

Paducah Gaseous Diffusion Plant

History and Mission

The Paducah Gaseous Diffusion Plant began operations in 1954 to produce low-enriched uranium that was then sent to the Portsmouth Gaseous Diffusion Plant for further enrichment. Operations were slowly expanded to include the recovery of transuranics, nuclear weapons disassembly and disposal, exotic metals recovery, uranium milling and disposal, and other activities. Initially the materials produced at Paducah were used in the U.S. nuclear weapons industry. Later the plant produced fuel for commercial nuclear power plants.¹

“Over its 50 year operating lifetime, the Paducah Plant has processed, or enriched, more than a million tons of uranium.”² Most of the enormous tonnage is still located on-site in the form of depleted uranium.

Paducah is the only gaseous diffusion plant in operation at this time. It produces enriched uranium for use in commercial reactors (3-5% U-235).³ As a byproduct of enriching uranium, Paducah’s depleted uranium is available for other uses, such as armor plating for tanks, and anti-tank penetrators.

The Paducah Gaseous Diffusion Plant is currently listed on the Superfund National Priorities List.

The current missions of the site include:

- Enrichment of uranium for use in domestic and foreign commercial power reactors.
- Environmental restoration, which include demonstration of innovative cleanup technologies.
- Continued interim storage of depleted uranium hexafluoride until a conversion facility is constructed.⁴

Location and Land

The Paducah Plant is located 10 miles west of Paducah, Kentucky (population 26,300) and approximately 3.5 miles south of the Ohio River. A number of smaller towns are located within a 5-mile radius of the plant. The plant is situated on 750 acres of land enclosed by fencing on a larger parcel of land of 3,422 acres. (See Figure 1.)

To transform the uranium enrichment process into a profitable industry, the United States Enrichment Corporation was established in 1993. This corporation presently leases portions of the Paducah site from the Department of Energy.

Number of people living within 50 miles of Paducah: Approximately 200,000⁵

Employees at Paducah: Approximately 2,100 employees as of 1997⁶

Three major geologic units are found beneath the site: 60 feet of soil composed of “clayey silt with interbedded sand and gravel”, known as the Upper Continental Recharge System.⁷ This system is underlain by 30 to 40 feet of gravel, which is known as the Regional Gravel Aquifer System. A semi-confining layer known as the McNairy System underlies the Regional Gravel Aquifer System.⁸ Groundwater is found in all three layers, but is in greatest abundance in the Regional Gravel Aquifer System. Due to the permeable soils, substantial leakage from the plant, a humid climate, and the migration of contaminants from the Upper Continental Recharge System, the Regional Gravel Aquifer is significantly contaminated.⁹ In addition the McNairy formation is now slightly contaminated.

Water Sources

Surface Water

Approximately 100 small lakes and ponds, 7 settling basins, and 17 gravel pits are found on-site. Bayou Creek is located to the west of the site. Little Bayou Creek is to the east of the site. Their tributaries and various man-made ditches drain the site. Five to 10 million gallons of wastewater per day are discharged on-site.¹⁰ Bayou Creek and Little Bayou Creek drain into the Ohio River, which is located about 3 miles north of the plant. Surface water recharges the Regional Gravel Aquifer via the Bayou Creek and Little Bayou Creek, as does precipitation seeping down through upper layers to the aquifer.

Aquifer

The main aquifer underlying the site is the Regional Gravel Aquifer. It is 10 to 40 feet thick. This aquifer is located uniformly approximately 60 feet below the surface, and is composed of permeable sands and gravels.¹¹ This important aquifer serves as a source of drinking and supply water for local residents. Groundwater in this aquifer moves towards the Ohio River.

Additionally groundwater beneath the site is found in the McNairy formation. The McNairy formation yields water-bearing zones, which are found in sand and clay layers.¹²

Groundwater flow in the Regional Gravel Aquifer: Northerly at a rate of 0.15 to 15.9 feet per day^{13,14}

Average Annual Precipitation: 48 inches per year¹⁵

The flow of groundwater in the Upper Continental Recharge System is very slow at 0.01 feet per day into the Ohio River. The Upper Continental Recharge System acts as a pathway for contamination to move down into the Regional Gravel Aquifer.¹⁶ Groundwater in the Regional Gravel Aquifer is moving much more rapidly, sometimes up to 15 feet per day, towards the Ohio River.

