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Centimeter

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1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0 4.5 5.0 5.6 6.3

1 of 3

FEMP–2342
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FERNALD
Environmental Management Project

1993

Site Environmental Report

Prepared for
U.S. Department of Energy
Fernald Field Office
Contract DE – AC05 – 92OR21972

Prepared by
Environmental Protection Department
Fernald Environmental Restoration Management Corporation

June 1994

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Acronyms and Abbreviations

ACA	Amended Consent Agreement
AEC	Atomic Energy Commission
AHF	Anhydrous Hydrogen Fluoride
ALARA	As Low As Reasonably Achievable
AMS	Air Monitoring Station
ANSI	American National Standards Institute
ARAR	Applicable or Relevant and Appropriate Requirement
ASER	Annual Site Environmental Report
AWWT	Advanced Wastewater Treatment
BAT	Best Available Technology
BDN	Biodenitrification Facility
BMP	Best Management Practices
BSL	Biodenitrification Surge Lagoon
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
CO	Carbon Monoxide
CPID	Closure Plan Information and Data
CX	Categorical Exclusion
D&D	Decontamination and Dismantling
DCG	Derived Concentration Guideline
DFO	Director's Final Findings and Orders
DOE	Department of Energy
DQO	Data Quality Objective
EA	Environmental Assessment
EDE	Effective Dose Equivalent
EIS	Environmental Impact Statement
EM	Environmental Monitoring
EML	Environmental Measurements Laboratory
ES&H	Environment, Safety, and Health
ETS	Effluent Treatment System
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FFA	Federal Facility Agreement
FFCAct	Federal Facility Compliance Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FMPC	Feed Materials Production Center
FONSI	Finding of No Significant Impact
FS	Feasibility Study
FS/PP	Feasibility Study/Proposed Plan
GQAPP	Groundwater Quality Assessment Program Plan
HSL	Hazardous Substances List
HWMU	Hazardous Waste Management Unit
IAWWT	Interim Advanced Wastewater Treatment
ICRP	International Commission on Radiological Protection
LDR	Land Disposal Restriction
MCL	Maximum Contaminant Level
μCi	microcurie
mrem	millirem
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants

NOD	Notice of Deficiency
NON	Notice of Noncompliance
NOV	Notice of Violation
NO_x	Nitrogen Oxide
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Response Center
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
OEPA	Ohio Environmental Protection Agency
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PACD	Proposed Amended Consent Decree
PCB	Polychlorinated Biphenyls
pCi	picocurie
PEIC	Public Environmental Information Center
PET	Proficiency Environmental Testing
PTI	Permit to Install
PTO	Permit to Operate
QA	Quality Assurance
QF	Quality Factor
RAO	Remedial Action Objective
RAWP	Removal Action Work Plan
RCRA	Resource Conservation and Recovery Act
rem	Roentgen Equivalent Man
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RM	River Mile
RQ	Reportable Quantity
SACD	Stipulated Amended Consent Decree
SARA	Superfund Amendments and Reauthorization Act
SCQ	Sitewide CERCLA Quality Assurance Project Plan
SDWA	Safe Drinking Water Act
SER	Site Environmental Report
SHPO	State Historic Preservation Officer
SO_2	Sulfur Dioxide
SPCC	Spill Prevention Control and Countermeasure
SSOD	Storm Sewer Outfall Ditch
SU	Standard Units
SWMU	Solid Waste Management Unit
SWRB	Stormwater Retention Basin
TLD	Thermoluminescent Dosimeter
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
UNH	Uranyl Nitrate Hexahydrate
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compounds
WEMCO	Westinghouse Environmental Management Company of Ohio
WM/PP	Waste Minimization/Pollution Prevention

Conversion Tables

Multiply	By	To Obtain	Multiply	By	To Obtain
Length					
inches	2.54	centimeters (cm)	cm	0.394	inches
feet	0.3048	meters (m)	m	3.281	feet
miles	1.61	kilometers (km)	km	0.62	miles
Volume					
cubic centimeters (cm^3)	1	milliliters (mL)	mL	1	cm^3
cubic inches (in^3)	16.39	mL	mL	0.061	in^3
fluid ounces	29.59	mL	mL	0.034	fluid ounces
grams (g)	1	mL (water)	mL (water)	1	g
kilograms (kg)	1	liter (L) (water)	L (water)	1	kg
mL	1,000	L	L	0.001	mL
gallons	3.79	L	L	0.264	gallons
quarts	0.95	L	L	1.057	quarts
cubic feet (ft^3)	0.02833	cubic meters (m^3)	m^3	35.3	ft^3
Mass					
ounces	28.33	g	g	0.035	ounces
pounds	455	g	g	0.0022	pounds
pounds	0.455	kg	kg	2.2	pounds
tons	0.907	metric tons	metric tons	1.1	tons
Activity					
Curies (Ci)	10^{12}	picocuries (pCi)	pCi	10^{-12}	Ci
Becquerel (Bq)	27.02	pCi	pCi	0.037	Bq
Ci	10^{6}	microcurie (µCi)	µCi	10^{-6}	Ci
pCi	0.037	Bq	Bq	27	pCi
Dose					
rem	1,000	millirem (mrem)	mrem	0.001	rem
Sieverts (Sv)	100	rem	rem	0.01	Sv
For Natural Uranium in Water					
micrograms per liter (µg/L)	1	parts per billion (ppb)	ppb	1	µg/L
µg/L	0.6757	pCi/L	pCi/L	1.48	µg/L
milligrams per liter (mg/L)	1	parts per million (ppm)	ppm	1	mg/L
mg/L	675.7	pCi/L	pCi/L	0.00148	mg/L
pCi/L	1.48	ppb	ppb	0.6757	pCi/L
For Natural Uranium in Soil					
µg/g	1	ppm	ppm	1	µg/g
µg/g	0.6757	pCi/g	pCi/g	1.48	µg/g
pCi/g	1.48	ppm	ppm	0.6757	pCi/g
For Temperature					
°F	x 9/5 + 32	°C	°C	- 32 x 5/9	°F

Multiple	Decimal Equivalent	Prefix	Symbol
10^{6}	1,000,000	mega-	M
10^{3}	1,000	kilo-	k
10^{2}	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	μ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

Executive Summary

Executive Summary

The Fernald site is a Department of Energy (DOE) owned facility that produced high-quality uranium metals for military defense for nearly 40 years. DOE suspended production at the site in 1989 and formally ended production in 1991. Although production activities have ceased, the site continues to examine the air and liquid pathways as possible routes through which pollutants from past operations and current remedial activities may leave the site.

The Site Environmental Report (SER) is prepared annually in accordance with DOE Order 5400.1, "General Environmental Protection Program." This 1993 SER provides the general public as well as scientists and engineers with the results from the site's ongoing Environmental Monitoring Program. Also included in this report is information concerning the site's progress toward achieving full compliance with requirements set forth by DOE, U.S. Environmental Protection Agency (USEPA), and Ohio EPA (OEPA).

For some readers, the highlights provided in this Executive Summary may provide sufficient information. Many readers, however, may wish to read more detailed descriptions of the information than those which are presented here. All information presented in this summary is discussed more fully in the main body of this report.

Environmental Monitoring

The Fernald site's Environmental Monitoring Program plays a key role in the effort to investigate the effects that years of operation have had on the local environment. Environmental monitoring primarily examines the air and water pathways; other program components address contamination risks associated with cleanup procedures. A summary of air and liquid pathway results is presented below.

Air Pathway

Monitoring the air pathway incorporates results from not only the air monitoring stations but also from soil, grass, produce, and milk sampling. (Radon is discussed separately below.) Overall, the air monitoring data from 1993 were consistent with data from 1992. While Boiler Plant emissions were higher than in 1992, all emissions were well below permit limits. The increase is attributable to returning the boilers to full service after a coal bunker fire in 1992 limited Boiler Plant operations.

Data collected from fenceline air monitoring stations showed that average concentrations of uranium were all less than 1% of the DOE standard. Airborne emissions for 1993 were estimated to be 0.21 kg (0.46 pound). This estimate is 9% lower than the 1992 estimate of 0.23 kg (0.51 pound). Airborne uranium emissions steadily dropped after processing operations were discontinued in 1989, and they have remained relatively constant since 1991.

Some onsite and nearby offsite soil samples continue to indicate elevated uranium concentrations due to deposition of airborne particles from past operations. One offsite sampling location, which is in the predominant wind direction northeast of the site, had a total uranium concentration of 5.3 pCi/g. A background level for uranium in soil is set at 2.8 pCi/g for the Fernald area.

The 1993 results from grass sampling indicated that uranium concentrations were higher at the fenceline than at offsite sampling locations. The onsite grass concentrations are better correlated to local airborne uranium concentrations than soil concentrations, which suggests that deposition of uranium is the source of the higher concentrations.

Home-grown sweet corn and tomatoes are two of the major crops sold from roadside stands within 5 km (3 miles) of the site. Local residents also grow and sell beets, potatoes, apples, lettuce, pumpkins, cucumbers, and peppers. Uranium concentrations in produce in 1993 were consistent with previous years' data. Laboratory analyses did not detect any significant differences in uranium concentrations between produce grown near the site (0 – 5 km or 0 – 3 miles) and produce grown at distant locations (11 – 42 km or 7 – 26 miles).

In general, uranium concentrations from the local dairy's milk were comparable to those from a background dairy in Indiana. The data demonstrated that milk from the local dairy is not affected by site emissions.

Measurements of direct radiation indicated that levels were higher with proximity to the K-65 silos. These measurements were consistent with the fact that the silos contain radium and radon gas which contribute to the direct radiation in the vicinity.

Radon Monitoring

Radon is transported through the air pathway and is, therefore, discussed here. However, radon monitoring results are reported separately in this Site Environmental Report from the air pathway in order to improve the presentation of information and regulations that are unique to radon.

In 1993, the average fenceline radon concentration was 0.63 ± 0.20 pCi/L. This concentration is greater than the 1992 average concentration of 0.57 ± 0.29 pCi/L, but it is well below the guideline of 3.0 pCi/L. For comparison, some established average background concentrations range from 0.2 to 0.4 pCi/L.

Liquid Pathway: Effluent and Surface Water

The effluent and surface water component of the liquid pathway is monitored to determine any impacts from the Fernald site on the Great Miami River and Paddys Run. The Environmental Monitoring Program examines the effluent and surface water results, along with sediment and fish results because they are also part of the liquid pathway.

Approximately 474 kg (1,044 pounds) of uranium were discharged to the Great Miami River during 1993. Of that total, 453 kg (998 pounds) were from Manhole-175, and 22 kg (48 pounds) were from South Plume groundwater pumping. Approximately 109 kg (241 pounds) of uranium reached Paddys Run through uncontrolled stormwater runoff during 1993.

The liquid effluent discharged to the Great Miami River resulted in a slightly higher measurement of uranium at the downriver sampling location than the upriver location. However, the downriver concentration was consistent with 1992 sampling results. Paddys Run continued to show effects of stormwater runoff from the site. Although the average uranium concentration at the nearest Paddys Run sampling location was higher than in 1992, it was only 1.7% of the DOE guideline for drinking water. (That guideline is used for comparison purposes only since there is no established guideline for uranium in surface water.)

Radionuclide concentrations in the Great Miami River and Paddys Run sediments for 1993 were consistent with previous years' data and did not indicate a build-up of radioactive pollutants in the sediment.

In 1993, fish from three locations along the Great Miami River were sampled for uranium. Results indicated that uranium concentrations were no greater in fish caught downstream of the site's effluent line than in those caught upstream.

The National Pollutant Discharge Elimination System (NPDES) permit specifies sampling locations, sampling and reporting schedules, discharge limits, water quality standards, and other restrictions on the Fernald site's effluents discharged to the Great Miami River and Paddys Run. There were only three violations of NPDES limits at Manhole-175, the final NPDES monitoring point before effluents are discharged to the river. Out of the 4,020 NPDES samples taken at internal and external monitoring locations in 1993, only 11 were not within permit limits.

Liquid Pathway: Groundwater

The site carefully monitors the groundwater beneath and in the vicinity of the site to identify and track the movement of pollutants which may be present in the Great Miami Aquifer. In 1993 the Fernald site routinely sampled 36 private wells for total uranium. Three of these wells, each of which is in an area of known groundwater contamination, had an average uranium concentration above the proposed USEPA standard of 13.5 pCi/L (20 ppb). These 36 wells were also sampled for several metals. Four wells showed concentrations of lead at or above the Primary Drinking Water Standard as listed for the control of lead. Additionally, as is common for an area with high natural concentrations of iron and manganese, such as the area surrounding the Fernald site, several private wells showed concentrations of these two metals above the USEPA Secondary Drinking Water Standards.

Aside from the private well sampling program, the Fernald site conducts comprehensive groundwater sampling of several site-owned wells. In 1993, the site sampled 454 on- and offsite wells for uranium, and 127 wells showed detections above the proposed USEPA guideline of 13.5 pCi/L (20 ppb). All of the offsite locations were in the South Groundwater Contamination Plume area. This comprehensive program also sampled those 454 wells for 11 metals and 31 Volatile Organic Compounds that have Primary Drinking Water Standards. Of these 42 constituents, 16 were detected above their primary standards in more than one well. Four other constituents showed single detections above their primary standards.

Estimated Radiation Dose for 1993

Scientists calculate potential radiation doses to nearby residents by entering offsite radionuclide concentrations, which are determined through environmental monitoring and sampling, into mathematical models.

In 1993, the hypothetical maximally-exposed individual living nearest the Fernald site, exclusively consuming local foodstuffs and fish, along with drinking water from a well in the Fernald area, could have received a maximum committed effective dose of approximately 1.0 mrem. (This dose is exclusive of the dose received from radon.) This dose can be compared to the limit of 100 mrem for all pathways (also exclusive of radon) that was established by the International Commission on Radiological Protection and adopted by DOE.

Dose Attributable to Radon

Just as radon monitoring results are discussed separately from the air pathway monitoring results, the dose attributable to radon is discussed separately from the rest of the estimated radiation dose for 1993.

As discussed above, the radon concentration measured at the site fenceline in 1993 was 0.63 ± 0.20 pCi/L. The effective dose calculated from this concentration was estimated to be 454 mrem, and it includes the annual dose received from average background levels of radon (approximately 200 mrem per year).

1

Introduction to the Site

1

Introduction to the Site

Today, the Fernald site, which is owned by the Department of Energy (DOE), focuses extensively on environmental restoration. Because it was formerly a uranium metals processing facility, scientists closely investigate the site and surrounding areas for contamination. Remedial techniques are then developed accordingly.

This Fernald Site Environmental Report (SER) documents the results of the Environmental Monitoring Program for calendar year 1993. In accordance with DOE Order 5400.1, "General Environmental Protection Program," the information in the 1993 SER is current from January 1, 1993, through December 31, 1993.[1] In order to put the material presented in this report into perspective, Chapter One contains the following introductory sections:

- **The Fernald Site Mission: Environmental Compliance and Restoration,** a historical overview of the site's former operations and its current cleanup mission leading to current site activities;
- **Environmental Program Information,** a description of site activities aimed at monitoring and maintaining environmental quality;
- **Local Geography,** an introduction to the physical, ecological, and human characteristics of the area;
- **Exposure Pathways to Humans,** an examination of the physical and biological surroundings as possible routes for contaminants to reach local communities; and
- **Environmental Standards and Guidelines,** a description of the various standards with which the Fernald site must comply to protect the local environment.

The Fernald Site Mission: Environmental Compliance and Restoration

In recent years, the mission at the Fernald site has become one of environmental compliance and restoration. However, when the site was established in the early 1950s, its primary mission was to produce uranium metal.

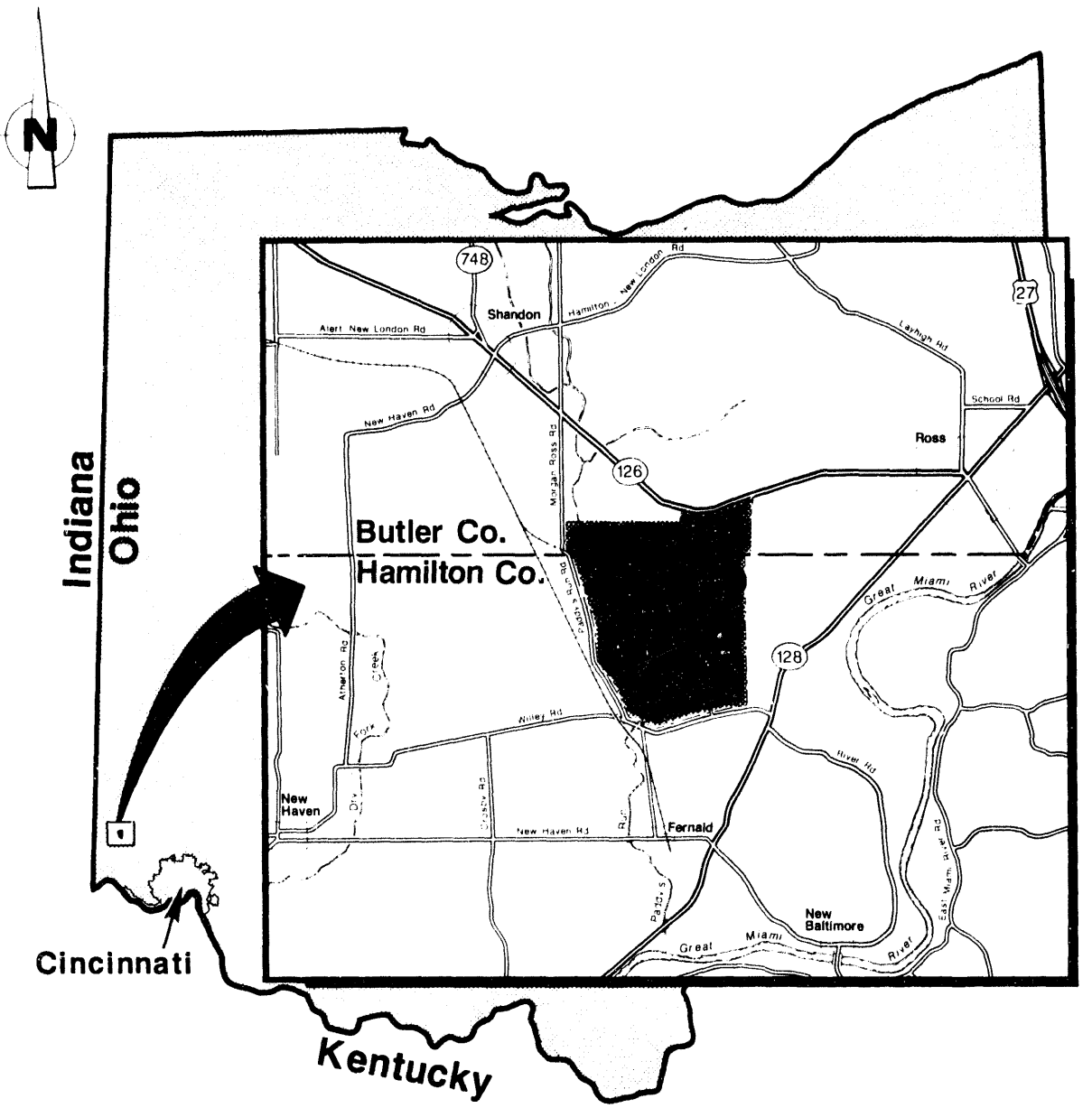
Shortly after the end of World War II, the United States recognized a need for new facilities to produce uranium metal in support of defense activities. Existing facilities, developed for the war effort, were neither economical to operate nor able to meet increasing demands. The Atomic Energy Commission (AEC) required an increase in the quality and quantity of uranium metal as well as improvements in the control and safety of production operations.

After evaluating several sites, the government selected a 425-hectare (1,050-acre) area, about 27 km (17 miles) northwest of downtown Cincinnati, Ohio, as the site for a new production facility (see Figure 1). This facility was sited just north of Fernald, Ohio, a small farming community. Ground was broken on May 16, 1951, and the first uranium derby was produced at the site's Pilot Plant on October 11, 1951. The major portion of construction was completed by 1954.

In general, the relative importance and corresponding funding of the former production and environmental activities reflect the course of U.S. Defense history from the end of World War II until today. Uranium-metal production reached a peak during the height of the Cold War in the 1950s and 1960s. During the late 1970s, funding for production and supporting organizations, including environmental monitoring, was significantly reduced, subsequently reducing supporting activities. Production accelerated again in the early 1980s when the United States increased Defense spending. By the late 1980s, however, an increasing demand for environmental accountability, combined with a decreasing demand for uranium metal at other DOE facilities, influenced DOE to change the site's mission from uranium production to environmental restoration.

Production was suspended in July 1989. In October 1990, DOE transferred management responsibility for the site from its Defense Programs organization to the Office of Environmental Restoration and Waste Management. In February 1991, DOE announced its intention to formally end the production mission and submitted a closure plan to Congress, which became effective in June 1991.

Figure 1: Fernald Site and Vicinity



The Fernald Site covers about 425 hectares (1,050 acres).

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An Overview of Former Production Operations

Although production at the Fernald site ended in 1989, a brief overview of the production process will provide the reader with a perspective on the ongoing Environmental Monitoring Program and other environmental investigations. The major steps in the production process are highlighted in Figure 2. A variety of materials were used in the process, including many that were received from other DOE sites. In fact, materials such as floor sweepings, dust collector residues, and production residues were recycled in order to recover as much uranium as possible.

Depleted and Enriched Uranium

Most of the uranium processed in more recent years at the site was depleted in the uranium-235 isotope; that is, it contained a smaller percentage of uranium-235 than does naturally occurring uranium — less than 0.71%. (Isotopes are discussed in Chapter Two, "Fundamentals of Radiation and Health Hazards.") For many years, much of the uranium processed was slightly enriched — 0.71% to 2% uranium-235

The first production steps involved chemical processing that ended with an intermediate product commonly called "green salt" (uranium tetrafluoride, UF_4). The green salt was then blended with magnesium-metal granules, placed in a closed reduction pot, and heated in furnaces in Plant 5 (see Figure 3). The product of this operation was uranium metal called a "derby."

Some derbies were sent directly to other DOE sites, while the site remelted the remainder, along with uranium scrap metal recovered from earlier production, and poured them into graphite molds to form ingots. Ingots varied in weight, size, and shape according to how they were used at this and other DOE sites. Machining of these ingots occurred in plants 6 and 9, after which the billets (machined ingots) were shipped to other DOE sites, principally the Savannah River Site in South Carolina and the Hanford Site in Richland, Washington.

Handling and Storing Radioactive and Hazardous Materials

Although the Fernald site no longer produces uranium metal, it continues to store materials once used here and at other DOE sites. Some of the radioactive and hazardous materials that were handled or stored onsite during 1993 include the following:

Radioactive

- Magnesium fluoride (MgF_2) contaminated with uranium,
- Pitchblende ore residues containing radium stored in the K-65 silos,
- Radioactive materials in the waste pits,
- Scrap metal contaminated with uranium compounds,
- Thorium and thorium compounds stored within the production area,
- Uranium compounds, and
- Uranium metal.

text continues on page 8

Figure 2: Former Site Production Process

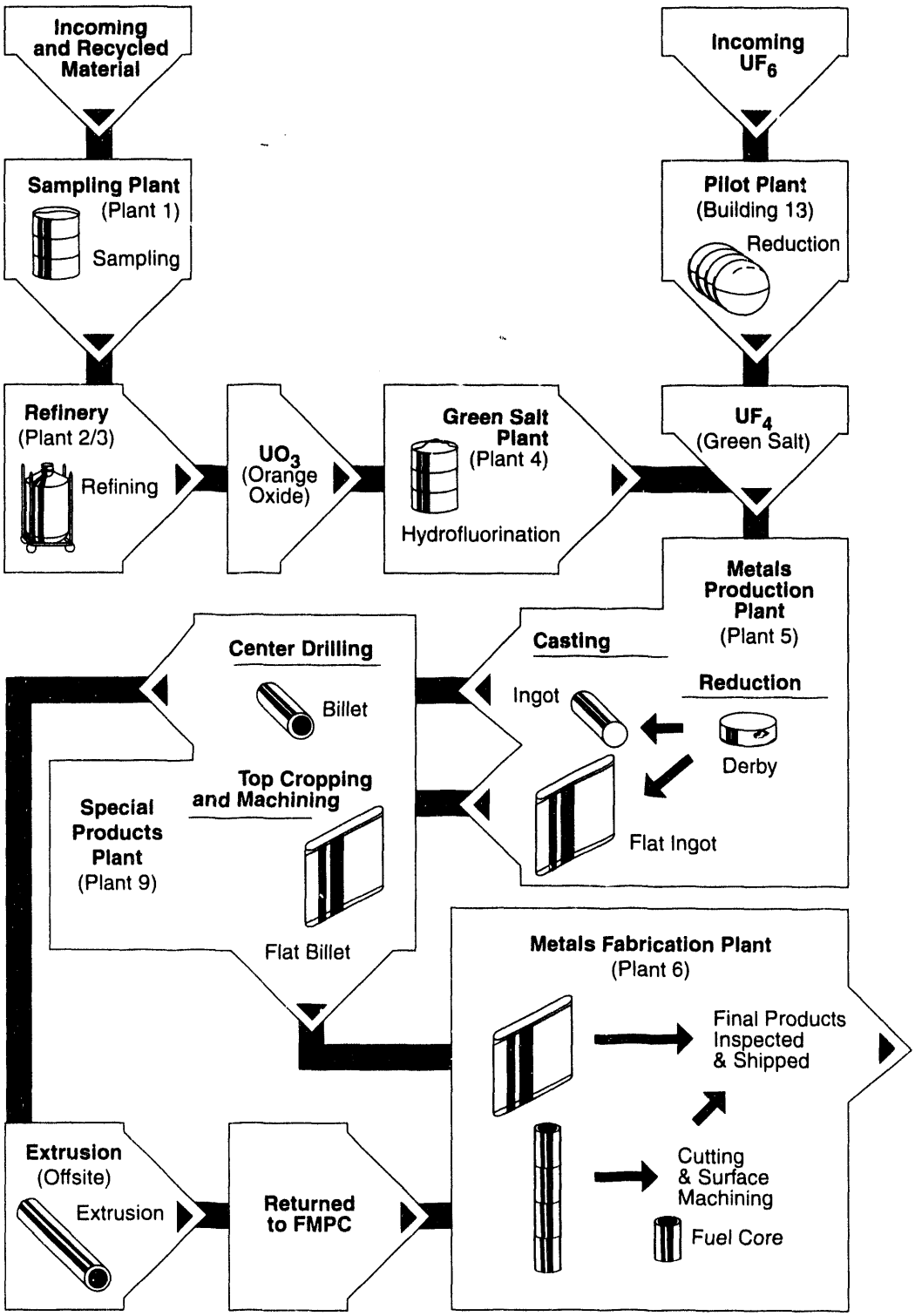
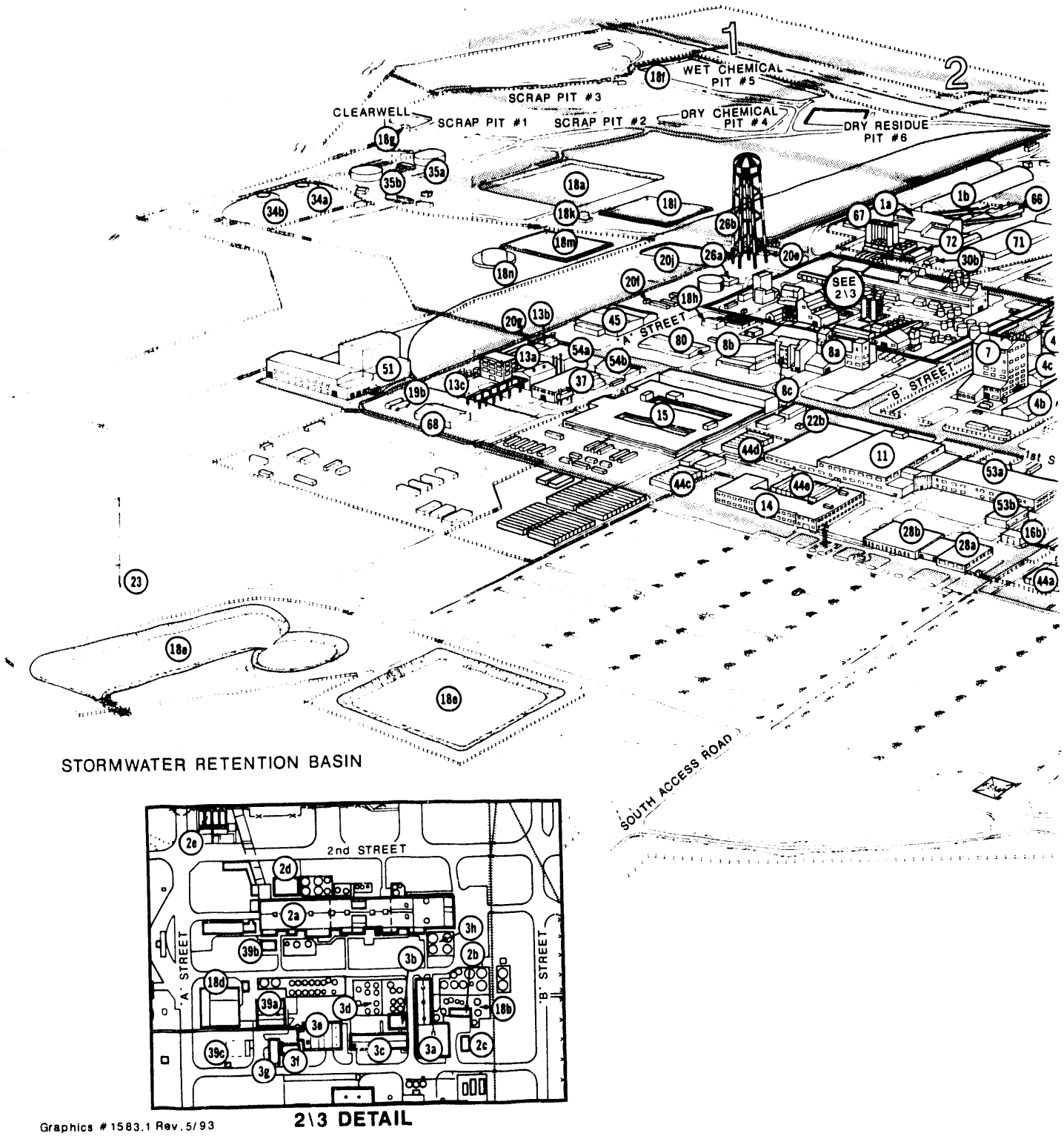


Figure 3: Fernald Site Perspective



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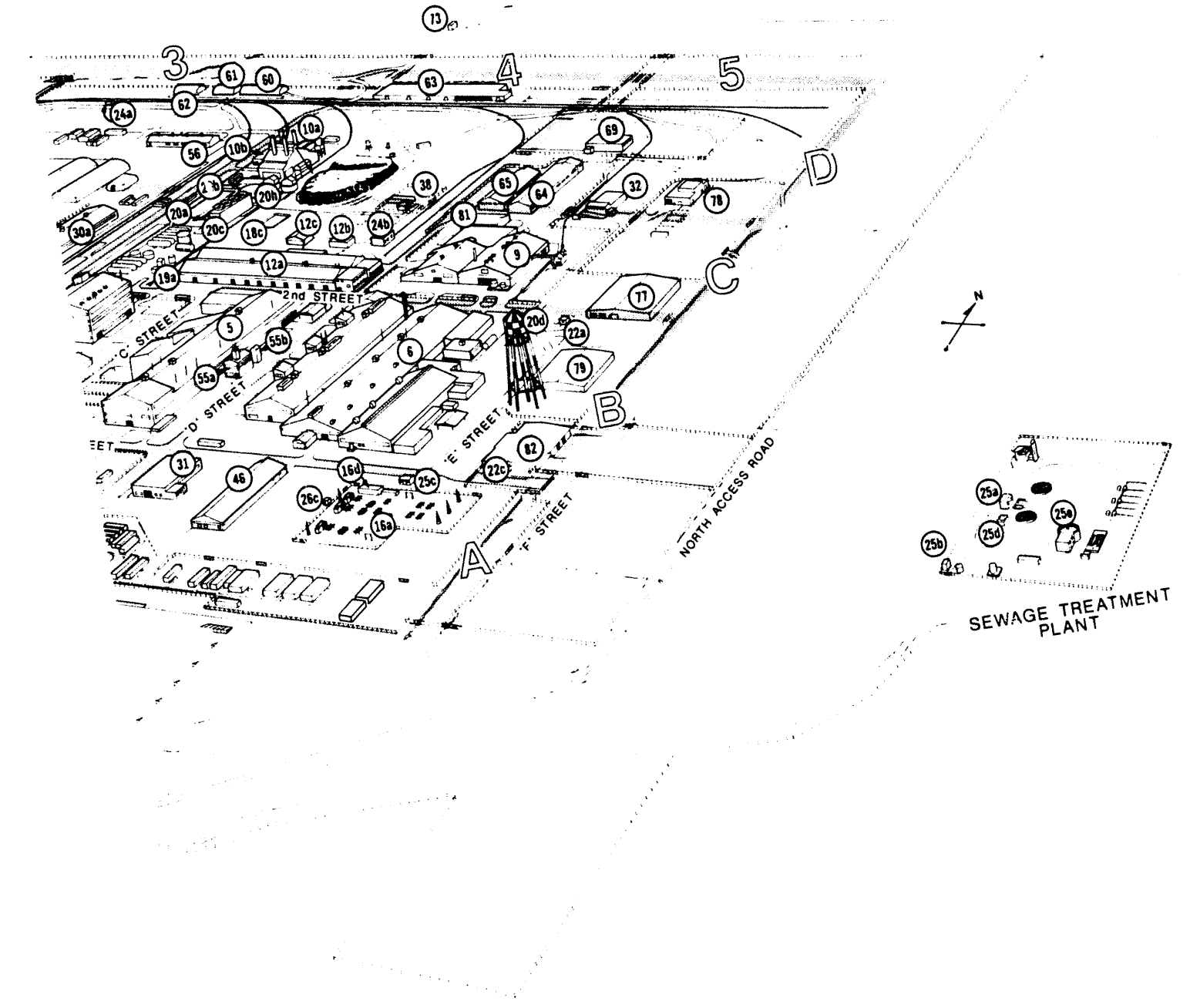

3
4
5
A
B
C
D
2nd STREET
'C' STREET
'D' STREET
'E' STREET
'F' STREET
NORTH ACCESS ROAD
N
SEWAGE TREATMENT PLANT

Building Identification

Building ID No.	Grid Coordinates	Title
00	**	General
1a	C-3	Preparation Plant
1b	C-3	Plant 1 Storage Building
2a	B-3	Ore Refinery Plant
2b	B-3	Lime Handling Building
2c	B-3	Bulk Lime Handling Building
2d	B-3	Metal Dissolver Building
2e	C-3	NFS Storage and Pump House
3a	B-3	Maintenance Building
3b	B-3	Ozone Building
3c	B-3	Control House
3d	B-3	NAR Towers
3e	B-3	Hot Raffinate Building
3f	B-3	Digestion Fume Recovery
3g	B-3	Refrigeration Building
3h	B-3	Refinery Sump
4a	B-4	Green Salt Plant
4b	B-4	Plant 4 Warehouse
4c	B-4	Plant 4 Maintenance Building
5	B-4	Metals Production Plant
6	B-5	Metals Fabrication Plant
7	B-4	Plant 7
8a	B-3	Recovery Plant
8b	B-3	Maintenance Building
8c	B-3	Rotary Kiln/Drum Reconditioning
9	C-5	Special Products Plant
10a	D-4	Boiler Plant
10b	D-4	Boiler Plant Maintenance Building
11	A-4	Service Building
12a	C-4	Maintenance Building (Main)
12b	C-4	Cylinder Storage Building
12c	C-4	Lumber Storage Building
13a	A-3	Pilot Plant Wet Side
13b	A-3	Pilot Plant Maintenance Building
13c	A-3	Sump Pump House
14	A-4	Administration Building
15	A-3	Laboratories
16a	A-5	Main Electrical Station
16b	A-4	Electrical Substation
18a	C-2	Biodenitrification Surge Lagoon
18b	B-3	General Sump
18c	C-4	Coal Pile Runoff Basin
18d	B-3	Biodenitrification Towers
18e	*	Stormwater Retention Basin
18f	D-1	Pit 5 Sluice Gate
18g	C-1	Clearwell Pump House
18h	B-3	BDN Effluent Treatment Facility
18k	B-2	Methanol Tank
18l	C-2	Low Nitrate Tank
18m	B-2	High Nitrate Tank
18n	B-2	High Nitrate Storage Tank
19a	C-4	Main Metal Tank Farm
19b	A-3	Pilot Plant Ammonia Tank Farm
20a	C-4	Pump Station and Power Center
20b	D-4	Water Plant
20c	C-4	Cooling Towers
20d	B-5	Elevated Storage Tank (Potable H ₂ 0)
20e	B-3	Well House #1
20f	B-3	Well House #2
20g	A-3	Well House #3
20h	D-4	Process Water Storage Tank
20j	B-2	Lime Slurry Pits
22a	B-5	Gas Meter Building
22b	A-3	Storm Sewer Lift Station
22c	A-5	Truck Scale
23	*	Meteorological Tower
24a	D-3	Railroad Scale House
24b	C-4	Railroad Engine Building
25a	*	Chlorination Building
25b	*	Manhole-175
25c	A-5	Sewage Lift Station Building
25d	*	U.V. Disinfection Building
25e	*	Digester Control Building
26a	B-3	Pump House - H.P. Fire Protection
26b	B-3	Elevated Water Storage Tank
28a	A-4	Security Building
28b	A-4	Human Resources Building
30a	C-3	Chemical Warehouse
30b	C-3	Drum Storage Warehouse
31	A-5	Engine House - Garage
32	D-5	Magnesium Storage
34a	B-1	K-65 Storage Tank - North
34b	B-1	K-65 Storage Tank - South
35a	C-1	Metal Oxide Storage Tank - North
35b	B-1	Metal Oxide Storage Tank - South
37	A-3	Pilot Plant Annex
38	D-4	Propane Storage
39a	B-3	Incinerator Building
39b	B-3	Shelter Storage Building
39c	B-3	Incinerator Building Sprinkler Riser House
44a	A-5	Trailer Complex — 6-Plex (East)
44c	A-3	Trailer Complex — 7-Plex (South)
44d	A-3	Trailer Complex — 7-Plex (North)
44e	A-4	Trailer Complex — 10-Plex
45	B-3	Rust Engineering Building
46	A-5	Heavy Equipment Garage
51	A-2	UF_6 to UF_4 Reduction Facility II
53a	A-4	Occupational Safety & Health
53b	A-4	In-Vivo Building
54a	A-3	UF_6 to UF_4 Reduction Facility I
54b	A-3	Pilot Plant Warehouse
55a	B-4	Slag Recycling Plant
55b	B-4	Slag Recycling Pit/Elevator
56	D-3	CP Storage Warehouse
60	D-3	Quonset Hut #1
61	D-3	Quonset Hut #2
62	D-3	Quonset Hut #3
63	D-4	KC-2 Warehouse
64	D-5	Thorium Warehouse
65	D-5	(Old) Plant 5 Warehouse
66	C-3	Drum Reconditioning Building
67	C-3	Plant 1 Thorium Warehouse
68	A-3	Pilot Plant Warehouse
69	D-5	Decontamination Building
71	C-3	General In-Process Storage Warehouse
72	C-3	Drum Storage Building
73	*	Fire Brigade Training Center Building
77	C-5	Finished Products Warehouse
78	*	New D&D Facility
79	B-5	Plant 6 Warehouse
80	B-3	Plant 8 Warehouse
81	C-5	Plant 9 Warehouse
82	B-5	Receiving & Incoming Materials Inspection Area

* Outside of Perimeter Security Fence
** NOTE: Any Unidentified Areas Referred to as 00 General

Hazardous

- Heavy metals,
- Hydrochloric acid,
- Laboratory chemicals,
- Methanol,
- Nitric acid,
- Process waste,
- Sodium hydroxide, and
- Sulfuric acid.

The site has repackaged some materials into new drums and removed materials no longer needed since production ended. For example, thorium previously stored in a deteriorating above-ground silo, in bins, and in drums on an outdoor pad has been repackaged in new drums and stored in a warehouse. The Fernald site has significantly reduced its inventory of chemicals once used for production by disposing of them at designated waste disposal facilities.

Environmental Program Information

As a result of the continued onsite storage of radioactive and hazardous waste, the Fernald site conducts environmental program activities to monitor and maintain environmental quality in the area surrounding the site. Some of these activities include the Environmental Monitoring Program, the Meteorology Program, Natural Resource Management, and the Waste Minimization Program which are described below.

Environmental Monitoring Program

Federal and state waste management requirements that were applied during the site operation period are still in effect because of the onsite waste storage. Earlier regulations were often less stringent, and the effects of past operations are still evident. Today, Fernald site personnel continue to investigate these effects on the environment. The Environmental Monitoring Program plays a key role in this effort. Like any complex program or investigation, the Environmental Monitoring Program was developed after careful consideration of many components. For example, former site production processes, which involved both radioactive and nonradioactive materials, resulted in air and liquid releases to the environment. The monitoring program is largely based upon the flow of these materials through the air and liquid pathways. Additional program components address contamination risks associated with cleanup procedures.

Environmental monitoring activities seek to determine the amount of radioactive and nonradioactive materials that leave the site and enter the surrounding environment. In short, this year-round Environmental Monitoring Program has several responsibilities:

- Ensure that the site has procedures in place to detect any release of materials so that corrective actions can be taken as quickly as possible,
- Closely monitor releases to ensure that air emission and liquid effluent standards and guidelines are not exceeded,
- Evaluate the impact of site activities (past and present) on the environment,
- Estimate the radiation dose that area residents may be exposed to as a result of former production operations and current cleanup activities at the site, and
- Measure progress in correcting problems from past operations and in implementing improved environmental management practices.

Meteorology Program

The Fernald site's meteorological monitoring system was installed in August 1986. The meteorological tower is 60 meters (200 feet) tall, with monitoring equipment at both the 10-meter (33-foot) and 60-meter (200-foot) heights. The tower instruments measure wind speed and direction, ambient air temperature, relative humidity, barometric pressure, and precipitation (see Table 1 on page A-2).

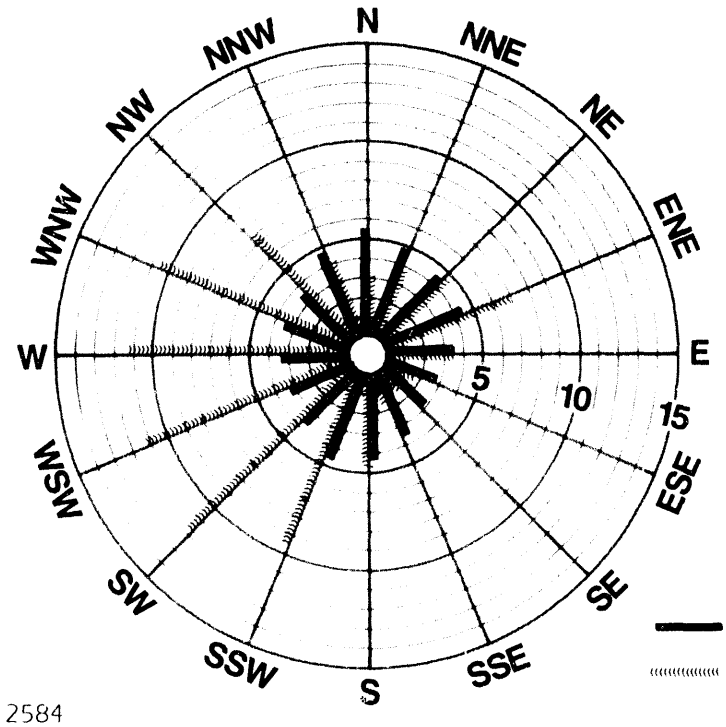
The meteorological instruments are inspected and re-calibrated regularly to ensure that they are functioning properly. The system is down during these routine maintenance periods but not for a length of time that significantly affects the database. While the system is down, it is possible to obtain meteorological data from the Greater Cincinnati – Northern Kentucky International Airport, located about 27 km (17 miles) south of the site.

The meteorological data gathered at the site are primarily used to evaluate climatic conditions at the site. The Environmental Monitoring Program uses atmospheric models to determine how airborne effluents are mixed and dispersed. These models are then used to assess the impact of operations on the surrounding environment, in accordance with DOE requirements.

Airborne pollutants are subject to whatever weather conditions exist. Wind speed and direction, rainfall, and atmospheric stability play a role in predicting how pollutants are distributed in the environment. Weather data, particularly wind speed and direction, provide guidance in collecting environmental samples and locating monitoring stations.

Figures 4 and 5 are annual wind roses, which illustrate the average wind speed and general direction measured at the 10-meter (33-foot) and 60-meter (200-foot) levels in 1993. The wind direction was predominantly toward the northeast, blowing from the southwest sector approximately 11% of the time at the 10-meter (33-foot) level

Figure 4: 1993 Wind Rose Data, 10-Meter Height



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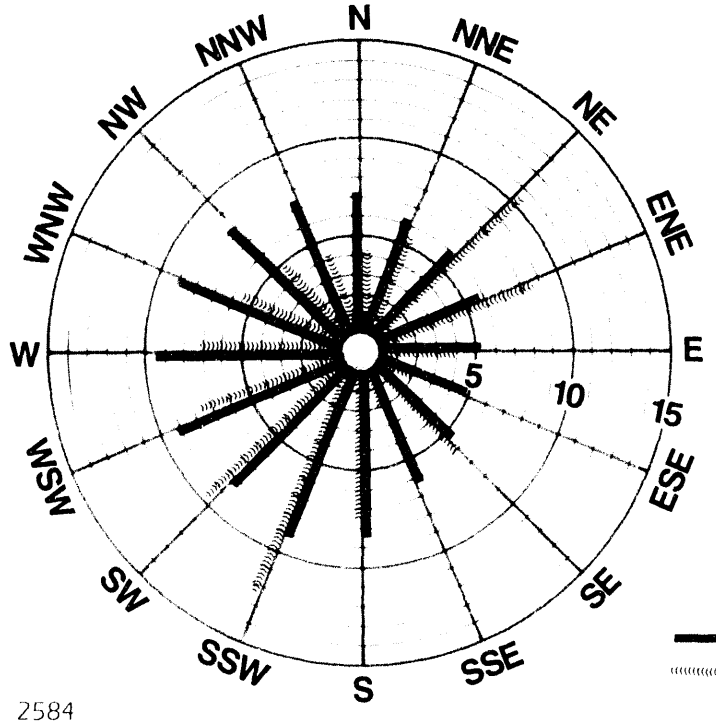
Average wind speed from this direction.

Percentage of time that the wind blew from this direction.

Figure 5: 1993 Wind Rose Data, 60-Meter Height



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Average wind speed from this direction.

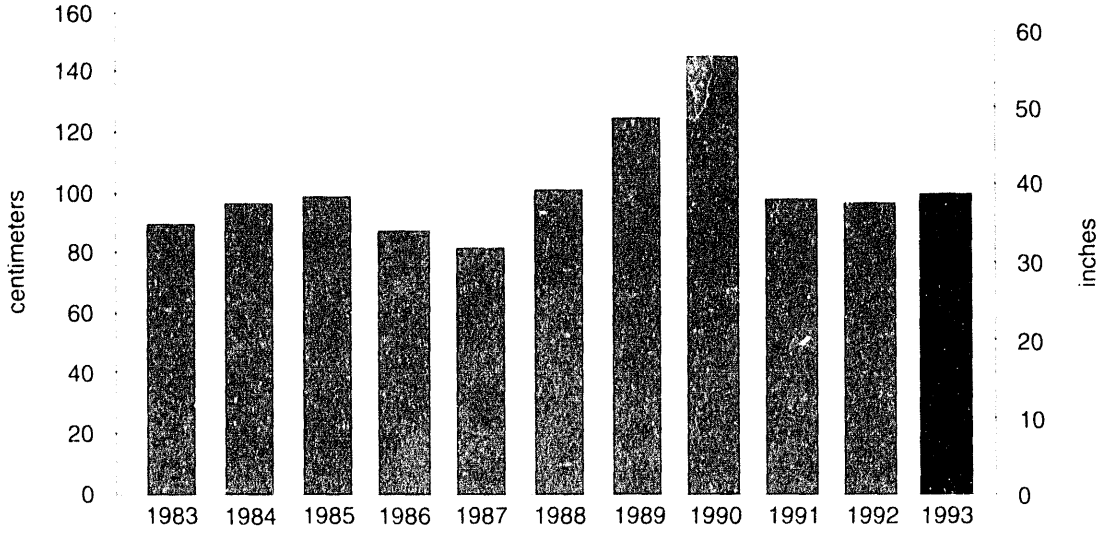
Percentage of time that the wind blew from this direction.

and from the south-southwest sector approximately 12% of the time at the 60-meter (200-foot) level. Winds were calm 13.4% of the time from the 10-meter (33-foot) level and 2.6% of the time from the 60-meter (200-foot) level.

Trees growing near the meteorological tower have had an effect on the measured wind speeds at the 10-meter (33-foot) level because they acted as a wind barrier. After considering the options, the site decided that the most effective and economical solution was tree removal. In November 1993, in coordination with National Environmental Policy Act (NEPA) requirements and after determining there would be no radiological impact, trees within a 107-meter (350-foot) radius were cut down. These trees were placed in several brush piles in the vicinity of the meteorology tower to enhance existing wildlife habitat. The meteorological tower instruments and computer system are being upgraded as well. These changes should more accurately reflect actual meteorological conditions at the Fernald site and will be detailed in the 1994 Site Environmental Report.

In 1993, the precipitation measured at the Fernald site was 98 cm (39 inches), which is slightly less than the average annual precipitation of 104 cm (41 inches) for 1963 through 1992. Figure 6 shows 1993 total precipitation for the area in relation to the annual precipitation amounts recorded since 1983. (Precipitation totals for 1983 through 1992 were taken from the measurements made at the Greater Cincinnati – Northern Kentucky International Airport because of a computer software problem at the site meteorological tower. This problem was corrected, and the 1993 total was taken from measurements made at the Fernald site.)

Figure 6: Annual Precipitation Data, 1983 – 1993*



* Data were taken from the Greater Cincinnati – Northern Kentucky International Airport except 1993 data which is from the Fernald site.

Waste Minimization Program

A challenge at the Fernald site, whose mission is environmental remediation, is to include waste minimization planning and concepts in all activities and minimize any secondary wastes resulting from the remediation activities. The Waste Minimization Program at Fernald matured in 1993. Programs that were initiated in 1992 began to show cost savings, cost avoidances, and a reduction in disposal volumes. It also became apparent in 1993 that there is a greater potential for minimizing wastes during remediation with new technologies and updated policies and procedures.

Large-scale recycling and reuse activities were initiated with a total of 6,335 m^3 (223,700 ft^3) of scrap metal either recycled or beneficially reused within the DOE complex. The successful implementation of this activity focused attention on the feasibility of recycling. A new Recycling Department was formed with the function of establishing mechanisms for the recycling and reuse of waste and scrap material from decontamination, decommissioning, and dismantling operations.

The Fernald site Waste Minimization and Pollution Prevention (WM/PP) Policy became effective in October 1993 and set forth a commitment to protect the environment through WM/PP efforts including source reduction, recycle/reuse, segregation, and good operating practices.

In an effort to integrate WM/PP practices into each site activity, an educational program was developed for all project and design engineers. The program's objective is to assist engineers in applying a life-cycle cost analysis of waste to determine the most environmentally sound and cost-effective project alternative using WM/PP practices.

Additional waste minimization accomplishments in 1993 include the following:

- Recycled 36,320 kg (80,000 pounds) of lead-acid batteries instead of disposing them as hazardous waste;
- Recovered and reused 29 kg (63 pounds) of freon from drinking fountains and air conditioning units;
- Recycled 1,453 kg (3,200 pounds) of metal from PCB- containing light ballasts;
- Segregated 5,429 m^3 (191,700 ft^3) of flyash and 130 m^3 (6,480 ft^3) of asbestos containing materials for disposal as sanitary waste instead of managing as low-level waste;
- Recycled 7,264 m^3 (256,500 ft^3) of office paper, cardboard, glass, and polystyrene;
- Recycled 2,588 kg (5,750 pounds) of aluminum cans and, as a result, donated $1,400 to a local elementary school for an ecology program;
- Segregated controlled-area office trash and established administrative controls in order to divert the trash from disposal as low-level waste, with a cost-savings of more than $62,000;

- Purchased laboratory chemicals as needed instead of in bulk;
- Revised the specifications for the purchase of paper products to require that the paper contains a recycled fiber content of 50% waste paper and 10% post consumer;
- Washed and reused cloth anti-contamination clothing instead of generating paper anti-contamination clothing, reducing the generation of approximately 1.1 m^3 (40 ft^3) of waste per day;
- Sponsored three "Reuse Days" in which unused, old, or extra office supplies were displayed for reuse instead of ordering new supplies; and
- Included waste minimization awareness in employee training courses.

Natural Resource Management

The management of natural resources will be an ongoing process as long as DOE retains ownership of the site. Natural resources have aesthetic, ecological, educational, historical, recreational, and scientific value to the United States. The following discussions provide information on the natural resources found on Fernald site property.

Ecology

Representative of the regional ecology, the area's natural vegetation is comprised of a broad-leafed deciduous forest, dominated by beech and maple hardwoods. Some of these naturally wooded areas still exist north of the site and in the Paddys Run watershed to the west. Sixty-two acres immediately north of the production area were planted with white and Austrian pines as part of a 1973 environmental improvement project. Non-native grasslands cover most of the remainder of the site, and local dairy farmers lease Fernald site pastures for their herds to graze, consistent with the property's former agricultural uses. The plant diversity provides abundant cover for deer, eastern cottontails, woodchucks, and bobwhite quail; predatory birds, such as red-tailed hawks, have also been observed on Fernald site property. Song sparrows, blue jays, cardinals, and robins nest in the pine plantations, while Paddys Run is home to numerous species of small fish, including minnows, darters, and shiners.

In 1986, biologists from Miami University in Oxford, Ohio, began a comprehensive ecological study of the site. In addition to collecting extensive ecological baseline data, they also studied plants and animals to determine if any species were being stressed by former site operations. Based on statistical analyses, the study concluded that the site's impact on the natural habitat did not appear to be different from the ecological impact of any other local industrial site. Their report, published in 1990, also concluded that no plants or animals found onsite at that time were on the federal endangered species list.[2]

Threatened and Endangered Species

The Endangered Species Act states that all federal agencies must seek to conserve federal-listed threatened and endangered species. The site has conducted surveys since the Miami University study to gather updated information on any threatened or endangered species that may be found onsite. The Indiana bat (*Myotis sodalis*) and the running buffalo clover (*Trifolium stoloniferum*), which are both on the federal list, may occur at the site, and suitable habitat has been identified on Fernald site property. Both of these species are found to occur in the surrounding areas. Several state-listed threatened and endangered species have been seen on or near the Fernald site property, including the cave salamander (*Eurycea lucifuga*), Sloan's crayfish (*Orconectes sloanii*), slender fingergrass (*Digitaria filiformis*), mountain bindweed (*Polygonum cilinode*), and spring coralroot (*Corallorhiza wisteriana*). There are several species of threatened and endangered migratory birds that pass through the site. Some of the birds that have actually been spotted onsite include the northern harrier (*Circus cyaneus*), northern waterthrush (*Seiurus noveboracensis*), and dark-eyed junco (*Junco hyemalis*).

Wetlands

Wetlands are defined as areas covered or saturated with water for enough time to support water-loving vegetation. A wetland delineation was conducted on the site in December 1992 and January 1993. A total of 15 hectares (36 acres) of freshwater wetlands were delineated on the Fernald site. Delineated wetlands included 11 hectares (27 acres) of palustrine forested wetlands, 3 hectares (7 acres) of drainage ditches/swales, and 1 hectare (2 acres) of isolated persistent emergent and scrub/shrub wetlands. A wetland delineation is scheduled to be conducted every three years in order to provide current information.

Floodplains

Floodplains within the site property are confined to the north-south corridor that contains Paddys Run. Outside of the site boundaries, the 100- and 500-year floodplains of the Great Miami River extend west of the "Big Bend" region, which is east of the Fernald site. It also extends northward along Paddys Run from the confluence of the two waterways past the southern boundary of the site. This area overlaps a body of uranium-contaminated groundwater called the South Plume.

Cultural Resources

The population and cultural growth of an area are determined by factors such as geologic setting, surface waters, soils, vegetation, and climate. The Fernald site and surrounding area are located in a region of rich soil and many sources of water, such as the Great Miami River. As a result, the area has a rich cultural resource diversity. This diversity is evident by the number of historical periods represented in the area's history. These periods include the following:

- Paleo-Indian Occupation (12000 BC – 8000 BC),
- Archaic Occupation (8000 BC – 1000 BC),

- Woodland Tradition (1000 BC – 1000 AD),
- Mississippian Tradition (1000 AD – 1660 AD), and
- Historic Times (1660 AD – Present).

Local Geography

A variety of regional physical, ecological, and human characteristics form the context in which environmental monitoring results must be analyzed. By studying various elements of the local geography, scientists and engineers are better able to identify the impact of former production activities. Remedial techniques are then designed to restore the physical environment to its original state or to an established cleanup standard. The following sections describe several of these characteristics, beginning with the geologic origins of the area.

Geologic History

About 450 million years ago, in the Late Ordovician period, sediments were deposited in a shallow sea. These sediments solidified over time to become predominantly shale with alternating thin layers of limestone. This strata is known universally as the Cincinnatian Series. The shale is the relatively impermeable bedrock underlying the site.

An ancient river cut into the shale bedrock to about 60 meters (200 feet) below the present-day Great Miami River, forming a channel named the New Haven Trough. Later, the Illinoisan and Wisconsin glaciers (about 40,000 years ago and 10,000 years ago, respectively) advanced into the area during the Pleistocene epoch. These glaciers crushed rocks as the ice moved southward from the arctic region. As the glaciers receded, they filled the trough with sand and gravel sediments.[3]

The last of the glaciers in the Fernald area deposited a relatively impermeable *glacial till* over the sands and gravel. A mix of clay, silt, sand, gravel, and cobbles, this glacial till is unevenly deposited throughout the area and makes up the local *overburden*.

The Great Miami River and its tributaries have eroded significant portions of the overburden and left *terrace remnants* which stand higher than surrounding bottom lands of the river valley. The Fernald site lies on top of one of these terrace remnants, about 177 meters (580 feet) above sea level. The property rises to 213 meters (700 feet) at the northern boundary of the site and slopes downward to 168 meters (550 feet) at Paddys Run. North and south-southwest of the site, the hills peak at about 260 meters (850 feet) and 235 meters (770 feet), respectively. The elevation of the Great Miami River, east of the site, is about 165 meters (540 feet), while the land rises gently to about 183 meters (600 feet) west of the site. Figure 7 presents a cross-section of the area.

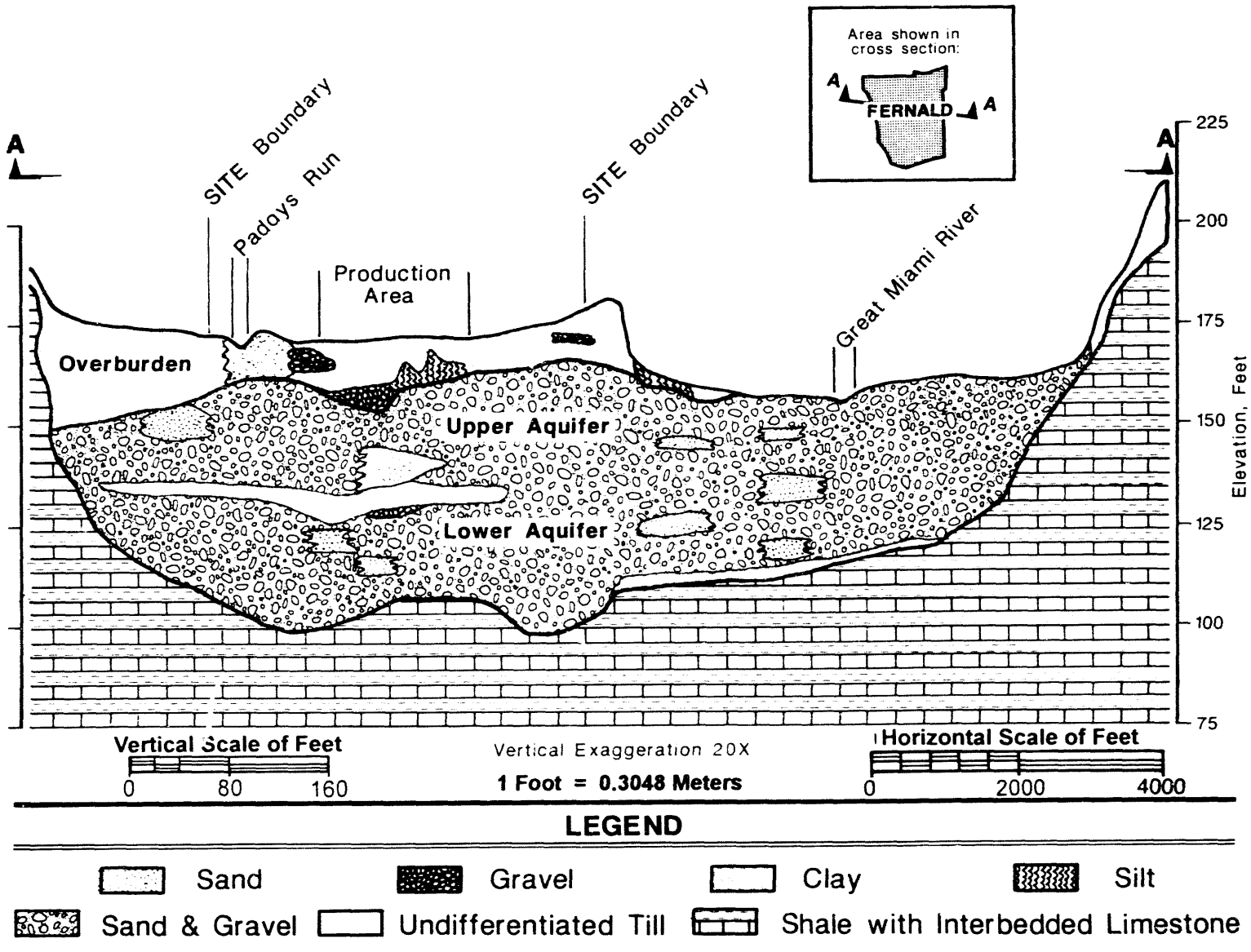


Figure 7: Cross-Section of the New Haven Trough, Looking North

Lithology

Lithology is the study, classification, and mapping of rocks and rock formations. This science is vital in determining the location, flow, and direction of groundwater. The shale underlying the site forms the floor and valley walls of the New Haven Trough and is generally between 18 and 60 meters (60 and 200 feet) below the ground surface. The elevation of the bedrock surface varies from 100 meters (330 feet) above sea level south of the production area to 122 meters (400 feet) just north of the site.[4]

Sand and gravel filling the New Haven Trough are up to 60 meters (200 feet) thick. This relatively porous material makes up the Great Miami Aquifer. About 30 to 38 meters (100 to 125 feet) below the surface of the Fernald site, the sand and gravel is divided by a greenish-black silty clay layer, about 3 to 6 meters (10 to 20 feet) thick.[4,5] Data collected as part of the ongoing Remedial Investigation and Feasibility Study (RI/FS) suggest that the clay layer extends from west of Paddys Run to the center of the production area and is present beneath the waste pit area. The clay layer does not extend east or south of the production area.

A silty clay glacial till overlies the sand and gravel aquifer. This dense overburden, ranging in thickness between 6 and 15 meters (20 and 50 feet), varies in composition both vertically and horizontally. The elevation of the base of the overburden is 165 meters (540 feet) above sea level.[4,5,6] The silty clay overburden continues north and east of the site, where it rests upon the shale bedrock. However, in the lower reaches of Paddys Run and the outfall ditch, the clay has eroded, exposing the underlying sand and gravel and giving the aquifer direct contact with surface runoff.

Groundwater Hydrology

Hydrology is the study of the properties, distribution, and circulation of water through the local environment. Surface hydrology, discussed in the next section, is the study of drainage systems like rivers, streams, and rainwater runoff. Groundwater hydrology, discussed here, focuses on the movement of water below the earth's surface.

Groundwater beneath the site exists in the glacial overburden as perched water in a sand and gravel aquifer and, to a much lesser extent, in the underlying bedrock. Perched water occurs when water sinking through the earth from the surface is trapped above very dense clay. Some of this perched water may slowly seep through the clay, but most remains trapped. At the Fernald site, perched water is generally found between 0.3 and 3 meters (1 to 10 feet) below the surface. Perched water in the glacial overburden occurs sporadically and is not a sufficient source of drinking water. In the overburden, water does not move as easily as water in the sand and gravel aquifer below since most perched water occurs in isolated pockets.[7]

Water sinking through the glacial overburden quickly collects in the sand and gravel aquifer, saturating it. Most water is prevented from sinking further by the nearly impermeable rock floor. The top of the aquifer is about 25 meters (82 feet) beneath the site, and the aquifer is between 38 and 53 meters (125 and 175 feet) thick. As shown in Figure 8, the groundwater in the sand and gravel aquifer is moving east under the waste pit and production areas, while on the southern edge of the facility, groundwater moves generally to the south. These groundwater flow data are used to track and forecast the movement of contaminants which may be found in the aquifer.

There may be groundwater even deeper in the slightly permeable rock layers below the sand and gravel aquifer; however, this water is essentially trapped in cracks and fissures and does not contribute any significant amount to the entire flow system.

