assessment
SMO	Sample Management Office
SMP	Site Management Plan
SOW	statement of work
STP	Site Treatment Plan
SVOA	semivolatile organic analyte
SWMU	solid waste management unit
^{99}Tc	technetium-99
TCE	trichloroethene
^{230}Th	thorium-230
TLD	thermoluminescent dosimeter
TSCA	Toxic Substances Control Act
TTL	Target Treatment Level
TVA	Tennessee Valley Authority
$^{233/234}U$	uranium-233 and uranium-234
^{234}U	uranium-234
^{235}U	uranium-235
^{238}U	uranium-238
UCRS	Upper Continental Recharge System
UDS	Uranium Disposition Services, LLC
UE	uranium enrichment
UF_6	uranium hexafluoride
URGA	Upper Regional Gravel Aquifer
USEC	United States Enrichment Corporation
UST	underground storage tank
VOA	volatile organic analyte
VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area
WMP	Watershed Monitoring Program
WM/PP	waste minimization/pollution prevention

Request for Comments

The U.S. Department of Energy (DOE) requires an annual site environmental report from each of the sites operating under its authority. This report presents the results from the various environmental monitoring programs and activities carried out during the year. This *Paducah Site Annual Site Environmental Report for Calendar Year 2008* was prepared to fulfill DOE requirements. This report is a public document that is distributed to government regulators, businesses, special interest groups, and members of the public.

This report is based on thousands of environmental samples collected at or near the Paducah Site. Significant efforts were made to provide the data collected and details of the site environmental management programs in a clear and concise manner. The editors of this report encourage comments in order to better address the needs of our readers in future site environmental reports. Please send comments to the following address:

U.S. Department of Energy
Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513

1 Site Operation and Overview

Abstract

The Paducah Gaseous Diffusion Plant (PGDP), located in McCracken County, Kentucky, has been producing enriched uranium since 1952. In July 1993, the U.S. Department of Energy (DOE) leased the production areas of the site to the United States Enrichment Corporation (USEC), a private company. DOE maintains responsibility for the environmental restoration, legacy waste management, nonleased facilities management, uranium hexafluoride (UF_6) cylinder management, and decontamination and decommissioning (D&D)/DOE Material Storage Area (DMSA) programs. DOE also implements an environmental monitoring and management program to ensure protection of human health and the environment and compliance with all applicable regulatory requirements. This document summarizes calendar year (CY) 2008 environmental management (EM) activities, including effluent monitoring, environmental surveillance, and environmental compliance status. It also highlights significant site program efforts conducted by DOE and its contractors and subcontractors at the Paducah Site. ***This report does not include USEC environmental monitoring activities.***

Introduction

DOE requires that environmental monitoring be conducted and documented for all of its facilities under the purview of DOE Order 231.1A Change 2, *Environment, Safety, and Health Reporting*. Several other laws, regulations, and DOE directives require compliance with environmental standards. The purpose of this Annual Site Environmental Report (ASER) is to summarize CY 2008 EM activities at the Paducah Site, including effluent monitoring, environmental surveillance, and environmental compliance status, and to highlight significant site program efforts. Paducah Site programs are coordinated by DOE's remediation contractor, Paducah Remediation Services, LLC (PRS). References in this report to the Paducah Site generally mean the property, programs, and facilities at or near PGDP for which DOE has ultimate responsibility.

Environmental monitoring consists of the following two major activities: effluent monitoring and environmental surveillance. Effluent monitoring is the direct measurement or the collection and analysis of samples of liquid and gaseous discharges to the environment. Environmental surveillance is the direct measurement or the collection and analysis of samples consisting of ambient air, surface water, groundwater, soil, biota, and other media. Environmental monitoring is performed to characterize and quantify contaminants, assess radiation exposure, demonstrate compliance with applicable standards and

permit requirements, and detect and assess the effects, if any, on the local population and environment. Multiple samples are collected throughout the year and are analyzed for radioactivity, chemical constituents, and various physical properties.

The overall goals for DOE/EM are to protect site personnel, the environment, and Paducah Site neighbors and to maintain full compliance with all current environmental regulations. The current environmental strategy is to prevent noncompliance, to identify any current compliance issues, and to develop a system for resolution. The long-range goal of DOE/EM is to reduce exposures of the public, workers, and biota to harmful chemicals and radiation.

Background

Before World War II, the area now occupied by PGDP was used for agricultural purposes. Numerous small farms produced various grain crops, provided pasture for livestock, and included large fruit orchards. During World War II, a 16,126-acre tract was assembled for construction of the Kentucky Ordnance Works, which subsequently was operated by the Atlas Powder Company until the end of the war. At that time, it was turned over to the Federal Farm Mortgage Corporation and then to the General Services Administration.

In 1950, the U.S. Department of Defense (DOD) and DOE's predecessor, the Atomic Energy Commission (AEC), began efforts to expand fissionable material production capacity. As part of this effort, the National Security Resources Board was instructed to designate power areas within a strategically safe area of the United States. Eight government-owned sites initially were selected as candidate areas. In October 1950, as a result of joint recommendations from DOD, U.S. Department of State, and AEC, President Harry S. Truman directed AEC to expand further production of atomic weapons. One of the principal facets of this expansion program was the provision for a new gaseous diffusion plant. On October 18, 1950, AEC approved the Paducah Site for uranium enrichment (UE) operations and formally requested the Department of the Army to transfer the site from the General Services Administration to AEC. Although construction of PGDP was not complete until 1954, production of enriched uranium began in 1952.

The plant's mission of UE has continued unchanged, and the original facilities still are in operation, albeit with substantial upgrading and refurbishment. Of the 7,566 acres acquired by the AEC, 1,361 acres subsequently were transferred to the Tennessee Valley Authority (TVA) (Shawnee Fossil Plant site), and 2,781 acres were conveyed to the Commonwealth of Kentucky for wildlife conservation and for recreational purposes [West Kentucky Wildlife Management Area (WKWMA)]. DOE's current holdings at the Paducah Site total 3,556 acres.

At Paducah's UE plant, recycled uranium from nuclear reactors was introduced into the PGDP enrichment "cascade" in 1953 and continued through 1964. In 1964, cascade feed material was switched solely to virgin-mined uranium. Use of recycled uranium resumed in 1969 and continued through 1976. In 1976, the practice of recycling uranium feed material from nuclear reactors was halted and never resumed. During the recycling time periods, Paducah received approximately 100,000 tons of recycled uranium containing an estimated 328 grams of plutonium-239 (^{239}Pu), 18,400 grams of neptunium-237 (^{237}Np), and 661,000 grams of technetium-99 (^{99}Tc). The majority of the ^{239}Pu and ^{237}Np was separated out during the initial chemical conversion to UF_6. Concentrations of transuranics (e.g., ^{239}Pu and ^{237}Np) and ^{99}Tc are believed to have been deposited on internal surfaces of process equipment and in waste products.

In October 1992, congressional passage of the 1992 National Energy Policy Act established USEC. Effective July 1, 1993, DOE leased the plant production operation facilities to USEC. Under the terms of the

lease, USEC assumed responsibility for environmental compliance activities directly associated with UE operations.

Description of Site Locale

Location

The Paducah Site is located in a generally rural area of McCracken County, Kentucky (population approximately 67,000). PGDP is an active uranium enrichment facility consisting of a diffusion cascade and extensive support facilities. The cascade, including product and tails withdrawal, is housed in six large process buildings. The plant is located on a reservation consisting of approximately 3,500 acres in western McCracken County, 10 miles west of Paducah, Kentucky, (population approximately 26,000), and 3.5 miles south of the Ohio River (Figure 1.1). The facility is on approximately 1,350 acres with controlled access. Roughly, 650 acres of the reservation are enclosed within a fenced security area. An uninhabited buffer zone of at least 400 yards surrounds the entire fenced area. During World War II, the Kentucky Ordnance Works, a trinitrotoluene production facility, was operated in an area southwest of the plant on what is now a wildlife management area.

Three small communities are located within 3 miles of the DOE property boundary at PGDP: Heath and Grahamville to the east and Kevil to the southwest. The closest commercial airport is Barkley Regional Airport, approximately 5 miles to the southeast. The population within a 50-mile radius of PGDP is about 500,000. Within a 10-mile radius of PGDP, the population is about 66,000 (DOC 2000).

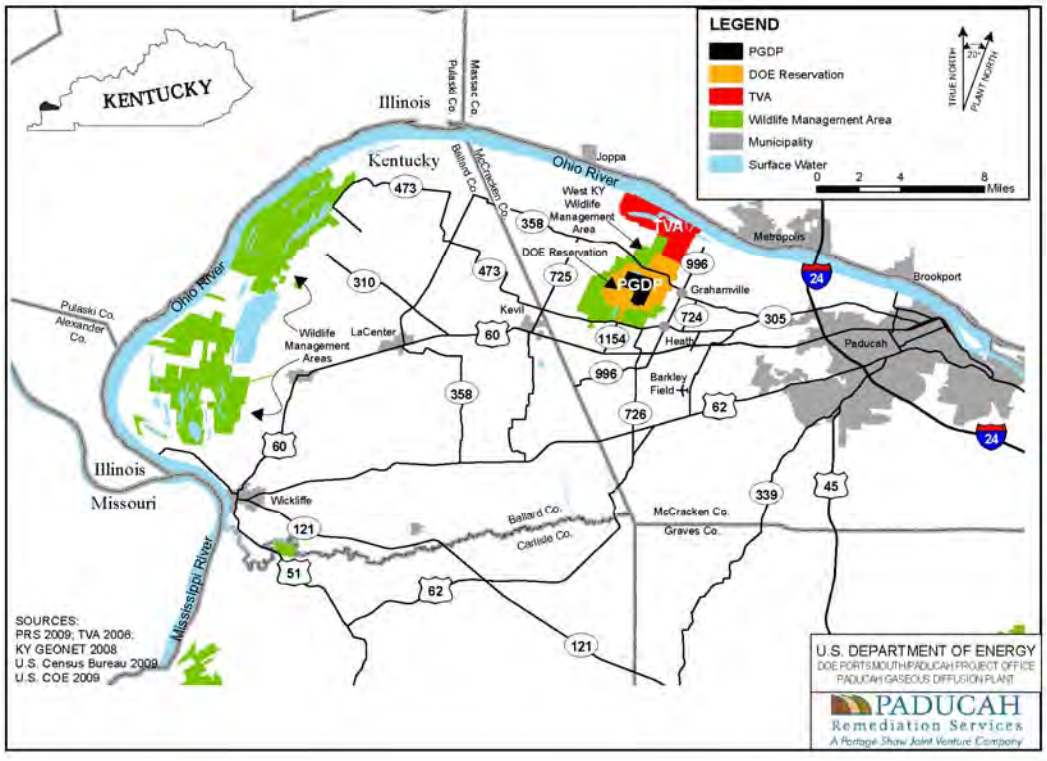

Figure 1.1. Location of the Paducah Site

Climate

The Paducah Site is located in the humid continental zone where summers are warm (July averages 79 °F) and winters are moderately cold (January averages 35 °F). Yearly precipitation averages about 49 inches. The prevailing wind is from the south-southwest at approximately 10 miles per hour.

Surface Water Drainage

The Paducah Site is situated in the western part of the Ohio River basin. The confluence of the Ohio River with the Tennessee River is about 15 miles upstream of the site, and the confluence of the Ohio River with the Mississippi River is about 35 miles downstream. PGDP is located on a local drainage divide. Surface water from the east side of the plant flows east-northeast toward Little Bayou Creek, and surface water from the west side of the plant flows west-northwest toward Bayou Creek. Bayou Creek is a perennial stream that flows toward the Ohio River along a 9-mile course. Little Bayou Creek is an intermittent stream that flows north toward the Ohio River along a 7-mile course. The two creeks converge 3 miles north of the plant before emptying into the Ohio River.

Flooding in the area is associated with Bayou Creek, Little Bayou Creek, and the Ohio River. Maps of the calculated 100-year flood elevations show that all three drainage systems have 100-year floodplains located within the DOE boundary at PGDP, but not within the industrialized area of PGDP. These 100-year floodplains range from approximately 340 to 380 feet (ft) above mean sea level. Plant elevations range from about 370 to 385 ft above mean sea level [U.S. Army Corps of Engineers (COE) 1994].

Wetlands

More than 1,100 separate wetlands, totaling over 1,600 acres, were found in a study area of about 12,000 acres in and around the Paducah Site (COE 1994; CDM 1994). More than 60 percent of the total wetland area is forested.

Soils and Hydrogeology

Soils of the area are predominantly silty loams that are poorly drained, acidic, and have little organic content.

The local groundwater flow system at the Paducah Site contains the following four major components (listed from shallowest to deepest): (1) the Terrace Gravel, (2) the Upper Continental Recharge System (UCRS), (3) the Regional Gravel Aquifer (RGA), and (4) the McNairy flow system.

The Terrace Gravel consists of shallow Pliocene gravel deposits in the southern portion of the plant site. These deposits usually lack sufficient thickness and saturation to constitute an aquifer, but may be an important source of groundwater recharge to the RGA.

The UCRS consists mainly of clay silt with interbedded sand and gravel in the upper continental deposits. The system is so named because of its characteristic recharge to the RGA.

The RGA consists of coarse-grained sediments in its upper portions that are adjacent to the base of the upper continental deposits, sand and gravel facies in the middle, and gravel and coarse sand portions that are directly adjacent to the upper McNairy. Near the Ohio River, alluvium lies adjacent to the upper RGA. These deposits have an average thickness of 30 ft and can be more than 70-ft thick along an axis that trends east-west through the site. The RGA is the uppermost and primary aquifer, formerly used by private residences north of the Paducah Site.

The McNairy flow system is composed of interbedded and interlensing sand, silt, and clay. Near PGDP, the McNairy Formation can be subdivided into three members: (1) a 60-ft thick sand-dominant lower member; (2) a 100- to 130-ft thick middle member, composed predominately of silty and clayey fine sand; and (3) a 30- to 50-ft thick upper member consisting of interbedded sands, silts, clays, and occasional gravel. Sand facies account for 40 to 50 percent of the total formation thickness of approximately 225 ft.

Groundwater flow originates south of the Paducah Site within Eocene sands and the Terrace Gravel. Groundwater within the Terrace Gravel discharges to local streams and recharges the RGA. Groundwater flow through the UCRS predominantly is downward, also recharging the RGA. From the plant site, groundwater generally flows northward in the RGA toward the Ohio River, which is the local base level for the system.

Ecological Resources

Vegetation

Much of the Paducah Site has been impacted by human activity. Vegetation communities on the reservation are indicative of old field succession (e.g., grassy fields, field scrub-shrub, and upland mixed hardwoods). The open grassland areas, most of which are managed by WKWMA personnel, are mowed periodically or burned to maintain early successional vegetation, which is dominated by members of the *Compositae* family and various grasses. Species commonly cultivated for wildlife forage are corn, millet, milo, and soybean (CH2M HILL 1992a).

Field scrub-shrub communities consist of sun tolerant wooded species such as persimmon, maples, black locust, sumac, and oaks (CH2M HILL 1991a). The undergrowth varies depending on the location of the woodlands. Wooded areas near maintained grasslands have an undergrowth dominated by grasses. Other communities contain a thick undergrowth of shrubs, including sumac, pokeweed, honeysuckle, blackberry, and grape.

Upland mixed hardwoods contain a variety of upland and transitional species. Dominant species include oaks, shagbark and shellbark hickory, and sugarberry (CH2M HILL 1991a). The undergrowth here varies, with limited undergrowth for more mature stands of trees, to dense undergrowth similar to that described for a scrub-shrub community.

Wildlife

Wildlife species indigenous to hardwood forests, scrub-shrub, and open grassland communities are present at the Paducah Site. A list of representative species is provided in the reference, CH2M HILL 1991a. Additionally, the Ohio River, which is 3 miles north of the Paducah Site, serves as a major flyway for migratory waterfowl (DOE 1995). Fish populations in Bayou Creek and Little Bayou Creek are dominated numerically by various species of shiner and sunfish. The Watershed Monitoring Report (PRS 2007a) provides a list of species present.

Threatened and Endangered Species

A threatened and endangered species investigation identified federally listed, proposed, or candidate species potentially occurring at or near the Paducah Site (COE 1994). Updated information is obtained on a regular basis from federal and state sources. Currently, potential habitat for eleven species of federal

concern exists in the study area. Nine of these species are listed as “endangered” under the Endangered Species Act of 1973 and two are candidate species (Section 2, Table 2.2). None of the federally listed or candidate species has been found on DOE property at the Paducah Site. Also, no property at the Paducah Site has been designated as “critical habitat” in accordance with the Endangered Species Act.

Site Program Missions

The following two major programs are operated by DOE at the Paducah Site: (1) EM and (2) Uranium Programs. Environmental Restoration, Materials Disposition, and D&D are projects under the EM Program. The mission of the Environmental Restoration Project is to ensure that releases from past operations at the Paducah Site are investigated and that appropriate response action is taken for protection of human health and the environment in accordance with the Federal Facility Agreement (FFA) (EPA 1998). The mission of the Waste Operations Project is to characterize and dispose of the legacy and newly generated waste stored on-site, including DMSAs, in compliance with the October 2003 Agreed Order (AO) between DOE and the Kentucky Division of Waste Management (KDWM) and other regulatory requirements. The major missions of the D&D Project are to manage and characterize the areas for disposition of waste. The major missions of the Uranium Program are to maintain safe, compliant storage of the DOE depleted UF_6 (DUF_6) inventory until final disposition and to manage facilities and grounds not leased to USEC. The environmental monitoring summarized in this report supports all DOE programs/projects.

2 Environmental Compliance

Abstract

The policy of DOE and its contractors and subcontractors at the Paducah Site is to conduct operations safely and minimize or eliminate the adverse impact of operations on the environment. Protection of the environment is considered a responsibility of paramount importance. The Paducah Site maintains an environmental compliance program aimed at satisfying all applicable requirements and protecting human health and the environment.

Introduction

State and federal agencies, including DOE, are responsible for enforcing the environmental regulations at the Paducah Site. Principal regulating agencies are the U.S. Environmental Protection Agency (EPA), Region 4, and the Kentucky Department for Environmental Protection (KDEP). These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable laws and regulations.

The EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by the U.S. Congress. In some instances, the EPA has delegated regulatory authority to KDEP when the Kentucky program meets or exceeds EPA requirements. Table 2.1 provides a summary of the Paducah Site environmental permits maintained by DOE in 2008.

Table 2.1. Permits Maintained by DOE for the Paducah Site for CY 2008

Permit Type	Issued By	Permit Number	Issued To
State Agency Interest ID# 3059			
Water			
Kentucky Pollutant Discharge Elimination System	KDOW	KY0004049	DOE/PRS/UDS
Water Withdrawal Permit	KDOW	1345	DOE
Solid Waste			
Residential Landfill (closed)	KDWM	SW07300014	DOE/PRS
Inert Landfill (closed)	KDWM	SW07300015	DOE/PRS
Solid Waste Contained Landfill (construction/operation)	KDWM	SW07300045	DOE/PRS
RCRA/Toxic Substances Control Act			
Hazardous Waste Facility Permit	KDWM	KY8-890-008-982	DOE/PRS

Under the lease agreement with USEC, DOE retained responsibility for the site Environmental Restoration Program; the Enrichment Facilities Program; the Legacy Waste Management Program, including all waste inventories predating July 1, 1993; and wastes generated by subsequent DOE activities. DOE, PRS, and Uranium Disposition Services, LLC, (UDS) are co-permittees on the Kentucky Pollutant Discharge Elimination System (KPDES) compliance permit. DOE is responsible for all outfalls addressed by this permit. UDS responsibility is limited to Outfall 017 only. PRS is responsible for the remaining Outfalls (001, 015, and 019). DOE also has retained responsibility of facilities not leased to USEC. DOE and USEC have negotiated the lease of specific plant site facilities, written memoranda of agreement to define their respective roles and responsibilities under the lease, and developed organizations and budgets to support their respective functions. DOE is the owner, and DOE and its contractor are co-operators for Resource Conservation and Recovery Act (RCRA)-permitted facilities and are responsible for compliance with the RCRA permit.

Resource Conservation and Recovery Act

Regulatory standards for the characterization, treatment, storage, and disposal of solid and hazardous waste are established by RCRA. Waste generators must follow specific requirements outlined in RCRA regulations for handling solid and hazardous wastes. Owners and operators of hazardous waste treatment, storage, and disposal facilities are required to obtain operating and closure permits for waste treatment, storage, and disposal activities. The Paducah Site generates solid waste, hazardous waste, and mixed waste (i.e., hazardous waste mixed with radionuclides) and operates four permitted hazardous waste storage and treatment facilities. The closed C-404 Hazardous Waste Landfill also is managed under requirements of the RCRA regulations and permit.

Resource Conservation and Recovery Act Hazardous Waste Permit

Part A and Part B permit applications of RCRA for storage and treatment of hazardous wastes initially were submitted for the Paducah Site in the late 1980s. At that time, EPA had authorized the Commonwealth of Kentucky to administer exclusively the RCRA-based program for treatment, storage, and disposal units, but had not given the authorization to administer 1984 Hazardous and Solid Waste Amendments provisions.

The current hazardous waste management facility permit was issued to DOE on September 30, 2004. The permit became effective on October 31, 2004, and is valid until October 31, 2014. The Part B permit application was modified on April 24, 2006, to identify PRS as an operator.

Resource Conservation and Recovery Act Notices of Violation

DOE received no RCRA notices of violation (NOVs) during 2008.

2003 Agreed Order with Commonwealth of Kentucky

The main accomplishments for the AO DWM-31434-042, DAQ-31740-030, DOW-2614-042, hereinafter referred to as the 2003 AO, are discussed briefly. The main program components in the 2003 AO pertained to RCRA-listed hazardous waste and DMSAs. Each DMSA was prioritized for removal based on the potential risk to plant workers and the environment, with “A” representing greatest potential risk, “B” representing medium potential risk, and “C” representing lowest potential risk. As required by the 2003 AO, all requirements for the highest priority DMSAs, Priority A, were met in 2004, and all of the requirements for the second-highest priority, Priority B, were met in 2006. Priority C DMSAs are required to be complete by September 30, 2009.

- DOE continues to complete characterization of DMSAs in accordance with the schedule outlined in the AO.

- A notice of intent to proceed with closure of a DMSA was submitted to KDWM in 2008. A total of 42 closure plans have been submitted to KDWM since the onset of the program.

Modifications to the Hazardous Waste Management Facility Permit

One permit modification was submitted in 2008 and a Class 2 RCRA Permit Modification was issued by KDWM on October 21, 2008. This modification revised the groundwater monitoring network for the C-404 Hazardous Waste Landfill, which allowed for more adequate groundwater monitoring.

Federal Facility Compliance Act—Site Treatment Plan

The Federal Facilities Compliance Act (FFC Act) was enacted in October 1992. This act waived the immunity from fines and penalties that had existed for federal facilities for violations of hazardous waste management as defined by RCRA. It also contained provisions for the development of site treatment plans (STPs) for the treatment of DOE mixed waste and for the approval of such plans by the states. As a result of the complex issues and problems associated with the treatment of mixed chemical hazardous and radioactive waste (mixed waste), DOE and KDEP signed, after consideration of stakeholder input, an AO/STP on September 10, 1997. The STP facilitates compliance with the FFC Act. A series of mixed waste treatment milestones are detailed in the STP. The STP also requires that DOE consider waste minimization in all projects and processes. The waste minimization program is discussed in Section 3.

Solid Waste Management

The PGDP disposes of a portion of its solid waste at its contained landfill facility, C-746-U. Construction of the C-746-U Landfill began in 1995 and was completed in 1996. The operation permit was received from KDWM in November 1996. Disposal of waste at the landfill began in February 1997. A new operation permit for the C-746-U Landfill was received from KDWM in November 2006. Two permit revisions that answered three modification requests from KDWM were made in 2008. These modifications served to make only minor corrections within the permit, and no operational changes were made as a result of these corrections. During 2008, the landfill received 821.32 tons of waste from varying Paducah Site operations.

The office waste generated by DOE and its contractors at the plant site is taken off-site for disposal. Only office waste generated at the C-746-U Landfill itself is disposed at the landfill. WastePath Services, LLC, in Calvert City, Kentucky, provides off-site disposal services of the office waste from the Paducah Site. The City of Kevil picks up the office waste from the office complexes in Kevil, Kentucky that house many of the administrative personnel who support activities at the site. PGDP has a sitewide recycling program for office waste, which is described in Section 3.

DOE did not receive any NOVs during 2008 for the C-746-U Landfill or the inactive C-746-S&T Landfills.

Underground Storage Tanks

Underground storage tank (UST) systems at the Paducah Site were used to store petroleum products such as gasoline, diesel fuel, and waste oil. These USTs are regulated under RCRA Subtitle I (40 *Code of*

Federal Regulations (*CFR*) Part 280) and Kentucky UST regulations [401 *Kentucky Administrative Regulations* (*KAR*) Chapter 42].

DOE is responsible for 16 of the 18 site USTs that have been reported to KDWM; USEC is responsible for the other two. At the end of 2006, DOE had received regulatory approval for closure of all DOE USTs. No additional actions were taken in 2008.

Comprehensive Environmental Response, Compensation, and Liability Act

DOE and EPA Region 4 entered into an Administrative Order by Consent (ACO) in August 1988 under Sections 104 and 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The ACO was in response to the off-site groundwater contamination detected at the Paducah Site in July 1988.

On May 31, 1994, the Paducah Site was placed on the EPA National Priorities List (NPL), which is a list of sites across the nation designated by EPA as having the highest priority for site remediation. The EPA uses the Hazard Ranking System to determine which sites should be included on the NPL.

Section 120 of CERCLA requires federal agencies with facilities on the NPL to enter into an FFA with the EPA. The FFA, which was signed February 13, 1998, by DOE, EPA, and KDEP, established a decision-making process for remediation of the Paducah Site and coordinates CERCLA remedial action requirements with RCRA corrective action requirements. The FFA parties—DOE, EPA, and KDEP—agreed to terminate the CERCLA ACO because those activities could be continued under the FFA. According to the FFA, DOE is required to submit an annual Site Management Plan (SMP) to EPA and KDEP. The SMP summarizes the remediation work completed to date, outlines remedial priorities, and contains schedules for completing future work. The SMP is submitted to the regulators annually in November to update the enforceable milestones and to include any new strategic approaches.

Comprehensive Environmental Response, Compensation, and Liability Act Reportable Quantities

In 2008, there were no spills of CERCLA-regulated substances above CERCLA reporting requirements.

National Environmental Policy Act

An evaluation of the potential environmental impact of certain proposed federal activities is required by the National Environmental Policy Act (NEPA). In addition, an examination of alternatives to certain proposed actions is required. Compliance with NEPA, as administered by DOE's NEPA Implementing Procedures (10 *CFR* § 1021) and the Council on Environmental Quality Regulations (40 *CFR* § 1500–1508), ensures that consideration is given to environmental values and factors in federal planning and decision making. In accordance with 10 *CFR* § 1021, the Paducah Site conducts NEPA reviews for proposed actions and determines if any proposal requires preparation of an environmental impact statement (EIS), an environmental assessment (EA), or is categorically excluded (CX) from preparation of either an EIS or an EA. The Paducah Site maintains records of all NEPA reviews.

Numerous minor activities were within the scope of the previously approved CXs for routine maintenance, small-scale facility modifications, and site characterization. The DOE Paducah Site Office and the Portsmouth/Paducah Project Office NEPA compliance officer approve and monitor the internal applications of previously approved CX determinations.

In accordance with the 1994 DOE Secretarial Policy Statement on NEPA, preparation of separate NEPA documents for environmental restoration activities conducted under CERCLA no longer is required. Instead, the DOE CERCLA process includes "NEPA values." The NEPA values are environmental issues that affect the quality of the human environment. Documentation of NEPA values in CERCLA documents allows the decision makers to consider the potential effects of proposed actions on the human environment. Actions conducted under CERCLA are discussed in Section 3 of this report.

National Historic Preservation Act

The National Historic Preservation Act of 1966 is the primary law governing a federal agency's responsibility for identifying and protecting historic properties [cultural resources included in or eligible for inclusion in the National Register of Historic Places, (NRHP)]. Historic properties include buildings of historic significance, and archeological sites. PGDP buildings were assessed in the *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (BJC 2006, hereinafter referred to as the Cultural Resources Management Plan). Archeological resources will be addressed as undisturbed land is developed for site use.

The Cultural Resources Management Plan identified an NRHP-eligible historic district at the facility. The PGDP Historic District contains 101 contributing properties and is eligible for the NRHP under National Register Criterion A for its military significance during the Cold War and for its role in commercial nuclear power development. The PGDP historic district encompasses the area of the process buildings; the switchyards; the C-100 Administration Building; cooling towers and pump houses; security facilities; water treatment facilities; storage tanks; and the support, maintenance, and warehouse buildings. A map and the rationale for designating the area as such are included in the Cultural Resources Management Plan.

Endangered Species Act

The Endangered Species Act of 1973, as amended, provides for the designation and protection of endangered and threatened animals and plants. The act also serves to protect ecosystems on which such species depend. At the Paducah Site, proposed projects are reviewed, in conjunction with EMS or the CERCLA process, to determine if activities have the potential to impact these species. If necessary, project-specific field surveys are performed to identify threatened and endangered species and their habitats, and mitigating measures are designed, as needed. When appropriate, DOE initiates consultation with the U.S. Fish and Wildlife Service and Kentucky Department for Fish and Wildlife Resources prior to implementing a proposed project.

Table 2.2 includes eleven federally listed, proposed, or candidate species that have been identified as potentially occurring at or near the Paducah Site. No DOE project at the Paducah Site during 2008 impacted any of these eleven species or their potential habitats.

Table 2.2. Federally Listed, Proposed, and Candidate Species Potentially Occurring within the Paducah Site Study Area in 2008[a]

Common Name	Scientific Name	Endangered Species Act Status
Indiana Bat[b]	*Myotis sodalis*	Listed Endangered
Interior Least Tern	*Sterna antillarum*	Listed Endangered
Pink Mucket	*Lampsilis abrupta*	Listed Endangered
Ring Pink	*Obovaria retusa*	Listed Endangered
Orangefoot Pimpleback	*Plethobasus cooperianus*	Listed Endangered
Fat Pocketbook	*Potamilus capax*	Listed Endangered
Sheepnose	*Plethobasus cyphyus*	Candidate
Clubshell	*Pleurobema clava*	Listed Endangered
Rough Pigtoe	*Pleurobema plenum*	Listed Endangered
Fanshell	*Cyprogenia stegaria*	Listed Endangered
Spectaclecause	*Cumberlandia monodonta*	Candidate

[a] All of the listed species are discussed in *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky, Volume III*, COE Nashville District, and May 1994. Note that the study area encompasses 11,719 acres and extends to include the Ohio River, which is over 3 miles north of the DOE reservation. None of these species have been reported as sighted on the DOE reservation, although potential summer habitat exists there for the Indiana bat. No critical habitat for any of these species has been designated anywhere in the study area.

[b] Specimens of the Indiana bat were netted, identified, measured, and released on WKWMA property in 1991 and 1999.

Floodplain/Wetlands Environmental Review Requirements

Title 10 *CFR* Part 1022, establishes procedures for compliance with Executive Order 11988, "Floodplain Management," and Executive Order 11990, "Protection of Wetlands."

In 2008, no floodplain or wetlands assessments were prepared or approved. Also, no floodplain or wetlands notices of involvement were published in the *Federal Register* for the Paducah Site. In addition, DOE did not apply for any individual permits from COE or for any water quality certifications from the state. DOE activities did not result in significant impacts to floodplains or wetlands at the Paducah Site in 2008.

Clean Water Act

The Clean Water Act (CWA) was established primarily through the passage of the Federal Water Pollution Control Act Amendments of 1972. The CWA established the following four major programs for control of water pollution:

(1) Regulating point-source discharges into waters of the United States;
(2) Controlling and preventing spills of oil and hazardous substances;
(3) Regulating discharges of dredge and fill materials into "waters of the United States"; and
(4) Providing financial assistance for construction of publicly owned sewage treatment works.

The Paducah Site is affected primarily by the regulations for point source discharges regulated under the KPDES permit.

Kentucky Pollutant Discharge Elimination System Permit

The CWA applies to all nonradiological DOE discharges to waters of the United States. At the Paducah Site, the regulations are applied through issuance of a KPDES permit for effluent discharges to Bayou Creek and Little Bayou Creek. The Kentucky Division of Water (KDOW) issued KPDES Permit No. KY0004049 to the Paducah Site. This permit became effective November 1, 2006, and is enforced by KDOW. This permit applies to the following four DOE outfalls: 001, 015, 017, and 019. The KPDES permit calls for monitoring as an indicator of discharge related effects in the receiving streams. The permit will expire on October 31, 2011. Following the issuance of the permit, several parties petitioned KDOW for a hearing on the permit. The parties involved with KDOW on the hearings included: DOE, USEC, PRS, UDS, and the Kentucky Resource Council. An Order to Mediate was issued by the Kentucky

Environmental and Public Protection Cabinet (now the Kentucky Energy and Environment Cabinet). Negotiations on an AO to settle all parties' disputes with the permit were completed on December 7, 2007, with the approval of an AO. Information on the AOs is summarized in Table 2.1.

There was one exceedance of effluent permit limits in 2008. In October 2008, the discharge from Outfall 017 had a 30-day average of 11 mg/L of oil and grease, which exceeded the permit limit of 10 mg/L. KDOW issued an NOV for this exceedance on June 4, 2009. Immediate investigations of the site conditions for October 2008 revealed no obvious direct cause for the reported analytical result, and there had been no spills or releases. The most probable explanation would be parking lot and roadway runoff from vehicles and runoff from a newly constructed asphalt parking lot serving the DUF_6 facility. A Corrective Action Plan was submitted to KDOW on July 7, 2009, closing the NOV.

Toxic Substances Control Act

In 1976, the Toxic Substances Control Act (TSCA) was enacted with a twofold purpose: (1) to ensure that information on the production, use, and environmental and health effects of chemical substances or mixtures is obtained by the EPA; and (2) to provide the means by which the EPA can regulate chemical substances/mixtures.

Polychlorinated Biphenyls

The Paducah Site complies with polychlorinated biphenyl (PCB) regulations (40 *CFR* § 761) and the TSCA-UE-Federal Facilities Compliance Agreement (FFCA). The major activities performed in 2008 to ensure compliance included the following: maintaining compliant storage of PCB waste and PCB-contaminated wastewater; shipping PCB waste for treatment and disposal, treating and discharging PCB contaminated wastewater; maintaining the troughing system; and reporting and recordkeeping.

The TSCA-UE-FFCA between EPA and DOE was signed in February 1992. Under this agreement, action plans have been developed and implemented for removal and disposal of large volumes of PCB material at the Paducah Site. Table 2.3 shows a summary of PCB equipment in service at the Paducah Site at the end of 2008. These items are utilized in USEC operations.

Table 2.3. Summary of PCB Equipment in Service at the End of CY 2008

Type	Number in Service	Volume (gal)	PCBs (kg)
PCB Transformers	66	95,040	279,346
PCB Contaminated Transformers	9	2,299	0.95
PCB Contaminated Electrical Equipment	7	2,094	1.14
PCB Capacitors	559	1,650	10,104

The PCB annual document provides details of facility activities associated with the management of PCB materials. The annual report provides details from the previous year on all PCB items that are in use, stored for reuse, generated as waste, stored for disposal, or shipped off-site for disposal. All Paducah Site TSCA-UE-FFCA milestones for 2008 were completed. During CY 2008, 1,681 containers of solid and liquid PCB remediation wastes, lab wastes, bulk product wastes, and liquid wastes, weighing approximately 41,675 kg, were shipped for treatment and/or landfill disposal at Energy*Solutions* in Clive, Utah, or for incineration at the DOE TSCA Incinerator in Oak Ridge, Tennessee.

The facilities operated by USEC utilize equipment that contains PCB capacitors as well as transformers, electrical equipment, and other miscellaneous PCB equipment. Both radioactive and nonradioactive PCB wastes are stored on-site in units that meet TSCA and/or TSCA-UE-FFCA compliance requirements, as applicable. Nonradioactive PCBs are transported off-site to EPA-approved facilities for disposal.

Radioactively contaminated PCB wastes are authorized by the TSCA-UE-FFCA for long-term on-site storage at the Paducah Site (i.e., beyond two years). Technology for the treatment and/or disposal of radioactively contaminated PCB wastes is being evaluated.

Emergency Planning and Community Right-to-Know Act

Also referred to as Title III of the Superfund Amendments and Reauthorization Act, the Emergency Planning and Community Right-to-Know Act (EPCRA) requires reporting of emergency planning information, hazardous chemical inventories, and releases to the environment.

EPCRA's primary purpose is to inform communities and citizens of chemical hazards in their areas. In order to ensure proper and immediate responses to potential chemical hazards, EPCRA Section 304 requires facilities to notify State Emergency Response Commissions and Local Emergency Planning Committees of releases of hazardous substances and extremely hazardous substances when the release equals or exceeds the reportable quantity. Sections 311 and 312 of EPCRA require businesses to report the locations and quantities of chemicals stored on-site to state and local governments in order to help communities prepare to respond to chemical spills and similar emergencies. EPCRA Section 313 requires EPA and the states to collect data annually on releases and transfers of certain toxic chemicals from industrial facilities, and make the data available to the public.

The Paducah Site did not have any releases that were subject to EPCRA Section 304 notification requirements during 2008. No EPCRA Section 311 notifications were required in 2008. The EPCRA Section 312 Tier II report of inventories for 2008 included UF_6, activated carbon pellets, magnesium fluoride, sodium chloride, sulfuric acid, gasoline, and diesel fuel associated with DOE activities. [UF_6 was reported even though radioactive material is not subject to EPCRA Sections 311 and 312 (52 *FR* 38344-01).]

Clean Air Act

Authority for enforcing compliance with the Clean Air Act (CAA) and subsequent amendments resides with EPA Region 4 and/or the Kentucky Division for Air Quality (KDAQ). The Paducah Site complies with federal and state rules by implementing the CAA and its amendments.

Clean Air Act Compliance Status

The largest air emission sources in 2008 were the Northwest Plume Groundwater System (NWPGS) and the Northeast Plume Containment System (NEPCS). These systems are interim remedial actions (IRAs) under CERCLA that address the containment of groundwater contamination at the Paducah Site. These systems remove trichloroethene (TCE) contamination from the groundwater by air stripping. At the NWPGS, the TCE-laden groundwater passes through an air stripper to remove the TCE. The off-gas from the air stripper then passes through a carbon adsorption system to remove the TCE prior to atmospheric discharge. At the NEPCS, a cooling tower system acts as an air stripper for TCE. Concentrations of TCE in the Northeast Plume are sufficiently low that a carbon adsorption system is not required to keep emission below regulatory threshold levels.

Asbestos Program

Numerous facilities at the Paducah Site contain asbestos materials. Compliance programs for asbestos management include identification of asbestos materials, monitoring, abatement, and disposal. Procedures and program plans are maintained that delineate scope, roles, and responsibilities for maintaining compliance, as applicable, with EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements. There were no noncompliances with environmental protection standards identified in 2008.

