2020
PADUCAH SITE
Annual Site Environmental Report

FRNP-RPT-0198

This report is intended to fulfill the requirements of U.S. Department of Energy (DOE) Order 231.1B and DOE Order 458.1. The data and information contained in this report were collected in accordance with the Paducah Site Environmental Monitoring Plan (FRNP 2021a) 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.

FRNP-RPT-0198

Paducah Site
Annual Site Environmental Report
for Calendar Year 2020

September 2021

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

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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CONTENTS

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FIGURES

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TABLES

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ACRONYMS

AEA	Atomic Energy Act of 1954
AFFF	aqueous film forming foam
AFV	alternative fuel vehicles
ALARA	as low as reasonably achievable
AP	accreditation program
ASER	Annual Site Environmental Report
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASL	approved suppliers list
BCG	biota concentration guide
CAFO	Consent Agreement and Final Order
CAP-88	Clean Air Act Assessment Package—Version 4.1.02
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CY	calendar year
DCS	derived concentration technical standard
DOE	U.S. Department of Energy
DOECAP	DOE Consolidated Audit Program
DUF_6	depleted uranium hexafluoride
EISA	Energy Independence and Security Act
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERPP	Environmental Radiation Protection Program
FFA	Federal Facility Agreement
FR	*Federal Register*
FRNP	Four Rivers Nuclear Partnership, LLC
FY	fiscal year
GHG	greenhouse gas
HSWA	Hazardous and Solid Waste Amendments
HVAC	heating, ventilation, and air conditioning
HWMFP	Hazardous Waste Management Facility Permit
ILA	industrial, landscaping, and agricultural
KAR	*Kentucky Administrative Regulations*
KDAQ	Kentucky Division for Air Quality
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KDWM	Kentucky Division of Waste Management
KPDES	Kentucky Pollutant Discharge Elimination System
LA	limited area
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LED	light-emitting diode
MCS	Mid-America Conversion Services, LLC
MEI	maximally exposed individual
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOV	notice of violation

NRC	Nuclear Regulatory Commission
OREIS	Oak Ridge Environmental Information System
OSL	optically-stimulated luminescence
PEGASIS	PPPO Environmental Geographic Analytical Spatial Information System
PEM	palustrine emergent
PEMS	Project Environmental Measurements System
PFAS	per- and polyfluoroalkyl substances
PFO	palustrine forested
PGDP	Paducah Gaseous Diffusion Plant
PPA	property protection area
PPPO	Portsmouth/Paducah Project Office
QA	quality assurance
QC	quality control
QSM	Quality Systems Manual
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
SST	Swift & Staley Inc.
SWMU	solid waste management unit
TLD	thermoluminescent dosimeter
TSCA	Toxic Substances Control Act
TSS	total suspended solids
TVA	Tennessee Valley Authority
VOC	volatile organic compound
WET	whole effluent toxicity
WKWMA	West Kentucky Wildlife Management Area
YOY	year-over-year

REQUEST FOR COMMENTS

The U.S. Department of Energy (DOE) requires an annual site environmental report from each of its sites. This *Paducah Site Annual Site Environmental Report for Calendar Year 2020* presents the results from the various environmental monitoring programs and activities carried out during the year. 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. You can complete a comment form online using the following link:

https://form.jotform.com/81494625478166

If you prefer, written comments may be sent to the following address:

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

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EXECUTIVE SUMMARY

The U.S. Department of Energy's (DOE) Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. Originally, a munitions plant, the Paducah Site became one of three uranium enrichment plants used for national security and the commercial sector.

Since 1988, DOE's Office of Environmental Management (EM) has been conducting cleanup operations at Paducah even as the site supported the commercial nuclear sector. DOE's activities at the site include:

Figure ES.1. A Deer Emerges from the Woods at the Paducah Site

- Environmental restoration from past operations to protect human health and the environment;
- Stabilization of infrastructure and removal of radioactive and hazardous wastes from facilities;
- Characterization and disposal of wastes stored or generated on-site; and,
- Decontamination and demolition of gaseous diffusion plant and support facilities.

Each year the Paducah Site prepares the Annual Site Environmental Report (ASER) according to the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*. The ASER is a key component of DOE's effort to keep the public informed about environmental conditions at the Paducah Site. This report and previous ASER's can be found at:

https://www.energy.gov/pppo/downloads/paducah-annual-site-environmental-reports.

DOE conducts environmental monitoring to assess the impact, if any, that site activities may have on public health and the environment. In 2020, measurements for direct radiation were taken on and around the Paducah Site; more than 1,600 samples of air, sediment, and water were collected and analyzed for radioactive and nonradioactive contaminants.

Chapters within the report provide a more detailed overview of the activities at Paducah, including:

Chapter 1: Introduction to the site history and mission;

Chapter 2: Summary of compliance with laws and regulations;

Chapter 3: Details about the environmental management programs conducted on-site;

Chapter 4: Types of radiological environmental monitoring conducted at the site and the calculated impacts;

Chapter 5: Nonradiological monitoring including air, surface water, and sediment;

Chapter 6: Groundwater protection; and

Chapter 7: Actions taken to ensure the quality of information from field sampling to analytical laboratory to data management.

DOE conducts environmental monitoring, which consists of effluent monitoring and environmental surveillance activities, and which supports the evaluation and assessment of unplanned releases. Major sampling components of environmental monitoring completed by DOE in 2020 are summarized below:

- DOE monitors for radionuclides, chemicals, and other water quality parameters at 15 locations that flow into Bayou Creek and Little Bayou Creek under the Kentucky Pollutant Discharge Elimination System (KPDES) Permit.

- External radiation was measured continuously at 65 locations. The measurements were collected quarterly.[1]

- Ambient air was sampled at nine locations on-site and off-site, and was analyzed for radionuclides.

- Surface water samples were collected quarterly from seven locations and annually from two locations on-site and off-site, and analyzed for radionuclides. Two of the locations on-site were analyzed for metals and volatiles; one of the locations off-site was analyzed for trichloroethene.

- Sediment was sampled at six locations and analyzed for radionuclides and 14 locations for polychlorinated biphenyls (PCBs).

- Surface water sampling included testing fathead minnows and water fleas for chronic toxicity at two locations and acute toxicity at one location.

- More than 200 wells were sampled at varying frequencies to monitor corrective actions, movement of groundwater contaminants, and groundwater quality.

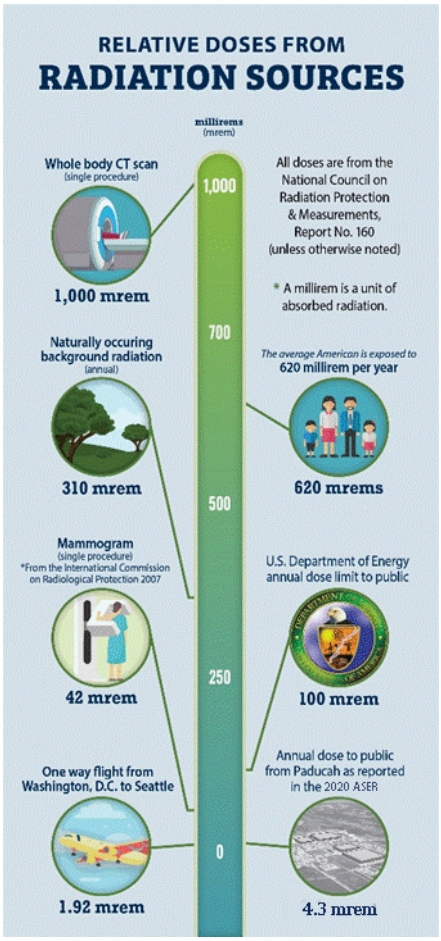

Figure ES.2. Relative Doses from Radiation Sources

2020 Environmental Performance Summary

In 2020, DOE's monitoring performance at Paducah is summarized below:

- Environmental monitoring data collected in 2020 are similar to data collected in previous years and indicate that radionuclides, metals, and other chemicals released by Paducah would have a minimal effect on human health and the environment.

[1] The terms "external radiation" and "direct radiation" are used synonymously in this document.

- The dose of radiation (based on calculations) that could be received by a member of the public from all pathways of exposure was 4.3 millirem (mrem)/year, which is approximately 4.3% of the DOE annual dose limit of 100 mrem/year.

- Concentrations of most contaminants detected within the groundwater plumes at Paducah were stable or decreasing in 2020. A groundwater strategy initiative is being performed to better understand the scope and trends of contaminants in off-site groundwater plumes.

- The Paducah Site began investigating the history and on-site use of per- and polyfluoroalkyl substances (PFAS) compounds in 2017. Based on the most likely known potential source of PFAS contaminants, samples were collected from two groundwater monitoring wells in the Fire Training Area and analyzed for 18 PFAS compounds. Analytical results indicate detectable levels of PFAS contamination in groundwater in the vicinity of the Fire Training Area.

- In areas where the groundwater either is known to be contaminated or has the potential to become contaminated in the future, DOE has provided water hookups to the West McCracken County Water District and pays water bills for affected residences and businesses.

- Ambient air monitoring contaminant levels for radionuclides continue either to be not detected, detected below DOE standards, or within background levels.

- The 2020 sediment radiological results are similar in magnitude to those measured during previous years. Overall, uranium activity is above background in Little Bayou Creek and Bayou Creek near and downstream of the plant site.

- PCBs were detected in sediment samples and are being addressed as a part of the ongoing site cleanup mission. Total PCBs (also listed as polychlorinated biphenyls in laboratory reports) were detected in sediment during 2020 ranging from 2.01 µg/kg to 361 µg/kg, within the acceptable risk range.

During 2020, Paducah reported the following:

- Four Notices of Violation (NOVs) were received during calendar year 2020. In June 2020, an NOV was received from KPDES for a total suspended solids exceedance at Outfall 004 that occurred in January 2020 resulting from infrastructure construction activities coupled with heavy rain. In October 2020, three NOVs were received. First, an NOV was received for a failed whole effluent toxicity (WET) test at Outfall 001 from October 2019 (retest passed). This NOV was discussed in the 2019 ASER. Second, an NOV was received for failure to comply with Outfall 020 monitoring and reporting requirements for the March 2020 reporting period; and finally, an NOV was received for a failed WET test at Outfall 010 from May 2020 (retest passed).

DOE and its contractors at Paducah are committed to enhancing environmental stewardship and to reducing any impacts that site operations may cause to the environment. Paducah implements sound stewardship practices in the protection of land, air, water, and other natural or cultural resources potentially impacted by their operations. A report of progress in achieving specified Environmental Management System (EMS) goals is submitted annually to DOE Headquarters. The environmental stewardship scorecard assesses agency performance under the Environmental Management System. The environmental stewardship scorecard for Paducah in fiscal year 2020 was "green," which indicates standards for the Environmental Management System implementation were met.

A complete summary of the environmental program can be found in the chapters following this Executive Summary.

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1. INTRODUCTION

The U.S. Department of Energy (DOE) requires that environmental monitoring be conducted and documented for its facilities under the purview of DOE Order 231.1B, *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 is to summarize calendar year (CY) 2020 environmental management activities at the Paducah Site, including effluent monitoring and environmental surveillance, environmental compliance status, and to highlight significant site program efforts. References in this report to the Paducah Site generally mean the property, programs, and facilities at or near Paducah Gaseous Diffusion Plant (PGDP) for which DOE has ultimate responsibility. Several documents are referenced within this report; where available, electronic hyperlinks to the documents are provided.

Environmental monitoring consists of the following two major activities: (1) effluent monitoring and (2) environmental surveillance. Effluent monitoring is the direct measurement or the collection and analysis of samples of liquid and gaseous discharges to the environment. At the Paducah Site, environmental surveillance is the direct measurement or the collection and analysis of samples consisting of ambient air, surface water, groundwater, and sediment. Effluent monitoring and environmental surveillance are 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. Samples are collected throughout the year and are analyzed for radioactivity, chemical constituents, and various physical properties.

The overall goals for DOE Environmental Management are to protect site personnel, the environment, and the community and to maintain full compliance with all current applicable environmental regulations. DOE operates the Paducah Site in a manner that controls and reduces exposures of the public, workers, and the environment to harmful chemicals and radiation.

Prime contractors performing work to support DOE missions at the Paducah Site include the following: Mid-America Conversion Services, LLC (MCS); Swift & Staley Inc. (SST);[2] and Four Rivers Nuclear Partnership, LLC (FRNP).

1.1 SITE LOCATION AND HISTORY

The Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River (Figure 1.1).

[2] Swift & Staley Inc. is known as SST at the Paducah Site.

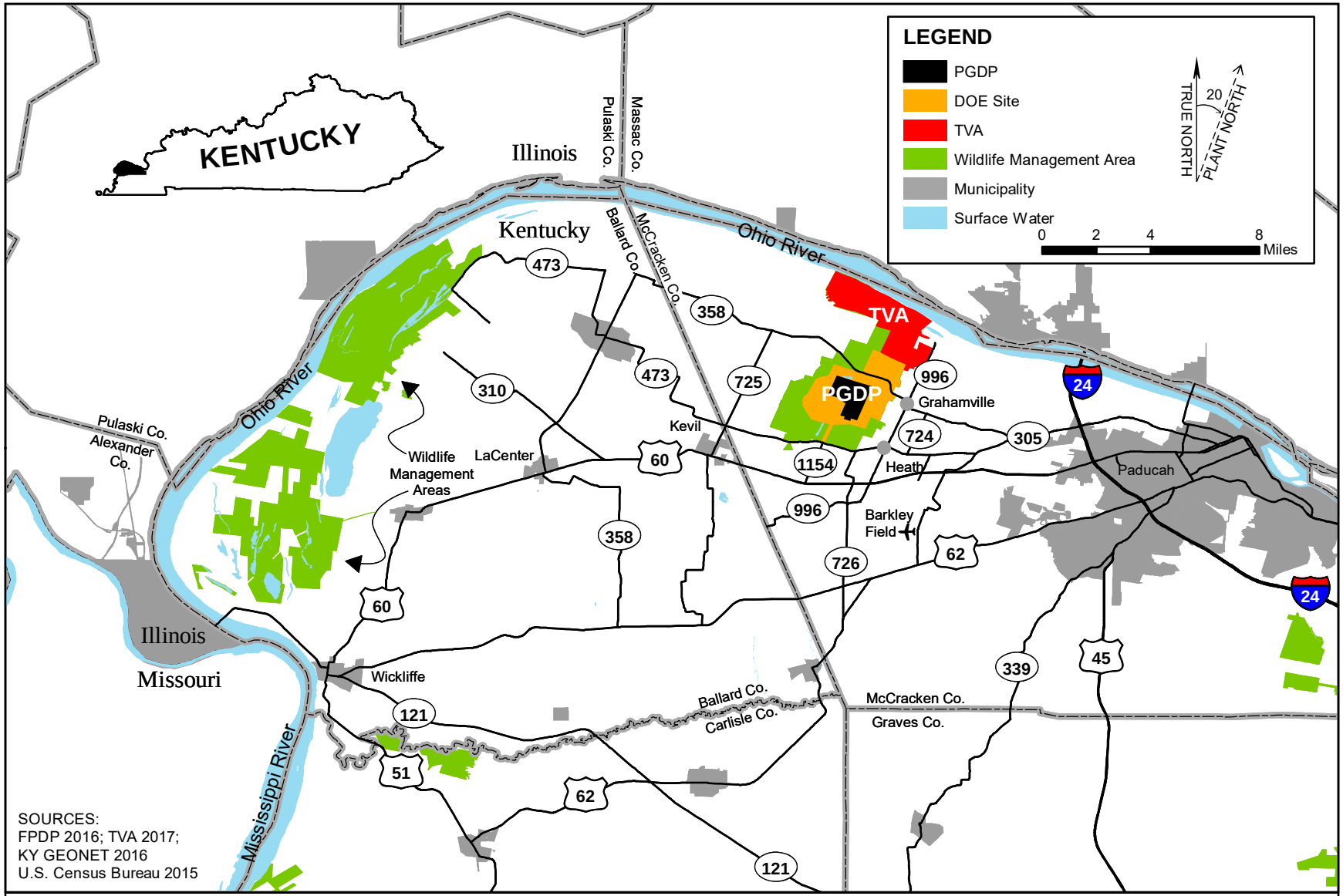

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Figure 1.1. Location of the Paducah Site

The plant is on a 3,556-acre DOE site, approximately 1,986 acres of which are licensed to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area (WKWMA).

WKWMA consists of woodlands, meadows, and cultivated fields and is used by hunters, trappers, and anglers each year. Hunting and trapping activities may include such wildlife as rabbit, deer, quail, raccoon, squirrel, dove, turkey, waterfowl, and beaver. Additionally, the Kentucky Department of Fish and Wildlife Resources sponsors field hunting trials for dogs within the WKWMA.

During World War II, Kentucky Ordnance Works operated its main process and some storage areas in an area southwest and west of the plant on what is now WKWMA.

The plant was constructed in the early 1950s and started uranium enrichment in 1952. Until 2013, the Paducah Site was an active uranium enrichment facility. The Energy Policy Act of 1992 provided for lease of the enrichment facilities to a commercial entity that operated the enrichment facilities from 1998 to 2013. In 2014, the leased facilities were returned to DOE control, and a DOE contractor began management of the uranium enrichment facilities for DOE. These returned facilities are undergoing deactivation in preparation for decommissioning.

1.2 GENERAL ENVIRONMENTAL SETTING

1.2.1 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.

1.2.2 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. The Paducah Site 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 developed in support of the National Flood Insurance Program show a flood hazard located within the DOE boundary at the Paducah Site, but only slightly within the industrialized area of the Paducah Site (FEMA 2018). This flood hazard defines the 100-year flood line.

1.2.3 Wetlands

Approximately 1,100 separate wetlands, totaling over 1,500 acres, were found in a study area of about 12,000 acres in and around the Paducah Site (COE 1994). More than 60% of the total wetland area is forested.

1.2.4 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 is described in Section 6.1.

1.2.5 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 1992). In 2020, corn, soybeans, and sunflowers were cultivated within the WKWMA.

Field scrub-shrub communities consist of sun tolerant wooded species such as persimmon, maples, black locust, sumac, and oaks (CH2M HILL 1991). 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 hardwood communities contain a variety of upland and transitional species. Dominant species include oaks, shagbark and shellbark hickory, and sugarberry (CH2M HILL 1991). The undergrowth varies, with limited undergrowth for more mature stands of trees, to dense undergrowth similar to that described for a scrub-shrub community.

1.2.6 Wildlife

Wildlife species indigenous to hardwood forests, scrub-shrub, and open grassland communities are present at the Paducah Site. Some areas near the Paducah Site are frequented by rabbits, mice, opossum, vole, mole, raccoon, and deer. Birds include red-winged blackbirds, quail, sparrows, shrikes, mourning doves, turkeys, cardinals, meadowlarks, hawks, and owls. Several groups of coyotes also reside in these areas around the Paducah Site. Aquatic habitats are used by muskrat and beaver at the Paducah Site. A list of representative species is provided in Results of the Site Investigation Phase 1 (CH2M HILL 1991). Additionally, the Ohio River, which is 3.5 miles north of the Paducah Site, serves as a major flyway for migratory waterfowl (DOE 1995a). Harvestable fish populations exist in Bayou Creek, especially near the mouth of the creek at the Ohio River. Fish populations in Little Bayou Creek are in the minnow category (DOE 2020a).

1.2.7 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 Commonwealth of Kentucky sources. Currently, potential habitat for 16 species of federal concern exists in the study area. Fourteen of these species are listed as “endangered” under the Endangered Species Act of 1973, and two are “threatened” (Chapter 2, Table 2.3). While there are potential habitats for endangered species on DOE property, none of the federally listed or candidate species have been found on DOE property at the Paducah Site.

1.3 SITE MISSION

DOE established the Portsmouth/Paducah Project Office (PPPO) on October 1, 2003, to provide focused leadership to the environmental management missions at the Portsmouth, Ohio, and Paducah, Kentucky, gaseous diffusion plants.

The PPPO Lexington, Kentucky, office opened in January 2004, and is located midway between the Kentucky and Ohio facilities. Although the PPPO manager is located in the Lexington office, frequent and routine site interactions occur by this office at both the Portsmouth and Paducah Sites. Additionally, DOE maintains a strong presence at the sites on a daily basis through its Portsmouth and Paducah Site offices. The mission of the PPPO is to conduct the safe, secure, compliant, and cost-effective environmental cleanup of the Portsmouth and Paducah Uranium Enrichment Sites on behalf of the local communities and the American taxpayers.

In addition to gaseous diffusion plant stabilization, deactivation, and infrastructure management, DOE's PPPO mission is to accomplish the following at the Portsmouth and Paducah Sites (http://energy.gov/pppo/pppo-mission).

- Environmental Remediation
- Waste Management
- Depleted Uranium Hexaflouride (DUF_6) Conversion
- Decontamination and Decommissioning

1.4 PRIMARY OPERATIONS AND ACTIVITIES AT THE PADUCAH SITE

The entrance to the Paducah Site is shown in Figure 1.2. The following two major programs are operated by DOE at the Paducah Site: (1) Environmental Management and (2) Uranium Program.

Figure 1.2. DOE Paducah Site Entrance

The Environmental Management Program includes Environmental Restoration; Facility Stabilization, Deactivation, Infrastructure Optimization; and Waste Management projects. Additional information regarding these activities is found in Section 3.1.

- 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 actions are taken for protection of human health and the environment in accordance with the Federal Facility Agreement (FFA) (EPA 1998).

- The mission of Facility Stabilization, Deactivation, and Infrastructure Optimization is to remove radioactive and hazardous materials from the facility, safely shut down facility systems, and optimize infrastructure that will continue to support the site.

- The mission of the Waste Management Project is to characterize and dispose of waste stored and generated on-site in compliance with regulatory requirements and DOE Orders.

- The mission of Decontamination and Demolition is to tear down the former gaseous diffusion plant and support facilities and dispose of the demolition debris in compliance with regulatory requirements and DOE Orders.

The major missions of the Uranium Program are to maintain safe, compliant storage of the DOE DUF_6 inventory until final disposition, operation of a facility for conversion of DUF_6 to a more stable oxide and hydrofluoric acid, and to manage associated facilities and grounds.

1.5 DEMOGRAPHIC INFORMATION

The population of McCracken County, Kentucky, is approximately 65,000. The major city in McCracken County is Paducah, Kentucky, whose population is approximately 25,000 (DOC 2010). Three small communities are located within 3 miles of the DOE property boundary at the Paducah Site: 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 the Paducah Site is about 534,000 according to the 2010 census.

2. COMPLIANCE SUMMARY

The U.S. Environmental Protection Agency (EPA), Region 4, primarily provides oversight of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup activities at the Paducah Site. The Kentucky Department for Environmental Protection (KDEP) also oversees CERCLA cleanup at the Paducah Site as well as issues regulatory permits and oversees compliance with applicable environmental laws and regulations for which they have implementation authority.

The EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by the U.S. Congress. In most instances, EPA has delegated regulatory authority to KDEP when the Kentucky program meets or exceeds EPA requirements.

2.1 ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

2.1.1 Comprehensive Environmental Response, Compensation, and Liability Act

DOE and EPA Region 4 entered into an Administrative Consent Order in August 1988 under Sections 104 and 106 of CERCLA. The Administrative Consent Order 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, 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 National Priorities List.

Section 120 of CERCLA requires federal agencies with facilities on the National Priorities List 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 Resource Conservation and Recovery Act (RCRA) corrective action requirements. DOE, EPA, and KDEP agreed to terminate the CERCLA Administrative Consent Order because those activities could be continued under the FFA. The FFA, a three-party agreement among DOE, EPA, and KDEP, defines the process for all remediation activities undertaken at the Paducah Site. The FFA contains requirements for implementing investigations; selection and implementation of appropriate remedial and removal actions; and establishing priorities for action and development of schedules, consistent with priorities, goals, and objectives of the agreement.

Significant milestones completed under CERCLA and the FFA for CY 2020 at the Paducah Site are included in Table 2.1.

2.1.2 Superfund Amendments and Reauthorization Act

The Superfund Amendments and Reauthorization Act amended CERCLA on October 17, 1986. The Act reflected EPA's experience in administering the complex Superfund program and made several important changes and additions to the program. Changes of particular importance are (1) increased the focus on human health problems posed by hazardous waste sites, and (2) encouraged greater citizen participation in making decisions on how sites should be cleaned up. DOE utilizes various methods to engage citizen participation in cleanup decision making for the Paducah Site. These programs are described in Section 3.2.

Table 2.1. CERCLA FFA Significant Milestones Completed in CY 2020

Document/Activity	Date Due	Date Completed
C-400 Remedial Investigation Field Start	2/15/2020	11/25/2019[a]
C-400 Remedial Investigation/Feasibility Study Work Plan D2/R1 (page changes)	3/17/2020	3/5/2020
Southwest Plume RAWP D2	3/31/2020	3/30/2020
Site Management Plan Fiscal Year (FY) 2020 D2	4/21/2020	4/21/2020
Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Work Plan D1	5/1/2020	5/1/2020
Site Management Plan FY 2022 D2/R1	5/15/2020	5/14/2020
Community Relations Plan 2020 D1	6/30/2020	6/18/2020
Northeast Plume O&M Plan D3/R7	9/30/2020	8/19/2020
Northwest Plume O&M Plan D4/R6	9/30/2020	8/19/2020
Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Work Plan D2	9/8/2020	9/8/2020
Community Relations Plan 2020 D2	11/8/2020	10/26/2020
Northeast Plume O&M Plan D3/R8	11/6/2020	11/6/2020
Site Management Plan FY 2021 D1	11/15/2020	11/6/2020
Northwest Plume O&M Plan D4/R7	11/22/2020	11/23/2020[b]
Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Work Plan D2/R1 (page changes)	12/17/2020	12/17/2020

[a] This milestone was due in 2020; however, it was completed in 2019.
[b] The date completed was the first working day following the date due.

2.1.3 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/or postclosure 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 three permitted hazardous waste storage and treatment facilities (C-733, C-746-Q, and C-752-A). The closed C-404 Hazardous Waste Landfill also is managed under requirements of the RCRA regulations and permit.

The DUF_6 contractor is registered as a Small Quantity Generator and manages hazardous waste under RCRA, but is not required to have a permit as a small quantity generator. On September 24, 2020, the Kentucky Division of Waste Management (KDWM) conducted a virtual site inspection, due to COVID-19 restrictions, of the DUF_6 facility. The inspection showed there were no issues, and no violations were noted on the inspection report. This was documented in the KDWM Compliance Inspection Report dated September 24, 2020.

2.1.4 Resource Conservation and Recovery Act Hazardous Waste Permit

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

The current Hazardous Waste Management Facility Permit (HWMFP) was issued by KDWM to DOE in July 2015 and became effective on August 23, 2015. The federal portion of the HWMFP is known as a HSWA Permit. The HSWA permit contains federal permit conditions for all HSWA provisions applicable to the Paducah facility for which KDWM is not yet authorized. On April 3, 2019, KDWM received final authorization from EPA for certain HSWA provisions, including organic air emission standards and land disposal restrictions. As a result, applicable HSWA requirements will be met through the KDWM HWMFP, and renewal of the HSWA permit will not be necessary. On December 5, 2019, a revision to the HWMFP was submitted to KDWM, and changes, including HSWA provisions, were approved by KDWM on February 21, 2020.

DOE is required to report compliance issues as part of the annual Hazardous Waste Report submittal to KDWM. In 2020, three issues were reported. The first compliance issue was related to a shipment of six 55-gal drums of low-level waste that was shipped to a disposal facility. One of the 55-gal drums contained hazardous waste that exceeded the Toxicity Characteristic Leaching Procedure for one or more analytes, indicating it was mixed low-level waste. A revised Uniform Hazard Waste Manifest for the one drum of waste was provided for the compliant disposal of the waste. There were no spills or releases to the environment associated with these containers. The second compliance issue was related to the compliant storage and packaging of hazardous waste. Three ST-90 boxes of cables were discovered unlabeled with an additional 20 3-ft cable sections lying unpackaged on the floor in C-400. These containers were relocated and labeled compliantly, and the additional waste was packaged into a fourth ST-90 box which was compliantly stored. There were no spills or releases to the environment associate with these containers. The third compliance issue was related to a 30-gal drum of waste that was stored in a 90-day hazardous waste accumulation area that exceeded the 90-day waste accumulation storage limit. The 30-gal drum containing mixed low-level waste was relocated to compliant storage facility. There were no spills or releases to the environment associate with these containers.

2.1.5 Federal Facility Compliance Act—Site Treatment Plan

The Federal Facility Compliance 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 for the treatment of DOE mixed waste and for the approval of such plans by the Commonwealth of Kentucky. As a result of the complex issues and problems associated with the treatment of low-level hazardous and radioactive waste (mixed waste), DOE and KDEP signed, after consideration of stakeholder input, an Agreed Order/Site Treatment Plan on September 10, 1997. The Site Treatment Plan facilitates compliance with the Federal Facility Compliance Act. For the reporting period of January 1 to December 31, 2020, no addition of mixed low-level waste was added to the Site Treatment Plan (DOE 2021a).

The Agreed Order requires that DOE implement a Waste Minimization and Pollution Prevention Awareness Program to minimize the amount of new wastes added to the Site Treatment Plan each year. All projects at the Paducah Site are evaluated for waste minimization/pollution prevention opportunities. Waste minimization/pollution activities at the Paducah Site related to the STP WM goals include the following:

- Reducing the quantity of wastes generated at their sources;
- Draining, decanting, drying, dewatering, evaporating, and otherwise removing liquid from wastes when possible;
- Segregating, sorting, consolidating, and reducing the volume of like wastes; and

- Reusing or recycling materials that otherwise would be managed as hazardous or radioactive mixed waste.

Waste minimization/pollution prevention activities at the Paducah Site are listed in Chapter 3.

2.1.6 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* Part 1021) and the Council on Environmental Quality Regulations (40 *CFR* Parts 1500–1508), ensures that consideration is given to environmental values and factors in federal planning and decision making. In accordance with 10 *CFR* Part 1021, the Paducah Site conducts NEPA reviews for proposed non-CERCLA actions and determines if any proposal requires preparation of an environmental impact statement, an environmental assessment, or a categorical exclusion. The Paducah Site maintains records of all NEPA reviews.

In accordance with Section II.E of the June 13, 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 incorporates NEPA values. The NEPA values encompass environmental issues that affect the quality of the human environment. Documentation of NEPA values in CERCLA documents allows decision makers to consider the potential effects of proposed actions on the human environment. Actions conducted under CERCLA (with respect to Environmental Restoration, Waste Disposition, and Deactivation and Decommissioning) are discussed in Chapter 3 of this report.

A categorical exclusion was approved for switchyards, transmission towers, and auxiliary equipment dismantlement and disposition. Numerous minor activities conducted in 2020, such as routine maintenance, small-scale facility modifications and demolition, site characterization, facility deactivation, and utility consolidation, were within the scope of either an approved environmental impact statement, or an environmental assessment, or in categorical exclusions. PPPO initiated an environmental assessment in 2012 to assess the environmental impacts associated with potential transfer of the Paducah Site real property to third parties for possible economic development.

PPPO initiated an environmental assessment in 2019 to assess the environmental impacts associated with transportation and disposal of waste and excess materials to support deactivation and other non-CERCLA activities. The environmental assessment will analyze the potential impacts of management and disposition of 5,050,000 cubic ft of waste and excess materials over the next 12 years. On July 27, 2020, DOE issued the Finding of No Significant Impact (DOE 2020b).

PPPO initiated a supplemental environmental impact statement in 2018 to assess the environmental impacts associated with transportation and disposal of uranium oxide in DOE inventory that had been produced from the conversion of DUF_6. After a public comment period, the statement was finalized and made available to the public on April 24, 2020 (DOE/EIS-0359-S1 and DOE/EIS-0360-S1).

2.1.7 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 (e.g., PCBs, asbestos, chlorofluorocarbons, and lead).

The Paducah Site complies with PCB regulations (40 *CFR* Part 761) and the Modification to the February 20, 1992, Compliance Agreement between DOE and EPA for the TSCA. The Compliance Agreement between DOE and EPA that went into effect on February 20, 1992 (EPA 1992) was modified on September 25, 1997 (BJC 1998), and then modified again on May 30, 2017 (EPA 2017). The most prominent revisions to the agreement effective May 30, 2017, include the following: (1) creation of an annual meeting between PPPO and EPA, along with generation of an integrated schedule and a long-term schedule to support the annual meeting; (2) alteration of the frequency and timing of air sampling in the process buildings; (3) update of the approach to the regulatory one-year storage requirement associated with PCBs and PCB items; and (4) modifications pertaining to the management of building demolition waste, building slabs, building demolition waste that is to be processed for disposal, and other PCB wastes removed prior to a building's demolition. The major activities performed in 2020 are documented in the annual compliance agreement report for the PGDP (FRNP 2020a) and the PCB annual document (FRNP 2020b).

2.2 RADIATION PROTECTION STATUTES, REGULATIONS, AND DIRECTIVES

The Paducah Site is subject to radiation protection statutes and regulations designed to protect the health and safety of the public, workforce, and the environment. The Paducah Site maintains and implements several programs and procedures to ensure compliance with the relevant laws and regulations described in the following sections. See Chapter 4 for additional information about radiation protection.

