2019
PADUCAH SITE
Annual Site Environmental Report

This report is intended to fulfill the requirements of U.S. Department of Energy Order (DOE) 231.1B. The data and information contained in this report were collected in accordance with the Paducah Site Environmental Monitoring Plan (FRNP 2019a) 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-0137

Paducah Site
Annual Site Environmental Report
for Calendar Year 2019

October 2020

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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ACRONYMS

AFFF	aqueous film forming foam
ALARA	as low as reasonably achievable
ASL	approved suppliers list
BCG	biota concentration guide
CAP-88	Clean Air Act Assessment Package—Version 4.0.1.17
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
HWMFP	Hazardous Waste Management Facility Permit
HSWA	Hazardous and Solid Waste Amendments
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
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
MCS	Mid-America Conversion Services, LLC
N/A	not applicable
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOV	notice of violation
OREIS	Oak Ridge Environmental Information System
PEGASIS	PPPO Environmental Geographic Analytical Spatial Information System
PEM	palustrine emergent
PEMS	Project Environmental Measurements System
PGDP	Paducah Gaseous Diffusion Plant
PFAS	per- and polyfluoroalkyl substances
PFO	palustrine forested
PPPO	Portsmouth/Paducah Project Office
QA	quality assurance
QC	quality control

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
VOC	volatile organic compound
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 2019* 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
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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.

Figure ES.1. A Deer Peers Through the Woods at the Paducah Site

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:

- 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.

DOE conducts environmental monitoring to assess the impact, if any, that site activities may have on public health and the environment. In 2019, more than 2300 samples of air, water, direct radiation, vegetation, fish, and wildlife were collected from on and around the Paducah site and analyzed for radioactive and nonradioactive contaminants.

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.

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: A summary of compliance with laws and regulations;

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

Chapter 4: The 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: Which discusses the actions taken to ensure the quality of information from field sampling to analytical laboratory to data management.

Major sampling components of environmental monitoring completed by DOE in 2019 are summarized below:

- Discharges of radionuclides, chemicals, and other water quality parameters to Bayou Creek and Little Bayou Creek were measured at 15 locations called Kentucky Pollutant Discharge Elimination System (KPDES) Outfalls.
- External radiation was measured continuously at 51 on-site and off-site locations. The measurements were collected quarterly.
- Ambient air was sampled at nine locations on-site and off-site, and 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. Surface water samples were also collected from two locations on-site, and analyzed for metals and volatiles, and one location off-site, and analyzed for trichloroethene.
- Sediment was sampled at six locations and analyzed for radionuclides and 14 locations for polychlorinated biphenyls (PCBs).
- Biota sampling includes 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.

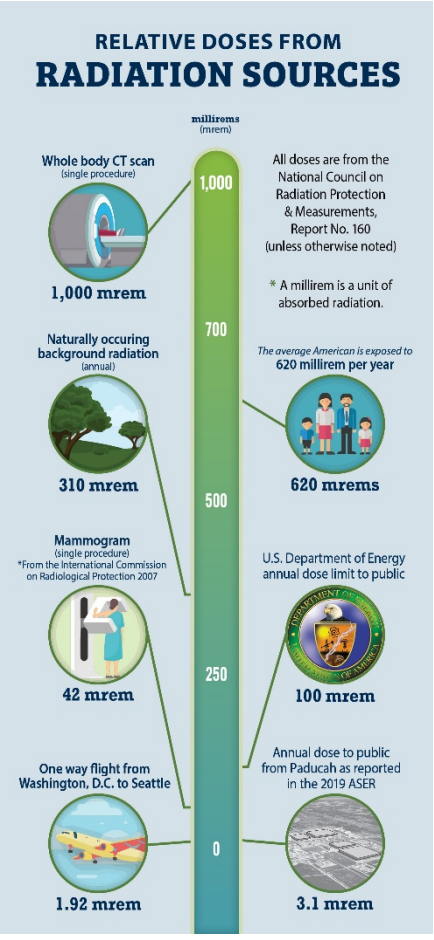

Figure ES.2. Relative Doses from Radiation Sources

2019 Environmental Performance Summary

In 2019, DOE's monitoring performance at Paducah is summarized below:

- Environmental monitoring data collected in 2019 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.
- The dose of radiation (based on calculations) that could be received by a member of the public from all pathways of

exposure was 3.1 millirem (mrem)/year, which is approximately 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 2019. Groundwater programs continue to remediate contamination in off-site groundwater plumes and on-site source areas.

- 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.

- Levels of radionuclides in sediments in 2019 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. Concentrations in sediment samples were detected ranging from 2.59 µg/kg to 378 µg/kg, within the acceptable risk range established by the U.S. Environmental Protection Agency (EPA).

During 2019, Paducah reported the following:

- Four drums of hazardous waste were not being managed in the appropriate storage location. Once discovered, these containers were relocated to a compliant storage facility and later shipped off-site for final disposal. There were no spills or releases to the environment associated with these containers.

- The site received results from an EPA inspection conducted to determine compliance with Risk Management Program regulations associated with chemical accident protection. EPA provided a list of potential violations related to administrative and procedural requirements such as labeling, roles and responsibilities documentation, and compliance certification. Changes in documentation were made to the appropriate procedures to address the administrative issues identified by EPA.

- Two Notices of Violation (NOVs) were issued by the Kentucky Division of Water (KDOW) related to a fish die-off event that was caused by accidentally over dispensing sodium hypochlorite, which is used for disinfection, during a temporary change in operations at the C-615 Sewage Treatment Plant. As a result of the over dispensing, Outfall 008 exceeded the KPDES permit limit for pH. An alternate disinfection process was developed to prevent future reoccurrence.

- The KPDES Permit requires toxicity sampling for some permitted outfalls. KPDES Outfall 001 experienced two noncompliant sampling results for toxicity in July and October. Accelerated follow up testing was completed for each sample that failed the toxicity limit and each produced passing results. No additional actions were necessary and there were no environmental impacts related to the toxicity events.

- During a KDOW inspection of the C-611 Water Treatment Plant, one sample for chlorine residual was found to be below the 0.20 mg/L threshold for free residual chlorine. All other samples analyzed during the month (99% of total) were within the acceptable chlorine residual range. No follow up actions were required because the overall regulatory requirement was met.

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 2019 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.

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) 2019 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);[1] 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).

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

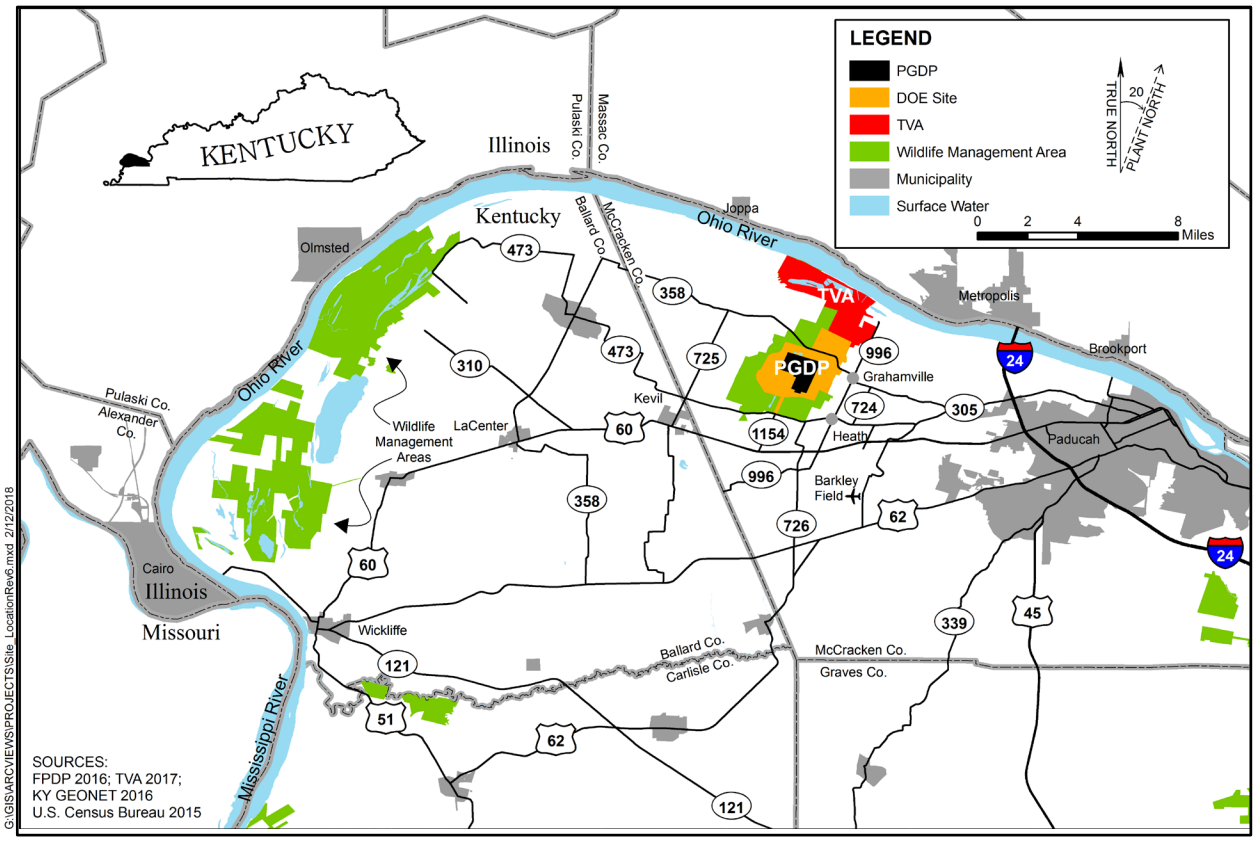

Figure 1.1. Location of the Paducah Site

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 2019, 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 2019a).

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 has 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.

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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 2019 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 2019

Document/Activity	Date Due	Date Completed
Site Management Plan Fiscal Year (FY) 2018 and FY 2019 D2/R1	4/28/2019	4/26/2019
CY 2018 CERCLA Five-Year Review for Remedial Actions D2	5/31/2019	5/17/2019
Site Management Plan FY 2018 and FY 2019 D2/R2	8/20/2019	8/20/2019
C-400 Remedial Investigation/Feasibility Study Work Plan D2	9/19/2019	9/18/2019
90% Remedial Design Report for Solid Waste Management Unit (SWMU) 211-A for VOC Sources to the Southwest Groundwater Plume D1	11/8/2019	11/7/2019
Site Management Plan FY 2020 D1	11/15/2019	11/15/2019
SWMU 211-A Enhanced *In Situ* Bioremediation for VOC Sources to the Southwest Groundwater Plume Remedial Action Work Plan D1	12/8/2019	12/5/2019
Certified for Construction Remedial Design Report for SWMU 211-A for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky	1/4/2020	12/19/2019

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 manages hazardous waste under RCRA, but is not required to have a permit as a small quantity generator. On August 28, 2019, the Kentucky Division of Waste Management (KDWM) conducted a site inspection of the DUF_6 facility. During inspection of the waste accumulation areas, it was noted that containers of waste had hazardous waste labels; however, labels indicating the type of hazard were missing. This condition was noted on the inspection form as "Out of Compliance-Violations Documented," but was corrected the same day with no follow-up needed from KDWM. This was documented in the KDWM Compliance Inspection Report dated August 30, 2019.

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 2019, one issue was reported. The compliance issue was related to four accumulation containers of hazardous waste that were not being managed in a satellite accumulation area or RCRA-permitted waste storage facility. Four 55-gal drums of low-level waste were found in a generator storage area; the drums contained concentrations that exceeded the Toxicity Characteristic Leaching Procedure limits for one or more analytes, indicating it was mixed low-level waste. These containers were relocated to a compliant storage facility and later shipped off-site for final disposal. There were no spills or releases to the environment associated with these containers.

On April 1, 2019, KDWM granted approval for on-site treatment to complete a one-time, short-duration neutralization and scrubbing of fluorine and chlorine trifluoride for ongoing hazardous material removal. This neutralization process resulted in a less hazardous waste that allows for safer storage, transport, and disposal.

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 January 1 to December 31, 2019, no addition of mixed low-level waste was added to the Site Treatment Plan (DOE 2020a).

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 prevention 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.

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 construction of a new substation at the DOE Paducah Site. A categorical exclusion was approved for the design and construction of a new electrical distribution system at the DOE Paducah Site to bypass the existing C-531 Switchyard. Numerous minor activities conducted in 2019, such as routine maintenance, small-scale facility modifications and demolition, site characterization, facility deactivation, and utility consolidation, were within the scope of an approved environmental impact statement, environmental assessment, or categorical exclusions. The DOE Paducah Site Office and the PPPO NEPA compliance officer approve and monitor the internal applications of previously approved categorical exclusion determinations. 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. On December 14, 2015, DOE issued a Finding of No Significant Impact. A link to the final environmental assessment and finding is found below.[2]

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.

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). PPPO initiated Supplement Analysis for Bulk Hydrogen Storage Construction at the Paducah and Portsmouth DUF_6 Sites in 2019 to analyze the addition of a bulk hydrogen storage backup supply. This bulk hydrogen storage backup supply will be utilized such that uninterrupted hydrogen supply is maintained to plant operations. On November 19, 2019, DOE issued the Supplemental Analysis (DOE/EIS-0359-SA-02 and DOE/EIS-0360-SA-02), and a link to the final analysis is found at https://www.energy.gov/sites/prod/files/2019/11/f68/eis-0359-sa-02-eis-0360-sa-02-final-duf6-2019-11-19.pdf.

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

[2] http://www.energy.gov/pppo/downloads/paducah-gaseous-diffusion-plant-final-environmental-assessment-potential-land-and.

mixtures is obtained by the EPA; and (2) to provide the means by which the EPA can regulate chemical substances/mixtures [e.g., polychlorinated biphenyls (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 Toxic Substances Control Act. The Compliance Agreement between DOE and EPA for the Toxic Substances Control Act went into effect on February 20, 1992 (EPA 1992); subsequently it was modified on September 25, 1997 (BJC 1998), and it was 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 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 2019 are documented in the Annual Compliance Agreement Report for the Paducah Gaseous Diffusion Plant (FRNP 2020a) and the PCB Annual Document (FRNP 2020b).

In February 2019, during container reviews for shipment preparations, Waste Management personnel identified a drum containing oil from the C-337 Transformer project that contained PCBs. The drum included a Date-to-Storage of October 10, 2017, and had been stored in an accumulation area until it was completely filled on January 29, 2019. At that time, the drum was moved to the C-752-A Waste Storage Facility. The drum exceeded the one-year storage allowance specified by TSCA regulations and the TSCA Compliance Agreement. The Date-to-Storage dates are considered to start when the waste first is placed into a storage container. Once discovered, the drum was characterized immediately and scheduled for shipment and off-site disposition. Corrective actions to minimize the potential reoccurrence also were implemented. A review was performed on PCB accumulation areas, and no other noncompliant containers were identified.

2.2 RADIATION PROTECTION

The Atomic Energy Act of 1954 provides authority to DOE to implement DOE Order 458.1, *Radiation Protection of the Public and the Environment,* and DOE Order 435.1, *Radioactive Waste Management.* These orders establish requirements for protection of the public and the environment against any undue risk associated with radiological activities and ensures radioactive waste management is conducted in a safe manner that is protective of the worker, public, and the environment. Authorized Limits have been approved for a KDWM-permitted solid waste landfill at the Paducah Site and for DOE-owned property outside the Limited Area. DOE uses these Authorized Limits to establish concentrations or quantities of residual radioactive material that are protective of human health and the environment and are allowed on or within waste to be disposed of in landfills, on or within materials to be reused by the public, or on land and buildings to be transferred to the public. Additionally, Authorized Limits have been approved for unrestricted release of aqueous hydrofluoric acid generated during DUF_6 conversion operations for reuse; for shipping low-level waste to Waste Control Specialists, LLC, RCRA Landfill; and

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.

for disposal of waste containing residual radioactive materials at the Energy*Solutions* Carter Valley Landfill, Tennessee.