Radionuclide National Emission Standards for Hazardous Air Pollutants Program

Airborne emission of radionuclides from DOE facilities are regulated under 40 *CFR* § 61, Subpart H, the National Emission Standards for Hazardous Air Pollutants regulations. Potential radionuclide sources at the Paducah Site in 2008 were from C-752-A waste management activities, the Northwest Plume Groundwater System, C-746-A West End Smelter demolition, C-301 DMSA Outside (OS)-12 metal reduction, and fugitive dust source emissions. The fugitive dust source emissions include piles of contaminated scrap metal, roads, and roofs. DOE utilized ambient air monitoring data to verify insignificant levels of radionuclides in off-site ambient air. The Radiation/Environmental Monitoring Section of the Radiation Health and Toxic Agents Branch (RHTAB) of the Department for Public Health of the Kentucky Cabinet for Health Services conducted ambient air monitoring during 2008. Ambient air data were collected at 10 sites surrounding PGDP in order to measure radionuclides emitted from Paducah Site sources, including fugitive emissions. The calculated emissions for each monitored activity were less than the 40 *CFR* § 61, Subpart H, limit of 0.1 millirem (mrem) dose to the maximally exposed individual. These results are discussed in further detail in Section 4.

Pollutants and Sources Subject to Regulation

Any stationary source emitting more than 10 tons/year of any hazardous air pollutant (HAP) or 25 tons/year of any combination of HAPs is considered a major source and is subject to regulation. EPA Region 4 must examine other sources for regulation under an “area source” program. The Paducah Site is not a major source by virtue of its individual or total HAP emissions.

Stratospheric Ozone Protection

The DOE refrigeration units contain less than 50 pounds of ozone-depleting substances; therefore, the only CAA Title VI provision that applies to the Paducah Site is the requirement to control refrigerants from leaking systems.

Clean Air Act Notices of Violation

The PGDP did not receive any CAA violations in 2008.

Kentucky/Department of Energy Agreement in Principle

The Kentucky/DOE Agreement in Principle (AIP) reflects the understanding and commitments between DOE and the Commonwealth of Kentucky regarding DOE’s provision of technical and financial support to Kentucky for environmental oversight, surveillance, remediation, and emergency response activities. The goal of the AIP is to maintain an independent, impartial, and qualified assessment of the potential environmental impacts from present and future DOE activities at the Paducah Site. The AIP is intended to support nonregulated activities, whereas, the FFA covers regulated activities. The AIP includes a grant to support the Commonwealth of Kentucky in conducting independent monitoring and sampling, both on-site and off-site, and to provide support in a number of emergency response planning initiatives. Included are cooperative planning, conducting joint training exercises, and developing public information about preparedness activities.

Regulatory Inspections

Paducah Site programs are overseen by several organizations, both inside and outside the DOE complex. Each year, numerous appraisals, audits, and surveillances of various aspects of the environmental compliance program are conducted.

In 2008 the KDEP inspected the KPDES outfalls permitted under the KPDES program, the contained landfill (C-746-U), and RCRA container/tank storage facilities. In addition, KDEP (under contract of EPA Region 4) inspected TSCA compliance points. The inspections showed that permit conditions are being met; no violations or exceedances were noted as a result of the inspections.

3 Environment Program Information

Abstract

Environmental monitoring, environmental restoration, waste operations, facilities management, UF_6 cylinder management activities, D&D, and DMSA management occur at DOE facilities within PGDP. Programs that support these activities are presented in this section to inform the public.

Environmental Monitoring Program

The Environmental Monitoring Program at PGDP consists of effluent monitoring and environmental surveillance. Requirements for routine environmental monitoring programs were established to measure and monitor effluents from DOE operations and maintain surveillance on the effects of those operations on the environment and public health through measurement, monitoring, and calculation. The Environmental Monitoring Program is documented in the *Paducah Site Environmental Monitoring Plan* (PRS 2007c; PRS 2009) in accordance with DOE Order 450.1a, *Environmental Protection Program.* The results of this program are discussed in detail in subsequent sections of this ASER.

Before the DOE/USEC transition (described in Section 1), DOE's primary mission at the Paducah Site consisted of enriching uranium. Since the transition on July 1, 1993, DOE's mission at the site has been focused on environmental restoration, DUF_6 cylinder management, waste management, and D&D/DMSA management. This change in mission also changed the direction and emphasis of the Environmental Monitoring Program. In November 1995, the site Environmental Monitoring Plan (EMP) was reissued to address DOE operations exclusively. The environmental monitoring plan is reviewed annually and updated at least every three years. The fiscal year (FY) 2008 EMP (PRS 2007c) was in effect and covered data collected during the time frame of January 2008 to September 2008. The FY 2009 EMP (PRS 2009) was in effect and covered data collected during the time frame of October 2008 to December 2008.

Environmental Restoration Program

The goal of the Environmental Restoration Program is to ensure that releases from past operations and waste management activities are investigated and that the appropriate response action is taken for the protection of human health and the environment. In May 1994, PGDP was added to EPA's NPL. Two federal laws, RCRA and CERCLA, are the dominant regulatory drivers for monitoring and restoration activities at PGDP. RCRA sets the standards for managing hazardous waste and requires that permits be obtained for DOE facilities that treat, store, or dispose of hazardous waste and requires assessment and

cleanup of hazardous waste releases at solid waste management units (SWMUs). CERCLA addresses uncontrolled releases of hazardous substances and requires cleanup of inactive waste sites. As a result of PGDP being placed on the NPL, DOE, EPA, and KDEP entered into an FFA in 1998. The FFA coordinates compliance with both RCRA and CERCLA requirements.

The environmental restoration program supports investigations and environmental response actions, D&D of facilities no longer in use, projects designed to demonstrate or test advancements in remedial technologies, and other projects related to action for the protection of human health and the environment.

Background

In July 1988, the Kentucky Radiation Control Branch, in conjunction with the Purchase District Health Department, sampled several residential groundwater wells north of the plant in response to concerns from a local citizen regarding the quality of water in a private well. Subsequent analyses of these samples revealed elevated gross beta levels indicative of possible radionuclide contamination. On August 9, 1988, these results were reported to the Paducah Site, which responded by sampling several private groundwater wells adjacent to the site on August 10, 1988. Upon analysis, some of the samples collected contained elevated levels of both TCE and ^{99}Tc. In response, DOE immediately instituted the following actions:

- Provided a temporary alternate water supply to affected residences;
- Sampled surrounding residential wells to assess the extent of contamination;
- Began extension of a municipal water line to affected residences as a long-term source of water; and
- Began routine sampling of residential wells around the Paducah Site.

Following the initial response actions, DOE and EPA entered into an ACO in August 1988 under Sections 104 and 106 of CERCLA. The major requirements of the ACO include monitoring of residential wells potentially affected by contamination, providing alternative drinking water supplies to residents with contaminated wells, and investigating the nature and extent of off-site contamination.

Pursuant to the ACO, DOE continued routine sampling of residential wells and initiated a two-phase site investigation (SI) to identify the nature and extent of off-site contamination at the Paducah Site. Phase I of the SI, from summer 1989 to March 1991, evaluated the extent of off-site contamination through extensive groundwater monitoring and surface water sampling. Results of these activities are reported in *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1991). Phase II of the SI, from November 1990 to October 1991, focused on identification and characterization of on-site sources contributing to off-site contamination. Phase II determined the level of risk to human health and the environment from exposure to contaminated media and biota and developed an initial list of remedial alternatives. Results are reported in *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1992b). Risks to human health and the environment from exposure to contamination originating at the Paducah Site were reported in *Results of the Public Health and Ecological Assessment, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1992a). This report used data collected during the SI to quantitatively assess risks to human health and to qualitatively assess risks to the environment.

As part of the residential well sampling program that began when off-site contamination was discovered, DOE established a water policy in 1994. This policy provides that in the event contamination originating from the Paducah Site is detected above plant action levels a response would be initiated by the Paducah Site. These levels are established at the analytical laboratory detection limits of 25 picocuries per liter (pCi/L) for ^{99}Tc and 1 part per billion (ppb) for TCE. Accordingly, residents, as well as state and EPA officials, are notified immediately of sampling results above these levels, and alternative water supplies are provided to those residences through connection to the municipal water system, or, in the event of a

time lapse between discovery and the ability to complete connections, bottled water is made available. In accordance with the water policy of 1994, DOE pays installation cost of water systems and the monthly charges for water service to residences within the established water policy area.

DOE modified this water policy in 1994 to include provisions to extend a municipal water line to the entire area of the groundwater contamination originating from the Paducah Site. All residents within the defined area, regardless of whether their wells were contaminated, were given the option to receive municipal water at DOE's expense. DOE also provided municipal water to new residences and some new businesses in the area.

ACO activities identified two off-site groundwater contamination plumes, referred to as the Northwest and Northeast Plumes; identified several potential on-site source areas requiring additional investigation; and included the evaluation of alternatives and implementation of several interim activities. Upon signing the FFA in February 1998, the FFA parties declared that the ACO requirements were satisfied and terminated the ACO because the remaining cleanup would be continued under the authority of the FFA. A series of remedial investigations (RIs) and feasibility studies (FSs) were initiated under the FFA (e.g., WASTE AREA GROUPS 1, 3, 6, 7, 22, 23, 27, and 28), including the ongoing evaluation of all major contaminant sources impacting groundwater and surface water. In accordance with the ACO and FFA, DOE actions have focused primarily on reducing potential risks associated with off-site contamination. The following are examples of the significant actions and the dates they were completed through CY 2008:

- Imposed land use controls (fencing and posting) to restrict public access to contaminated areas in certain outfall ditches and surface water areas (1993).

- Extended municipal water lines as a permanent source of drinking water to affected residents to eliminate exposure to contaminated groundwater (1995).

- Constructed and implemented groundwater treatment systems for both the Northwest and Northeast Plumes to reduce contaminant migration (1995 and 1997, respectively).

- Rerouted surface runoff away from highly contaminated portions of the North-South Diversion Ditch (NSDD) to reduce potential migration of surface contamination (1995).

- Excavated soil with high concentrations of PCBs in on-site areas to reduce off-site migration and potential direct-contact risks to plant workers (1998).

- Removed and disposed of "drum mountain," a contaminated scrap pile potentially contributing to surface water contamination so that a potential direct-contact risk to plant workers would be eliminated and an off-site migration risk would be reduced (2000).

- Applied *in situ* treatment of TCE-contaminated soil at the cylinder drop test site using innovative technology (i.e., the Lasagna™ technology) to eliminate a potential source of groundwater contamination (2002).

- Removed petroleum-contaminated soil from SWMU 193, the former McGraw Construction Yards, now the Southside Cylinder Yards, to eliminate a potential source of groundwater contamination (2002).

- Completed installation of a sediment control basin at Outfall 001 to control the potential migration of contaminated sediment (2002).

- Completed a treatability study that demonstrated the effectiveness of the six-phase heating technology for *in situ* treatment of dense nonaqueous-phase liquid (DNAPL) at C-400 (2003).
- Completed installation of a retention basin and excavation of the on-site portions of the NSDD, which removed a source of direct-contact risk to plant workers and a potential source of surface water contamination (2004).
- Investigated potential source areas contributing to the Southwest Plume, the results of which remain pending (2005).
- Completed D&D of the C-603 Nitrogen Facility (2005).
- Performed an SI near the C-746-S&T Landfills and determined that TCE groundwater contamination is from SWMU 145, the Residential/Inert Landfill and Borrow Area (2006).
- Disposed of approximately 30,500 tons of scrap metal, which eliminated a potential direct-contact risk to plant workers and a source of surface water contamination (2006).
- Completed D&D of the C-402 Limehouse (2006).
- Initiated remedial design/action for volatile organic contamination in soil and groundwater at the C-400 Cleaning Building (2006).
- Completed D&D of the C-405 Incinerator (2007).
- Completed remedial action field investigation for the Burial Ground Operable Unit (2007).
- Completed D&D of the C-746-A West End Smelter (2008).
- Completed D&D of the C-342 Ammonia Disassociator Facility (2008).

Operable Units

The National Contingency Plan states that owners of large, complex sites with multiple source areas, such as federal facilities, may choose to divide their sites into smaller areas to characterize them and to implement response actions, rather than conducting a single sitewide comprehensive action. These discrete actions, referred to as operable units (OUs), may address a geographic portion of the site, or specific site problems, or include a series of interim actions followed by final actions. The PGDP site cleanup strategy adopts this approach and includes a series of high-priority actions, ongoing site characterization activities to support future response action decisions, and eventual D&D of the currently operating PGDP after it ceases operation, followed by a Comprehensive Sitewide Operable Unit (CSOU) evaluation. The timing and sequencing of these actions is based on a combination of factors, including risk, compliance, and technical considerations associated with PGDP operations and other criteria, as outlined in the Paducah SMP (DOE 2008a).

Groundwater is an example of an area that has unique technical factors that need special consideration in the sequencing and decision making process. The strategy includes the following four phases:

(1) Preventing human exposure to contaminated groundwater;

(2) Preventing or minimizing further migration of the contaminant plume;

(3) Preventing or minimizing further migration of contaminants from source materials to groundwater; and

(4) Returning groundwater to beneficial uses wherever practicable.

Phases One and Two

The first phase of the ongoing Paducah groundwater strategy focuses on preventing human exposure to contaminated groundwater by providing an alternate drinking water supply to certain area residences. The first phase is commonly referred to as the "water policy." The second phase of the strategy, to prevent or minimize further migration of the contaminant plumes, is being implemented through the installation of the groundwater treatment systems in both the Northwest and Northeast Plumes.

Phase Three

The third phase of the groundwater strategy is focused on the prevention or minimization of contaminant migration from source areas. As part of this phase, the Remedial Design Report was issued in 2007 that addressed electrical resistance heating remedial action for the C-400 area—the largest known DNAPL source of off-site contamination. A primary objective of this project is to contribute to the protection of off-site residences by addressing sources of groundwater contamination. The third phase also includes investigation of the Burial Grounds Operable Unit (BGOU), which was completed in 2007, and the Site-wide Soils OU to determine the presence of any additional groundwater contaminant sources and their contribution to the off-site plumes, if any. The third phase also will include a Groundwater OU (GWOU) project focused exclusively on the dissolved-phase plumes, including further assessment of the Northwest and Northeast Dissolved-Phase Plumes as well as the Southwest Dissolved-Phase Plume.

Phase Four

The fourth phase of the groundwater strategy is the evaluation of the technical practicability of returning groundwater to its expected beneficial use within a reasonable time frame. The evaluation will be conducted as part of the CSOU. Several technical factors must be considered in making a final decision for the groundwater, including the effectiveness of all source actions taken prior to the final one, the presence of any as yet unknown DNAPL source areas [including areas beneath the gaseous diffusion plant (GDP)] that might be contributing to groundwater contamination and require response action; and any effects that ceasing plant operations may have on groundwater flow. Each of these technical considerations is essential to effective remediation of the contaminants associated with the plumes. Some of these technical factors or data gaps cannot be completed until the plant ceases operations.

D&D

The scope of the D&D OU includes 17 currently inactive DOE facilities, those SWMUs and areas of concern associated with previous GDP operations, and the currently operating GDP. The 17 inactive DOE facilities are scheduled to undergo D&D before plant shutdown. The units associated with current GDP operations will be addressed during D&D of the GDP.

Final CSOU

The final CSOU evaluation will occur following completion of D&D of the GDP after plant shutdown. As part of the final CSOU evaluation, the land-use assumptions will be reassessed and modified, if necessary, to ensure consistency with the reasonably foreseeable land use, including any reuse initiatives

that might be under consideration at that time. The final CSOU will include a sitewide baseline human health and ecological risk assessment to evaluate residual risks remaining and to identify any additional actions necessary to ensure long-term protectiveness.

2008 Response Activities

Significant accomplishments for the Environmental Restoration Program conducted in 2008 include, but were not limited to, the following:

- Submitted an engineering evaluation/cost analysis (EE/CA) for the removal for the Soils Inactive Facilities.
- Completed remedial design and development of Remedial Action Work Plan and began fieldwork for C-400 Interim Remedial Action for volatile organic contamination in soil and groundwater at the C-400 Cleaning Building, the site's largest source of groundwater contamination. Initiated development of Southwest Plume Focused FS Report.
- Continued operation of the Northwest and Northeast Plume groundwater treatment systems.
- Submitted EE/CA for the Surface Water OU on-site hot spot removal action.
- Began removal of classified soils.
- Implemented sampling and analysis plans (SAPs) for the investigation of soil pile areas near Bayou Creek and other areas surrounding PGDP and in Ballard County, Kentucky.
- Completed the BGOU RI/FS field investigation of approximately 60 acres of old burial grounds and began drafting remedial decision documents.
- Completed D&D of the C-746-A West End Smelter and the C-342 Ammonia Dissociation Facility.

C-400 Interim Removal Action for Volatile Organic Compound Contamination in Groundwater

In 2005, a Record of Decision (ROD) was approved by DOE and submitted to the regulators for selecting the IRA for the GWOU volatile organic compounds (VOCs) source zone, comprised primarily of TCE, at the C-400 Cleaning Building at PGDP. The ROD includes discussion of the contribution that this IRA will make toward the final decision for the GWOU at PGDP.

The IRA was developed to accomplish the following:

- Prevent potential exposure to contaminated groundwater to on-site industrial workers through institutional controls (e.g., excavation/penetration permit program); and
- Initiate remedial design for the C-400 groundwater action fieldwork. Reduce contamination comprised of TCE and other VOCs found in UCRS soil in the C-400 Cleaning Building area to minimize the migration of these contaminants to RGA groundwater and to off-site points of exposure.

The major components of the remedy would include the following:

- Reduce the concentration of TCE and other VOCs in the soils in the C-400 Cleaning Building area through removal and treatment using electrical resistance heating in both the UCRS and RGA;
- Collect post-action sampling results;
- Conduct an Remedial Design Support Investigation (RDSI) to further determine areal and vertical extent of TCE and other VOC contamination in the C-400 Cleaning Building area to ensure optimum placement of the remediation system; and
- Implement land use controls at the C-400 Cleaning Building area.

In 2006, the RDSI was completed and the results were used as input during the development of the remedial design for the IRA. In accordance with the FFA for Paducah, a phased approach to the design (30%, 60%, 90%, and certified for construction versions) is required. The 30% and 60% designs were produced in 2006, as was the D2 Land Use Control Implementation Plan.

In 2007 the 90% design was developed and reviewed by the EPA and KDEP, as well as by an independent technical review team chartered by the DOE. Input from these reviews was used to develop the final design which is expected to be completed during the first quarter of 2008. The Remedial Action Work Plan was also developed in 2007, and subsequently was approved in 2008.

Southwest Plume Site Investigation

The *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2 (DOE 2006a), documents a 2004 investigation of the on-site Southwest Plume area. The SI was conducted in accordance with the approved *Site Investigation Work Plan for the Southwest Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2094&D2 (DOE 2004). The objectives of the SI were to collect sufficient data to do the following:

- Determine which units are sources of contamination to the Southwest Groundwater Plume;
- Determine which units are not sources of contamination to the Southwest Groundwater Plume;
- Fill data gaps for risk assessment of the identified source areas; and
- Reduce uncertainties and increase the understanding of the Southwest Groundwater Plume and potential sources so that appropriate response actions can be identified, as necessary.

The investigation evaluated the following four potential source areas of contamination to the Southwest Groundwater Plume and profiled the level and distribution of VOCs and ^{99}Tc in the plume along the west plant boundary.

(1) C-747-C Oil Landfarm (SWMU 1)

(2) C-720 Building, specifically areas near the northeast and southeast corners of the building

(3) Storm sewer between the south side of the C-400 Building and Outfall 008 (a part of SWMU 102)

(4) C-747 Contaminated Burial Yard (SWMU 4), addressed in BGOU FI/FS section

Very little investigation previously has focused on the storm sewer as a potential source of groundwater contamination. Three of the four potential source areas and the dissolved-phase plume have been addressed in earlier investigations.

As a result of reviews conducted by the EPA regarding the Southwest Plume SI Report (DOE 2004), DOE entered into dispute resolutions with the EPA during 2007. As a result of the negotiations, it was agreed that a focused FS would be developed to support the data collected in the SI. Work on the focused FS continued through CY 2008.

Northwest Plume Groundwater System

The IRA for the Northwest Plume is documented in a ROD signed by DOE and EPA in July 1993. KDEP concurred with the ROD. The results of the IRA led to the construction of the NWPGS. The NWPGS consists of two extraction well fields (each containing two extraction wells), transfer pipelines, and a fully enclosed treatment system. The NWPGS began operation August 28, 1995. The NWPGS, an interim action, is designed to contain the migration of TCE and ^{99}Tc in the high concentration portion of the Northwest Plume. TCE is removed by an air stripping process. The TCE is volatilized in a low-profile air stripper by introducing a large volume of air into the contaminated groundwater. Activated carbon filtration beds then are used to remove the TCE from the off-gas generated by the air stripper before the air is discharged to the atmosphere. ^{99}Tc is removed from the groundwater by an ion exchange process.

The NWPGS has extracted and treated over 1.1 billion gal of contaminated groundwater from startup in 1995 through the end of 2008. The NWPGS consistently has met the treatment goals documented in the ROD of 5 ppb TCE and 900 pCi/L of ^{99}Tc. The treated groundwater is released through KPDES-permitted Outfall 001. Radiological emissions from this facility are discussed in Section 4.

Northeast Plume Containment System

The IRA of the Northeast Plume was documented in a ROD signed by DOE and EPA in June 1995. The KDEP accepted the ROD and issued Hazardous Waste Permit Modification 8, dated June 26, 1995. The results of the IRA led to the construction of the NEPCS. The NEPCS consists of two extraction wells, an equalization tank, a transfer pump, a transfer pipeline, and instrumentation and controls. Characterization and construction activities were completed in December 1996. System startup and operational testing were conducted, and full operation began in February 1997.

System operation includes pumping groundwater contaminated with TCE from two extraction wells to the equalization tank. A transfer pump is used to pump the contaminated water from the equalization tank through a transfer pipeline (approximately 6,000 linear ft) to the top of the C-637-2A or C-637-2B Cooling Tower. C-637-2A is the primary destination; however, if C-637-2A is off-line, flow is transferred to the C-637-2B tower. The cooling tower acts as an air stripper and removes the TCE from the groundwater as it moves through the tower.

Through 2008, over 900 million gal of contaminated groundwater have been extracted and treated by the NEPCS. With the exception of July through September 1999, when the facility was taken off-line due to cooling tower maintenance, the system has been approximately 95 percent operational since startup. The system was at 100 percent operation in CY 2008.

Surface Water Operable Unit (On-Site)

The results of the *Site Investigation and Risk Assessment of the Surface Water Operable Unit (On-site)*, DOE/OR/07-2137&D2/R2 (DOE 2007a), the Baseline Human Health Risk Assessment (BHHRA), and

the Screening Ecological Risk Assessment (SERA) for the Surface Water OU (On-Site) have been summarized in the *Surface Water Operable Unit (On-Site) Site Investigation and Baseline Risk Assessment Report*, DOE/LX/07-0001&D2/R1 (DOE 2008b).

Based upon the results of the site investigation/baseline risk assessment (SI/BRA), hot spots (sediment located within the NSDD and outfall ditches defined in the SI/BRA as areas where contamination exceeds indicator levels in the SI indicating that unacceptable risk to human health and/or the environment may exist) were identified in the areas investigated. In response to the SI/BRA findings, a non-time-critical removal notification, *Removal Notification for the Surface Water Operable Unit (On-Site)*, DOE/LX/07-0011&D1 (DOE 2007b), was issued and approved by the regulators in CY 2007. The project prepared and submitted and EE/CA in CY 2008. During CY 2008, the EE/CA obtained regulatory approval. The EE/CA provides the basis for the development of the Action Memorandum to be issued after receipt and consideration of public comments on the EE/CA. The Action Memorandum is scheduled for CY 2009.

The scope of the Surface Water OU (On-Site) includes the following:

- NSDD Sections 3, 4, and 5;
- PGDP Outfalls 001 (those portions not addressed by the scrap metal basin), 002, 008, 010, 011, 012 (those portions down gradient of the storm sewer discharge point), and 015, and associated internal ditches and areas (including SWMU 92 and SWMU 97); and
- PGDP storm water sewer systems associated with C-333-A, C-337-A, C-340, C-535, and C-537.

Soil and Rubble Areas Investigation and Removal Action

In November 2006, several soil and rubble areas were found outside the fence on DOE property. During 2007, Soil Pile I was characterized as required in the SAP and associated Addendum 1-A. Addenda 2 and 1B soil areas were characterized in 2008 and the Site Evaluation Reports were drafted for the areas. Rubble area sampling and removal as a maintenance action was scheduled to be performed in CY 2009.

To support ongoing soil activities, a Scoping Survey Plan was scheduled for implementation in January 2009 to March 2009. The Scoping Survey Plan will entail a walkover and flyover of DOE and WKWMA areas outside of the limited access area to determine if any additional anomalies are present and, if so, characterize them to determine the potential nature and extent of contamination for future actions, if required.

Burial Grounds Operable Unit Remedial Investigation/Feasibility Study

The *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2179&D2/R1 (DOE 2006b), was issued to the regulators on August 28, 2006, and was revised in November 2006. The goals for the BGOU RI/FS are consistent with those established in the FFA and the Paducah SMP (DOE 2008a) negotiated among DOE, EPA, and KDEP. The goals of this RI/FS are as follows.

Goal 1: Characterize Nature of Source Zone—Characterize the nature of contaminant source materials by using existing data and, if required, by collecting additional data.

Goal 2: Define Extent of Source Zone and Contamination in Soil and Other Secondary Sources at All Units—Define the nature, extent (vertical and lateral), and magnitude of contamination in soils, sediments, surface water, and groundwater by using existing data and, if required, by collecting additional data; determine the

presence, general location (if practicable), and magnitude of any DNAPL zones as defined in the Paducah SMP (DOE 2008a).

Goal 3: Determine Surface and Subsurface Transport Mechanisms and Pathways—Gather existing quality data and, if necessary, collect additional adequate quality data to analyze contaminant transport mechanisms, evaluate risk, and support an FS.

Goal 4: Support Evaluation of Remedial Technologies—Determine if the existing data are sufficient to evaluate alternatives that will reduce risk to human health and the environment and/or control the migration of contaminants off-site.

The RI was performed from January through May 2007. The focus of the BGOU RI/FS Work Plan was to collect field and analytical data necessary to determine the nature and extent of any soil and groundwater contamination originating from, and immediately under, the burial cells; support the completion of a BHHRA and SERA; and evaluate appropriate remedial alternatives (if necessary) at each of the SWMUs. The RI addresses Goals 1–3. The FS was started in 2008 to further address Goal 3 and complete Goal 4.

Waste Operations Program

The Paducah Site Waste Operations Program directs the safe treatment, storage, and disposal of waste generated before July 1, 1993, (i.e., legacy wastes) and waste from current DOE activities. Waste managed under the program is divided into the following eight categories.

(1) *Hazardous waste*—Waste that contains one or more of the wastes listed as hazardous under RCRA or that exhibits one or more of the four RCRA hazardous characteristics: (1) ignitability, (2) corrosivity, (3) reactivity, and (4) toxicity.

(2) *Mixed waste*—Waste containing both a hazardous component regulated under RCRA and a radioactive component regulated under the Atomic Energy Act.

(3) *Transuranic waste*—Waste that contains more than 100 nanocuries of alpha emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years.

(4) *Low-level radioactive waste (LLW)*—Radioactive waste not classified as high-level or transuranic.

(5) *PCB-containing and PCB-contaminated waste*—Waste containing or contaminated with PCBs.

(6) *Asbestos waste*—Asbestos-containing materials from renovation and demolition activities.

(7) *Solid waste*—Solid sanitary/industrial waste basically is refuse or industrial/construction debris and is disposed of in landfills.

(8) *PCB radioactive waste*—PCB waste or PCB items mixed with radioactive materials.

In addition to compliance with current regulations, DOE supplemental policies are enacted for management of radioactive, hazardous, PCB, PCB/radioactive, and mixed wastes. These policies include reducing the amount of wastes generated; characterizing and certifying waste before it is stored, processed, treated, or disposed of; and pursuing volume reduction and use of on-site storage, if safe and cost-effective, until a final disposal option is identified. In 2008, activities were focused on the disposal of legacy waste. A total of 97,179 ft^3 of waste were disposed. Some waste was disposed of in the

C-746-U Landfill and other waste in storage was prepared and shipped off-site. Figure 3.1 shows the legacy waste disposition quantities in 2008.

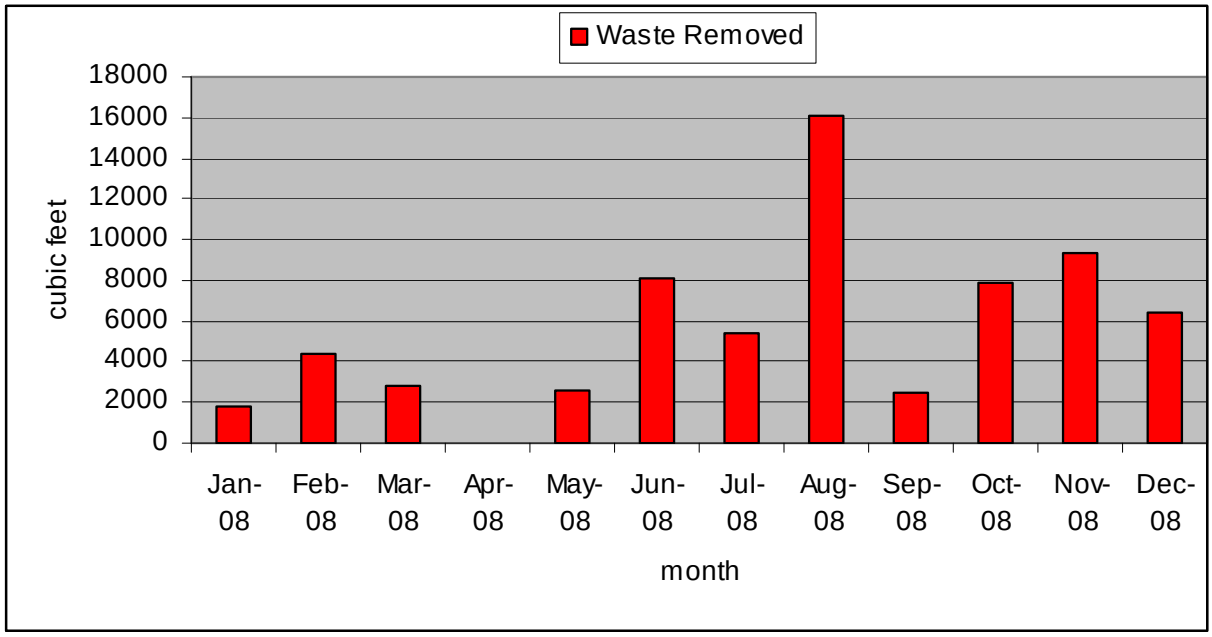

Figure 3.1. Legacy Waste Disposition during 2008

Waste Minimization/Pollution Prevention

The Waste Minimization/Pollution Prevention Program (WM/PP) at the Paducah Site provides guidance and objectives for minimizing waste generation. The program is set up to comply with RCRA and the Pollution Prevention Act, as well as applicable state and EPA rules, DOE Orders, Executive Orders, and the Site Treatment Plan. All PGDP projects are evaluated for WM/PP opportunities.

The program strives to minimize waste using the following strategies: source reduction, segregation, reuse of materials, recycling, and procurement of recycled-content products.

The program has the following goals and objectives:

- Reducing the quantity of wastes generated at their sources;
- Reusing or recycling materials;
- Identifying waste reduction opportunities;
- Integrating WM/PP technologies into ongoing projects;
- Coordinating recycling programs; and
- Tracking and reporting results.

Accomplishments of the WM/PP Program in 2008 include the following:

(1) Segregated all wastes found and/or generated to reduce the amount of LLW, mixed, hazardous, and PCB-contaminated wastes.

(2) Adhered to procedures that require employees to segregate individual items of personal protective equipment (PPE) according to the type of contaminants on them, and to place contaminated PPE into the waste containers that were the original contamination source of the PPE.

(3) Continued solid waste prevention practices which included: spent fuel filter recycling, clean scrap metal recycling, enhanced battery and electronic recycling, reuse of railroad ties, reuse of concrete test cores, reuse of waste soil as landfill cover after determination that the soil is clean by additional sampling, reuse of waste soil as a radiation shielding berm, and reuse of railroad tracks.

(4) Established collection areas for the recycling of certain items such as various types of batteries, fuses, and circuit boards.

(5) Recycled scrap metal, paper, tires, batteries, used oil, cardboard, toner cartridges, aluminum cans, and light bulbs.

(6) Utilized sustainable practices as part of purchasing activities.

The Office of the Federal Environmental Executive and EPA recognized the DOE Paducah Site as a bronze-level award winner in the 2008 Federal Electronics Challenge. The award was in recognition of the achievements in electronic stewardship actions undertaken that helped the federal government improve its sustainable practices when purchasing, managing, and disposing of their electronic assets.

Depleted Uranium Hexafluoride Cylinder Program

A product of the UE process, DUF_6 is a solid at ambient temperatures and is stored in large metal cylinders. At the end of 2008, the Paducah Site managed an inventory of approximately 38,000 cylinders containing approximately 454,000 metric tons of UF_6 (most containing DUF_6) stored in outdoor facilities, commonly referred to as cylinder storage yards. The inventory varies from time to time as a result of DOE agreements to receive or market DUF_6.

Stored as a crystalline solid at less than atmospheric pressure, when DUF_6 is exposed to moisture in the atmosphere, hydrogen fluoride and uranyl fluoride form. The uranium by-products form a hard crystalline solid that acts as a self-sealant within the storage cylinder. The acute hazard potential of DUF_6 primarily is chemical toxicity from any released hydrogen fluoride.

The mission of the DUF_6 Cylinder Program is to safely store the DOE-owned DUF_6 inventory until its ultimate disposition. DOE has an active cylinder management program that includes cylinder and cylinder yard maintenance, routine inspections, and other programmatic activities such as cylinder corrosion studies. The program maintains a cylinder inventory database that serves as a systematic repository for all cylinder inspection data.

On April 15, 1999, DOE issued the Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride (DOE 1999). In 2002, DOE selected UDS to design, build, and operate facilities at Paducah, Kentucky, and Portsmouth, Ohio. The facilities would convert the inventory of DUF_6 to triuranium octoxide, a more stable form of uranium that is suitable for disposal or reuse, and hydrofluoric acid that will be sold for commercial use.

Consistent with Public Law 107-206, construction began in July 2004 and continued through 2008. During 2008, all support structures/facilities were constructed. The majority of major operational equipment was delivered and placed. Installation of piping, electrical, and instrumentation has begun as well as bringing the site up to final grade with either rock and/or asphalt/concrete. Physical construction

of the facility was completed on December 19, 2008. Following systems testing and thorough readiness reviews, hot operation is scheduled to being in 2010 (Figure 3.2).

Figure 3.2. DUF_6 Facility Construction Activities

Decontamination and Decommissioning

D&D is conducted for inactive facilities and other structures contaminated with radiological and hazardous material. Facilities are accepted for D&D when they no longer are required to fulfill a site mission. Two major facilities comprising approximately 46,450 m^2 (500,000 ft^2) have been accepted for D&D at PGDP. These facilities are the C-340 Metal Reduction Plant complex, where UF_6 was converted to uranium metal and hydrogen fluoride, and the C-410 Uranium Hexafluoride Feed Plant complex, where uranium trioxide was converted to UF_6. Contaminants at these facilities include depleted uranium, natural uranium, transuranic radionuclides, uranium tetrafluoride, PCBs, asbestos, and lead paint.

Removal of the C-410 Complex infrastructure is being completed as a CERCLA non-time-critical removal action. Additional CERCLA documentation will be required for the C-410 Building demolition and for the C-340 Complex.

Twenty-one facilities initially were targeted for D&D by DOE. By the end of CY 2008, demolition had been completed for 13 of those facilities.

The following are significant D&D accomplishments in 2008:

- Completed structure demolition for the C-342 Ammonia Disassociator Facility on September 4, 2008.
- Scheduled two 20,000 gal tanks associated with the C-342 Facility for disposal. An on-site use for the tanks was found. The tanks were cleaned and are being reused as leachate collection tanks at the C-746-U Landfill.
- Completed structure demolition for the C-746-A West End Smelter on April 30, 2008.
- Asbestos-containing material (ACM) was removed from all but 2 of the 65 zones in C-410 Uranium Hexafluoride Feed Plant complex. As a result, approximately 30,000 ft^3 of ACM and LLW were shipped for disposal at the Energy*Solutions* Clive Operations Facility.
- A total 330 tons of inactive facilities debris was disposed of in the C-746-U Landfill in 2008.

- A total of 3,400 ft^3 of mixed, radiological and RCRA hazardous, waste was shipped from the C-410 Uranium Hexafluoride Feed Plant complex for treatment and disposal at the Energy*Solutions* Clive Operations Facility.

- Completed preparations for the demolition of the C-611 M&N Water Towers, which included all approvals, removal of ACM, and award of subcontracts.

- Received regulatory approval of the C-405 Incinerator Remedial Action Report in October 2008.

- Received regulatory approval of the C-746-A West End Smelter Removal Action Report in October 2008.

DOE Material Storage Areas

DMSAs are areas at PGDP containing uninventoried DOE material and equipment that require characterization. They are undergoing a characterization process consistent with requirements associated with nuclear criticality safety, RCRA, TSCA, and solid waste concerns. The 160 DMSAs originally were included with PGDP facilities leased to USEC. To facilitate Nuclear Regulatory Commission certification of PGDP, DMSAs were returned to DOE from USEC December 31, 1996. The DMSAs are located either in nonleased areas inside buildings leased to USEC or in nonleased outdoor areas.

The Kentucky Environmental and Public Protection Cabinet (now the Kentucky Energy and Environment Cabinet) filed an administrative complaint in October 2001 regarding the enforcement of NOVs that alleged violations of Kentucky's hazardous waste management program. Most of these NOVs alleged the failure to characterize materials in the DMSAs at PGDP or the unpermitted storage of hazardous waste in the DMSAs.

In October 2003, an AO between DOE and the Commonwealth of Kentucky was signed that resolved the administrative complaint. The AO established regulatory deadlines for characterization and removal of hazardous waste from the DMSAs and also established requirements relating to RCRA closure for the DMSAs that are found to contain hazardous waste. A total of 796,000 ft^3 of DMSA material has been disposed of/reassigned. The reassigned material includes characterized equipment that has been transferred to future D&D projects. Since the program's inception, 813,000 of 831,000 ft^3 have been characterized. Also, waste in 109 of 160 DMSAs have been dispositioned since the program's inception.

According to the 2003 AO, there were no requirements for Priority A, Priority B, or Priority C DMSAs in 2008. Requirements to complete Priority A and Priority B DMSAs were met in 2004 and 2006, respectively. The next requirement set forth in the 2003 AO is the completion of Priority C DMSAs by September 30, 2009.

DMSAs that may contain hazardous waste have a higher priority than those without it. DOE notifies the Commonwealth of Kentucky when hazardous waste is identified during the DMSA project.

Public Awareness Program

A comprehensive Community Relations and Public Participation Program exists for DOE activities at the Paducah Site. The purpose of the program is to provide the public with opportunities to become involved in decisions affecting environmental issues at the site.

Community/Educational Outreach

DOE and PRS Public Affairs supported several educational and community outreach activities during 2008. DOE managers spoke with civic groups, business leaders, and residents at prearranged events and at the regular board and task force meetings of the PGDP Citizens Advisory Board (CAB).

Citizens Advisory Board

The PGDP CAB, a site-specific advisory board chartered by DOE under the Federal Advisory Committees Act, completed its twelfth full year of operation in September 2008. During the year, the CAB held 11 regular board meetings and one retreat. The board includes three task forces and three subcommittees, which meet as necessary.

