LMS/FER/43783

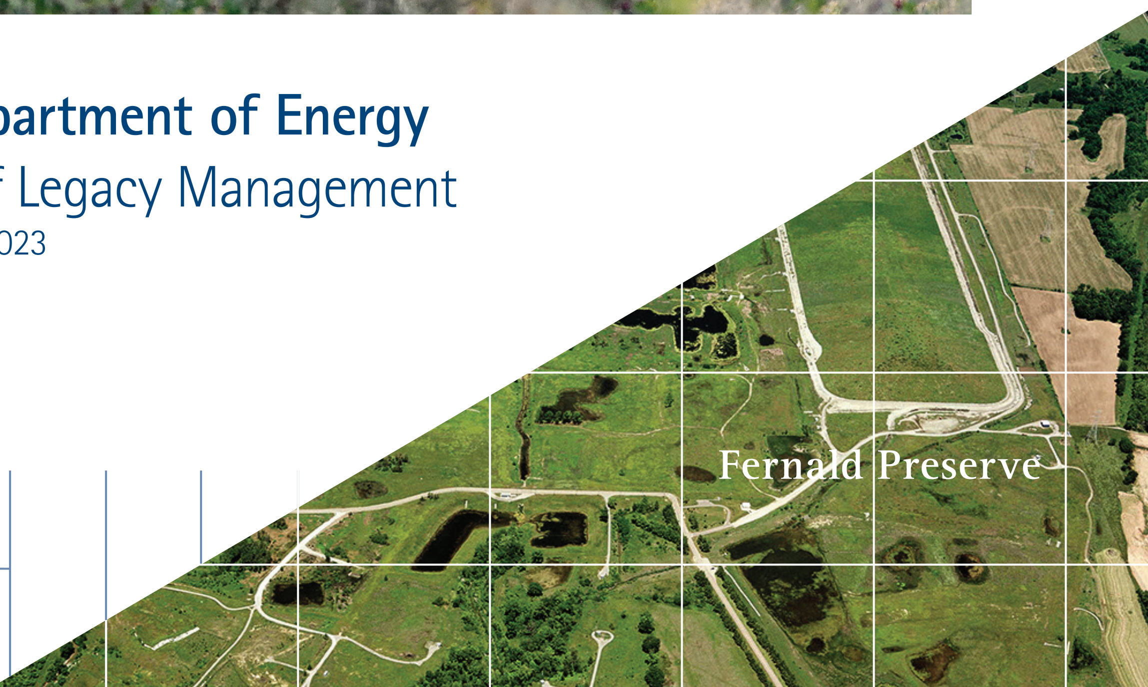
FERNALD PRESERVE

2022 Site Environmental Report

U.S. Department of Energy

Office of Legacy Management

Issued May 2023



Electronic versions of Fernald Preserve documents are available at https://www.energy.gov/lm/fernald-preserve-ohio-site.
U.S. Department of Energy Office of Legacy Management’s Geospatial Environmental Mapping System (GEMS) application is available at https://gems.lm.doe.gov/#site=FER

Cover image: White-tailed deer (*Odocoileus virginianus*) © Jeff Sluder 2023.

Contents

Figures

Tables

Appendixes

Abbreviations

ARAR	applicable or relevant and appropriate requirement
CAWWT	Converted Advanced Wastewater Treatment
CC	coefficient of conservatism
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facility Compliance Agreement
FQAI	Floristic Quality Assessment Index
FRL	final remediation level
IEMP	Integrated Environmental Monitoring Plan
LCS	leachate collection system
LDS	leak detection system
LM	Department of Energy, Office of Legacy Management
LMICP	*Comprehensive Legacy Management and Institutional Controls Plan*
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRMP	*Fernald Preserve, Ohio, Site Natural Resource Management Plan*
NRRP	Natural Resource Restoration Plan
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
OU5 ROD	Operable Unit 5 Record of Decision
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PPDD	Pilot Plant Drainage Ditch
RAMP	Restored Area Maintenance Plan
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SSOD	storm sewer outfall ditch
USC	*United States Code*

Executive Summary

The *Fernald Preserve 2022 Site Environmental Report* provides stakeholders with the results from the Fernald Preserve, Ohio, Site's environmental and ecological monitoring programs for 2022; a summary of U.S. Department of Energy (DOE) activities conducted onsite; a status of the ongoing groundwater remediation; and a summary of the site's compliance with the various environmental regulations, compliance agreements, and DOE policies that govern site activities. This report has been prepared in accordance with the Integrated Environmental Monitoring Plan, which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP).

Remediation of the Fernald Preserve has been successfully completed, with the exception of the groundwater. During 2022, activities at the Fernald Preserve included the following:

- Environmental monitoring activities related to groundwater and surface water
- Monitoring as specified in the site's National Pollutant Discharge Elimination System (NPDES) permit
- Extraction, monitoring, and treatment of contaminated groundwater from the Great Miami Aquifer (Operable Unit 5)
- On-Site Disposal Facility (OSDF) leak detection monitoring and collection, monitoring, and treatment of leachate from the OSDF
- Ecological restoration monitoring and maintenance, as well as inspections, care, and monitoring of the site and the OSDF to ensure that provisions of the LMICP are fully implemented
- Ongoing operation of the Fernald Preserve Visitors Center, associated outreach, and educational activities

Environmental monitoring programs were developed to ensure that the remedy remains protective of the environment. The requirements of these programs are described in detail in the LMICP and reported in this Site Environmental Report as outlined below.

Liquid Pathway Highlights

Groundwater Pathway

The groundwater pathway at the Fernald Preserve is routinely monitored to:

- Verify that hydraulic capture of the total uranium plume is maintained; track the aquifer restoration in the area of the plume, including non-uranium constituents; and evaluate water quality conditions in the aquifer that may indicate a need to modify the design or the operation of the well field.
- Meet compliance-based groundwater monitoring obligations.

During 2022, active restoration of the Great Miami Aquifer continued. A total of 93 groundwater monitoring wells were sampled to determine water quality. Aquifer water elevations were measured in 172 groundwater monitoring wells. The following highlights describe the key findings from the 2022 groundwater data:

- A total of 2 billion gallons of groundwater was extracted from the Great Miami Aquifer, and 354 pounds (lb) of uranium were removed from the aquifer in 2022.
- Since 1993, 55 billion gallons of water have been pumped from the Great Miami Aquifer, and 15,751 net pounds of uranium have been removed from the Great Miami Aquifer. Net pounds of uranium removed include a small amount of uranium that was reinjected into the aquifer between 1998 and 2004.
- Data collected in 2022 indicate that uranium concentrations within the footprint of the 30 micrograms per liter (µg/L) maximum uranium plume continue to decrease in response to pumping. The footprint of the maximum uranium plume in 2022 was approximately 74.0 acres, a decrease of 1 acre or approximately 1.3% from what was mapped in 2021. Since 2005, the area of the total uranium plume has decreased from 196.1 acres to 74.0 acres (62.3%).
- The results of the groundwater capture analysis and monitoring for total uranium and non-uranium constituents indicate that the design of the groundwater remedy for the aquifer restoration system remains appropriate for capture of the plume.
- Pumping of the South Plume/South Plume Optimization Module continued to meet the objective of preventing further southward migration of the southern total uranium plume beyond the extraction wells.

Groundwater Remedy

The current Operational Design for the groundwater remedy has been in effect since design changes were implemented on July 1, 2014. Three extraction wells that were no longer providing benefit to the remediation were shut down, and the pumping capacity from these wells was reallocated to extraction wells in the South Plume and southern portion of the South Field to accelerate cleanup of those areas. The system pumping rate was increased 300 gallons per minute (gpm) from 4,775 gpm to 5,075 gpm.

The current Operational Design is more aggressive than the previous design because, for the first 9 years, the target system pumping rate is 300 gpm higher. The current Operational Design is also more efficient because pumping rates are initially higher in the more concentrated areas of the plume, resulting in lower overall pumping rates as the remedy progresses. No planned operational changes to the groundwater remediation occurred in 2022, but two South Plume extraction wells were shut down permanently due to maintenance issues. As discussed below, DOE is planning to install two new extraction wells in the South Plume.

Data collected in 2022 show that more uranium was removed from the aquifer than the model predicted would be removed. This indicates that pumping remains effective in removing uranium, but that the cleanup will take longer than the model predicted. Higher pumping rates are also taking a toll on some of the extraction wells. Chemical treatments, to combat iron fouling in the extraction wells, are becoming less effective over time, and the chemical used in the treatments is slowly compromising the integrity of the metal components of the extraction wells.

As reported in the 2020 Site Environmental Report (DOE 2021), additional groundwater modeling was needed to determine whether the system could be optimized again, as it was in 2014. Modeling was completed in early 2022. The groundwater model was updated with uranium concentrations measured in the first half of 2021. Updated cleanup date predictions for the South Plume, the South Field and the Waste Storage Area were determined to be 2025, 2038, and 2045, respectively. These new cleanup time predictions assume that the no wellfield pumping changes are made to the current operational design. Continued use of the existing South Plume wells to complete remediation of the South Plume carried unacceptable risk. The aging extraction wells in the South Plume are no longer dependable. Some have been operating for over 28 years. Also, due to remediation progress, the wells are no longer located in optimal locations to complete remediation of the remaining South Plume.

DOE completed additional modeling in 2022 that provides an alternate operational approach to completing remediation of the South Plume. DOE is planning to install two new extraction wells in the South Plume. These two new wells are scheduled to be operational in 2024. When operational, the remaining old South Plume wells will no longer be needed to maintain capture of the South Plume or to complete the remediation of the South Plume.

DOE collaborated with the DOE National Laboratory Network in 2021 through two focus groups to determine ways to address the continuing issues with the aging aquifer restoration infrastructure (Focus Group 1) and improve the efficiency of the aquifer cleanup (Focus Group 2). DOE has begun implementing National Laboratory Network recommendations. With approval from the U.S. Environmental Protection Agency (EPA) and the Ohio Environmental Protection Agency (Ohio EPA), DOE conducted a small-scale field test on two recently rehabilitated extraction wells to determine whether routine chemical treatment with a biocide agent might improve biofouling issues in the wells better than periodic treatment with acid. The small-scale test ran for approximately 6 months from fall 2021 to late spring 2022. Based on the field test results, it was determined that the tested routine process provided no improvement in specific capacity (i.e., gallons of water pumped per foot of water drawdown in the well) than the periodic treatment has provided. DOE will continue to investigate ways to address maintenance issues of an aging system of extraction wells. All three National Laboratory Network recommendations from the first focus group pertain to extending the life of an extraction well. Considering the age of the existing extraction wells, rather than trying to prolong their lives further, the best option may be to just begin to strategically replace them. DOE will revisit all three of Focus Group 1 recommendations as deemed appropriate when replacement of an extraction well is being considered.

DOE is also implementing National Laboratory Network recommendations that target improving the aquifer remediation and providing better model predicted cleanup dates (Focus Group 2). In late 2022 to early 2023 DOE completed work using alternative mathematical functions to trend uranium concentration data and using three-dimensional aquifer interpretations over time to improve plume metrics used to assess cleanup progress. Both methods have been successfully added to the Fernald Preserve toolbox for evaluation of the aquifer remedy. More information concerning the National Laboratory Network collaboration and recommendations is provided in Section 3.4 and Appendix A.

The aquifer remedy in the current Operational Design is achieving the uranium discharge limits (i.e., average monthly concentration of less than 30 µg/L and 600 lb annually) established in the

Operable Unit 5 Record of Decision without routine groundwater treatment. Routine groundwater treatment has not been needed since 2010. Occasionally, groundwater is sent to treatment for very short periods of time. The reasons for the short periods of treatment vary, but most are related to times when wells pumping low uranium concentrations are turned off for maintenance and wells pumping higher uranium concentrations continue pumping.

In 2022, 2 billion gallons of groundwater were pumped from the Great Miami Aquifer and 4.5 million gallons (0.22%) of groundwater were treated.

OSDF Monitoring

Engineered features within the OSDF continue to perform as designed, indicating that a leak from the facility is not occurring. Leachate flow continues to diminish as expected, and leak detection system flow volumes indicate that the cell liners are performing as designed.

A few OSDF valve house maintenance issues were addressed in 2022. Over the years, several small, very minor leaks have occurred in the valve house piping that so far have been easily repaired. The liquid was contained within the valve houses and attributed to galvanic corrosion between two different types of metal components of the piping system. Rather than wait for more leaks to develop, with concurrence from EPA and Ohio EPA, DOE began replacing the metal pipes in the valve houses with plastic piping in late 2022. Smaller sampling ports are also being installed in the leachate detection system lines as part of the project.

In late 2021, a small amount of water was observed in OSDF valve house 7 in the area where the leachate collection system piping penetrates the valve house walls and enters the valve house through the east wall of the valve house. The leachate collection system is a double-walled pipe; the secondary containment system contained no liquid indicating that the liquid was not coming from the leachate collection system. The amount of liquid increased after precipitation events. Sampling of the liquid entering the valve house revealed that the uranium concentration matched the very low historical uranium concentrations in the perched groundwater in the area; therefore, the liquid in the valve house is attributed to water leaking into the valve house from immediately outside the valve house wall. DOE repaired the leak in valve house 7 in summer 2022. Unfortunately, additional leaks occurred along the inner surface of the same wall following the repair. It is believed that once the initial leak was fixed, later collection of water on the outside of the valve house wall found other entry points through the wall. Based on the nature of the leaks observed, it is assumed that water is collecting around the base of the east side of the valve house. DOE plans to investigate further when seasonal precipitation is lowest (i.e., late summer and early fall). If deemed appropriate, an engineered fix (e.g., French drain) will be evaluated.

Surface Water and Effluent Pathway

Surface water and effluent are monitored to determine the effects of Fernald Preserve activities on Paddys Run (an intermittent stream), the Great Miami River, and the underlying Great Miami Aquifer, as well as to meet compliance-based surface water and effluent monitoring obligations.

In 2022, 18 surface water locations and 1 effluent location were sampled at various frequencies. The following highlights describe the key findings from the 2022 surface water and effluent monitoring programs:

- Since 1995, the annual uranium mass discharged in Fernald Preserve effluent to the Great Miami River has been less than the Operable Unit 5 Record of Decision limit of 600 lb per year. A total of 335 lb of uranium was discharged in effluent to the Great Miami River in 2022.

- An estimated 32.4 lb of uranium were released to the environment through uncontrolled stormwater runoff from the site. Therefore, the total amount of uranium released through the effluent and uncontrolled surface water pathways during 2022 is estimated to be 367.4 lb.
- Analytical results of 7 of 31 surface water samples collected from location SWD-09 exceeded the surface water final remediation level for total uranium in 2022, the site's primary contaminant. SWD-09 is one of the two locations established to monitor the 2007 maintenance action completed west of the former Waste Pits Area. The second location, SWD-05, did not exceed the surface water final remediation level for uranium in 2022. These locations are in an area of the site that is not accessible to the public.

  Analytical results of surface water samples collected at location SWD-09 have been trending downward since 2010. The surface water from this area remains isolated and does not drain normally to Paddys Run; it either evaporates or infiltrates into the ground. Any infiltration down to the aquifer in this area is within the capture zone of nearby extraction wells operating as part of the groundwater remediation.
- Compliance sampling, consisting of sampling for nonradiological pollutants from uncontrolled runoff in the Storm Sewer Outfall Ditch and effluent discharges from the Fernald Preserve, is regulated under the state-administrated NPDES program. Discharges in 2022 were in compliance with limits identified in the NPDES permit.

In 2021, a review of surface water results at several locations over the past 10 years indicate that reductions in the surface water program are warranted. These reductions were incorporated into the surface water monitoring program for 2023 with approval of the LMICP. The final analytical results for these locations, which are all well within historical ranges, are presented in Appendix B.

Based on the number of years of data collected, DOE is proposing to reduce the weekly sampling at SWD-05 and SWD-09 to a semi-annual frequency to align with the surface water monitoring program outlined in the LMICP. Additional details are provided in Section 4.3.1 and Appendix B.

Natural Resources

The focus of restored area maintenance activities in 2022 involved continued eradication of invasive species, including targeted efforts on teasel species (*Dipsacus* species), giant reed (*Phragmites australis*), lesser celandine (*Ficaria verna*) and callery pear (*Pyrus calleryana*). Fall foliar herbicide application to Amur honeysuckle (*Lonicera maackii*), in conjunction with manual removal, also continued in 2022. Approximately 3 acres of restored prairie, heavy with invasive teasel (*Dipsacus* species), were mowed in the winter, treated with herbicide in the spring, and are planned to be overseeded with prairie seed mix in 2023. In total, approximately 323 acres were addressed for invasive species.

Prescribed burning is a prairie management tool used on the site. In 2022, DOE and the U.S. Forest Service entered into an inter-agency agreement to conduct prescribed burns at the site. On December 2, 2022, the U.S. Forest Service conducted two prescribed burns, burning approximately 20 acres of prairie in the Former Production Area. Additional detail is provided in Section 5.1.

In 2020, the Fernald Natural Resource Trustees conducted a 10-year review of the Restored Area Maintenance Plan, pursuant to the Natural Resource Restoration Plan. That review resulted in the development of the Natural Resource Management Plan (NRMP). This document presents a revised community-based approach for management and evaluation of ecologically restored areas across the Fernald Preserve. DOE implemented the Natural Resource Management Plan in 2021. Functional monitoring in 2022 continued to utilize a community-based approach, pursuant to the NRMP. The NRMP was incorporated as Appendix A of Volume I of the 2023 LMICP (DOE 2023).

Floristic inventories were conducted in prairie and successional areas across the site. Results of this effort indicate the ongoing presence of native vegetation within remediation prairie and remediation successional communities. The prairies appear to have plateaued in their development, as findings in 2022 were consistent with previous years. Early signs of ecological succession were observed in the remediation successional areas. Vegetation monitoring also occurs on the OSDF. These data are reported in the quarterly inspection reporting process. DOE is proposing that beginning in 2023, OSDF vegetation data be reported in the Site Environmental Report rather than the quarterly inspection reporting process. Additional information regarding monitoring activities for evaluation of ecologically restored communities is provided in Appendix C.

Quarterly site and OSDF inspections continued in 2022. Findings were mainly invasive vegetation and damage to deer exclosure fence in the restored areas, and woody vegetation on the cap of the OSDF. Starting in 2022, inspection findings are summarized in the Site Environmental Report and not reported quarterly, unless the finding is related to activity and use limitations of the site. This was the case for one finding in 2022. During the December 2022 inspection, it was discovered that the Main Drainage Corridor culvert was in need of repair. Concrete had degraded, which caused a grate preventing access to the culvert to become dislodged. Plans are being developed to repair the grating in 2023. Additional details on this finding are in Section 5 and Appendix C.

Debris continues to be found, primarily in the Former Production Area and the former Waste Storage Area. Examples of debris include pieces of concrete, rebar, clay tile, and metal. Weather, erosion, and earth-moving activities occasionally reveal small pieces of debris that were not visible during remediation and restoration efforts. A total of 128 pieces of debris were removed in 2022. No debris had fixed radiological contamination above background levels. A summary table of annual debris counts is provided in Appendix C, Table C-6.

With regulatory approval of the LMICP (DOE 2023) in early 2023, annual site inspection photographs will no longer be completed and reported in the Site Environmental Report. The 2022 set of photographs taken are provided in Appendix C along with the earliest photograph at each location. This final set of photographs demonstrates the ecological restoration progress across the site.

1.0 Site Background

Abbreviated Timeline: 1951-2006

1951	Construction of the Feed Materials Production Center began.
1952	Uranium production started.
1986	U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) signed the Federal Facility Compliance Agreement, thus initiating the remedial investigation/feasibility study process under the National Contingency Plan.
1989	Uranium production suspended. The Fernald site was placed on the National Priorities List, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites most in need of cleanup.
1991	As part of the Amended Consent Agreement, the site was divided into operable units for characterization and remedy determination. Uranium production formally ended. The site mission changed from uranium production to environmental remediation and site restoration.
1992	Large-scale groundwater pumping to contain the off-property South Plume began.
1994	Decontamination and dismantling of the first building was completed under the Operable Unit 3 Interim Record of Decision (ROD).
1996	The last operable unit's ROD was signed, signifying the end of the 10-year remedial investigation/feasibility study process. (The Operable Unit 4 ROD was later reopened.) Construction began in support of the Operable Unit 1 selected remedy. Soil remedial excavation began as part of the Operable Unit 5 selected remedy.
1997	Construction of the On-Site Disposal Facility (OSDF) began. First waste placement began in December. Environmental monitoring and reporting were consolidated under the Integrated Environmental Monitoring Plan.
1998	Operable Unit 2 remedial excavations began.
1999	Excavation of the waste pits began (Operable Unit 1 ROD), and the first rail shipment of waste was transported to Envirocare of Utah, Inc.
2000	The ROD Amendment for Operable Unit 4 Silos 1 and 2 Remedial Actions was signed by EPA, thus establishing a new selected remedy for Operable Unit 4.
2001	Cell 1 of the OSDF was capped. Remediation of the Operable Unit 2 Southern Waste Units was completed.
2002	The Silos 1 and 2 Radon Control System began operation and successfully reduced radon levels within the silos. The offsite transfer of nuclear product material was completed. Wastes were placed in OSDF Cells 2 through 5.
2003	All major Operable Unit 2 remedial actions were completed. In addition, approximately 412,000 cubic yards of waste were placed in OSDF Cells 3 through 6.
2004	Removal of Silos 1 and 2 wastes from the silos to the holding tank facility began. Plans to reduce the size of the site's wastewater treatment infrastructure were approved and implemented. The last of Fernald's 10 uranium production complexes, plus an additional 35 structures and 73 trailers, were demolished. All eight cells of the OSDF were capped or received waste. Approximately 513,000 cubic yards of waste were placed in Cells 4 through 8.
2005	Removal of Operable Unit 4, Silo 3 waste began and the first shipment of this waste arrived at Envirocare of Utah. Remedial actions for Operable Unit 1 were completed in June. The first shipment of Silos 1 and 2 waste arrived at Waste Control Specialists in Texas.
2006	With the exception of groundwater remediation, site remediation was completed October 29, 2006. The site was officially transferred to DOE's Office of Legacy Management on November 17, 2006.

In 1951, the U.S. Atomic Energy Commission, a predecessor agency of the U.S. Department of Energy (DOE), began building the Feed Materials Production Center on a 1,050-acre tract of land outside the small farming community of Fernald, Ohio. The facility's mission was to produce "feed materials" in the form of purified uranium compounds and metal for use by other government facilities involved in the production of nuclear weapons for the nation's defense.

Uranium metal was produced at the Feed Materials Production Center from 1952 through 1989. During that time, more than 500 million pounds (lb) of uranium metal products were delivered to other sites. These production operations caused releases to the surrounding environment, which resulted in contamination of soil, surface water, sediment, and groundwater on and around the site.