These authorized limits implement DOE Order 458.1 and ensure that doses to the public meet DOE standards and are ALARA, that groundwater is protected, that future remediation would not be needed, and that no radiological protection requirements are violated.

The Paducah Site, including the quality assurance (QA) programs, complies with DOE Order 435.1 and DOE Order 458.1. The programs described below outline ways the Paducah Site complies with these DOE Orders.

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

To help ensure compliance with the requirements of DOE Order 458.1 for the Paducah Site, DOE contractors implement an Environmental Radiation Protection Program (ERPP). The goals of the ERPP are as follows:

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

(2) To control the radiological clearance of real and personal property (see "clearance of property" in glossary);

(3) To ensure that potential radiation exposures to members of the public are ALARA;

(4) To monitor routine and nonroutine radiological releases and to assess the radiation dose to members of the public; and

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

2.2.2 DOE Order 435.1, Radioactive Waste Management

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.

CERCLA response actions also were a source of air emissions in 2019. 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 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. FRNP will evaluate the Consent Agreement and Final Order when issued and determine if FRNP will settle or pursue other options.

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 2019b). Radionuclide sources at the Paducah Site in 2019 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 2020d).

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.

During CY 2019, KDEP, Division of Water, issued two Notices of Violation (NOVs) for a fish die-off event that had occurred on March 7, 2019. The fish die-off event was caused by accidentally over dispensing sodium hypochlorite, which is used for disinfection, during a temporary change in operations at the C-615 Sewage Treatment Plant. During a temporary shutdown of the sanitary water system, the disinfection process at the C-615 Sewage Treatment Plant had been changed to a manual sodium hypochlorite feed that accidentally was overfed and resulted in a fish die-off at KPDES Outfall 008. The first NOV was issued for failure to operate and maintain facilities and equipment properly and failure to disinfect using an approved process. A second NOV was issued due to an Outfall 008 pH exceedance caused by overfeeding sodium hypochlorite. On September 24, 2019, FRNP was notified by KDEP that the case had been referred to the Kentucky Division of Enforcement of KDEP. During late CY 2019 and early CY 2020, FRNP and KDEP reached a settlement that consisted of an adjusted civil penalty and submittal of an alternate disinfection process description and 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. Implementation of the alternate disinfection process is scheduled for CY 2020.

The KPDES Permit requires quarterly toxicity testing for some permitted outfalls. KPDES Outfall 001 experienced two noncompliance events for toxicity failures during CY 2019. The CY 2019 toxicity failures occurred in July and October as part of the required, permitted quarterly testing. Accelerated follow-up testing was completed for each toxicity failure as required by the Permit, each produced passing results.

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

KDEP was notified of the toxicity failures and passing results in accordance with KPDES Permit reporting requirements. The Outfall 001 toxicity exceedance resulted in an NOV for failing to comply with Whole Effluent Toxicity limits specified in the KPDES Permit. 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. No environmental impacts related to the toxicity events were observed during the July and October monitoring periods.

Additional information on KPDES exceedances is provided in Table 2.2.

Table 2.2. KPDES Exceedances in CY 2019

Outfall	Parameter	Number of Permit Exceedances	Number of Samples Taken	Number of Compliant Samples	Percent Compliance	Month of Exceedance
008	pH	1	16	15	94%	March
001	Toxicity	2*	8	6	75%	July and October

*The July exceedance did not result in an NOV.

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 chronic whole effluent toxicity testing once per quarter at CERCLA Outfall 001 (DOE 2017a). During CY 2019, the 3rd Quarter CERCLA Outfall 001 sample results were received on July 26, 2019, and produced one failed toxicity test. To evaluate for continued toxicity, a follow-up test was conducted on August 4, 2019, that produced passing results. No further actions were taken because the follow-up test passed.

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), the Paducah Site implements energy and water audits. These audits typically cover the building shell, lighting, possible deployment of occupancy sensors, and leaking 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 2019. 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.

During CY 2019, 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 regulations. As part of the September 9, 2019, inspection, the inspectors collected and analyzed chlorine residual at a distribution point that was found to be below the 0.20 mg/L threshold for free residual chlorine. The regulations for disinfection treatment state that the chlorine residual cannot be undetectable in more than

5% of the samples each month. All other samples analyzed during the month (99% of total) were within the acceptable chlorine residual range. The KDOW inspection report noted the September 9, 2019, chlorine residual sample result as an out-of-compliance condition; however, no follow up action was required because the overall regulatory requirement was met.

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 2.3 includes 16 federally listed species that have been identified as potentially occurring at or near the Paducah Site. While there are potential habitats for endangered species on DOE property, none of the federally listed or candidate species has been found on DOE property at the Paducah Site, although potential summer habitat exists for the Indiana Bat (Garland 2008). No DOE projects at the Paducah Site during 2019 adversely impacted any of these identified species or their potential habitats.

Table 2.3. 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 2020).

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).

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 2019 include building demolition debris, asbestos-containing materials, boundary control station waste, and other dry active wastes generated during deactivation activities. Table 2.4 provides a summary of Authorized Limit disposal at the C-746-U Landfill during CY 2019, and the cumulative totals since Authorized Limit disposal began in May 2003.

Table 2.4. C-746-U Landfill Authorized Limit Disposal

Cumulative Activity from 2019 Disposal			Total Activity from Disposal 5/21/03 to 12/31/19		
Isotope	**Activity (Curies)**		**Activity (Curies)**	**Source Term Limit (Curies)[a]**	**Percent Utilized[b]**
Americium-241	3.55E-04		8.15E-03	79	0.01%
Cesium-137	9.16E-05		1.11E-02	43	0.03%
Neptunium-237	2.51E-04		1.28E-02	12	0.11%
Plutonium-238	4.88E-05		2.05E-03	88	0.00%
Plutonium-239/240	9.19E-04		1.93E-02	162	0.01%
Technetium-99	3.01E-02		1.19E+00	117	1.02%
Thorium-228	3.07E-04		7.21E-02	9	0.80%
Thorium-230	5.75E-03		2.36E-01	230	0.10%
Thorium-232	3.01E-04		7.21E-02	9	0.80%
Uranium-234	1.45E-02		3.79E-01	360	0.11%
Uranium-235	7.86E-04		1.81E-02	15	0.12%
Uranium-238	2.50E-02		4.38E-01	360	0.12%
					Total % 3.23%

Waste streams added (2019)	0
Mass disposed of (2019)	1,650 tons
Mass disposed of (2013–2019)	127,785 tons
Number of cells open	5
Volume of open cells	386,169 yd^3
Volume of usable airspace	145,299 yd^3
Volume of consumed airspace	133,594 yd^3
Volume of remaining permitted airspace	1,045,826 yd^3

Table 2.4. C-746-U Landfill Authorized Limit Disposal (Continued)

[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 units, etc.

SST completed construction of the C-208 Firing Range, which is a 5,749 ft^2 firing range for the Paducah Site Protection Force. Several green building specifications are being met, such as automatic lighting controls that operate light emitting diodes that lower overall energy consumption. 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 will begin 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. Also, several green building specifications will be met, such as automatic lighting controls that operate light emitting diodes and high-efficiency heating, ventilation, and air conditioning systems that lower overall energy consumption. 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.

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 (GHG). 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 2019. 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 2019.

Sections 311 and 312 of EPCRA require businesses to report the safety data sheet, 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 2019, no EPCRA Section 311 notifications were sent since no new chemicals triggered reporting at the Paducah Site in 2019. EPCRA Section 312 requires notification of the locations and quantities of the subject chemicals. The chemicals stored by all DOE contractors in 2019 (including FRNP, MCS, and SST) were included in an EPCRA 312 Report. The chemicals reported were activated carbon, aluminum oxide, aluminum sulfate, biodiesel, diesel fuel, calcium hydroxide, calcium oxide, carbon dioxide, chlorine, concrete mix, cryogenic and gaseous nitrogen, dichlorotetrafluoroethane (R-114), liquid and solid ferric sulfate, ferrous sulfate, fuel oil (No. 2), gasoline, hydrofluoric acid, lead acid batteries, nitric acid, oil, potassium hydroxide, propylene glycol, sodium carbonate, 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 2019. Table 2.5 summarizes the EPCRA reporting status for the Paducah Site for 2019.

Table 2.5. 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 2019.

2.10 UNPLANNED RELEASES

There were no unplanned releases above reportable quantities in 2019.

2.11 SUMMARY OF PERMITS

Table 2.6 provides a summary of the Paducah Site environmental permits maintained by DOE in CY 2019.

Table 2.6. Permits Maintained by DOE for the Paducah Site for CY 2019

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

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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 2019 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 2019a; FRNP 2020c).

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 2019 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[4]

DOE Goal	Current Performance Status	Performance & Plans
Multiple Categories		
Year-over-year (YOY) Scope 1 and 2 GHG emissions reduction from an FY 2008 baseline.	During FY 2019, electrical usage was reduced by 2.5% compared to FY 2018. Natural gas was reduced by 10% 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.
YOY Scope 3 GHG emissions reduction from a FY 2008 baseline.	During FY 2019, the Paducah Site continued implementing a consolidated 4-day/10-hour day workweek schedule with a slight increase in commuter mileage of approximately 5%.	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.

[4] The Paducah Site has one goal that is not listed on this 2019 DOE Sustainability Goal Summary Table. The goal to transfer 500 acres of real property to the public is not listed, but it is documented in FRNP-RPT-0014/R1, *Strategic Plan for Real Property Transfer at the Paducah Site, Paducah, Kentucky,* Date Issued—April 2018.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Energy Management		
30% energy intensity (BTU per gross ft^2) reduction in goal-subject buildings by FY 2015 from a FY 2003 baseline and 1.0% YOY thereafter.	The Paducah Site had usage reductions in electricity, natural gas, and potable water during FY 2019. The Paducah Site footprint was reduced by approximately 17,712 ft^2 with the demolition of 33 small structures/trailers.	The Paducah Site has identified 29 small structures for demolition in FY 2020.
EISA Section 432 continuous (4-year cycle) energy and water evaluations.	The Paducah Site completed an American Society of Heating, Refrigerating, and Air Conditioning Engineers Level I assessment 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 432 energy and water evaluations.
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.
Water Management		
20% potable water intensity (gal per gross ft^2) reduction by FY 2015 from a FY 2007 baseline and 0.5% YOY thereafter.	Overall, potable water usage has decreased by 3% when comparing FY 2019 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.
Non-potable fresh water 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.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Waste Management		
Reduce at least 50% of nonhazardous solid waste, excluding construction and demolition debris, sent to treatment and disposal facilities.	The Paducah Site diverted 61.3% 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.
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 2020 as opportunities are available.	The Paducah Site will continue actively diverting construction and demolition materials as opportunities are available.
Fleet Management		
20% reduction in annual petroleum consumption by FY 2015 relative to a FY 2005 baseline and 2.0 % YOY thereafter.	Interim Target: -4% Current Performance: -17.8%	Opportunities to reduce petroleum consumption will continue to be tracked and reviewed for opportunities for improvements.
10% increase in annual alternative fuel consumption by FY 2015 relative to a FY 2005 baseline; maintain 10% increase thereafter.	Interim Target: -20% Current Performance: 2397.3%	Opportunities to increase E85 usage will continue to be tracked and reviewed on a monthly basis.
75% of light duty vehicle acquisitions must consist of alternative fuel vehicles.	Interim Target: 10% Current Performance: 41%	Opportunities to increase alternative fuel vehicles usage will continue to be tracked and reviewed.
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. Renewable Energy target of 30.5% of total electricity to be from renewable energy sources for FY 2020.	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 20.5% Renewable Energy Certificates for the Paducah Site during FY 2019.	DOE PPPO has purchased Renewable Energy Certificates in the past and may continue in the future.
Continue to increase nonelectric 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.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Green Buildings		
At least 15% (by count) of owned existing buildings to be compliant with the revised Guiding Principles for High Performance Sustainable Building by FY 2020, 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.
Net Zero Buildings: All new buildings (> 5,000 gross ft^2) entering the planning process designed to achieve energy net zero beginning in FY 2020.	No existing Paducah Site 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.
Increase regional and local planning coordination and involvement.	The PGDP Citizens Advisory Board is chartered to provide advice to DOE-Environmental Management located at the Paducah Site. The Citizens Advisory Board provides advice and recommendations related to environmental cleanup priorities and issues at the DOE facility. The Citizens Advisory Board is comprised of individuals from Western Kentucky and Southern Illinois. Members represent business, academia, labor, local government, environmentalists, special interest groups, and the general public. In addition to DOE, EPA, Kentucky, and WKWMA are represented on the board in an advisory capacity.	The Paducah Site will implement as opportunities present themselves. The Citizens Advisory Board will continue as chartered.
Acquisition and Procurement		
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring bio-preferred and bio-based 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, nonozone depleting, contain recycled content, and nontoxic or less toxic alternatives, as appropriate.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Measures, Funding, and Training		
Annual targets for sustainability investment with appropriated funds and/or financed contracts to be implemented in FY 2019 and annually thereafter.	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. Energy audit was completed in main office areas, with 66% compliance with lights and fans off at the end of the day. Paducah Site employees were reminded to switch off the lights in administrative areas at the end of each day.	DOE and Tennessee Valley Authority 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 2020.
Electronic Stewardship		
Purchases—95% of eligible acquisitions each year are Electronic Product Environmental Assessment Tool-registered products.	Interim Target: 95% Current Performance: 98%	The Paducah Site will continue to acquire electronic products that meet or exceed purchasing specifications and standards required for federal agencies.
Power management—100% of eligible personal computers, laptops, and monitors have power management enabled.	Interim Target: 100% Current Performance: 100%	Continue to meet goal.
Automatic duplexing—100% of eligible computers and imaging equipment have automatic duplexing enabled.	Interim Target: 100% Current Performance: 100%	Continue to meet goal.
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.
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	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.
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.

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 2019, the Paducah Site diverted 61.33% 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 2019 were the following (DOE 2020a). 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 10,540 lb of activated carbon, averting disposal.
- Recycled/reclaimed 6 lb of mercury-containing items.
- Recycled 1,535 lb of various light bulbs.
- Recycled 39,423 lb of various batteries.
- Recycled 296,645 gal of non-PCB oil from a C-360 transformer and the C-533 Switchyard.
- Reduced the amount of hazardous chemicals at the Paducah Site by neutralizing 175 lb of fluorine and the 260 lb of chlorine trifluoride inventory on-site. This neutralization process also yielded a significantly less hazardous material and facilitated packaging and shipment off-site for disposal.
- Shipped 17,252 lb of miscellaneous liquids from radiological areas to be burned for energy recovery.

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 2019, the Paducah Site managed an inventory of 50,878 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 octaoxide (U_3O_8), a more stable form of uranium, and hydrofluoric acid sold for commercial use. During 2019, MCS converted approximately 6,335 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 supports investigations and environmental response actions, 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 2019.

- Submitted the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision FY 2018 and FY 2019,* DOE/LX/07-2418&D2/R1 (DOE 2019b).

- Submitted the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision FY 2018 and FY 2019,* DOE/LX/07-2418&D2/R2 (DOE 2019b).

- Received federal and state regulatory approval of the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision FY 2018 and FY 2019,* DOE/LX/07-2418&D2/R2 (DOE 2019b).

- Submitted 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 (DOE 2019c).

- Received federal and state regulatory approval of 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 (DOE 2019c).

- Submitted the *Site Management Plan Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision Fiscal Year 2020,* DOE/LX/07-2444&D1 (DOE 2019d).

- 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&D1 (DOE 2019e).