Since the climate for this area is typically humid, rainwater serves as a source of recharge to the groundwater.¹⁷ Fourteen wells currently monitor groundwater quality.

Contamination

Contaminants enter the groundwater beneath Paducah by means of improper disposal practices, accidental or deliberate releases, spills, and indirect leaching from buried waste materials.¹⁸ Burial grounds, former test areas, lagoons and pits, spills, leaks, and leachate from scrap metal are ongoing sources of contamination. Approximately 13% (by mass) of all DOE military uranium was buried at Paducah.

Between 1952 and 1985, 7 million pounds of uranium was buried on site, 60,000 pounds was released to local streams, and 130,000 pounds were released to the atmosphere.¹⁹ Any uranium released to the atmosphere, subsequently, is deposited on the ground and migrates to surface and subsurface waters. The release of uranium into the environment has continued since 1985.

The first discovery of contamination having spread offsite occurred in 1988. The main contaminants are trichloroethylene, an industrial degreasing solvent, and technetium-99, a fission byproduct of uranium enrichment. Also found is uranium from enrichment operations. Other contaminants such as neptunium and plutonium, heavy metals, and other chemicals are also present.

Groundwater contamination at Paducah is extensive. It is generally confined to the Upper Continental Recharge System and the Regional Gravel Aquifer, although it has also been found in the McNairy formation.²⁰ Three groundwater plumes of contamination have been identified. With two of these plumes are heading towards the Ohio River. These three plumes are the Northwest Plume, the Northeast Plume, and the Southwest Plume.²¹ Several sources of contamination exist for each plume. (See Figures 2 and 3.) The Northwest Plume leads to the Ohio River; the Northeast Plume heads close to the Ohio River; and the Southwest Plume is a small extension of the Northwest Plume.²²

According to the US General Accounting Office contamination in these plumes is extensive: “About 10 billion gallons of contaminated water are spreading offsite in 3 different plumes, at least one of which may have reached the Ohio River. About 250 million gallons of groundwater are contaminated with technetium-99.”²³ Technetium, a radionuclide that is not naturally present, is a by-product from enriching uranium that has been recycled from reprocessing plants at Hanford and Savannah.

The Northwest Plume is contaminated with technetium-99 and TCE. It extends three miles offsite in a northwest direction and covers about 1.6 square miles.

A key source of contamination to the surface water is the thousands of tons of contaminated scrap metal that still remain on-site. Storm water washes the contaminants from these materials and transports the contaminants into the soil. Another source of surface water contamination results from the discharge of wastewater from operations on-site into pits and eventually into the creeks.²⁴ “These various waste materials have contaminated the area’s groundwater, surface water, soils, and air.”²⁵

Contaminants of Potential Concern found in aquifer

Volatile Organic Compounds:

Bromodichloromethane, carbon tetrachloride, chloroform, dichloroethylene, 1,1-Dichloroethene, 1,2-Dichloroethene, methylene chloride, pentachlorophenol, perchloroethylene, polychlorinated biphenyls, tetrachloroethylene, trichloroethene, trichloroethylene, and vinyl chloride

Metals:

Arsenic, beryllium, cadmium, chromium, fluoride, lead, nickel, nitrate, sulfate, sulfide, thallium, and vanadium

Radionuclides:

Radon, neptunium, plutonium, technetium, and uranium

A primary source of contamination is Building C-400. Large pits storing degreasing materials have leaked hundreds of thousands of gallons of contaminated liquids. Other release sites include the Uranium Burial Grounds and the Oil Landfarm. The Uranium Burial Grounds disposed of pyrophoric (spontaneously ignites in air) metal shavings left over from uranium metalworking by placing the shavings into barrels of oil, and then burying them. Oil was dumped into a field and plowed into the ground at the Oil Landfarm; the contaminants have traveled to the groundwater below.²⁶

Another major source of contamination lies in the northwest portion of the site containing over 65,000 tons of scrap metal, much of which still remains as the most visible sign of contamination at Paducah.²⁷ A portion of this source of contamination was known as “Drum Mountain”, a 35-foot tall pile of 8,000 tons of crushed drums, once used primarily for storing greensalt (UF₄). As of August 2000, the mountain of contamination was shipped to a Utah disposal site.