In 1991, the mission of the site officially changed from uranium production to environmental cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund), as amended (Title 42 *United States Code* Section 9601 et seq. [42 USC 9601 et seq.]). The site was renamed the Fernald Environmental Management Project in 1991. In 2003, the site name changed to the Fernald Closure Project to reflect the mission of the site as on a path to closure. In 2007, the site name changed to the Fernald Preserve to reflect the completion of the cleanup (with the exception of groundwater) ushered in by the successful transition to the DOE Office of Legacy Management (LM) in late 2006. In addition to completing groundwater remediation, the LM mission is now to be an asset to the community as an undeveloped park, with an emphasis on wildlife.

Abbreviated Timeline: 2006 - Present

2008	The old Silos Warehouse was remodeled into the new Fernald Preserve Visitors Center and opened to the public in August 2008. The community was allowed unescorted access to the Fernald Preserve.
2012	The throughput capacity of the Converted Advanced Wastewater Treatment Facility (CAWWT) was reduced from 1,800 gallons per minute (gpm) to 500−600 gpm.
2014	On July 1, 2014, a new groundwater remediation operational design was implemented (DOE 2014). The target system pumping rate was 300 gpm higher than the previous design and accelerated cleanup.
2015	The decision to reduce wastewater treatment capacity to 50 gpm was made.
2017	Completed removal of treatment media, demolition of existing piping and tanks to allow room for the new wastewater treatment system within CAWWT, and design of the new system, which began in 2016. Low-level radioactive waste from the demolition project was disposed of at Waste Control Specialists in Texas. Construction of the new treatment system began.
2018	The new water treatment system became operational in April 2018.
2019	The refurbished CAWWT backwash basin was operational in November 2019.

DOE's Legacy Management Support contractor continues to perform site activities, including the ongoing groundwater remedy. The U.S. Environmental Protection Agency (EPA) Region 5 and the Southwest District Office of the Ohio Environmental Protection Agency (Ohio EPA) provide regulatory oversight.

In the 1980s, the goals of environmental monitoring were to assess the impact of production operations and monitor the environmental pathways through which residents of the local community might be exposed to contaminants from the site (exposure pathways). The environmental monitoring program provided comprehensive on- and off-property surveillance of contaminant levels in surface water, groundwater, air, and biota (agricultural produce). The goal was to measure the levels of contaminants associated with uranium production operations and report this information to the regulatory agencies and stakeholders.

After the conclusion of the site's uranium production and the completion of the CERCLA remedy selection process, the focus was on the safe and efficient implementation of environmental remediation activities and facility decontamination and dismantling operations. In recognition of this shift in emphasis toward remedy implementation, in 1997 the environmental monitoring program was revised to align with the remediation activities planned for the Fernald site. The site's environmental monitoring program is described in the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP) (DOE 2019). Noting that it is expected that fewer changes to the LMICP will be required, DOE proposed to EPA and Ohio EPA that the variance process established in the Fernald Preserve Quality Assurance Project Plan (DOE 2014) be used to communicate LMICP changes instead of updating the entire document each year. This process was approved, and changes required to be implemented for calendar year 2021 were documented and approved by the regulatory agencies in January 2021. This process was again utilized in 2022; a full revision of the LMICP was completed and approved for implementation in calendar year 2023 (DOE 2023).

The environmental monitoring program is designed to ensure the continued protectiveness of the completed remedial actions as well as implementation of the ongoing groundwater remedy and performance of the On-Site Disposal Facility (OSDF). This *Fernald Preserve 2022 Site Environmental Report* summarizes the findings from the monitoring program and provides a status on the progress toward final site restoration. This report consists of the following:

- **Summary Report:** The summary report (Sections 1.0 through 5.0) documents the results of environmental monitoring activities at the Fernald Preserve in 2022. It includes a discussion of ongoing groundwater remediation activities and summaries of environmental data from groundwater, surface water and effluent, and natural resources monitoring programs. It also summarizes the information contained in the appendixes. A glossary is included at the end of the summary report.

- **Appendixes:** The detailed appendixes provide the 2022 environmental monitoring data for the various media, primarily in the form of graphs, figures, and tables. The appendixes are generally distributed only to the regulatory agencies. However, a complete copy of the appendixes is available on the LM public website at https://www.energy.gov/lm/fernald-preserve-ohio-site or by contacting LM at (513) 648-3333; by contacting Interpretive Service at (513) 648-6000; or by sending an email to fernald@lm.doe.gov.

CERCLA Remedial Process

The process of cleaning up sites under CERCLA consists of the following general phases:

Site Characterization: During this phase, contaminants are identified and quantified, and the potential impacts of those contaminants on human health are determined. This phase includes the remedial investigation and the baseline risk assessment.

Remedy Selection: During this phase, cleanup alternatives are developed and evaluated. Activities include the feasibility study and proposed remedial action plan. After public comments are received and addressed, a remedy is selected and documented in a ROD.

Remedial Design and Remedial Action: This phase of the CERCLA process includes the detailed design and implementation of the remedy. The CERCLA process ends with certification and site closure.

A CERCLA five-year review process is triggered by the onset of construction for the first operable unit remedial action that will result in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure. Of all the operable units, the site preparation construction to support the Waste Pits Project under the Operable Unit 1 ROD (DOE 1995b) was the first such action. This construction began on April 1, 1996. To date, DOE has conducted, and the regulatory agencies have approved, five CERCLA five-year reviews (April 2001 [DOE 2001c], April 2006 [DOE 2006b], September 2011 [DOE 2011], September 2016 [DOE 2016b]), and September 2021. These reviews verify that the remedy remains effective and continues to be protective of human health and the environment.

Long-Term Stewardship of CERCLA Remedies: Site closure, relative to the completion of remediation, was defined in the contract between Fluor Fernald Inc. and DOE as the physical completion of the scope of work required by the five RODs with the exception of the groundwater remedy.

LM assumed the long-term surveillance monitoring and maintenance of the Fernald site on November 17, 2006, to ensure continued protection of human health and the environment and continued operation of the groundwater remedy. The *Comprehensive Legacy Management and Institutional Controls Plan* (DOE 2019) defines the activities to be conducted with respect to long-term stewardship at the Fernald Preserve. The CERCLA five-year review process will continue to provide stakeholders information on remedy performance and long-term stewardship.

The remainder of this introductory Section 1.0 provides:

- An overview of the environmental remediation completed as well as ongoing remedy implementation.
- A description of environmental monitoring activities at the Fernald Preserve.
- A description of the physical and ecological characteristics of the Fernald Preserve.

1.1 The Path to Site Closure

In 1986, the Fernald site initiated working through the CERCLA process to characterize the nature and extent of contamination at the site, to establish risk-based cleanup standards, and to select the appropriate remediation technologies to achieve those standards. To facilitate this process, in 1991 the site was organized into five operable units. The purpose of the operable unit concept under CERCLA was to organize site components by geographical location and by the potential for similar technologies to be used for environmental remediation. The remedy selection process culminated in 1996 with the approval of the final Records of Decision (RODs) for all five operable units. However, several of the RODs (including those for Operable Units 1, 4, and 5) have subsequently been modified through issuance of Explanation of Significant Difference documents or ROD Amendment documents. These documents were prepared, submitted for EPA and public review, and issued in accordance with CERCLA regulations. Following approval of the initial RODs, work began on the design and implementation of the operable unit remedies. Table 1 describes each operable unit and gives an overview of its associated remedy.

Table 1. Operable Unit Remedies

Operable Unit	Description	Remedy Overview
1	• Waste Pits 1–6 • Clear well • Burn pit • Berms, liners, caps, and soil within the boundary	ROD approved: March 1995 Explanation of Significant Differences approved: September 2002 ROD Amendment approved: November 2003 Excavation of materials with constituents of concern above final remediation levels (FRLs), waste processing and treatment by thermal drying (as necessary), offsite disposal at a permitted facility, and soil remediation/certification. **Remedial actions completed: June 2005** **Final Remedial Action Report approved: August 2006**
2	• Solid waste landfill • Inactive fly ash pile • Active fly ash pile (now inactive) • North and South Lime Sludge Ponds • Other South Field areas • Berms, liners, and soil within the operable unit boundary	ROD approved: May 1995 Post-ROD fact sheet approved: April 1999 Excavation of all materials with constituents of concern above FRLs, treatment for size reduction and moisture control as required, onsite disposal in the OSDF, and offsite disposal of excavated material that exceeded the waste acceptance criteria for the OSDF. This was the first ROD to specify an onsite disposal in the OSDF. **Remedial actions completed: June 2006** **Final Remedial Action Report approved: September 2006**
3	Former Production Area, associated facilities, and equipment (includes all above- and below-grade improvements), including but not limited to: • All structures, equipment, utilities, effluent lines, and K-65 transfer line • Wastewater treatment facilities • Fire training facilities • Coal pile • Scrap metals piles • Drums, tanks, solid waste, waste product, feedstocks, and thorium	ROD for Interim Remedial Action approved: June 1994 ROD for Final Remedial Action approved: August 1996 Adoption of Operable Unit 3 Interim ROD; alternatives to disposal through the unrestricted or restricted release of materials as economically feasible for recycling, reuse, or disposal; treatment of material for onsite or offsite disposal; required offsite disposal for process residues, product materials, process-related metals, acid brick, concrete from specific locations, and any other material exceeding the OSDF waste acceptance criteria; and onsite disposal for material that meets the OSDF waste acceptance criteria. Post-ROD fact sheet that identifies clean buildings, structures, and materials for beneficial reuse under LM. Approved: December 2006. **Remedial actions completed: October 2006** **Final Remedial Action Report approved: February 2007**

Table 1. Operable Unit Remedies (continued)

Operable Unit	Description	Remedy Overview
4	• Silos 1 and 2 (containing K-65 residues; demolished in 2005) • Silo 3 (containing cold metal oxides; demolished in 2006) • Silo 4 (empty and never used; demolished in 2003) • Decant tank system • Berms and soil within the operable unit boundary	ROD approved: December 1994 Explanation of Significant Differences for Silo 3 approved: March 1998 ROD Amendment for Silos 1 and 2 approved: July 2000 ROD Amendment for Silo 3 approved: September 2003 Explanation of Significant Differences for Silos 1 and 2 approved: November 2003 Explanation of Significant Differences for Operable Unit 4 approved: January 2005 Removal of Silo 3 materials for treatment and Silos 1 and 2 residues and decant sump tank sludges with onsite stabilization of materials, residues, and sludges followed by offsite disposal. Excavation of silos area soils contaminated above the FRLs with onsite disposal for contaminated soils and debris that met the OSDF waste acceptance criteria; and site restoration. Concrete from Silos 1 and 2 and contaminated soil and debris that exceeded the OSDF waste acceptance criteria were disposed of offsite. **Remedial actions for Silo 3 completed: April 2006** **Remedial actions involving the completion of the shipment of stabilized Silos 1 and 2 material to a temporary storage facility in Texas completed: May 2006.** **Final Remedial Action Report approved: September 2006** **Permanent disposal of the 3,776 containers of Silos 1 and 2 material began on October 7, 2009, and the last container was placed on November 2, 2009.**
5	• Groundwater • Surface water and sediments • Soil not included in the definitions of Operable Units 1 through 4 • Flora and fauna	ROD approved: January 1996 Explanation of Significant Differences was approved in November 2001, formally adopting EPA's Safe Drinking Water Act maximum contaminant level for uranium of 30 micrograms per liter as both the FRL for groundwater remediation and the monthly average uranium effluent discharge limit to the Great Miami River. Extraction of contaminated groundwater from the Great Miami Aquifer to meet FRLs at all affected areas of the aquifer. Treatment of contaminated groundwater, storm water, and wastewater to attain concentration and mass-based discharge limits and FRLs in the Great Miami River. Excavation of contaminated soil and sediment to meet FRLs. Excavation of contaminated soil containing perched water that presented an unacceptable threat through contaminant migration to the underlying aquifer. Onsite disposal of contaminated soil and sediment that met the OSDF waste acceptance criteria. Soil and sediment with contaminant concentrations that exceeded the waste acceptance criteria for the OSDF was treated, when possible, to meet the OSDF waste acceptance criteria or was disposed of at an offsite facility. Also includes site restoration, institutional controls, and postremediation maintenance. **Interim Remedial Action Report approved: August 2008**

1.2 Environmental Monitoring Program

In the 1980s, DOE initiated an environmental monitoring program to assess the impact of past operations on the environment and to monitor potential exposure pathways to the local community. Additionally, for nearly 10 years DOE conducted characterization activities at the Fernald site through the remedial investigation phase of the CERCLA process. The initial environmental evaluations performed during the remedial investigation/feasibility study process were used to select the final remedy for Operable Unit 5, which addressed contamination in soil, groundwater, surface water, sediment, air, and biota—in short, all environmental media and contaminant exposure pathways affected by past uranium production operations at the site. The selected remedy for Operable Unit 5 defined the site's final contaminant cleanup levels and established the extent of on- and off-property remedial actions necessary to provide permanent solutions to environmental concerns posed by the site.

The Operable Unit 5 remedy included plans for removing the contamination that might be released through these exposure pathways and for monitoring these pathways to measure the site's continuing impact on the environment as remediation progressed. The characterization data used to develop the final remedy were also used to focus on and develop the environmental monitoring program documented in the IEMP. The following describes the IEMP's key elements:

- The IEMP defines monitoring activities for environmental media, such as groundwater, surface water and effluent, and natural resources. In general, the primary exposure pathway is monitored, and the program focuses on assessing the effect on the surrounding environment.
- The IEMP establishes a data evaluation and decision-making process for each environmental medium. Through this process, environmental conditions at the site are continually evaluated. For example, environmental data are routinely evaluated to identify any significant trends that may indicate the potential for an unacceptable future impact to human health or the environment if action is not taken.
- The IEMP is reviewed annually and revised as necessary to ensure that the monitoring program adequately addresses monitoring requirements.
- The IEMP consolidates routine reporting of environmental data into this comprehensive annual report.

1.3 Characteristics of the Site and Surrounding Area

The natural settings of the Fernald Preserve and nearby communities were important factors in selecting the final remedy and remain important in the continual evaluation of the environmental monitoring program. Land use and demography, local geography, geology, surface hydrology, meteorology, and natural resources all impact monitoring activities and implementation of the site remedy.

1.3.1 Land Use and Demography

Economic activities in the area rely heavily on the physical environment. Land in the area is used primarily for crop farming and gravel pit excavation operations. A private water utility approximately 2 miles east of the Fernald Preserve pumps groundwater primarily for industrial use.

Downtown Cincinnati is approximately 18 miles southeast of the Fernald Preserve (Figure 1). The cities of Fairfield and Hamilton are 6 and 8 miles to the east and northeast, respectively (Figure 2). Scattered residences and several villages, including Fernald, New Baltimore, New Haven, Ross, and Shandon, are also near the site.

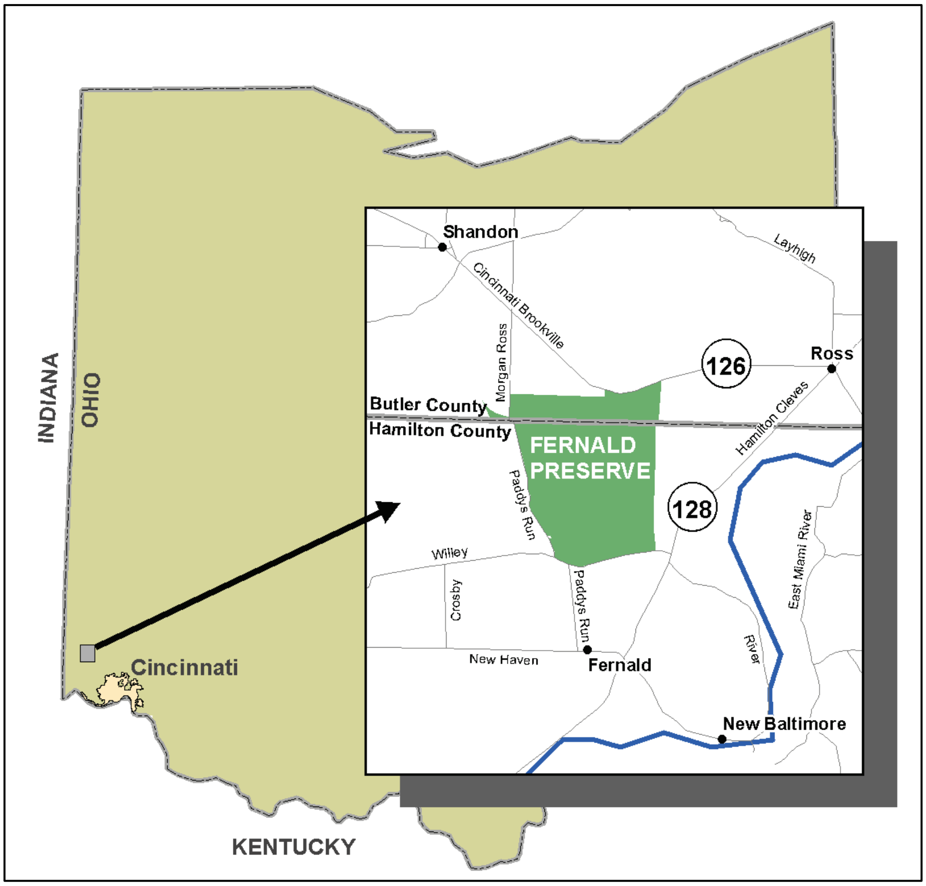


Figure 1. Fernald Preserve and Vicinity

1.3.2 Geography

Figure 3 depicts the location of the major physical features of the site, such as the buildings and supporting infrastructure. The Former Production Area and the OSDF dominate this view. The Former Production Area occupied approximately 136 acres in the center of the site and the OSDF occupies approximately 100 acres. The Great Miami River cuts a terraced valley to the east of the site, and Paddys Run (an intermittent stream) flows from north to south along the site's western boundary. In general, the site lies on a terrace that slopes gently among vegetated bedrock outcrops to the north, southeast, and southwest.

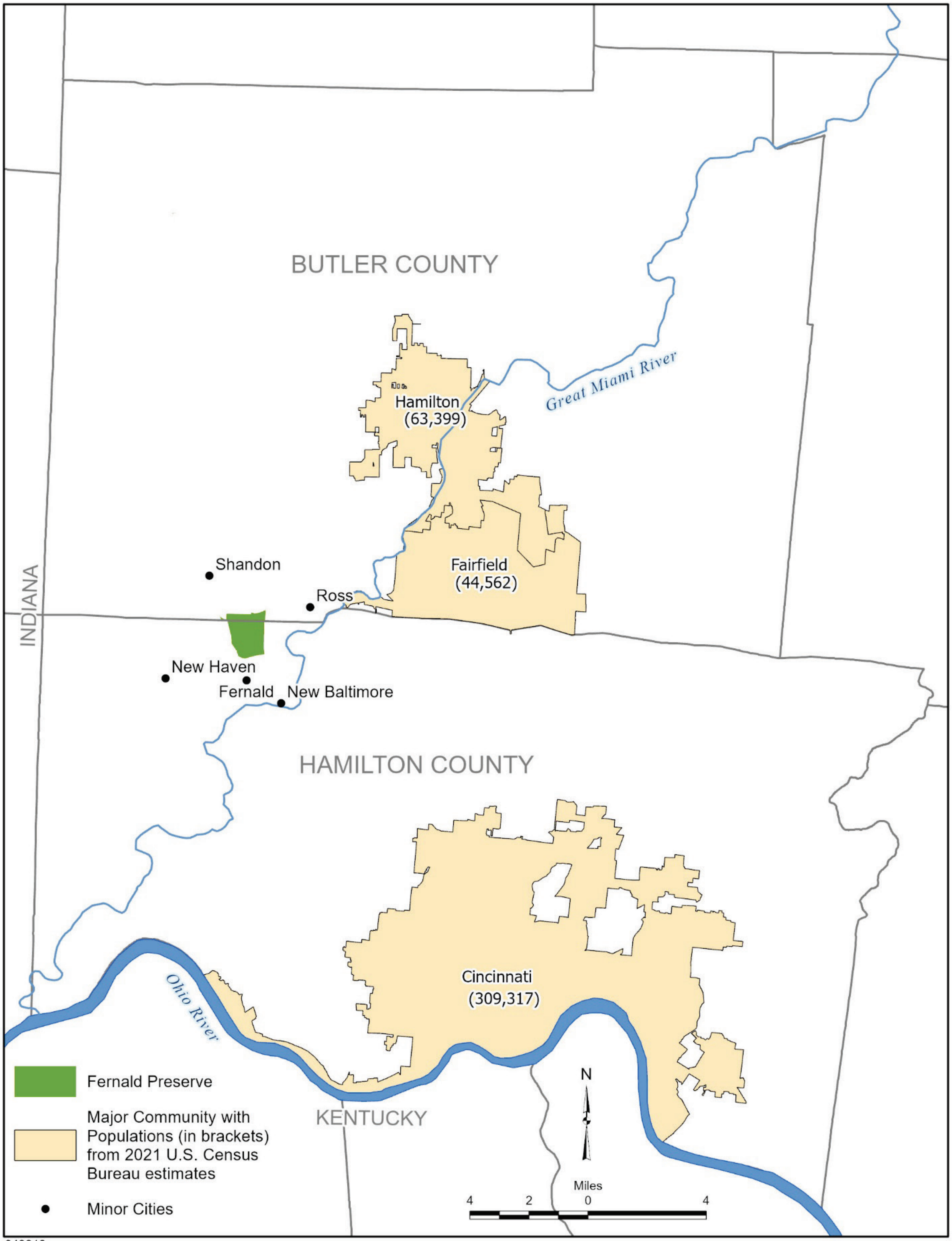


Figure 2. Major Communities in Southwestern Ohio

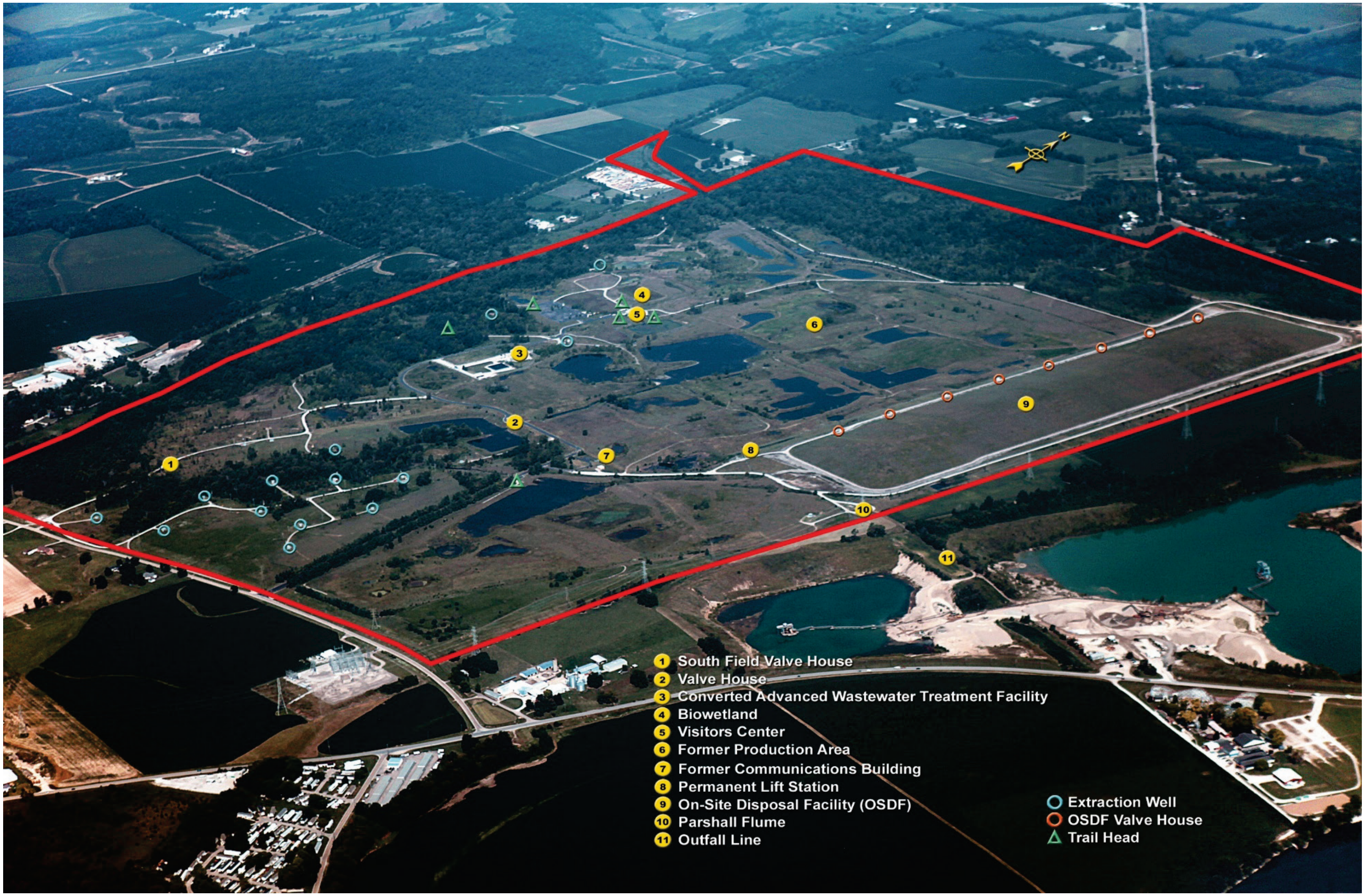


Figure 3. Fernald Preserve Perspective

1.3.3 Geology

Bedrock in the area indicates that approximately 450 million years ago a shallow sea covered the Cincinnati area. Sediments that later became flat-lying shale with interbedded limestone were deposited in the shallow sea, as evidenced by the abundance of marine fossils in the bedrock. In the more recent geologic past, the advance and retreat of three separate glaciers shaped the southwestern Ohio landscape. A large river drainage system south of the glaciers created river valleys up to 200 feet (ft) deep, which were then filled with sand and gravel when the glaciers melted. These filled river valleys are called buried valleys.