- Submitted the *30% Remedial Design Report for SWMU 211-A and SWMU 211-B for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2435&D1 (DOE 2019f).

- Submitted the *60% Remedial Design Report for SWMU 211-A for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2435&D1 (DOE 2019f).

- Submitted the *90% Remedial Design Report for SWMU 211-A for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-2435&D1 (DOE 2019f).

- Received federal and state regulatory approval of the *Certified for Construction Remedial Design Report for SWMU 211-A for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2435&D2 (DOE 2019f).

- Submitted the *CY 2018 CERCLA Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX07-2426&D2 (DOE 2019g).

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 2019.

- Completed neutralization of 175 lb of fluorine from C-410-D, and 260 lb of chlorine trifluoride/chlorine difluoride from C-350.

- Completed disposition of excess chemicals, including calcium hydroxide, nitric acid, potassium permanganate, Amerifloc® 490, and ferrous sulfate.

- Continued deactivation of C-400 to include removal of dip tank, removal of 168 internal transite panels, and continued with removal of thermal insulation.

- Completed C-533 utility isolation and drained oil.

- Disposed of 33 small structures/trailers and associated waste.

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 2018a).

DOE continued conducting guided public tours of its Paducah Site in 2019. Twelve tours were conducted in 2019, totaling 408 participants, for the public to learn about the history of PGDP.

3.2.2 Community/Educational Outreach

DOE supported several educational and community outreach activities during 2019 (Figure 3.1). Site employees participated in a "Feds Feed Families" program in which employees brought nonperishable food items to donate to local food pantries.

Figure 3.1. DOE and its Contractors Work with School Students as a Part of its Community Outreach Efforts

DOE and its contractors engaged students through educational outreach programs such as the annual DOE National Science Bowl, for which regional competitions were held in February for Western Kentucky and Southern Illinois middle and high schools. A total of 15 middle schools and 14 high schools participated in the event. DOE and its contractors also supported the Western Kentucky Regional Science Fair, local school career fairs, and a middle school and high school Science, Technology, Engineering, and Math program (Figure 3.2). In 2019, students from the Marshall County School district visited the Paducah Site for development of the annual site environmental report summary.

Figure 3.2. STEM 4 Girls Event

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/.

In 2019, DOE sponsored a 10-week Internship Program for college students to work and be mentored by engineers, project managers, and leaders in the business, safety, and regulatory departments to get a first-hand, realistic perspective of what they would like to do after graduation. A total of 20 students participated in the program.

Figure 3.3. Interns walkdown C-335 Building as part of a Nuclear Criticality Safety posting configuration control project

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. During the CY, the Citizens Advisory Board held several regular board meetings and additional subcommittee meetings.

The Citizens Advisory Board is composed of up to 18 members, representing the general public from western Kentucky and surrounding areas. The Citizens Advisory Board is committed to reflecting the concerns of the communities impacted by environmental management of the plant site. It meets bimonthly to focus on early participation in environmental cleanup priorities and related issues at the DOE facility. 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 generally 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. An active educational series operating in an administrative and preparatory manner to prepare board members and future subcommittees for the task of advising DOE. The educational series was developed based on future project priorities, as selected by the board members, with guidance from DOE (PGDP CAB 2017). The educational series during the CY consisted of the following:

- Paducah Site Baseline
- C-400 Complex Operable Unit
- Deactivation and Non-destructive Assay

All regular board meetings are open to the public and publicly advertised. In addition to its voting members, the Citizens Advisory Board also has liaison members representing EPA Region 4, Kentucky Cabinet for Health and Family Services, and WKWMA.

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 a.m. to 9 p.m., Friday and Saturday from 9 a.m. to 6 p.m., and Sunday from 1 p.m. to 6 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

4.1 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 2019a; FRNP 2020c). 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.

4.1.1 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.

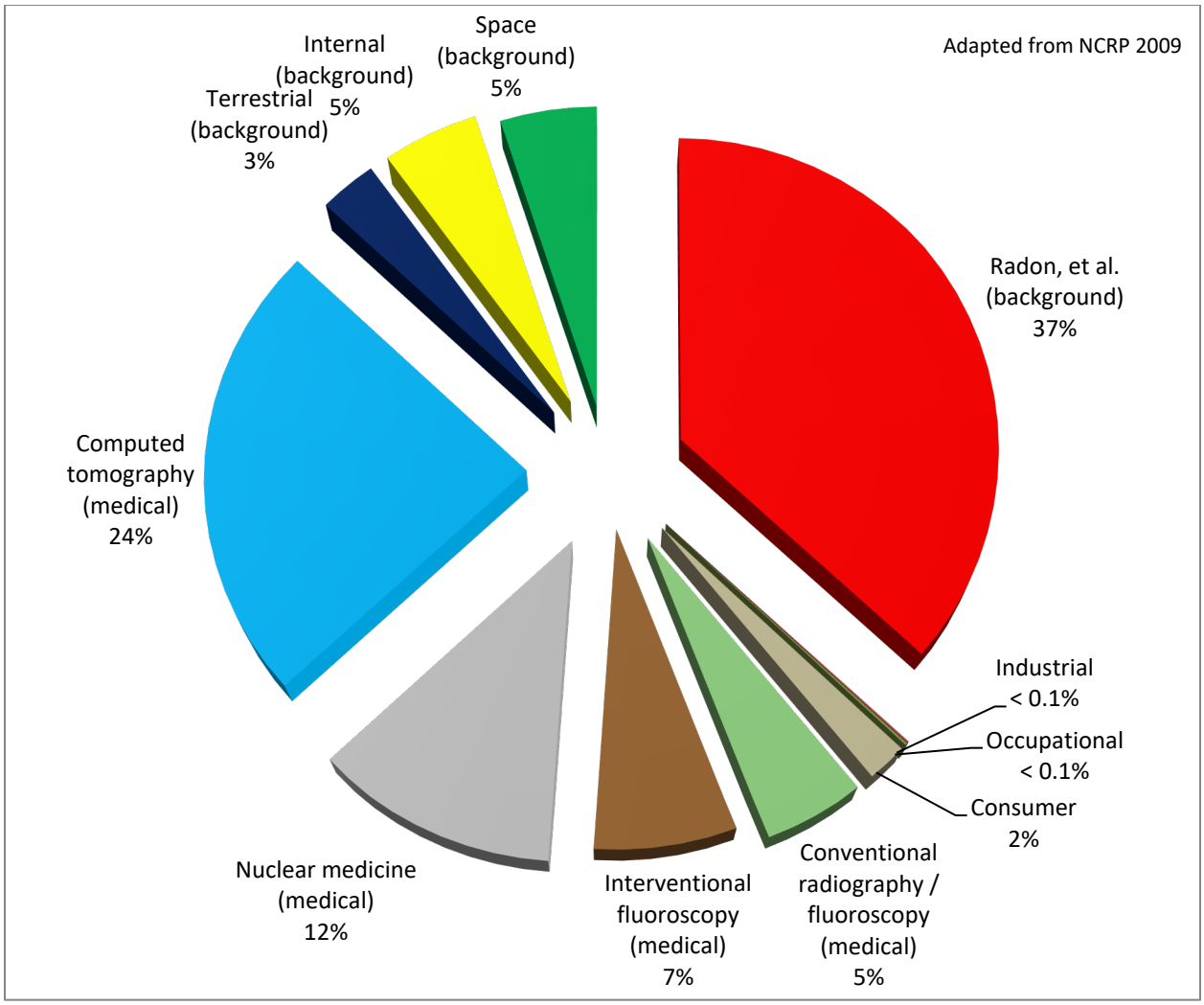

Figure 4.1. Sources of Radiation

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

Section 2.2 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.

4.1.2 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 2019a).

4.1.3 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.

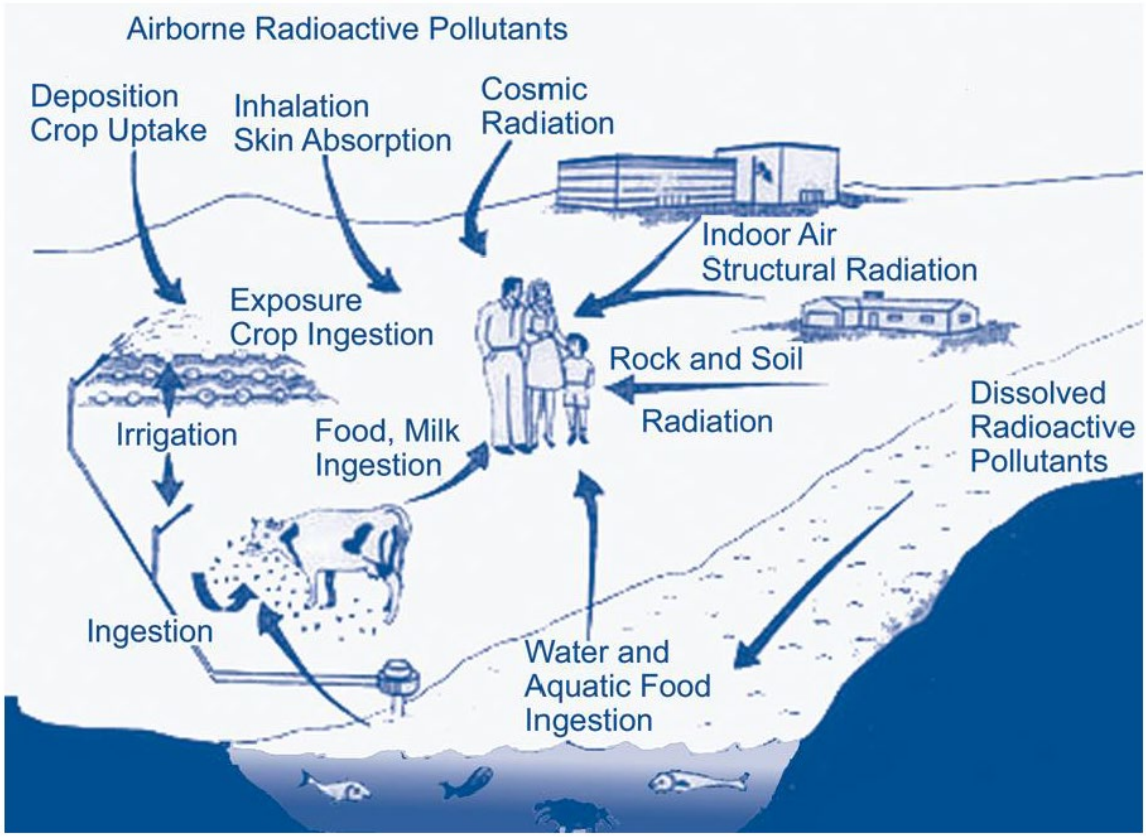

Figure 4.2. Potential Exposure Pathways

4.1.4 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 2019a). 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 maximally exposed individual and the collective total effective dose to the population within a 50-mile radius and estimated background dose (DOE 2011a).

The maximally exposed individual 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 maximally exposed individual 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 maximally exposed individual are to be reasonable and not underestimate the dose or substantially overestimate the dose. The maximally exposed individual 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 2019a).

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 maximally exposed individual 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 maximally exposed individual located at the nearest plant neighbor.

4.1.5 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 2019 were the following:

- Northwest Plume Groundwater Treatment System;
- Northeast Plume Containment System Treatment Units;
- DUF_6 Conversion Facility;
- Laboratory Hoods;
- 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 2019 and FY 2020 Environmental Monitoring Plans (FRNP 2019a; FRNP 2020c).

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 2019 from stacks and diffuse sources on the Paducah Site (Table 4.1) were modeled using the EPA-approved Version 4.0.1.17 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 2019 (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.

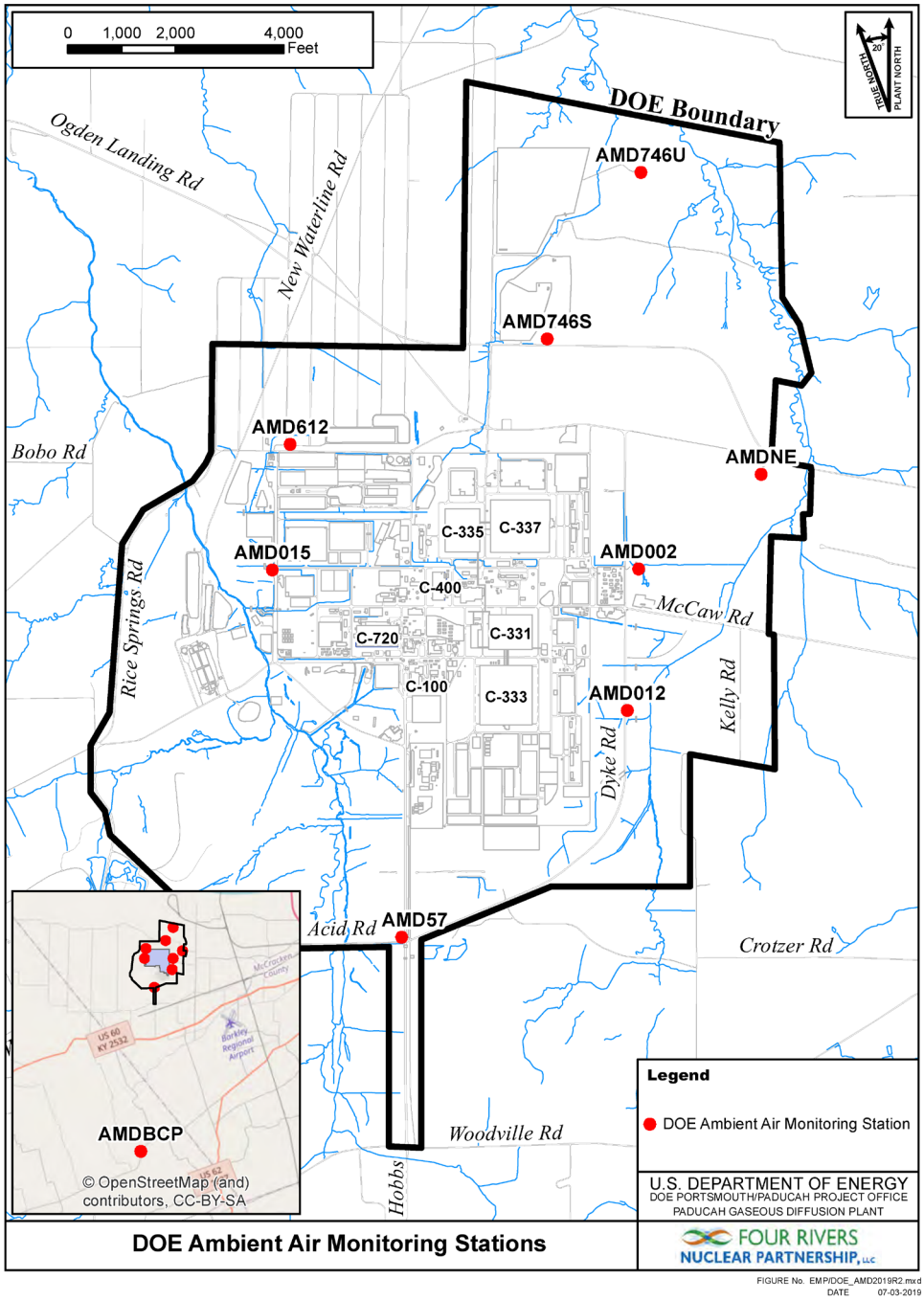

Figure 4.3. Air Monitoring Locations

Table 4.1. Radionuclide Atmospheric Releases for CY 2019 (in Curies) for the Paducah Site*

FRNP Total Radionuclide Emissions (Ci) - CY 2019								
	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	8.07E-05	8.92E-06	3.89E-06	0.00E+00	0.00E+00	1.43E-06	9.50E-05	Tc-99
U-234	0.00E+00	0.00E+00	0.00E+00	5.16E-05	1.03E-06	8.61E-06	6.12E-05	U-234
U-235	0.00E+00	0.00E+00	0.00E+00	2.38E-06	4.70E-08	4.65E-07	2.90E-06	U-235
U-238	0.00E+00	0.00E+00	0.00E+00	8.99E-06	2.52E-06	3.44E-06	1.50E-05	U-238
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.29E-09	3.29E-09	Np-237
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.53E-09	7.53E-09	Pu-239
Th-230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.67E-09	7.67E-09	Th-230
Th-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.69E-07	0.00E+00	1.69E-07	Th-231
Th-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-05	0.00E+00	1.55E-05	Th-234
Pa-234m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E-05	0.00E+00	1.55E-05	Pa-234m
Total	8.07E-05	8.92E-06	3.89E-06	6.30E-05	3.48E-05	1.40E-05	2.05E-04	

*Values are taken from *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2019* (FRNP 2020d).