ALARA means "**as low as reasonably achievable**," which is an approach to radiation protection to manage and control releases of radioactive material to the environment, the workforce, and members of the public so that levels are as low as reasonably achievable, taking into account societal, environmental, technical, economic, and public policy considerations. ALARA is defined in DOE-HDBK-1215-2014 (DOE 2014). ALARA is not a specific release or dose limit, but a process that has the goal of optimizing control and managing release of radioactive material to the environment and doses so they are as far below the applicable limits as reasonably achievable. ALARA optimizes radiation protection.

2.2.1 Atomic Energy Act of 1954

To ensure proper management of radioactive materials, the Atomic Energy Act of 1954 (AEA) and its amendments include provisions to delegate roles and responsibilities to control radioactive materials and nuclear energy primarily to DOE, the U.S. Nuclear Regulatory Commission (NRC), and the EPA. Through the AEA, DOE regulates the control of radioactive materials under its authority, including the treatment, storage, and disposal of low-level radioactive waste from its operations. Sections of the AEA authorize DOE to establish radiation protection standards for itself and its contractors. Accordingly, DOE promulgated a series of regulations (e.g., 10 *CFR* Part 820, Procedural Rules for DOE Nuclear Activities; 10 *CFR* Part 830, Nuclear Safety Management; and 10 *CFR* Part 835, *Occupational Radiation Protection*). Additional DOE directives to protect public health and the environment from potential risks associated with radioactive materials include DOE Order 458.1, *Radiation Protection of the Public and Environment*, current revision; and DOE Order 435.1, *Radioactive Waste Management*, current revision. Paducah Site operations are subject to these regulations and directives.

2.2.1.1 By-Product Material

As defined by Section 11e.(2) of the AEA, the Paducah Site has no by-product material. Material defined as Section 11e.(3) or 11e.(4) by-product material in the AEA (e.g., sealed radioactive sources) is managed under 10 *CFR* Part 835.

2.2.2 DOE Order 458.1, Radiation Protection of the Public and the Environment

The purpose of DOE Order 458.1 is to establish requirements to protect the public and the environment against undue risk from radiation associated with radiological activities conducted under the control of DOE.

DOE Order 458.1 applies to all DOE elements and contractors performing work for DOE, as provided by law and/or contract, and as implemented by the appropriate contracting officer. DOE Order 458.1 was developed and issued under the authority of the AEA as amended.

The objectives of DOE Order 458.1 are the following:

(1) To conduct DOE radiological activities so that exposure to members of the public is maintained within the dose limits established in this Order;

(2) To control the radiological clearance of DOE real and personal property;

(3) To ensure that potential radiation exposures to members of the public are as low as is reasonably achievable;

(4) To ensure that DOE sites have the capabilities, consistent with the types of radiological activities conducted, to monitor routine and non-routine radiological releases and to assess the radiation dose to members of the public; and

(5) To provide protection of the environment from the effects of radiation and radioactive material.

Table 2.2 provides the standards (dose limits) for radiation protection of the public and the environment from DOE operations. While the public dose limit of 100 mrem/year [1 millisievert (mSv)/year] is the primary dose limit, other regulations impose additional constraints on the dose that may be received through specific exposure pathways. The air and water pathways are also regulated by the EPA and the Commonwealth of Kentucky; they are discussed in more detail in Sections 2.3 and 2.4. DOE Order 458.1 provides dose limits for the protection of aquatic and terrestrial plants and animals in the vicinity of radiological activities on the Paducah Site. In addition, dose constraints are provided for the dose that could be received by a member of the public from certain activities, including radioactive waste management, storage, and disposal, as well as unrestricted release to the public or clearance of real and personal property.

These radiation standards are dose limits but not DOE's expectation for dose to the public and the environment. DOE Order 458.1 requires the application of the "as low as reasonably achievable" (ALARA) process to all routine radiological activities to further reduce (optimize) radionuclide releases and resulting doses to the extent possible.

Table 2.2. Radiation Protection Standards for the Public and the Environment from All Routine DOE Operations[a]

All Pathways (DOE Order 458.1)		
Exposure of members of the public will not cause a total effective dose exceeding 100 mrem (1 mSv) in a year.	Total Effective Dose[c]	
	mrem/year	*mSv/year*
Routine public dose	100	*1*
Temporary public dose[b] under special circumstances with specific authorization and justification.	> 100, < 500	*> 1, < 5*
Air Pathway Dose Constraints (40 *CFR* § 61.92)		
Emissions of radionuclides shall not cause any member of the public to receive an effective dose equivalent of 10 mrem/year.	Effective Dose Equivalent[c]	
	mrem/year	*mSv/year*
	10	*0.1*
Water Pathway Dose Constraints (40 *CFR* § 141.66(d))		
The average annual dose equivalent to the total body or to any internal organ from beta particle and photon radioactivity from man-made radionuclides in drinking water shall not exceed 4 mrem/year.	Dose Equivalent[c]	
	mrem/year	*mSv/year*
	4	*0.04*
Protection of Biota (DOE Order 458.1, DOE-STD-1153-2019)		
Radiological activities must be conducted to protect populations of aquatic animals, terrestrial plants, and terrestrial animals.	Absorbed Dose[c]	
	rad/day	*mGy/day*
Aquatic animal	1	*10*
Riparian animal	0.1	*1*
Terrestrial plant	1	*10*
Terrestrial animal	0.1	*1*
Radioactive Waste Dose Constraint (DOE Order 458.1)		
Exposure from radioactive waste management, storage, and disposal activities shall be ALARA and meet dose constraint.	Total Effective Dose[c]	
	mrem/year	*mSv/year*
Public dose constraint	25	*0.25*
Release and Clearance of Property (DOE Order 458.1)		
Exposure from release of real (land and buildings) and personal property shall be controlled to be ALARA and meet dose constraints.	Total Effective Dose[c]	
	mrem/year	*mSv/year*
Public dose constraint from real property	25	*0.25*
Public dose constraint from personal property	1	*0.01*

NOTE: Excepts doses received from radon and its decay products in the air, doses received from medical sources of radiation, doses received by volunteers in medical research programs, doses from background radiation, and doses from occupational exposure under NRC, Agreement State License, or to general employees under 10 *CFR* Part 835.

NOTE: International dose units shown in *italics* are not provided in the order or rules but are provided for information.

[a] Routine DOE operations imply normal, planned activities and do not include actual or potential accidental or unplanned releases.

[b] DOE-PPPO may request specific authorization from DOE-HQ for a temporary public dose greater than 100 mrem/year (1mSv/year). The request must document the justification, alternative considered, and the application of the ALARA process. (see Glossary for definition of ALARA process)

[c] Dose units are those in the cited regulation, order, or standard.

2.2.2.1 Authorized Limits at the Paducah Site

DOE uses authorized limits to establish concentrations or quantities of residual radioactive material that are protective of human health and the environment. Authorized limits ensure that doses to the public meet DOE standards and are ALARA, that groundwater is protected, that future remediation is not needed, and that no radiological protection requirements are violated. In addition to pre-approved authorized limits, the following authorized limits were approved for use in 2020.

- Release Limits for Hydrofluoric Acid and Calcium Fluoride from Depleted Uranium Hexafluoride (DUF_6) conversion.

- C-746-U Landfill Authorized Limits Approval and Implementation Requirements.

- Authorized Limits for the U.S. Department of Energy-Owned Property Outside the Limited Area in Paducah, Kentucky, Approval and Implementation Requirements.

- Authorized Limits for Lube Oil and Dielectric Fluids allow for incineration at the following facilities:

  — Veolia Environmental Services, Port Arthur, Texas; and
  — Clean Harbors Environmental Services, Inc., Deer Park, Texas.

- Authorized Limits for Freon allow for incineration at the following facilities:

  — Clean Harbors Aragonite, Dugway, Utah;
  — Clean Harbors El Dorado, El Dorado, Arkansas; and
  — Veolia North America/Port Arthur, Beaumont, Texas.

- Authorized Limits for Paducah and Portsmouth Personal Property Being Dispositioned Through the Bulk Survey for Release Process for Disposal to the Carter Valley Landfill in Tennessee.

- DOE has a basic ordering agreement with Waste Control Specialists, LLC, in Andrews, Texas, to disposition various Paducah waste streams, as applicable to the landfill's waste acceptance criteria. These waste streams include, but are not limited to, RCRA waste, TSCA waste, and debris and soil-like material that contains residual radioactivity.

2.2.3 DOE Order 435.1, Radioactive Waste Management

The purpose of DOE Order 435.1 is to establish requirements to manage high-level waste, transuranic waste, and low-level waste, including the radioactive component of mixed waste (high-level waste, transuranic waste, and low-level waste containing chemically hazard constituents) in a safe manner that is protective of the worker, public health, and the environment. DOE Order 435.1 takes a cradle-to-grave approach to managing waste and includes requirements for waste generation, storage, treatment, disposal, and post-closure monitoring of facilities.

Radioactive wastes shall be managed such that the requirements of other DOE orders, standards, and regulations are met, including 10 *CFR* Part 835, *Occupational Radiation Protection*; DOE Order 441.1B, *Worker Protection Program for DOE (Including the National Nuclear Security Administration) Federal Employees*; and DOE Order 458.1, *Radiation Protection of the Public and the Environment*. For facilities undergoing CERCLA removal actions or CERCLA remedial actions, DOE Order 435.1 may not be Applicable or Relevant and Appropriate Requirements as defined in Section 121(d) of the CERCLA.

The Paducah Site manages low-level and transuranic waste, if produced, in compliance with DOE Order 435.1 using a number of storage and disposal units. Procedures utilized for management of these wastes ensure compliance with this Order.

2.3 AIR QUALITY AND PROTECTION

2.3.1 Clean Air Act

Authority for enforcing compliance with the Clean Air Act and subsequent amendments resides with EPA Region 4 and/or the Kentucky Division for Air Quality (KDAQ). The Paducah Site complies with federal and Commonwealth of Kentucky rules by implementing the Clean Air Act and its amendments. The Paducah Site includes two separate programs that require air permitting. The Environmental Remediation, Waste Management and Decontamination and Decommissioning missions (identified as the Deactivation

and Remediation Project) are combined under one air permit and the DUF_6 Conversion mission is on a separate air permit.

The Deactivation and Remediation Project has identified the potential emission of hydrogen fluoride, a hazardous air pollutant, in excess of 10 tons per year. KDAQ considers the project to be major source requiring the project to maintain a Title V Air Permit.

Activities performed as part of CERCLA projects (e.g., groundwater treatment systems) are not subject to the Title V Air Permit. Instead of being permitted under the Clean Air Act, the substantive requirements of the Clean Air Act for the emissions associated with these CERCLA actions are applied to the actions as applicable or relevant and appropriate. Groundwater pump and treat systems at the Paducah Site remove trichloroethene (TCE) and other volatile organic compound (VOC) contamination from the groundwater by air stripping. For the Northwest Plume Groundwater Treatment System, the off-gas from the air stripper then passes through a carbon adsorption system to remove the TCE prior to atmospheric discharge. For the Northeast Plume Containment System, concentrations of TCE are sufficiently low that a carbon adsorption system is not required to keep emissions below regulatory levels.

The DUF_6 Conversion facility has the potential to emit more than 10 tons per year of hydrogen fluoride, but the DUF_6 air permit limits potential hydrogen fluoride emissions to less than 10 tons per year. As such, KDAQ considers DUF_6 facility to be a conditional major source that requires a Conditional Major Operating Air Permit.

In April 2018, EPA conducted a compliance monitoring inspection at the Paducah Site, pursuant to the Clean Air Act, Section 112(r)(7), to determine compliance with Risk Management Program regulations found at 40 *CFR* Part 68. On February 26, 2019, EPA issued notice of potential Risk Management Program violations. These potential violations are related to administrative and procedural requirements such as labeling, roles and responsibility documentation, and compliance certification. To date, changes have been made to the appropriate procedures to address the administrative issues identified by EPA during the 2018 inspection. On December 5, 2019, EPA issued Risk Management Program violations for roles and responsibilities documentation and procedural requirements. On March 16, 2021, EPA issued a Consent Agreement and Final Order (CAFO) for the Risk Management Plan violations. The final, signed CAFO was executed and filed on April 8, 2021. The penalty for the CAFO was issued to and paid for by FRNP on April 23, 2021, and the order was closed.

2.3.2 National Emission Standards for Hazardous Air Pollutants Program

Airborne emission of radionuclides from the Paducah Site are regulated under 40 *CFR* Part 61, Subpart H, the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations. DOE also manages radionuclide air emissions in accordance with the NESHAP Management Plan for Emission of radionuclides (FRNP 2019). Radionuclide sources at the Paducah Site in 2020 were from deactivation projects of PGDP, DUF_6 Conversion Facility, groundwater pump-and-treat systems (Northeast Plume Containment System and Northwest Plume Groundwater Treatment System), and fugitive and diffuse sources. DOE maintains ambient air monitoring data to verify a low emission rate of radionuclides in ambient air in accordance with the NESHAP Management Plan. The fugitive and diffuse sources include building ventilation, uranium transfers, transport and disposal of waste, demolition of contaminated facilities, decontamination of contaminated equipment, and environmental remediation activities. Ambient air data were collected at nine locations surrounding the Paducah Site in order to measure radionuclides emitted from Paducah Site sources, including fugitive emissions. The ambient air results are discussed in further detail in Chapter 4 (FRNP 2021b).

2.4 WATER QUALITY AND PROTECTION

2.4.1 Clean Water Act

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

(1) Regulating point-source and storm water 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.

2.4.2 Kentucky Pollutant Discharge Elimination System

The Clean Water Act applies to all non-radiological DOE discharges to waters of the United States. At the Paducah Site, the regulations are applied through issuance of Kentucky Pollutant Discharge Elimination System (KPDES) permits for effluent discharges to Bayou Creek and Little Bayou Creek. In September 2017, the Kentucky Division of Water (KDOW) renewed KPDES Permit Number KY0004049 for Outfalls 001, 002, 004, 006, 008, 009, 010, 011, 012, 013, 015, 016, 017,[3] 019, and 020. The KPDES permit calls for monitoring as an indicator of discharge-related effects in the receiving streams. Discharge monitoring reports are issued monthly and quarterly. Additionally, the KPDES permit requires the development and implementation of a Best Management Practices Plan to prevent or minimize the potential for the release of pollutants. These Best Management Practices have requirements for operations and are implemented through the site Environmental Management System (EMS) and work control.

Actions completed during CY 2020 addressed two existing NOVs that were issued to the Paducah Site during CY 2019. During late CY 2019 and early CY 2020, FRNP and KDEP reached a settlement from a fish die-off event that occurred during CY 2019 from accidentally over-dispensing sodium hypochlorite during a temporary change in operations at the C-615 Sewage Treatment Plant. The settlement consisted of an adjusted civil penalty, the submittal of an alternate disinfection process description, and an updated Best Management Practices Plan. The KDEP Demand for Civil Penalty (Case No. DOW-19-03-0108) letter, dated June 1, 2020, stated that the violations had been addressed, and the letter acknowledged submittal and acceptance of the alternate disinfection procedure and the updated Best Management Practices Plan. In response to the Demand for Civil Penalty letter, FRNP transmitted the agreed civil penalty payment under correspondence dated June 18, 2020. Installation of the alternate disinfection process was completed in August 2020 and testing was successfully completed in November 2020. The alternate treatment system is operable and available for use should there by a disruption to the primary treatment system.

The Paducah Site received four NOVs during CY 2020; however, one of these four NOVs was for a toxicity violation that took place in October 2019. KPDES Outfall 001 experienced a toxicity failure in October 2019 as part of the required, permitted quarterly testing. Accelerated follow-up testing was completed as required by the Permit and produced passing results. Because the follow-up testing produced passing results, no further action was required by the Permit or by the NOV for the October 2019 exceedance.

During CY 2020, there were three noncompliances which resulted in the Paducah Site receiving NOVs.

[3] Permit Number KY0004049 also includes MCS as a permittee for Outfall 017.

The Paducah Site was issued an NOV for failing to comply with the total suspended solids (TSS) permitted limit for KPDES Outfall 004. The TSS permitted limit for Outfall 004 daily maximum is less than or equal to 60 mg/L. During a heavy rain event on January 11, 2020, muddy water was discovered flowing from KPDES Outfall 004 (which is an internal outfall for the C-615 Sewage Treatment Facility). The muddy water was determined to be originating from an open excavation/trench from a construction site into a newly installed uncapped pipe that was connected to the sanitary sewer system. The pipe was isolated on January 12, 2020. Personnel continued to walkdown the area until the KPDES Outfall 004 was observed to be running clear. Additional samples were collected from KPDES Outfall 004 to demonstrate compliance with the monthly average limit. The additional sampling demonstrated that the muddy water discharge was an atypical event.

Another NOV was issued for failure to comply with KPDES Permit KY0004049 Outfall 020 monitoring and reporting requirements for the March 2020 monitoring period. Although there was a discharge through Outfall 020 during March 2020, a sample was not collected due to internal miscommunication. The missed sampling event caused 20 individual results to not be reported in the electronic Network Discharge Monitoring Report as required by the Permit. Actions were implemented to prevent future miscommunication.

The last NOV issued during CY 2020 was the result of a failed toxicity test at KPDES Outfall 010. The chronic test ending May 19, 2020 using Pimephales promelas had a failing result of 1.14 TUc. The permitted limit for toxicity is TU = (< 1.00 TUc). No environmental impacts related to the failed toxicity test were observed, and a retest was conducted on June 18, 2020, as required by the Permit. The retest results were passing, therefore, no further action was required by the Permit. The NOV noted the passing retest results and stated that no further action was required.

Additional information on CY 2020 KPDES exceedances is provided in Table 2.3.

Table 2.3. KPDES Exceedances in CY 2020

Outfall	Parameter	Number of Permit Exceedances	Number of Samples Taken	Number of Compliant Samples	Percent Compliance	Month of Exceedance
004	TSS	1	35	34	97%	January
010	Toxicity	1	6	5	83%	May

2.4.3 CERCLA Outfall

The *Operation and Maintenance Plan for the Northeast Plume Containment System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1535&D3/R6, requires testing at CERCLA Outfall 001 (DOE 2017a). Sampling parameters and frequencies are listed in the Environmental Monitoring Plan (FRNP 2021a).

2.4.4 Storm Water Management and the Energy Independence and Security Act of 2007

In compliance with the Energy Independence and Security Act (EISA), regarding new construction projects > 5,000 ft^2, the predevelopment hydrology is maintained or restored after construction. This allows compliance with EISA because predevelopment storm water will be maintained during the construction of an energy-efficient building. Furthermore, the Paducah Site implements energy and water audits. These audits typically cover the building shell, lighting, possible deployment of occupancy sensors, and leaking and/or old water fixtures. The findings of these audits are assessed and prioritized based on the mission of the Paducah Site. A list of previous audits is presented in the Site Sustainability Plan (SST 2019).

2.4.5 Safe Drinking Water Act

The Paducah Site supplies on-site drinking water from the Ohio River to its facilities. The drinking water system was operated and managed by FRNP, in accordance with the Safe Drinking Water Act regulations for CY 2020. FRNP maintains a water withdrawal permit from KDOW for up to 30 million gal per day. Water is pumped from the Ohio River and treated for on-site distribution.

FRNP operates a nontransient, noncommunity water system, regulated by KDOW. KDOW's requirement to submit monitoring plans to demonstrate compliance with regulations is applicable to the FRNP nontransient, noncommunity water system. Various sampling locations in the FRNP nontransient, noncommunity water system are monitored in accordance with these plans, and the monitoring results are submitted to KDOW.

On September 14, 2020, KDOW conducted a comprehensive on-site inspection of the C-611 Water Treatment Plant. The inspection was conducted to determine compliance with 401 *KAR* Chapter 8. The KDOW inspector found no issues and no concerns.

2.5 OTHER ENVIRONMENTAL STATUTES

2.5.1 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 the 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 of Fish and Wildlife Resources prior to implementing a proposed project.

Table 2.4 includes 16 federally listed species that have been identified as potentially occurring at or near the Paducah Site. None of these species have been reported as sighted on the DOE property, although the potential for a summer habitat for the Indiana Bat exists at certain areas of the property (Garland 2011). No DOE projects at the Paducah Site during 2020 adversely impacted any of these identified species or their potential habitats.

2.5.2 Impacts of Invasive Species

Executive Order 13751, *Safeguarding the Nation from the Impacts of Invasive Species*, calls upon government agencies to take steps to prevent the introduction and spread of invasive species, and to support efforts to eradicate and control invasive species that are established. Zebra mussels are an invasive species that can be found in the two intake supply lines utilized by the Paducah Site water treatment plant. This invasive species is controlled by draining one intake supply line at a time and allowing the mussels to die and then backwashing the drained line, flushing out the mussels. DOE takes steps to minimize the spread of invasive plant species found at the Paducah Site via routine site maintenance (i.e., mowing and spraying for weeds).

Table 2.4. Federally Listed Species Potentially Occurring near the Paducah Site*

Group	Common Name	Scientific Name	Endangered Species Act Status
Mammals	Gray Bat	*Myotis grisescens*	Endangered
	Indiana Bat	*Myotis sodalis*	Endangered
	Northern Long-eared Bat	*Myotis septentrionalis*	Threatened
Clams	Clubshell	*Pleurobema clava*	Endangered
	Fanshell	*Cyprogenia stegaria*	Endangered
	Fat Pocketbook	*Potamilus capax*	Endangered
	Northern Riffleshell	*Epioblasma torulosa rangiana*	Endangered
	Orangefoot Pimpleback	*Plethobasus cooperianus*	Endangered
	Pink Mucket	*Lampsilis abrupta*	Endangered
	Purple Cat's Paw	*Epioblasma obliquata*	Endangered
	Rabbitsfoot	*Quadrula cylindrica*	Threatened
	Ring Pink	*Obovaria retusa*	Endangered
	Rough Pigtoe	*Pleurobema plenum*	Endangered
	Sheepnose Mussel	*Plethobasus cyphyus*	Endangered
	Spectaclecase	*Cumberlandia monodonta*	Endangered
Birds	Least Tern	*Sterna antillarum*	Endangered

*All of the listed species are identified as an Endangered, Threatened, or Candidate Species known or with the potential to be located near the Paducah Site within McCracken County, Kentucky, by the U.S. Fish and Wildlife Service (FWS 2021).

2.5.3 Migratory Bird Treaty Act

The Memorandum of Understanding on Migratory Birds (2013) between DOE and the U.S. Fish and Wildlife Service and Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, direct federal agencies to take certain actions to further implement the Migratory Bird Treaty Act. The Migratory Bird Treaty Act of 1918 is applicable to the Paducah Site. DOE takes measures to minimize impacts to migratory birds by avoiding disturbance of active nests. Work control documents implement this restriction.

2.5.4 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*. Clearing for the new transmission right-of-way resulted in re-classification of 0.345 acres of palustrine forested (PFO) wetland to palustrine emergent (PEM) wetland, with short-term impacts to PEM wetlands and very minor long-term impacts on PFO wetlands. A wetland assessment was prepared in accordance with 10 *CFR* Part 1022.

2.5.5 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). Historic properties include buildings of historic significance and archeological sites. PGDP buildings were assessed in the Cultural Resources Survey (BJC 2006a). Archeological resources will be addressed as undisturbed land is developed for site use, or if undisturbed sites are considered to be impacted by DOE operations.

The Cultural Resources Management Plan identified a National Register of Historic Places-eligible historic district at the facility (BJC 2006b). The PGDP Historic District contains 101 contributing properties and is eligible for the National Register of Historic Places 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.

2.5.6 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 with EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements, as applicable.

2.5.7 Solid Waste Management

The Paducah Site disposes of a portion of its solid waste at its contained landfill facility, C-746-U Solid Waste Contained Landfill, under Solid Waste Permit, SW07300045. Construction of the first 5 cells (units) of the C-746-U Landfill began in 1995 and was completed in 1996. The operation permit was received from KDWM in November 1996, which allows for 23 cells. Disposal of waste at the landfill began in February 1997. Operating and groundwater reports for the C-746-U Landfill are submitted quarterly to KDWM. The C-746-U Landfill is permitted to accept for disposal all nonhazardous solid waste including residential, commercial, institutional, industrial, and municipal waste; shredded tires; nonhazardous spill cleanup residue generated at the Paducah Site; and any materials that meet the Authorized Limits. Construction of two new phases of the C-746-U Landfill was completed during 2019. Construction of Phases 6 and 7 began April 24, 2019, and construction was completed in August 2019. A Construction Progress Report was submitted to KDWM on September 9, 2019, and, after comments were addressed, KDWM approved the Construction Progress Report on September 27, 2019. Currently, a minor permit modification is pending approval from KDWM that addresses leachate generation and storage capacity for Phases 6 and 7.

DOE placed approximately 1,650 tons of solid waste into the C-746-U Landfill using the C-746-U Authorized Limits. The C-746-U Landfill waste acceptance criteria includes established volumetric and surficial Authorized Limits that govern disposal. Authorized Limits for the C-746-U Landfill initially were established in 2003 and have been maintained since that time. The latest revision was approved by DOE in 2011. Waste streams disposed of within the C-746-U Landfill during CY 2020 include building demolition debris, asbestos-containing materials, boundary control station waste, and other dry active wastes generated during deactivation activities. Table 2.5 provides a summary of Authorized Limit disposal at the C-746-U Landfill during CY 2020, and the cumulative totals since Authorized Limit disposal began in May 2003.

Table 2.5. C-746-U Landfill Authorized Limit Disposal through CY2020

Cumulative Activity from 2020 Disposal			Total Activity from Disposal 5/21/03 to 12/31/20		
Isotope	Activity (Curies)		Activity (Curies)	Source Term Limit (Curies)[a]	Percent Utilized[b]
Americium-241	5.02E-04		8.66E-03	79	0.01%
Cesium-137	1.30E-04		1.12E-02	43	0.03%
Neptunium-237	3.56E-04		1.31E-02	12	0.11%
Plutonium-238	6.91E-05		2.12E-03	88	0.00%
Plutonium-239/240	1.30E-03		2.06E-02	162	0.01%
Technetium-99	4.26E-02		1.24E+00	117	1.06%
Thorium-228	4.34E-04		7.25E-02	9	0.81%
Thorium-230	8.14E-03		2.44E-01	230	0.11%
Thorium-232	4.26E-04		7.25E-02	9	0.81%
Uranium-234	2.05E-02		3.99E-01	360	0.11%
Uranium-235	1.11E-03		1.92E-02	15	0.13%
Uranium-238	3.54E-02		4.73E-01	360	0.13%
					Total % 3.31

Waste streams added (2020)	0
Mass disposed of (2020)	2,336 tons
Mass disposed of (2013–2020)	130,121 tons
Number of cells open	2
Volume of open cells	5,400 yd^3
Volume of usable airspace	71,410yd^3
Volume of consumed airspace	144,835 yd^3
Volume of remaining permitted airspace	1,034,585 yd^3

[a] This column contains the maximum source term limit, if it is the only isotope present and is reduced when there is a mixture of radionuclides.
[b] Percent utilized is the percentage of total activity disposed of divided by the disposal inventory limit, per isotope. The total percentage shown represents the sum of fractions for the Source Term of the Landfill.

2.6 DEPARTMENTAL SUSTAINABILITY; FEDERAL LEADERSHIP IN ENVIRONMENTAL, ENERGY, AND ECONOMIC PERFORMANCE

2.6.1 Departmental Sustainability

DOE Order 436.1, *Departmental Sustainability*, was enacted May 2, 2011. The Paducah Site currently has no buildings that meet the Guiding Principles of High Performance and Sustainable Buildings. No large renovation projects are viable at this time for buildings at the Paducah Site, but the site continues to implement small upgrades as opportunities present themselves through maintenance replacements such as heating, ventilation, and air conditioning (HVAC) units, etc.

The Paducah Site completed construction of the C-208 Firing Range, which is a 5,749 ft^2 firing range for the Paducah Site Protective Force. Several green building specifications are being met, including the use of automatic lighting controls that operate light-emitting diodes (LED) and lower overall energy consumption. Some of the green building features meet principles from the Guiding Principles from the Federal Energy Management Program including Guiding Principle 5, building-level utility metering; Guiding Principle 7, high-efficiency water fixtures; Guiding Principle 8, nonirrigated landscape; and Guiding Principle 10, storm-water management techniques.

The Paducah Site began construction in FY 2020 on one building over 5,000 ft^2. The building is a 6,317 ft^2 Security Management Building (C-210). The building will be metered for water and electricity. Several green building specifications are being met and will lower overall energy consumption, including the use of automatic lighting controls that operate LED; and high-efficiency HVAC systems. The building's energy

usage is 30% better than the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 90.1 requirements due to ventilation and lighting controls, and metered electric power. The ventilation also meets indoor environmental quality requirements. The plumbing fixtures are low water consumption and the water is metered, which meets water conservation requirements. Some of the green building features include Guiding Principles from the Federal Energy Management Program such as building-level utility metering from Guiding Principle 5, high efficiency water fixtures from Guiding Principle 7, nonirrigated landscape that complies with Guiding Principle 8, and storm-water management techniques that satisfy Guiding Principle 10.

The Paducah Site began construction in FY 2020 a new annex to the existing C-304 Training and Cascade Office Building. The C-304 Annex consists of a 7,018 ft^2 modular building connected to the existing C-304 Training and Cascade Office Building by a site-built connector building section of 927 ft^2. The total new building area will be 7,945 ft^2. A water meter will be included for the C-304 Annex water. Energy-efficient lights and occupancy sensors will be utilized. A meter will be provided to measure the C-304 Annex power consumption. HVAC will be a site-built unit located at the north end of the connector building. The modular building will have eight individual HVAC units. The building addition provides, as applicable, optimized energy performance, water conservation, and indoor environmental quality according to the Guiding Principles for Sustainable Federal Buildings and Associated Instructions, The Council on Environmental Quality, February 2016. This includes metering, as stated above, low water consumption plumbing fixtures, ventilation and lighting controls, and energy usage of 30% better than the ASHRAE 90.1.

The Paducah Site acquired six office trailers and one shower trailer. The new trailers will allow for the reduction of the personnel footprint and will allow for the further deactivation of buildings at the Paducah Site. Many of the new trailers will not have their own restroom facilities, but will share facilities located in a central location to reduce the amount of utilities needed for the individual trailers. The restroom and shower facilities will utilize water fixtures that use auto shutoff sink and shower hardware to minimize water usage. LED light fixtures will be utilized that abide by ASHRAE 90.1 standards in the office and shower trailers.

The Paducah site began construction on a new C-538 Substation in FY 2019 and continued construction activities during FY 2020. Completion of the substation is anticipated during FY 2021. The new substation allows for the use of fewer transformers, which lowers the amount of voltage lost through thermal energy during standby operation. Tennessee Valley Authority (TVA) will now be supplying a lower voltage through the C-538 Substation because of the reduced need for energy, allowing for substantial savings. DOE is using the DOE Energy Conservation Program to fund the new C-538 Substation. Payback is based on shutdown of the PGDP transformers and using right-sized transformers at the new location.

2.6.2 Federal Leadership in Environmental, Energy, and Economic Performance

On May 17, 2018, the President signed Executive Order 13834, *Efficient Federal Operations*. Executive Order 13834 requires that federal agencies meet energy and environmental performance statutory requirements in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects the environment. In support of DOE's goals to meet requirements of Executive Order 13834, DOE submitted a Site Sustainability Plan report identifying the site's progress towards sustainability goals in December 2019 (SST 2019). Details of the objectives of the Site Sustainability Plan are outlined in Chapter 3 of this report.

2.7 EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT AND TITLE III OF THE SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT

Also referred to as Title III of 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, including greenhouse gases (GHGs). The Paducah Site, as a federal facility, is subject to these reporting requirements.

EPCRA's primary purpose is to increase the public's knowledge and access to information of chemical hazards in their communities. In order to ensure proper and immediate responses to potential chemical hazards, EPCRA Section 302-304 requires facilities to notify state emergency response commissions and local emergency planning committees of inventories and releases of hazardous substances and extremely hazardous substances, when the inventory or release equals or exceeds the reportable quantity. EPCRA Section 302-303 requires notifications to the state and local agencies within 60 days of when a substance on the list of extremely hazardous substances first becomes present at the facility in excess of the respective established threshold planning quantity. Notifications also are required if there is a revision to the list that results in the facility exceeding the revised threshold planning quantity or if there are changes at the facility relevant to emergency planning. These notifications are required within 60 days and 30 days, respectively, of the facility becoming subject to the requirements. The Paducah Site did not receive any such shipments, have production amounts, or make changes at the facility relevant to emergency planning that triggered Section 302-303 reporting for 2020. EPCRA Section 304 requires immediate notification of releases. The Paducah Site did not have any releases equal to or above the minimum reportable quantities; therefore, Section 304 reporting was not required for 2020.