A total of 52,000 barrels of waste are stored on-site.²⁸ “In 1959, 450 gallons of trichloroethylene and uranium were buried at the site in 30-gallon drums. By 1984 most of these drums were missing; possibly the drums corroded and the contents leaked away.”²⁹

In addition to leaking barrels of waste, twelve burial grounds exist on-site and contain a variety of waste.³⁰ There are two classified landfills on-site, one of which received parts of decommissioned and deconstructed nuclear bombs. The landfill known as C-404 Landfill is a burial ground for low-level radioactive waste. Until 1986, this landfill was used for the disposal of uranium-contaminated solid wastes; it is a major source of contamination.³¹

Another source of contamination is releases of uranium and other toxins to the air. Airborne uranium will travel in whichever direction the wind is blowing and then be deposited on plants, fields and surface bodies of water. One hundred and thirty thousand pounds of uranium were releases to the atmosphere.³² Contamination found in the subsurface and aboveground must be contained and removed from Paducah. The humid climate enhances the spread of contamination across the site as well as into the subsurface. It is only a matter of time before more contaminants on-site are washed into the groundwater system below, unless the sources of contamination are removed and the environment is decontaminated.

Remediation

A few methods of remediation proposed, in place or tested at Paducah include: Dynamic Underground Stripping, Permeable Treatment Zone, In-situ Technology, and Pump-and-Treat. Dynamic Underground Stripping is accomplished with the use of Dual Phase-Extraction. Many of these techniques are still in the development and testing phase.

The Dual Phase Extraction process injects steam into the ground so contaminants rise. As this happens, the contaminants are extracted and treated. A treatability study of Six Phase Heating and C-Sparge await funding, although they have been approved by DOE and the regulators. Six Phase Heating remediates soils contaminated with volatile and semi-volatile organic compounds through electrical heating and soil vapor extraction. C-Sparge combines vapor extraction through horizontal wells and injection of small quantities of ozone into the groundwater through microporous points.

The Permeable Treatment Zone is an example of new technology, initially seen as very promising, then plagued with problems. This treatment injects a gummy substance, containing iron filings, into the aquifer as a barrier to absorb technetium and trichloroethylene out of the groundwater plumes.³³ Due to the depth of the contamination at Paducah, the substance must be injected as deep as 120 feet beneath the surface of the ground. Injection to this depth has never been done before. A key problem with this process is that the barriers plug up with contaminants and then can no longer trap water. So both water and contaminants pass through freely. Currently, there is no method of removal or remediation of the plugged-up barriers.³⁴

The first attempt to use this technology was abandoned, due to the inefficiency of a high-pressure water nozzle. Complications of patent ruling have presented a challenge to the second attempt at this treatment. By 2002, DOE had abandoned use of this technology at Paducah – a major setback for the cleanup of groundwater.

Another method of remediation, known as Lasagna, is being tested at the Cylinder Drop Test Site. This method is an in-situ technology that uses electro-osmosis to mobilize moisture and contaminants in fine-grained or clay soils; the contaminants are treated as they pass through in-ground treatment cells.³⁵ Because of the depth of much contamination at Paducah, this method is ineffective.

Pump-and-treat is being used on some of the contaminated plumes and involves contaminated water being withdrawn and run through a pilot plant where technetium-99 is removed via ion exchange and TCE removed via air stripping and charcoal filter. The effectiveness of this method has not been proven. After the treatment, the water is released. Contaminated water from the Northeast Plume is removed and taken through cooling towers and sent straight into the air as steam.³⁶

Major uncertainties exist. Some of these methods of remediation may prove to be more effective than others at Paducah. However, there is not a single method in place that will completely remediate the contamination. More work must be done to remove the technetium, uranium and TCE from the groundwater, and more work must be done to remove the sources of contamination.