The task forces review issues for the following areas:

- Water Quality
- Waste Disposition
- Community Outreach
- Long-Range Strategy and Stewardship

All meetings are open to the public and all regular board meetings are publicly advertised. In addition to its voting members, the CAB also has liaison members representing DOE, Commonwealth of Kentucky, and EPA. In 2008, the CAB had ten voting members, four liaison members, a deputy-designated federal official, and a federal coordinator.

The CAB is composed of up to 18 members, chosen to reflect the diversity of gender, race, occupation, views, and interests of persons living near the PGDP. The CAB is committed to reflecting the concerns of the communities impacted by environmental management of the plant site. It meets monthly, except in December, to focus on early citizen participation in environmental cleanup priorities and related issues at the DOE facility. Additional information concerning the CAB may be obtained at www.pgdpcab.org.

End State Vision Document

The End State Vision Process for PGDP was initiated in 2004. The End State Vision Document was developed and issued in August 2005 as a planning tool for the site's future use. This process identifies the condition of the property after cleanup that would be protective of human health and the environment, while taking into account the future use of the property (e.g., industrial, recreational, or residential) and any potential contaminants and hazards. The process also identifies any variances between the currently planned end state and the potential alternative end state.

The *End State Vision for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky 2007 Update* (DOE/LX/07-0013&D1) which was drafted in 2007 contained the following significant changes:

- Updated information for the Surface Water OU, based on the recently completed Surface Water OU (On-Site) SI;
- Updated information for the GWOU, based on the recently initiated implementation of ROD remedy;
- Added information regarding the identification of soil and rubble areas that may contain contaminated soils or materials both on and off DOE property;

- Modified title to be consistent with the Portsmouth DOE facility document; and
- Added information regarding PGDP cleanup strategy consistent with the Site Management Plan.

SWMU 3 moved from Hazard Area 3 (BGOU Group 1) to Hazard Area 1 GWOU to be consistent with the GWOU strategy and some recently collected information regarding possible contaminant migration from this unit.

Environmental Information Center

The public has access to Administrative Records and programmatic documents at the DOE Environmental Information Center (EIC) in the Barkley Center, 115 Memorial Drive, Paducah, Kentucky. The EIC is open Monday through Friday from 8 a.m. to 4 p.m. and by appointment. The EIC's phone number is (270) 554-6979.

Documents for public comment also are placed in the McCracken County Public Library (formerly the Paducah Public Library), 555 Washington Street, Paducah, Kentucky. The library is open Monday through Thursday from 9 a.m. to 9 p.m., Friday through Saturday from 9 a.m. to 6 p.m., and Sunday from 1 p.m. to 6 p.m.

The EIC and other public Web pages related to DOE work at the PGDP can be accessed at www.prs-llc.net.

4 Radiological Effluent Monitoring

Abstract

Releases to the atmosphere from the NWPGS, NEPCS, C-301 DMSA OS-12 Waste Removal Project, the C-752-A waste management activities, and the C-746-A West End Smelter Demolition Project were estimated for 2008. The calculated emissions for each activity were less than the 40 CFR § 61, Subpart H, limit of 0.1 mrem dose to the maximally exposed individual. Dose to the public from airborne radionuclides is discussed in Section 6.

Analyses of samples of liquid effluents from PGDP indicate that detectable levels of uranium and ^{99}Tc are at levels that are protective of human health.

Introduction

Some materials like uranium, which consists of several types of radionuclides, are radioactive and give off radiation when the nucleus breaks down or disintegrates. The three kinds of radiation generated by radioactive materials or sources are alpha particles, beta particles, and gamma-rays. When ionizing radiation interacts with the human body, it gives its energy to the body tissues. The amount of energy absorbed per unit weight of the organ or tissue is called absorbed dose. Many radiation sources are naturally occurring and are considered terrestrial sources (i.e., sun, earth). The body absorbs the radiation from these terrestrial sources, as well as sources that are not naturally occurring. Radioactivity can be measured in differing units (i.e., becquerel, curies). PGDP effluents are monitored for these radionuclides that are known to be present, either now or in the past.

The monitoring program for radioactivity in liquid and airborne effluents is described fully in Paducah Site EMPs. In 2008, two separate EMPs defined the relationship of each element of the Environmental Monitoring Program. The FY 2008 EMP (PRS 2007c) was in effect and covered data collected during the time frame of January 2008 to September 2008. The FY 2009 EMP (PRS 2009) was in effect and covered data collected during the time frame of October 2008 to December 2008.

Airborne Effluents

In accordance with DOE Order 450.1, effluent monitoring is to be conducted to meet *General Environmental Protection Program Standards.* DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, sets dose standards for members of the public at 10 mrem per year from airborne releases and at 100 mrem per year through all exposure pathways resulting from routine DOE operations.

Radiological airborne releases from DOE facilities also are regulated under 40 *CFR* § 61, Subpart H, which governs radionuclide emissions, other than radon. This regulation was amended in 1989 to include specific sampling requirements for each emission point that has the potential to emit radionuclides at an effective dose equivalent of 0.1 mrem to the most potentially affected off-site resident. This refers to the resident who has the greatest chance of being affected by a release of airborne contaminants.

DOE had the sources described here of airborne radionuclides in 2008. DOE also had fugitive air sources that were measured by air monitoring stations around the site that are discussed in Section 5.

Northwest Plume Groundwater System

The CERCLA IRA ROD, signed July 22, 1993, established the NWPGS. Although administrative requirements (e.g., permits) of environmental regulations do not apply to projects conducted under CERCLA, DOE has continued to provide pertinent information about emissions to the regulators. The Operations and Maintenance Plan describes sampling and methodologies to be used at the NWPGS. The air emissions methodology is to estimate air emissions based on influent water sample results. The analysis of the air stripper influent water provides a more accurate measurement of airborne discharges than actual stack measurements due to the low, practically immeasurable, radionuclide airborne effluents associated with the facility.

On August 28, 1995, DOE began operation of the NWPGS. The facility is located just outside the northwest corner of the PGDP security area. The facility consists of an air stripper to remove volatile organics and an ion exchange unit for the removal of ^{99}Tc from water. The air stripper is located upstream of the ion exchange unit. The ^{99}Tc concentration in the influent and effluent water of the air stripper and the quantity of the water passing through the air stripper were used to calculate total potential ^{99}Tc emissions from the facility in 2008. The emissions were used to calculate dose rates associated with this operation. In 2008, releases to the atmosphere from the NWPGS were estimated to be 8.19E-5 curies (Ci) of ^{99}Tc.

Northeast Plume Containment System

The NEPCS is a CERCLA interim action to remediate contaminated groundwater. Although administrative requirements (e.g., permits) of environmental regulations do not apply to projects conducted under CERCLA, DOE has continued to provide pertinent information about emissions to the regulators. In 2008, ^{99}Tc was detected in small amounts in the groundwater that was extracted.

The wells and pumping facility are located northeast of the PGDP security area. The water is pumped to the C-637-A Cooling Tower where the contaminants evaporate from the extracted groundwater. The ^{99}Tc concentration and the quantity of the water pumped to the cooling tower were used to calculate total potential ^{99}Tc emissions from the facility in 2008. The estimated emissions from the NEPCS were estimated to be 5.13E-6 Ci of ^{99}Tc.

C-301 DMSA Outside-12

During 2008, C-301 DMSA OS-12 continued metal size reduction and packaging for off-site disposal. Figure 4.1 shows metal size reduction being performed at C-301 DMSA OS-12. Fugitive airborne radionuclide emissions may have resulted from dust created by these activities. The estimated emissions from C-301 DMSA OS-12 were 2.89E-06 Ci.

Figure 4.1. Metal Size Reduction at C-301 DMSA OS-12

C-746-A West End Smelter Demolition

During 2008, the C-746-A West End Smelter was demolished. Fugitive airborne radionuclide emissions may have resulted from dust created by demolition and removal of the debris. The estimated emissions from the C-746-A West End Smelter Demolition activities were 1.45E-04 Ci.

C-752-A Waste Management Activities

During 2008, waste containing fine particulate radioactive material was repackaged. The particulate waste was repackaged in a ventilated enclosure within C-752-A. The ventilation for the enclosure passes through high-efficiency particulate air filters and then is exhausted through two stacks. The estimated emissions from these activities were 4.89E-06 Ci.

Table 4.1 summarizes the effluent emissions that were released to the atmosphere in 2008 for each project.

Table 4.1. Airborne Effluent Results Summary

Project	Releases to Atmosphere, Ci
NWPGS	8.19E-5
NEPCS	5.13E-6
C-746-A West End Smelter Demolition	1.45E-04
C-752 Waste Management Activities	4.89E-06
C-301 DMSA OS-12	2.89E-06

The total estimated emissions in 2008 was 2.40E-04 Ci. The maximally exposed individual to all of these sources received an estimated dose of 5.5E-04 mrem, which is well below the regulated emission criteria of 10 mrem. Dose calculations based upon these atmospheric releases are discussed in Section 6.

Liquid Effluents

The CWA for the Paducah Site is administered by KDOW through the KPDES Wastewater Discharge Permitting Program. The sitewide KPDES permit (KY0004049) became effective November 1, 2006. This permit was challenged by citizen groups, DOE, USEC, and UDS; consequently, the conditions of the previous permit remained in effect, for the 2008 reporting period, except for the monitoring requirements. In addition to nonradiological parameters on the KPDES permit, specific radionuclide analyses, in addition to gross alpha and beta activity analyses, are conducted on liquid effluent samples. Grab samples and composite samples collected at weekly or monthly monitoring frequencies are used to measure discharges. Figures 4.2 and 4.3 illustrate KPDES outfalls and landfill surface water monitoring locations. Figure 4.4 shows sample collection at an outfall.

DOE Orders 450.1 and 5400.5 establish effluent monitoring requirements to provide confidence that radiation exposure limits of 100 mrem per year are not exceeded. DOE Order 5400.5 sets guidelines for allowable concentrations of radionuclides in various effluents to protect public health and requires radiological monitoring. This protection is achieved at the Paducah Site by meeting derived concentration guidelines (DCGs), which are the concentrations of given radionuclides that would result in an effective dose equivalent of 100 mrem per year. The DCGs are based on the assumption that a member of the public has continuous, direct access to the liquid effluents. In reality, exposure is not continuous; therefore, the allowable concentrations for the DCGs are very conservative. Further information on DCGs is provided in Appendix B.

For monitoring purposes, the Paducah Site uses estimates of DCG levels and outfall flow characteristics (rainfall dependent) to determine sampling frequencies. Neither continuous monitoring nor continuous sampling is required by DOE Order 5400.5. Sampling for radiological priority pollutants was not required by the KPDES permit; however, the analyses will be performed twice prior to the KPDES renewal application in May 2011.

Other radiological effluent monitoring is required by KDWM landfill permits 073-00014, 073-00015, and 073-00045 for the C-746-S, C-746-T, and C-746-U Landfills, respectively. Surface runoff is analyzed to determine if landfill constituents are being discharged into nearby receiving streams.

Outfall 001 is a continuous flow outfall that receives discharges from a variety of permitted units, including the following:

(1) USEC's C-616 Liquid Pollution Abatement Facility (LPAF), a once-through cooling water system, 0.8 million gal per day (MGD);

(2) DOE's NWPGS, 0.3 MGD;

(3) DOE's waste management activities including routinely generated C-404 treated leachate, C-733 and C-612-A sump water, and other waste management activities resulted in a cumulative discharge of approximately 40,000 gal; and

(4) DOE's discharge operations at the Northwest Stormwater Collection Basin (also referred to as the C-613 Sedimentation Basin).

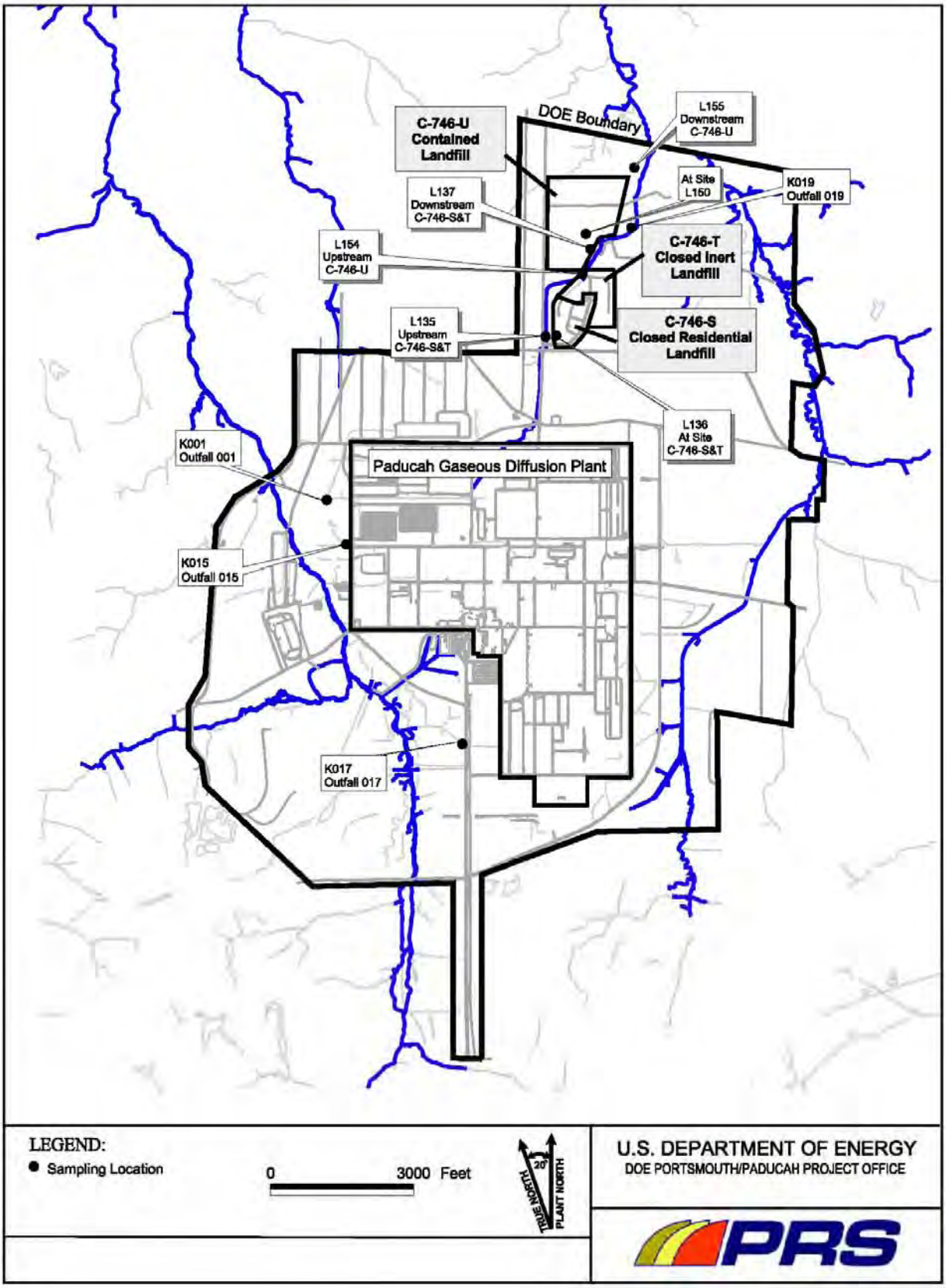

Figure 4.2. KPDES Outfalls and Landfill Surface Water Monitoring Locations through October 2008

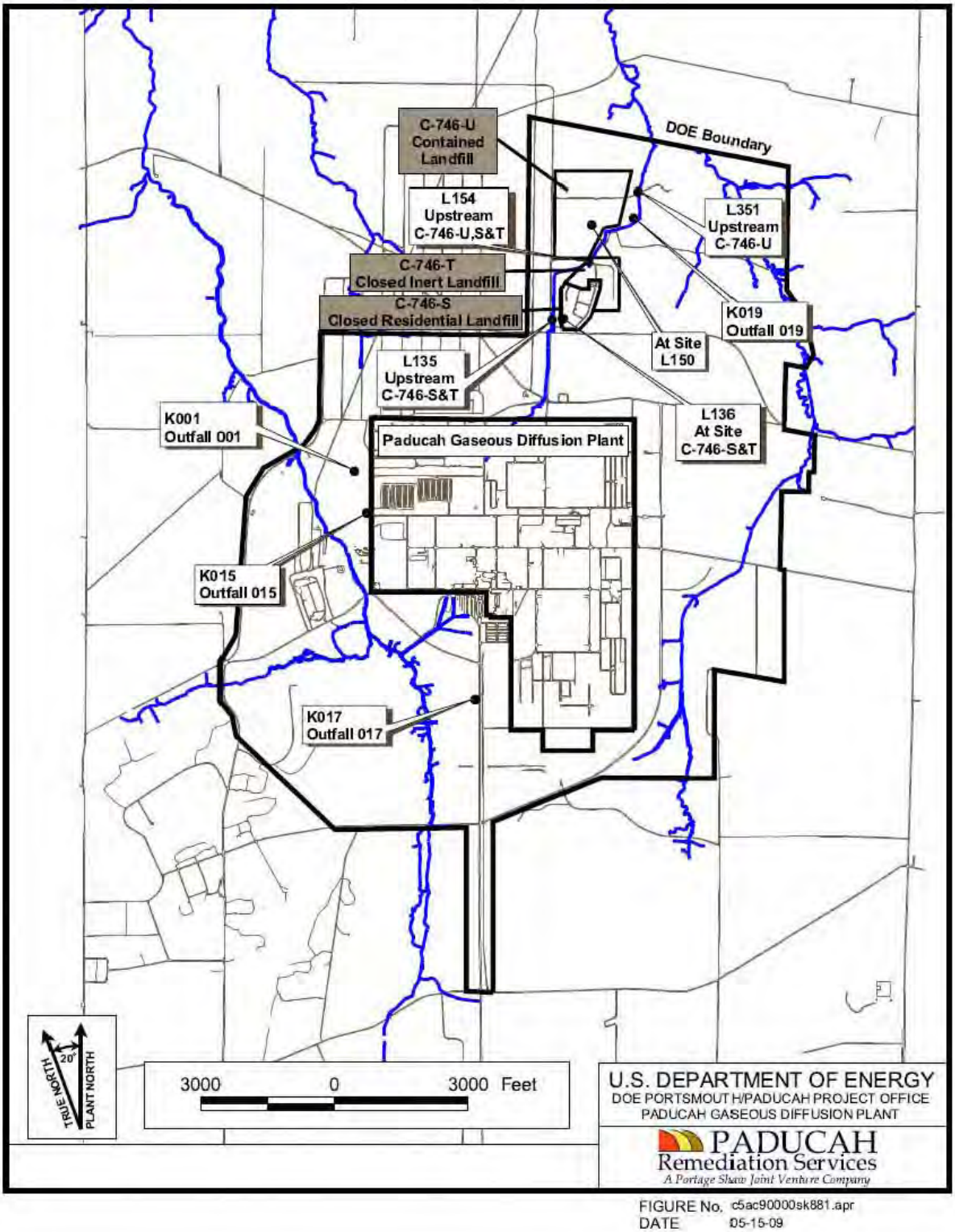

Figure 4.3. KPDES Outfalls and Landfill Surface Water Monitoring Locations from November 2008

Figure 4.4. Sample Collection at a DOE Outfall

DOE's NEPCS is treated through the C-637 Cooling Tower; the water from this is transferred to C-616 LPAF for air stripping. Next, the water is transferred by an underground pipeline to the C-616-F Full Flow Lagoon, and ultimately discharged into Outfall 001. In addition, surface-water runoff is collected in the C-613 Sedimentation Basin and then discharged into Outfall 001. The C-613 Sedimentation Basin was designed to collect surface runoff from the scrap metal yards. With the removal of waste from these areas, that source of contamination has been reduced significantly.

Outfall 015 receives surface-water runoff from the east-central sections of the plant. Outfall 017 receives surface-water runoff from the southeast section of the plant (primarily the cylinder storage yards). Outfall 019 receives surface-water runoff from C-746-U (DOE's operational nonhazardous, solid waste landfill). Radiological effluent data are presented in Section 1, Tables 1.1 through 1.4, of Volume II of this report.

Landfill Surface Runoff

Surface runoff from the closed C-746-S Residential Landfill and the C-746-T Inert Landfill is monitored quarterly. Due to their close proximity, the C-746-S&T Landfills are monitored as one landfill ("L" locations shown in Figures 4.2 and 4.3). Also, surface runoff is monitored from the operating C-746-U Contained Landfill. Surface runoff from these landfills is monitored for gross alpha and gross beta concentrations. Grab samples are taken from the landfill runoff, the receiving ditch upstream of the runoff discharge point, and the receiving ditch downstream of the runoff discharge point. Sampling is performed to comply with KDWM permit for landfill operations. Sampling data are presented in Section 1, Tables 1.5 through 1.10, of Volume II of this report.

Liquid Effluent Monitoring Results

Table 4.2 indicates the minimum, average, and maximum concentrations of uranium and maximum uranium activity concentrations discharged at each outfall monitoring location for CY 2008. A normal isotopic distribution was assumed during the conversion of uranium concentrations to uranium activities.

Table 4.2. Total Uranium Concentration in DOE Outfalls for 2008

Outfall	Number of Samples	Minimum Uranium (mg/L)	Average Uranium (mg/L)	Maximum Uranium (mg/L)	Converted Maximum Uranium Activity (pCi/L)[b]
001	55	0.001	0.0144	0.218	148
015	9	0.0669	0.137	0.343	233
017	13	0.001	0.0028	0.01	6.8
019	17	0.001	0.00651	0.0158	10.7

[a] DCG for uranium is 600 pCi/L.
[b] Maximum uranium concentration was converted to an activity basis by assuming a normal isotopic distribution (99.3% ^{238}U 0.71% ^{235}U and 0.0054% ^{234}U).

Table 4.3 indicates the minimum, average, and maximum ^{99}Tc activity concentrations discharged at each outfall monitoring location for CY 2008. These ^{99}Tc concentrations are well below the DCG of 100,000 pCi/L, and thus protective of human health.

Table 4.3. Technetium-99 Activity in DOE Outfalls for 2008

Outfall	Number of Samples	Minimum (pCi/L)[a]	Average (pCi/L)[a]	Maximum (pCi/L)[a]
001	4	-2.7	6.1	12.3
015	4	0.652	21.6	40.7
017	5	-15.2	-3.47	3.21
019	6	-8.47	-0.72	9.74

[a] DCG for ^{99}Tc is 100,000 pCi/L.

5 Radiological Environmental Surveillance

Abstract

The radiological environmental surveillance program assesses the effects of DOE's activities on the surrounding population and environment. Surveillance includes analyses of surface water, groundwater, sediment, terrestrial wildlife, direct radiation, and ambient air. Surveillance results from 2008 indicate that radionuclide concentrations in sampled media were within applicable DOE standards.

Introduction

The Radiological Environmental Surveillance Program at the Paducah Site is based on DOE Orders 450.1, *Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment.* These orders require that an environmental surveillance program be established at all DOE sites to monitor the radiological effects, if any, of DOE activities on the surrounding population and environment. Surveillance includes analyses of surface water, groundwater (Section 9), sediment, terrestrial wildlife, direct radiation, and ambient air. Surveillance results from 2008 indicate that radionuclide concentrations in sampled media were within applicable DOE standards.

Ambient Air

In accordance with the 1993 DOE/USEC lease agreement, USEC is responsible for their radionuclide airborne point-source discharges at PGDP, while DOE is responsible for the NWPGS, the NEPCS, C-405 removal activities, C-752-A waste activities, and DMSA OS-12 waste reduction and packaging activities. Using Kentucky Cabinet for Health and Family Services (KCHFS)-operated air monitors, DOE monitors fugitive emission sources such as building roof tops, piles of contaminated scrap metal, roads, concrete rubble piles, and the decontamination of machinery and equipment used in remediation activities.

DOE utilized ambient air monitoring data to verify radionuclide levels in off-site ambient air. Ambient air samples are collected at 10 sites surrounding the plant (see Figure 5.1) in order to measure the radionuclides emitted from Paducah Site sources, including fugitive emissions. The Radiation/Environmental Monitoring Section of the RHTAB of the KCHFS's Department for Public Health conducted ambient air monitoring during 2008. Based on 2008 results, plant-derived radionuclides were not detected by the RHTAB's air monitoring network. The monitoring results for 2008 are listed in Section 2, Table 2.1 of Volume II, of this report.

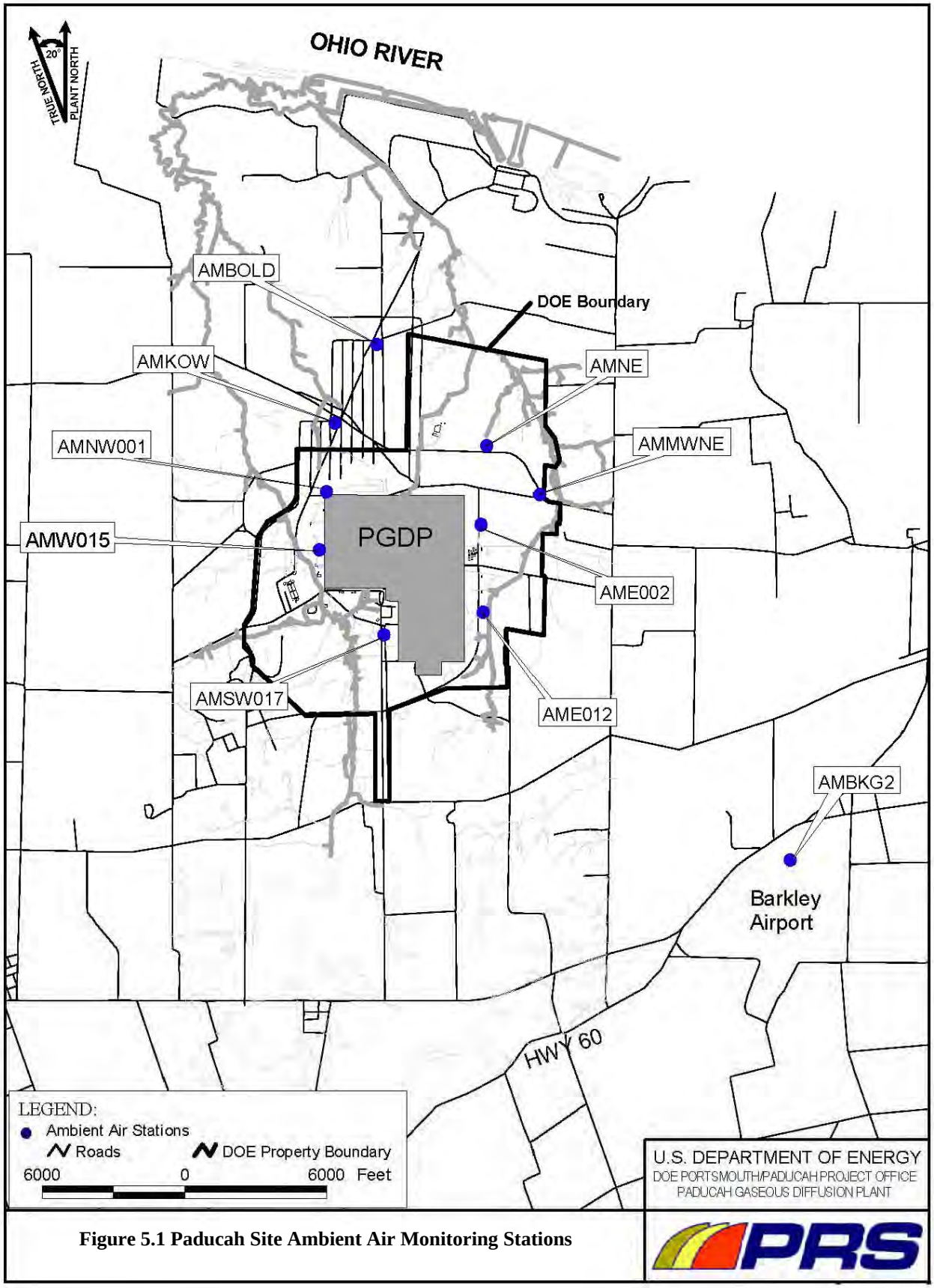

Figure 5.1 Paducah Site Ambient Air Monitoring Stations

Meteorological Monitoring

Computer-aided atmospheric-dispersion modeling uses emission and meteorological data to determine the impacts of plant operations to the community. Modeling is used at the Paducah Site to simulate the transport of air contaminants and predict the effects of abnormal airborne emissions from a given source. In addition, a multitude of emergency scenarios can be developed to estimate the effects of unplanned releases to employees and population centers downwind of the source. Historical meteorological monitoring data collected at the site, as well as regional National Weather Service meteorological monitoring data is used in the modeling analysis.

Surface Water

Paducah Site surface water runoff is released through plant outfalls either to the west in Bayou Creek or to the east in Little Bayou Creek. These merge north of the site and discharge into the Ohio River. The net impact of the Paducah Site on surface waters is evaluated by comparing data from samples collected upstream of the site to data from samples collected downstream of the site or from ecologically similar waterways that have not been impacted by PGDP activities. Bayou Creek and Little Bayou Creek are not used as drinking water supplies; therefore, EPA safe-drinking-water standards do not apply. Radioactive effluents from PGDP are managed in accordance with DOE Order 5400.5.

Table 5.1 shows the radiological analytical parameters analyzed under the quarterly surveillance surface water sampling program. This table does not include the quarterly seep locations, which are upwellings of groundwater in the Little Bayou Creek bed. The radiological contaminants of concern at PGDP are alpha, beta, and ^{99}Tc.

Table 5.1. Radiological Parameters for Surface Water Samples

Parameter	Parameter
Americium-241 (^{241}Am)	Alpha Activity
Cesium-134 (^{134}Cs)	Beta Activity
Cesium-137 (^{137}Cs)	Technetium-99 (^{99}Tc)
Cobalt-60 (^{60}Co)	Thorium-228 (^{228}Th)
Dissolved Alpha	Thorium-230 (^{230}Th)
Suspended Alpha	Thorium-232 (^{232}Th)
Dissolved Beta	Thorium-234 (^{234}Th)
Suspended Beta	Uranium (U)
Neptunium-237 (^{237}Np)	Uranium-234 (^{234}U)
Plutonium-238 (^{238}Pu)	Uranium-235 (^{235}U)
Plutonium-239/240 ($^{239/240}$Pu)	Uranium-235 (^{235}U) Activity
Potassium-40 (^{40}K)	Uranium-238 (^{238}U)

Figure 5.2 shows 20 surveillance surface water sampling and 3 seep locations. Radiological sampling is conducted at the following surface water sampling locations:

- Upstream Bayou Creek (L1);
- Bayou Creek near the plant site (C612, C616, K001UP, K015UP, S31, and L291);
- Downstream Bayou Creek (L5 and L6);
- Little Bayou Creek near the plant site (L10 and L194);

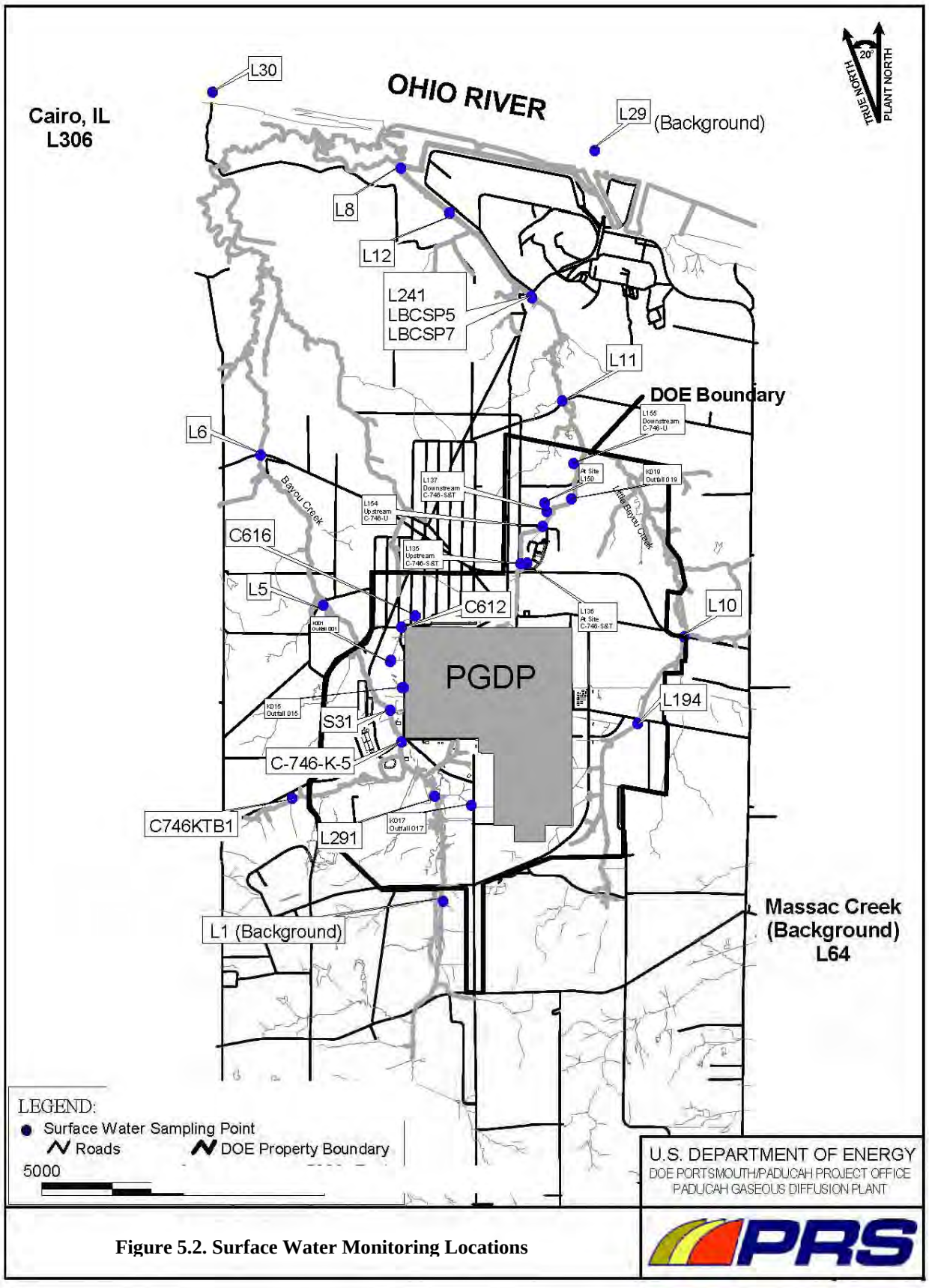

Figure 5.2. Surface Water Monitoring Locations

- Downstream Little Bayou Creek (L11, L12, and L241);

- From the C-746-K Landfill (C-746-K-5 and C746KTB1);
- Upstream Ohio River (L29);
- Downstream Ohio River (L30);
- Downstream Ohio River at the confluence with the Mississippi River (L306), which is the closest public drinking water supply intake point downstream of the plant;
- Background stream Massac Creek (L64); and
- Sampling is also performed at two seep locations, Downstream Little Bayou Creek Seeps (LBCSP5 and LBCSP7).

No sample point exists for upstream Little Bayou Creek because the flow in that part of the watershed is too low to monitor. Nearly all water in Little Bayou Creek is comprised of discharges from plant outfalls; therefore, reference water quality for Little Bayou Creek is based on Bayou Creek at station L1 (upstream Bayou Creek). Data from sampling locations, L129 (Ohio River) and L64 (Massac Creek), also are used as references for water quality in comparison to Little Bayou Creek.

Locations in Little Bayou Creek (LBCSP5 and LBCSP7), known as seeps, are upwellings of groundwater in the Little Bayou Creek bed. Two locations were chosen to sample each quarter to trend and observe changes in data. These seeps are located downstream of the plant site approximately halfway between the site and the Ohio River (Figure 5.2).

The surface water results are compared to the DCGs, which are the maximum levels that are considered protective of human health and the environment. These levels are given in DOE Order 5400.5. These values are maximum allowable concentrations calculated from the dose of 1 mrem from one isotope and one exposure pathway.

Surface Water Surveillance Results

Table 5.2 provides the average concentrations of radionuclides upstream and downstream of plant effluents in Bayou Creek, downstream of plant effluents in Little Bayou Creek; at the C-746-K Landfill; near the plant site in Bayou Creek and Little Bayou Creek; upstream and downstream in the Ohio River and at the confluence of the Mississippi River (Cairo, Illinois); and at the reference stream, Massac Creek. The table only reflects radionuclide parameters in which at least one sampling location was reported at a concentration greater than the laboratory detection limit; therefore, not all parameters listed in Table 5.1 are cited in Table 5.2. Additionally, although the table is a compilation of averaged data results, it should be noted that only detected concentrations were used in the averaging process. Therefore, there may be instances where the reported average result is the maximum reported result if all other results throughout the year were undetected for a given radionuclide.

Comparisons of downstream data to upstream data and/or reference data are one of the factors used to determine the impact of plant effluents on Little Bayou Creek and Bayou Creek. Concentrations of ^{40}K, ^{99}Tc, ^{234}Th, ^{234}U, ^{235}U, ^{238}U, and dissolved alpha and beta activities were elevated near the plant site and in downstream creek locations. In background samples from upstream Bayou Creek only ^{99}Tc was detected at levels only slightly below those found near and downstream from the plant site. It should be noted, however, that the radionuclide levels found, that could be referenced to plant operations, were well below their respective DCGs.

Table 5.2. 2008 Average Radiological Results for Surface Water Surveillance Samples[a]

Parameter (pCi/L) except where noted	DCG[b]	Up-stream Bayou[1]	Bayou near Site[2]	Down-stream Bayou[3]	Little Bayou near Site[4]	Down-stream Little Bayou[5]	C-746-K Landfill[6]	Up-stream Ohio[7]	Down-stream Ohio[8]	Cairo, IL[9]	Massac Creek[10]
Activity of U-235	--	ND	0.706	ND	0.138	ND	ND	ND	ND	ND	ND
Dissolved Alpha	--	ND	51.8	ND	ND	6.77	ND	7.55	ND	ND	ND
Suspended Alpha	--	ND	ND	ND	ND	ND	ND	12.5	ND	ND	ND
Dissolved Beta	--	ND	43.6	19.3	10.8	14.5	ND	9.33	13.2	ND	ND
Suspended Beta	--	ND	19.5	ND	ND	ND	ND	27.5	ND	8.72	ND
Potassium-40	7,000	ND	53.8	28.1	ND	34	39	ND	47.5	ND	30.5
Plutonium-239/240	--	ND	0.0837	ND	ND	ND	ND	ND	ND	ND	ND
Technetium-99	100,000	17.2	26	ND	ND	27	ND	ND	ND	ND	ND
Thorium-234	10,000	ND	60.1	ND	ND	ND	ND	ND	ND	ND	ND
Uranium (mg/L)	--	ND	0.0105	ND	0.012	0.007	ND	ND	ND	ND	0.009
Uranium	600	ND	32.7	1.68	5.87	2.99	ND	ND	ND	ND	ND
Uranium-234	500	ND	6.68	0.569	0.844	0.419	ND	ND	ND	ND	0.603
Uranium-235	600	ND	0.436	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-235 (wt %)	--	ND	0.446	ND	0.257	ND	ND	ND	ND	ND	ND
Uranium-238	600	ND	15.8	0.582	2.41	1.13	0.17	0.196	0.195	0.18	0.556

[a] = Average concentration for the seep locations (LBCSP5 and LBCSP7) are found in Table 5.3.
[b] = Derived Concentration Guide (see Liquid Effluents section for definition).
-- = DCGs for these radionuclides not provided.
ND = Not Detected
The following footnotes correspond with column titles in the above table. These are groupings of sampling locations in the area described in the title.
1 = L1 (Background)
2 = C612, C616, K001UP, K015UP, L291, S31
3 = L5, L6
4 = L10, L194,
5 = L11, L12, L241
6 = C746KTB1,C-746-K-5
7 = L29 (Background)
8 = L30
9 = L306
10 = L64 (Background)

Concentrations of radionuclides in surface water effluents at the Paducah Site and downstream of it were far below DCGs.