Surface Hydrology

The Fernald site is part of the Great Miami River drainage basin, although it is above the floodplain (see Figure 9). Natural drainage from the Fernald site to the Great Miami River is primarily via Paddys Run, a small creek which begins north of the site and flows southward along the western edge of the site. This intermittent stream begins losing flow to the underlying sand and gravel aquifer south of the waste pit area. Finally, about 2.4 km (1.5 miles) south of the site, Paddys Run empties into the Great Miami River.

In addition to natural drainage through Paddys Run, site runoff is collected, treated, and discharged to the Great Miami River through an effluent pipeline. The river, about 1 km (0.6 mile) east and south of the Fernald site, runs in a southerly direction and flows into the Ohio River about 39 km (24 miles) downstream of the site. Although turbulence makes the Great Miami River unsafe for swimming, some people do fish there. The segment of the river between the Fernald site and the Ohio River is not designated as a source of public drinking water.

The average flow rate for the Great Miami River in 1993 was 137 cubic meters per second (4,836 cubic feet per second), measured daily about 16 km (10 river miles) upstream of the effluent discharge. Flow rate also fluctuates throughout the year. In 1993, the maximum rate was 860 cms (30,400 cfs) measured in November; the minimum flow was 19 cms (679 cfs) measured in September.[8]

Demography and Land Use

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the site (see Figure 10). Downtown Cincinnati is approximately 27 km (17 miles) southeast of the site, and the cities of Hamilton and Fairfield are 10 to 13 km (6 to 8 miles) to the northeast. There is an estimated population of 14,600 within 8 km (5 miles) of the Fernald site, and an estimated 2.74 million within 80 km (50 miles). Table 2 on page A-3 shows an estimate of population distribution in the surrounding areas.

text continues on page 22

Figure 8: Buried Valley Aquifer Underlying the Fernald Site and Vicinity

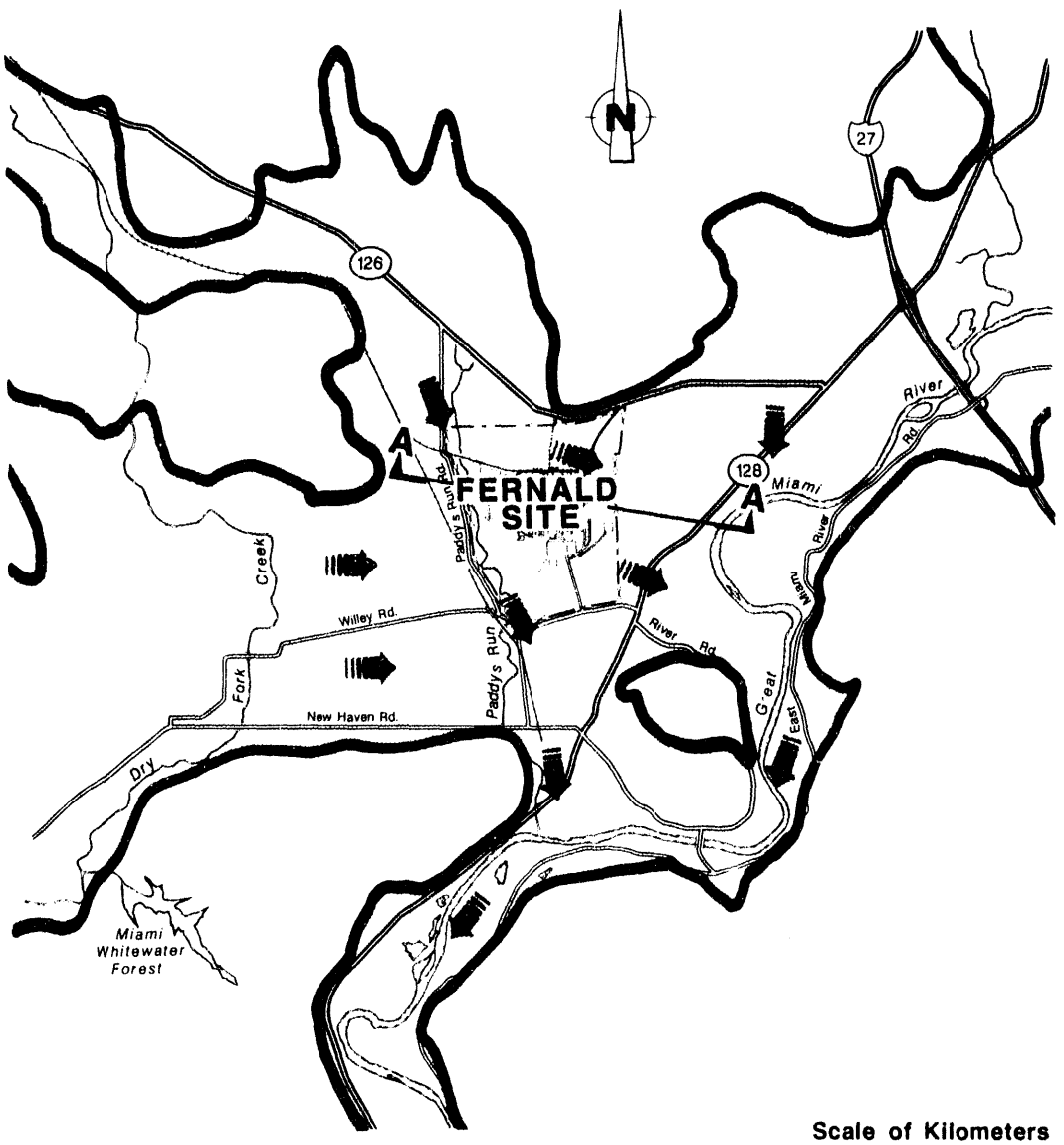


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Figure 9: Great Miami River Drainage Basin

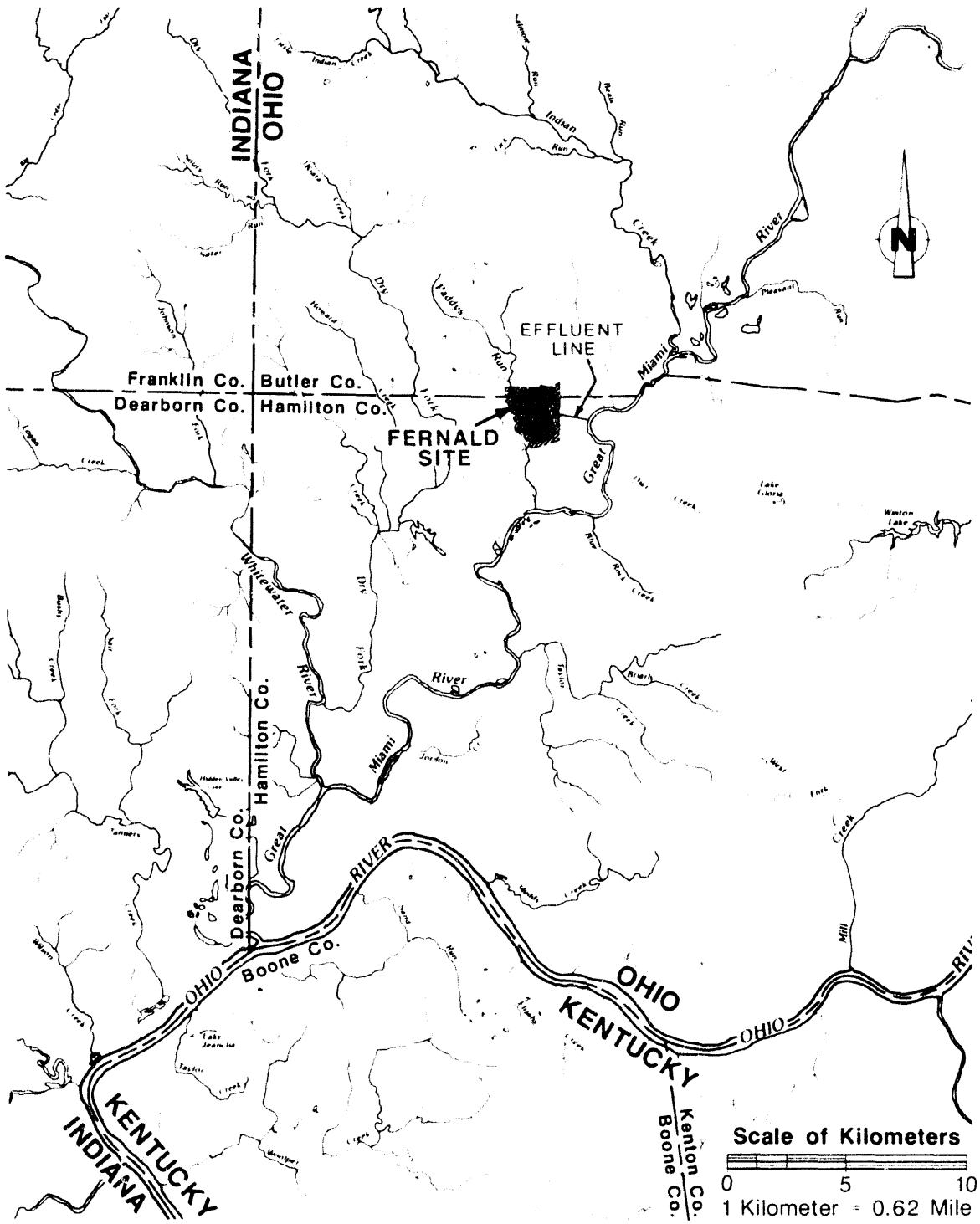

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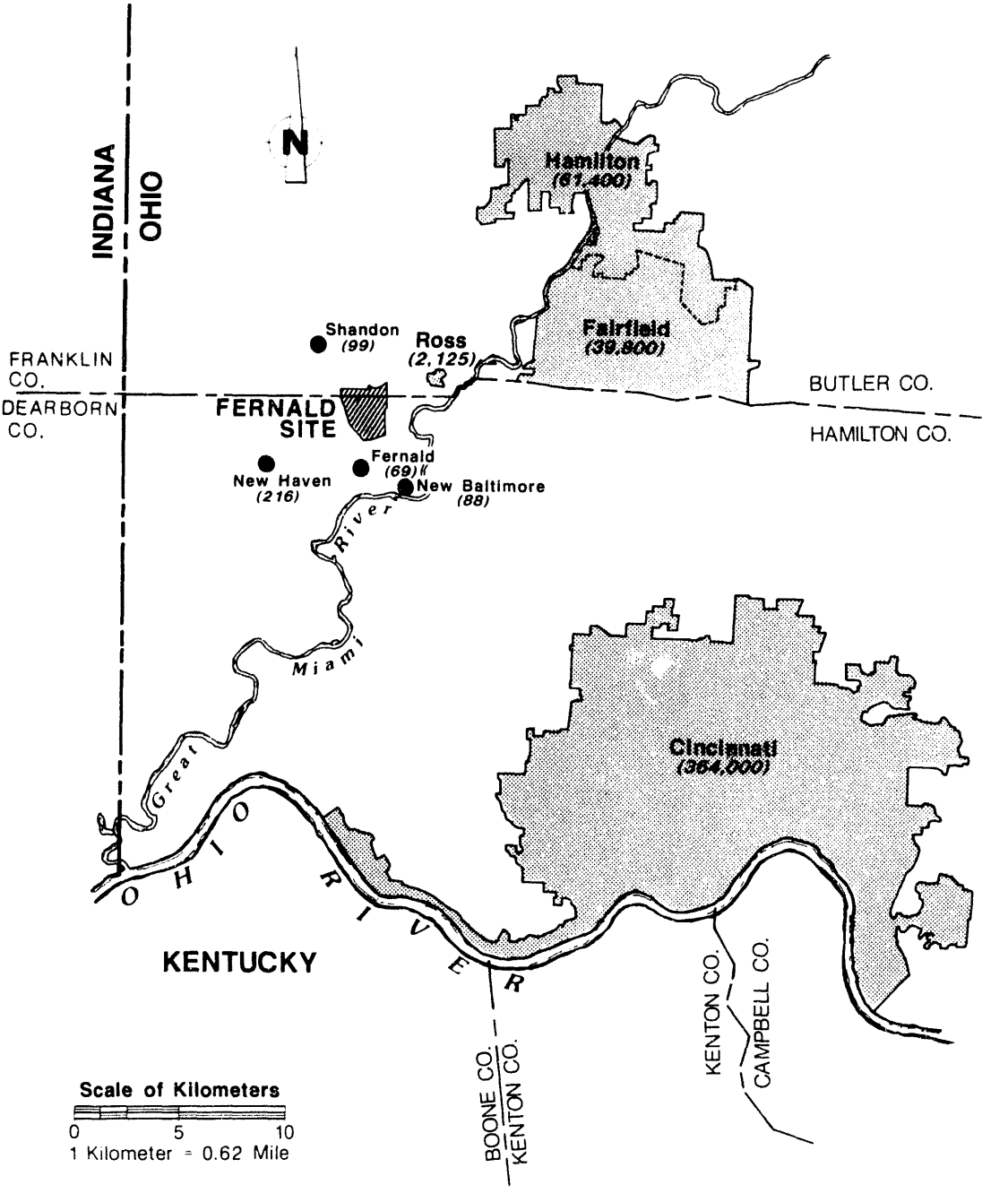
Figure 10: Major Communities in Southwestern Ohio



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The area's major economic activities rely heavily on the physical environment. Farming and raising dairy and beef cattle account for the majority of the land use in the area. Major crops include field corn, sweet corn, soybeans, and winter wheat. Several nearby farms also sell produce locally or in nearby urban markets.

Other important commercial products from the area include sand, gravel, and water from the aquifer. Many gravel pit operations exist along the Great Miami River valley. A water company is located 2 km (1.25 miles) upstream of the site's effluent discharge to the river; presently, this company pumps about 76,000 m^3 (20 million gallons) of groundwater per day, for sale primarily to Greater Cincinnati industries.

Exposure Pathways to Humans

To protect the local environment, the Environmental Monitoring Program focuses on *exposure pathways*. A pathway is a route by which materials could travel between the point of release and the point of delivering a radiation or chemical dose to a person. These pollutants may reach people directly via a primary pathway, through contaminated air or water, or through a secondary pathway, such as the food chain. One example of a secondary pathway is the air-to-soil-to-roots-to-produce-to-human pathway. In this scenario, a gas or dust particle released from a stack settles on a field or a plant and is absorbed into the soil. A plant may then absorb the pollutant through its roots; the chemical would then pass into the rest of the plant, including the edible portions.

This scenario presents a simplified pathway that materials may take. The actual route of the material can be very complex, and the quantity of material that could eventually reach people would be very small. To develop an understanding of the complexity, take another look at the pathway and consider that not all materials released settle out of the air; some fraction may be washed out by rain and enter surface water or groundwater. Of the fraction that does settle, not all falls onto fields, and not all of that fraction on fields is absorbed by the roots of plants. This process of dilution and separation continues until some small fraction of what is released in the air may reach the leaves or fruit of the plant. Although certain plants, animals, and soils may concentrate specific materials and are therefore important points in pathways that should be sampled, pathways frequently overlap, and it is difficult to trace them precisely. Environmental sampling and analysis are performed to detect the presence and concentration of pollutants throughout the air and liquid pathways.

Although both radioactive and nonradioactive materials can reach people through the same pathways, the pathway scenarios presented here and throughout the report will focus on radioactive contamination since this is of significant concern at the Fernald site. Much of this report, as well as the Environmental Monitoring Program itself, focuses on radioactive contamination. Uranium is the major radioactive pollutant at the site; however, some of the uranium processed was recycled from nuclear reactors and contains trace concentrations of fission products (such as

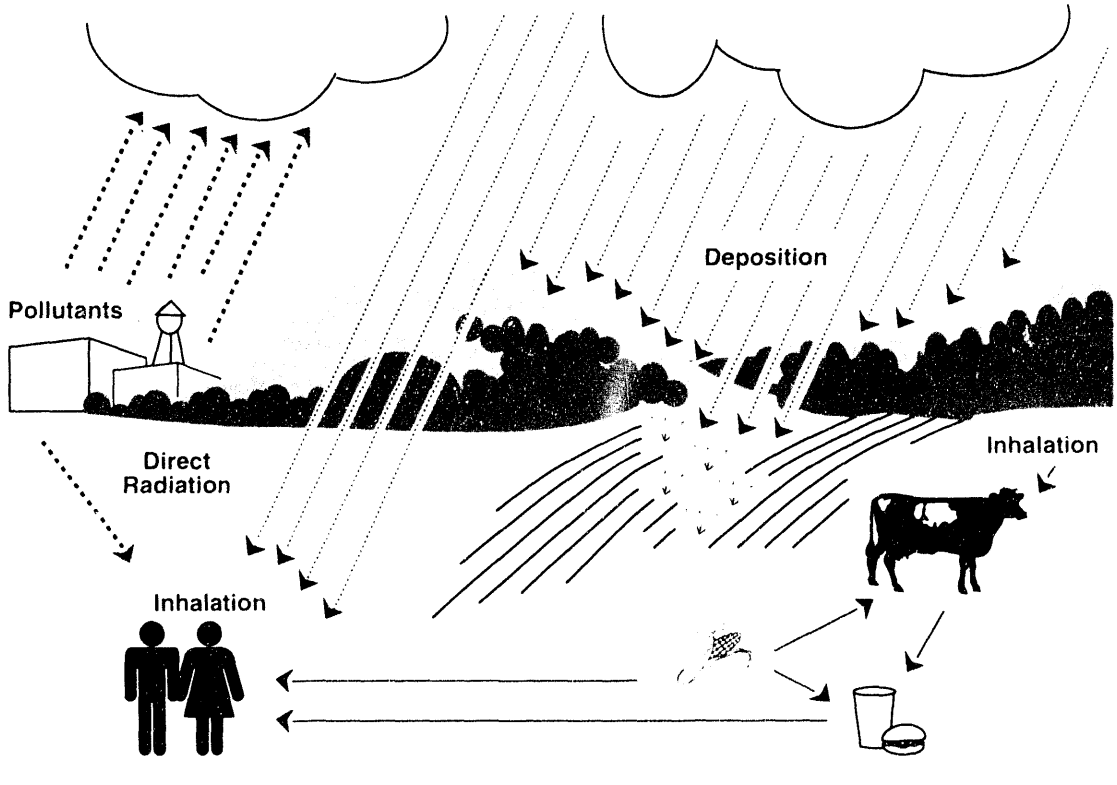
strontium–90 and cesium–137) and transuranics (such as neptunium–237, plutonium–239, and plutonium–240). These nuclides are radioactive, and the site monitors for them in air and liquid discharges to the environment. These trace radionuclides also exist in the environment as a result of fallout from weapons testing and emissions from other nuclear facilities.

To organize the many pathways that exist, the Environmental Monitoring Program centers on two major pathways: air and liquid. These pathways provide a basis for the environmental sampling program and direct which environmental samples and models will be used in estimating dose. (Direct radiation, a third pathway, is monitored with radiation detection instruments that measure radiation emitted directly from the site, particularly from the K-65 silos. Direct radiation is discussed further in Chapter Four.) The following sections describe how materials may follow the air and liquid pathways and briefly describe environmental monitoring procedures.

Air Pathway

The air pathway includes not only all the airborne pollutants that may be carried from the Fernald site through emissions but also through direct radiation (see Figure 11). Stack and building vent emissions are obvious sources of pollutants, but dust from construction and remediation activities, waste handling, and wind erosion are also important potential sources. The form and chemical makeup of pollutants influence

Figure 11: General Air Pathways to Humans



how they are dispersed in the environment as well as how they may deliver radiation doses. For example, fine particles and gases may be inhaled, while larger, heavier particles tend to settle and deposit on grass or soil. Chemical properties determine whether the pollutant will dissolve in water, be absorbed by plants and animals, or settle in sediments and soils.

For the environmental scientist, the first step in monitoring the air pathway is to measure the concentration of the pollutants at the point of release, after they have gone through treatments and filtering. This provides preliminary information on how much pollutant is released and how it will behave in the environment. It is also possible to estimate the concentration of contaminants in the air once the emissions pass through the stack. The site operated 20 air monitoring stations 24 hours a day, seven days a week, during 1993 to monitor these air emissions.

Liquid Pathway

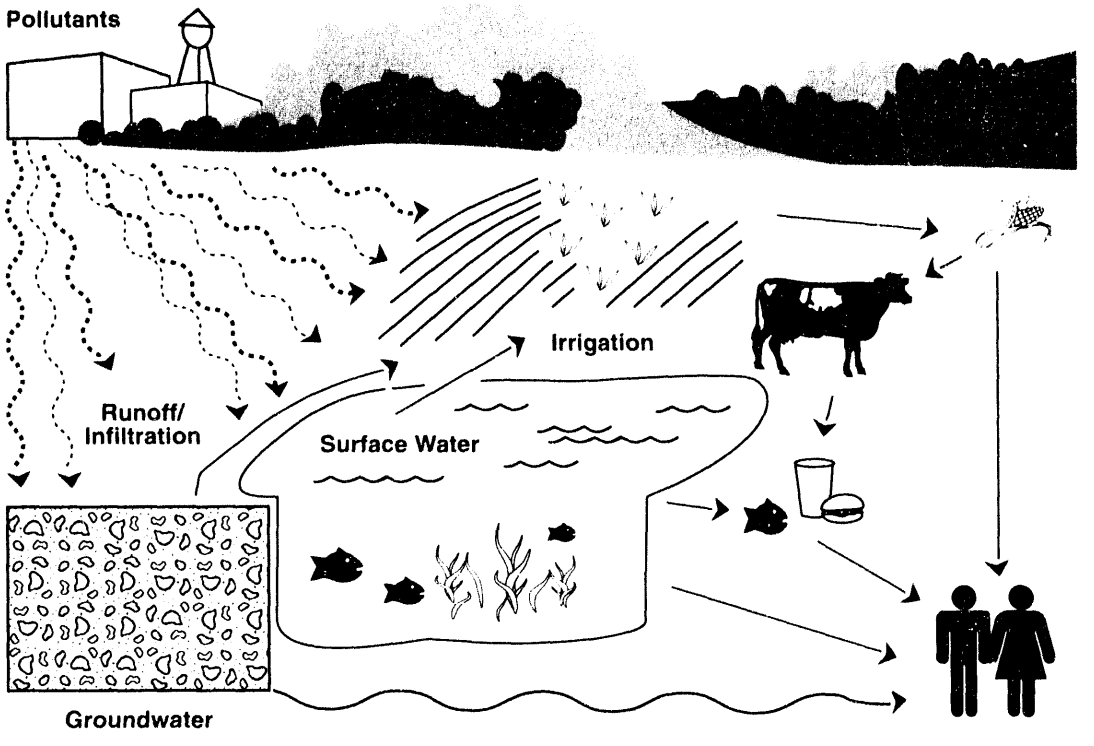
The liquid pathway includes all releases that could carry waterborne pollutants (see Figure 12). The principal liquid pathways include the effluent discharge line to the Great Miami River, the overflow spillway from the Stormwater Retention Basin, uncontrolled stormwater runoff, and groundwater. Just as with the air pathway, the first step in monitoring the liquid pathway is to sample the effluent streams as they leave the site. The potential dose that could be delivered via the liquid pathway can be estimated by the type and concentration of each pollutant. Some pollutants in the liquid effluent may be carried along as suspended solids, which eventually settle out as sediment in the stream bed; other pollutants are dissolved in the water and could be absorbed by plants and animals.

Sediment sampling in Paddys Run and the Great Miami River provides information on whether pollutants are accumulating in the stream beds. Fish sampling can show whether pollutants are being absorbed by aquatic animals and how much radioactive material could reach people if they eat fish from the Great Miami River. Fish are known as *biological indicators* because they can concentrate certain pollutants as they come into contact with them. Therefore, the longer-term influence of the Fernald site can be measured through fish sampling.

Groundwater is an important component of the liquid pathway because it is the source of water for homes and farms in the area. Extensive sampling of the wells on the site and in the surrounding area provides information about the aquifer. By sampling the aquifer in many locations and at varying depths, site personnel can determine the extent of any contamination.

Each pathway has specific standards and guidelines which define the allowable dose limits for the pathway, and these are discussed in the next section.

Figure 12: General Liquid Pathways to Humans



Environmental Standards and Guidelines

As part of data analysis, site personnel compare the data to established standards and guidelines whenever possible. These standards and guidelines have been established by numerous national and international scientific and government groups, including the National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), United States Environmental Protection Agency (USEPA), Ohio EPA (OEPA), and DOE.

These groups have studied the effects of radioactive and nonradioactive materials moving through the many environmental pathways to people. From this information, standards and guidelines have been established to ensure that employees, people in the surrounding communities, and the environment are protected.

DOE adopts standards recommended by various groups of experts and publishes them in DOE orders, thereby establishing the recommendations as limits to be met by DOE facilities. For example, DOE Order 5400.5, "Radiation Protection of the Public and the Environment," defines the guidelines for radiation exposure to the public based upon recommendations of the ICRP.[9,10] Through reports and other

guidance, the ICRP recommended a system of dose limits. Almost all countries with nuclear programs have adopted these recommendations, which provide a scientific basis for radiological protection and the selection of dose limits.

Once DOE publishes a standard in a DOE Order, such as 5400.5, each DOE site must meet the limits of radiation exposure established in that order. These limits refer to the amount of exposure that a person beyond a facility's boundary could receive from breathing the air or drinking the water. The standards in DOE Order 5400.5 require that routine activities not cause a member of the public to receive an annual effective dose from all radioactive sources (except radon and its decay products) greater than 100 mrem. This dose, known as the primary dose limit, is in addition to natural background radiation (discussed in Chapter Two). Underlying all rules and requirements is the philosophy of keeping exposures As Low As Reasonably Achievable (ALARA). Therefore, DOE expects doses from its operations to be just a small fraction of the 100 mrem per year limit.

In addition to the requirements of the primary dose limit and the ALARA process, DOE is subject to several pathway and source-specific limits defined in other federal regulations. These imposed dose limits include, but are not restricted to, doses from the air pathway and from the liquid pathway. For example, the Clean Air Act states that the air pathway (air emissions and fugitive emissions from a facility) cannot contribute more than a 10 mrem effective dose in one year to a member of the public. Again, doses from radon and its decay products are covered separately.[11] For drinking water, DOE operations cannot contribute more than a 4 mrem effective dose in one year to a member of the public.[12]

DOE Order 5400.5 also establishes guidelines for concentrations of radionuclides in air emissions and in liquid effluent. These concentrations, referred to as Derived Concentration Guidelines (DCGs), are initial screening levels that enable site personnel to review emissions and effluent data and determine if there is a need for further investigation.

The Fernald site follows these standards and guidelines in its daily operations and must provide monitoring results on a regular basis to DOE, USEPA, and OEPA in reports that include the following:

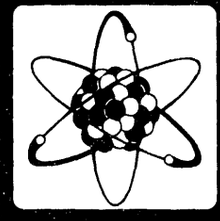
- Annual Radionuclide Air Emissions Report to DOE and USEPA,
- NPDES Monthly Discharge Monitoring Report to OEPA,
- Effluent Information System/Onsite Discharge Information System to DOE, and
- Monthly Consent Agreement Report to USEPA.

This SER compares the results of the site's monitoring program to specific standards for various pollutants. Some pollutants do not yet have standards and DCGs established. Furthermore, there are instances where standards do not exist for specific media, such as uranium in soil, grass, produce, or fish. Where no standards or guidelines are available, other points of reference are presented in order to help the reader assess the impact of Fernald site operations. For example, results are compared with background data from areas unaffected by the Fernald site activities. Results from 1993 are also compared with results from previous years to look for trends.

The remainder of this report discusses some basic facts about radiation and other health hazards, compliance activities, and the Environmental Monitoring Program for 1993.

2

Fundamentals of Radiation and Health Hazards



2

Fundamentals of Radiation and Health Hazards

Since radioactive materials and hazardous chemicals are stored at the Fernald site, it is important to understand the possible health hazards associated with these materials. Also, terms unique to radiation and its potential health effects are used extensively throughout this report. As a result, some of the important information in the report may be difficult for the non-scientist to interpret. This chapter provides a way to put that information into perspective and includes the following topics:

- The atom,
- Radioactivity and radiation,
- The units used to measure radiation,
- Background radiation,
- The effects of radiation,
- Definitions of terms,
- Laws regulating health hazards, and
- Types of health threats.

Readers who are already familiar with the concepts and terms used in the study of radiation and other health hazards may wish to proceed directly to the next chapter, the Environmental Compliance Summary.

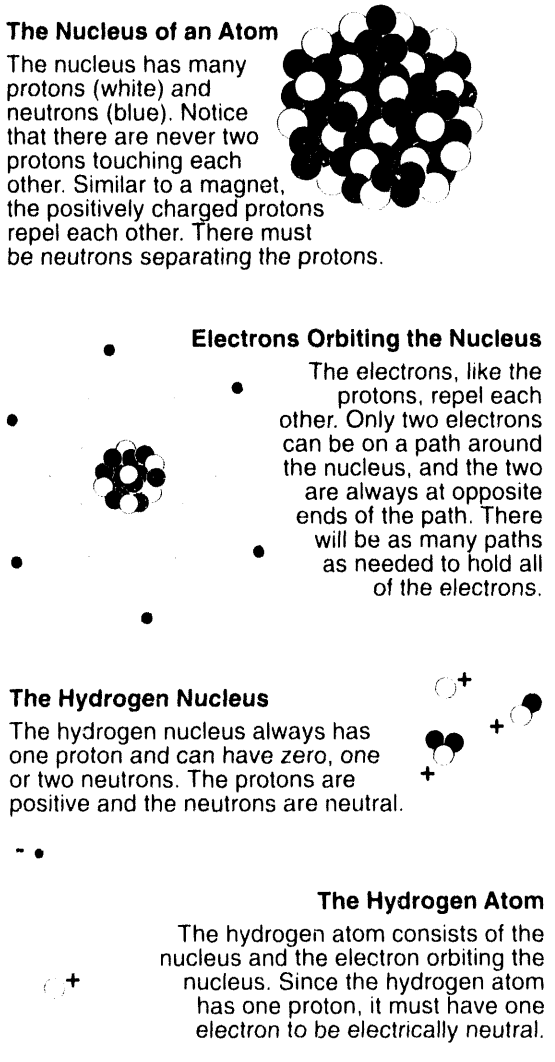
The Atom

The world is made up of atoms. Atoms consist of two basic parts:

- The nucleus, and
- The electrons orbiting the nucleus.

The nucleus is made up of protons, which are positively charged, and neutrons, which have no charge. Protons and neutrons are similar in size, and both are considerably larger than electrons (about 1,800 times more massive). Therefore, the weight and mass of the atom is principally concentrated in the nucleus. The electrons circling the nucleus have a negative charge. Atoms tend to move toward a neutral state in which the negative electrical charge of the orbiting electrons balances the positive charge of the nucleus. To keep the atom electrically neutral, the number of electrons in an atom must equal the number of protons (see Figure 13).

Figure 13: Structure of the Atom



Protons and electrons have many characteristics similar to magnets. Just as opposite magnetic poles are drawn toward each other, protons and electrons are attracted toward each other. This attraction keeps the electrons orbiting around the nucleus. The electrons are not pulled into the nucleus because of the electrons' energy. This energy keeps them constantly moving and away from the protons. The energy in the electrons and the attraction of the electrons to the protons balance each other and keep the electrons in orbit. Just as energy in the electrons keeps them orbiting, energy in the nucleus keeps the protons and neutrons together.

The number of protons in the nucleus is referred to as the atomic number, and it is the identifier of the atom. If the atomic number changes, then the number of electrons and the chemical properties of the atom change. For example, for an atom to be hydrogen, it must have one proton. If a hydrogen atom were to gain a proton, it would no longer be hydrogen; it would be helium, which has two protons. Uranium, the substance of most concern at this site, has 92 protons. Since protons are positively charged, the atom must also have 92 electrons for it to be electrically neutral.

The sum of the protons and neutrons in the nucleus is called the mass number. Unlike protons, the number of neutrons contained in a specific atom can vary since neutrons have no charge and do not need to be balanced by electrons. Therefore, the mass number can vary. For example, a hydrogen atom always has one proton, but it can have either zero, one, or two neutrons. The different hydrogen atoms are called isotopes of hydrogen. Isotopes are labelled with their mass number. A hydrogen atom without a neutron is referred to as hydrogen–1 where 1 is the mass number. The hydrogen isotope with one neutron is referred to as hydrogen–2, and the isotope with two neutrons is referred to as hydrogen–3.

Most of the uranium at the Fernald site contains 146 neutrons to go with the 92 protons present in every uranium nucleus; therefore, the mass number is 238 (146 neutrons + 92 protons = 238). Uranium–234 has 142 neutrons + 92 protons, uranium–235 has 143 neutrons + 92 protons, and uranium–236 has 144 neutrons + 92 protons. All isotopes of uranium are radioactive. Radioactivity and radiation are described in the next section.

Radioactivity and Radiation

Radioactivity is a process in which a nucleus of an unstable atom spontaneously decays or disintegrates. Radiation is the energy that is released as particles or waves when the disintegration or decay of the nucleus occurs. This section includes a discussion of radioactive decay and the three main forms of radiation produced by radioactivity:

- Alpha particles,
- Beta particles, and
- Gamma rays.

It should be noted, however, that not all radioactive substances emit all three types of radiation. Some homeowners have expressed concern about receiving radiation from gamma rays due to the presence of uranium–238 in well water. However, uranium–238 emits alpha particles, not gamma rays. The differences between alpha particles and gamma rays will be clarified in the discussions that follow.

Radioactive Decay

Atoms are radioactive because their nucleus is too large (because of the number of protons and neutrons) or has too much energy to remain stable. By emitting radiation, the nucleus releases energy and moves toward a more stable, less energetic state and eventually becomes a stable atom. Radioactive decay occurs everywhere on earth because of naturally occurring radioactive elements. When most radioactive elements decay, the resulting atom is also radioactive. This is called a radioactive decay chain. There are four natural radioactive decay chains. A common chain begins with uranium–238 and ends with lead–206 (this isotope of lead is stable,

which means it does not decay). Each of the various radioactive atoms (radionuclides) created during the decay sequence has its own natural rate of decay.

It takes a different amount of time for each element to decay to the next element in the chain. The amount of time it takes for a radioactive substance to lose half of its radioactivity, or for half to become the next element in the chain, is its half-life. All decay chains found in nature begin with an isotope with an extremely long half-life. It is assumed that these atoms were formed at the same time as all the other atoms on earth and are still present because their half-lives are comparable to the age of the earth.

The uranium decay sequence is a common example in nature and here at the Fernald site. (The uranium and thorium decay chains are presented on the following page.) Uranium–238 emits an alpha particle (two protons and two neutrons) and becomes thorium–234. Then a neutron in thorium–234 becomes a proton and an electron. The electron is emitted as a beta particle. Then thorium–234 decays to protactinium–234. The decay process proceeds in this manner until the element becomes stable as lead–206. Much of the uranium and thorium at the Fernald site has been chemically purified and separated from other elements shown in the decay series. Elements separated from uranium and thorium are some of the wastes stored onsite. The material stored in the K-65 silos is an example of such waste.

Addressing Homeowner Concerns about Uses of Well Water

Several homeowners near the Fernald site have expressed concern as to why well water with low concentrations of natural uranium may be acceptable for household utility uses such as washing clothes, bathing, and watering plants, but may not be acceptable for drinking or cooking. To some, this has seemed an inconsistency and cause for misunderstanding.

The key to understanding why the water is acceptable for external uses is an understanding of how alpha particles, of prime concern when dealing with uranium, deliver a radiation dose. Alpha particles are large, charged particles that readily interact with other materials. This interaction prevents the particles from ever penetrating very deeply. Even the most energetic alphas from uranium are stopped by the outer layers of dead skin.

However, inside the body, there are no protective dead cell layers to prevent the alpha particles from interacting with live organ cells; all emitted energy is delivered as dose to the organ. The alpha-emitting radionuclide may also be incorporated into specific kinds of cells, depending on its chemical properties. For example, the body processes several radionuclides as though they were calcium; predictably, they end up being deposited in the bones. Research has shown that uranium tends to concentrate in the bone and, to a lesser extent, in the liver, kidneys, and other tissues.

There is also a chemical toxicity associated with uranium, independent of its associated radiation hazards. Studies on animals have indicated that uranium is toxic to the kidney at concentrations of approximately 70,000 pCi/L.[13]

Although the concentrations of concern in these studies are several thousand times greater than the concentration of uranium in local groundwater, it is desirable to limit the intake of uranium. While no measurable increase in health effects can be expected by drinking water with slightly higher than typical background concentrations of uranium, decreasing the amount of uranium ingested may provide valuable peace of mind to those concerned. And, even with slightly higher uranium concentrations, the water is still acceptable for external, household utility use.

Nuclides of the Uranium Decay Chain

Isotope	Half-life	Radiation
Uranium-238	4,500,000,000 years	alpha
Thorium-234	24 days	beta, gamma
Protactinium-234m	1.2 minutes	beta, gamma
Uranium-234	250,000 years	alpha, gamma
Thorium-230	80,000 years	alpha, gamma
Radium-226	1,622 years	alpha, gamma
Radon-222	3.8 days	alpha
Polonium-218	3.05 minutes	alpha
Lead-214	26.8 minutes	beta, gamma
Astatine-218	2.0 seconds	alpha
Bismuth-214	19.7 minutes	beta, gamma
Polonium-214	0.000164 second	alpha, gamma
Thallium-210	1.3 minutes	beta, gamma
Lead-210	22 years	beta, gamma
Bismuth-210	5.0 days	beta
Polonium-210	138 days	alpha, gamma
Thallium-206	4.2 minutes	beta
Lead-206	Stable	none

Nuclides of the Thorium Decay Chain

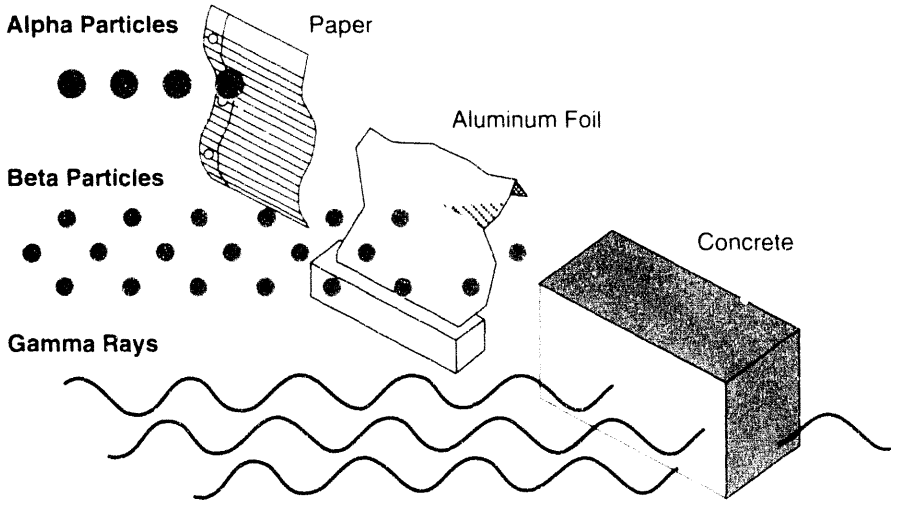
Isotope	Half-life	Radiation
Thorium-232	14,000,000,000 years	alpha
Radium-228	6.7 years	beta
Actinium-228	6.13 hours	beta, gamma
Thorium-228	1.9 years	alpha, gamma
Radium-224	3.64 days	alpha, gamma
Radon-220	55 seconds	alpha
Polonium-216	0.16 second	alpha
Lead-212	10.6 hours	beta, gamma
Bismuth-212	60.5 minutes	alpha, beta, gamma
Polonium-212	0.000000304 second	alpha
Thallium-208	3.1 minutes	beta, gamma
Lead-208	Stable	none

EXAMPLE To illustrate the idea of half-life, let's look at the isotope thorium–234. Its half-life is 24 days. If you started with 1,000 atoms of thorium–234, after 24 days you would have 500. After another 24 days you would have 250, and so on. The half-life of some isotopes, such as uranium–238, is very long. The middle column in the uranium and thorium decay chain examples contains the half-life periods of the elements in the decay chain. All the radionuclides in the Uranium Chain can be thought of as "potential" lead–206 atoms. This will be the case many billions of years into the future when all natural radioactive isotopes will have decayed to their stable end products.

Alpha Particles

Alpha particles consist of two protons and two neutrons and have a positive charge. Because they are charged, they interact with other atoms by scattering off other charged particles, thus losing their energy. Moreover, because of their large size, alpha particles do not travel very far when emitted (1 to 8 centimeters in air). They are unable to penetrate any solid material, such as paper or skin, to any significant depth (see Figure 14). However, if alpha particles are released inside the body, they can damage the soft internal tissues because they deposit all their energy in a very small volume. Uranium decays by emitting alpha particles, so if uranium particles are inhaled or swallowed, the emitted alpha particles may damage internal tissue. Some other radionuclides present at the Fernald site that decay by emitting alpha particles include thorium–228, –230, and –232.

Figure 14: Types of Ionizing Radiation



Beta Particles

Beta particles are electrons that carry a negative electrical charge. They are much smaller than alpha particles and travel at nearly the speed of light; thus, they can travel approximately 2 to 4 meters (6 to 12 feet) in air and penetrate solid materials about 1 cm (0.4 inch). Beta particles interact with other atoms in ways similar to alpha particles, but since they are smaller, faster, and have less charge, they cause less concentrated damage when interacting with tissue. Thorium–234, a decay product of uranium–238, emits beta particles.

Gamma Rays

Gamma rays are bundles of electromagnetic energy which behave as though they were particles. These pseudo-particles are called photons. They are similar to visible light, but of a much higher energy. For example, X-rays are a type of high-energy electromagnetic radiation, and excessive exposure to X-rays can damage the body. Gamma rays are generally more energetic than X-rays. They can travel long distances and can penetrate not only skin, but, depending on their energy, can penetrate

substantial distances into solid materials such as concrete or steel. Gamma rays are often released during radioactive decay along with alpha and beta particles. Some of the materials stored in the K-65 silos decay by emitting gamma rays. Potassium–40 is an example of a naturally occurring radionuclide found in all human tissue that decays by emitting a relatively high-energy gamma ray. The typical human body contains about 110,000 picocuries of potassium–40. (Units of radiation are discussed below.)

Interaction with Matter

When radiation interacts with other materials, it affects the atoms of those materials principally by knocking the negatively charged electrons out of orbit. This causes the atom to lose its electrical neutrality and become positively charged. An atom that is charged, either positively or negatively, is called an ion. Anything that creates an ion is said to be ionizing.

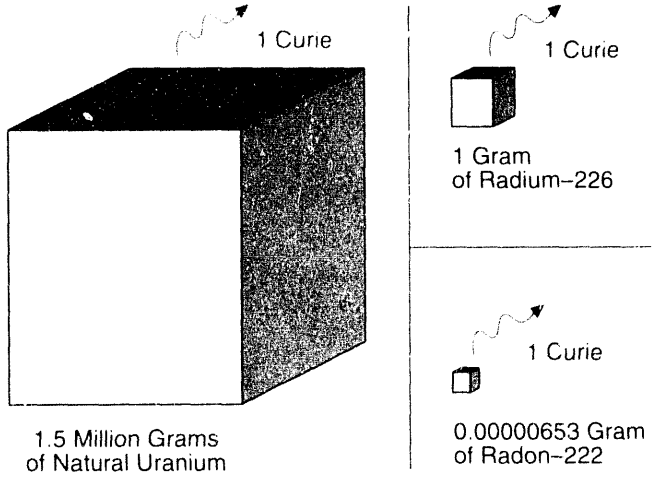
Units of Measurement

To measure the effect of radiation, scientists have developed ways to measure levels and intensity of radiation. Some of these measurement units are technical and may require some explanation. Additional terms are included in the glossary of this report.

Activity

Activity is the number of nuclei in a material that decays per unit of time. An amount of radioactive material that decays at a rate of 37 billion atoms per second has an activity of one Curie (Ci). Smaller sub-units of the Curie are often used in this report. Two common units are the microcurie (μCi), one millionth of a Curie, and the picocurie (pCi), one trillionth of a Curie. The amount of radioactive material required to emit one Curie depends on the disintegration rate. For example, about one gram of radium–226, with a half-life of 1,622 years, is one Curie of activity. On the other hand, it would require about 1.5 million grams of natural uranium, which has a half-life of 4.5 billion years, to equal one Curie because natural uranium is less radioactive than radium–226. Radon–222, with a half-life of only 3.8 days, is even more radioactive than radium–226, and only 0.0000065 gram of radon–222 is needed to equal one Curie (see Figure 15).

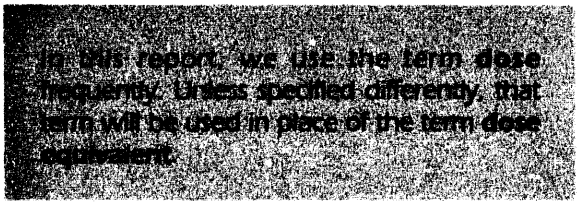
Figure 15: Comparison of Disintegration Rate*



* Not Drawn to Scale

Dose Equivalent

When a person comes into contact with radiation, that person has been exposed to radiation. Dose equivalent is a measure of the amount of radiation that is delivered to the body. Alpha, beta, and gamma radiation affect the body to different degrees. To take these different effects into account, each type of radiation is assigned a quality factor (QF). The more damaging the type of radiation, the higher the QF. For beta and gamma radiation, the QF is one. For alpha radiation, the QF is 20. The QF number is multiplied by an absorbed dose to calculate an exposed person's dose equivalent. Dose equivalent, or simply dose, is used when comparing the effects of different types of radiation. The Roentgen equivalent man (rem) unit is used to express dose equivalent. The more rem, the higher the potential damage. Since the amount of radiation we receive from background and the Fernald site is so small, millirem (mrem) is often used instead of rem. One mrem is equal to 1/1000 of a rem.



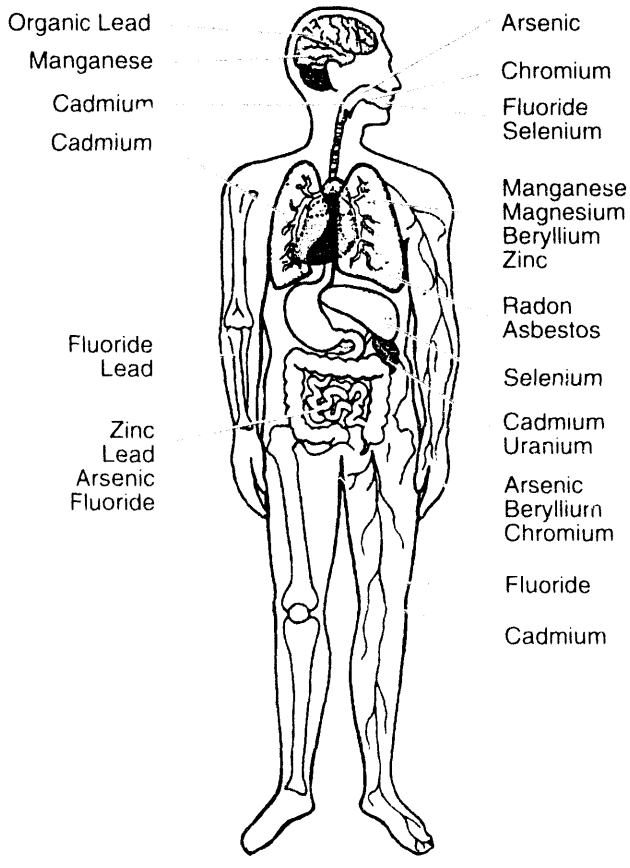
The term dose is used in four different ways in this report: organ dose, effective dose, committed effective dose, and whole body dose.

The organ dose is the amount of radiation received by an individual organ in the body. The amount of radiation any organ will absorb depends upon a variety of factors (for example, the way the radiation entered the body and the type of radiation). Therefore, when discussing the organ dose, scientists often refer only to the organ of greatest importance called the *critical organ*. The critical organ varies from situation to situation. It is determined based on things such as the amount of radiation received, the chemistry of the radionuclide, the sensitivity of that organ to the particular form of radiation, and the importance of that organ to the body. Based on the radionuclides found onsite, scientists have identified the critical organs as the lung, kidney, and bone surface (endosteum). Figure 16 shows which organs are most affected by various substances found at the site.

The effective dose expresses how much of a health risk radiation doses pose to individuals. To determine the effective dose, scientists first estimate each organ dose. Then, since some organs are more sensitive to radiation than others, the organs are given different weighting factors, similar to quality factors. The greater the risk an organ has of developing cancer and the more important that organ is to human health, the higher the weighting factor. The weighting factor is multiplied by the organ dose for each organ. These numbers are then added together to give the effective dose.

The NCRP and ICRP recommend that an individual be exposed to no more than 100 mrem effective dose per year for all pathways (over and above the amount a person receives from background and medical radiation). This recommendation applies to the general public for long-term, continuous exposures.[14] The DOE guideline for

Figure 16: Organs Affected by Substances Found at the Fernald Site



dose to members of the public is 100 mrem per year from all pathways (excluding radon). The National Emission Standards for Hazardous Air Pollutants (NESHAP) limit for effective dose is 10 mrem per year from radionuclides (except radon) released via the air pathway.[11]

The committed effective dose is the total amount of radiation an individual receives over a specified period of time from radioactive materials inside the body. When a person breathes or eats something that contains radioactive materials, the radiation within those materials is not all released at once. Half of the radiation is released over a period of time equal to the half-life of the radioactive material. Meanwhile, the body excretes radioactive materials at various rates determined by the individual's metabolism and the biochemistry of the radioactive material. Scientists have developed the concept of the committed effective dose to estimate the total amount of radiation one will receive over time (generally a 50-year period) from the radioactive materials taken into the body in a given time period.

The whole body dose is the amount of radiation an individual receives when the entire body is irradiated evenly by direct (gamma) radiation. Most radionuclides present at the Fernald site do not contribute toward a whole body dose because they concentrate more in some organs than others and do not emit significant amounts of gamma radiation.

Organ or Tissue	Weighting Factor
Gonads	0.25
Breasts	0.15
Red Bone Marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder	0.30

"Remainder" means the five other organs with the highest dose (e.g., liver, kidney, spleen, thymus, adrenal, pancreas, stomach, small intestine, or upper and lower large intestine, but excluding skin, lens of the eye, and extremities). The weighting factor for each of these organs is 0.06.

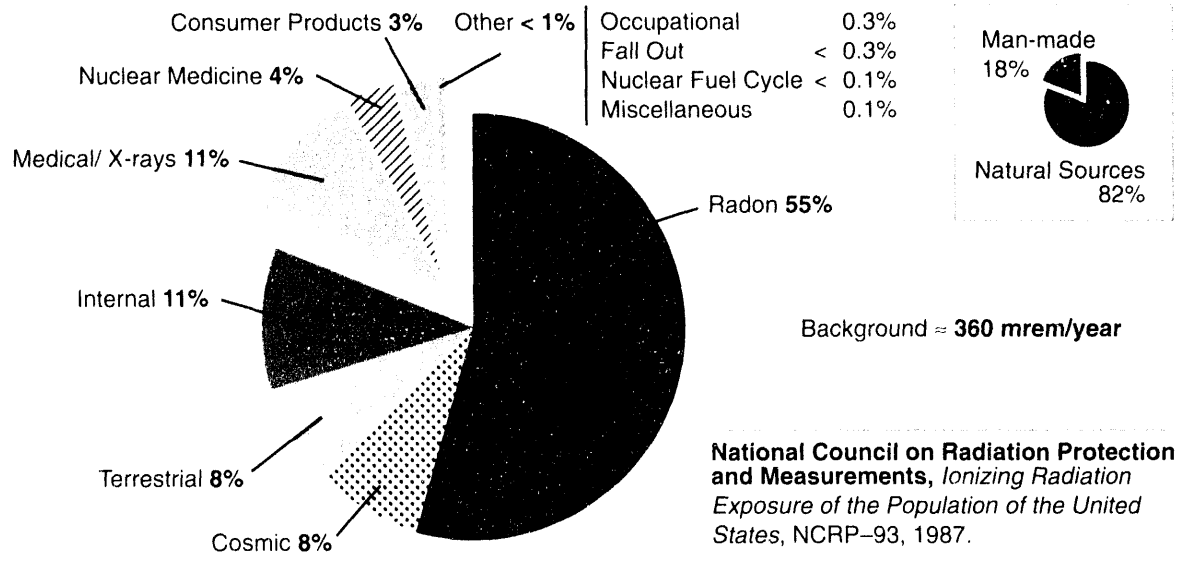
Exposure to Background Radiation

The dose terms defined in the preceding paragraphs apply to more than just the radiation we may be exposed to from facilities like the Fernald site. All people are constantly exposed to other background and man-made sources of radiation. Such radiation includes the decay of radioactive elements in the earth's crust, a steady stream of high-energy particles from space called cosmic radiation, naturally occurring radioactive isotopes in the human body like potassium–40, medical procedures, man-made phosphate fertilizers (phosphates and uranium are often found together in nature), and even household items like televisions.[15] In the United States, a person's average annual exposure to background radiation is 360 mrem.[14] The DOE guidelines (as well as other radiological guidelines) apply to exposures individuals receive in addition to background radiation and medical procedures.

As the Exposure to Background Radiation Chart shows, radon is the largest contributor to background radiation (see Figure 17). At an average of 200 mrem per year, naturally occurring radon accounts for more than half of the background dose in the United States.[10] (Radon is discussed further in Chapter Eight.)

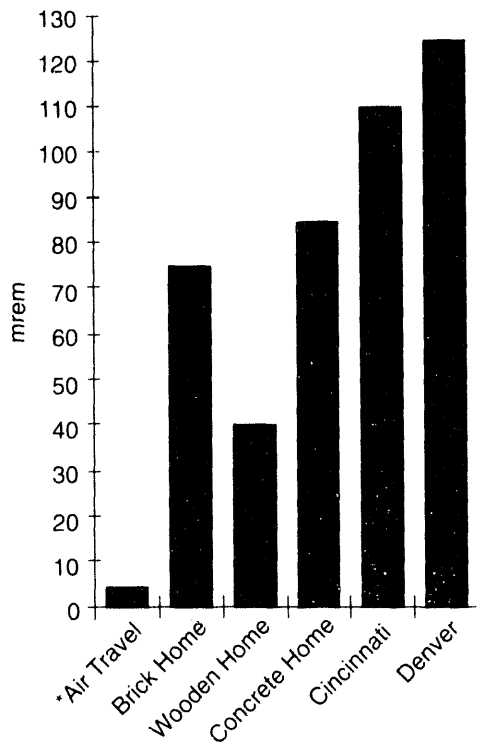
Background radiation dose will vary in different parts of the country. For example, living in the Cincinnati area will produce an exposure level of approximately 110 mrem, while the dose received annually from living in Denver is approximately 125

Figure 17: Exposure to Background Radiation



National Council on Radiation Protection and Measurements, *Ionizing Radiation Exposure of the Population of the United States*, NCRP–93, 1987.

Figure 18: Breakdown of Average U.S. Radiation Exposures



* 1 mrem for each 4,030 km (2,500 miles)

mrem. This difference can be attributed to soil composition and distance above sea level. Another factor which affects annual radiation dose is the type of building material used in homes. Figure 18 shows that the annual dose received from living in a brick or concrete house is about two times greater than from living in a wood frame house. Also shown in the bar chart is that a single round trip flight from Cincinnati to London (or the equivalent) produces an exposure of approximately 4 mrem.[16] In comparison, the dose received at the site's fenceline from an entire year is approximately 1.0 mrem.

One way to measure how much radiation we are exposed to is to complete a personal radiation dose worksheet, like the one on the next page. The next section provides information on the effects of low-level radiation, whether it is naturally occurring or originates from a facility like the Fernald site.

Effects of Radiation

The effects of radiation on humans are divided into two categories, somatic and genetic. Somatic effects are those that develop in the directly exposed individual, including a developing fetus. Genetic effects are those that are observed in the offspring of the exposed person.

Because we are constantly exposed to both natural and man-made sources of radiation, and because the body has the capacity to repair damage from low levels of radiation, it is extremely difficult to determine the effects from low-level radiation. This section explains why this is true and how somatic and genetic effects may occur.

Personal Background Radiation Dose Worksheet*

Source of Radiation		Annual Dose (mrem)
Earth and Sky		
	Cosmic radiation at sea level	26
	Cosmic radiation above sea level Add 1 mrem for every 100 feet above sea level (Cincinnati is approximately 600 feet above sea level.)	
	Jet plane travel/high altitude exposure to cosmic radiation Add 1 mrem for every 2,500 miles flown	
	Terrestrial Radiation	28
	Radon (background)	200
	Nuclear testing fallout	5
Your Body		40
Television Viewing	Add 0.15 mrem for every hour of viewing per day (For example, if you watched an average of 4 hours of TV a day in 1993, add 0.6 mrem.)	
Medical X-ray and Radiopharmaceutical Diagnosis		
	Add 10 mrem for each chest X-ray	
	Add 500 mrem for lower gastrointestinal-tract X-ray procedure	
	Add 300 mrem for each radiopharmaceutical examination	
Total		

* The information is drawn from two major sources:

- BEIR Report–III–National Academy of Sciences, Committee on Biological Effects of Ionizing Radiations, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences, Washington, DC, 1980, and
- National Council on Radiation Protection and Measurements Report No. 93, 1987.

Somatic Effects

Continuous exposure to low levels of radiation can produce gradual somatic changes over extended time. For example, someone may develop cancer from man-made radiation, background radiation, or some other source not related to radiation. Because all illnesses caused by low-level radiation can also be caused by other factors, it is presently impossible to determine individual health effects of low-level radiation. However, there are a few groups of people under medical observation because they have been exposed to higher levels of radiation. These include the survivors of Hiroshima and Nagasaki, uranium miners in the United States and eastern Europe, a group of workers who used paint containing radium, early users of X-ray machines, some DOE employees working in the defense facilities, and people suffering from illnesses where radioactive material was used for treatment.

Even after studying the health effects of radiation on these groups of people, scientists are still not able to determine with certainty how much cancer, if any, may have been caused by low-level radiation.

Those individuals exposed to high levels of radiation are at greater risk. We know this because at these higher radiation doses, we see that the number of radiation effects increases as the level of radiation dose increases.

A whole-body dose of 1,000 rem of radiation delivered instantaneously will probably kill a person. A dose of 600 to 1,000 rem causes severe sickness, but there is some chance for recovery. A dose of 200 to 600 rem causes some sickness with a very good chance for recovery. A dose of 100 to 200 rem could possibly cause some vomiting, but probably no demonstrable long-lasting effects.[17]

Significant clinical symptoms of radiation probably will not be seen in individuals who have been exposed to less than 100 rem.[18] (The dose to the maximally exposed individual from all pathways, except radon, was approximately 1.0 mrem in 1993.) Most scientists believe that there are no directly observable short-term radiation effects on human beings exposed to less than 10 rem because the biological damage created by this level of radiation is too small to result in near-term clinical symptoms.

Estimates on the value of the threshold level for radiation effects, if such a level exists, vary significantly. As mentioned above, some scientists believe it could be as high as 10 rem.[17] Others insist there is no threshold level below which radiation exposure is safe.[19] They feel there is always a direct relation between the amount of radiation to which people are exposed and the number of related radiation effects.

Somatic effects have been documented only at high radiation levels. These include clouding of the lens of the eye, lowered fertility rate, and a reduced number of white cells in the blood. Problems caused by radiation seen in the development of the embryo result from large doses, not the low levels characteristic of background radiation. Therefore, the most likely somatic effect of low-level radiation is believed to be a small increased risk of cancer.[15]

Genetic Effects

A single ionizing event has the potential to cause a genetic effect. To understand why this is true, it is helpful to look at the structure of a human cell.

Human cells normally contain 46 chromosomes--23 transmitted from the mother and 23 from the father. These 46 chromosomes contain about 10,000 genes which are passed on to the next generation and determine many physical and psychological characteristics of the individual.

Radiation can cause physical changes or mutations in these genes. Chromosome fibers can break and rearrange, causing interference with the normal cell division of chromosomes by affecting the number and structure. A cell can rejoin the ends of a broken chromosome, but if there are two breaks close enough together in space and time, the broken ends from one break may join incorrectly with those from another. This can cause translocations, inversions, rings, and other types of structural rearrangement.[15] Radiation is not the only mechanism by which such changes can occur. Spontaneous mutations and chemically induced mutations have been observed.

The mutated genes from one parent can then be passed on to offspring. They typically have no effect on the offspring as long as the genes from the other parent are not mutated in the same way. However, the genes stay in the body of the offspring and are passed on to following generations. If they meet similar genes when reproducing, they would then become present in the characteristics of the offspring.[17]

There is no evidence that there are radiation levels below which chromosomes are not affected; however, genetic effects of radiation have never been clearly demonstrated to occur in people.[20, 21]

Health Hazards at the Fernald Site

Aside from radiation and its effects, there are other health hazards associated with the Fernald site. In order to understand these other health hazards, it is helpful to be familiar with the terminology and laws that define and regulate these hazards.

Definitions of Terms

Many terms refer to substances that are subject to regulation under one or more federal environmental laws. State laws and regulations also provide similar terminology that may be confused with the federally defined terms. Many of these terms appear to be synonymous and are easily confused.

A ***hazardous chemical***, as defined by OSHA, is any chemical which is a physical hazard or a health hazard. Physical hazards include combustible liquids, compressed gases, explosives, flammables, organic peroxides, oxidizers, pyrophorics, and reactives. A health hazard, on the other hand, is any chemical for which there is good evidence that acute or chronic health effects occur in exposed people. Among the list of hazardous chemicals are carcinogens, irritants, corrosives, neurotoxins, and agents that damage the lungs, skin, eyes, or mucous membranes.

A ***hazardous material***, as defined by the Department of Transportation, is a substance or material in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce. A Hazardous Materials Table, with more than 16,000 entries, includes explosives, oxidizing materials,

corrosives, flammables, gases, poisons, radioactive substances, and agents capable of causing disease.

A ***hazardous substance*** is any substance designated under Section 311 of the Clean Water Act; any element, compound, mixture, solution, or substance designated as hazardous under Section 102 of CERCLA; any listed or characteristic RCRA hazardous waste; any toxic or pollutant listed under Section 307 of the Clean Water Act; any hazardous air pollutant listed under Section 112 of the Clean Air Act; and any imminently hazardous chemical substance or mixture subject to Section 7 of the Toxic Substances Control Act.

A ***hazardous waste*** is a solid waste that must be treated, stored, transported, and disposed of in accordance with applicable requirements under Subtitle C of RCRA. Hazardous wastes may cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness. These kinds of wastes may also pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed. Hazardous wastes are either listed in the regulations promulgating RCRA or are "characteristic" wastes. "Characteristic" hazardous wastes include those that are ignitable, corrosive, reactive, or toxic. All RCRA Subtitle C listed or characteristic hazardous wastes are also CERCLA hazardous substances.[22]

Laws Regulating Health Hazards

Some of the federal laws that regulate health hazards are discussed below. The first, ***CERCLA***, provides for the remediation of hazardous substances at National Prioity List (Superfund) sites. As well, CERCLA has its own reporting and response requirements when a hazardous substance released to the environment exceeds a reportable quantity.

RCRA Subtitle C, as discussed above, provides for the safe treatment and disposal of hazardous waste and regulates hazardous waste management practices for generators, transporters, and owners and operators of treatment, storage, and disposal facilities.

Section 6 of ***TSCA*** authorizes USEPA to initiate civil actions regarding hazardous chemical substances or mixtures which present an imminent and unreasonable risk of serious or widespread injury to health or the environment. There is no "list" of imminently hazardous chemical substances or mixtures, but USEPA currently regulates PCBs, fully halogenated chlorofluoroalkanes, asbestos, and hexavalent chromium under Section 6 of TSCA.

Under the ***Clean Air Act***, National Emission Standards for Hazardous Air Pollutants (NESHAP) are established. There are many hazardous air pollutants, including asbestos, benzene, beryllium, coke oven emissions, inorganic arsenic, mercury, radionuclides, and vinyl chloride.

Types of Health Threats

There are many types of potential health threats (aside from the radioactive risks already discussed) related to the hazardous substances at the site. They should all be addressed and understood by both area residents and onsite workers so the substances will be handled properly and safely or avoided whenever possible. Carcinogens, corrosives, explosives, flammables, irritants, and poisons/toxins are all potentially harmful.

Carcinogens are substances that have the potential to cause cancer. A common carcinogen located at the Fernald site is asbestos. When asbestos particles are inhaled into the lungs, they may damage the alveoli (the air sacs lining the lungs). This damage makes the lungs more susceptible to cancer, especially in smokers.

When a chemical causes a substance to wear away or deteriorate, it is said to be ***corrosive***. Many common chemicals are potentially corrosive. For example, vapors from ammonia may be corrosive to the eyes, respiratory system, and other moist tissues. Blindness may result from a large exposure to these vapors.

Explosions can occur in many situations. If an unstable solid or liquid changes suddenly into a quickly expanding gas, especially in a tightly closed container, an explosion can occur. Rapid nuclear fission may also cause a substance to explode. During these explosions, energy is released, often in the form of heat and sometimes radiation. This energy release may cause injury resulting from the impact of debris or burns to exposed skin.

Flammable materials are any materials which can be easily set on fire and burn readily. Paints, gases, and fuels are common flammable materials at the site. Hydrogen, for example, is a very flammable gas. An obvious health hazard associated with flammable material is the potential for burns.

An ***irritant*** is a substance which causes an organ or any part of the body to become inflamed or sore. A common solvent used at the site, 1,1,1–trichloroethane, can be an irritant to the skin and the eyes upon contact.

Poisons and toxins are substances that may cause illness or death when ingested or absorbed into the body. Nearly all chemicals have the potential to become poisonous or toxic when used improperly or in excessive amounts. A toxin that destroys nerves or nervous tissue is called a neurotoxin.