Challenges

Trichloroethylene, a major groundwater contaminant at Paducah, has a low solubility in water. This means that trichloroethylene will sink to the bottom of the aquifer or will rest upon a less permeable layer within an aquifer, thereby forming pools. Not only are these pools extremely difficult to clean up, they will then inevitably serve as a continuing source of contamination for plumes that are migrating toward the Ohio River.³⁷ Trichloroethylene and other similar hazardous materials stored are liable to spread the longer they remain on-site.

In addition it is unclear whether new technologies being tested at Paducah will be able to remove technetium and uranium from the underlying aquifer. Furthermore, technical risks exist when new technologies, unproven to fit the site's conditions, are put in place.

Some areas of the site, including the DOE Material Storage Areas and unused structures present a threat for further contamination.³⁸

One of the greatest challenges at Paducah is the uncertainty about the extent, source, and nature of contamination. As more contaminants are discovered, the cost of cleanup is likely to increase. Without adequate funding, remediation will be delayed. Reduced funding also means the probability that less expensive and less thorough techniques for cleanup will be used.

Cleanup of the site is also complicated by the ongoing operation of the gaseous diffusion plant which continues to produce uranium fuel for commercial nuclear reactors, both domestic and foreign, and continues to release toxins to the environment.

¹ Makhijani et al. *Nuclear Wastelands*, 2000: 206.

² US GAO. "Nuclear Waste Cleanup: DOE's Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities", April 28, 2000: GAO/RCED-00-96.

³ Mark Donham of RACE/Heartwood. *Email*. September 26, 2001.

⁴ US DOE. "NDAA Report to Congress on Long-term Stewardship", January 2001: 7.

⁵ Estimated from the US Census 2000. <<http://factfinder.census.gov/servlet/BasicFactsServlet>>.

⁶ Schwartz, S.I. "Paducah Gaseous Diffusion Plant", <<http://nuclearfiles.org/sites/pgdp.html>>.

⁷ Bechtel Jacobs, LLC. "Annual Site Environmental Report for 1999", Chapter 9: 9-8.

⁸ US DOE. "ITRD Year End Report FY 2000", 35.

⁹ US DOE. "Recommendations for Accelerated Cleanup at Paducah", March 7, 2000, <<http://www.em.doe.gov/news/padrecomm.html>>.

¹⁰ US DOE. "Recommendations for Accelerated Cleanup at Paducah", March 7, 2000, <<http://www.em.doe.gov/news/padrecomm.html>>.

¹¹ Bechtel Jacobs, LLC. "Annual Site Environmental Report for 1999", Appendix D: D-2.

¹² ATSDR. "Public Health Assessment", <www.atsdr.cdc.gov/HAC/PHA/paducah/pad_p1.html>.

¹³ US DOE. "Recommendations for Accelerated Cleanup at Paducah", March 7, 2000, <<http://www.em.doe.gov/news/padrecomm.html>>.

¹⁴ TechCon. "Paducah: TCE and Technetium in Groundwater", <<http://web.ead.anl.gov/techcon/remed/index.cfm>>.

¹⁵ Coyle et al. *Deadly Defense: Military Radioactive Landfills*, 1988: 77.

¹⁶ US DOE. "Recommendations for Accelerated Cleanup at Paducah", March 7, 2000, <<http://www.em.doe.gov/news/padrecomm.html>>.

¹⁷ Bechtel Jacobs, LLC. "Annual Site Environmental Report for 1999", Chapter 9: 9-3.

¹⁸ ATSDR. "Public Health Assessment", <www.atsdr.cdc.gov/HAC/PHA/paducah/pad_p1.html>.

¹⁹ Coyle et al. *Deadly Defense: Military Radioactive Landfills*, 1988: 76-77.

²⁰ US DOE. "Recommendations for Accelerated Cleanup at Paducah", March 7, 2000, <<http://www.em.doe.gov/news/padrecomm.html>>.