The last glacier to reach the area left a glacial overburden—a low-permeability mixture of clay and silt with minor amounts of sand and gravel—deposited across the land surface. The Fernald Preserve is situated on a layer of glacial overburden that overlies portions of a 2- to 3-mile-wide buried valley. This valley, known as the New Haven Trough, makes up part of the Great Miami Aquifer. The impermeable shale and limestone bedrock that defines the edges and bottom of the New Haven Trough restricts the groundwater to the sand and gravel within the buried valley. Where present, the glacial overburden limits the downward movement of precipitation and surface water runoff into the underlying sand and gravel of the Great Miami Aquifer.

The Great Miami River and its tributaries have eroded considerable portions of the glacial overburden and exposed the underlying sand and gravel of the Great Miami Aquifer. Thus, in some areas, precipitation and surface water runoff can easily migrate into the underlying Great Miami Aquifer and also transport contaminants to the aquifer. Natural and man-made breaches of the glacial overburden in some areas of the Fernald site were key pathways where contaminated water entered the aquifer, causing the groundwater contamination plumes that are being addressed by aquifer restoration activities. Figure 4 provides a view of the structure of subsurface deposits in the region along an east-west cross section beneath the site and through the New Haven Trough, and Figure 5 presents the regional groundwater flow patterns in the Great Miami Aquifer.

1.3.4 Surface Hydrology

The Fernald Preserve is in the Great Miami River drainage basin (Figure 6). Natural drainage from the site to the Great Miami River occurs primarily via Paddys Run. This intermittent stream begins losing flow to the underlying sand and gravel aquifer south of the former Waste Pits Area. Paddys Run empties into the Great Miami River 1.5 miles south of the site. The Great Miami River, 0.6 mile east of the Fernald Preserve, runs in a southerly direction and flows into the Ohio River about 24 miles downstream of the site. The segment of the Great Miami River between the Fernald Preserve and the Ohio River is not used as a source of public drinking water.

The average flow volume for the Great Miami River in 2022 was 4,629 cubic feet per second. This average is based on daily measurements collected at the U.S. Geological Survey Hamilton stream gauge (USGS 3274000) approximately 10 river miles upstream of the site's effluent discharge.

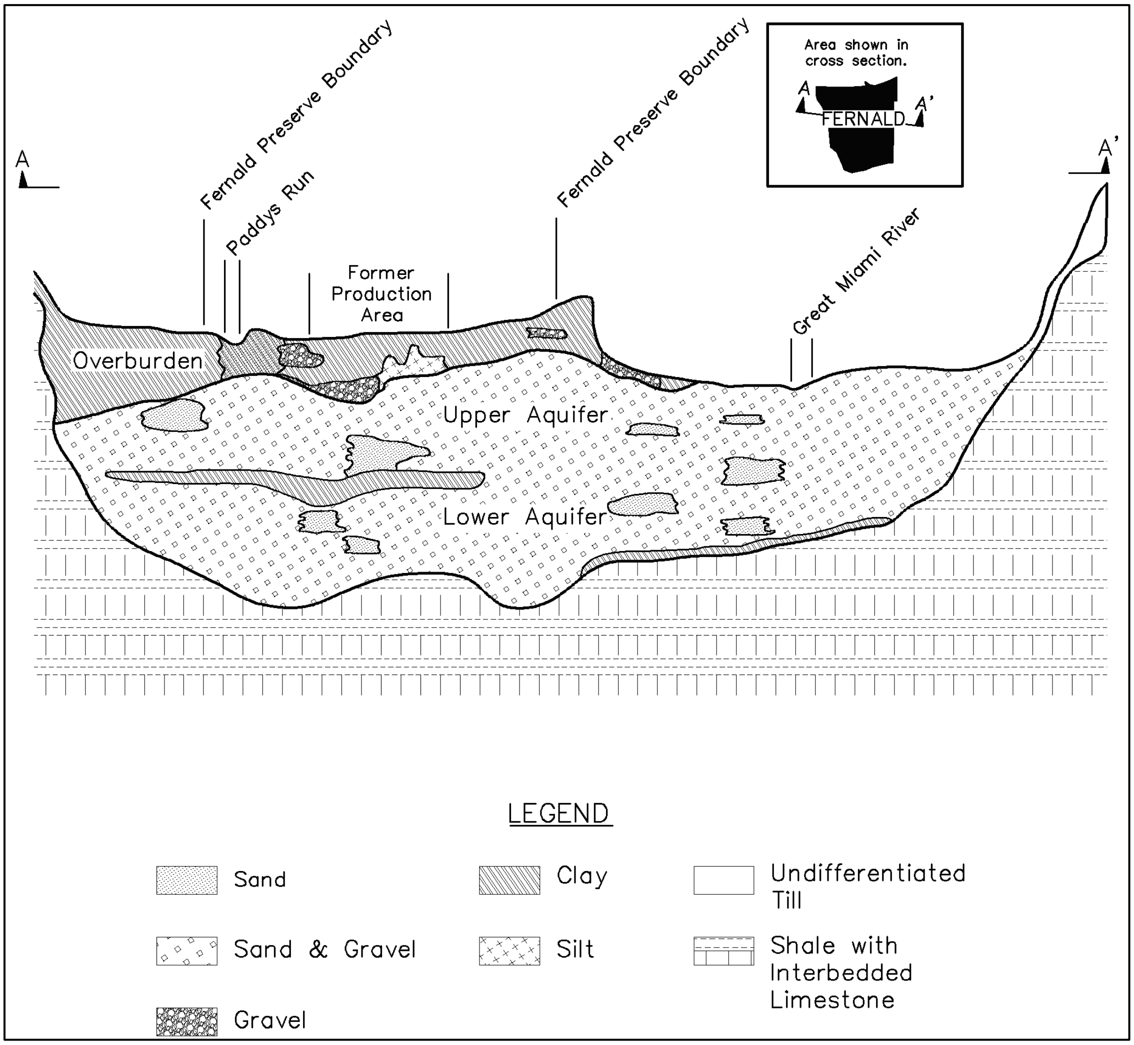


Figure 4. Schematic Cross Section of the New Haven Trough, Looking North

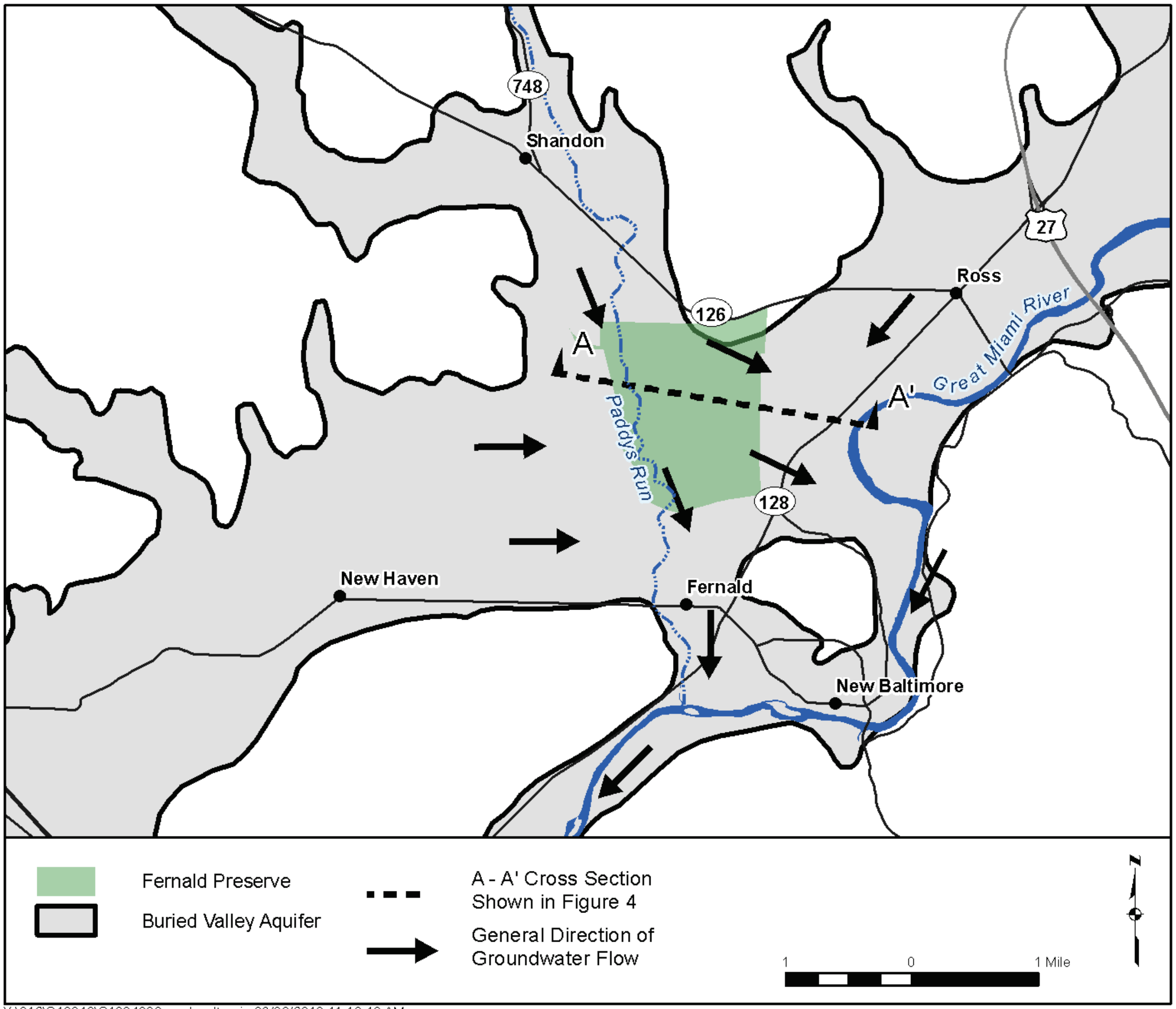


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Figure 5. Regional Groundwater Flow in the Great Miami Aquifer

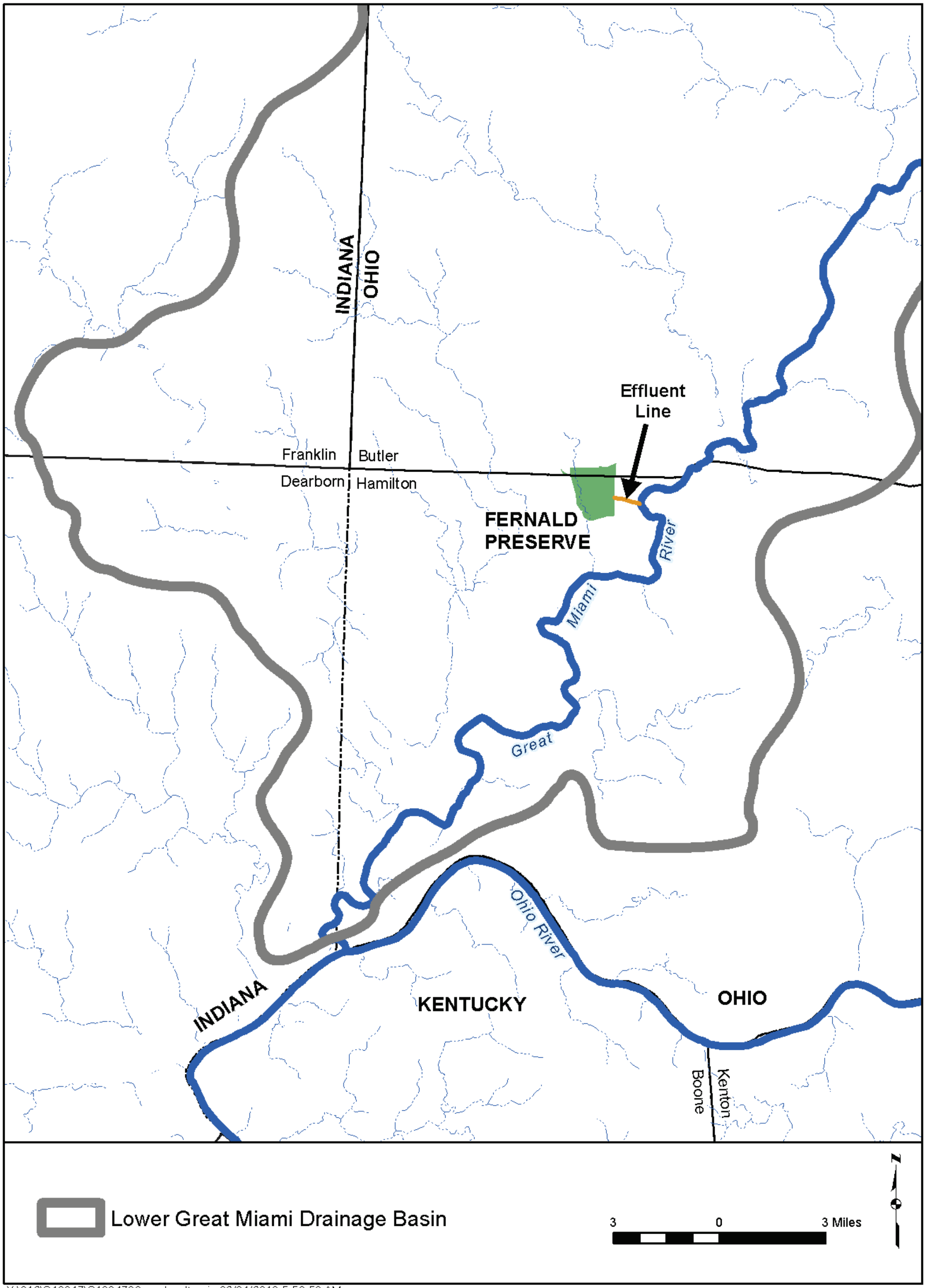

Figure 6. Southern Portion of the Great Miami River Drainage Basin

In 2022, 40.5 inches of precipitation were measured at the Butler County Regional Airport. This measurement, which represents precipitation at the site, is higher than the average annual Cincinnati-area precipitation of 41.4 inches for 1951 through 2022. Figure 7 shows the total annual precipitation recorded at the Fernald Preserve for each year from 1991 through 2022 and the average annual precipitation for the Cincinnati area from 1951 through 2022. Figure 8 shows monthly precipitation at the site for 2022 compared to the Cincinnati-area average monthly precipitation for 1951 through 2022.

1.3.5 Natural Resources

Natural resources have important aesthetic, ecological, economic, educational, historical, recreational, and scientific value to the United States. Their establishment and protection is an ongoing process at the Fernald Preserve. Section 5.0 discusses the site's diverse natural and cultural resources, and summarizes 2022 ecological restoration activities, including results of inspection, monitoring, maintenance, and repair.

The site is located near the transition of the Interior Plateau and Eastern Corn Belt Plains ecoregions. These ecoregions are subsections of the Eastern Deciduous Forest which consists of mosaic of oak-hickory and beech-maple forests. Regional ecology has been greatly altered by past agricultural and land management practices. Large portions of forests have been cleared and converted into agricultural land or pasture. These changes led to a fragmented landscape with a patchwork of cleared land, old fields, and second growth woodlands, with very little mature forest remaining. At the Fernald Preserve, additional changes took place with the planting of several areas of pine plantations in the northern and southern portions of the property. Additional wet forest habitat was recognized in the northern portion of the site as part of sitewide wetland delineation efforts in the 1990s.

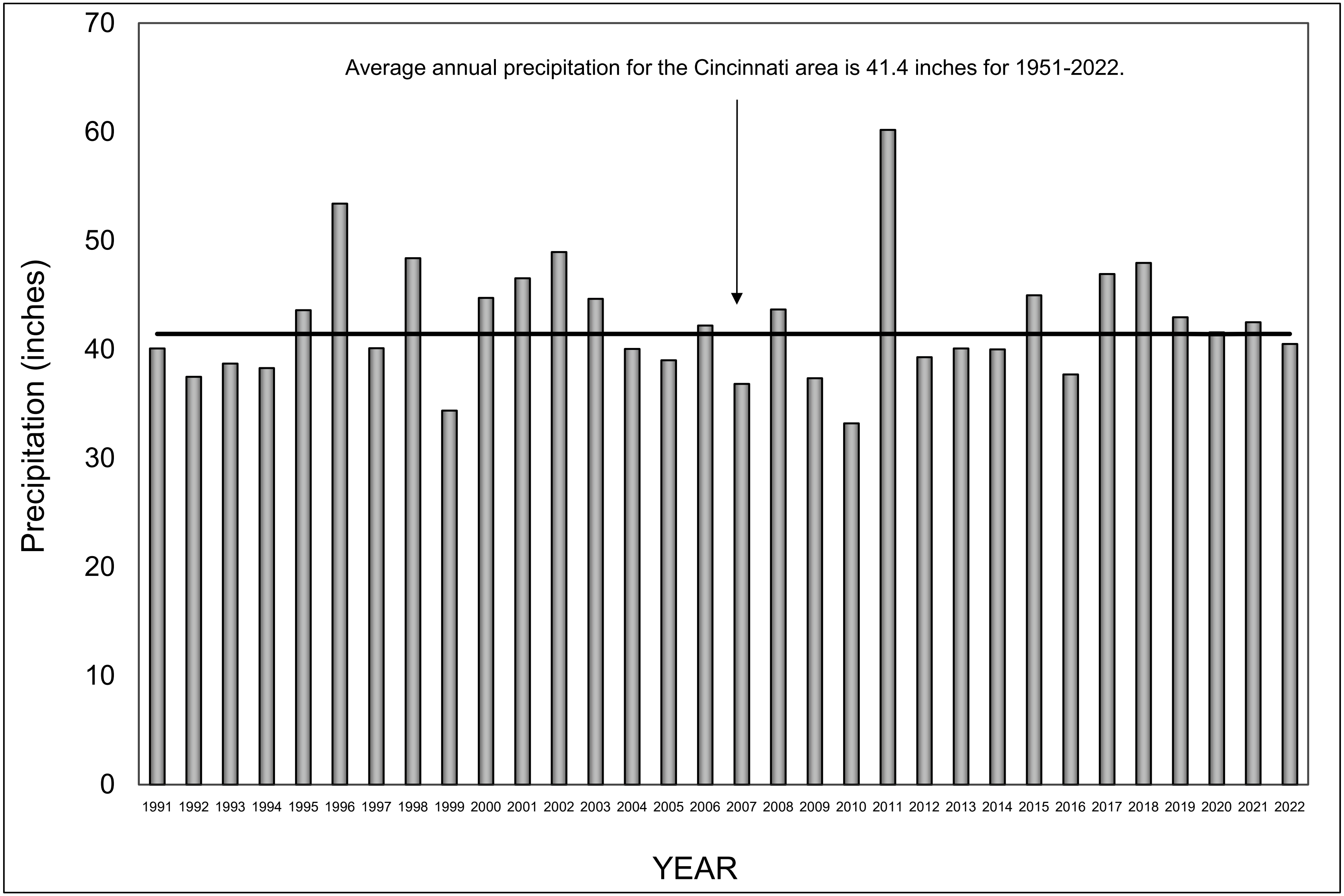

Figure 7. Cincinnati Area Annual Precipitation, 1991–2022

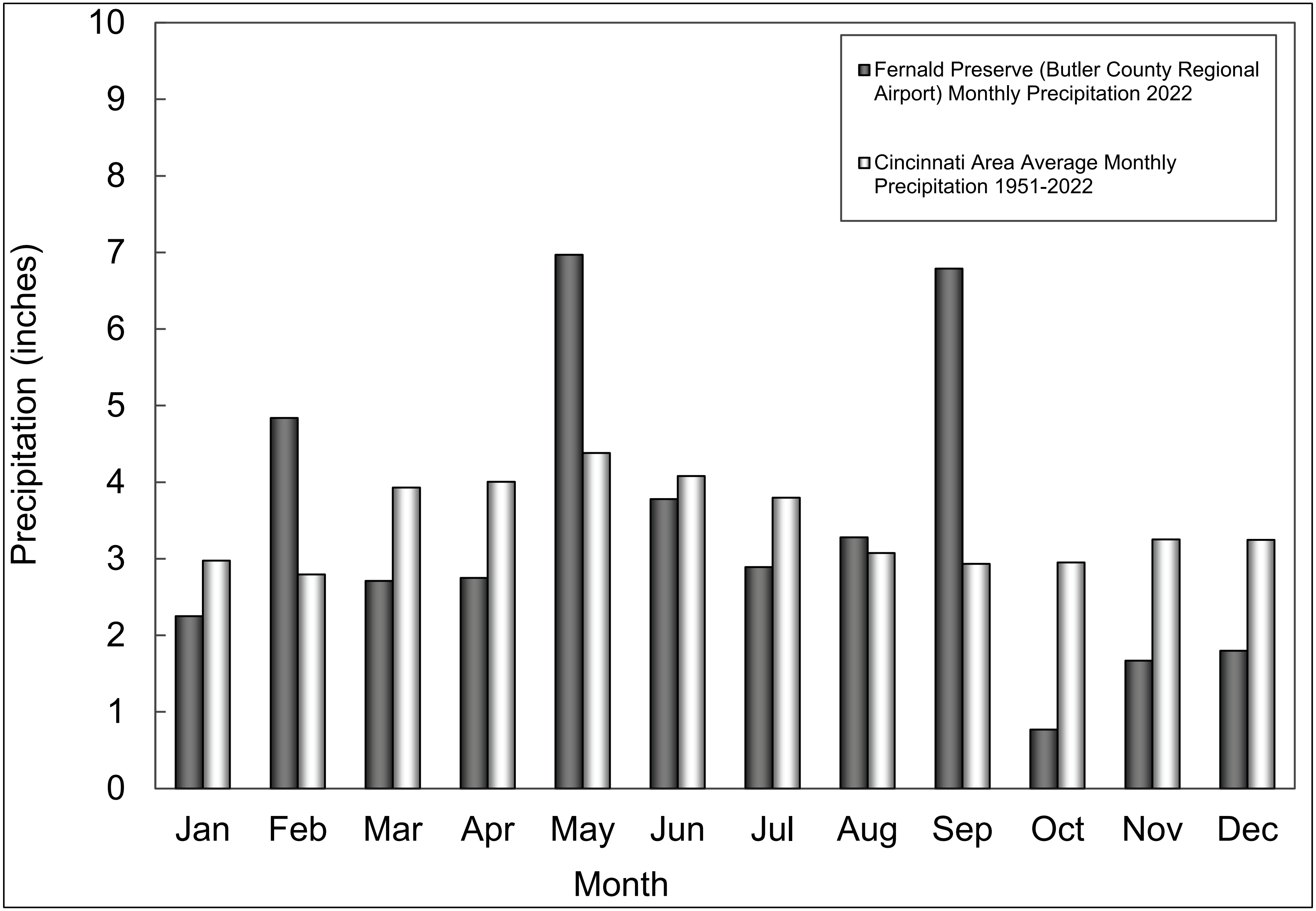

Figure 8. Monthly Precipitation for 2022 Compared to Average Monthly Precipitation for 1951–2022

2.0 Remediation Status and Compliance Summary

This section provides a summary of CERCLA remediation activities in 2022 and summarizes compliance activities with other applicable environmental laws, regulations, and legal agreements. Compliance under CERCLA dictates the environmental remediation of the Fernald Preserve.