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 maximally exposed individual 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 maximally exposed individual for each point source could differ from the maximally exposed individual for the plant.

Table 4.2. Dose Calculations for Airborne Releases for CY 2019

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/C-710 Laboratory Hoods	2.00E-05	2.00E-05
Group F—SX/WA Group	5.30E-06	4.30E-06
Northwest Plume Treatment System	5.70E-05	5.70E-05
Northeast Plume Treatment Unit C-765	4.70E-06	1.80E-06
Northeast Plume Treatment Unit C-765-A	1.80E-06	7.40E-07
DUF_6 Conversion Facility	1.80E-06	1.20E-06
Total from All Sources		**8.50E-05**

The individual who would receive the maximum hypothetical cumulative dose from all pathways, also termed the maximally exposed individual, was calculated potentially to receive an effective dose equivalent of 0.0000850 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 2019

Effective Dose to Maximally Exposed Individual (mrem)	Percent of Standard (%)	Collective Effective Dose (person-rem)
8.50E-05	0.000850	5.01E-04

A complete summary of this emissions data can be found in the *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2019* (FRNP 2020d).

4.1.6 Liquid Discharge Monitoring and Estimated Dose from Liquid Effluents

4.1.6.1 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 the 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 conversion factors 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.

For environmental surveillance monitoring, surface water was sampled quarterly at five locations for radiological parameters (L10, L14DWN, L241, L5, and L11) in 2019 (see Figure 4.4). Background location L1 was sampled annually, and L29A was sampled quarterly. Additionally, a location in the Ohio River immediately downgradient of the plant (L30) was sampled annually and a location near the nearest public water withdrawal location, Cairo, Illinois, (L306) was sampled quarterly. 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. Areas removed/remediated as part of a 2010 removal action for contaminated sediment associated with the Surface Water Operable Unit are denoted on Figure 4.4 (DOE 2011b).

Gross alpha and beta analysis is performed at each environmental surveillance surface water location and locations near KPDES-permitted outfalls. If the gross alpha and beta analysis results are greater than 14 pCi/L and 300 pCi/L, respectively, a full isotopic analysis is performed. These values are calculated based on a concentration that would account for 10% of the DCS for common radionuclides at the Site. If, by the end of the CY, isotopic analysis has not been performed at a given location, then isotopic analysis for radionuclides is performed on the final sample within the CY to provide data for trending. Monitoring results are available through the PPPO Environmental Geographic Analytical Spatial Information System (PEGASIS) website at https://pegasis.pad.pppo.gov/.

Locations from which the maximum detected uranium isotopes were collected are just downstream of K015 (location named K015ERPP) for uranium-234, just downstream of K015 (location named K015ERPP) for uranium-235, and just downstream of K011 (location named K011ERPP) for uranium-238 (see Figure 4.4).

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.

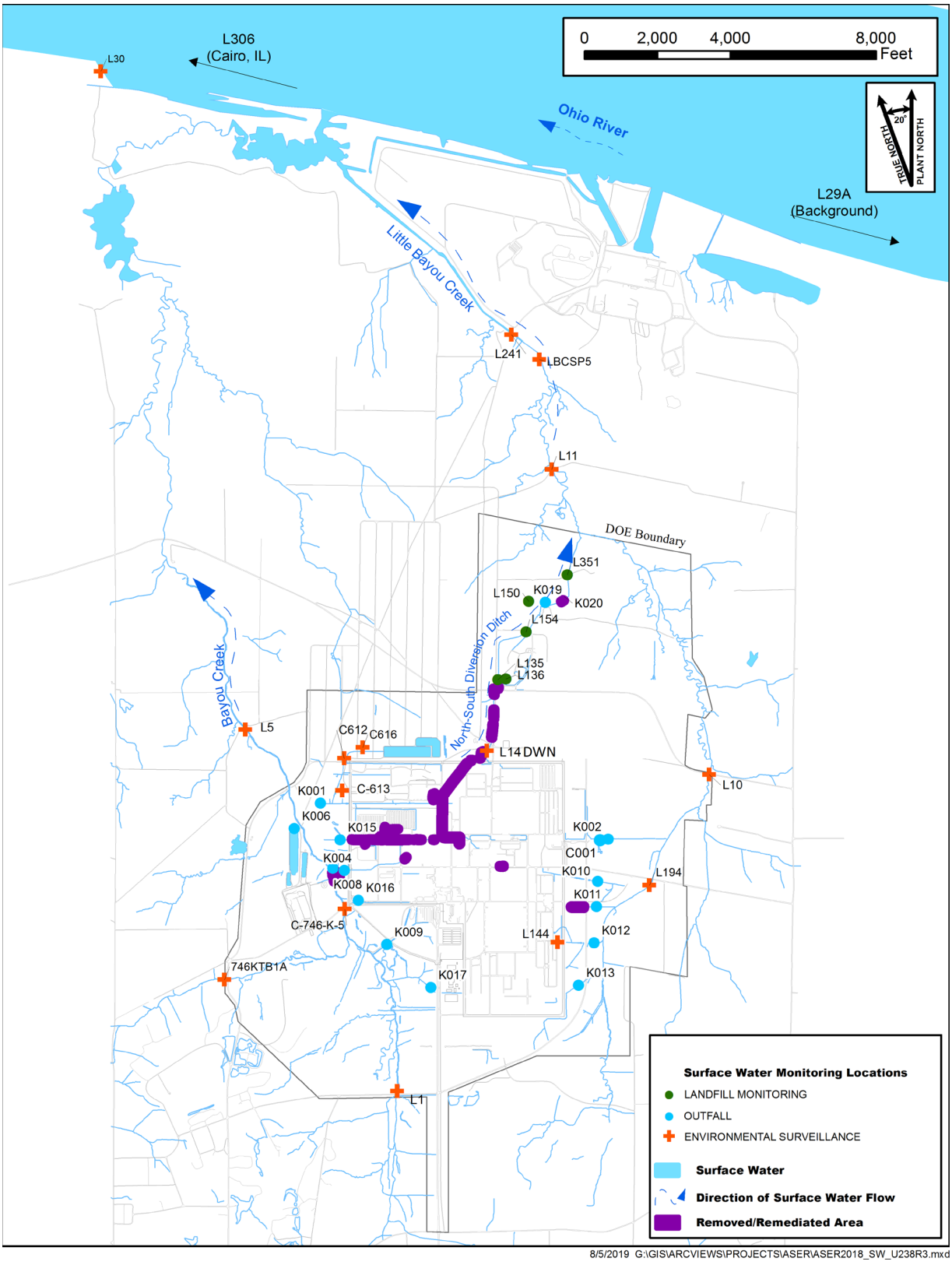

Figure 4.4. Surface Water Monitoring Locations

In addition to surface water monitoring conducted under DOE Orders, the KPDES permit, and the solid waste landfills permit, surface water monitoring is also conducted as a separate monitoring program under CERCLA for the Northeast Plume Containment System effluent via outfall C001. This outfall is monitored for technetium-99 according to the Remedial Action Work Plan for Optimization of the Northeast Plume Interim Remedial Action (DOE 2018b). The highest surface water result for technetium-99 detected 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. No other technetium-99 results were detected in surface water at a location other than C001; therefore, technetium-99 is not used in the dose calculation. 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 PEGASIS website at https://pegasis.pad.pppo.gov/.

4.1.6.2 Drinking water

Surface water from the Paducah Site is not consumed by people as a drinking water source; however, it eventually is discharged into the Ohio River, which is 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 during CY 2019. The maximum beta activity detected was 2.94 pCi/L. The maximum alpha activity detected was 2.97 pCi/L.

The drinking water pathway dose was calculated where a maximally exposed individual 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 2019, therefore, an estimated collective dose has been calculated by multiplying the dose to the maximally exposed individual 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.

4.1.6.3 Incidental ingestion of surface water

Dose to the bounding maximally exposed individual is calculated based on incidental ingestion of surface water due to swimming in Bayou and Little Bayou Creeks and their tributaries (including outfall locations).[5]

[5] The dose to the maximally exposed individual 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.

The assumptions based on *Methods for Conducting Risk Assessments and Risk Evaluations* are that a bounding recreator may swim 45 days a year, for 2.6 hours a day, with an incidental ingestion of 0.05 liters per hour and be in different locations throughout the wildlife management area (DOE 2019a). The highest monthly surface water results from the various sampling locations are utilized to calculate the bounding dose to the maximally exposed individual. The annual dose to the maximally exposed individual from incidental ingestion of surface water is 0.052 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 maximally exposed individual 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 2019 Surface Water Samples

Isotope	Maximum Detect
Technetium-99 (pCi/L)	7.41E+01*
Uranium-234 (pCi/L)	9.28E+00
Uranium-235 (pCi/L)	1.79E+00
Uranium-238 (pCi/L)	3.83E+01

*Technetium-99 detects were found only at location C001. C001 sampling results 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, this sampling result for technetium-99 is not used in the dose calculation.

4.1.6.4 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/.

4.1.6.5 Groundwater

DOE has numerous groundwater monitoring wells, which are more fully described in Chapter 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 maximally exposed individual. Similarly, groundwater as a drinking water source is not considered in the calculation of cumulative dose to the surrounding population.

4.1.7 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.

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 maximally exposed individual 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 maximally exposed individual from incidental ingestion of sediment by a total estimated number of visitors hiking within the WKWMA annually (150 persons), which resulted in a representative collective dose of 0.0094 person-rem/yr (DOE 2019a).

4.1.7.1 Sediment surveillance program

Sediment sampling at the Paducah Site in CY 2019 included radiological and non-radiological constituents (FRNP 2019a). This sampling occurred in June, August, and December 2019. Sampling locations have been 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 (see Section 5.3 for discussion related to non-radiological sediment sampling) and also may be found on the PEGASIS website at https://pegasis.pad.pppo.gov/. The radiological results for CY 2019 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 S28 provides background concentrations for non-radiological sediment sampling; 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.

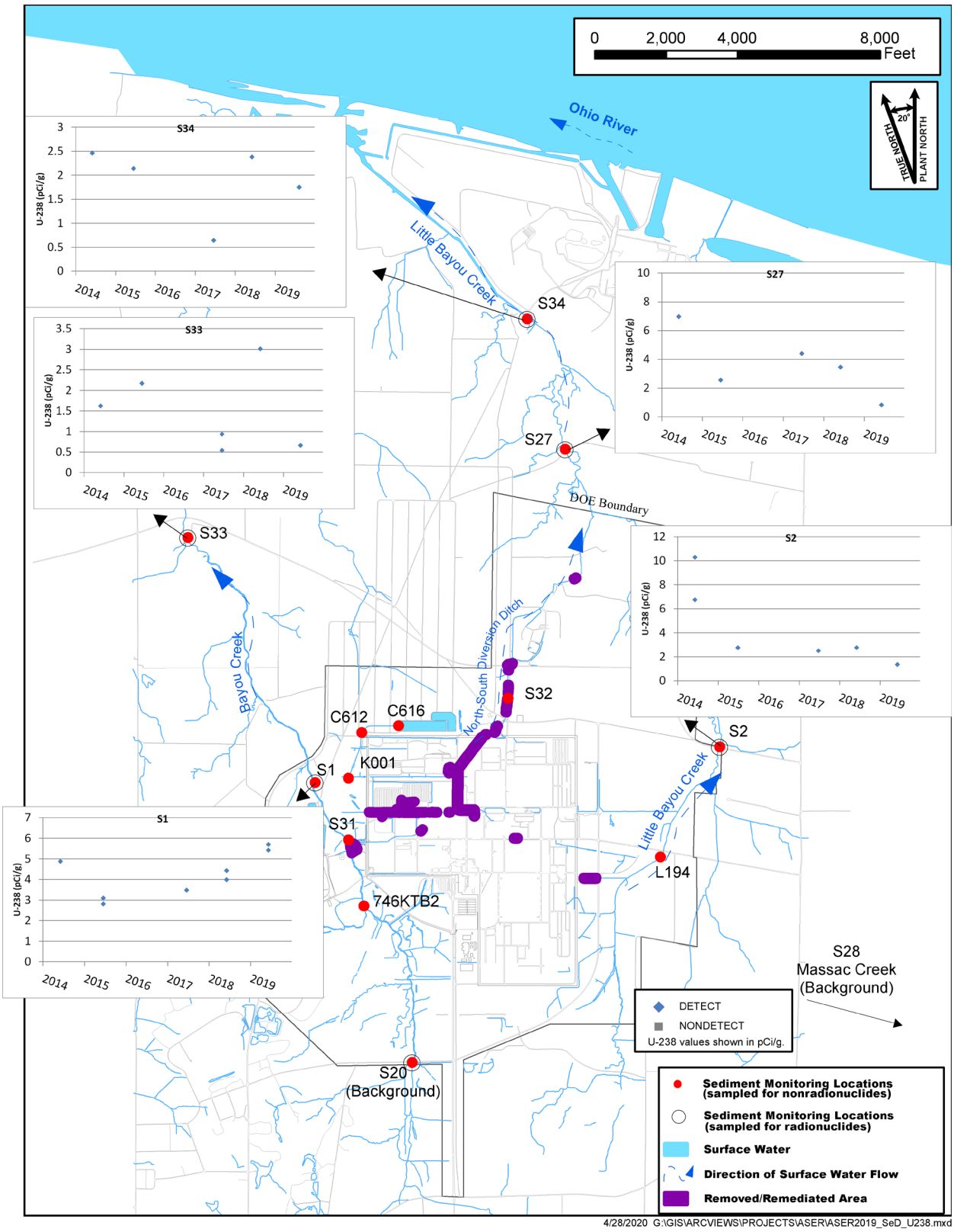

Figure 4.5. Sediment Monitoring Locations with Uranium-238 Trends

Table 4.5. Radiological Activities for Sediment Sampling[a]

Parameter	S1	S1 (duplicate)	S2	S20 (background)	S27	S33	S34
Alpha activity	1.33E+01	1.14E+01	5.97E+00	1.14E+01	1.29E+01	1.04E+01	1.65E+01
Beta activity	3.01E+01	2.28E+01	9.94E+00	1.56E+01	1.26E+01	9.01E+00	1.58E+01
Americium-241	-5.44E-02[b]	-9.32E-02[b]	3.81E-02[b]	-6.11E-02[b]	-1.2E-01[b]	2.03E-02[b]	1.50E-02[b]
Cesium-137	3.17E-02[b]	6.47E-03[b]	-1.28E-02[b]	1.33E-01	-2.05E-02[b]	7.85E-03[b]	1.34E-02[b]
Neptunium-237	1.44E-02[b]	-8.27E-03[b]	-3.48E-02[b]	5.51E-03[b]	2.56E-02[b]	1.01E-01[b]	-1.03E-01[b]
Plutonium-238	1.48E-02[b]	-5.50E-02[b]	-6.16E-02[b]	1.14E-01[b]	1.76E-01[b]	-1.01E-01[b]	1.36E-02[b]
Plutonium-239/240	1.75E-01[b]	9.32E-02[b]	5.54E-02[b]	-1.99E-02[b]	-1.44E-01[b]	2.43E-01[b]	1.71E-01[b]
Technetium-99	1.51E+01	1.68E+01	8.40E-01[b]	2.60E-02[b]	2.06E+00[b]	2.90E-01[b]	2.43E+00[b]
Thorium-230	6.39E-01[b]	6.54E-01	2.41E-01[b]	6.83E-01	9.55E-01	8.93E-01	1.72E+00
Total Uranium	9.31E+00	8.82E+00	1.59E+00	1.08E+00	1.23E+00	1.08E+00	2.78E+00
Uranium-234	3.44E+00	3.19E+00	2.16E-01[b]	7.79E-01	3.10E-01[b]	4.17E-01	8.58E-01
Uranium-235	1.71E-01[b]	2.13E-01[b]	2.10E-02[b]	-1.41E-02[b]	8.64E-02[b]	-3.14E-02[b]	1.74E-01
Uranium-238	5.70E+00	5.42E+00	1.35E+00	2.99E-01	8.29E-01	6.62E-01	1.75E+00

[a] Units are in pCi/g for all.
[b] Result reported at concentrations less than the laboratory's reporting limit. Negative values are possible and observed regularly with radiological data. Negative results may be reported due to a statistical determination of the counts seen by a detector, minus a background count (DOE 2019a).