²¹ US DOE. "Vadose Zone Fact Sheet", September 2000, <<http://www.em.doe.gov/vadose/contents.html>>.

²² Mark Donham of RACE/Heartwood. Telephone Interview. August 10, 2001.

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- ²³ US GAO. “Nuclear Waste Cleanup: DOE’s Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities”, April 28, 2000: GAO/RCED-00-96.
- ²⁴ Mark Donham of RACE/Heartwood. Telephone Interview. August 10, 2001.
- ²⁵ US GAO. “Nuclear Waste Cleanup: DOE’s Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities”, April 28, 2000: GAO/RCED-00-96.
- ²⁶ Mark Donham of RACE/Heartwood. Telephone Interview. August 10, 2001.
- ²⁷ US GAO.. “Nuclear Waste Cleanup: DOE’s Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities”, April 28, 2000: GAO/RCED-00-96.
- ²⁸ US GAO. “Uncertainties and Management Problems Have Hindered Cleanup at Two Nuclear Waste Sites”, GAO/T-RCED-00-248, 07/12/2000.
- ²⁹ Makhijani et al. *Nuclear Wastelands*, 2000: 206.
- ³⁰ US GAO. “Nuclear Waste Cleanup: DOE’s Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities”, April 28, 2000: GAO/RCED-00-96.
- ³¹ Bechtel Jacobs, LLC. “Annual Site Environmental Report for 1999”, Chapter 9: 9-9.
- ³² Coyle et al. *Deadly Defense: Military Radioactive Landfills*, 1988: 76-77.
- ³³ US GAO. “Nuclear Waste Cleanup: DOE’s Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities”, April 28, 2000: GAO/RCED-00-96.
- ³⁴ Mark Donham of RACE/Heartwood. Email. September 26, 2001.
- ³⁵ US DOE. “Vadose Zone Fact Sheet”, September 2000, <<http://www.em.doe.gov/vadose/contents.html>>.
- ³⁶ Mark Donham of RACE/Heartwood. Telephone Interview. August 10, 2001.
- ³⁷ Bechtel Jacobs, LLC. “Annual Site Environmental Report for 1999”, Chapter 9: 9-3.
- ³⁸ US GAO. “Nuclear Waste Cleanup: DOE’s Paducah Plan Faces Uncertainties and Excludes Costly Cleanup Activities”, April 28, 2000: GAO/RCED-00-96.