Sections 311 and 312 of EPCRA require businesses to report the safety data sheets, 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 (when chemicals exceed a 10,000-lb reporting threshold). EPCRA Section 311 requires a one-time submittal of safety data sheets of hazardous chemicals present on-site at or above the reporting threshold. In 2020, no EPCRA Section 311 notifications were sent since no new chemicals triggered reporting at the Paducah Site in 2020. EPCRA Section 312 requires notification of the locations and quantities of the subject chemicals. The chemicals stored by all DOE contractors in CY 2020 (including FRNP, MCS, and SST) were included in an EPCRA 312 Report. The chemicals reported were carbon, aluminum oxide, cyclohexylamine (Bluegrass 16M), diesel fuel, calcium hydroxide, calcium oxide (Quicklime), carbon dioxide, chlorine, cryogenic and gaseous nitrogen, dichlorotetrafluoroethane (R-114), liquid and solid ferric sulfate, ferric oxide, fuel oil (No. 2), gasoline, hydrofluoric acid, lead acid batteries, oil, Portland Cement, potassium hydroxide, propylene glycol, quartz, sodium fluoride, sulfuric acid (nonbattery), uranium hexafluoride (UF_6), and uranium oxide. [UF_6 was reported as a courtesy, because radioactive substances are not subject to EPCRA Sections 311 and 312 (52 *FR* 38344 01).]

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 site submitted 313 Reports for hydrofluoric acid and chlorine for CY 2020. Table 2.6 summarizes the EPCRA reporting status for the Paducah Site for CY 2020.

Table 2.6. Status of EPCRA Reporting

EPCRA Section	Description of Reporting	Status*
EPCRA Sec. 302–303	Planning Notification	Not Required
EPCRA Sec. 304	Extremely Hazardous Substance Release Notification	Not Required
EPCRA Sec. 311–312	Material Safety Data Sheet/Chemical Inventory	Yes
EPCRA Sec. 313	Toxic Release Inventory Reporting	Yes

*An entry of "yes," "no," or "not required" is sufficient for "Status."

2.8 OTHER MAJOR ENVIRONMENTAL ISSUES AND ACTIONS

2.8.1 Green and Sustainable Remediation

Green and sustainable remediation is the practice of using sustainable methods to reduce environmental and social impacts of remedial cleanup and closure activities in a cost effective way. Green and sustainable remediation also offers opportunities to meet compliance obligations at lower overall cost and environmental impact. At the Paducah Site, environmental aspects including, but not limited to, energy use, water use, waste management, air pollution, and reuse of resources are evaluated when planning remediation activities.

2.9 CONTINUOUS RELEASE REPORTING

Section 103(a) of CERCLA requires that hazardous substance releases in excess of a reportable quantity be reported immediately to the National Response Center. Section 103(f)(2) provides relief from the Section 103(a) reporting requirement for hazardous substance releases that are continuous, stable in quantity and rate, and already have been reported. For such releases, notice must be given annually or at such time there is any statistically significant increase in the quantity of hazardous substance released. Releases of this nature typically are included in the Superfund Amendments and Reauthorization Act Title III reports and notifications listed in Section 2.7. There were no continuous releases in 2020.

2.10 UNPLANNED RELEASES

There were no unplanned releases above reportable quantities in 2020.

2.11 SUMMARY OF PERMITS

Table 2.7 provides a summary of the Paducah Site environmental permits maintained by DOE in CY 2020.

Table 2.7. Permits Maintained by DOE for the Paducah Site for CY 2020

Permit Type	Issued By	Permit Number	Issued To
State Agency Interest ID No. 3059			
Clean Water Act			
Kentucky Pollutant Discharge Elimination System	KDOW	KY0004049	DOE/FRNP/MCS
Permit to Withdraw Public Water	KDOW	0900	FRNP
Water Treatment Registration	KDOW	Public Water System KY0732457	FRNP
Clean Air Act			
Conditional Major Operating Air Permit	KDAQ	F-15-042 R1	MCS
Title V Air Permit	KDAQ	V-14-012 R3	FRNP
RCRA—Solid Waste			
Residential Landfill (closed)	KDWM	SW07300014	DOE/FRNP
Inert Landfill (closed)	KDWM	SW07300015	DOE/FRNP
Solid Waste Contained Landfill (construction/operation)	KDWM	SW07300045	DOE/FRNP
RCRA—Hazardous Waste			
Hazardous Waste Management Facility Permit	KDWM	KY8-890-008-982	DOE/FRNP
Hazardous and Solid Waste Amendments Portion of the RCRA Permit*	EPA	KY8-890-008-982	DOE/FRNP

*The federal HSWA permit terms and conditions ended on February 21, 2020, when Kentucky issued a modification to the HWMFP that incorporated the HSWA provisions.

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3. ENVIRONMENTAL MANAGEMENT SYSTEM

The EMS is designed to integrate environmental protection, environmental compliance, pollution prevention, and continual improvement into work planning and execution throughout all work areas. The Paducah Site implements sound stewardship practices in the protection of land, air, water, and other natural or cultural resources potentially impacted by site operations. The objectives are integrated into the Integrated Safety Management System established by the DOE Policy 450.4A, *Safety Management System Policy*.

Environmental protection programs at the Paducah Site conform to the six core elements of the International Organization for Standardization EMS ISO 14001:2015 standard through self-declaration. The major elements of an effective System include leadership, planning, support, operation, performance evaluation, and improvement. Through implementation of the EMS, effective protection to workers, the surrounding communities, and the environment can be achieved while meeting operating objectives that comply with legal and other requirements. Feedback information is analyzed to determine the status of the program relative to implementation, integration, and effectiveness.

DOE Contractors' Environmental Policy Statements emphasize conservation and protection of environmental resources by incorporating pollution prevention and environmental protection into the daily conduct of business. The DOE contractors implemented this policy through the programs described in this document, environmental cleanup, pollution prevention programs, and by integrating environmental protection, environmental regulatory compliance, and continual improvement into the daily planning and performance of work at the Paducah Site. The environmental policies are communicated to employees through various methods. The DOE contractor program manager reviews and communicates the commitments in the policy with all of the other members of the DOE contractor management team. The policy is communicated to employees and to subcontractors through sitewide communication, EMS awareness training, and publications.

The EMS environmental stewardship scorecard assesses agency performance in environmentally preferable purchasing; EMS implementation; electronics stewardship; high performance sustainable buildings; and environmental compliance management improvement. The EMS environmental stewardship scorecard for the Paducah Site in FY 2020 was "green" (which indicates standards for EMS implementation have been met).

3.1 ENVIRONMENTAL OPERATING EXPERIENCE AND PERFORMANCE MEASUREMENT

DOE and its contractors are committed to enhancing environmental stewardship and to reducing any impacts that site operations may cause to the environment. The Environmental Monitoring Program at the Paducah Site consists of effluent monitoring, environmental surveillance, and air monitoring around the plant. 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. FRNP implements the Environmental Monitoring Program for the Paducah Site documented in the Environmental Monitoring Plan (FRNP 2021a).

In addition to environmental monitoring documented in the Environmental Monitoring Plan, MCS also monitors radionuclide air emissions as required by their air permit. The results of these programs are discussed in detail in subsequent chapters of this report.

3.1.1 Site Sustainability Plan

In accordance with DOE Order 436.1 and Executive Order 13834, this report provides information concerning the requirements and responsibilities of managing sustainability on the Paducah Site including (1) to ensure DOE carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, while advancing sustainable, reliable and efficient energy for the future; (2) to initiate wholesale cultural change to factor sustainability and GHG reductions into all of DOE's corporate management decisions; and (3) to ensure that DOE achieves the sustainability goals established in its Site Sustainability Plan pursuant to any applicable laws, regulations, executive orders, sustainability initiatives, and related performance scorecards.

Table 3.1 is adapted from the Paducah Site FY 2020 Site Sustainability Plan from the web-based DOE Sustainability Dashboard. Site sustainability plans now are organized by overarching categories, rather than by goals, to reduce redundancies and streamline reporting.

When enrichment operations at the Paducah Site ended in FY 2014 and previously leased facilities were returned to DOE, the Environmental Management footprint went from 722,390 gross square footage in 2008 to 8,174,722 gross square footage in 2014. With the return of the previously leased facilities, the site incurred significant increases in utility consumption compared to its baseline values established in FY 2008, which skew attainment of planned goals.

Table 3.1. DOE Sustainability Goal Summary Table

Prior DOE Goal	Current Performance Status	Planned Actions and Contribution	Overall Risk of Non-Attainment
Energy Management			
30% energy intensity (British thermal units per gross square foot) reduction in goal-subject buildings by FY 2015 from a FY 2003 baseline and 1.0% year-over-year (YOY) thereafter.	The Paducah Site had usage reductions in electricity, natural gas, and potable water during FY 2020. The Paducah Site footprint was reduced by approximately 8,828 ft^2 with the demolition of 19 small structures/trailers.	The Paducah Site has identified 5 small structures and 33 tanks for demolition in FY 2021. The Paducah Site will continue to evaluate additional outdoor and indoor lighting for LED or solar opportunities. The Paducah Site will install LED lighting in various locations as fluorescent bulbs go out.	Given the baseline and subsequent mission at the Paducah Site, the overall risk of non-attainment is medium. In facilities where electrical consumption and natural gas usage will continue, the risk of non-attainment is high.
EISA Section 432 continuous (four-year cycle) energy and water evaluations.	An American Society of Heating, Refrigerating, and Air Conditioning Engineers Level I assessment was completed in November 2016. The assessment reviewed the C-337 Process Building, C-752-A and C-753-A waste storage facilities, and the C series trailers representing approximately 2,337,137 ft^2 or 28.9% of the Paducah Site facilities.	The Paducah Site will use the condition asset surveys with supplemental energy and water checks to meet the EISA Section 432 energy and water evaluations.	Given the subsequent mission at the Paducah Site, the overall risk of non-attainment is low with EISA Section 432 evaluations being completed.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

Prior DOE Goal	Current Performance Status	Planned Actions and Contribution	Overall Risk of Non-Attainment
Meter all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	Most PGDP facilities were built in the early 1950s, and many facilities are not metered individually for any utilities. The Paducah Site will install and track meters for use of power, natural gas, water, and other fuels, when repairs are made to the utility service for a building/group of buildings, such that installation of the meters are practicable to DOE. New meters will be installed on any new construction if utilities are used.	The Paducah Site has identified those meters that have been added or deleted during the Contract period. New office facilities will have electrical meters, and new shower/restroom facilities will have electric and water meters.	Given the baseline and subsequent mission at the Paducah Site, the overall risk of non-attainment is medium.
Water Management			
20% potable water intensity (gal per gross square foot) reduction by FY 2015 from a FY 2007 baseline and 0.5% YOY thereafter.	Overall, potable water usage has decreased by 18% when comparing FY 2020 to a baseline year of FY 2015.	Future plans include getting all air compressors and associated equipment off single pass cooling water and reconfigure either to recirculated cooling water or to air-cooled compressors.	Given the baseline and subsequent mission at the Paducah Site, the overall risk of non-attainment is medium.
Non-potable freshwater consumption (gal) reduction of industrial, landscaping, and agricultural (ILA). YOY reduction; no set target.	The Paducah Site does not have any ILA water.	The Paducah Site does not anticipate using any ILA water.	N/A
Waste Management			
Reduce at least 50% of non-hazardous solid waste, excluding construction and demolition debris, sent to treatment and disposal facilities.	The Paducah Site diverted 51.2% of nonhazardous solid waste from treatment and disposal.	The Paducah Site will continue existing recycle activities and will initiate new recycling opportunities as they become available.	Non-attainment risk is high due to the differing work scopes of the site.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities. YOY reduction; no set target.	The Paducah Site will continue to divert demolition materials and debris in FY 2021, as opportunities are available.	The Paducah Site will continue actively diverting construction and demolition materials as opportunities are available.	Given the subsequent mission at the Paducah Site, the overall risk of non-attainment is low.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

Prior DOE Goal	Current Performance Status	Planned Actions and Contribution	Overall Risk of Non-Attainment
Fleet Management			
20% reduction in annual petroleum consumption by FY 2015 relative to a FY 2005 baseline and 2.0% YOY thereafter.		Opportunities to reduce petroleum consumption will continue to be tracked and reviewed for opportunities for improvements.	Non-attainment risk is medium due to the differing work scopes of the site.
10% increase in annual alternative fuel consumption by FY 2015 relative to a FY 2005 baseline; maintain 10% increase thereafter.		Opportunities to increase E85 usage will continue to be tracked and reviewed on a monthly basis.	Non-attainment risk is low due to close monitoring of fuel reports to detect non-compliance of alternative fuel usage.
75% of light duty vehicle acquisitions must consist of alternative fuel vehicles (AFV).		Opportunities to increase AFV usage will continue to be tracked and reviewed.	Medium risk of non-attainment due to AFV vehicle availability during acquisition.
Clean & Renewable Energy			
"Renewable Electric Energy" requires that renewable electric energy account for not less than 7.5% of a total agency electric consumption by FY 2013 and each year thereafter.	The Paducah Site continues to operate nine air monitoring stations powered by solar panels, which saves over 2,800 kWh per year. DOE PPPO purchased 30.5% Renewable Energy Certificates for the Paducah Site during FY 2020.	DOE PPPO has purchased Renewable Energy Certificates in the past and may continue in the future.	Given the baseline and subsequent mission at the Paducah Site, the overall risk of non-attainment is low.
Continue to increase non-electric thermal usage. YOY increase; no set target but an indicator in the Office of Management and Budget scorecard.	DOE PPPO has purchased Renewable Energy Certificates in the past and may continue in the future.	DOE PPPO has purchased Renewable Energy Certificates in the past and may continue in the future.	Given the baseline and subsequent mission at the Paducah Site, the overall risk of non-attainment is low.
Green Buildings			
At least 15% (by count) of owned existing buildings to be compliant with the *revised* Guiding Principles for Sustainable Buildings by FY 2021, with annual progress thereafter.	No existing Paducah facilities meet this criterion.	Due to the age of PGDP facilities, it will be difficult to implement the goal; however, the Paducah Site will implement as appropriate. There is no estimate to meet this goal at this time.	Given the subsequent mission at the Paducah Site, the overall risk of non-attainment is high.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

Prior DOE Goal	Current Performance Status	Planned Actions and Contribution	Overall Risk of Non-Attainment
Acquisition & Procurement			
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring BioPreferred and biobased provisions and clauses are included in all applicable contracts.	The Paducah Site assesses contract actions to maximize the supply or use of products and services that are energy efficient, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, and nontoxic or less toxic alternatives, as appropriate.	The Paducah Site assesses contract actions to maximize the supply or use of products and services that are energy efficient, water efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled content, and nontoxic or less toxic alternatives, as appropriate.	Given the subsequent mission at the Paducah Site, the overall risk of non-attainment is low.
Measures, Funding, & Training			
Site set annual targets for sustainability investment with appropriated funds and/or financed contracts for implementation.	Construction of the new C-538 Substation to allow for properly sized transformers to be used and allow shutdown of Paducah Site's current transformers.	DOE and TVA entered into a utility energy savings performance contract agreement to reduce excess power usage by constructing the new C-538 Substation that is right-sized for the site. Construction of the new C-538 Substation will continue, with estimated completion in FY 2021.	Given the subsequent mission at the Paducah Site, the overall risk of non-attainment is low.
Electronic Stewardship			
End of Life: 100% of used electronics are reused or recycled using environmentally sound disposition options each year.	Interim Target: 100% Current Performance: 100%	Continue to meet goal.	Risk of non-attainment is low due to the maintenance of adequate inventory controls and continuously surveying property to identify excess. It is the site's policy to use a certified R2 recycling agency.
Data Center Efficiency: Establish a power usage effectiveness target for new and existing data centers; discuss efforts to meet targets.	Interim Target: < 1.5 Current Performance: 1.5 is the Power Usage Effectiveness of the server room. This is the ratio of Information Technology equipment to the total room power with overhead (HVAC).	Will review server and power infrastructure and pursue options to improve efficiency by replacement of older equipment and continuing efforts to virtualize the server environment.	Risk of non-attainment is high, due to no plans under contract to establish a different facility matrix.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

Prior DOE Goal	Current Performance Status	Planned Actions and Contribution	Overall Risk of Non-Attainment
Organizational Resilience			
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols.	The Paducah Site Emergency Management Program addresses all hazards events including natural phenomena (e.g., severe weather, earthquakes, etc.) and man-made and technological emergencies through emergency plans, implementing procedures, and facility Emergency Actions Plans.	Annual protective action drills will continue to be completed as scheduled.	Given the subsequent mission at the Paducah Site, the overall risk of non-attainment is low with a robust emergency management program already in place.
Multiple Categories			
YOY Scope 1 and 2 GHG emissions reduction from a FY 2008 baseline.	During FY 2020, electrical usage was reduced by 16.6% compared to FY 2019. Natural gas usage was reduced by 49.9% compared to the previous FY. Through these reductions, GHG Scope 1 and 2 emissions will be reduced.	The Scope 1 and 2 GHG goal will be extremely difficult, if not impossible, to achieve given the FY 2008 baseline and current status of the Paducah Site. Anticipate continued reductions with utility optimization projects, space consolidation, and reductions to site footprint.	Given the baseline and subsequent mission at the Paducah Site, the overall risk of non-attainment is medium. In facilities, where electrical consumption and natural gas usage will continue, the risk of non-attainment is high.
YOY Scope 3 GHG emissions reduction from a FY 2008 baseline.	During FY 2020, the Paducah Site continued implementing a consolidated 4-day/10-hour day workweek schedule. Also, there was a decrease in commuter mileage of approximately 43% due to COVID-19 mitigation activities.	The Scope 3 GHG goal will be extremely difficult, if not impossible, to achieve given the FY 2008 baseline and current status of the Paducah Site. Anticipate continued 4-day/10-hour day workweek consolidated schedule.	There is a high risk of non-attainment at the Paducah site due to the FY 2008 baseline.

3.1.2 Waste Minimization/Pollution Prevention

The Waste Minimization/Pollution Prevention Program 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 Commonwealth of Kentucky and EPA rules, DOE Orders, executive orders, and the Site Treatment Plan. All of the Paducah Site projects are evaluated for waste minimization/pollution prevention opportunities. Materials recycled included oils, paper, toner cartridges,

scrap metal (non-radiological), aluminum cans, light bulbs, batteries, tires, plastics, cardboard, and over seven tons of used electronics.

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:

- Eliminate or reduce the amount and toxicity of all waste generated at the site;
- Comply with federal and state regulations and DOE requirements for waste minimization;
- Reuse or recycle materials when possible;
- Identify waste reduction opportunities;
- Integrate waste minimization/pollution prevention technologies into ongoing projects;
- Coordinate recycling programs; and
- Track and report results.

Waste minimization/pollution prevention efforts for the site are reported in DOE's Sustainability Dashboard. As part of waste minimization/pollution prevention efforts at the Paducah Site, SST offers excess reusable items to Paducah Area Community Reuse Organization. During CY 2020, the Paducah Site diverted 51.2% of its waste from disposal in municipal landfills, including paper, scrap metal, wood pallets, batteries, cardboard, plastic, and electronic items.

Waste minimization/pollution prevention accomplishments at the Paducah Site related to the Site Treatment Plan waste minimization/pollution prevention in CY 2020 were the following (DOE 2021a). This list does not represent all recycling efforts made at the Paducah Site and is only the potential hazardous waste that was diverted. Note that activated carbon is sent off-site for regeneration and subsequent reuse.

- Regenerated 21,840 lb of activated carbon, averting disposal.
- Recycled/reclaimed 5 lb of mercury-containing items.
- Recycled 1,044 lb of various light bulbs.
- Recycled 27,335 lb of various batteries.

3.1.3 Depleted Uranium Hexafluoride Cylinder Program

A byproduct of the uranium enrichment process, DUF_6 is a solid at ambient temperatures and is stored in large metal cylinders. At the end of 2020, the Paducah Site managed an inventory of 51,177 cylinders stored in cylinder storage yards.

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.

The DUF_6 facility converts the inventory of DUF_6 to triuranium octoxide (U_3O_8), a more stable form of uranium, and hydrofluoric acid sold for commercial use. During 2020, MCS converted approximately 1,187 metric tons of DUF_6 to a more stable oxide and hydrofluoric acid. Off-site shipment is discussed in Section 4.2.

3.1.4 Environmental Remediation

The environmental remediation program executes environmental investigations and implements environmental response actions. In addition, the environmental remediation program supports deactivation and decommissioning of facilities, 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.

The following are Paducah Site significant accomplishments in 2020.

- Completed deactivation of the C-400 Cleaning Building, providing the investigation team with complete access inside the building.

- Began drilling activities for the C-400 Complex Operable Unit Remedial Investigation.

- Submitted page changes for the *Remedial Investigation/Feasibility Study Work Plan for the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2433&D2/R1 (DOE 2020c) for specific information available once an analytical laboratory was contracted to support the remedial investigation.

- Received federal and state regulatory concurrence on the page changes for the *Remedial Investigation/Feasibility Study Work Plan for the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2433&D2/R1 (DOE 2020c).

- Submitted the *Remedial Action Work Plan for SWMU 211-A Enhanced In Situ Bioremediation for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2443&D2 (DOE 2020d).

- Submitted the *Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Preliminary Investigation Work Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2447&D1 (DOE 2020e).

- Submitted the *Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Preliminary Investigation Work Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2447&D2 (DOE 2020f).

- Submitted page changes for the *Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Preliminary Investigation Work Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2447&D2/R1 (DOE 2020g).

- Received federal and state regulatory concurrence on the page changes for the *Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Preliminary Investigation Work Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2447&D2/R1 (DOE 2020g).

- Initiated field activities for the Plant Area Industrial Vapor Intrusion Assessment with the walkdown of the facilities to mark subslab sample locations.

- Submitted the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision Fiscal Year 2020*, DOE/LX/07-2444&D2/R1 (DOE 2020h).

- Received federal and state regulatory approval of the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision Fiscal Year 2020*, DOE/LX/07-2444&D2/R1 (DOE 2020h).

- Submitted the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision Fiscal Year 2021*, DOE/LX/07-2450&D1 (DOE 2020i).

- Received federal and state regulatory approval of the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision Fiscal Year 2021*, DOE/LX/07-2450&D1 (DOE 2020i).

- Submitted the *Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant*, DOE/LX/07-2448&D1 (DOE 2020j).

- Submitted the *Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant*, DOE/LX/07-2448&D2 (DOE 2020k).

- Received federal and state regulatory approval of the *Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant*, DOE/LX/07-2448&D2 (DOE 2020k).

- Submitted the *Operation and Maintenance Plan for the Northeast Plume Containment System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1535&D3/R7 (DOE 2020l).

- Submitted the *Operation and Maintenance Plan for the Northeast Plume Containment System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1535&D3/R8 (DOE 2020m).

- Received federal and state regulatory approval of the *Operation and Maintenance Plan for the Northeast Plume Containment System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1535&D3/R8 (DOE 2020m).

- Submitted the *Operation and Maintenance Plan for the Northwest Plume Groundwater System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1253&D4/R6 (DOE 2020n).

- Submitted the *Operation and Maintenance Plan for the Northwest Plume Groundwater System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1253&D4/R7 (DOE 2020o).

- Received federal and state regulatory approval of the *Operation and Maintenance Plan for the Northwest Plume Groundwater System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1253&D4/R7 (DOE 2020o).

3.1.5 Emergency Management

Emergency management planning is a systematic, integrated effort at the Paducah Site in the rare event that site activities could impact site workers or the public. Members of the Paducah Site Emergency Response Organization include the Crisis Manager and the Emergency Operations Center cadre, an Incident

Commander, and the Emergency Squad. In the event of an emergency, the Joint Public Information Center provides timely and accurate information to the community.

The Paducah Site also maintains a fully staffed fire department along with protective force officers and a medical facility. DOE's various contractors have separate emergency response procedures that they practice during training exercises to bolster their ability to work together.

3.1.6 Facility Stabilization, Deactivation, and Infrastructure Optimization

Stabilization and deactivation projects at the Paducah Site involve isolating utilities, removal and compliant disposition of hazardous materials from facilities, and downgrading radiological facilities to make ready for demolition. The following are significant Paducah Site accomplishments in 2020.

- Completed seal exhaust and wet air (SX/WA) characterization and disposition.
- Completed trailer demolition and tank disposition.
- Completed asbestos/transite removal.
- Completed high pressure fire water dry hybrid and conversion.
- Completed line recorder/assay machine/datum pump characterization and disposition.
- Demolished items within facilities and applied fixative for radiological contamination control.
- Installed new trailers and storm shelters at various locations.

3.2 ACCOMPLISHMENTS, AWARDS, AND RECOGNITION

DOE and its contractors are committed to enhancing public awareness and community/educational outreach. The Paducah Citizens Advisory Board and the DOE Environmental Information Center are both avenues through which DOE interacts with the public. In addition to public outreach, DOE's contractors have received recognition for their work.

3.2.1 Public Awareness Program

A comprehensive Community Relations Plan exists for DOE activities at the Paducah Site (DOE 2020j); however, out of an abundance of caution and to help slow the spread of COVID-19, some DOE programs may have been affected during CY 2020. Some of the site's activities, such as community involvement and recent cleanup mission achievements, were publicized using media releases. A discussion of many of the DOE programs and their CY 2020 status are briefly described in Section 3.2.2.

3.2.2 Community/Educational Outreach

DOE supported several educational and community outreach activities during 2020, including the DOE West Kentucky Regional Science Bowl (Figure 3.1), which engaged high school and middle school students across the region. Due to COVID-19 safety protocols, the Science Bowl was organized as a virtual event. Site employees also participated virtually in a campaign to support the "Feds Feed Families" program. This program helps local food pantries keep their shelves stocked during the summer months when they traditionally see a decrease in donations and an increase in needs from their communities. The program has traditionally been a canned goods drive; however, in the summer of 2020, the campaign was launched as a digital campaign that encouraged Paducah Site workers and DOE to pledge funds to one of several food pantries.

DOE and its contractors also engage students through educational outreach programs such as the annual DOE National Science Bowl. The Science Bowl, designed as a quick-recall, fast-paced, question-and-answer contest, quizzes students on their knowledge of various subjects including biology, chemistry, earth and space, energy, mathematics and physics. For CY 2020, the regional competitions were held virtually in February for Western Kentucky and Southern Illinois middle and high schools. A total of six middle schools and eight high schools participated in the event. Also in CY 2020, DOE conducted a site overview virtual presentation with Marshall County High School students, which was provided in lieu of a site tour. In 2020, the Kentucky Research Consortium for Energy and the Environment, working with students from Marshall County High School, produced an ASER summary.

Figure 3.1 West Kentucky Regional Science Bowl

Due to COVID-19 safety protocols, some DOE programs were cancelled for CY 2020. One of the cancelled programs included the DOE Internship Program. This program typically lasts 10 weeks and offers college students practical experience working on projects that support the Paducah Site's deactivation and remediation operations.

Also cancelled for CY 2020 was the DOE Community Tours Program. DOE conducts plant tours and briefings for community members, leaders, new CAB members, Paducah Area Chamber of Commerce representatives, senior DOE headquarters officials and members of Congressional staff. The tours highlight PGDP's unique history and pay honor to former workers who met the nation's defense and energy needs for many years.

In CY 2020, the Middle School Groundwater Lessons program was postponed due to the COVID-19 pandemic. In this program, local sixth grade students are invited to participate in a mentoring program designed to give the students a better understanding of groundwater cleanup at the plant-site.

The Kentucky Research Consortium for Energy and Environment continued development of the "Virtual Museum for the Paducah Site." This Web resource maintains an archive of information that can be used to communicate to stakeholders, especially the public, the history, local impact, and cleanup of the Paducah Site. As part of this development, the Kentucky Research Consortium for Energy and Environment worked with the site to develop content. Additional information is available at the following link: http://www.ukrcee.org/about.html

3.2.3 Citizens Advisory Board

The Paducah Citizens Advisory Board is a site-specific advisory board chartered by DOE under the Federal Advisory Committees Act. The board is composed of up to 15 members, representing the general public from Western Kentucky and Southern Illinois. In addition, the Citizens Advisory Board also has liaison members representing EPA Region 4, Kentucky Cabinet for Health and Family Services, and WKWMA. The board is committed to reflecting the concerns of the communities impacted by environmental management of the plant site. Additional information concerning the Citizens Advisory Board may be obtained at https://www.energy.gov/pppo/pgdp-cab/paducah-citizens-advisory-board.

The Paducah Citizens Advisory Board typically works to achieve its mission through its subcommittee structure, and each year the board holds a planning meeting to determine how best to address its mission.

Executive committee members participate in administrative meetings to prepare board members and subcommittees for the task of advising DOE. The educational series was developed to address project priorities selected by the board, with guidance from DOE (PGDP CAB 2017). The intended educational series for CY 2020 consisted of the following:

- Land Transfer/Footprint Reduction;
- Remediation Technology; and
- Risk and Communication.

Meetings are typically open to the public and publicly advertised; however, due to COVID-19 safety concerns, beginning in April 2020, all regular board meetings were conducted virtually.

3.2.4 Environmental Information Center

The public has access to the electronic version of the Administrative Records and programmatic documents at the Environmental Information Center located at the Emerging Technology Center, Room 221, 5100 Alben Barkley Drive, Paducah, Kentucky. The Environmental Information Center is open Monday through Friday from 8 a.m. to 12 p.m. and by appointment. The Environmental Information Center's phone number is (270) 554-3004.

Documents for public comment also are placed in the McCracken County Public Library, 555 Washington Street, Paducah, Kentucky. The library is open Monday through Thursday from 9:00 a.m. to 7:00 p.m., Friday and Saturday from 9:00 a.m. to 5:00 p.m., and Sunday from 1:00 p.m. to 5:00 p.m.

The Environmental Information Center and other public Web pages related to DOE work at the Paducah Site can be accessed at https://eic.pad.pppo.gov/ and http://energy.gov/pppo/paducah-site.

4. ENVIRONMENTAL RADIOLOGICAL PROTECTION PROGRAM AND DOSE ASSESSMENT

Each year an estimate is made of the potential radiological dose to the public that is attributable to Paducah Site operations and effluents during that CY. Estimates are calculated to confirm that no individual could have received a dose that exceeded the limits for protection of the public, as established by DOE or EPA. This section provides estimates of the maximum potential dose to the public and to the plants and animals (biota) from 2020 Paducah Site activities.

4.1 2020 HIGHLIGHTS

As in previous years, the estimated potential dose from the Paducah Site to the maximally exposed individual (MEI) was well below applicable EPA standards and DOE public dose limits, and a very small fraction of the 620 mrem that the public receives annually from natural and man-made sources. The estimated annual dose has been negligible from the Paducah Site in recent years.

Total Dose from All Pathways: The dose of radiation (based on calculations) that could be received by a member of the public from all pathways of exposure was 4.3 mrem/year, which is approximately 4.3% of the DOE annual dose limit of 100 mrem/year.

Dose from the Air Pathway: Annual radionuclide air emissions are regulated by the EPA and limited to 10 mrem (0.1 mSv) per year to any member of the public. The total annual dose from airborne emissions in 2020 was 6.1E-05 mrem (6.15E-07 mSv). This level is 0.00061% of the EPA limit.

Dose from the Water Pathway: Dose from the surface water pathway is evaluated by its contribution to the DOE total of all pathways dose limit of 100 mrem per year. The estimated dose from ingestion of surface water releases from the Paducah Site was 0.157 mrem/year (1.57E-03 mSv/year). This level is 0.157% of the DOE annual dose limit of 100 mrem/year from all pathways to members of the public. Groundwater is not considered an exposure pathway because DOE provides public water to downgradient residents.

Dose from the Direct Radiation Pathway: The estimated dose to the MEI was 4.1 mrem/year (4.1E-02 mSv/year). This estimated dose is 4.1% of the DOE annual dose limit of 100 mrem/year from all pathways to members of the public.

Dose to Biota: Biota dose modeling indicates the plants and animals living on or near the Paducah Site are not exposed to doses in excess of the DOE biota dose standard.

4.2 ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM

Routine DOE operations at the Paducah Site result in releases of radioactive materials to the environment by atmospheric and liquid pathways. These releases potentially result in a radiation exposure to the public. In accordance with DOE Order 458.1, *Radiation Protection of the Public and the Environment*, DOE has an environmental surveillance program that includes radiological monitoring of pathways which may contribute to dose to the public. Surveillance includes analyses of surface water, groundwater, sediment, direct radiation, and ambient air (FRNP 2021a). DOE has established dose limits for the public and biota. The dose limit to the public is 100 millirem (mrem) per year summed over all sources of ionizing radiation and exposure pathways. Doses are to be optimized through the application of ALARA principles so that DOE operations will not contribute significantly to the average annual exposure. Doses to biota is limited

to 1 rad/day (a unit of absorbed dose) for protection of aquatic organisms, 1 rad/day for protection of terrestrial plants, and 0.1 rad/day for protection of terrestrial animals. To confirm that doses are below public and biota dose limits, the Paducah Site calculates annual dose estimates using effluent release data, environmental monitoring data, and surveillance data combined with relevant site specific data (such as meteorological conditions, population characteristics, and stream flows).