4.1.7.2 Sediment Dose

For the purpose of calculating dose to the bounding maximally exposed individual, it is assumed that exposure to contaminated sediment in Bayou Creek and Little Bayou Creek could occur during hunting or other recreational activities. Exposure is 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 is calculated based on the radionuclide activity and the amount of exposure via ingestion. Exposure is calculated using the methods presented in the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2019a), 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. Results from background location S20 are subtracted from other sample results to arrive at a dose associated with site releases. The downstream location with the maximum dose is assumed to represent the dose received from this pathway by the maximally exposed individual from the exposure scenario.

Doses are calculated for ingestion of sediments for both Bayou Creek and Little Bayou Creek using the radiological results for sediment surveillance samples for CY 2019. The highest annual dose was calculated to be at location S1 (0.063 mrem/year), downstream at Little Bayou Creek, near the Little Bayou Creek/North-South Diversion Ditch confluence. This dose calculation is based on the assumption that a person continually returns to the same location (i.e., S1). A comparison of sediment sampling data is provided in Table 4.5. Dose results for sediment sample locations are provided in Table 4.6.

4.1.8 Terrestrial Environment Monitoring and Estimated Dose

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).

Table 4.6. Average Annual Dose Estimates for CY 2019 Incidental Ingestion of Sediment

	Total Effective Dose (mrem/year)—Sediment Ingestion										
Location	**Am-241**	**Cs-137**	**Np-237**	**Pu-238**	**Pu-239/ Pu-240**	**Tc-99**	**Th-230**	**U-234**	**U-235**	**U-238**	**Total (mrem)**
S20 (background)[b]	0.00E+00	2.68E-02	3.55E-04	1.08E-03	0.00E+00	8.10E-07	5.94E-03	1.52E-03	0.00E+00	2.69E-03	3.83E-02
S1[b]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-03	4.96E-04	0.00E+00	4.95E-03	8.24E-03	4.74E-02	6.25E-02
S2[b]	3.96E-04	0.00E+00	0.00E+00	0.00E+00	5.68E-04	2.54E-05	0.00E+00	0.00E+00	9.01E-04	9.47E-03	1.14E-02
S27[b]	0.00E+00	0.00E+00	1.30E-03	5.85E-04	0.00E+00	6.34E-05	2.37E-03	0.00E+00	3.71E-03	4.77E-03	1.28E-02
S33[b]	2.11E-04	0.00E+00	6.16E-03	0.00E+00	2.49E-03	8.22E-06	1.83E-03	0.00E+00	0.00E+00	3.27E-03	1.40E-02
S34[b]	1.56E-04	0.00E+00	0.00E+00	0.00E+00	1.75E-03	7.49E-05	9.02E-03	1.54E-04	7.47E-03	1.31E-02	3.17E-02
Net Exposure from Paducah Site to the Maximally Exposed Individual[a,b,c,d] (Downstream Little Bayou) =											**6.25E-02**

[a] Maximum allowable exposure is 100 mrem/year for all contributing pathways and 25 mrem/year from one source (DOE Order 458.1).
[b] Radionuclide dose from S20 is considered background and has been subtracted from Paducah Site-related doses. If location dose is less than background dose or less than zero, the dose is specified as 0.00E+00 mrem/year.
[c] Dose calculated as ratio of listed dose for Adult Recreator in Table A.8 in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE 2019a), which includes the ingestion, inhalation, and external gamma pathways.
[d] When more than one sample is present at the listed location, the doses of each sample are averaged.

4.1.9 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.

4.1.10 Direct Radiation Monitoring and Estimated Dose

4.1.10.1 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. In 2019, environmental thermoluminescent dosimeters (TLDs) with a calcium fluoride and lithium fluoride matrix were placed at the monitoring locations and collected and analyzed quarterly for a period of one year. Optically stimulated luminescence dosimeters were used to monitor for neutron radiation. These monitoring locations are shown in Figure 4.6. Monitoring results indicate that 17 of 51 locations were consistently above background levels, as reported in the *Annual Report on External Radiation Monitoring for Calendar Year 2019, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FRNP 2020e). These locations were adjacent to or in close proximity to publicly accessible areas in the vicinity of UF_6 cylinder storage yards. Because security protocols prohibited the public from gaining prolonged access to the UF_6 cylinder storage yards, the potential radiation doses calculated at or in close proximity to the fence are not directly applicable to the maximally exposed individual dose.

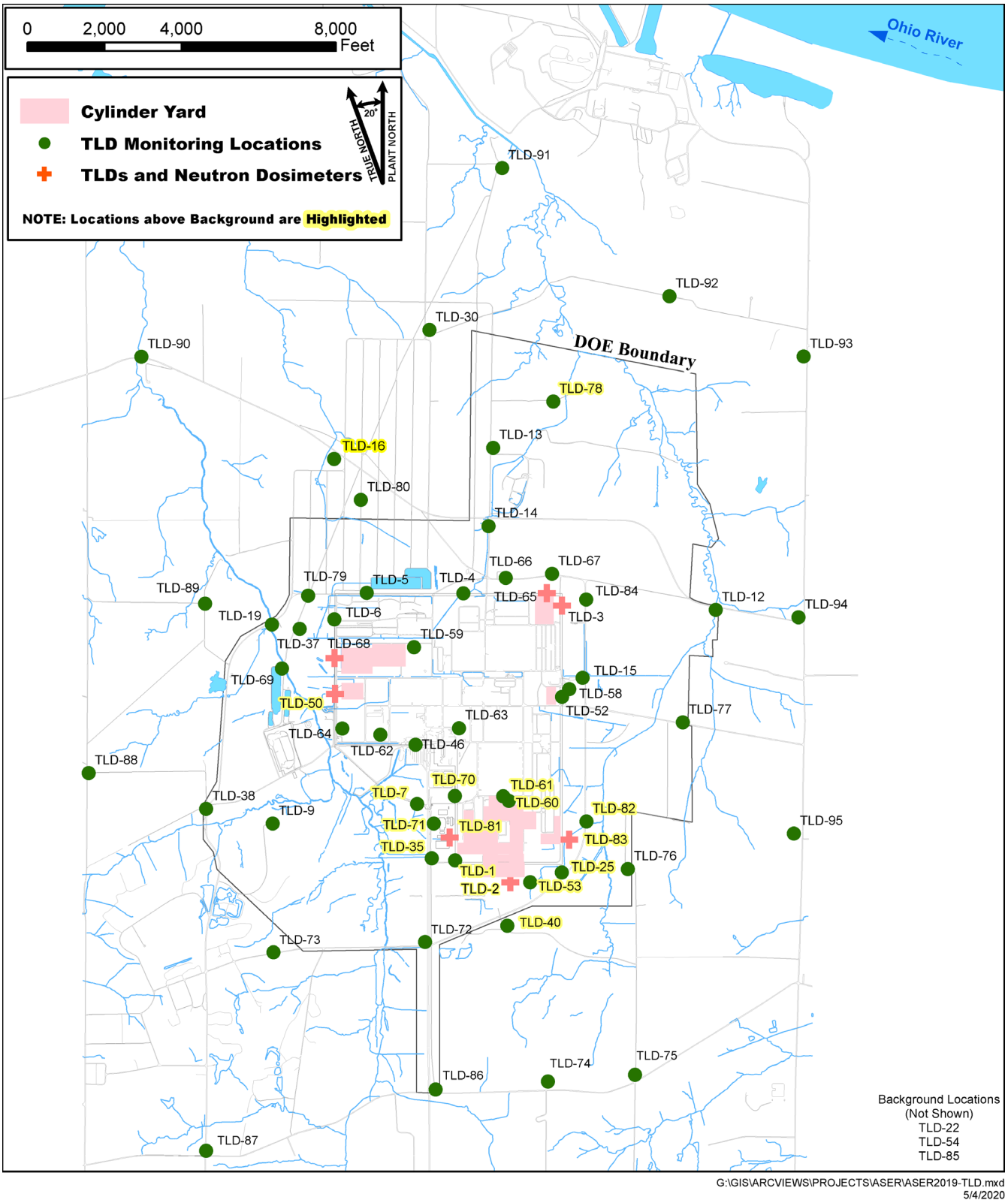

Figure 4.6. Dosimeter Locations in the Vicinity of the Paducah Site

4.1.10.2 Direct radiation dose

Due to Paducah Site security protocols in CY 2019, no members of the public routinely were allowed prolonged access to UF_6 cylinder storage yards. The external radiation doses measured by TLDs in areas accessible to the public were not statistically above background; however, the effective dose potentially received by a member of the public passing through accessible portions of the DOE Reservation would receive 3 mrem/year in a scenario where areas of highest exposure are visited 80 hours/year (DOE 2019a). In 2019, TLD-14 and TLD-40 represented the closest locations that would be accessible to the public. TLD-14, which is near Harmony Cemetery, located north of the plant security fence and south of Ogden Landing Road, represents the nearest location routinely accessible by the public. Measurements at this location indicated external radiation doses statistically equivalent to the background radiation level. In 2019, TLD-40 located on the DOE Reservation boundary with the DOE-leased WKWMA area off of Dyke Road also indicated external radiation dose measured to be slightly above background levels, but below the DOE limit of 100 mrem/year. The maximally exposed individual at the private residences adjacent to the Paducah Site was calculated to be at background levels.

For 2019, an estimated collective dose has been calculated by multiplying the dose to the maximally exposed individual from direct radiation by a total estimated number of visitors hiking within the WKWMA annually (150 persons), which resulted in a representative collective dose of 0.45 person-rem/yr (DOE 2019a).

4.1.10.3 Cumulative dose calculation

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. Table 4.7 provides a summary of the radiological dose for 2019 from the Paducah Site that could be received by a member of the public (i.e., the maximally exposed individual) 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 maximally exposed individual 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 sediments. 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. The combined (internal and external) dose to an individual member of the public was calculated at 3.1 mrem/year. This level is below the DOE annual dose limit of 100 mrem/year to members of the public and the EPA limit of 10 mrem airborne dose to the public. Table 4.7 also shows the percentage of the DOE annual dose limit that is received by the maximally exposed individual.

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 2019a).

The cumulative 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 cumulative population dose from all relevant pathways. The annual cumulative population dose, based on representative assumptions is 0.46 person-rem. Table 4.7 provides a summary of the representative population dose calculations.

Table 4.7. Summary of Potential Radiological Dose to the Maximally Exposed Individual[i] from the Paducah Site for CY 2019[a]

Pathway[a]	Dose to Maximally Exposed Individual (mrem/year)	Percent of DOE 100 mrem/ year Limit	Estimated Collective (Population Dose) (person-rem/year)	Population within 50 miles
Air[c]	8.50E-05	0.0000850%	5.01E-04	~534,116
Water[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	5.20E-02	0.052%	[g]	[g]
Sediments (incidental ingestion)	6.3E-02	0.063%	9.4E-03[h]	150
Direct radiation	3.0E+00	3%	4.5E-01[h]	150
All Relevant Pathways[a]	**3.1E+00[b]**	**3.1%**	**4.6E-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 maximally exposed individual 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 maximally exposed individual 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] Maximally exposed individual is a combination of the maximally exposed individual for each pathway; actual combined maximally exposed individual does not exist due to different locations and identities of maximally exposed individuals.

4.1.11 Biota Monitoring and Estimated Dose

4.1.11.1 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.

4.1.11.2 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 2019 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 4.8 summarizes the radiological dose to aquatic and terrestrial biota for Bayou Creek. Table 4.9 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/.

4.2 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 potentially containing 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.

Table 4.8. Bayou Creek 2019 Evaluation of Dose to Aquatic and Terrestrial Biota[a]

	Aquatic Animal								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	4.38E+02	N/A	Yes	-5.44E-02[c]	6.80E+05	-8.00E-08	No	-8.00E-08
Cs-137	8.42E-01[c]	1.05E+03	8.04E-04	No	3.17E-02[c]	4.93E+04	6.43E-07	No	8.04E-04
K-40	6.15E+00[c]	2.90E+03	2.12E-03	No	N/A	5.79E+04	N/A	No	2.12E-03
Np-237	3.03E-01[c]	6.85E+01	4.42E-03	Yes	1.44E-02[c]	7.86E+04	1.83E-07	No	4.42E-03
Pu-238	2.20E-01[c]	1.76E+02	1.25E-03	Yes	1.48E-02[c]	3.95E+06	3.75E-09	No	1.25E-03
Pu-239[d]	0.00E+00[c]	1.87E+02	0.00E+00	Yes	1.75E-01[c]	7.05E+06	2.48E-08	No	2.48E-08
Tc-99	-6.68E+00[c]	2.47E+06	-2.71E-06	No	1.68E+01	4.59E+05	3.66E-05	No	3.39E-05
Th-230	N/A	2.57E+03	N/A	Yes	6.54E-01[c]	2.74E+06	2.38E-07	No	2.38E-07
Th-234	4.59E+01[c]	2.66E+05	1.73E-04	Yes	N/A	4.32E+04	N/A	No	1.73E-04
U-234	4.14E-01[c]	2.02E+02	2.05E-03	Yes	3.44E+00	3.03E+06	1.14E-06	No	2.05E-03
U-235	2.37E-01[c]	2.18E+02	1.09E-03	Yes	2.13E-01[c]	1.10E+05	1.94E-06	No	1.09E-03
U-238	1.34E+00	2.24E+02	5.99E-03	Yes	5.70E+00	4.29E+04	1.33E-04	No	6.13E-03
Summed	-	-	1.79E-02	-	-	-	1.74E-04	-	1.81E-02
	Riparian Animal								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	1.46E+03	N/A	No	-5.44E-02[c]	5.15E+03	-1.06E-05	Yes	-1.06E-05
Cs-137	8.42E-01[c]	4.27E+01	1.97E-02	Yes	3.17E-02[c]	3.13E+03	1.01E-05	Yes	1.97E-02
K-40	6.15E+00[c]	2.49E+02	2.47E-02	Yes	N/A	4.42E+03	N/A	Yes	2.47E-02
Np-237	3.03E-01[c]	1.16E+04	2.62E-05	No	1.44E-02[c]	7.63E+03	1.89E-06	Yes	2.81E-05
Pu-238	2.20E-01[c]	5.51E+02	4.00E-04	No	1.48E-02[c]	5.73E+03	2.58E-06	Yes	4.02E-04
Pu-239[d]	0.00E+00[c]	6.22E+02	0.00E+00	No	1.75E-01[c]	5.87E+03	2.98E-05	Yes	2.98E-05
Tc-99	-6.68E+00[c]	6.67E+05	-1.00E-05	Yes	1.68E+01	4.14E+04	4.06E-04	Yes	3.96E-04
Th-230	N/A	1.39E+04	N/A	No	6.54E-01[c]	1.04E+04	6.27E-05	Yes	6.27E-05
Th-234	4.59E+01[c]	3.80E+06	1.21E-05	No	N/A	4.32E+03	N/A	Yes	1.21E-05
U-234	4.14E-01[c]	6.84E+02	6.06E-04	No	3.44E+00	5.27E+03	6.53E-04	Yes	1.26E-03
U-235	2.37E-01[c]	7.37E+02	3.22E-04	No	2.13E-01[c]	3.79E+03	5.63E-05	Yes	3.78E-04
U-238	1.34E+00	7.57E+02	1.77E-03	No	5.70E+00	2.49E+03	2.29E-03	Yes	4.06E-03
Summed	-	-	4.75E-02	-	-	-	3.50E-03	-	5.10E-02
	Terrestrial Animal								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	2.02E+05	N/A	No	-5.44E-02[c]	3.65E+25	-1.49E-27	No	-1.49E-27
Cs-137	8.42E-01[c]	5.99E+05	1.41E-06	No	3.17E-02[c]	3.65E+25	8.68E-28	No	1.41E-06
K-40	6.15E+00[c]	1.93E+06	3.18E-06	No	N/A	3.65E+25	N/A	No	3.18E-06
Np-237	3.03E-01[c]	6.49E+06	4.67E-08	No	1.44E-02[c]	3.65E+25	3.95E-28	No	4.67E-08
Pu-238	2.20E-01[c]	1.89E+05	1.16E-06	No	1.48E-02[c]	3.65E+25	4.05E-28	No	1.16E-06
Pu-239[d]	0.00E+00[c]	2.01E+05	0.00E+00	No	1.75E-01[c]	3.65E+25	4.79E-27	No	4.79E-27
Tc-99	-6.68E+00[c]	1.54E+07	-4.34E-07	No	1.68E+01	3.65E+25	4.60E-25	No	-4.34E-07
Th-230	N/A	4.52E+05	N/A	No	6.54E-01[c]	3.65E+25	1.79E-26	No	1.79E-26
Th-234	4.59E+01[c]	4.31E+06	1.06E-05	No	N/A	3.65E+25	N/A	No	1.06E-05
U-234	4.14E-01[c]	4.05E+05	1.02E-06	No	3.44E+00	3.65E+25	9.42E-26	No	1.02E-06
U-235	2.37E-01[c]	4.20E+05	5.64E-07	No	2.13E-01[c]	3.65E+25	5.84E-27	No	5.64E-07
U-238	1.34E+00	4.06E+05	3.30E-06	No	5.70E+00	3.65E+25	1.56E-25	No	3.30E-06
Summed	-	-	2.09E-05	-	-	-	7.39E-25	-	2.09E-05