The next chapter, "Environmental Compliance Summary," presents the Fernald site's status with several environmental regulations. The environmental monitoring data are presented in chapters Four, Five, and Six. Chapter Seven presents a discussion of the estimated radiation doses to which the people near the site might be exposed and how these results were calculated. Then, in Chapter Eight, the Radon Monitoring Program is discussed, and the 1993 radon monitoring and dose results are presented.

3

Environmental Compliance Summary

3

Environmental Compliance Summary

The Fernald site must comply with environmental requirements established by a number of agencies governing daily operations at the site. These requirements fall into four general categories:

- Requirements imposed by federal statutes and regulations,
- Requirements imposed by state and local statutes and regulations,
- Requirements imposed by DOE Orders and directives, and
- Site-specific requirements imposed through agreements with regulatory agencies.

Because these requirements are initiated by several different sources, enforcement likewise falls under several federal, state, and local agencies. OEPA is the primary agency that issues permits, reviews compliance reports, inspects facilities and operations, and oversees compliance with applicable regulations. USEPA Region V governs the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process with the cooperation and active participation of OEPA. In addition, USEPA develops, publishes, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by Congress. For some programs, USEPA has authorized the State of Ohio so that the regulatory program is enforced in lieu of the federal oversight. For these programs, OEPA promulgates state regulations which must be at least as stringent as the federal requirements and may exceed the federal requirements. The site is also subject to several legal agreements with USEPA Region V and OEPA. DOE Headquarters issues directives to its field offices and conducts compliance audits. In addition, the Fernald site conducts internal audits.

The Fernald site's progress toward achieving full compliance with all environmental regulations is summarized in this chapter. It is divided into two main sections — "Compliance Status" and "Current Issues and Accomplishments." Additionally, the status of several environmental permits is discussed within the appropriate regulatory categories. This summary covers calendar year 1993 as required by DOE reporting requirements.

Compliance Status

This section presents a summary of the Fernald site's compliance status with respect to federal and state environmental regulations.

CERCLA

The Fernald site is on the National Priorities List (NPL) of sites requiring environmental cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. Consistent with the requirements of Section 120 of CERCLA, a Consent Agreement was signed by DOE and USEPA in April 1990 which outlined activities and schedules to be performed in order to remedy the site condition. This agreement was amended in September 1991. Collectively, the Consent Agreement and the Amended Consent Agreement (ACA), jointly referred to as the ACA, established the following operable units to more effectively manage the ongoing CERCLA cleanup:

- Operable Unit 1 (OU1) – Waste Pit Area,
- Operable Unit 2 (OU2) – Other Waste Units,
- Operable Unit 3 (OU3) – Former Production Area,
- Operable Unit 4 (OU4) – Silos 1 – 4,
- Operable Unit 5 (OU5) – Environmental Media, and
- Sitewide Operable Unit – A comprehensive unit encompassing operable units 1 through 5 to ensure that actions taken under the individual operable units are protective of human health and the environment on a sitewide basis.

The ACA provided new schedules for the completion of the ongoing Remedial Investigation and Feasibility Study (RI/FS) activities for each operable unit; initiated removal actions, which are tasks undertaken to abate immediate threats to the environment and health; and provided a mechanism for the site to add additional removal actions on a yearly basis.

Additionally, the ACA, which establishes a CERCLA milestone compliance schedule agreed upon by both USEPA and DOE, required the completion of the following RI/FS activities in 1993:

- The submittal deadline for the OU1 RI Report/Baseline Risk Assessment was October 12, 1993. The first draft RI Baseline Risk Assessment for OU1 was submitted on October 5, 1993. The final draft was scheduled to be submitted in January 1994.
- The submittal deadline for the OU4 RI Report/Baseline Risk Assessment was April 19, 1993. The report was submitted in draft form on April 19, 1993 and approved by OEPA on November 23, 1993. Approval by USEPA is expected in 1994.
- The submittal deadline for the OU4 Feasibility Study Proposed Plan was September 10, 1993. The report was submitted on September 9, 1993. USEPA reviewed this document, and their approval on the revised plan is expected in 1994.

- The submittal deadline for the OU5 Initial Screening of Alternatives was April 16, 1993. The final draft was submitted to USEPA on March 26, 1993.

Additionally, the OU3 RI/FS Work Plan Addendum was approved by USEPA on August 4, 1993.

In December 1992, comments were received from USEPA on the Remedial Investigation (RI) report for OU2, including requirements for additional field investigations. The site agreed that additional investigation was needed and requested an extension of the schedule imposed by the ACA for submittal of the RI report. This prompted a dispute with USEPA that was resolved through informal dispute resolution. As a result of this resolution, USEPA has accepted the revised schedule for submittal of the RI Report and for submittal of the Feasibility Study and Record of Decision (ROD). The revised schedule requires the submittal of the OU2 Feasibility Study/Proposed Plan (FS/PP) on April 29, 1994, and the OU2 ROD on January 5, 1995. USEPA also agreed that, as an alternative to paying a large stipulated penalty, DOE will fund and implement a Supplemental Project in OU5 to provide additional treatment for uranium removal from Fernald site wastewater streams. The dispute resolution also accelerated the schedules for OUs 1, 2, 3, and 5.

SARA

The Superfund Amendments and Reauthorization Act of 1986 (SARA) was written to clarify and expand CERCLA ("Superfund") requirements. The SARA Title III, Section 312 report for 1993 was completed and submitted to OEPA. This report lists the amount and location of hazardous substances stored or used in amounts greater than the minimum reporting threshold.

The SARA Title III, Section 313 Toxic Chemical Release Inventory Report was submitted to OEPA and USEPA on July 1, 1993. This report is required for any toxic chemical that is manufactured, processed, or otherwise used at a facility in quantities greater than a minimum reporting threshold. A report was completed for methanol and sulfuric acid which were processed or otherwise used at the Fernald site. The Toxic Chemical Release Inventory Report lists routine and accidental releases, as well as information about the activities, uses, and waste for each reported toxic chemical. The report also included source reduction and recycling information as required by the Pollution Prevention Act of 1990.

For any offsite release exceeding the reportable quantity, SARA Title III, Section 304 requires immediate notifications to Local Emergency Planning Committees and State Emergency Response Commissions. All releases are evaluated to ensure that proper notifications are made in accordance with SARA. In addition to SARA, releases are also evaluated for notification under CERCLA Section 103, Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), the Clean Air Act, the Clean Water Act, Ohio environmental laws and regulations, and the Ohio Fire Code. Department of Transportation regulations are also followed. Depending

on the respective requirements, notifications may also be made to the National Response Center (NRC), and to the appropriate federal, state, and local regulatory entities.

Although not reported under SARA, three release notifications were issued to offsite agencies during 1993. First, on April 28, 1993, there was a release of approximately 30 gallons (113 kg or 250 pounds) of uranyl nitrate hexahydrate (UNH) solution to the sidewalk and gravel outside Plant 2/3 in the former production area. This solution contained barium, chromium, and uranyl nitrate but not in concentrations resulting in a release above their respective reportable quantities. The material was classified as RCRA hazardous waste. This release was reportable under RCRA because it exceeded the 1 pound reportable quantity for release from a hazardous tank system. This was reported to the OEPA Regional Administrator. Also, the pH of this solution was less than 2.0. This pH and the quantity (greater than 45 kg [100 pounds]) qualified as a reportable CERCLA release and was reported to the NRC. It was not a reportable SARA release because it did not leave the site.

On August 11, 1993, there was a spill of approximately 0.5 pint or 0.2 kg (0.46 pound) of hydraulic fluid into a suspected wetland in the K-65 area. Site personnel determined that this release qualified as "immediately reportable" under the Clean Water Act, and it was reported to the NRC. Follow-up investigations revealed that the release had not actually occurred in a designated wetland and, therefore, would not have been reportable.

On December 22, 1993, approximately 6 liters (1.5 gallons) of antifreeze, containing 80% ethylene glycol, or approximately 5.2 kg (11 pounds), was released from the water line of a portable trailer into the gravel near Plant 7 in the production area. This currently qualifies as a reportable CERCLA release and was reported to the NRC. It was not SARA reportable because it did not leave the site.

RCRA

The Resource Conservation and Recovery Act regulates treatment, storage, and disposal of hazardous waste. OEPA has been authorized to enforce its hazardous waste regulations (which are derived from federal RCRA regulations).

Past operations and ongoing cleanup activities generate both hazardous wastes and mixed wastes (containing hazardous and radioactive components). As a management practice, some wastes are accumulated in quantities less than 55 gallons at the point of generation in locations known as satellite accumulation areas. The waste may remain in these areas until 55 gallons have been accumulated, at which time it must be moved to a permitted RCRA storage area.

Because there are a limited number of facilities in the United States that can treat or dispose of mixed waste, a final disposal site for all Fernald site mixed waste is not yet available. Although some waste was shipped to the K-25 incinerator in Oak

Ridge for incineration in 1993, most of the mixed waste currently remains onsite. The Federal Facilities Compliance Act (FFCAct) of October 1992 provides DOE with relief from enforcement under the Land Disposal Restriction storage prohibition until 1995, provided that the waste is stored in accordance with all other RCRA requirements. The site submitted an initial conceptual treatment plan to OEPA in October 1993 and is scheduled to submit a draft plan in August 1994.

In addition to being subject to state and federal regulation, RCRA waste is handled according to the 1988 Consent Decree between the State of Ohio and DOE. In 1990, negotiations between the State of Ohio, DOE, and the former operating contractor (Westinghouse Environmental Management Corporation (WEMCO)) resulted in the Proposed Amended Consent Decree (PACD). The PACD was signed by all parties in January 1993 and became known as the Stipulated Amended Consent Decree (SACD).

In accordance with the SACD and RCRA, the site completed or initiated several activities relating to mixed waste storage during 1993. These included submittal of the RCRA Annual Report, revision of the RCRA Part B Permit Application, additional RCRA training of personnel, and continued weekly inspections of the mixed waste storage areas. Two storage areas were also upgraded to include floor coatings and secondary containment for storage of liquids.

OEPA conducted a routine compliance evaluation inspection of the Fernald site in June 1993. The physical inspection of the facility was conducted on June 16 and 17 and was continued on June 23 in order to review specific records. As a result of these inspections, the Fernald site received a Notice of Violation, which addressed storage of wastes restricted from land disposal for a period of time greater than allowed by law.

As required by the FFCA, on September 14, 1993, USEPA conducted a Comprehensive Monitoring Evaluation of the site's Alternative RCRA Groundwater Monitoring Program. A report of the evaluation is anticipated from USEPA in early 1994.

In December 1993, OEPA issued notice of several deficiencies resulting from an inspection by OEPA of the uranyl nitrate solution tank system, but it did not initiate an enforcement action. A response will be submitted to OEPA in early 1994 addressing resolution of these findings. Additional information is provided under "Neutralization of UNH Inventories" on page 60.

Clean Air Act

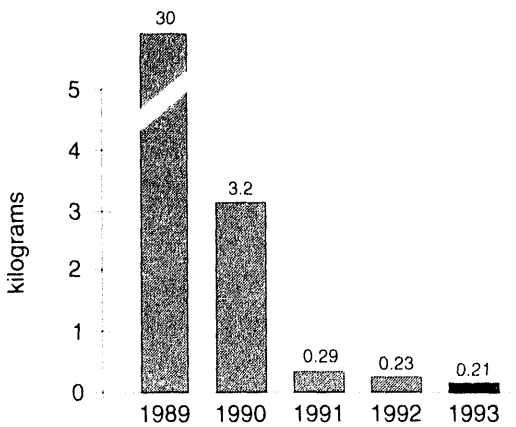
In Ohio, authority to enforce requirements of the Clean Air Act has been delegated by USEPA to OEPA, except for the enforcement of the National Emission Standards for Hazardous Air Pollutants (NESHAP) for radionuclides and radon. Most

Fernald site air emission sources are regulated by USEPA as radionuclide sources and by OEPA as particulate, chemical, or toxic emission sources.

The NESHAP standard for radionuclide air emissions from DOE facilities imposes a limit of 10 mrem per year on the effective dose equivalent (EDE) to the maximally-exposed individual as a result of all emissions (with the exception of radon) from the facility in a single year. This standard also imposes requirements for continuous monitoring of certain emission sources and periodic confirmatory measurements of smaller sources. All NESHAP monitoring points at the Fernald site are in compliance with the requirements.

Because the Fernald site is a former uranium processing plant, uranium is the radioactive particulate of most concern in monitoring airborne emissions. The Fernald site estimated that airborne uranium emissions for 1993 totalled 0.21 kg (0.46 pound). This is slightly lower than the 0.23 kg (0.51 pound) estimated in 1992 (see Figure 19). Airborne uranium emissions steadily dropped after processing operations were discontinued in 1989, and they have remained relatively constant since 1991.

Figure 19: Total Kilograms of Uranium to Air, 1989 - 1993



In 1993, the State of Ohio regulation limiting sulfur dioxide (SO_2) emissions became effective which reduced the allowable SO_2 emission level from the Fernald site's coal-fired burners (sole Clean Air Act-defined major source) from 0.91 kg (2.0 pounds) $SO_2/10^6$btu heat input to 0.60 kg (1.33 pounds) $SO_2/10^6$btu heat input. The Fernald site began purchasing a low-sulfur coal in 1991 when the regulation was revised, and the site has been in compliance with the reduced limit since that time.

Under the Ohio Administrative Code, the Fernald site must obtain a Permit to Install (PTI) prior to the construction of an air pollutant source. The Fernald site is also required to obtain a Permit to Operate (PTO) for all operating air pollutant sources. Applications have been prepared for all required air permits. Due to the ongoing remedial activities (as opposed to production activities), the number of air permits will continue to diminish.

Clean Water Act

Under the Clean Water Act, the Fernald site is governed by National Pollutant Discharge Elimination System (NPDES) regulations that require the control of discharges of nonradioactive pollutants to Ohio waters.

NPDES Effluent Regulation

The NPDES permit issued by the State of Ohio specifies discharge and sampling locations, sampling and reporting schedules, and discharge limitations. The permit was modified effective May 20, 1993, deleting two monitored outfalls and adding a sewage sludge monitoring location. Current monitoring locations are referenced in Figure 20. Other changes to the NPDES permit include eliminating certain pollutants, modifying monitoring frequencies and clarifying sampling techniques.

In 1993, the Fernald site was compliant with the discharge limits specified by the NPDES permit 99.73% of the time. Of the 4,020 monitoring results, only 11 were not within the discharge limits specified by the permit. Of those 11 instances, three occurred at the site's discharge point (Manhole-175) and eight occurred at internal monitoring points. The Manhole-175 occurrences involved pH and suspended solids. Occurrences at the internal monitoring points involved pH and chromium.

NPDES Stormwater Regulation

Issuance of a "Stormwater Permit Associated with Industrial Activity" is still pending OEPA review and action. The application for this permit was submitted for four stormwater discharges into Paddys Run in September 1992. These four monitoring locations are shown in Figure 20 as follows:

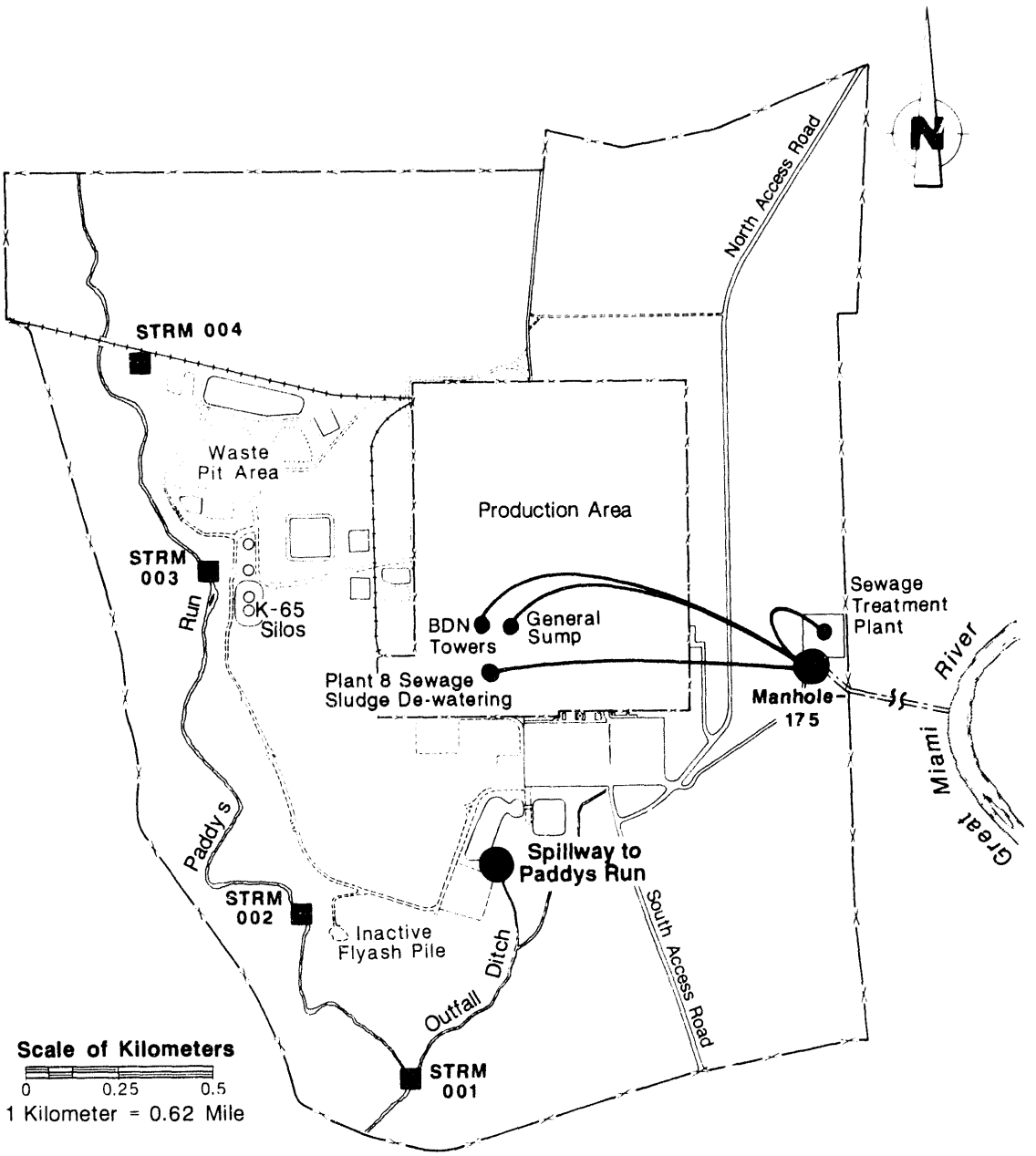
- STRM 001 – Collecting runoff from the east and south;
- STRM 002 – Collecting runoff from the Inactive Flyash pile;
- STRM 003 – Collecting runoff from the western property perimeter, excluding the waste management facilities; and
- STRM 004 – Collecting runoff from the northern property perimeter.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) regulates generation and treatment of drinking water supplied to the public. The Fernald site drinking water system is regulated by OEPA as a non-transient, non-community public drinking water system.

During 1993, the site monitored and reported results for nitrate, nitrite, lead, copper, coliform bacteria, and 58 volatile organic compounds in addition to alkalinity, pH, stability, phosphate, hardness, and chlorine residuals. All results met applicable standards.

Figure 20: NPDES Effluent and Stormwater Monitoring Locations



LEGEND

- NPDES Internal Monitoring Location
- NPDES External Discharge to Ohio Waters
- NPDES Stormwater Monitoring Location
- Plant Perimeter
- Production Area Perimeter
- Effluent Line to Great Miami River

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Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) regulates the manufacturing, use, storage, and disposal of toxic materials. Under TSCA, USEPA regulates polychlorinated biphenyl (PCBs) and PCB items at the Fernald site. The site ships non-radiologically contaminated PCBs and PCB items to commercial facilities for recycle or disposal on an ongoing basis. Radiologically contaminated PCBs and PCB items from past operations, maintenance activities, and remediation are stored onsite as disposal options are explored.

The site shipped four drums of PCB contaminated fluorescent light ballasts to a recycler in New York in October 1993. Additional shipments of both radiologically and non-radiologically contaminated PCBs and PCB items are scheduled for 1994 and 1995. The radiologically contaminated PCBs and PCB items are stored in Building 81 in compliance with TSCA requirements. Some PCBs and PCB items will remain onsite indefinitely due to the lack of treatment and disposal facilities for radiologically contaminated PCBs while on- and offsite disposal options are explored.

The site prepares the PCB Annual Document Log by July 1 of each year. The Annual Document Log includes signed manifests for PCB shipments, certificates of disposal, conversation reports, and PCB One-Year Exception Reports. The Annual Document Log must be maintained by the facility for a minimum of three years after the facility ceases using or storing PCBs or PCB items.

A Notice of Violation (NOV) was received on the Spill Control and Countermeasure (SPCC) Plan for PCB storage during 1993 as a result of a 1992 inspection. PCBs had been moved from Building 79 to Building 81 in 1992 without the necessary revision of the SPCC. A revised SPCC Plan was completed and provided to USEPA on a timely basis along with photographs of PCB storage facilities. USEPA accepted the submittal resolving the NOV during 1993.

Ohio Solid Waste Act

This 1988 act and its subsequent revisions regulate infectious waste. In 1993, the Fernald site generated more than the 23 kg (50 pounds) per month limit of infectious waste and subsequently registered with OEPA as a large generator. All infectious wastes generated in the medical department are transported to a licensed treatment facility for incineration. Fernald site personnel conduct annual surveillances of the onsite medical department, the transporter, and the treatment facility to ensure that the waste is properly managed.

Federal Insecticide, Fungicide, and Rodenticide Act

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), USEPA regulates the registration, storage, labeling, and use of insecticides, herbicides, and rodenticides. Fernald site pesticide applications have been performed by site personnel since September 1993. Prior to this time, pesticide applications were performed by subcontractors. Herbicide applications are being performed by subcontractors. All pesticide and herbicide applications at the site are conducted according to Federal and state regulatory requirements. An annual FIFRA inspection by USEPA Region V in August 1993 identified no FIFRA violations. Pesticide applications are made in the administrative area as well as the former production area. Herbicide applications are made in various locations for weed control within the former production area.

Construction began on a pesticide storage area located on the first floor of the Services Building in October 1993 and is scheduled to be completed in 1994. The primary function of this area will be for storage of chemicals and equipment that are now being used for pesticide application. This area will house a pesticide recycling station to support the Waste Minimization/Pollution Prevention program.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires a formal evaluation of environmental, social, economic, and cultural impacts before any action, such as a construction project, is initiated by a Federal agency. DOE has published formal regulations specifically addressing the integration of NEPA with other regulatory requirements.

A total of 11 removal actions were approved as Categorical Exclusions (CXs) in 1993. In addition to these removal actions deemed as CXs, 23 other CXs were approved. Other NEPA related activities in 1993 included:

- Natural Resource Damage Assessment Trustees were notified and a Strategy Paper was submitted to DOE,
- The OU1 Feasibility Study/Proposed Plan-Draft Environmental Assessment was submitted to DOE,
- The OU3 Proposed Plan-Environmental Assessment was approved by USEPA,
- The OU4 Feasibility Study/Proposed Plan-Draft Environmental Impact Statement was submitted to DOE,
- A cultural resource survey was completed for the Horizontal Grout Barrier project and the report was submitted to DOE for submittal to the Ohio Historic Preservation Office, and
- Surveys for the state-threatened Sloan's crayfish and cave salamander were completed and the reports were submitted to DOE.

Endangered Species Act

The Endangered Species Act requires the protection of any federal-listed threatened or endangered species found at the site as well as any critical habitat that is essential for the species' existence. In addition, USEPA ecological guidelines direct CERCLA sites to identify any threatened species present on the property or in offsite areas affected by site activities. The baseline ecological survey conducted by Miami University (Oxford, Ohio) in 1986 and 1987, as well as RI/FS surveys in 1988 and consultation with the Ohio Department of Natural Resources, have established a list of federal- and state-listed threatened and endangered species that are or may be at the Fernald site or have habitat at the site.

In 1993, surveys to update the information on federal- and state-listed threatened and endangered species of the property were initiated. A study on the cave salamander (*Eurycea lucifuga*), which is on Ohio's endangered species list, was conducted to update information from a 1988 study. Because of additional information gained on the life history of this species since the 1988 survey, areas along Paddys Run are no longer considered suitable habitat. However, preliminary data from the 1993 study show moderate habitat in one onsite limestone-lined well, marginal habitat in a northern ravine, and moderate habitat in an offsite well adjacent to the southern boundary of the site. No salamanders were found in any of these areas.

A preliminary study for the Sloan's crayfish (*Orconectes sloanii*) was initiated to update species information found in the 1990 Miami University report. Qualitative sampling in Paddys Run in September 1993 found populations of this species onsite in the northern section of Paddys Run and offsite in the southern section. However, Paddys Run was dry in sections between these locations. To verify that the populations are large enough to migrate upstream during regular water flow, an updated survey is planned for the spring of 1994.

A Public Water Supply Project (discussed further in Chapter Six) involves the offsite installation of water pipelines along approximately 23 km (14 miles) of county and state roadways. Along the route of the pipeline are areas which may include threatened and endangered species or habitat. A threatened and endangered species survey for the project was completed in April 1993. While habitats for both the cave salamander and Sloan's crayfish were found, none of the species were seen because of the season in which the study was conducted. Prior to completion of the project, a site ecologist will temporarily move any individuals of these species seen at that time to an upstream location.

Executive Order 11990, "Protection of Wetlands"

This Executive Order is a directive requiring federal agencies to institute programs to identify and protect wetlands and is implemented by the site through 10 CFR 1022. A wetlands delineation for the Fernald site was conducted in December 1992 and approved by the U.S. Army Corps of Engineers in August 1993. A total of 15 hectares (ha) (40 acres) of freshwater wetlands were delineated of the Fernald site. Delineated wetlands included 11 ha (27 acres) of palustrine forested wetlands, 3 ha (7 acres) of drainage ditches/swales, and 1 ha (2 acres) of isolated persistent emergent and scrub/shrub wetlands. In 1993, this delineation was utilized to prepare 10 CFR 1022 wetland assessments for the OU3 Interim Remedial Action (decontamination and dismantlement of all OU3 facilities and structures), remedial actions associated with OU4 (silos 1-4 and associated properties), and the Vitrification Pilot Plant also for OU4.

Executive Order 11988, "Floodplain Management"

This Executive Order instructs federal agencies to avoid construction in river floodplains and implements the order for DOE Regulation 10 CFR 1022. In 1993, HEC-2 modeling runs were conducted to determine the pool elevations for both the 100- and 500-year flood for the portion of Paddys Run adjacent to the Fernald site. Modeling results predicted a maximum discharge rate of 15.8 m^3/sec (11,150 ft^3/sec) at the confluence of the Paddys Run and the Great Miami River at a 100-year flood flow. The 100-year flood elevation ranged from 172 meters (567 ft) mean sea level at the site's northern boundary to 164 meters (542 ft) mean sea level at the southern edge of the site. Based upon the pool elevations predicted by the model, the 100-year and 500-year flood flow would be retained within the banks of Paddys Run.

National Historic Preservation Act

In accordance with the National Historic Preservation Act, activities at the Fernald site are required to take into account the impact on any cultural resources. Consultation and coordination with federal and state preservation agencies are required when there may be an impact to cultural resources.

Consultation with the State Historic Preservation Officer had established that certain areas would not require a cultural resources survey due to radiological or chemical contamination concerns. However, a survey and consultation for land disturbance activities outside these areas and at offsite locations are required. To address such activities, a Cultural Resource Management Plan was drafted and is currently being revised for the site.

The South Groundwater Contamination Plume Removal Action required an archeological survey and consultation. Archeological surveys were conducted to verify the South Plume projects will not adversely affect cultural resources. The reports identified several cultural resources within the area. Through consultation with the State Historic Preservation Officer, no adverse affects were found within the project area.

The Public Water Supply Project involves the installation of water pipelines along approximately 23 km (14 miles) of state and county roadways in Hamilton and Butler counties. An archeological survey for this project was conducted and revealed a number of historic and prehistoric artifacts. Through consultation with the State Historic Preservation Officer, it was determined that artifacts found at the proposed reservoir site were not significant and the site would not be eligible for the National Register. However, consultation on other portions of the Public Water Supply is currently ongoing, with expected determinations to be made available in early 1994.

A cultural resources survey was required for the proposed site of the Horizontal Grout Barrier Demonstration Project, a technology demonstration being conducted by the site. No adverse impacts were found on cultural resources within the area surveyed.

Current Accomplishments and Issues

This section presents significant compliance-related accomplishments and issues for 1993.

CERCLA

In the course of a RI/FS effort, conditions occasionally call for a necessary action to abate an immediate threat to health and the environment, including actions necessary to monitor, assess, or evaluate the threat. These actions, called removal actions, are coordinated with USEPA and OEPA.

Completed Removal Actions

By 1993, the Fernald site had identified 30 removal actions. Ten of these had been completed prior to this reporting period. The following six removal actions were completed, in part or in whole, in 1993.

Scrap Metal Piles – The onsite portion of this removal action was completed in October 1993 when approximately 2,200 tons of recoverable low-level radioactive waste scrap metal were successfully containerized. This action eliminated potential air pollutant emission sources and risks to the Great Miami River by surface water runoff. The containerized material included approximately 1,300 tons of scrap copper and other small metal piles. All non-ferrous metal, a total of 105 tons, has been shipped to Quadrex. Additionally, the site completed the shipping of 2,278 tons of ferrous metal to SEG. Both Quadrex and SEG are commercial Treatment, Storage, and Disposal Facilities (TSDF), located in Oak Ridge, Tennessee. Through December 30, 1993, approximately 2,000 tons of ferrous metal had been melted for restricted reuse. Metal melting at offsite facilities is expected to be completed in March 1994. Also, processing for unrestricted reuse should be completed in January 1994.

Collect Uncontrolled Production Area Runoff (Northeast) – This removal action was completed in August 1993. The objective of this removal action was to collect uncontrolled process area runoff. This removal action involved the redirection of subdrainage areas and the collection of run-off from the perimeter of the former process area to the Stormwater Retention Basin, thereby significantly reducing the release of uranium and other contaminants to Paddys Run. Additionally, mitigation of the flow of contaminants from surface water to the underlying aquifer will be achieved as a result of these activities.

Waste Pit Area Containment Improvement – The purpose of this removal action was to mitigate sources of potential airborne dust emissions and contaminated surface water runoff from the Waste Pit Area. The removal action, completed in June 1993, involved both the revegetation (seeding) of the pit area for erosion control and regrading of some existing stormwater ditches in the pit area to promote positive drainage.

Pilot Plant Sump – The stainless steel sump, located southeast of the Pilot Plant, was intended to remove and collect liquids from the floors of the Pilot Plant. Analytical sump sample results revealed high concentrations of lead, copper, chromium, nickel, thorium, and volatile organic compounds. In order to mitigate this source of potential environmental releases, both the sump and the contaminated liquids and solids contained in the sump were removed. The project was completed in October 1993.

Nitric Acid Tank Car and Area – This stainless steel tank car operated from 1952 until 1989 as a nitric acid storage vessel for production purposes at the Fernald site. The tank car and surrounding area are designated as a Hazardous Waste Management Unit in the site's Part A and Part B permit applications. The removal action involved the removal of acid from the tank car prior to its decontamination and disposal. In October 1993, the contents of the rail car were transferred to the Tank F1-24 of the Nitric Acid Recovery System of the Wastewater Treatment System for eventual treatment. Samples taken from the tank base and surrounding area, after completion of this removal action, indicated chromium to be below regulatory concern. The final report was submitted to DOE on October 18, 1993, and was transmitted to both Ohio and USEPA on November 2, 1993.

Stabilization of Paddys Run Bank Near the Inactive Flyash Pile – This "time critical" removal action was performed in two phases. Phase 1, an interim action completed in May 1993, involved the placement of a 67-meter (220-foot) long rock berm along the bank of Paddys Run in the immediate proximity of the flyash pile. This activity mitigated the threat of erosion-induced slope failure that could potentially result in the discharge of flyash to the creek. The rock berm enhancement project, Phase 2, was accomplished in September 1993 by the addition of aggregate material to the rock berm. Phase 2 was determined to be necessary to control additional erosion not originally anticipated by Phase 1 planning activities.

Ongoing Removal Actions

The following eleven removal actions are underway to alleviate immediate threats to the environment:

- Contaminated Water Under Fernald Site Buildings,
- South Groundwater Contamination Plume,
- Plant 1 Pad Continuing Release,
- Removal of Waste Inventories,
- Safe Shutdown,
- Plant 1 Ore Silos,
- Contaminated Soils Adjacent to Sewage Treatment Plant Incinerator,
- Scrap Metal Pile (offsite activities),
- Plant 7 Dismantling,
- Stabilization of Uranyl Nitrate Inventories, and
- Asbestos Removals.

The remaining removal actions, listed below, are in the planning or implementation process:

- Improved Storage of Soil and Debris,
- Management of Contaminated Structures, and
- Contamination at the Fire Training Facility.

Other CERCLA Accomplishments and Issues

Advanced Wastewater Treatment (AWWT) Facility – Construction on the advanced wastewater treatment system began on May 11, 1993, progressed throughout 1993, and is on-going. The purpose of the AWWT is to provide uranium removal for contaminated wastewater, stormwater, and a portion of the South Plume.

Comprehensive Groundwater Monitoring Evaluation – On September 14 and 15, 1993, USEPA Region V, joined by OEPA, conducted a RCRA Comprehensive Groundwater Monitoring Evaluation of the site's RCRA groundwater monitoring system, known as the routine system. The evaluation was conducted per the September 10, 1993, Director's Final Findings and Orders (DFOs) for groundwater monitoring. The RCRA Comprehensive Groundwater Monitoring Evaluation involved determining the condition of the monitor wells and the groundwater sampling procedures and documentation. No violations of Ohio's hazardous waste regulations pertaining to groundwater monitoring were noted. However, three deficiencies for specific monitor wells were identified:

- The concrete pad at Well 3106 appeared to be loose and must be replaced;
- The concrete pad at Well 3431 appeared to be loose and must be replaced; and
- The teflon hose attached to the dedicated pump on Well 3070 was crimped and damaged and must be replaced.

USEPA also recommended that each routine system monitor well have bumper guards placed around the wellhead and dedicated sampling pumps installed. The site is currently addressing the above deficiencies and recommendations.

Neutralization of UNH Inventories – The stabilization of UNH inventories will remove and prepare approximately 230,000 gallons of acidic UNH for safe storage that is currently stored in 21 tanks in and around Plant 2/3. This activity was previously part of the Safe Shutdown removal action but is being performed as a separate, expedited response. In April 1993, UNH from a storage tank was inadvertently pumped to wastewater tanks resulting in the spillage of approximately 30 gallons of material. The project was halted pending implementation of the recommendations resulting from the DOE Class B investigation. A December 1993 OEPA inspection resulted in a finding of deficiencies for three RCRA tanks. Two deficiencies were corrected by pumping liquid from secondary containment within 24 hours of the inspection. Repairs to minor pipe leaks are in progress. A dedicated project team has been assembled to develop a new tank configuration designed for safe and efficient neutralization and disposition of the stored materials.

Plant 1 Ore Silos – The Plant 1 Pad ore silo removal action will dismantle 14 ore silos and associated support structures. This will eliminate the potential threat of additional releases and the safety hazard due to structural deterioration of the silos and associated support structures. On December 17, 1993, FERMCO issued a contract termination letter to the Size Reduction Operation subcontractor for failure to perform its contractual obligations. A revised construction operation schedule has been developed and all construction/dismantling activities are tentatively scheduled for completion in September 1994. It is anticipated that there should be no delay in the Consent Agreement commitment date of December 19, 1994, for this Removal Action.

Plant 7 Dismantling – Plant 7 decontamination and dismantling (D&D) operations will mitigate potential releases and support the DOE Integrated Technology Demonstration Program. The Plant 7 D&D operations will also serve as a pilot program for the future remediation of the site. Phase 1 activities, primarily involving the relocation of stored drum material and the removal of interior asbestos insulation, were completed in October 1993. Gross decontamination activities of the interior building components were essentially finished in November 1993. Subcontractor dismantling operations are on-going.

Director's Final Findings and Order – The DFO, signed September 10, 1993, describes an alternate groundwater monitoring system with a routine monitoring program that allows hazardous waste monitoring requirements to be fulfilled by the CERCLA process already underway. This resolves the integration process concerning the state regulations and the CERCLA requirements at the Fernald site.

RCRA

The Stipulated Amended Consent Decree requires that the site identify all Hazardous Waste Management Units (HWMUs) at the facility. As a result, burners, incinerators, furnaces, stills, process equipment, tank units, dust collectors, and other potential waste containment units were evaluated to determine if these units were HWMUs or Solid Waste Management Units (SWMUs). Beginning in 1993, the site reviewed the evaluation process, regulatory basis, and technical assumptions used to determine whether the designation of these units as HWMUs was justified. OEPA approval has been sought to change the designation for the HWMUs which should be designated as SWMUs. In 1993, concurrence was obtained from OEPA to change the determination of five of the 53 HWMUs to SWMUs. This review of the evaluation process will continue in 1994.

Thorium Management

A Thorium Management Strategy and schedule of accomplishments were developed as part of the SACD to provide a plan to complete RCRA determinations of thorium materials and to improve the storage of thorium materials at the Fernald site. The Thorium Management Strategy was initiated as part of the SACD and is based on three primary objectives:

- To maintain environmentally stable interim storage of the thorium inventory while minimizing personnel radiation exposure,
- To implement required further actions to complete RCRA evaluations of the thorium materials, and
- To implement long-term storage and disposal alternatives.

In 1993, three drums of thorium materials were shipped to the Nevada Test Site. Also in 1993, the site completed the overpacking of 6,100 drums of thorium materials and expects to have approval to ship those materials to Nevada in 1994.

Land Disposal Restriction Waste

The Fernald site stores mixed waste subject to the RCRA Land Disposal Restrictions (LDR). These restrictions currently prohibit the storage of certain hazardous waste streams unless an extension is approved by USEPA or the appropriate state regulatory agency. Due to the lack of available treatment and disposal facilities for mixed wastes, DOE facilities, including the Fernald site, are continuing to store this mixed waste. The FFCA of October 1992 provides DOE with relief from enforcement under the LDR storage prohibition until October 1995, provided that the waste is stored in accordance with all other RCRA requirements. This time period may be extended further if DOE submits and obtains approval of a plan for providing the required treatment for LDR mixed waste. Such a plan must be approved before October 1995. The Fernald site submitted an initial conceptual plan in October 1993 and is scheduled to submit a draft plan to OEPA in August 1994.

RCRA Closures

During 1993, activities were underway to plan and implement the closure of Fernald site HWMUs. Many of these activities consisted of proposing, obtaining OEPA approval, and implementing RCRA closures in conjunction with the CERCLA response actions being undertaken under the Amended Consent Agreement with USEPA. RCRA closure activities during calendar year 1993 are charted on next page.

Environment, Safety, and Health Assessments

The concept of Environment, Safety, and Health (ES&H) Assessments was developed to evaluate compliance of all DOE facilities with regulatory requirements. To determine the actions taken in response to previous ES&H Assessment findings, the Secretary of Energy ordered that small, focused Progress Assessments be performed. The ES&H Progress Assessment at the Fernald site, conducted from October 15 through October 25, 1991, was the pilot progress assessment for this program. Key findings were cited representing potential compliance issues related to federal and state regulations or DOE Orders.

The latest draft Action Plan in response to the Progress Assessment was submitted to DOE Headquarters for review and approval in December 1993. The plan contains 103 response actions. FERMCO has completed all actions for which it was responsible. Pending DOE approval, five actions, for which DOE is responsible, are scheduled to be completed during 1994.

An Environment, Safety, and Health and Quality Assurance functional appraisal of the Fernald site was conducted in November 1992. The final audit report identified 72 deficiencies related to federal and state regulatory requirements. Deficiencies were categorized into one of the three functional categories of FERMCO's Quality Assurance Program Description as follows: 17 deficiencies in Program, 41 deficiencies in Performance, and 14 deficiencies in Assessment.

An Environmental Management Assessment of the Fernald site was conducted by DOE Headquarters in March 1993. The assessment identified 20 findings. Fourteen of these findings were in the management systems areas, and six were in the technical areas of radiation and quality assurance. A draft action plan in response to the 20 deficiencies identified was issued in June 1993. FERMCO has not received comments on the action plan.

DOE-Headquarters, Office of Nuclear Safety, performed a Radiological Evaluation in May 1993. The evaluation identified 32 deficiencies that were consolidated into seven external corrective action reports. Deficiencies were categorized into one of the three functional categories of FERMCO's Quality Assurance Program Description as follows: eight deficiencies in Program, 19 deficiencies in Performance, and five

HWMU No.	HWMU Description	Status Of Closure/Submittal
1	Fire Training Facility	RAWP[1]/CPID[2] submitted August 6, 1993
2	Parts Cleaner in Welding Shop	Received OEPA approval to withdraw November 1, 1993
4	Drum Storage Area Near Loading Dock #1ab	CPID submitted to OEPA April 4, 1993
6	Drummed HF Storage Inside Plant 4	Responded to NOD[3] February 13, 1993; closure certification due to OEPA in 1994
7	Drummed HF Residue Storage NW of Plant 4	CPID to be replaced with administrative closure
9	Nitric Acid Rail Car and Area	RAWP/CPID approved March 8, 1993; RAWP/CPID field work completed October 1993
10	Nitric Acid Recovery System Components	Submitted CPID June 30,1993; in OEPA review
23	Well Drilling Storage Area	Received OEPA approval to withdraw November 1, 1993
24	Equipment Storage Area	Received OEPA approval to withdraw November 1, 1993
26	Detrex Still	Submitted CPID November 5, 1993; in OEPA review
31/32	Bulk Storage Tanks T-5 and T-6	Amendment to CPID submitted November 18, 1993; in OEPA review
36	Storage Pad North of Plant 6	Amendment to CPID submitted December 30, 1993; in OEPA review
39	Clearwell	Received OEPA approval to withdraw June 7, 1993
43	Lime Sludge Ponds	Received OEPA approval to withdraw June 7, 1993
44	Coal Pile Runoff Basin	Received OEPA approval to withdraw June 7, 1993
45	Underground Storage Tank No. 5	Received OEPA approval to withdraw November 1, 1993
46-50	UNH Tanks	Undergoing closure under Removal Actions 12 and 20; CPID submitted June 22, 1993
52	North & South Spent Solvent Tanks	CPID submitted December 30, 1993; in OEPA review

[1] Removal Action Work Plan
[2] Closure Plan Information and Data
[3] Notice of Deficiency

deficiencies in Assessment. As a result of the 32 deficiencies identified, a Corrective Action plan was submitted to DOE-Fernald Field Office. All deficiencies were corrected prior to plan submittal.

A Technical Assist Visit was conducted by DOE-Headquarters in August 1993 of the site's Emergency Preparedness Plan (as required by DOE Orders). The Technical Assist Visit, a new program conducted at only three DOE facilities in 1993, was developed to provide a mechanism through which the DOE-Headquarters inspectors can provide program recommendations and advice in a non-enforcement capacity. No verbal findings were received from DOE-Headquarters inspectors at the time of the visit. The final Technical Assist Visit report has not been received by the Fernald site at this time.

The remainder of this report presents the results from the Environmental Monitoring Program at the Fernald site, beginning with a discussion on the Air Pathway. The estimated radiation doses for 1993 are also presented, as well as the Radon Monitoring Program results.

4

Air Pathway Monitoring

4

Air Pathway Monitoring

This chapter describes the air pathway and its components that may become contaminated as a result of airborne emissions from the site. Although it is not a true component of the air pathway, a discussion of the direct radiation monitoring program and results are included here for convenience.

As discussed in Chapter One, the public may be exposed to radiation from the site through the air pathway. This includes emissions from specific point sources (such as plant stacks), as well as dust from large, open areas, such as the waste pit area. When production operations were suspended in mid-1989, the major point source emissions from the site were eliminated. Since then, the principal sources of airborne uranium emissions have been the cooling tower mists, which have low levels of uranium contamination, and fugitive dust from locations where environmental cleanup activities are underway.

Fugitive Dust

The term fugitive dust is used to describe the small amounts of contaminated soil, waste materials, and construction dusts which are released from the Fernald site as a result of the ongoing remediation work. Sources of fugitive dust at the Fernald site include dust generated as contaminated material is moved or repackaged, small amounts of soil carried away by the wind during the excavation of a trench, wind erosion of waste pit materials which are not covered by water, and soil erosion during dry, windy weather.

Air pathway monitoring focuses on the airborne pollutants that may be carried from the Fernald site as a particulate or gas and how these pollutants are distributed in the environment. Stack and building vent emissions are obvious sources of pollutants, but dust from construction and remediation activities, waste handling, and wind erosion are also important potential sources. The form and chemical makeup of pollutants influence how they are dispersed in the environment as well as how they may deliver radiation doses. For example, fine particles and gases remain suspended, while larger, heavier particles tend to settle and deposit on grass or soil. Chemical properties determine whether the pollutant will dissolve in water, be absorbed by plants and animals, or settle in sediments and soils.

Results in Brief: 1993 Air Pathway

Air – Data collected from fenceline air monitoring stations show that average concentrations of uranium were all less than 1% of the DOE standard. Airborne uranium emissions for 1993 were estimated to be 0.21 kg (0.46 pound).

Soil – Some onsite and nearby offsite soil samples continue to indicate elevated uranium concentrations due to deposition of airborne particles from past operations. One offsite sampling location, in the predominant wind direction northeast of the site, had a total uranium concentration of 5.3 pCi/g, which is above the background level of 2.8 pCi/g for the Fernald area.[23]

Grass – The 1993 results indicate that uranium concentrations are higher at fenceline and onsite locations than at offsite locations. The onsite grass concentrations are better correlated to local airborne uranium concentrations than soil concentrations, which suggests that deposition is the source of the higher concentrations.

Produce – Uranium concentrations in produce were consistent with previous years' data. Laboratory analyses did not detect any significant differences in uranium concentrations between produce grown near the plant and produce grown at locations distant from the plant.

Milk – In general, uranium concentrations from the local dairy are comparable to those from a background dairy in Indiana. The data demonstrate that milk from the local dairy is not affected by site emissions.

Direct Radiation – Measurements of direct radiation indicate that levels increase with proximity to the K-65 silos. These measurements are consistent with the fact that the silos contain radium and radon gas which contribute to the direct radiation in the vicinity.

Boiler Plant – All emissions were well below permit limits.

Monitoring for Radioactive Pollutants

During 1993, Fernald site personnel continued to monitor radioactive materials in the air pathway by sampling air, soil, grass, produce, and milk. This monitoring enables scientists to evaluate the effects of the cleanup efforts at the site, as well as fulfill the site's obligations toward ongoing environmental surveillance and dose estimating.

Air Sampling for Radioactive Particulates

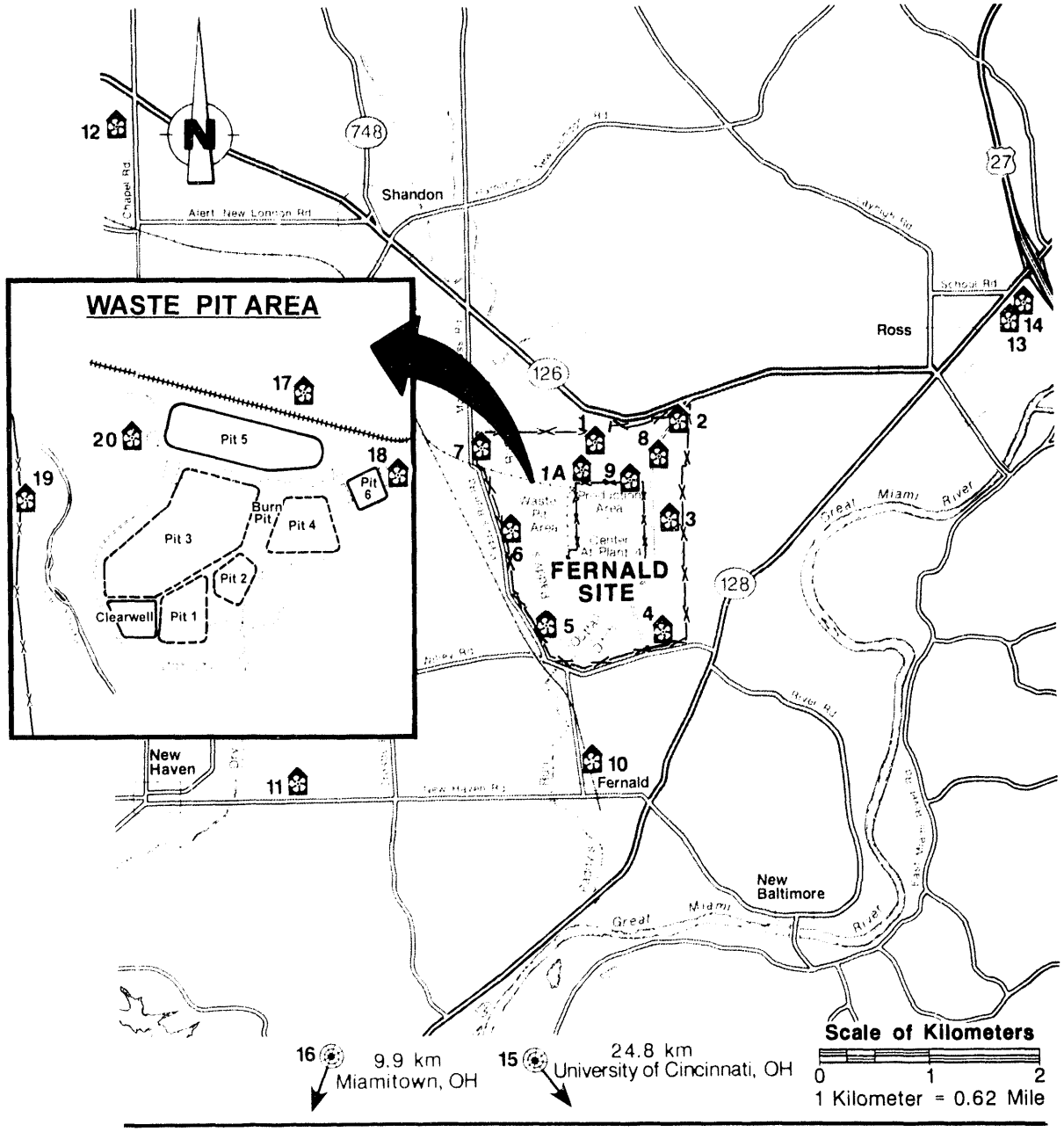
The first step in monitoring the air pathway is measuring the emission rate of the pollutants at the point of release after they have gone through treatments and filtering. This is done by means of stack sampling, and it provides preliminary information on how much pollutant is released and how it will behave in the environment. The second step in air pathway monitoring involves measuring the polluted concentration in ambient air onsite and at the site boundary. Since only a few stacks and vents continue to emit pollutants at the site, airborne emissions from monitored stacks are substantially lower than during the years of production. However, monitoring of overall site emissions (stack and fugitive emissions) continues through the use of air monitoring stations (AMS) located onsite, near the site fenceline, and at several locations in nearby communities.

Airborne pollutants are subject to existing weather conditions; thus wind speed and direction, rainfall, and temperature play a role in predicting how pollutants are distributed in the environment. Weather data, particularly wind speed and direction, provide input for selecting locations for the collection of environmental samples and locating monitoring stations.

During 1993, the site operated 20 air monitoring stations 24 hours a day, seven days a week as part of the Air Monitoring Program. Scientists selected the locations for the AMSs, as shown in Figure 21, for several reasons:

- AMS 1 through 7 provide data at the fenceline because this is where the public has closest access to the site and guidelines for offsite exposure apply. In order to comply with DOE and EPA monitoring criteria, AMS 1 was moved to a location closer to the former production area in mid-1993. The new location was designated AMS 1A and is no longer on the site boundary;
- AMS 8 and 9 are in the prevailing wind direction at the site. They were added in 1986 to the northeast sector of the site based on a computer model that predicted where the highest ground-level concentrations of airborne uranium from plant operations would be found;
- AMS 10 through 14 are located at schools and industries near the site and provide additional monitoring of emissions at these points;
- AMS 15 and 16 were installed in 1989 to obtain additional background data – AMS 15 is located near the University of Cincinnati, in Cincinnati, Ohio; AMS 16 is located in Miamitown, Ohio; and

Figure 21: Air Monitoring Locations



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- AMS 17 through 20 were installed in 1992 to provide increased monitoring of waste pit emissions. These monitors will provide valuable information on any pit emissions which occur during waste pit remediation.

At each AMS, air is drawn through a 20 cm by 25 cm (8 inches by 10 inches) filter at a rate of about 1.3 m^3 per minute (about 45 ft^3 per minute). Technicians account for any changes in flow rate over the sampling period by inspecting charts that continuously record flow data.

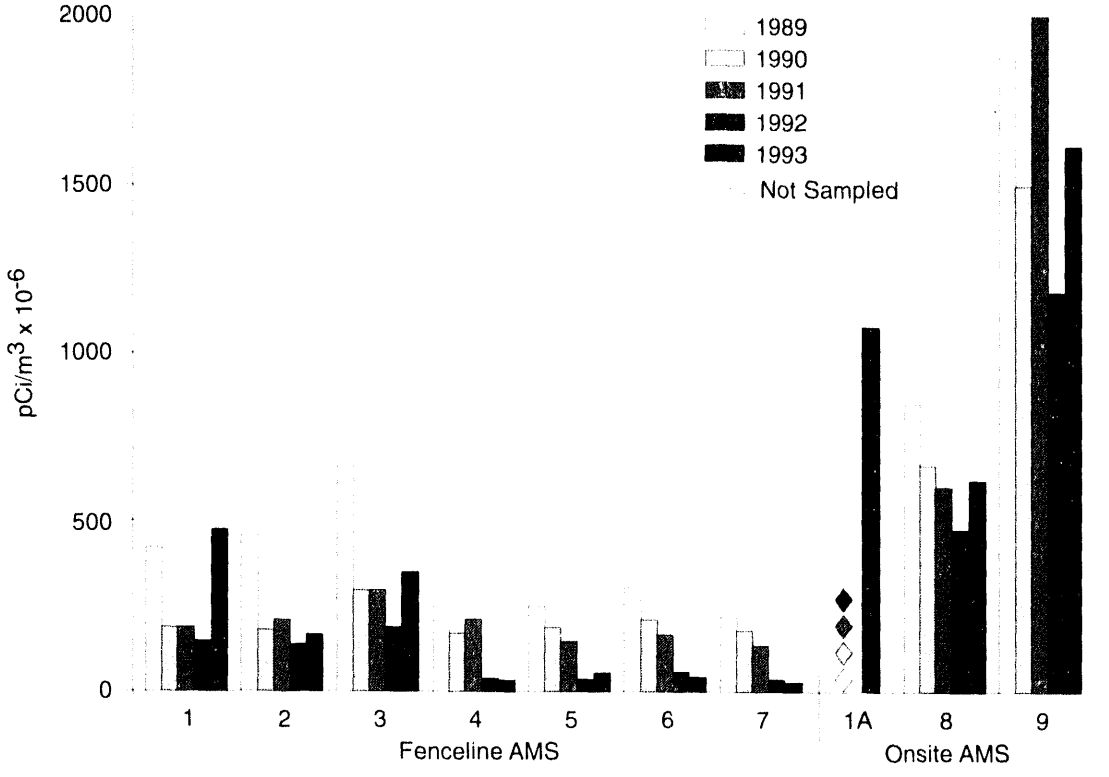
Environmental monitoring personnel collect the filters from the AMSs for analysis at weekly intervals. At the laboratory, technicians store the filters for at least three days following collection to allow naturally occurring, short-lived radionuclides (such as radon daughters) to decay. It is important to note that this holding period does not affect the amount of uranium on the filters. After the holding period, laboratory technicians heat the filters to 550°C (1,022°F) to remove organic matter. Finally, they dissolve these filters in acid and analyze the resulting solutions for uranium. A portion of each of these solutions is retained each week to prepare an annual composite, which is then analyzed for trace concentrations of radionuclides such as isotopes of radium, neptunium, plutonium, and thorium.

Method Used to Determine Airborne Emissions

The total airborne uranium emissions are determined by summing the estimated and measured emissions from a number of stacks, vents, and processes onsite. Measured and estimated uranium emissions for 1993 totaled 0.21 kg (0.46 pound). This represents a decrease of 9% from the 1992 estimated air emissions (0.23 kg or 0.51 pound). Uranium discharges from monitored stacks were the only measured emissions. Emissions from all other sources listed here were estimated. Airborne emissions are expected to remain at these low levels for several years. However, a future increase in emissions is possible as contaminated buildings and equipment are torn down during remediation of the site.

Emission Category	Percentage of Uranium Emission	Sources	Comments
Monitored Stacks	<1%	Five stacks	Increase from one stack in 1992 reflects increase in remediation activity
Unmonitored Stacks	18%	Two Plant 8 stacks	Some estimated emissions were from the processing of wastes for shipment offsite
Water Cooling Towers	58%	Cooling towers at Boiler Plant; loss as a mist	Estimated using uranium concentration of cooling water
Lab Emissions	22%	Exhausts from 24 fume hoods where radioactive materials are analyzed	Estimated based on results of stack emission tests
Fugitive Emissions from Waste Pits	2%	Uranium-contaminated soil and dust from	Estimated according to approved USEPA method[24]

Figure 22: Average Uranium Concentrations in Air, 1989 - 1993

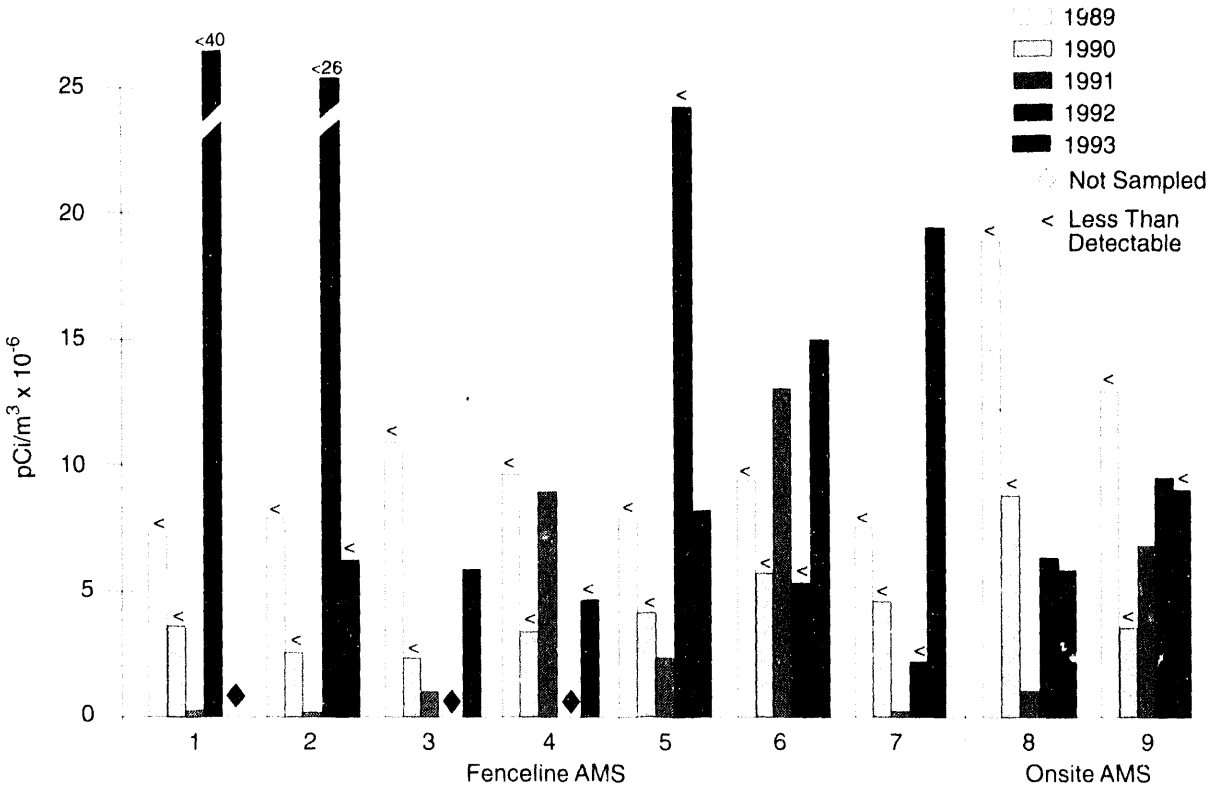


DOE Order 5400.5, "Radiation Protection of the Public and the Environment," establishes guidelines for concentrations of radionuclides in air emissions. These guidelines, referred to as Derived Concentration Guidelines (DCGs), are concentrations of radionuclides that, under conditions of continuous exposure for one year by one exposure mode, would result in a dose of 100 mrem. The intent of the DCGs is to provide reference values that enable site personnel to review effluent data and determine if there is a potential to exceed the limits on dose to members of the public.

The average concentrations of uranium at the seven fenceline AMSs (AMS 1 through 7) were all less than 1% of the DOE guideline. Table 3 on page A-4 lists 1993 data for uranium concentrations. Figure 22 compares uranium concentrations at the air monitoring stations for 1989 through 1993. The higher concentrations measured at AMS 9, located within the former production area, are in part attributed to the emissions from contaminated scrap metal pile that was located in the northeast section of the production area. The contaminated scrap metal was packaged and removed from the site during 1993.

The data on the concentrations of trace radionuclides in 1993 are presented in Table 4 on pages A-5 through A-7. The results indicate that concentrations of trace radionuclides at the onsite and fenceline locations are well below DOE guidelines. Concentrations of thorium–232, measured at the AMSs, for 1989 through 1993 are presented in Figure 23. Thorium–232 is stored in quantity at several locations onsite and is considered a potential environmental contaminant.

Figure 23: Average Thorium–232 Concentrations in Air, 1989 – 1993



Less Than Detectable Concentrations

The less than symbol (<) is used here when the concentration of thorium–232 in air could not be reliably measured in the sample which was analyzed. That is, the amount of thorium–232, if present at all in the sample, was below the minimum measurable concentration. Thus, a concentration of <40 pCi/m^3 x 10^{-6} means that the thorium concentration was less than 40 pCi/m^3 x 10^{-6} but actually could have been anywhere from 0.00 to 39.9 pCi/m^3 x 10^{-6}. While it is difficult to accurately compare these data from year to year that do not have reliable measurements, it is important to keep in mind that even the highest concentrations shown here are well below the DOE limit. The DCG for thorium-232 in air is 7,000 pCi/m^3 x 10^{-6}.

Comparison of Measured and Estimated Emissions

Scientists compared average air concentrations of uranium measured at the seven fenceline air monitoring locations to the predicted concentrations at the stations based on the emissions estimate of 0.21 kg (0.46 pound) of uranium. The comparison provides a means to evaluate the accuracy of the estimated emissions.

Results of the comparison are provided in Table 5 on page A-8. The results indicate that the measured concentrations are higher than the predicted concentrations. This finding suggests that the estimated emissions are higher than 0.21 kg (0.46 pound). Fugitive dust from various remediation work is a possible cause of the higher measured concentrations. All sources of fugitive dust are not accounted for in the 0.21 kg (0.46 pound) estimate. For example, wind erosion of contaminated soils is not included. However, given the comparatively low emissions and limited accuracy of the model used to predict the concentrations, the predicted results are considered reasonably accurate. Currently, USEPA requires the site to use the estimated values in its calculations for compliance with NESHAP.