EPA and Ohio EPA enforce the environmental laws, regulations, and legal agreements governing work at the Fernald Preserve. EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards. EPA regional offices and state agencies enforce these regulations and standards by review of data collected at the Fernald Preserve. EPA Region 5 has regulatory oversight of the CERCLA process at the Fernald Preserve, with active participation from Ohio EPA.

For some programs—such as those under the Resource Conservation and Recovery Act (RCRA), as amended (42 USC 6901 et seq.); the Clean Air Act, as amended (42 USC 7401 et seq.), excluding National Emissions Standards for Hazardous Air Pollutants compliance; and the Clean Water Act, as amended (33 USC 1251 et seq.)—EPA has authorized the State of Ohio to act as the primary enforcement authority. For these programs, the State of Ohio promulgates state regulations that must be at least as stringent as federal requirements. Several legal agreements between DOE, EPA Region 5, and Ohio EPA identify site-specific requirements for compliance with the regulations. To comply with these regulations, DOE Headquarters issues directives to its field and area offices and conducts audits to ensure compliance with all regulations and compliance agreements.

2.1 CERCLA Remediation Status

By October 2006, remedial actions were completed for four of the five operable units. As of October 29, 2006, the only remaining active remediation involves the ongoing groundwater remedy under Operable Unit 5. Activities under CERCLA during 2022 involved monitoring the performance of the completed remedies and implementing the requirements of the LMICP.

All cleanup-related CERCLA documentation, including a copy of the Administrative Record (AR), is available online at https://www.energy.gov/lm/fernald-preserve-ohio-site. The original and a copy of the AR are in the records warehouse at the LM Business Center in Morgantown, West Virginia. The Fernald Preserve staff can be contacted by phone at (513) 648-3106 for assistance in searching for a document in the CERCLA AR. The CERCLA AR is updated as new documents are created.

The completion and closure of a National Priorities List (NPL) site encompasses several milestones and specific documentation requirements for each milestone completed, as specified in the EPA publication *Close Out Procedures for National Priorities List Sites* (EPA 2011). These milestones begin with remedial action completion and end with deletion from the NPL and include:

- Remedial action completion (Final or Interim Remedial Action Reports).
- Construction completion (Preliminary Closeout Report)—all construction activities are complete, immediate threats are addressed, and long-term threats are under control.

- Site completion (Final Closeout Report)—all site cleanup goals are met, all RODs are complete, institutional controls are in place, and site conditions are protective of human health and the environment.
- Site deletion from the NPL (Notice of Intent to Delete).

DOE has prepared, and both EPA and Ohio EPA have approved, Final Remedial Action Reports for Operable Units 1, 2, 3, and 4. EPA approved the *Interim Remedial Action Report for Operable Unit 5* (DOE 2008) in August 2008. That report detailed the ongoing aquifer restoration activities and provided information indicating that all required groundwater infrastructure had been installed and was functioning as designed. Furthermore, the report provides information that all soils have been remediated (except those associated with the aquifer restoration infrastructure) and that the OSDF is functioning as designed. Operable Unit 5 will remain open until a future final Remedial Action Report for Operable Unit 5 has been prepared. DOE will develop that report once groundwater actions are complete and all soils and infrastructure associated with the groundwater remedy have been adequately addressed (estimated completion date in 2039, based on modeling projections reported in the 2014 Operational Design report [DOE 2014]). EPA issued the *Preliminary Closeout Report, U.S. DOE Feed Materials Production Center, Fernald, Ohio* (EPA 2006) in December 2006. The estimated durations for certifying the last area of the aquifer as being clean and for removing the wellfield infrastructure can be found in the *Fernald Groundwater Certification Plan* (DOE 2006a).

CERCLA Section 121(c) also requires a five-year review process for remedial actions implemented under the signed ROD for each operable unit. The purpose of a five-year review is to determine, through evaluation of performance of the selected remedy, whether the remedy at a site remains protective of human health and the environment. The methods, findings, and conclusions are documented in five-year review reports. In addition, the five-year review reports identify issues found during the review, if any, and document recommendations to address the issues.

EPA approved the first five-year review report for the Fernald Preserve (DOE 2001c) in September 2001. The second five-year review report was submitted in April 2006 (DOE 2006b) and approved by EPA in September 2006. The third five-year review report was submitted to EPA in March 2011 (DOE 2011) and approved by EPA in August 2011. The fourth five-year review began in 2015 and was approved by EPA in September 2016 (DOE 2016b). The fifth five-year review began in fall 2020 and was approved in September 2021 (DOE 2021b).

In the site's fourth CERCLA five-year review report, DOE was required to address the presence of perfluorinated compounds, now called per- and polyfluoroalkyl polyfluorinated alkyl substance (PFAS). PFAS are a large group of emerging potential chemicals of concern, of which perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are the two most prevalent. PFASs could be present at the Fernald site because very small volumes (i.e., less than 25 gallons) of aqueous foam firefighting agents containing PFOA and PFOS were used for fire training exercises at the former Fire Training Facility from 1976 to 1990. During the extensive site remediation, over 13,000 cubic yards of impacted soil were removed from the Fire Training Facility alone.

In December 2016, DOE submitted the *Draft Perfluorinated Compound Groundwater Screening Sampling and Analysis Plan* (DOE 2016c). In March 2018, DOE submitted the *Draft Polyfluorinated Alkyl Substances (PFASs) Investigation Plan for the Fernald Preserve*

(DOE 2018b). Based on information presented in both documents, PFAS are not a widespread issue at the Fernald Preserve. Interim recommendations were established for PFOA and PFOS by EPA in December 2019 (EPA 2019). To date, no sampling for these emerging contaminants has occurred at the Fernald Preserve.

In the fifth CERCLA five-year review report, DOE reviewed and evaluated the potential for all emerging contaminates currently recognized by the EPA to have been present at the site. An emerging contaminant is a chemical or material that is characterized by a perceived, potential, or real threat to human health or the environmental or by lack of published health standards. This evaluation is presented in the approved *Final Fifth Five-Year Review Report for the Fernald Preserve* (DOE 2021b). With the exception of PFAS, no other emerging contaminant required additional evaluation. The initial evaluation of PFAS at the site focused on aqueous film-forming firefighting foams, but new information has identified additional industrial processes that may have used PFAS. An evaluation of these newly identified general industrial uses of PFAS was conducted to determine if they were historically used at the Fernald site and may have the potential to adversely impact human health and the environment. That evaluation (DOE 2022a) was submitted to the regulators in fall 2022 and indicated that large volumes of PFAS-containing chemicals were not used in any historical processes at the site. Of the approximately 60 general industry PFAS uses evaluated, 5 potential uses of PFAS in historical processes were identified including firefighting foams; laboratory-related supplies; lubricants and greases; pipes, pumps, fittings, and liners; sealants; and water and effluent treatment. Generally, liquid-phase PFAS chemicals would have the most potential to cause environmental concerns if used or disposed directly into the environment. Of the uses identified, firefighting foams and a calibrant used in the laboratory are the only liquid-phase PFAS chemicals identified. No manufacturing of PFAS chemicals or large-scale of PFAS-containing chemicals were identified in this evaluation.

CERCLA remediation highlights during 2022 included the following:

- For 2022, the ongoing groundwater remedy resulted in extraction of 2 billion gallons of groundwater from the Great Miami Aquifer and removal of 354 lb of uranium from the aquifer. Section 3.0 discusses groundwater monitoring and remediation performance.
- The OSDF continues to operate as designed. The OSDF cap underwent four formal inspections. Such inspections are part of the standard operation and maintenance requirements for the facility. Minor maintenance of the cap and associated drainages continues; examples include the removal of small trees and shrubs, spot herbicide application on woody stumps and other invasive plant species and repairing animal burrows. A planned spring prescribed burn of the OSDF cell cap vegetation was postponed while an inter-agency agreement between DOE and the U.S. Forest Service for the conduct of prescribed burns at the Fernald Preserve was finalized. The eight leachate valve houses continued to be inspected daily via operational rounds. Leachate generation has continued to decline as expected, and liner performance is meeting design requirements. Leachate flow and leak detection performance is discussed in Section 3.0. Cap performance is discussed further in Section 5.0.
- Figure 9 indicates soil areas that remain uncertified, pending completion of aquifer restoration and the decontamination and decommissioning of related facilities and associated utilities.
- Elevated uranium concentrations persist in surface water in an area adjacent to former Waste Pit 3. (This issue is further discussed in Section 4.0.) Weekly surface water monitoring in that area continued in 2022. The Paddys Run streambank stabilization project

was completed in 2016 to prevent migration of the Paddys Run streambed into this area. In 2017, DOE replaced several boulders on an in-stream crossvane that were dislodged during 2016 flooding. One additional stone became dislodged in 2018. Site personnel monitored the streambed in 2022 and determined that repairs were not needed. The area will continue to be evaluated in 2023.

- Monitoring and maintenance of ecologically restored areas continued during 2022. Ecological monitoring continued using floristic inventories; remediation prairie and remediation successional areas were evaluated in 2022.
- All required site and OSDF inspections were performed in 2022. Inspection findings in 2022 were similar to those from previous years and consisted mainly of the presence of invasive vegetation and deer enclosure fencing that was damaged by fallen trees and limbs. Debris also continues to be found, primarily in the Former Production Area and the former Waste Storage Area. Minor violations of the institutional controls established in the LMICP included occasional instances of hikers straying off trail. Section 5.0 includes further discussion of the restored area activities and the inspection process.

Construction of on-site modular offices for site field personnel was initiated in 2022. The modular office area is located adjacent to the CAWWT facility. Portions of subsurface infrastructure (buried electric and water lines) have been installed within the uncertified CAWWT footprint. Uncertified soil removed during construction was stockpiled within the CAWWT uncertified area. Sanitary waste from this facility will be treated at the Visitors Center bio-wetland.

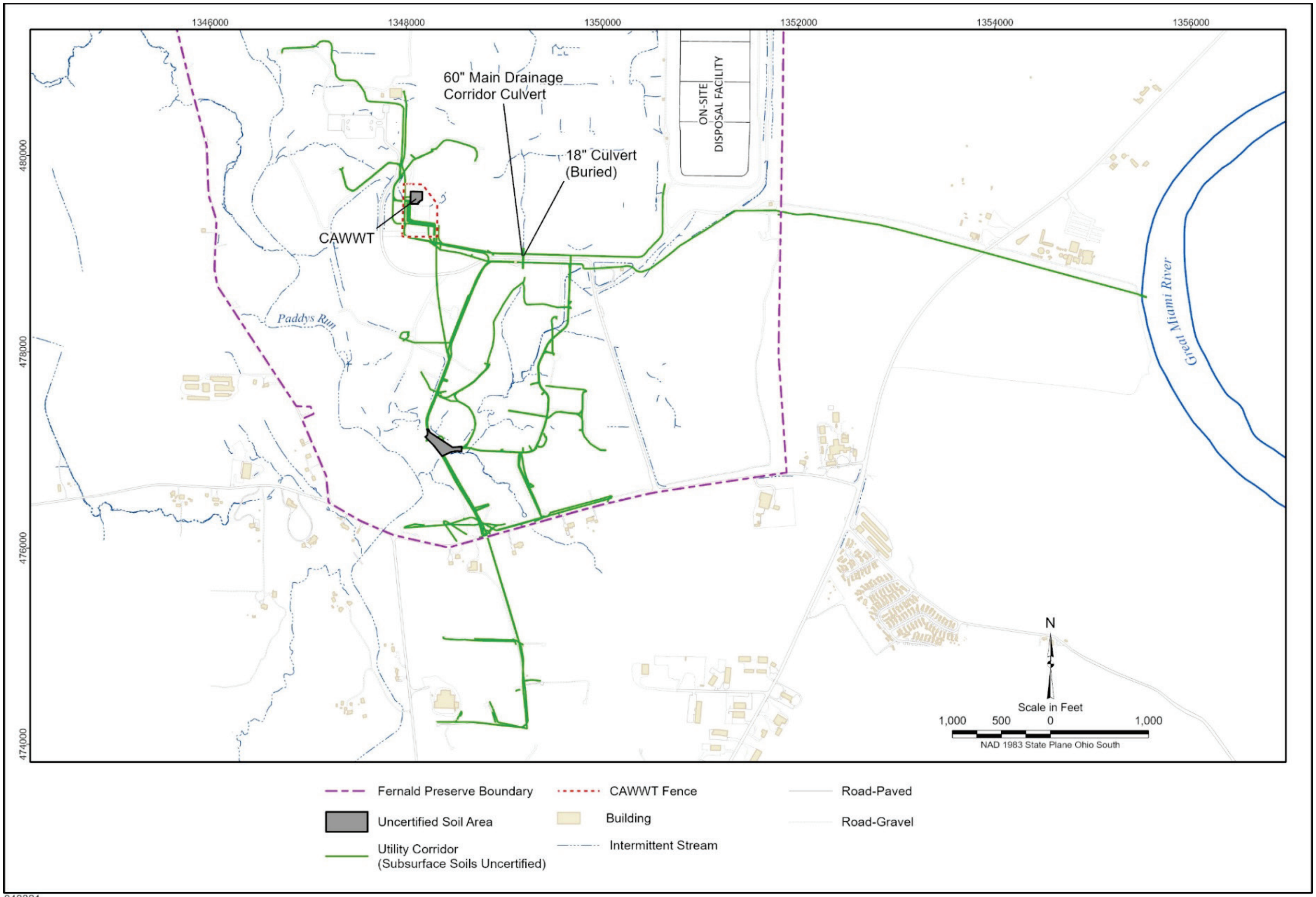

Figure 9. Uncertified Areas and Subgrade Utility Corridors

2.2 Summary of Compliance with Other Requirements

CERCLA requires compliance with other laws and regulations as part of remediation of the Fernald Preserve. These requirements are referred to as applicable or relevant and appropriate requirements (ARARs). ARARs that are pertinent to remediation of the Fernald Preserve are specified in the ROD for each operable unit. This section of the report highlights some of the major requirements related to environmental monitoring and waste management and describes how the Fernald Preserve complied with these requirements in 2022.

The regulations discussed in this section have been identified as ARARs within the RODs. The Fernald Preserve must comply with these regulations while site remediation under CERCLA is underway; compliance is enforced by EPA and Ohio EPA. Some of these requirements include permits for effluent discharges to the Great Miami River, which are also discussed in this section.

2.2.1 RCRA

RCRA regulates the treatment, storage, and disposal of hazardous waste and mixed waste (waste that contains radioactive and hazardous waste components). These wastes are regulated under RCRA and Ohio hazardous waste management regulations; therefore, the Fernald Preserve must comply with legal requirements for managing hazardous and mixed wastes. EPA has authorized Ohio EPA to enforce its hazardous waste management regulations in lieu of the federal RCRA program. In addition, hazardous-waste management is subject to the 1988 Consent Decree between the State of Ohio and DOE, the 1993 Stipulated Amendment to the Consent Decree between the State of Ohio and DOE, and a series of Director's Final Findings and Orders issued by Ohio EPA.

2.2.1.1 RCRA Property Boundary Groundwater Monitoring

The Ohio EPA Director's Findings and Orders for Groundwater, which were signed September 10, 1993, described an alternative monitoring system for RCRA groundwater monitoring. A revision of this document was approved on September 7, 2000, to align with the groundwater monitoring strategy identified in the IEMP. Section 3.3.2 provides a more detailed discussion of the groundwater monitoring program.

2.2.1.2 Waste Management

The Fernald Preserve had one hazardous waste shipment consisting of excess or expired laboratory chemicals on July 26, 2022. No additional treatment, storage, or disposal activities were conducted during 2022. Other wastes managed during 2022 were limited to universal waste (e.g., spent batteries) and uncontaminated solid wastes.

2.2.2 Clean Water Act

Under the Clean Water Act, as amended, the Fernald Preserve is governed by National Pollutant Discharge Elimination System (NPDES) regulations that require the control of discharges of nonradiological pollutants to waters of the State of Ohio. The NPDES permit, issued by the State of Ohio for storm water and wastewater, specifies discharge and sample locations, sampling and reporting schedules, and discharge limitations. Until June 1, 2022, the site operated under an NPDES permit that took effect on March 1, 2015. A new permit was approved and took effect on March 2, 2022. This permit will expire on May 31, 2027. Fernald Preserve submits monthly reports on NPDES activities to Ohio EPA to document compliance with stipulated discharge limits. There were no instances of noncompliance at any of the permitted outfalls in 2022.

A Notice of Intent to use the Ohio General Construction Permit was submitted on May 12, 2022, and approved on May 16, 2022, for construction activities related to the modular office area near CAWWT. Weekly and post-rainfall event inspections were conducted as needed. The annual stormwater evaluation, which is no longer required as part of the new NPDES Permit was conducted on December 19, 2022, as a best management practice, and no issues were identified.

2.2.3 Clean Air Act

Ohio EPA is authorized to enforce the State of Ohio's air standards for particulate matter at the Fernald Preserve. DOE maintains compliance by implementing the Fugitive Dust Control Policy negotiated between DOE and Ohio EPA in 1997. The policy allows for visual observation of fugitive dust and implementation of dust control measures.

2.2.4 Superfund Amendments and Reauthorization Act of 1986

The Superfund Amendments and Reauthorization Act of 1986 (SARA) amended CERCLA and was enacted, in part, to clarify and expand CERCLA requirements. SARA Title III is also known as the Emergency Planning and Community Right-to-Know Act. No chemicals exceeded threshold reporting quantities during 2022, so no report was required.

Another SARA Title III report, the Section 313 Toxic Chemical Release Inventory Report (Form R), is required if quantities of chemicals used or released at the Fernald Preserve exceed an applicable threshold for any SARA 313 chemical. If required, the Toxic Chemical Release Inventory Report lists routine and accidental releases and information about the activities, uses, and waste for each reported toxic chemical. No chemical usage or releases have exceeded the threshold for several years at the Fernald Preserve and, as in past years, no chemical exceeded a reporting threshold during 2022.

Also under SARA Title III, any offsite release meeting or exceeding a reportable quantity as defined by SARA Title III, Section 304, requires that immediate notifications be made to local emergency planning committees and the state emergency response commission. Notifications are also made to the National Response Center and other appropriate federal, state, and local regulatory entities. DOE evaluates and documents all releases that might occur at the Fernald Preserve to ensure that proper notifications are made in accordance with SARA and under CERCLA Section 103, RCRA, the Toxic Substances Control Act, the Clean Air Act, the Clean Water Act, and Ohio environmental laws and regulations. During 2022, there were no releases at the Fernald Preserve that met the reporting criteria.

2.2.5 Other Environmental Regulations

In addition to those described above, the Fernald Preserve is also required to comply with other environmental laws and regulations. Table 2 summarizes compliance with each of these requirements for 2022.

2.2.6 Permits and Licenses

Certain environmental regulations are implemented through permits. The Fernald Preserve's permit for discharging water under NPDES regulations is discussed in Section 2.2.2. In addition, the Fernald Preserve maintains permits administered through the U.S. Fish and Wildlife Service and the Ohio Department of Natural Resources (ODNR) for collection of wildlife specimens. A permit is also obtained to remove Canada goose nests, if necessary. A commercial pesticide applicator license is maintained by site personnel in order to apply herbicide at the Fernald Preserve. As a result of the 2022 interagency agreement between DOE and the U.S. Forest Service for conducting prescribed burns, the U.S. Forest Service secures burn-ban waivers and permits for prescribed burning activities on site. These activities are discussed in Section 5.0.