Table 4.8. Bayou Creek 2019 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

	Terrestrial Plant								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	6.80E+08	N/A	No	-5.44E-02[c]	3.65E+26	-1.49E-28	No	-1.49E-28
Cs-137	8.42E-01[c]	4.93E+07	1.71E-08	No	3.17E-02[c]	3.65E+26	8.68E-29	No	1.71E-08
K-40	6.15E+00[c]	5.79E+07	1.06E-07	No	N/A	3.65E+26	N/A	No	1.06E-07
Np-237	3.03E-01[c]	7.86E+07	3.86E-09	No	1.44E-02[c]	3.65E+26	3.95E-29	No	3.86E-09
Pu-238	2.20E-01[c]	3.95E+09	5.58E-11	No	1.48E-02[c]	3.65E+26	4.05E-29	No	5.58E-11
Pu-239[d]	0.00E+00[c]	7.05E+09	0.00E+00	No	1.75E-01[c]	3.65E+26	4.79E-28	No	4.79E-28
Tc-99	-6.68E+00[c]	4.59E+08	-1.46E-08	No	1.68E+01	3.65E+26	4.60E-26	No	-1.46E-08
Th-230	N/A	2.74E+09	N/A	No	6.54E-01[c]	3.65E+26	1.79E-27	No	1.79E-27
Th-234	4.59E+01[c]	4.32E+07	1.06E-06	No	N/A	3.65E+26	N/A	No	1.06E-06
U-234	4.14E-01[c]	3.03E+09	1.37E-10	No	3.44E+00	3.65E+26	9.42E-27	No	1.37E-10
U-235	2.37E-01[c]	1.10E+08	2.16E-09	No	2.13E-01[c]	3.65E+26	5.84E-28	No	2.16E-09
U-238	1.34E+00	4.29E+07	3.12E-08	No	5.70E+00	3.65E+26	1.56E-26	No	3.12E-08
Summed	-	-	1.21E-06	-	-	-	7.39E-26	-	1.21E-06

Summed total ratio for limiting organism: 6.29E-02.
Summed water ratio for limiting organism: 5.94E-02.
Summed sediment ratio for limiting organism: 3.51E-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 2019 maximum results for L5 and S1.
[b] BCG is the biota concentration guide value.
[c] Result was reported at concentrations less than the laboratory's reporting limit.
[d] Analytical data in PEGASIS are reported as Pu-239/240.

Table 4.9. Little Bayou Creek 2019 Evaluation of Dose to Aquatic and Terrestrial Biota[a]

	Aquatic Animal								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	4.38E+02	N/A	Yes	-1.20E-01[c]	6.80E+05	-1.76E-07	No	-1.76E-07
Cs-137	N/A	1.05E+03	N/A	No	-2.05E-02[c]	4.93E+04	-4.16E-07	No	-4.16E-07
Np-237	N/A	6.85E+01	N/A	Yes	2.56E-02[c]	7.86E+04	3.26E-07	No	3.26E-07
Pu-238	N/A	1.76E+02	N/A	Yes	1.76E-01[c]	3.95E+06	4.46E-08	No	4.46E-08
Pu-239[d]	N/A	1.87E+02	N/A	Yes	-1.44E-01[c]	7.05E+06	-2.04E-08	No	-2.04E-08
Tc-99	-4.33E+00[c]	2.47E+06	-1.75E-06	No	2.06E+00[c]	4.59E+05	4.49E-06	No	2.74E-06
Th-230	1.51E-01[c]	2.57E+03	5.88E-05	Yes	9.55E-01	2.74E+06	3.48E-07	No	5.91E-05
U-234	1.20E+00[c]	2.02E+02	5.94E-03	Yes	3.10E-01[c]	3.03E+06	1.02E-07	No	5.94E-03
U-235	-1.16E-01[c]	2.18E+02	-5.33E-04	Yes	8.64E-02[c]	1.10E+05	7.88E-07	No	-5.32E-04
U-238	3.05E+00	2.24E+02	1.36E-02	Yes	8.29E-01	4.29E+04	1.93E-05	No	1.37E-02
Summed	-	-	1.91E-02	-	-	-	2.48E-05	-	1.91E-02
	Riparian Animal								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	1.46E+03	N/A	No	-1.20E-01[c]	5.15E+03	-2.33E-05	Yes	-2.33E-05
Cs-137	N/A	4.27E+01	N/A	Yes	-2.05E-02[c]	3.13E+03	-6.55E-06	Yes	-6.55E-06
Np-237	N/A	1.16E+04	N/A	No	2.56E-02[c]	7.63E+03	3.36E-06	Yes	3.36E-06
Pu-238	N/A	5.51E+02	N/A	No	1.76E-01[c]	5.73E+03	3.07E-05	Yes	3.07E-05
Pu-239[d]	N/A	6.22E+02	N/A	No	-1.44E-01[c]	5.87E+03	-2.45E-05	Yes	-2.45E-05
Tc-99	-4.33E+00[c]	6.67E+05	-6.49E-06	Yes	2.06E+00[c]	4.14E+04	4.98E-05	Yes	4.33E-05
Th-230	1.51E-01[c]	1.39E+04	1.09E-05	No	9.55E-01	1.04E+04	9.16E-05	Yes	1.02E-04
U-234	1.20E+00[c]	6.84E+02	1.76E-03	No	3.10E-01[c]	5.27E+03	5.88E-05	Yes	1.81E-03
U-235	-1.16E-01[c]	7.37E+02	-1.57E-04	No	8.64E-02[c]	3.79E+03	2.28E-05	Yes	-1.35E-04
U-238	3.05E+00	7.57E+02	4.03E-03	No	8.29E-01	2.49E+03	3.33E-04	Yes	4.36E-03
Summed	-	-	5.63E-03	-	-	-	5.36E-04	-	6.17E-03

Table 4.9. Little Bayou Creek 2019 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

	Terrestrial Animal								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	2.02E+05	N/A	No	-1.20E-01[c]	3.65E+25	-3.29E-27	No	-3.29E-27
Cs-137	N/A	5.99E+05	N/A	No	-2.05E-02[c]	3.65E+25	-5.62E-28	No	-5.62E-28
Np-237	N/A	6.49E+06	N/A	No	2.56E-02[c]	3.65E+25	7.01E-28	No	7.01E-28
Pu-238	N/A	1.89E+05	N/A	No	1.76E-01[c]	3.65E+25	4.82E-27	No	4.82E-27
Pu-239[d]	N/A	2.01E+05	N/A	No	-1.44E-01[c]	3.65E+25	-3.95E-27	No	-3.95E-27
Tc-99	-4.43E+00[c]	1.54E+07	-2.81E-07	No	2.06E+00[c]	3.65E+25	5.64E-26	No	-2.81E-07
Th-230	1.51E-01[c]	4.52E+05	3.34E-07	No	9.55E-01	3.65E+25	2.62E-26	No	3.34E-07
U-234	1.20E+00[c]	4.05E+05	2.96E-06	No	3.10E-01[c]	3.65E+25	8.49E-27	No	2.96E-06
U-235	-1.16E-01[c]	4.20E+05	-2.76E-07	No	8.64E-02[c]	3.65E+25	2.37E-27	No	-2.76E-07
U-238	3.05E+00	4.06E+05	7.51E-06	No	8.29E-01	3.65E+25	2.27E-26	No	7.51E-06
Summed	-	-	1.02E-05	-	-	-	1.14E-25	-	1.02E-05
	Terrestrial Plant								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	6.80E+08	N/A	No	-1.20E-01[c]	3.65E+26	-3.29E-28	No	-3.29E-28
Cs-137	N/A	4.93E+07	N/A	No	-2.05E-02[c]	3.65E+26	-5.62E-29	No	-5.62E-29
Np-237	N/A	7.86E+07	N/A	No	2.56E-02[c]	3.65E+26	7.01E-29	No	7.01E-29
Pu-238	N/A	3.95E+09	N/A	No	1.76E-01[c]	3.65E+26	4.82E-28	No	4.82E-28
Pu-239[d]	N/A	7.05E+09	N/A	No	-1.44E-01[c]	3.65E+26	-3.95E-28	No	-3.95E-28
Tc-99	-4.43E+00[c]	4.59E+08	-9.44E-09	No	2.06E+00[c]	3.65E+26	5.64E-27	No	9.44E-09
Th-230	1.51E-01[c]	2.74E+09	5.50E-11	No	9.55E-01	3.65E+26	2.62E-27	No	5.50E-11
U-234	1.20E+00[c]	3.03E+09	3.96E-10	No	3.10E-01[c]	3.65E+26	8.49E-28	No	3.96E-10
U-235	-1.16E-01[c]	1.10E+08	-1.06E-09	No	8.64E-02[c]	3.65E+26	2.37E-28	No	-1.06E-09
U-238	3.05E+00	4.29E+07	7.11E-08	No	8.29E-01	3.65E+26	2.27E-27	No	7.11E-08
Summed	-	-	6.11E-08	-	-	-	1.14E-26	-	6.11E-08

Summed total ratio for limiting organism: 2.02E-02.
Summed water ratio for limiting organism: 1.96E-02.
Summed sediment ratio for limiting organism: 5.94E-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 2019 maximum results for L11 and S27.
[b] BCG is the biota concentration guide value.
[c] Result was reported at concentrations less than the laboratory's reporting limit.
[d] Analytical data in PEGASIS are reported as Pu-239/240.

In 2019, FRNP authorized, with concurrence from DOE, 523 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; U.S. Department of Energy (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 2019, SST authorized, with concurrence from DOE, 451 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; U.S. Department of Energy (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 2019, 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 2019, 1,132,000 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; U.S. Department of Energy (DOE) Order 458.1, Radiation Protection of the Public and Environment; or other DOE approved limits. Also in 2019, MCS authorized, with concurrence from DOE, 426 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.

4.3 UNPLANNED RADIOLOGICAL RELEASES

There were no unplanned radiological releases in 2019.

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[6], 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.

Project-specific surface water sampling for decommissioning and environmental remediation projects is 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 2019 ranging from 2.59 µg/kg to 378 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[7] for Total PCBs is 179 µg/kg, and the action level[8] is 17,900 µg/kg for the recreational user (DOE 2019a). 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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[6] Permit Number KY0004049 also includes MCS as a permittee for Outfall 017.
[7] 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.
[8] 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.

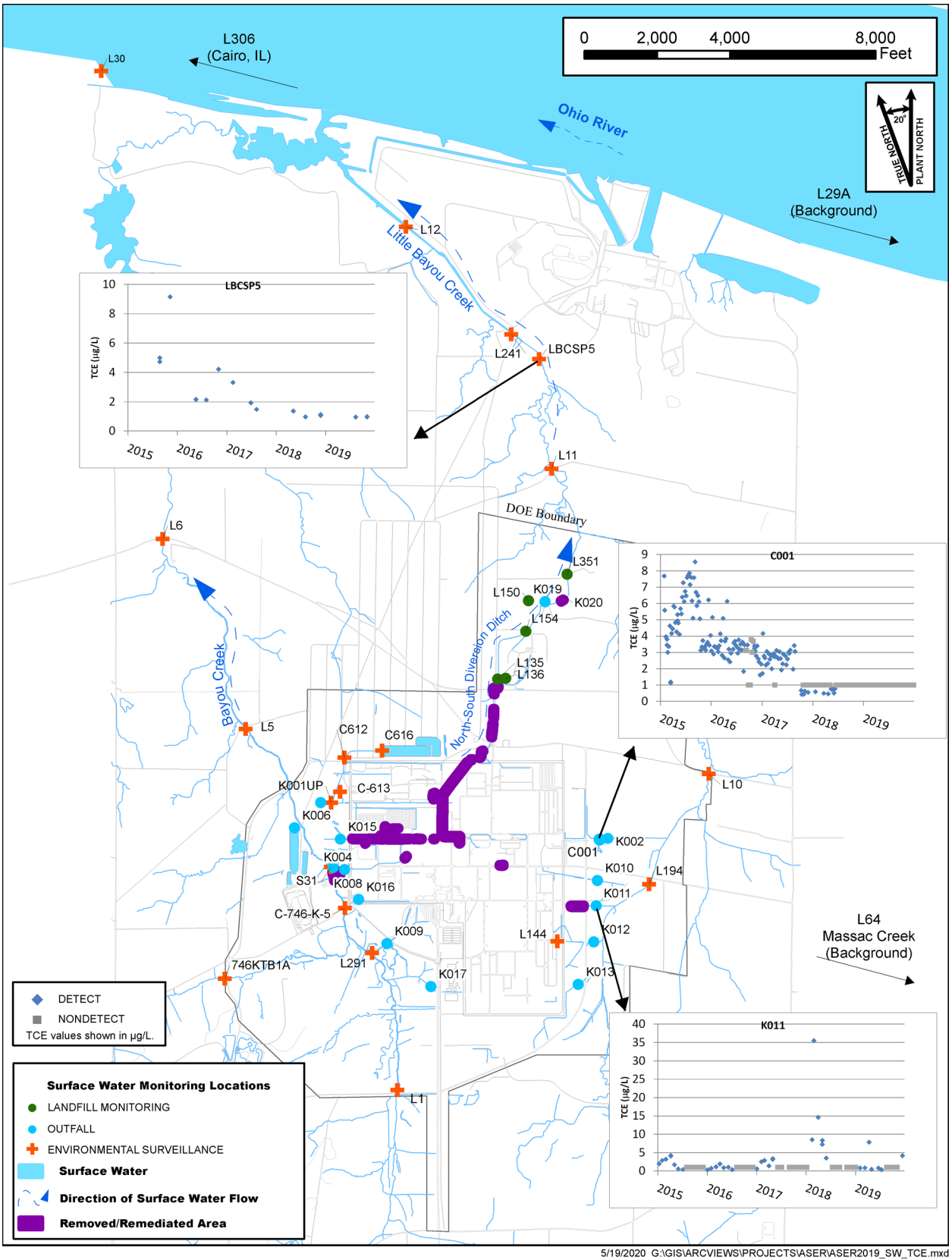

Figure 5.1. Surface Water and Seep Monitoring Locations with TCE Trends

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

Program and Reporting Location	Locations (see Figure 4.4)
Effluent Watershed Monitoring Program	
C-746-S and C-746-T Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2019 (January—March) Second Quarter 2019 (April—June) Third Quarter 2019 (July—September) Fourth Quarter 2019 (October—December)	L135, L136, L154*
C-746-U Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2019 (January—March) Second Quarter 2019 (April—June) Third Quarter 2019 (July—September) Fourth Quarter 2019 (October—December)	L150, L154*, 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, L10, L11, L241, L29A, L30, L306, L5, L14DWN
Seep	LBCSP5
Northeast Plume Effluent *Semiannual FFA Progress Reports:* Second Half of FY 2019 (Data reported January–June 2019) First Half of FY 2020 (Data reported July–December 2019)	C001

*Location is listed for both C-746-S and C-746-T and for C-746-U.