Table 5.3 provides the average concentrations of radiological parameters at two seep locations, LBCSP 5 and LBCSP7. Results indicate that the concentration of ^{99}Tc is higher at both seeps than at other surface water locations on Little Bayou Creek; however, these concentrations are well below the Northwest Plume Interim Remedial Action target treatment level of 900 pCi/L, and the EPA maximum contaminant limit of 900 pCi/L. Additional radiological surface water data are presented in Section 2, Tables 2.2 through 2.24 in Volume II of this report.

Table 5.3. 2008 Average Radiological Sample Results for Surface Water Seeps in Little Bayou Creek

Parameter (pCi/L)	LBCSP5	LBCSP7	DCG
Alpha Activity	-1.14	3.48	--
Beta Activity	116	52	--
Technetium-99	114	57.8	100,000
Uranium	0.125	0.0753	600

DCG levels established by DOE Order 5400.5 are screening values for the protection of human health and the environment. Radiological sample results for all surface water and seep locations sampled in 2008 were less than DCG levels.

Sediment

Sediment is an important constituent of the aquatic environment. If a pollutant is a suspended solid or attached to suspended sediment, it can settle to the bottom, be taken up by certain organisms, or become attached to plant surfaces. Pollutants transported by water can adsorb on suspended organic and inorganic solids or be assimilated by plants and animals. Suspended solids, dead biota, and excreta settle to the bottom and become part of the organic substrata that support the bottom-dwelling community of organisms. Sediments can play a significant role in aquatic ecological impacts by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels thus creating the need for sediment sampling.

Sediment Surveillance Program

Because DOE retained responsibility for historic environmental issues, ditch sediments are sampled semiannually through a radiological environmental surveillance program. Sediment samples were taken from 14 locations (Figure 5.3). Table 5.4 shows the radiological analytical parameters.

Table 5.4. Radiological Parameters for Sediment Samples

Parameter
Alpha Activity
Americium-241 (^{241}Am)
Beta Activity
Cesium-137 (^{137}Cs)
Cobalt-60 (^{60}Cs)
Neptunium-237 (^{237}Np)
Plutonium-239/240 ($^{239/240}$Pu)
Potassium-40 (^{40}K)
Technetium-99 (^{99}Tc)
Thorium-230 (^{230}Th)
Uranium (U)
Uranium-234 (^{234}U)
Uranium-235 (^{235}U)
Uranium-238 (^{238}U)

Sediment Surveillance Results

Table 5.5 shows the concentrations of radionuclides in the sediments upstream and downstream of DOE. The sample locations are similar to those of the surface water surveillance program, except for the addition of NSDD, and the deletion of the Ohio and Mississippi Rivers from sediment surveillance (Figure 5.3).

Table 5.5 only reflects radionuclide parameters in which at least one sampling location was reported at a concentration greater than the laboratory detection limit. Therefore, not all parameters listed in Table 5.4 are cited in Table 5.5. Additionally, although the table is a compilation of averaged data results, it should be noted that only detected concentrations were used in the averaging process. Therefore, there may be instances where the reported average result is the maximum reported result if all other results throughout the year were undetected for a given radionuclide.

In general, S32, within Section 3 of the NSDD, has the highest levels of most radionuclides. Section 3 is outside the security fence (Table 5.5), and access to this area is limited. This area will be the subject of a

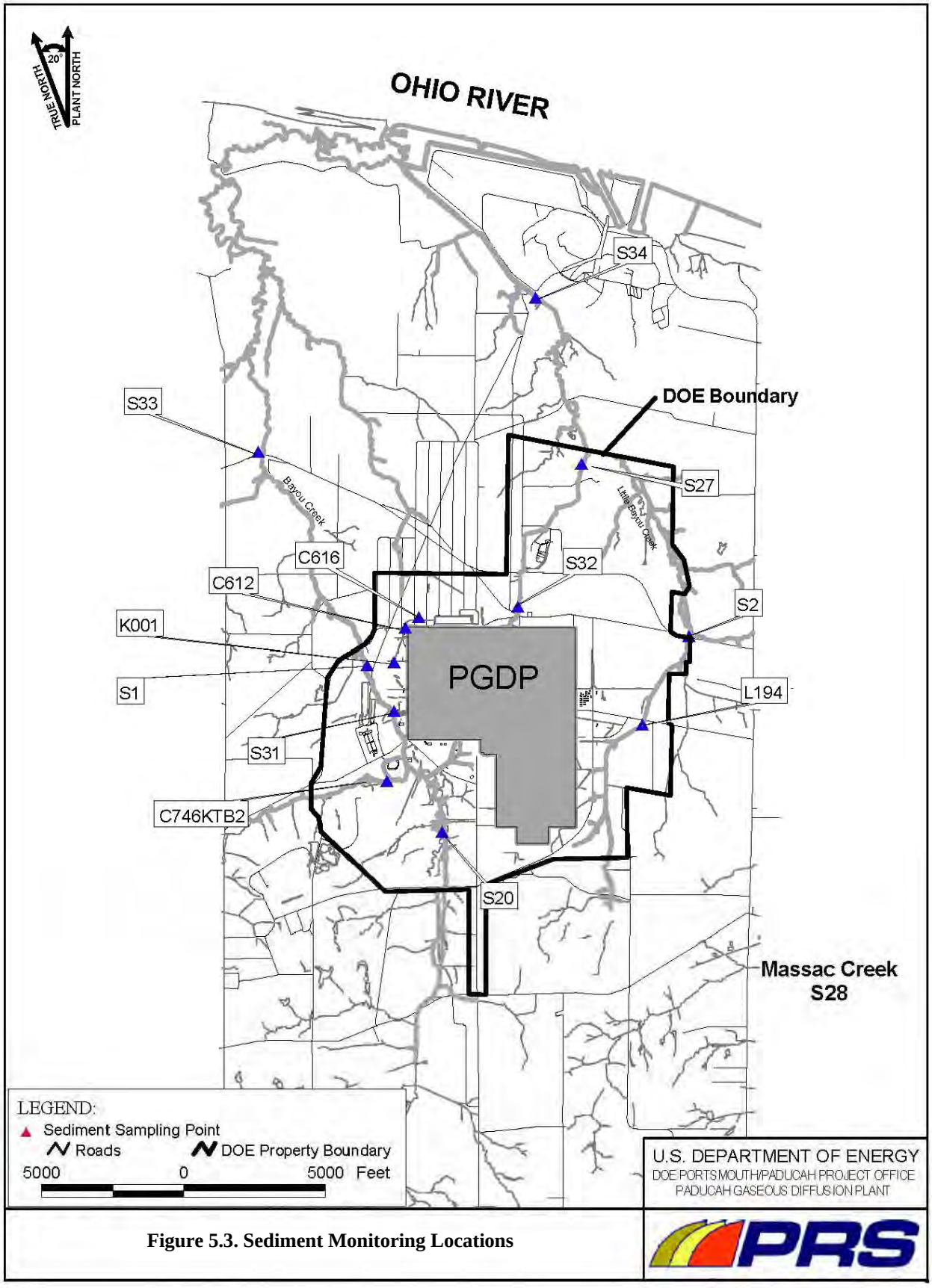

Figure 5.3. Sediment Monitoring Locations

Table 5.5. CY 2008 Average[a] Radiological Results for Sediment Surveillance Samples

Parameter	Up-stream Bayou[1]	Bayou Near Site[2]	Down-stream Bayou[3]	Little Bayou Near Site[4]	Down-stream Little Bayou[5]	C-746-K Area[6]	NSDD[7]	Massac Creek[8]
Alpha Activity (pCi/g)	3.32	9.49	3	5.3	6.73	4.06	103	3.9
Americium-241(pCi/g)	ND	0.03	ND	ND	0.0132	ND	1.03	ND
Beta Activity (pCi/g)	2.78	18.1	3.29	7.28	7	4.47	83.2	1.82
Cesium-137 (pCi/g)	ND	0.0728	0.0351	ND	0.0372	ND	0.652	ND
Neptunium-237 (pCi/g)	ND	0.099	ND	ND	0.0125	ND	1.06	ND
Plutonium-239/240 (pCi/g)	ND	0.061	0.0111	ND	0.0568	0.0322	3.26	ND
Potassium-40 (pCi/g)	7.2	5.17	3.55	3.208	3.05	3.52	6.9	2.4
Technetium-99 (pCi/g)	0.489	3.55	2.92	ND	1.28	0.329	7.58	0.654
Thorium-230 (pCi/g)	0.292	0.695	0.306	0.183	0.935	0.201	55.5	0.109
Uranium (pCi/kg)	ND	6550	1390	3320	1920	2090	10,200	ND
Uranium-234 (pCi/g)	0.127	3.46	0.637	0.494	0.44	0.852	4.4	0.0441
Uranium-235 (pCi/g)	ND	0.164	0.03	0.053	0.0336	0.0457	0.221	ND
Uranium-235 (wt%)	ND	0.823	0.634	0.307	0.371	0.591	0.605	ND
Uranium-238 (pCi/g)	0.116	2.93	0.725	2.76	1.45	0.643	5.64	ND

a = The average within each group of locations.
ND = Not Detected
The following footnotes correspond with column titles in the above table. These are groupings of sample locations in the area described in the title and are shown on Figure 5.3.

1 = S20 (Background)
2 = C612, C616, K001, S1, S31
3 = S33
4 = S2, L194
5 = S27, S34
6 = C746KTB2
7 = S32
8 = S28 (Background)

future CERCLA investigation, under the Surface Water OU, the results of which will determine if the levels of radionuclides pose an unacceptable risk to humans and/or the environment.

Uranium activity is elevated in Little Bayou Creek and Bayou Creek near the plant site and downstream. The downstream location (S34) on Little Bayou Creek corresponds with the surface water seep sites (LBCSP5 and LBCSP7) previously mentioned.

Other radionuclides, although present, are not significantly above background levels. Additional sediment data are presented in Tables 2.25 through 2.38 in Volume II, Section 2 of this report.

Areas that contain elevated radionuclide levels are controlled within the DOE property boundaries or are posted for protection of the public.

Annual Deer Harvest

In 2008, a total of five deer were harvested in the WKWMA as part of DOE's ongoing effort to monitor the effects of the Paducah Site on the ecology of the surrounding area. No reference deer were collected in 2008 due to the availability of sufficient historical data, which were used for comparison. Reference deer historically have been harvested from neighboring counties (e.g., Ballard County, Livingston County). Liver, muscle, and bone samples were analyzed for several radionuclides (^{137}Cs, ^{237}Np, ^{239}Pu, ^{99}Tc, ^{230}Th, $^{233/234}$U, ^{235}U, and ^{238}U). In addition, thyroid samples were analyzed for ^{99}Tc. Because the liver and muscle tissues are considered consumable by humans, these tissues can be evaluated for radiological risks (dose) if analyses reveal detectable levels. Bone and thyroid samples are used only as indicators of contamination.

In 2008, $^{233/234}$U and ^{230}Th were detected in the liver and $^{233/234}$U in the muscle tissue only of the sampled deer. As will be discussed in Section 6 of this ASER, dose assessments were conducted regarding the two reported radionuclides. With all conservative risk assessments considered, the deer muscle and liver are considered acceptable for consumption.

Additional deer data are presented in Section 2, Tables 2.40 through 2.43 in Volume II of this report. Section 6 of this volume, discusses dose calculations associated with eating deer from the WKWMA.

Direct Radiation

A potential concern from DOE's operations at the Paducah Site is direct external radiation exposure. External radiation exposure is defined as exposure attributed to radioactive sources outside the body (e.g., cosmic gamma radiation). Sources of external radiation exposure at the Paducah Site include the cylinder storage yards, the operations inside the cascade building, and small sources such as instrument check locations. Cylinder storage yards have the largest potential for a dose to the public because of their proximity to the PGDP security fence.

The Paducah Site EMP (PRS 2007c) established DOE's program for monitoring external gamma radiation at areas accessible to members of the public. The External Radiation Exposure Monitoring Program has the following three objectives:

(1) To establish the potential radiation dose a member of the public may receive from direct exposure to DOE operations at the boundary of the DOE perimeter fence;

(2) To establish the potential dose a member of the public may receive while visiting or passing through accessible portions of the DOE Reservation; and

(3) To calculate the radiation dose equivalent for the maximally exposed individual member of the public.

In 2008, direct radiation was monitored by quarterly placement, collection, and analysis of environmental thermoluminescent dosimeters (TLDs). These monitoring locations are shown in Figure 5.4. Monitoring results indicate that 7 of 42 locations were consistently above background levels (PRS 2008a). These locations were all at or near the PGDP security fence in the vicinity of UF_6 cylinder storage yards in areas not accessible to members of the public.

Annual dose rates for the background locations and seven locations above background were calculated. Based on the analysis of TLDs placed away from DOE property, the mean annual background exposure was determined to be 89 milliRoentgen (mR) (PRS 2008a). For each location, the mean background exposure was subtracted from the annualized total exposure to obtain a net annual exposure. The net annual exposure represents the total exposure at that location for the entire CY 2008 attributed to the Paducah Site (Table 5.6). Exposure measured at these locations is assumed to result from DOE operations. Since all of the locations shown in Table 5.6 are in areas not accessible to the public, dose from direct radiation exposure to the maximally exposed individual member of the public from DOE operations is estimated to be zero.

Dose calculations associated with direct radiation exposure are discussed further in Section 6. Additional data are presented in Volume II, Section 2 of this report.

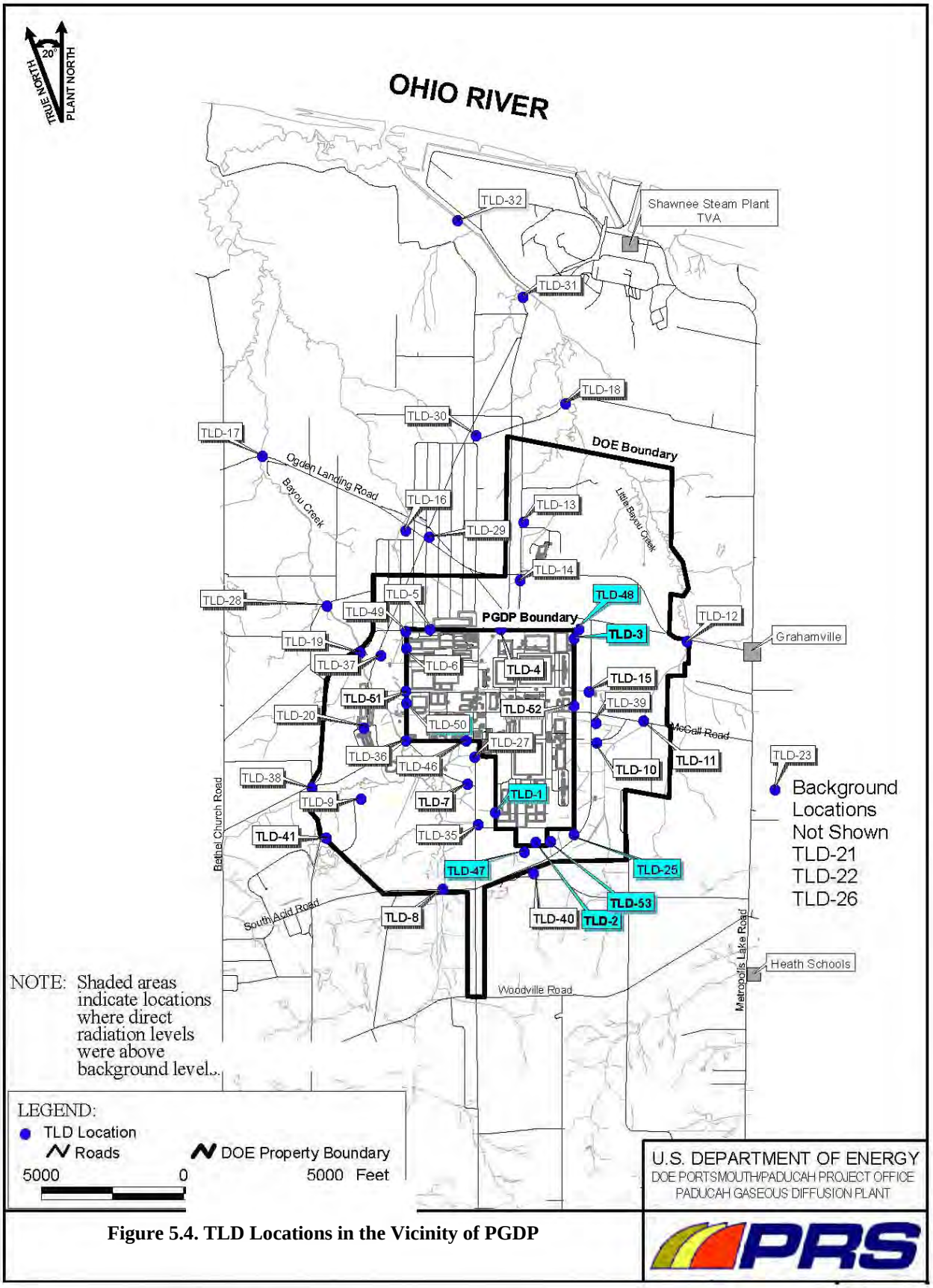

Figure 5.4. TLD Locations in the Vicinity of PGDP

Table 5.6. Net Annual Exposure from Direct Radiation Attributed to the Paducah Site for 2008 (mR)

Location	TLD-1	TLD-2	TLD-3	TLD-25	TLD-47	TLD-48	TLD-53
Total annual exposure	1,058	1,241	268	124	342	134	414
Background[a]	89	89	89	89	89	89	89
Net annual exposure[b]	969	1,152	179	35	253	43	325

[a] Background is calculated based on the analysis of TLDs placed away from DOE property (PRS 2008a).
[b] Locations with net annual exposure from direct radiation above background levels are in areas not accessible to the public.

6 Radiological Dose Calculations

Abstract

For 2008, exposure pathways potentially contributing to radiological dose include ingestion of surface water, ingestion of sediments, ingestion of deer meat, direct radiation, and atmospheric releases. The highest estimated dose a maximally exposed individual might have received from all combined DOE exposure pathways (worst-case scenario) was 0.38 mrem per year. This dose is less than 0.4 percent of the applicable federal standard of 100 mrem per year.

Introduction

This section presents the calculated radiological doses to individuals and the surrounding population from atmospheric and liquid releases from the Paducah Site, as well as from direct radiation (Sections 4 and 5). In addition, potential doses from special-case exposure scenarios, such as wildlife meat consumption, were calculated based upon deer sample analyses. Doses from naturally occurring sources are discussed in Appendix A. The highest estimated dose that a maximally exposed individual might have received from all combined DOE exposure pathways (worst-case scenario) was 0.38 mrem per year. This dose is less than 0.4 percent of the applicable federal standard of 100 mrem per year.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, limits the dose to members of the public to less than 100 mrem per year total effective dose equivalent from all pathways resulting from operation of a DOE facility. Information on the demography and land use of the area surrounding the plant was used to develop exposure pathways of concern. On-site operations were used to determine which radionuclides to evaluate.

An early preliminary assessment of risk to public health from contaminants at the Paducah Site identified the following four primary exposure routes, each of which could contribute at least 1 percent to the total off-site dose: (1) groundwater ingestion, (2) sediment ingestion, (3) wildlife ingestion, and (4) exposure to direct radiation. Since that preliminary assessment, groundwater wells that supplied drinking water downgradient from PGDP have been replaced with public drinking water, resulting in the loss of that exposure route. A drinking water pathway for consumption of surface water at the nearest public drinking water source [Ohio River at Cairo, Illinois (L306)] is included in dose calculations. Surface water is not used for drinking water in the PGDP area. Initiation of the NWPGS and the NEPCS resulted in another airborne pathway that is included in the dose calculations. In 2006, the C-301 DMSA OS-12 activities were added to the airborne dose and it remained a contributing factor in 2008 as well. Waste management activities at the C-752-A Building were added in 2008 and the demolition of the C-746-A West End Smelter was added in 2008.

To assess fully the potential dose to the public, a hypothetical set of extreme characteristics was used to postulate an upper limit to any real dose. This is referred to as the worst-case scenario. The actual dose received is likely to be considerably less than the hypothetical dose calculated.

Terminology and Internal Dose Factors

Most of the human health consequences associated with radionuclides released to the environment are caused by interactions between human tissue and various types of radiation emitted by the radionuclides. These interactions involve the transfer of energy from radiation to tissue and can result in tissue damage. Radiation may come from radionuclides outside the body or from radionuclides deposited inside the body (by inhalation, ingestion, and, in a few cases, absorption through the skin). Exposures to radiation from radionuclides outside the body are called external exposures; exposures to radiation from radionuclides inside the body are called internal exposures. This distinction is important because external exposure occurs only as long as a person is near the radionuclide; simply leaving the area of the source will stop the exposure. Internal exposure continues as long as the radionuclide remains inside the body.

Damage associated with exposures to radiation results primarily from the deposition of radiant energy in tissue. The exposure is defined in terms of the amount of incident radiant energy absorbed by tissue and the biological consequences of that absorbed energy. These terms or quantities include the following:

- *Committed effective dose equivalent (CEDE)*—the total internal dose (measured in mrem) received over a 50-year period resulting from the intake of radionuclides in a one-year period. The CEDE is the product of the annual intake (pCi) and the dose conversion factor for each radionuclide (mrem/pCi).

- *Effective dose equivalent*—includes the CEDE from internal deposition of radionuclides and the dose from penetrating radiation from sources external to the body. This is a risk-equivalent value and can be used to estimate the health risk to the exposed individual.

- *Total effective dose equivalent*—includes the sum of the effective dose equivalent (for external exposures) and the CEDE (for internal exposures). For purposes of compliance, dose equivalent to the whole body may be used as the effective dose equivalent for external exposures.

The effect of an intake of a radionuclide by ingestion depends on the concentration of the radionuclide in food and drinking water and on the individual's consumption patterns. The estimated intake of a radionuclide is multiplied by the appropriate ingestion dose factor to provide the CEDE estimate resulting from the intake. Internal dose factors for several radionuclides of interest at the Paducah Site are included in Appendix A.

Landfill Authorized Limits

DOE Authorized Limits were established for the landfill in July 2003 under DOE Order 5400.5. The limits are based on conservative modeling to assure that the annual dose to workers will not exceed 2.1 mrem per year. Other users of the reservation area around the landfill site and members of the public will not receive more than 1 mrem of additional radiation per year as a result of landfill operations. The authorized limits apply to the disposal of soil, metal, and debris wastes into the C-746-U Landfill generated from construction, maintenance, environmental restoration, and D&D activities at the PGDP.

Direct Radiation

In 2008, DOE conducted continuous monitoring for direct external radiation exposure (Section 5). Access to PGDP is limited due to the increased boundary security implemented in September 2001. The monitoring results indicate that dose to the neighbor living closest to the PGDP security fence did not vary statistically from background because of the limited access of the public to radioactive material areas (PRS 2008a).

For purposes of this ASER, an additional potential receptor was considered. In a conservative exposure scenario, this receptor is assumed to be exposed to the location at TLD-14 for 8.3 hours for the year. TLD-14 is near Harmony Cemetery, located north of the plant security fence and south of Ogden Landing Road (Figure 5.4). The 8.3 hours-per-year assumption is based on an individual driving past this location twice per day at 1 minute per trip, five days per week, 50 weeks per year. It is likely that actual exposure at this location is probably less than that assumed because shielding from the receptor's vehicle was not considered. This location's total annual exposure was 75 mrem and resulted in a calculated hypothetical external radiation exposure that is below background. Thus, based on results from this location and other data obtained from all locations, the dose to the maximally exposed individual member of the public from DOE operations was estimated to be negligible.

Surface Water

The most common surface water exposure pathway is through drinking water containing radionuclides. Surface water pathway dose was calculated for an individual assumed to consume water from the public drinking water supply at Cairo, Illinois (L306). Cairo is the closest drinking water system (approximately 30 miles downstream) that uses water downstream of PGDP effluents. Cairo is located at the confluence of the Ohio and Upper Mississippi Rivers. The average concentrations of radionuclides that were detected near the surface water collection inlet at Cairo were used to calculate the exposure resulting from consumption of surface water.

As shown in Table 5.2, only ^{238}U was detected in Cairo at an average concentration of 0.18 pCi/L. This result is well below its respective DCG level of 600 pCi/L. Although ^{238}U is an alpha emitter, no detectable concentrations of total alpha activity was reported at Cairo. Due to the low concentration of ^{238}U and a higher laboratory reporting limit for alpha activity, no concern is warranted regarding this difference. Other sources of ^{238}U other than the Paducah Site may attribute to the concentrations reported at Cairo.

For the dose calculation from this isotope, the maximally exposed receptor was assumed to consume all of his/her daily required water, 8 glasses, each containing 8 ounces (a total of approximately 2 L), 365 days a year from the public drinking water supply. The maximum dose to an individual, without subtracting the background dose, was determined to be 0.017 mrem in 2008, which is significantly less than the 100 mrem allowed by DOE Order 5400.5.

Contaminated Sediment

Exposure to contaminated sediment in Bayou Creek and Little Bayou Creek could occur during fishing, hunting, or other recreational activities. Exposure is possible through incidental ingestion of contaminated sediment. The worst-case ingestion assumption is that an adult individual would splash around in one of the creeks every other day during the season and ingest a small amount of sediment each visit (50 mg/day). A dose then is calculated based on the radionuclide concentrations and the amount of exposure via ingestion. Massac Creek samples are assumed to be background and are subtracted from downstream sample results to arrive at a dose associated with site releases. The downstream location with

the maximum dose is assumed to represent the dose received from this pathway by the maximally exposed individual.

Doses are calculated for ingestion of sediments for both Bayou Creek and Little Bayou Creek. The worst-case dose was calculated to be at S32, the NSDD (Figure 5.3). The estimated worstcase dose above background from sediment ingestion was 0.360 mrem in 2008. This exposure pathway is by far the major contributor to the worst-case combined exposure to the public, and it is significantly less than the DOE annual dose limit of 100 mrem/year. Dose results for all locations are provided in Table 6.1.

Table 6.1 2008 Annual Dose Estimates for 2008 Incidental Ingestion of Sediment from Bayou Creek and Little Bayou Creek

Location	Committed Effective Dose Equivalent (mrem)										Total (mrem)
	^{241}Am	^{137}Cs	^{237}Np	$^{239/240}$Pu	^{40}K	^{99}Tc	^{230}Th	^{234}U	^{235}U	^{238}U	
S1	--	1.92E-05	4.17E-03	5.28E-06	4.98E-04	2.83E-05	1.52E-03	5.10E-04	1.50E-04	8.44E-04	7.74E-03
S2	--	--	--	--	5.05E-04	--	7.72E-04	1.15E-04	7.11E-05	7.50E-04	2.21E-03
S20	--	--	--	--	1.22E-03	3.99E-06	1.46E-03	2.53E-05	--	2.53E-05	2.74E-03
S27	5.21E-04	--	4.83E-04	2.54E-05	4.19E-04	2.39E-05	4.35E-03	1.10E-04	8.47E-05	3.87E-04	6.41E-03
S28 (Bkgd)	--	--	--	--	4.07E-04	4.46E-06	5.47E-04	1.31E-05	--	--	9.71E-04
S31	9.39E-04	6.07E-05	5.44E-03	8.07E-05	7.61E-04	2.23E-05	8.03E-03	2.03E-03	2.49E-04	1.13E-03	1.87E-02
S32 (Max)	3.44E-02	2.98E-04	4.29E-02	1.55E-03	1.17E-03	1.01E-04	2.78E-01	1.05E-03	1.48E-04	1.23E-03	3.61E-01
S33	--	1.61E-05	--	5.27E-06	6.03E-04	3.90E-05	1.53E-03	1.52E-04	1.55E-04	1.58E-04	2.66E-03
S34	--	5.92E-06	--	2.82E-05	6.18E-04	1.03E-05	5.02E-03	9.99E-05	9.68E-05	2.42E-04	6.12E-03
C612	--	1.46E-05	1.35E-03	1.04E-05	8.53E-04	4.91E-05	1.64E-03	2.20E-04	1.66E-04	2.54E-04	4.55E-03
C616	4.35E-04	1.82E-05	4.42E-03	1.35E-05	1.39E-03	6.50E-05	2.10E-03	3.38E-04	1.62E-04	4.18E-04	9.36E-03
C746KTB2	--	--	--	8.32E-06	5.98E-04	4.41E-06	1.01E-03	1.12E-04	1.44E-04	1.40E-04	2.01E-03
L194	--	--	--	--	5.85E-04	--	1.06E-03	1.21E-04	7.90E-05	4.52E-04	2.30E-03
K001	--	1.66E-05	--	8.22E-06	9.53E-04	6.10E-05	1.83E-03	4.40E-04	2.11E-04	2.87E-04	3.81E-03
Net Exposure from Paducah Site to maximally exposed individual[a] (S32 – S28) =											0.360

--- not detected
[a] Maximum allowable exposure is 100 mrem/year for all contributing pathways (DOE Order 5400.5).

Ingestion of Deer

The effect of an intake of a radionuclide by ingestion depends on the concentration of the radionuclide in food and drinking water and on the individual's consumption patterns. The estimated intake of a radionuclide is multiplied by the appropriate ingestion dose factor to provide the CEDE estimate resulting from the intake.

Terrestrial wildlife, such as deer, can come into contact with contaminated soil, ingest contaminated plants through contaminant uptake or airborne deposition, or ingest contaminated water. Hunting is permitted in the WKWMA surrounding the Paducah Site, and the limit for deer harvest is two deer per person per season. Approximately 100 deer are harvested per year from WKWMA. The Paducah Site dose calculations assume that an individual kills two average-weight deer and consumes the edible portions of those deer during the year (approximately 100 pounds of meat and five pounds of liver). The dose is calculated for each deer sampled.

In 2008, five deer from the Paducah Site were sampled; $^{233/234}U$ was detected in the liver of two deer and muscle of one deer, and ^{230}Th was detected in the liver of one deer. The dose contribution from these isotopes using the maximum values found for calculation purposes was determined and the result was essentially 0 mrem/year.

Airborne Radionuclides

DOE had five radionuclide airborne point sources that contributed to the public dose in 2008. These sources were the NWPGS, the NEPCS, the waste activities at C-752-A, C-301 DMSA OS-12, and C-746-A West End Smelter Demolition. The five point sources were discussed in Section 4. These point-sources were reviewed or monitored to determine the extent to which the general public could be exposed and to demonstrate compliance with EPA regulations.

The 50-year CEDE (internal) from DOE air sources to the maximally exposed individual, who under most circumstances is the person living closest to the plant in the predominant wind direction, is calculated each year. EPA-supplied CAP-88 software was used to calculate the off-site dose from PGDP air emissions. This software provides a framework for developing dose and risk assessments for the purpose of demonstrating compliance with 40 *CFR* § 61.93(a). It assesses both collective populations and maximally exposed individuals. The dose to the maximally exposed individual for the plant from DOE radioactive air emissions was calculated to be 1.4E-05 mrem from the NWPGS; 2.5E-07 mrem from the NEPCS; 4.8E-04 mrem from the C-746-A West End Smelter demolition; 2.1E-06 mrem from C-301 DMSA OS-12; and 5.5E-05 mrem from C-752-A waste management activities. The maximally exposed individual to all of these sources received an estimated dose of 5.5E-04 mrem. The maximally exposed individual from all plant emissions is located 2,040 meters north of the C-400 group source (a USEC source). The dose from both DOE and USEC emissions is estimated to be 8.7E-03 mrem, which is well below the 10 mrem limit of 40 *CFR* Part 61, Subpart H.

Conclusions

Table 6.2 provides a summary of the radiological dose for 2008 from the Paducah Site that could be received by a member of the public assuming worst-case exposure from all major pathways. The largest contributor to the calculated dose is from ingestion of sediment. The groundwater pathway from DOE sources is assumed to contribute no dose to the population because DOE has supplied all residents with public water. The worst-case combined (internal and external) dose to an individual member of the public was calculated at 0.38 mrem. This level is well below the DOE annual dose limit of 100 mrem/year to members of the public and below the EPA limit of 10 mrem airborne dose to the public.

Estimates of radiation doses presented in this report were calculated using the dose factors provided by DOE and EPA guidance documents. These dose factors are based on ICRP Publication 30 (ICRP 1980). Figure 6.1 shows the potential (worst-case) annual dose as calculated for the past five years.

Table 6.2. Summary of Potential Radiological Dose from the Paducah Site for 2008 (Worst-Case Combined Exposure Pathways)

Pathway	Dose[a] (mrem/year)	Percent of total
Ingestion of surface water	0.017	5
Ingestion of sediments	0.360	95
Ingestion of deer meat	0	0
Direct radiation	0	0
Atmospheric releases[b]	5.5×10^{-4}	0
Total annual dose above background (all pathways)	**0.38**	**100**

[a] Maximum allowable exposure is 100 mrem/year (DOE Order 5400.5).
[b] DOE source emissions were from NWPGS, NEPCS, C-752-A waste activities, DMSA OS-12, and C-746-A demolition.

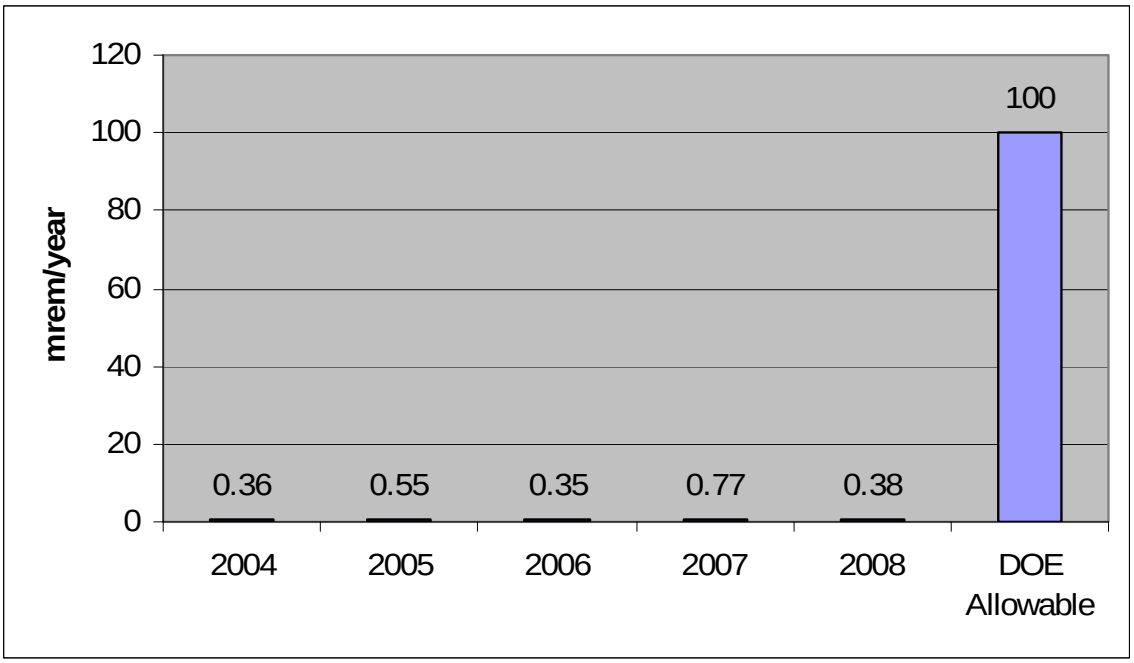

Figure 6.1. Potential Radiological Dose from DOE Activities at the Paducah Site, 2004–2008

7 Nonradiological Point Source Effluent Monitoring

Abstract

Liquid effluent monitoring was conducted at the DOE permitted outfalls and at landfill surface water runoff locations. One exceedance of the KPDES permit effluent limits occurred in 2008. The exceedance was minor and did not result in a deterioration of the stream quality. However, KDOW did issue a Notice of Violation for this exceedance of the KPDES limit with no fine or penalty assessed.

DOE had two point sources and several fugitive sources for nonradiological air emissions.

Introduction

Responsibility for nearly all nonradioactive airborne emission sources at PGDP was turned over to USEC as a result of the 1993 lease agreement between USEC and DOE. Only a few fugitive sources, such as gravel roads, soil piles (resulting from construction excavation), and two point sources, remained the responsibility of DOE in 2008. The small amount of emissions from DOE sources results in CAA classification of the Paducah Site as a minor air emissions source.

Monitoring of nonradiological parameters in liquid effluents is summarized in the Paducah Site EMP (PRS 2007c) and is based on KPDES Permit KY0004049 and KDWM landfill permits 073-00014, 073-00015, and 073-00045. Effluents are monitored for nonradiological parameters listed on the permit.

Nonradiological Airborne Effluents

Airborne Effluent Applicable Regulations

The KDAQ administers much of the CAA at the Paducah Site. DOE has responsibility only for air emission sources under DOE program control; therefore, this report does not address emissions from the PGDP sources leased to USEC.

Airborne Effluent Monitoring Program

The point sources of air emissions other than radionuclides (Section 4) for the Paducah Site in 2008 were the NWPGS and the NEPCS. These systems combined removed approximately 1,995 pounds of TCE, which is a VOC and HAP, from approximately 173,687,525 gal of groundwater. These facilities remove

TCE contamination from the groundwater by air stripping. At the NWPGS, TCE-laden air passes through activated carbon to remove TCE. The air stream then is released to the atmosphere where any remaining TCE naturally breaks down. The NEPCS uses the existing C-637-2A Cooling Tower at PGDP for stripping the TCE from groundwater. The NWPGS and NEPCS facilities operated in compliance with CERCLA decision documents during 2008.

Nonradiological Liquid Effluents

Liquid Effluent Applicable Regulations

At the Paducah Site, the CWA regulations were applied through issuance of a KPDES permit for effluent discharges to Bayou Creek and Little Bayou Creek. The KDOW issued KPDES Permit No. KY0004049 to the Paducah Site on September 29, 2006. This permit applies to the following four DOE outfalls: 001, 015, 017, and 019. The KPDES permit called for chemical monitoring and toxicity monitoring as an indicator of discharge related effects in the receiving streams. Biological monitoring (fish evaluations and analyses) was not required under the specifications listed in the renewed KPDES permit. Additionally, the watershed monitoring plan was revised to reflect the changes in the renewed permit as is further discussed in Section 9 of the ASER. The renewed permit is set to expire on October 31, 2011.

Following the issuance of the permit, several parties petitioned KDWM for a hearing on the permit. An Order to Mediate was issued by the Kentucky Environmental and Public Protection Cabinet (now named the Energy and Environment Cabinet).

An AO to settle all parties' disputes with the permit was signed on December 7, 2007. A revised KPDES permit reflecting the changes set forth in the AO will be issued; however, it was not complete at the close of 2008.

The KDWM specifies in landfill permits 07300014, 073-00015, and 073-00045 that surface runoff will be analyzed to ensure that landfill constituents are not discharging into nearby receiving streams.