Surface water is not used as a source of public drinking water on the DOE Reservation; however, data from these outfalls are included as part the incidental surface water ingestion pathway. To assess fully the potential dose to the public, a hypothetical set of realistic characteristics was used to postulate an upper bound exposure scenario.

4.2.1 What Is Dose?

Dose is the amount of energy absorbed by the human body as a result of a radioactive source; it is measured in rem [which equals 0.01 sievert (Sv)] or in mrem, which is one-thousandth of a rem. These exposures/intakes involve the transfer of energy from radiation to tissue and can result in tissue damage. 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.

Members of the public are routinely exposed to natural and man-made sources of ionizing radiation. An individual living in the U.S. is estimated to receive an average annual effective dose of about 620 mrem (6.2 mSv) (NCRP 2009). Half of the radiation dose to a member of the public, about 310 mrem/year, is from natural background sources of cosmic and terrestrial origin (Figure 4.1). The other half is from man-made sources, including diagnostic and therapeutic X-rays, tomography, and fluoroscopy; nuclear medicine; consumer products, such as cigarettes and smoke detectors; fallout from nuclear weapons tests; industrial, research, and educational applications; and effluents from nuclear facilities.

Unless otherwise noted, the generic term “dose” used in this report is the total effective dose to a person, which includes both the committed effective dose (50-year committed dose) from internal deposition of radionuclides and the effective dose attributable to sources external to the body. Use of the total effective dose allows doses from different types of radiation and to different parts of the body to be expressed on the same basis. National Council on Radiation Protection and Measurements Report No. 160 noted that the average member of the U.S. population was exposed to significantly more radiation from medical procedures than from any other source. Approximately half of an average individual’s dose is attributed to natural sources (radon 37% and 13% is cosmic, terrestrial, and internal). Dose from nuclear power was grouped into a category comprising < 0.1%. The remaining dose was from medical exposures (approximately 48% of the total dose).

DOE has established dose limits to the public so that DOE operations will not contribute significantly to this average annual exposure. DOE Order 458.1 establishes 100 mrem/year above background as the total annual dose limit to a member of the public. The established 100 mrem/year dose limit is consistent with Nuclear Regulatory Commission and Kentucky Radiation Health Branch dose limits for the public. Each year, DOE operations at the Paducah Site contribute to the public dose through radiological releases and direct radiation. Emissions and effluents are controlled so that releases are maintained ALARA (refer to the Glossary of this report for a definition of ALARA). To confirm that doses to the public and biota are below established limits, the Paducah Site calculates annual dose estimates using effluent release data, direct radiation monitoring data, and environmental monitoring data combined with relevant site specific data (such as meteorological conditions and population characteristics). These dose calculations use various

computer codes that model the environmental dispersion of radionuclides that originate from on-site activities. Note that natural background sources of cosmic and terrestrial origin and man-made activity (excluding medical doses) from fallout are subtracted from radiological measurements to determine Paducah Site doses.

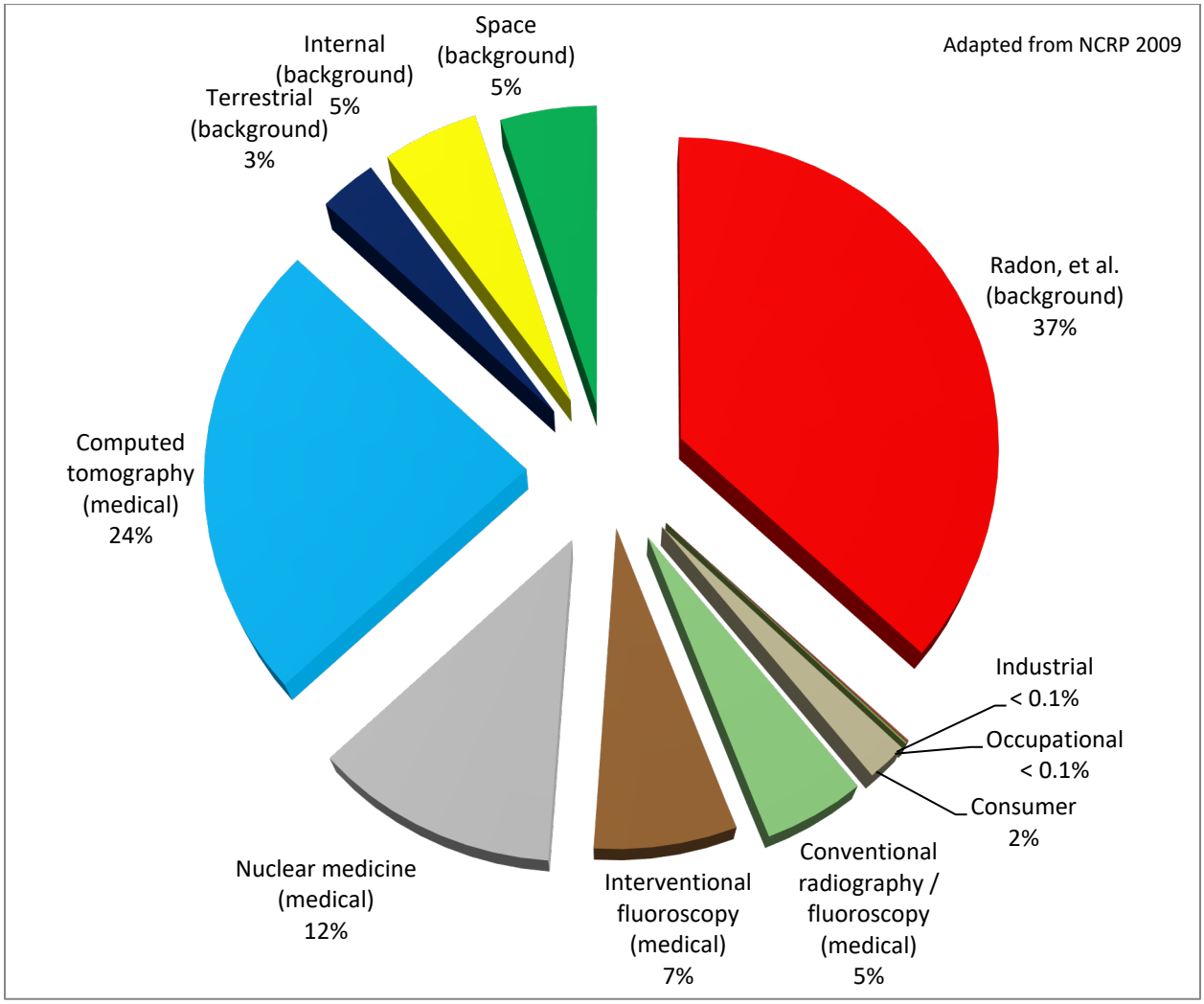


Figure 4.1. Sources of Radiation

4.2.2 Radioactive Materials at the Paducah Site

Radioactive materials present at the Paducah Site are the result of processing raw and recycled uranium. The Paducah Site associated radionuclides of concern and their half-lives are listed below:

- Uranium-234 (245,000 year half-life)
- Uranium-235 (704,000,000 year half-life)
- Uranium-238 (4,470,000,000 year half-life)
- Thorium-230 (75,400 year half-life)
- Technetium-99 (211,000 year half-life)
- Plutonium-238 (87.7 year half-life)
- Plutonium-239 (24,100 year half-life)
- Plutonium-240 (6,560 year half-life)

- Neptunium-237 (2,140,000 year half-life)
- Americium-241 (432 year half-life)
- Cesium-137 (30.2 year half-life)

Decay products for the radionuclides listed above also are present at the Paducah Site in minute quantities. As discussed in Section 4.1.1, members of the public are routinely exposed to natural background and man-made sources of ionizing radiation. The radioactive materials present at the Paducah Site do not contribute significantly to the public's average annual exposure when compared to natural background and man-made sources of radiation (excluding medical doses).

The monitoring program for radioactivity in liquid and airborne effluents is described fully in the Paducah Site Environmental Monitoring Plan (FRNP 2021a).

4.2.3 What is an Exposure Pathway?

An exposure pathway is how a radioactive material is released to the environment, transported to a receptor (person, animal, or plant), and comes into contact with a receptor (Figure 4.2). Routine operations at the Paducah Site may release incidental radioactive materials into the environment through atmospheric and liquid discharges. The principal routes by which people come into contact with released radioactive material are the following:

- Inhalation of gases and particulates;
- Ingestion of vegetables, crops, wild game, milk, and fish;
- Ingestion of surface water and groundwater;
- Skin absorption (also called dermal absorption); and
- External exposure to ionizing radiation.

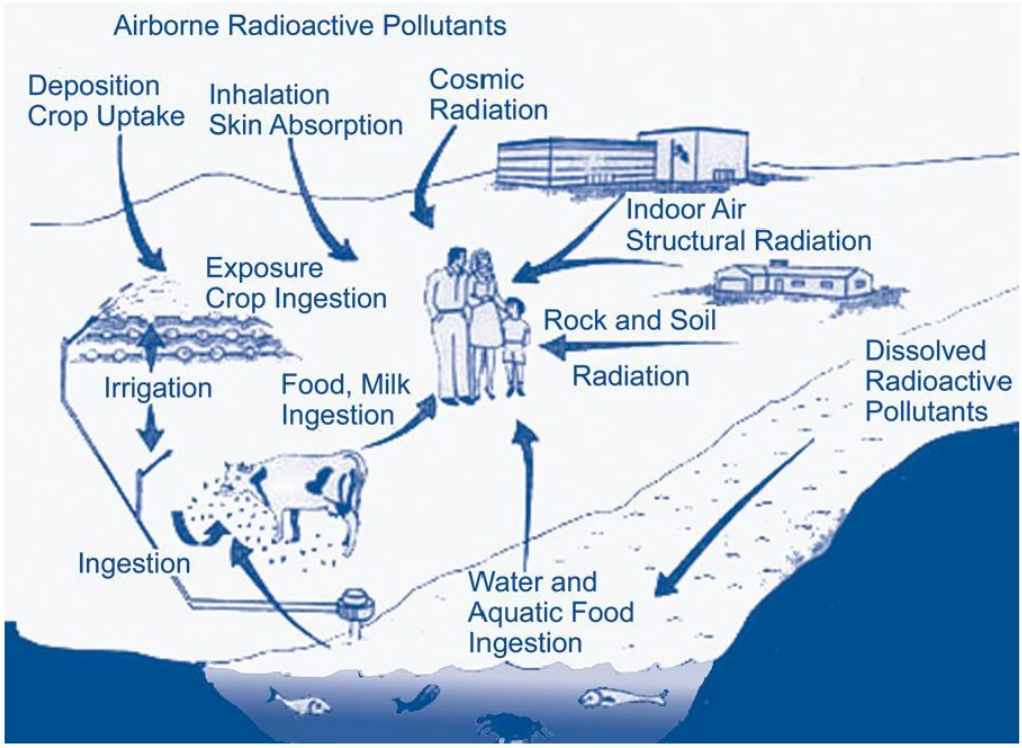


Figure 4.2. Potential Exposure Pathways

4.2.4 Dose Assessment Methodology

Radiological exposure assessments are modeled using exposure pathways applicable to the Paducah Site utilizing methods consistent with the requirements of DOE Order 458.1 and various guidance, including the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2020a). First, measurements (and/or estimates) of radionuclide concentrations in liquid and air released from the Paducah Site are assembled from the CY of interest. Then EPA- and DOE-approved models, or factors derived from those models, are used to estimate the total effective dose to the MEI and the collective total effective dose to the population within a 50-mile radius.

The MEI is the resident who has the greatest probability of being affected by a radiological release for that pathway.

For determining compliance with the DOE public dose requirements, the Paducah Site calculates the potential off-site doses from the Paducah Site effluent releases of radioactive materials (atmospheric and liquid) for the MEI and the population living within a 50-mile radius of the Paducah Site. In accordance with DOE Order 458.1, the pathway and exposure assumptions for the MEI are to be reasonable and not underestimate the dose or substantially overestimate the dose. The MEI for each pathway at the Paducah Site is established based on lifestyle assumptions for radiological exposure that would yield an upper bound dose for an individual who lives near the Paducah Site at the location where the highest concentration of radionuclides in air has been modeled; consumes milk, meat, and vegetables produced at that location; spends time on or near Bayou or Little Bayou Creeks; and hunts on the wildlife reservation (DOE 2020a). Dose is expected to be upper bounding because certain assumptions (such as swimming in nearby creeks) are not expected. The drinking water pathway at Paducah is not a valid exposure pathway because all persons potentially impacted by the Paducah Site have access to public water. Surface water for irrigation of crops is assumed to come from an uncontaminated source and not from either Bayou or Little Bayou Creek, which have too little flow for this use in comparison to the Ohio River. Furthermore, Little Bayou Creek does not support aquatic life for consumption, and few game size fish could be caught from Bayou Creek, except when there is a major influx of fish from the Ohio River during a backwater event. Because of this, dose from fish ingestion is not included. The general population dose from surface water is calculated assuming ingestion at the nearest public withdrawal location, Cairo, Illinois. The MEI dose from incidental sediment and surface water ingestion is based on assumptions for recreational use of the Bayou and Little Bayou Creeks on the reservation. Dose associated with airborne releases are calculated for the MEI located at the nearest plant neighbor.

4.2.5 Air Monitoring and Estimated Dose from Airborne Effluents

DOE operations result in airborne releases from various sources including CERCLA remedial actions. Radionuclide sources at the Paducah Site evaluated in 2020 were the following:

- Northwest Plume Groundwater Treatment System;
- Northeast Plume Containment System Treatment Units;
- DUF_6 Conversion Facility;
- Building Exhaust Vents; and
- Fugitive Emissions.

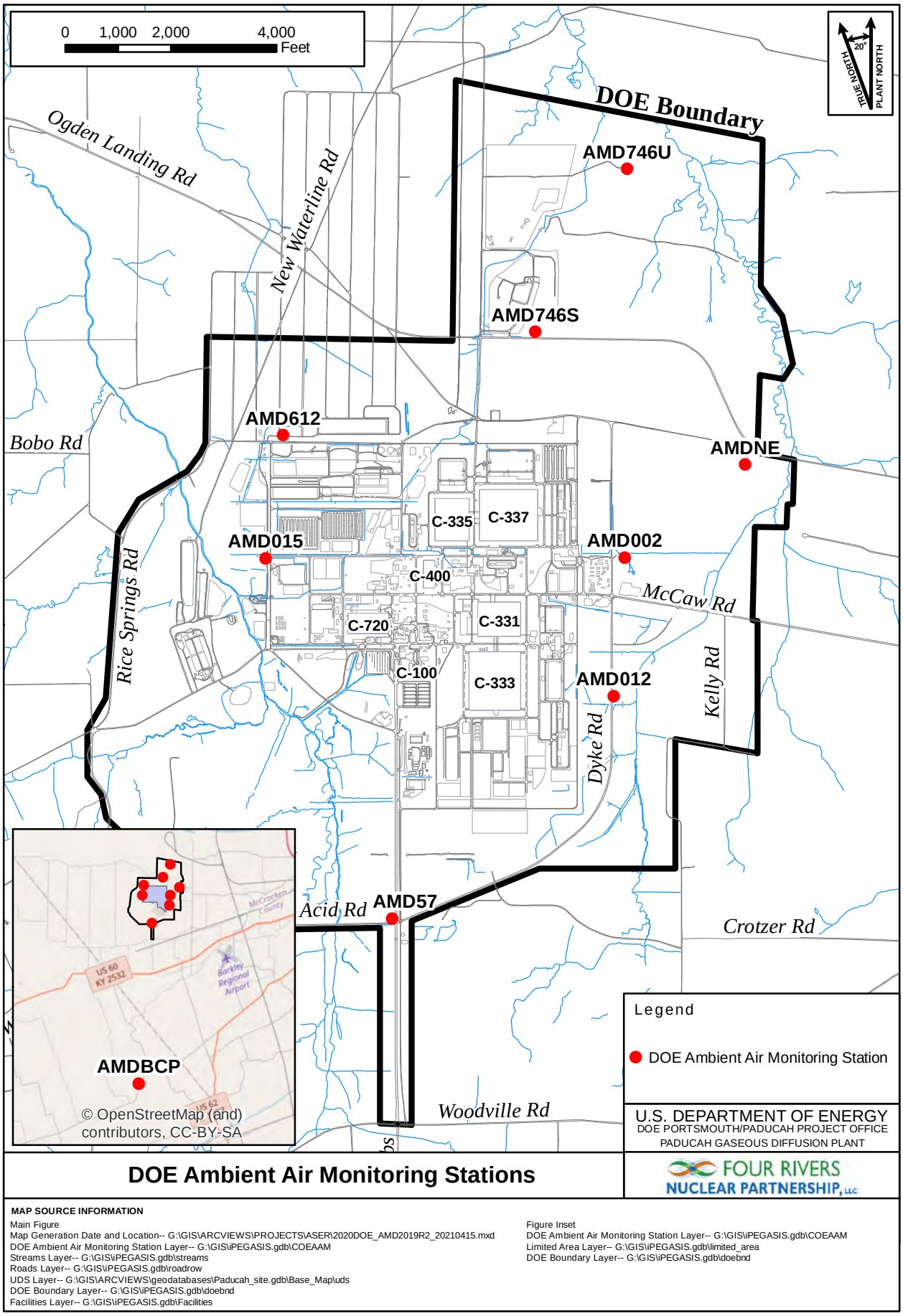
Specific activities that could generate fugitive emissions include transport and disposal of waste, decontamination of contaminated equipment, and most environmental remediation activities. Ambient air monitoring, which monitors fugitive emissions from all Paducah Site operations (including DUF_6 Conversion Facility operations), is conducted using nine continuous air monitors surrounding the Paducah Site reservation. One of these air monitors collects data from a background location. See Figure

4.3 for air sampling locations. Radiological analytes are presented in the FY 2020 Environmental Monitoring Plan (FRNP 2020c) and FY 2021 Environmental Monitoring Plans (FRNP 2021a).

Airborne radionuclide emissions are regulated by EPA under the Clean Air Act and its implementing regulations. DOE facilities are subject to 40 *CFR* Part 61, Subpart H, NESHAP, which contains the national emission standards for radionuclides other than radon from DOE facilities. The applicable standard is a maximum of 10 mrem (0.1 mSv) effective dose equivalent to any member of the public in any year.

Airborne radioactive materials released in 2020 from stacks and diffuse sources on the Paducah Site (Table 4.1) were modeled using the EPA-approved Version 4.1.0.2 of the Clean Air Act Assessment Package–1988 (CAP-88) PC computer program. This air dispersion model estimates effective dose equivalents based on the ingestion, inhalation, air immersion, and ground surface pathways including consumption of vegetables, milk, and meat. Site-specific data for CY 2020 (radionuclide releases in curies per year) were input into the CAP-88 PC program, as were on-site meteorological data.

For radionuclides at the Paducah Site, the effective dose equivalent is assumed to be equivalent to the effective dose. January 2020 guidance from DOE's Office of Public Radiation Protection (AU-22) states, "AU-22 considers the reported CAP-88 PC dose to be a very close approximation of a modeled ED result and well within the uncertainty bounds of the dose estimate." The DOE guidance is available at https://www.energy.gov/sites/prod/files/2020/02/f71/DOE-Info-Brief-on-NESHAPS-Jan-2020.pdf.



MAP SOURCE INFORMATION

Main Figure
Map Generation Date and Location-- G:\GIS\ARCVIEWS\PROJECTS\ASER\2020DOE_AMD2019R2_20210415.mxd
DOE Ambient Air Monitoring Station Layer-- G:\GIS\iPEGASIS.gdb\COEAAM
Streams Layer-- G:\GIS\iPEGASIS.gdb\streams
Roads Layer-- G:\GIS\iPEGASIS.gdb\roadrow
UDS Layer-- G:\GIS\ARCVIEWS\geodatabases\Paducah_site.gdb\Base_Map\uds
DOE Boundary Layer-- G:\GIS\iPEGASIS.gdb\doebnd
Facilities Layer-- G:\GIS\iPEGASIS.gdb\Facilities

Figure Inset
DOE Ambient Air Monitoring Station Layer-- G:\GIS\iPEGASIS.gdb\COEAAM
Limited Area Layer-- G:\GIS\iPEGASIS.gdb\limited_area
DOE Boundary Layer-- G:\GIS\iPEGASIS.gdb\doebnd

Figure 4.3. Air Monitoring Locations

Table 4.1. Radionuclide Atmospheric Releases for CY 2020 (in Curies) for the Paducah Site*

FRNP Total Radionuclide Emissions (Ci) - CY 2020								
	FRNP Emissions							
Group	**A**	**B**	**C**	**D**	**E**	**F**		
Nuclide	Northwest Plume Groundwater Treatment System C-612	Northeast Plume Containment System Treatment Unit C-765	Northeast Plume Containment System Treatment Unit C-765-A	C-709 & C-710	DUF_6 Conversion Facility	Seal Exhaust/Wet Air Group	Total Site Emissions	Nuclide
Tc-99	8.72E-05	1.10E-05	4.47E-06	0.00E+00	0.00E+00	9.04E-08	1.03E-04	Tc-99
U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E-07	5.43E-07	8.12E-07	U-234
U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.23E-08	2.93E-08	4.16E-08	U-235
U-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.61E-07	2.17E-07	8.78E-07	U-238
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E-10	2.07E-10	Np-237
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	Pu-239
Th-230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E-10	4.84E-10	Th-230
Th-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-07	0.00E+00	2.21E-07	Th-231
Th-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-05	0.00E+00	2.02E-05	Th-234
Pa-234m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-05	0.00E+00	2.02E-05	Pa-234m
Total	8.72E-05	1.10E-05	4.47E-06	0.00E+00	4.16E-05	8.80E-07	1.45E-04	

*Values are taken from *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2020* (FRNP 2021b).

Table 4.1 shows the estimates of radionuclide atmospheric releases in curies (i.e., units of radioactivity), Table 4.2 provides the effective dose to the MEI for each individual point source in mrem (i.e., dose of radiation) received in a CY. Due to location differences, emission rates, and multiple other factors, the MEI for each point source could differ from the plant.

Table 4.2. Dose Calculations for Airborne Releases for CY 2020

Emission Sources	EDE to the Maximum Exposed Individual for Each Source (mrem)	Dose to the Maximum Exposed Individual for the Plant (mrem)
Group D—C-709/710 Laboratory	0.00E+00	0.00E+00
Group F—SX/WA Group	3.20E-07	2.50E-07
Northwest Plume Treatment System	5.80E-05	5.80E-05
Northeast Plume Treatment Unit C-765	5.50E-06	2.10E-06
Northeast Plume Treatment Unit C-765-A	2.00E-06	7.90E-07
DUF_6 Conversion Facility	5.20E-07	3.30E-07
Total from All Sources		**6.15E-05**

The individual who would receive the maximum hypothetical cumulative dose from all pathways, also termed the MEI, was calculated potentially to receive an effective dose equivalent of 0.0000615 mrem/yr, which is below the NESHAP standard of 10 mrem/yr. Based upon 2010 population census data, the

collective effective dose to the entire population (534,000 persons) within 50 miles of the Paducah Site is shown in Table 4.3, as estimated by the CAP-88 PC program.

Table 4.3. Calculated Radiation Doses from Airborne Releases for the Paducah Site for CY 2020

Effective Dose to Maximally Exposed Individual (mrem)	Percent of Standard (%)	Collective Effective Dose (person-rem)
6.15E-05	0.00061	2.74E-04

A complete summary of this emissions data can be found in the *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2020* (FRNP 2021b).

4.2.6 Liquid Discharge Monitoring and Estimated Dose from Liquid Effluents

4.2.6.1 Surface water

In general, radioactive contaminants released to surface water may remain dissolved or suspended in surface water, deposited in sediment, deposited on ground or vegetation by irrigation, absorbed into plants and animals, or may infiltrate to the groundwater.

Surface water leaving the Paducah Site includes rainfall runoff from cylinder yards and landfills and effluent from site processes (e.g., the C-612 Northwest Plume Groundwater Treatment System and the C-613 Sedimentation Basin). The discharges from the Paducah Site flow into Bayou and Little Bayou Creeks, which then flow into the Ohio River.

DOE Order 458.1 requires the control and management of radionuclides from DOE activities in liquid discharges and sets guidelines for allowable concentrations of radionuclides in effluents to protect public health. This protection is achieved at the Paducah Site by meeting the limits set in DOE Order 458.1. Ingestion limits for all radionuclides are calculated using the composite DOE-STD-1196-2011, Derived Concentration Technical Standard (DCS) (DOE 2011a). The dose limits set by DOE Order 458.1 are the legal limits, but are not DOE's expectation for dose to the public and the environment. DOE Order 458.1 requires application of the ALARA process to all routine radiological activities to reduce radionuclide releases and resulting doses to the extent possible.

Derived concentration technical standard (DCS)—A DOE technical standard that documents a derived concentration value for a radionuclide in water that would result in a dose of 100 mrem in a year to a gender- and age-weighted reference person using DOE-approved dose coefficients and assuming continuous exposure. The standard is referenced in DOE Order 458.1, *Radiation Protection of the Public and the Environment*.

The ingested water DCS value for a radionuclide is the concentration of the radionuclide in drinking water that is calculated (derived) to result in an annual dose of 100 mrem to a person. That is, if the person's entire annual drinking water intake contained a radionuclide at the DCS level, that person would receive 100 mrem. In reality, people do not intentionally drink any water from surface streams in the area surrounding the Paducah Site. The DCS is different for each radionuclide because of the differences in radiation type, radioactive energy, and half-life.

The Environmental Radiation Protection Program (ERPP) monitors effluent and surface water runoff for radiological constituents to monitor potential contamination released to the receiving streams and tributaries from plant operations. Sampling locations were selected to support site-specific radiation exposure pathway

analysis. Locations were prioritized for areas of public access, introduction of plant effluents to the environment, and verification of the effectiveness of the Paducah Site effluent control and monitoring.

Radionuclide analysis was performed monthly at 14 surface water locations located downstream of KPDES-permitted outfalls as identified in the environmental monitoring plan (FRNP 2021a). These locations are K001ERPP, K002ERPP, K004ERPP, K008ERPP, K009ERPP, K010ERPP, K011ERPP, K012ERPP, K013ERPP, K015ERPP, K016ERPP, K017ERPP, K019ERPP, and K020ERPP. These locations are shown on Figure 4.4.

Radionuclide analysis was performed quarterly at three Little Bayou Creek surface water locations as identified in the environmental monitoring plan (FRNP 2021a). These locations are L10, L14DWN, and L241. These locations are shown on Figure 4.4.

L241 was not sampled during the first quarter of 2020 because the creek was flooded.

Radionuclide analysis was performed quarterly at one Bayou Creek surface water location as identified in the environmental monitoring plan (FRNP 2021a). This location was L5. This location is shown on Figure 4.4.

Radionuclide analysis was performed quarterly at one North-South Diversion Ditch surface water location as identified in the environmental monitoring plan (FRNP 2021a). This location was L11. This location is shown on Figure 4.4.

Radionuclide analysis was performed quarterly at one background location (L29A) and one location near the nearest public water withdrawal location, Cairo, Illinois (L306) as identified in the environmental monitoring plan (FRNP 2021a). These locations are shown on Figure 4.4.

L29A and L306 was not sampled during the first quarter of 2020 because the river was in flood stage and the samplers could not access the location.

Radionuclide analysis was performed annually at one background location (L1) and one background location for the public water source location in the Ohio River immediately downgradient of the plant (L30) as identified in the environmental monitoring plan (FRNP 2021a).

Background location L1 was chosen to support data comparisons of data generated as part of the environmental monitoring plan and the ERPP effluent and surface water runoff program.

The 2020 ERRP surface water sampling locations with the maximum detectable radionuclides used to support site-specific radiation exposure pathway analyses are K001ERPP for technetium-99, K008ERPP for uranium-234, K001ERPP for uranium-235, and K020ERPP for uranium-238.

Sampling for surface water runoff at the C-746-S&T and C-746-U Landfills (L135, L136, L150, L154, and L351) is permit-driven and analyzed for alpha activity and beta activity. These locations are shown on Figure 4.4

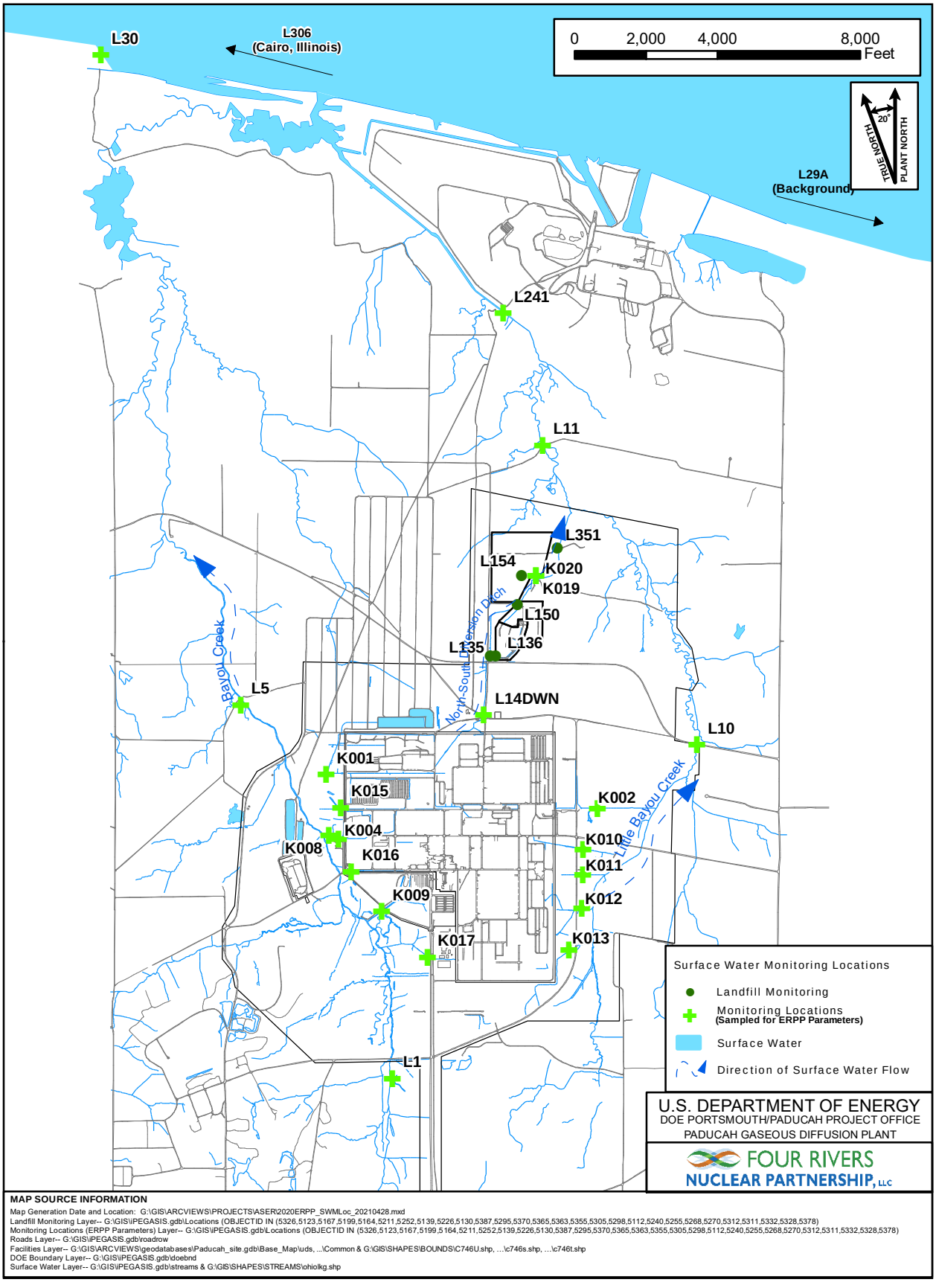


Figure 4.4. Surface Water Monitoring Locations

In addition to surface water monitoring conducted under DOE Orders, the KPDES permit, and the solid waste landfills permit, surface water monitoring was also conducted as a separate monitoring program under CERCLA for the Northeast Plume Containment System effluent via outfall C001. This outfall was monitored for technetium-99 according to the Remedial Action Work Plan for Optimization of the Northeast Plume Interim Remedial Action (DOE 2018). The 2020 highest surface water result for technetium-99 (60.5 pCi/L) was found at C001. C001 is not used for calculating dose because it is a project-specific effluent and is not indicative of a body of water that a person could enter. Relocation of the two Northeast Plume extraction wells upgradient, as part of the optimization of the interim remedial action (see Section 6), has placed the wells where slightly higher technetium-99 results have been observed in area monitoring wells when compared to technetium-99 results in area monitoring wells in proximity to the previously used extraction wells. As such, a slight increase in technetium-99 in the extracted groundwater is not unexpected. The presence of technetium-99 was evaluated and determined not to pose potential threat to human health or the environment upon surface discharge as documented in the Record of Decision for Interim Remedial Action at the Northeast Plume (DOE 1995b). Additional monitoring results are available through the PPPO Environmental Geographic Analytical Spatial Information System (PEGASIS) website at https://pegasis.pad.pppo.gov/.