Soil Sampling for Uranium

Site technicians take annual soil samples at the air monitoring stations and on-site locations to evaluate changes in uranium concentrations that might occur through deposition, soil resuspension or other mechanisms (see Figure 24 for sampling locations). Any uranium found in the soil may be naturally occurring, added by fertilizers, or a result of site operations. The amount of uranium naturally present in rocks and soils varies greatly (see Figure 25). For example, out of twelve samples collected throughout Ohio, the range of uranium–238 concentrations was 0.76 pCi/g to 2.2 pCi/g.[25] (The total radioactivity from uranium would be about twice this range because naturally occurring uranium in soil typically contains equal amounts of uranium–238 and uranium–234 radioactivity.) As a result, it is not possible to establish a single value for the background level of uranium and other minerals for an area such as near the Fernald site. While no DOE or USEPA guidelines or standards have been established for uranium in soil, 35 pCi/g or greater is recognized as a level at which to begin cleanup activities. However, this value may change depending on the future use of the site and remediation guidelines.[26]

To better evaluate the uranium concentration in soil, the site conducted a study to determine the amount of uranium naturally present in soil near the site. Soil samples were analyzed for a number of radionuclides; however, only uranium results are reported here. Results from this study show that the mean uranium concentration is 2.1 pCi/g with an upper limit (95% tolerance limit) of 2.8 pCi/g.[23]

As part of the soil sampling program, technicians collect cores of soil from undisturbed plots at two depths, 0–5 cm (0–2 inches) and 5–10 cm (2–4 inches), taking care to exclude grass from the soil samples. Results show that uranium concentrations in the soil samples taken at two onsite locations ranged between 6.9 and 18

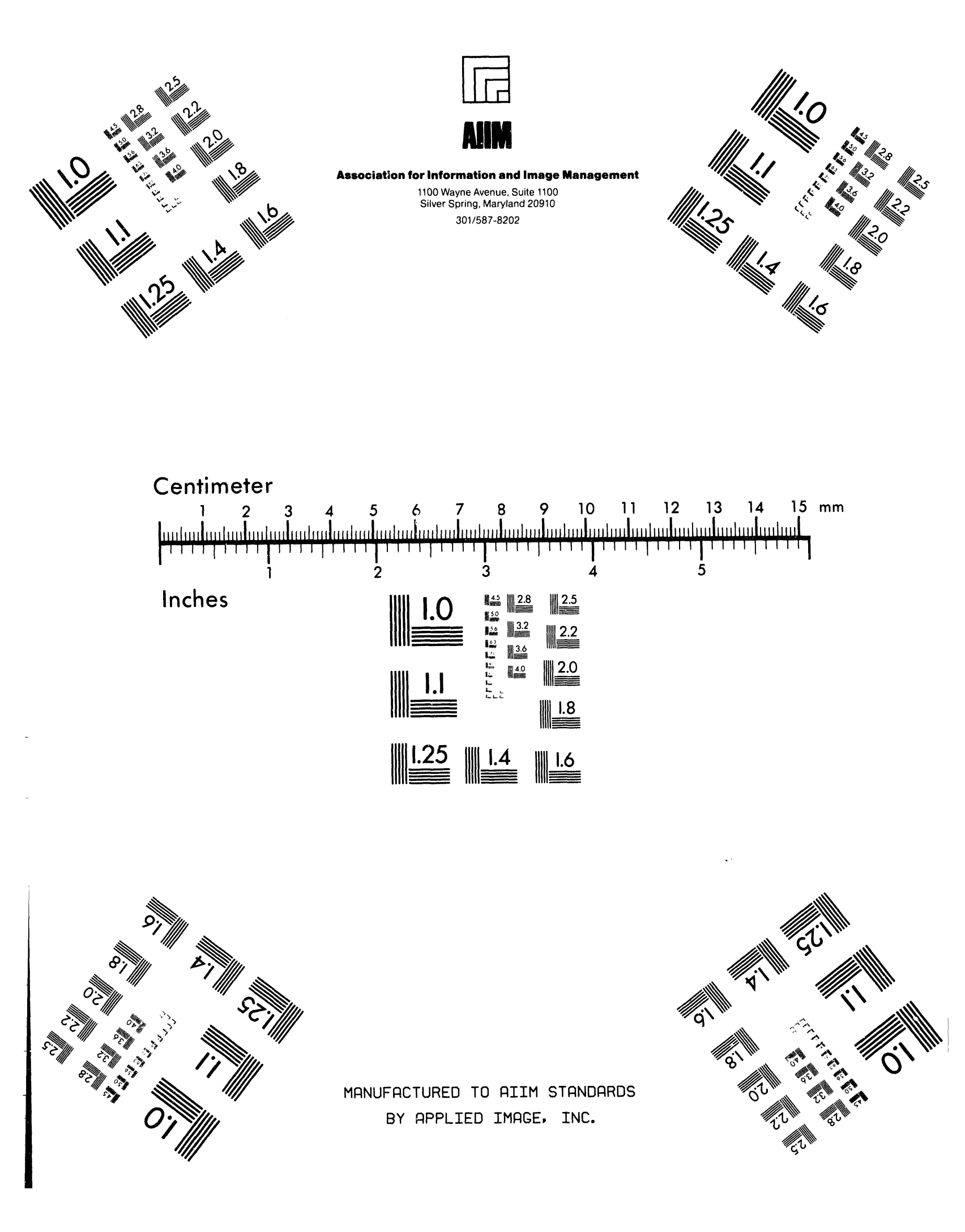

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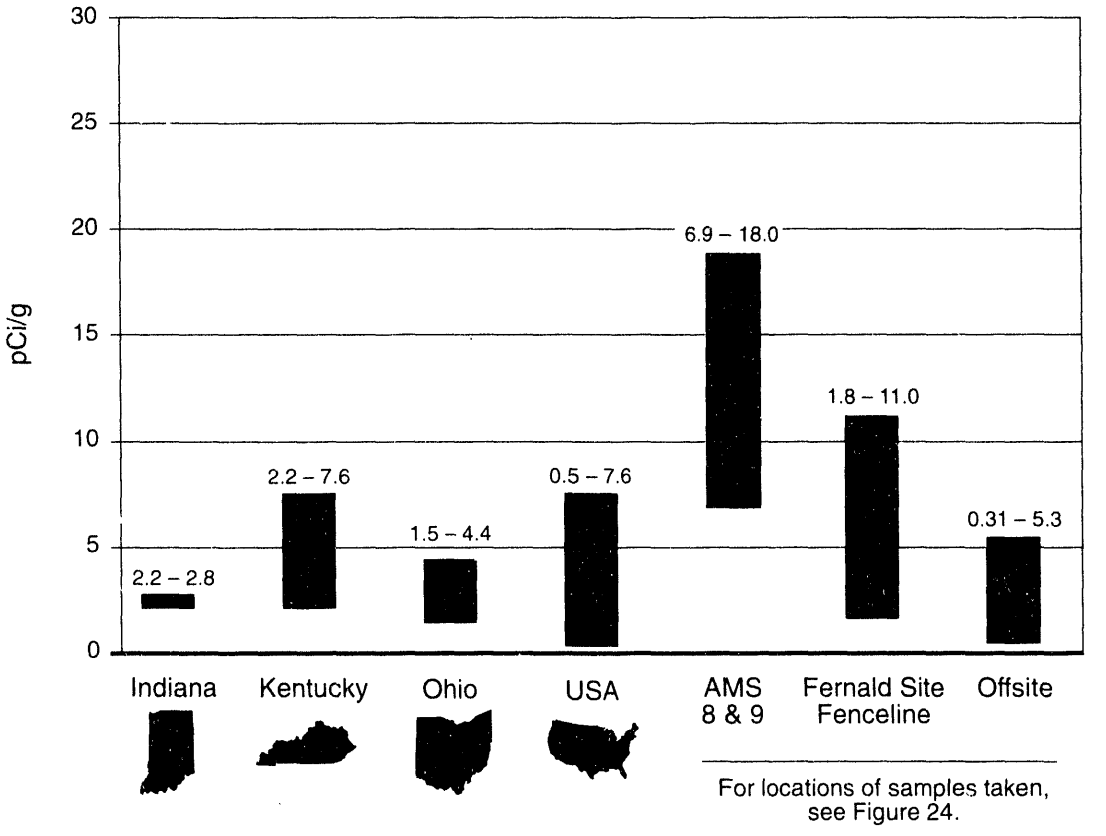
Figure 25: Range of Total Uranium Occurring in Surface Soils



pCi/g dry weight, while samples collected along the fenceline ranged between 1.8 and 11 pCi/g dry weight (see Table 6 on page A-9). The higher concentrations in onsite soil are indicative of the soil contamination known to exist, particularly in the northeastern quadrant of the site. The uranium concentration in offsite samples ranged from 0.31 pCi/g dry weight at sample location 36 to 5.3 pCi/g at sample location 30, which is northeast of the site. Above-background concentrations at sampling locations north and northeast of the site have been reported in past annual reports and are probably the product of airborne emissions and deposition during the period of uranium production. With the exception of the several locations north of the site, results from other offsite locations are within the range of naturally occurring uranium concentrations in Ohio soil.

For soil: 1 µg uranium/g = 1 ppm = 0.68 pCi/g
1 pCi uranium/g = 1.48 ppm

Grass Sampling for Uranium

Uranium contamination in vegetation may result from transfer of uranium from the soil through absorption by the plant, deposition of eroded soil, or from uranium deposited on the surface of the plant from the air. As a general rule, uranium is not selectively absorbed by plants since it serves no useful purpose in the plant's

metabolic processes; however, small amounts of uranium may be absorbed through a plant's normal growth processes. Fernald site personnel analyze grass for uranium to determine if airborne emissions are affecting the uranium concentration in grass.

Samples of grass were collected at the same locations as soil. Subsamples of grass are collected from the area around the soil sample location and then combined to form a composite sample. Each grass sample was a composite of at least three subsamples clipped near ground level. The composite samples each weighed about 500 grams (1 pound). An offsite laboratory air-dried and then analyzed the samples for uranium.

Standards have not been established for uranium in grass; however, comparing results of samples collected at the site with the results of samples collected offsite and distant from the site provides a means to evaluate the impact of site emissions on uranium concentrations in grass.

In addition to soil sample results, Table 6 on page A-9 reports the following uranium concentrations in onsite, fenceline, and offsite grass samples:

- Onsite and fenceline results ranged from 0.017 to 0.72 pCi/g dry weight, and
- Offsite results ranged from 0.004 to 0.026 pCi/g dry weight.

The results indicate that uranium concentrations are higher at onsite and fenceline locations. The onsite grass concentrations are better correlated to local airborne uranium concentrations than soil concentrations, which suggests that deposition is the source of the higher concentrations.

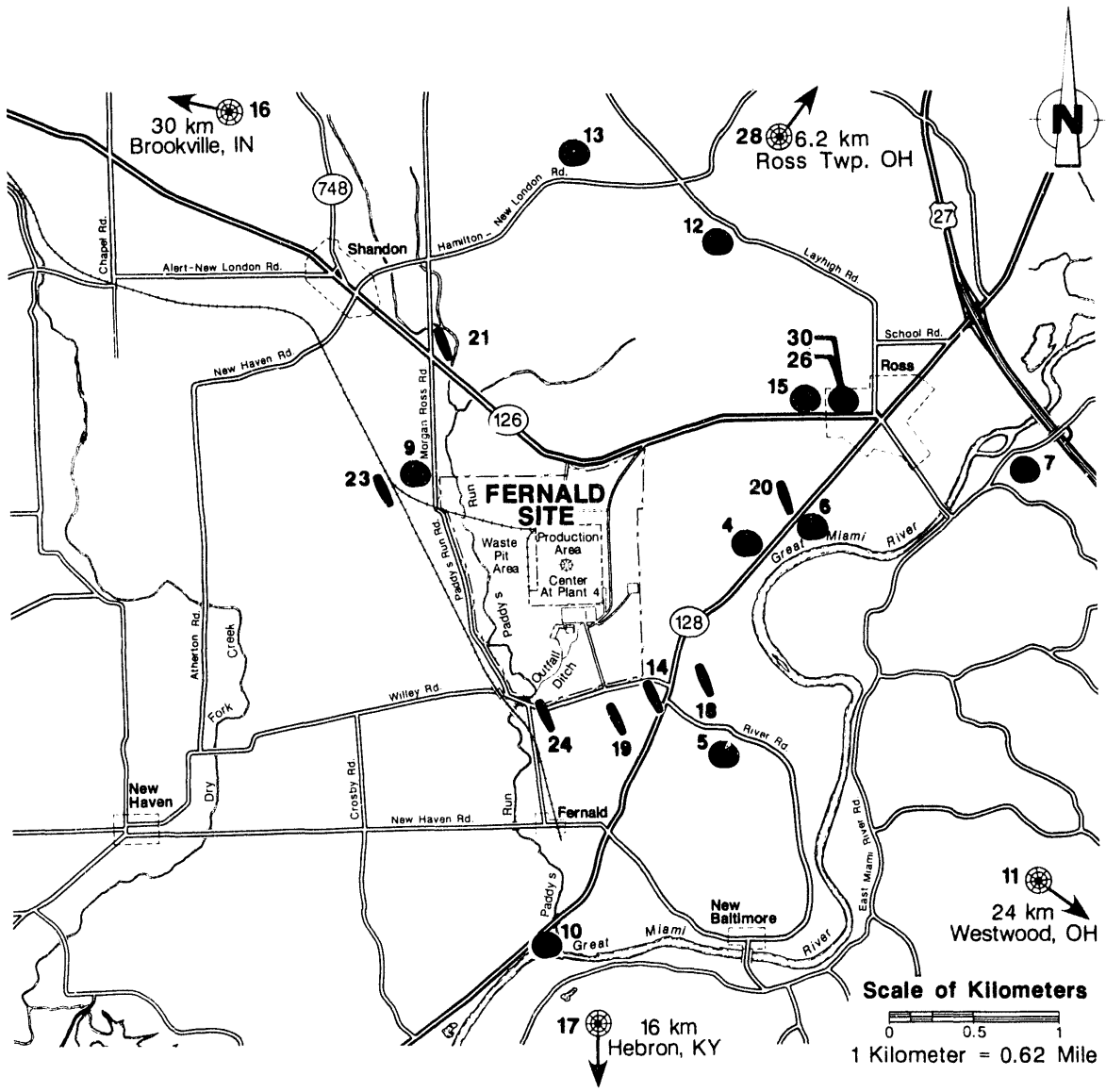
Produce Sampling for Uranium

As mentioned in Chapter One, the Fernald site is surrounded by farmland. Home-grown sweet corn and tomatoes are two of the major crops sold from roadside stands within three miles of the site. Local residents also grow and sell beets, potatoes, apples, lettuce, pumpkins, cucumbers, and peppers.

With air emissions reduced to very low levels, the possibility of uranium contamination in produce that is caused by air deposition is also very low. While washing the produce before eating removes any surface contamination which may be present, some uranium may be taken up by plants through their root systems and incorporated into their edible portions. Uranium detected in produce may be uranium that is naturally occurring in the soil, added by fertilizers, or deposited on the ground from airborne emissions.

Technicians sample produce each year to determine if uranium concentrations in produce grown near the site (0–5 km or 0–3 miles) are higher than concentrations in produce grown at distant locations (11–42 km or 7–26 miles) and are, therefore, a pathway of exposure from site emissions (see Figure 26 for sampling locations).

Figure 26: Produce Sampling Locations



LEGEND

Sampling Locations:
- Cash Crop
- Garden Produce

- Plant Perimeter
- Production Area Perimeter
- Distance from Center of Production Area to Sampling Locations off Map

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The sample results are then used to estimate the potential dose to people from this component of the air pathway (see Chapter Seven).

The results of the produce and soil sampling program are reported in Table 7 on pages A-10 and A-11. In general, uranium concentrations varied greatly for each type of produce. A comparison between the uranium concentrations in corn and tomatoes grown near the site with concentrations in corn and tomatoes grown distant from the site determined that the average concentrations were higher in corn and tomatoes grown distant from the site. These comparisons suggest that there is no substantial impact today from past or current Fernald site emissions on produce grown in the area.

Technicians also sample the soil in which the produce is grown. This sampling is in addition to the soil sampling described earlier and is conducted to compare uranium concentrations found in soil with the concentrations found in produce. To date, no strong correlation between uranium concentrations in soil and produce has been established. Uranium concentrations in the soil taken along with produce ranged from 0.4 to 2 pCi/g and were within the range of naturally occurring uranium concentrations in area soils.

Milk Sampling for Radionuclides

Even though uranium is not normally concentrated in milk, the site monitors cows' milk as a component of the air pathway in response to public concerns about the dairy farm located next to the Fernald site. In 1993, technicians collected monthly samples of milk from the dairy adjacent to the site, as well as milk from a dairy in Indiana about 37 km (23 miles) west of the Fernald site. The milk samples were then frozen and shipped to an offsite laboratory for uranium analysis. In addition to monthly uranium analyses, once a year a set of milk samples is analyzed for radioactive materials present in trace concentrations (radium, thorium, etc.) in site emissions.

Table 8 on page A-12 presents the data from monthly milk sampling in 1993. In general, the results show uranium concentrations in milk from the local dairy were comparable to the uranium concentrations measured in milk from the background dairy in Indiana. In fact, the average concentration at the background dairy was higher than the concentration at the local dairy.

Table 9 on page A-13 presents the results of the trace radionuclide analyses from milk. Laboratory difficulties in analyses of trace radionuclides resulted in suspect data for beryllium–7, bismuth–214, lead–214, radium–228, and strontium–90. However, the results show that the concentrations of radionuclides in milk from the local dairy are similar to the concentrations in milk at the background dairy.

Monitoring for Direct Radiation

Direct radiation (X-rays, gamma rays, energetic beta particles, and neutrons) originates from sources such as cosmic radiation, naturally occurring radionuclides in soil, worldwide fallout, and radioactive materials at the Fernald site. The largest source of direct radiation at the site is the material stored in the K-65 silos. Gamma rays and X-rays are the dominant types of radiation emitted from the silos. Energetic beta particles and neutrons are not a significant component of direct radiation at the Fernald site because uranium, thorium, and their decay products do not emit this radiation at levels that create a public exposure concern.

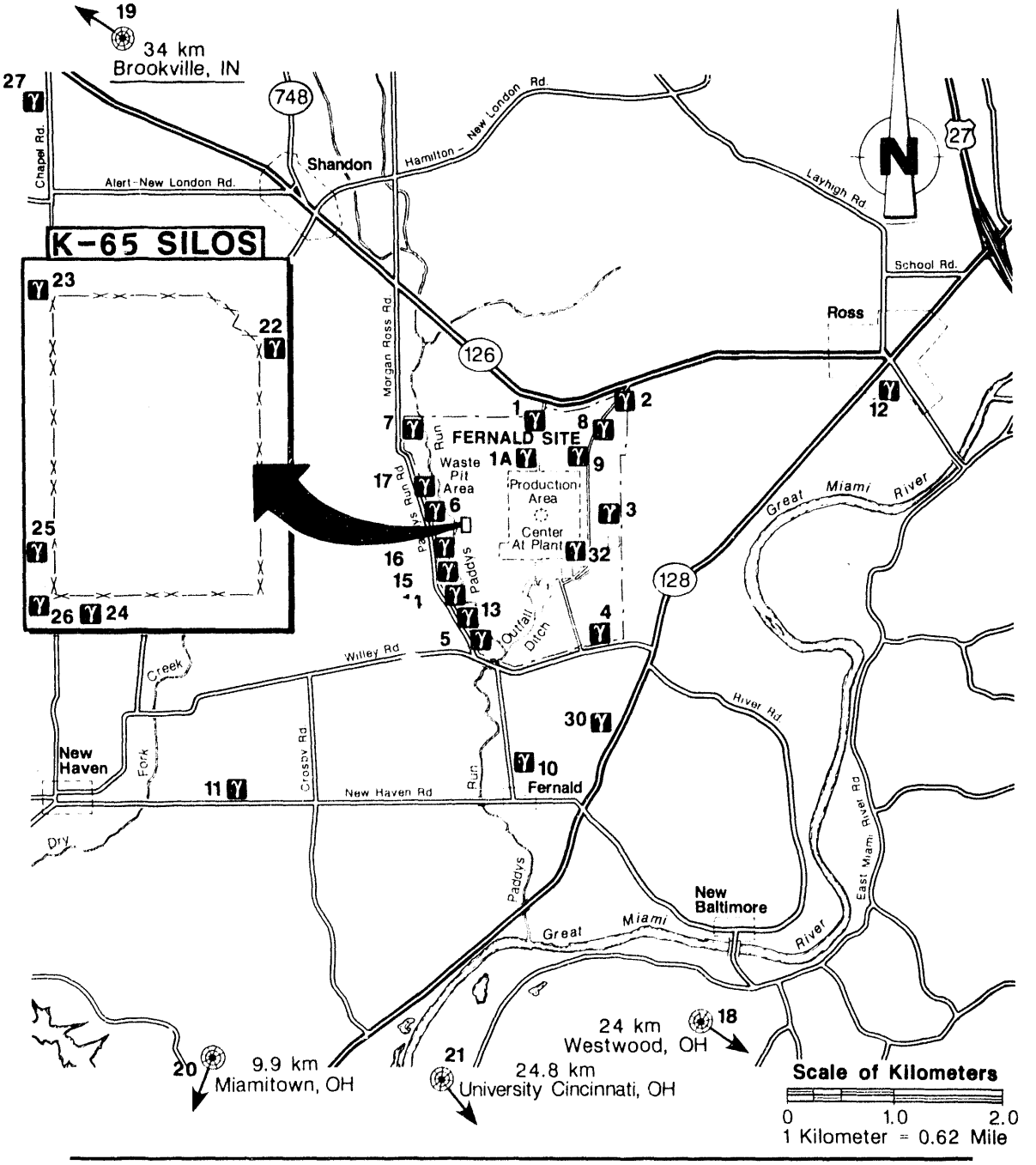
Direct radiation levels at and around the site are continuously measured at 29 locations with thermoluminescent dosimeters (TLD). TLDs absorb and store the energy of direct radiation within the thermoluminescent material. By heating the thermoluminescent material under controlled conditions, the stored energy is released, measured, and correlated to the amount of direct radiation. Figure 27 shows the location of the TLD monitoring points. These monitoring points were selected based on the need to monitor the K-65 silos, the site boundary, and several offsite locations, including background locations. Three TLDs are placed at each monitoring location for a three-month period, yielding more reliable quarterly measurements.

Results of direct radiation measurements for 1992 and 1993 are provided in Table 10 on page A-14. Direct radiation fields vary from one location to another because of the differences in the terrestrial and cosmic components of natural background radiation. For example, varying concentrations of naturally occurring radium, thorium, and their decay products in soil result in different measured radiation levels. Measurements of direct radiation indicate that levels are higher in the area near the K-65 silos as expected. However, these levels are clearly lower than radiation levels measured in 1991 prior to the addition of the bentonite layer within the K-65 silos. An estimated dose from direct radiation is provided in Chapter Seven.

Monitoring for Nonradioactive Pollutants

OEPA requires an estimate of emissions from the Boiler Plant as part of the site's effort to demonstrate compliance with the Clean Air Act. The site estimated the amount of nonradioactive pollutants including sulfur dioxide (SO_2), nitrogen oxides (NO_X), and carbon monoxide (CO) and measured the shade, or density, of particulate emissions from the coal-fired boilers. Shade, or density, is also called *opacity* and is a measure of how much light is blocked by particulates present in stack emissions.

Figure 27: Direct Radiation Monitoring Locations



LEGEND

- Dosimeter Location
- Distance from Center of Production Area to Dosimeter Locations off Map
- Plant Perimeter
- Production Area Perimeter

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In order to estimate SO_2 emissions, scientists regularly determine the sulfur content of the coal. Using this information and the total amount of coal burned, the amount of SO_2 emissions can be calculated. For 1993, SO_2 emissions were calculated to be 290,000 kg (630,000 pounds).[27] This was well below the allowable limit of 1.6 million kg (3.5 million pounds) calculated from information in the Permit to Operate issued by OEPA.

The NO_X emissions are estimated using USEPA-developed emission factors. Nitrogen oxide emissions for 1993 were estimated to be 150,000 kg (340,000 pounds). To date, the State of Ohio has not set NO_X or CO limits for Fernald site industrial processes. Carbon monoxide emissions were estimated using USEPA-developed emission factors. Carbon monoxide emissions in 1993 were estimated to be 54,000 kg (120,000 pounds).

Air Emissions

OEPA maintains an inventory system for actual air emissions from major point sources; the inventory is prepared by the Department of Environmental Services – Air Quality Management (formerly the Southwestern Ohio Air Pollution Control Agency). The totals presented here are in kilograms. The increase in Boiler Plant emissions in 1993 is attributable to returning the boilers to full service after a coal bunker fire in 1992 limited boiler plant operation.

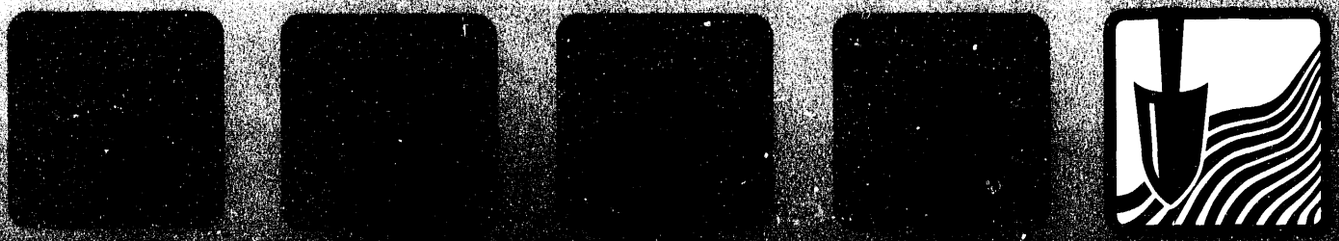
	Hamilton County 1992	Butler County 1992	Combined Counties 1992	Fernald Site Boiler Plant 1992	Fernald Site Boiler Plant 1993
Particulates	1,700,000	3,800,000	5,500,000	7,300	16,000
SO_2	67,000,000	8,500,000	76,000,000	74,000	290,000
NO_X	28,000,000	4,500,000	33,000,000	68,000	152,000
CO	1,600,000	21,000,000	22,000,000	24,000	54,000

Electrostatic precipitators reduce particulate emissions from the Boiler Plant. These emissions were estimated to be 16,000 kg (36,000 pounds) for 1993. This estimate was based on emission factors developed from stack testing in 1988. The opacity of the emissions from the two site coal-fired boilers were continuously monitored by instruments designed for that purpose. During 1993, the boilers operated 11,128 hours, and 111,280 measurements were made and recorded at six-minute intervals. A total of five excursions failed to meet the opacity standard. These excursions were brief, typically less than 18 minutes in length, and associated with boiler start up or load changes.

In addition to directly affecting concentrations of contaminants in soil, grass, and other media discussed in this chapter, the air pathway can indirectly influence contaminant concentrations in the liquid pathway. Stormwater runoff is one way materials deposited in the air can be transported into surface water such as Paddys Run. Eventually, these contaminants may affect groundwater quality as well. The next two chapters describe the Fernald site's monitoring program for the liquid pathways, beginning with Effluent and Surface Water Monitoring in Chapter Five.

5

Liquid Pathway: Effluent and Surface Water Monitoring



5

Liquid Pathway: Effluent and Surface Water Monitoring

The Fernald site investigates the effects of past and current operations on the second major pathway, the liquid pathway. Since contaminants can leave the site through the regulated liquid effluents and uncontrolled stormwater runoff, this chapter discusses sampling methodologies and results used to evaluate the site's effluents. It also discusses any impacts from the site on the Great Miami River and Paddys Run.

Results in Brief: 1993 Liquid Pathway: Effluent and Surface Water

Effluent – Approximately 474 kg (1,044 pounds) of uranium were discharged to the Great Miami River during 1993. Of that total, 453 kg (998 pounds) were from Manhole-175 and 22 kg (48 pounds) were from South Plume groundwater pumping. Approximately 109 kg (241 pounds) of uranium reached Paddys Run through uncontrolled stormwater runoff during 1993.

Surface Water – The liquid effluent discharged to the Great Miami River resulted in a slight increase in downriver uranium concentration from the upriver location. However, the downriver concentrations were consistent with 1992. Paddys Run continued to show effects of stormwater runoff from the site. Although the average uranium concentration at the nearest offsite sampling location was higher than in 1992, it was only 0.71% of the DOE guideline for drinking water, which is used for comparison purposes.

Sediments – Radionuclide concentrations in the Great Miami River and Paddys Run sediments for 1993 were consistent with previous years' data and did not indicate a build-up of radioactive pollutants in the sediment.

Fish – Uranium concentrations in 1993 were no greater in fish caught in the Great Miami River downstream of the site's effluent line than in those caught upstream.

NPDES – During 1993 there were only three violations of NPDES limits at Manhole-175, the final NPDES monitoring point before effluents are discharged to the river. Out of the yearly total of 4,020 NPDES samples taken at internal and external monitoring locations, only 11 were not within permit limits.

Monitoring for Radioactive Pollutants

The first section of this chapter centers on the radioactive pollutants and begins with an examination of the liquid effluent sampling and analysis program. A discussion of the river and creek surface water sampling program follows. The Fernald site conducts these programs because radionuclides in the regulated liquid effluent and in uncontrolled stormwater runoff may be a source of radiation exposure to the public.

Effluent Sampling for Radionuclides

The site's liquid effluents have been categorized into eleven basic sources. All site generated liquid effluents are monitored and, if necessary, treated before they leave the site. Figure 28 illustrates the flow of the effluents and where they are treated and monitored before they are discharged.

Sources of Effluent During 1993

The first two sources of liquid effluent are ***controlled contaminated stormwater runoffs from the waste pit area and perimeter***, which are collected and pumped to the Biodenitrification Surge Lagoon (BSL).

The third source of liquid effluent is ***perched groundwater,*** which is treated for volatile organic compounds (VOCs) and sent on to the Plant 8 Sump for further treatment.

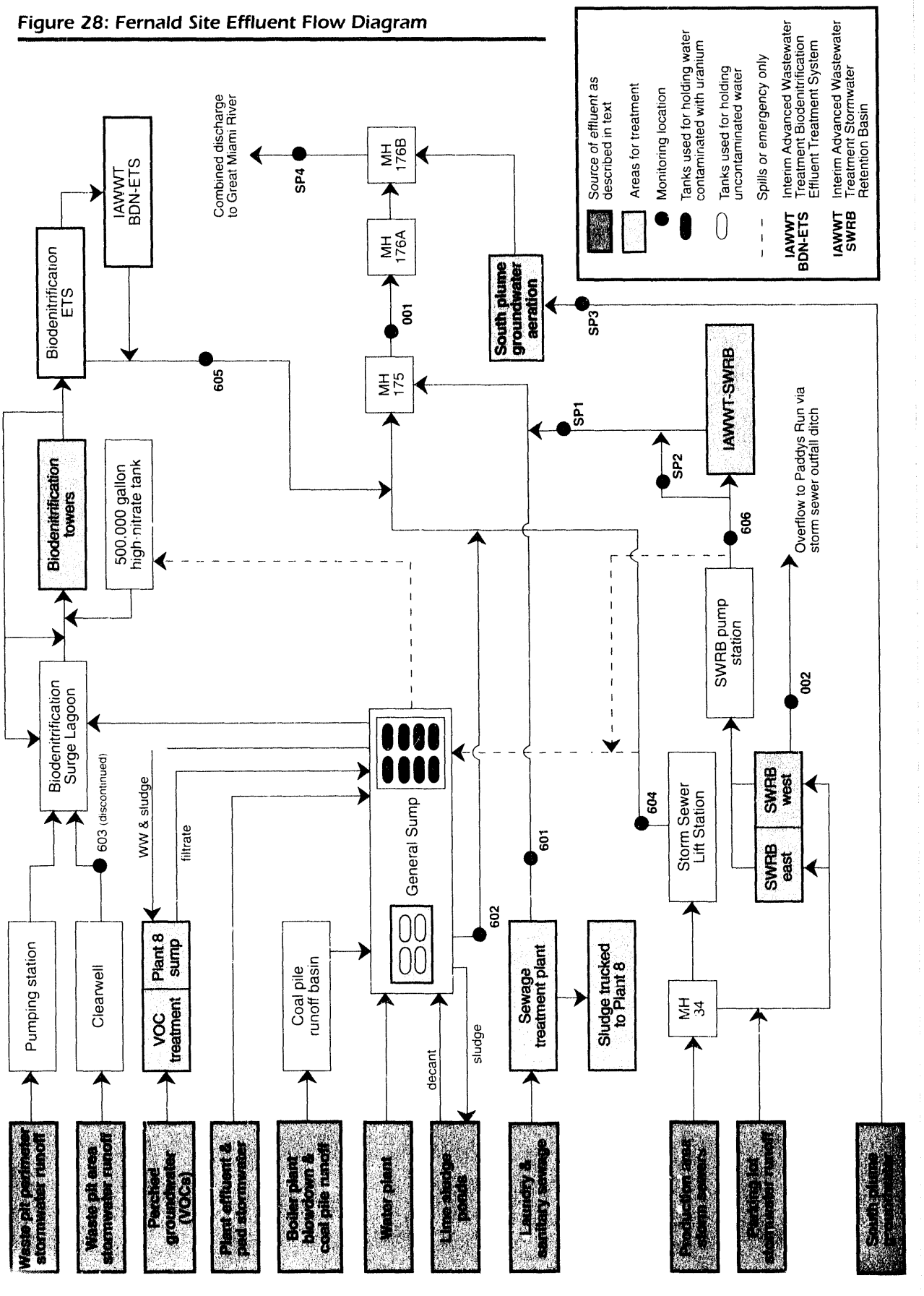
The fourth source of effluent is the combination of ***sanitary sewage and liquid from the laundry***, which is processed at the Sewage Treatment Plant to remove biological contaminants. After treatment, the liquid is sent to Manhole-175 and the sewage sludge is trucked to the Plant 8 Sump.

At the Plant 8 Sump, sludges are dewatered. The resulting liquid is sent to the contaminated side of the General Sump, and the dewatered sludge is drummed and stored as a low-level radioactive waste.

The combination of ***plant effluent and pad stormwater*** is the fifth source of effluent, and it is sent directly to the contaminated side of the General Sump. All liquids from the contaminated side of the General Sump are combined and, if needed, are sent to the Plant 8 Sump where they are treated. If treatment is not required, they are sent on to the BSL.

At the BSL, runoff mixes with liquid from the contaminated side of the General Sump and the combined liquid effluent is treated in the Biodenitrification Facility (BDN) towers to reduce nitrates. From there, the liquid flows through the BDN effluent treatment system, after which the combined treated effluent flows to an Interim Advanced Wastewater Treatment (IAWWT) System where uranium may be removed before it flows to Manhole-175.

Figure 28: Fernald Site Effluent Flow Diagram



The sixth through the eighth sources of effluent are all collected in the noncontaminated side of the General Sump. ***Boiler plant blowdown and coal pile runoff*** are collected in the coal pile runoff basin and, after clarification, are sent to the noncontaminated side of the General Sump. ***Water plant effluent*** and ***Lime Sludge Pond*** decants are sent directly to the noncontaminated side of the General Sump. After settling, the liquid in the noncontaminated side of the General Sump is then sent to Manhole-175, and the sludge is sent to the North Lime Sludge Pond.

The ninth and tenth sources of effluent are produced from rain which has been collected by the ***production area storm sewers*** and ***parking lot runoff*** (see Figure 29). Stormwater runoff from the former production area is collected by a network of storm sewers that converge at Manhole-34. Normally all runoff is directed to the Stormwater Retention Basin (SWRB); but if needed, effluent can be pumped to Manhole-175 from the Storm Sewer Lift Station. At the SWRB the effluent mixes with runoff from the parking lot storm sewers and is allowed to settle before being pumped to an IAWWT. From there the effluent is sent to Manhole-175. At Manhole-175, the effluents are monitored, and sent to Manhole-176B.

South Plume Groundwater Pumping

Pumping of South Plume groundwater began in May 1993. Since the South Plume groundwater is pumped back onsite before it is discharged to the Great Miami River, it is considered a source of effluent from the Fernald site. The effluents generated from the South Plume groundwater are monitored separately from the effluents generated onsite. After monitoring, all effluents are combined at Manhole-176B before being discharged to the river. Even though the effluents originating from the site and South Plume groundwater are monitored separately, the combined effluent is required to comply with all applicable permits, guidelines, and standards. This is accomplished by combining the measured concentrations.

The final source of effluent is generated from the pumping of the ***South Plume groundwater***. The South Plume groundwater is monitored at SP3 before being pumped to the South Plume Aeration building where it can be aerated if needed and then sent to Manhole-176B.

In summary, the Fernald site controls site-generated liquid effluents, monitors, and treats them as necessary before they all eventually enter Manhole-176B. There, the effluents combine to form a single liquid before the effluent flows to the Great Miami River.

On an average day during 1993, about 12 billion liters (3.1 billion gallons) of Great Miami River water flowed past the site's effluent line.[8] The site discharged an average of 5.8 million liters (1.5 million gallons) of effluent, with 3.4 million liters (0.89 million gallons) coming from the South Plume and 2.4 million liters (0.65 million gallons) originating from Manhole-175, into the river each day. Therefore, on average, each liter of effluent discharged was combined with about 2,100 liters of river water.

Sampling Methodologies

The mixed effluent, described above, is sampled at Manhole-175 and SP3 by flow-proportional samplers, continuously operating devices that collect the amount of the effluent proportional to the volume of effluent flow. After every 24 hours of operation, the collected liquid is removed from the automatic sampler to provide a daily flow-weighted sample of the effluent (see Figure 30).

Figure 29: Area of Controlled Stormwater Runoff

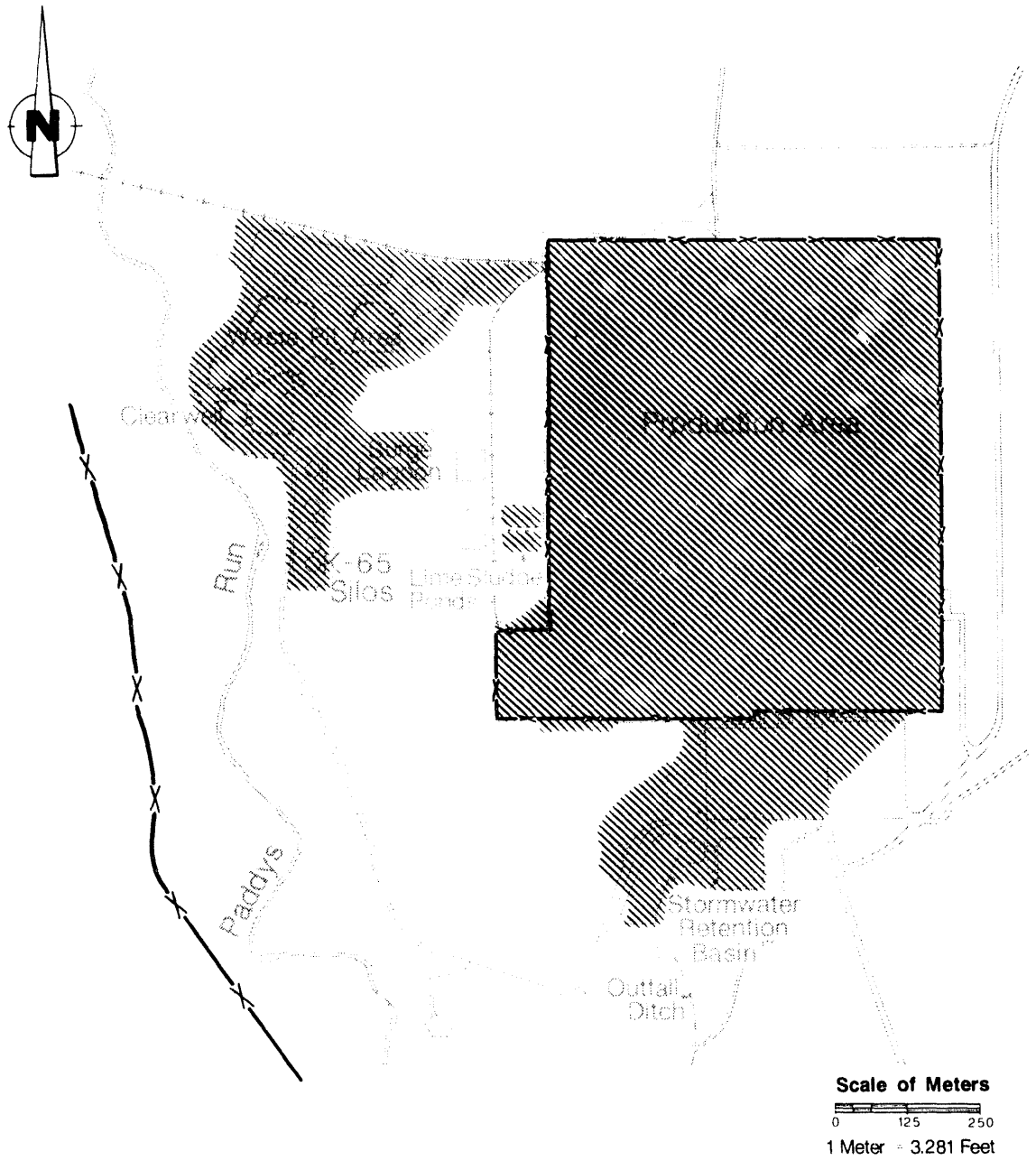


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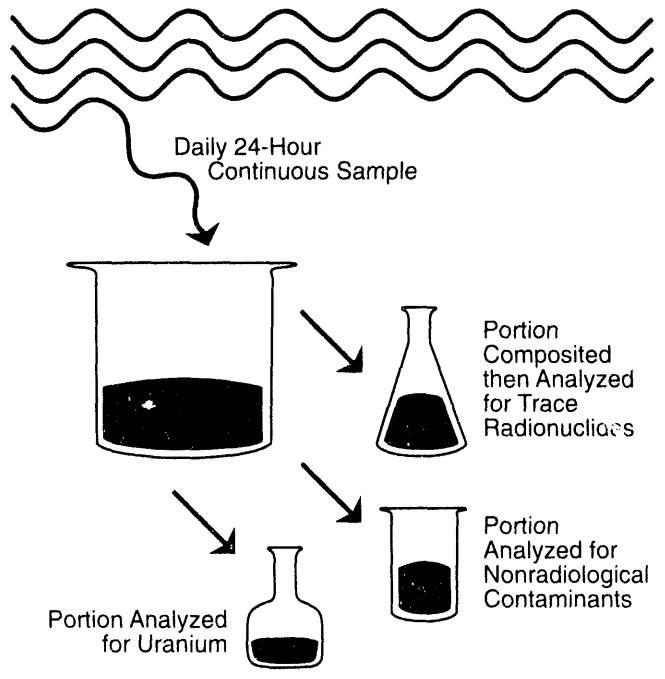
Figure 30: Continuous Sampling



Scientists analyzed a portion of each daily sample of effluent flowing through Manhole-175 and SP3 to determine the amount of total uranium discharged to the Great Miami River. In addition, monthly composites are formed for Manhole-175 and SP3 by combining the month's daily samples at each location. The monthly composites were analyzed for four uranium isotopes and nine other radionuclides listed in Table 11 on page A-15. Composites, rather than daily samples, were analyzed because many of the radionuclides have been present in only trace amounts, and it is neither practical nor cost-effective to perform more frequent analyses for them.

The Fernald site also monitors any discharges to Paddys Run that occur from the overflow of the SWRB. Since the SWRB began operating in 1986, the amount of uranium entering the outfall ditch has been substantially reduced. During 1993 the SWRB did not overflow.

Results of Laboratory Analyses

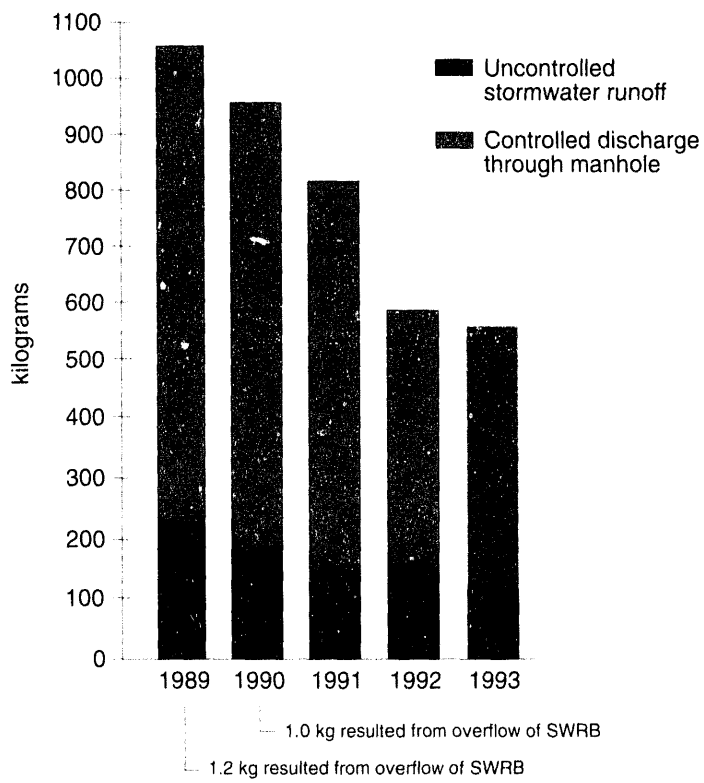
Table 11 on page A-15 is a summary of the radionuclide analysis of the liquid effluent discharged to the Great Miami River. The table shows the total Curies discharged during 1993 and the average concentration (in pCi/L) of each radionuclide in 1993.

The average concentration of each radionuclide is compared to the Derived Concentration Guideline (DCG) or standard. DOE Orders state that a dose must be estimated based on all of the radionuclides present in the effluent. The annual average percentages of the DCG for each radionuclide, when added together (Manhole-175 and SP3 combined), must not exceed 100%. When the total is above 100%, the site is required to use the "best available technology" to reduce radionuclide concentrations in its effluent.

An Advanced Wastewater Treatment Facility is presently under construction to provide "best available technology" treatment of both stormwater and process wastewater before their discharge to the Great Miami River. Similar technology has been used at the SWRB with an Interim Advanced Wastewater Treatment facility. In 1993, another Interim Advanced Wastewater Treatment system began operation to extract uranium from wastewater discharged from the BSL.

During 1993, a total of 0.27 Curie (474 kg or 1,044 pounds) of uranium was discharged to the Great Miami River. This was a decrease of 7% on an activity basis and an increase of 7% on a mass basis, in comparison to the 0.29 Curie (443 kg or 975 pounds) of uranium discharged to the river during 1992. However, the uranium contained in all effluents discharged from the site decreased from an estimated 595 kg (1,309 pounds) in 1992 to an estimated 583 kg (1,283 pounds) in 1993. The total decrease may be attributed to the completion of the Waste Pit Area Stormwater Runoff project that collects runoff (which previously flowed uncontrolled to Paddys Run), allowing it to be treated before being discharged to the river. Comparisons of uranium discharges to the Great Miami river during 1993 and the four previous years are shown in Figure 31.

Figure 31: Total Uranium Discharged from the Site, 1989 - 1993

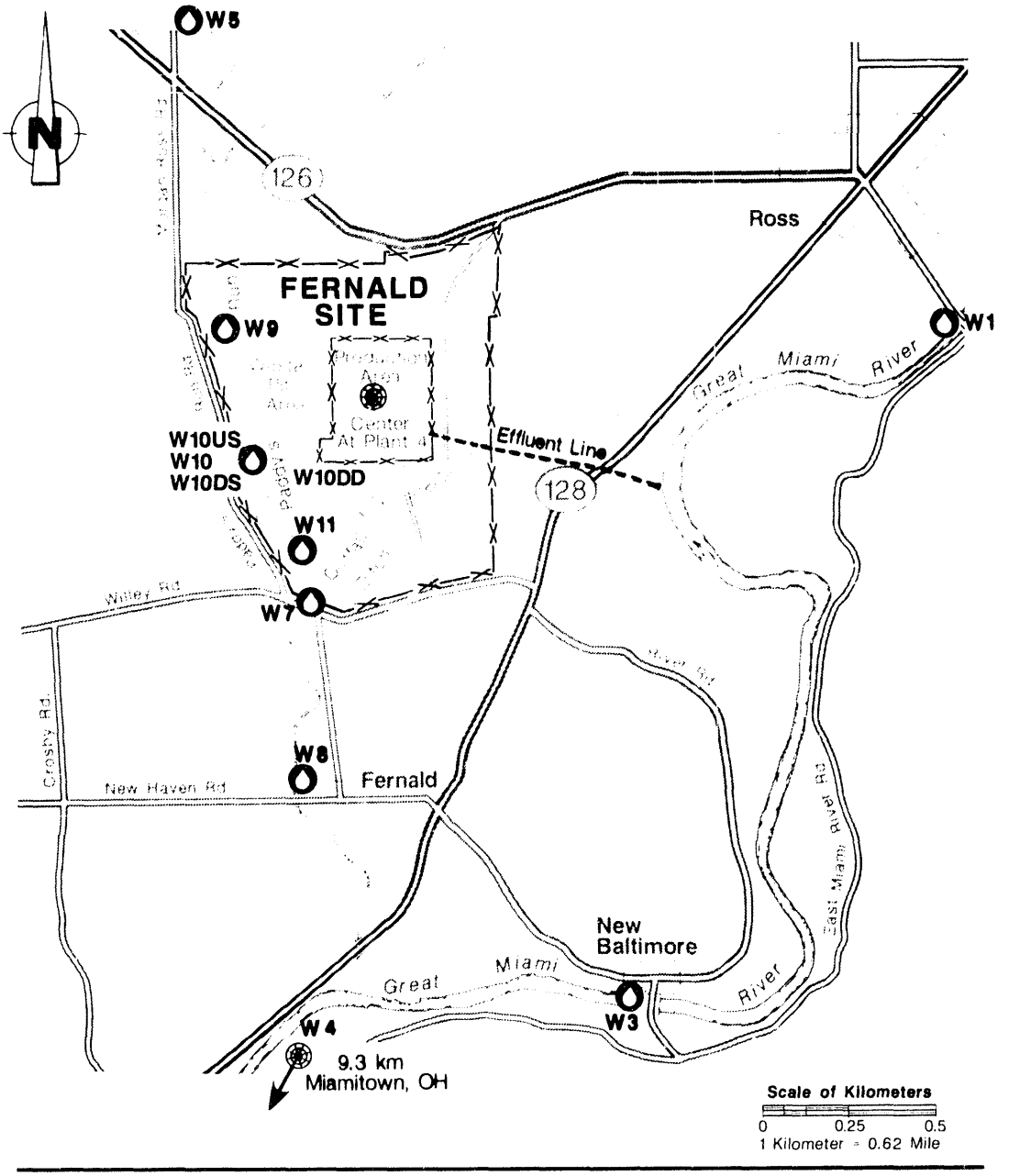


The Fernald site reports an estimate of uranium in uncontrolled stormwater runoff into Paddys Run to USEPA. Fernald site personnel had developed a general estimate of 2.8 kg (6.3 pounds) of uranium in the runoff to Paddys Run for every inch of rain. For 1993, the estimate of uranium in stormwater runoff to Paddys Run was reported as 109 kg (241 pounds). This estimate was based on the amount of precipitation recorded by the site meteorological system (98 cm or 39 inches). Actinium, radium, and thorium concentrations were all within acceptable limits. Their percentage of the applicable DCGs ranged from 0.0054% for thorium–231 to 4.8% for radium–228.

Surface Water Sampling for Radionuclides

The site's surface water sampling program measures the effects of two potential sources of contamination on local waterways: the discharge of liquid effluents into the Great Miami River and the effects of uncontrolled stormwater runoff into Paddys Run and overflow from the SWRB (which did not occur in 1993). Figure 29 on page 85 shows the area of controlled stormwater runoff.

Figure 32: Surface Water Sampling Locations



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Sampling Methodologies

During 1993, surface water was sampled at the following locations identified in Figure 32:

- Three locations along the Great Miami River (W1 – upstream from the effluent discharge, W3, and W4);
- Five onsite locations along Paddys Run (W9, W10-US, W10, W10-DS, and W11);
- One location along the drainage ditch originating near the Pilot Plant (W10-DD); and
- Three offsite locations along Paddys Run (W5 – upstream from the site, W7, and W8).

Each week, the onsite laboratory analyzed one of the daily samples from each river sampling location for total uranium. Portions of the daily samples collected along the Great Miami River were combined to form weekly and monthly composites for each location, which were then analyzed for radium–226 and radium–228. Six-month composites, taken from the individual monthly composites, were analyzed for cesium–137, strontium–90, and technetium–99.

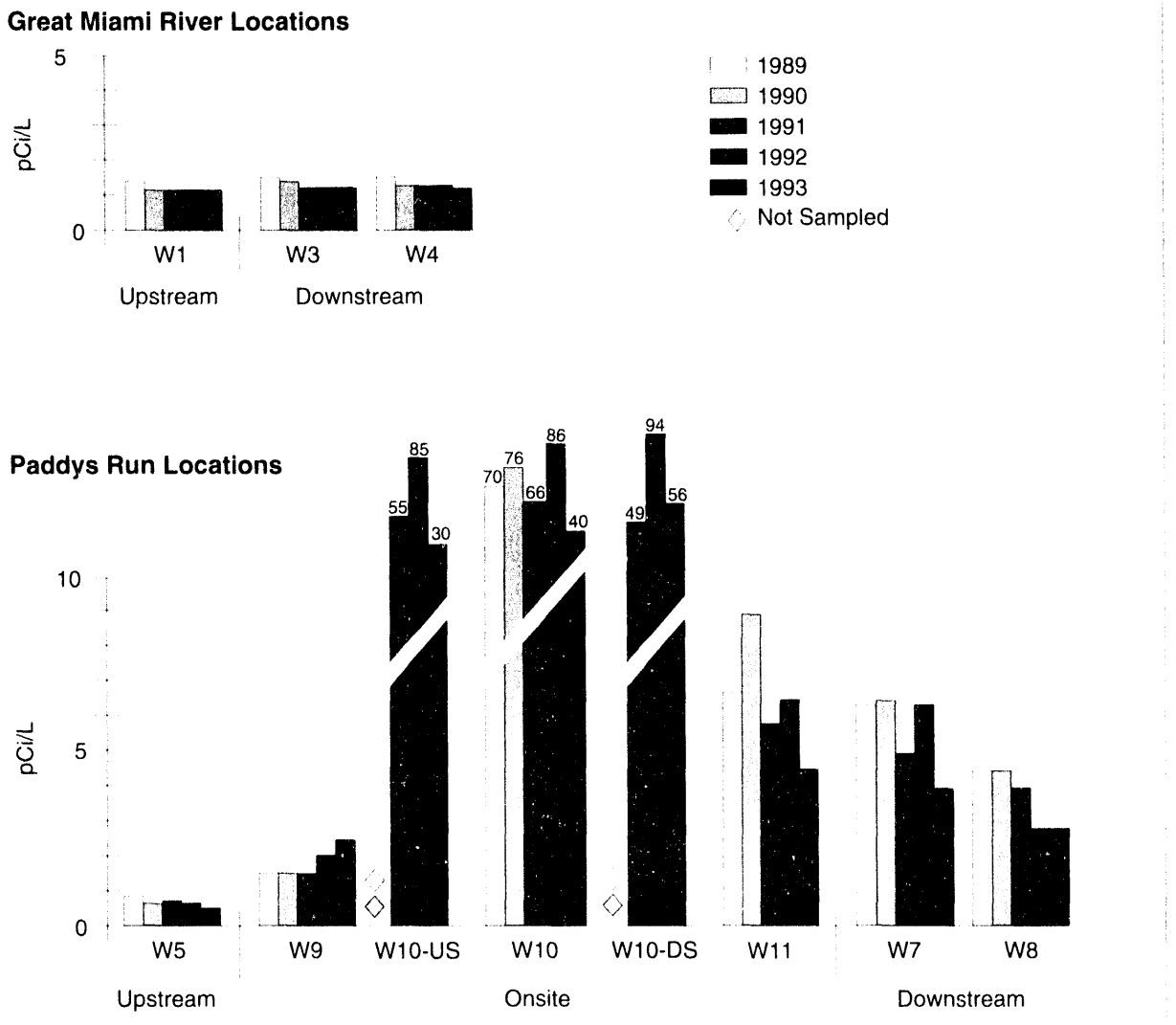
Weekly grab samples were collected at the five onsite locations along Paddys Run, one location along the drainage ditch, one location upstream (north) of the site, and two locations downstream (south) of the site. All samples collected along Paddys Run were analyzed weekly for total uranium. Two-month composites of weekly samples from W5 were analyzed for isotopic radium, as were monthly composites at W7 (or W8 if there was not enough water at W7). Oftentimes there is not enough water present in Paddys Run to collect a sample.

Uranium concentrations at W10 have varied greatly. This may be due to the fact that uranium concentrations in surface water are not directly comparable over time due to different states of dilution as a result of varying precipitation and flow rates. Consequently, representative samples cannot always be obtained because the effluent from the drainage ditch often does not have sufficient time to completely mix with the water in Paddys Run to provide a homogeneous liquid for sampling. In order to account for this problem, three sampling locations (W10-US – upstream of W10 and near the K-65 silos, W10-DD – along the drainage ditch, and W10-DS – just downstream of W10) were sampled.

Results of Laboratory Analyses

The radionuclide concentrations found in surface water samples collected during 1993 are summarized in Table 12 on pages A-16 and A-17. The data indicate that differences in uranium concentrations in the Great Miami River were very small. However, they are statistically significant. Average uranium concentrations at W3 and W4 (1.2 pCi/L) were well below the DOE guideline for drinking water (used for

Figure 33: Average Uranium Concentrations in Surface Water, 1989 - 1993



comparison purposes only). Both concentrations were at 0.22% of the DCG. Figure 33 shows five-year trends of uranium concentrations in surface water from the Great Miami River and Paddys Run.

Surface water samples collected in 1993 from the Great Miami River and analyzed for radium–226, radium–228, strontium–90, cesium–137, and technetium–99 were consistent with previous years. These data support the results in Table 11, demonstrating that the concentrations of these radionuclides in the liquid effluent discharged to the river were very low and resulted in very little, if any, increase in the concentrations already present in the river.

Environmental monitoring personnel used upstream sampling point W5 to determine concentrations of uranium and radium normally present in Paddys Run. The data indicate that the uranium concentrations found in this stream were significantly higher downstream (W7 and W8) of the site than they were upstream (W5). The average concentration at W5 was 0.67 pCi/L compared to 3.9 pCi/L at W7. However, average uranium concentrations at all Paddys Run monitoring locations were well within DOE guidelines for drinking water (again used for comparison purposes only), ranging from 0.44% of the DCG at W9 to 10% at W10-DS. W10-DD, leading into Paddys Run is 69% of the DCG.

High average values from W10-US, W10, and W10-DS are due to a few very high weekly results. The median value may better represent the actual conditions of the stream, rather than the average, because the median is not as easily changed by a few extreme results. The median values of these locations are 2.2 pCi/L at W10-US, 4.3 pCi/L at W10, and 13 pCi/L at W10-DS. The elevated levels in W10-DD, combined with the fact that the average uranium concentration at W10-DS and W-10 is higher than W10-US, suggest that the drainage ditch from which W10-DD is collected contributed to the uranium concentrations in Paddys Run (see Table 12 on pages A-16 and A-17). The increase in both the median and average concentration from W9 to W10-US, indicates that factors other than the drainage ditch may have also influenced the uranium concentration levels in Paddys Run.

Sediment Sampling for Radionuclides

Contaminants present in surface water can settle or precipitate and thereby accumulate in sediment. Sampling and analysis of sediments provide a way to evaluate possible cumulative effects of routine discharges of treated effluents into the Great Miami River and the effects of stormwater runoff into Paddys Run.

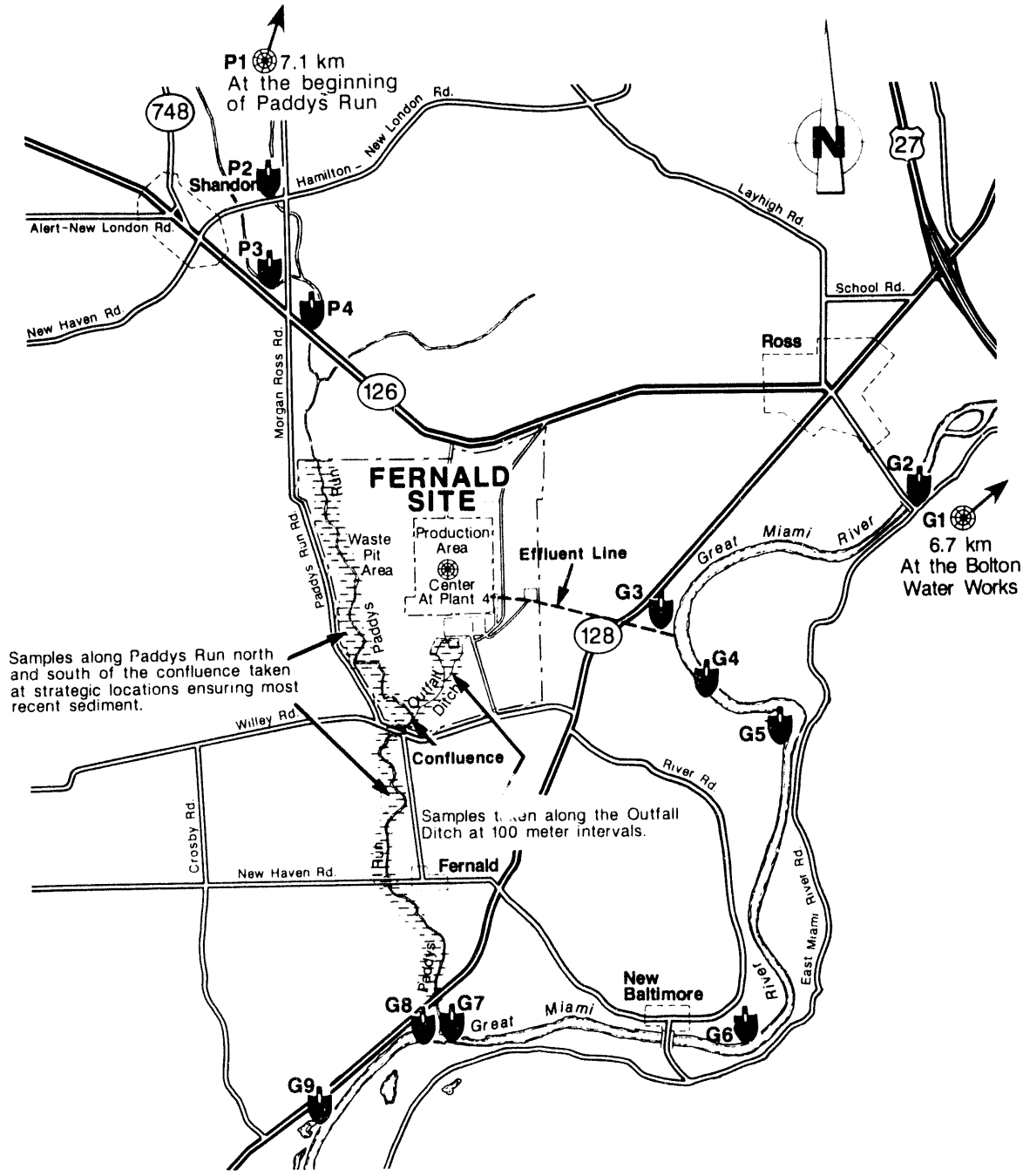
Sampling Methodologies

Technicians collected sediment samples only at those locations where sediment was most likely to accumulate. In early August, samples were collected from the following locations identified in Figure 34:

- Eight locations at 100-meter (33-foot) intervals along the Storm Sewer Outfall Ditch (SSOD);
- Nine locations along the Great Miami River;
- Twelve locations along Paddys Run north of the SSOD;
- Twelve locations along Paddys Run south of the SSOD; and
- Four background locations along Paddys Run, north of the site.

Technicians collected one sample at each location. All samples were taken from strategically chosen locations to ensure that they were representative of the most recent and greatest amount of sediment deposited.

Figure 34: Sediment Sampling Locations



LEGEND

- Single Sampling Location
- Distance from Center of Production Area to Sampling Locations off Map
- Plant Perimeter
- Production Area Perimeter

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In 1993, all sediment samples were analyzed for total uranium. Samples taken from the SSOD, Paddys Run above the SSOD, and Paddys Run background were also analyzed for radium–226 and isotopes of thorium. There are currently no DOE or USEPA guidelines or standards for uranium or other radionuclides in sediment.

Results of Laboratory Analyses

The data in Table 13 on page A-18 show there were no noticeable differences in the concentration of uranium and other radionuclides found in sediment samples collected from the Great Miami River upstream and downstream of the site's effluent discharge line. Therefore, the site's liquid effluent discharges did not cause any discernible increase in the levels of radionuclides in Great Miami River sediment.

Radium and thorium results for 1993 were consistent with those found in recent years. Total uranium results from Paddys Run locations in 1993 were also similar to those in 1992. However, the average uranium concentration in the outfall ditch (6.5 pCi/g) was still above background levels. Uranium concentrations in individual locations along this ditch have been elevated in previous years as well, probably because of runoff from onsite stormwater flowing into the outfall ditch over th years.

Fish Sampling for Uranium

The fish population of the Great Miami River is another component of the liquid pathway. Fernald site personnel, with the help of a research team from the University of Cincinnati, have been sampling fish in the river for ten years. The sampling team collects fish by electrofishing. This method is among the most efficient methods of collecting fish samples unbiased with respect to size and species.

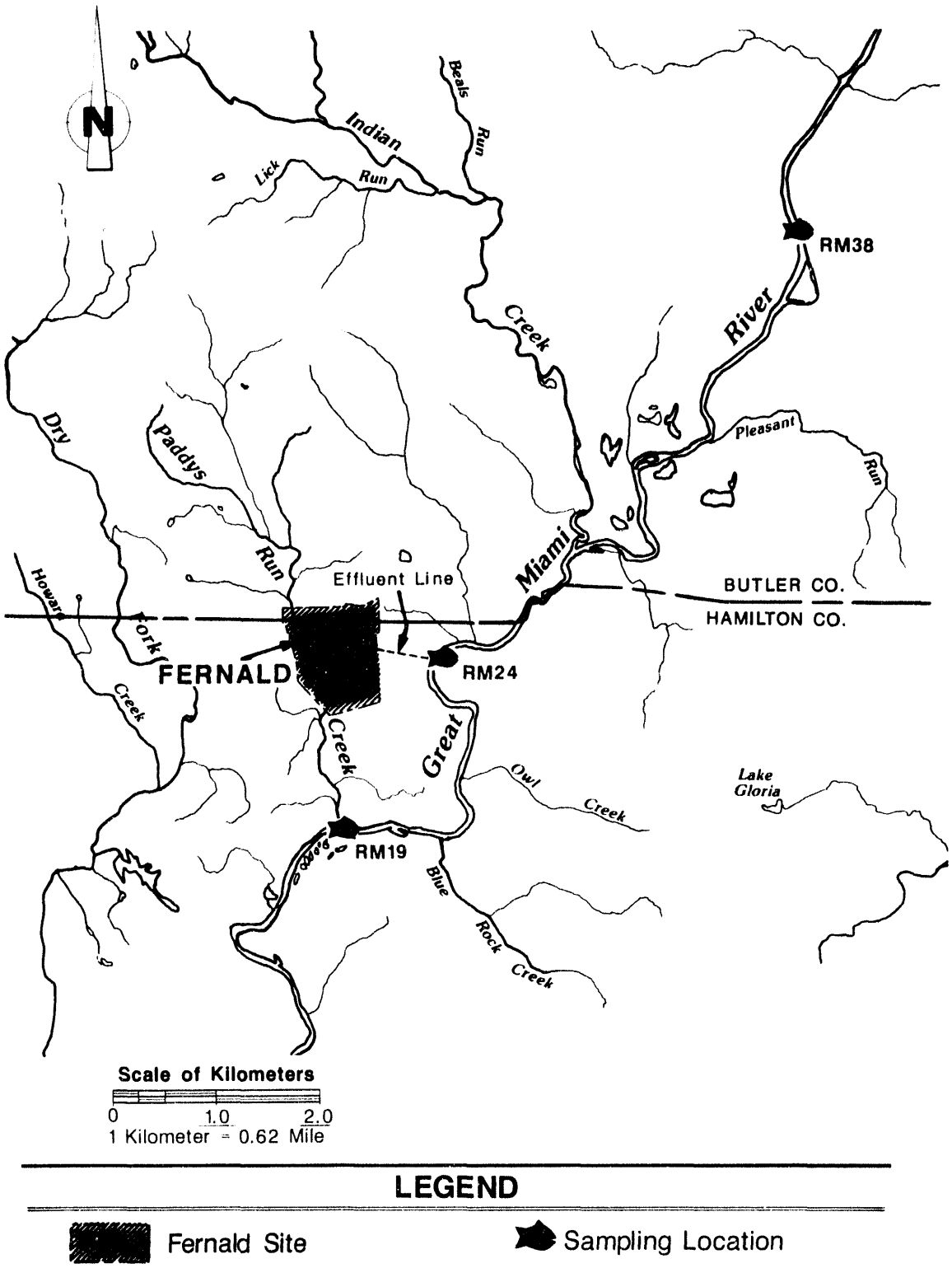
Sampling Methodologies

In August 1993, the team collected over 224 fish representing 26 species from three sites along the Great Miami River (see Figure 35):

- River Mile (RM) 38 – below the Route 127 bridge, north of Hamilton;
- RM 24 – at the Fernald site effluent discharge; and
- RM 19 – at the outfall point of Paddys Run.