Table 5.2. Ranges of Detected Analytes in 2019 Surface Water Samples

Analyte	Range
Anions	
Chloride (µg/L)	322–11,800
Sulfate (µg/L)	1,680–81,900
Wet Chemistry Parameters	
Biochemical Oxygen Demand (µg/L)	3,070–15,200
Chemical Oxygen Demand (µg/L)	13,200–215,000
Dissolved Solids (µg/L)	62,900–870,000
Hardness—Total as $CaCO_3$ (µg/L)	18,500–237,000
Suspended Solids (µg/L)	600–13,700,000
Total Organic Carbon (µg/L)	3,610–21,400
Total Solids (µg/L)	91,000–13,800,000
Volatile Organic Compounds	
Trichloroethene (µg/L)	0.35–7.84

Table 5.2. Ranges of Detected Analytes in 2019 Surface Water Samples (Continued)

Analyte	Range
PCBs	
PCB-1248 (µg/L)	0.0445–0.0876
PCB-1254 (µg/L)	0.0349–0.0605
PCB-1260 (µg/L)	0.0384–0.101
Total PCBs (µg/L)	0.0413–0.181
Other Organics	
Oil and Grease (µg/L)	1,120–3,170
Metals	
Aluminum (µg/L)	21.3–1,470
Barium (µg/L)	43.3–50.8
Calcium (µg/L)	11,300–25,600
Copper (µg/L)	0.964–4.83
Iron (µg/L)	75.4–61,400
Lead (µg/L)	1.03–1.03
Magnesium (µg/L)	2,590–5,290
Manganese (µg/L)	23.5–127
Nickel (µg/L)	0.627–2.23
Phosphorous (µg/L)	94.2–663
Potassium (µg/L)	2,040–5,110
Sodium (µg/L)	885–24,400
Uranium (µg/L)	0.075–168
Zinc (µg/L)	9.17–81

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 whole effluent toxicity 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 2019 and shows the 2016 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).

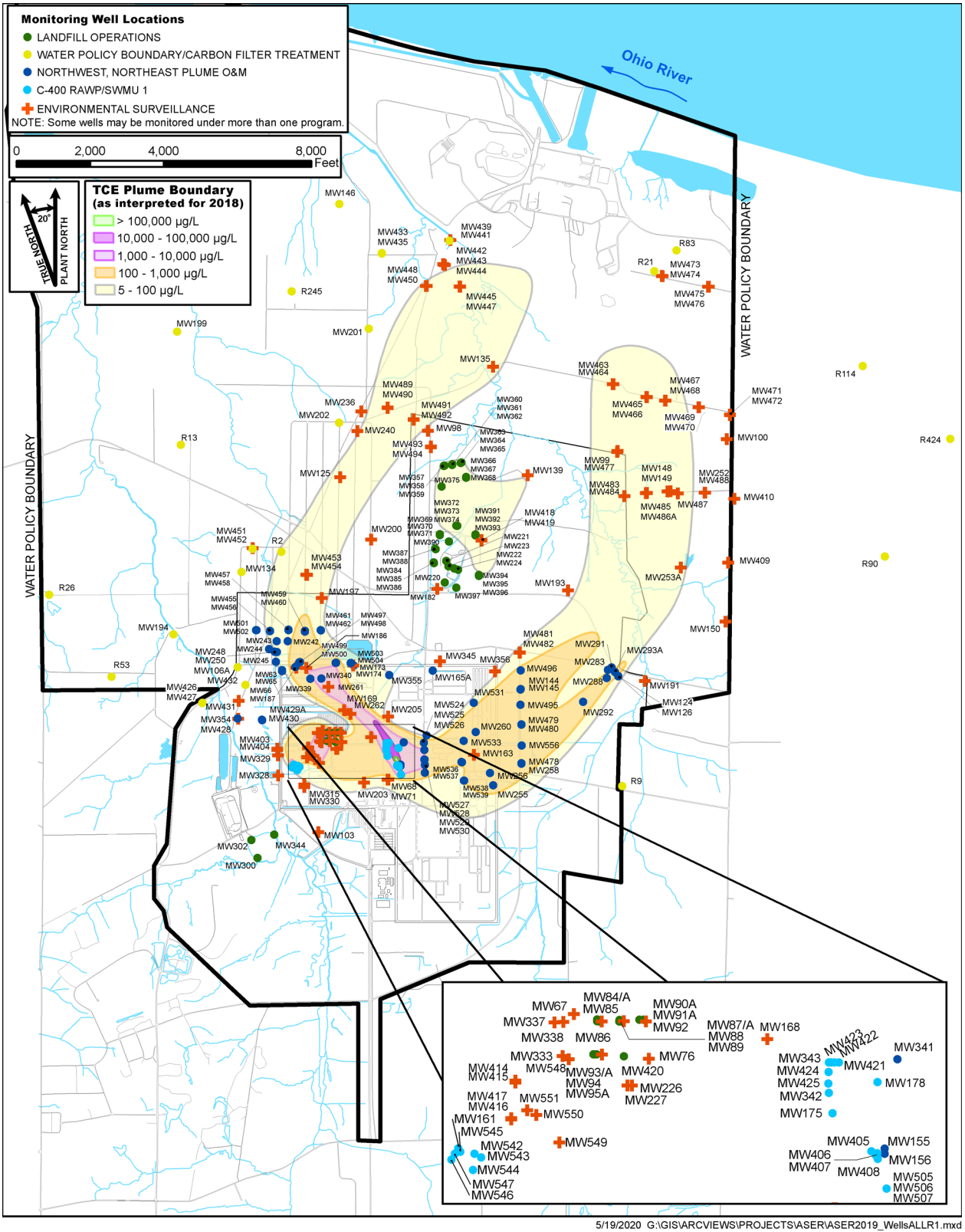


Figure 6.1. Monitoring Wells Sampled in CY 2019

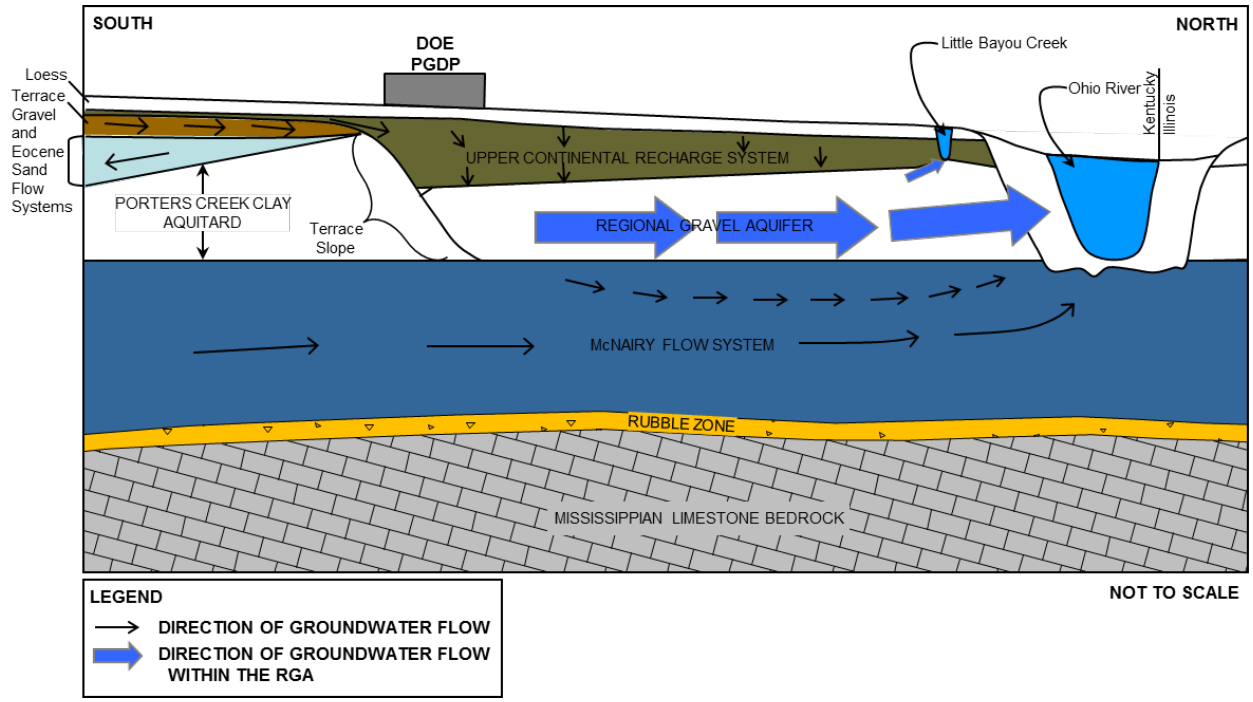


Figure 6.2. Paducah Site Groundwater Flow System and Water-Bearing Zones

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 2019a). Over 200 monitoring wells and residential wells were sampled in accordance with DOE Orders and federal, state, and local requirements during 2019. 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 2019 (January–March) Second Quarter 2019 (April–June) Third Quarter 2019 (July–September) Fourth Quarter 2019 (October–December)	0	4	14	0	0	18[b]
C-746-U Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2019 (January–March) Second Quarter 2019 (April–June) Third Quarter 2019 (July–September) Fourth Quarter 2019 (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 2019 Semiannual Groundwater Report (October 2018–March 2019) C-404 Hazardous Waste Landfill November 2019 Semiannual Groundwater Report (April 2019–September 2019)	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 2019 (Data reported January–June 2019) First Half of FY 2020 (Data reported July–December 2019)	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 (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	19	0	0	19
Northeastern Wells (annual)	0	0	5	0	0	5
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	2	29	0	1	32
Biennial Wells	0	4	80	0	0	84
Semiannual Wells	0	0	5	0	0	5
Quarterly Wells	0	0	3	0	0	3
Geochemical Wells	0	0	2	0	0	2

[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 2019 are shown in Table 6.2. Groundwater samples also were collected for per- and polyfluoroalkyl substances (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 2019g). 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. Due to well integrity concerns, in June 2019, compliance wells MW84, MW87, and MW93 were abandoned and replaced with MW84A, MW87A, and MW93A. In 2019, trichloroethene (TCE) and arsenic concentrations in MW84 (January sampling) and TCE in MW84A (July sampling) were statistically different from background well concentrations. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, (PRS 2007a) demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedances of TCE in MW84/MW84A. The arsenic exceedance was shown to be consistent with the 2007 demonstration, and therefore also concluded to not be attributed to the landfill.

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 2019. 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 2019.

Table 6.2. Ranges of Detected Analytes in 2019 Monitoring Well Groundwater Samples

Analyte	Range
Volatile Organic Compounds	
1,1,1-Trichloroethane (µg/L)	1.26–1.79
1,1,2-Trichloroethane (µg/L)	0.96–3.17
1,1-Dichloroethane (µg/L)	0.35–17
1,1-Dichloroethene (µg/L)	0.34–50.5
1,2-Dichloroethane (µg/L)	0.37–0.96
Acetone (µg/L)	1.8–26
Benzene (µg/L)	3.81–3.89
Carbon disulfide (µg/L)	2.85–2.85
Carbon tetrachloride (µg/L)	0.38–117
Chloroform (µg/L)	0.36–372
cis-1,2-Dichloroethene (µg/L)	0.34–4220
Methylene chloride (µg/L)	1.91–2.82
Tetrachloroethene (µg/L)	0.34–2.25
Toluene (µg/L)	0.66–0.73
Total Xylene (µg/L)	35.6–35.6
trans-1,2-Dichloroethene (µg/L)	0.34–4.7
Trichloroethene (µg/L)	0.34–52,800
Vinyl chloride (µg/L)	0.56–241
Radionuclides	
Alpha activity (pCi/L)	4.28–13.6
Beta activity (pCi/L)	4.29–627
Radium-226 (pCi/L)	0.727–0.727
Radium-228 (pCi/L)	3.39–4.99
Technetium-99 (pCi/L)	12–20,100
Uranium-234 (pCi/L)	1.58–3.89
Uranium-238 (pCi/L)	1.12–2.31
PCBs	
PCB-1242 (µg/L)	0.0466–0.0989
PCB-1260 (µg/L)	0.054–0.054
Total PCBs (µg/L)	0.0466–0.0989
Wet Chemistry Parameters	
Alkalinity as CaCO3 (µg/L)	59,800–187,000
Chemical Oxygen Demand (µg/L)	9,380–166,000
Dissolved Solids (µg/L)	141,000–687,000
Iodide (µg/L)	234–735
Silica (µg/L)	17,400–21,700
Total Organic Carbon (µg/L)	660–13,300
Total Organic Halides (µg/L)	3.5–195

Analyte	Range
Anions	
Bromide (µg/L)	106–1,120
Chloride (µg/L)	487–155,000
Fluoride (µg/L)	95.9–788
Nitrate as Nitrogen (µg/L)	62.1–6,280
Sulfate (µg/L)	4,330–983,000
Metals	
Aluminum (µg/L)	19.5–7,700
Antimony (µg/L)	1.07–1.67
Arsenic (µg/L)	2–38
Barium (µg/L)	23.4–424
Beryllium (µg/L)	0.222–0.292
Boron (µg/L)	5.38–1,520
Cadmium (µg/L)	0.325–0.481
Calcium (µg/L)	5,910–247,000
Chromium (µg/L)	3.17–381
Cobalt (µg/L)	0.314–9.75
Copper (µg/L)	0.327–16.3
Iron (µg/L)	33.3–141,000
Lead (µg/L)	0.51–5.02
Magnesium (µg/L)	3,260–60,300
Manganese (µg/L)	1–15,800
Mercury (µg/L)	0.082–0.094
Molybdenum (µg/L)	0.21–22.5
Nickel (µg/L)	0.604–182
Potassium (µg/L)	138–33,300
Selenium (µg/L)	2.01–3.54
Silver (µg/L)	0.599–0.599
Sodium (µg/L)	8,480–145,000
Uranium (µg/L)	0.067–5.18
Uranium-235 (µg/L)	0.019–0.0929
Uranium-238 (µg/L)	2.13–8.7
Vanadium (µg/L)	3.42–20.3
Zinc (µg/L)	3.32–38.9
Arsenic, Dissolved (µg/L)	2.02–15.9
Barium, Dissolved (µg/L)	23.1–408
Chromium, Dissolved (µg/L)	3.18–12.6
Lead, Dissolved (µg/L)	0.7–1.02
Mercury, Dissolved (µg/L)	0.075–0.079
Selenium, Dissolved (µg/L)	2.08–2.08
Uranium, Dissolved (µg/L)	0.07–4.41