Liquid Effluent Monitoring Program

DOE conducts nonradiological effluent monitoring for outfalls under its jurisdiction (Section 4, Figure 4.2). Outfalls 001, 015, 017, and 019 were monitored for KPDES permit parameters. The specific sample collection, preservation, and analytical methods acceptable for the types of constituents analyzed are listed in the permit and applicable regulations. The KPDES permit is available at the EIC, Barkley Centre, 115 Memorial Drive, in Paducah, Kentucky, for review by the public. Permit analytes and physical measurements are listed in Table 7.1. In this table, some results are not available for all parameters. This is signified by a descriptor of NR meaning that the result was "not reported" because that parameter was not required at that particular location; therefore, a sample was not collected. The ND acronym signifies that the concentration was less than the laboratory reporting limit; therefore, the result was considered "not detected."

Surface runoff from the closed C-746-S Residential Landfill, the closed C-746-T Landfill, and the operating C-746-U Landfill was monitored quarterly. Grab samples were monitored for chemical oxygen demand, chloride, conductivity, dissolved oxygen, total dissolved solids, flow rate, total iron, pH, sodium, sulfate, total suspended solids, temperature, total organic carbon, and total solids. Two sets of samples are collected; one set for the C-746-U and one set for the C-746 S&T Landfills. The samples taken include landfill runoff, the receiving ditch upstream of the runoff discharge point, and the receiving ditch downstream of the runoff discharge point (Section 4, Figure 4.2). Sampling was performed in compliance with the KDWM requirements for operation of the contained landfill.

Table 7.1. KPDES Effective Permit Sampling Routine Nonradiological Maximum Detected Analyses for CY 2008

Parameter	Permit Discharge Limits During 2008	K001	K015	K017	K019
1,1-Dichloroethene, µg/L	Report	NR	NR	0.14	NR
4,4'-DDD, µg/L	Report	0.0028	ND	0.0034	ND
4,4'-DDE, µg/L	Report	ND	ND	ND	0.0122
4,4'-DDT, µg/L	Report	ND	0.0084	0.0026	ND
Acrylonitrile, µg/L	Report	0.044	0.025	ND	ND
Aldrin, µg/L	Report	ND	ND	0.0031	ND
Alkalinity, mg/L	-	ND	20	ND	ND
alpha-BHC, µg/L	Report	ND	0.0046	0.0254	0.0016
alpha-Chlordane, µg/L	Report	ND	ND	ND	0.0033
Ammonia as Nitrogen, mg/L	Avg -3.36a/Max-10a	ND	ND	ND	0.3
Benz(a)anthracene, µg/L	Report	0.011	0.0024	0.017	ND
Benzidine, µg/L	Report	ND	0.046	0.081	ND
Benzo(a)pyrene, µg/L	Report	0.013	ND	0.027	ND
Benzo(k)fluoranthene, µg/L	Report	0.011	0.0027	0.004	ND
beta-BHC, µg/L	Report	ND	0.0083	0.0049	0.0023
Bis(2-ethylhexyl)phthalate, µg/L	Report	0.71	0.22	0.82	0.79
Cadmium, mg/L	Report	0.000073	0.000068	0.000022	0.00005
Chrysene, µg/L	Report	0.011	ND	0.018	ND
Conductivity, umho/cm	-	2760	1470	633	1427
Copper, mg/L	Report	0.0095	0.0045	0.0025	0.0017
Cyanide, mg/L	Report	0.0082	ND	ND	ND
Dibenz(a,h)anthracene, µg/L	Report	0.016	ND	ND	ND
Dieldrin, µg/L	Report	0.0039	ND	0.0032	0.0096
Dissolved Oxygen, mg/L	-	12.57	11.63	15.07	10.48
Endosulfan I, µg/L	Report	0.012	0.0058	0.0227	0.0227
Endosulfan II, µg/L	Report	ND	ND	0.0019	ND
Endrin, µg/L	Report	ND	0.007	ND	ND
Flow Rate, mgd	Report	6.06	1.325	4.375	0.8
gamma-Chlordane, µg/L	Report	0.0085	0.0015	0.0017	0.0019
Hardness—Total as CaCO3, mg/L	Report	430	180	110	530
Heptachlor, µg/L	Report	0.065	0.007	0.0449	0.002
Heptachlor epoxide, µg/L	Report	ND	ND	0.0018	ND
Indeno(1,2,3-cd)pyrene, µg/L	Report	0.015	ND	0.036	ND
Iron, mg/L	Report	ND	1.37	ND	0.606
Lead, mg/L	Report	0.00054	0.00093	0.00079	0.00036
Lindane, µg/L	Report	0.005	ND	0.0128	0.0019
Mercury, mg/L	Report	0.000029	0.000012	0.0000062	0.00000234
Oil and Grease, mg/L	Report	ND	ND	11	ND
pH, std unit	6.0<pH<9.0	8.17	8.39	8.29	7.86
Phosphorous, mg/L	1	0.55	ND	ND	ND
Selenium, mg/L	Report	0.0032	0.00076	ND	0.00083
Suspended Solids, mg/L	Avg-30b/Max-60b	49	97	15	43
Temperature, ^{o}F	89^{o}F	87.2	77.5	77.9	87.3
Tetrachloroethene, mg/L	Report	ND	ND	0.014	ND
Thallium, mg/L	Report	0.00017	0.00013	ND	ND
Turbidity, NTU	-	ND	27.1	ND	ND
Uranium, mg/L	Report	0.218	0.343	0.00579	0.0158
Zinc, mg/L	Avg-120c/Max-0.120c	ND	ND	0.16	0.0398

[a] = Per the Agreed Order, these limits have been stayed until new permit has been issued.
[b] = Per the Agreed Order, these limits have been stayed for K001, K015, and K017 until new permit has been issued.
[c] = Per the Agreed Order, these limits have been stayed for K017 until new permit has been issued. The limit for K019 is Report.
ND – not detected
NR – not reported/collected. Parameter was not required by the permit at this location.
-- - A permit limit was not established during 2008 for this parameter; however, monitoring was required for this parameter.

Liquid Effluent Monitoring Results

Analytical results from the four DOE outfalls are reported to KDOW in monthly and quarterly discharge monitoring reports. As stated above, the monitoring results for the outfalls are listed in Table 7.1.

There was one exceedance of effluent permit limits in 2008. In October 2008, the discharge from Outfall 017 had a 30-day average of 11 mg/L of Oil and Grease, which exceeded the permit limit of 10 mg/L. KDOW issued an NOV for this exceedance on June 4, 2009.

Data for the KPDES samples and the surface runoff samples from the landfills are presented in Section 3, Tables 3.1 through 3.10 of Volume II of this report.

8 Nonradiological Environmental Surveillance

Abstract

The nonradiological environmental surveillance program at the Paducah Site assesses the effects of DOE operations on the site and the surrounding environment. Surveillance includes analyses of air, surface water, groundwater (Section 9), sediment, soil, vegetation, terrestrial wildlife, fish, and other aquatic life. Surveillance results for 2008 were similar to results reported in previous ASERs.

Introduction

Nonradiological surveillance at the Paducah Site involves the sampling and analysis of surface water, groundwater, sediment, soil, terrestrial wildlife, and benthic macroinvertebrate. This section discusses the nonradiological results of surveillance activities. Surveillance results were compared to the data obtained from the background locations, as well as historical results for trending purposes.

Ambient Air

As a result of the transfer of the operations of the plant to USEC in 1993, major air emission sources were transferred to USEC; therefore, DOE does not conduct ambient air monitoring for nonradiological parameters at the Paducah Site.

Surface Water

Surface water monitoring (except for toxicity monitoring) downstream of KPDES outfalls is not required by the KPDES permit; however, it is performed at the Paducah Site as part of the Environmental Surveillance Program. Figure 5.2 shows surveillance surface water sampling locations. Table 8.1 shows the analytical parameters that are analyzed on a quarterly or semiannual basis.

As described in Section 5, locations in Little Bayou Creek (LBCSP5 and LBCSP7) were added to the surface water sampling program in 2002. These locations, known as seeps, are upwellings of groundwater in the Little Bayou Creek bed. Two locations were chosen to sample each quarter to trend and observe changes in data. These locations are downstream of the plant site approximately halfway between the site and the Ohio River (Figure 5.2). Table 8.1 does not apply to the quarterly seep locations. A different list of analytical parameters is analyzed for the seeps, as presented in Table 8.2.

Table 8.1. Nonradiological Parameters for Surface Water Samples

Parameters	
Aluminum	Nickel
Antimony	Nitrate/Nitrite as Nitrogen
Arsenic	Alkalinity
Barium	PCB Aroclors
Beryllium	pH
Cadmium	Phosphorous
Calcium	Polychlorinated biphenyl, Total
Chloride	Potassium
Chromium	Selenium
Cobalt	Silver
Conductivity	Sodium
Copper	Suspended Solids
Cyanide	Temperature
Dissolved Oxygen	Thallium
Flow Rate	Trichloroethene
Iron	Ammonia
Lead	Turbidity
Magnesium	Uranium
Manganese	Vanadium
Mercury	Zinc

Table 8.2. Nonradiological Parameters for Surface Water Seep Sample Locations

Parameters	
Chloride	1,1-Dichloroethene
Sulfate	1,2-Dichloroethane
Alkalinity	1,2-Dimethylbenzene
Conductivity	Benzene
Dissolved Oxygen	Bromodichloromethane
pH	Carbon tetrachloride
Temperature	Chloroform
Calcium	*cis*-1,2-Dichloroethene
Magnesium	Ethylbenzene
Manganese	m,p-Xylene
Potassium	Tetrachloroethene
Sodium	Toluene
1,1,1-Trichloroethane	*trans*-1,2-Dichloroethene
1,1,2-Trichloroethane	Trichloroethene
1,1-Dichloroethane	Vinyl chloride

Surface Water Surveillance Results

Table 8.3 shows a water chemistry comparison between upstream and downstream locations associated with the plant by presenting the average of maximum concentrations of selected parameters. Selected parameters include only the parameters in which at least one result was reported above the laboratory detection limits.

Reportable concentrations of TCE were detected in background samples. Since TCE was a commonly used solvent in industrial settings, it is not a contaminant considered to be solely associated with the site. Though TCE

was reported at some of the surface water sample locations, only the sample collected downstream on Little Bayou Creek was reported at a concentration greater than the background value. The maximum average concentration at this site was 39.3 micrograms per liter (µg/L) which is similar to previous reporting years.

Table 8.3. Selected Routine Nonradiological Surface Water Surveillance Results (average of maximum results) for 2008[a]

Parameter (mg/L) except where noted	Up-stream Bayou[1]	Bayou near Site[2]	Down-stream Bayou[3]	Little Bayou near Site[4]	Down-stream Little Bayou[5]	C-746-K Landfill[6]	Up-stream Ohio[7]	Down-stream Ohio[8]	Massac Creek[9]	Cairo, IL[10]
Alkalinity	13.2	24.5	24	20	17.2	22.8	17.8	17.5	16.9	90.5
Aluminum	0.864	0.8	2.43	1.11	2.02	2.67	5.6	3.52	0.593	3.34
Ammonia Nitrogen	ND	0.75	0.14	ND	ND	0.22	0.12	0.215	ND	ND
Barium	0.0512	0.135	0.0457	0.0533	0.0794	0.0499	0.0745	0.062	0.0442	0.05835
Beryllium	ND	0.00609	ND	0.00604	ND	ND	ND	ND	ND	0.00102
Calcium	15.6	120.8	51.5	22.8	35	19.4	34.7	35.6	12	35.8
Chloride	11.2	237.5	95.2	40	28	20.2	19	20.2	14	22
Cobalt	ND	0.00169	ND	ND	0.00216	ND	0.0102	0.00176	ND	0.00117
Conductivity (umho/cm)	220	2390	964	456	354	279	334	349	497	380
Copper	ND	0.011	0.00571	ND	ND	0.00753	ND	ND	ND	0.0142
Dissolved Oxygen	8.61	9.52	11	8.52	9.41	9.37	8.61	8.29	10.2	5.92
Flow Rate (mgd)	1.43	3.26	9.41	1.7	2.06	5.35	ND	ND	4.3	ND
Hardness—Total as CaCO3	56	540	226	101	114	72.6	129	137	43.5	140
Iron	0.518	0.587	1.7	0.827	1.27	0.805	6.88	3.7	0.925	3.18
Lead	ND	ND	ND	ND	ND	ND	0.0117	ND	ND	0.0076
Magnesium	3.62	55.6	25.3	9.52	7.56	5.19	10.8	11.1	2.83	11.9
Manganese	0.0946	0.0706	0.0605	0.0509	0.209	0.0451	0.359	0.208	0.218	0.132
Nickel	ND	0.0119	0.00714	ND	ND	ND	ND	0.00642	ND	ND
Nitrate as Nitrogen	0.868	5.98	1.92	0.84	0.988	0.73	0.67	0.738	0.582	0.948
pH (Std Unit)	7.6	8.42	7.5	7.87	7.54	7.71	7.77	7.83	7.85	7.96
Phosphorous	0.137	0.553	0.293	0.38	0.185	0.143	0.37	0.37	0.09	0.273
Potassium	3.32	34.8	13.2	3.64	3.19	3.82	3.43	3.24	2.11	3.52
Selenium	ND	0.00537	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	21.5	267	101	48.2	36	26.3	16.2	17	12.3	18
Suspended Solids	NR	18	17	21	59	NR	379	75.5	NR	176
Temperature (°F)	60.5	73.2	65.2	70.1	60.6	63.3	63.2	64.8	55.8	63.3
Trichloroethene (µg/L)	1.85	2.2	ND	ND	39.3	ND	ND	ND	ND	ND
Uranium	ND	0.0105	0.0022	0.0135	0.007	ND	ND	ND	0.009	ND

[a] = The results presented in the table are the average values for the locations within the area grouping using the highest value for each location in the average calculations.
ND = not detected
NR = not reported
The following footnotes correspond with column titles in the above table. These are groupings of sampling locations in the area described in the title. See Figure 5.2 for sampling locations.

1 = L1 (Background)
2 = C612, C616, L291, S31, K001UP, K015UP
3 = L5, L6
4 = L10, L194
5 = L11, L12, L241
6 = C746K-5, C746KTB1
7 = L29 (Background)
8 = L30
9 = L64 (Background)
10 = L306

Table 8.4 presents the average of maximum concentrations of selected parameters for the seep sampling locations. As in Table 8.3, selected parameters are those where at least one result was above the laboratory detection limit. Results were compared to the Downstream Little Bayou results which are in Table 8.3 since this location is downstream of the seep locations. The only parameter that was significantly different as a result of this comparison was TCE; however, the TCE results do not vary greatly compared to previous years' reports. There were no detections of PCBs in these seep samples for a third consecutive year.

Additional data are presented in Section 4, Tables 4.1 through 4.23, of Volume II of this report.

Table 8.4. Selected Routine Nonradiological Surface Water Seep Sampling Surveillance Results (average of maximum concentrations) for CY 2008[a]

Parameter	LBCSP5	LBCSP7
Alkalinity (mg/L)	17	14.5
Calcium (mg/L)	23.7	25.6
Chloride (mg/L)	29.5	32.5
Conductivity (umho/cm)	344	362
Dissolved Oxygen (mg/L)	3.4	3.08
Magnesium (mg/L)	7.88	8.86
pH	6.86	6.55
Potassium (mg/L)	1.75	1.81
Sodium (mg/L)	32.5	33.2
Sulfate (mg/L)	17	20
Temperature (°F)	59.6	58.8
Trichloroethene (µg/L)	365	155

[a] = The results presented in the table are the average values for the locations using the highest value for each location in the average calculations.
NR = Sample not collected at by the sampling personnel.
Seep sampling is representative of groundwater. Seep sampling results are compared to groundwater maximum contaminant levels for evaluation. Sample results for TCE at a surface water location downstream of the seeps at L241 showed levels less than the KPDES permitted level.

Sediment

Sediment is an important constituent of the aquatic environment. If a pollutant is a suspended solid or is attached to suspended sediment, it can settle to the bottom (thus creating the need for sediment sampling), be taken up by certain organisms, or become attached to plant surfaces. Pollutants transported by water can adsorb either on organic and inorganic solids or be assimilated by plants and animals. Suspended solids, dead biota, and excreta settle to the bottom and become part of the organic substrata that supports the bottom dwelling community of organisms. Sediments can play a significant role in aquatic ecological impacts by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels.

Sediment Surveillance Program

Creek and ditch sediments are sampled semiannually as part of a nonradiological environmental surveillance program. Sediment samples were taken from 14 locations in 2008 (Figure 5.3). Sediments were sampled for the parameters listed in Table 8.5.

Table 8.5. Semiannual Nonradiological Parameters for Sediment Samples

Parameter		
Aluminum	Lead	Vanadium
Antimony	Magnesium	Zinc
Arsenic	Manganese	PCB-1016
Barium	Mercury	PCB-1221
Beryllium	Nickel	PCB-1232
Cadmium	Potassium	PCB-1242
Calcium	Selenium	PCB-1248
Chromium	Silver	PCB-1254
Cobalt	Sodium	PCB-1260
Copper	Thallium	PCB-1268
Iron	Uranium	Polychlorinated Biphenyl

Sediment Surveillance Results

Table 8.6 shows the average values for locations within the area group for specific parameters. Some of the 14 locations were consolidated for reporting purposes within this document so that a more comprehensive profile could be developed for comparison purposes. These consolidation summaries are listed in the footnote section of Table 8.6.

Only the parameters that had detected results are shown. The upstream (or background) and downstream results for detected parameters are compared to identify concentrations above background. Aluminum, barium, calcium, chromium, cobalt, copper, iron, lead, magnesium, sodium, and zinc were detected at all sites. The highest levels of metals were seen at the NSDD and Bayou Creek near the plant site.

Near the plant site in Bayou and Little Bayou Creeks, downstream in Little Bayou Creek, in the C-746-K Landfill area, and in the NSDD, chromium was reported at concentrations above background. Chromium has also been reported as an increased inorganic constituent in previous years' reports. Lead was reported in 2007 at a concentration of 52.5 mg/kg near the plant site in Bayou Creek. Although not reported at any sample location in 2008, it has been a reported parameter in past years at this same location point.

PCBs were found in the NSDD and Bayou Creek near the plant site and Little Bayou near the plant site, with the highest levels seen in Bayou Creek. The aroclors present were PCB-1254 and PCB-1260. Additional sediment data are presented in Section 4, Tables 4.24 through 4.37, of Volume II of this report. PCB results are consistent with levels seen in previous years' data. The PCB-contaminated areas either are within the DOE-controlled area or are posted for protection of the public.

No regulatory criteria is established for any parameters for the sediment matrix; however, a comparison of the results are made to previous year's reports for trending purposes.

Table 8.6. Selected Routine Nonradiological Sediment Surveillance Results (average of maximum concentrations) for 2008[a]

Parameter (mg/kg) except where noted	Upstream Bayou[1]	Bayou Near Site[2]	Downstream Bayou[3]	Little Bayou Near Site[4]	Downstream Little Bayou[5]	C-746-K Area[6]	NSDD[7]	Massac Creek[8]
Aluminum	3860	4980	2630	3290	3390	3300	8850	1990
Barium	47	60.2	22.9	39	25.8	24	58.2	21.6
Beryllium	ND	0.661	ND	ND	ND	ND	0.556	ND
Calcium	330	2350	464	726	489	674	2600	200
Chromium	6.22	15.1	6.6	12.6	19.7	16.2	31.2	4
Cobalt	3.43	4.94	2.69	3.79	2.66	3.05	4.84	ND
Copper	3.77	20.2	4.13	5.64	3.67	4.5	24.3	ND
Iron	4200	13000	3980	5460	4100	7420	8120	3610
Magnesium	444	724	287	376	267	292	938	193
Manganese	78	300	49.1	188	96.4	146	150	154
Mercury	0.012	0.299	ND	0.02	ND	0.02	0.122	ND
Nickel	5.46	13.59	ND	ND	ND	5.06	22.7	ND
PCB-1254 (µg/kg)	ND	580	ND	120	ND	220	380	ND
PCB-1260 (µg/kg)	ND	700	ND	170	ND	ND	300	ND
Polychlorinated biphenyl (µg/kg)	ND	1280	ND	220	ND	220	680	ND
Potassium	200	439	170	152	178	225	788	148
Sodium	ND	207	ND	ND	ND	ND	ND	ND
Vanadium	9.62	18.2	8.4	8.9	6.84	13	17.4	6.36
Zinc	ND	69.7	ND	45.8	ND	22.2	76.7	ND

[a] = The results presented in the table are the average values for the locations within the area grouping using the highest value for each location in the average calculations.

ND = not detected

The following footnotes correspond with column titles in the above table. These are groupings of sampling locations in the area described in the title. See Figure 5.3 for sampling locations.

1 = S20 (Background)
2 = C612, C616, K001, S1, S31
3 = S33
4 = S2, L194
5 = S27, S34
6 = C746KTB2
7 = S32
8 = S28 (Background)

Soil

The major source of soil contamination is deposition from air pathways. Because DOE no longer operates any major air emission sources, routine soil surveillance is not performed; however, surface soil contamination at the Paducah Site is being addressed by the Surface Soils OU (see Environmental Restoration Program in Section 3).

Vegetation

Because DOE no longer operates any major air emission sources, routine vegetation surveillance activities are not performed.

Terrestrial Wildlife

Annual Deer Harvest

The deer population in the WKWMA is sampled annually to determine levels of radionuclides (Section 5), PCBs, and inorganic elements that might be attributable to past plant practices. There were five deer harvested in 2008 from the WKWMA and one deer harvested in 2002 from the Stewart Island Habitat Reservation in Livingston County, Kentucky, to serve as a reference sample.

A comparison of the metals detected in the 2008 deer with the average chemical data from background deer collected over the past 10 years shows no chemicals significantly above background. Overall, evaluation of the results indicates that deer consumption is not a threat to human health.

Additional deer data are presented in Section 4, Tables 4.38 through 4.41, of Volume II, of this report.

Fish and Other Aquatic Life

Starting in 1987, aquatic or biological monitoring of Bayou Creek and Little Bayou Creek had been conducted following guidelines set forth in the Watershed Monitoring Program (WMP). The criteria in the WMP were established by the KPDES permit. In September 2006, the KDOW issued a renewed KPDES permit for PGDP to DOE, PRS and UDS with an effective date of November 1, 2006. It required that a revised Watershed Monitoring Plan be submitted to KDOW by December 1, 2006, removing the fish sampling from the program due to previous extensive sampling. Further fish collection could have a deleterious effect on the aquatic community. Therefore, the 2007 WMP removed the fish community and the fish tissue sampling (bioaccumulation). Toxicity and benthic macroinvertebrate monitoring were conducted, as required, by the KPDES permit.

Warning signs along Bayou and Little Bayou Creek remain in order to warn members of the public about the possible risks posed by recreational contact with these waters, stream sediments, and fish caught in the creeks.

Study Area and Methods

Benthic macroinvertebrate samples were collected with a Surber square-foot bottom sampler from appropriate locations within a designated riffle at each site. Samplers selected locations within the reaches of the stream and samples were processed in a laboratory following EPA methods. Sampling locations are identified in Figure 8.1. The Modified Hilsenhoff-Biotic Index was used to evaluate the water quality of the sample locations based on the presence or absence of specific macroinvertebrates. Organisms were identified to the lowest practical taxon and counted. Instream and riparian habitat and water quality were assessed at each site following standard procedures outlined by the EPA. An analysis of the data includes general descriptive comparisons and parametric statistics to evaluate trends in temporal and spatial changes that could be associated with abatement activities or remedial actions. Metrics of the benthic macroinvertebrate community are included in the analysis of the data presented in the *Watershed Monitoring Report Letter, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2008b). Some of the metrics included are as follows:

- Total density;
- Total taxonomic richness;
- Taxonomic richness of the pollution-sensitive *Ephemeroptera, Plecoptera,* and *Trichoptera*;

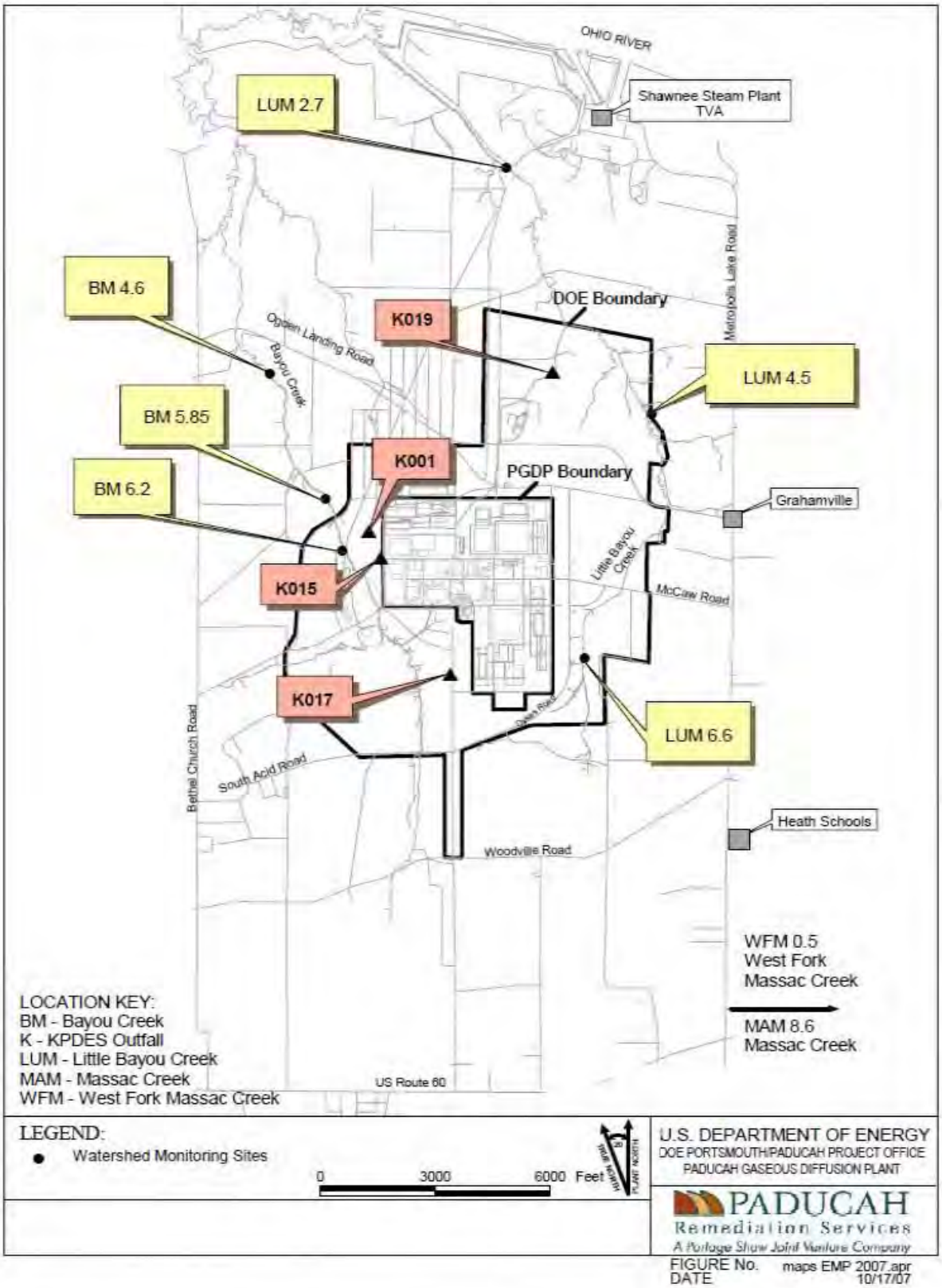

Figure 8.1. Biological Monitoring Locations

- Percent community similarity index; and
- Dominants in common.

Watershed Monitoring

Based on previous extensive sampling, enough historical data had been collected in order to make an informed decision in the event of an inadvertent spill or fish kill. Benthic macroinvertebrate sampling remains in the program documenting the habitat, identification, and enumeration of the benthic macroinvertebrate. Toxicity sampling was conducted and was discussed in Section 2 of this document.

The majority of habitats for the benthic macroinvertebrates were found to be suboptimal or marginal which are the middle rankings on a four-level ranking system. The few poor rankings, bottom end of ranking system, were received for some habitats due to poor pool variability and hard surface areas, which resulted in limited root matting systems. The types of benthic macroinvertebrate identified were typical of previous year's findings.

The objectives of the WMP are as follows:

- Determine whether discharges from the Paducah Site and its associated SWMUs are adversely affecting instream fauna;
- Assess the ecological health of Bayou Creek and Little Bayou Creek;
- Assess the degree to which abatement actions ecologically benefit Bayou Creek and Little Bayou Creek;
- Provide guidance for remediation; and
- Provide an evaluation of changes in potential human health concerns.

9 Groundwater

Abstract

The primary objectives of groundwater monitoring at the Paducah Site are to detect contamination and provide the basis for groundwater quality assessments, if contamination is detected. Monitoring includes the exit pathways at the perimeter of the plant and off-site water and monitoring wells. Primary off-site contaminants continue to be TCE, an industrial degreasing solvent, and ^{99}Tc, a fission by-product. Evidence suggests the presence of TCE as a DNAPL in groundwater beneath the site.

Introduction

Monitoring and protection of groundwater resources at the Paducah Site are required by federal and state regulations and by DOE Orders. Groundwater is not used for on-site purposes and when off-site contamination from the Paducah Site was discovered in 1988, DOE provided an alternate water supply to affected residences.

A CERCLA/ACO SI, completed in 1991, determined the primary off-site contaminants in the RGA to be TCE and ^{99}Tc. TCE was used until 1993 as an industrial degreasing solvent and ^{99}Tc is a fission by-product contained in nuclear power reactor returns that were brought on-site through 1976 for re-enrichment of ^{235}U (DOE 2001). Such reactor returns no longer are used in the enrichment process; however, ^{99}Tc still is present in the system. Known or potential sources of TCE and ^{99}Tc include former test areas and other facilities, spills, leaks, buried waste, and leachate derived from contaminated scrap metal.

Investigations of the on-site source areas of TCE at the Paducah Site are ongoing. The main source of TCE contamination in the groundwater is near the C-400 Cleaning Building. TCE belongs to a class of contaminants called DNAPLs, which are characterized by higher density, relative to water, and low solubility. DNAPLs typically sink through the subsurface and may form pools in less permeable layers of the subsurface, as well as the base of the aquifer. This physical nature of DNAPLs makes treatment difficult because these pools constitute a continuous source of dissolved-phase contamination (i.e., plumes) deep within the aquifer. The highest concentration of DNAPL at the Paducah Site is associated with past activities at C-400.

Continued groundwater monitoring serves to detect the extent of contamination, identify the fate of the contaminants, and determine the movement of groundwater near the plant. Figure 9.1 presents the latest maps (CY 2005) of the TCE and ^{99}Tc plumes associated with PGDP.

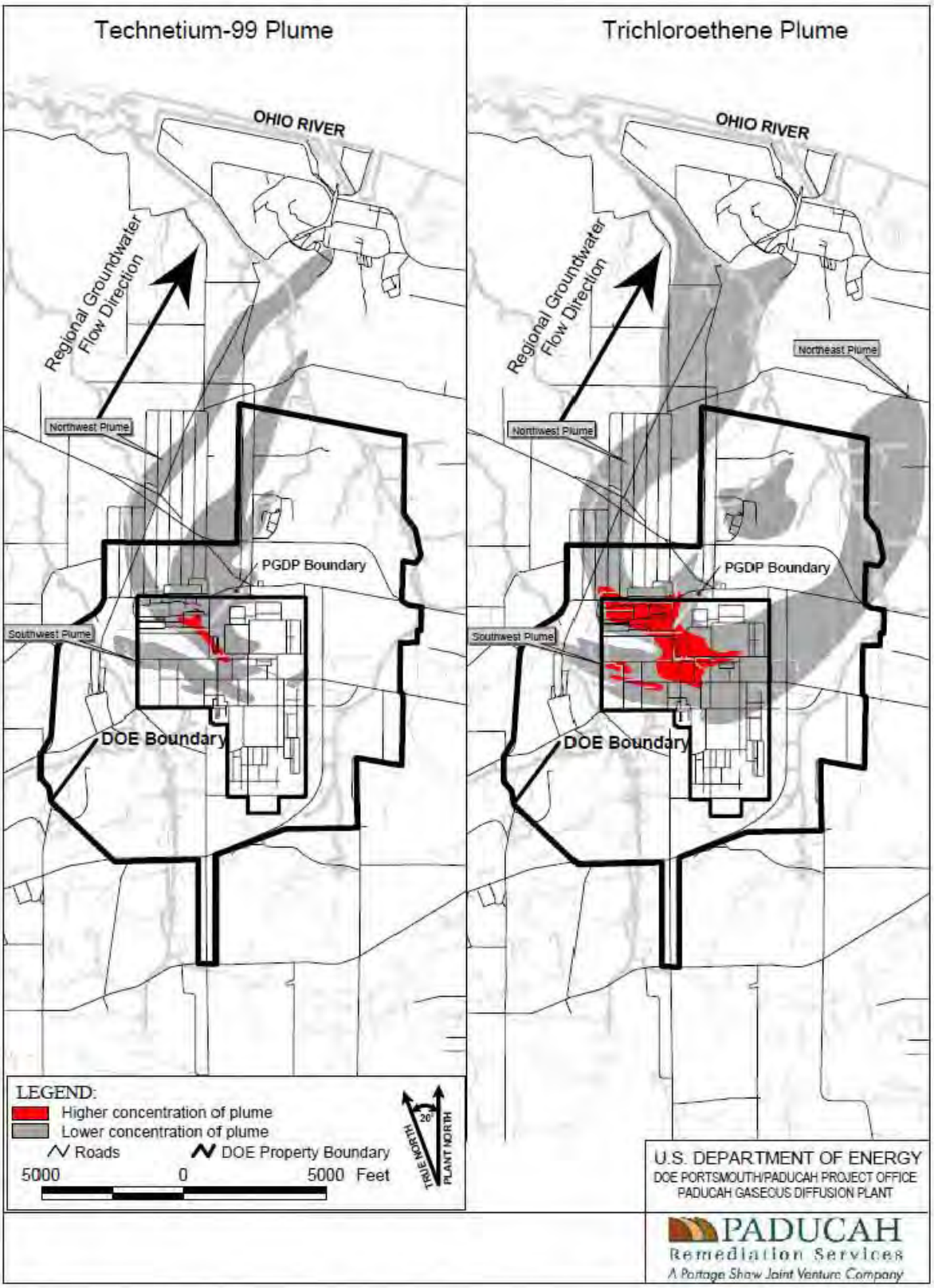

Figure 9.1. Estimated Off-Site Extent of Groundwater Plumes, 2005

Groundwater Hydrology

When rain falls to the ground, some of it flows across the surface eventually entering streams or lakes, some of it is used by plants, some evaporates and returns to the atmosphere, and some sinks into the ground. The water that sinks into the ground infiltrates the spaces between the particles of soil and rock. Groundwater is stored in and moves slowly through an aquifer. Aquifers typically consist of layers of sand and gravel or porous (sometimes fractured) rock. The speed that groundwater flows through the subsurface depends on the porosity of the soil or rock and how well the spaces are connected. Hydraulic conductivity is the physical property that describes the ease with which water can move through the pore spaces and fractures in soil, gravel, sand, and rock.

The area in the subsurface where water fills these pore spaces is called the saturated zone (Figure 9.2). The top of the saturated zone is the water table, which is the boundary between the unsaturated and saturated zones. This boundary generally gently mirrors the surface topography and is higher at natural exits such as springs, swamps, and beds of gaining streams and rivers. Groundwater can be brought to the surface naturally, either through discharge as a spring or as flow into lakes and streams, or it can be extracted through a well drilled into the aquifer. A well is a pipe/screen assembly in the ground that fills with groundwater, which then can be brought to the surface using a pump.

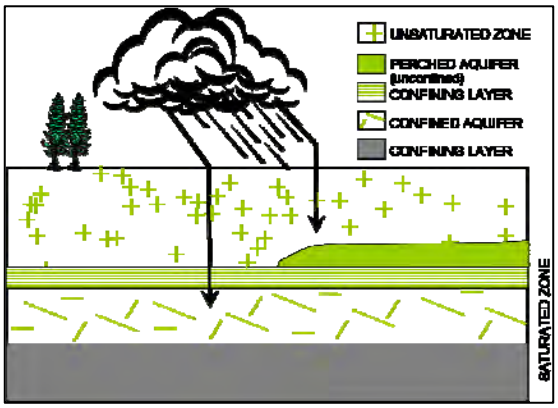

Figure 9.2. Typical Path for Rainwater Accumulation as Groundwater

Monitoring wells are used extensively at the Paducah Site to assess the effect of plant operations on groundwater quality. Wells positioned to sample groundwater flowing away from a site are called downgradient wells, and wells placed to sample groundwater flowing toward a site are called upgradient wells. Any contamination in the downgradient wells that is not present in the upgradient wells may be the result of that site.

Groundwater movement is determined by differences in the elevation of the top of the groundwater column at a specific location compared to the elevation elsewhere. This is called hydraulic head. Hydraulic head is considered to be the total energy in any water mass resulting from three components: pressure, velocity, and elevation. Water will rise in a well casing in response to the pressure of the water surrounding the well's screened zone. The depth to water in the well is measured and the elevation calculated to determine the hydraulic head of the water in the monitored zone (Figure 9.3). The hydraulic gradient measures the difference in hydraulic head over a specified distance. By comparing the water levels in adjacent wells screened in the same zone, a horizontal hydraulic gradient can be determined and the lateral direction of groundwater flow can be predicted.

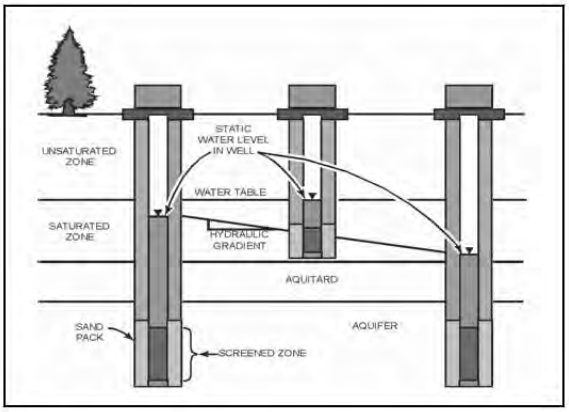

Figure 9.3. MW Construction Showing the Relationship between the Screened Zone and the Water Level in Wells Where Flow in the Aquifer is to the Right

Only wells screened in the same zones are considered when determining the horizontal gradient. Wells screened above and below an aquitard (a geologic unit that inhibits groundwater flow) can have different hydraulic heads, thus defining a vertical gradient. If the water levels in deeper wells are lower than those in shallower wells, then the flow is through the aquitard and primarily downward.

Groundwater aquifers are one of the primary pathways by which potentially hazardous substances can spread through the environment. Substances in the soil may migrate downward due to gravity or be dissolved in rainwater, which transports them downward through the unsaturated zone into the aquifer. The contaminated water then flows laterally downgradient toward the discharge point.

Geologic and Hydrogeologic Setting

The Paducah Site, located in the Jackson Purchase region of western Kentucky, lies near the northern boundary of the Mississippi Embayment portion of the Gulf Coastal Plain Province. The Mississippi embayment is a large sedimentary trough oriented nearly north-south that received sediments during the Cretaceous and Tertiary geologic time periods.

During the Cretaceous Period, the PGDP area was a coastal marine environment. The derived sediments constitute a thick deposit of sand beneath PGDP (270 ft), with frequent lenses of silt and clay in the upper part that is called the McNairy Formation. A similar depositional environment continued into the early Paleocene Epoch. These sediments, indistinguishable in lithologic sample from the McNairy Formation, are named the Clayton Formation. (PGDP geologists commonly refer to the collective Cretaceous and lower Paleocene sediments as the McNairy Formation.)