The 1993 collection was made at the same time of year as in 1992. RM 38 is used as a background location because the fish population is physically isolated from downstream activity and migration of fish by the two Hamilton dams, whereas the other locations are not. Location RM 24 and RM 19 have the potential to be influenced by the backwater species that migrate up from the Ohio River. The variety of fish species collected included gizzard shad, skipjack herring, mooneye, golden redhorse, shorthead redhorse, spotfin shiner, largemouth bass, striped bass, smallmouth bass, white bass, immature bass, river carpsucker, highfin carpsucker, quillback carpsucker, drum, bluegill, hybrid longear and bluegill, longear sunfish, green sunfish, immature sunfish, sauger, carp, mirror carp, channel catfish, flathead catfish, and brown bullhead.

Figure 35: Fish Sampling Locations



The fish population of the Great Miami River has been stable over the course of this study. In 1993, diversity of fish caught was nearly the same at all locations. The fish species richness at each site was proportional to the number of fish caught. The fish species appear to be in similar health regardless of sampling location.[28]

Results of Laboratory Analyses

Table 14 on page A-19 contains the average uranium concentrations reported in fish from all three sampling locations. Since all uranium concentrations in fish were not normally distributed, the geometric mean was provided rather than the arithmetic mean (average) in order to make meaningful comparisons between locations and/or families. Statistical comparisons were made to determine:

- If the uranium concentrations of all fish in general caught at RM 38 (background location) were different from the fish caught at RM 24 and RM 19 taken collectively,
- If the uranium concentrations of all fish caught in any one site were greater than the fish caught from the other two locations taken individually, and,
- If any one family of fish had higher uranium concentrations when sampled at one location as opposed to the other two locations.

It was statistically proven with $p \leq 0.05$ that:

- No single location had statistically greater uranium concentrations than the other two locations taken collectively;
- In general, all fish caught at RM 24 had statistically higher concentrations then those caught at RM 38 and RM 19 taken individually; and
- Families one and two were found at no locations with statistically higher concentrations than the other two locations, families three and five displayed statistically higher concentrations at RM 24 then at RM 19 (family five was not found at RM 38), and family four showed statistically higher concentrations at RM 19 then at RM 38 (RM 24 provided only one fish from family four).[29]

Overall, the 1993 total uranium results are consistent with or lower than results from recent years at all locations. The estimated dose from eating fish caught in the Great Miami River at the Fernald site outfall is discussed in Chapter Seven.

Monitoring for Nonradioactive Pollutants

This section of the chapter looks at concentrations of nonradioactive pollutants discharged through the site's liquid effluent, to the Great Miami River, and to Paddys Run. The site controls the discharge of nonradioactive pollutants in liquid effluent to meet the requirements of the site's National Pollutant Discharge Elimination System (NPDES) permit.

NPDES Summary for 1993

The NPDES permitting process for the site is under the jurisdiction of the State of Ohio to control the discharge of nonradioactive pollutants to Ohio waters. The permit specifies sampling locations, sampling and reporting schedules, discharge limits, and other restrictions on the site's effluents discharged to the Great Miami River and Paddys Run. Table 15 on pages A-20 through A-22 contains the NPDES compliance data for 1993 with a diagram of all monitoring locations in Figure 28. Fernald site personnel did not collect NPDES samples from Paddys Run since the SWRB did not overflow during 1993. Out of 4,020 NPDES samples taken in 1993, only 11 were not in compliance (99.7% compliance). Effective May 20, 1993, modifications to the NPDES permit were made including:

- pH monitoring was reduced to daily grab samples at internal monitoring locations;
- Sampling of sewage sludge was added;
- Fluoride, copper, nickel, and total chromium sampling were reduced to monthly monitoring at the sewage treatment plant;
- Cyanide, silver, and lead at Manhole-175 were eliminated;
- Chromium (+6) and pH at discharge 602 were eliminated; and
- All monitoring at discharges 604 and 606 (shown in Figure 28 on page 83) was eliminated.

By controlling the concentration of radionuclides in the effluent and by reducing the amount of stormwater runoff to Paddys Run, the site can lessen its impact on the various components of the liquid pathway. In particular, surface water runoff can enter the aquifer and influence groundwater quality. The next chapter looks at the groundwater component of the liquid pathway.

6

Liquid Pathway: Groundwater Monitoring

6

Liquid Pathway: Groundwater Monitoring

This chapter continues the discussion of the liquid pathway, as surface water runoff can leach through the soil and may contaminate the groundwater. The site carefully monitors the groundwater beneath and in the vicinity of the site to identify and track the movement of pollutants which may be present in the Great Miami Aquifer. Scientists can analyze the groundwater and soils sampled during drilling operations to learn much about the soil and its ability to restrict the movement of contaminants into the groundwater. This enables the site to better define the steps it should take to control present contamination and to prevent additional contamination from occurring.

Results in Brief: 1993 Liquid Pathway: Groundwater

Private Well Sampling – A total of 36 private wells were routinely sampled for total uranium in 1993. Three of these wells had an average uranium concentration above the proposed USEPA standard of 13.5 pCi/L (20 ppb). Each of these wells is in an area of known groundwater contamination. These 36 wells were also sampled for several metals. As is common for an area with high natural concentrations of iron and manganese, such as the area surrounding the Fernald site, several private wells showed concentrations of these two metals above the USEPA Secondary Drinking Water Standards. Additionally, four wells showed concentrations of lead at or above the USEPA action level guideline.

Comprehensive Sampling – Of the 454 on- and offsite site-owned wells that were sampled for uranium, 127 wells showed detections above the proposed USEPA guideline of 13.5 pCi/L (20 ppb). All offsite locations were in the South Plume area. The Comprehensive Groundwater Monitoring Program also samples for 11 metals and 31 Volatile Organic Compounds which have applicable Primary Drinking Water Standards. Of these 42 constituents, 16 were detected above the primary standards in more than one well. Four other constituents showed single detections above their primary standards.

History of Groundwater Monitoring at the Site

Several groundwater monitoring programs have evolved throughout the history of the site. The original three production wells drilled during the construction of the Feed Materials Production Center in 1951 were the first to be monitored. From 1959 to 1965, the site installed eleven monitoring wells in the waste pit area to see if pit operations were affecting the groundwater. These waste pit and production area wells constituted the original ***Environmental Monitoring Groundwater Program***.

In late 1981, the State of Ohio sampled three wells south of the site and found elevated levels of beta activity. It was found that this activity was due to potassium–40, a naturally occurring radionuclide which was not present in site production materials. However, sampling also detected above-background concentrations of uranium in other wells near the site. This information was reported to the State in November 1981.

These findings prompted an expansion of groundwater monitoring in the area. Environmental Monitoring began sampling existing area wells in February 1982, and by 1984, the Fernald site officially established the ***Radiological Environmental Monitoring (Private Well) Program*** with the monthly sampling of 19 privately owned wells.

Around this same time, the site focused more attention on onsite groundwater contamination. The disposal of barium chloride in Waste Pit 4 from 1980 to 1983 led to the establishment of the ***RCRA Detection and Groundwater Quality Assessment Programs***, separate from the existing environmental monitoring activities. Federal and state environmental regulations required the Fernald site to determine whether or not hazardous waste had entered the groundwater, and, if so, to identify the rate and extent of migration and the concentration of any hazardous waste in the groundwater. When the RCRA Detection Program confirmed that the groundwater had been impacted, the RCRA Groundwater Quality Assessment Program began in May 1988 and has since provided valuable information on the quality of groundwater beneath the waste pit area. (Analytical results of this sampling and assessment can be found in the *RCRA Annual Report for 1993*.[30])

Also in May 1988, additional groundwater sampling was initiated as part of the ***Remedial Investigation and Feasibility Study (RI/FS)***. This CERCLA-driven study investigates the nature and extent of potential environmental impacts from past and current operations at the site, with particular regard to the Great Miami Aquifer.

By late 1989, more than 200 wells were being sampled under the various programs. To eliminate duplication of efforts, all long-term groundwater monitoring responsibilities were shifted to the Environmental Monitoring group. In 1990, this group developed the ***Comprehensive Groundwater Monitoring Program*** to coordinate the sampling schedules of the original Environmental Monitoring Groundwater

Program, and the RCRA Assessment Program. In December 1992, the administration of the Comprehensive Groundwater Monitoring Program was transitioned to OU5. This change was implemented to consolidate all groundwater monitoring and data interpretation under one group.

Today, as this Comprehensive Groundwater Monitoring Program monitors site-owned wells in accordance with the applicable regulations, the private well sampling program continues under Radiological Environmental Monitoring as a service to local residents and as an additional source of offsite groundwater information. Results are presented in this chapter as either private well results or as comprehensive sampling results.

Monitoring for Radioactive Pollutants

As part of the total liquid pathway, the movement of radioactive pollutants into and through the groundwater is of significant concern. This section discusses the results of private well sampling and of the Fernald site's comprehensive sampling program.

Private Well Sampling for Uranium

The Radiological Environmental Monitoring Program encompasses all sampling of privately owned wells. The program itself is divided into non-routine sampling and routine sampling.

At a property owner's request, any drinking water well near the site will be sampled for uranium to gain additional information about local groundwater quality, and the one-time sample results are reported to the well owner. If one of these "special request" samples shows a questionable or significant total uranium concentration, or if the well is believed to be representative of an area based on its location, the property owner has the option to participate in the routine sampling program. This program has grown from 19 wells in 1984 to 36 wells in 1993. Well locations are shown in Figure 36. The data from the routine sampling program are presented in Table 16 on page A-23. Figure 37 shows average uranium concentrations found in private wells from 1989 to 1993.

During 1993, the 36 offsite wells belonging to individuals and industries in the vicinity of the site were sampled monthly or quarterly and analyzed for total uranium. Average uranium concentrations in all but five wells were less than 2 pCi/L (3 ppb) and, therefore, less than 15% of the proposed USEPA standard. Only wells 12, 13, and 15 exceeded this proposed standard in 1993. These concentrations can also be compared to national background levels for total uranium in groundwater of 0.07 to 6.8 pCi/L (0.1 to 10 ppb) or local background levels of 0.07 to 2.0 pCi/L (0.1 to 3.0 ppb), which scientists have determined using a 95% confidence interval.[31,32]

Figure 36: Private Well Monitoring Locations

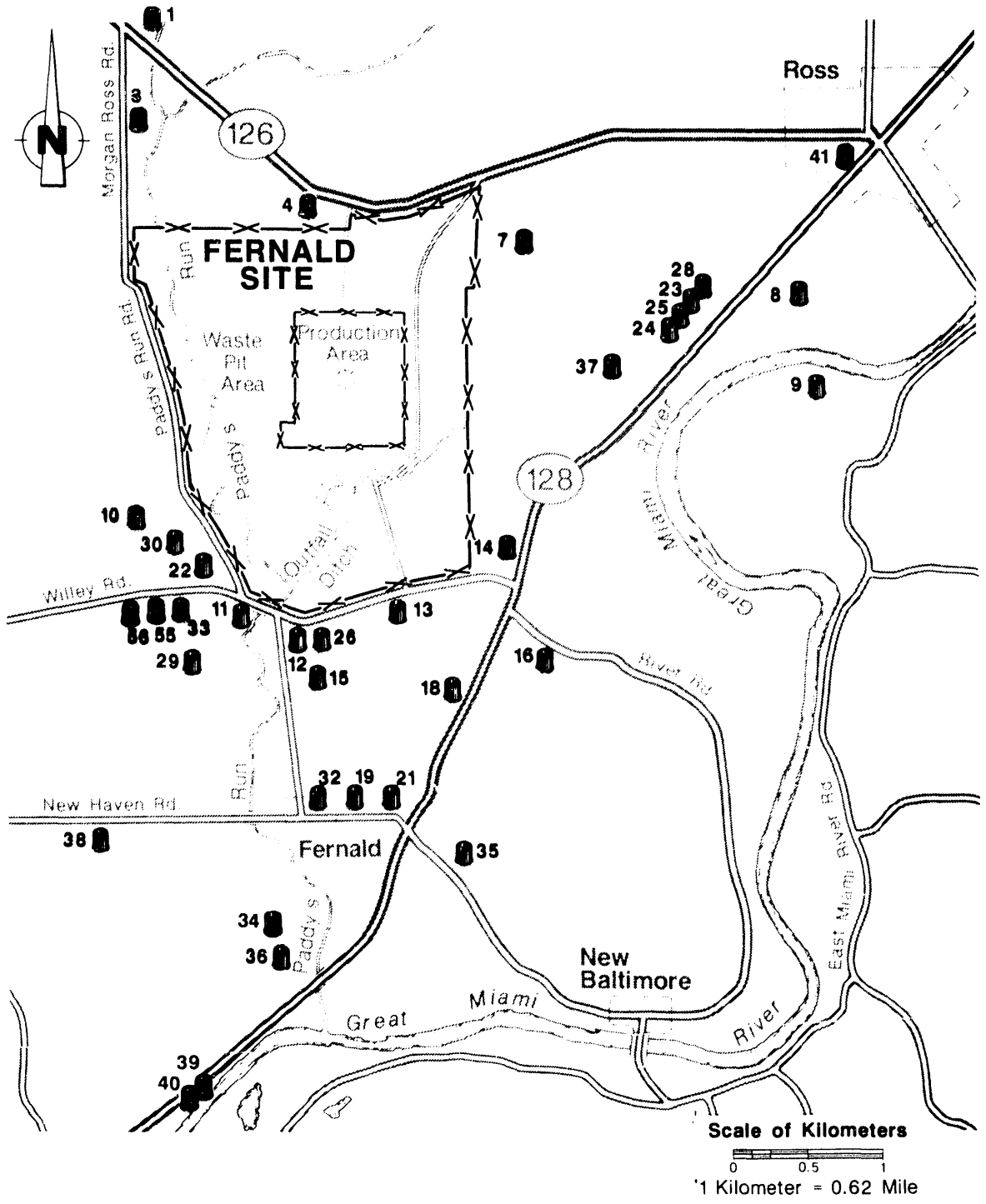


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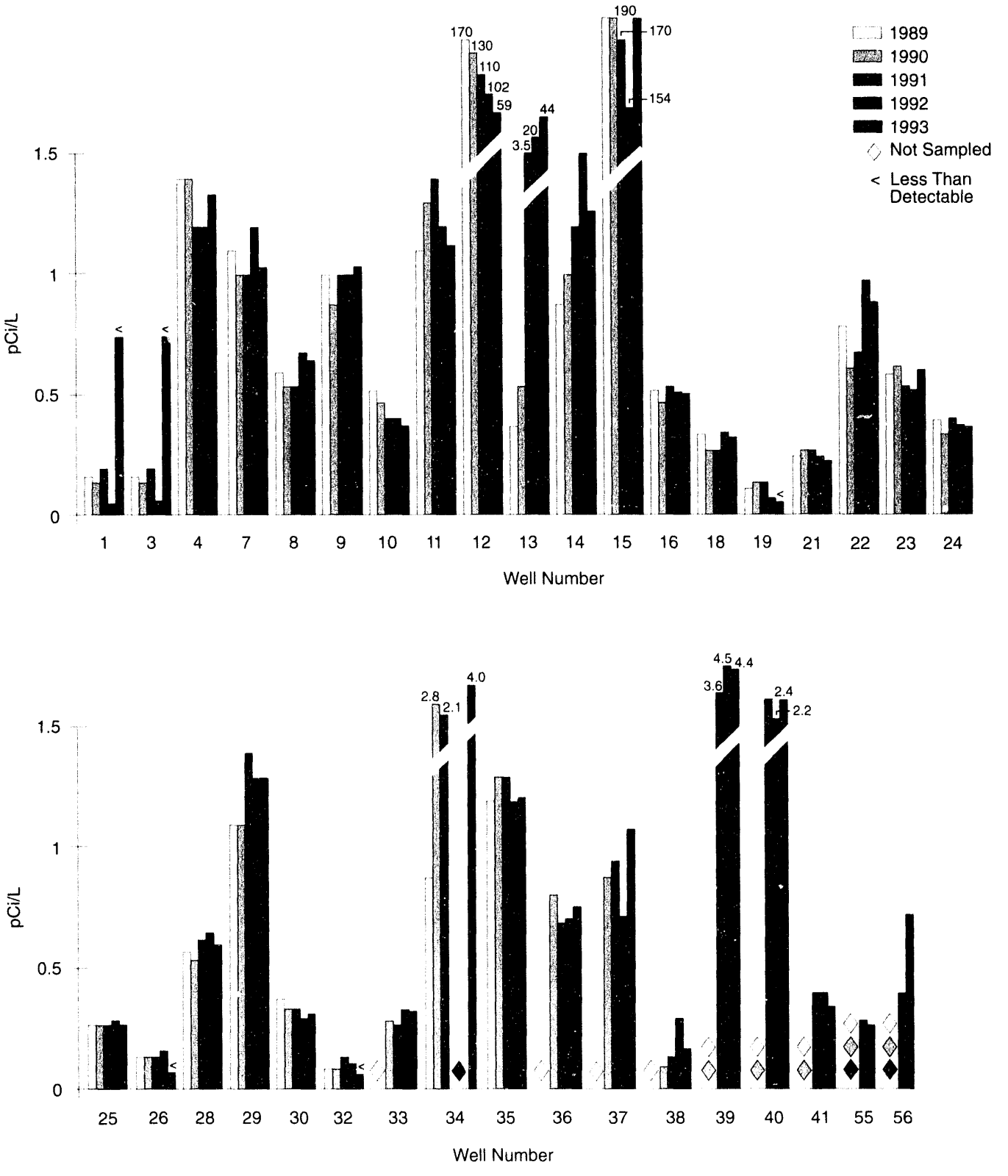
Figure 37: Average Uranium Concentrations in Private Wells, 1989 – 1993



Proposed USEPA Standard for Uranium in Drinking Water

In addition to comparing results against background levels for substances in the environment, environmental monitoring results are often compared to standards or guidelines. These standards set concentration limits for specific substances in a medium. Standards and guidelines are always set lower than the lowest concentration known to cause illness or injury to humans or the environment.

USEPA is responsible for setting standards for substances in drinking water throughout the United States; National Primary Drinking Water Standards are enforceable by federal law. However, in the absence of a USEPA standard for a particular substance, guidelines are set by other agencies such as DOE and the Nuclear Regulatory Commission; these guidelines, however, are only applicable to DOE- or NRC-governed sites.

Through 1990, the only reference for uranium in drinking water was a DOE guideline of 20 pCi/L or 30 parts per billion (ppb). Past site reports have used this reference for comparison. However, in 1991, USEPA proposed a standard for uranium in drinking water of 13.5 pCi/L or 20 ppb. As of December 1993, this standard had not yet been approved. This 1993 report will continue to use this proposed USEPA standard for comparison with well monitoring results, as it is the more stringent of the two.

The uranium concentration at Well 13 has been slowly increasing since 1989. In June 1992, an ion exchange system was installed at this location. This system is designed to remove the uranium from the well water by filtering the water. Results from the water filtered through the ion exchange system indicate that the uranium is removed and the uranium concentration in the treated water is within the background range for this area. Well 13 is located just south of the site, in an area of known groundwater contamination, and continues to be a point of monitoring.

The uranium-contaminated water in this area, known as the South Plume, will be pumped from the aquifer as part of the South Groundwater Contamination Plume Removal Action. The plume itself is discussed later in this chapter.

Comprehensive Sampling for Uranium

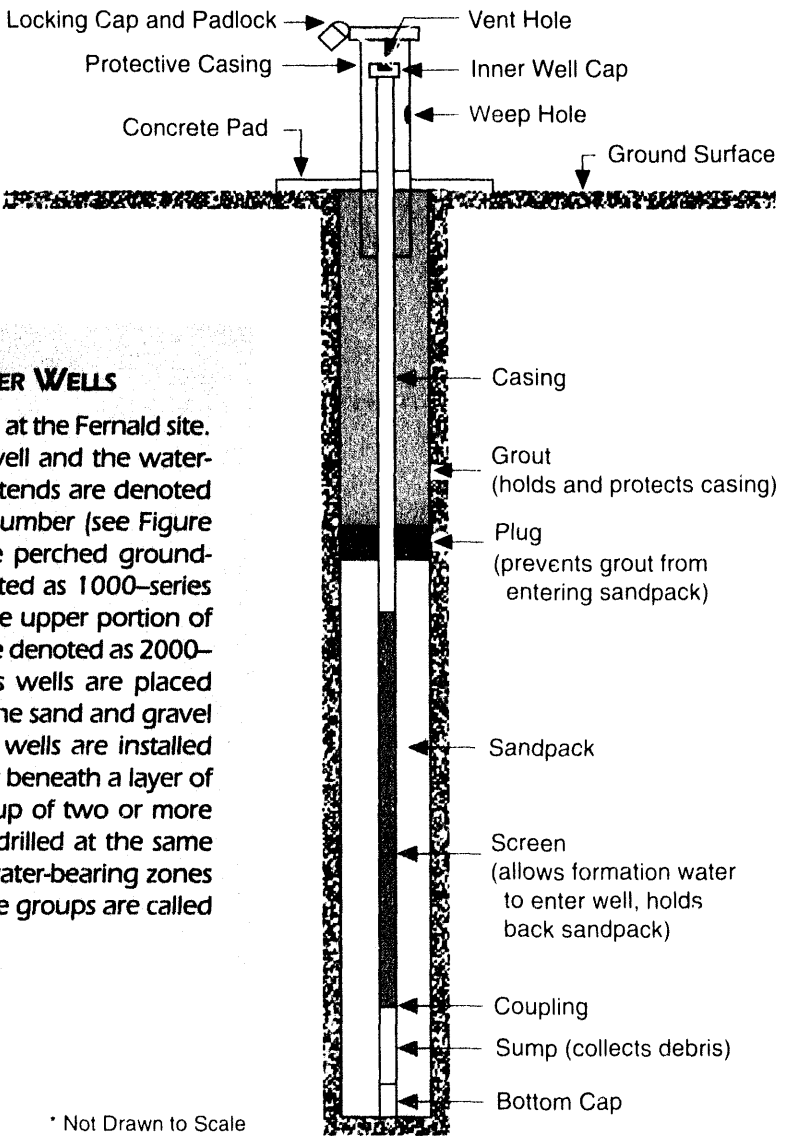
The Comprehensive Groundwater Monitoring Program encompasses all sampling of site-owned monitoring wells. Groundwater monitoring personnel do not monitor all wells each quarter, nor do they monitor all wells for the same constituents. As discussed earlier, site personnel sample as necessary to provide each of the groundwater monitoring subprograms with a complete database for reporting purposes. However, when taken together, as done here, the comprehensive sampling results present a rather detailed and complete description of groundwater under and around the site.

The movement of uranium in the groundwater has been a key factor in determining the sources of contamination in the area. In 1993, the Groundwater Monitoring Program received results from 2,003 analyses for total uranium from samples at 454 on- and offsite locations. As compared to previous years' monitoring activities, there were several more detections of total uranium found in 1993. This greater number of detections is due to an increase in monitoring activities that were required in 1993 for the final OU5 Remedial Investigation, and it is not an indication of greater contamination in the area.

Of these 2,003 uranium analyses, the highest concentration was 91,120 pCi/L (136,000 ppb), well above the proposed USEPA standard of 13.5 pCi/L (20 ppb). This sample was drawn from Well 1324 in the glacial overburden directly beneath the production area. Most above-guideline detections at the other sampled wells were below 6,757 pCi/L (10,000 ppb). More than 240 uranium concentrations above the proposed USEPA drinking water guideline were found at 126 other on- and offsite locations. (All offsite locations were in the South Plume area, currently being addressed by a RI/FS removal action.) All of the above-guideline sample concentrations and their relative locations are listed in Table 17 on pages A-24 through A-27.

Figure 38: Well Diagram*

This diagram depicts the construction of a typical well used for sampling groundwater. These wells are located both on and off the Fernald site. They range from 11 – 76 meters (35 – 250 feet) deep.

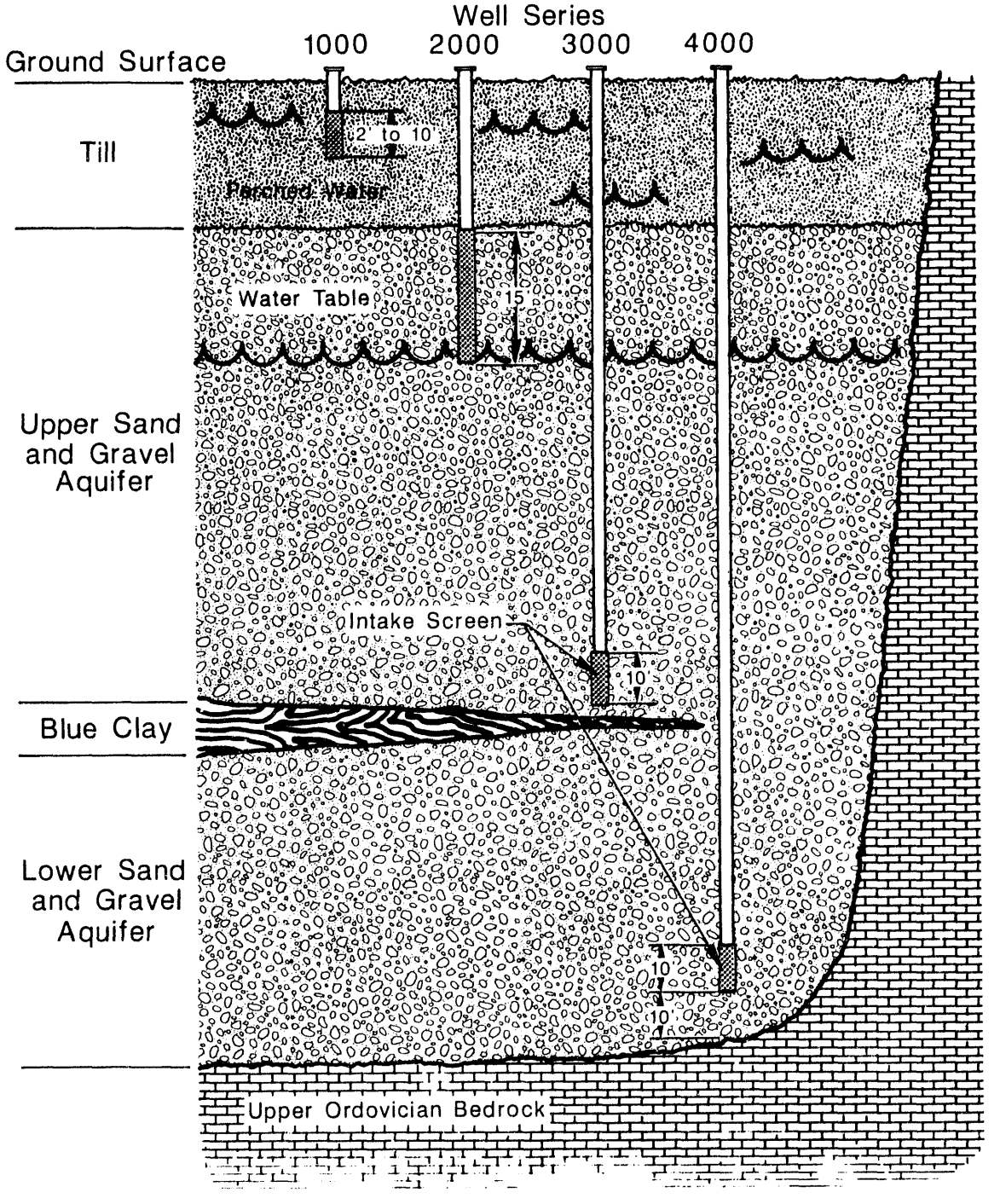


* Not Drawn to Scale

Fernald Site Groundwater Wells

Figure 38 depicts a typical well at the Fernald site. The depth of a Fernald site well and the water-bearing zone into which it extends are denoted by the first digit of the well number (see Figure 39). Wells extending into the perched groundwater within the till are denoted as 1000–series wells. Wells extending into the upper portion of the sand and gravel aquifer are denoted as 2000–series wells. The 3000–series wells are placed within the middle portion of the sand and gravel aquifer, and the 4000–series wells are installed in the sand and gravel aquifer beneath a layer of "blue clay." Sometimes a group of two or more wells of different depths are drilled at the same location to sample different water-bearing zones within the groundwater; these groups are called cluster wells.

Figure 39: Monitoring Well Depths and Screen Locations



Metric Conversion
1 Foot = 0.3048 Meters

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Comprehensive Groundwater Monitoring for Other Radionuclides

The Comprehensive Groundwater Monitoring Program also samples for radium–226, radium–228, strontium–90, technetium–99, and thorium–232. Gross alpha activity, gross beta activity, cesium, plutonium, ruthenium, and neptunium in the groundwater are also monitored as indicators of radionuclide contamination. Results from 1991 and 1992 monitoring for these radionuclides have been invalidated and cannot be reported with any assurance of data quality.

The Comprehensive Groundwater Monitoring Program sampled for these radionuclides again in 1993. These data are not available at this time, but they will be included in the Operable Unit 5 Remedial Investigation report and in the 1994 Site Environmental Report.

South Groundwater Contamination Plume

Groundwater monitoring results over the past several years have led to the identification of the South Groundwater Contamination Plume, an area immediately south of the site with known levels of uranium contamination. Contamination from the site flows with the groundwater, generally to the east and south, toward the Great Miami River.

Because groundwater in the Fernald area travels very slowly as compared to surface water, some areas may not see the effects of the contamination for years. Also, since the contamination moves in about the same direction as the groundwater, environmental monitoring personnel can track the movement of this plume by monitoring the movement of the groundwater. Figure 40 shows the South Groundwater Contamination Plume as it appeared at the end of 1993.

The South Groundwater Contamination Plume Removal Action was initiated to restrict further southward movement of the plume, to limit access and exposure to contaminated groundwater, and to protect the groundwater environment.

Public Water Supply Program

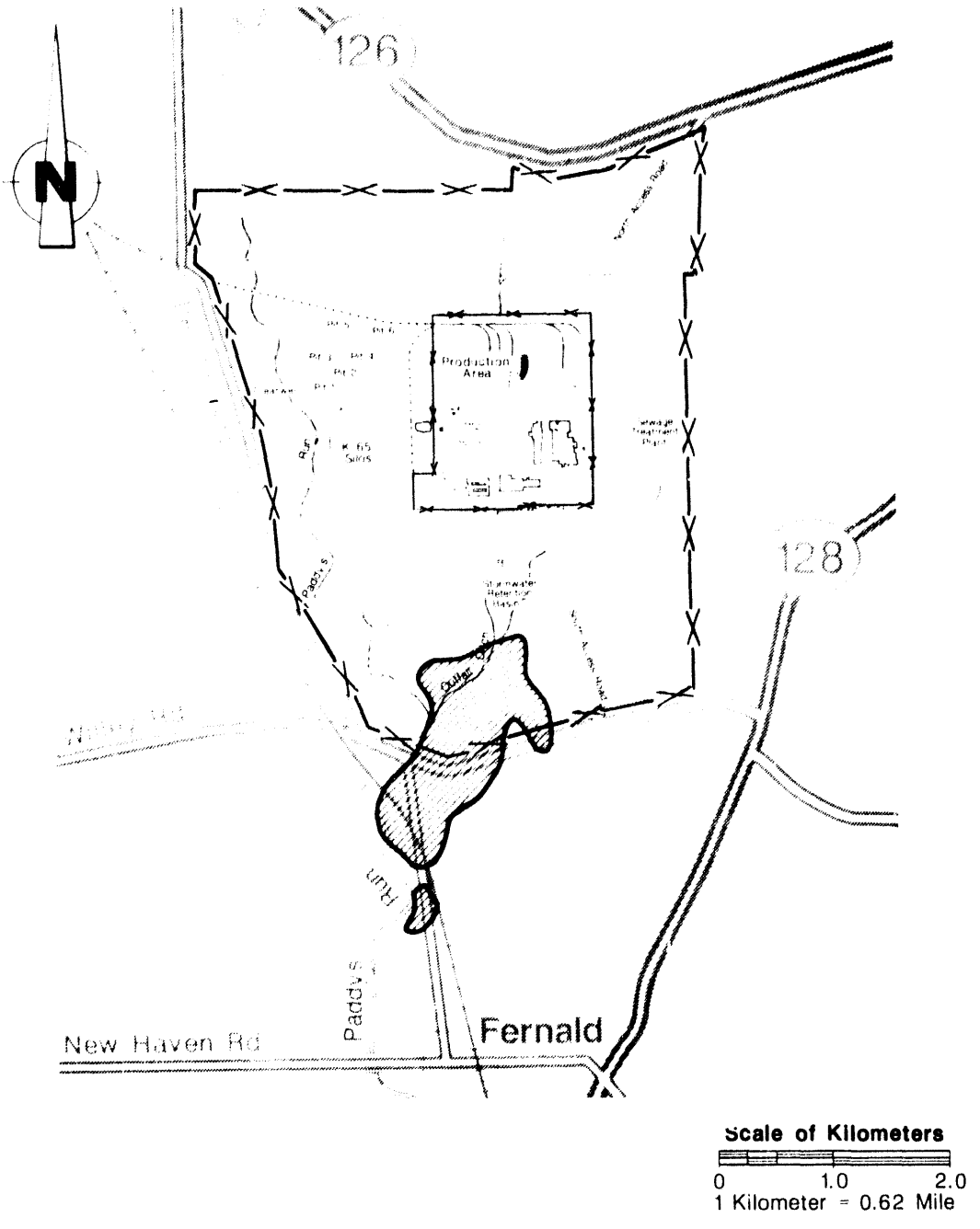
DOE has supplied bottled water to homeowners whose private wells have been impacted by the South Plume. This action is, however, considered only a temporary solution. The preferred alternative is to eliminate individual homeowner wells that withdraw water from the aquifer and to provide these residents with water from a public water supply.

The primary objective of this program is to protect public health by providing this permanent, reliable, and safe water supply to local residents. DOE has committed to providing its fair share of the cost for installation of the water mains in the South Plume area. This funding is in conjunction with the Hamilton County Department of Public Works, the agency responsible for coordinating all water supply within Hamilton County.

The portion of this proposed action that is of concern to DOE involves the installation of approximately 23 km (14 miles) of pipeline within Hamilton and Butler counties. This installation will occur along East Miami River Road from Bolton Water Works to the intersection of state routes 126 and 128, then south along State Route 128 to approximately 2.7 km (1.7 miles) south of the New Haven Road intersection. Installation will also occur along Willey, New Haven, and Paddys Run roads.

The Public Water Supply Program was proposed in 1992. The overall schedule is contingent on the construction schedule of Hamilton County, but the tentative completion date of the public water supply is set for mid-1995.

Figure 40: South Groundwater Contamination Plume



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Monitoring for Nonradioactive Pollutants

Protection of the Great Miami Aquifer also includes monitoring for a number of nonradioactive pollutants and general water quality indicators. Site technicians generally sample for those constituents listed in the National Primary and Secondary Drinking Water Standards. Primary standards apply to those substances that pose definite health threats if present beyond the regulated concentrations; secondary standards control contaminants that primarily affect the aesthetic qualities of drinking water and are not federally enforceable.[33] In addition to these USEPA-listed constituents, the RCRA wells within the Comprehensive Groundwater Monitoring Program are sampled for many RCRA-listed constituents.

Private Well Sampling for Metals

The 1993 samples from the private wells were analyzed for the 16 metals listed in Table 18 on pages A-28 through A-30. Of these 16 metals, no DOE or USEPA standards have been established for calcium, magnesium, nickel, potassium, or sodium, but they continue to be monitored for comparison purposes. Although concentrations of iron and manganese were higher than the secondary drinking water guidelines in a number of wells, high concentrations of those natural elements are typical for groundwater in this area.[5, 12, 33] As specified by USEPA, lead has an action level of 0.015 mg/L. Four wells showed lead concentrations above this level. All other metal concentrations were well within the appropriate guidelines.

Comprehensive Sampling for Hazardous Substances

Various groundwater sampling programs monitor for nonradioactive constituents in the groundwater to identify areas that might have harmful chemical concentrations as a result of past and present site activities. All site wells sampled are analyzed for metals, volatile organic compounds (VOCs), and water quality indicators listed in the National Primary and Secondary Drinking Water Standards. This section focuses on the incidences in which these constituents occur above the applicable standards. Those wells with detections above the primary standards and the proposed USEPA guideline for uranium are mapped in figures 41 through 44.

Detections above Primary Standards

The site analyzes for 11 metals and 31 VOCs which have applicable Primary Drinking Water Standards. Of those 42 metals and VOCs, the constituents that had detections above their respective Primary Drinking Water Standard Maximum Contaminant Levels (MCL) are listed on the next page and in Table 19 on pages A-31 through A-36.

Metals

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cyanide
- Mercury
- Nickel
- Selenium
- Thallium

Volatile Organic Compounds

- Benzene
- Carbon tetrachloride
- 1,2-Dichloroethane
- 1,2-Dichloropropane
- Ethylbenzene
- Toluene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- Vinyl chloride

Toluene, 1,1,2-trichloroethane, 1,2-dichloropropane, and ethylbenzene, had only one detection each above their respective standards. The remaining sixteen constituents had more than one detection above their standards in 1993. These detections and the areas in which they were found are discussed below.

Antimony was detected above the 0.006 mg/L MCL in 17 wells during 1993. These wells were located primarily in the production area and the waste pit area. Five detections were south or southwest of the Stormwater Retention Basin, one in the northwest corner of the site, and one in the South Plume. There was also one detection offsite, just northwest of the site property. These detections above the MCL ranged from 0.0061 to 0.135 mg/L.

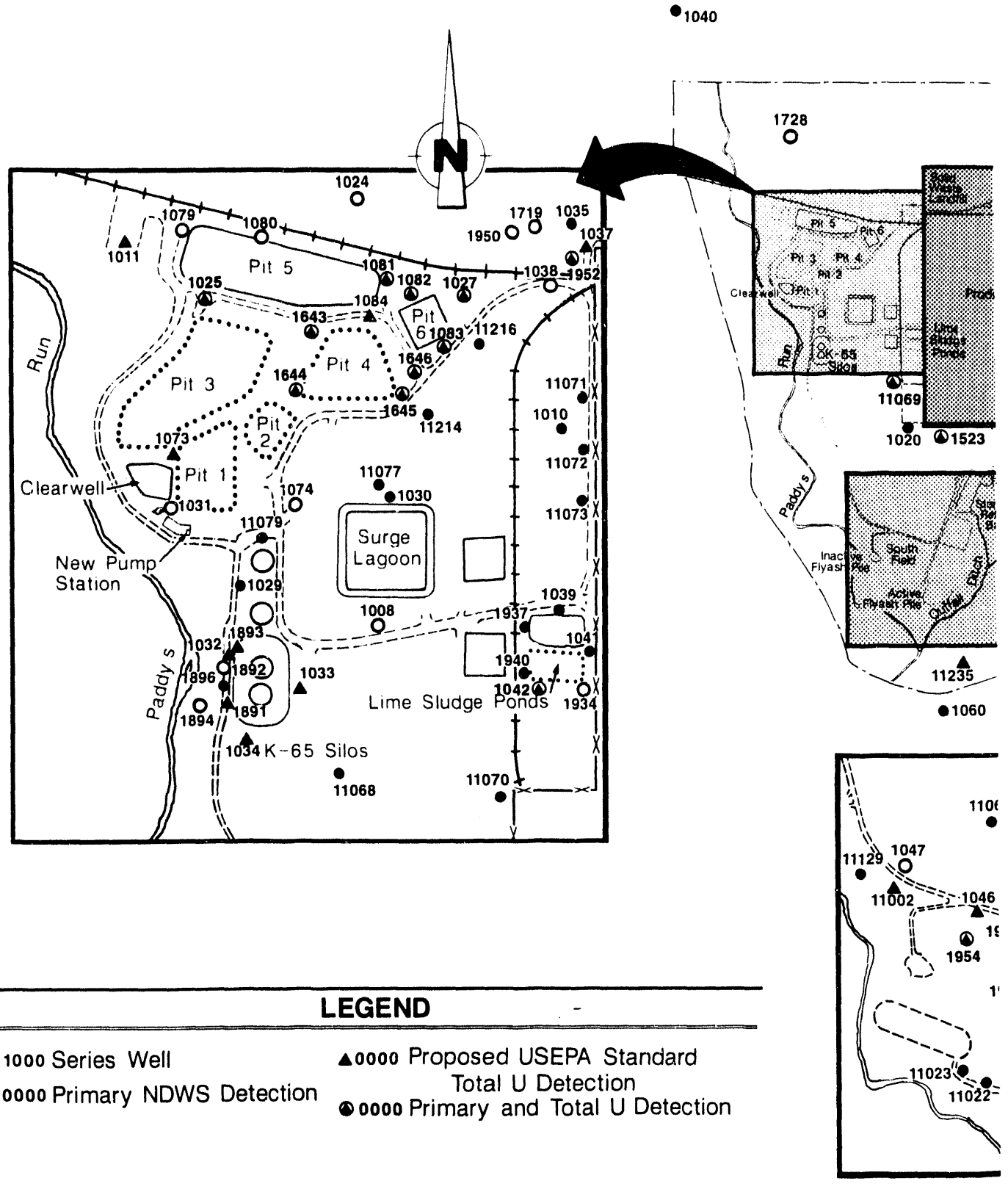
Arsenic was detected above the 0.050 mg/L MCL at seven wells. Three detections were in the waste pit area, six were in the northwest section of the site, two were near Paddys Run just south of the silos, and two were in the Paddys Run Road Site area. These detections above the MCL ranged from 0.0711 to 0.313 mg/L.

Barium has a MCL of 2.00 mg/L. It was detected at two wells, and the detections were 2.26 and 3.35 mg/L. One well was located in the production area, and one was just north of the production area.

Fourteen wells had detections of beryllium above the MCL of 0.004 mg/L. These detections ranged from 0.004 to 0.131 mg/L. Most of these wells are in the production and waste pit areas. Other detections were found south of the silo area, southwest of the Stormwater Retention Basin, and one each in both the northwest and northeast sections of the site.

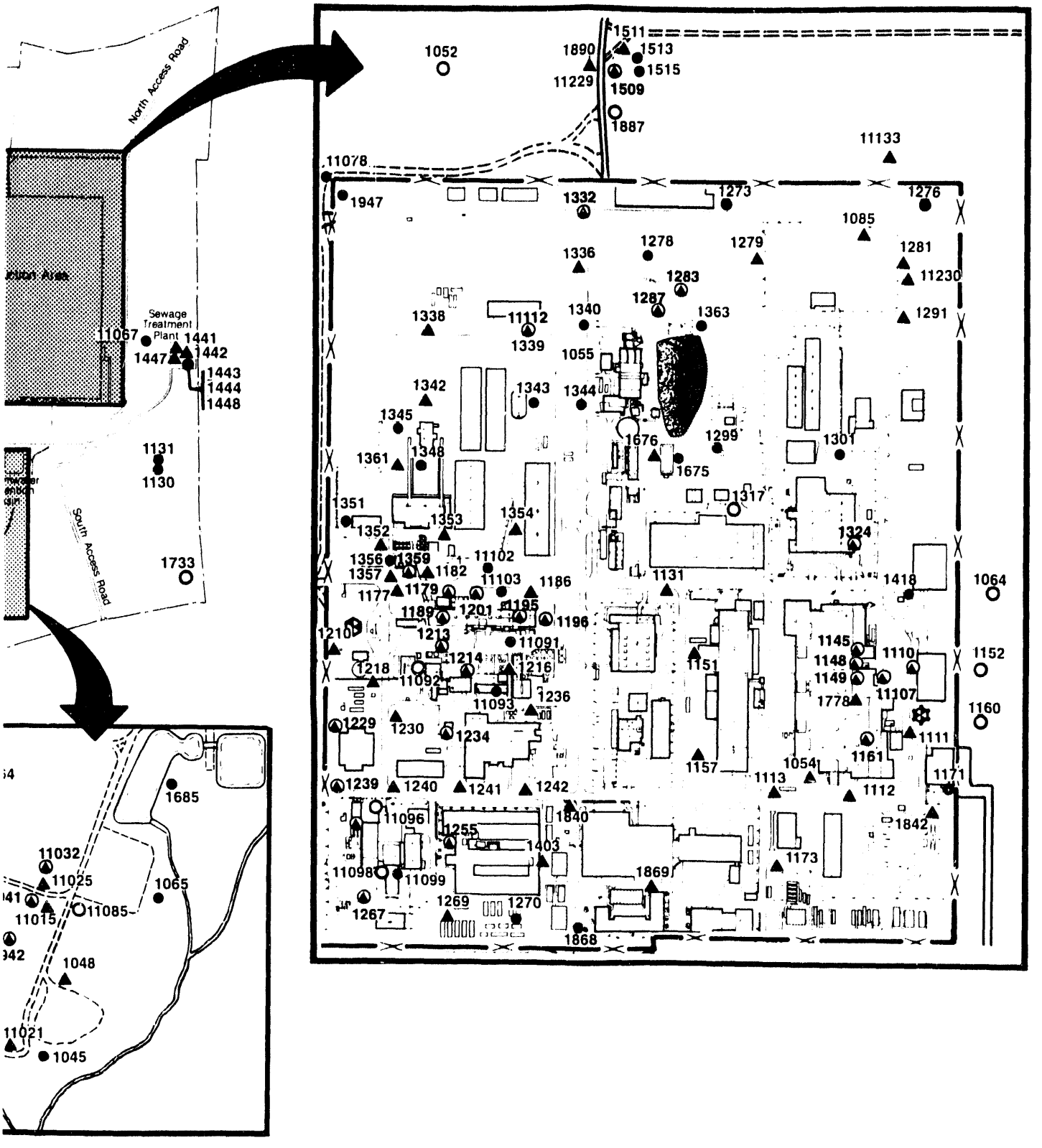
text continues on page 113

Figure 41: 1000-Series Wells



LEGEND

- ● 1000 Series Well
- ○ 0000 Primary NDWS Detection
- ▲ 0000 Proposed USEPA Standard Total U Detection
- ◮ 0000 Primary and Total U Detection


North Access Road
Sewage Treatment Plant
South Access Road
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1685
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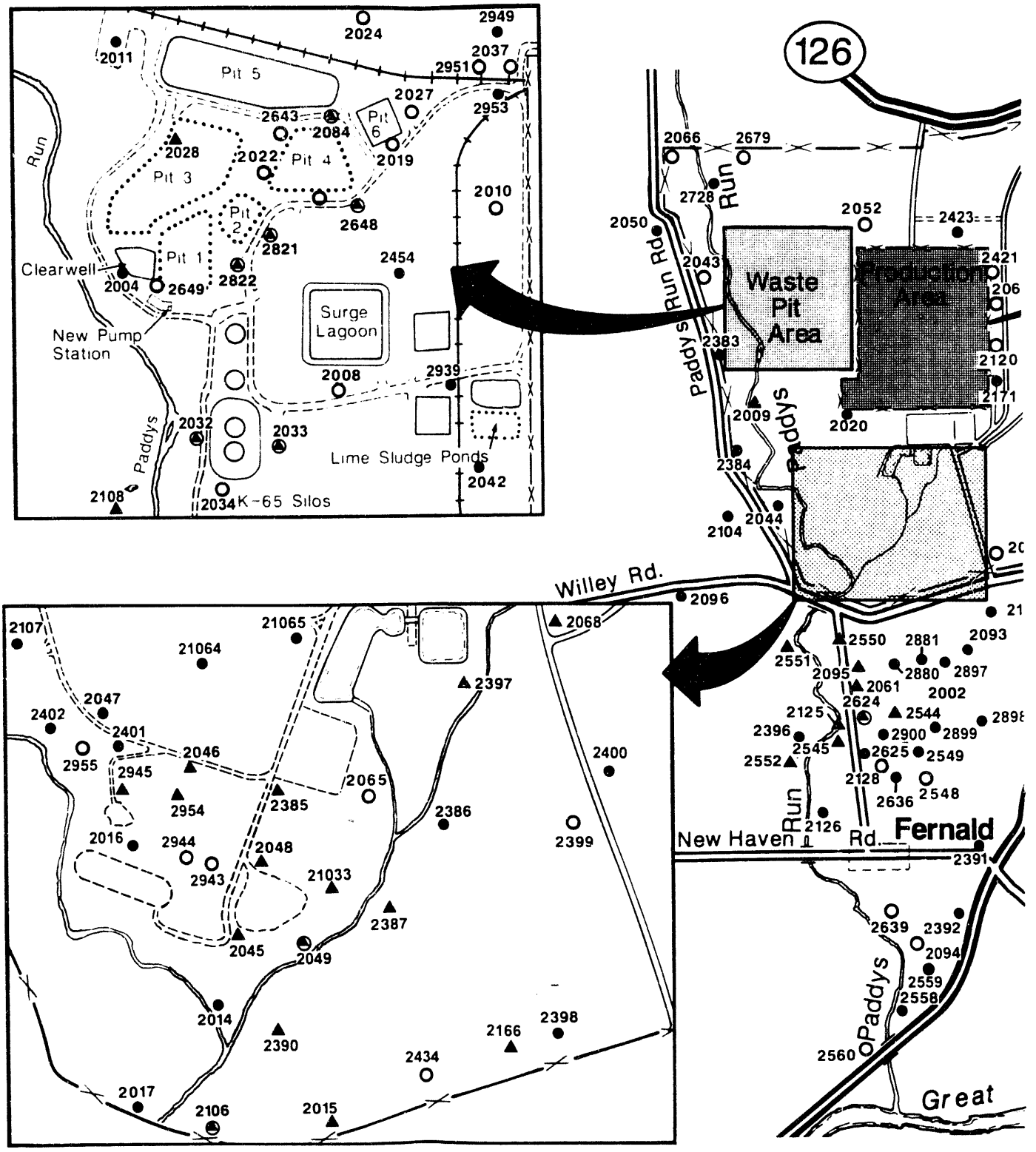
Figure 42: 2000-Series Wells



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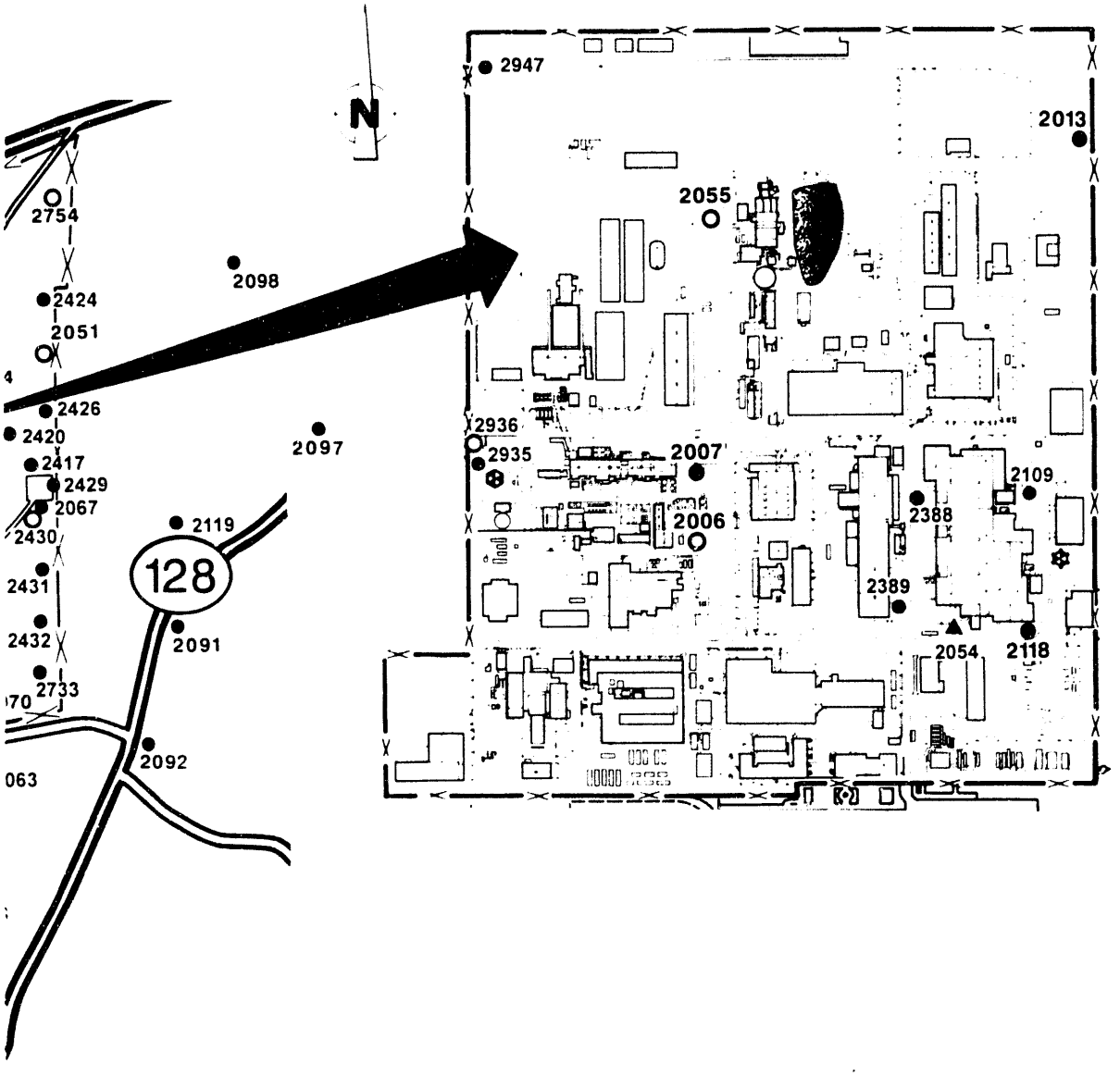
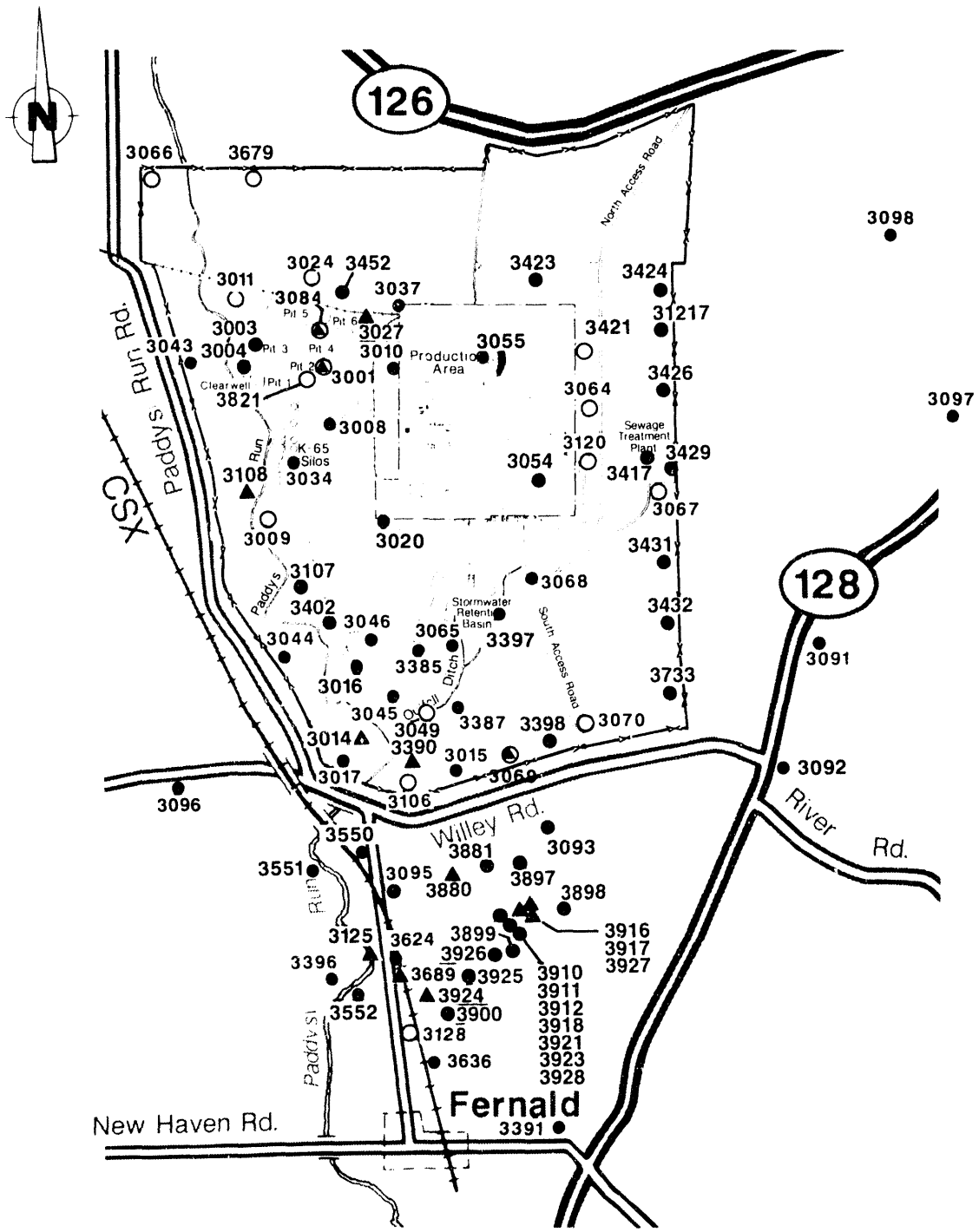


LEGEND

- ● 2000 Series Well
- ○ 0000 Primary NDWS Detection
- ▲ 0000 Proposed USEPA Standard Total U Detection
- ◔ 0000 Primary and Total U Detection

Figure 43: 3000–Series Wells

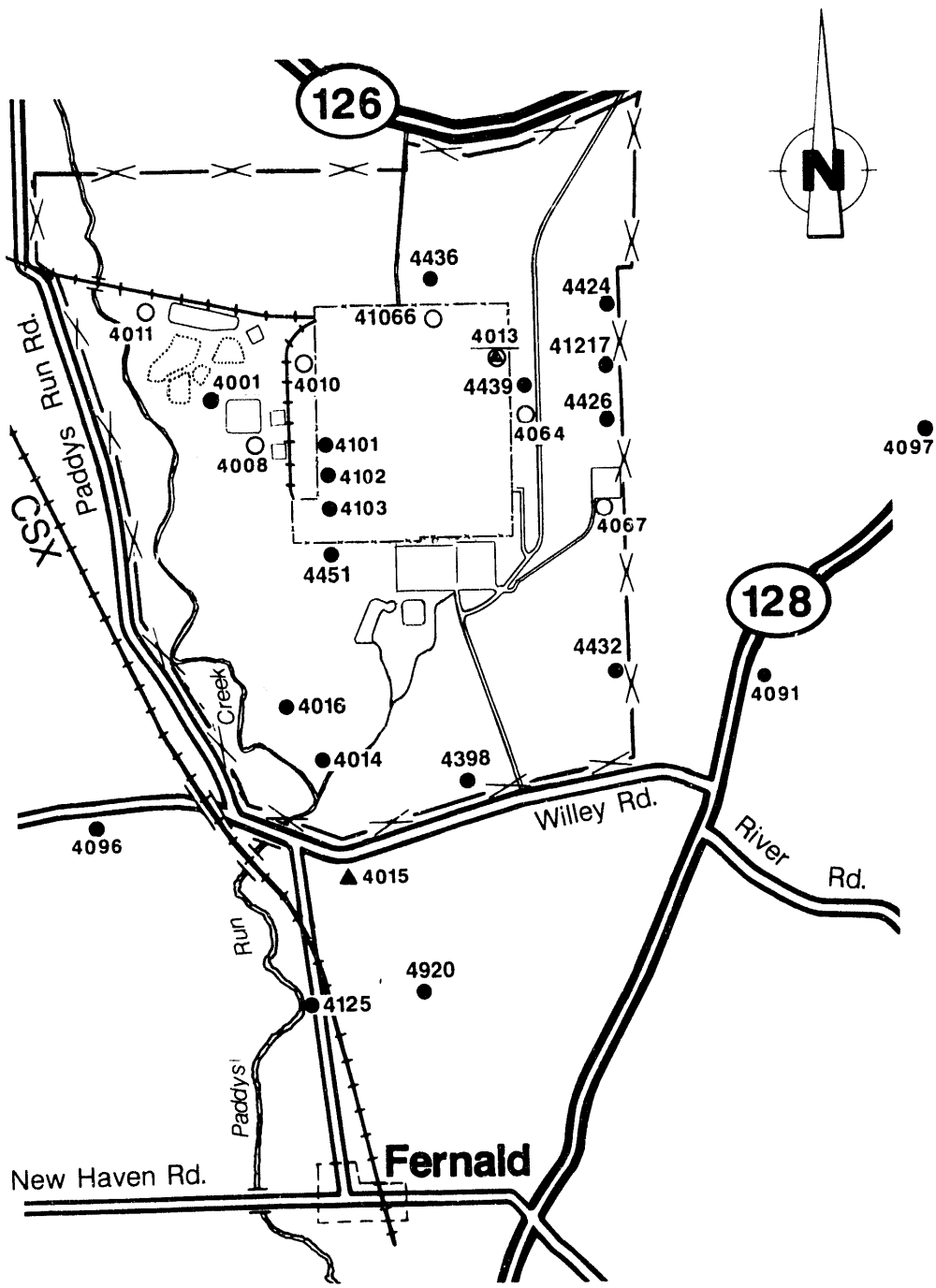


LEGEND

- ● 3000 Series Well
- ○ 0000 Primary NDWS Detection
- ▲ 0000 Proposed USEPA Standard Total U Detection
- ◔ 0000 Primary and Total U Detection

2584

Figure 44: 4000–Series Wells



LEGEND

● 4000 Series Well

○ 0000 Primary NDWS Detection

▲ 0000 Proposed USEPA Standard Total U Detection

◔ 0000 Primary and Total U Detection

2584

Cadmium had detections at 35 wells above the MCL of 0.005 mg/L. These detections fell in the range of 0.005 to 0.165 mg/L. Primarily these detections were in the production area with a few in the waste pit and silo areas. Several detections also showed at wells northeast, east, and southeast of the production area, and south of the Stormwater Retention Basin. Three detections were shown in the northeast corner of the site.

Twenty-five wells showed detections of chromium above the MCL of 0.100 mg/L. The detections ranged from 0.105 to 7.710 mg/L, and were mainly in or near the production area. In addition, there were detections in the South Plume, southwest of the Stormwater Retention Basin, near the silos, and one in the northwest section of the site.

Cyanide had detections at one well of 0.354 and 0.360 mg/L. These detections were at a well near Paddys Run, south of the silos. The MCL for cyanide is 0.200 mg/L.

Two detections of mercury were found above the MCL of 0.002 mg/L. These came from a single well and were 0.0077 and 0.0139 mg/L. This well was near Paddys Run, south of the silo area.

Nickel has a MCL of 1.00 mg/L. It was detected at 29 wells, and the detections ranged from 1.01 to 3.930 mg/L. Most of these were located in the production area and waste pit area. However, detections were also shown southwest of the stormwater retention basins, north and northeast of the production area, in the South Plume, at a location near State Route 128, and at a location in the northwest section of the site.

Two wells showed detections of selenium above the MCL of 0.050 mg/L. These detections were in the range of 0.0563 to 0.214 mg/L. The wells were located northeast of the production area and south of the silos near Paddys Run.

There were also detections of thallium that exceeded the MCL of 0.002 mg/L. They ranged from 0.002 to 0.094 mg/L and came from a total of four wells. The locations of these wells included the waste pit area and the area near the silos.

Benzene was detected at two wells above the MCL of 0.005 mg/L. These detections were 0.005 and 0.011 mg/L, and were from a well in the production area and a well south of New Haven Road.

Two detections of carbon tetrachloride were 0.005 and 0.021 mg/L, both of which exceed the MCL of 0.005 mg/L. These detections were in the production area.

Four wells showed detections of 1,2-dichloroethane to exceed the MCL of 0.005 mg/L. These detections ranged from 0.011 to 0.072 mg/L, and came from wells located in the production area and near the Fire Training Facility.

The MCL for 1,1,1-trichloroethane is 0.200 mg/L. This was exceeded by detections at four wells in a range of 0.200 to 5.900 mg/L. These detections came from the production area and a well from the Fire Training Facility area.