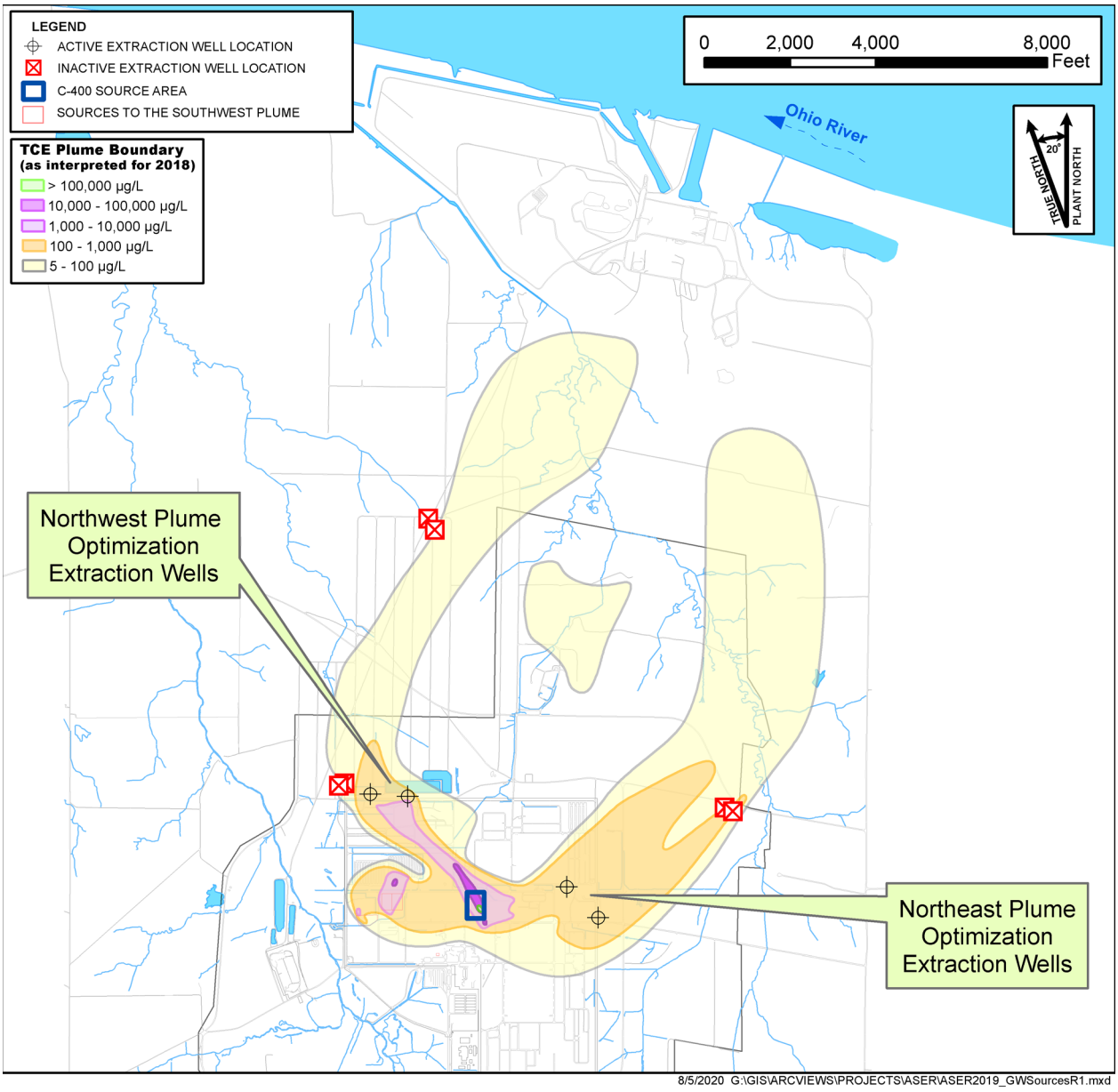
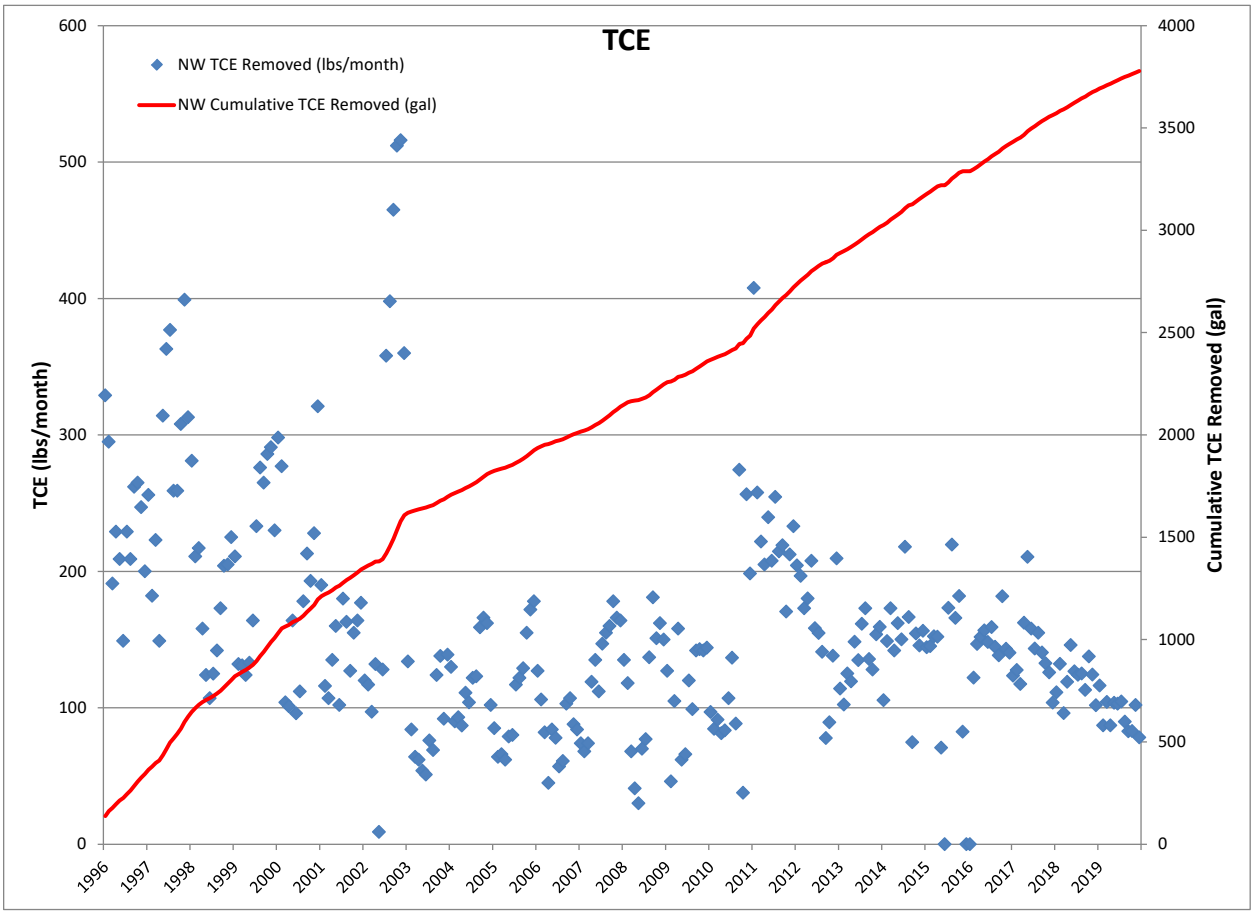


Figure 6.3. Locations of Groundwater Contamination Sources

Table 6.3. Cumulative TCE Removed at Paducah

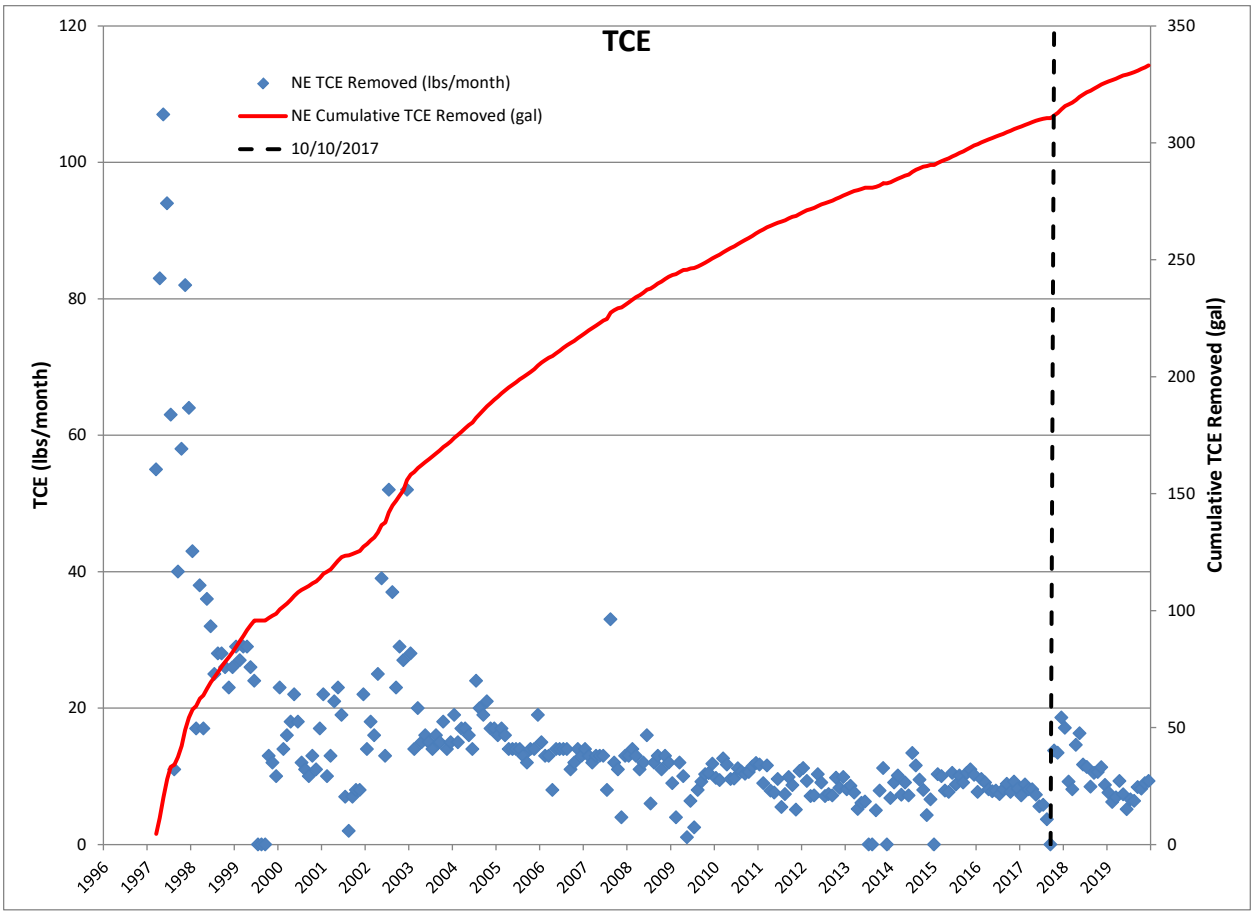
Source Area	Cumulative TCE Removed (gal)[a,b]
Northwest Plume Groundwater Treatment System	3,778
Northeast Plume Containment System	337
C-400 Cleaning Building Interim Remedial Action (including treatability study)	3,572
Southwest Plume Sources Remedial Action	24
LASAGNA™ treatment at Cylinder Drop Test Site	246

[a] TCE values include liquid VOCs and recovered VOCs on carbon.
[b] Cumulative through December 31, 2019. Values taken from DOE 2020b.



Source: DOE 2019h

Figure 6.4. Northwest Plume Groundwater Treatment System TCE Removed



Source: DOE 2019h

Figure 6.5. Northeast Plume Containment System TCE Removed

The Kentucky Solid Waste Facility (401 *KAR* 47:030 § 6) maximum contaminant level exceedances for 2019 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 2019

Upper Continental Recharge System	Upper RGA	Lower RGA
C-746-S and C-746-T Landfills		
MW390: beta activity	MW221: chromium MW369: beta activity MW372: beta activity, trichloroethene MW384: beta activity MW387: beta activity MW391: trichloroethene	MW370: beta activity MW373: trichloroethene MW385: beta activity MW388: beta activity MW392: trichloroethene
C-746-U Landfill		
No exceedances	MW366: beta activity, trichloroethene MW369: beta activity MW372: beta activity, trichloroethene	MW358: trichloroethene MW361: trichloroethene MW364: trichloroethene MW367: trichloroethene MW370: beta activity MW373: trichloroethene

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

There has been increasing federal and state regulatory interest 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 may be regulated by EPA in the future.

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. A document and database search also 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. 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	5720	4880	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; 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 Quality Systems Manual (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.

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7. QUALITY ASSURANCE

The Paducah Site maintains a 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. The DOE Consolidated Audit Program (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.

In 2019, 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 2019a).

The Paducah Programmatic Quality Assurance Project Plan was implemented in 2013 and was updated in 2019 (DOE 2019i). 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 2019. 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 2019a). 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, soil, 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
	Laboratory control samples

[a] Blanks = Samples of deionized water used to assess potential contamination from a source other than the media being sampled.
[b] Spikes = Samples that have been mixed with a known quantity of a chemical to measure overall method effectiveness during the analysis process, as well as possible sample/matrix interferences.
[c] Rinseates = Samples of deionized water 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 2019.

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 DOECAP. DOECAP-Accreditation Program provides certification of environmental laboratories through third-party organizations. 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 an annual basis. If not in DOECAP, laboratories 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 2019.

- GEL Laboratories, LLC
- Test America St. Louis, MO
- ALS Global (Fort Collins, CO; Cincinnati, OH; Salt Lake City, UT labs)
- Southwest Research Institute
- Materials and Chemistry Laboratory
- Pace Analytical Services, LLC (Mt. Juliet, TN; Madisonville, KY labs)
- Summit Environmental

The following are the waste treatment, storage, and disposal facilities maintained on the ASL and used by the Paducah Site in 2019.

- Integrated Environmental Services, Inc.
- Nuratec Project Services
- Perma-Fix (DSSI, FL and Northwest facilities)
- Waste Control Specialist, LLC
- Clean Harbors, LLC (Deer Park, TX; El Dorado, AR facilities)
- Energy*Solutions* (Clive, UT; Bear Creek, TN 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, 97 packages were validated in CY 2019.

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.

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 as low as reasonably achievable (ALARA) process requirements. An authorized limit also may include conditions or measures that limit or control the disposition of property.

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

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

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

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

- **committed effective dose equivalent/committed effective dose**—The sum of total absorbed dose (measured in mrem) to a tissue or organ received over a 50-year period resulting from the intake of radionuclides, multiplied by the appropriate weighting factor. The committed effective dose equivalent is the product of the annual intake (pCi) and the dose conversion factor for each radionuclide (mrem/pCi). Committed effective dose equivalent is expressed in units of rem (or sievert).

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

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

downgradient—In the direction of decreasing hydrostatic head.

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

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

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.

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

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

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.

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.

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.