4.2.6.2 Drinking water

Surface water from the Paducah Site was not consumed by people as a drinking water source; however, it eventually was discharged into the Ohio River, which was used as a public drinking water source. Cairo, Illinois, is the closest drinking water system (approximately 30 miles downstream) that uses water downstream of the Paducah Site effluents. Cairo, Illinois, is located at the confluence of the Ohio and Mississippi Rivers. No radionuclides were detected near the surface water collection inlet at Cairo (L306) during CY 2020. The maximum alpha activity detected was 3.57 pCi/L. There was no detectable beta activity.

The drinking water pathway dose was calculated where a MEI is assumed to consume water from the public drinking water supply at Cairo, Illinois (L306). For the dose estimate, because no radionuclides were detected, a value of 0.0 mrem/year was used in the dose calculation.

Most of the individuals within a 50-mile radius of the Paducah Site do not obtain their daily drinking water from sources downgradient of the Paducah Site (see Sections 4.1.4 and 6.2). For 2020, therefore, an estimated collective dose has been calculated by multiplying the dose to the MEI from annual ingestion of drinking water from the Cairo supply (prior to treatment) by the estimated number of residents of Cairo in 2010 (2,830 persons) (Moonshadow Mobile 2015), which resulted in a representative collective dose of 0.0 person-rem/yr.

4.2.6.3 Incidental ingestion of surface water

Dose is calculated for the bounding MEI based on incidental ingestion of surface water due to swimming in Bayou and Little Bayou Creeks and their tributaries (including outfall locations).[4] The assumptions based on *Methods for Conducting Risk Assessments and Risk Evaluations* are that a bounding recreator may swim

[4] The dose to the MEI is a bounding, yet realistic, estimate because the derivation of this dose is based on swimming, which is an unlikely activity for both Bayou and Little Bayou Creeks. For example, in an interview with the manager of the WKWMA, the manager noted that any water contact would be brief and be limited to wading across creeks. In a Health Assessment, the Agency for Toxic Substances and Disease Registry stated, "there is very little swimming, wading, or other human activity in Bayou and Little Bayou Creeks." Finally, the Kentucky Department of Fish and Wildlife Resources did not identify swimming (as compared to limited fishing and traversing incidental to hunting) as a recreational use of Little Bayou or Bayou Creeks in recreational usage information provided in 1995 or in the 2014 recreational usage update. The recreational usage information is documented in Appendix E of the Risk Methods Document located at https://pubdocs.pad.pppo.gov/Risk%20Methods%20Document/RMD%202020/RMD%202020%20D2R11V1%20Human%20Health%20Appendix%20E%20%28CD%29/Appendix%20E.pdf.

45 days a year, for 2.6 hours a day, with an incidental ingestion of 0.092 liters per hour and be in different locations throughout the wildlife management area (DOE 2020a). The highest monthly surface water results from the various sampling locations are utilized to calculate the bounding dose to the MEI. The annual dose to the MEI from incidental ingestion of surface water is 0.157 mrem/year.

Collective dose is not calculated for the incidental ingestion pathway because it is unlikely that a population of individuals would repeatedly swim in either Bayou or Little Bayou Creeks. This pathway is more likely to involve individuals; therefore, it is more suited for the MEI dose calculation.

Table 4.4 summarizes the maximum isotopic detections of radionuclides at the surface water sampling locations and KPDES-permitted outfalls previously described. These maximum results are used to calculate dose based on incidental ingestion of surface water.

Table 4.4. Maximum Detected Radionuclides in 2020 Surface Water Samples

Isotope	Maximum Detect
Technetium-99 (pCi/L)	3.65E+01*
Uranium-234 (pCi/L)	1.85E+01
Uranium-235 (pCi/L)	2.23E+00
Uranium-238 (pCi/L)	6.08E+01

*Technetium-99 maximum detects were found in two locations, C001 and K001ERPP. C001 data are not used for calculating dose of incidental ingestion of surface water because it is a direct discharge of a treatment system and not representative of waters that a person may swim in; therefore, the technetium-99 data was not used in the dose calculation. The technetium-99 data for K001ERPP was used for calculating dose of incidental ingestion of surface water.

4.2.6.4 Landfill leachate

Leachate collected from the C-746-U and C-746-S Landfills is sampled routinely and compared to DOE Order 458.1 limits. This data is used to determine programmatic management of landfill leachate. Leachate is treated and discharged through permitted outfalls at the site which are also monitored for compliance with permit limits. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

4.2.6.5 Groundwater

DOE has numerous groundwater monitoring wells, which are more fully described in Section 6. Groundwater wells that supplied drinking water to residents in the water policy area downgradient of the Paducah Site have been abandoned or taken out of service and the houses are provided with public drinking water; therefore, there is no groundwater drinking water source as an exposure route. Because groundwater is not used as a drinking water source, it is not considered in the calculation of dose to the MEI. Similarly, groundwater as a drinking water source is not considered in the calculation of cumulative dose to the surrounding population.

4.2.7 Sediment Monitoring and Estimated Dose

Sediment is an important constituent of the aquatic environment. Radionuclides transported by water can adsorb onto 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. Thus, sediments can play a significant role in aquatic ecological impacts by serving as a repository for radioactive substances that pass via bottom-feeding biota to the higher trophic levels.

A single sediment sample can represent information that would require a large number of water samples, spaced over a period of time, to reconstruct. Sediment acts to collect, concentrate, and store specific kinds of contaminants at specific locations. Concentrations of contaminants in sediments represent integrated measures of aqueous contaminant concentrations over some preceding period of time.

4.2.7.1 Sediment surveillance program

Sediment sampling at the Paducah Site in CY 2020 included radiological and non-radiological constituents (FRNP 2021a). Sediment sampling for non-radiological constituents are discussed in Section 5.3. Sampling locations were selected to facilitate the site-specific radiation exposure pathway analysis and to provide an indication of the accumulation of undissolved radionuclides in the aquatic environment (Figure 4.5).

Locations were prioritized for areas of public access, introduction of plant effluents to the environment, any unplanned release, and verification of the effectiveness of the Paducah Site effluent monitoring. Areas removed/remediated as part of a 2010 removal action for contaminated sediment associated with the Surface Water Operable Unit are denoted on the figure (DOE 2011b).

Sediment radiological analytical results are shown in Table 4.5 and also may be found on the PEGASIS website at https://pegasis.pad.pppo.gov/. The radiological results for CY 2020 are similar in magnitude to those measured during previous years. Figure 4.5 shows the sampling locations and five year trending for the radionuclide that has historically been the highest at sediment monitoring locations sampled for radionuclides. Location S20 provides background concentrations for radiological sediment sampling. Location S1 is located on Bayou Creek within the DOE boundary surrounding the Paducah Site. Location S2 is located downstream at Little Bayou Creek near the DOE boundary. Locations S27 and S34 are located within Little Bayou Creek just north of the DOE Paducah Site boundary. Location S33 is located within Bayou Creek north of the DOE boundary. Overall, uranium activity is above background in Little Bayou Creek and Bayou Creek near and downstream of the plant site.

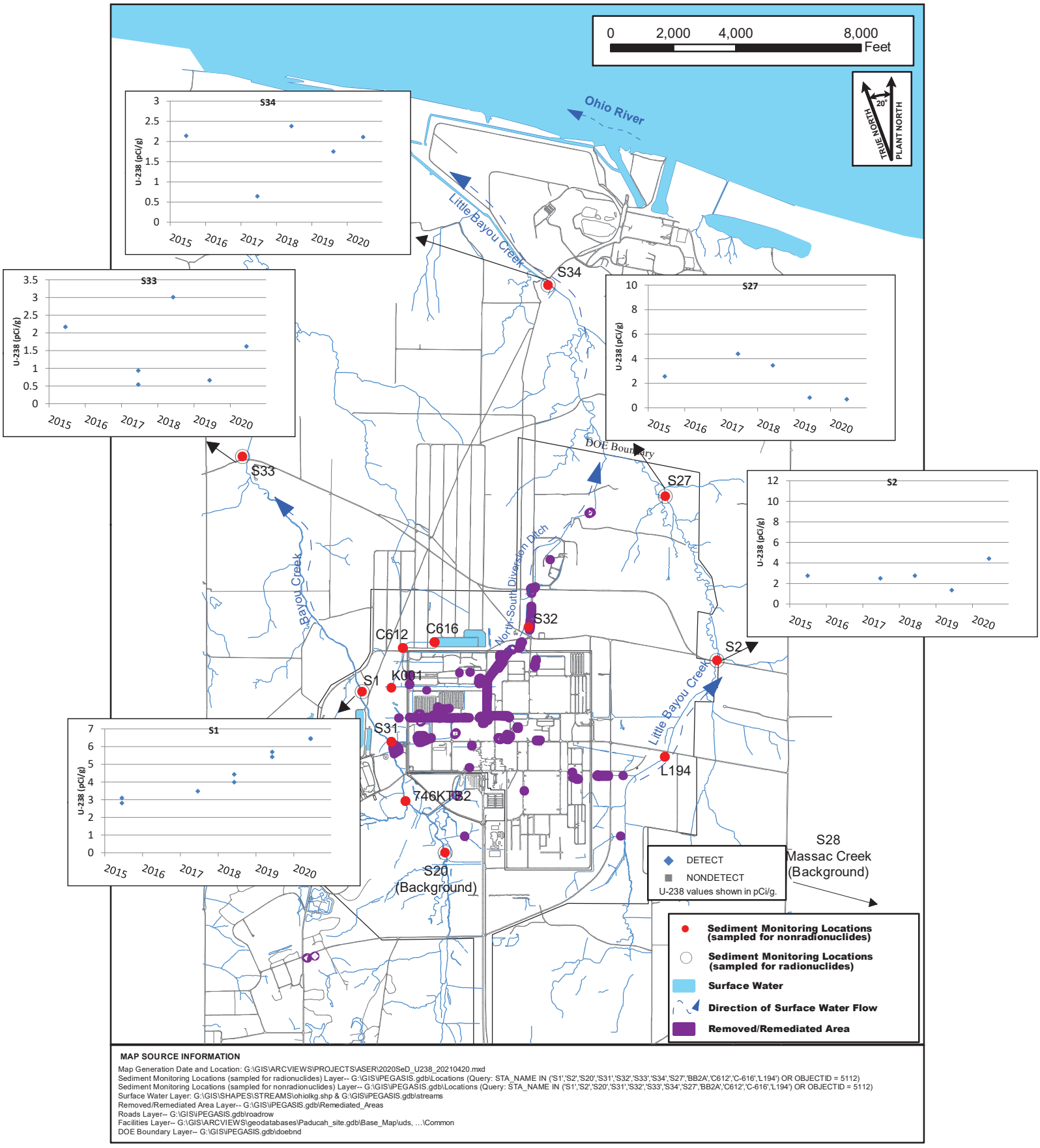


Figure 4.5 Sediment Monitoring Locations with Uranium-238 Trends

Table 4.5. Radiological Activities for Sediment Sampling (pCi/g)[a,b]

Parameter	S1[c]	S1 (duplicate)	S1 (avg)	S2[d]	S20[e] (background)	S27[f]	S33[g]	S34[h]
Alpha activity	2.01E+01	1.69E+01	1.85E+01	5.76E+00	7.08E+00	1.27E+01	9.71E+00	1.46E+01
Beta activity	3.20E+01	3.42E+01	3.31E+01	7.01E+00	7.42E+00	1.44E+01	1.28E+01	2.23E+01
Americium-241	1.22E-01	4.06E-01	2.64E-01	2.96E-01	2.35E-01	9.46E-02	4.47E-02	4.03E-02
Cesium-137	1.81E-02	3.32E-02	2.57E-02	3.70E-03	3.74E-02	-2.14E-02	0.00E+00	-1.57E-03
Neptunium-237	-8.75E-02	1.77E-02	-3.49E-02	-1.75E-02	6.42E-02	-1.24E-01	-1.11E-01	0.00E+00
Plutonium-238	5.85E-02	1.59E-01	1.09E-01	0.00E+00	3.55E-02	5.73E-02	2.37E-01	-2.31E-02
Plutonium-239/240	5.84E-02	5.74E-02	5.79E-02	7.05E-02	-2.79E-02	8.73E-02	-8.66E-02	1.18E-01
Technetium-99	1.47E+01	1.24E+01	1.36E+01	1.60E+00	8.48E-01	5.73E-01	2.56E-01	3.21E+00
Thorium-230	8.75E-01	6.73E-01	7.74E-01	7.29E-01	9.34E-01	1.41E+00	6.75E-01	1.73E+00
Total Uranium	1.06E+01	9.76E+00	1.02E+01	5.53E+00	1.70E+00	1.31E+00	2.33E+00	3.47E+00
Uranium-234	3.99E+00	3.15E+00	3.57E+00	1.03E+00	9.38E-01	6.16E-01	6.71E-01	1.33E+00
Uranium-235	1.68E-01	1.64E-01	1.66E-01	7.38E-02	1.32E-01	0.00E+00	3.82E-02	2.61E-02
Uranium-238	6.46E+00	6.44E+00	6.45E+00	4.42E+00	6.26E-01	6.92E-01	1.62E+00	2.11E+00

[a] Negative values are possible and observed regularly with radiological data.
[b] Negative results may be reported due to a statistical determination of the counts seen by a detector, minus a background count (DOE 2020a).
[c] Results for Americium-241, Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240 and Uranium-235 are less than the laboratory reporting limit.
[d] Results for Americium-241, Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240, Technetium-99, and Uranium-235 are less than the laboratory reporting limit.
[e] Results for Americium-241, Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240, Technetium-99, and Uranium-235 are less than the laboratory reporting limit.
[f] Results for Americium-241, Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240, Technetium-99, Uranium-234, and Uranium-235 are less than the laboratory reporting limit.
[g] Results for Americium-241, Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240, Technetium-99, and Uranium-235 are less than the laboratory reporting limit.
[h] Results for Americium-241, Cesium-137, Neptunium-237, Plutonium-238, Plutonium-239/240, Technetium-99, and Uranium-235 are less than the laboratory reporting limit.

4.2.7.2 Sediment Estimated Dose

For the purpose of calculating dose to the bounding MEI, it was assumed that exposure to contaminated sediment in Bayou Creek and Little Bayou Creek could occur during hunting or other recreational activities. Exposure was possible through incidental ingestion of contaminated sediment. The ingestion assumption consists of an adult individual (i.e., an Adult Recreational User) who would wade around at one creek location every other day during the hunting season (104 days/year) and ingest a small amount of sediment during each visit (100 mg/day). A dose then was calculated based on the radionuclide activity and the amount of exposure via ingestion. Exposure was calculated using the methods presented in the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2020a), which includes the ingestion, inhalation, and external gamma pathways. Table A.8 of that document provides site-specific soil screening levels for receptors due to site-related radionuclides. Background location is S20. Results from background location S20 are subtracted from other sample results to arrive at a dose associated with site releases. When background dose results are less than zero or a radionuclide-specific dose is less than the background dose, a dose of 0.00E+00 mrem was used. Location S1 dose is calculated from an average of the dose from the S1 results and the S1 duplicate results. The sample location with the highest total mrem was assumed to represent the dose received from this pathway by

the MEI from the exposure scenario. Table 4.6 represents the estimated average annual dose estimate for the incidental ingestion of sediment for CY 2020 for each location sampled.

Table 4.6. Average Annual Dose Estimates for CY 2020 Incidental Ingestion of Sediment

Sample Location	Am-241	Cs-137	Np-237	Pu-238	Pu-239/240	Tc-99	Th-230	U-234	U-235	U-238	Total (mrem)
S20 (Background)	2.45E-03	7.53E-03	4.14E-03	3.35E-04	0.00E+00	2.64E-05	8.12E-03	1.83E-03	5.67E-03	5.64E-03	3.57E-02
S1(avg)	3.02E-04	0.00E+00	0.00E+00	6.91E-04	5.94E-04	3.96E-04	0.00E+00	5.14E-03	1.46E-03	5.25E-02	**6.11E-02**
S2	6.35E-04	0.00E+00	0.00E+00	0.00E+00	7.23E-04	2.34E-05	0.00E+00	1.80E-04	0.00E+00	3.42E-02	3.57E-02
S27	0.00E+00	0.00E+00	0.00E+00	2.06E-04	8.95E-04	0.00E+00	4.14E-03	0.00E+00	0.00E+00	5.95E-04	5.83E-03
S33	0.00E+00	0.00E+00	0.00E+00	1.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.95E-03	1.09E-02
S34	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.21E-03	7.36E-05	6.92E-03	7.66E-04	0.00E+00	1.34E-02	2.23E-02

Based on the dose estimates provided in Table 4.6, the highest estimated dose was calculated at location S1, downstream at Bayou Creek at the Bayou Creek/Outfall K001 confluence, within the DOE boundary surrounding the Paducah Site. This dose calculation was based on the assumption that a person continually returns to the same location, which for CY 2020 was S1. The estimated dose to the MEI was 0.061 mrem/year. This estimated dose is consistent with previous years and is a very small fraction of the 100 mrem/year DOE dose limit from all contributing pathways.

Prior to the CY 2018 annual site environmental report, collective dose for annual incidental ingestion of sediment was not estimated because it was not a plausible exposure for residents who reside within 50 miles of the Paducah Site. The pathway was more likely to involve individuals; therefore, it was more suited for the MEI dose calculation.

In order to be consistent with the estimated collective dose for direct radiation, an estimated collective dose has been calculated by multiplying the dose to the MEI from incidental ingestion of sediment by a total estimated number of visitors hiking within the WKWMA annually (150 persons), which resulted in a representative estimated collective dose of 0.0092 person-rem/year (DOE 2020a).

4.2.8 Terrestrial Environment Monitoring

Wildlife and farm-raised animal products, including meat, eggs, and milk, may become contaminated through animal ingestion of contaminated water, sediment, other animals, or through direct contact with contaminated areas. The subsequent ingestion of these products can lead to public dose. As discussed earlier, a portion of the airborne radionuclides is estimated to be deposited in soil, ingested by animals, taken up by food crops, and ground surface pathways including consumption of vegetables, milk, and meat. Irrigation and deposition through waterborne radionuclides is an incomplete pathway because municipal water is used at nearby residences for household purposes (including activities such as irrigation of crops and lawns).

4.2.9 Wildlife

Wildlife from the DOE property have been sampled in past years for non-radiological and radiological constituents. Deer monitoring was performed annually for many past years and data was utilized for site dose assessment. During FY 2011, DOE performed an extensive review of data sets from 20 years of deer harvesting events. As a result of the 2011 review, DOE eliminated the deer harvesting in 2012 because of a downward trend and a continued lack of detection in the results, as well as an overall downward trend in the concentration

of contaminants found at the Paducah Site due to remediation efforts. This exposure route and associated dose has been captured in the food chain models associated with the CAP-88 PC air program.

4.2.10 Direct Radiation Monitoring and Estimated Dose

4.2.10.1 Direct radiation surveillance

External radiation exposure from DOE's operations at the Paducah Site potentially contributes to the overall dose to the public. 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 items such as instrument calibration sources. Cylinder storage yards have the largest potential for a dose to the public because of their proximity to publicly accessible areas.

The external gamma and neutron radiation monitoring program is designed to provide data on external radiation exposure from DOE operations to members of the public. The primary factor in selecting the monitoring locations was the potential for a member of the public to be exposed to external radiation.

Secondary factors in selecting monitoring locations were accessibility and representative exposure potentially received by members of the public and area monitoring for individuals passing through the DOE site.

A surveillance network of thermoluminescent dosimeters (TLD) and optically stimulated luminescence (OSL) dosimeters monitored areas that included locations inside the Paducah Site security fence, Paducah Site perimeter, outfalls, ditches, and background locations. Dosimeters were also placed in areas that historically received the highest radiation exposure.

In 2020, the network used a total of 65 TLD locations to measure external gamma radiation and 7 OSL locations to measure external neutron radiation. The network of TLD and OSL locations, along with analysis of their data, served to monitor changes in external radiation measures over time and any accidental releases of radioactive material related to operational activities conducted for DOE.

These monitoring locations are shown in Figure 4.6.

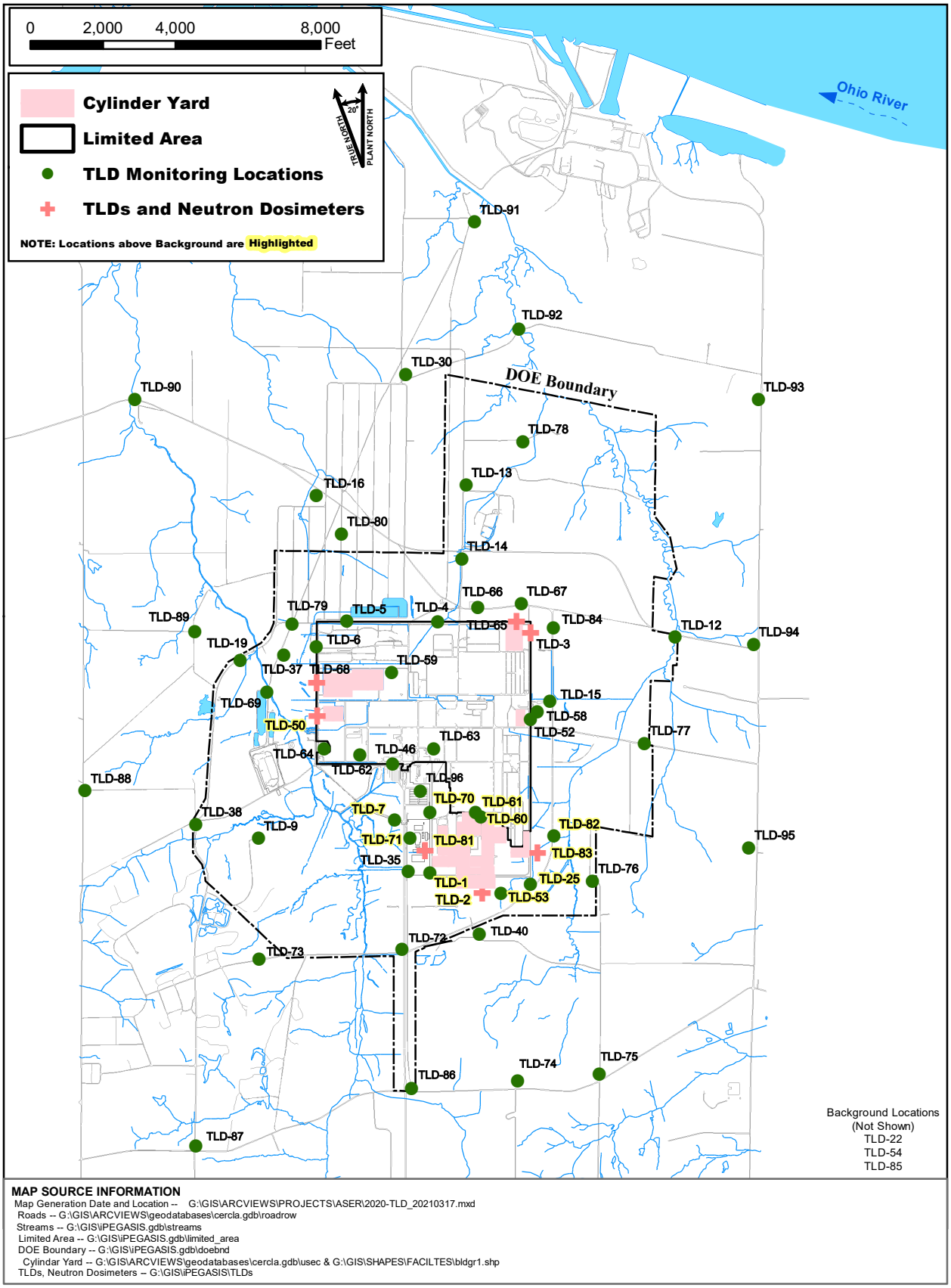
4.2.10.2 Direct radiation dose

A complete summary of the direct radiation dose can be found in the *Annual Report on External Radiation Monitoring for Calendar Year 2020 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FRNP 2021c).

In CY 2020, 13 locations out of 52 showed results statistically above background with 99.7% confidence. These 13 locations were consistently the areas with the highest measured results throughout the monitoring period. All of these locations were adjacent to or in close proximity to cylinder storage yards which are not regularly accessible to the public. This means the potential external radiation dose calculated from these locations is not representative of the actual public external radiation dose.

The MEI member of the public is considered to be a member of the public at the nearest local residence. Results for the MEI were found to be equivalent to naturally occurring background. The potential effective dose to the MEI was 0 mrem for CY 2020.

The Paducah Site licensed a portion of the DOE Reservation to the Kentucky Department of Fish and Wildlife Resources for recreational uses. These areas were open to the public for use, but do not have any residences



MAP SOURCE INFORMATION

Map Generation Date and Location -- G:\GIS\ARCVIEWS\PROJECTS\ASER\2020-TLD_20210317.mxd
Roads -- G:\GIS\ARCVIEWS\geodatabases\cercla.gdb\roadrow
Streams -- G:\GIS\iPEGASIS.gdb\streams
Limited Area -- G:\GIS\iPEGASIS.gdb\limited_area
DOE Boundary -- G:\GIS\iPEGASIS.gdb\doebnd
Cylindar Yard -- G:\GIS\ARCVIEWS\geodatabases\cercla.gdb\usec & G:\GIS\SHAPES\FACILTES\bldgr1.shp
TLDs, Neutron Dosimeters -- G:\GIS\iPEGASIS\TLDs

Figure 4.6. Dosimeter Locations in the Vicinity of the Paducah Site

within the Paducah Site boundary. Public traffic was allowed on the main reservation roads outside of the active plant area as a courtesy to the public, and some members of the public visited the DOE Reservation for recreational purposes. Recreational purposes and durations of time spent in the area by the public were less than full-time.

In CY 2020, there were two TLD locations that were accessible to members of the public. These locations were TLD-14 and TLD-96.

- TLD-14 is near Harmony Cemetery and is located north of the security fence and south of Ogden Landing Road. In CY 2009, security restrictions were eased to allow regular public access to Harmony Cemetery. In 2020, the monitoring results for TLD-14 were statistically equivalent to the average mean background for CY 2020. The estimated external radiation dose to a member of the public at this location was 0 mrem.

- In CY 2020, a food vendor TLD location was established in the C-810 parking lot. The monitoring results for TLD-96 were statistically equivalent to the average mean background for CY 2020. The estimated external radiation dose to the food vendor at this location was 0.54 mrem.

Although there were no results for TLD locations accessible to the public that were statistically above background with 99.7% confidence, the TLD location along the DOE boundary with the highest net annualized dose rate was TLD-40.

- TLD-40 is located outside the DOE boundary and within the WKWMA off of Dyke Road. A member of the public would receive an external radiation effective dose of 1.89 mrem/year at this location at the Paducah Site boundary.

Based on the results of measurements in areas accessible to the public or near the closest local residence, external radiation levels were found to be equivalent to background levels; therefore, the effective dose received by a member of the public is considered to be negligible.

For 2020, the scenario used for a potential external radiation effective dose was a member of the public passing through accessible portions of the DOE Reservation where areas of highest exposure were visited 80 hours per year. This scenario showed a member of the public would potentially receive 4.1 mrem/year. This result is consistent with previous results cited in annual site environmental reports. See Table 4.7.

For 2020, an estimated external radiation effective collective dose was calculated by multiplying the scenario dose in the preceding paragraph by a total number of estimated visitors hiking within the WKWMA annually, (i.e., 150 persons), which resulted in an estimated external radiation effective collective dose of 0.61 person-rem/year. This result is consistent with previous results cited in annual site environmental reports. See Table 4.7.

Table 4.7. Comparison of Potential Radiological Dose to the MEI for the Direct Radiation Pathway

Direct Radiation Pathway	2015	2016	2017	2018	2019	2020
Dose to MEI (mrem/year)	5.1E+00	4.2E+00	3.8E+00	5.0E+00	3.0E+00	4.1E+00
Percent of DOE 100 mrem/year Limit	5.1%	4.2%	3.8%	5.0%	3.0%	4.1%
Estimated Collective (Population Dose) (person-rem/year)	7.7E-01	6.4E-01	5.6E-01	7.5E-01	4.5E-01	6.1E-01
Population within 50 miles*	150	150	150	150	150	150

*Population dose for direct radiation is based on a representative assumption using the estimated visitors hiking in the WKWMA only (DOE 2020a).

4.2.11 Estimated Dose from All Pathways

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. Estimates of radiation doses presented in this report were calculated using the dose factors provided by DOE and EPA guidance documents and dose-based screening levels found within the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2020a).

Section 4.2.11.7 provides a summary of the radiological dose for 2020 from the Paducah Site that could be received by a member of the public (i.e., the MEI) assuming exposure from all relevant pathways. The largest contributor to the calculated dose is from direct radiation. Also contributing to the dose that could be received by the MEI are atmospheric releases, including ingestion pathways considered in the CAP-88PC food chain modeling routines, incidental ingestion of surface water, ingestion of drinking water (in Cairo, Illinois), and incidental ingestion of sediment. The groundwater pathway from DOE sources is assumed to contribute no dose to the population, because DOE has supplied all potentially impacted residents with access to public water.

As in previous years, the estimated potential dose from the Paducah Site to the MEI was well below applicable EPA standards and DOE public dose limits, and a very small fraction of the 620 mrem that the public receives annually from natural and man-made sources. There has been negligible change in the estimated annual dose from the Paducah Site in recent years.

4.2.11.1 Total Estimated Dose from All Pathways

The dose of radiation (based on calculations) that could be received by a member of the public from all pathways of exposure was calculated at 4.3 mrem/year, which is approximately 4.3% of the DOE annual dose limit of 100 mrem/year. This result is consistent with previous results cited in annual site environmental reports. See Table 4.8. The estimated collective dose to members of the public residing within 50 miles of the Paducah Site has also been determined. Population dose was calculated for each exposure pathway and is summed to determine the estimated collective population dose from all relevant pathways. The annual collective population dose, based on representative assumptions is 6.2E-01 person-rem/year (6.2E-03 person-Sv/year). This result is consistent with previous results cited in annual site environmental reports. See Table 4.8

Table 4.8. Comparison of Potential Radiological Dose to the MEI and Collective Population from All Relevant Pathways

All Relevant Pathways[a,b]	2015	2016	2017	2018	2019	2020
Dose to MEI mrem/year[b] (mrem * .01 = mSv)	5.4E+00	4.5E+00	4.1E+00	5.1E+00	3.1E+00	4.3E+00
Percent of DOE 100 mrem/year Limit	5.4%	4.5%	4.1%	5.1%	3.1%	4.3%
Estimated Collective Population Dose person-rem/year (person-rem * .01 = person-Sv)	1.0E+00	8.9E-01	8.1E-01	7.6E-01	4.6E-01	6.2E-01

[a] Pathways defined in previous sections.
[b] Maximum allowable exposure from all sources is 100 mrem/year (DOE Order 458.1), which is consistent with 902 *KAR* 100:019, Section 10 (1)(a).

4.2.11.2 Estimated Dose from the Groundwater Pathway

Groundwater is not considered an exposure pathway because DOE provides public water to downgradient residents. See Section 4.1.6.5 for additional information.

4.2.11.3 Estimated Dose from the Ingestion of Drinking Water Pathway

The drinking water pathway dose was calculated where a MEI is assumed to consume water from the public drinking water supply at Cairo, Illinois (L306). For the dose estimate, because no radionuclides were detected, a value of 0.0 mrem/year was used in the dose calculation. See Section 4.1.6.2 for additional information. This result is consistent with previous results cited in annual site environmental reports. See Table 4.9.

Table 4.9. Comparison of Potential Radiological Dose to the MEI for Ingestion of Drinking Water Pathway

Ingestion of Drinking Water[a]	2015	2016	2017	2018	2019	2020
Dose to MEI mrem/year[b] (mrem * .01 = mSv)	9.0E-02	9.0E-02	9.0E-02	0.0E+00	0.0E+00	0.0E+00
Percent of DOE 100 mrem/year Limit	0.09%	0.09%	0.09%	0.00%	0.00%	0.00%
Estimated Collective Population Dose person-rem/year[b] (person-rem * .01 = person-Sv)	2.5E-01	2.5E-01	2.5E-01	0.0	0.0	0.0
Population within 50 miles	2,830	2,830	2,830	2,830	2,830	2,830

[a] Ingestion of drinking water is assessed from the nearest surface water intake, Cairo, Illinois.
[b] Population dose for ingestion of drinking water from Cairo, Illinois, is based on a representative assumption using the estimated population of Cairo, Illinois, only.

4.2.11.4 Estimated Dose from the Incidental Ingestion of Surface Water Pathway

Dose from the surface water pathway is evaluated by its contribution to the DOE total all pathways dose limit of 100 mrem per year. The estimated dose from ingestion of surface water releases from the Paducah Site was 1.6E-01 mrem/year (1.6E-03 mSv/year). This level is 0.16% of the DOE annual dose limit of 100 mrem/year

from all pathways to members of the public. See Section 4.1.6.3 for addition information. This result is consistent with previous results cited in annual site environmental reports. See Table 4.10.