Finally, vinyl chloride, a volatile organic compound used in a variety of processes involving solvents, paints, and gasoline, was found in two wells with detections above the standard of 0.002 mg/L.[34] These detections were 0.031 and 0.120 mg/L. The wells are located in the production area.

Detections above Secondary Standards

Several constituents were detected above their secondary standards in 1993. However, it should be noted that many of these secondary constituents are naturally occurring, and their presence does not pose a threat to human health or to the environment except at considerably higher concentrations.[35]

Iron and manganese are two particularly noteworthy examples of such naturally occurring elements. Both are commonly found at high levels in southwest Ohio. Iron was detected above its secondary standard at 525 on- and offsite wells, and manganese was detected above its standard at 622 wells.

One detection of copper at 1.030 mg/L exceeded the standard of 1.000 mg/L. This detection was from the Fire Training Facility.

Fifty-one wells had detections of lead in the range of 0.015 to 0.262 mg/L, all of which exceeded its standard of 0.015 mg/L. These detections were primarily from the production and waste pit areas. Detections were also found south and southwest of the Stormwater Retention Basin, in the South Plume, just east of the production area, near the sewage treatment plant, at the northeast corner of the site, in the northwest section of the site, at the south access road, and just northwest of the site boundary.

RCRA Groundwater Monitoring at the Fernald Site

The disposal of barium chloride in Waste Pit 4 from 1980 to 1983 necessitated groundwater monitoring under RCRA at the Fernald site. In response, a Detection Monitoring Program was initiated at Waste Pit 4 in August 1985. The program included monitoring of 41 wells upgradient and downgradient of Waste Pit 4 for general water quality, drinking water suitability, and indicator parameters.

Based on the statistical comparisons that were completed as part of the Detection Monitoring Program, USEPA and OEPA were notified in November 1987 that Waste Pit 4 may be affecting groundwater quality in the vicinity of the pit. At that time, the RCRA Detection Monitoring Program was changed to the RCRA Assessment Monitoring Program, and the RCRA Groundwater Quality Assessment Program Plan (GQAPP) was submitted to USEPA and OEPA. Beginning in March 1988, wells were sampled quarterly for one year. In March 1989, the GQAPP was revised on the basis of a detailed evaluation of the available water quality and flow information. Forty-three wells were identified for quarterly monitoring of 35 site-specific analytical parameters. Another revision of the GQAPP was submitted in

April 1991 to include findings from previous RCRA sampling, address regulatory comments, and provide more detailed sampling procedures. This revision also expanded the program by adding 11 more wells.

The RCRA Assessment Monitoring Program at the Fernald site was altered in 1991 when the RCRA Part A Permit Application identified 51 Hazardous Waste Management Units, including nine land-based HWMUs requiring groundwater monitoring. Before June 1991, Waste Pit 4 was the only identified regulated unit requiring groundwater monitoring. The RCRA Groundwater Monitoring Plan was submitted to the EPAs in December 1991, replacing the GQAPP. The Groundwater Monitoring Plan was designed to monitor groundwater downgradient of the nine land-based units. Three monitoring well networks were defined to provide adequate monitoring of the Waste Pit Area, the Production Area, and the site's property boundary.

By mid-1993, the property boundary network was near completion and well installation on the Production Area network was proceeding. At that time, it was determined that it would be both impractical and impossible to meet RCRA requirements under the current monitoring program. Specifically, difficulties were encountered while trying to comply with RCRA requirements, causing a duplication of efforts in CERCLA and RCRA activities at the site.

In an effort to integrate CERCLA and RCRA monitoring activities under a single program, DOE proposed an Alternate Monitoring Program. This program is comprised of two components:

- Groundwater characterization activities under CERCLA as defined by the OU5 RI/FS Work Plan and Addenda, and
- Quarterly groundwater monitoring of the downgradient property boundary under the Routine Monitoring Program as defined in the "Project Specific Plan for the Routine Groundwater Monitoring Program Along the Downgradient Boundary of the FEMP."

The Project Specific Plan was submitted in July 1993 and defined the objectives of the Routine Monitoring Program. This program is comprised of 33 monitoring wells at the property boundary, including the monitoring wells installed for the downgradient facility boundary monitoring network defined in the RCRA Groundwater Monitoring Plan. In September 1993, after negotiations with DOE, OEPA issued the Director's Findings and Orders, which provided guidance on the Alternate Monitoring Program, identified elements to be included in the 1993 RCRA Annual Groundwater Report, and identified elements to be revised in the Project Specific Plan for the Routine Monitoring Program. A revision of the Plan was submitted to OEPA in October 1993.

Both the air and liquid pathways allow radioactive and non-radioactive materials to leave the Fernald site and are, therefore, monitored. The results from these monitoring activities are used to estimate potential radiation dose, which is discussed next in Chapter Seven.

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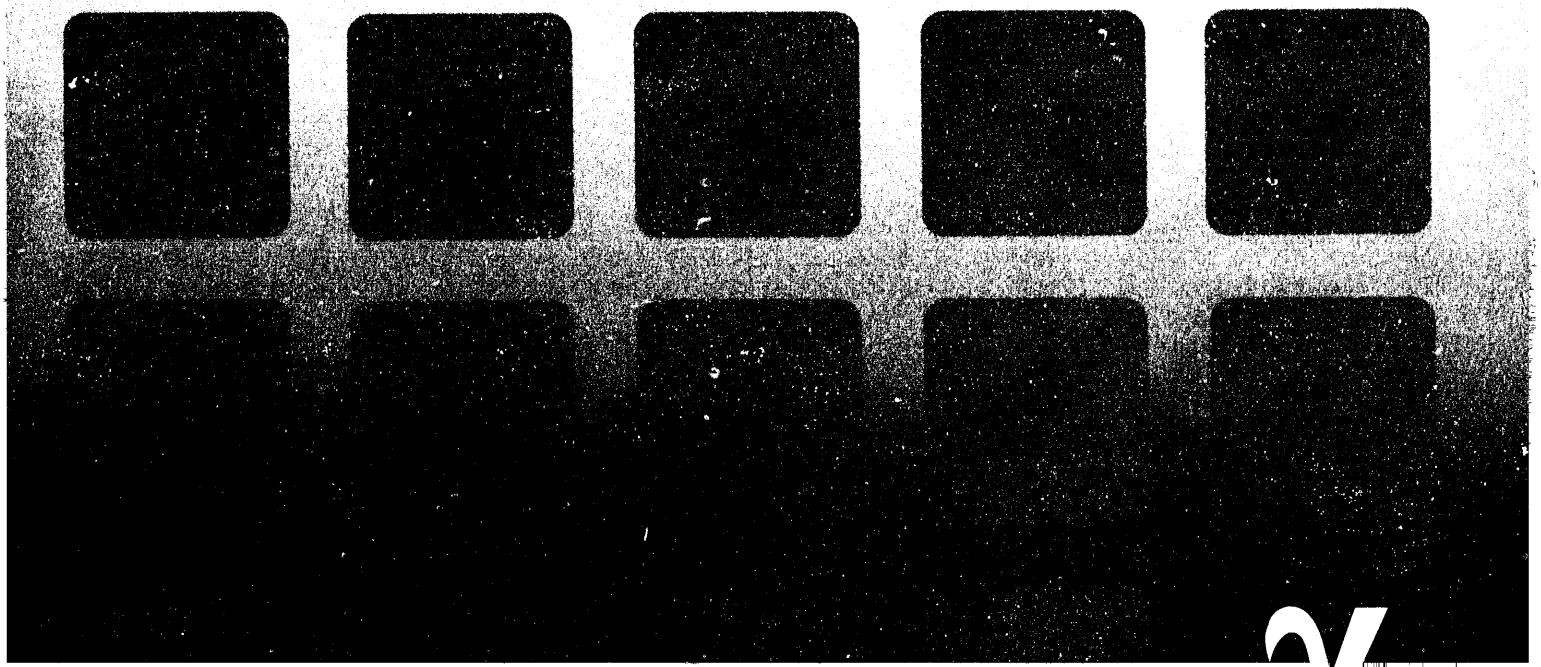
Estimated Radiation Doses for 1993



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Estimated Radiation Doses for 1993

One of the chief public concerns about any facility that handles radioactive materials is that people working and living in the area may be exposed to harmful amounts of radiation. In response to this concern and environmental regulations, Fernald site personnel are monitoring the ways in which radioactive material could move through the environment and reach people. Background radiation levels and naturally occurring radioactive materials present technical as well as practical problems in trying to directly measure the dose people may actually receive from the Fernald site; therefore, scientists estimate dose using models and the results of environmental samples. This chapter provides the following information:

- An explanation of how dose estimates are calculated,
- Dose estimates from several different pathways for 1993, and
- An interpretation of the significance of these estimated doses.

Results in Brief: 1993 Estimated Doses*

Air Pathway

Airborne Emissions – The estimated maximum committed effective dose to a member of the public from 1993 airborne emissions was calculated as 0.016 mrem.

Foodstuffs – The committed effective dose from eating foodstuffs produced within three miles of the site was estimated to be 0.01 mrem.

Direct Radiation – There was no statistical difference between direct radiation measurements at the site fenceline and measurements at background locations. Therefore, no dose was attributed to direct radiation for 1993.

Liquid Pathway

Well Water – The estimated committed effective dose from drinking well water from the area around the Fernald site was 0.7 mrem.

Fish – The estimated committed effective dose from eating fish from the river near the Fernald site effluent line was 0.01 mrem.

* These doses for 1993 are also presented in Table 20 on page A-37. Information on doses received from other sources is also provided in that table.

Methodology for Calculating Total Radiation Dose

DOE Orders and USEPA regulations require the Fernald site to demonstrate that its radionuclide airborne emissions are low enough to ensure that no one in the public receives an effective dose of 10 mrem or more in any one year. (This excludes radon-222 emissions, which are covered under different regulations. Radon regulations, emissions, and estimated dose from radon are presented in Chapter Eight of this report.) Moreover, to determine whether the site is well within the DOE dose limit to members of the public of 100 mrem per year from all exposure pathways, Fernald site personnel estimate doses from other components of the air and liquid pathways, as well as direct radiation dose from materials stored onsite. The DOE limit of 100 mrem per year from all pathways is the sum of the doses from radiation external to the body during the year plus the dose from radionuclides taken into the body during the year. This latter dose is called the committed effective dose and is received over a 50-year period.

As described in Chapter One, pathways are the routes along which radioactive material moves and may deliver a dose to the public. Total dose estimates incorporate dose from the air and liquid pathways. Direct radiation is included as a component of the air pathway dose. Monitoring of the air and liquid pathways provides the basis for the extensive environmental sampling described in chapters Four, Five, and Six. Using these measurements, a dose from each pathway can be estimated using models.

Environmental and Dose Modeling

The Fernald site, like many other nuclear facilities, uses models to estimate doses to the public. Models play an important role in environmental monitoring because current technology and the low concentrations of radioactive pollutants in the environment make it impractical to measure environmental doses with standard instruments. The nature of radioactivity and the presence of naturally occurring radioactive materials create difficulties in detecting low levels of radioactivity and distinguishing between natural radioactivity and radioactivity from the Fernald site. Models also estimate pollutant concentrations and doses which are below the detection capabilities of instruments and laboratory measurements. These concentrations and doses would be left out in assessing the environmental impacts of the site if models were not used. Environmental and dose models are briefly explained below.

Environmental modeling is a way to represent a complex environmental process, such as atmospheric dispersion of emissions or the air-to-soil-to-produce process, as a set of mathematical formulas. By studying an environmental process, such as dispersion of a pollutant from a stack as it is carried by the wind, scientists can develop a mathematical formula that models the process. They can then use this model to predict the concentration of the pollutant at a specific location. As additional processes are modeled, it is possible to interconnect them so that the movement of pollutants is predicted by a larger environmental model.

Dose models are developed similarly. By modeling radioactive decay, absorption and removal of radioactive materials in the body, and other physical and biological processes, scientists can develop a dose model to evaluate how radioactive materials deliver a dose. Connecting the dose model to the environmental model provides a means of estimating dose using information gathered through environmental sampling. Models are usually translated into computer programs to conveniently handle the data and calculations.

Although models may be the only comparative way for scientists to estimate dose, they do not necessarily predict all environmental processes. Since the mathematical formulas that represent the environmental and biological processes are simplifications and generalizations, applying them to the specific conditions at the site may lead to differences between predicted and actual concentrations or doses. The results or outputs of models always involve some uncertainty in the accuracy of the estimated dose, and many have built-in assumptions which strongly influence the results. Models may be most beneficial because of their ability to estimate the upper limit of the dose and identify the most influential pollutant or pathway of exposure.

Although the uncertainty associated with the radiation dose calculations has not been quantified, whenever Fernald-specific data were not available for parameter values (for example, food consumption values) conservative values were selected from the literature for use in the dose calculations. Thus, the estimated doses should be viewed as maximum estimates of potential doses resulting from Fernald releases.

Air Pathway Dose Calculations

The air pathway is a route for contaminants to reach people directly as emissions and indirectly through foods contaminated by airborne emissions. This section uses data from air and produce sampling as well as estimates of airborne releases (refer to Chapter Four) to calculate doses. Dose from radon is presented in the following chapter of this report.

Estimated Doses from Airborne Emissions

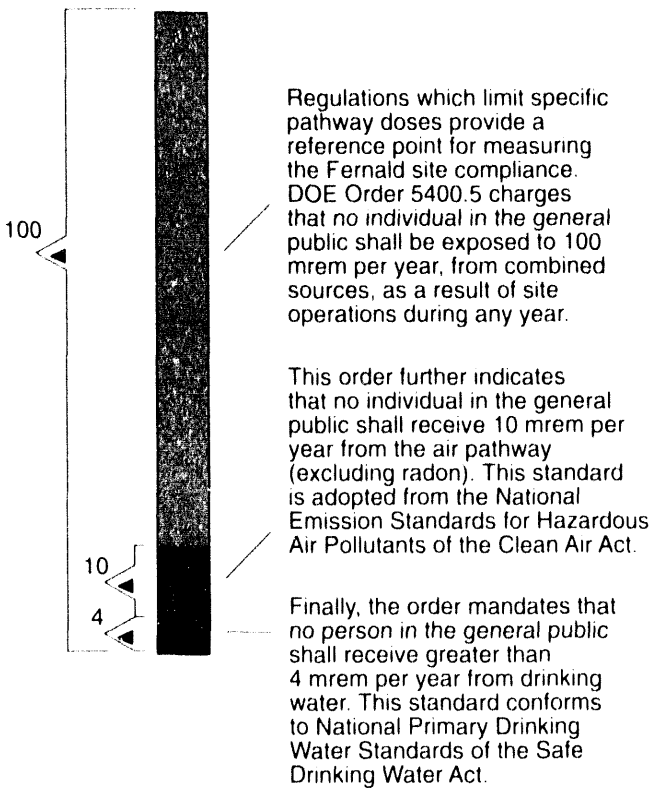
At the Fernald site, scientists obtain dose estimates from onsite airborne emissions measurements using a set of computer programs called CAP-88. The site uses CAP-88 to determine compliance with the NESHAP requirements of the Clean Air Act. Within the CAP-88 set of programs, the AIRDOS program calculates concentrations of radionuclides in the air, on the ground, and in food based on estimates of the amount of airborne radioactive material released. The concentrations are then used to calculate the intakes and subsequent doses to people.

The CAP-88 program calculates airborne radionuclide concentrations based on onsite airborne emissions measurements. The results from the fenceline ambient air monitoring stations are compared to the CAP-88 concentrations, but are not used in inhalation dose calculations.

The CAP-88 computer programs calculate both individual and collective doses. Collective dose is the sum of individual doses to people in the Fernald area and is reported in the units of *person-rem*. (For example, if 10 people each receive 1 rem, the collective dose is "10 person-rem;" if 20 people each receive 0.5 rem, that collective dose also is "10 person-rem.") The person-rem unit is used as a broad measure of the radiological impacts of the site and is useful in comparing the risks from site operations with other facilities and industries.

The CAP-88 programs require a large amount of data to estimate dose, which includes the number, height, and location of release points, wind speed and direction, the amount of radioactive material released, and population distribution in the Fernald area. (Wind rose data are shown in figures 4 and 5 in Chapter One, and estimated airborne radionuclide emissions and population distribution are presented in tables 2 and 21.) Although some of the data were obtained through measurements and sampling, many were not readily available and were estimated. Examples of estimated data are the amounts of airborne radioactive material released from the Laboratory Building and the Cooling Tower. The site made very *conservative estimates* for these and all other emission sources which were not measured directly. Conservative estimates, used frequently in environmental monitoring and dose calculations, are based on assumptions about an exposure situation that should result in the highest estimate of a dose. For example, an assumption about estimated doses at the air monitoring stations is that a person is outdoors at one location for 100% of the time during the year. The assumptions are conservative in the sense that they provide a margin of error for underestimating emissions and doses. Conservative estimates of emissions are used to ensure that dose estimates are not underestimated but are the maximum doses that could have resulted from site operations during 1993.

Figure 45: Department of Energy Dose Limits



Results of the CAP-88 programs estimated the maximum effective dose from 1993 airborne emissions to be 0.016 mrem to a person located north of the former production area. This dose estimate assumed that the person remained outside his or her home 100% of the time in 1993. The dose was well below the NESHAP standard of 10 mrem from the air pathway and was only 0.016% of the DOE guideline of 100 mrem per year from all pathways (see Figure 45).

The collective effective dose from 1993 airborne emissions (not including radon) to the population within 80 km (50 miles) of the site was also calculated by CAP-88. This dose was estimated to be 0.3 person-rem for a population of 2,740,000. For comparison, the same group of people received an estimated collective effective dose of 300,000 person-rem from background radiation, excluding radon.

Estimated Dose from Eating Foodstuffs Produced near the Fernald Site

Since the CAP-88 program only calculated doses from 1993 airborne emissions, scientists made additional dose calculations to estimate doses from past emissions that may have accumulated through the food chain. These additional calculations estimate potential dose from consuming locally grown fruits, vegetables, and milk.

Uranium deposited in soil during the years the Fernald site was in production may be absorbed by produce and farm animals and, therefore, deliver a secondary pathway dose. This estimated dose is based on the conservative assumption that 100% of a person's diet of fruit, vegetables, and milk comes from gardens and farms in the Fernald area. This modeled diet assumes an annual consumption of 18 kg (40 pounds) of leafy vegetables (cabbage, lettuce, etc.), 45 kg (100 pounds) of grains (corn, soy beans, wheat, etc.), 68 kg (150 pounds) of fruit, 28 kg (62 pounds) of below-ground vegetables (potatoes, carrots, etc.), 45 kg (100 pounds) of other vegetables, and 112 liters (30 gallons) of milk.[36] Scientists analyzed cabbage, corn, soybeans, apples, potatoes, tomatoes, cucumbers, and milk sampled from local gardens and farms for uranium to represent the foods in the diet. The maximum uranium concentration found in locally produced foods was used to estimate dose. The average background uranium concentration in foods was subtracted from the maximum concentration to account for the natural occurrence of uranium in foods.

The laboratory analysis of foodstuffs determines the total amount of uranium (all uranium isotopes) in the sample. Because any dose from uranium is based on the isotopic composition of uranium, an assumption about the isotopic composition of uranium in foodstuffs must be made to calculate the dose. Scientists assume any uranium detected in the foodstuffs has the isotopic composition of natural uranium. This assumption is reasonable because a large amount of uranium produced at the Fernald site had an isotopic composition similar to naturally occurring uranium. Scientists used dose conversion factors to convert the intake of uranium to dose. The conversion factors themselves are the result of modeling the radioactive decay and metabolism of radionuclides in the body.[37]

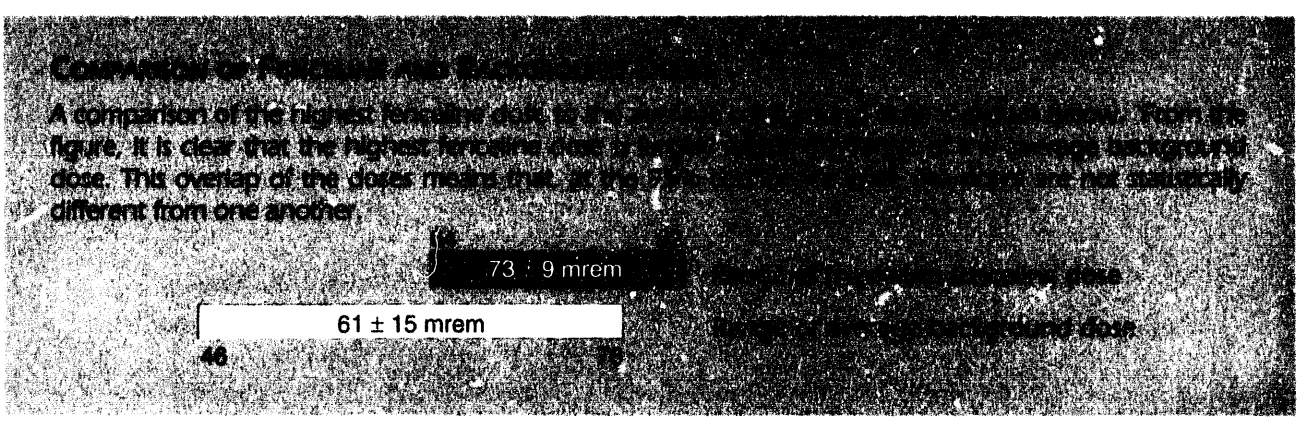
The committed effective dose received over the course of 50 years was calculated to be 0.01 mrem, only 0.01% of the DOE dose limit of 100 mrem per year for all pathways. This dose is comparable to the estimated doses from foodstuffs in past years.

Direct Radiation Dose

Unlike the air and liquid pathways where a radionuclide in the form of a particulate or gas delivers its dose after inhalation or ingestion, direct radiation dose is the result of radiation (gamma and X-rays) emitted from radionuclides stored onsite. The largest sources of direct radiation are the wastes stored in the K-65 silos and thorium compounds stored at several locations onsite. Direct radiation dose is estimated using environmental thermoluminescent dosimeters (TLD) measurements (see Chapter Four), rather than through the use of models.

Direct radiation dose was estimated using the highest dose from the twelve fenceline monitoring locations (see Table 10 on page A-14) and subtracting the average dose measured at three background TLD locations (locations 18, 19, and 20 as shown in Figure 27 on page 79). Limits in the precision on TLD data and variations in natural background radiation require consideration of the uncertainty (the plus/minus (±) values) associated with each measurement in calculating dose. The uncertainty is calculated for a 95% confidence interval (2 sigma) about the average.

From the data in Table 10, the highest 1993 fenceline dose occurred at location 15 and is 73 ± 9 mrem per year (2 sigma). The average background dose from locations 18, 19, and 20 is 61 ± 15 mrem per year. At first glance, it appears that the direct radiation dose would be 12 mrem per year above background at the site fenceline. However, when the range of the background dose measurements is taken into account, there is no statistical difference between the fenceline dose and the average background dose. The data indicate that the highest fenceline dose is between 64 mrem per year (73-9) and 82 mrem per year (73+9), while the average background dose is between 46 mrem per year (61-15) and 76 mrem per year (61+15). Since the range of background doses largely envelops the range of fenceline doses, there is no firm basis for stating that there is a difference between the fenceline and average background doses. Given this lack of statistical difference between the doses, no dose was attributed to direct radiation for 1993.



Liquid Pathway Dose Calculations

Dose estimates from the liquid pathway are calculated using environmental sample results and dose conversion factors. Measurements of radionuclide concentrations in groundwater, the Great Miami River, and fish from the river are used to estimate dose from the liquid pathway. Descriptions of the monitoring programs for these environmental samples are given in chapters Five and Six.

Estimated Dose from Drinking Well Water in the Area around the Fernald Site

As discussed in Chapter Six, the site monitors a number of private drinking water wells for uranium contamination. While most wells have uranium concentrations which are within the 0.07 to 2 pCi/L (0.1 to 3.0 ppb) range of background concentrations, several wells have higher concentrations and are considered to be a source of dose from the site.

In order to estimate dose from drinking well water in the area around the site, the average uranium concentration in wells located north and west of the site was subtracted from the maximum concentration found in wells located south and east of the site. Data from wells 1, 3, 4, 10, 22, and 30 were used to provide the average background concentration. The maximum concentration in a drinking water well south and east of the site was found in Well 34. For the purpose of dose calculation, the uranium in Well 34 is assumed to have the isotopic composition of natural uranium. Using a consumption rate of 2 liters (0.5 gallon) of water per day, the committed effective dose received from drinking water from Well 34 would be 0.7 mrem.

Estimated Dose from Drinking Great Miami River Water

Although the Great Miami River downstream of the site is not designated as a public water supply by OEPA, the site estimated the radiation dose to an individual if that person drank only the water from the river downstream of the discharge point after mixing had occurred.

Scientists used data on the amounts of radionuclides discharged to the Great Miami River (see Table 11 on page A-15) and the average river flow to calculate concentrations in river water. Dose conversion factors were used to convert the intake of radionuclides to dose. Assuming a daily consumption of 2 liters (0.5 gallon) of water, the committed effective dose from Fernald releases received over the course of 50 years would be 0.01 mrem.[36]

Estimated Dose from Eating Fish from the Great Miami River

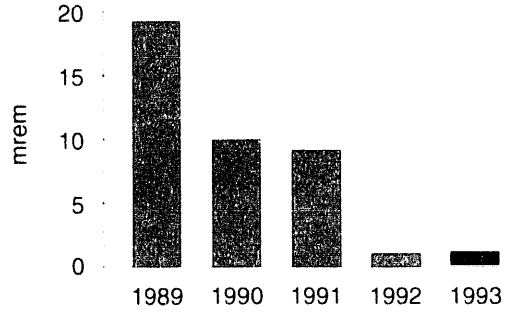
The estimated dose from eating fish from the river was calculated using the maximum uranium concentration in edible fish collected at RM 19 and RM 24 (see Figure 35 in Chapter Five). The average background uranium concentration in edible fish collected at RM 38 was subtracted from the maximum concentration to account for natural occurrence of uranium in the fish. As with other dose calculations, any uranium detected in the fish was assumed to have the isotopic composition of natural uranium.

Assuming an annual consumption of 4.5 kg (10 pounds) of fish from the Great Miami River, the committed effective dose would be 0.01 mrem.[36] This dose is well below the DOE guideline of 100 mrem effective dose per year from all pathways.

Total of Doses to a Maximally-Exposed Individual

The maximally-exposed individual is a hypothetical member of the public who receives the highest calculated effective dose based on the location of his or her home, weather conditions, and the individual pathway doses. Since it is not possible to single out a specific individual in the Fernald area who receives the most dose, the results of the individual pathways and the CAP-88 evaluation are added to predict the maximum dose that a person could receive. The dose to the maximally-exposed individual is a total of estimated doses from breathing 1993 airborne emissions (excluding radon), consuming foodstuffs produced in the Fernald area, drinking water from a well in the Fernald area, eating fish from the Great Miami River, and the direct radiation dose above background at the site fenceline. The conservative assumptions used throughout the dose calculation process ensure that the dose to the maximally-exposed individual is the upper limit of the actual dose any member of the public receives.

Figure 46: Dose to Maximally-Exposed Individual, 1989 – 1993



The dose to the maximally-exposed individual is estimated to be 1.0 mrem, well below the guideline of 100 mrem per year for all pathways. Figure 46 shows the doses to the maximally-exposed individual from 1989 to 1993.

DOSE TO MAXIMALLY-EXPOSED INDIVIDUAL

Pathway	Dose Attributable to the site		Applicable Guideline	
Air				
Estimated 1993 emissions	0.016	mrem	10	mrem/air
Foodstuffs grown in Fernald area	0.01	mrem	100	mrem/all pathways
Direct radiation	0.0	mrem	100	mrem/all pathways
Liquid				
Well water in the Fernald area	0.7	mrem	4	mrem/drinking water
Fish from Great Miami River	0.01	mrem	100	mrem/all pathways
Maximally-exposed individual	**~1.0**	**mrem**	**100**	**mrem/all pathways**

Significance of Estimated Radiation Doses for 1993

One method of evaluating the significance of the estimated doses is to compare them with doses received from background radiation (see Chapter Two). Background radiation yields approximately 100 mrem per year from natural sources, excluding radon. Comparing the maximally-exposed individual dose to the background dose demonstrates that, even with the conservative estimates, the dose from the site is much less than background. Although the estimated dose will be received in addition to the background dose, this comparison provides a basis for evaluating the significance of the estimated doses. A dose that is small in comparison to that of background radiation will produce no measurable health effects.

Another method of determining the significance of the estimated doses is to compare them with dose limits developed to protect the public. The International Commission on Radiological Protection (ICRP) has recommended that members of the public receive no more than 100 mrem per year as a result of site operations, and DOE has incorporated this limit into Order 5400.5 as well. The sum of all estimated doses from site operations for 1993 was well within this limit.

Radon is subject to different regulations than other components of the air pathway. Likewise, the dose received from radon is regulated separately. Therefore, the Radon Monitoring Program is discussed separately in the next chapter, as well as the dose received from radon at the Fernald site.

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Estimated Radiation Doses for 1993

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The Radon Monitoring Program

Radon is a radioactive gas that occurs naturally throughout the environment. Everyone is exposed to radon at varying concentrations, and exposure to radon is part of the annual background radiation dose that people receive. As discussed in Chapter Two, this background exposure contributes approximately 55% to a person's average annual dose.

In addition to the radon found naturally in the environment, the Fernald site stores some materials onsite that radioactively decay to form radon. Because these materials are present, the Radon Monitoring Program has monitored radon levels onsite since the early 1980s. This program operates in compliance with the requirements of DOE Order 5400.5, "Radiation Protection of the Public and the Environment." Radon monitoring results and attributable dose are reported separately from the air pathway in order to improve the presentation of information and regulations that are unique to radon.

Results in Brief: 1993 Radon Monitoring

Fenceline Concentrations – Average fenceline concentrations measured in 1993 were 0.63 ± 0.20 pCi/L, well below the DOE guideline of 3.0 pCi/L. The 1992 results were 0.57 ± 0.29 pCi/L.

Dose Received from Radon – The calculated dose at the fenceline was estimated to be 454 mrem incorporating the methodology used by the National Council on Radiation Protection. The 1992 dose would have been 410 mrem at the fenceline if the same dose calculation method had been used. These dose calculations include the annual dose received from average background levels of radon (approximately 200 mrem per year), and they were calculated using a more conservative method than was previously used.

Introduction to Radon

The general term radon refers to the radon–222 *isotope*. Radon–222 is a naturally occurring decay product of uranium–238 which is widespread in the earth's crust. Radon–222 has the longest half-life of the radon isotopes, 3.8 days, which allows for radon–222 to be a significant contributor of radon exposure to the public. Radon–222 is virtually everywhere because of the widespread distribution of its parent *radionuclides*, radium–226 and uranium–238, in the earth's crust. The other isotopes of radon found in the environment are radon–219 (actinon), a daughter in the uranium–235 decay chain and radon–220 (thoron), a daughter in the thorium–232 decay chain. The decay chains for the parents of the radon isotopes are shown in Figure 47.

Radon–222 decays into a series of short-lived radionuclides that are collectively referred to as radon "daughter products." As radon and its daughter products decay, alpha particles are emitted. The daughter products are adsorbed on inert dust present in the atmosphere. When the dust in the atmosphere is inhaled with the attached daughter products, some of this dust is deposited in the lung, which may cause an internal exposure to the lung. These daughter products, which are deposited in the lung, will emit alpha particles when they decay. The alpha particles may then cause damage to the cells lining the airways.

Radon–220, or thoron, with a half-life of 55.6 seconds, behaves similarly to radon–222. Individuals may receive an internal exposure to the lungs, due to inhaling dust with attached thoron daughters. However, the dose to the lung from thoron and its daughters does not add significantly to the dose received from the radon series.

Radon in the Environment

Radon–222 is present in the environment virtually everywhere because of the widespread distribution of its parent radionuclides, radium–226 and uranium–238, in the earth's crust. The physical characteristics of the soil and local weather conditions affect radon's ability to migrate into air and water. Upon decay, radon may escape into the air spaces around soil particles and diffuse into the atmosphere. Local rainfall and snowcover may inhibit radon's ability to escape from the soil.

The outdoor concentration of radon in the atmosphere shows daily, seasonal, and annual fluctuations. These changes are caused, in part, by atmospheric conditions. They are also caused by changes in the rate that radon is released from the ground because of precipitation and freezing temperatures. Because radon tends to accumulate under stagnant weather conditions, concentrations increase during periods of calm winds and temperature inversions. (During temperature inversions, warm air traps cooler air near the earth's surface and prevents mixing and turbulence of the air near the surface. When these inversions occur, radon is also trapped near the earth's surface.)

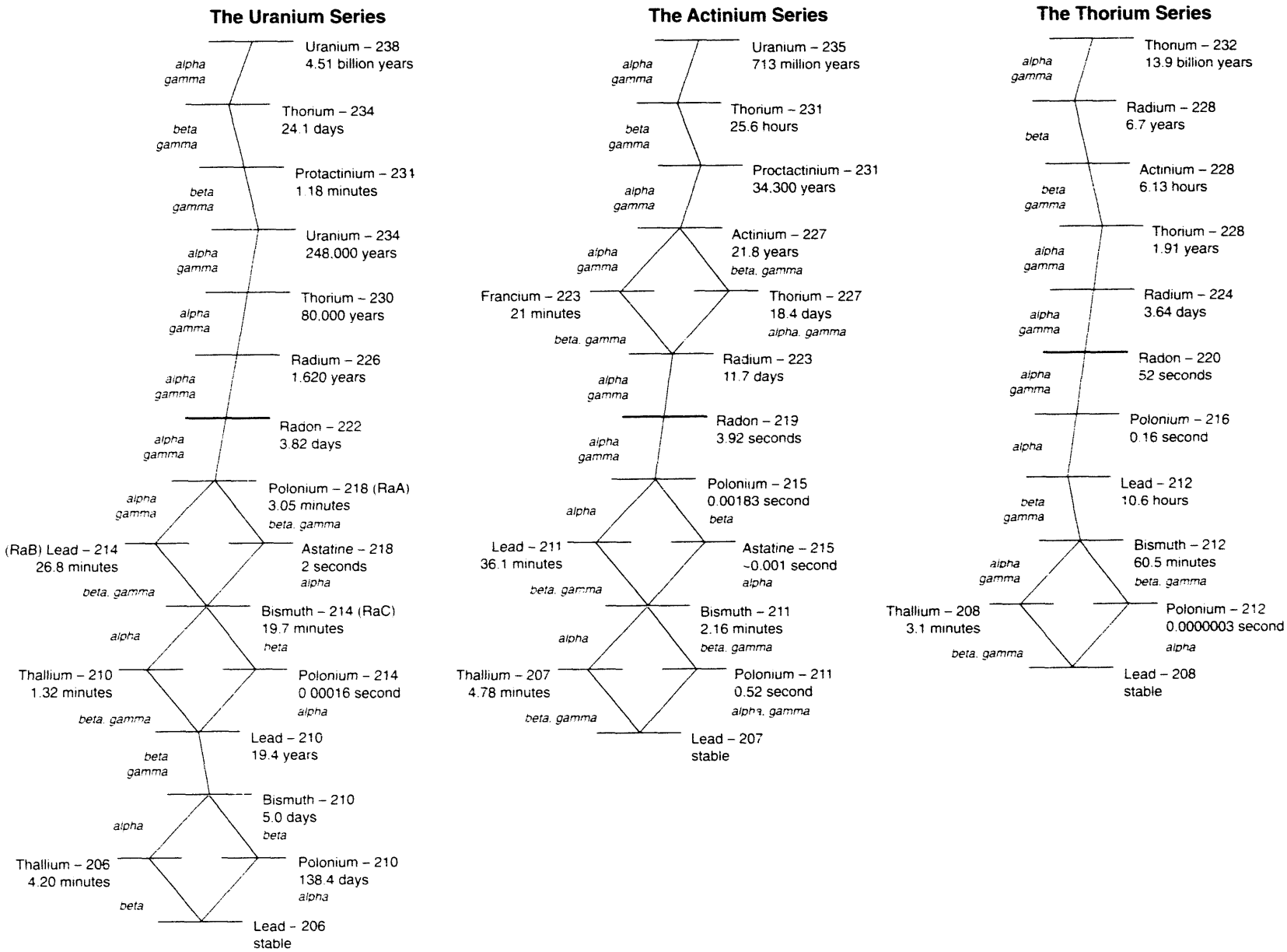

Figure 47: Decay Chains

Radon at the Fernald Site

In addition to the radon formed naturally in the environment, the Fernald site stores some materials which radioactively decay to form radon. The principal source of radon emissions from the site is the ***K-65 silos***. The silos contain high concentrations of radon producing elements. Radon can escape through the cracks and access ports on top of the K-65 silos.

The site was required by the Federal Facility Agreement (FFA) to measure radon-flux from all waste pits known to contain radium. These measurements were taken at pits 1, 2, and 3 in 1991, and all were below the 20 pCi/m^2 per second standard. In January 1993, DOE verified with USEPA that emissions from Waste Pit 4, which is covered with a clay cap and liner, were below the 20 pCi/m^2 per second standard and was, therefore, exempt from the requirement. Because pits 5 and 6 and the Clearwell are water covered, radon-flux measurements would not be required if the exposed material above the water line was submerged. After completion of the "Control of Exposed Material in Waste Pit 5" and "Control of Exposed Material in Waste Pit 6" removal actions, all exposed material was submerged, and radon-flux measurements for these pits were not required.

Radon Monitoring at the Fernald Site

All releases applicable to site activities are monitored at each DOE facility and radiation exposures to members of the public are assessed. This monitoring provides assurance that members of the public and the environment are protected from radiation exposure.

Radon concentrations and emissions in the atmosphere above facility surfaces or openings are guided by DOE Order 5400.5, "Radiation Protection of the Public and the Environment." This order defines radiological protection requirements and guidelines for cleanup of residual radioactive material, the management of resulting wastes and residues, and the radiological release of property. These requirements and guidelines are applicable at the time the property is released. These requirements state that radon levels must not exceed the following limits when added to background levels:

- 100 pCi/L at any given point,
- An annual average concentration of 30 pCi/L over the facility site,
- An annual average concentration of 3 pCi/L at or above any location outside the facility site, or
- *Flux rates* greater than 20 pCi/m^2 per second from the storage of radon producing wastes.

Monitoring Methods

The Environmental Radon Monitoring Program at the Fernald site uses two types of radon detectors to measure radon concentrations in the environment: alpha-track etch detectors and alpha-scintillation detectors.

An ***alpha-track etch detector*** is a cup that contains a special plastic chip inside. Some of the alpha particles from the decay of radon (or its daughter products) will interact with the plastic chip by leaving a latent track in the material. The tracks are made detectable by chemical or electrochemical etching. The number of etches or tracks in the material is proportional to the number of alpha particles that have reached the plastic. This number can then be related to the average concentration of radon in the cup. Filters are placed over the cup to allow only radon to enter the cup and be measured. All environmental radon data presented in this 1993 report are from the alpha track-etch radon detectors, and pertinent environmental data can be found in Table 22 on pages A-39 and A-40. These detectors are exchanged every three months to provide long-term radon measurements.

The Environmental Radon Monitoring Program obtains data from 20 locations at the site boundary using alpha track-etch detectors, as well as from three area residences and four background locations (see Figure 48). The background locations are shown as air monitoring stations 15 and 16 and background locations 1 and 2. Alpha track-etch detectors were also used to measure radon concentrations adjacent to the silos and in the predominant wind direction from the silos (see Figure 49).

Alpha-scintillation detectors use alpha-scintillation cells to continuously monitor radon concentrations. These continuous monitors record radon concentrations on an hourly basis. An *alpha-scintillation cell* detects alpha particles from the decay of radon gas by the interaction of the alpha particle with the material inside the scintillation cell. The interactions produce light pulses which are amplified and counted. The number of light pulses counted is proportional to the radon concentration inside the cell. When monitoring the ambient outside air, the air diffuses into the scintillation cell through a foam barrier. The radon gas present in the diffused air decays into its daughter products, emitting alpha particles which are then counted. This technique is called passive sampling. It takes approximately a half-hour to achieve the same radon gas level inside the cell as is present in the surrounding air.

Continuous monitoring was conducted at select fenceline locations during 1993, namely, air monitoring stations 1, 6, and 7. Continuous monitoring was also conducted at various locations on site. These locations include the perimeter of the silo berm and headspace of the silos. The locations of these monitors are shown in Figure 50. Although the data obtained from the continuous monitoring are not included in this report, some of the data are reported to USEPA through the Federal Facility Agreement.

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Figure 48: Offsite and Fenceline Radon Monitoring Locations

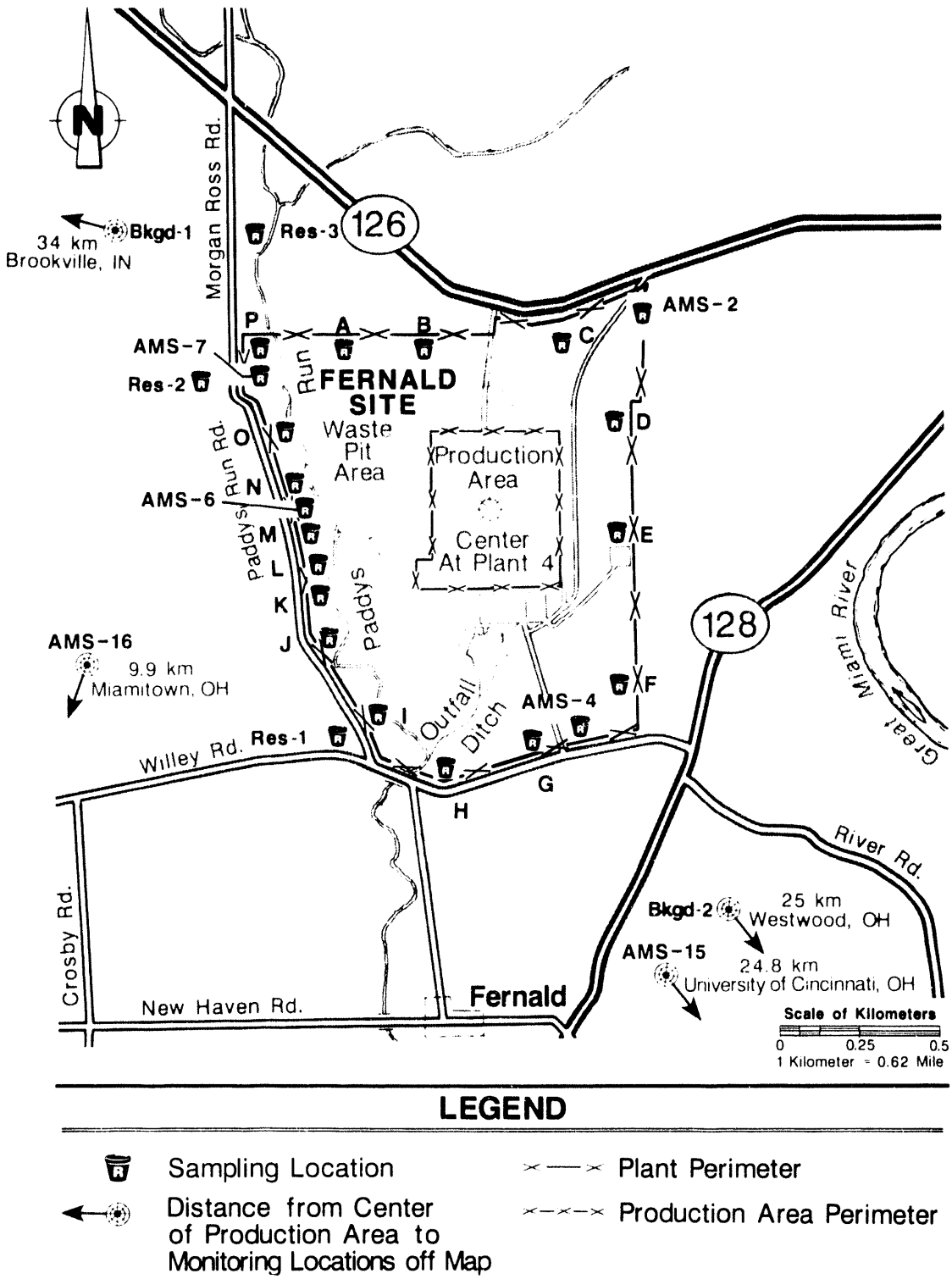

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Figure 49: Radon Monitoring Locations Near the Silos

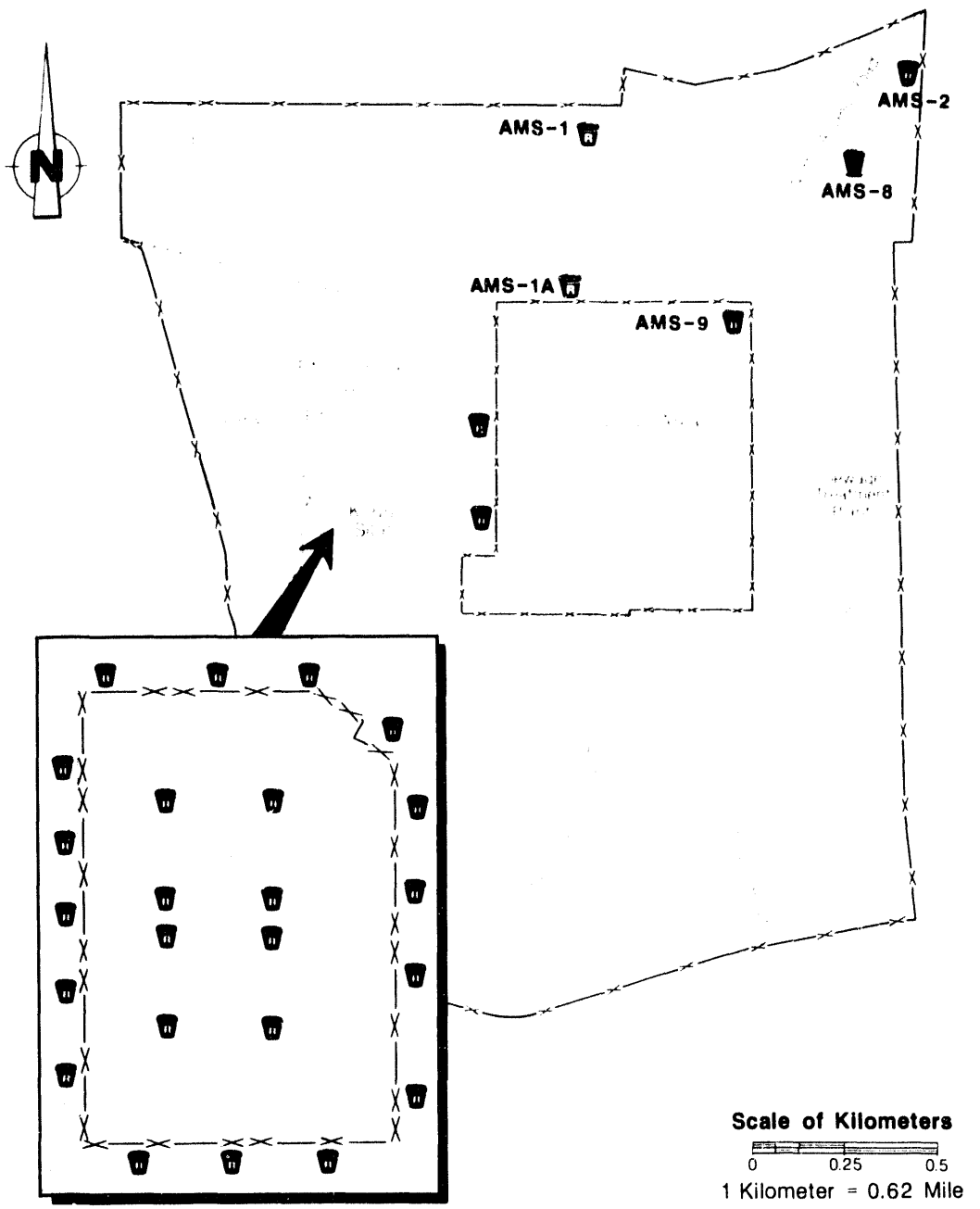

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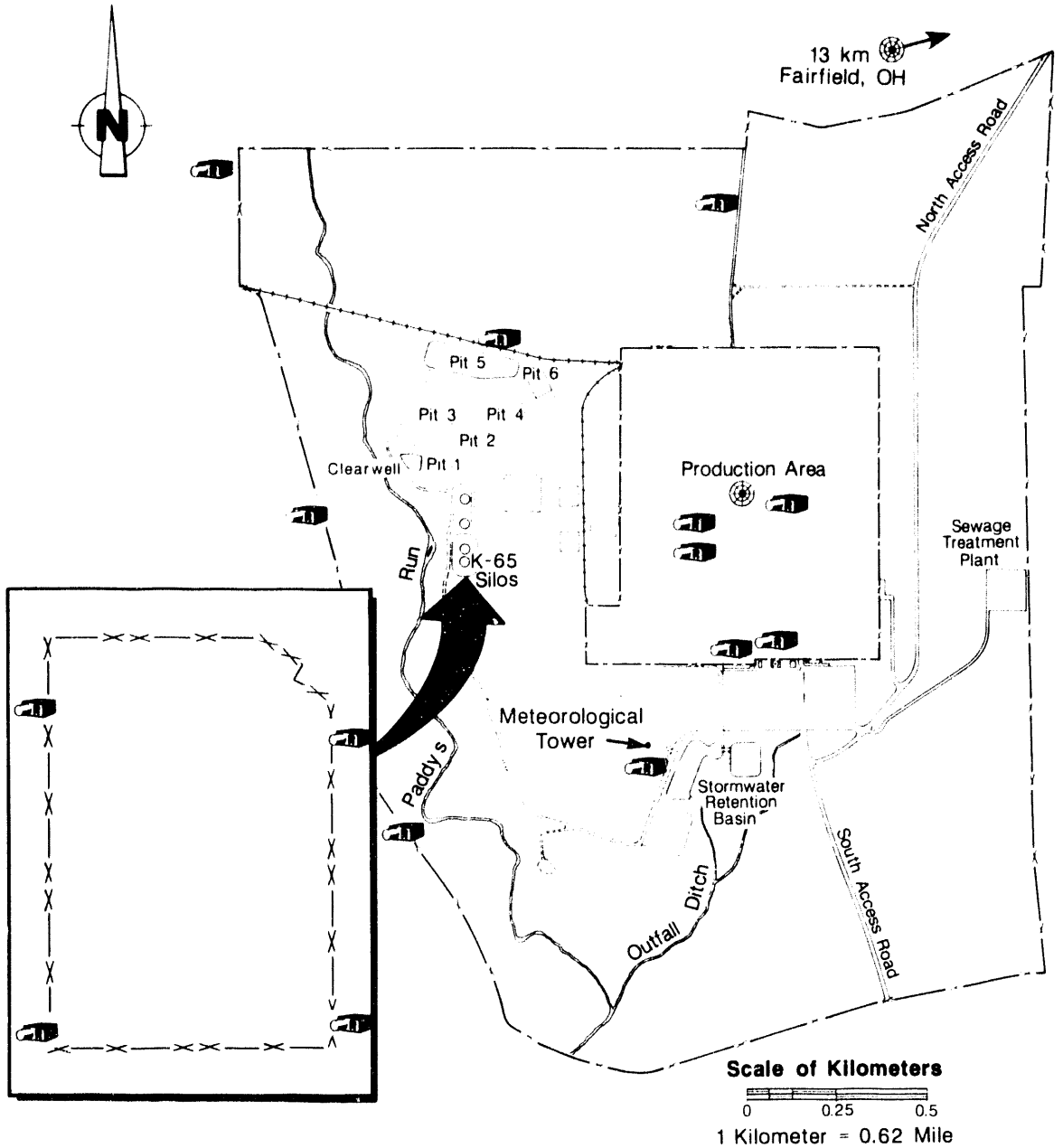
Figure 50: Continuous Radon Monitoring Locations



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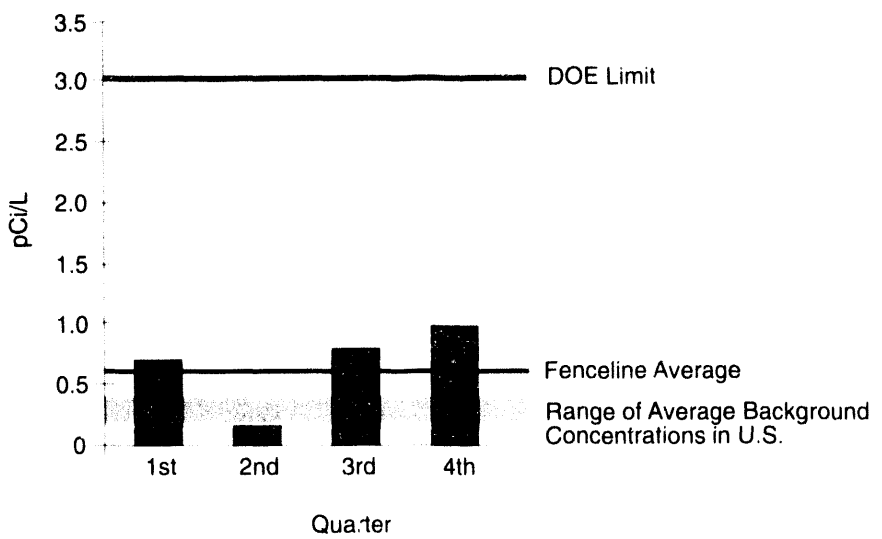
1993 Environmental Radon Monitoring Results

Table 22 on pages A-39 and A-40 summarizes the 1993 environmental radon monitoring results. These quarterly results are also shown in Figure 51. Average fenceline radon concentrations were considerably less than the DOE limit of 3.0 pCi/L. The average radon concentration at the fenceline was 0.63 ± 0.20 pCi/L. The range of values for any location on the fenceline varied from less than 0.1 pCi/L to a maximum of 1.58 pCi/L. The maximum measurement was still considerably less than the DOE limit.

The average background radon concentration was greater than the average fenceline concentration in 1993. The results in Table 22 show that all monitored locations demonstrated a significant increase in radon concentrations during the third and fourth quarters of 1993. The average background radon concentration for 1993 was 0.95 ± 0.24 pCi/L. The concentration for any of the four background locations varied from 0.13 pCi/L to a maximum of 2.15 pCi/L.

Figure 51: Quarterly Fenceline Radon Concentrations, 1993



Quality assurance problems were noted with the vendor analytical services in 1993, which rendered some of the quarterly data suspect. The vendor reported high errors in background sample concentrations in the magnitude of several hundred percent. Therefore, the radon data reported here are more of a qualitative nature than quantitative and serve as a general indicator of relative radon concentrations. Radon data obtained by other monitoring techniques supported an apparent increase in background radon concentrations for the third and fourth quarters, but it was substantially lower than the data reported with the track-etch cups.

Since the 1993 background locations yielded radon concentrations much higher than the typical values for ambient outdoor radon concentrations throughout the country, different locations may need to be selected to find locations that are more representative of background. The third and fourth quarter background concentrations were extremely high in 1993. Background locations with concentrations less than onsite concentrations are needed for valid comparisons with onsite radon data to assess offsite radon contributions attributable to the Fernald site.

Estimated Radiation Dose from Radon

The radiation dose from radon in 1993 was estimated using a methodology that is more conservative than previous estimates. The methodology used incorporates that which is used by the National Council on Radiation Protection (NCRP).[38]

In 1993, the dose from radon was estimated to be 454 mrem. This dose was calculated from the average annual fenceline radon concentration. As was previously stated, the average background radon concentration was greater than the average fenceline concentration. The radon dose calculation here is only useful for comparing the dose from "natural" radon at the fenceline to the estimated national background average of 200 mrem. The chart below presents the 1993 dose estimates for 1993 including any background radon present at the fenceline. For comparison purposes, the chart also presents 1992 radon dose estimates using the same methodology as was used in 1993. The changes used in this year's calculation methodology are expected to be continued in the future.

1993 Radon Dose Estimates at the Fenceline

Annual Average Fenceline Values	1993	1992	Comments
Radon Concentration, (pCi/L)	0.63	0.57	
Estimated Dose, (mrem)	454	410	Individual engaged in light activity 24 hours a day
Estimated Dose, (mrem)	403	365	Individual engaged in light activity 16 hours a day, 8 hours resting
Estimated Dose, (mrem)	189	171	Dose estimated using 1992 methodology (assuming 50% equilibrium), including background

The 1993 dose estimate assumed that the ambient concentration ratio of radon to radon daughters offsite (radon–222:RaA:RaB:RaC) was at a ratio of 1:0.9:0.7:0.7 – approximately a 0.7 equilibrium ratio. (Figure 47 on page 129 labels radon–222 daughters RaA, RaB, and RaC.) This ratio for ambient outside air is in accordance with widespread sampling conducted throughout the United States that is referenced in the NCRP report. Actual values for radon daughters have not been measured at offsite or fenceline monitoring locations.

The dose estimate also assumed that the dose was calculated for a maximally-exposed individual who continuously breathed air at the fenceline while engaged in light physical activity for 24 hours a day for an entire year. The dose estimates presented in this report are for the "standard person," which assumes an average body size and breathing rate.

An exposure conversion factor, using the above mentioned assumptions, was used to calculate the radiation exposure to the lung from radon and its daughters based on radon concentrations in the air. The exposure was converted to a lung dose by using the quality factor for internal alpha particles.[39] The lung dose was converted to an estimated dose equivalent (whole body dose) by using the weighting factor for the lung.[40]

The second dose estimate is presented to illustrate the effects of changing any one factor in the calculation of an estimated dose from radon. This estimate used a more realistic assumption that the hypothetical person continuously breathed air at the fenceline for 24 hours a day but spent 8 hours resting and 16 hours engaged in light activity each day for the entire year. Dose estimates for radon use variables with a range of possible values. Therefore, the radon dose conversion factor can be as high as approximately 120% of the values reported if all parameters except the radon–222 concentration are unspecified.

Control of Radon at the Fernald Site

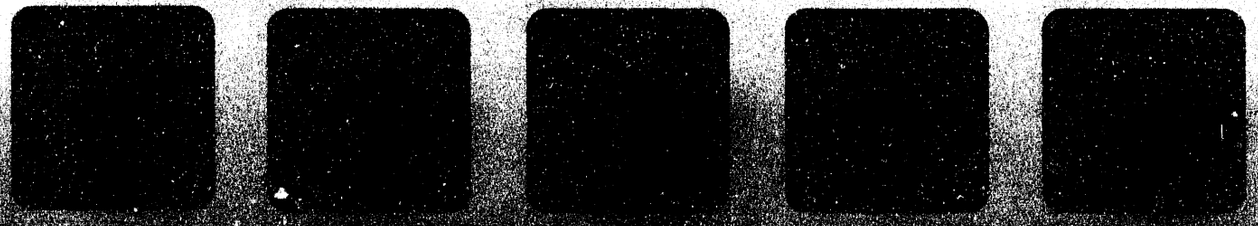
DOE strives to operate its facilities and conduct its activities so that radiation exposures to members of the public are As Low As Reasonably Achievable (ALARA).

Steps have been taken at the site to control radon emissions. In November 1991, a bentonite (clay) sealant layer was placed over the residues contained in the K-65 silos to reduce the amount of radon emitted to the environment. This removal action was performed with the approval of USEPA. The clay layer essentially acts as a filter. As a result, lower concentrations of radon are observed in the silo headspace than were observed before the bentonite addition. Concentrations that were initially estimated at 25 to 30 million pCi/L were recently observed at less than 4 million pCi/L. This value is slightly higher than previously recorded values observed since the bentonite addition, and it appears to be rising slightly. Efforts to validate the data obtained thus far are scheduled for 1994.

The next chapter discusses the procedures and practices at the Fernald site that are used to ensure that environmental monitoring data are accurate representations of the conditions at the site.

9

Quality Assurance for the Environmental Monitoring Program



QA

Quality Assurance for the Environmental Monitoring Program

Acquiring data of known quality is essential to environmental sampling and analysis. Because decisions are made and regulatory compliance is derived from environmental data, the Fernald site has developed comprehensive procedures that define how environmental sampling and analysis are to be conducted. These procedures generate consistency between programs and ensure that USEPA, DOE, or industry-accepted practices and standards for conducting environmental sampling and analysis are used. Quality Assurance (QA) provides the guidelines necessary to monitor the performance of these procedures in a controlled and consistent manner.

Adherence to QA requirements generates confidence that environmental data are reliable. The QA process identifies the variability in data, establishes the objectives, and defines the level of confidence needed to meet the objectives. The consistency and precision of sampling and field analysis are measured using QA. In the laboratory, QA measures the accuracy and precision of the analyst and analytical procedures used.

Results in Brief: 1993 Quality Assurance

DOE's Environmental Measurements Laboratory (EML) Evaluation – Soil and air analyses of the DOE EML samples were shown to be within acceptable limits.

USEPA's Discharge Monitoring Report – All but one of the Fernald site analyses of USEPA wastewater samples were within acceptable limits.

Proficiency Environmental Testing (PET) – Of the 477 PET samples analyzed, 96% were within acceptable limits.

Sitewide CERCLA Quality Assurance Project Plan

USEPA requires that environmental sampling and analysis activities that they mandate or support contain a centrally managed QA program. Since the Fernald site generates data under CERCLA, it is required to implement procedures that ensure precision, accuracy, completeness, and representativeness of the entire program.

Collection and analysis of environmental samples are integral parts of fulfilling the site's mission and complying with environmental regulations. A single sample of a specific item from a specific location may provide information for a number of remedial investigation, restoration, waste management, and regulatory uses. Therefore, it is necessary that environmental sampling and analysis be conducted in a consistent manner. This will result in usable, valid data of known quality so that use across programs is possible and the level of uncertainty associated with such data is known.

The Sitewide CERCLA Quality Assurance Project Plan (SCQ) was developed for environmental sampling and analysis activities. It established minimum standards of performance for operational and analytical activities, while ensuring that these standards are followed by all programs. Implementation of the SCQ is scheduled to be completed in 1994 at the Fernald site.

Data Quality Objectives

Prior to sample collection, the Data Quality Objective (DQO) process begins. The DQO process provides a means for the decision maker and the technical team to define the level of quality needed in the data to support a decision. The regulatory requirements are identified and the sampling and analysis plans are designed before the samples are generated. In designing the sampling and analysis plans, the variables established through the DQO process are used to determine the number of samples needed, including QA samples, and to ensure that the total level of uncertainty from sampling and analysis is acceptable.

Quality Assurance: Field Activities

QA on field activities is an important part of the environmental monitoring process. The site's environmental monitoring procedures contain detailed QA measures for meeting the criteria established in the DQOs. Only trained personnel who have demonstrated proficiency in making field measurements and collecting representative samples are permitted to perform these functions. Examples of field activities follow.

Field Analysis

Field measurements offer benefits in time and cost. The measurements provide immediate results on environmental conditions, ensuring that the site maintains compliance with certain parameters. Measurements are made with instruments calibrated against known standards and according to accepted methods. QA measures for instruments include routine performance checks, maintenance, and calibration to help ensure proper operation and accurate field measurements.

Field Documentation

Technicians must accurately and systematically record results of field measurements and information pertinent to sample collection for subsequent evaluation and reference. Procedures direct the environmental sampling process from before collection begins to delivery to the laboratory. In field logbooks, technicians record events and observations such as weather, location, time of sampling, and any unusual events that may influence the sample. Signing and dating all documents helps ensure the traceability and accountability of results when needed in the future.

Field QA/Representative Sampling

Environmental samples that field technicians collect must be representative of actual conditions in the environment. As such, the site designs sampling programs to reduce sample degradation, sampling variability, and cross-contamination.

The Fernald site takes precautions to prevent changing of sample constituents by purchasing certified clean sample containers and using sample preservatives when needed. Such precautions are necessary to prevent changes that can occur in some samples due to biodegradation from microorganisms, the loss of volatile compounds with increasing temperature, or the loss of trace metals from solution by adsorption onto sample container walls. Refrigeration, or icing, and the addition of chemical preservatives (such as nitric or sulfuric acid) are used to decrease volatility of organic compounds, control biological and chemical changes, and maintain trace metals in solution.

The use of standardized procedures reduces sampling variability. These procedures ensure consistency from one collection to another. Sampling variability is measured by taking multiple samples of the same type. The precision of the site's sample

collection and laboratory reproducibility is demonstrated when the analysis results for the duplicate samples are within acceptable limits.

When conducting duplicate sampling, a technician collects two samples from the same location. The samples are then submitted to the same laboratory or submitted to separate laboratories as a means of assessing the precision of the analysis.

The quality of the sample collection process is also evaluated by means of field and equipment blanks. These sample blanks provide valuable data and provide a means of monitoring the sampling process for cross-contamination. The blanks are transported along with the sample containers being taken by the sampling team into the field. When sampling is complete, the blanks are submitted along with the field samples for laboratory analyses. A brief description of different types of blanks follows.

Trip blanks are prepared by filling sample containers with de-ionized water. Anything that will be added to the samples to preserve them after collection is also added to the blanks. The containers are then sealed with tamper-proof tape and transported to the sampling location along with the empty sample containers. The analytical results of the trip blanks detect contamination of samples from empty sample containers and preservatives. Trip blanks are also used to determine the sensitivity of analytical equipment. The result from a trip blank is subtracted from the rest of the samples to obtain a result that has not been influenced by the sensitivity of the equipment used to analyze the sample.

Field blanks are prepared in the laboratory or in the field by filling sample containers with de-ionized water. Unlike trip blanks, field blanks are not sealed until after all samples have been collected. The container is opened and exposed to the air while other samples are being collected. Results from the field blanks determine if airborne contamination may have entered the field samples during the collection process.

Equipment rinsate blanks consist of a composite of de-ionized water that has been used for a final rinse in cleaning sampling equipment. Results of equipment rinsate blanks are used to evaluate whether or not sampling equipment was free of contamination before being used to collect additional samples.