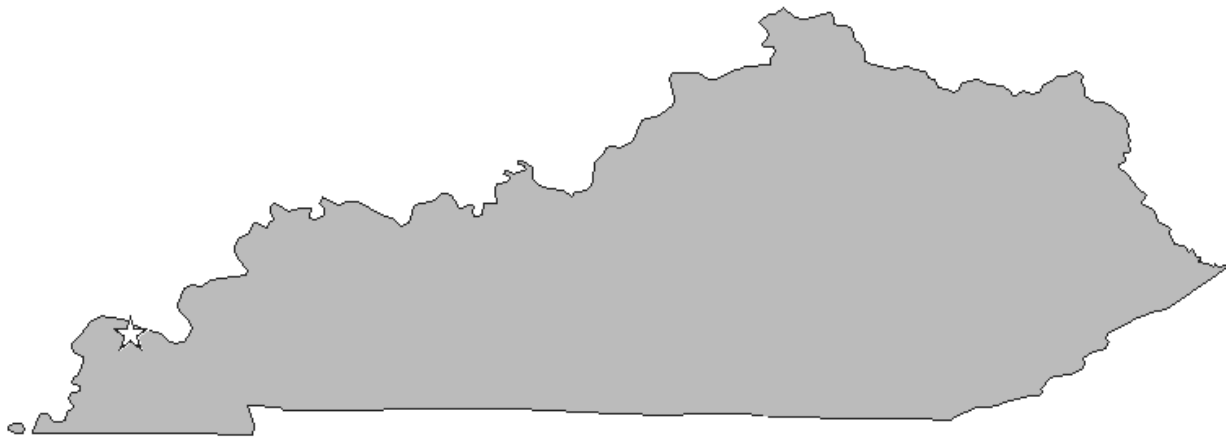


Figure 1: Location of Paducah Site and Surface Water on Site

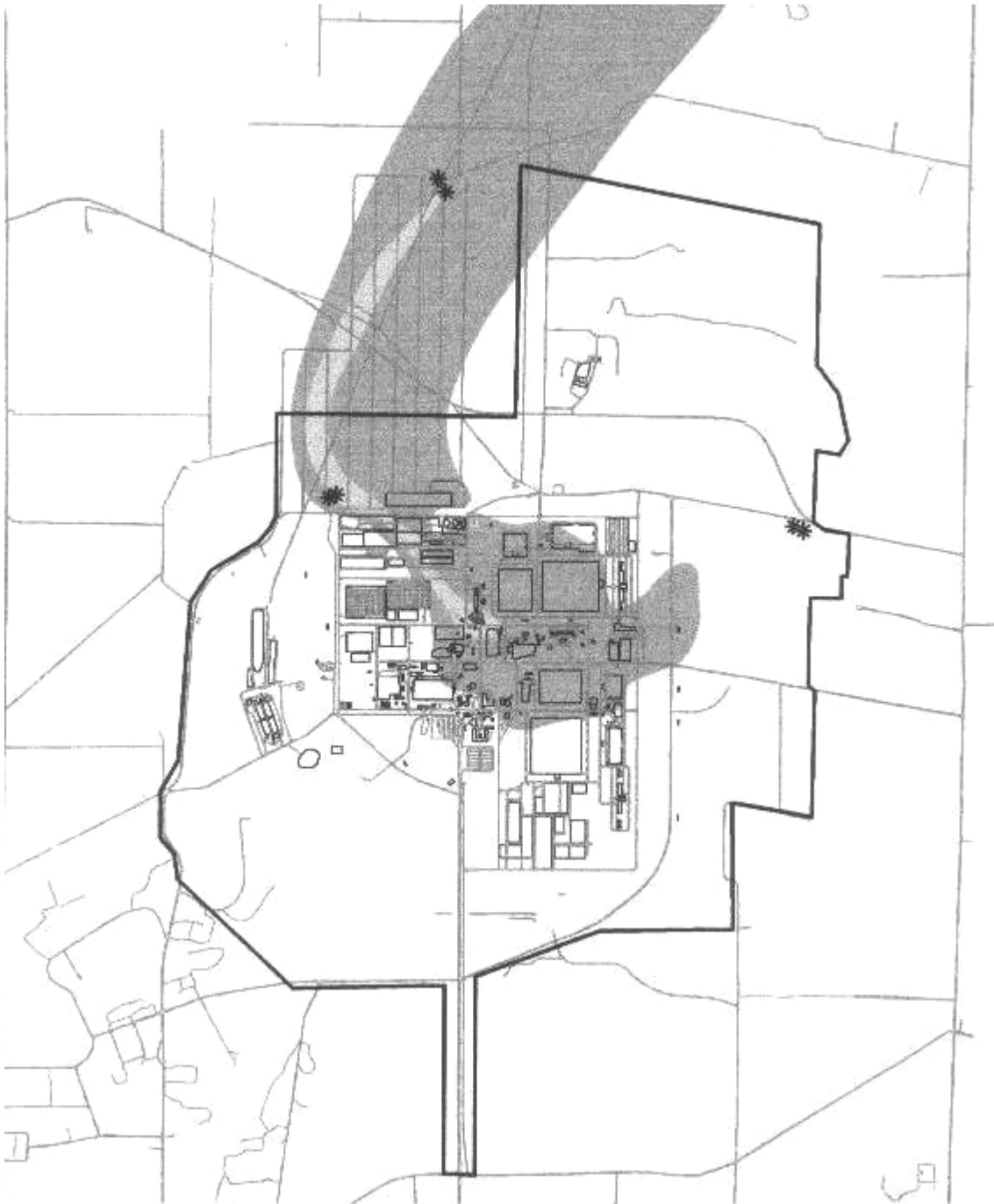