Table 4.10. Comparison of Potential Radiological Dose to the MEI for Incidental Ingestion of Surface Water Pathway

Incidental Ingestion of Surface Water	2015	2016	2017	2018	2019	2020
Dose to MEI mrem/year (mrem * .01 = mSv)	1.7E-01	1.9E-01	1.1E-01	6.7E-02	5.2E-02	1.6E-01
Percent of DOE 100 mrem/year Limit	0.17%	0.19%	0.11%	0.067%	0.052%	0.16%
Estimated Collective Population Dose person-rem/year[a] (person-rem * .01 = person-Sv)	a	a	a	a	a	a
Population within 50 miles	a	a	a	a	a	a

[a] Incidental ingestion of surface water within plant creeks and ditches is not applicable for calculation of collective dose to residents who reside within 50 miles of the Paducah Site. Collective dose is not calculated for the incidental ingestion pathway due to the lack of a plausible exposure scenario. This pathway is more likely to involve individuals; therefore, it is more suited for the MEI dose calculation.

4.2.11.5 Estimated Dose from the Incidental Ingestion of Sediment Pathway

The estimated dose to the MEI from incidental ingestion of sediment was 0.061 mrem/year (6.1E-04 mSv/year). This level is 0.061% of the DOE annual dose limit of 100 mrem/year from all pathways to members of the public. See Section 4.1.7.2 for addition information. This result is consistent with previous results cited in annual site environmental reports. See Table 4.11.

Table 4.11. Comparison of Potential Radiological Dose to the MEI for Incidental Ingestion of Sediment Pathway

Incidental Ingestion of Sediment	2015	2016	2017	2018	2019	2020
Dose to MEI mrem/year (mrem * .01 = mSv)	4.3E-02	6.2E-02	5.0E-02	5.4E-02	6.3E-02	6.11E-02
Percent of DOE 100 mrem/year Limit	0.043%	0.062%	0.050%	0.054%	0.063%	0.061%
Estimated Collective Population Dose person-rem/year[a,b] (person-rem * .01 = person-Sv)	a	a	a	8.1E-03	9.4E-03	9.2E-03
Population within 50 miles[b]	a	a	a	150	150	150

[a] Prior to the CY 2018 annual site environmental report, collective dose for annual incidental ingestion of sediment was not estimated because it was not a plausible exposure for residents who reside within 50 miles of the Paducah Site. The pathway was more likely to involve individuals; therefore, it was more suited for the MEI dose calculation.
[b] Population dose for incidental ingestion of sediment is based on a representative assumption using the estimated visitors hiking in WKWMA only (DOE 2020a).

4.2.11.6 Estimated Dose from the Direct Radiation Pathway

The estimated dose to the MEI was 4.1 mrem/year (4.1E-02 mSv/year). This estimated dose is 4.1% of the DOE annual dose limit of 100 mrem/year from all pathways to members of the public. See Section 4.1.10.2 and Table 4.7 for addition information.

4.2.11.7 Summary of Potential Radiological Dose to the Maximally Exposed Individual from the Paducah Site for CY 2020

Table 4.12 summarizes the potential dose to the MEI and the estimated collective population dose for CY 2020. The monitoring results in this table demonstrate the continued effectiveness of radiological control measures practiced at the Paducah Site.

Table 4.12. Summary of Potential Radiological Dose to the Maximally Exposed Individual[i] from the Paducah Site for CY 2020

Pathway[a]	Dose to Maximally Exposed Individual mrem/year[b] (mrem * .01 = mSv)	Percent of DOE 100 mrem/year Limit	Estimated Collective Population Dose person-rem/year (person-rem * 0.01 = person-Sv)	Population within 50 miles
Atmospheric releases[c]	6.15E-05	0.000062%	2.74E-04	~534,116
Ingestion of groundwater[d]	d	d	d	d
Ingestion of drinking water[e]	0.0E+00	0.00%	0.0[f]	2,830
Incidental ingestion of surface water	1.57E-01	0.157%	g	g
Incidental ingestion of sediment	6.11E-02	0.061%	9.2E-03[h]	150
Direct Radiation	4.1E+00	4.1%	6.1E-01[h]	150
All Relevant Pathways[a,b]	4.3E+00	4.3%	6.2E-01	

[a] Pathways defined in previous sections.
[b] Maximum allowable exposure from all sources is 100 mrem/year (DOE Order 458.1), which is consistent with 902 *KAR* 100:019, Section 10 (1)(a).
[c] Doses associated with atmospheric releases also include ingestion pathways considered in the CAP-88PC food chain modeling routines. DOE source emissions were from Northwest Plume groundwater treatment system, Northeast Plume treatment units, DUF_6 Conversion Facility, building exhaust vents, and laboratory hoods.
[d] Groundwater is not a viable pathway for the MEI due to DOE's providing public water to downgradient residents.
[e] Ingestion of drinking water is assessed from the nearest surface water intake, Cairo, Illinois.
[f] Population dose for ingestion of drinking water from Cairo, Illinois, is based on a representative assumption using the estimated population of Cairo, Illinois, only.
[g] Incidental ingestion of surface water within plant creeks and ditches is not applicable for calculation of collective dose to residents who reside within 50 miles of the Paducah Site. Collective dose is not calculated for the incidental ingestion pathway due to the lack of a plausible exposure scenario. This pathway is more likely to involve individuals; therefore, it is more suited for the MEI dose calculation.
[h] Population dose for direct radiation and incidental ingestion of sediment is based on a representative assumption using the estimated visitors hiking in WKWMA only.
[i] MEI is a combination of the MEI for each pathway; actual combined MEI does not exist due to different locations and identities of MEIs.

4.2.12 Biota Monitoring and Estimated Dose

4.2.12.1 Biota surveillance

Radionuclides from both natural and man-made sources may be found in environmental media such as water, sediments, and soils. Contaminants may bioaccumulate in animals from eating contaminated feed, drinking contaminated water, and breathing contaminated air. Contaminants may bioaccumulate in fish when they eat contaminated foods and equilibrate with surrounding contaminated waters. Because plant and animal populations residing in or near these media or taking food or water from these media may be exposed to a greater extent than humans, DOE prepared a technical standard, DOE-STD-1153-2019, that provides methods and guidance to be used to evaluate doses from ionizing radiation to populations of aquatic animals, riparian animals (i.e., those that live along banks of streams or rivers), terrestrial plants, and terrestrial animals.

Because both measured concentrations and bioconcentration factors associated with radionuclides of concern at the Paducah Site in animals and fish are low, routine site-specific pathway assessments, to include biota sampling, are not performed. Biota in the watersheds has been sampled extensively in the past, to the point that further collection of aquatic organisms could result in a deleterious effect on the aquatic community.

Sediment samples, as discussed in Section 4.1.7, are sampled annually for radionuclides. Surface water surveillance locations, as discussed in Section 4.1.6, are monitored quarterly.

4.2.12.2 Biota dose

Methods in the DOE Technical Standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2019), were used to evaluate radiation doses to aquatic and terrestrial biota from CY 2020 operations. Doses were assessed for compliance with the limit in DOE Order 458.1 for native aquatic animal organisms (1 rad/day) and for compliance with the thresholds for terrestrial plants (1 rad/day), and for compliance with the thresholds for terrestrial animals (0.1 rad/day), as discussed in DOE-STD-1153-2019. The RESRAD-BIOTA computer model (version 1.8) is a calculation tool provided by DOE for implementing the technical standard and compares existing radionuclide concentration data from environmental sampling with biota concentration guide (BCG) screening values and to estimate upper bounding doses to biota.

Dose to biota was evaluated for Bayou and Little Bayou Creeks. Sample locations are shown in Figures 4.4 and 4.5. Locations L5 and S1 were used to represent water and sediment, respectively, in Bayou Creek. Data obtained from water sample location L11 and collocated sediment sample location S27 were used to represent water and sediment, respectively, in Little Bayou Creek. Outfalls 019 and 020, which flow into Little Bayou Creek, were not considered due to their intermittent flow. Also, L11 and S27 represent a location on Little Bayou Creek that is downstream of the confluence with the North-South Diversion Ditch. The creek at this point is more substantial and more likely to support aquatic life than those areas upstream. Data from water and sediment sampling locations on Bayou and Little Bayou Creeks were entered into the RESRAD-BIOTA model to calculate dose to biota from Paducah Site operations. The value for each radionuclide was divided by its corresponding BCG to calculate a partial fraction for each nuclide in each medium. Partial fractions for each medium were added to produce a sum of fractions. Exposures from the aquatic pathway may be assumed to be less than the aquatic dose limit from DOE Order 458.1 if the sum of fractions for the water plus that for the sediment is less than 1.0.

In accordance with the graded approach described in DOE-STD-1153-2019, a screening was conducted using the maximum radionuclide concentrations from surface waters and sediments. Table 4.13 summarizes the radiological dose to aquatic and terrestrial biota for Bayou Creek. Table 4.14 summarizes the radiological dose to aquatic and terrestrial biota for Little Bayou Creek. For each assessment, the limiting organism (i.e., the organism that is most sensitive to the potential radiological dose) is identified. The sum of fractions (or ratios) for each assessment and for the limiting organism was less than 1.0, indicating that the applicable BCGs were met for both the aquatic and terrestrial evaluations. These summed values are presented in the footnotes of each table. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

Table 4.13. Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a]

Aquatic Animal									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	4.38E+02	N/A	Yes	4.06E-01	6.80E+05	5.97E-07	No	5.97E-07
Cs-137	7.97E-01	1.05E+03	7.61E-04	No	3.32E-02	4.93E+04	6.73E-07	No	7.61E-04
K-40	6.65E+01	2.90E+03	2.30E-02	No	N/A	5.79E+04	N/A	No	2.30E-02
Np-237	6.07E-01	6.85E+01	8.86E-03	Yes	1.77E-02	7.86E+04	2.25E-07	No	8.86E-03
Pu-238	1.86E-01	1.76E+02	1.06E-03	Yes	1.59E-01	3.95E+06	4.03E-08	No	1.06E-03
Pu-239[e]	-1.14E-01	1.87E+02	-6.10E-04	Yes	5.84E-02	7.05E+06	8.29E-09	No	-6.10E-04
Tc-99	5.54E+00	2.47E+06	2.24E-06	No	1.47E+01	4.59E+05	3.20E-05	No	3.43E-05
Th-230	N/A	2.57E+03	N/A	Yes	8.75E-01	2.74E+06	3.19E-07	No	3.19E-07
Th-234	6.71E+01	2.66E+05	2.52E-04	Yes	N/A	4.32E+04	N/A	No	2.52E-04
U-234	1.05E+00	2.02E+02	5.20E-03	Yes	3.99E+00	3.03E+06	1.32E-06	No	5.20E-03
U-235	3.37E-01	2.18E+02	1.55E-03	Yes	1.68E-01	1.10E+05	1.53E-06	No	1.55E-03
U-238	6.02E-01	2.24E+02	2.69E-03	Yes	6.46E+00	4.29E+04	1.51E-04	No	2.84E-03
Summed			**4.27E-02**				**1.87E-04**		**4.29E-02**

Table 4.13. Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

Riparian Animal									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	1.46E+03	N/A	No	4.06E-01	5.15E+03	7.89E-05	Yes	7.89E-05
Cs-137	7.97E-01	4.27E+01	1.87E-02	Yes	3.32E-02	3.13E+03	1.06E-05	Yes	1.87E-02
K-40	6.65E+01	2.49E+02	2.67E-01	Yes	N/A	4.42E+03	N/A	Yes	2.67E-01
Np-237	6.07E-01	1.16E+04	5.24E-05	No	1.77E-02	7.63E+03	2.32E-06	Yes	5.47E-05
Pu-238	1.86E-01	5.51E+02	3.38E-04	No	1.59E-01	5.73E+03	2.78E-05	Yes	3.66E-04
Pu-239[e]	-1.14E-01	6.22E+02	-1.83E-04	No	5.84E-02	5.87E+03	9.95E-06	Yes	-1.73E-04
Tc-99	5.54E+00	6.67E+05	8.30E-06	Yes	1.47E+01	4.14E+04	3.55E-04	Yes	3.63E-04
Th-230	N/A	1.39E+04	N/A	No	8.75E-01	1.04E+04	8.39E-05	Yes	8.39E-05
Th-234	6.71E+01	3.80E+06	1.77E-05	No	N/A	4.32E+03	N/A	Yes	1.77E-05
U-234	1.05E+00	6.84E+02	1.54E-03	No	3.99E+00	5.27E+03	7.57E-04	Yes	2.29E-03
U-235	3.37E-01	7.37E+02	4.57E-04	No	1.68E-01	3.79E+03	4.44E-05	Yes	5.02E-04
U-238	6.02E-01	7.57E+02	7.96E-04	No	6.46E+00	2.49E+03	2.59E-03	Yes	3.39E-03
Summed			**2.88E-01**				**3.96E-03**		**2.92E-01**

Table 4.13. Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

Terrestrial Animal									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	2.02E+05	N/A	No	4.06E-01	3.65E+25	1.11E-26	No	1.11E-26
Cs-137	7.97E-01	5.99E+05	1.33E-06	No	3.32E-02	3.65E+25	9.10E-28	No	1.33E-06
K-40	6.65E+01	1.93E+06	3.44E-05	No	N/A	3.65E+25	N/A	No	3.44E-05
Np-237	6.07E-01	6.49E+06	9.35E-08	No	1.77E-02	3.65E+25	4.85E-28	No	9.35E-08
Pu-238	1.86E-01	1.89E+05	9.84E-07	No	1.59E-01	3.65E+25	4.36E-27	No	9.84E-07
Pu-239[e]	-1.14E-01	2.01E+05	-5.68E-07	No	5.84E-02	3.65E+25	1.60E-27	No	-5.68E-07
Tc-99	5.54E+00	1.54E+07	3.60E-07	No	1.47E+01	3.65E+25	4.03E-25	No	3.60E-07
Th-230	N/A	4.52E+05	N/A	No	8.75E-01	3.65E+25	2.40E-26	No	2.40E-26
Th-234	6.71E+01	4.31E+06	1.56E-05	No	N/A	3.65E+25	N/A	No	1.56E-05
U-234	1.05E+00	4.05E+05	2.59E-06	No	3.99E+00	3.65E+25	1.09E-25	No	2.59E-06
U-235	3.37E-01	4.20E+05	8.02E-07	No	1.68E-01	3.65E+25	4.60E-27	No	8.02E-07
U-238	6.02E-01	4.06E+05	1.48E-06	No	6.46E+00	3.65E+25	1.77E-25	No	1.48E-06
Summed			**5.71E-05**				**7.36E-25**		**5.71E-05**

Table 4.13. Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

Terrestrial Plant									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	6.80E+08	N/A	No	4.06E-01	3.65E+26	1.11E-27	No	1.11E-27
Cs-137	7.97E-01	4.93E+07	1.62E-08	No	3.32E-02	3.65E+26	9.10E-29	No	1.62E-08
K-40	6.65E+01	5.79E+07	1.15E-06	No	N/A	3.65E+26	N/A	No	1.15E-06
Np-237	6.07E-01	7.86E+07	7.72E-09	No	1.77E-02	3.65E+26	4.85E-29	No	7.72E-09
Pu-238	1.86E-01	3.95E+09	4.71E-11	No	1.59E-01	3.65E+26	4.36E-28	No	4.71E-11
Pu-239[e]	-1.14E-01	7.05E+09	-1.62E-11	No	5.84E-02	3.65E+26	1.60E-28	No	-1.62E-11
Tc-99	5.54E+00	4.59E+08	1.21E-08	No	1.47E+01	3.65E+26	4.03E-26	No	1.21E-08
Th-230	N/A	2.74E+09	N/A	No	8.75E-01	3.65E+26	2.40E-27	No	2.40E-27
Th-234	6.71E+01	4.32E+07	1.55E-06	No	N/A	3.65E+26	N/A	No	1.55E-06
U-234	1.05E+00	3.03E+09	3.46E-10	No	3.99E+00	3.65E+26	1.09E-26	No	3.46E-10
U-235	3.37E-01	1.10E+08	3.07E-09	No	1.68E-01	3.65E+26	4.60E-28	No	3.07E-09
U-238	6.02E-01	4.29E+07	1.40E-08	No	6.46E+00	3.65E+26	1.77E-26	No	1.40E-08
Summed			**2.75E-06**				**7.36E-26**		**2.75E-06**

Summed total ratio for limiting organism: 3.09E-01.
Summed water ratio for limiting organism: 3.05E-01.
Summed sediment ratio for limiting organism: 3.96E-03.
N/A in this table indicates radionuclide was not analyzed. Ratios were not included and not summed for radionuclides that were not analyzed.
[a] Bayou Creek evaluated based on 2020 maximum results for L5 and S1.
[b] BCG is the biota concentration guide value.
[c] Results were reported at concentrations less than the laboratory's reporting limit.

Table 4.13. Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

[d] Results for Tc-99, Th-230, U-234 and U-238 were above laboratory reporting limit all other results were reported at concentrations less than the laboratory's reporting limit.
[e] Analytical data in PEGASIS are reported as Pu-239/240.

Table 4.14. Little Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a]

Aquatic Animal									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	4.38E+02	N/A	Yes	9.46E-02	6.80E+05	1.39E-07	No	1.39E-07
Cs-137	N/A	1.05E+03	N/A	No	-2.14E-02	4.93E+04	-4.34E-07	No	-4.34E-07
Np-237	N/A	6.85E+01	N/A	Yes	-1.24E-01	7.86E+04	-1.58E-06	No	-1.58E-06
Pu-238	N/A	1.76E+02	N/A	Yes	5.73E-02	3.95E+06	1.45E-08	No	1.45E-08
Pu-239[e]	N/A	1.87E+02	N/A	Yes	8.73E-02	7.05E+06	1.24E-08	No	1.24E-08
Tc-99	9.12E+00	2.47E+06	3.70E-06	No	5.73E-01	4.59E+05	1.25E-06	No	4.94E-06
Th-230	2.63E+00	2.57E+03	1.02E-03	Yes	1.41E+00	2.74E+06	5.14E-07	No	1.02E-03
U-234	9.56E-01	2.02E+02	4.73E-03	Yes	6.16E-01	3.03E+06	2.03E-07	No	4.73E-03
U-235	1.60E-01	2.18E+02	7.35E-04	Yes	0.00E+00	1.10E+05	0.00E+00	No	7.35E-04
U-238	3.98E+00	2.24E+02	1.78E-02	Yes	6.92E-01	4.29E+04	1.61E-05	No	1.78E-02
Summed			**2.43E-02**				**1.63E-05**		**2.43E-02**

Table 4.14. Little Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

Riparian Animal									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	1.46E+03	N/A	No	9.46E-02	5.15E+03	1.84E-05	Yes	1.84E-05
Cs-137	N/A	4.27E+01	N/A	Yes	-2.14E-02	3.13E+03	-6.84E-06	Yes	-6.84E-06
Np-237	N/A	1.16E+04	N/A	No	-1.24E-01	7.63E+03	-1.63E-05	Yes	-1.63E-05
Pu-238	N/A	5.51E+02	N/A	No	5.73E-02	5.73E+03	1.00E-05	Yes	1.00E-05
Pu-239[e]	N/A	6.22E+02	N/A	No	8.73E-02	5.87E+03	1.49E-05	Yes	1.49E-05
Tc-99	9.12E+00	6.67E+05	1.37E-05	Yes	5.73E-01	4.14E+04	1.38E-05	Yes	2.75E-05
Th-230	2.63E+00	1.39E+04	1.89E-04	No	1.41E+00	1.04E+04	1.35E-04	Yes	3.25E-04
U-234	9.56E-01	6.84E+02	1.40E-03	No	6.16E-01	5.27E+03	1.17E-04	Yes	1.52E-03
U-235	1.60E-01	7.37E+02	2.17E-04	No	0.00E+00	3.79E+03	0.00E+00	Yes	2.17E-04
U-238	3.98E+00	7.57E+02	5.26E-03	No	6.92E-01	2.49E+03	2.78E-04	Yes	5.54E-03
Summed			**7.08E-03**				**5.64E-04**		**7.64E-03**

Table 4.14. Little Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

Terrestrial Animal									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	2.02E+05	N/A	No	9.46E-02	3.65E+25	2.59E-27	No	2.59E-27
Cs-137	N/A	5.99E+05	N/A	No	-2.14E-02	3.65E+25	-5.86E-28	No	-5.86E-28
Np-237	N/A	6.49E+06	N/A	No	-1.24E-01	3.65E+25	-3.40E-27	No	-3.40E-27
Pu-238	N/A	1.89E+05	N/A	No	5.73E-02	3.65E+25	1.57E-27	No	1.57E-27
Pu-239[e]	N/A	2.01E+05	N/A	No	8.73E-02	3.65E+25	2.39E-27	No	2.39E-27
Tc-99	9.12E+00	1.54E+07	5.93E-07	No	5.73E-01	3.65E+25	1.57E-26	No	5.93E-07
Th-230	2.63E+00	4.52E+05	5.82E-06	No	1.41E+00	3.65E+25	3.86E-26	No	5.82E-06
U-234	9.56E-01	4.05E+05	2.36E-06	No	6.16E-01	3.65E+25	1.69E-26	No	2.36E-06
U-235	1.60E-01	4.20E+05	3.81E-07	No	0.00E+00	3.65E+25	0.00E+00	No	3.81E-07
U-238	3.98E+00	4.06E+05	9.80E-06	No	6.92E-01	3.65E+25	1.90E-26	No	9.80E-06
Summed			**1.89E-05**				**9.27E-26**		**1.89E-05**

Table 4.14. Little Bayou Creek 2020 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

Terrestrial Plant									
	Water				Sediment				TOTAL
Radionuclide	Concentration (pCi/L)[c]	BCG (pCi/L)[b]	Ratio	Limiting Organism	Concentration (pCi/g)[d]	BCG (pCi/g)[b]	Ratio	Limiting Organism	Ratio
Am-241	N/A	6.80E+08	N/A	No	9.46E-02	3.65E+26	2.59E-28	No	2.59E-28
Cs-137	N/A	4.93E+07	N/A	No	-2.14E-02	3.65E+26	-5.86E-29	No	-5.86E-29
Np-237	N/A	7.86E+07	N/A	No	-1.24E-01	3.65E+26	-3.40E-28	No	-3.40E-28
Pu-238	N/A	3.95E+09	N/A	No	5.73E-02	3.65E+26	1.57E-28	No	1.57E-28
Pu-239[e]	N/A	7.05E+09	N/A	No	8.73E-02	3.65E+26	2.39E-28	No	2.39E-28
Tc-99	9.12E+00	4.59E+08	1.99E-08	No	5.73E-01	3.65E+26	1.57E-27	No	1.99E-08
Th-230	2.63E+00	2.74E+09	9.58E-10	No	1.41E+00	3.65E+26	3.86E-27	No	9.58E-10
U-234	9.56E-01	3.03E+09	3.15E-10	No	6.16E-01	3.65E+26	1.69E-27	No	3.15E-10
U-235	1.60E-01	1.10E+08	1.46E-09	No	0.00E+00	3.65E+26	0.00E+00	No	1.46E-09
U-238	3.98E+00	4.29E+07	9.28E-08	No	6.92E-01	3.65E+26	1.90E-27	No	9.28E-08
Summed			**1.15E-07**				**9.27E-27**		**1.15E-07**

Summed total ratio for limiting organism: 2.49E-02.
Summed water ratio for limiting organism: 2.43E-02.
Summed sediment ratio for limiting organism: 5.87E-04.
N/A in this table indicates radionuclide was not analyzed. Ratios were not included and not summed for radionuclides that were not analyzed.
[a] Little Bayou Creek evaluated based on 2020 maximum results for L11 and S27.
[b] BCG is the biota concentration guide value.
[c] Results for U-238 were above laboratory reporting limit all other results were reported at concentrations less than the laboratory's reporting limit.
[d] Results for Th-230 and U-238 were above laboratory reporting limit all other results were reported at concentrations less than the laboratory's reporting limit.
[e] Analytical data in PEGASIS are reported as Pu-239/240.

4.3 CLEARANCE OF PROPERTY CONTAINING RESIDUAL RADIOACTIVE MATERIAL

This section addresses clearance of personal property (see glossary) containing residual radioactive material. The Paducah Site has begun efforts to transfer real property (see glossary), but clearance of real property has not yet taken place.

DOE contractors use the processes, guidelines, and limits found in DOE Order 458.1 and associated guidance for the clearance of property with residual radioactive material (see glossary). Release criteria for surface contamination limits, as specified in DOE Order 458.1, *Radiation Protection of the Public and Environment*, are used for clearance of objects with the potential for surface contamination, while specific authorized limits have been derived to control whether items with potential volumetric contamination are released. Property, which potentially contains residual radioactive material, will not be cleared from the Paducah Site unless the property is demonstrated to be within acceptable limits. Property clearance requirements are governed by procedures established by each DOE contractor.

In 2020, FRNP authorized, with concurrence from DOE, 807 releases of personal property that were surveyed for contamination. Several of these releases were in support of reuse and recycling efforts and deactivation operations. Multiple radiological surveys were performed to measure the radiological status of the property. Items released included, but were not limited to, heavy equipment, vehicles, containers, tanks, monitoring equipment, activated carbon, and batteries. The measurements and/or historical data associated with the materials support the unconditional radiological release of the materials and equipment and are below the release criteria for surface contamination limits as specified in 10 *CFR* Part 835 Appendix D; DOE Order 458.1, *Radiation Protection of the Public and Environment*; or other DOE approved limits. If survey measurements exceeded 80% of the specified release limit, independent verification was conducted.

In 2020, SST authorized, with concurrence from DOE, 590 releases of personal property that were surveyed for surface contamination. Most of these were in support of SST operations including, but not limited to, vehicles, mowers, miscellaneous equipment and parts, furniture, electronics, and fire extinguishers. The measurements and/or historical data associated with the materials support the unconditional radiological release of the materials and equipment and are below the release criteria for surface contamination limits as specified in 10 *CFR* Part 835 Appendix D; DOE Order 458.1, *Radiation Protection of the Public and Environment*; or other DOE approved limits. If survey measurements exceeded 80% of the specified release limit, independent verification was conducted.

In 2020, MCS shipped off-site hydrofluoric acid produced by the DUF_6 Conversion Facility, which converts DUF_6 into uranium oxide and hydrofluoric acid. Each shipment must meet the authorized limit of less than 3 pCi/mL of total uranium activity. During 2020, approximately 201,297 gal of hydrofluoric acid were shipped off-site, and the total uranium activity of each shipment was below the detection limit of 1.06 pCi/mL. The measurements and/or historical data associated with the materials support the unconditional radiological release of the materials and equipment and are below the release criteria for surface contamination limits as specified in 10 *CFR* Part 835 Appendix D; DOE Order 458.1, *Radiation Protection of the Public and Environment*; or other DOE approved limits. Also in 2020, MCS authorized, with concurrence from DOE, 143 releases of personal property that had been surveyed for contamination. Most of these were in support of MCS operations, including, but not limited to, company issued laundry, vehicles, environment, safety, and health instruments, materials and testing equipment, industrial hygiene samples, boxes of records, waste, subcontractor equipment, and items to be excessed. MCS did not release any items above the MDA (< 50% of the release level), so independent verifications were not needed or performed.

4.4 UNPLANNED RADIOLOGICAL RELEASES

There were no unplanned radiological releases in 2020.

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5. ENVIRONMENTAL NON-RADIOLOGICAL PROGRAM INFORMATION

5.1 AIR MONITORING

No active emission points at the Paducah Site require non-radiological air monitoring.

5.2 SURFACE WATER MONITORING

At the Paducah Site, the Clean Water Act 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 DOE and FRNP for Outfalls 001, 002, 004, 006, 008, 009, 010, 011, 012, 013, 015, 016, 017[5], 019, and 020. The permit combined outfalls that formerly were covered under both this permit and KPDES Permit KY0102083. In addition to the KPDES permit, a CERCLA outfall (C001) related to the Northeast Plume Pump-and-Treat operation discharges to surface water. Surface water from the C-613 Basin, a storm-water control facility that collects storm water runoff from scrapyards located in the northwestern portion of the Paducah Site, is sampled per the Northwest Storm Water Control Facility Operations and Maintenance Plan (DOE 2009) prior to discharge to Outfall 001. Further, KDWM specifies in landfill permit SW07300014, SW07300015, and SW07300045 that surface runoff will be analyzed to ensure that landfill constituents are not discharging into nearby receiving streams. Storm-water discharge from the KDWM-permitted solid waste landfill is sampled under the KPDES permit.

Surface water monitoring locations and the monitoring program under which they are sampled routinely at the Paducah Site are shown in Figure 5.1 and in Table 5.1, respectively. Figure 5.1 shows trends for TCE results in selected surface water monitoring locations over the last five years. Table 5.1 also shows the reporting for each of these programs. Permit exceedances are described in Chapter 2. Monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/ and are summarized in Table 5.2.

Surface water sampling for project-specific decommissioning and environmental remediation projects, and non-routine sampling events, are not summarized within this report.

5.3 SEDIMENT MONITORING

Sediment monitoring locations are shown in Figure 4.5. Total PCBs (also listed as polychlorinated biphenyls in laboratory reports) were detected in sediment during 2020 ranging from 2.01 µg/kg to 361 µg/kg, within the acceptable risk range. EPA's generally acceptable risk range is 10^{-4} to 10^{-6} for carcinogenic risk and below the hazard index of 1 for noncarcinogens (EPA 1999). According to *Methods for Conducting Risk Assessments and Risk Evaluations*, the no action level[6] for Total PCBs is 179 µg/kg, and the action level[7] is 17,900 µg/kg for the recreational user (DOE 2020a). The recreational user is used for comparison because it is the most reasonably anticipated scenario. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

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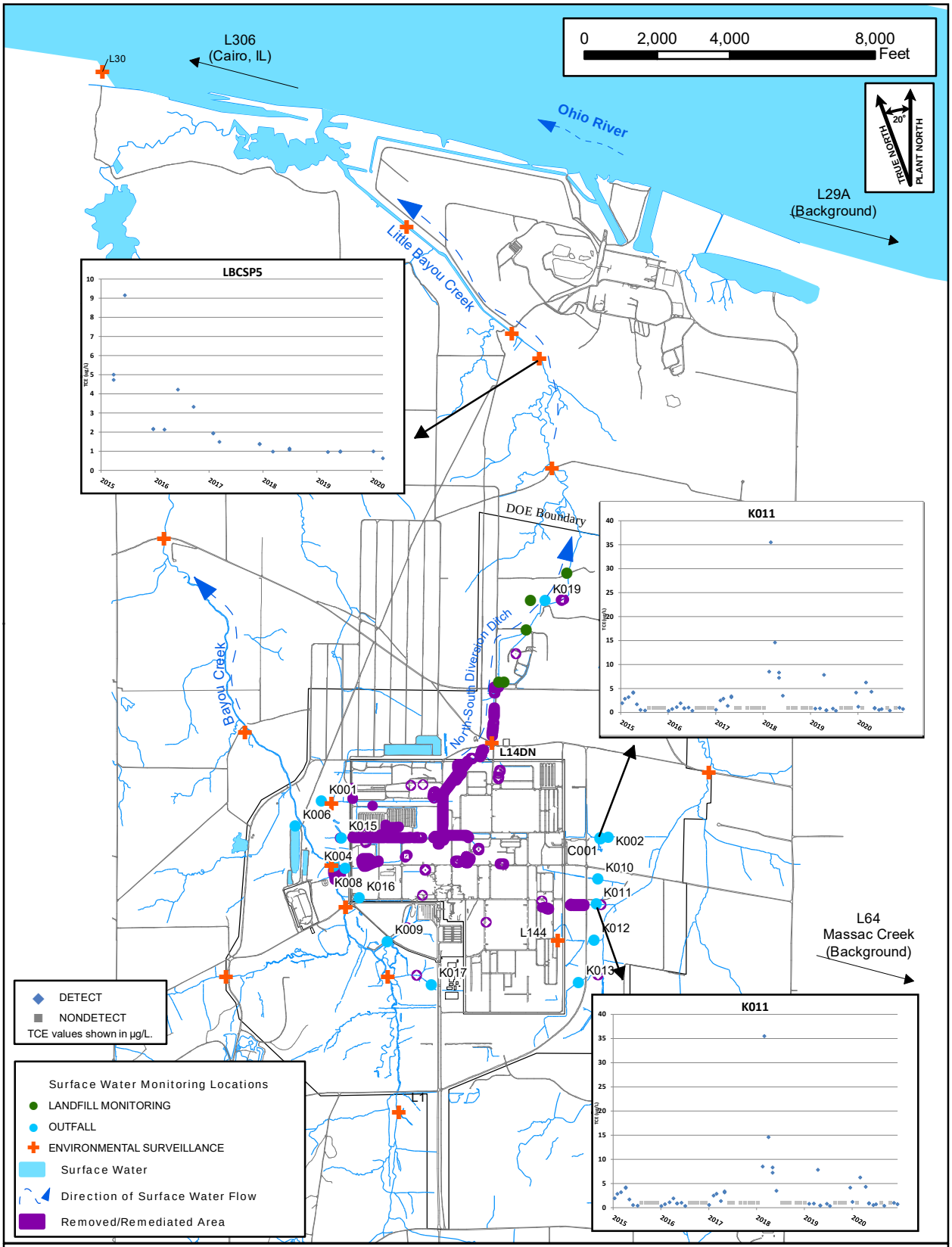
[5] Permit Number KY0004049 also includes MCS as a permittee for Outfall 017.
[6] The no action level is the concentration that represents the lesser of an excess lifetime cancer risk of 10^{-6} and a hazard index of 0.1.
[7] The action level is the concentration that represents the lesser of an excess lifetime cancer risk of 10^{-4} and a hazard index of 3.