Sample Custody

Most environmental samples must be managed according to USEPA protocols. One such protocol is referred to as *chain-of-custody*. The custody procedure provides requirements for maintaining sample custody by approved personnel. A sample container and sample must be under custody at all times through final disposition. All samples are obtained and documented according to the chain-of-custody procedure. All personnel relinquishing and receiving custody of samples are required to sign, date, and note the time on a chain-of-custody record. This practice is done so that the sample integrity is maintained and all data are legally defensible.

Analytical Laboratory Quality Assurance

The Fernald site uses a variety of procedures to ensure that the laboratories analyzing its samples obtain reliable results. These procedures typically begin with the receipt of samples from the field technicians. Laboratory QA is designed to:

- Ensure use of appropriate measuring equipment,
- Ensure use of approved analytical methods,
- Evaluate analytical performance systematically and objectively,
- Detect and prevent the use of questionable data, and
- Identify appropriate corrective actions.

Analytical Methods

Many of the analytical methods used at the Fernald site are stipulated by federal laws and regulations. From time to time, modifications to these methods are needed to adjust for matrix effects or other interferences. In addition, other methods, primarily those used in radiological analyses, have not been established as standard USEPA methods. As part of QA, periodic review of the procedures verifies that the appropriate procedures are being used and procedure changes have been approved.

Analytical Performance

QA sample analyses provide a day-to-day evaluation of the performance of the site laboratory as well as the contract laboratories. This evaluation is conducted by laboratories analyzing National Institute of Standards and Technology reference materials, USEPA radionuclide solutions, standardized reference solutions, spiked samples (samples to which known amounts of contaminants have been added), blank samples, and external proficiency samples. In addition, the site prepares duplicate samples and submits them to the laboratories conducting the analyses. At least 10% of the total number of samples analyzed are duplicate samples that are processed along with the field samples.

The Fernald site evaluates the QA sample results and regularly submits reports to the laboratories to identify potential areas of concern. In addition to analyzing QA samples, all laboratories perform daily instrument calibrations, stability checks, and reagent checks to monitor for laboratory interference.

Procedural performance is also monitored through sample and matrix spikes. Using these spikes, laboratories determine the percent recoveries of known amounts of analytes that were added to the samples. In addition, matrix interferences can be identified and the accuracy of the analytical procedures can be established.

Detection of Data Problems and Corrective Action

As part of the QA program, internal and external groups perform surveillances on laboratory operations. Successful completion of on-the-job training and test sample performances are required for all new analysts, and routine performance checks assess their ability to correctly perform the analytical procedures. The accuracy of the analytical method is measured by the results of QA samples. If a problem is indicated, the QA department notifies the laboratory so that corrective actions can be taken and suspect results can be evaluated and qualified. As a means of managing variations that occur in the analytical and data generation process, deviations are recorded on Corrective Action Reports. These reports are issued to the responsible manager and can be used as a means to track improvements in the quality system.

Independent Evaluations of the Fernald Site Laboratories

In addition to the comprehensive internal QA program, onsite laboratories regularly take part in several QA programs conducted by independent organizations. Participation in these external QA programs provides unbiased evaluations of the onsite laboratory performance and generates added confidence that results obtained for environmental samples are reliable.

External QA evaluations are conducted in the following manner. The organization conducting the evaluation prepares QA samples to which known amounts of a chemical or radioactive components are added. The samples, but not the known values of the test components, are distributed to the participating laboratories that analyze the samples and return the results. The organization administering the program then provides a performance evaluation report comparing the laboratories' results to the true values of the test components. In most cases, the report compares the results obtained by the other participating laboratories. These comparisons show whether the laboratories' analyses are within acceptable limits of accuracy or if improvements are required. The various programs are described below.

DOE's Environmental Measurements Laboratory

The Environmental Measurements Laboratory (EML) Program evaluates the performance of laboratories carrying out radionuclide analyses on environmental samples. Routinely, the Fernald site receives and analyzes air filters and soil samples for uranium and submits results for comparison with other laboratories in the program. In making the comparison, DOE computes a ratio by dividing the site's result by the EML result for each analyte. The ratio equals 1.00 when the results agree exactly. Results within 50% (ratios greater than 0.50) are considered acceptable.

The ratios for samples analyzed for uranium during 1993 are listed in Table 23 on page A-41. The result for the 1993 soil sample was within acceptable limits since the

ratio of the result was 0.64. The 1993 air filter sample ratio was 0.91 which is also acceptable. The Fernald site has established requirements for all of its contract laboratories to participate in the EML program and their results must be within 50% of the EML results.

USEPA's Discharge Monitoring Report

USEPA requires all laboratories that perform NPDES permit wastewater analyses to participate in the Discharge Monitoring Report (DMR) QA program. The DMR QA evaluations of the Fernald site laboratories' performance began in 1985. This program evaluates the ability of laboratories to measure nonradioactive contaminants in wastewater. As directed by USEPA, a corresponding QA sample must be analyzed for each parameter listed in the NPDES permit. The NPDES permit parameters that are measured by the Fernald site laboratories are discussed in Chapter Five under "NPDES Summary for 1993." USEPA evaluates the results for the QA samples as acceptable or unacceptable.

Results obtained by the Fernald site laboratories for the 1993 DMR QA samples are summarized in Table 24 on page A-42. All but one of the site results submitted during 1993 for DMR QA were determined to be acceptable by USEPA. The analysis designated as unacceptable was for lead. An investigation was conducted to determine the cause of the problem, but no apparent cause was found. This should not cause a problem in the future since USEPA has approved a modification of the permit to no longer specify lead as a monitored pollutant under the NPDES permit as of May 20, 1993.

Commercial Proficiency Environmental Testing

The Fernald site laboratories also participate in the Proficiency Environmental Testing (PET) QA program. This is a voluntary program administered by a commercial vendor of analytical laboratory QA services. Each laboratory pays a fee to participate. Periodically, the Fernald site submits PET samples to the various onsite laboratories concurrently with field samples. Results obtained from these QA samples are compiled and submitted for evaluation by the commercial vendor. A monthly evaluation report is then provided by the vendor comparing the Fernald site laboratories' results to the reference values for each sample and to the results obtained by other laboratories participating in the PET program. By using this commercial service, the site has an additional resource for evaluating its laboratory performance.

A summary of the performance of the site laboratories in the PET QA program during 1993 is provided in Table 25 on pages A-43 and A-44. For the 27 parameters reported, 96% of the results met acceptable criteria. The PET program does not specify criteria for overall evaluation of a laboratory; however, 96% shows a good performance, consistent with 96% in 1992.

Ohio Department of Health Split Samples

Another enhancement to the Fernald site QA program is the Ohio Department of Health (ODH) Split Water and Milk Program. The site has participated in this program with the state since 1987. As the split sample program compares results of samples collected directly from the environment, the true variability in analysis between laboratories is measured.

This program is very similar to the duplicate sample program described above. Although the sampling is similar, the duplicate samples may measure a single laboratory's precision, whereas the ODH split program measures proficiency between two laboratories.

To obtain split samples, technicians alternately add a portion of the sample being collected to their individual sample containers. This collection method helps ensure that both samples are as identical as possible. Split samples are then submitted to two independent laboratories for analysis.

The site did not receive results for ODH samples collected during 1992 in time to be included in the 1992 SER, so they are presented in this report (see Table 26 on pages A-45 through A-47). Also, the results for the 1993 ODH split samples were not received in time for inclusion in the 1993 report but will be presented in next year's report.

Contract Laboratory Quality Assurance

Because of the great number of analyses required to support all its various environmental sampling and analyses programs, the site uses commercial laboratories to supplement its onsite analytical laboratories. Commercial laboratories must meet stringent requirements before being selected to provide environmental analytical services. Commercial laboratories, in many cases, must also be certified and have licenses from the state. To select the best qualified laboratory, experienced auditors conduct comprehensive reviews of the laboratory's management, operations, and performance. These reviews are conducted before and also during the service life of the contract. Topics typically reviewed during the audits are:

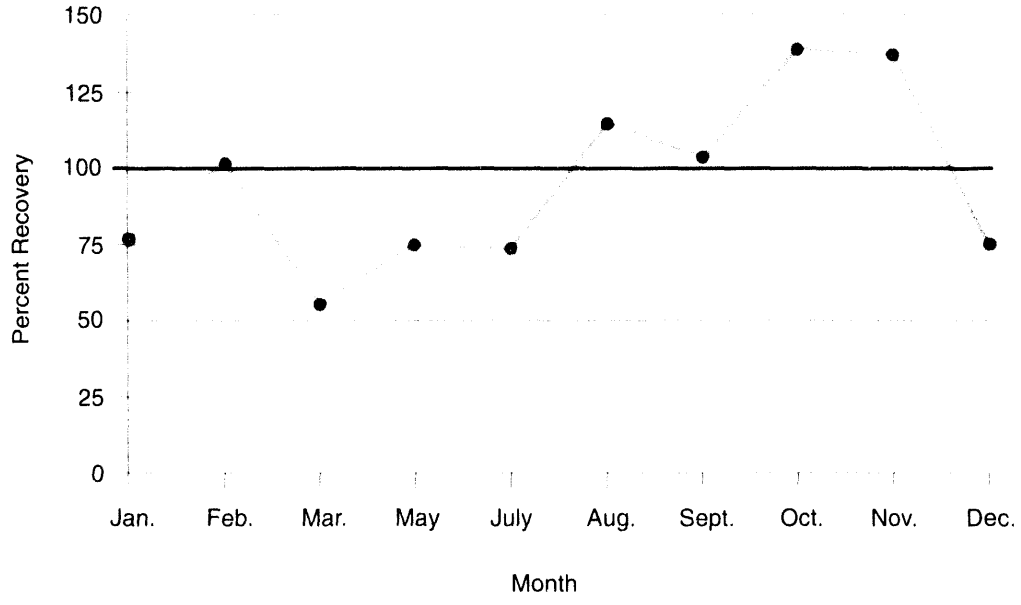
- Analytical equipment;
- Analytical procedures;
- Personnel qualifications;
- Sample handling and preservation;
- Data evaluation and record keeping; and
- Requirements for precision, accuracy, and detection levels.

Auditors also review results obtained in independent QA programs as part of the evaluation of each candidate laboratory's analytical capabilities. Onsite audits of the laboratories' facilities and operations are then conducted by Sampling and Analysis Management, Procurement, and QA personnel before final selections are made. After selecting the laboratories, QA samples are submitted regularly with field samples in order to evaluate the contract laboratories' performance on a continuing basis.

As part of the ongoing activities for evaluating the performance of contract laboratories, the site regularly submits QA samples along with field samples to the laboratory that analyzes offsite air filter samples. Nine QA air filter samples, prepared with amounts of uranium known only to the site, were submitted to the laboratory with 1993 field samples. The known amounts of uranium on the QA filters were in the range of the amounts normally present in field samples. The percent recovery of the analyses ranged from 63 to 105%. All the results were in the acceptable range for spiked samples (50 to 150%).

The Fernald site employed the same QA measures to evaluate the contract laboratory's analysis of uranium in milk samples. Spiked sample recoveries measure the accuracy of the analyses. Figure 52 shows the percent recovery for the milk QA spike samples sent to the contract laboratory used for all 1993 milk samples (data also included in Table 8 on page A-12). The values ranged from 59 to 131% with an average of 94%. All these recoveries were within the acceptable range and much improved from the range obtained in 1992 (1 to 233%).

Figure 52: Milk/Uranium QA Samples, 1993



Appendices

Fernald Site Environmental Monitoring Data for 1993

Numerous sampling and analysis data are required to evaluate compliance with environmental regulations and to obtain accurate indications of the Fernald site's operations during 1993. The sampling and analysis results are provided in summary tables.

Many of the numerical values listed in the following data tables are preceded by the "less than" symbol (<). The less than symbol is used when the concentration of a chemical species (ion, molecule, compound, or radionuclide) in an environmental media (air, water, or sediment) could not be reliably measured in the sample which was analyzed. That is, the amount of the species, if present at all in the sample, was below the minimum measurable concentration. Thus, a value of <0.68 pCi/L listed as the concentration of uranium in milk means that the uranium concentration was less than 0.68 pCi/L but actually could have been anywhere from 0.00 to 0.67 pCi/L.

The minimum measurable concentration is not the same for all chemical species. For example, 0.25 pCi/g of radium–226 and 0.21 pCi/g of plutonium–238 are the approximate minimum measurable concentrations for sediment samples. These variations exist because of differences in chemical and physical properties of species in addition to differences in the capabilities of instruments available to measure these properties.

Also, the minimum measurable concentration is not always the same for a specific species in all samples of the same environmental media. That is, the minimum measurable concentration for uranium in groundwater samples may vary for water samples from two different locations. This is so because variations in the kinds or amounts of other substances in the two samples can influence how well a substance can be measured.

In addition, the minimum measurable concentration of a species will not always be the same for identical samples from the same location which are analyzed at different times. This variance occurs because of unavoidable minor fluctuations in the performance of analytical instrumentation used to perform sample measurements.

Negative results indicate that the radionuclide activity in the sample was less than the background activity within the measurement laboratory. A negative value is obtained by subtracting the laboratory background measurement from the sample measurement. Negative results are not actual concentrations but are useful in the statistical analysis of data.

TABLE 1: Meteorological Data, 1993

	Units	January	February	March	April	May	June	July	August	September	October	November	December
10 – Meter Wind Speed													
Maximum hourly average	kph (a)	20	19	36	27	19	16	15	15	18	19	20	24
Minimum hourly average	kph (a)	0.51	0.72	0.21	0.74	0.60	0.31	0.51	0.43	0.14	0.05	0.31	0.02
60 – Meter Wind Speed													
Maximum hourly average	kph (a)	39	39	51	44	30	32	27	24	36	36	34	34
Minimum hourly average	kph (a)	0.80	1.7	2.5	1.2	0.95	0.82	1.3	0.56	0.80	0.02	0.21	0.80
Ambient Air Temperature (b)													
Average	°C	1.2	-2.0	4.3	11	17	21	25	23	17	11	6.2	0.77
Maximum	°C	16	18	20	25	30	32	35	33	30	27	20	13
Minimum	°C	-11	-19	-13	-0.29	5.0	5.5	10	11	-0.52	-1.7	-5.7	-16
Dew Point (b)													
Average	°C	(c)	(c)	(c)	(c)	8.5 (d)	15 (d)	18 (d)	17	12 (d)	4.3	0.5 (d)	(c)
Maximum	°C	(c)	(c)	(c)	(c)	18	21	24	23	21	17	15	(c)
Minimum	°C	(c)	(c)	(c)	(c)	-0.38	0.85	8.6	6.0	-2.0	-6.4	-10	(c)
Precipitation													
Monthly Total	cm (e)	10	7.5	6.5	10	7.6	14	4.5	7.2	7.7	7.6	10	4.9
Daily Maximum	cm (e)	3.9	2.1	1.9	2.8	3.0	7.5	1.6	3.7	2.5	2.4	3.0	2.1

(a) To obtain wind speeds in miles per hour, divide by 1.6093.

(b) Ambient air temperature is measured at the 10-meter (33-foot) level. To obtain °F, multiply °C by 9, divide by 5, and add 32.

(c) Data not available due to sensor problems.

(d) Only partial data are available for calculations.

(e) To obtain precipitation amounts in inches, divide by 2.54.

TABLE 2: Estimated Population Distribution within 80 km (50 miles) of the Fernald Site, 1993 (a)

Compass Sector	0 – 1.6 km (0 – 1 mile)	1.6 – 3.2 km (1 – 2 miles)	3.2 – 4.8 km (2 – 3 miles)	4.8 – 6.4 km (3 – 4 miles)	6.4 – 8 km (4 – 5 miles)	8 – 16 km (5 – 10 miles)	16 – 32 km (10 – 20 miles)	32 – 48 km (20 – 30 miles)	48 – 64 km (30 – 40 miles)	64 – 80 km (40 – 50 miles)
N	2	54	193	20	140	2,157	15,117	7,201	16,590	13,291
NNE	0	71	51	113	147	12,263	8,174	9,742	30,568	86,398
NE	2	202	827	97	90	34,292	38,797	88,477	214,495	331,340
ENE	5	87	1,766	219	13	31,999	32,998	32,039	14,739	29,771
E	3	3	179	301	248	38,285	75,213	50,799	17,863	10,218
ESE	8	54	78	558	739	42,893	160,628	68,672	22,433	13,541
SE	10	200	52	394	680	53,789	271,217	96,398	28,351	11,194
SSE	6	349	165	217	492	21,506	226,652	58,844	12,567	8,122
S	3	7	17	253	538	9,177	32,980	38,030	8,392	9,825
SSW	3	27	205	40	188	5,638	8,999	7,630	5,390	10,277
SW	2	37	26	355	60	4,486	14,209	9,197	3,523	4,341
WSW	0	15	40	511	313	8,540	5,255	7,725	7,556	4,681
W	6	13	37	286	596	1,664	3,547	10,295	5,357	15,708
WNW	5	20	60	123	121	1,093	4,675	4,205	5,714	11,295
NW	1	18	261	269	254	1,196	1,423	3,757	22,376	8,795
NNW	2	7	97	312	722	1,239	12,713	5,128	48,409	15,256
Total	58	1,164	4,054	4,068	5,341	270,217	912,597	498,139	464,323	584,053
Total for all sectors: 2,744,014										

(a) Based on an extrapolation from 1990 census data by Geographic Data Systems Section, Computing and Telecommunications Division at Oak Ridge National Laboratory, April 1992.

TABLE 3: Uranium in Air, 1993

Sampling Location [a]	Number of Samples	Concentration ($pCi/m^3 \times 10^{-6}$) [b]			Percent of Standard [c]		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Fenceline							
AMS 1	28	-30	3,600	490	0.0	3.6	0.49
AMS 2	52	0.0	710	160	0.0	0.71	0.16
AMS 3	51	-60	3,300	380	0.0	3.3	0.38
AMS 4	52	-20	330	63	0.0	0.33	0.063
AMS 5	52	-10	350	73	0.0	0.35	0.073
AMS 6	52	5	190	62	0.005	0.19	0.062
AMS 7	52	-30	310	49	0.0	0.31	0.049
Onsite							
AMS 1A	25	64	4,100	1,100	0.064	4.1	1.1
AMS 8	51	43	4,100	650	0.043	4.1	0.65
AMS 9	51	100	17,000	1,600	0.10	17	1.6
Waste Pit Area							
AMS 17	52	-26	1,100	140	0.0	1.1	0.14
AMS 18	52	0.0	3,900	930	0.0	3.9	0.93
AMS 19	52	-47	410	97	0.0	0.41	0.097
AMS 20	52	-38	730	150	0.0	0.73	0.15
Offsite							
AMS 10	52	-30	55	19	0.0	0.055	0.019
AMS 11	52	-30	54	17	0.0	0.054	0.017
AMS 12	52	-40	51	12	0.0	0.051	0.012
AMS 13	52	-30	180	26	0.0	0.18	0.026
AMS 14	52	-30	58	22	0.0	0.058	0.022
AMS 15	52	-20	59	25	0.0	0.059	0.025
AMS 16	52	-30	78	25	0.0	0.078	0.025

(a) See Figure 21 on page 68 for locations.

(b) The amount of uranium in each sample is chemically determined and converted to units of activity using the conversion constant of 0.68 pCi/µg (natural uranium). Negative results indicate that the amount of uranium in the sample was less than the amount of uranium measured in a blank filter.

(c) Standard is 100,000 x 10^{-6} pCi/m^3, as listed in DOE Order 5400.5, "Radiation Protection of the Public and Environment."

TABLE 4: Radionuclides in Air, 1993

Sampling Location[b]	Concentration[a] ($pCi/m^3 \times 10^{-6}$) Strontium–90	Technetium–99	Cesium–137	Radium–226	Radium–228
AMS 2	< 5.1	< 6.6	< 20	< 2.1	< 78
AMS 3	< 6.4	< 94	< 24	< 1.9	< 98
AMS 4	< 5.1	< 76	< 19	15 ± 7.1	< 75
AMS 5	< 5.1	< 69	< 18	19 ± 7.4	< 55
AMS 6	< 5.1	< 73	< 18	7.4 ± 5.7	< 70
AMS 7	< 5.1	< 64	< 20	54 ± 11	< 58
AMS 8	39 ± 12	670 ± 120	< 21	19 ± 6.9	< 85
AMS 9	11 ± 3.5	76 ± 13	< 23	35 ± 9.3	< 87
AMS 10	< 4	53 ± 13	< 16	650 ± 95	< 63
AMS 11	< 4	< 20	< 13	130 ± 23	70 ± 40
AMS 12	22 ± 6.5	< 30	< 15	210 ± 30	< 60
AMS 13	< 4	< 38	< 15	220 ± 35	85 ± 48
AMS 14	< 4	< 28	< 15	220 ± 28	< 60
AMS 15	14 ± 4.5	< 28	500 ± 45	80 ± 14	75 ± 30
AMS 16	13 ± 4.0	< 25	< 15	17 ± 4.3	78 ± 43
DCG[c]	9,000,000	2,000,000,000	400,000,000	1,000,000	3,000,000

TABLE 4: Radionuclides in Air, 1993

Sampling Location[b]	Concentration[a] ($pCi/m^3 \times 10^{-6}$) Thorium–228	Thorium–230	Thorium–232	Neptunium–237	Plutonium–238
AMS 2	< 3.9	< 6.6	< 6.2	< 2.2	< 0.66
AMS 3	8.8 ± 12	33 ± 17	5.9 ± 10	< 2.7	< 0.17
AMS 4	< 3.4	12 ± 11	< 4.8	< 34	< 1.7
AMS 5	14 ± 11	42 ± 17	7.8 ± 8.5	< 7.0	< 3.0
AMS 6	< 21	< 18	< 15	< 1.6	0.71 ± 0.35
AMS 7	< 7.8	53 ± 22	19 ± 12	< 1.6	< 8.6
AMS 8	12 ± 11	27 ± 14	5.2 ± 8.0	< 2.1	< 0.85
AMS 9	10 ± 11	17 ± 13	< 8.7	< 5.5	0.85 ± 0.76
AMS 10	< 8.3	13 ± 8.5	< 5.8	8.5 ± 6.3	< 6
AMS 11	7.8 ± 2.5	8.3 ± 2.8	5.0 ± 2	< 1.4	< 1.2
AMS 12	< 110	< 88	< 130	< 0.5	< 0.43
AMS 13	9.8 ± 3.3	9.3 ± 3	7.5 ± 2.5	< 1.2	< 0.30
AMS 14	53 ± 24	21 ± 11	38 ± 18	0.55 ± 0.45	< 0.17
AMS 15	19 ± 14	< 4.3	< 13	< 130	< 0.11
AMS 16	98 ± 100	13 ± 20	< 33	< 0.3	< 0.3
DCG[c]	40,000	40,000	7,000	20,000	30,000

TABLE 4: Radionuclides in Air, 1993

Sampling Location[b]	Concentration[a] ($pCi/m^3 \times 10^{-6}$) Plutonium–239/240	Uranium–234	Uranium–235[d]	Uranium–236[d]	Uranium–238
AMS 2	< 0.78	87 ± 13	3.6 ± 0.55	2.3 ± 0.34	75 ± 11
AMS 3	< 0.59	130 ± 20	5.6 ± 0.84	3.5 ± 0.53	120 ± 17
AMS 4	< 6.7	36 ± 5.4	1.5 ± 0.23	0.94 ± 0.14	31 ± 4.7
AMS 5	< 0.70	41 ± 6.2	1.7 ± 0.26	1.1 ± 0.16	36 ± 5.4
AMS 6	< 0.47	35 ± 5.3	1.5 ± 0.22	0.91 ± 0.14	30 ± 4.5
AMS 7	< 0.35	28 ± 4.2	1.2 ± 0.18	0.73 ± 0.11	24 ± 3.6
AMS 8	< 0.93	370 ± 55	15 ± 2.3	9.6 ± 1.4	320 ± 48
AMS 9	< 1.9	870 ± 130	36 ± 5.5	23 ± 3.4	750 ± 110
AMS 10	< 6.0	24 ± 6	2.0 ± 1.1		2.2 ± 5.5
AMS 11	< 1.2	24 ± 6	1.5 ± 0.95		28 ± 6.8
AMS 12	< 0.17	24 ± 6	0.98 ± 0.78		25 ± 6.3
AMS 13	< 0.70	25 ± 6	1.3 ± 0.80		28 ± 6.5
AMS 14	< 0.17	30 ± 8	1.5 ± 1.1		28 ± 7.5
AMS 15	0.35 ± 0.30	30 ± 7.3	1.6 ± 0.95		33 ± 7.8
AMS 16	< 1.1	30 ± 7.5	2.0 ± 1.3		30 ± 7.8
DCG[c]	20,000	90,000	100,000	100,000	100,000

(a) Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(b) See Figure 21 on page 68 for sampling locations. Results from AMS 1 and AMS 1A were invalidated due to error in sampling and analysis.

(c) Derived concentration guides from DOE Order 5400.5, "Radiation Protection of the Public Environment," February 1990. Continuous inhalation of this concentration will result in a committed effective dose equivalent of 100 mrem (1 mSv).

(d) Concentration of uranium–235 plus uranium–236. Offsite AMS samples analyzed for isotopic uranium by alpha spectrometry which measures combined uranium–235 and uranium–236 activities; individual measurements of uranium isotopes performed by mass spectrometry on samples from other AMS locations.

Table 5: Comparison of Measured and Estimated Airborne Uranium Concentrations at the Fernald Site Fenceline

Uranium Concentration ($pCi/m^3 \times 10^{-6}$)

Location	Measured[(a)]	Estimated
AMS 2	130	5.0
AMS 3	360	7.9
AMS 4	40	2.3
AMS 5	50	2.8
AMS 6	40	3.5
AMS 7	20	7.3

(a) Corrected for background.

TABLE 6: Uranium in Grass and Soil, 1993

Sampling Location[a]	Distance from Center of the Site (km)	Grass Uranium Concentration (pCi/g dry)[b]	Soil Uranium Concentration (pCi/g)[b] 0 – 5 cm	Soil Uranium Concentration (pCi/g)[b] 5 – 10 cm
Onsite				
9	0.10	0.72 ± 0.15	18 ± 3.7	6.9 ± 1.5
8	0.15	0.19 ± 0.04	18 ± 3.9	12 ± 2.4
Fenceline				
1	0.16	0.038 ± 0.008	6.2 ± 1.3	3.0 ± 0.6
3	0.16	0.084 ± 0.018	11 ± 2.4	7.2 ± 1.5
4	0.49	0.022 ± 0.005	3.5 ± 0.7	2.8 ± 0.6
6	0.63	0.024 ± 0.005	4.4 ± 0.9	4.4 ± 0.9
5	0.64	0.064 ± 0.013	5.9 ± 1.2	5.5 ± 1.1
2	1.1	0.017 ± 0.004	4.2 ± 0.9	4.1 ± 0.9
7	1.3	0.023 ± 0.005	2.1 ± 0.4	1.8 ± 0.4
Offsite				
30	1.3	0.010 ± 0.002	5.3 ± 1.1	5.0 ± 1.1
31	1.9	0.026 ± 0.006	4.8 ± 1.0	3.6 ± 0.7
15	1.9	0.0095 ± 0.0020	1.2 ± 0.3	1.2 ± 0.3
12	2.2	0.0080 ± 0.0017	1.1 ± 0.2	1.1 ± 0.2
24	2.4	0.016 ± 0.003	2.9 ± 0.6	3.3 ± 0.7
10	2.6	0.0091 ± 0.0025	2.3 ± 0.5	2.9 ± 0.6
25	2.7	0.020 ± 0.004	1.3 ± 0.3	2.1 ± 0.4
11	3.7	0.012 ± 0.003	1.1 ± 0.2	0.95 ± 0.20
17	3.7	0.0043 ± 0.0009	0.65 ± 0.14	0.67 ± 0.14
20	3.7	0.010 ± 0.003	0.52 ± 0.11	0.51 ± 0.11
21	3.9	0.011 ± 0.002	0.32 ± 0.07	0.41 ± 0.09
33	4.2	0.010 ± 0.002	0.54 ± 0.11	0.60 ± 0.13
23	4.3	0.011 ± 0.002	0.52 ± 0.11	0.62 ± 0.13
22	5.0	0.014 ± 0.004	0.56 ± 0.12	0.50 ± 0.11
18	5.1	0.010 ± 0.002	0.66 ± 0.14	0.68 ± 0.14
14	5.4	0.013 ± 0.003	0.60 ± 0.13	0.53 ± 0.11
37	8.6	0.0045 ± 0.0010	0.39 ± 0.08	0.35 ± 0.07
19	8.8	0.012 ± 0.003	0.54 ± 0.11	0.52 ± 0.11
36	9.6	0.0074 ± 0.0019	0.38 ± 0.08	0.31 ± 0.07
35	9.8	0.0065 ± 0.0016	0.38 ± 0.08	0.34 ± 0.07
29	24	0.016 ± 0.003	0.41 ± 0.09	0.40 ± 0.08
28	40	(c)	0.44 ± 0.09	0.53 ± 0.11

(a) Locations (see Figure 24 on page 73) are listed in order of increasing distance from the center of the Fernald site production area (Plant 4).

(b) To obtain Bq/g, multiply pCi/g by 0.037. The plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(c) No grass was available to sample.

TABLE 7: Uranium in Produce and Soil, 1993

Sampling Location[a]	Distance from Center of the Site (km)	Concentration (pCi/g dry) [b]
Soil		
19	1.4	0.99 ± 0.10
14	1.6	2.0 ± 0.2
9	1.6	1.1 ± 0.1
23	1.6	1.0 ± 0.01
23	1.6	1.2 ± 0.1
24	1.6	1.5 ± 0.2
4	1.9	1.2 ± 0.1
18	1.9	0.87 ± 0.09
18	1.9	0.98 ± 0.10
18	1.9	0.58 ± 0.06
18	1.9	1.4 ± 0.01
6	2.0	1.2 ± 0.1
20	2.1	1.4 ± 0.2
15	2.4	1.8 ± 0.2
21	2.4	0.39 ± 0.41
21	2.4	0.82 ± 0.09
26	2.6	0.59 ± 0.06
30	2.6	0.64 ± 0.07
5	2.9	0.92 ± 0.10
12	3.6	1.2 ± 0.1
13	3.8	0.74 ± 0.08
10	4.0	0.83 ± 0.09
7	4.9	0.68 ± 0.07
28	6.2	0.60 ± 0.06
17	16	0.52 ± 0.05
11	24	0.59 ± 0.06
16	30	0.56 ± 0.06

Sampling Location[a]	Concentration (pCi/g dry) [b]
Tomatoes	
9	0.0014 ± 0.0002
4	0.0011 ± 0.0001
6	0.00040 ± 0.00005
15	0.0013 ± 0.0001
26	0.0020 ± 0.0002
30	0.0019 ± 0.0002
5	0.0017 ± 0.0002
12	0.0020 ± 0.0002
13	0.0016 ± 0.0002
10	0.0010 ± 0.0001
7	0.0035 ± 0.0004
28	0.00091 ± 0.00011
17	0.0012 ± 0.0001
11	0.0012 ± 0.0001
16	0.00060 ± 0.0007
Green (G) & Red (R) Peppers	
4 (G)	0.0047 ± 0.0005
4 (R)	0.0011 ± 0.0001
30 (G)	0.0049 ± 0.0005
5 (G)	0.0011 ± 0.0001
5 (R)	0.00082 ± 0.00010
12 (G)	0.00078 ± 0.00008
11 (G)	0.0013 ± 0.0001
16 (G)	0.00035 ± 0.00004

Sampling Location[a]	Concentration (pCi/g dry) [b]
Corn	
19	0.000086 ± 0.000011
14	0.00013 ± 0.00001
23	0.000032 ± 0.000004
4	0.00078 ± 0.00009
18	0.00021 ± 0.00002
18	0.000086 ± 0.000001
6	0.0014 ± 0.0002
21	0.00012 ± 0.00001
5	0.0015 ± 0.0003
13	0.00032 ± 0.00003
7	0.00019 ± 0.00003
28	0.0012 ± 0.0001
17	0.000064 ± 0.000008

TABLE 7: Uranium in Produce and Soil, 1993

Sampling Location[a]	Concentration (pCi/g dry) [b]
Potatoes (P) & Onions (O)	
15 (P)	0.0061 ± 0.0007
12 (P)	0.0037 ± 0.0004
7 (P)	0.0029 ± 0.0003
17 (P)	0.0020 ± 0.0003
17 (O)	0.0011 ± 0.0001
Apples	
9	0.00034 ± 0.00004
30	0.0015 ± 0.00016
13	0.00020 ± 0.00002
10	0.00035 ± 0.00004
17	0.00033 ± 0.00004
11	0.00084 ± 0.00010
Soybeans	
23	0.00045 ± 0.00005
24	0.00030 ± 0.00001
18	0.00057 ± 0.00006
18	0.00093 ± 0.00001
20	0.00017 ± 0.00002
21	0.0025 ± 0.0003

Sampling Location[a]	Concentration (pCi/g dry) [b]
Cucumber (C), Eggplant (E), Green Beans (G), & Squash (S)	
4 (C)	0.0054 ± 0.0006
4 (S)	0.0053 ± 0.0006
4 (S)	0.0065 ± 0.0001
4 (E)	0.00094 ± 0.00010
6 (B)	0.011 ± 0.001
15 (S)	0.0017 ± 0.0002
15 (S)	0.0014 ± 0.0002
30 (C)	0.0017 ± 0.0002
5 (E)	0.00064 ± 0.00007
10 (S)	0.019 ± 0.020
7 (S)	0.00027 ± 0.00004
7 (S)	0.00036 ± 0.00004
17 (C)	0.00026 ± 0.00004
17 (B)	0.0011 ± 0.0001

(a) Locations (see Figure 26 on page 76) are listed in order of increasing distance from the center of the Fernald site production area (Plant 4).

(b) To obtain Bq/g, multiply pCi/g by 0.037. The plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

TABLE 8: Uranium in Milk, 1993

Concentration of Uranium

Month	Local Dairy (pCi/L)[a]	Background Dairy[b] (pCi/L)[a]	QC Spike Recovery (pCi/L)[a] Background Dairy	
			Expected	Measured
January	0.009 ± 0.033	0.036 ± 0.042	3.4	2.6 ± 0.30
February	0.059 ± 0.054	0.094 ± 0.057	3.4	3.7 ± 0.42
March	0.047 ± 0.039	0.22 ± 0.09	3.4	2.1 ± 0.4
April	0.11 ± 0.06	0.091 ± 0.062	(c)	
May	0.14 ± 0.04	0.058 ± 0.050	3.4	2.5 ± 0.4
June	0.15 ± 0.07	0.11 ± 0.07	(c)	
July	0.020 ± 0.032	0.067 ± 0.060	10	6.9 ± 0.70
August	0.019 ± 0.033	0.11 ± 0.050	3.4	4.1 ± 0.43
September	0.020 ± 0.033	0.034 ± 0.059	3.6	3.8 ± 0.5
October	0.024 ± 0.042	0.012 ± 0.043	14	18 ± 2.2
November	0.0050 ± 0.16	0.052 ± 0.12	3.4	4.4 ± 1.4
December	0.095 ± 0.17	0.13 ± 0.21	3.3	2.6 ± 0.90

(a) To obtain Bq/L, multiply pCi/L by 0.037. Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(b) Dairy is about 37 km (23 miles) WSW of the Fernald site.

(c) Sample invalidated due to error in laboratory processing.

TABLE 9: Radionuclides in Milk, 1993

Radionuclide	Local Dairy (pCi/L)[a]	Background Dairy[b] (pCi/L)[a]
Beryllium–7	(c)	(c)
Bismuth–214	(c)	(c)
Cesium–137	9.1 ± 5.8	8.2 ± 5.7
Lead–212	26 ± 19	25 ± 19
Lead–214	(c)	(c)
Radium–226	-1.4 ± 0.31	-1.2 ± 0.32
Radium–228	(c)	(c)
Protactinium–234	1,300 ± 940	660 ± 900
Strontium–90	(c)	(c)
Technetium–99	-300 ± 81	-180 ± 6.3
Thallium–208	11 ± 8.0	8.5 ± 7.9
Thorium–228	1.5 ± 1.1	0.047 ± 0.19
Thorium–230	1.1 ± 0.91	0.085 ± 0.08
Thorium–232	-0.15 ± 0.34	0.047 ± 0.19
Uranium–234	0.0013 ± 0.0045	0.065 ± 0.033
Uranium–235	0.00065 ± 0.0032	-0.0035 ± 0.0076
Uranium–238	(d)	0.067 ± 0.033

(a) To obtain Bq/L, multiply pCi/L by 0.037. Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level. Negative results indicate that the radionuclide activity in the sample was less than the background activity within the measurement laboratory.

(b) Dairy is about 37 km (23 miles) WSW of the Fernald site.

(c) Laboratory difficulties in analysis resulted in suspect data.

(d) Results not available due to errors in laboratory analysis.

TABLE 10: Environmental TLD Direct Radiation Measurements, 1993

Location Description[a]	Location Number	1992 Dose Rate (mrem/yr)[b, c]	1993 Dose Rate (mrem/yr)[b, c]
Fenceline			
AMS 1[d]	1	60 ± 10	64 ± 2.4
AMS 2	2	70 ± 12	72 ± 1.5
AMS 3	3	68 ± 11	65 ± 2.1
AMS 4	4	68 ± 11	67 ± 1.3
AMS 5	5	69 ± 11	66 ± 1.1
AMS 6	6	65 ± 11	68 ± 0.9
AMS 7	7	63 ± 10	64 ± 1.3
Site fenceline near K–65 silos	13	68 ± 11	69 ± 1.3
Site fenceline near K–65 silos	14	64 ± 11	65 ± 1.2
Site fenceline near K–65 silos	15	67 ± 11	73 ± 9.1
Site fenceline near K–65 silos	16	65 ± 11	68 ± 1.2
Site fenceline near K–65 silos	17	66 ± 11	67 ± 0.9
Onsite			
AMS 1A[e]	1A	—	120 ± 2.0
AMS 8	8	64 ± 10	67 ± 2.0
AMS 9	9	87 ± 14	91 ± 2.7
K-65 perimeter fence	22	180 ± 30	250 ± 13
K-65 perimeter fence	23	170 ± 29	260 ± 10
K-65 perimeter fence	24	140 ± 23	160 ± 2.9
K-65 perimeter fence	25	150 ± 24	200 ± 6.4
K-65 perimeter fence	26	130 ± 21	140 ± 4.3
OSH Building, Room 218[f]	32	47 ± 8	50 ± 1.0
Offsite			
AMS 10	10	51 ± 8	52 ± 1.1
AMS 11	11	63 ± 10	62 ± 1.0
AMS 13	12	56 ± 9	57 ± 0.7
Westwood, OH	18	67 ± 11	69 ± 1.0
Brookville, IN	19	59 ± 10	61 ± 0.6
AMS–15, Miamitown	20	51 ± 8	54 ± 3.0
AMS–16, University of Cincinnati	21	55 ± 9	56 ± 0.9
AMS 12	27	59 ± 10	61 ± 0.8
Beta Building, St. Rt. 128[f]	30	47 ± 8	53 ± 1.2

(a) See Figure 27 on page 79 for locations.

(b) Plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

(c) Dose is calculated from the sum of quarterly measurements at each location.

(d) 1993 dose for AMS 1 is based on two quarterly measurements.

(e) 1993 dose for AMS 1A is based on one quarterly measurement. AMS 1A was not sampled in 1992.

(f) TLDs 30 and 32 are located inside buildings and are used as control locations.

TABLE 11: Radionuclides Discharged to the Great Miami River, 1993

Manhole-175

Radionuclide [a]	Total Curies 1993	1993 Average Concentration (pCi/L)[b]	Standard[c] pCi/L	Percent of Standard[d]
Actinium–228[e]	< 0.0043	< 4.8	60,000	0.008
Radium–224[f]	< 0.00015	< 0.17	400	0.042
Radium–226	< 0.0022	< 2.5	100	2.5
Radium–228	< 0.0043	< 4.8	100	4.8
Thorium–228	< 0.00015	< 0.17	400	0.042
Thorium–230	0.00018	< 0.20	300	0.067
Thorium–231	0.0058	5.4	100,000	0.0054
Thorium–232	< 0.00009	< 0.10	50	0.20
Thorium–234[g]	0.15	140	10,000	1.4
Uranium–234	0.099	96	500	19
Uranium–235	0.0058	5.4	600	0.9
Uranium–236	0.0040	3.7	500	0.7
Uranium–238	0.15	140	600	23

South Plume (SP3)

Radionuclide [a]	Total Curies 1993	1993 Average Concentration (pCi/L)[b]	Standard[c] pCi/L	Percent of Standard[d]
Actinium–228[e]	< 0.00057	< 0.47	60,000	0.00078
Radium–224[f]	< 0.00017	< 0.14	400	0.035
Radium–226	< 0.0023	< 1.9	100	1.9
Radium–228	< 0.00057	< 0.47	100	0.47
Thorium–228	< 0.00017	< 0.14	400	0.035
Thorium–230	< 0.00057	< 0.47	300	0.16
Thorium–231	0.00032	0.10	100,000	0.00010
Thorium–232	< 0.0024	< 0.10	50	0.20
Thorium–234[g]	0.0061	0.14	10,000	0.0014
Uranium–234	0.0038	3.1	500	0.62
Uranium–235	0.00034	0.28	600	0.047
Uranium–236	< 0.00012	< 0.10	500	0.020
Uranium–238	0.0073	6.0	600	1.0

(a) Radionuclide concentrations in the plant effluent discharged to the Great Miami River through the effluent pipeline are determined from monthly or quarterly composites of daily, 24-hour continuous samples at Discharge 001 (Manhole-175) and SP3.

(b) Averages are flow-weighted. To obtain Bq/L, multiply pCi/L by 0.037.

(c) As stated in DOE Order 5400.5, "Radiation Protection of the Public and Environment."

(d) Percent of standard relates to the average concentration. Where less than (<) is reported, the maximal possible value is assumed.

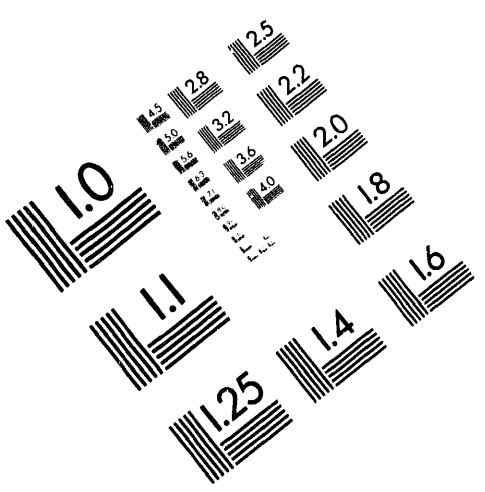
(e) Calculated based on radioactive decay equilibrium with radium–228.

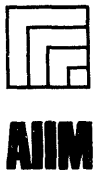
(f) Calculated based on radioactive decay equilibrium with thorium–228.

(g) Calculated based on radioactive decay equilibrium with uranium–238.

TABLE 12: Radionuclides in Surface Water, 1993

Parameter	Sampling Location[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Standards (pCi/L)[c]	Percent of Standard Minimum	Maximum	Average
Great Miami River									
Total Uranium									
Upstream of Effluent Line	W1	52	0.74	1.6	1.1	550	0.13	0.29	0.20
Downstream of Effluent Line	W3	52	0.74	1.8	1.2	550	0.13	0.33	0.22
Downstream of Effluent Line	W4	52	0.81	1.6	1.2	550	0.15	0.29	0.22
Radium–226[d]									
Upstream of Effluent Line	W1	12	< 0.60	2.2	< 2.1	100	< 0.60	2.2	< 2.1
Downstream of Effluent Line	W3	12	< 1.9	5.6	< 2.4	100	< 1.9	5.6	< 2.4
Downstream of Effluent Line	W4	12	< 1.6	2.5	< 2.1	100	< 1.6	2.5	< 2.1
Radium–228[d]									
Upstream of Effluent Line	W1	12	< 0.34	4.4	< 2.0	100	< 0.34	4.4	< 2.0
Downstream of Effluent Line	W3	12	< 0.34	4.4	< 2.0	100	< 0.34	4.4	< 2.0
Downstream of Effluent Line	W4	12	< 0.34	4.4	< 1.9	100	< 0.34	4.4	< 1.9
Strontium–90[d]									
Upstream of Effluent Line	W1	2	< 0.39	< 0.39	< 0.39	1,000	< 0.039	< 0.039	< 0.039
Downstream of Effluent Line	W3	2	< 0.39	< 0.39	< 0.39	1,000	< 0.039	< 0.039	< 0.039
Downstream of Effluent Line	W4	2	< 0.39	< 0.39	< 0.39	1,000	< 0.039	< 0.039	< 0.039
Cesium–137[d]									
Upstream of Effluent Line	W1	2	< 4.4	< 4.8	< 4.6	3,000	< 0.15	< 0.16	< 0.15
Downstream of Effluent Line	W3	2	< 4.7	< 4.8	< 4.8	3,000	< 0.16	< 0.16	< 0.16
Downstream of Effluent Line	W4	2	< 4.6	< 4.8	< 4.7	3,000	< 0.15	< 0.16	< 0.16
Technetium–99[d]									
Upstream of Effluent Line	W1	2	< 7.2	< 7.3	< 7.2	100,000	< 0.0072	< 0.0073	< 0.0072
Downstream of Effluent Line	W3	2	< 7.2	< 7.2	< 7.2	100,000	< 0.0072	< 0.0072	< 0.0072
Downstream of Effluent Line	W4	2	< 7.3	< 7.5	< 7.4	100,000	< 0.0073	< 0.0075	< 0.0074





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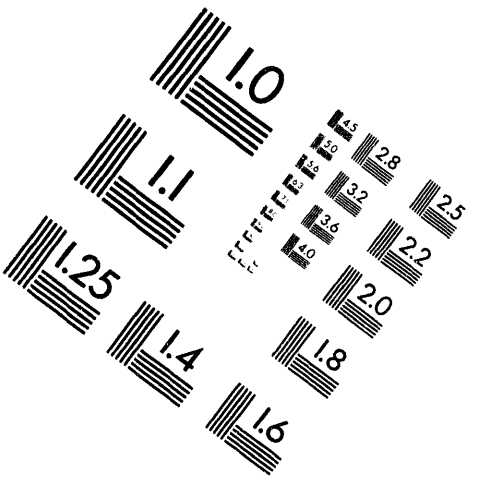

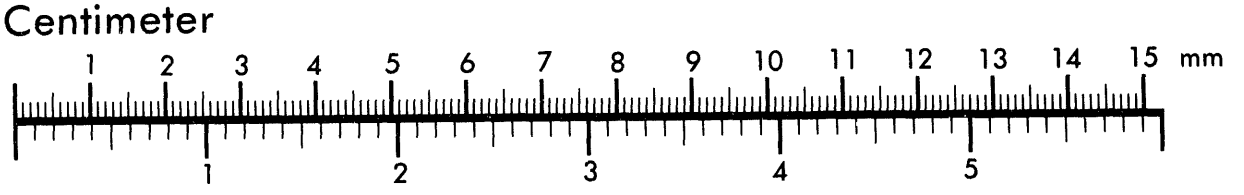

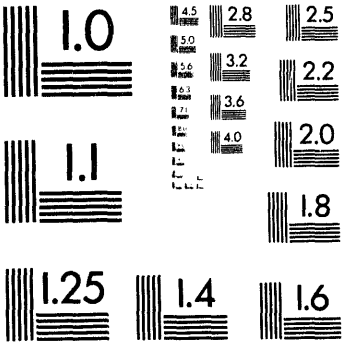

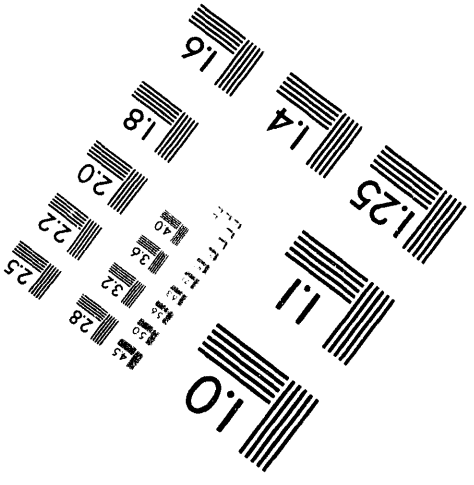

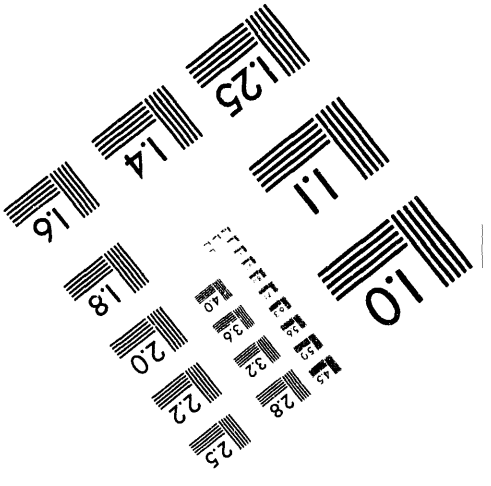

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TABLE 12: Radionuclides in Surface Water, 1993

Parameter	Sampling Location[a]	Number of Samples	Concentration (pCi/L)[b] Minimum	Maximum	Average	Standards (pCi/L)[c]	Percent of Standard Minimum	Maximum	Average
Paddys Run									
Total Uranium									
Upstream of the Site	W5	47	0.34	1.4	0.67	550	0.062	0.25	0.12
Onsite	W9	37	0.34	40	2.4	550	0.062	7.3	0.44
Onsite	W-10 US	30	0.88	430	32	550	0.16	78	5.8
Onsite	W10	30	0.81	430	40	550	0.15	78	7.3
Onsite	W-10 DD	34	1.2	1,100	380	550	0.22	200	69
Onsite	W-10 DS	29	1.1	470	56	550	0.20	85	10
Onsite	W11	24	1.6	13	4.4	550	0.29	2.4	0.80
Downstream of the Site	W7	24	2.0	6.2	3.9	550	0.36	1.1	0.71
Downstream of the Site	W8	39	1.2	5.7	2.8	550	0.22	1.0	0.51
Radium–226[d]									
Upstream of the Site	W5	6	< 1.6	2.5	< 2.1	100	< 1.6	2.5	< 2.1
Downstream of the Site	W7	8	< 1.6	2.2	< 2.1	100	< 1.6	2.2	< 2.1
Downstream of the Site	W8	4	< 2.2	2.2	< 2.2	100	< 2.2	2.2	< 2.2
Radium–228[d]									
Upstream of the Site	W5	6	< 0.34	2.2	< 1.6	100	< 0.34	2.2	< 1.6
Downstream of the Site	W7	8	< 0.34	2.2	< 1.5	100	< 0.34	2.2	< 1.5
Downstream of the Site	W8	4	< 2.2	2.2	< 2.2	100	< 2.2	2.2	< 2.2

(a) See Figure 32 on page 88 for sampling locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) Standards as listed in DOE Order 5400.5, "Radiation Protection of the Public and Environment." The standards are based on drinking 730 liters (about 200 gallons) of water per year. The Fernald site compares data from the Great Miami River and Paddys Run to these standards even though neither is designated as a public water supply by OEPA (OEPA Regulations, Vol. 1, 3475–1–21).

(d) Samples are composited as follows:
- One-month composites of daily samples from W1 and W3,
- One-month composites of weekly samples from W4 and either W7 or W8,
- Two-month composites of weekly samples from W5, and
- Semiannual composites were used for those isotopes where two samples are recorded.

TABLE 13: Radionuclides in Great Miami River, Paddys Run and Storm Sewer Outfall Ditch Sediments, 1993[a]

Radionuclide	Number of Samples	Concentration (pCi/g dry)[b,c] Minimum	Maximum	Average for All Samples[c]
Great Miami River North of the Effluent Line				
Total Uranium	2	0.50 ± 0.05	0.75 ± 0.08	0.62
Great Miami River at the Effluent Line				
Total Uranium	1	0.82 ± 0.09	0.82 ± 0.09	0.82
Great Miami River South of the Effluent Line, and North of Paddys Run				
Total Uranium	4	0.30 ± 0.03	0.73 ± 0.08	0.57
Great Miami River South of Paddys Run				
Total Uranium	2	0.78 ± 0.08	0.82 ± 0.09	0.80
Paddys Run Background (North of S.R. 126)				
Radium–226	4	0.25 ± 0.15	0.63 ± 0.15	0.37
Thorium–228	4	0.25 ± 0.03	0.60 ± 0.07	0.35
Thorium–230	4	0.30 ± 0.03	0.60 ± 0.07	0.43
Thorium–232	4	0.26 ± 0.03	0.48 ± 0.09	0.33
Total Uranium	4	0.57 ± 0.06	0.88 ± 0.09	0.72
Paddys Run North of the Storm Sewer Outfall Ditch				
Radium–226	12	-0.19 ± 0.09	0.68 ± 0.12	0.23
Thorium–228	12	0.25 ± 0.04	0.50 ± 0.05	0.35
Thorium–230	12	0.08 ± 0.10	0.79 ± 0.07	0.45
Thorium–232	12	0.22 ± 0.35	0.47 ± 0.05	0.33
Total Uranium	12	0.55 ± 0.06	2.5 ± 0.27	1.3
Storm Sewer Outfall Ditch				
Radium–226	8	0.29 ± 0.08	0.95 ± 0.13	0.61
Thorium–228	8	0.30 ± 0.04	0.73 ± 0.06	0.51
Thorium–230	8	0.53 ± 0.05	1.9 ± 0.15	1.1
Thorium–232	8	0.32 ± 0.04	0.81 ± 0.06	0.49
Total Uranium	8	1.4 ± 0.15	11 ± 1.1	6.5
Paddys Run South of Storm Sewer Outfall Ditch				
Total Uranium	12	0.49 ± 0.05	3.8 ± 0.40	1.5

(a) See Figure 34 on page 92 for sampling locations.

(b) Multiply pCi/g by 0.037 to obtain Bq/g. Negative results indicate that the radionuclide activity in the sample was less than the background activity within the measurement laboratory.

(c) The plus/minus (±) values are the uncertainty in the analytical results at the 95% confidence level.

TABLE 14: Uranium Concentrations in Fish from the Great Miami River, 1993

Sampling Location[a]	Family[b]	Number of Samples	Concentration pCi/g [c]		
			Minimum	Maximum	Geometric Mean
RM 38	1	11	0.0027	0.0094	0.0061
Upstream of	2	4	0.0013	0.011	0.0039
the Hamilton Dam	3	2	0.0013	0.0020	0.0016
	4	6	0.0018	0.013	0.0041
	5	0	—	—	—
	Location Summary	**23**	**0.0013**	**0.013**	**0.0045**
RM 24	1	8	0.0033	0.012	0.0071
At the Effluent Line	2	3	0.0021	0.082	0.0075
	3	4	0.0038	0.0081	0.0058
	4	1	0.0083	0.0083	0.0083
	5	6	0.0025	0.029	0.0083
	Location Summary	**22**	**0.0021**	**0.082**	**0.0066**
RM 19	1	2	0.0031	0.0052	0.0040
At Confluence	2	4	0.0012	0.0042	0.0026
of Paddys Run and	3	4	0.0013	0.0039	0.0020
the Great Miami River	4	5	0.0041	0.027	0.015
	5	6	0.0008	0.0034	0.0014
	Location Summary	**21**	**0.0008**	**0.027**	**0.0033**

(a) See Figure 35 on page 94 for sampling locations.

(b) Family:
1 = Cyprinidae (carp and shiner)
2 = Catostomidae (carpsucker, redhorse, and buffalo)
3 = Centrarchidae, Percidae, Percichthyidae and Sciaenidae (bass, sunfish, drum, sauger, bluegill, longear, and gar)
4 = Clupeidae (gizzard shad and skipjack herring)
5 = Ictaluridae (catfish and bullhead)

(c) All concentrations are reported in dry weight. Multiply by 0.037 to obtain Bq/g (dry weight).

TABLE 15: NPDES Data, 1993

Sampling Location and Parameter	Units[a]	Monitoring Requirements	Daily Monitoring Results			Permit Limits[c]		Percent Compliance[d]
			Minimum	Maximum	Average[b]	Daily Maximum	Monthly Average	
Discharge 001 (MH175 to Great Miami)								
Flow Rate	MGD	Continuous	0.052	1.7	0.64	NA	NA	NA
pH	S.U.	Continuous	4.8	10	NA	Range = 6.5 to 9.0		99.73[e]
Dissolved Oxygen	mg/L	Weekly/Grab	5.6	12	8.7	Minimum = 5.0		100.0
Suspended Solids	mg/L	Wk/24hr Comp	2.0	70	9.0	45	30	98.28
Oil & Grease	mg/L	Weekly/Grab	< 5.0	7	< 5.0	15	15	100.0
Cyanide[e]	mg/L	Weekly/Grab	< 0.005	< 0.005	< 0.005	0.076	0.036	100.0
Copper	µg/L	Wk/24hr Comp	< 14	20	< 14	94	23	100.0
Silver[e]	µg/L	Wk/24hr Comp	< 10	< 10	< 10	26	12	100.0
BOD-C	mg/L	Wk/24hr Comp	0.35	4.2	1.4	30	20	100.0
Lead[e]	µg/L	Wk/24hr Comp	< 3.0	5.8	< 3.3	780	60	100.0
Suspended Solids	kg/day	Wk/24hr Comp	1.6	120	20	150	99	100.0
Oil & Grease	kg/day	Weekly/Grab	< 3.7	28	< 11	50	50	100.0
Cyanide[e]	kg/day	Weekly/Grab	< 0.0061	< 0.028	< 0.014	0.25	0.12	100.0
Copper	kg/day	Wk/24hr Comp	< 0.010	0.080	< 0.031	0.31	0.077	100.0
Silver[e]	kg/day	Wk/24hr Comp	< 0.012	< 0.056	< 0.027	0.086	0.040	100.0
BOD-C	kg/day	Wk/24hr Comp	0.33	16	3.7	99	66	100.0
Lead[e]	kg/day	Wk/24hr Comp	< 0.0036	0.019	< 0.0089	2.6	0.20	100.0
							Percent Compliance	**99.79**
Discharge 002 (Spillway to Paddys Run)								
Flow Rate	MGD	Estimate	The Stormwater Retention Basin did not overflow during 1993.			NA	NA	NA
pH	S.U.	Event/Grab				Range = 6.5 to 9.0		100.0[e]
Suspended Solids	mg/L	Event/Comp				100	NA	100.0
Chromium (total)	µg/L	Event/Comp				3,986	NA	100.0
Chromium (+6)	µg/L	Event/Comp				19	NA	100.0
Oil & Grease	mg/L	Event/Grab				15	NA	100.0
Copper	µg/L	Event/Comp				45	NA	100.0
Nickel	µg/L	Event/Comp				3,137	NA	100.0
Silver	µg/L	Event/Comp				11.6	NA	100.0
							Percent Compliance	**100.0**

TABLE 15: NPDES Data, 1993

Sampling Location and Parameter	Units[a]	Monitoring Requirements	Daily Monitoring Results			Permit Limits[c]		Percent Compliance[d]
			Minimum	Maximum	Average[b]	Daily Maximum	Monthly Average	
Discharge 601 (Sewage Treatment Plant)								
Flow Rate	MGD	Continuous	0.018	0.34	0.17	NA	NA	NA
pH[g]	S.U.	Continuous	6.5	8.3	NA	Range = 6.5 to 9.0		100.0
Suspended Solids	mg/L	Wk/24hr Comp	< 2.0	16	< 3.0	40	20	100.0
Chromium (total)[f]	µg/L	Wk/24hr Comp	< 6.0	< 6.0	< 6.0	32	13	100.0
Fecal Coliform[h]	#Col/100 ml	Wk/24hr Comp	0.0	1,500	22	2,000	1,000	100.0
Fluoride[f]	mg/L	Wk/24hr Comp	0.25	0.34	0.29	5.1	2.3	100.0
Copper[f]	µg/L	Wk/24hr Comp	< 14	< 14	< 14	110	53	100.0
Nickel[f]	µg/L	Wk/24hr Comp	< 17	< 17	< 17	49	32	100.0
BOD-5	mg/L	Wk/24hr Comp	0.77	11	2.8	40	20	100.0
Suspended Solids	kg/day	Wk/24hr Comp	< 0.58	13	< 2.0	19	9.5	100.0
Chromium (total)[f]	kg/day	Wk/24hr Comp	< 0.0022	< 0.0053	< 0.0041	0.015	0.006	100.0
Fluoride[f]	kg/day	Wk/24hr Comp	0.096	0.29	0.20	2.4	1.1	100.0
Copper[f]	kg/day	Wk/24hr Comp	< 0.0052	0.012	< 0.0096	0.053	0.025	100.0
Nickel[f]	kg/day	Wk/24hr Comp	< 0.0063	< 0.015	< 0.012	0.023	0.015	100.0
BOD-5	kg/day	Wk/24hr Comp	0.39	6.8	2.0	19	9.5	100.0
							Percent Compliance	**100.0**
Discharge 602 (General Sump)								
Flow Rate	MGD	Continuous	0.033	0.20	0.046	NA	NA	NA
pH[e]	S.U.	Weekly/Grab	7.0	9.1	NA	Range = 6.5 to 9.0		94.74
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	22	< 7.1	54	41	100.0
Chromium (+6)[e]	µg/L	Wk/24hr Comp	< 6.0	< 6.0	< 6.0	17	12	100.0
Copper	µg/L	Wk/24hr Comp	< 14	24	< 14	110	66	100.0
Nickel	µg/L	Wk/24hr Comp	< 17	110	< 20	160	91	100.0
Chromium (total)	kg/day	Wk/24hr Comp	< 0.0008	0.0024	< 0.0011	0.013	0.010	100.0
Chromium (+6)[e]	kg/day	Wk/24hr Comp	< 0.0008	< 0.0040	< 0.0010	0.004	0.003	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0018	0.0064	< 0.0022	0.027	0.016	100.0
Nickel	kg/day	Wk/24hr Comp	< 0.0021	0.017	< 0.0032	0.040	0.022	100.0
							Percent Compliance	**99.76**
Discharge 604 (LiftStation)[e]								
Flow Rate	MGD	Continuous	0.004	0.73	0.15	NA	NA	NA
pH	S.U.	Continuous	6.7	9.2	NA	Range 6.5 to 9.0		100.0[i]
Suspended Solids	mg/L	Wk/24hr Comp	< 2.0	83	< 12	100	30	100.0
Oil & Grease	mg/L	Weekly/Grab	< 5.0	11	< 5.0	15	15	100.0
							Percent Compliance	**100.00**

TABLE 15: NPDES Data, 1993

Sampling Location and Parameter	Units[a]	Monitoring Requirements	Daily Monitoring Results Minimum	Maximum	Average[b]	Permit Limits[c] Daily Maximum	Monthly Average	Percent Compliance[d]
Discharge 605 (Bioreactor)								
Flow Rate	MGD	Continuous	0.002	0.22	0.10	NA	NA	NA
pH[g]	S.U.	Continuous	6.5	8.6	NA	Range = 6.5 to 9.0		100.0[i]
Suspended Solids	mg/L	Wk/24hr Comp	2.0	30	11	45	30	100.0
Nitrate-Nitrogen	mg/L	Wk/24hr Comp	0.4	30	4.7	140	73	100.0
Chromium (total)	µg/L	Wk/24hr Comp	< 6.0	21	9.4	27	12	96.43
Copper	µg/L	Wk/24hr Comp	< 14	1	< 14	90	45	100.0
Nickel	µg/L	Wk/24hr Comp	< 17	< 17	< 17	42	29	100.0
BOD-5	mg/L	Wk/24hr Comp	0.30	34	3.8	45	30	100.0
Suspended Solids	kg/day	Wk/24hr Comp	0.18	16	4.6	38	26	100.0
Nitrate-Nitrogen	kg/day	Wk/24hr Comp	0.10	16	1.4	120	62	100.0
Chromium (total)	kg/day	Wk/24hr Comp	<0.0003	0.010	< 0.0038	0.023	0.010	100.0
Copper	kg/day	Wk/24hr Comp	< 0.0006	0.012	< 0.0058	0.077	0.039	100.0
Nickel	kg/day	Wk/24hr Comp	< 0.0008	< 0.014	< 0.0068	0.036	0.025	100.0
BOD-5	kg/day	Wk/24hr Comp	0.027	14	1.5	38	26	100.0
							Percent Compliance	**99.78**
Discharge 606 (Retention Basin)[e]								
Flow Rate	MGD	Continuous	0.037	0.75	0.38	NA	NA	NA
pH	S.U.	Continuous	4.5	9.6	NA	Range = 6.5 to 9.0		97.34[i]
							Percent Compliance	**97.34**
							Total Compliance	**99.73**

(a) MGD stands for million gallons per day, and S. U. stands for standard units.

(b) Flow-weighted daily averages are shown as less than (<) if more than one quarter of the values were less than the detection limit.

(c) Values have been rounded for consistency of data presentation.

(d) Percent compliance is determined by comparing the noncompliance with the compliance opportunities.

(e) Permit modified to eliminate monitoring requirement effective May 20, 1993.

(f) Permit modified to reduce monitoring requirement to monthly monitoring effective May 20, 1993.

(g) Permit modified to reduce monitoring requirement to daily grab effective May 20, 1993.

(h) Average value has been calculated as a geometric mean.

(i) Individual excursions of less than one hour and the sum of all excursions totalling less than 7.26 hours a month are not noncompliances.