Throughout most of the Mississippi Embayment and extending to under the south side of the PGDP, the Paleocene Porters Creek Clay overlies the McNairy/Clayton Formation. Locally, the Porters Creek Clay consists predominately of silt with sand and clay interbeds that were deposited in marine and brackish water environments. Much later erosion, associated with formation of the ancestral Tennessee River basin, thinned the Porters Creek Clay to the north and completely removed it under most of the PGDP and adjacent area to the north. The McNairy and Clayton Formations and the Porters Creek Clay uniformly dip 30 to 35 ft per mile [5.7 to 6.6 meter (m) per kilometer (km)] to the south-southwest.

Pliocene-Pleistocene (the geologic age of these formations is uncertain) gravels (and lesser sands), representing a broad alluvial fan deposit that extended across all of the Jackson Purchase region at one time, overlie the Porters Creek Clay to the south. These gravels constitute the oldest member of the lower continental deposits. The ancestral Tennessee River cut through the PGDP area (close to the present course of the Ohio River) later in the Pleistocene, eroding through the Porters Creek Clay to form a wide valley. A subcrop of the Porters Creek Clay, buried in the sediments beneath the PGDP, marks the south side of the ancestral Tennessee River valley. Braided river deposits of sand and gravel, commonly 30-ft (9.1-m) thick, fill the lower portion of the ancestral Tennessee River valley. These sands and gravels form the youngest member of the lower continental deposits.

As sediments from retreating Pleistocene glaciers plugged tributaries to the Mississippi River, lakes formed in the ancestral Tennessee River valley. These lake deposits predominately consisted of silt. Intervals of common sand and gravel lenses within the silt beneath PGDP attest to minor periods of active erosion of the Pliocene-Pleistocene (the geologic age of these formations is uncertain) gravels to the south and redeposition within the valley. (The thick silt interval, with interbedded sand and gravel member, is collectively called the upper continental deposits). Finally, layers of loess, wind-blown silt derived from the receding glaciers, blanketed the entire Jackson Purchase region. The combined thickness of upper continental deposits and loess at PGDP is commonly 60 ft (18.3 m) thick.

The local groundwater flow systems at the Paducah Site include the following (from shallowest to deepest): (1) the Terrace Gravel flow system, (2) UCRS, (3) RGA, and (4) the McNairy flow system. The Terrace Gravel consists of shallow Pliocene-Pleistocene (the geologic age of these formations is uncertain) gravel deposits in the southern portion of the Paducah Site. These deposits usually lack sufficient thickness and saturation to constitute an aquifer, but are a locally important source of groundwater recharge to the RGA.

The UCRS consists of the silts, with sand and gravel interbeds, of the upper continental deposits and overlying loess. Groundwater flow within the UCRS is predominately downward and is the primary recharge to the RGA. The RGA is the uppermost aquifer at the Paducah Site and was used formerly as a drinking water source by private residences north of the site. It consists primarily of the Lower Continental Deposits, a thick unit of sand and gravel formed by the ancestral Tennessee River, and includes contiguous sands and gravels of the Upper Continental Deposits, the McNairy Formation, and alluvium of the Ohio River. The Ohio River is the regional discharge/drainage feature for the area hydrologic system. Flow in the RGA and McNairy is northward to discharge into the Ohio River.

Uses of Groundwater in the Vicinity

The WKWMA and some lightly populated farmlands are in the immediate vicinity of the Paducah Site. Homes are sparsely located along rural roads in the vicinity of the site. Two communities, Grahamville and Heath, lie within 2 miles (3.2 km) east of the plant.

Historically, groundwater was the primary source of drinking water for residents and industries in the vicinity of the plant area. Some area residents and industries have chosen to replace groundwater sources with water supplied by the West McCracken County Water District. In areas where the groundwater is either known to be contaminated or is suspected of becoming contaminated in the future, the Paducah Site continues to provide municipal water. Several residential out-of-service wells are utilized by DOE for monitoring (per written agreements). Residential wells that no longer are sampled have been capped and locked.

PGDP uses surface water from the Ohio River for process waters and on-site drinking water. The nearest community downstream of Paducah using surface water for drinking water is Cairo, IL, which is located at the confluence of the Upper Mississippi and Ohio Rivers.

Groundwater Monitoring Program

The primary objectives of groundwater monitoring at the Paducah Site are early detection of any contamination resulting from past and/or present land disposal of wastes and provision of data, which can be used for decision documents, if contamination is detected. Additional objectives outlined in DOE Order 450.1, *Environmental Protection Program,* require implementation of a sitewide approach for groundwater monitoring.

The sitewide approach is outlined in the following three documents related to groundwater monitoring: (1) Groundwater Protection Plan, (PRS 2007b); (2) Groundwater Protection Plan (BJC 2004); and (3) the Paducah Site EMP (PRS 2007c). Approximately 170 monitoring wells (MWs) and residential wells are sampled in accordance with DOE orders and federal, state, and local requirements. Well sampling is included in several different monitoring programs, which are described as follows.

Resource Conservation and Recovery Act Permit Monitoring Programs

The only hazardous waste facility at the Paducah Site that requires groundwater monitoring is the C-404 Landfill (Figure 9.4). The C-404 Low-Level Radioactive Waste Burial Ground was used for the disposal of uranium-contaminated solid wastes until 1986 when it was determined that, of the wastes disposed there, gold dissolver precipitate was considered a hazardous waste under RCRA. The landfill was covered with a RCRA-compliant cap and was certified "closed" as a hazardous waste landfill in 1987.

The landfill now is monitored under post-closure monitoring requirements. According to the Kentucky C-404 Post-Closure Permit, 14 wells (MWs 84–95, 226, and 227) monitor groundwater quality. Four of the 14 wells monitor the UCRS while 10 of the wells monitor the underlying RGA. An additional MW was installed, MW420, in 2007. The sampling requirements associated with this MW will be included in a revised permit modification in CY 2008. The sampling results are also examined with respect to the gradient of the well. Six of the 14 wells are considered upgradient to the landfill while the remaining eight wells are downgradient to the landfill. All sampling events were conducted on a semiannual basis per the Permit. On November 20, 2008, a new permit was issued changing the number and location of MWs associated with the C-404 Landfill; however, semiannual sampling events for 2008 were conducted prior to the issuance of the new permit.

During 2008, MWs at the C-404 Landfill were sampled and analyzed for total and dissolved chromium, arsenic, cadmium, lead, mercury, selenium, and uranium. Also monitored are TCE, ^{99}Tc and the activity concentrations of the uranium radionuclides. Field parameters (i.e., temperature, pH, depth to water, etc.) are also collected at the C-404 Landfill MW locations. TCE exceeded the regulatory maximum contaminant level (MCL) in all six upgradient wells and in three downgradient wells. The extent of the contamination is likely related to the northwest and southwest TCE plume and not C-404 itself. Remediation of the TCE plume will take place as a CERCLA action under the GWOU. Chromium exceeded the regulatory MCL in two upgradient wells and one downgradient well. Tc-99 exceeded its regulatory value at one downgradient well. Results are reported to KDWM semiannually. Regulatory MCL exceedances are reported to KDWM in the semiannual report. A summary of the detected maximum results for each of the wells is provided in Table 9.1. Parameters with no detections are not listed.

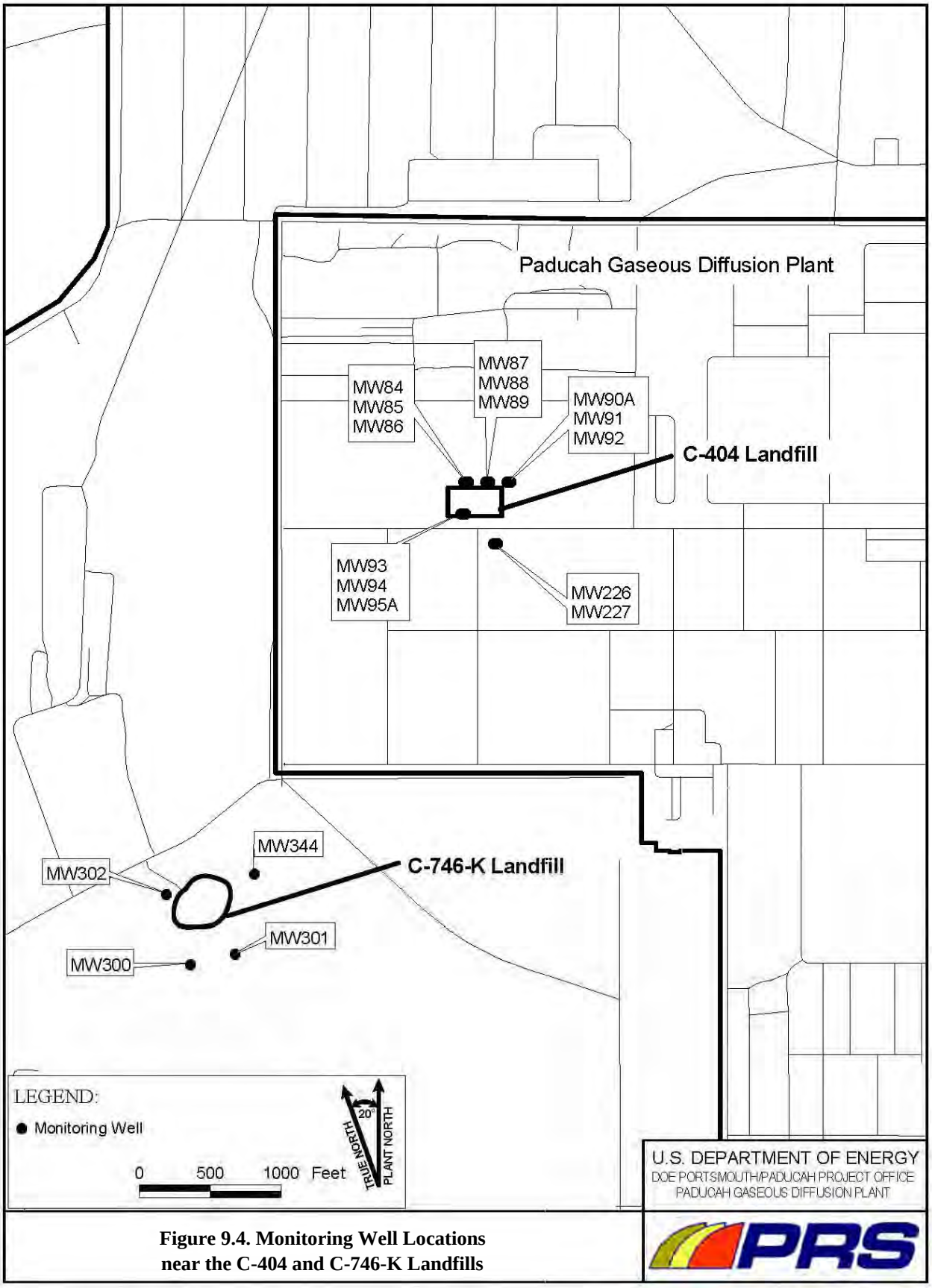

Figure 9.4. Monitoring Well Locations near the C-404 and C-746-K Landfills

Table 9.1. Summary of Maximum Groundwater Results from the RGA at C-404 Landfill for CY 2008

		Upgradient Wells						Downgradient Wells								
		RGA					UCRS	RGA					UCRS			
Chemical Name	**Units**	**MW 226**	**MW 227**	**MW 93**	**MW 94**	**MW 95A**	**MW 84**	**MW 86**	**MW 87**	**MW 89**	**MW 90A**	**MW 92**	**MW 85**	**MW 88**	**MW 91**	**Reference Value**
Arsenic	mg/L	0.00279	ND	0.00235	ND	0.00142	0.00203	0.00191	ND	ND	ND	ND	0.0153	ND	0.00206	0.05
Arsenic, Dissolved	mg/L	ND	ND	0.00172	ND	ND	0.00167	0.00106	ND	ND	ND	ND	0.0127	ND	ND	--
Chromium	mg/L	**0.389**	**0.641**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**0.341**	0.1
Lead	mg/L	ND	0.00389	ND	0.0024	ND	ND	ND	ND	0.0013	ND	ND	ND	0.00242	ND	0.05
Selenium	mg/L	0.0122	0.00536	0.00524	0.00641	0.00509	ND	0.00535	ND	ND	ND	ND	ND	ND	0.00746	0.05
Selenium, Dissolved	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0074	--
Technetium-99	pCi/L	110	ND	ND	242	ND	ND	ND	18.8	ND	ND	ND	162	36.5	**1,240**	900[1]
Trichloroethene	µg/L	**640**	**110**	**830**	**11**	**410**	**600**	**550**	**130**	4.6	3.7	ND	1.3	2.5	**85**	5
Uranium	mg/L	ND	ND	ND	0.00419	ND	ND	ND	ND	ND	ND	ND	0.00201	ND	ND	0.03
Uranium, Dissolved	mg/L	ND	ND	ND	0.00388	ND	ND	ND	ND	ND	ND	ND	0.00194	ND	ND	--
Uranium-234	pCi/L	ND	ND	ND	1.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.838	--
Uranium-238	pCi/L	ND	ND	ND	1.19	ND	ND	0.198	ND	0.324	ND	0.156	0.73	ND	1.01	--
Barometric Pressure	Inches/Hg	30.33	30.36	30.3	30.3	30.3	30.3	30.3	30.3	30.21	30.3	30.24	30.3	30.21	30.24	--
Conductivity	umho/cm	410	300	300	1250	288	292	291	297	221	293	169	489	662	547	--
Depth to Water	ft	54.53	54.81	54.63	15.83	53.34	55.3	52.42	52.58	57.6	50.75	50.94	13.91	13.25	12.39	--
Dissolved Oxygen	mg/L	0.45	6.17	1.26	0.69	0.88	2.13	1.13	1.54	1.54	0.9	0.97	2.73	0.91	2.33	--
pH	Std Unit	6.02	6.1	6.1	6.39	6.03	6.12	6.16	6.29	5.98	6.28	5.87	6.6	5.77	5.98	--
Redox	mV	498	424	343	488	592	571	394	447	371	372	383	371	396	419	--
Temperature	°F	65.6	65.4	66.4	67	66.7	65	70	64.8	73.3	64.4	66.2	70.2	68.7	74.1	--
Turbidity	NTU	69.1	318	8.4	92.1	3.5	4	76.7	12.2	36.2	5.1	17.3	12.7	45.4	128	--

[1] Technetium-99 has a reference value from the target treatment level for Northwest Plume (TTL).

ND – not detected

-- – no reference value for this parameter

Bold – **exceeds criteria**

Solid Waste Landfill Groundwater Monitoring Programs

Post-closure groundwater monitoring continues for the C-746-S Residential Landfill. The landfill stopped receiving solid waste by July 1, 1995, and was certified closed on October 31, 1995, by an independent engineering firm. The groundwater monitoring system for the C-746-S Residential Landfill also encompasses the C-746-T Landfill, which was certified closed in November 1992. No monitoring is done on the C-746-T Landfill because it had fulfilled the two years of post-closure environmental monitoring and maintenance requirements that were required as part of its closure.

The groundwater monitoring system for C-746-S&T consists of upgradient, sidegradient, and downgradient wells (Figure 9.5). The monitoring system is designed to monitor the UCRS, the upper portion of the RGA (URGA), and lower portion of the RGA (LRGA).

The MWs at C-746-S&T are sampled quarterly and in accordance with 401 *KAR* 48:300. The analytes are dictated by a KDWM-approved solid waste landfill permit modification.

During 2008, beta activity exceeded regulatory MCLs in all three well systems (LRGA, URGA, and UCRS); however, no regulatory exceedances occurred in upgradient wells. Trichloroethene concentrations exceeded regulatory MCLs in some downgradient LRGA wells, as well as some upgradient and downgradient URGA wells. The KDWM was notified of the exceedances. In addition, results were reported to KDWM on a quarterly basis. A summary of the maximum results of the LRGA, URGA, and UCRS wells monitored by gradient is provided in Table 9.2.

The C-746-U Contained Landfill, a solid waste landfill at the Paducah Site, was completed in 1996 and operation was initiated in 1997. Solid waste regulations require groundwater monitoring of the landfill. Monitoring wells were installed in clusters of three. The three well clusters had wells in the UCRS, URGA, and LRGA (Figure 9.5) and are additionally monitored by gradient (upgradient, sidegradient, and downgradient).

During 2008, beta activity exceeded regulatory MCLs in LRGA and UCRS wells. Radium-228 exceeded regulatory MCLs in the sidegradient LRGA wells and downgradient UCRS wells. PCBs were detected in downgradient and upgradient URGA wells and upgradient UCRS wells. Trichloroethene concentrations exceeded regulatory MCLs in upgradient and downgradient LRGA and upgradient UCRS wells. The KDWM was notified of the exceedances. In addition, results were reported to KDWM on a quarterly basis. A summary of the maximum results of the LRGA, URGA, and UCRS wells monitored by gradient is provided in Table 9.3.

Based on groundwater data obtained from sampling events conducted in 2006 at the C-746-U Landfill, a groundwater assessment plan was required by the permit due to data exceedances. In February 2007, DOE submitted a final assessment plan to the regulatory agency. This plan described the planned methods to assess the contaminants and provide a process of planned steps to perform groundwater evaluations. This plan was implemented in 2008.

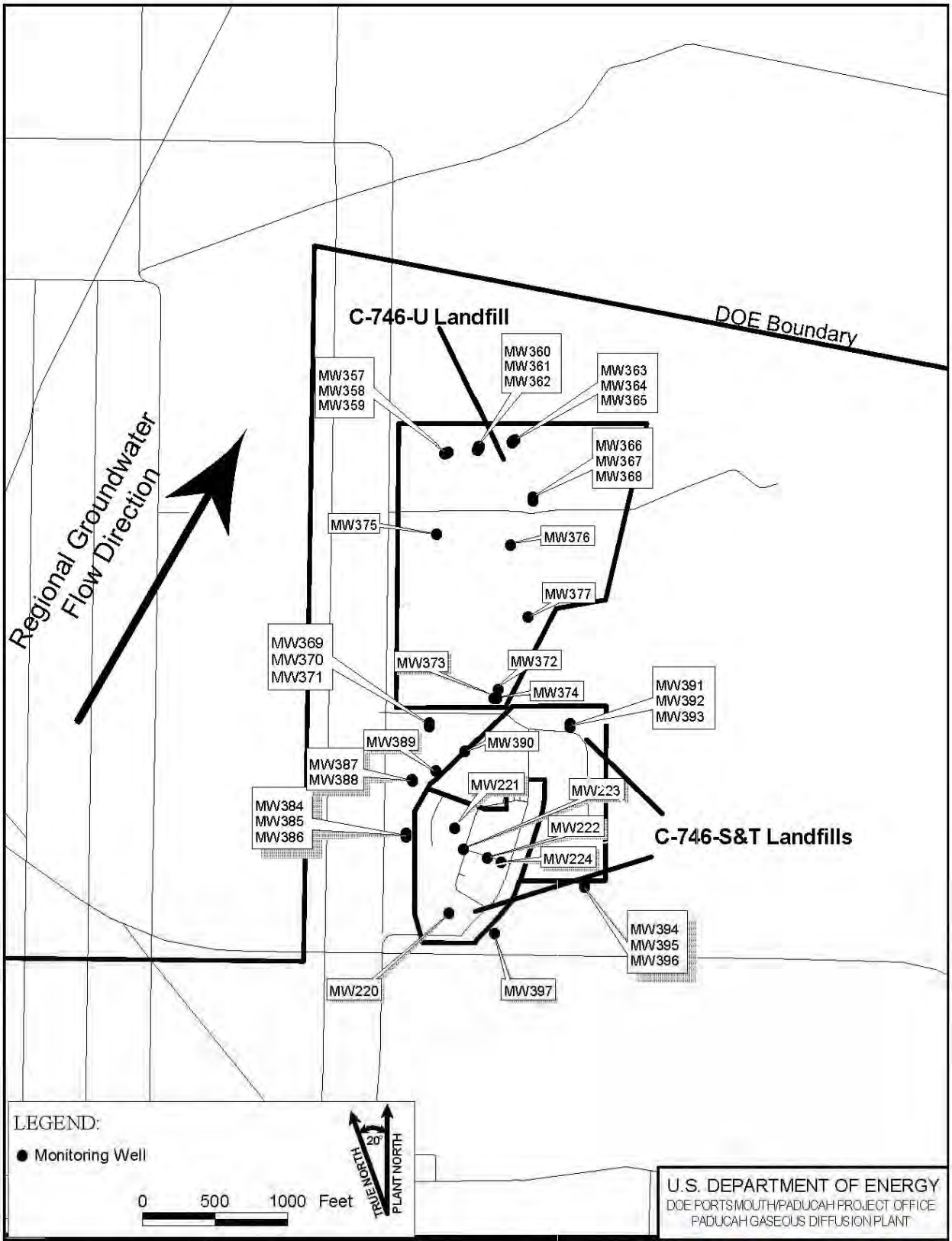

Figure 9.5. Monitoring Well Locations near the C-746-S&T and C-746-U Landfills

Table 9.2. Summary of Maximum Groundwater Results at C-746-S&T Landfills for CY 2008

		Lower RGA			Upper RGA			UCRS Wells				
	Parameter	Down-gradient	Side-gradient	Up-gradient	Down-gradient	Side-gradient	Up-gradient	Down-gradient	Side-gradient	Up-gradient	Reference	Value
ANION (mg/L)	Bromide	ND	ND	ND	ND	ND	ND	ND	2.2	ND	--	
	Chloride	48	35	49	50	69	51	19	200	95	--	
	Fluoride	0.28	0.33	0.15	0.93	0.26	0.2	0.15	0.59	0.53	KYREG	4
	Nitrate as Nitrogen	1.4	1.2	1.8	1.8	1.6	1.9	ND	2.5	ND	KYREG	10
	Sulfate	25	20	12	36	24	17	7.1	43	18	--	
METAL (mg/L)	Aluminum	ND	0.549	0.292	1.5	ND	ND	ND	0.537	1.17	--	
	Arsenic	0.00381	0.00219	0.00224	0.0042	0.00568	0.00278	0.00321	0.00664	0.00362	KYREG	0.05
	Barium	0.243	0.221	0.269	0.384	0.185	0.303	0.105	0.438	0.428	KYREG	2
	Beryllium	0.0011	ND	ND	0.00206	ND	ND	ND	ND	ND	KYREG	0.005
	Calcium	28.6	31.5	28.3	36.4	35.4	34.1	10.6	55.5	43.3	--	
	Chromium	ND	ND	ND	0.0103	ND	0.0118	ND	ND	ND	KYREG	0.1
	Cobalt	ND	ND	ND	0.00707	ND	0.0027	ND	0.0083	0.00227	--	
	Iron	1.79	0.279	0.417	2.67	0.561	3.47	3.97	7.5	3.36	--	
	Magnesium	12.1	10.7	11.7	14.9	13.5	13.6	3.26	22	18.4	--	
	Manganese	0.455	0.0154	0.00623	0.365	0.0494	0.0297	0.0346	1.11	0.576	--	
	Molybdenum	ND	ND	ND	0.00587	ND	0.00264	ND	0.00361	0.00103	--	
	Nickel	ND	0.0108	0.00566	0.138	ND	0.19	ND	0.00643	ND	--	
	Potassium	1.98	1.74	2.59	4.54	1.6	6.14	0.458	0.561	1.2	--	
	Selenium	0.012	0.00793	0.0102	0.0112	0.0174	0.0127	ND	0.0299	0.0154	KYREG	0.05
	Sodium	45.6	43.2	48.2	66.2	62.1	38.1	76.1	140	126	--	
METAL-D (mg/L)	Barium, Dissolved	0.228	0.221	0.25	0.372	0.189	0.261	0.102	0.45	0.423	--	
	Chromium, Dissolved	ND	ND	ND	0.0105	ND	ND	ND	ND	ND	--	
METEO	Barometric Pressure (in/Hg)	30.45	30.36	30.3	30.42	30.42	30.42	30.42	30.33	30.27	--	
PHYSC	Depth to Water (feet)	42.58	42.26	63.73	72.53	41.94	58.35	26.1	37.23	11.7	--	
	Dissolved Oxygen (mg/L)	4.94	4.85	6.21	5.05	2.15	6.31	1	3.95	1.01	--	
	Dissolved Solids (mg/L)	256	239	225	296	320	236	259	539	515	--	
	pH (Std Unit)	6.42	6.86	6.26	6.28	6.5	6.29	6.29	6.73	6.59	--	
	Redox (mV)	483	430	578	729	231	609	226	360	187	--	
	Temperature (^{o}F)	64.2	64.7	67.1	67.7	65.5	64.6	65.8	65.4	67.7	--	

Table 9.2. Summary of Maximum Groundwater Results at C-746-S&T Landfills for CY 2008 (Continued)

		Lower RGA			Upper RGA			UCRS Wells				
	Parameter	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Reference**	**Value**
RADS (pCi/L)	Alpha activity	5.96	7.6	4	5.04	**16.4**	ND	ND	ND	ND	KYREG	15
	Beta activity	**130**	**167**	12.5	**169**	**277**	17.5	ND	**81.1**	6.75	KYREG	50
	Technetium-99	168	229	25.5	249	434	29.6	ND	96.1	ND	TTL	900
	Thorium-230	ND	ND	ND	ND	ND	ND	ND	0.422	ND	--	
VOA (µg/L)	*Cis*-1,2-Dichloroethene	ND	ND	ND	1.2	ND	ND	ND	ND	ND	MCL	70
	Trichloroethene	**15**	ND	4.9	**21**	ND	**12**	ND	ND	ND	KYREG	5
WETCHEM	Chemical Oxygen Demand (mg/L)	ND	ND	ND	ND	ND	ND	ND	69	26	--	
	Conductivity (umho/cm)	494	570	409	549	583	419	457	1156	942	--	
	Iodide (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	2.6	--	
	Suspended Solids (mg/L)	ND	14	ND	ND	ND	ND	ND	ND	14	--	
	Total Organic Carbon (mg/L)	2.5	1	ND	1	9.5	ND	4.5	26.5	9.1	--	
	Total Organic Halides (µg/L)	75.7	22.7	16.8	23.9	12.5	27.9	62.8	505	249	--	
	Turbidity (NTU)	14.6	15.7	21.3	20.4	13.9	32.6	52.3	10.4	23.2	--	

ND – not detected
Bold – **exceeds criteria**
TTL – target treatment level for Northwest Plume
MCL – maximum contaminant level
-- – no reference value for this parameter
KYREG – Kentucky regulations
PHYSC – physical parameters
VOA – volatile organic analyte
WETCHEM – wet chemistry parameters

Table 9.3. Summary of Maximum Groundwater Results at C-746-U Landfill for CY 2008

		Lower RGA			UCRS Wells		Upper RGA				
	Parameter	Down-gradient	Side-gradient	Up-gradient	Down-gradient	Up-gradient	Down-gradient	Side-gradient	Up-gradient	Reference	Value
ANION (mg/L)	Bromide	ND	ND	ND	ND	2	ND	ND	ND	--	
	Chloride	34	42	48	14	110	29	42	51	--	
	Fluoride	0.21	0.18	0.18	0.36	0.33	0.27	0.32	0.24	KYREG	4
	Nitrate as N	1.5	ND	1.5	1.6	1.8	4.7	ND	1.3	KYREG	10
	Sulfate	110	32	200	75	15	76	39	130	--	
METAL (mg/L)	Aluminum	0.262	0.349	ND	3.53	0.773	0.708	0.216	0.486	--	
	Arsenic	0.00184	0.00459	0.00292	0.00143	0.00471	0.0016	0.00156	0.00338	KYREG	0.05
	Barium	0.13	0.213	0.213	0.16	0.182	0.218	0.271	0.443	KYREG	2
	Boron	0.308	ND	1.35	ND	ND	0.324	ND	1.03	--	
	Calcium	42	30	70.7	32	25.9	31.3	26.4	56.8	--	
	Cobalt	0.0126	0.00431	0.00201	0.0203	0.00457	0.0198	0.00289	0.0589	--	
	Copper	ND	ND	ND	ND	ND	0.0208	ND	ND	--	
	Iron	1.16	19.5	0.456	5.96	0.582	2.67	1.74	10.6	--	
	Lead	ND	0.00491	ND	0.00149	ND	ND	ND	ND	KYREG	0.05
	Magnesium	17.3	11	28.9	14.2	10.4	12.6	10.7	23.2	--	
	Manganese	0.419	2.29	0.153	1.87	0.117	1.05	0.808	0.586	--	
	Molybdenum	ND	ND	ND	0.00294	0.00105	ND	ND	ND	--	
	Nickel	ND	ND	ND	0.0142	0.00902	0.00659	ND	0.00968	--	
	Potassium	2.73	2.73	3.27	0.561	0.643	1.78	1.91	2.57	--	
	Selenium	0.00688	ND	0.00926	ND	0.0331	0.00692	0.00706	0.00907	KYREG	0.05
	Sodium	47.6	39.9	61	164	136	66.2	84.5	59.6	--	
	Uranium	ND	ND	ND	0.014	0.00205	ND	ND	ND	KYREG	0.03
	Zinc	0.0293	ND	ND	ND	ND	ND	ND	ND	--	
METAL-D (mg/L)	Barium, Dissolved	0.132	0.222	0.214	0.165	0.181	0.221	0.257	0.467	--	
	Uranium, Dissolved	ND	ND	ND	0.0134	0.00183	ND	ND	ND	--	
METEO (in/Hg)	Barometric Pressure	30.3	30.3	30.36	30.42	30.3	30.27	30.27	30.33	--	
PHYSC	Depth to Water (ft)	46.52	47.49	42.16	44.19	28.94	47.35	47.03	41.7	--	
	Dissolved Oxygen (mg/L)	4.85	1.73	3.44	4.72	4.54	4.41	1.62	2.26	--	
	Dissolved Solids (mg/L)	325	238	537	537	432	278	293	434	--	
	pH (Std Unit)	6.39	6.26	6.16	6.9	6.87	6.34	6.61	6.3	--	
	Redox (mV)	414	127	378	387	468	469	489	310	--	
	Temperature ^{o}F	64.5	64.1	67.4	65.3	65	66.7	64.6	67.9	--	
Pesticide/ PCB (µg/L)	PCB-1016	ND	ND	ND	1.85	ND	0.42	ND	0.32	--	
	PCB-1242	ND	ND	ND	1.69	ND	0.51	ND	0.4	--	
	PCB-1248	ND	ND	ND	0.93	ND	0.62	ND	0.26	--	
	PCBs	ND	ND	ND	**1.91**	ND	**0.99**	ND	0.49	MCL	0.5
RADS (pCi/L)	Alpha activity	5.11	ND	ND	6.83	ND	ND	ND	8.07	KYREG	15
	Beta activity	**59.8**	**55.8**	45.8	10.5	ND	42.2	**59.9**	**106**	KYREG	50
	Radium-226	ND	ND	0.528	ND	ND	ND	ND	ND	KYREG	5
	Radium-228	ND	**6.53**	ND	ND	ND	ND	**59.2**	ND	KYREG	5
	Technetium-99	64.8	81.6	50.1	16.3	66.9	53.2	67.1	117	TTL	900
VOA (µg/L)	Acetone	ND	ND	ND	13	ND	ND	ND	ND	--	
	Trichloroethene	**5.4**	1.4	**13**	ND	ND	4.1	2.3	**14**	KYREG	5
WET CHEM	Conductivity (umho/cm)	628	473	976	941	895	542	562	851	--	
	Suspended Solids (mg/L)	ND	13	ND	ND	ND	ND	ND	20	--	

Table 9.3. Summary of Maximum Groundwater Results at C-746-U Landfill for CY 2008 (Continued)

		Lower RGA			Upper RGA			UCRS Wells			
	Parameter	Down-gradient	Side-gradient	Up-gradient	Down-gradient	Side-gradient	Up-gradient	Down-gradient	Up-gradient	Reference	Value
	Total Organic Carbon (mg/L)	1	1	ND	5.6	2.6	1.9	4.4	3.1	--	
	Total Organic Halides (µg/L)	40.5	13.2	31.9	65.8	55.2	27.1	84.9	41.8	--	
	Turbidity (NTU)	6.7	31.3	21	31.6	8.6	40.7	16.1	17.9	--	--

ND – not detected
Bold – **exceeds criteria**
-- – no reference value for this parameter
KYREG – Kentucky regulations
TTL – target treatment level for Northwest Plume
PHYSC – physical parameters
VOA –volatile organic analyte
MCL – maximum contaminant level
WETCHEM – wet chemistry parameters

C-746-K Sanitary Landfill Groundwater Monitoring

The C-746-K Sanitary Landfill was used at the PGDP between 1951 and 1981 primarily for the disposal of fly ash. Postclosure groundwater monitoring continues for the C-746-K Landfill on a quarterly basis and these results are summarized in Table 9.4. Regulatory MCL exceedances of reference values were found for PCBs, beta activity, 1,1-dichloroethane, 1,1-dichloroethene, *cis*-1,2-dichloroethene, and vinyl chloride. The UCRS and RGA are not present at the C-746-K site. Wells at the landfill are installed to monitor groundwater in the Terrace Gravel (Figure 9.4).

Table 9.4. Summary of Maximum Groundwater Results at C-746-K Landfill for CY 2008

	Parameter	MW300	MW301	MW302	MW344	Reference	Value
ANION (mg/L)	Chloride	16	70	9.5	22	--	
	Ferrous	110	230	ND	0.7	--	
	Nitrate as N	ND	ND	1.1	ND	KYREG	10
	Sulfate	1400	1970	150	160	--	
METAL (mg/L)	Aluminum	ND	ND	0.23	3.36	--	
	Arsenic	0.00368	0.00151	0.00151	0.00447	KYREG	0.05
	Barium	0.0203	0.0259	0.0634	0.0683	KYREG	2
	Calcium	346	547	50.9	59.8	--	
	Iron	117	240	0.281	3.64	--	
	Magnesium	70.2	117	27.5	19.2	--	
	Manganese	16.9	16.3	0.319	0.256	--	
	Nickel	0.051	0.015	0.00624	0.00577	--	
	Potassium	23.7	44.7	0.375	1.6	--	
	Sodium	23.6	88	89.4	29	--	
	Uranium	ND	0.0132	ND	ND	KYREG	0.03
METAL-D (mg/L)	Arsenic, Dissolved	0.00386	0.00187	ND	0.00388	--	
	Barium, Dissolved	0.0207	0.0261	0.066	0.0515	--	
	Lead, Dissolved	ND	0.00166	ND	0.00185	--	
	Uranium, Dissolved	ND	0.0128	ND	ND	--	
METEO (in/Hg)	Barometric Pressure	30.36	30.27	30.36	30.3	--	
PHYSC	Depth to Water (Feet)	6	8.91	12.34	24.85	--	
	Dissolved Oxygen (mg/l)	3.32	1.03	2.72	1.26	--	
	pH (Std Unit)	5.52	6.1	6.2	6.25	--	
	Redox (mV)	470	230	700	420	--	
	Temperature (^{o}F)	66.5	64.4	62.2	61	--	
PPCB (µg/L)	PCB-1016	ND	0.54	ND	ND	--	
	PCB Total	ND	**0.54**	ND	ND	MCL	0.5

Table 9.4. Summary of Maximum Groundwater Results at C-746-K Landfill for CY 2008 (Continued)

	Parameter	MW300	MW301	MW302	MW344	Reference	Value
RADS (pCi/L)	Beta Activity	**64.4**	**79.9**	ND	ND	KYREG	50
VOA (µg/L)	1,1-Dichloroethane	34	3.9	ND	ND	--	
	1,1-Dichloroethene	**48**	3.8	ND	ND	KYREG	7
	cis-1,2-Dichloroethene	**450**	52	ND	ND	MCL	70
	Vinyl chloride	**65**	**4.4**	ND	ND	KYREG	2
WETC CHEM	Alkalinity (mg/L)	120	460	250	110	--	
	Conductivity (umho/cm)	2090	3530	753	574	--	
	Turbidity (NTU)	98.7	186	4.4	51.4	--	

VOA – volatile organic analyte
ND – not detected
-- – no reference value for this parameter
KYREG – Kentucky regulations; **Bold** – **exceeds criteria**
WETCHEM – wet chemistry parameters

Residential (Federal Facility Agreement) Monitoring

DOE conducts sampling of 19 residential wells potentially affected by the contaminant plume (DOE 1998). Residents are protected under the DOE Water Policy in that the residents are provided a municipal water source. During 2008, seventeen of the wells were monitored annually and two wells were sampled on a monthly basis. All residential wells were analyzed for TCE and ^{99}Tc. Additionally, the wells that were monitored monthly were sampled for alpha and beta activity. Field parameters (e.g., depth to water, pH) also were collected for all samples; however, only the TCE and ^{99}Tc are addressed in this data evaluation of the ASER.

As stated previously, the hydrologic unit in which residential wells are screened is uncertain; however, most are believed to be RGA wells. Out of the 17 wells that are sampled annually, ^{99}Tc was detected in one well, R2, and TCE was detected in three wells, R2, R23, and R83. TCE was detected in both wells that are sampled monthly, R294 and R302; however, ^{99}Tc, a beta emitter, was not detected in either of these two wells. A summary of the detected concentrations is reflected in Table 9.5. All residents whose wells were sampled were notified by mail of the results. The residential water results are collected from residential wells that are not operated for consumption.

For one residential well, R424, DOE has provided the residents with a carbon filter treatment system to allow them to have safe drinking water. These filters are replaced semiannually, and the groundwater is sampled before and after filter replacement. Before treatment, the groundwater in the well contains TCE above levels established by the EPA Safe Drinking Water Act (SDWA); however, after treatment, the concentrations are below those levels. The location of the well relative to PGDP makes it highly improbable that the contaminants migrated from the Paducah Site. Based upon this rationale, the results from this residential well were not included in the summary presented in Table 9.5.

Table 9.5. Summary of Maximum Groundwater Results from Residential Monitoring for CY 2008

Well Number	^{99}Tc, pCi/L	TCE, µg/L	Type monitoring
R2	16.8	**37**	annually
R23	ND	1	annually
R83	ND	2	annually
R294	ND	5	monthly
R302	ND	8	monthly
	MCL=NA	MCL = 5	

ND – not detected
NR – not reported
MCL – maximum contaminant level (for reference only)
Bold – **exceeds criteria**

Environmental Surveillance Monitoring

Environmental surveillance monitoring is defined as perimeter-exit-pathway (off-site exposure) monitoring and off-site water well monitoring. Environmental surveillance monitoring is conducted in support of DOE Orders and other laws and regulations as addressed in the Paducah Site EMP (PRS 2007c).

During 2008, surveillance wells located on and off DOE property were sampled for volatiles, total and dissolved metals, radionuclides, and anions. Additionally, wet chemistry and field parameters were analyzed. Table 9.6 provides a summary of the maximum detected results for each hydrogeologic unit sampled for the surveillance program. From the routine well monitoring program in the RGA, several parameters were reported as exceeding the regulatory MCLs, including the following: anions (nitrate), metals (chromium), radionuclides (alpha and beta activity, and ^{99}Tc), and volatiles (1,1-dichloroethene, carbon tetrachloride, TCE, and vinyl chloride). The maximum TCE value reported (from routine monitoring program wells) in the RGA is 660,000 µg/L. TCE also was detected in the McNairy at 15 µg/L, and the UCRS at 21,000 µg/L. These values exceed the regulatory MCL value of 5 µg/L. During 2008, the maximum ^{99}Tc value reported (from routine monitoring program wells) in the RGA was 9,710 pCi/L. The contamination in the RGA is being addressed by CERCLA actions for the GWOU, Section 3.