2.2.7 Federal Facility Compliance Agreement

In July 1986, DOE entered into a Federal Facility Compliance Agreement (FFCA) with EPA, which requires the Fernald Preserve to:

- Maintain a sampling program for the South Plume extraction wells and report the results to EPA, Ohio EPA, and the Ohio Department of Health. The sampling program conducted to address this requirement has been modified over the years and is currently governed by an agreement reached with EPA and Ohio EPA on May 1, 1996 (DOE 1996a). These data are reported in Appendix A.
- Maintain a continuous sample collection program for radiological constituents at the effluent discharge point and report the results to EPA, Ohio EPA, and the Ohio Department of Health. The sampling program was modified several times and was governed by an agreement reached with EPA and Ohio EPA that became effective May 1, 1996 (DOE 1996a). The first IEMP, finalized in 1997, was developed to combine the multiple programs (including the FFCA effluent monitoring) under one reporting structure to facilitate review of the performance of the environmental protection actions for various media under CERCLA remediation of the site. These data are reported in Appendix B.

Table 2. Compliance with Other Environmental Regulations

Regulation and Purpose	Background Compliance Issues	2022 Compliance Activities
Toxic Substances Control Act		
Regulates the manufacturing, use, storage, and disposal of toxic materials, including polychlorinated biphenyls (PCBs) and PCB items.	EPA Region 5 conducted the last routine Toxic Substances Control Act (15 USC 2601 et seq.) inspection of the Fernald Preserve's program on September 21, 1994. No violations of PCB regulations were identified during the inspection.	No PCB liquids or items were used, stored, or shipped in 2022.
Ohio Solid Waste Act		
Regulates infectious waste.	The Fernald Preserve was registered with Ohio EPA as a generator of infectious waste (generating more than 50 lb per month) until December 6, 1999, when Ohio EPA concurred with the Fernald Preserve’s qualification as a small quantity generator.	No infectious waste was generated in 2022.
Federal Insecticide, Fungicide, and Rodenticide Act		
Regulates the registration, storage, labeling, and use of pesticides (such as insecticides, herbicides, and rodenticides).	The last inspection of the Federal Insecticide, Fungicide, and Rodenticide Act (7 USC 136 et seq.) program conducted by EPA Region 5 on September 21, 1994, found the Fernald Preserve to be in full compliance with the requirements of the mandated Act.	Pesticide applications at the Fernald Preserve were conducted according to federal and state regulatory requirements.
National Environmental Policy Act		
Requires the evaluation of environmental, socioeconomic, and cultural impacts before any action, such as a construction or cleanup project, is initiated by a federal agency.	An Environmental Assessment for proposed final land use was issued for public review in 1998. It was prepared under DOE’s guidelines for implementation of the National Environmental Policy Act, Title 10 *Code of Federal Regulations* Section 1021. The assessment requires DOE to consult the public before making any decisions on land use; it includes previous DOE commitments.	No National Environmental Policy Act activities were required in 2022.

Table 2. Compliance with Other Environmental Regulations (continued)

Regulation and Purpose	Background Compliance Issues	2022 Compliance Activities
Endangered Species Act		
Requires the protection of any threatened or endangered species found at the site as well as any critical habitat that is essential for the species' existence.	Ecological surveys conducted by Miami University and DOE, in consultation with the Ohio Department of Natural Resources and the U.S. Fish and Wildlife Service, have established the following list of threatened and endangered species and their habitats existing on site: • Cave salamander (*Eurycea lucifluga*), state endangered, marginal habitat—small limestone outcrops and streams—none found. • Sloan's crayfish (*Orconectes sloanii*), state-threatened—found on northern sections of Paddys Run. • Indiana bat (*Myotis sodalis*), federally endangered—found in northern wooded areas along Paddys Run. • Northern long-eared bat (*Myotis septentrionalis*), federally threatened—potential habitat within northern wooded areas along Paddys Run—none found. • Running buffalo clover (*Trifolium stoloniferum*), federally endangered—potential habitat on disturbed areas along Paddys Run—none found. • Spring coralroot (*Corallorhiza wisteriana*), state-threatened—potential habitat within northern wooded areas—none found. • American burying beetle (*Nicrophorus americanus*), federally endangered—potential habitat within a variety of restored areas—released as part of ongoing recovery efforts.	As of 2022, Sloan's crayfish (*Orconectes sloanii*) is no longer listed as threatened by the state of Ohio. Monitoring is no longer required at the site for Sloan's Crayfish. Running buffalo clover (*Trifolium stoloniferum*) was delisted in 2021 and is no longer considered endangered or threatened. Monitoring is no longer required at the site for running buffalo clover. The Cincinnati Zoo requested termination of the 5-year Cooperative Agreement with the U.S. Fish and Wildlife Service and the Cincinnati Zoo to introduce the federally endangered American burying beetle to the Fernald Preserve (DOE 2012a and DOE 2017). The agreement was originally set to expire in 2022, but the Cincinnati Zoo determined the resources were better applied at other release sites across the region (Ray 2021). All parties agreed to terminate the agreement, As of 2021, the American burying beetle has been down listed from endangered to threatened.
Floodplains/Wetlands Review Requirements		
DOE regulations require a floodplain/wetlands assessment for DOE construction and improvement projects. The Clean Water Act also protects jurisdictional wetlands and "Waters of the U.S."	A wetlands delineation of the Fernald Preserve, completed in 1992 and approved by the U.S. Army Corps of Engineers in August 1993, identified 36 acres of freshwater wetlands on the Fernald Preserve property. Wetland mitigation monitoring activities from 2009 to 2011 resulted in the delineation of approximately 31 acres (13 hectares) of mitigated jurisdictional wetlands on the Fernald Preserve property (DOE 2012c).	Monitoring of wetlands will continue in 2024 as part of sitewide ecological restoration monitoring.
National Historic Preservation Act		
Establishes a program for the protection, maintenance, and stewardship of federal prehistoric and historic properties.	The Fernald Preserve is in an area of sensitive historic and prehistoric cultural resources that are eligible for or are listed on the National Register of Historic Places. These cultural resources include historic structures, buildings, and bridges, plus Native American villages and campsites.	No archaeological surveys were required, and no unexpected cultural discoveries were identified in 2022.

Table 2. Compliance with Other Environmental Regulations (continued)

Regulation and Purpose	Background Compliance Issues	2022 Compliance Activities
Native American Graves Protection and Repatriation Act		
Establishes a means for Native Americans to request the return or repatriation of human remains and other cultural items. Federal agencies must return human remains, associated funerary objects, sacred objects, and objects of cultural patrimony to the Native American nations or tribes with cultural affiliation to the remains or material.	Native American remains have been discovered during remediation activities at the Fernald Preserve. Native American remains and artifacts have been removed or left in place with consultation from Native American nations, tribes, and groups.	No Native American remains were discovered or repatriated to Native American nations, tribes, or groups in 2022.
Natural Resource Requirements Under CERCLA and Executive Order 12580		
Requires DOE to act as a trustee (i.e., guardian) for natural resources at its federal facilities.	DOE and the other trustees, which include Ohio EPA and the U.S. Department of the Interior (administered by the U.S. Fish and Wildlife Service), meet regularly to discuss potential impacts to natural resources and to coordinate trustee activities. The trustees also interact with the Fernald Community Alliance, which is a stakeholder organization that works to promote the Fernald Preserve as an asset to the community. In November 2008, the State of Ohio and DOE reached a settlement of the 1986 natural resource injury claim at the Fernald site. While the components of restoration had been established through a 2001 Memorandum of Understanding (DOE 2001d), the State of Ohio and DOE settled outstanding issues such as the payment of monetary penalties, establishment of environmental covenants, and a mutually agreed-upon Natural Resource Restoration Plan (NRRP), which is Appendix B of the *Consent Decree Resolving Ohio's Natural Resource Damage Claim Against DOE* (State of Ohio 2008). In 2009, activities commenced as required in the final NRRP.	In 2020, the Fernald Natural Resource Trustees conducted a 10-year review of the Restored Area Maintenance Plan, pursuant to the NRRP. The review resulted in the development of the Fernald Natural Resource Management Plan. This document presents a revised community-based approach for management and evaluation of ecologically restored areas across the Fernald Preserve. DOE implemented the revised Natural Resource Management Plan in 2021. The Natural Resource Management Plan was incorporated as Appendix A of Volume I of the 2023 LMICP (DOE 2023). The Natural Resource Trustees have drafted a crosswalk that demonstrates completion of all commitments in the Consent Decree and NRRP.

2.3 Split Sampling Program

Since 1987, DOE has participated in a split sampling program with Ohio EPA. Split samples are obtained when technicians alternately add portions of a sample to two individual sample containers. This collection method helps ensure that both samples are as close as possible to being identical. The split samples are then submitted to two analytical laboratories; this allows for an independent comparison of data to ascertain quality assurance for laboratory analysis and field sampling methods. Ohio EPA occasionally performs independent sampling in addition to split sampling.

Table 3 provides the analytical results of groundwater samples. Figure 10 shows the split sample location.

Table 3. 2022 DOE and Ohio EPA Groundwater Split Sampling Total Uranium Result Comparison

Sample Location	2022 Sample Date	DOE Result (µg/L)[a]	Ohio EPA Result (µg/L)	FRL[b] (µg/L)
2060	May	22.4	20.25	30
2060	November	25.6	25.72	30

[a] µg/L = micrograms per liter
[b] The groundwater pathway and final remediation levels (FRLs) are discussed in Section 3.0.

Prior to 2022, the three wells sampled in the split sampling program are private homeowner wells and are the longest running groundwater monitoring effort at the site. The program was initiated in 1982 in response to monitoring results indicating above background concentrations of uranium in private wells near the site. By 1984, the site had officially established the program with the monthly sampling of 19 privately-owned wells. In 1996, the private well program had grown to 32 private wells. At a property owner's request, any drinking water well near the site was sampled for uranium, and the one-time results were reported to the well owner. If any special request sample showed a questionable or significant total uranium concentration, or if the private well was determined to provide critical groundwater information in an area, the property owner had the option to participate in the routine sampling program. These private wells were sampled monthly or quarterly depending upon location, and sampling results were reported annually in the Site Environmental Report. Three private wells (13, 14, and 2060) were included in the monitoring effort (DOE 1997a). These three private wells continued to be sampled through 2022. In 1997, with implementation of the IEMP, the private well program was modified to only include these three private wells and included the private well where off-property contamination was initially reported in 1981 (monitoring well 2060). The other private wells previously monitored were not carried forward into the IEMP program because a public water supply was made available to the surrounding properties that had been affected by the off-property groundwater contamination (DOE 1998). Data from these three remaining private wells have contributed to the delineation of the total uranium plume presented in Section 3.0.

Well 13 has been below the final remediation level (FRL) since 2002 and well 14 has been below the FRL since this well was first sampled in 1988. These wells are located off-site and are outside of the uranium plume boundary identified in Section 3.0 and have been below the FRL for over 20 years. For these reasons, DOE proposed to eliminate monitoring in two of the private wells which are outside the current plume (13 and 14) and to continue monitoring in well 2060. Section 3.3.2 and Appendix A.2 presents additional information concerning these wells.

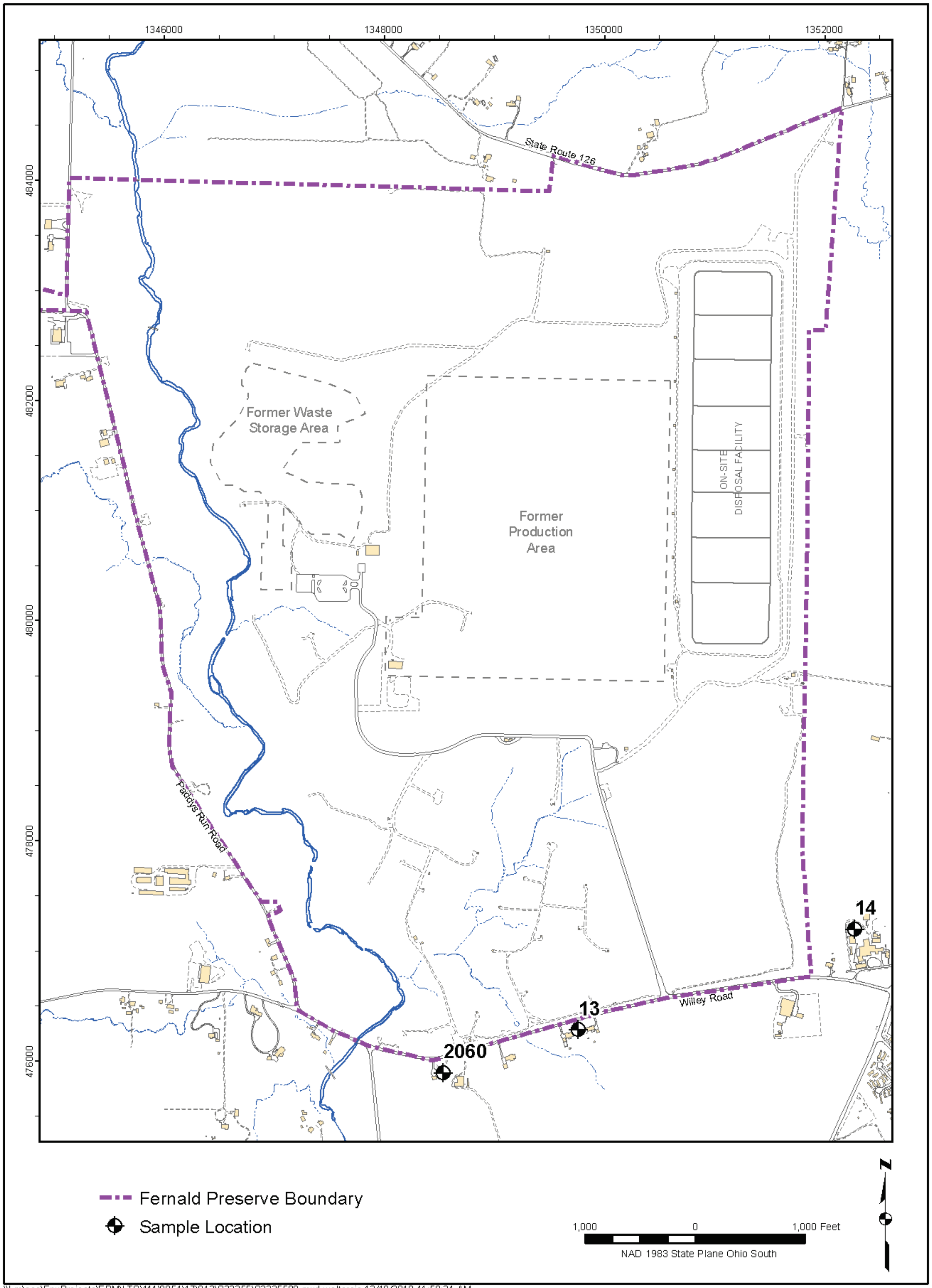

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Figure 10. DOE and Ohio EPA Groundwater Split Sample Locations

3.0 Groundwater Pathway

Results in Brief: 2022 Groundwater Pathway

Groundwater Remedy

Since 1993

- 55,123 Mgal of water have been pumped from the Great Miami Aquifer.
- 15,751 net lb of uranium have been removed from the Great Miami Aquifer.

During 2022

- 2,007.52 Mgal of water were pumped from the Great Miami Aquifer.
- 354 lb of uranium were removed from the Great Miami Aquifer.

Groundwater Monitoring Results: Data collected in 2022 show continued progress in reducing the footprint of the maximum uranium plume and that the pumping wells were capturing the uranium plume. Between 2021 and 2022:

- The footprint of the greater than or equal to 30 µg/L total uranium plume was reduced by 1.0 acre (1.3%).
- The footprint of the greater than or equal to 50 µg/L total uranium plume increased by 0.7 acre (1.4%).
- The footprint of the greater than or equal to 100 µg/L total uranium decreased by 0.5 acres (1.8%).

During 2022, the well field underwent an annual planned shutdown that lasted for 43 days (from June 6 through July 18, 2022).

OSDF Monitoring: In 2022, Great Miami Aquifer wells of each of the eight OSDF cells were sampled semiannually for 13 parameters. The leachate collection system, leak detection system, and horizontal till well of each cell were sampled semiannually for uranium, boron, sodium, and sulfate. Flow data from the disposal facility, coupled with the water quality monitoring results and the results of quarterly facility physical inspections, indicate that the OSDF performed as designed in 2021.

This section provides background information on the nature and extent of groundwater contamination in the Great Miami Aquifer due to past operations at the Fernald Preserve, and it summarizes aquifer restoration progress and groundwater monitoring activities and results for 2022.

Restoration of the affected portions of the Great Miami Aquifer and continued protection of the groundwater pathway are primary considerations in the groundwater remediation strategy for the Fernald Preserve. The groundwater pathway will be monitored following remediation according to the *Fernald Groundwater Certification Plan* (DOE 2006a).

3.1 Summary of the Nature and Extent of Groundwater Contamination

The *Remedial Investigation Report for Operable Unit 5* (DOE 1995d) described the nature and extent of groundwater contamination from operations at the Fernald site and evaluated the risk to human health and the environment from those contaminants. As documented in that report, the primary groundwater contaminant at the site is uranium.

Groundwater contamination resulted from infiltration of contaminated surface water through the bed of Paddys Run, the storm sewer outfall ditch (SSOD), the Pilot Plant Drainage Ditch (PPDD), and the old drainage ditch from the Plant 1 Pad. In these areas, the glacial overburden is absent (eroded), creating a direct pathway between surface water and the sand and gravel of the aquifer. To a lesser degree, groundwater contamination also resulted where past excavations (such as the waste pits) removed some of the protective clay contained in the glacial overburden and exposed the aquifer to contamination.

Figure 11 shows the 2022 maximum extent (most conservative) footprint of the 30 micrograms per liter (µg/L) uranium plume within the aquifer, as well as the current active restoration modules involved in the groundwater remedy. The current active restoration modules are represented by the cross-hatched areas in the figure, as well as the extraction wells that belong to each module.

3.2 Selection and Design of the Groundwater Remedy

> **Groundwater Modeling at the Fernald Preserve**
> The Fernald Preserve uses a computer model to make predictions about how the concentration and location of contaminants in the aquifer will change over time. Because the model contains simplifying assumptions about the aquifer and the contaminants, the predictions about future behavior must be verified with laboratory analyses of groundwater samples collected during monitoring activities.
>
> If groundwater monitoring data indicate the need for operational changes to the groundwater remedy, the groundwater model is run to predict the effect those changes might have on the aquifer and the contaminants. If the predictions indicate the proposed changes would increase cleanup efficiency and potentially reduce the cleanup time and cost, the operational changes are made once EPA and Ohio EPA concurrence is obtained. Monitoring data are then collected after the changes to verify whether model predictions were correct. If model predictions prove to be incorrect, modifications may be made to the model to improve its predictive capabilities.

While a remedial investigation/feasibility study was in progress and a groundwater remedy was being selected, off-property contaminated groundwater was being pumped from the South Plume area by the South Plume Removal Action System (referred to as the South Plume Module). In 1993, this system was installed south of Willey Road and east of Paddys Run Road to stop the uranium plume in this area from migrating any farther to the south. Figure 11 shows South Plume Module extraction wells 3924, 3925, 3926, and 3927. These extraction wells have successfully stopped further southward migration of the uranium plume beyond the wells and have contributed to significantly reducing total uranium (i.e., sum of all of the isotopes of uranium, measured in µg/L) concentrations in the off-property portion of the plume.

After the nature and extent of groundwater contamination was defined in the *Remedial Investigation Report for Operable Unit 5* (DOE 1995d), various remediation technologies were evaluated in the *Feasibility Study Report for Operable Unit 5* (DOE 1995a). Remediation cost and various land-use scenarios were considered during the development of the preferred remedy for restoring the quality of groundwater in the aquifer. The *Feasibility Study Report for Operable Unit 5* recommended a concentration-based, pump-and-treat remedy for the groundwater contaminated with uranium, consisting of 28 groundwater extraction wells located on and off property. Groundwater modeling suggested that the 28 extraction wells pumping at a combined rate of 4,000 gallons per minute (gpm) would remediate the aquifer within 27 years.

The recommended groundwater remedy, which included EPA, Ohio EPA, and community acceptance, was presented in the *Proposed Plan for Operable Unit 5* (DOE 1995c) as the preferred groundwater remedy. Once the proposed plan was approved, the *Record of Decision for Remedial Actions at Operable Unit 5* (OU5 ROD) (DOE 1996b) was issued. The OU5 ROD formally defines the selected groundwater remedy and establishes FRLs for all constituents of concern.

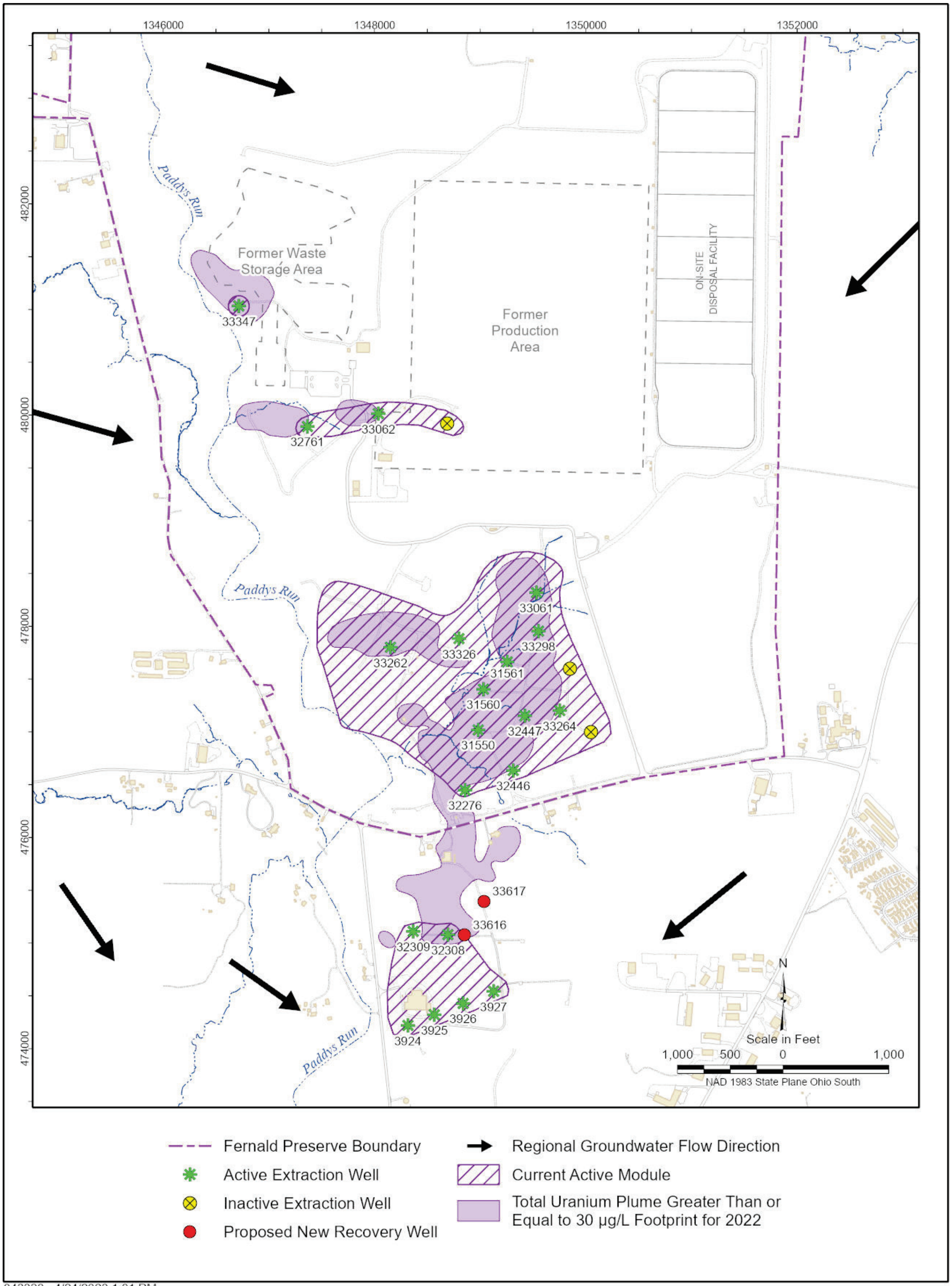

Figure 11. Extraction Wells Active in 2022

Reinjection at the Fernald Site
From 1998 to 2004, reinjection was an enhancement to the groundwater remedy at the Fernald site, supplementing pump-and-treat operations. The term "well-based" refers to the injection of treated groundwater through specially designed reinjection wells. Groundwater pumped from the aquifer was treated via ion exchange to remove contaminants and then reinjected into the aquifer at strategic well locations. Because the treatment process was not 100% efficient, a small amount of uranium was reinjected into the aquifer with the treated water. However, the reinjected groundwater increased the speed at which dissolved contaminants moved through the aquifer and were pulled by extraction wells, thereby decreasing the overall remediation time. Based on updated groundwater modeling and the unfavorable results of a cost–benefit analysis, well-based reinjection was discontinued in 2004.