TABLE 16: Uranium in Private Wells, 1993

Well Number[a]	Number of Samples	Concentration (pCi/L)[b]			Percent of Standard[c]		
		Minimum	Maximum	Average	Minimum	Maximum	Average
1	12	< 0.1	0.14	< 0.7	< 1.0	1.0	< 0.52
3	12	< 0.1	0.14	< 0.7	< 1.0	1.0	< 0.50
4	12	0.81	2.2	1.4	6.0	16	10
7	7	0.95	1.1	1.0	7.0	8.0	7.5
8	12	0.54	0.61	0.59	4.0	4.5	4.3
9	12	0.74	1.4	1.0	5.5	11	7.7
10	12	0.27	0.47	0.37	2.0	3.5	2.8
11	12	0.81	1.5	1.1	6.0	11	8.2
12[d]	12	28	110	59	210	800	440
13[d]	26	30	53	44	230	390	330
14	24	1.0	1.4	1.2	7.5	10	9.0
15[d]	12	150	210	190	1,100	1,600	1,400
16	12	0.34	0.61	0.50	2.5	4.5	3.7
18	12	0.20	0.34	0.27	1.5	2.5	2.0
19	11	< 0.1	0.10	< 0.05	< 1.0	0.74	< 0.37
21	12	0.14	0.27	0.21	1.0	2.0	1.6
22	12	0.61	1.2	0.78	4.5	8.0	5.8
23	12	0.27	0.95	0.59	2.0	7.0	4.4
24	12	0.20	0.41	0.34	1.5	3.0	2.6
25	4	0.20	0.27	0.25	1.5	2.0	1.9
26	12	< 0.1	0.14	< 0.08	< 1.0	1.0	< 0.59
28	4	0.54	0.68	0.59	4.0	5.0	4.4
29	12	1.2	1.6	1.3	9.0	12	9.6
30	4	0.27	0.34	0.32	2.0	2.5	2.4
32	12	< 0.1	0.20	< 0.07	< 1.0	1.5	< 0.51
33	12	0.20	0.41	0.34	1.5	3.0	2.5
34	7	2.7	5.1	4.0	20	38	29
35	12	1.2	1.6	1.3	8.0	12	9.6
36	12	0.68	0.95	0.75	5.0	7.0	5.6
37	1	—	—	1.1	—	—	8.1
38[e]	4	0.07	0.27	0.19	0.5	2.0	1.4
39[d]	12	3.2	6.7	4.4	24	50	33
40[d]	12	2.0	2.9	2.4	15	22	18
41	12	0.34	0.41	0.35	2.5	3.0	2.6
55	4	0.14	0.34	0.25	1.0	2.5	1.9
56	5	0.27	1.8	0.71	2.0	13	5.3

(a) See Figure 36 on page 100 for well locations. Wells are numbered in order of first time sampled.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) Proposed USEPA standard of 13.5 pCi/L (20 ppb).

(d) These wells are used for monitoring purposes only.

(e) Sample collected from a cistern.

TABLE 17: Comprehensive Groundwater Samples with Uranium Concentrations above USEPA Proposed Standard, 1993 (a)

Well(b)	Location	Sample Date	Concentration (pCi/L)(c)	Concentration (ppb)
1011	West of Pit # 5	July 16	30	45
1011	West of Pit # 5	July 16	28	41
1025	Pit # 5	July 7	19	28
1027	Pit # 6	April 16	300	440
1027	Pit # 6	April 16	280	420
1032	K-65 Silo Area	July 7	140	210
1033	K-65 Silo Area	July 12	19	28
1033	K-65 Silo Area	July 12	19	27
1037	Production Area	July 7	1,000	1,500
1037	Production Area	July 7	760	1,100
1042	W of Production Area	April 22	27	40
1042	W of Production Area	April 22	21	30
1046	SW of S. Water Ret.	May 11	15	22
1048	SW of S. Water Ret.	April 28	21	31
1054	Production Area	June 23	48	71
1054	Production Area	June 23	33	49
1054	Production Area	June 25	38,000	56,000
1055	Production Area	May 15	28	42
1073	Pit # 1	July 15	1,700	2,600
1073	Pit # 1	July 15	1,600	2,400
1081	Production Area	April 13	15	23
1081	Production Area	April 13	15	22
1082	Pit # 6	April 13	510	750
1082	Pit # 6	April 13	460	690
1083	Pit # 6	April 16	98	140
1083	Pit # 6	April 16	96	140
1084	Pit # 4	July 24	83	79
1084	Pit # 4	July 24	47	69
1085	Production Area	April 21	3,700	5,500
1085	Production Area	April 21	3,500	5,200
1110	Production Area	June 10	35	51
1110	Production Area	June 10	28	42
1111	Production Area	June 10	17	25
1112	Production Area	June 11	580	860
1112	Production Area	June 11	330	480
1113	Production Area	June 10	1,300	1900
1131	Production Area	May 27	430	640
1145	Production Area	June 17	17,000	25,000
1145	Production Area	June 17	17,000	25,000
1149	Production Area	February 3	63,000	94,000
1157	Production Area	June 10	24	35
1157	Production Area	June 10	20	30
1161	Production Area	February 23	68,000	100,000
1177	Production Area	May 21	52	77
1177	Production Area	May 21	32	47
1179	Production Area	June 16	87	130
1179	Production Area	June 16	60	89
1182	Production Area	June 16	650	970
1186	Production Area	June 25	40,000	59,000
1189	Production Area	June 28	12,000	17,000
1189	Production Area	June 28	9,900	15,000
1195	Production Area	June 28	5,800	8,600
1195	Production Area	June 28	6,000	8,800
1196	Production Area	October 27	7,700	11,000
1201	Production Area	June 29	240	350
1201	Production Area	June 29	150	220
1210	Production Area	July 14	36	54
1210	Production Area	July 14	35	52
1213	Production Area	March 9	7,600	11,000
1214	Production Area	June 29	52,000	78,000
1214	Production Area	June 29	61,000	75,000
1216	Production Area	June 9	340	510

TABLE 17: Comprehensive Groundwater Samples with Uranium Concentrations above USEPA Proposed Standard, 1993 (a)

Well(b)	Location	Sample Date	Concentration (pCi/L)(c)	Concentration (ppb)
1216	Production Area	June 9	280	410
1218	Production Area	May 17	62	92
1218	Production Area	May 17	55	82
1230	Production Area	May 17	1,400	2,100
1230	Production Area	May 17	700	1,000
1234	Production Area	May 17	970	1,400
1234	Production Area	May 17	930	1,400
1236	Production Area	May 17	3,100	4,600
1236	Production Area	May 17	390	580
1239	Production Area	May 13	22	32
1240	Production Area	May 15	770	1,100
1240	Production Area	May 15	740	1,100
1241	Production Area	May 15	580	860
1241	Production Area	May 15	310	460
1242	Production Area	May 15	860	1,300
1242	Production Area	May 15	92	140
1246	Production Area	July 22	78	120
1246	Production Area	July 22	70	100
1255	Production Area	May 13	520	760
1255	Production Area	May 13	310	460
1267	Production Area	May 16	44	65
1267	Production Area	May 16	38	56
1269	Production Area	May 11	17	25
1269	Production Area	May 11	14	21
1279	Production Area	May 25	69	100
1279	Production Area	June 2	62	92
1279	Production Area	June 26	40	60
1279	Production Area	June 29	35	52
1279	Production Area	June 29	32	48
1281	Production Area	June 30	550	810
1281	Production Area	June 30	530	790
1283	Production Area	May 25	59	88
1283	Production Area	May 25	41	61
1287	Production Area	May 25	140	200
1287	Production Area	May 25	140	200
1287	Production Area	May 25	140	200
1291	Production Area	July 1	640	940
1324	Production Area	July 10	92,000	140,000
1324	Production Area	July 10	87,000	130,000
1336	Production Area	May 27	110	170
1336	Production Area	May 27	110	160
1338	Production Area	July 8	780	1,100
1339	Production Area	May 26	450	670
1339	Production Area	May 26	430	640
1339	Production Area	July 7	410	600
1352	Production Area	May 28	40	59
1352	Production Area	May 28	39	58
1357	Production Area	May 28	24	36
1359	Production Area	May 26	340	500
1359	Production Area	May 26	280	420
1359	Production Area	May 26	34	50
1361	Production Area	May 27	32	46
1403	Production Area	May 16	32	48
1403	Production Area	May 16	100	160
1441	Waste Treatment Plant	May 25	96	140
1441	Waste Treatment Plant	May 25	78	120
1442	Waste Treatment Plant	July 8	200	290
1447	Waste Treatment Plant	May 26	180	270
1447	Waste Treatment Plant	May 26	290	430
1509	Production Area	June 2	240	360
1509	Production Area	June 2	110	170
1511	Production Area	June 2	93	140

TABLE 17: Comprehensive Groundwater Samples with Uranium Concentrations above USEPA Proposed Standard, 1993 (a)

Well(b)	Location	Sample Date	Concentration (pCi/L)(c)	Concentration (ppb)
1511	Production Area	June 2	93	140
1523	Production Area	April 16	20	30
1523	Production Area	April 16	18	27
1643	Pit # 4	April 13	63	93
1643	Pit # 4	April 13	55	82
1644	Pit # 4	April 17	49	73
1644	Pit # 4	April 17	49	73
1645	Pit # 4	April 17	24	36
1645	Pit # 4	April 17	21	32
1646	Pit # 4	April 17	290	420
1646	Pit # 4	April 17	280	410
1676	Production Area	May 12	19	29
1676	Production Area	May 12	18	26
1840	Production Area	May 4	160	230
1842	Production Area	Sept. 24	130	190
1842	Production Area	March 9	66	97
1869	Production Area	May 4	20	29
1891	K-65 Silo Area	April 23	210	320
1892	K-65 Silo Area	April 23	840	1,200
1941	Southwest of SWRB	April 30	370	550
1941	Southwest of SWRB	May 28	260	390
1942	Southwest of SWRB	May 28	390	570
1942	Southwest of SWRB	May 1	230	340
1952	NW of Production Area	May 15	38	60
1954	Southwest of SWRB	June 22	44	64
1954	Southwest of SWRB	June 22	26	39
2009	SW of K-65 Silo Area	June 7	18	27
2009	SW of K-65 Silo Area	June 7	18	27
2015	South Plume, Onsite	May 24	130	200
2015	South Plume, Onsite	May 24	130	200
2028	Pit # 3	July 28	17	25
2032	K-65 Silo Area	June 7	14	21
2032	K-65 Silo Area	May 14	14	20
2045	South Plume, Onsite	August 3	350	520
2045	South Plume, Onsite	April 28	260	380
2045	South Plume, Onsite	April 28	250	360
2046	Southwest of SWRB	May 11	310	460
2046	Southwest of SWRB	May 11	290	420
2049	South Plume, Onsite	May 10	75	110
2049	South Plume, Onsite	May 10	61	90
2049	South Plume, Onsite	August 11	42	62
2084	Southwest of SWRB	April 8	18	27
2084	Southwest of SWRB	April 8	16	24
2095	South Plume, Offsite	May 11	63	93
2095	South Plume, Offsite	May 11	54	82
2106	South Plume, Onsite	July 26	47	70
2106	South Plume, Onsite	August 16	39	57
2106	South Plume, Onsite	April 17	46	68
2106	South Plume, Onsite	April 17	42	62
2108	SW of K-65 Silo Area	June 7	17	25
2108	SW of K-65 Silo Area	June 7	15	22
2125	South Plume, Offsite	May 20	29	43
2125	South Plume, Offsite	May 20	28	41
2166	South Plume, Onsite	January 25	72	110
2385	South of SWRB	April 28	67	99
2385	South of SWRB	April 28	56	82
2387	South Plume, Onsite	April 23	240	350
2387	South Plume, Onsite	April 23	220	330
2387	South Plume, Onsite	August 5	190	290
2390	South Plume, Onsite	June 2	82	120
2390	South Plume, Onsite	June 2	82	120
2397	South of SWRB	August 2	340	500

TABLE 17: Comprehensive Groundwater Samples with Uranium Concentrations above USEPA Proposed Standard, 1993 (a)

Well(b)	Location	Sample Date	Concentration (pCi/L)(c)	Concentration (ppb)
2397	South of SWRB	May 12	210	320
2397	South of SWRB	May 12	200	300
2545	South Plume, Offsite	May 25	45	66
2545	South Plume, Offsite	May 25	33	49
2550	South Plume, Offsite	May 11	64	94
2550	South Plume, Offsite	May 11	51	76
2551	South Plume, Offsite	May 17	40	58
2551	South Plume, Offsite	May 17	37	55
2624	South Plume, Offsite	May 25	41	61
2648	Pit # 4	April 16	16	24
2648	Pit # 4	April 16	15	22
2821	Pit # 2	April 7	24	35
2821	Pit # 2	April 7	22	33
2822	Pit # 1	April 26	45	66
2822	Pit # 1	April 26	44	65
2945	Southwest of SWRB	April 28	1,400	2,100
2945	Southwest of SWRB	May 26	1,200	1,800
2954	Southwest of SWRB	June 21	790	1,200
2954	Southwest of SWRB	June 21	760	1,100
3001	West of Pit # 2	April 5	19	28
3001	West of Pit # 2	April 5	15	22
3014	South Plume, Onsite	May 6	14	20
3037	Production Area	April 22	20	29
3069	South Plume, Onsite	April 6	15	22
3069	South Plume, Onsite	Apirl 6	14	21
3084	Pit # 5	April 8	55	82
3084	Pit # 5	April 8	53	78
3084	Pit # 5	August 17	22	33
3084	Pit # 5	August 17	20	30
3108	South of K-65 Silo Area	June 7	21	32
3108	South of K-65 Silo Area	June 7	21	32
3125	South Plume, Offsite	May 20	32	48
3125	South Plume, Offsite	May 20	31	45
3390	South Plume, Onsite	June 3	70	100
3689	South Plume, Offsite	May 14	35	52
3689	South Plume, Offsite	May 14	23	34
3880	South Plume, Offsite	April 28	35	52
4013	Production Area	April 20	20	30
11032	South of SWRB	June 30	15	23
11069	SW of Production Area	July 24	18	27
11069	SW of Production Area	July 25	14	20
11107	Production Area	August 3	310	460
11107	Production Area	August 5	83	120
11107	Production Area	July 30	21	31
11107	Production Area	July 30	54	80
11107	Production Area	August 3	36	54
11107	Production Area	August 3	36	54
11107	Production Area	July 5	43	65
11230	Production Area	Sept. 8	630	940
11230	Production Area	Sept. 9	280	420
11229	Fire Training Facility	Sept. 16	26	38
11229	Fire Training Facility	Sept. 16	25	37
21033	South Plume, onsite	June 17	29	43
21033	South Plume, onsite	June 17	28	41

(a) Proposed USEPA standard of 13.5 pCi/L (20 ppb).

(b) See figures 41 through 44 on pages 109 through 112 for well locations.

(c) To obtain Bq/L, multiply pCi/L by 0.037.

TABLE 18: Metals in Private Wells, 1993

Metals Listed in Primary Drinking Water Regulations

Well Number[a]	Concentration (mg/L) Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Selenium
1	0.018	0.42	< 0.0050	< 0.010	< 0.025	0.0048	< 0.0050
3	0.018	0.51	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
4	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.0068	< 0.0050
7	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
8	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
9	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
10	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
11	< 0.010	< 0.20	< 0.0050	< 0.010	0.030	0.020	< 0.0050
12	< 0.010	< 0.20	< 0.0050	< 0.010	0.055	0.043	< 0.0050
13	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
14	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.0077	< 0.0050
15	< 0.010	< 0.20	< 0.0050	< 0.010	0.039	0.0074	< 0.0050
16	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.015	< 0.0050
18	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
19	0.049	< 0.20	< 0.0050	< 0.010	< 0.025	0.018	< 0.0050
21	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
22	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.020	< 0.0050
23	< 0.010	< 0.20	< 0.0050	< 0.010	0.038	< 0.0030	< 0.0050
24	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
25	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
26	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.013	< 0.0050
28	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
29	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.025	< 0.0050
30	< 0.010	< 0.20	< 0.0050	< 0.010	0.027	< 0.0030	< 0.0050
32	0.013	< 0.20	< 0.0050	< 0.010	< 0.025	0.013	< 0.0050
33	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
34	< 0.010	< 0.20	< 0.0050	< 0.010	0.042	0.0085	< 0.0050
35	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
36	< 0.010	< 0.20	< 0.0050	< 0.010	0.11	0.0075	< 0.0050
37	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
38[b]	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	0.0076	< 0.0050
39	< 0.010	< 0.20	< 0.0050	< 0.010	0.078	0.0077	< 0.0050
40	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
41	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
56	< 0.010	< 0.20	< 0.0050	< 0.010	< 0.025	< 0.0030	< 0.0050
55	< 0.010	< 0.20	< 0.0050	< 0.010	0.034	< 0.0030	< 0.0050
Primary Standard[c]	**0.05**	**2.0**	**0.005**	**0.1**	**1.0[d]**	**0.015[d]**	**0.05**

TABLE 18: Metals in Private Wells, 1993

Metals Listed in Secondary Drinking Water Regulations

Well Number[a]	Concentration (mg/L) Iron	Manganese	Silver	Zinc
1	3.6	0.019	< 0.010	0.026
3	3.7	0.015	< 0.010	< 0.020
4	0.10	< 0.015	< 0.010	0.054
7	1.9	0.14	< 0.010	0.056
8	0.20	0.15	< 0.010	0.055
9	< 0.10	0.23	< 0.010	0.025
10	4.0	0.29	< 0.010	< 0.020
11	< 0.10	< 0.015	< 0.010	0.23
12	3.3	0.13	< 0.010	1.5
13	< 0.10	0.031	< 0.010	0.032
14	0.63	0.34	< 0.010	0.075
15	0.72	< 0.015	< 0.010	0.060
16	2.2	0.33	< 0.010	0.10
18	3.1	0.25	< 0.010	0.082
19	1.5	0.30	< 0.010	0.024
21	1.1	0.24	< 0.010	0.077
22	< 0.10	0.049	< 0.010	0.024
23	0.11	0.074	< 0.010	< 0.020
24	< 0.10	0.10	< 0.010	0.035
25	< 0.10	< 0.015	< 0.010	< 0.020
26	3.9	0.30	< 0.010	0.064
28	0.11	0.076	< 0.010	< 0.020
29	2.0	0.19	< 0.010	0.020
30	< 0.10	< 0.015	< 0.010	< 0.020
32	0.91	0.36	< 0.010	< 0.020
33	< 0.10	< 0.015	< 0.010	< 0.020
34	1.5	0.015	< 0.010	0.22
35	< 0.10	< 0.015	< 0.010	< 0.020
36	< 0.10	< 0.015	< 0.010	0.090
37	0.29	0.22	< 0.010	< 0.020
38[b]	< 0.10	0.015	< 0.010	2.5
39	0.18	0.027	< 0.010	0.021
40	0.20	0.019	< 0.010	0.17
41	< 0.10	< 0.015	< 0.010	< 0.020
55	0.17	< 0.015	< 0.010	< 0.020
56	1.9	0.13	< 0.010	0.051
Secondary Standard[c]	**0.3**	**0.05**	**0.01**	**5.0**

TABLE 18: Metals in Private Wells, 1993

Metals Not Listed in Drinking Water Regulations

Well Number[a]	Concentration (mg/L)				
	Calcium	Magnesium	Nickel	Potassium	Sodium
1	80	25	< 0.040	< 5.0	20
3	78	25	< 0.040	< 5.0	35
4	130	60	< 0.040	< 5.0	48
7	110	32	< 0.040	< 5.0	9.3
8	94	29	< 0.040	< 5.0	19
9	73	27	< 0.040	< 5.0	30
10	120	33	< 0.040	< 5.0	15
11	77	23	< 0.040	< 5.0	10
12	86	23	< 0.040	< 5.0	11
13	91	25	< 0.040	< 5.0	21
14	110	30	< 0.040	10	25
15	97	26	< 0.040	< 5.0	18
16	110	31	< 0.040	< 5.0	59
18	100	26	< 0.040	< 5.0	13
19	74	34	< 0.040	63	28
21	96	24	< 0.040	< 5.0	10
22	88	23	< 0.040	< 5.0	17
23	88	25	< 0.040	< 5.0	6.1
24	120	34	< 0.040	< 5.0	9.4
25	110	31	< 0.040	< 5.0	9.2
26	93	23	< 0.040	< 5.0	11
28	89	25	< 0.040	< 5.0	6.0
29	91	25	< 0.040	< 5.0	9.7
30	86	24	< 0.040	< 5.0	14
32	93	24	< 0.040	12	7.6
33	98	26	< 0.040	< 5.0	14
34	100	26	< 0.040	< 5.0	11
35	120	32	< 0.040	< 5.0	33
36	120	27	< 0.040	< 5.0	15
37	140	36	< 0.040	< 5.0	8.3
38[b]	46	10	< 0.040	< 5.0	1.3
39	190	33	< 0.040	< 5.0	68
40	140	30	< 0.040	< 5.0	22
41	110	35	< 0.040	< 5.0	37
55	12	31	< 0.040	< 5.0	9.1
56	100	26	< 0.040	< 5.0	5.6

(a) See Figure 36 on page 100 for well locations. One sample was collected from each well. All samples were taken during the month of July.

(b) Samples collected from a cistern.

(c) USEPA drinking water regulations taken from 40 CFR Part 141, National Interim Primary Drinking Water Regulations - Subpart B – Maximum Contaminant Levels, July 1992, and from CFR Part 143, National Secondary Drinking Water Regulations – Section 143.3 – Secondary Maximum Contaminant Levels.

(d) USEPA drinking water regulations taken from 40 CFR Part 141, National Interim Primary Drinking Water Regulations - Subpart I – Control of Lead and Copper, July 1992.

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1993

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Antimony	1332 Production Area	April 17	0.135	0.006
Antimony	4013 Production Area	April 20	0.0792	0.006
Antimony	1645 Waste Pit Area	April 17	0.0786	0.006
Antimony	1080 Waste Pit Area	April 17	0.0771	0.006
Antimony	1646 Waste Pit Area	April 17	0.0709	0.006
Antimony	1230 Production Area	May 17	0.0704	0.006
Antimony	1645 Waste Pit Area	April 17	0.0679	0.006
Antimony	4013 Production Area	April 20	0.0662	0.006
Antimony	1644 Waste Pit Area	April 17	0.0623	0.006
Antimony	1080 Waste Pit Area	April 17	0.06160	0.006
Antimony	1646 Waste Pit Area	April 17	0.0538	0.006
Antimony	1240 Production Area	May 15	0.0517	0.006
Antimony	2066 NW Corner of Fernald Site	April 7	0.0439	0.006
Antimony	1361 Production Area	May 27	0.0305	0.006
Antimony	1059 NW Offsite	September 29	0.0272	0.006
Antimony	1189 Production Area	June 28	0.0156	0.006
Antimony	1065 South of SWRB	May 4	0.0141	0.006
Antimony	1941 South of SWRB	April 30	0.0132	0.006
Antimony	1954 Southwest of SWRB	June 22	0.012	0.006
Antimony	11085 Southwest of SWRB	June 16	0.0074	0.006
Antimony	11032 Southwest of SWRB	June 30	0.0061	0.006
Arsenic	1644 Waste Pit Area	April 17	0.313	0.050
Arsenic	1644 Waste Pit Area	April 17	0.191	0.050
Arsenic	3009 Paddys Run, South of Silos	June 7	0.186	0.050
Arsenic	2094 South of Fernald Site	July 26	0.168	0.050
Arsenic	2094 South of Fernald Site	July 26	0.161	0.050
Arsenic	3066 NW Corner of Fernald Site	April 7	0.156	0.050
Arsenic	3009 Paddys Run, South of Silos	June 7	0.15	0.050
Arsenic	3679 NW Corner of Fernald Site	May 24	0.148	0.050
Arsenic	3066 NW Corner of Fernald Site	April 7	0.145	0.050
Arsenic	3679 NW Corner of Fernald Site	May 24	0.144	0.050
Arsenic	2679 NW Corner of Fernald Site	May 24	0.136	0.050
Arsenic	2679 NW Corner of Fernald Site	May 24	0.101	0.050
Arsenic	1189 Production Area	June 28	0.101	0.050

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1993

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Barium	11229 North of Production Area	September 16	3.35	2.0
Barium	1189 Production Area	June 28	2.26	2.0
Beryllium	3009 Paddys Run, South of Silos	June 7	0.131	0.004
Beryllium	3009 Paddys Run, South of Silos	June 7	0.125	0.004
Beryllium	1719 NW of Production Area	July 7	0.0282	0.004
Beryllium	11229 North of Production Area	September 16	0.0231	0.004
Beryllium	2754 NE Corner of Fernald Site	July 22	0.0116	0.004
Beryllium	1201 Production Area	June 29	0.0113	0.004
Beryllium	1189 Production Area	June 28	0.0111	0.004
Beryllium	1152 East of Production Area	June 11	0.01	0.004
Beryllium	1214 Production Area	June 29	0.0099	0.004
Beryllium	11085 Southwest of SWRB	June 16	0.0096	0.004
Beryllium	1728 NW Corner of Fernald Site	July 24	0.0095	0.004
Beryllium	11032 Southwest of SWRB	June 30	0.0061	0.004
Beryllium	1161 Production Area	February 12	0.0050	0.004
Beryllium	1148 Production Area	February 4	0.0046	0.004
Beryllium	1359 Production Area	May 26	0.004	0.004
Cadmium	3009 Paddys Run, South of Silos	June 7	0.165	0.005
Cadmium	3009 Paddys Run, South of Silos	June 7	0.161	0.005
Cadmium	2754 NE Corner of Fernald Site	July 22	0.127	0.005
Cadmium	1189 Production Area	June 28	0.070	0.005
Cadmium	2420 Production Area	July 15	0.0459	0.005
Cadmium	2754 NE Corner of Fernald Site	July 22	0.0345	0.005
Cadmium	1065 South of SWRB	May 4	0.034	0.005
Cadmium	2420 Production Area	July 15	0.0333	0.005
Cadmium	1201 Production Area	June 29	0.030	0.005
Cadmium	1267 Production Area	May 16	0.0246	0.005
Cadmium	1214 Production Area	June 29	0.021	0.005
Cadmium	2754 NE Corner of Fernald Site	September 24	0.0205	0.005
Cadmium	2733 SE Corner of Fernald Site	July 28	0.0197	0.005
Cadmium	2733 SE Corner of Fernald Site	July 28	0.0191	0.005
Cadmium	2171 East of Production Area	June 7	0.01690	0.005
Cadmium	2417 East of Production Area	June 8	0.0168	0.005
Cadmium	1281 Production Area	June 30	0.0155	0.005
Cadmium	2424 NE of Production Area	July 28	0.0155	0.005

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1993

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Cadmium	1363 Production Area	July 1	0.0141	0.005
Cadmium	3024 North of Waste Pit Area	April 12	0.0135	0.005
Cadmium	2426 East of Production Area	July 28	0.0115	0.005
Cadmium	1025 Waste Pit Area	July 7	0.0113	0.005
Cadmium	2432 SE of Production Area	July 28	0.0102	0.005
Cadmium	1230 Production Area	May 17	0.0097	0.005
Cadmium	2432 SE of Production Area	July 28	0.0096	0.005
Cadmium	2431 SE of Production Area	September 14	0.0095	0.005
Cadmium	2429 East of Production Area	September 21	0.0094	0.005
Cadmium	1357 Production Area	May 28	0.0090	0.005
Cadmium	2417 East of Production Area	June 8	0.0083	0.005
Cadmium	1719 NW of Production Area	July 7	0.0082	0.005
Cadmium	1291 Production Area	June 30	0.0082	0.005
Cadmium	1345 Production Area	May 28	0.0079	0.005
Cadmium	1353 Production Area	July 7	0.0072	0.005
Cadmium	1354 Production Area	July 9	0.0070	0.005
Cadmium	2426 East of Production Area	July 28	0.0065	0.005
Cadmium	2417 East of Production Area	July 27	0.0065	0.005
Cadmium	11071 Production Area	July 1	0.0061	0.005
Cadmium	2432 SE of Production Area	September 15	0.0059	0.005
Cadmium	1029 Silo Area	July 12	0.0056	0.005
Cadmium	11032 Southwest of SWRB	June 30	0.0056	0.005
Cadmium	1719 NW of Production Area	July 7	0.0055	0.005
Cadmium	1352 Production Area	May 28	0.0054	0.005
Cadmium	2733 SE Corner of Fernald Site	September 17	0.0054	0.005
Cadmium	2398 South Edge of Fernald Site	September 17	0.0053	0.005
Cadmium	2011 Waste Pit Area	June 10	0.0053	0.005
Cadmium	1281 Production Area	June 30	0.0052	0.005
Cadmium	1218 Production Area	May 17	0.0051	0.005
Cadmium	1034 Silo Area	July 12	0.0050	0.005

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1993

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Chromium	2754 NE of Production Area	July 22	7.710	0.1
Chromium	1766 Waste Pit Area	June 24	2.750	0.1
Chromium	2624 South of Fernald Site	May 25	1.110	0.1
Chromium	11229 North of Production Area	September 16	0.820	0.1
Chromium	1032 Silo Area	July 25	0.491	0.1
Chromium	1182 Production Area	June 16	0.312	0.1
Chromium	1728 NW Section of Fernald Site	July 24	0.283	0.1
Chromium	3009 Paddys Run, South of Silos	June 7	0.278	0.1
Chromium	3009 Paddys Run, South of Silos	June 7	0.262	0.1
Chromium	1073 Waste Pit Area	July 16	0.261	0.1
Chromium	1189 Production Area	June 28	0.261	0.1
Chromium	1152 East of Production Area	June 11	0.260	0.1
Chromium	11069 SW of Production Area	July 24	0.236	0.1
Chromium	1201 Production Area	June 29	0.223	0.1
Chromium	1031 Waste Pit Area	April 26	0.221	0.1
Chromium	2754 NE of Production Area	September 24	0.213	0.1
Chromium	1214 Production Area	June 29	0.202	0.1
Chromium	11085 Southwest of SWRB	June 16	0.196	0.1
Chromium	11032 Southwest of SWRB	June 30	0.167	0.1
Chromium	2636 South Plume	May 25	0.155	0.1
Chromium	2125 South Plume	May 20	0.151	0.1
Chromium	1074 Waste Pit Area	April 13	0.145	0.1
Chromium	1267 Production Area	May 16	0.144	0.1
Chromium	41066 Production Area	July 25	0.142	0.1
Chromium	1324 Production Area	July 10	0 140	0.1
Chromium	1179 Production Area	June 16	0.126	0.1
Chromium	1324 Production Area	July 10	0.121	0.1
Chromium	1359 Production Area	May 26	0.116	0.1
Chromium	1073 Waste Pit Area	July 22	0.105	0.1
Cyanide	3099 Paddys Run, South of Silos	June 7	0.36	0.2
Cyanide	3099 Paddys Run, South of Silos	June 7	0.354	0.2
Mercury	3099 Paddys Run, South of Silos	June 7	0.0139	0.002
Mercury	3099 Paddys Run, South of Silos	June 7	0.0077	0.002

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1993

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Nickel	2754 NE of Production Area	July 22	3.930	0.1
Nickel	2754 NE of Production Area	September 24	2.0	0.1
Nickel	11229 North of Production Area	September 16	1.47	0.1
Nickel	2624 South Plume	May 25	0.621	0.1
Nickel	2754 NE of Production Area	July 22	0.589	0.1
Nickel	1074 Waste Pit Area	April 13	0.536	0.1
Nickel	1728 NW Section of Fernald Site	July 24	0.442	0.1
Nickel	1074 Waste Pit Area	April 13	0.398	0.1
Nickel	11069 SW of Production Area	July 24	0.361	0.1
Nickel	1189 Production Area	June 28	0.352	0.1
Nickel	11085 Southwest of SWRB	June 16	0.339	0.1
Nickel	1267 Production Area	May 16	0.333	0.1
Nickel	1152 East of Production Area	July 11	0.319	0.1
Nickel	1201 Production Area	June 29	0.300	0.1
Nickel	11032 Southwest of SWRB	June 30	0.243	0.1
Nickel	1145 Production Area	June 23	0.206	0.1
Nickel	1214 Production Area	June 29	0.202	0.1
Nickel	1031 Waste Pit Area	April 26	0.201	0.1
Nickel	1182 Production Area	June 16	0.185	0.1
Nickel	1149 Production Area	February 3	0.144	0.1
Nickel	3009 Paddys Run, South of Silos	June 7	0.137	0.1
Nickel	1941 South of SWRB	May 28	0.136	0.1
Nickel	2560 South of Fernald, near SR128	May 15	0.135	0.1
Nickel	3009 Paddys Run, South of Silos	June 7	0.131	0.1
Nickel	1359 Production Area	May 26	0.130	0.1
Nickel	1246 Production Area	July 22	0.128	0.1
Nickel	1954 Southwest of SWRB	June 22	0.127	0.1
Nickel	1952 NW Corner of Production Area	May 15	0.118	0.1
Nickel	41066 Production Area	July 25	0.117	0.1
Nickel	1942 South of SWRB	May 28	0.116	0.1
Nickel	1110 Production Area	June 10	0.110	0.1
Nickel	1179 Production Area	June 16	0.101	0.1
Nickel	1317 Production Area	June 15	0.101	0.1

TABLE 19: Nonradioactive Substances above Primary Drinking Water Standards, 1993

Substance	Well Location[a]	Sample Date	Concentration (mg/L)	Primary Standard (mg/L)[b]
Selenium	3009 Paddys Run, South of Silos	June 7	0.192	0.050
Selenium	3009 Paddys Run, South of Silos	June 7	0.189	0.050
Selenium	2754 NE of Production Area	July 22	0.0563	0.050
Thallium	3009 Paddys Run, South of Silos	June 7	0.094	0.002
Thallium	3009 Paddys Run, South of Silos	June 7	0.0895	0.002
Thallium	1025 Waste Pit Area	July 7	0.006	0.002
Thallium	2034 Silo Area	June 14	0.0022	0.002
Thallium	1733 SE Corner of Fernald Site	July 30	0.0020	0.002
Benzene	2639 South of New Haven Road	March 29	0.011	0.005
Benzene	1196 Production Area	October 27	0.0050	0.005
Carbon Tetrachloride	1149 Production Area	February 3	0.021	0.005
Carbon Tetrachloride	11092 Production Area	August 6	0.0050	0.005
1,2-Dichloroethane	1149 Production Area	February 3	0.072	0.005
1,2-Dichloroethane	1148 Production Area	February 3	0.068	0.005
1,2- Dichloroethane	1145 Production Area	June 17	0.061	0.005
1,2-Dichloroethane	1509 Fire Training Facility	June 2	0.011	0.005
1,2-Dichloropropane	1196 Production Area	October 27	0.0050	0.005
Ethylbenzene	2639 South of New Haven Road	March 29	1.6	0.7
Toluene	2639 South of New Haven Road	March 29	1.6	1.0
1,1,1-Trichloroethane	1509 Fire Training Facility	June 2	5.9	0.20
1,1,1-Trichloroethane	1287 Production Area	May 25	0.31	0.20
1,1,1-Trichloroethane	1145 Production Area	June 17	0.27	0.20
1,1,1-Trichloroethane	1283 Production Area	May 25	0.20	0.20
1,1,2-Trichloroethane	1196 Production Area	October 27	0.0050	0.005
Vinyl Chloride	11096 Production Area	August 5	0.12	0.002
Vinyl Chloride	11098 Production Area	August 7	0.031	0.002

(a) See figures 41 through 44 on pages 109 through 112 for well locations.

(b) USEPA drinking water regulations taken from 40 CFR Part 141, National Uranium Primary Drinking Water Regulations – Subpart B – Maximum Contaminant Levels, July 1984.

TABLE 20: Summary of Radiation Dose[a]

Type of Dose	Dose[b]	Standard[c]	Percent of Standard
I. Individual	**mrem[d]**	**mrem[d]**	
A. Maximum individual dose from air emissions, excluding radon[e]	0.016	10	0.16
B. Ingestion[f]			
Produce (204 kg/year or 449 pounds/year) and milk	0.01	100	0.01
Well water (2 L/day or 0.5 gallons/day)	0.7	100	0.7
Great Miami River fish (4.4 kg/year or 10 pounds/year)	0.01	100	0.01
C. Direct radiation[g]	0.0	100	0.0
D. Radon Maximum dose to public at the site *fenceline* 8,760 hrs/year	450	(h)	
II. 80 km (50 miles) Population Dose[e]	**person-rem**		
Total collective dose equivalent from air emissions excluding radon for 2,740,000 people living within 80 km (50 miles)	0.3	(h)	
III. Other Sources of Dose[i]			
A. Natural radioactivity	**mrem/year**		
1. Radon in homes	200		
2. Other natural background radiation: cosmic radiation plus natural terrestrial isotopes, both external and internal.	100		
3. Well water in Fernald site area	0.4		
B. Medical diagnosis[j]	50		
C. Consumer products	10		
D. Atmospheric weapons tests	4.6		

(a) Including dose from all radionuclides listed in Table 21.

(b) The effective dose is the weighted sum of doses delivered to the individual organs of the body. Effective doses are comparable to whole body dose equivalents when considering the effects and risks of low-level radiation doses.

(c) Standards are as included in DOE Order 5400.5., "Radiation Protection of the Public and Environment." Also incorporated are the air emission dose standards of regulation 40 CFR 61, Subpart H (NESHAP).

(d) To obtain mSv, multiply mrem by 0.01.

(e) Effective dose equivalent received as a result of 1993 estimated emissions

(f) Fifty-year committed dose equivalents based on environmental measurements of uranium in produce, milk, water, and fish.

(g) Whole body dose calculated from highest measurement along the Fernald site fenceline, using environmental thermoluminescent dosimeters corrected for background.

(h) There are no applicable standards.

(i) From NCRP-93, "Ionizing Radiation Exposure of the Population of the United States."

(j) Medical dose estimates are population averages and will not necessarily be applicable to each individual.

TABLE 21: Estimated Airborne Emissions for the Fernald Site, 1993

Radionuclide	Total Curies	Measured Curies[a]	Estimated Curies[b]	
			Waste Pit 5[c]	Remaining Sources[d]
Uranium–234	0.000056	0.00000012	0.0000019	0.000054
Uranium–235	0.0000029	0.000000012	0.000000078	0.00000028
Uranium–236	0.0000022	(e)	0.00000019	0.0000020
Uranium–238	0.000061	0.00000010	0.0000014	0.000069
Radium–226	0.0000012	(e)	0.0000012	0.000000046
Radium–228	0.00000033	(e)	0.00000015	0.00000018
Thorium–228	0.000013	0.000000043	0.00000020	0.000013
Thorium–230	0.000023	0.000000019	0.000022	0.0000013
Thorium–232	0.00000045	(e)	0.00000015	0.00000030
Thorium–234	0.00028	0.0000000025	0.0000014	0.00028

(a) Measured emissions are from a single laboratory stack that was updated in 1993.

(b) There were no nonroutine radiological releases during 1993.

(c) Fugitive emissions from the waste pits.

(d) Includes three unmonitored stacks, two building vents, laboratory hoods, and the cooling tower.

(e) No analyses were conducted for these radionuclides.

TABLE 22: Radon in Air, 1993

Fenceline Locations[a]	Radon Concentration (pCi/L)[b]				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
AMS 1	0.10	0.13	(c)	(c)	0.12
AMS 2	0.10	0.13	0.58	0.95	0.44
AMS 4	0.10	0.13	0.68	1.2	0.52
AMS 6	0.10	0.03	0.78	0.95	0.47
AMS 7	0.30	0.23	0.58	1.0	0.54
A	0.40	0.03	0.28	1.2	0.49
B	0.60	0.13	0.58	1.0	0.59
C	0.70	0.23	0.28	0.95	0.54
D	0.80	0.33	0.58	1.2	0.74
E	0.50	0.23	0.48	1.2	0.62
F	0.30	0.23	1.6	0.55	0.67
G	(d)	0.33	0.78	1.0	0.72
H	0.60	0.03	0.48	0.75	0.46
I	1.2	0.13	0.48	0.95	0.69
J	1.0	0.03	0.58	0.75	0.59
K	1.5	0.13	0.68	0.95	0.82
L	0.40	0.43	1.2	0 85	0.72
M	1.6	0.23	1.1	(d)	0.97
N	1.6	0.03	0.98	0.85	0.87
O	1.5	0.23	1.5	0.75	0.99
P	0.10	0.33	1.1	(d)	0.50
Quarterly Averages	0.68	0.18	0.76	0.96	0.63

TABLE 22: Radon in Air, 1993

Background Locations[a]	Radon Concentration (pCi/L)[b]				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
Bkgd 1	0.40	0.13	1.2	2.2	0.97
Bkgd 2	0.40	0.13	1.3	2.0	0.97
AMS 15	0.40	0.23	1.5	1.6	0.92
AMS 16	0.50	0.13	1.3	1.8	0.94

Other Locations[a]	Radon Concentration (pCi/L)[b]				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
AMS 1A	(c)	(c)	0.48	0.85	0.67
AMS 8	0.10	0.03	0.38	0.95	0.37
AMS 9	0.50	0.13	0.78	1.4	0.69
AMS 10	0.30	0.03	0.58	(d)	0.30
AMS 11	0.30	0.13	0.48	0.75	0.42
AMS 12	0.10	0.03	0.78	0.65	0.39
AMS 13	0.10	0.03	0.28	1.2	0.42
RES 1	0.30	0.03	0.78	0.85	0.49
RES 2	0.30	0.33	0.68	1.23	0.62
RES 3	0.30	0.53	0.78	1.0	0.67
Quarterly Averages	0.26	0.14	0.61	0.89	0.50

(a) See Figure 48 on page 132 for locations.

(b) Corrected for instrument background except for the first quarter.

(c) Fenceline monitoring location AMS 1 was relocated to AMS 1A for the third and fourth quarters of 1993.

(d) Data invalidated due to instrument error.

TABLE 23: DOE Quality Assessment Program for Environmental Radionuclide Analyses Fernald Site Laboratories Performance Results, 1993

Sample Type	Sample Number	Units	Uranium Values		Ratio
			Site Laboratories	EML (a)	Site Value/EML Value
Air Filter	93–09	µg/Filter	4.9	5.4	0.91
Soil	93–09	µg/g	1.3	2.0	0.64

(a) DOE's Environmental Measurements Laboratory (EML).

TABLE 24: USEPA Quality Assurance Program for Wastewater Analyses Fernald Site Laboratories Performance Evaluation, 1993 (a)

Parameter	Units(b)	Values Site Laboratories	True(c)	USEPA Acceptance Limits(d)	USEPA Performance Evaluation(e)
Chromium	µg/L	460	460	380 – 530	ACCEPTABLE
Copper	µg/L	460	410	360 – 460	ACCEPTABLE
Lead	µg/L	340	450	390 – 510	UNACCEPTABLE
Nickel	µg/L	1,300	1,300	1,200 – 1,400	ACCEPTABLE
pH	S.U.	6.1	6.1	6.0 – 6.2	ACCEPTABLE
Total Suspended Solids	mg/L	33	33	24 – 35	ACCEPTABLE
Oil & Grease	mg/L	27	32	14 – 28	ACCEPTABLE
Ammonia – Nitrogen	mg/L	9.5	9.8	7.8 – 12	ACCEPTABLE
Nitrate – Nitrogen	mg/L	7.2	7.1	5.7 – 8.4	ACCEPTABLE
Carbonaceous BOD	mg/L	14	20	6.3 – 32	ACCEPTABLE
5 Day BOD	mg/L	24	22	12 – 32	ACCEPTABLE
Total Cyanide	mg/L	0.10	0.13	0.082 – 0.17	ACCEPTABLE

(a) USEPA Discharge Monitoring Report (DMR) Quality Assurance (QA) Program. The Fernald site, along with all other National Pollutant Discharge Elimination Systems (NPDES) permit holders, is required to participate in these annual laboratory performance evaluation studies (Section 308[a] of the Clean Water Act).

(b) S.U. stands for standard units.

(c) Actual parameter concentrations established by USEPA based on theoretical calculations or a reference value when necessary.

(d) Laboratory measured values which fall within this range are considered acceptable by USEPA.

(e) USEPA DMR–QA Study Number 013 conducted during 1993.

TABLE 25: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1993

Summary of Performance of the Fernald Site's Laboratories

Parameter	Units	Number of Analyses	Range of True Values	Percent Recovery[a] Min.	Max.	Avg.	Deviations from Mean[b] Min.	Max.	Avg.	Percentage Acceptable[c]
Ammonia-Nitrogen	mg/L	16	0.19 – 9.2	57	110	91	0.002	4.5	0.86	94
Biochemical Oxygen Demand	mg/L	18	6.7 – 290	88	120	100	0.063	1.1	0.50	100
Calcium	mg/L	18	2.3 – 56	93	100	98	0.094	0.76	0.35	100
Chloride	mg/L	20	20 – 150	93	120	100	0.031	2.7	0.81	90
Fluoride	mg/L	18	0.060 – 14	92	150	100	0.018	2.2	0.44	100
Magnesium	mg/L	18	1.9 – 24	91	100	96	0.022	0.95	0.48	100
Nitrate-Nitrogen	mg/L	16	0.35 – 9.8	92	100	99	0.017	2.8	0.50	94
Oil & Grease	mg/L	16	2.1 – 45	89	120	110	0.005	2.1	0.76	100
Potassium	mg/L	18	2.6 – 79	92	110	100	0.25	2.4	0.81	100
Sodium	mg/L	18	22 – 140	95	110	100	0.021	2.6	0.56	94
Sulfate	mg/L	20	12 – 150	78	150	100	0.12	4.5	1.5	85
Total Suspended Solids	mg/L	16	24 – 330	83	100	92	0.004	1.5	0.75	100
pH	S.U.	18	2.6 – 9.6	98	100	100	0.007	0.92	0.50	100
Arsenic	µg/L	18	19 – 470	72	110	96	0.32	2.9	1.3	83
Barium	µg/L	18	180 – 2,500	9.6	100	93	0.014	17	1.3	94
Cadmium	µg/L	18	24 – 240	100	110	100	0.051	1.2	0.43	10
Chromium (Total)	µg/L	18	22 – 290	96	110	100	0.040	1.1	0.29	100
Chromium (Hexavalent)	µg/L	13	0.022 – 0.42	86	110	100	0.037	1.7	0.51	100
Copper	µg/L	18	30 – 270	62	110	98	0.079	4.6	1.3	100
Iron	µg/L	18	42 – 780	94	110	100	0.002	1.1	0.48	89
Lead	µg/L	18	33 – 480	10	1,500	170	0.048	140	9.0	100
Manganese	µg/L	18	28 – 480	97	110	100	0.009	1.6	0.30	89
Nickel	µg/L	18	27 – 290	92	110	100	0.13	1.2	0.54	100
Selenium	µg/L	18	14 – 200	76	110	96	0.048	1.5	0.44	100
Silver	µg/L	18	21 – 380	940	100	100	0.033	0.82	0.33	100
Uranium	µg/L	18	80 – 900	1.00	130	98	0.099	37	4.1	83
Zinc	µg/L	18	24 – 240	77	120	97	0.030	1.8	0.64	100
Total		477								96

TABLE 25: Proficiency Environmental Testing Quality Assurance Program for Water Analyses, 1992

(a) Percent recovery is the site's measured value, divided by the true parameter concentration, multiplied by 100.

(b) The standard deviation indicates the closeness of the site's measurement result to the mean value reported by Analytical Products Group, Inc., which conducts the testing program. The standard deviation would be 0.00 if the site's result and the mean value were exactly the same. The mean value is calculated from the results obtained by all laboratories participating in the control program. Any measurement results which are significantly different from the true parameter concentration or statistically different from the majority of results obtained by the other laboratories are not included in evaluating the mean value.

(c) This is the percentage of the site's measurement results for each parameter which met the USEPA "Acceptable" criteria of being within 2.58 standard deviations of the mean value.

TABLE 26: Fernald Site – ODH Uranium Sampling Comparison, 1992

Groundwater Sampling Locations

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
Well 3	September 29	0.07	< 1.0
Well 4	January 22	1.2	1.5
Well 4	February 26	1.0	1.9
Well 4	March 25	1.2	1.4
Well 4	April 22	1.4	2.0
Well 4	May 27	1.3	< 1.0
Well 4	June 30	0.95	1.9
Well 4	July 22	1.3	1.4
Well 4	August 26	1.1	< 1.0
Well 4	October 28	1.1	2.0
Well 4	November 30	1.4	< 1.0
Well 4	December 26	1.2	2.0
Well 7	May 27	0.47	< 1.0
Well 11	January 22	0.95	1.0
Well 12	February 26	120	1.1
Well 14	January 22	1.3	1.4
Well 14	February 26	1.6	2.5
Well 14	March 25	1.7	1.3
Well 14	April 22	1.7	1.5
Well 14	May 27	1.6	< 1.0
Well 14	June 30	1.5	1.4
Well 14	July 22	1.5	< 1.0
Well 14	August 26	1.4	< 1.0
Well 14	September 29	1.2	< 1.0
Well 14	October 28	1.7	< 1.0
Well 14	November 30	1.2	2.0
Well 14	December 26	1.4	1.8
Well 15[c]	January 22	140	170
Well 15[c]	February 26	140	120
Well 15[c]	March 25	160	130
Well 15[c]	April 22	140	160
Well 15[c]	May 27	160	170
Well 15[c]	June 30	180	150
Well 15[c]	July 22	160	130
Well 15[c]	August 26	160	110
Well 15[c]	September 29	140	130
Well 15[c]	October 28	160	150
Well 15[c]	November 30	150	120
Well 15[c]	December 26	170	130
Well 16	August 26	0.47	< 1.0
Well 19	January 22	0.07	< 1.0
Well 19	February 26	0.07	< 1.0
Well 19	March 25	0.07	< 1.0
Well 19	April 22	0.07	< 1.0
Well 19	May 27	0.07	< 1.0
Well 19	June 30	0.07	< 1.0
Well 19	July 22	0.07	< 1.0
Well 19	August 26	0.07	< 1.0
Well 19	September 29	0.07	< 1.0
Well 19	October 28	0.07	< 1.0
Well 19	November 30	0.20	4.0
Well 19	December 26	0.07	< 1.0
Well 22	March 25	0.68	< 1.0
Well 24	December 26	0.41	< 1.0
Well 25	April 22	0.34	< 1.0
Well 28	October 28	0.61	1.0
Well 29	June 30	1.6	1.4
Well 35	July 22	1.2	1.3
Well 41	November 30	0.61	1.0

TABLE 26: Fernald Site – ODH Uranium Sampling Comparison, 1992

Surfacewater Sampling Locations

Sampling Location[a]	Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
W1	January 22	1.0	1.7
W1	February 26	1.1	1.1
W1	March 25	1.2	1.6
W1	April 22	1.1	< 1.0
W1	May 27	1.1	< 1.0
W1	June 30	1.5	< 1.0
W1	July 22	1.1	< 1.0
W1	August 26	1.1	< 1.0
W1	September 29	0.81	1.0
W1	October 28	1.1	< 1.0
W1	November 30	1.4	2.0
W1	December 23	1.1	1.7
W3	January 22	1.4	2.1
W3	February 26	1.4	1.5
W3	March 25	1.1	2.1
W3	April 22	1.2	< 1.0
W3	May 27	1.0	< 1.0
W3	June 30	1.5	1.3
W3	July 22	1.4	< 1.0
W3	August 26	1.0	3.0
W3	September 29	0.89	< 1.0
W3	October 28	1.2	< 1.0
W3	November 30	1.5	1.2
W3	December 23	1.3	2.0
W4	January 22	1.1	1.6
W4	February 26	1.4	1.6
W4	March 25	1.1	1.4
W4	April 22	1.3	1.0
W4	May 27	1.0	1.8
W4	June 30	1.4	1.3
W4	July 22	1.5	1.3
W4	August 26	0.95	< 1.0
W4	September 29	1.1	1.0
W4	October 28	1.3	< 1.0
W4	November 30	1.5	2.0
W4	December 23	1.3	< 1.0
W7	March 25	6.6	7.0
W7	April 22	2.5	2.3
W7	November 30	7.4	4.7
W7	December 23	7.4	5.0
W8	January 22	4.9	7.4
W8	February 26	2.7	3.2
W8	March 22	2.4	4.0
W8	May 27	1.7	1.2
W8	July 22	2.0	1.0
W8	August 26	1.4	2.0
W8	September 29	1.6	1.4
W8	October 28	1.8	< 1.0
W8	November 30	6.0	8.1
W8	December 23	1.8	1.0
W9	January 22	2.4	1.9
W9	February 26	2.2	2.1
W9	March 25	2.1	1.4
W9	April 22	1.7	1.2
W9	May 27	0.95	1.0
W9	June 30	0.88	1.4
W9	July 22	1.5	1.5
W9	August 26	0.68	< 1.0
W9	September 29	2.2	< 1.0
W9	October 28	1.7	1.0
W9	November 30	2.7	2.0
W9	December 23	1.8	2.0

TABLE 26: Fernald Site – ODH Uranium Sampling Comparison, 1992

Milk Sampling

Sampling Date	Concentration (pCi/L)[b] Fernald Site	ODH
March 25	0.072	< 1.0
June 30	0.059	< 1.0
September 29	0.027	< 1.0
December 23	- 0.02	< 1.0

(a) See figures 32 and 36 on pages 89 and 100 for locations.

(b) To obtain Bq/L, multiply pCi/L by 0.037.

(c) These wells are used for monitoring purposes only.

B

Chemical Release Information for 1993

Among the information presented in the SER for the Fernald site are estimates on both radiological and nonradiological emissions to the environment. The information in this appendix includes chemical release estimates from the Superfund Amendments and Reauthorization Act of 1986 (SARA) 313 report for 1993 and a summary of emissions from the Boiler Plant during 1993. This summary includes the chemical name, type and quantity of release, major release sources, and the basis of estimate.

To estimate releases, the Fernald site used a method that followed guidelines defined by SARA 313. These estimates do not reflect actual measured emissions. Rather, the Fernald site estimated releases through material balance calculation, monitoring data, or engineering calculations.

In cases where quantitative monitoring data, inventory estimates, or emission factors were not readily available, release estimates were based on best engineering judgments. Information obtained from air permits, rate of operation, quantities used, and known treatment efficiencies were used to estimate quantities released into the environment. Typically, assumptions based on best engineering judgment were required in order to perform the calculations when all variables were not known.

Calculations for Boiler Plant emissions were based on published AP–42 emission factors and coal use and analysis records for the Fernald site during 1993.

The SARA 313 chemicals included in this appendix are a summary of the SARA Title III, Section 313 Report, required by SARA legislation. This legislation requires facilities to report any listed chemical manufactured or processed the previous year in excess of 25,000 pounds, or otherwise used in excess of 10,000 pounds. This report is submitted to USEPA and OEPA each year on July 1 for the previous calendar year and contains chemicals on USEPA's toxic substance list.

Fernald Site Chemical Release Information for 1993

Section One: Summary of SARA 313 Report

Chemical Name	Type of Release	Quantity Released (lb/kg)	Release Sources	Basis of Estimate
Methanol	Air: fugitive	860/390	Chemical Processing Aid	Published Emission Factors
	Air: point source	150/70	Chemical Processing Aid	Published Emission Factors
	Water: Great Miami River	1,700/770	Chemical Processing Aid	Best Engineering Judgment
Sulfuric Acid	None	25/11	Battery Spills	Best Engineering Judgment

Section Two: Boiler Plant Emissions

Chemical Name	Type of Release	Quantity Released (lb/kg)	Major Release Sources	Basis of Estimate
Particulates	Air: stack emissions	36,000/16,000	Fossil Fuels Combustion	Stack Testing
Sulfur Dioxide	Air: stack emissions	630,000/290,000	Fossil Fuels Combustion	AP–42 Emission Factors (a)
Nitrogen Oxide	Air: stack emissions	336,000/152,000	Fossil Fuels Combustion	AP–42 Emission Factors
Carbon Monoxide	Air: stack emissions	120,000/54,000	Fossil Fuels Combustion	AP–42 Emission Factors
Non-methane Volatile Organic Compounds	Air: stack emissions	1,700/760	Fossil Fuels Combustion	AP–42 Emission Factors

(a) Calculations were based on AP–42 emission factors and 1993 Fernald site coal use and analysis records.

Fernald Site Source Reduction Information for 1993

Section One: Summary of SARA 313 Report

Chemical Name	Type of Treatment	Quantity (lb/kg)	Treatment Method	Basis of Estimate
Methanol	Treated onsite	78,000/35,000	Biological-Aerobic	Best Engineering Judgment

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Glossary

Activity the rate of disintegration, expressed as disintegrations per second (Becquerels) or in units of Curies (one Curie = 3.7 x 10^{10} Becquerels).

ALARA a phrase and acronym (As Low As Reasonably Achievable) used to describe an approach to radiation exposure and emissions control or management whereby the exposures and resulting doses to the public are maintained as far below the specified limits as economic, technical, and practical considerations will permit.

Aliquot the fraction of a field sample taken for complete processing through an analytical procedure (a "laboratory sample" of a field sample).

Alpha Particle type of particulate radiation (identical to the nucleus of the helium atom) consisting of two protons and two neutrons.

Anion the negatively charged atom in an ionic compound.

Aquifer a body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

Background Radiation the radiation in the natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of humans and animals.

Backlog onsite waste awaiting permitted treatment, storage, or disposal options.

Beta Particle type of particulate radiation emitted from the nucleus of an atom that has a mass and charge equal in magnitude to that of the electron.

Billet machined ingots. During production times at the site, these billets were shipped to other DOE sites for use.

Biological Indicator organisms that reveal the presence of pollution in an ecosystem. For instance, algal blooms indicate organically or nutrient enriched waters.

Blank a sample of the carrying agent (gas, liquid, or solid) normally used to selectively measure a material of interest that is subjected to the usual analytical procedures process to establish a baseline or background value. This value is then used to adjust or correct the routine analytical results.

Calibration the adjustment of the system and the determination of system accuracy using known sources and instrument measurements. Adjustment of flow, temperature, humidity, or pressure gauges and the determination of system accuracy should be conducted using standard operating procedures and sources that are traceable to the National Institute of Standards and Technology.

Confidence Coefficient the chance or probability, usually expressed as a percentage, that a confidence interval includes some defined parameter of a population. The confidence coefficients usually associated with confidence intervals are 90%, 95%, and 99%. For a given sample size, the width of the confidence interval increases as the confidence coefficient increases.

Confidence Interval a value interval that has a designated probability (the confidence coefficient) of including some defined parameter of the population.

Conservative Estimate used frequently in environmental monitoring and dose calculation, it is based on assumptions about an exposure situation that should result in the highest estimate of a dose.

Contamination any substance or material that is somewhere it is not supposed to be.

Critical Organ the human organ or tissue receiving the largest fraction of a specified dose limit.

Critical Pathway the specific route of transfer of radionuclides from one environmental component to another that results in the greatest fraction of an applicable dose limit to a population group or an individual's whole body, organ, or tissue.

Curie (Ci) and Becquerel (Bq) are units of radioactivity that measure the rate of spontaneous, energy-emitting transformations in the nuclei of atoms. One Curie equals 37 billion transformations per second. One Becquerel equals one transformation per second. One Curie (37 billion Bq) of natural uranium is equivalent to a mass of about 1,500 kilograms (3,300 pounds).

Daughter a nucleus that results from radioactive decay; also, progeny.

Decay the disintegration process of an atomic nucleus.

Derby the main product of the former site processing of uranium metal.

Derived Concentration Guideline the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (for example, drinking water or breathing the air) that would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and the lens of the eye.

Dose quantity of radiation absorbed in tissue.

Drum Equivalent the number of 55-gallon drums that it would take to contain a given volume of waste.

Effluent Monitoring the collection and analysis of samples or measurements of liquid, gaseous, or airborne effluents for the purpose of characterizing and quantifying contaminants and process stream characteristics, assessing radiation exposures to members of the public, and demonstrating compliance with applicable standards.

Enrichment a process to increase the percentage of a desired isotope such as uranium–235.

Environmental Detection Limit the lowest concentration at which a radionuclide in an environmental medium can be unambiguously distinguished for a given confidence level using a particular combination of sampling and measurement procedures, sample volume, analytical detection limit, and processing procedure.

Exposure Pathway a route by which materials could travel between the point of release and the point of delivery of a radiation or chemical dose to a person.

Fission the splitting of a heavy nucleus into two approximately equal parts, accompanied by the release of large amounts of energy and generally one or more neutrons.

Flux Rate a measurement of the emission rate of radon.

Fugitive Dust dust that did not flow through a production stack. This includes materials such as dust from the waste storage areas, administration areas, and dust that originated from construction activities.

Gamma Ray type of electromagnetic radiation of discreet energy emitted during radioactive decay of many radioactive elements.

Glacial Till the mix of clay, silt, sand, gravel, and boulders deposited by the glaciers.

Half Life the length of time for half the atoms of a given radioactive substance to decay.

Hydrology the study of the properties, distribution, and circulation of water through the local environment.

ICRP International Commission on Radiological Protection is an organization founded in 1928 and whose function is to recommend international standards for radiation protection.

Ingot remelted derbies and uranium scrap-metal from the former site production process. They varied in weight, size, and shape according to how they were used at this and other DOE sites.

Ionization removal of electrons from an atom, such as by means of interaction with radiation.

Isotope atoms with the same atomic number but different mass number. Isotopes usually have the same chemical properties, but could have very different radiological properties (such as half-life and type of radiation emitted).

Less than Detectable refers to a measurement or calculated concentration that is not statistically different from the associated background or control value at a selected confidence level.

Lithology the study, classification, and mapping of rocks and rock formations.

Lower Limit of Detection the smallest amount of a contaminant that can be distinguished in a sample by a given measurement procedure at a given confidence level.

Minimum Detection Level the minimum amount of the constituent or species of interest that can be observed by an analytical instrument and distinguished from background and instrument noise with a specified degree of probability.

Mixed Wastes hazardous waste that has been contaminated with low-level radioactive materials.

Monitor 1) to measure certain constituents or parameters in an effluent stream continuously or at a frequency that permits a representative estimate of the amount over a specified interval of time;
2) the instrument or device used in monitoring.

NCRP National Council on Radiation Protection and Measurements chartered by Congress in 1914 and charged with developing radiation protection standards.

Nuclide a general term applicable to all atomic forms of the elements, including isotopes.

Null Allele an inactive group of genes.

Occurrence any sudden release or sustained deviation from a regulated or planned performance of an operation that has environmental protection and compliance significance.

Onsite refers to the area within the boundaries of a facility or site that is or can be controlled with respect to access by the general public.

Opacity how much light is blocked by particulates present in stack emissions.

Operable Unit a discrete action that comprises an incremental step toward comprehensively addressing site problems. Operable units may address geographical portions of a site, specific site problems, or initial phases of an action performed over time, or any actions that are concurrent but located in different parts of the site.

Overburden the soil, rock, and other naturally occurring material overlying the bedrock.

Overpacking the act of placing a deteriorating drum inside a new, larger drum to prevent further deterioration or the possible release of contaminants during storage.

Parent Material a radionuclide that produces a specific "daughter" product either directly or as a later result of radioactive decay or disintegration.

Person-rem a collective dose to a population group. For example, a dose of one rem to ten people results in a collective dose of ten person-rem.

Plate Out a thermal, electrical, chemical, or mechanical action that results in a loss of material by deposition on surfaces.

Point Source the single defined point (origin) of a release such as a stack, vent, pipe, or other discernable conveyance.

Positive Interference during sampling analysis, this produces a result that indicates the presence of a radionuclide when, in fact, there is very little or no presence of this radionuclide in the sample.

Potable Water water that is suitable for consumptive purposes.

Radioactive Emissions releases of radioactive materials to the environment.

Radioactive Material refers to any material or combination of materials that spontaneously emits ionizing radiation.

Radioisotope a radioactive isotope.

Radionuclide refers to a radioactive nuclide. There are several hundred known radionuclides, both artificially produced and naturally occurring; radionuclides are characterized by the number of neutrons and protons in an atom's nucleus and their characteristic decay processes.

Random Samples samples that are obtained in such a manner that all items or members of the lot, or population, have an equal chance of being selected in the sample.

Remedial Action — an action that is consistent with the final remedy following a formal examination of the nature and extent of the release, or threat of release, assessment of the risk, and selections of the final remedy based on an evaluation of possible alternatives (RI/FS process).

Removal Action — any necessary action to abate an immediate threat to health and the environment, including actions necessary to monitor, assess, or evaluate the threat.

Representative Sample — a sample taken to depict the characteristics of a lot or population as accurately and precisely as possible. A representative sample may be a "random sample" or a "stratified sample" depending upon the objective of the sampling and the characteristics of the conceptual population.

Roentgen Equivalent Man (rem) and Sievert (Sv) — units of dose which account for the relative biological damage due to the type of radiation involved. One rem equals 0.01 Sv.

Roentgen (R) and Coulombs per kilogram (C/kg) — units of exposure to radioactivity. One R equals 2.6 x 10^{-4} C/kg, and is a measure of the ionization in air due to a source of radioactivity.

Sample — 1) a subset or group of objects selected from a larger set, called the population; 2) an extracted portion of a subset of an effluent stream or environmental medium.

Sampling — the extraction of a prescribed portion of an effluent stream or of an environmental medium for purposes of inspection and/or analysis.

Scintillation Cell — produces a light pulse when struck by an alpha particle and is able to be counted.

Sensitivity — the minimum amount of a radionuclide or other material of interest that can repeatedly be detected by an instrument, system, or procedure.

Site Characterization — designed to provide the information needed to identify site hazards and to select worker protection methods.

Spiked Sample — a normal sample of material (gas, liquid, or solid) to which a known amount of some substance of interest is added. Spiked samples are used to check on the performance of a routine analysis or the recovery efficiency of an analytical method.

Terrace Remnants — land that stands higher than its surroundings due to erosion.

Thermoluminescent Dosimeter — used to monitor the amount of radiation to which it has been exposed.

Tolerance Limits — a particular type of confidence limit used frequently in quality control work, where the limits apply to a percentage of the individual values of the population.

Transuranic — an element with an atomic number greater than uranium.

Wetland — areas covered or saturated with water for enough time to support water-loving vegetation. Typical wetlands include swamps, marshes, and bogs.

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