MAP SOURCE INFORMATION

Map Generation Date and Location: G:\GIS\ARCVIEWS\PROJECTS\ASER\2020SW_TCE_20210421.mxd
Environmental Surveillance Layer-- G:\GIS\iPEGASIS.gdb\Locations (Query: STA_NAME IN ('L14DWN','L291','L1','L5','L144','L136','L135','L154','L150','L351','L306','746KTB1A','L30','L29A','L241','L11','L12','LBCSP5','L10','C-746-K-5','S31','L6') OR OBJECTID = 5112)
Outfalls Layer: G:\GIS\shapes\OUTFALLS\outfalls(points).shp
Landfill Monitoring Layer-- G:\GIS\iPEGASIS.gdb\Locations (Query: STA_NAME IN ('L14DWN','L291','L1','L5','L144','L136','L135','L154','L150','L351','L306','746KTB1A','L30','L29A','L241','L11','L12','LBCSP5','L10','C-746-K-5','S31','L6') OR OBJECTID = 5112)
Removed/Remediated Area Layer-- G:\GIS\iPEGASIS.gdb\Remediated_Areas
Surface Water Layer-- G:\GIS\SHAPES\STREAMS\ohiolkg.shp & G:\GIS\iPEGASIS.gdb\streams
Roads Layer-- G:\GIS\iPEGASIS.gdb\roadrow
Facilities Layer-- G:\GIS\ARCVIEWS\geodatabases\Paducah_site.gdb\Base_Map\uds, ...\Common
DOE Boundary Layer-- G:\GIS\iPEGASIS.gdb\doebnd

Figure 5.1. Surface Water and Seep Monitoring Locations with TCE Trends

Table 5.1. Summary of Surface Water Monitoring at the Paducah Site

Program and Reporting Location	Locations (see Figure 5.1)
Effluent Watershed Monitoring Program	
C-746-S and C-746-T Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2020 (January–March) Second Quarter 2020 (April–June) Third Quarter 2020 (July–September) Fourth Quarter 2020 (October–December)	L135, L136, L154[a]
C-746-U Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2020 (January–March) Second Quarter 2020 (April–June) Third Quarter 2020 (July–September) Fourth Quarter 2020 (October–December)	L150, L154[a], L351
KPDES Discharge Monitoring Reports	K001, K002, K004, K006, K008, K009, K010, K011, K012, K013, K015, K016, K017, K019, K020
C-613 Northwest Storm Water Control Facility Reported to KDWM via electronic mail	C-613
Environmental Surveillance Watershed Monitoring Program	
Surface Water	746KTB1A, C746K-5, L1[b], L10[b], L11[b], L241[b], L29A[b], L30[b], L306[b], L5[b], L14DWN[b]
Seep	LBCSP5
Northeast Plume Effluent *Semiannual FFA Progress Reports:* Second Half of FY 2020 (Data reported January–June 2020) First Half of FY 2021 (Data reported July–December 2020)	C001

[a] Location is listed for both C-746-S and C-746-T and for C-746-U.
[b] Locations are sampled to support the ERPP.

Table 5.2. Ranges of Detected Analytes in 2020 Surface Water Samples

Analyte	Range
Anions	
Chloride (µg/L)	320–4,920
Sulfate (µg/L)	1,190–48,100
Wet Chemistry Parameters	
Biochemical Oxygen Demand (µg/L)	1,670–26,700
Chemical Oxygen Demand (µg/L)	10,500–138,000
Dissolved Solids (µg/L)	11,400–249,000
Hardness—Total as $CaCO_3$ (µg/L)	20,000–184,000
Non-settable solids (µg/L)	200-34,400
Settable solids (µg/L)	200-404,000
Suspended Solids (µg/L)	400–3,140,000
Total Organic Carbon (µg/L)	3,080–26,900
Total Solids (µg/L)	77,000–2,590,000
Volatile Organic Compounds	
Trichloroethene (µg/L)	0.36–6.25

Table 5.2. Ranges of Detected Analytes in 2020 Surface Water Samples (Continued)

Analyte	Range
PCBs	
PCB-1242 (µg/L)	0.0599-0.0599
PCB-1248 (µg/L)	0.0337–0.243
PCB-1254 (µg/L)	0.0333–0.089
PCB-1260 (µg/L)	0.0357–0.124
Total PCBs (µg/L)	0.0599–0.303
Other Organics	
Oil and Grease (µg/L)	1,160–16,600
Metals	
Aluminum (µg/L)	71.6–1,470
Barium (µg/L)	42.8–53.9
Calcium (µg/L)	10,500–21,500
Copper (µg/L)	1.53–45.0
Iron (µg/L)	75.1–8,760
Lead (µg/L)	0.825–4.53
Magnesium (µg/L)	1,770–3,990
Manganese (µg/L)	36.1–64.9
Nickel (µg/L)	0.795–8.0
Phosphorous (µg/L)	70.1–1,050
Potassium (µg/L)	1,850–5,790
Sodium (µg/L)	496–19,700
Uranium (µg/L)	0.077–189
Zinc (µg/L)	9.39–97.6

5.4 BIOTA MONITORING

Biological monitoring (i.e., fish or benthic macroinvertebrate sampling) was not required under the specifications listed in the KPDES permits.

5.4.1 Aquatic Life

Starting in 1987, aquatic or biological monitoring of Bayou Creek and Little Bayou Creek began. Current guidelines for monitoring are set forth in the most recent Watershed Monitoring Plan (LATA Kentucky 2011). Requirements set forth in the Watershed Monitoring Plan followed conditions in the KPDES permit (KY0004049) and best management practices. Initially, the permit required sampling of fish and benthic macroinvertebrate in the receiving creeks, as well as chronic and acute toxicity sampling at the KPDES outfalls. After years of collecting fish and benthic macroinvertebrate samples, KDOW issued a new KPDES permit in 2009, eliminating the requirements for the fish and benthic macroinvertebrate sampling; however, the chronic and acute toxicity sampling remained a KPDES permit condition. In order to provide data for future ecological assessments, DOE continued the benthic macroinvertebrate sampling efforts through 2010. Benthic macroinvertebrate sampling was eliminated in 2011. Chronic and acute toxicity sampling remain in the KPDES permit. Chronic and acute toxicity testing are the two basic types of WET testing that describe the aggregate toxic effects of the whole effluent wastewater discharge as measured by an organism's response upon exposure to the sample. These tests replicate the total effect of environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants.

Warning signs are posted along Bayou and Little Bayou Creeks 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.

5.5 FIRE PROTECTION MANAGEMENT AND PLANNING

Fire protection management and planning at the Paducah Site follows the *Wildland Fire Management Plan*, CP2-EP-1005. The program includes fire prevention and hazard mitigation efforts including, but not limited to, training, work restrictions, combustible vegetation controls, safe facility location, and fire protection design considerations. If a wildland fire were to occur, a multiagency response would be activated to bring all available firefighting and related emergency response functions to bear, to combat the fire promptly, minimizing the risk of fire exposure to the public, site personnel, and critical facilities and programs.

DOE's Deactivation and Remediation Contractor, FRNP, is responsible for wildland fire management of all DOE owned property, except for the 1,986 acres licensed to WKWMA. West McCracken Fire Department is responsible for the area licensed to WKWMA.

5.6 RECREATIONAL HUNTING AND FISHING

Permitted recreational activities in WKWMA include youth turkey hunting, horseback riding, hiking, dog training and trials, hunting with a gun for small game, bow hunting for deer, mountain biking, and nature hiking. Additional information regarding hunting seasons and hunting and fishing limits is available from the Kentucky Department of Fish and Wildlife Resources website http://fw.ky.gov/.

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6. GROUNDWATER PROTECTION PROGRAM

The Results of the Site Investigation Phase 1 in 1991 determined the primary off-site contaminants in the Regional Gravel Aquifer (RGA), the primary aquifer for local groundwater users, to be TCE and technetium-99 (CH2M HILL 1991). TCE was used until 1993 as an industrial degreasing solvent and technetium-99 is a fission by-product contained in nuclear power reactor returns that were brought on-site through 1976 for reenrichment of uranium-235 (DOE 2001). Known or potential sources of TCE and technetium-99 include former test areas, spills, leaks, buried waste, and leachate derived from contaminated scrap metal previously stored on-site.

Investigations of the on-site source areas of TCE at the Paducah Site are ongoing. The main source and highest concentration of TCE contamination in the groundwater is near the C-400 Cleaning Building. TCE has a low solubility and a higher density than water and is included in a chemical group referred to as dense nonaqueous-phase liquids. As a result of these characteristics, TCE typically sinks through the subsurface and may form pools in less permeable layers of the subsurface, as well as the base of the aquifer. The pooling makes treatment difficult because these pools constitute a continuous source of dissolved-phase contamination (i.e., plumes) deep within the aquifer.

Groundwater monitoring serves to detect the nature and extent of contamination (i.e., types of contaminants, concentration of contaminants) and to determine the movement of groundwater near the plant. Data obtained from groundwater monitoring supports the decision making process for the ultimate disposition of the contaminants. Figure 6.1 presents monitoring wells sampled in CY 2020 and shows the 2018 TCE plume associated with the Paducah Site (FRNP 2018a). See Section 6.4 for additional information about the plumes associated with the Paducah Site.

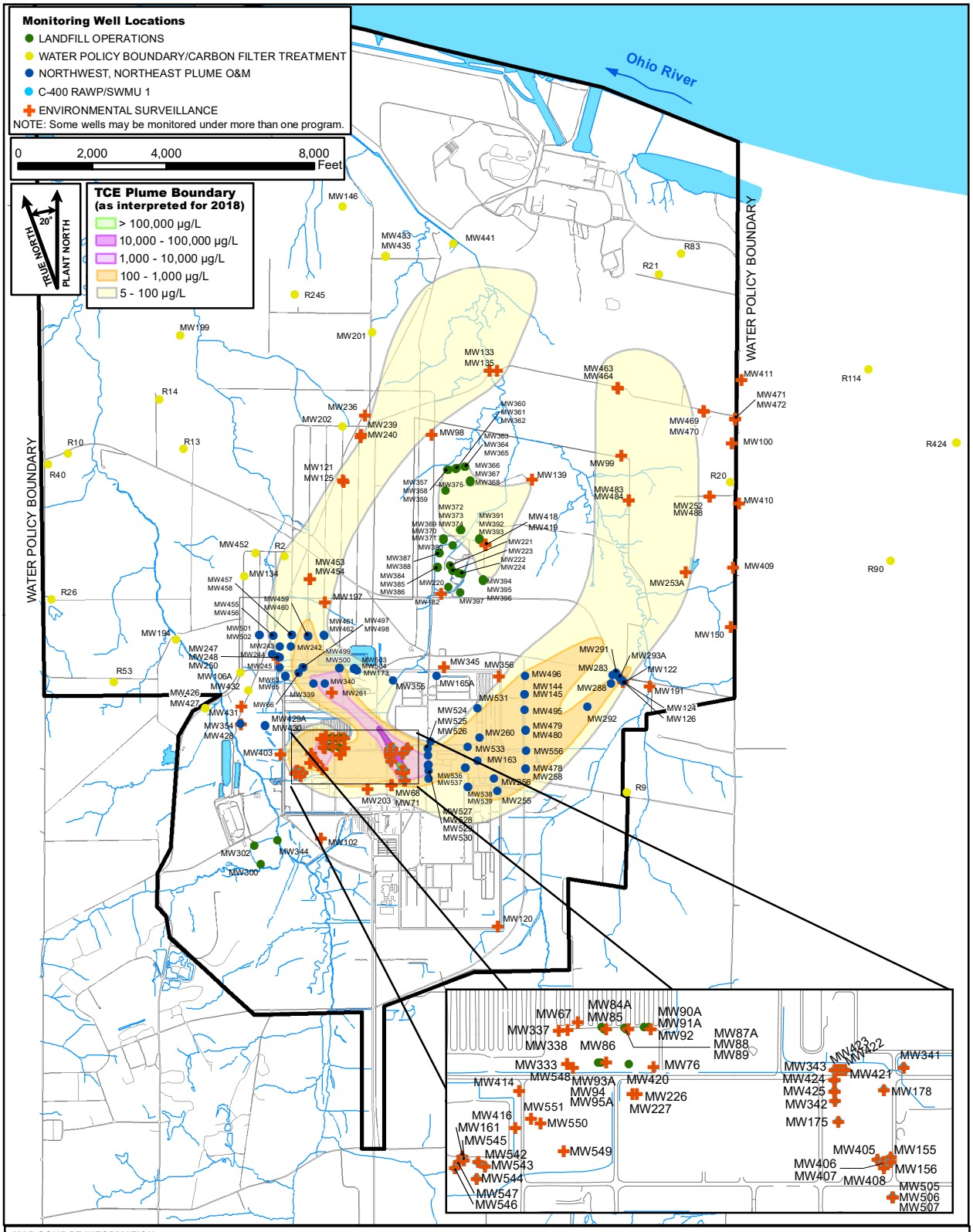
For access to historical groundwater data, visit the PEGASIS website at https://pegasis.pad.pppo.gov/ to view data for monitoring wells and groundwater locations at the Paducah Site.

6.1 GEOLOGIC AND HYDROGEOLOGIC SETTING

The local groundwater flow systems at the Paducah Site include the following (from shallowest to deepest): (1) the Terrace Gravel flow system, (2) Upper Continental Recharge System, (3) RGA, and (4) the McNairy flow system. Additional water-bearing zones monitored at the Paducah Site are the Eocene Sands and the Rubble Zone (i.e., the weathered upper portion of the Mississippian bedrock). These components are illustrated on Figure 6.2.

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 Upper Continental Recharge System 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. Flow in the McNairy beneath the Paducah Site also is northward to discharge into the Ohio River.

Additional information regarding the geology and hydrogeology of the Paducah Site can be found in the *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (available at https://eic.pad.pppo.gov/Search.aspx?accession=I-02500-0030) (MMES 1992). In 2016, a revision of the sitewide groundwater flow model was completed (DOE 2017b).



MAP SOURCE INFORMATION

Main Figure:
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Environmental Surveillance Layer-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
C-400 RAWP/SWMU 1 Layer-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Northwest, Northeast Plume O&M Layer-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Water Policy Boundary/Carbon Filter Treatment-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Landfill Operations-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
2018 Plume Layer-- G:\GIS\SHAPES\PLUMES\2018\TCE_100000.shp
& G:\GIS\SHAPES\PLUMES\2018\TCE_10000.shp & G:\GIS\SHAPES\PLUMES\2018\TCE_01000.shp
& G:\GIS\SHAPES\PLUMES\2018\TCE_00100.shp & G:\GIS\SHAPES\PLUMES\2018\TCE_00005.shp
Water Policy Layer-- G:\GIS\SHAPES\BOUNDS\WTRPBND.shp
Roads Layer-- G:\GIS\PEGASIS.gdb\roadrow
Facilities Layer-- G:\GIS\ARCVIEWS\geodatabases\Paducah_site.gdb\Base_Map\Common
& G:\GIS\ARCVIEWS\geodatabases\Paducah_site.gdb\Base_Map\uds
Surface Water Layer-- G:\GIS\PEGASIS.gdb\streams & G:\GIS\SHAPES\STREAMS\ohiolkg.shp
DOE Boundary Layer-- G:\GIS\PEGASIS.gdb\doebnd

Figure Inset:
Environmental Surveillance Layer-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
C-400 RAWP/SWMU 1 Layer-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Northwest, Northeast Plume O&M Layer-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Water Policy Boundary/Carbon Filter Treatment-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Landfill Operations-- G:\GIS\PEGASIS.gdb\MWs_2020.shp
Roads Layer-- G:\GIS\PEGASIS.gdb\roadrow
Facilities Layer-- G:\GIS\ARCVIEWS\geodatabases\Paducah_site.gdb\Base_Map\Common
& G:\GIS\ARCVIEWS\geodatabases\Paducah_site.gdb\Base_Map\uds
Surface Water Layer-- G:\GIS\PEGASIS.gdb\streams
DOE Boundary Layer-- G:\GIS\PEGASIS.gdb\doebnd

Figure 6.1. Monitoring Wells Sampled in CY 2020

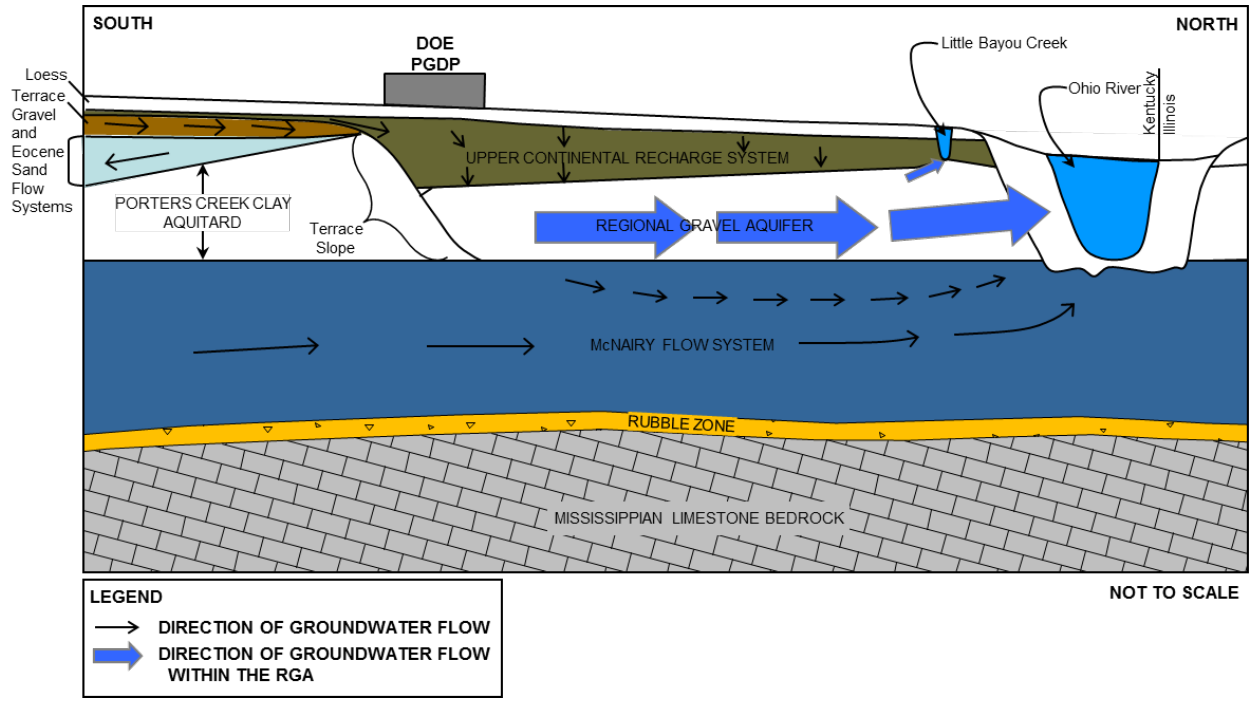


Figure 6.2. Paducah Site Groundwater Flow System and Water-Bearing Zones

6.2 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 east of the plant.

Historically, groundwater was the primary source of drinking water for residents and businesses in the vicinity of the plant area. In areas where the groundwater either is known to be contaminated or has the potential to become contaminated in the future, DOE has provided water hookups to the West McCracken County Water District since 1994 and pays water bills for affected residences and businesses. An educational mailer was developed in 2016 and has been updated as necessary and mailed to residents and businesses annually since then in an effort to ensure public awareness of the groundwater contamination.

6.3 GROUNDWATER MONITORING PROGRAM

Monitoring wells are used extensively at the Paducah Site to assess the effect of plant operations on groundwater quality. The primary objectives of the groundwater monitoring program at the Paducah Site are obtaining data to determine baseline and/or current conditions of groundwater quality and quantity; demonstrating compliance with and implementation of all applicable regulations and DOE Orders; providing data to allow early detection of groundwater pollution or contamination; identifying existing and potential groundwater contamination sources and maintaining surveillance of these sources; and providing data for making decisions about waste disposal on land-based units and the management and protections of groundwater resources. The groundwater monitoring program consists of routine compliance and facility monitoring designed to ensure protection of public health and the environment.

The sitewide approach is outlined in the following two documents related to groundwater monitoring: (1) Groundwater Protection Plan (FRNP 2018b); and (2) and the Paducah Site Environmental Monitoring Plan (FRNP 2021a). Over 200 monitoring wells and residential wells were sampled in accordance with DOE Orders and federal, state, and local requirements during 2020. Well sampling is included in several different monitoring programs, as shown in Table 6.1. Shown also in Table 6.1 are the number of wells sampled in each flow system and each program (note that some wells are sampled under more than one program) and the reporting locations for each of these programs. Monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

Table 6.1. Summary of Groundwater Monitoring at the Paducah Site

Program and Reporting Location	Number of Wells[a]					
	Terrace Gravel/ Eocene Sands	Upper Continental Recharge System	RGA	McNairy Flow System	Rubble Zone	Total
Groundwater Monitoring Program for Landfill Operations						
C-746-S and C-746-T Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2020 (January–March) Second Quarter 2020 (April–June) Third Quarter 2020 (July–September) Fourth Quarter 2020 (October–December)	0	4	14	0	0	18[b]
C-746-U Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2020 (January–March) Second Quarter 2020 (April–June) Third Quarter 2020 (July–September) Fourth Quarter 2020 (October–December)	0	7	12	0	0	19
C-404 Landfill Wells (required by permit) *Semiannual C-404 Groundwater Monitoring Reports:* C-404 Hazardous Waste Landfill May 2020 Semiannual Groundwater Report (October 2019–March 2020) C-404 Hazardous Waste Landfill November 2020 Semiannual Groundwater Report (April 2020–September 2020)	0	4	5	0	0	9
C-404 Landfill Wells (Not Committed)	0	0	17	0	0	17

Table 6.1. Summary of Groundwater Monitoring at the Paducah Site (Continued)

Program and Reporting Location	Number of Wells[a]					
	Terrace Gravel/ Eocene Sands	Upper Continental Recharge System	RGA	McNairy Flow System	Rubble Zone	Total
Groundwater Monitoring Program for Landfill Operations (Continued)						
C-746-K Landfill Wells *Semiannual FFA Progress Reports:* Second Half of FY 2020 (Data reported January–June 2020) First Half of FY 2021 (Data reported July–December 2020)	3	0	0	0	0	3
Northeast Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)						
Quarterly Optimization Wells	0	0	36	0	0	36
Northwest Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)						
Semiannual Wells	0	0	32	0	0	32
Quarterly Wells	0	0	1	0	0	1
C-400 Cleaning Building Interim Remedial Action Monitoring Wells *Semiannual FFA Progress Reports:* (see links above)						
Semiannual Wells	0	0	8	0	0	8
Quarterly Wells	0	0	11	0	0	11
Former Oil Landfarm Solid Waste Management Unit (SWMU) 1 Monitoring Wells *Annual Site Environmental Report*						
Semiannual Wells	0	0	7	0	0	7
Water Policy Boundary Monitoring Program *Annual Site Environmental Report*						
Northwestern Wells (quarterly)	0	0	22	0	0	22
Northeastern Wells (annual)	0	0	6	0	0	6
Carbon Filter Treatment System *Annual Site Environmental Report*	0	0	1	0	0	1
Environmental Surveillance Groundwater Monitoring Program *Annual Site Environmental Report*						
Annual Wells	0	1	28	0	1	30
Biennial Wells	0	0	0	0	0	0
Semiannual Wells	0	0	6	8	0	14
Quarterly Wells	0	0	3	0	0	3
Geochemical Wells	0	0	0	0	0	0

[a] Some wells are sampled under more than one program.
[b] RGA wells MW369, MW370, MW372, and MW373 are sampled with the C-746-U Landfill sampling events; these four wells are not counted in the sampling event for the C-746-S&T Landfills, but are reported in the Compliance Monitoring Reports for the C-746-U and C-746-S&T Landfills.

6.4 GROUNDWATER MONITORING RESULTS

Groundwater monitoring at the Paducah Site addresses programs including general environmental surveillance, current and inactive landfills, groundwater plume pump-and-treat operations, the C-400 Cleaning Building Interim Remedial Action monitoring, and area residential wells. The Environmental Surveillance Groundwater Monitoring Program is reviewed each year and modified as appropriate to continue to delineate the boundaries of the contaminant plumes over time. Groundwater monitoring results from all sampling efforts conducted by the Paducah Site are compiled in the Paducah Oak Ridge Environmental Information System (OREIS) database. Analytical results of interest are available upon request (by e-mailing PegasisAdmins@pad.pppo.gov) or by visiting the PEGASIS website at https://pegasis.pad.pppo.gov/ to view data. A summary of detected analytes from monitoring well groundwater samples (i.e., typically station names that begin with "MW") in 2020 are shown in Table 6.2. Groundwater samples also were collected for PFAS in MW315 and MW330 in CY 2019. DOE committed to provide these results to EPA and KDEP in the CERCLA Five-Year Review (DOE 2019). These results are presented in Section 6.5.

The C-404 Hazardous Waste Landfill is subject to semiannual groundwater monitoring and statistical analyses of the data, in accordance with the Hazardous Waste Management Facility Permit.

The Paducah Site groundwater plume maps are used to facilitate planning to optimize the site groundwater cleanup. These maps depict the general footprint of the TCE and technetium-99 contamination in the RGA and convey the general magnitude and distribution of contamination within the plumes above the MCL. For additional description of the Paducah Site plumes, please see *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2018 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FRNP 2018a). This document is available from the Environmental Information Center (https://eic.pad.pppo.gov).

Records of decision have been put in place under the Groundwater Operable Unit for the following Projects:

- SWMU 91 (DOE 1998a);
- Northwest Plume (DOE 1993 and DOE 2010);
- Northeast Plume (DOE 1995b and DOE 2015);
- C-400 Cleaning Building source area (DOE 2005); and
- Southwest Plume (DOE 2012).

These documents can be found in the Environmental Information Center (https://eic.pad.pppo.gov). The locations of groundwater contamination sources are shown in Figure 6.3. Table 6.3 lists the cumulative TCE removed from liquid VOCs and VOCs on carbon recovered through CY 2020. The graphs shown in Figures 6.4 and 6.5 illustrate the cumulative TCE removed from liquid by the Northwest Plume Groundwater Treatment System and the Northeast Plume Containment System through CY 2020.

Table 6.2. Ranges of Detected Analytes in 2020 Monitoring Well Groundwater Samples

Analyte	Range
Volatile Organic Compounds	
1,1,2-Trichloroethane (µg/L)	0.7–0.7
1,1-Dichloroethane (µg/L)	0.54–10.5
1,1-Dichloroethene (µg/L)	0.37–49.0
1,2-Dichloroethane (µg/L)	0.63–0.78
Acetone (µg/L)	1.82–4.83
Carbon tetrachloride (µg/L)	0.74–18.2
Chloroform (µg/L)	0.39–20.2
cis-1,2-Dichloroethene (µg/L)	0.34–2,410
cis-1,3-Dichloropropene (µg/L)	0.57-0.57
Methylene chloride (µg/L)	1.67–1.8
Tetrachloroethene (µg/L)	0.39–1.45
trans-1,2-Dichloroethene (µg/L)	0.39-20
trans-1,3-Dichloropropene (µg/L)	0.46-1.05
Trichloroethene (µg/L)	0.34–78,700
Vinyl chloride (µg/L)	1.33–129
Radionuclides	
Alpha activity (pCi/L)	4.11–14
Beta activity (pCi/L)	3.84–702
Radium-226 (pCi/L)	0.873–1.47
Radium-228 (pCi/L)	4.58–4.72
Technetium-99 (pCi/L)	13.8–25,300
PCBs	
PCB-1242 (µg/L)	0.0382–0.0939
PCB-1260 (µg/L)	0.0489–0.0489
Total PCBs (µg/L)	0.0382–0.0939
Wet Chemistry Parameters	
Alkalinity as CaCO3 (µg/L)	80,400–190,000
Chemical Oxygen Demand (µg/L)	9,070–114,000
Cyanide (µg/L)	2.09-3.22
Dissolved Solids (µg/L)	133,000–529,000
Iodide (µg/L)	442–747
Total Organic Carbon (µg/L)	416–13,800
Total Organic Halides (µg/L)	3.34–122

Analyte	Range
Anions	
Bromide (µg/L)	93.6-921
Chloride (µg/L)	473–161,000
Fluoride (µg/L)	95.3–787
Nitrate as Nitrogen (µg/L)	58.7–7,920
Sulfate (µg/L)	3,850–894,000
Metals	
Aluminum (µg/L)	19.5–4,860
Arsenic (µg/L)	2.04–33.7
Barium (µg/L)	23–465
Beryllium (µg/L)	0.232–0.263
Boron (µg/L)	5.21–1,970
Cadmium (µg/L)	0.313–0.503
Calcium (µg/L)	5,770–219,000
Chromium (µg/L)	3.02–617
Cobalt (µg/L)	0.365–36.8
Copper (µg/L)	0.322–27.1
Iron (µg/L)	33.6–140,000
Lead (µg/L)	0.501–3.88
Magnesium (µg/L)	1,940–52,800
Manganese (µg/L)	1.2–11,800
Mercury (µg/L)	0.067–0.122
Molybdenum (µg/L)	0.201–9.84
Nickel (µg/L)	0.619–164
Potassium (µg/L)	153–27,700
Selenium (µg/L)	2.02–6.31
Silver (µg/L)	0.595–3.95
Sodium (µg/L)	9,200–146,000
Uranium (µg/L)	0.069–16.2
Uranium-235 (µg/L)	0.00224–0.0161
Uranium-238 (µg/L)	0.135–2.32
Vanadium (µg/L)	3.3–50.4
Zinc (µg/L)	3.32–31.6
Arsenic, Dissolved (µg/L)	2.06–25.2
Barium, Dissolved (µg/L)	21.3–450
Cadmium, Dissolved (µg/L)	0.326-0.355
Chromium, Dissolved (µg/L)	3.18–212
Lead, Dissolved (µg/L)	0.507–0.539
Mercury, Dissolved (µg/L)	0.067–0.067
Selenium, Dissolved (µg/L)	2.04–2.04
Uranium, Dissolved (µg/L)	0.69–3.86