Monitoring Well Rehabilitation

In May 2007, KDWM issued a notice of deficiency for the C-746-U Groundwater Assessment Plan that stated that sulfamic acid well rehabilitation is not an approved well-rehabilitation method for the C-746-U Landfill because the acid could bias the sample results obtained at the C-746-U Landfill. Upon the request by KDWM, a revised well maintenance plan was developed. The plan stated that removal of accumulated biofilm and blocking materials contained within the well and surrounding aquifer should be removed using surging techniques with chemical treatment viewed as a final resort which would be utilized only upon the consent by KDWM. During the development of a new well maintenance plan, monitoring well rehabilitation did not occur. An aggressive plan for rehabilitation is planned for CY 2009 with 45 wells scheduled to be rehabilitated.

Table 9.6. Summary of Maximum Groundwater Results from Environmental Surveillance Monitoring for 2008

	Parameter	Eocene	McNairy	RGA	Rubble Zone	UCRS	Reference	Value
ANION (mg/L)	Chloride	NA	NA	84	NA	55	--	
	Ferrous	NA	NA	5.2	NA	NA	--	
	Fluoride	NA	NA	0.25	NA	0.24	MCL	4
	Nitrate as Nitrogen	NA	NA	**22**	NA	3.9	MCL	10
	Sulfate	NA	NA	80	NA	100	--	
METAL (mg/L)	Aluminum	NA	NA	0.286	NA	0.562	--	
	Arsenic	NA	NA	0.00553	NA	0.00247	MCL	0.05
	Barium	NA	NA	0.365	NA	0.268	MCL	2
	Calcium	NA	NA	44.3	NA	35.2	--	
	Chromium	NA	NA	**0.422**	NA	**0.273**	MCL	0.1
	Cobalt	NA	NA	0.0148	NA	0.00863	--	
	Iron	NA	NA	5.94	NA	6.69	--	
	Lead	NA	NA	0.00305	NA	NA	SDWA	0.015
	Magnesium	NA	NA	17.7	NA	13.7	--	
	Manganese	NA	NA	1.66	NA	0.201	--	
	Molybdenum	NA	NA	0.0136	NA	0.00224	--	

Table 9.6. Summary of Maximum Groundwater Results from Environmental Surveillance Monitoring for 2008 (Continued)

	Parameter	Eocene	McNairy	RGA	Rubble Zone	UCRS	Reference	Value
	Nickel	NA	NA	0.129	NA	1.11	--	
	Potassium	NA	NA	6.66	NA	2.92	--	
	Selenium	NA	NA	0.0199	NA	0.0123	MCL	0.05
	Sodium	NA	NA	76.8	NA	60.3	--	
	Uranium	0.00175	ND	0.0104	NA	**0.0972**	MCL	0.02
METAL-D (mg/L)	Arsenic, Dissolved	NA	NA	0.00378	NA	ND	--	
	Barium, Dissolved	NA	NA	0.329	NA	0.256	--	
	Calcium, Dissolved	NA	NA	44.8	NA	35.8	--	
	Chromium, Dissolved	NA	NA	0.0115	NA	ND	--	
	Cobalt, Dissolved	NA	NA	0.011	NA	0.00359	--	
	Iron, Dissolved	NA	NA	0.833	NA	ND	--	
	Magnesium, Dissolved	NA	NA	18.1	NA	14	--	
	Manganese, Dissolved	NA	NA	1.26	NA	0.0497	--	
	Molybdenum, Dissolved	NA	NA	0.00174	NA	ND	--	
	Nickel, Dissolved	NA	NA	0.13	NA	1.15	--	
	Potassium, Dissolved	NA	NA	7.42	NA	3.15	--	
	Selenium, Dissolved	NA	NA	0.00584	NA	ND	--	
	Sodium, Dissolved	NA	NA	60.4	NA	61.4	--	
METEO (in/Hg)	Barometric Pressure	30.06	30.09	30.59	30.06	30.42	--	
PHYSC	Depth to Water (ft)	12.36	59.03	59.63	60.49	62.36	--	
	Dissolved Oxygen (mg/L)	3.03	4.8	7.71	0.4	5.8	--	
	Dissolved Solids (mg/L)	NA	NA	348	NA	356	--	
	pH (Std Unit)	7.07	6.43	7.89	6.98	6.86	--	
	Redox (mV)	329	168	691	59	601	--	
	Temperature (^{o}F)	58.6	61	79.5	63.9	77.5	--	
RADS (pCi/L)	Alpha activity	ND	ND	**93.5**	ND	**83.8**	MCL	15
	Beta activity	7.03	7.92	**7,560**	13.4	**209**	MCL	50
	Technetium-99	ND	ND	**9,710**	ND	172	TTL	900
	Uranium	ND	ND	0.009	ND	**0.093**	MCL	0.02
VOA (µg/L)	1,1,1-Trichloroethane	ND	ND	2	NA	NA	--	
	1,1-Dichloroethane	ND	ND	21	NA	NA	--	
	1,1-Dichloroethene	ND	ND	**34**	NA	**9.2**	MCL	7
	Carbon tetrachloride	ND	ND	**62**	NA	NA	MCL	5
	Chloroform	ND	ND	69	NA	NA	--	
	cis-1,2-Dichloroethene	ND	ND	140,000	NA	270	--	
	Methane	ND	ND	0.88	NA	NA	--	
	Trichloroethene	ND	**15**	**660,000**	NA	**21000**	MCL	5
	Vinyl chloride	ND	ND	**300**	NA	NA	MCL	2
WETCHEM	Alkalinity (mg/L)	NA	NA	144	NA	130	--	
	Conductivity (umho/cm)	578	642	1403	726	886	--	
	Silica (mg/L)	NA	NA	28	NA	27	--	
	Total Organic Carbon (mg/L)	NA	NA	1.6	NA	1.4	--	
	Turbidity (NTU)	798	62.4	392	23.5	2000	--	

NA = no analysis; ND = not detected; -- = no reference value for this parameter; TTL – target treatment level for Northwest Plume; VOA – volatile organic analyte;
Bold – exceeds criteria
PHYSC = physical parameters; WETCHEM = wet chemistry parameters; MCL – maximum contaminant level

Environmental Restoration Activities

Northwest Plume Monitoring

The NWPGS started operation in 1995 to initiate control of the highest TCE concentration portion (greater than 1,000 ppb) of the Northwest Plume. Two extraction well fields, each containing two extraction

wells, were installed. Each set of extraction wells is surrounded by MWs (Figure 9.6). The network is used for monitoring groundwater quality and water levels to determine the effectiveness of the interim action.

There were no significant TCE concentration changes in the CY 2008 MW data. All MWs indicate that the highest TCE concentration portion of the plume is being controlled. Likewise, ^{99}Tc concentrations in CY 2008 were similar to those measured in CY 2007, and all were less than the 900 pCi/L reference value.

Summaries of the program's monitoring results are listed in Table 9.7. The data for this program are reported in the FFA Semiannual Progress Report.

Northeast Plume Monitoring

The EPA approved an Interim ROD for treatment of the Northeast Plume in June of 1995. The treatment system was completed in 1996 and operation began in 1997 and included two extraction wells, several MWs (Figure 9.7), and facilities required to transfer the TCE-contaminated water to the USEC C-637 Cooling Towers for treatment. Groundwater quality and water-level information obtained from the MWs is used to evaluate the effectiveness of the remedial action. The upgradient MWs also are used to measure ^{99}Tc contamination within the plume before it reaches the extraction wells.

There were no significant TCE concentration changes in the CY 2008 MW data. All MWs indicate that the highest TCE concentration portion of the plume is being controlled when upgradient wells are compared to downgradient wells. Likewise, ^{99}Tc concentrations in CY 2008 were similar to those measured in CY 2007. All ^{99}Tc concentrations were well below the 900 pCi/L reference value.

A summary of the program's monitoring results is listed in Table 9.8. The data for this program are reported in the FFA Semiannual Progress Report.

Groundwater Monitoring Results

The major objectives of groundwater monitoring at the Paducah Site are being met by the monitoring programs. A detectable concentration of analytes, in which the source is associated with the site, has been detected in groundwater off-site. Through the monitoring program, in conjunction with RIs, a footprint of the groundwater contamination has been mapped. The program is modified each year to delineate the boundaries of the contaminant plume over time and to identify source locations for contaminants. Monitoring wells upgradient and downgradient from individual underground waste disposal facilities are sampled and analyzed for contaminants of concern. Contaminants identified by the monitoring program are evaluated by technical assessment and statistical analysis as required by permit, legal agreements, and other standard environmental practices to determine if the source of the contaminants could be from the disposal site being monitored. Found in the off-site and on-site contamination plumes were 1,1-dichloroethane, 1,1-dichloroethene, *cis*-1,2-dichloroethene, alpha and beta activity, PCBs, TCE, ^{99}Tc, and vinyl chloride. Groundwater monitoring results from all sampling efforts conducted by the Paducah Site are compiled in the Paducah Oak Ridge Environmental Information System (OREIS) database. A complete listing of analytical results is available upon request from the PRS Public Affairs department.

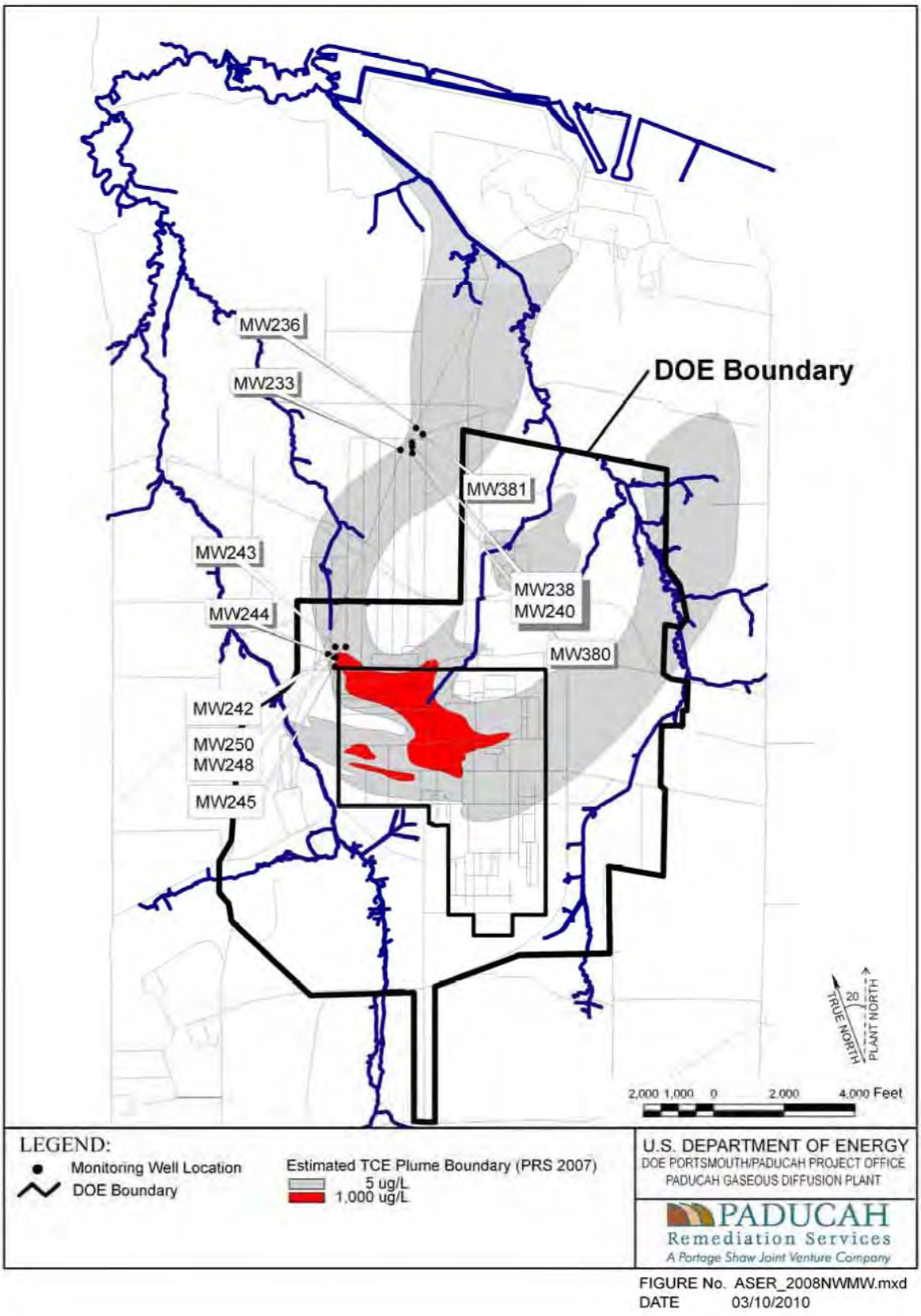

Figure 9.6. Northwest Plume Monitoring Wells

Table 9.7. Summary of Maximum Groundwater Results from the Northwest Plume Groundwater Monitoring for 2008

	Parameter	MW 233	MW 236	MW 238	MW 240	MW 242	MW 243	MW 244	MW 245	MW 248	MW 250	MW 380	MW 381	Reference/ Value	
ANION (mg/L)	Chloride	NA	NA	NA	NA	65	64	NA	NA	NA	NA	NA	38	--	
	Fluoride	NA	NA	NA	NA	0.13	0.12	NA	NA	NA	NA	NA	0.16	MCL	4
	Nitrate as N	NA	NA	NA	NA	1	1.4	NA	NA	NA	NA	NA	1.6	MCL	10
	Sulfate	NA	NA	NA	NA	15	12	NA	NA	NA	NA	NA	23	--	
METAL (mg/L)	Arsenic	NA	NA	NA	NA	0.0055	0.00354	NA	NA	NA	NA	NA	0.00244	MCL	0.05
	Barium	NA	NA	NA	NA	0.245	0.171	NA	NA	NA	NA	NA	0.162	MCL	2
	Calcium	NA	NA	NA	NA	28	27.8	NA	NA	NA	NA	NA	24.1	--	
	Cobalt	NA	NA	NA	NA	0.00353	ND	NA	NA	NA	NA	NA	0.161	--	
	Iron	NA	NA	NA	NA	2.93	0.143	NA	NA	NA	NA	NA	10	--	
	Magnesium	NA	NA	NA	NA	11.8	11.6	NA	NA	NA	NA	NA	0.00975	--	
	Manganese	NA	NA	NA	NA	0.303	ND	NA	NA	NA	NA	NA	38	--	
	Molybdenum	NA	NA	NA	NA	0.00174	0.00153	NA	NA	NA	NA	NA	ND	--	
	Nickel	NA	NA	NA	NA	0.0286	ND	NA	NA	NA	NA	NA	ND	--	
	Potassium	NA	NA	NA	NA	1.01	1.12	NA	NA	NA	NA	NA	1.32	--	
	Selenium	NA	NA	NA	NA	0.00883	0.0162	NA	NA	NA	NA	NA	0.0136	MCL	0.05
	Sodium	NA	NA	NA	NA	30.7	25.4	NA	NA	NA	NA	NA	30.2	--	
METAL-D (mg/L)	Arsenic, Dissolved	NA	NA	NA	NA	0.00211	ND	NA	NA	NA	NA	NA	ND	--	
	Barium, Dissolved	NA	NA	NA	NA	0.242	0.166	NA	NA	NA	NA	NA	0.157	--	
	Calcium, Dissolved	NA	NA	NA	NA	28	29	NA	NA	NA	NA	NA	24.8	--	
	Cobalt, Dissolved	NA	NA	NA	NA	0.00359	ND	NA	NA	NA	NA	NA	ND	--	
	Magnesium, Dissolved	NA	NA	NA	NA	11.8	11.8	NA	NA	NA	NA	NA	10.4	--	
	Manganese, Dissolved	NA	NA	NA	NA	0.307	ND	NA	NA	NA	NA	NA	ND	--	
	Molybdenum, Dissolved	NA	NA	NA	NA	0.00152	0.00106	NA	NA	NA	NA	NA	ND	--	
	Nickel, Dissolved	NA	NA	NA	NA	0.031	ND	NA	NA	NA	NA	NA	ND	--	
	Potassium, Dissolved	NA	NA	NA	NA	1.12	1.15	NA	NA	NA	NA	NA	1.37	--	
	Sodium, Dissolved	NA	NA	NA	NA	30.8	27.2	NA	NA	NA	NA	NA	31.9	--	
METEO (in/Hg)	Barometric Pressure					30.09	30.45	30.09	30.09	30.09	30			--	
PHYSC	Depth to Water (ft)	48.89	48.18	49	48.45	46.3	45.19	44.17	45.48	44.71	43.95	68.7	48.61	--	
	Dissolved Oxygen (mg/L)	3.33	3.42	3.5	3.81	3.6	5.17	4.53	1.34	3.98	5.06	3.39	4.33	--	
	Dissolved Solids (mg/L)	NA	NA	NA	NA	234	209	NA	NA	NA	NA	NA	222	--	
	pH (Std Units)	6.14	6.24	6.13	6.15	6.01	6.12	6.29	6.18	6.19	6.21	6.15	6.23	--	
	Redox (mV)	273	304	312	305	293	510	423	213	427	363	306	254	--	
	Temperature (^{o}F)	59.2	60.6	59.7	63	58.9	59.7	60.8	65.6	66.4	65	63.1	59.9	--	

Table 9.7. Summary of Maximum Groundwater Results from the Northwest Plume Groundwater Monitoring for 2008 (Continued)

	Parameter	MW 233	MW 236	MW 238	MW 240	MW 242	MW 243	MW 244	MW 245	MW 248	MW 250	MW 380	MW 381	Reference/ Value	
RADS (pCi/L)	Alpha Activity	NA	NA	NA	NA	11.5	6.58	ND	ND	12.2	ND	NA	NA	MCL	50
	Beta Activity	5.24	18.8	8.77	10.4	176	212	39.2	ND	371	52.9	24.7	41.7	--	
	Radon-222	NA	NA	NA	NA	216	237	78.5	241	261	172	NA	NA	--	
	Technetium-99	ND	16.8	ND	ND	173	254	41.2	ND	387	59.6	23.2	46.7	TTL	900
VOA (µg/L)	1,1-Dichloroethene	ND	ND	ND	ND	2	ND	ND	ND	1.9	ND	ND	ND	MCL	7
	cis-1,2-Dichloroethene	ND	ND	ND	ND	3.3	ND	ND	2.2	6.5	ND	ND	ND	--	
	Ethylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.022	--	
	Tetrachlorethene	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND	--	
	Toluene	ND	ND	ND	ND	ND	ND	5.8	ND	ND	ND	ND	ND	--	
	Trichloroethene	3.5	**29**	**13**	**9.8**	**140**	**380**	**9**	**130**	**2100**	**12**	**64**	**94**	MCL	5
WET CHEM	Alkalinity (mg/L)	NA	NA	NA	NA	81	72	NA	NA	NA	NA	NA	94	--	
	Conductivity	204	360	350	369	409	392	329	354	371	333	358	374	--	
	Silica (mg/L)	NA	NA	NA	NA	16	15	NA	NA	NA	NA	NA	17	--	
	Turbidity (NTU)	7.3	11.1	23.6	43.7	196	6.3	3.5	78.2	806	2.9	45.8	10.9	--	

NA – not analyzed
ND – not detected
TTL – target treatment level for Northwest Plume
VOA – volatile organic analyte
-- – No reference value for this parameter
Bold – exceeds criteria
PHYSC - physical parameters
WETCHEM - wet chemistry parameters
MCL – maximum contaminant level

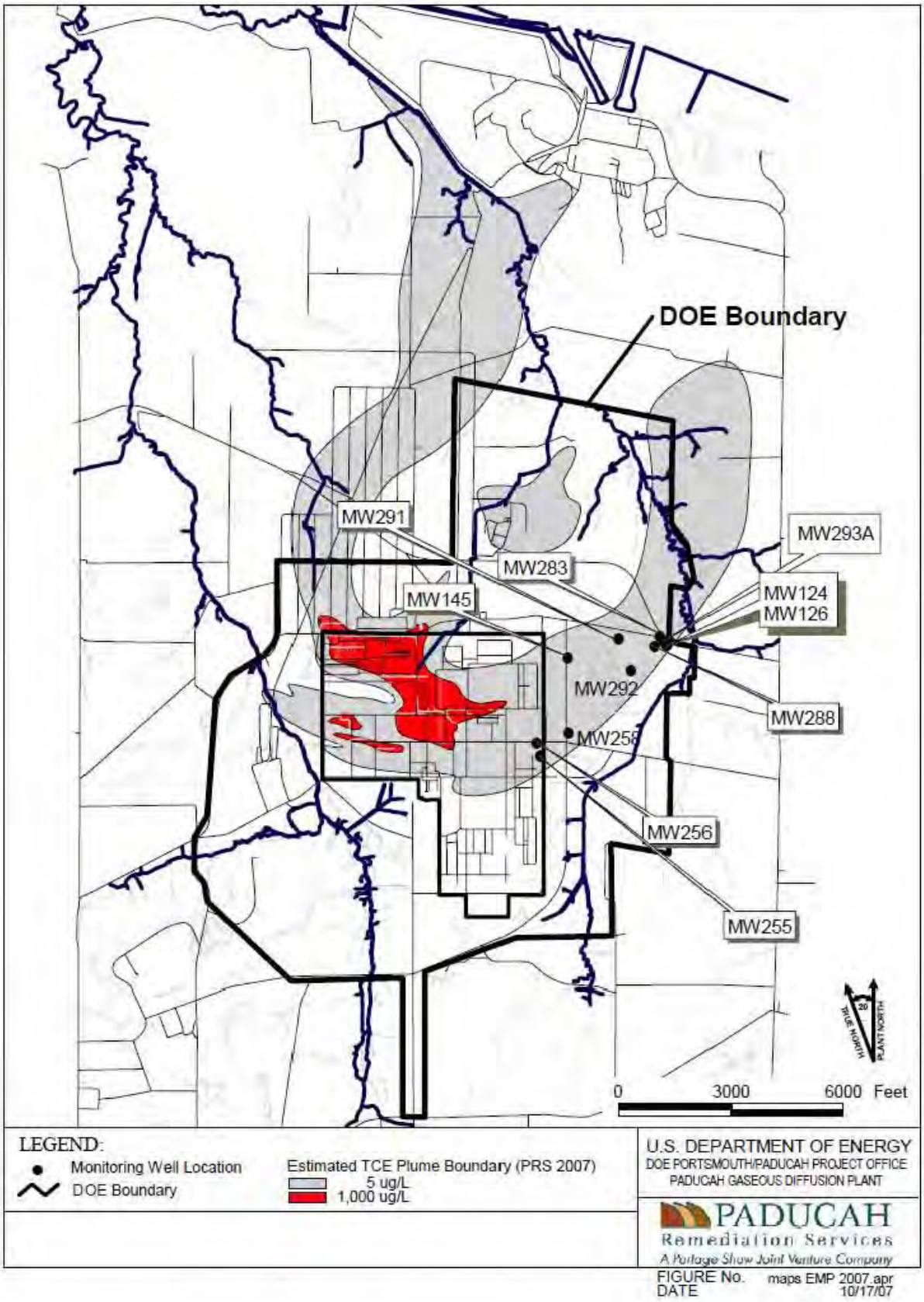

Figure 9.7. Northeast Plume Monitoring Wells

Table 9.8. Summary of Maximum Groundwater Results from the Northeast Plume Groundwater Monitoring for 2008

	Parameter	MW 124	MW 126	MW 145	MW 255	MW 256	MW 258	MW 283	MW 288	MW 291	MW 292	MW 293A	Reference/ Value	
ANION (mg/L)	Chloride	NA	NA	81	59	51	41	NA	64	60	54	NA	--	
	Fluoride	NA	NA	0.21	0.26	0.23	0.24	NA	0.16	0.15	0.19	NA	MCL	4
	Nitrate as Nitrogen	NA	NA	ND	ND	1	ND	NA	1	1.2	1.1	NA	MCL	10
	Sulfate	NA	NA	91	44	27	29	NA	20	6.4	21	NA	--	
METAL (mg/L)	Aluminum	NA	NA	1.25	1.71	ND	0.494	NA	ND	ND	ND	NA	--	
	Arsenic	NA	NA	0.00228	0.00288	0.00144	0.0014	NA	0.00394	0.00327	0.00312	NA	MCL	0.05
	Barium	NA	NA	0.0629	0.154	0.192	0.16	NA	0.263	0.237	0.224	NA	MCL	2
	Calcium	NA	NA	44.1	30.5	28.1	22.2	NA	29.8	23.7	26.7	NA	--	
	Chromium	NA	NA	**0.722**	0.0168	ND	0.0274	NA	**0.43**	0.013	0.0396	NA	MCL	0.1
	Cobalt	NA	NA	ND	0.00694	ND	ND	NA	ND	ND	ND	NA	--	
	Iron	NA	NA	2.09	1.96	ND	0.395	NA	3.31	0.103	0.598	NA	--	
	Magnesium	NA	NA	17.3	12	11.1	8.73	NA	12	9.77	10.8	NA	--	
	Manganese	NA	NA	ND	1.08	0.0135	0.0065	NA	ND	ND	ND	NA	--	
	Molybdenum	NA	NA	0.00873	0.00322	ND	0.00172	NA	0.038	ND	0.00174	NA	--	
	Nickel	NA	NA	0.0145	0.007	ND	ND	NA	0.012	ND	0.00719	NA	--	
	Potassium	NA	NA	5.25	1.7	1.78	1.74	NA	1.7	1.4	1.71	NA	--	
	Selenium	NA	NA	0.0132	0.00973	0.0081	0.00942	NA	0.0213	0.0194	0.0204	NA	MCL	0.05
	Sodium	NA	NA	64.8	89.1	63.8	60.7	NA	42.1	35.6	51.4	NA	--	
METAL-D (mg/L)	Barium, Dissolved	NA	NA	0.0575	0.131	0.185	0.15	NA	0.258	0.236	0.223	NA	--	
	Calcium, Dissolved	NA	NA	43	30.3	27.7	23.4	NA	30.1	23.8	26.8	NA	--	
	Cobalt, Dissolved	NA	NA	ND	0.00435	ND	ND	NA	ND	ND	ND	NA	--	
	Iron, Dissolved	NA	NA	ND	0.186	ND	ND	NA	ND	ND	ND	NA	--	
	Magnesium, Dissolved	NA	NA	17.1	11.8	10.9	9.21	NA	12.1	9.81	10.7	NA	--	
	Manganese, Dissolved	NA	NA	ND	1.02	0.0128	ND	NA	ND	ND	ND	NA	--	
	Molybdenum, Dissolved	NA	NA	ND	0.00131	ND	ND	NA	0.00139	ND	ND	NA	--	
	Nickel, Dissolved	NA	NA	ND	ND	ND	ND	NA	ND	ND	0.00502	NA	--	
	Potassium, Dissolved	NA	NA	5.07	1.72	1.81	1.79	NA	1.74	1.41	1.74	NA	--	
	Selenium, Dissolved	NA	NA	ND	ND	ND	0.00628	NA	0.00558	0.00505	0.00792	NA	--	
	Sodium, Dissolved	NA	NA	64.2	87.3	65.4	66.7	NA	43.6	36.5	52.4	NA	--	
METEO (in/Hg)	Barometric Pressure	30.33	30.33	30.21	30.39	30.39	30.42	30.24	30.47	30.47	30.45	30.21	--	
PHYSC	Depth to Water (ft)	42.5	41.86	57.28	60.06	60.91	59.53	47.4	49.22	48.48	53.48	43.28	--	
	Dissolved Oxygen (mg/L)	2.47	3.34	2.13	0.89	0.72	1.66	3.96	3.91	5.14	2.53	3.72	--	
	Dissolved Solids (mg/L)	ND	ND	410	364	292	271	ND	252	203	262		--	
	pH (Std Units)	6.18	6.2	6.11	6.54	6.37	6.38	6.11	6.15	6.12	6.12	6.06	--	
	Redox (mV)	465	458	460	222	484	451	463	643	556	564	554	--	
	Temperature (deg F)	61.7	62.4	67.8	66.8	69.5	64.8	67.8	64.7	64.4	60.2	59.8	--	

Table 9.8. Summary of Maximum Groundwater Results from the Northeast Plume Groundwater Monitoring for 2008 (Continued)

	Parameter	MW124	MW126	MW145	MW255	MW256	MW258	MW283	MW288	MW291	MW292	MW293A	Reference/ Value	
RADS (pCi/L)	Alpha Activity	ND	5.12	ND	ND	ND	ND	ND	6.53	ND	ND	ND	MCL	50
	Beta Activity	11.1	6.42	37.8	6.78	105	9.84	12	42.4	6.71	46.2	ND	--	
	Technetium-99	ND	ND	47.3	ND	135	18.7	ND	40.9	ND	61.1	ND	TTL	900
VOA (µg/L)	1,1-Dichloroethane	ND	ND	ND	ND	16	ND	ND	3	ND	ND	ND	--	
	1,1-Dichloroethene	3.2	ND	ND	ND	**94**	**11**	ND	**21**	ND	**35**	ND	MCL	7
	cis-1,2-Dichloroethene	ND	ND	3	8.4	7.4	3.1	4.4	7.1	2.5	ND	ND	--	
	Trichloroethene	**140**	**14**	**71**	**380**	**460**	**290**	**88**	**230**	**76**	**320**	**270**	MCL	5
WETCHEM	Alkalinity (mg/L)	NA	NA	126	200	160	150	NA	113	88	131	NA	--	
	Conductivity (umho/cm)	448	451	766	748	614	555	488	540	391	533	383	--	
	Silica (mg/L)	NA	NA	16	17	16	16	NA	16	17	17	NA	--	
	Total Organic Carbon (mg/L)	NA	NA	1.3	1.2	ND	ND	NA	ND	ND	ND	NA	--	
	Turbidity (NTU)	26.5	16.8	41.5	30.1	3.6	12.2	11.5	86.1	15.8	30.7	8.7	--	

NA – not analyzed
ND – not detected
TTL – target treatment level for Northwest Plume
VOA – volatile organic analyte
-- – No reference value for this parameter
Bold – exceeds criteria
PHYSC – physical parameters
WETCHEM – wet chemistry parameters
MCL – maximum contaminant level

10 Quality Assurance

Abstract

The Paducah Site maintains a Quality Assurance/Quality Control (QA/QC) Program to verify the integrity of data generated within the Environmental Monitoring Program. Sampling methods, instruments, locations, schedules, and other sampling and monitoring criteria are based on applicable guidelines from various established authorities.

Introduction

The Paducah Site maintains a QA/QC Program to verify the integrity of data generated within the Environmental Monitoring Program. Each aspect of the monitoring program, from sample collection to data reporting, must comply with quality requirements and assessment standards. Requirements and guidelines for the QA/QC Program at the Paducah Site are established by DOE Order 414.1C, *Quality Assurance;* state and federal regulations; and guidance from the EPA, the American National Standards Institute, the American Society of Mechanical Engineers, the American Society of Testing and Materials (ASTM), and the American Society for Quality Control. The QA/QC Program specifies organizational and programmatic elements to control equipment, design, documents, data, nonconformances, and records. Emphasis is placed on planning, implementing, and assessing activities and implementing effective corrective actions as necessary. Program requirements are specified in project and subcontract documents to ensure that requirements are included in project-specific QA plans and other planning documents.

In 2008, two separate EMPs defined the relationship of each element of the Environmental Monitoring Program. The FY 2008 EMP (PRS 2007c) was in effect and covered data collected during the time frame of January 2008 to September 2008. The FY 2009 EMP (PRS 2009) was in effect and covered data collected during the time frame of October 2008 to December 2008.

In 2008, two separate QA plans defined the relationship of each element of the Environmental Monitoring Program to key quality and data management requirements. The *Environmental Monitoring Quality Assurance Project Plan* and the *Environmental Monitoring Data Management Implementation Plan* in the FY 2008 EMP (PRS 2007c) was in effect and covered data collected during the time frame of January through September 2008. The *Environmental Monitoring Quality Assurance Project Plan* and *Environmental Monitoring Data Management Implementation Plan* in the FY 2009 EMP (PRS 2009) covered October 2008 through December 2008. Training requirements, sample custody, procedures, instrument calibration and maintenance, and data review are a few of the subjects discussed in the two QA plans.

Field Sampling Quality Control

Data Quality Objectives and Sample Planning

From the start of any sampling program, data quality objectives (DQOs) play an important role in setting the number of samples, location of sampling sites, sampling methods, sampling schedules, and coordination of sampling and analytical resources to meet critical completion times. These sampling program criteria are documented in the Paducah Site EMP (PRS 2007c).

Each sampling location and sample collected is assigned a unique identification number. Each segment of the identification number sequence is used to designate information concerning the location from which a sample is collected. To progress from planning to implementing the DQOs, an analytical statement of work (SOW) for the analytical laboratory is generated from a system within the Paducah Integrated Data System. From this system, the Project Environmental Measurements System (PEMS), an electronic database used for managing and streamlining field-generated and laboratory-generated data, is populated with sample identification numbers, sampling locations, sampling methods, analytical parameters, analytical methods, and sample container and preservative requirements. This information is used to produce sample bottle labels and chain-of-custody forms for each sampling event.

Field Measurements

Field measurements for the groundwater and surface water monitoring program are collected in the field and include water level measurements, pH, conductivity, flow rate, turbidity, temperature, dissolved oxygen, total residual chlorine, Eh (oxidation/reduction potential), and barometric pressure. Environmental conditions, such as ambient temperature and weather, also are recorded. Field measurements are collected, downloaded electronically, recorded on appropriate field forms or in logbooks, and input into PEMS.

Sampling Procedures

Samples are collected using media-specific procedures, which are written according to EPA-approved sampling methods. Sample media consist of surface water, groundwater, sediment, and biota, such as fish and deer. Sample information recorded during a sampling event consists of the sample identification number, station (or location), date collected, time collected, and person who performed the sampling, etc. This information, which is documented in a logbook, on a chain-of-custody form, and on the sample container label, then is input directly into PEMS. Chain-of-custody forms are maintained from the point of sampling, and the samples are protected properly until they are placed in the custody of an analytical laboratory.

Field Quality Control Samples

The QC program for both groundwater and environmental monitoring activities specifies a minimum target rate of 5 percent, or one per 20 environmental samples, for field QC samples. Table 10.1 shows the types of field QC samples collected and analyzed. Analytical results of field QC samples are evaluated to determine if the sampling event biased the sample results.

Table 10.1. Types of QC Samples

Field QC Samples	Laboratory QC Samples
Field blanks[a]	Laboratory duplicates
Field duplicates	Reagent blanks
Trip blanks[a]	Matrix spikes[b]
Equipment rinseates[c]	Matrix spike duplicates
	Surrogates
	Performance evaluations
	Laboratory control samples

[a] Blanks–Samples of deionized water used to assess potential contamination from a source other than the media being sampled.
[b] Spikes–Samples that have been mixed with a known quantity of a chemical to measure overall method effectiveness during the analysis process, as well as possible sample/matrix interferences.
[c] Rinseates - Samples of deionized water which have been used to rinse the sampling equipment. It is collected after completion of decontamination and prior to sampling. It is used to assess adequate decontamination of sampling equipment.

Analytical Laboratory Quality Control

Analytical Procedures

When available and appropriate for the sample matrix, EPA-approved SW-846 methods are used for sample analysis. When SW-846 methods are not available, other nationally recognized methods, such as those developed by DOE and ASTM, are used. Analytical methods are identified in a SOW for laboratory services. Using guidance from EPA, laboratories document the steps in sample handling, analysis, and reporting results, and follow chain-of-custody procedures.

Laboratory Quality Control Samples

Laboratory QC samples are prepared and analyzed as required by the analytical methods used. Typical laboratory QC samples are identified in Table 10.1. If acceptance criteria are not met for the QC samples, then appropriate action, as denoted by the analytical method, is taken or the analytical data are qualified appropriately.

Independent Quality Control

The Paducah Site is required by DOE and EPA to participate in independent QC programs. The site also participates in voluntary independent programs to improve analytical QC. These programs generate data that readily are recognized as objective measures that provide participating laboratories and government agencies a periodic review of their performance. Results that exceed acceptable limits are investigated and documented according to formal procedures. Although participation in certain programs is mandatory, the degree of participation is voluntary, so that each laboratory can select parameters of particular interest to that facility. These programs are conducted by EPA, DOE, and commercial laboratories. The laboratories supporting the Paducah DOE KPDES program participate in a Discharge Monitoring Report QA Study conducted annually by EPA. Final results for the Discharge Monitoring Report QA Study Number 28 were “acceptable,” with the exceptions of iron and 48-hour acute toxicity for the fathead minnow. A corrective action report was submitted to EPA in December 2008.

Laboratory Audits/Sample Management Office

Laboratory audits are performed annually by the DOE Consolidated Audit Program (DOECAP) to ensure that the laboratories are in compliance with regulations, methods, and procedures. The audited laboratories are included on the DOECAP-approved listing for use by the Sample Management Office (SMO). Findings are documented and addressed by the audited laboratory through corrective actions.

Data Management

Project Environmental Measurements System

The data generated from sampling events are stored in PEMS, a consolidated site data system for tracking and managing data. The system is used to manage field-generated data, import laboratory generated data, input data qualifiers identified during the data review process, and transfer data to the Paducah OREIS database for reporting. PEMS uses a variety of references and code lists to ensure consistency and standardization of the data.

Paducah OREIS

Paducah OREIS is the database used to consolidate data generated by the EM Program. Data consolidation consists of the activities necessary to prepare the evaluated data for the users. The PEMS files containing the assessed data are transferred from PEMS to Paducah OREIS for future use. The data manager is responsible for notifying the project team and other data users of the available data. Data used in reports distributed to external agencies (e.g., the quarterly landfill reports and the ASER) are obtained from Paducah OREIS and have been through the data review process. [The data review process is documented in *Data and Documents Management and Quality Assurance Plan for Paducah Environmental Management and Enrichment Facilities*, DOE/OR/07-1595&D2, Section 8.4 (DOE 1998)].

Electronic Data Deliverables

A “results only” Electronic Data Deliverable (EDD) is requested for all samples analyzed by each laboratory. The results and qualifier information from the EDD are checked in addition to the format of all fields provided. Discrepancies are reported immediately to the laboratory so corrections can be made or new EDDs can be issued. Approximately 10 percent of the EDDs are randomly checked to verify that the laboratory continues to provide adequate EDDs.

Data Packages

A “forms only” Level III data package is requested from the laboratory when data validation is to be performed on a specific sampling event or media. All data packages received from the fixed base laboratory are tracked, reviewed, and maintained in a secure environment. The following information is tracked: sample delivery group number, date received, receipt of any EDD, and comments. The contents of the data package and the chain-of-custody forms are compared and discrepancies identified. Discrepancies are reported immediately to the laboratory and data validators. All data packages are forwarded to the Document Management Center for permanent storage.

Laboratory Contractual Screening

Laboratory contractual screening is the process of evaluating a set of data against the requirements specified in the analytical SOW to ensure that all requested information is received. The contractual

screening includes, but is not limited to, the chain-of-custody form, analytes requested, method used, units, holding times, and reporting limits achieved. The contractual screening is conducted electronically upon receipt of data from the analytical laboratory. Any exception to the SOW is identified and documented.

Data Verification, Validation, and Assessment

Data verification is the process for comparing a data set against a set standard or contractual requirement. Verification is performed electronically, manually, or by a combination of both. Data verification includes contractual screening and other criteria specific to the data. Data are flagged as necessary. Verification qualifiers are stored in PEMS and transferred with the data to Paducah OREIS.