The OU5 ROD commits to an ongoing evaluation of innovative remediation technologies so that remedy performance can be improved as such technologies become available. As a result of this commitment, an enhanced groundwater remedy was presented in the Operable Unit 5 *Baseline Remedial Strategy Report, Remedial Design for Aquifer Restoration (Task 1)* (DOE 1997b).

Groundwater modeling studies conducted to design the enhanced groundwater remedy suggested that, with the early installation of additional extraction wells and the use of reinjection technology, the remedy could potentially be reduced to 10 years. EPA and Ohio EPA approved the enhanced groundwater remedy that relied on pump-and-treat and reinjection technology. The groundwater remedy included the use of well-based reinjection until September 2004.

Evolution of the enhanced groundwater remedy has been documented through a series of approved designs. These designs are:

- Operable Unit 5 *Baseline Remedial Strategy Report, Remedial Design for Aquifer Restoration (Task 1)* (DOE 1997b).
- *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001a).
- *Design for Remediation of the Great Miami Aquifer South Field (Phase II) Module* (DOE 2002).
- *Comprehensive Groundwater Strategy Report* (DOE 2003).
- *Groundwater Remedy Evaluation and Field Verification Plan* (DOE 2004).
- *Waste Storage Area Phase II Design Report* and Addendum (DOE 2005b).
- *Operational Design Adjustments-1, WSA Phase-II Groundwater Remediation Design, Fernald Preserve* (DOE 2014).

The enhanced groundwater remedy commenced in 1998 with the startup of the South Field (Phase I), the South Plume Optimization, and the Reinjection Demonstration Modules. It focused primarily on the removal of uranium but was also designed to limit further expansion of the plume, achieve removal of all targeted contaminants to concentrations below designated FRLs, and prevent undesirable groundwater drawdown impacts beyond the site boundary. Startup of the enhanced groundwater remedy included a year-long reinjection demonstration that began in September 1998. Through the years, extraction and reinjection wells had been added and removed from these initial restoration modules.

In 2001, EPA and Ohio EPA approved the *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001a). Approval of this design initiated the installation of the next planned aquifer restoration module. The design specified three extraction wells in the former Waste Storage Area to address contamination in the PPDD plume (Phase I) and two extraction wells to address the remaining contamination after the waste pits excavation was completed (Phase II). One of the three Phase I Waste Storage Area wells (well 32761) was installed in 2000 to support an aquifer pumping test to help determine the restoration well field design. The remaining two Phase I wells (well 33062 and well 33063) were installed in summer 2001 after EPA and Ohio EPA approved the design. All three wells became operational on May 8, 2002. Well 33063 was abandoned in 2004 to facilitate site remediation work. A replacement well (well 33347) was installed and began operating in 2006. Figure 11 shows the existing well locations.

The *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001a) also provided data indicating that the uranium plume in the former Plant 6 Area was no longer present. It was believed that the uranium concentrations in the plume had decreased to levels below the FRL as a result of plant operations shutting down in the late 1980s and the pumping of highly contaminated perched water as part of the Perched Water Removal Action No. 1 in the early 1990s. Because a uranium plume with concentrations above the groundwater FRL was no longer present in the former Plant 6 Area at the time of the design, a restoration module for the area was determined to be unnecessary. Groundwater monitoring continues in the former Plant 6 Area, with one well (well 2389) in the area identified as having intermittent uranium FRL exceedances. This well is further discussed in Attachment A.2. Figure 12 shows the location of monitoring well 2389.

In 2002, EPA and Ohio EPA approved the next planned groundwater restoration design document, the *Design for Remediation of the Great Miami Aquifer South Field (Phase II) Module* (DOE 2002). The Phase II design presents an updated interpretation of the uranium plume in the South Field area along with recommendations on how to proceed with remediation in the area, based on the updated plume interpretation. Installation of Phase II components began in 2002. The overall system (Phases I and II) is referred to as the South Field Module.

In 2003, groundwater remediation approaches were evaluated to determine the most cost-effective groundwater remedy infrastructure, including the wastewater treatment facility, to remain after site closure. An evaluation of alternatives was presented in the *Comprehensive Groundwater Strategy Report* (DOE 2003). In October 2003, DOE held initial discussions with the regulators and the public concerning the various alternatives identified in the report. These discussions culminated in an identified path forward to work collaboratively with the Fernald Citizens Advisory Board, EPA, and Ohio EPA to determine the most appropriate course of action for the ongoing aquifer restoration and water treatment activities at the Fernald site.

In 2004, following regulatory and public input, a decision regarding the future aquifer restoration and wastewater treatment approach was made. In May 2004, EPA and Ohio EPA approved the decision to reduce the size of the advanced wastewater treatment facility and in June 2004 approved the decision to discontinue the use of well-based reinjection. Reducing the size of the advanced wastewater treatment facility provided the opportunity to dismantle and dispose of approximately 90% of the existing facility in the OSDF in time to meet the 2006 closure schedule. This resulted in a protective, more cost-effective, long-term water treatment facility to complete aquifer restoration. Well-based reinjection was discontinued in 2004 on the basis of groundwater modeling cleanup predictions presented in the *Comprehensive Groundwater Strategy Report* (DOE 2003) and the *Groundwater Remedy Evaluation and Field Verification Plan* (DOE 2004). As a result of refined modeling input, updated modeling indicated that the aquifer restoration time frame would likely be extended beyond dates previously predicted.

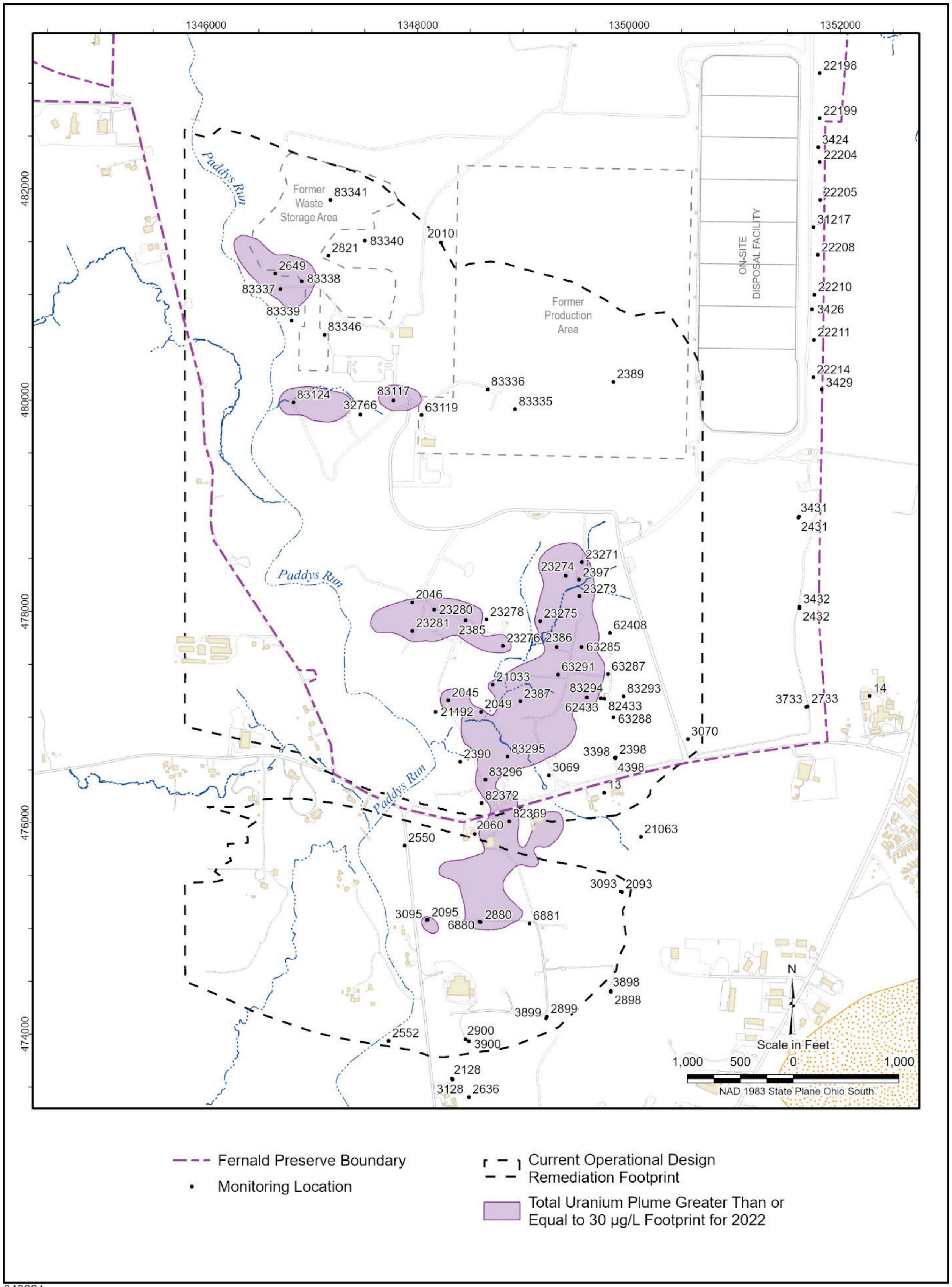

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Figure 12. Locations for Semiannual Total Uranium Monitoring

The updated modeling also indicated that continued use of the groundwater reinjection wells would shorten the aquifer remedy by approximately 3 years. However, the cost of maintaining the reinjection infrastructure was more than operating the extraction well field for this time period. Therefore, well-based reinjection was discontinued in September 2004 to support construction of the CAWWT. All reinjection wells remain in place as potential groundwater remedy performance monitoring locations.

In 2005, the *Waste Storage Area Phase II Design Report* (DOE 2005b) was issued. Comments received from EPA and Ohio EPA resulted in the issuance of an addendum to the report in December 2005. The design consisted of the installation of one more extraction well (well 33347) in the former Waste Storage Area, near the former silos area. Figure 11 shows the location of well 33347.

In 2005, an infiltration test was conducted in the SSOD. The test consisted of gauging the flow into and out of the SSOD with six Parshall flumes to obtain the overall infiltration rate along the SSOD. Findings from the test were included in the *Storm Sewer Outfall Ditch Infiltration Test Report* (DOE 2005a). The decision was made that pumped, clean groundwater would supplement natural storm water flow into the SSOD. This activity continued from 2006 through 2012, when DOE concluded that enough data had been collected to document infiltration rates through the base of the SSOD. Under normal flow conditions, potential infiltration to the aquifer from within the monitored portion of the SSOD (while flowing at or near 500 gpm) is approximately 109–129 gpm. With Ohio EPA and EPA concurrence, supplemental pumping of clean groundwater to the ditch was stopped and the flumes were removed in 2013 to allow water to freely flow down the SSOD. The rapid movement of water through the ditch during storm events will help to scour the ditch channel of fine-grained sediment and is expected to increase the potential for infiltration.

The *Fernald Groundwater Certification Plan* (DOE 2006a) defines a programmatic strategy for certifying completion of the aquifer remedy. It was developed through a series of four technical information exchange meetings held in 2005 among DOE, EPA, and Ohio EPA. Approved by EPA and Ohio EPA, the *Fernald Groundwater Certification Plan* identifies that the IEMP will continue to be the plan that includes remedy performance monitoring requirements.

In 2006, the Waste Storage Area Phase II Module components became operational, marking completion of the groundwater remediation system design. Completion of the Waste Storage Area Phase II Module construction brought the total number of extraction wells in the former Waste Storage Area to four (wells 32761, 33062, 33334, and 33347). These four well locations are shown in Figure 11.

In 2014, with approval from EPA and Ohio EPA, DOE implemented operational changes to optimize the groundwater remedy. Three wells no longer providing benefit to the groundwater remediation were shut down. The freed-up pumping budget was reallocated to the South Plume and South Field to accelerate cleanup of those areas. The operational changes were based on groundwater modeling results reported in 2014 (DOE 2014). The new 2014 design is referred to in this report as the current Operational Design and was implemented on July 1, 2014. Figure 11 shows the extraction well locations. The following subsections present the operational information associated with these modules.

Groundwater modeling conducted in 2012 (in support of the 2014 operational changes) predicted that under the current pumping rates, pumping would continue until 2022 in the South Plume and Southern South Field, 2030 in the northern South Field, and 2035 in the former Waste Storage Area. Annual monitoring results used to track remedy progress indicate that these dates will not be achieved.

In early 2022, the groundwater model was re-run to determine what the new cleanup times would be if uranium concentrations measured in the first half of 2021 were loaded into the model as initial conditions.

As was done for past model runs, modeled predicted cleanup date uncertainty due to changes in the elevation of the water table in the aquifer over time was bracketed by modeling using three different sets of boundary conditions for the elevation of the water table (i.e., wet, nominal, and dry). During wet boundary conditions the water table elevation is at its highest, and during dry boundary conditions the water table elevation is at its lowest. Nominal is the average elevation of the water table. The results were as follows:

Plume Area	Wet Boundary Conditions	Nominal Boundary Conditions	Dry Boundary Conditions
South Plume	2024	2025	2024
South Field	2035	2033	2038
Waste Storage Area	2040	2040	2045

As was done in previous modeling runs, the maximum model predicted cleanup date for each boundary condition was selected as the new targeted cleanup date, resulting in the following new predicted cleanup years.

- South Plume – 2025
- South Field – 2038
- Waste Storage Area – 2045

These new cleanup time predictions assume that the no wellfield pumping changes are made to the current operational design.

Model-predicted cleanup predictions have not been realized in the past, therefore, South Plume wells may need to continue pumping past 2025. Groundwater modeling predicts that capture of the remaining South Plume can be achieved using the existing six South Plume recovery wells pumping at lower rates without impacting the model-predicted cleanup date of 2025. Pumping at lower rates from the existing wells should prolong the operational life of the wells, but continued operation of the existing aging wells comes at an operational risk because their dependability is uncertain. Also, the existing six South Plume wells are no longer situated in good locations to remediate the remaining uranium plume. The leading edge of the South plume is now north of recovery wells 3924, 3925, 3926, and 3927. New wells that are better positioned to remediate the present location of the plume would produce a more efficient cleanup.

To reduce the operational risk of continuing to pump the existing South Plume recovery wells, and to provide for a more efficient cleanup of the remaining South plume, a modeled operational alternative was selected that replaces the six existing South Plume recovery wells with two new recovery wells. The two new recovery wells are better positioned to capture and remediate the remaining South Plume than the current six recovery wells. The modeling further predicts that when the two new wells are operational, the existing South Plume recovery wells (3924, 3925, 3926, and 3927) will no longer be needed to maintain capture of the remaining South plume.

This operational alternative (replacing the six existing South plume wells with two newly positioned recovery wells) is being implemented by DOE. The operational alternative removes the risk involved with the continued operation of the existing aging recovery wells and is not predicted to prolong the remediation of the South Plume. Use of this operational alternative also provides DOE with the option of continuing to operate remaining South Plume recovery wells (3924, 3925, 3926, and 3927) at lower pumping rates to provide additional flushing of the South Plume. The two new wells are scheduled to be operational in early 2024. The locations of the two new wells are shown on Figure 11.

3.3 Groundwater Monitoring Highlights for 2022

Groundwater monitoring results are discussed in terms of restoration and compliance monitoring. The key elements of the Fernald Preserve groundwater monitoring program design are described below. Site personnel completed all groundwater monitoring requirements.

Sampling: Sample locations, frequency, and constituents address operational assessment, restoration assessment, and compliance requirements. Monitoring is conducted to ascertain groundwater quality and groundwater flow direction.

As part of the comprehensive groundwater monitoring program specified in the current IEMP, 93 wells were monitored for water quality in 2022. Figure 12 identifies the location of the current water quality sampling locations for uranium. Figure 13 is a diagram of a typical groundwater monitoring well. Figure 14 illustrates relative monitoring well depths and screen locations. Figure 15 indicates the locations for non-uranium monitoring. In addition to water quality monitoring, 172 wells are used to measure groundwater elevations to verify groundwater flow direction. Figure 16 depicts the routine water-level (groundwater elevation) monitoring wells.

Figure 14 illustrates that there are six different types of monitoring wells (i.e., Type 1, 2, 3, 4, 6, and 8). Monitoring well types 1, 2, 3, 4, and 6 are single-level monitoring wells with a well screen that is 10 or 15 ft in length. Type 8 monitoring wells are multichannel monitoring wells that contain three to six individual 10 ft screens. The Type 8 multichannel monitoring wells provide for sampling a depth profile at a single location. The single-level wells monitor a single 10 ft depth. As summarized below, the location of the monitoring depth is identified by the first digit in the well identification number:

- Type 1: Screen positioned in perched groundwater in the glacial overburden
- Type 2: Screen positioned at the water-table zone of the Great Miami Aquifer
- Type 3: Screen positioned above a clay layer in the Great Miami Aquifer
- Type 4: Screen positioned below a clay layer in the Great Miami Aquifer
- Type 6: Screen positioned at a depth that is between a Type 2 and Type 3

Additionally, 27 locations were sampled using a direct-push (i.e., temporary) sampling tool in 2022. Results are provided in Appendix A, Attachment A.2.

Data Evaluation: The integrated data evaluation process involves review and analysis of the data collected from wells and direct-push sampling locations. The evaluation determines capture and restoration of the total uranium plume, capture and restoration of non-uranium FRL constituents, water quality conditions in the aquifer that indicate a need to modify the design and installation of restoration modules, and the impact of ongoing Fernald Preserve groundwater restoration on the downgradient Paddys Run Road Site plume. The Paddys Run Road Site is a separate contaminant plume, unrelated to the Fernald Preserve, which resulted from industrial activities on privately owned land in the area south of the Fernald Preserve along Paddys Run Road.

Reporting: All data listed for collection in the IEMP are reported in the annual Site Environmental Reports.