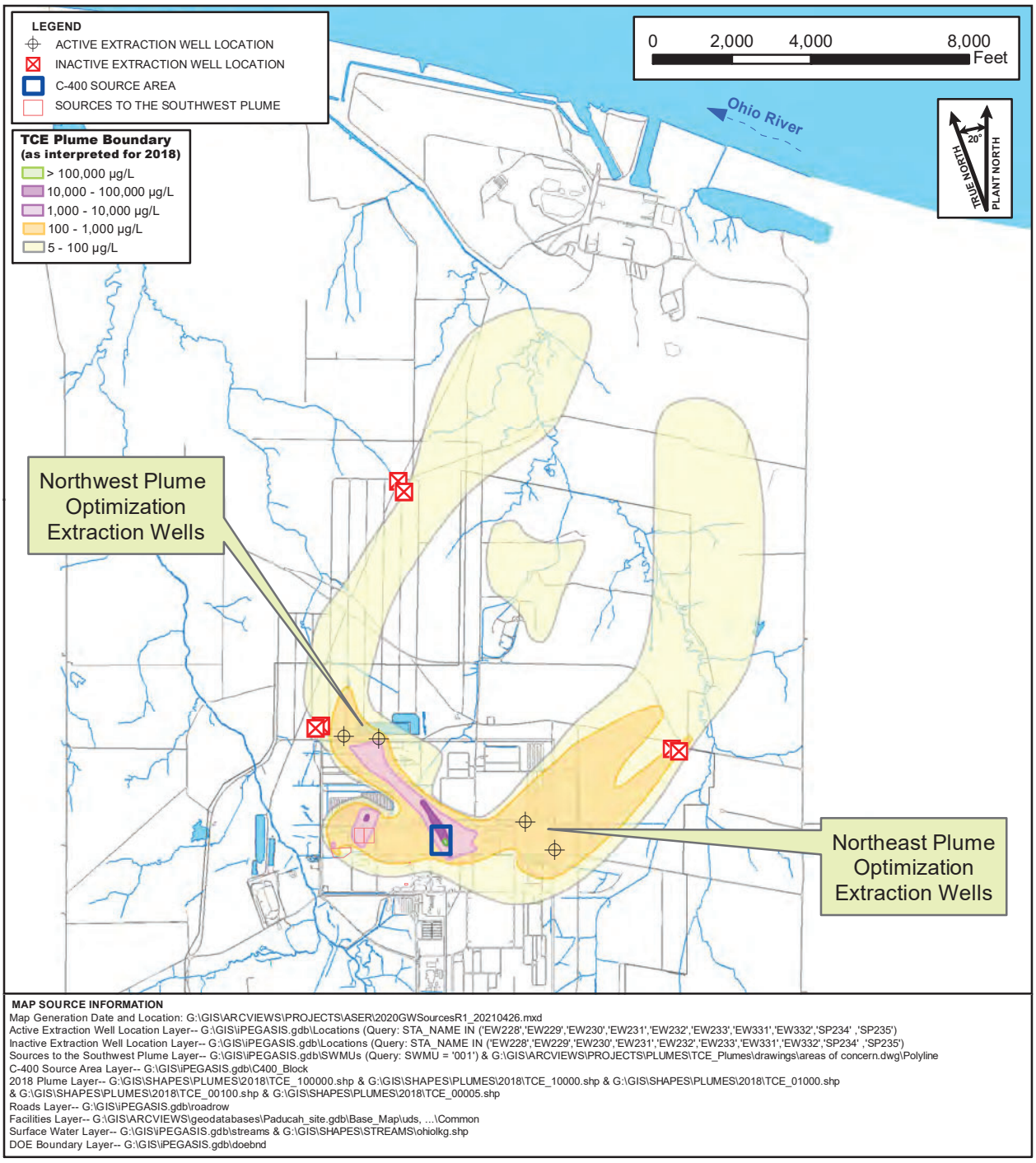
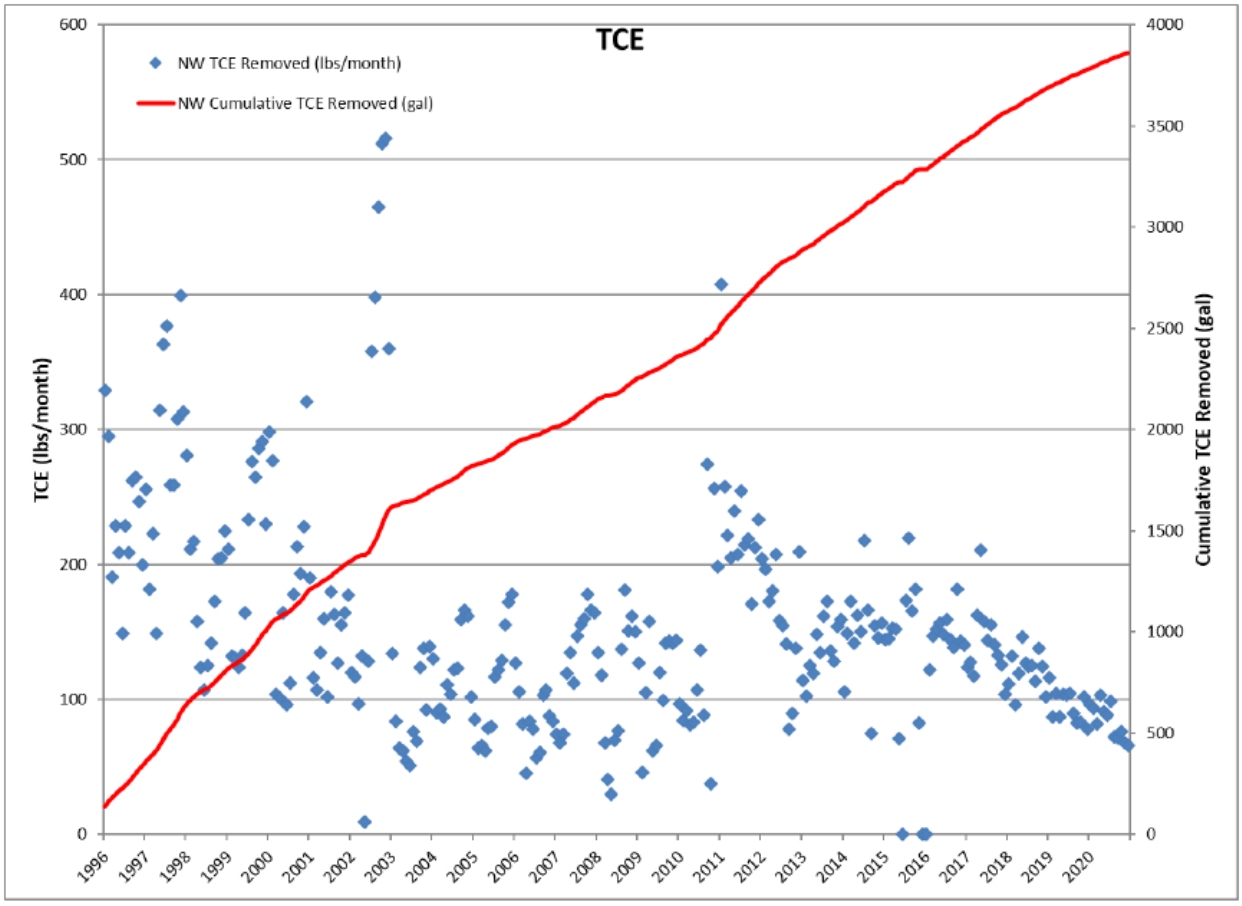


Figure 6.3. Locations of Groundwater Contamination Sources

Table 6.3. Cumulative TCE Removed at Paducah

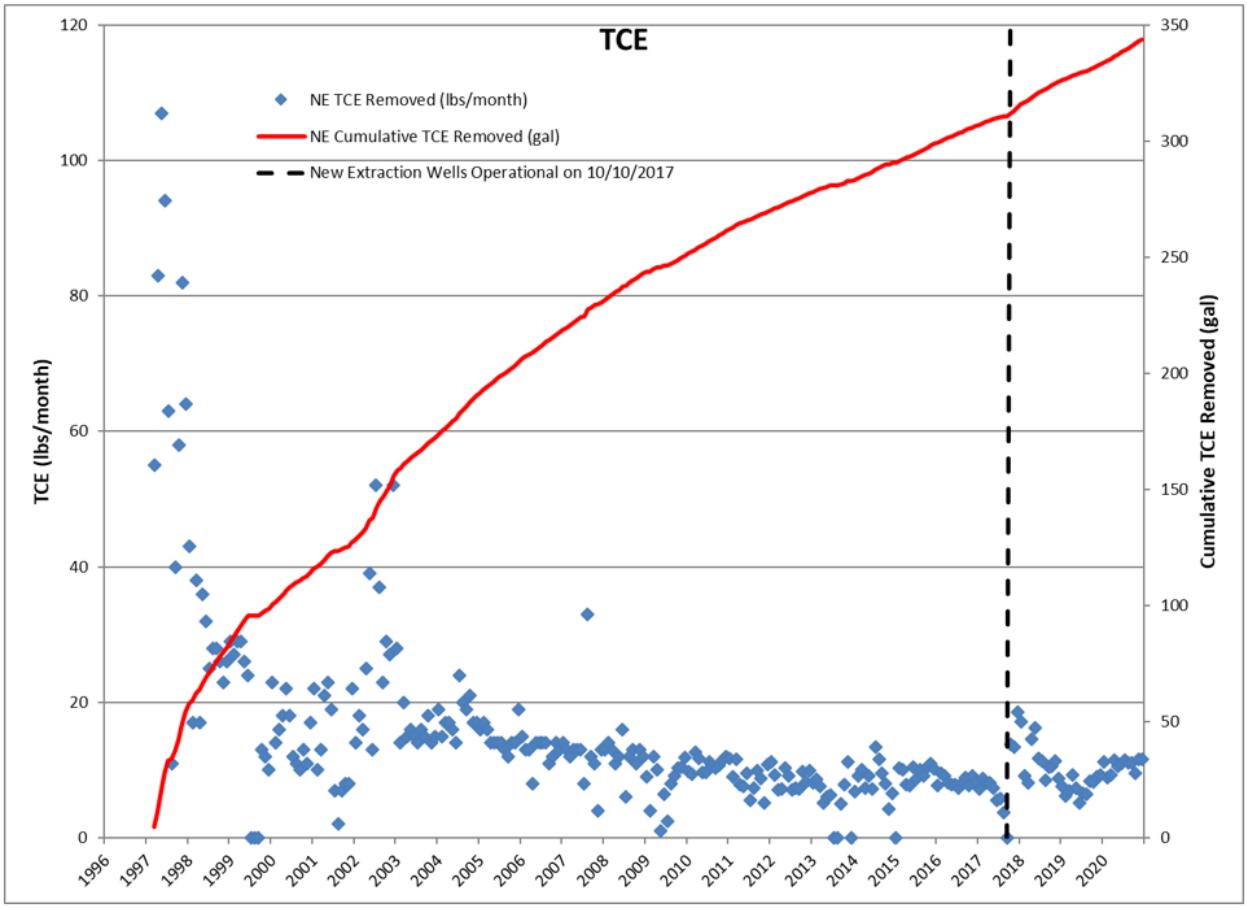
Source Area	Cumulative TCE Removed (gal)[a]
Northwest Plume Pump-and-Treat	3,861[b]
Northeast Plume Pump-and-Treat	347[b]
C-400 Six-Phase Treatability Study	1,900
C-400 Phase I	535
C-400 Phase IIa	1,137
Southwest Plume (SWMU 1)	24[c]
Other sources (i.e., SWMU 91–LASAGNA™)	246
Total	8,050

[a] TCE values may contain other VOCs.
[b] Cumulative through December 31, 2020.
[c] Removed during deep soil mixing operations.



Source: DOE 2021b

Figure 6.4. Northwest Plume Groundwater Treatment System TCE Removed



Source: DOE 2021b

Figure 6.5. Northeast Plume Containment System TCE Removed

The Kentucky Solid Waste Facility (401 *KAR* 47:030 § 6) maximum contaminant level exceedances for 2020 are listed in Table 6.4.

Table 6.4. Summary of Maximum Contaminant Level Exceedances for C-746-S & -T and C-746-U in 2020

Upper Continental Recharge System	Upper RGA	Lower RGA
C-746-S and C-746-T Landfills		
MW390: beta activity	MW372: beta activity, trichloroethene MW387: beta activity MW391: trichloroethene	MW370: beta activity MW385: beta activity MW388: beta activity MW392: trichloroethene
C-746-U Landfill		
MW374: beta activity	MW372: beta activity, trichloroethene	MW361: trichloroethene MW364: trichloroethene MW367: trichloroethene MW370: beta activity

Shading indicates a background monitoring well.

A Groundwater Assessment Report documented that there was no evidence indicating a release from the C-746-U Landfill (LATA Kentucky 2013). The data used to support this assessment were groundwater analyses of quarterly and semiannual monitoring for the period 2002 through 2012 and the focused

sampling of October 2006. The report found that the beta activity (associated with technetium-99) and TCE in the wells are not landfill-related, but originate upgradient of the C-746-S, C-746-T, and C-746-U Landfills.

Statistical analyses also are used to evaluate compliance monitoring wells at the C-746-S and C-746-T Landfill, the C-746-U Landfill, and the C-404 Landfill. Each report lists any statistical exceedance that is found. Reports for each landfill are listed in Table 6.1.

6.5 PER- AND POLYFLUOROALKYL SUBSTANCES AND EMERGING CONTAMINANTS

Federal and state regulatory interest has increased in emerging contaminants of concern that may be present at industrial sites including per- and polyfluoroalkyl substances (PFAS) and other persistent contaminants that have been detected in surface waters and groundwater. PFAS are a group of man-made chemicals that have been manufactured and used by a variety of industries since 1940. PFAS are found in aqueous film forming foam (AFFF) that is used in firefighting and fire training activities, and PFAS also are used in water and stain repellant materials and in certain industrial lubricants. There is evidence that exposure to PFAS can lead to adverse human health effects. Although not regulated currently at the federal level, these emerging contaminants are proposed for regulation by EPA in the future. EPA maintains a website which provides PFAS tools and resources, as well as outlines actions that EPA is taking on the topic at: https://www.epa.gov/pfas. On March 22, 2019, the Kentucky Governor signed S.B. 104, banning the use of firefighting foam containing PFAS for training and testing purposes. This law went into effect on July 2020.

The Paducah Site began investigating the history and on-site use of PFAS compounds in 2017. Interviews with site staff, including the PGDP fire chief, indicated that AFFF had not been used to fight a fire at the Paducah Site during the previous approximate 30-year time frame, but it had been used in fire training exercises at the Fire Training Area. The PGDP no longer uses AFFF for training and testing purposes; however, a small inventory is maintained in the event of a lube oil or fuel oil fire. The Paducah Site is in the process of reducing the inventory of lube oil and fuel oil at the site. Once that is complete, the inventory of AFFF on-site will be reduced or eliminated. A document and database search conducted in 2017 concluded that no PFAS sampling ever had been completed at the Paducah Site.

In 2018, PFAS sampling at the Fire Training Area was added to the Paducah Site Environmental Monitoring Plan for sampling and analysis in CY 2019. Currently there is no EPA approved analytical method for PFAS in groundwater, surface water, and wastewater; therefore, the most appropriate available method was used (a modified version of the drinking water method, EPA Method 537.1). Based on the most likely known potential source of PFAS contaminants, sampling of two groundwater monitoring wells was conducted in the Fire Training Area in August and September 2019. Samples were collected from MW315 (UCRS) and MW330 (RGA), which are approximately 75 ft from each other. The samples were analyzed for 18 PFAS compounds, and results were validated by an independent third party. Analytical results indicate detectable levels of PFAS contamination in groundwater in the vicinity of the Fire Training Area. These analytical results were added to the publicly available data repository (PEGASIS) on March 26, 2020, and are presented in Table 6.5.

Currently the Paducah Site has approximately 545 gal of AFFF in storage for the Fire Department. An additional 15 gal is contained in a fire truck. Approximately 220 gal of additional AFFF was shipped for treatment and disposal in CY 2020.

As emerging contaminants, federal and state agencies are working to develop reliable and consistent laboratory methods to characterize PFAS in the environment, and are developing guidance to facilitate

cleanup of contaminated groundwater and new tools and materials to communicate about PFAS. Paducah Site personnel continue to participate in the DOE Headquarters PFAS Working Group to obtain DOE Headquarters' direction for other actions consistent with those across the DOE complex.

Table 6.5 Paducah Site: Per-and Polyfluoroalkyl Substances

Analyte	First Sampling Event			Second Sampling Event		
	MW315	MW315 (Duplicate)	MW330	MW315	MW315 (Duplicate)	MW330
	8/22/2019	8/22/2019	8/22/2019	8/29/2019	8/29/2019	9/10/2019
Perfluorobutanesulfonate (PFBS)	10,000	10,100	15.8	5,720	4,880	21.9
Perfluorobutyric acid (PFBA)	886	850 J	6	850 B	605 B	7.88
Perfluorodecanesulfonate (PFDS)	843 U	844 U	1.67 U	86 U	86.6 U	1.73 U
Perfluorodecanoic acid (PFDA)	1.14 J	1.11 J	1.72 U	88.7 U	89.3 U	1.79 U
Perfluorododecanoic acid (PFDoA)	1.74 U	1.74 U	1.72 U	88.7 U	89.3 U	1.79 U
Perfluoroheptanesulfonate (PFHpS)	3040	2560	0.924 J	1640	1310	3.77
Perfluoroheptanoic acid (PFHpA)	1370	1300	2.71	1420	1200	3.56
Perfluorohexadecanoic acid (PFHxDA)	2 U	500 U	8.91 U	88.7 U	89.3 U	1.79 U
Perfluorohexanesulfonate (PFHxS)	63,200	59,600	44.7	38,100	42,400	89.3
Perfluorohexanoic acid (PFHxA)	14,000	12,300	22.2	11,800	9940	29.3
Perfluorononanoic acid (PFNA)	870 U	871 U	1.08 J	88.7 U	89.3 U	1.26 J
Perfluorooctadecanoic acid (PFODA)	2 U	500 U	8.91 U	88.7 LL1U	89.3 LL1U	1.79 U
Perfluorooctanesulfonate (PFOS)	128,000	117,000	29.6	40,000	36,600	174
Perfluorooctanoic acid (PFOA)	5230	5190	7.38	3890	3520	10.7
Perfluoropentanoic acid (PFPeA)	2570	2560	6.96	2380	1830	7.27
Perfluorotetradecanoic acid (PFTeDA)	1.74 U	1.74 U	1.72 U	88.7 U	89.3 U	1.79 U
Perfluorotridecanoic acid (PFTrDA)	1.74 U	1.74 U	1.72 U	88.7 U	89.3 U	1.79 U
Perfluoroundecanoic acid (PFUdA)	1.74 U	1.74 U	1.72 U	88.7 U	89.3 U	1.79 U

Notes:
1. MW315 is an Upper Continental Recharge System well and MW330 is an RGA well.
2. Concentrations are in units of nanograms/liter (ng/L), also commonly referred to as parts per trillion (ppt).
3. A duplicate is collected at the same time, using the same procedures, the same type of equipment, and in the same types of containers as the original samples. Duplicate samples also are preserved in the same manner and submitted for the same analyses as the original sample. Data from duplicate samples may be used to assess sampling variability in comparison to the original sample.
4. The first sampling event was conducted using Teflon™ tubing and conventional bladder pumps.
5. The second sampling event was conducted using high-density polyethylene tubing and certified, PFAS-free bladder pumps.
6. MW315 was purged 5 minutes prior to both sample collection events. MW330 was purged 12 minutes prior to the first sample collection and 11 minutes prior to the second event.

7. Analytical method used was a modified version of EPA Method 537.1 and is noted in PEGASIS as 537.1M. This method is a liquid chromatography tandem mass spectroscopy method. This method is a referenced method by U.S. Department of Defense/U.S. Department of Energy Quality Systems Manual (QSM); however, because the method is not an EPA-promulgated method qualifier code, QSM-METH, was assigned to the data set to indicate a possible uncertainty to the data set. (QSM-METH = Result generated by DoD/DOE QSM referenced method (non-promulgated method)

B = Analyte found in the associated blank.
L = Laboratory Control Sample (LCS) or Laboratory Control Sample Duplicate (LCSD) recovery outside of control limits.
L1 = LCS/LCSD relative percent difference outside acceptance criteria.
U = Analyte analyzed for, but not detected at or below the lowest concentration reported.
J = Estimated value.

7. QUALITY ASSURANCE

The Paducah Site maintains a Quality Assurance (QA)/Quality Control (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 the following:

- DOE Order 414.1D, *Quality Assurance*;
- Environmental Management Quality Assurance Program, EM-QA-001, Rev 1;
- *Quality Assurance Program Description for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, CP2-QA-1000/FR1A;
- Commonwealth of Kentucky and federal regulations and guidance from EPA;
- American National Standards Institute;
- American Society of Mechanical Engineers;
- American Society for Testing and Materials; and
- 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. The Paducah Site uses laboratories audited through the DOE Consolidated Audit Program (DOECAP). DOECAP implements annual performance qualification audits of environmental analytical laboratories and commercial waste treatment, storage, and disposal facilities to support complex-wide DOE mission activities.

The *Environmental Monitoring Quality Assurance Project Plan* (QA Plan) defined the relationship of each element of the Environmental Monitoring Program to key quality and data management requirements. The QA Plan is an appendix to the Environmental Monitoring Plan (FRNP 2021a).

The Paducah Programmatic Quality Assurance Project Plan was implemented in 2013 and was updated in 2021 (DOE 2021c). This plan is based on the Uniform Federal Policy for Quality Assurance Project Plans. Additionally, the following procedures further ensure quality:

- Field forms are maintained in accordance with CP3-RD-0010, *Records Management Process*.
- Communication and documentation between the sample management office and field sampling personnel are conducted in accordance with CP4-ES-5007, *Data Management Coordination*.
- Sample labels and chains-of-custody are completed according to CP4-ES-2708, *Chain-of-Custody Forms, Field Sample Logs, Sample Labels, and Custody Seals*.

- Data assessment is conducted by a technical reviewer or their designee according to CP3-ES-5003, *Quality Assured Data*.

- Logbooks and data forms are prepared in accordance with CP4-ES-2700, *Logbooks and Data Forms*.

The QA Plan and the procedures cited above were in effect and covered data collected during the time frame of January through December 2020. Additional subjects included in the QA Plan are training requirements, sample custody, procedures, and instrument calibration and maintenance.

7.1 FIELD SAMPLING QUALITY CONTROL

7.1.1 Data Quality Objectives and Sample Planning

From the start of any sampling program, data quality objectives 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 Environmental Monitoring Plan (FRNP 2021a). The Paducah Site Environmental Monitoring Plan is evaluated and modified, as appropriate, using the data quality objectives methodology on a FY basis (i.e., October 1 through September 30) following EPA data quality objectives guidance (EPA QA/G-4).

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 data quality objectives, an analytical statement of work 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.

7.1.2 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, 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 recorded in logbooks, and input into PEMS.

7.1.3 Sampling Procedures

Samples are collected using media-specific procedures, which are written according to EPA-approved sampling methods. Sample media consists of surface water, groundwater, sediment, and air filters. 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. This information, which is documented in a logbook or data form, 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.

7.1.4 Field Quality Control Samples

The QC program for both groundwater and environmental monitoring activities specifies a minimum target rate of 5%, or 1 per 20 environmental samples, for field QC samples. Table 7.1 shows the types of field QC samples collected and analyzed. Analytical results of field QC samples are evaluated to determine if the sampling activities biased the sample results.

Table 7.1. 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
	Performance evaluations
	LCS

[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 that have been used to rinse the sampling equipment. The water is collected after completion of decontamination and prior to sampling. It is used to assess adequate decontamination of sampling equipment.

7.2 ANALYTICAL LABORATORY QUALITY CONTROL

7.2.1 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 American Society for Testing and Materials, are used. Analytical methods are identified in a statement of work for laboratory services. Using guidance from EPA, laboratories document the steps in sample handling, analysis, reporting results, and follow chain-of-custody procedures.

7.2.2 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 7.1. If QC acceptance criteria are not met, then appropriate action, as denoted by the analytical method, is taken or the analytical data are qualified appropriately.

7.2.3 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. These programs are conducted by EPA, DOE, and commercial laboratories. Data that do not meet acceptable criteria 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.

KDOW requires that each laboratory performing analyses of samples for KPDES permit compliance hold a Kentucky Wastewater Laboratory Certification. Two laboratories and the FRNP sampling organization held a Kentucky Wastewater Laboratory Certification in 2020.

Additional information about the certification can be found at https://eec.ky.gov/Environmental-Protection/Water/PermitCert/LabCert/Pages/default.aspx.

7.2.4 Laboratory Audits/Sample Management Office

Laboratories used by FRNP are participants in the DOECAP—Accreditation Program (AP). The DOECAP-AP provides certification/accreditation of environmental laboratories through third-party organizations (i.e., American Association for Laboratory Accreditation, Perry Johnson Laboratory Accreditation, Inc., and ANSI National Accreditation Board). This ensures that the laboratories are in compliance with regulations, methods, and procedures. Findings are documented and addressed by the audited laboratory through corrective actions. FRNP reviews the audit reports and laboratory corrective action plans for compliance with FRNP requirements on a biennial basis. Laboratories that do not participate in the DOECAP-AP are audited by FRNP for compliance with DOECAP and approved suppliers list (ASL) requirements.

The following are the analytical laboratories maintained on the ASL and used by the Paducah Site in 2020.

- Advanced Terra Testing
- GEL Laboratories, LLC
- Eurofins TestAmerica (St. Louis, Missouri; Denver, Colorado; Knoxville, Tennessee)
- ALS Global (Fort Collins, Colorado; Cincinnati, Ohio; Salt Lake City, Utah labs)
- Southwest Research Institute
- Materials and Chemistry Laboratory
- Pace Analytical Services, LLC (Mt. Juliet, Tennessee; Madisonville, Kentucky labs)
- Summit Environmental

The following are the waste treatment, storage, and disposal facilities maintained on the ASL and used by the Paducah Site in 2020.

- Veolia Environmental Services Technical Solutions, Port Arthur, Texas
- Perma-Fix (Diversified Scientific Services, LLC, Florida, and Northwest facilities)
- Waste Control Specialist, LLC
- Clean Harbors, LLC (Deer Park, Texas; El Dorado, Arkansas facilities)
- Energy*Solutions* (Clive, Utah; Bear Creek, Tennessee facilities)

7.3 DATA MANAGEMENT

7.3.1 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.

7.3.2 Paducah OREIS

Paducah OREIS is the database used to consolidate data generated by the Environmental Monitoring 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 Environmental Monitoring and Sample Management Office Project 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 this Annual Site Environmental Report) 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*, Section 8.4 (DOE 1998b)]. Environmental data loaded to Paducah OREIS have been assessed, verified, and validated (if applicable), as specified in CP3-ES-5003, *Quality Assured Data*.

7.3.3 PEGASIS

PEGASIS is designed to provide dynamic mapping and environmental monitoring data display. PEGASIS allows public access to environmental sampling data and site-specific geographic information system features through the Internet. PEGASIS includes analytical sample results from various environmental studies, restoration reports and supporting documents, and maps. Environmental data from Paducah OREIS is loaded into PEGASIS on a quarterly basis. PEGASIS does not contain data related to waste, deactivation, demolition, or facility characterization. Access to PEGASIS is available at https://pegasis.pad.pppo.gov/.

7.3.4 Electronic Data Deliverables

A "results only" electronic data deliverable is requested for all samples analyzed by each laboratory. The results and qualifier information from the electronic data deliverable 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 electronic data deliverables can be issued. Approximately 10% of the electronic data deliverables are checked randomly to verify that the laboratory continues to provide adequate electronic data deliverables.

7.3.5 Data Packages

A Level IV 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 electronic data deliverable, 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 electronically to the Document Management Center for permanent storage.

7.3.6 Laboratory Contractual Screening

Laboratory contractual screening is the process of evaluating a set of data against the requirements specified in the analytical statement of work 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 statement of work is identified and documented.

7.3.7 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 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% of the total data packages. Each of the selected data packages, which make up 5% of the total number of data packages, is validated 100%. From the environmental monitoring data, 101 packages were validated in CY 2020.

Data assessment is the process for assuring that the type, quality, and quantity of data are appropriate for its intended use based on the data quality objectives. 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% 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. Rejected data identified in the verification or validation process are noted as rejected in Paducah OREIS.

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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.

activity—See radioactivity.

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

air stripping—The process of bubbling air through water to remove volatile organic compounds (VOCs) from the water.

ALARA (as low as reasonably achievable)—An approach to radiation protection to manage and control releases of radioactive material to the environment, and exposure to the work force and to members of the public so that the levels are ALARA, taking into account societal, environmental, technical, economic, and public policy considerations. As used in DOE Order 458.1, ALARA is not a specific release or dose limit, but a process that has the goal of optimizing control and management of releases of radioactive material to the environment and doses so that they are far below the applicable limits of DOE Order 458.1 as reasonably achievable.

ALARA process—A graded process for evaluating alternative operations, processes, and other measures for optimizing releases of radioactive material to the environment and exposure to the workforce and to members of the public taking into account societal, environmental, technical, economic, and public policy considerations to make a decision concerning the optimum level of public and environmental protection. A graded approach provides the flexibility to perform qualitative or quantitative ALARA analyses. For low doses, qualitative evaluations normally will suffice.

alpha activity—A measure of the emission of alpha particles during radioactive decay. Alpha particles are positively charged particles 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.

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

assimilate—To take up or absorb.

authorized limit—A limit on the concentration or quantity of residual radioactive material on the surfaces or within property that has been derived consistent with U.S. Department of Energy (DOE) directives including the ALARA process requirements. An authorized limit also may include conditions or measures that limit or control the disposition of property.

background radiation—Radiation from: (1) naturally occurring radioactive materials that have not been technologically enhanced [i.e., background radiation does not include technologically enhanced naturally occurring radioactive material (TENORM)]; (2) cosmic sources; (3) global fallout as it exists in the environment (such as from the testing of nuclear explosive devices); (4) radon and its decay products in concentrations or levels existing in buildings or the environment that have not been elevated as a result of

current or prior activities; and (5) consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation.

beta activity—A measure of the emission of beta particles during radioactive decay. Beta particles are negatively charged particles 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.

biota concentration guide (BCG)—The limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose limits for protection of populations of aquatic and terrestrial biota (as used in DOE technical standard, DOE-STD-1153-2019) to be exceeded.

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

clearance of property—The removal of property that contains residual radioactive material from DOE radiological control under 10 *CFR* Part 835 and DOE Order 458.1.

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.

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 radioactive material on the surfaces of structures, areas, objects, or personnel; or introduction of microorganisms, chemicals, toxic substances, wastes, or wastewater into water, air, and soil in a concentration greater than that found naturally.

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.

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—The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

detected value—The value reported by the laboratory for an analysis that the laboratory or a third-party data validator does not qualify with a "U" or "<."

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

dose—A general term for absorbed dose, equivalent dose, effective dose, committed equivalent dose, committed effective dose, or total effective dose, as defined by DOE Order 458.1.

- **absorbed dose**—The average energy imparted by ionizing radiation to the matter in a volume element per unit mass of irradiated material. Absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 Gy).

- **effective dose equivalent/dose equivalent/equivalent dose (H_T)**—40 *CFR* Part 61 Subpart H uses the term effective dose equivalent, 40 *CFR* Part 141 uses the term dose equivalent and DOE Order 458.1 uses the term equivalent dose. While the terms are different, the definition can be summed up using the definition from DOE Order 458.1. The product of average absorbed dose ($D_{T,R}$) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (W_R). For external dose, the equivalent dose to the whole body is assessed at a depth of 1 cm in tissue; the equivalent dose to lens of the eye is assessed at a depth of 0.3 cm in tissue, and the equivalent dose to the extremity and skin is assessed at a depth of 0.007 cm in tissue. Equivalent dose is expressed in units of rems (or sieverts).

- **committed equivalent dose ($H_{T,50}$)**—The equivalent dose calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed equivalent dose is expressed in units of rems (or sieverts).

- **committed effective dose (E_{50})**—The sum of the committed equivalent doses to various tissues or organs in the body ($H_{T,50}$), each multiplied by the appropriate tissue weighting factor (W_T)—that is, $E_{50} = \Sigma W_T H_{T,50} + W_{Remainder} H_{Remainder,50}$, where $W_{Remainder}$ is the tissue weighting factor assigned to the remainder organs and tissues and $H_{Remainder,50}$ is the committed equivalent dose to the remainder organs and tissues. Committed effective dose is expressed in units of rems (or sieverts).

- **effective dose (E)**—The summation of the products of the equivalent dose received by specified tissues or organs of the body (H_T) and the appropriate tissue weighting factor (W_T)—that is, $E = \Sigma W_T H_T$. It includes the dose from radiation sources internal and/or external to the body. For purposes of compliance with DOE Order 458.1, equivalent dose to the whole body may be used as effective dose for external exposures. The effective dose is expressed in units of rems (or sieverts).

- **total effective dose**—The sum of the effective dose (for external exposures) and the committed effective dose.

- **collective dose**—The sum of the total effective dose to all persons in a specified population received in specified period of time. For clearance of property the collective dose refers to the population

potentially exposed to the cleared property. Collective dose is expressed in units of person-roentgen equivalent man (rem) (or person-sievert).

downgradient—In the direction of decreasing hydrostatic head.

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.

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.

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 radionuclide has a unique half-life.

hardness—The amount of dissolved calcium and magnesium in water.

high-level waste—High-level radioactive waste 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.

internal exposure—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.

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).

laboratory 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.

limited area—The industrial area at the Paducah Site, comprising approximately 615 acres.

low-level waste—Low-level waste is radioactive waste that is not high-level waste; spent nuclear fuel; transuranic waste; byproduct material (as defined in Section 11e.(2) of the *Atomic Energy Act of 1954*, as amended); or naturally occurring radioactive material.

maximally exposed individual (MEI)—A hypothetical individual who, because of realistically assumed proximity, activities, and living habits, would receive the highest radiation dose, taking into account all pathways, from a given event, process, or facility.

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

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.

personal property—Property of any kind, except for real property.

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.

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

process water—Water used within a system process.

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.

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 weighting factor (W_R)—The modifying factor used to calculate the equivalent dose from the average tissue or organ absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate radiation weighting factor.

radioactivity—The spontaneous discharge of radiation from atomic nuclei. This is usually in the form of beta or alpha radiation, together with gamma radiation. Beta or alpha emission results in transformation of the atom into a different element, changing the atomic number by +1 or -2 respectively.

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.

real property—Land and anything permanently affixed to the land such as buildings, fences, and those things attached to the buildings, such as light fixtures, plumbing, and heating fixtures, or other such items, that would be personal property, if not attached.

record of decision—A public document that explains which cleanup alternatives will be used to clean up a Superfund site.

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.

reportable quantity—An amount set by a regulation in which release to the environment must be reported to regulatory agencies.

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

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

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

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.

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.

TENORM—Any naturally occurring radioactive materials whose radionuclide concentrations or potential for human exposure have been increased above levels encountered in the natural state by human activities.

terrestrial radiation—Ionizing radiation emitted from radioactive materials, primarily K-40, 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.

tissue weighting factor (W_T)—The fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The equivalent dose to tissue, (H_T), is multiplied by the appropriate tissue weighting factor to obtain the effective dose (E) contribution from that tissue.

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

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

upgradient—In the direction of increasing hydrostatic head.

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.

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