Data validation is the process performed by a qualified individual for a data set, independent from sampling, laboratory, project management, or other decision-making personnel. Data validation evaluates the laboratory adherence to analytical method requirements. Validation qualifiers are stored in PEMS and transferred with the data to Paducah OREIS. Data from routine sampling events are validated programmatically at a frequency of 5 percent of the total data packages. Each of the selected data packages, which make up 5 percent of the total number of data packages, is validated 100 percent.

Data assessment is the process for assuring that the type, quality, and quantity of data are appropriate for their intended use based on the DQOs. It allows for the determination that a decision (or estimate) can be made with the desired level of confidence, given the quality of the data set. Data assessment follows data verification and data validation (if applicable) and must be performed at a rate of 100 percent to ensure data are useable. The data assessment is conducted by trained technical personnel in conjunction with other project team members. Assessment qualifiers are stored in PEMS and transferred with the data to Paducah OREIS. Data are made available for reporting from Paducah OREIS upon completion of the data assessment, and associated documentation is filed with the project files.

The EPA and KDOW require, as part of their QA program, a laboratory QA study. Each laboratory performing analyses to demonstrate KPDES permit compliance is required to participate. Four laboratories and one sampling organization participated in the study in 2008. Final results for the Discharge Monitoring Report QA Study Number 28 were “acceptable,” with the exceptions of iron and 48-hour acute toxicity for the fathead minnow. A corrective action report was submitted to EPA in December 2008. The Discharge Monitoring Report QA Study results were provided to KDOW and EPA, as required.

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Glossary

absorption – The process by which the number and energy of particles or photons entering a body of matter are reduced by interaction with the matter.

adsorption – The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

activity – See radioactivity.

air stripping – The process of bubbling air through water to remove volatile organic compounds from the water.

alpha particle – A positively charged particle emitted from the nucleus of an atom having the same charge and mass as that of a helium nucleus (two protons and two neutrons).

ambient air – The atmosphere around people, plants, and structures.

analyte – A constituent or parameter being analyzed.

analytical detection limit – The lowest reasonably accurate concentration of an analyte that can be detected; this value varies depending on the method, instrument, and dilution used.

aquifer – A geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs.

aquitard – A geologic unit that inhibits the flow of water.

assimilate – To take up or absorb.

atom – Smallest particle of an element capable of entering into a chemical reaction.

beta particle – A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.

biota – The animal and plant life of a particular region considered as a total ecological entity.

CERCLA-reportable release – A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act.

chain-of-custody form – A form that documents sample collection, transport, analysis, and disposal.

closure – Formal shutdown of a hazardous waste management facility under Resource Conservation and Recovery Act requirements.

compliance – Fulfillment of applicable requirements of a plan or schedule ordered or approved by government authority.

concentration – The amount of a substance contained in a unit volume or mass of a sample.

conductivity – A measure of a material's capacity to convey an electric current. For water, this property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made.

confluence – The point at which two or more streams meet; the point where a tributary joins the main stream.

congener – Any particular member of a class of chemical substances. A specific congener is denoted by a unique chemical structure.

contained landfill – A solid waste site or facility that accepts disposal of solid waste. The technical requirements for contained landfills are found in 401 *KAR* 47:080, 48:050, and 48:070 to 48:090.

contamination – Deposition of unwanted material on the surfaces of structures, areas, objects, or personnel.

cosmic radiation – Ionizing radiation with very high energies that originates outside the earth's atmosphere. Cosmic radiation is one contributor to natural background radiation.

curie (Ci) – A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are used commonly:

- **kilocurie (kCi)** – 10^{3} Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
- **millicurie (mCi)** – 10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.
- **microcurie (µCi)** – 10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.
- **picocurie (pCi)** – 10^{-12} Ci, one-trillionth of a curie; 3.7×10^{-2} disintegrations per second.

daughter – A nuclide formed by the radioactive decay of a parent nuclide.

decay, radioactive – The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide or into a different energy state of the same radionuclide.

dense nonaqueous-phase liquid (DNAPL) – The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

derived concentration guide (DCG) – The concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and the lens of the eye. The guidelines for radionuclides in air and water are given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*

disintegration, nuclear – A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dose – The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram in any medium.

- **absorbed dose** – The quantity of radiation energy absorbed by an organ divided by the organ's mass. Absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 Gy).

- **dose equivalent** – The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 Sv).

- **committed dose equivalent** – The calculated total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. Contributions from external dose are not included. Committed dose equivalent is expressed in units of rem (or sievert).

- **committed effective dose equivalent** – The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or sievert).

- **effective dose equivalent** – The sum of the dose equivalents received by all organs or tissues of the body after each one has been multiplied by an appropriate weighting factor. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent attributable to sources external to the body.

- **collective dose equivalent/collective effective dose equivalent** – The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within a 50-mile (80-km) radius expressed in units of person-rem (or person-sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-sievert). The 50-mile distance is measured from a point located centrally with respect to major facilities or DOE program activities.

downgradient – In the direction of decreasing hydrostatic head.

downgradient well – A well that is installed hydraulically downgradient of a site and that may be capable of detecting migration of contaminants from a site.

drinking water standards (DWS) – Federal primary drinking water standards, both proposed and final, as set forth by the EPA in 40 *CFR* § 141 and 40 *CFR* § 143.

effluent – A liquid or gaseous waste discharge to the environment.

effluent monitoring – The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures to members of the public, and demonstrating compliance with applicable standards.

Environmental Restoration – A DOE program that directs the assessment and cleanup of its sites (remediation) and facilities (decontamination and decommissioning) contaminated with waste as a result of nuclear-related activities.

exposure (radiation) – The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is that exposure to ionizing radiation received at a person's workplace. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation – Exposure to ionizing radiation when the radiation source is located outside the body.

fauna – The population of animals in a given area, environment, formation, or time span.

flora – The population of plants in a given area, environment, formation, or time span.

formation – A mappable unit of consolidated or unconsolidated geologic material of a characteristic lithology or assemblage of lithologies.

gamma ray – High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an excited atom. Gamma rays are identical to X-rays except for the source of the emission.

Gaussian puff/plume model – A computer-simulated atmospheric dispersion of a release using a Gaussian (normal) statistical distribution to determine concentrations in air.

grab sample – A sample collected instantaneously with a glass or plastic bottle placed below the water surface to collect surface-water samples (also called dip samples).

groundwater, unconfined – Water that is in direct contact with the atmosphere through open spaces in permeable material.

half-life, radiological – The time required for half of a given number of atoms of a specific radionuclide to decay. Each nuclide has a unique half-life.

hardness – The amount of calcium carbonate dissolved in water, usually expressed as part of calcium carbonate per million parts of water.

high-level waste - High-level radioactive waste or HLW means: (1) Irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

hydrogeology – Hydraulic aspects of site geology.

hydrology – The science dealing with the properties, distribution, and circulation of natural water systems.

in situ – In its original place; field measurements taken without removing the sample from its origin; remediation performed while groundwater remains below the surface.

internal dose factor – A factor used to convert intakes of radionuclides to dose equivalents.

internal radiation – Occurs when natural radionuclides enter the body by ingestion of foods or liquids or by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

ion – An atom or compound that carries an electrical charge.

irradiation – Exposure to radiation.

isotopes – Forms of an element having the same number of protons but differing numbers of neutrons in the nuclei.

- **long-lived isotope** – A radionuclide that decays at such a slow rate that a quantity of it will exist for an extended period (half-life is greater than three years).

- **short-lived isotope** – A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (half-life is two days or less).

lower limit of detection – The smallest concentration or amount of analyte that can be reliably detected in a sample at a 95 percent confidence level.

maximally exposed individual – A hypothetical individual who remains in an uncontrolled area and would, when all potential routes of exposure from a facility's operations are considered, receive the greatest possible dose equivalent.

migration – The transfer or movement of a material through air, soil, or groundwater.

milliroentgen (mR) – A measure of X-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable concentration – The smallest amount or concentration of a radionuclide that can be distinguished in a sample by a given measurement system at a preselected counting time and at a given confidence level.

monitoring – Process whereby the quantity and quality of factors that can affect the environment or human health are measured periodically to regulate and control potential impacts.

mrem – The dose equivalent that is one-thousandth of a rem.

natural radiation – Radiation from cosmic and other naturally occurring radionuclide (such as radon) sources in the environment.

nuclide – An atom specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

outfall – The point of conveyance (e.g., drain or pipe) of wastewater or other effluents into a ditch, pond, or river.

part per billion (ppb) – A unit measure of concentration equivalent to the weight/volume ratio expressed as µg/L or mg/mL.

part per million (ppm) – A unit measure of concentration equivalent to the weight/volume ratio expressed as mg/L.

pathogen – A disease-producing agent; usually refers to living organisms.

person-rem – Collective dose to a population group. For example, a dose of 1 rem to 10 individuals results in a collective dose of 10 person-rem.

pH – A measure of the hydrogen-ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 7, neutral solutions have a pH equal to 7, and basic solutions have a pH greater than 7.

piezometer – An instrument used to measure the hydraulic potential of groundwater at a given point; also, a well designed for this purpose.

polychlorinated biphenyl (PCB) – Any chemical substance that is limited to the biphenyl molecule and that has been chlorinated to varying degrees.

polynuclear aromatic hydrocarbon (PAH) – Any organic compound composed of more than one benzene ring.

process water – Water used within a system process.

purge – To remove water before sampling, generally by pumping or bailing.

quality assurance (QA) – Any action in environmental monitoring to ensure the reliability of monitoring and measurement data.

quality control (QC) – The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes.

quality factor – The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. A quality factor is used because some types of radiation, such as alpha particles, are more biologically damaging than others.

rad – An acronym for Radiation Absorbed Dose. The rad is a basic unit of absorbed radiation dose. (This is being replaced by the "gray," which is equivalent to 100 rad.)

radiation detection instruments – Devices that detect and record the characteristics of ionizing radiation.

radioactivity – The spontaneous emission of radiation, generally alpha or beta particles or gamma rays, from the nucleus of an unstable isotope.

radioisotopes – Radioactive isotopes.

radionuclide – An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reference material – A material or substance with one or more properties that is sufficiently well established and used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

release – Any discharge to the environment. Environment is broadly defined as any water, land, or ambient air.

rem – The unit of dose equivalent (absorbed dose in rads multiplied by the radiation quality factor). Dose equivalent is frequently reported in units of millirem (mrem), which is one-thousandth of a rem.

remediation – The correction of a problem. See Environmental Restoration.

Resource Conservation and Recovery Act (RCRA) – Federal legislation that regulates the transport, treatment, and disposal of solid and hazardous wastes.

RFI Program – RCRA Facility Investigation Program; EPA-regulated investigation of a solid waste management unit with regard to its potential impact on the environment.

roentgen – A unit of exposure from X-rays or gamma rays. One roentgen equals 2.58×10^{4} coulombs per kilogram of air.

screen zone – In well construction, the section of a formation that contains the screen, or perforated pipe, that allows water to enter the well.

semivolatile organic analyte (SVOA) – Any organic compound with a high boiling point which will volatilize upon heating.

sievert (Sv) – The SI (International System of Units) unit of dose equivalent; 1 Sv = 100 rem.

slurry – A suspension of solid particles (sludge) in water.

source – A point or object from which radiation or contamination emanates.

specific conductance – The ability of water to conduct electricity; this ability varies in proportion to the amount of ionized minerals in the water.

stable – Not radioactive or not easily decomposed or otherwise modified chemically.

storm-water runoff – Surface streams that appear after precipitation.

strata – Beds, layers, or zones of rocks.

substrate – The substance, base, surface, or medium in which an organism lives and grows.

surface water – All water on the surface of the earth, as distinguished from groundwater.

suspended solids – Mixture of fine, nonsettling particles of any solid within a liquid or gas.

terrestrial radiation – Ionizing radiation emitted from radioactive materials, primarily ^{40}K, thorium, and uranium, in the earth's soils. Terrestrial radiation contributes to natural background radiation.

thermoluminescent dosimeter (TLD) – A device used to measure external gamma radiation.

total activity – The total quantity of radioactive decay particles that are emitted from a sample.

total solids – The sum of total dissolved solids and suspended solids.

total suspended particulates – Refers to the concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

transuranic element (TRU) – An element above uranium in the Periodic Table, that is, with an atomic number greater than 92. All 11 TRUs are produced artificially and are radioactive. They are neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, and lawrencium.

troughing system – A collection and containment system designed to collect leaks of oil that have been contaminated with PCBs.

turbidity – A measure of the concentration of sediment or suspended particles in solution.

upgradient – In the direction of increasing hydrostatic head.

vadose zone – Soil zone located above the water table.

volatile organic compound (VOC) – Any organic compound that has a low boiling point and readily volatilizes into air (e.g., trichloroethane, tetrachloroethene, and trichloroethene).

watershed – The region draining into a river, river system, or body of water.

wetland – A lowland area, such as a marsh or swamp, inundated or saturated by surface or groundwater sufficiently to support hydrophytic vegetation typically adapted to life in saturated soils.

Appendix A: Radiation

This appendix provides basic information about radiation. This information is intended to be a basis for understanding normal radiation dose from sources unassociated with the Paducah Site. People are constantly exposed to radiation. For example, radon in air; potassium in food and water; and uranium, thorium, and radium in the earth's crust are all sources of radiation. The following discussion describes important aspects of radiation, including atoms and isotopes; types, sources, and pathways of radiation; radiation measurement; and dose information.

ATOMS AND ISOTOPES

All matter is made up of **atoms**. The atom is thought to consist of a dense central nucleus surrounded by a cloud of electrons. The nucleus is composed of protons and neutrons. Table A.1 summarizes the basic components of an atom. In an electrically neutral atom, the number of protons equals the number of electrons. Atoms can lose or gain electrons through ionization. The number of protons in the nucleus determines an element's atomic number, or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the number of neutrons may vary among atoms of the same element. The number of neutrons and protons determines the atomic weight of the atom.

Atoms of the same element with a different number of neutrons are called **isotopes**. Isotopes have the same chemical properties but different atomic weights. Figure A.1 depicts

isotopes of the element hydrogen. Uranium, which has 92 protons, is another example of an element that has isotopes. All isotopes of uranium have 92 protons; however, each uranium isotope has a different number of neutrons. Uranium-234 has 92 protons and 142 neutrons; ^{235}U has 92 protons and 143 neutrons; and ^{238}U has 92 protons and 146 neutrons.

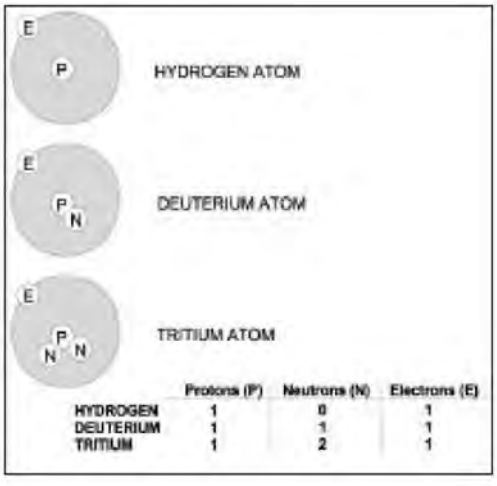

Figure A.1.Isotopes of the Element Hydrogen

Table A.1. Summary of the Basic Parts of an Atom

Particle	Location	Charge	Comments
Protons	Nucleus	+ positive	The number of protons determines the element. If the number of protons changes, the element changes.
Neutrons	Nucleus	No charge	Atoms of the same element have the same number of protons, but can have a different number of neutrons. This is called an isotope.
Electrons	Orbit nucleus	– negative	This negative charge is equal in magnitude to the proton's positive charge.

BASIC INFORMATION ABOUT RADIATION

Radioactivity was discovered in 1896 by the French physicist Antoine Henri Becquerel when he observed that the element uranium can blacken a photographic plate, even when separated from the plate by glass or black paper. In 1898, the French chemists Marie Curie and Pierre Curie concluded that radioactivity is a phenomenon associated with atoms, independent of their physical or chemical state. The Curies measured the heat associated with the decay of radium and established that 1 g (0.035 oz) of radium gives off about 100 cal of energy every hour. This release of energy continues hour after hour and year after year, whereas the complete combustion of a gram of coal results in the production of a total of only about 8,000 cal of energy. Radioactivity attracted the attention of scientists throughout the world, following these early discoveries. In the ensuing decades, many aspects of the phenomenon were thoroughly investigated (Encarta 2002a).

Radiation is energy in the form of waves or particles moving through space. Radiation occurs because unstable atoms give off excess energy to become stable. **Ionization** is the process of removing electrons from neutral atoms. NOTE: Ionization should not be confused with radiation. Ionization is a result of the interaction of radiation with an atom and is what allows the radiation to be detected. **Ionizing radiation** is energy (particles or rays) emitted from radioactive atoms that can cause ionization. Ionizing radiation is capable of displacing electrons and changing the chemical state of matter and, subsequently, causing biological damage; therefore, ionizing radiation is potentially harmful to human health. Examples of ionizing radiation include alpha, beta, and gamma radiation. **Nonionizing radiation** bounces off or passes through matter without displacing electrons. Nonionizing radiation does not have enough energy to ionize an atom. It is unclear whether nonionizing radiation is harmful to human health. Examples include visible light, radar waves, microwaves, and radio waves. **Radioactivity** is the process of unstable or radioactive atoms becoming stable by emitting radiant energy. Radioactivity that occurs over a period of time is called **radioactive decay**. The discovery that radium decays to produce radon proved conclusively that radioactive decay is accompanied by a change in the chemical nature of the decaying element. A **disintegration** is a single atom undergoing radioactive decay. **Radioactive half-life** is the time it takes for one-half of the radioactive atoms present to decay.

TYPES, SOURCES, AND PATHWAYS OF RADIATION

Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from the sunlight, they actually are absorbing the radiant energy emitted by the sun. Electromagnetic radiation is radiation in the form of electromagnetic waves; examples include gamma rays, ultraviolet light, and radio waves. Particulate radiation is radiation in the form of particles; examples include alpha

and beta particles. The spectrum of particle and electromagnetic radiations ranges from the extremely short wavelengths of cosmic rays and electrons to very long radio waves that are hundreds of kilometers in length. Figure A.2 shows the difference between a longer wavelength and a shorter wavelength. Figure A.3 illustrates the wavelengths of several types of radiation along with an example of something that is approximately the same dimension in length.

The radiation's ability to penetrate material is an important consideration in protecting human health. Adequate shielding decreases the power of radiation by absorbing part or all of it. Figure A.4 shows the different penetrating power of alpha, beta, and gamma rays. Alpha rays are stopped by the thickness of a few sheets of paper or a rubber glove. A few centimeters of wood or a thin sheet of copper stops beta rays. Gamma rays and X-rays require thick shielding of a heavy material, such as iron, lead, or concrete (Encarta 2002b).

Radiation is everywhere. Most occurs naturally, but a small percentage is from humanmade sources. Naturally occurring radiation is identical to the radiation resulting from human-made sources.

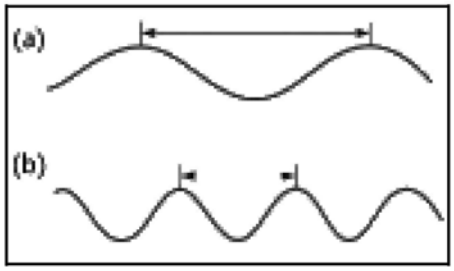

Figure A.2. Comparison between Longer (a) and Shorter (b) Wavelengths[1]

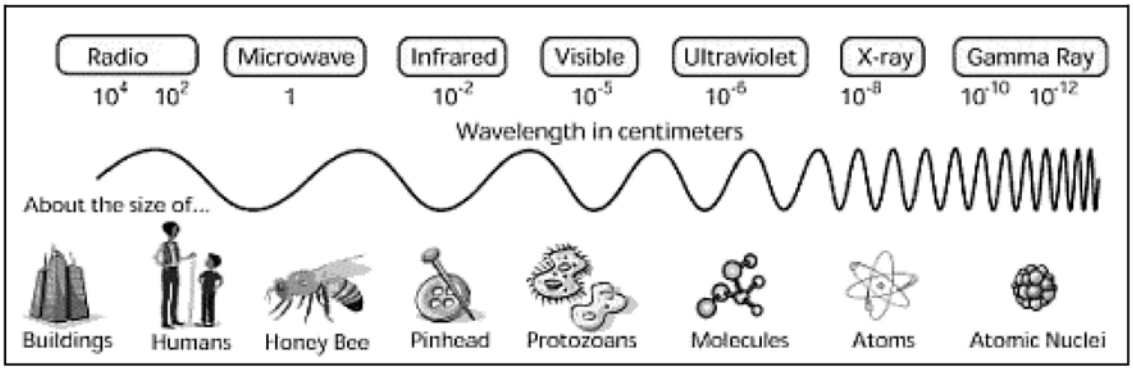

Figure A.3. The Approximate Wavelengths of the Various Regions of the Electromagnetic Spectrum and an Example of Something That Is Approximately the Same Size[2]

[1] ("Electromagnetic…" 2002, Appendix A references)
[2] ("Exploring …" 2002, Appendix A references)

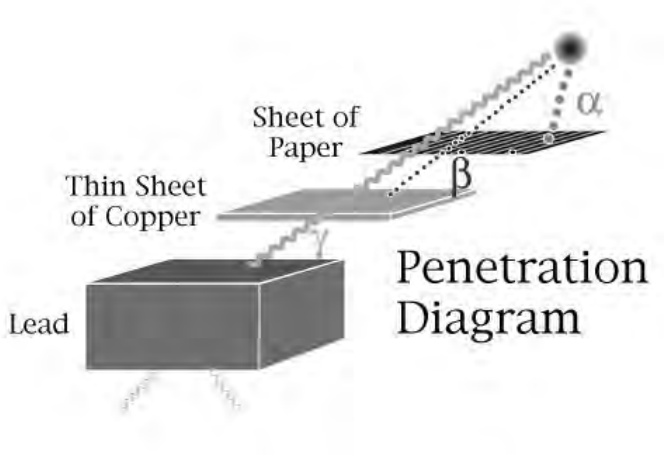

Figure A.4. The Penetrating Potential of the Three Types of Ionizing Radiation: Alpha (α), Beta (β), and Gamma (γ)[3]

Naturally occurring radiation is known as **background radiation**. In fact, this naturally occurring radiation is the major source of radiation in the environment. People have little control over the amount of background radiation to which they are exposed. Background radiation remains relatively constant over time. The amount of background radiation present in the environment today is much the same as it was hundreds of years ago. Sources of background radiation include uranium in the earth, radon in the air, and potassium in food. Depending on its origin, background radiation is categorized as cosmic, terrestrial, or internal. **Cosmic radiation** comes from the sun and outer space and is made up of energetically charged particles from that continuously hit the earth's atmosphere. Because the atmosphere provides some shielding against cosmic radiation, the intensity of cosmic radiation increases with altitude above sea level. Therefore, a person in Denver, Colorado, is exposed to more cosmic radiation than a person in Paducah, Kentucky. **Terrestrial radiation** refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn); radon progeny, the relatively short-lived decay products of radium-235 (^{235}Ra); potassium (^{40}K); isotopes of thorium (Th); and isotopes of uranium (U) are the elements responsible for most terrestrial radiation. **Internal radiation** is radiation that is inside the body and is in close contact with body tissue. Internal radiation can deposit large amounts of energy in a small amount of tissue. Radioactive material in the environment enters the body through the air people breathe, the food they eat, and even through an open wound. Natural radionuclides in the body include isotopes of U, Th, Ra, Rn, Pu, bismuth (Bi), and lead in the ^{238}U and ^{212}Th decay series.

In addition, the body contains isotopes of sodium-24 (^{24}Na), ^{40}K, rubidium (Rb), and carbon-14 (^{14}C). Most of our internal exposure comes from ^{40}K. In addition to background radiation, there are human-made sources of radiation to which most people are exposed. Examples include consumer products, medical sources, and other sources. Some **consumer products** are sources of radiation. In some of these products, such as smoke detectors and airport X-ray baggage inspection systems, the radiation is essential to the performance of the device. In other products, such as televisions and tobacco products, the radiation occurs incidentally to the product function. **Medical sources** of radiation account for the majority of the exposure people receive from human-made radiation. Radiation is an important tool of diagnostic medicine and treatment. Exposure is deliberate and directly beneficial to the patients exposed. Generally, diagnostic or therapeutic medical exposures result from X-ray beams directed to specific areas of the body. Thus, all body organs generally are not irradiated uniformly.

Radiation and radioactive materials are also used in a wide variety of pharmaceuticals and in the

[3] ("Experiment…" 2002, Appendix A references)

preparation of medical instruments, including the sterilization of heat-sensitive products such as plastic heart valves. Nuclear medical examinations and treatment involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body. **Other sources** of radiation include fallout from atmospheric atomic weapons tests; emissions of radioactive materials from nuclear facilities such as uranium mines, fuel processing plants, and nuclear power plants; emissions from mineral extraction facilities; and transportation of radioactive materials. Atmospheric testing of atomic weapons has been suspended. About one-half of 1 percent of the United States population performs work in which radiation in some form is present. Radiation and radioactive material in the environment can reach people through many routes. Potential routes for radiation are referred to as **pathways**. Several radiation pathways are shown in Figure A.5. For example, radioactive material in the air could fall on a pasture. Cows could then eat the grass, and the radioactive material on the grass would show up in the cow's milk. People drinking the milk would thus be exposed to this radiation, or people could simply inhale the radioactive material in the air. The same events could occur with radioactive material in water. Fish living in the water would be exposed. People eating the fish would then be exposed to the radiation in the fish, or people swimming in the water would be exposed.

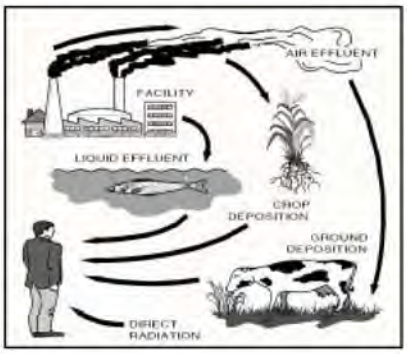

Figure A.5. Possible Radiation Pathways

MEASURING RADIATION

To determine the possible effects of radiation on the environment and the health of people, the radiation must be measured. More precisely, its potential to cause damage must be determined. When measuring the amount of radiation in the environment, what actually is being measured is the rate of radioactive decay, or **activity**. The rate of decay varies widely among the various radioisotopes. For that reason, 1 g of one radioactive substance may contain the same amount of activity as several tons of another substance. Activity is measured by the number of disintegrations a radioactive material undergoes in a certain period of time. In the United States, activity is expressed in a unit of measure known as a **curie (Ci)**. In the international system of units, activity is expressed in a unit of measure known as a **becquerel (Bq)**. One disintegration per second (dps) equals one becquerel (Bq). One curie equals:

- 37,000,000,000 atom disintegrations per second ($3.7x10^{10}$ dps)
- 37,000,000,000 becquerels ($3.7x10^{10}$ Bq)
- 1,000,000 microcuries ($1x10^{6}$ μCi)

DOSE INFORMATION

The total amount of energy absorbed per unit mass as a result of exposure to radiation is expressed in a unit of measure known as a **radiation absorbed dose (rad)**. In the international system of units, 100 rad = 1 gray. However, in terms of human health, it is the effect of the absorbed energy that is important

because some forms of radiation are more harmful than others. The unit, rad, does not take into account the potential effects that different types of radiation have on the body. The measure of potential biological damage caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a **roentgen equivalent man (rem)**. One rem of any type of radiation has the same total damaging effect and pertains to the human body. Dose is expressed in millirems (mrem), because a rem represents a fairly large dose. One millirem is equal to 1/1000 rem. The International System of Units uses the **Sievert (Sv)**, l00 rem = 1 Sievert (Sv), 100 mrem = 1 millisievert (mSv).

Many terms are used to report dose, as listed in Table A.2. Several factors are taken into account, including the amount of radiation absorbed, the organ absorbing the radiation, and the effect of the radiation over a 50-year period. The term "dose," in this report, includes the committed effective dose equivalent (EDE) and the EDE attributable to penetrating radiation from sources external to the body.

Determining dose is an involved process using complex mathematical equations based on several factors, including the type of radiation, the rate of exposure, weather conditions, and typical diet. Basically, radiant energy is generated from radioactive decay or activity. People absorb some of the energy to which they are exposed. This absorbed energy is calculated as part of an individual's dose. Whether radiation is natural or human made, its effects on people are the same.

A comparison of some dose levels is presented in Table A.3. Included is an example of the type of exposure that may cause such a dose or the special significance of such a dose. This information is intended to help the reader become familiar with the type of doses individuals may receive. The average annual dose received by residents of the United States from cosmic radiation is about 27 mrem (0.27 mSv) (NCRP 1987). The average annual dose from cosmic radiation received by residents in the Paducah area is about 45 mrem (0.45 mSv). The average annual dose received from terrestrial gamma radiation in the United States is about 28 mrem (0.28 mSv). The terrestrial dose varies geographically across the country (NCRP 1987); typical reported values are 16 mrem (0.16 mSv) at the Atlantic and Gulf coastal plains and 63 mrem (0.63 mSv) at the eastern slopes of the Rocky Mountains. In the Paducah area, background levels of radionuclides in soils are within typical levels indicating that the dose received from terrestrial gamma radiation is within the range of typical reported values (DOE 1988). The major contributors to the annual dose equivalent for internal radionuclides are the short-lived decay products of radon, mostly Rn-222. They contribute an average dose of about 200 mrem (2.00 mSv) per year. This dose estimate is based on an average radon concentration of about 1 pCi/L (0.037 Bq/L) (NCRP 1987). The average dose from other internal radionuclides is about 39 mrem (0.39 mSv) per year, most of which can be attributed to the naturally occurring isotope of potassium, ^{40}K. The concentration of radioactive potassium in human tissues is similar in all parts of the world. Table A.4 presents the internal dose factors for an adult. The United States average annual dose received by an individual from consumer products is about 10 mrem (0.10 mSv) (NCRP 1987). The dose from medical sources includes nuclear medicine examinations, which involve the internal administration of radiopharmaceuticals and generally account for the largest portion of the dose received from humanmade sources; however, the radionuclides used in specific tests are not distributed uniformly throughout the body. In these cases, comparisons are made using the concept of EDE, which relates exposure of organs or body parts to one effective whole-body dose. The average annual EDE from medical examinations is 53 mrem (0.53 mSv), including 39 mrem (0.39 mSv) for diagnostic X-rays and 14 mrem (0.14 mSv) for nuclear medicine procedures (NCRP 1989). The actual doses received by individuals who complete such medical exams are much higher than these values, but not everyone receives such exams each year (NCRP 1989). The dose from other sources include small doses received by individuals that occur as a result of radioactive fallout from atmospheric atomic weapons tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to the average dose to an individual (NCRP 1987). A comprehensive EPA report of 1984 projected the average occupational dose to monitored radiation workers in medicine, industry, the nuclear fuel cycle, government, and miscellaneous industries to be

105 mrem (1.05 mSv) per year for 1985, down slightly from 110 mrem (1.10 mSv) per year in 1980 (EPA 1984).

Table A.2. Dose Terminology

Term	Description
absorbed dose	Quantity of radiation energy absorbed by an organ divided by an organ's mass
dose equivalent	Absorbed dose to an organ multiplied by a quality factor
effective dose equivalent	Single weighted sum of combined dose equivalent received by all organs
committed dose equivalent	Effective dose equivalent to an organ over a 50-year period following intake
committed effective dose equivalent	Total effective dose equivalent to all organs in the human body over a 50-year period following intake
collective effective dose equivalent	Sum of effective dose equivalents of all members of a given population
quality factor	A modifying factor used to adjust for the effect of the type of radiation, for example, alpha particles or gamma rays, on tissue
weighting factor	Tissue-specific modifying factor representing the fraction of the total health risk from uniform, whole-body exposure

Table A.3. Comparison and Description of Various Dose Levels

Dose Level	Description
1 mrem (0.01 mSv)	Approximate daily dose from natural background radiation, including radon.
2.5 mrem (0.025 mSv)	Cosmic dose to a person on a one-way airplane flight from New York to Los Angeles.
10 mrem (0.10 mSv)	Annual exposure limit, set by the EPA for exposures from airborne emissions from operations of nuclear fuel cycle facilities, including power plants and uranium mines and mills.
45 mrem (0.45 mSv)	Average yearly dose from cosmic radiation received by people in the Paducah area.
46 mrem (0.46 mSv)	Estimate of the largest dose any off-site person could have received from the March 28, 1979, Three Mile Island nuclear power plant accident.
66 mrem (0.66 mSv)	Average yearly dose to people in the U.S. from human-made sources.
100 mrem (1.00 mSv)	Annual limit of dose from all DOE facilities to a member of the public who is not a radiation worker.
110 mrem (1.10 mSv)	Average occupational dose received by U.S. commercial radiation workers in 1980.
244 mrem (2.44 mSv)	Average dose from an upper gastrointestinal diagnostic X-ray series.
300 mrem (3.00 mSv)	Average yearly dose to people in the U.S. from all sources of natural background radiation.
1-5 rem (0.01-0.05 Sv)	EPA protective action guidelines state that public officials should take emergency action when the dose to a member of the public from a nuclear accident will likely reach this range.
5 rem (0.05 Sv)	Annual limit for occupational exposure of radiation workers set by NRC and DOE.
10 rem (0. 10 Sv)	The BEIR V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer, caused by the radiation, of 0.8%.
25 rem (0.25 Sv)	EPA guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency.
75 rem (0.75 Sv)	EPA guideline for maximum dose to emergency workers volunteering for lifesaving work.
50-600 rem (0.50-6.00 Sv)	Doses in this range received over a short period of time will produce radiation sickness in varying degrees. At the lower end of this range, people are expected to recover completely, given proper medical attention. At the top of this range, most people would die within 60 days.

Adapted from *Savannah River Site Environmental Report for 1993* (SRS 1994).

Table A.4. Internal Dose Factors for an Adult

Isotope	Half-life (years)	Intake[a] (mrem/pCi) Inhalation (soluble)	Inhalation (slightly soluble)	Inhalation (insoluble)	Ingestion
^{241}Am	430	NA	5.2E-01	NA	3.64E-03
^{137}Cs	30	3.2E-05	NA	NA	5.00E-05
^{60}Co	5.3	NA	3.0E-05	1.5E-04	1.02E-05
^{237}Np	2,140,000	NA	4.9E-01	NA	4.44E-03
$^{239/240}$Pu	24,000	NA	5.1E-01	3.3E-01	5.18E-05
^{40}K	1,260,000,000	1.2E-05	NA	NA	1.86E-05
^{99}Tc	212,000	8.4E-07	7.5E-06	1.2E-01	1.46E-06
^{230}Th	80,000	UN	3.2E-01	2.6E-01	5.48E-04
^{234}U	247,000	2.7E-03	7.1E-03	1.3E-01	2.61E-05
^{235}U	710,000,000	2.5E-03	6.7E-03	1.2E-01	2.67E-05
^{238}U	4,510,000,000	2.4E-03	6.2E-03	1.2E-01	2.38E-05

[a] Sources: U.S. DOE. July 1988. *Internal Dose Conversion Factors for Calculations of Dose to the Public*, DOE/EH-0071, and U.S. EPA. September 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, EPA-520/1-88-020.
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Appendix B: Radionuclide and Chemical Nomenclature

Table B.1. Half-Life and Derived Concentration Guide for Selected Radionuclides

Radionuclide	Symbol	Half-life	Ingested Water DCG (µCi/ml)
Americium-241	^{241}Am	432 years	3E-08
Bismuth-210	^{210}Bi	5.01 days	2E-05
Cesium-137	^{137}Cs	30.2 years	3E-06
Cobalt-60	^{60}Co	5.3 years	1E-05
Lead-206	^{206}Pb	Stable	None
Lead-210	^{210}Pb	21 years	3E-08
Lead-214	^{214}Pb	26.8 minutes	2E-04
Neptunium-237	^{237}Np	2,140,000 years	3E-08
Plutonium-239	^{239}Pu	24,110 years	3E-08
Polonium-210	^{210}Po	138.9 days	8E-08
Polonium-214	^{214}Po	164 microseconds	None
Polonium-218	^{218}Po	3.05 minutes	None
Potassium-40	^{40}K	1,260,000,000 years	7E-06
Protactinium-234m	^{234m}Pa	1.17 minutes	None
Radium-226	^{226}Ra	1,602 years	1E-07
Radon-222	^{222}Rn	3.821 days	None
Technetium-99	^{99}Tc	212,000 years	1E-04
Thorium-230	^{230}Th	80,000 years	3E-07
Thorium-231	^{231}Th	25.5 hours	1E-04
Thorium-234	^{234}Th	24.1 days	1E-05
Uranium-234	^{234}U	247,000 years	5E-07
Uranium-235	^{235}U	710,000,000 years	6E-07
Uranium-236	^{236}U	23,900,000 years	5E-07
Uranium-238	^{238}U	4,510,000,000 years	6E-07

Derived Concentration Guide (DCG) is the concentration of a radionuclide in air or water that would result in an effective dose equivalent of 100 mrem under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation). DCGs do not consider decay products when the parent radionuclide is the cause of the exposure.

Table B.2. Nomenclature for Elements and Chemical Compounds

Constituent	Symbol	Constituent	Symbol
Aluminum	Al	Manganese	Mn
Ammonia	NH_3	Mercury	Hg
Antimony	Sb	Nickel	Ni
Arsenic	As	Nitrate	NO^{3-}
Barium	Ba	Nitrite	NO^{2-}
Beryllium	Be	Nitrogen	N
Cadmium	Cd	Oxygen	O
Calcium	Ca	Ozone	O_3
Calcium carbonate	$CaCO_3$	Phosphate	PO_4^{3-}
Carbon	C	Phosphorus	P
Chlorine	Cl	Potassium	K
Chromium	Cr	Radium	Ra
Chromium, hexavalent	Cr^{6+}	Radon	Rn
Cobalt	Co	Selenium	Se
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Hydrogen fluoride	HF	Sulfate	SO_4^{2-}
Iron	Fe	Sulfur dioxide	SO_2
Lead	Pb	Thorium	Th
Lithium	Li	Uranium	U
Magnesium	Mg	Zinc	Zn

Units of Radiation Measure

Current System	System International	Conversion
curie (Ci)	becquerel (Bq)	1 Ci = 3.7 x 10^{10} Bq
rad (radiation absorbed dose)	gray (Gy)	1 rad = 0.01 Gy
rem (roentgen equivalent man)	sievert (Sv)	1 rem = 0.01 Sv

Conversions

Multiply	***by***	***to obtain***	***Multiply***	***by***	***to obtain***
in	2.54	cm	cm	0.394	in
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.4538	kg	kg	2.205	lb
gal	3.785	L	L	0.264	gal
ft^2	0.093	m^2	m^2	10.764	ft^2
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.31	ft^3
acres	0.40468	ha	ha	2.471	acres
dpm	0.45	pCi	pCi	2.22	dpm
pCi	10^{-6}	µCi	µCi	10^6	pCi
pCi/L (water)	10^{-9}	µCi/mL (water)	µCi/mL (water)	10^9	pCi/L (water)
pCi/m^3 (air)	10^{-12}	µCi/mL (air)	µCi/mL (air)	10^{12}	pCi/m^3 (air)

ha = hectares

PRS-ENM-0045
Volume I

Paducah Site

Annual Site Environmental Report

2008

EM Environmental Management

safety ❖ performance ❖ cleanup ❖ closure