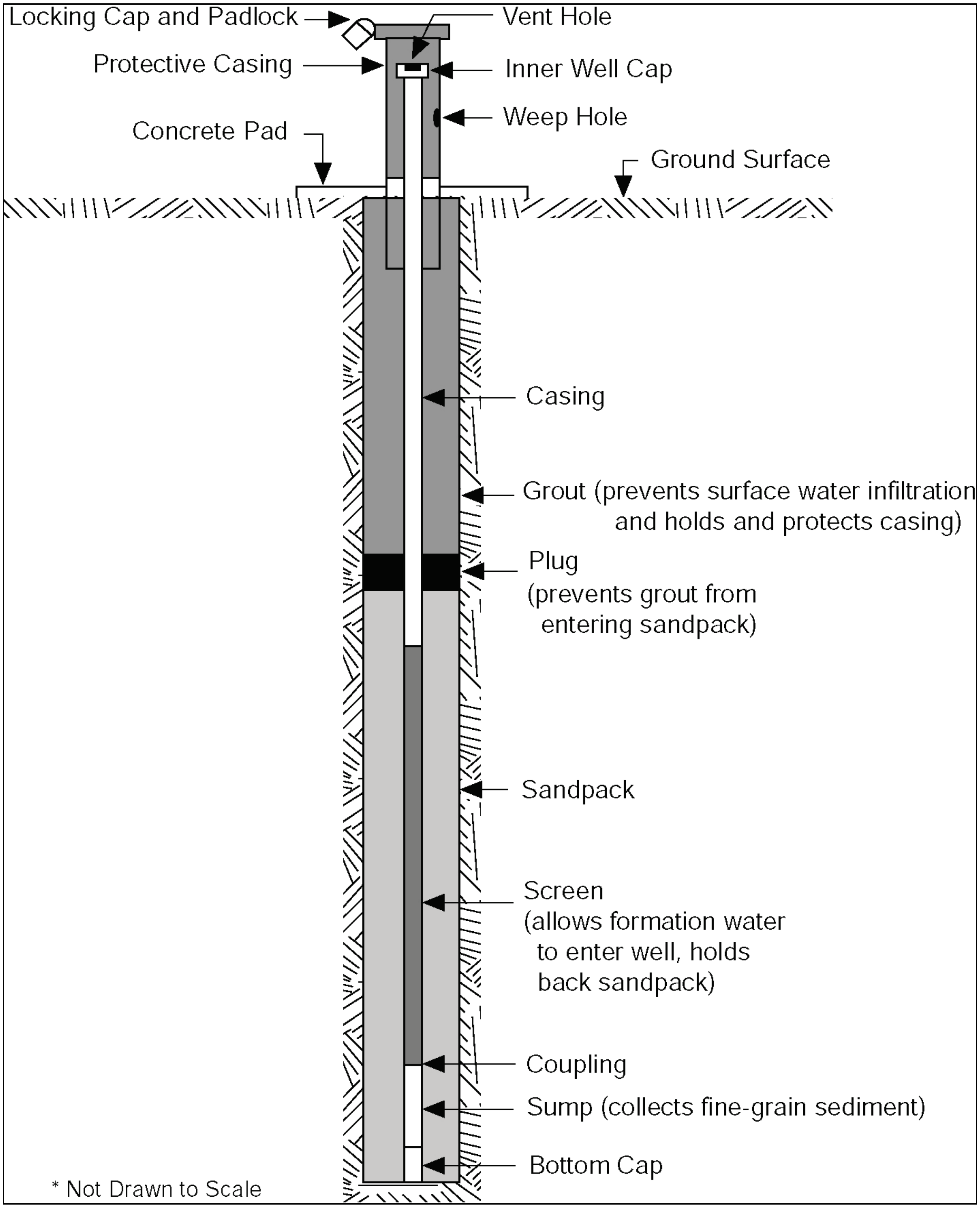


Figure 13. Diagram of a Typical Groundwater Monitoring Well

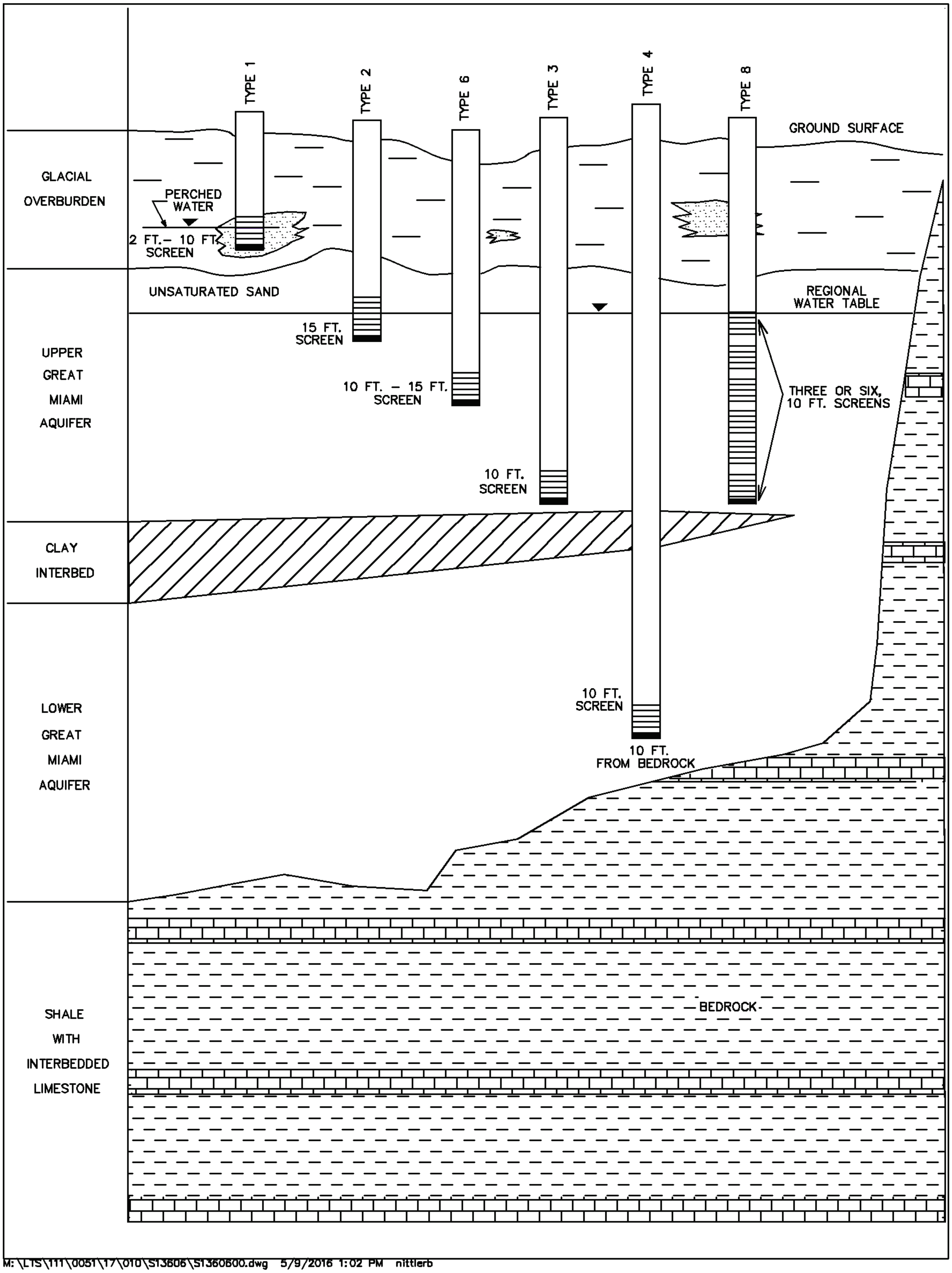


Figure 14. Monitoring Well Screen Locations

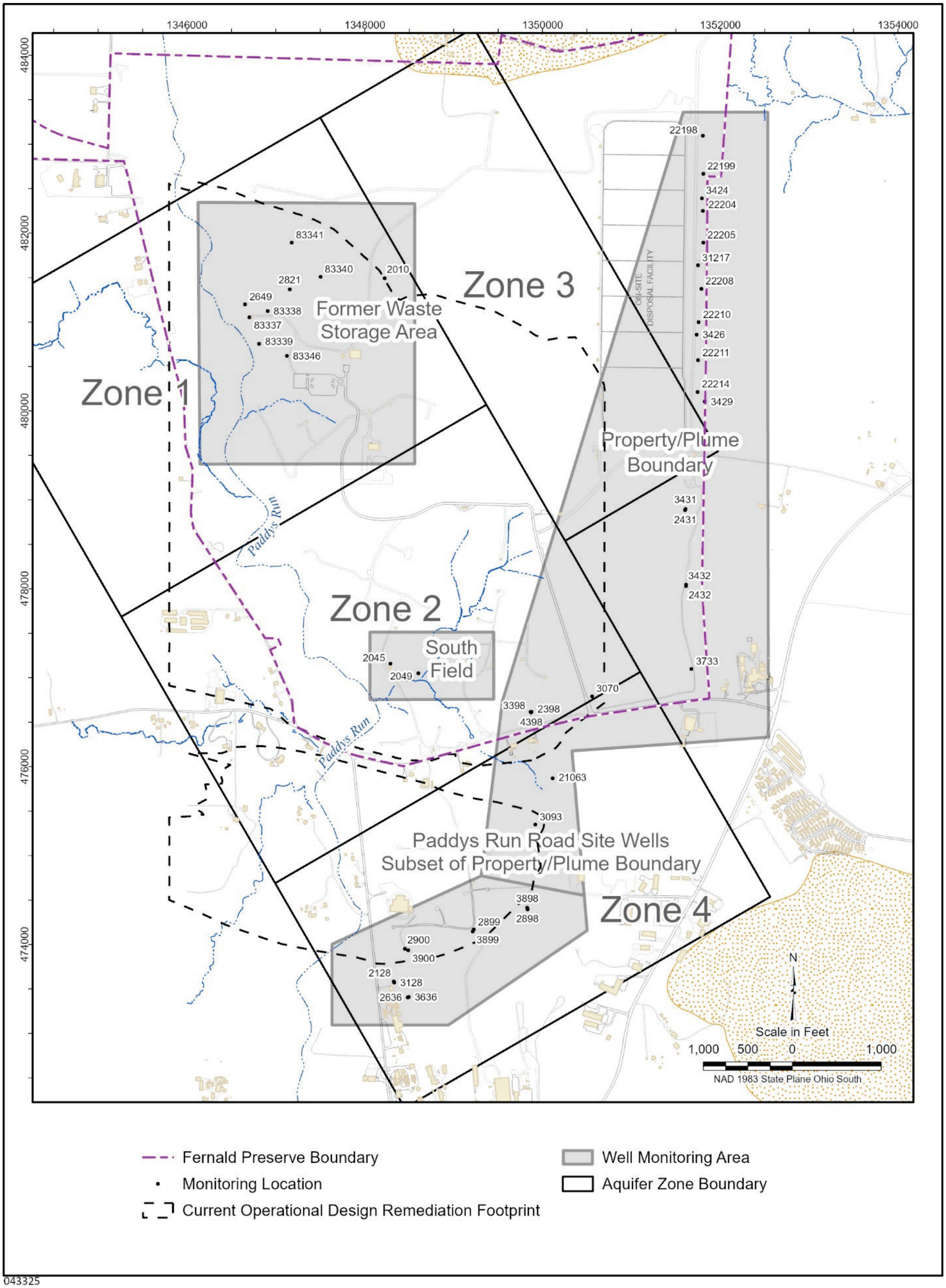


Figure 15. Locations for Non-Uranium Monitoring

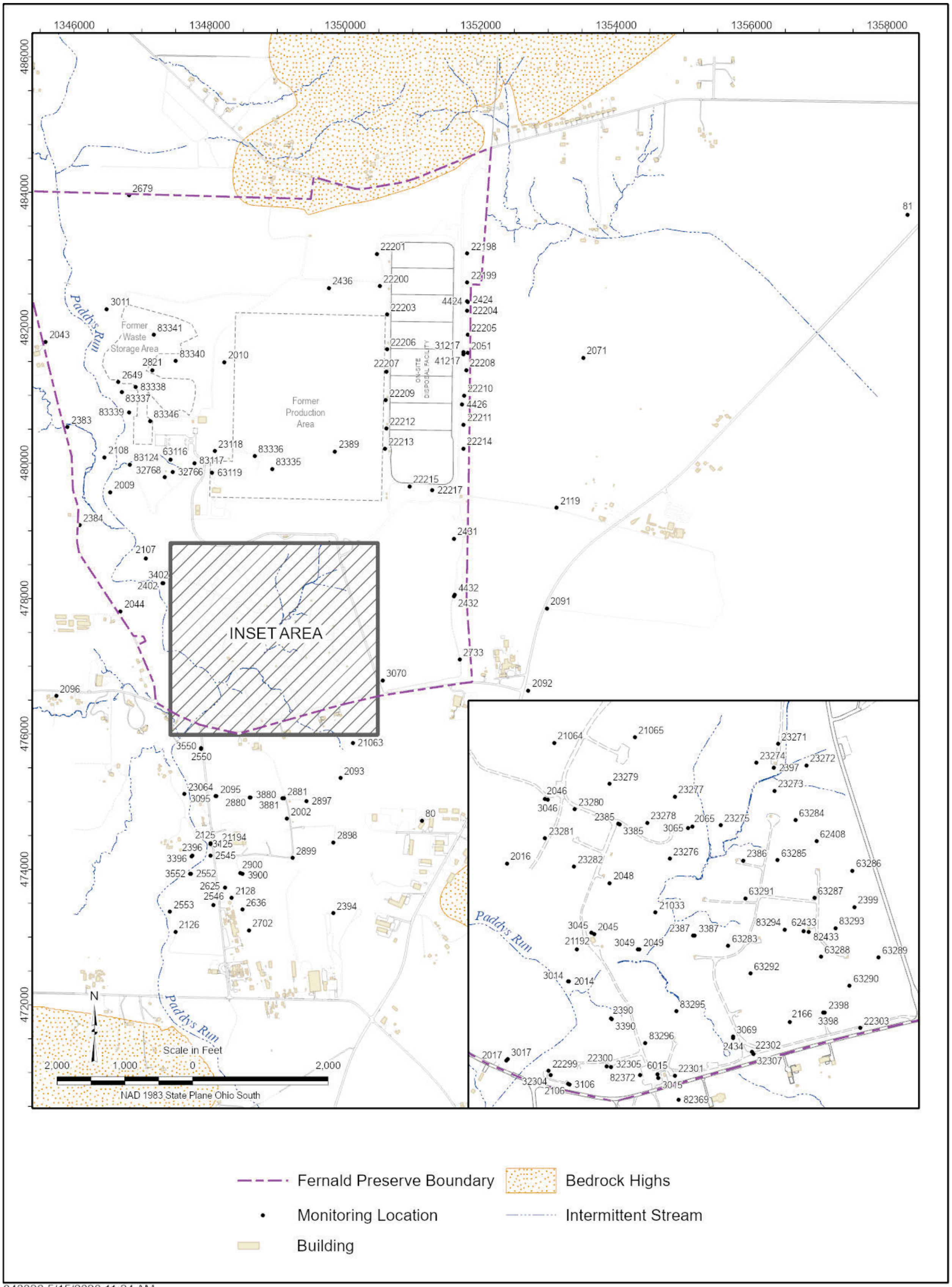


Figure 16. Groundwater Elevation Monitoring Wells

3.3.1 Restoration Monitoring

The Operable Unit 5 ROD (DOE 1996b) states that "areas of the Great Miami Aquifer exceeding final remediation levels will be restored through extraction methods." Uranium is the primary constituent of concern for groundwater. The groundwater FRL for total uranium is 30 µg/L. The background total uranium concentration for unfiltered groundwater samples from the Great Miami Aquifer near the Fernald Preserve is 1.2 µg/L (DOE 1994). Both the area of the aquifer targeted for remediation and the statistical procedures that will be used to verify that the aquifer cleanup objectives have been achieved are presented in the *Fernald Groundwater Certification Plan* (DOE 2006a).

In general, restoration monitoring tracks the progress of the pump-and-treat stage of the groundwater remedy and water quality conditions. Operations are evaluated throughout the year to determine the progress of aquifer remediation. Total uranium concentration maps are developed from analytical data and compared with groundwater elevation maps to show the status of remediation progress and to verify capture of the total uranium plume.

Appendix A provides more-detailed information. Sections that follow identify the specific attachment of Appendix A where the detailed information can be found.

3.3.1.1 Operational Summary

Since 1993:

- 55,123 Mgal of water have been pumped from the Great Miami Aquifer.
- 1,936 Mgal of treated water were reinjected into the Great Miami Aquifer.
- 15,751 net lb of total uranium have been removed from the Great Miami Aquifer.

Appendix A, Attachment A.1, provides detailed operational information on each extraction well. The following sections provide an overview of the individual modules.

Table 4. Groundwater Restoration Module Status for 2022

Modules and Restoration Wells	Target Design Pumping Rate	Volume Pumped	Uranium Removed
	gpm	Mgal	lb
South Plume/ South Plume Optimization Module: 3924, 3925, 3926, 3927, 32308, 32309	1,300[a]	398	56
South Field Module: 31550, 31560, 31561, 32276, 32446, 32447, 33061, 33262, 33264, 33298, 33326	2,875	1,277	237
Waste Storage Area Module: 32761, 33062, 33347	800	332	60
Aquifer Restoration System Total	4,975[a]	2,008	354

[a] In July 2018, the pumping rate of well 3927 was reduced from 200 to 100 gpm.

CAWWT

As presented in the *Fernald Preserve 2015 Site Environmental Report* (DOE 2016a), the CAWWT system had become oversized and reached the end of its useful life. Additionally, equipment corrosion and corrective maintenance had become ongoing issues for facility operations.

In March 2015, a CAWWT Condition Assessment Report was finalized (Whitman, Requardt & Associates 2015) confirming that many of the treatment system components were at or nearing the end of their useful life. A decision was made to replace the CAWWT treatment system with a 50 gpm system inside the CAWWT building. DOE received concurrence on a path forward in July 2015 from EPA and Ohio EPA and in August 2015 from the Fernald Community Alliance. DOE planning for the project began in August 2015.

The project was initiated in 2016 and completed in April 2018. The new system became operational on April 3, 2018.

Refurbishment of the nearby backwash basin occurred in 2019. The backwash basin is used to temporarily store wastewater originating from a variety of sources (i.e., well rehabilitation, CAWWT backwash, OSDF leachate, groundwater sampling, CAWWT laboratory, and CAWWT storm water drainage). Construction began in late summer of 2019 and was completed in December 2019. Accumulated sediment was removed, dried, and packaged for shipment to a licensed low-level radioactive waste disposal facility, Waste Control Specialists, in Texas. The basin liner and wall panels were replaced, and aeration cover systems were installed.

Pulse Pumping

In September 2012, with concurrence from EPA and Ohio EPA, a pulse-pumping exercise began at extraction wells 31550, 31560, 31561, and 33061. These four wells are equipped with pumps and motors that operate most efficiently at rates of approximately 300 gpm. The Waste Storage Area (Phase II) Design called for a target pumping rate of 100 gpm for each of these wells. The 100 gpm rate was being achieved by throttling back on the flow from each of the wells; however, this type of operation was not energy efficient.

To become more energy efficient, beginning in 2012, the wells were being pumped at a higher rate for a shorter period each day to remove the daily volume of water prescribed by the Waste Storage Area (Phase II) Design (DOE 2005b). Specifically, the wells are being pumped for 300 gpm for 8 hours a day (a total of 144,000 gallons per day) rather than 100 gpm for 24 hours a day (a total of 144,000 gallons per day). Flow and particle path monitoring predictions indicate that the new pumping schedule will maintain capture of the total uranium plume. With implementation of the current Operational Design in July 2014, the target pumping rate of extraction well 31561 was increased from 100 to 200 gpm, so pulse pumping was stopped at this well. Pulse pumping continues for the other three wells.

Figure 11 shows the extraction well locations associated with the restoration modules operating in 2022. Also shown in Figure 11 are the three extraction wells that were shut down in April 2014 (33265, 33266, and 33334). Table 4 summarizes the mass of total uranium removed and the volume of groundwater pumped during 2022. Additional details are provided in the module operational summaries in Sections 3.3.1.2 through 3.3.1.4. Figure 17 identifies the yearly and cumulative mass of total uranium removed from the Great Miami Aquifer from 1993 through 2021.

3.3.1.2 South Plume/South Plume Optimization Module Operational Summary

The four extraction wells (3924, 3925, 3926, and 3927) of the South Plume Module began operating in August 1993. The two extraction wells (32308 and 32309) of the South Plume Optimization Module began operating in August 1998. Figure 18 illustrates the southern extent of capture observed for the South Plume/South Plume Optimization Module at the end of 2022.

During 2022, the South Plume/South Plume Optimization Module removed 398 Mgal of groundwater and 56 lb of total uranium from the Great Miami Aquifer. Based on analysis of the data collected in 2022, the module continues to meet its primary objectives as demonstrated by the following:

- Southward movement of the total uranium plume beyond the southernmost extraction wells has not been detected.
- Active remediation of the central portion of the off-property total uranium plume continues to reduce plume concentration. Nearly the entire off-property total uranium plume concentration is now below 100 µg/L. When pumping began in 1993, areas in the off-property total uranium plume had concentrations of over 300 µg/L.
- The Paddys Run Road Site plume (contamination not attributed to Fernald site operations), south of the Fernald Preserve extraction wells, is not being pulled toward the South Plume extraction wells.

In 2022, the South Plume recovery wells continued to experience operational challenges due to their age. Exposure to liquid acid descaler during periodic well treatments and rehabilitations has slowly attacked the metal components of the wells, resulting in leaks. In 2022, South plume recovery wells 3926, 3927, and 32308 experienced operational problems. DOE repaired South Plume recovery well 3926, but, as described below, decisions were made in 2022 to permanently shut down South Plume recovery wells 3927 and 32308.

South Plume recovery well 3927 was able to maintain its design setpoint of 200 gpm from 1993 to 2018. As discussed in Section A.1.9, in 2018 the target pumping rate of South Plume recovery well 3927 was lowered to 100 gpm. In June of 2022, the well was no longer able to maintain 100 gpm and was turned off. DOE attempted several repairs to try to continue operating the well. In July 2022, a new pump and motor were installed, but the pitless adaptor was not able to be seated on the well casing causing the well to leak. In August 2022, the pump and motor were replaced again, but the pitless adaptor would not seat properly a second time. The date of June 6, 2022, is recognized as the official date that this well was permanently turned off. Given that DOE is in the process of installing two new wells that will eliminate the need for recovery wells 3924 through 3927, DOE decided to direct resources toward installing the new wells rather than spending additional resources trying to get recovery well 3927 operating again which would have involved excavations.

In July 2022, an underground leak developed in recovery well 32308 and the well was shut down permanently on July 25, 2022, after 23 years of operation. From 1998 to 2022, the well met its design setpoint of 300 gpm. Groundwater modeling conducted in 2022 demonstrated that the well was no longer located where it needed to be located to efficiently cleanup the remaining South Plume. Given that DOE was already planning a replacement for this well at a more optimal location, DOE decided to direct resources toward installing the new well rather than investigating the cause of the underground leak and implementing costly repairs on a well that was already in the process of being replaced.