Figure 2: Tc-99 Plume Extending Off-site, Toward Ohio River

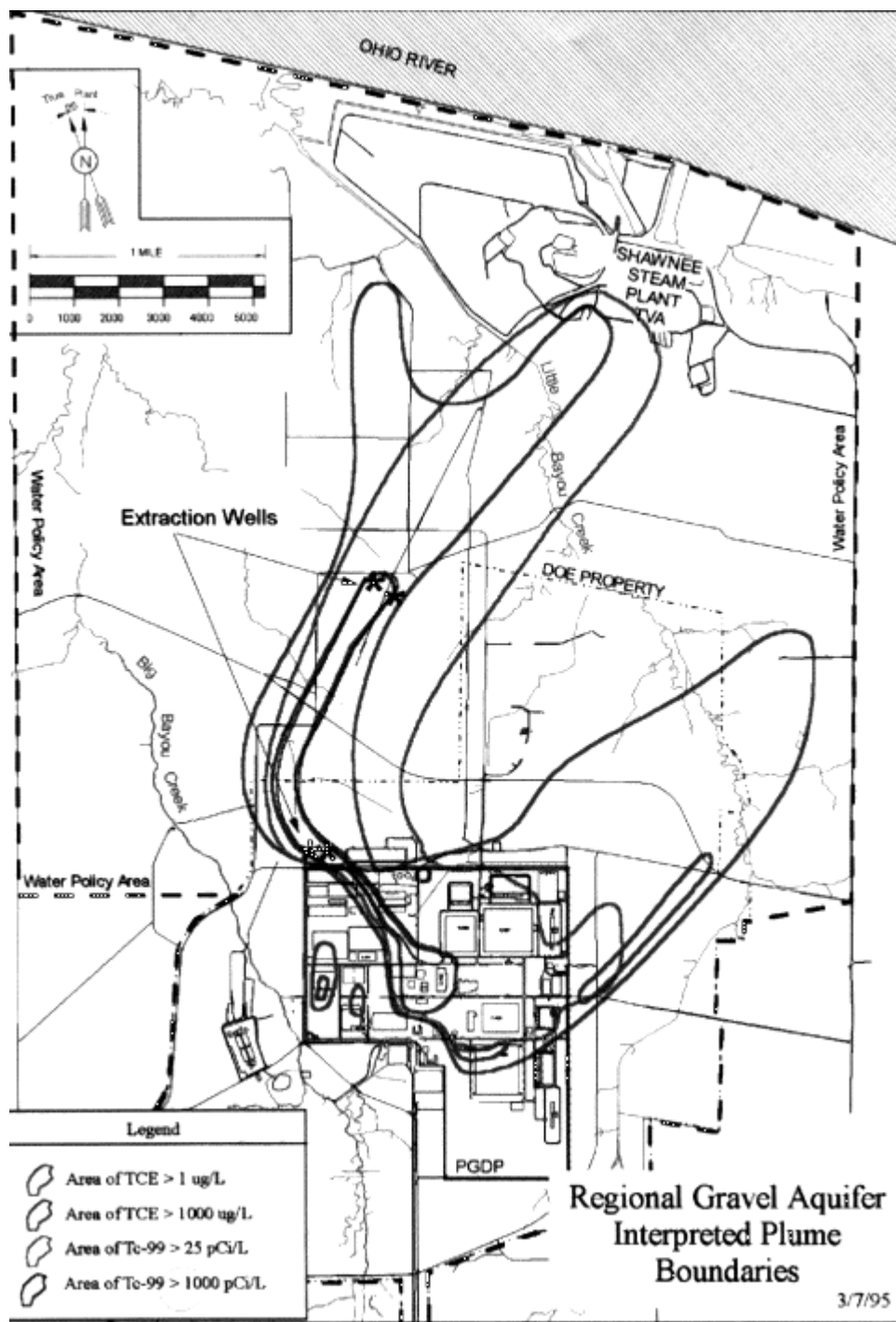


Figure 3: TCE and Tc-99 Plumes Extending Off-site, Toward Ohio