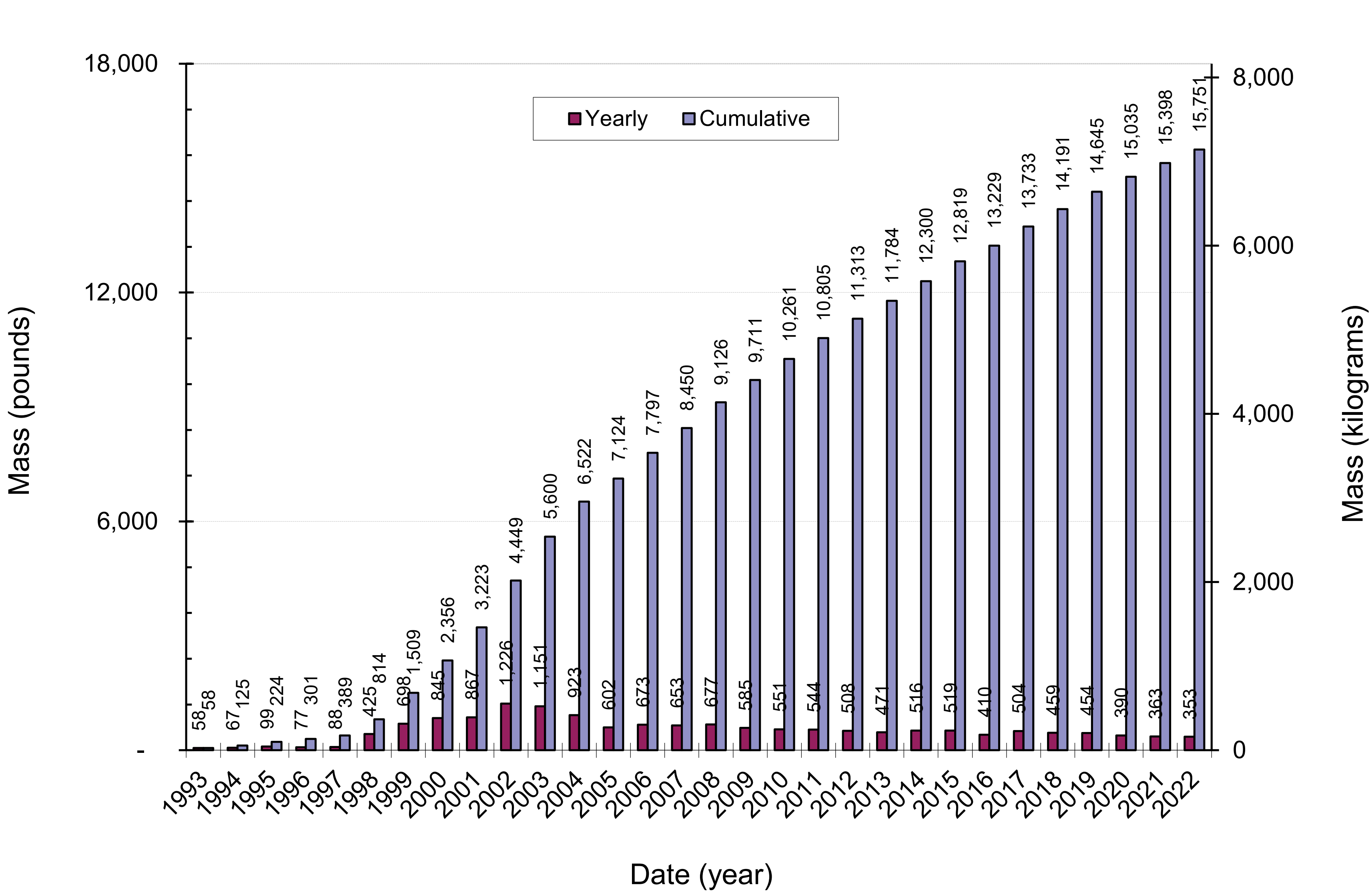


Figure 17. Yearly and Cumulative Mass of Uranium Removed from the Great Miami Aquifer, 1993–2022

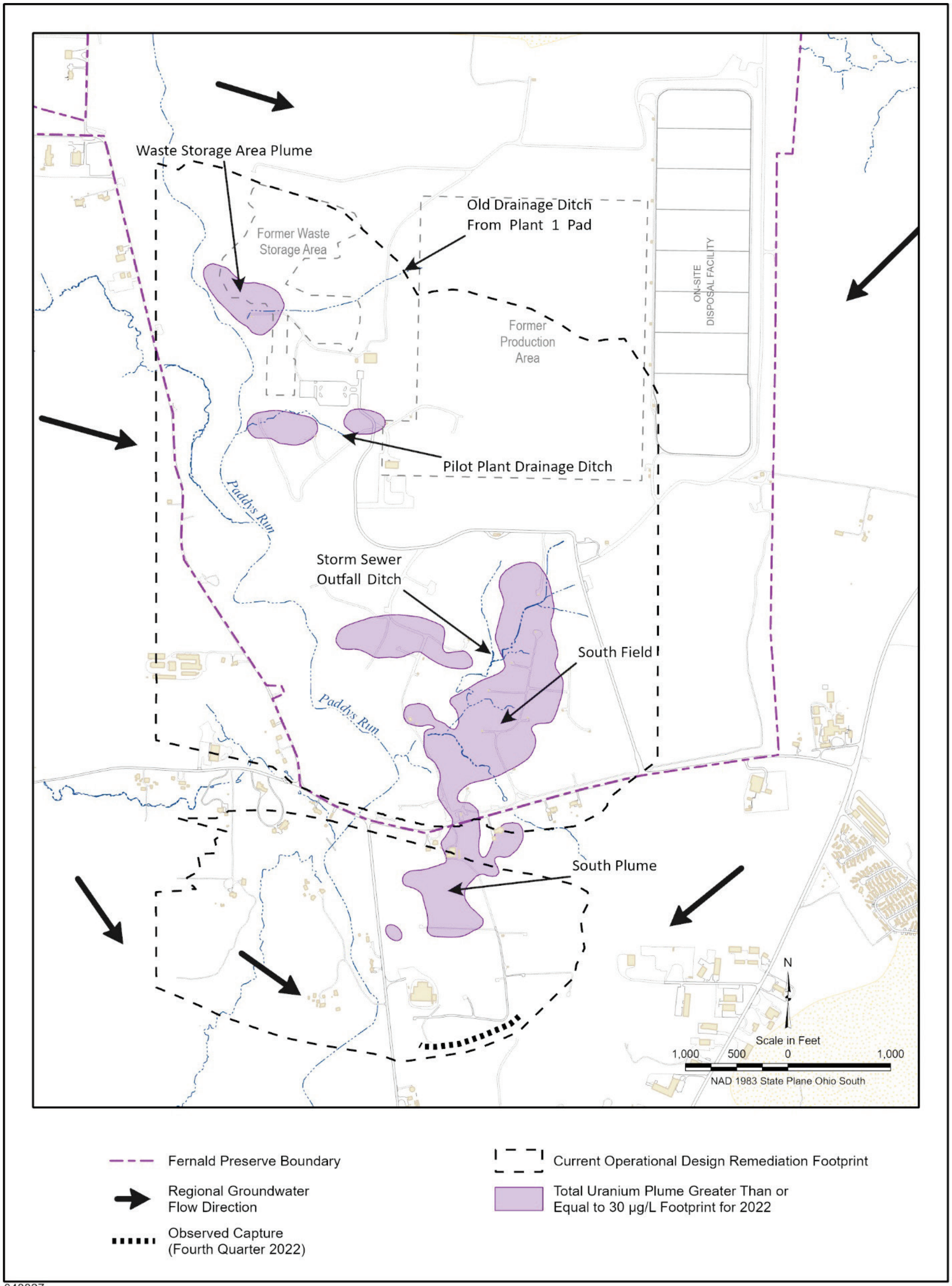


Figure 18. Total Uranium Plume in the Aquifer with Concentrations Greater Than or Equal to 30 µg/L at the End of 2022

3.3.1.3 South Field Module Operational Summary

The South Field Module was constructed in two phases. Phase I began operating in July 1998, and Phase II began operating in July 2003. During 2022, 11 extraction wells were operational.

The 10 original extraction wells installed under Phase I were 31550, 31560, 31561, 31562, 31563, 31564, 31565, 31566, 31567, and 32276. Six of the original 10 wells have been shut down (31562, 31563, 31564, 31565, 31566, and 31567).

- Extraction wells 31564 and 31565 were shut down in December 2001 and May 2001, respectively. Because these wells were located near the upgradient edge of the plume, total uranium concentrations in that region of the aquifer were low. In addition, soil remediation was underway in the area around the wells.
- Extraction well 31566 was shut down in August 1998 and was replaced by extraction well 33262, which was installed as part of South Field (Phase II) Module.
- Extraction well 31563 was shut down in December 2002 and converted to a reinjection well that operated in 2003 and 2004.
- Extraction well 31562 was shut down in March 2003 and replaced by extraction well 33298.
- Extraction well 31567 was shut down in September 2005 and replaced by extraction well 33326.

Three new extraction wells (32446, 32447, and 33061) were added to the South Field Module between 1998 and 2002. These new wells were installed in the eastern, downgradient portion of the South Field plume at locations where total uranium concentrations were considerably above the FRL. Two of these three wells (32446 and 32447) were installed in late 1999 and began pumping in February 2000. The third extraction well (33061) was installed in 2001 and became operational in 2002.

Phase II components of the South Field Module are described in the *Design for Remediation of the Great Miami Aquifer, South Field (Phase II) Module* (DOE 2002), which was issued in May 2002. The design provided an updated characterization of the total uranium plume in the Great Miami Aquifer beneath the southern portion of the site and a modeled design for the South Field Module in that area. All Phase II design components became operational in 2003. The components include:

- Four additional extraction wells; one in the former Southern Waste Units (extraction well 33262) and three along the eastern edge of the on-property portion of the southern total uranium plume (extraction wells 33264, 33265, and 33266).
- One additional reinjection well in the former Southern Waste Units (reinjection well 33263).
- An extraction well (31563) that was converted into a reinjection well.
- An injection pond that was located in the western portion of the former Southern Waste Units excavations.

In September 2004, the South Field Module reinjection components were shut down. In 2014, operational changes were made to wells in the South Field following recommendations made in a modeling study that was released in 2014 (DOE 2014). On April 14, 2014, extraction wells 33265 and 33266 were shut down because the data indicated that they were no longer providing benefit to the groundwater remedy.

During 2022, the South Field Module removed 1,277 Mgal of groundwater and 237 lb of total uranium from the Great Miami Aquifer.

3.3.1.4 Waste Storage Area Module Operational Summary

The Waste Storage Area Module was constructed in two phases. Phase I became operational on May 8, 2002, nearly 17 months ahead of the October 1, 2003, start date established in the Operable Unit 5 Remedial Action Work Plan. Phase I consisted of three extraction wells (32761, 33062, and 33063). These three wells were installed to remediate a total uranium plume in the PPDD area, according to the *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001a). In July 2004, extraction well 33063 was plugged and abandoned to make way for surface excavation activities required for site remediation. A replacement well for extraction well 33063 was installed in 2005 (extraction well 33334) and became operational on June 29, 2006. Phase II consisted of one additional extraction well (extraction well 33347), which became operational on October 5, 2006.

In 2014, operational changes were made to wells in the former Waste Storage Area following recommendations made in a modeling study that was released in 2014 (DOE 2014). On April 14, 2014, extraction well 33334 was shut down because the data indicated that it no longer provided a benefit to the groundwater remedy.

During 2022, 332 Mgal of groundwater and 60 lb of uranium were removed from the Great Miami Aquifer through the Waste Storage Area Module.

3.3.1.5 Monitoring Results for Total Uranium

Total uranium is the primary FRL constituent because it is the most prevalent site contaminant and it has affected the largest area of the aquifer. Focusing on remediating the uranium plume also addresses the remaining contaminants. Figure 18 shows the mapped outline of the total uranium plumes in the aquifer through the end of 2022. The total uranium plumes identified in the figure represent the interpreted size of the maximum total uranium plume in which concentrations are at or above the 30 µg/L groundwater FRL for total uranium.

Data collected in 2022 show continued progress in reducing the uranium footprint, as described below:

- The mapped footprint of the total uranium plume decreased in size by 1 acre (1.3%). The area at or above 30 µg/L in 2021 was mapped as being 75.0 acres, and the area above 30 µg/L in 2022 was mapped as being 74.0 acres.
- The area of the total uranium plume above a concentration of 50 µg/L increased in size by 0.7 acre (1.4%). The area at or above 50 µg/L in 2021 was mapped as being 48.7 acres, and the area above 50 µg/L in 2022 was mapped as being 49.4 acres.
- The area of the total uranium plume above a concentration of 100 µg/L decreased in size by 0.5 acres (1.8%). The area at or above 100 µg/L in 2021 was mapped as being 28.3 acres, and the area above 100 µg/L in 2022 was mapped as being 27.8 acres.

Figure 18 identifies hydraulic capture observed during the fourth quarter of 2022 for the active restoration modules and also presents regional groundwater flow directions. The map indicates that the existing extraction system is hydraulically capturing the South Plume and preventing further movement of uranium to the south beyond the extraction wells. Figure 18 also depicts the zone of influence remediation footprint that was predicted by modeling the current Operational Design.

Appendix A, Attachment A.2, provides detailed total uranium plume maps for 2022. Appendix A, Attachment A.3, provides quarterly groundwater elevation maps and capture interpretations, along with graphical displays of groundwater elevation data. Highlights for 2022 for the former Waste Storage Area, former Plant 6 area, and South Field/South Plume area are provided below.

Geoprobe (Direct-Push) Sampling
The Geoprobe, a hydraulically powered, direct-push sampling tool, is used at the Fernald Preserve to obtain groundwater samples at specific depth intervals without installing a permanent monitoring well. Direct-push employs the weight of the vehicle the tool is mounted on and percussive force (hammering) to push the tool into the ground without drilling (or cutting) to displace soil in the tool's path. The Fernald Preserve uses this technique to collect data on the progress of aquifer restoration and to determine the optimal location and depth of additional monitoring and extraction wells that may be installed in the future.

Former Waste Storage Area: This area includes the PPDD plume. In 2022, no direct-push samples were collected from the former Waste Storage Area to supplement routine sampling of monitoring wells.

Between 2021 and 2022 the mapped footprint of the 30 µg/L total uranium plume remained the same at 12.5 acres. This is because no direct-push sampling took place in the Former Wase Storage area in 2022. Figure 18 shows the outline of the maximum total uranium plumes in the former Waste Storage Area, as measured in 2022. Data are presented in Appendix A, Attachment A.2.

Former Plant 6 Area: Plans for a restoration module in the former Plant 6 area were abandoned in 2001 based on the outcome of the *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001a). The design data indicated that the total uranium plume in the former Plant 6 area was no longer present. EPA and Ohio EPA concurred with this decision. Monitoring in the area continues.

Monitoring well 2389 is the only well remaining in the area. Total uranium FRL exceedances were detected at this well again in 2022. As discussed in past Site Environmental Reports, FRL exceedances occur in this area when the water-table elevation exceeds 515 ft above mean sea level. The two samples collected in 2022 at monitoring well 2389 had total uranium concentrations above 30 µg/L. Both samples were collected when the water table had an elevation above 515 ft above mean sea level. The former Plant 6 area will continue to be targeted for additional direct-push sampling when the water table is high to determine whether the total uranium groundwater FRL exceedance is dissipating over time. This location is within the capture zone of the pump-and-treat system.

South Field and South Plume Areas: In 2022, direct-push samples were collected at 27 locations in the South Field and South Plume areas to supplement routine sampling of monitoring wells. Direct-push data for 2022 are presented in Appendix A, Attachment A.2.

In 2022, the mapped footprint of the 30 µg/L total uranium plume in the South Field and South Plume decreased by 1 acre. The area above 30 µg/L in 2021 was mapped as 62.5 acres, and the area above 30 µg/L in 2022 was mapped as 61.5 acres.

In 2022, the area of the total uranium plume in the South Field and South Plume above a concentration of 50 µg/L increased by 0.6 acre. The area above 50 µg/L in 2021 was mapped as 38.9 acres, and the area above 50 µg/L in 2022 was 39.5 acres.

In 2022, the area of the total uranium plume in the South Field and South Plume above a concentration of 100 µg/L decreased by 0.41 acres. The area above 100 µg/L in 2021 was mapped as 20.41 acres, and the area above 100 µg/L in 2022 was 20 acres.

3.3.1.6 Monitoring Results for Non-Uranium Constituents

Although the groundwater remedy is primarily targeting remediation of the total uranium plume, other FRL constituents within the total uranium plume are also being monitored. Figure 19 identifies the locations of the monitoring wells that had non-uranium FRL exceedances. Table 5 shows the number of wells with non-uranium constituents exceeding FRLs in 2022, the number of wells with constituents exceeding FRLs outside the current Operational Design Remediation Footprint, the groundwater FRLs, and the range of 2022 data inside and outside the current Operational Design Remediation Footprint.

Table 5. Non-Uranium Constituents with Results Above FRLs During 2022

Constituent	Number of Wells Exceeding the FRL	Number of Wells Exceeding the FRL Outside the Current Operational Design Remediation Footprint	Groundwater FRL[a]	Range of 2022 Data Inside the Current Operational Design Remediation Footprint[a]	Range of 2022 Data Outside the Current Operational Design Remediation Footprint[a,b]
General Chemistry			(mg/L)	(mg/L)	(mg/L)
Nitrate + Nitrite as Nitrogen	6	0	11[c]	11.6 to 46.8	NA
Inorganics			(mg/L)	(mg/L)	(mg/L)
Molybdenum	1	0	0.10	0.175 to 0.601	NA
Zinc	1	1	0.021	NA	0.0370
Organics			(µg/L)	(µg/L)	(µg/L)
Trichloroethene	1	0	5	8.53	NA
Radionuclides			(pCi/L)	(pCi/L)	(pCi/L)
Technetium-99	2	0	94	322 to 347	NA

[a] mg/L = milligrams per liter, µg/L = micrograms per liter, pCi/L = picocuries per liter.
[b] NA = not applicable.
[c] FRL is based on nitrate from OU5 ROD, Table 9-4; however, the sampling results are for nitrate + nitrite as nitrogen.

During 2022, five non-uranium constituents had FRL exceedances. One location was outside the current uranium-based Operational Design Remediation Footprint (monitoring well 22205, zinc). Additional routine samples will be collected from monitoring well 22205 in 2023 for zinc to determine whether the exceedance is persistent. No plumes were identified for the non-uranium constituents above FRLs at the locations outside the current Operational Design Remediation Footprint in the extensive groundwater characterization efforts evaluated as part of the *Remedial Investigation Report for Operable Unit 5* (DOE 1995d). More details are provided in Appendix A, Attachment A.4.

Non-uranium constituents with FRL exceedances in 2021 at the well locations outside the current Operational Design Remediation Footprint were further evaluated in 2022 to determine if they were random events or if they were persistent according to criteria discussed in Appendix A, Attachment A.4. Additional routine data collected in 2022 were used to determine that the FRL exceedance detected in well 3128 in 2021 was not persistent.

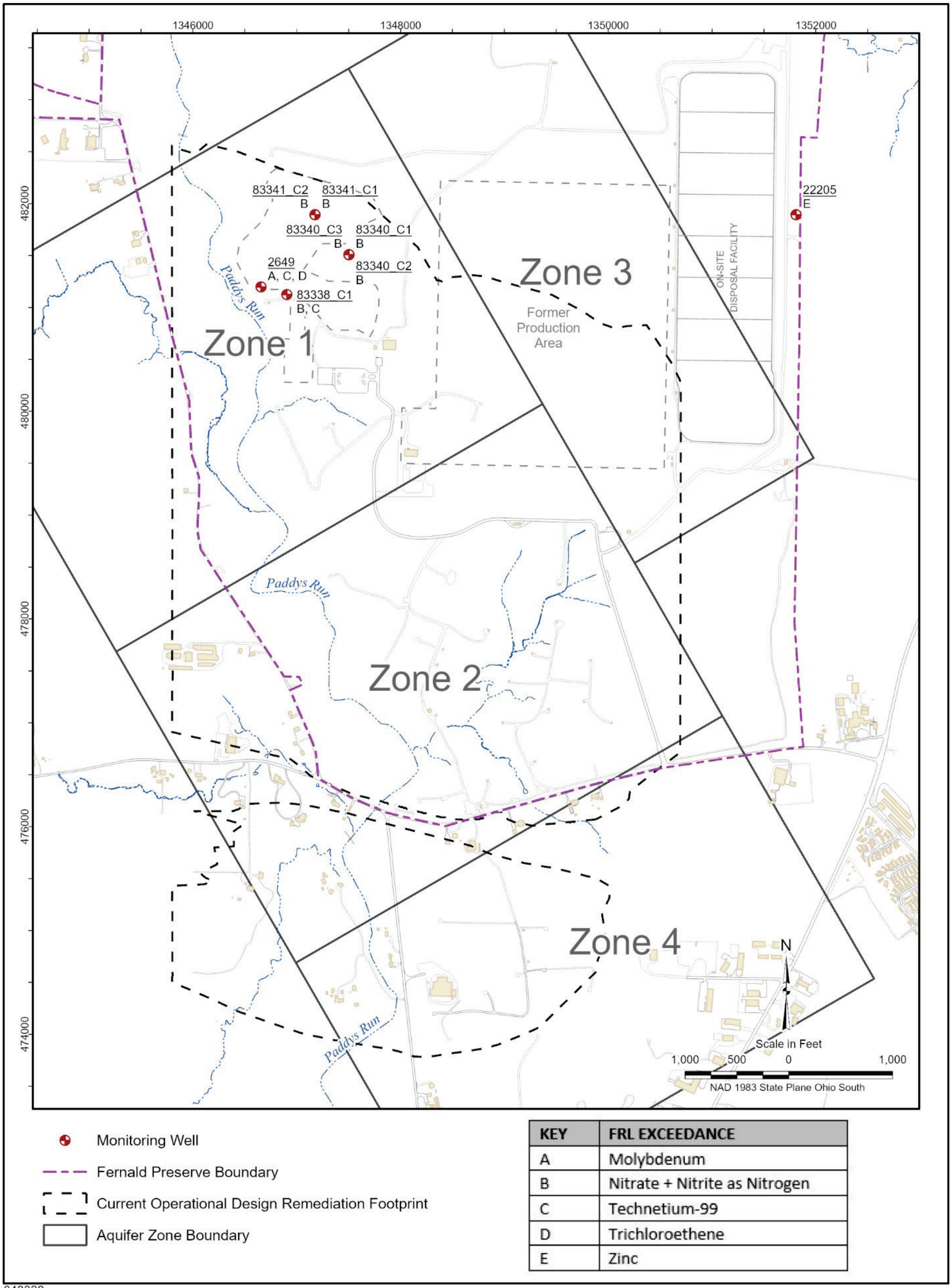
3.3.2 Other Monitoring Commitments

Two other groundwater monitoring activities are included in the IEMP: private well monitoring and property boundary monitoring. As stated earlier, the groundwater data from these activities, along with the data from all other IEMP groundwater monitoring activities, are collectively evaluated for total uranium and, where necessary, non-uranium constituents of concern. This section provides additional details on these two other compliance monitoring activities.

The three private wells (2060, 13, and 14) located along Willey Road were monitored under the IEMP in 2022 to assist in the evaluation of the total uranium plume migration. Off-property groundwater contamination was initially detected at one of these wells (well 2060) in 1981. In 1997, a DOE-sponsored public water supply became available to Fernald site neighbors who were affected by off-property groundwater contamination. When the public water supply became available, DOE discontinued monitoring at many off-property private wells. Data from the three private wells sampled under the IEMP are detailed in Section 2.3 and were incorporated into the total uranium plume maps shown in Figure 18 and Appendix A, Attachment A.2. Non-uranium data from these wells are included in Section 3.3.1.6. Data collected from the 11 wells in the Paddys Run Road area indicate that the Paddys Run Road Site plume (contamination not attributed to Fernald site operations), downgradient of the Fernald Preserve extraction wells, is not being pulled toward the South Plume extraction wells.

With problems associated with the privately-owned pump in well 13 and with an Ohio EPA proposal to reduce split sampling, DOE proposed in the 2021 Site Environmental Report (DOE 2022b) to eliminate monitoring in two of the private wells which are outside the current plume (13 and 14) but continue monitoring in well 2060. Appendix A, Attachment A.2 presents additional information concerning these wells. Following discussions with the homeowners, and with concurrence from EPA and Ohio EPA this change was implemented beginning in 2023.

As indicated in Section 2.0, Ohio EPA issued the Director's Findings and Orders on September 7, 2000. These orders specify that the site's groundwater monitoring activities will be implemented in accordance with the IEMP. The revised language allows modification of the groundwater monitoring program as necessary, via the IEMP revision or variance process (subject to Ohio EPA approval), without issuance of a new Director's Order. As determined by Ohio EPA, the IEMP will remain in effect following remediation.



KEY	FRL EXCEEDANCE
A	Molybdenum
B	Nitrate + Nitrite as Nitrogen
C	Technetium-99
D	Trichloroethene
E	Zinc

Figure 19. Non-Uranium Constituents with 2022 Results Above FRLs

3.4 Groundwater Remediation Assessment

Data collected in 2022 indicate that the maximum total uranium plume continues to decrease in response to pumping. Table 6 provides a summary.

Table 6. Comparison of 2021 and 2022 Maximum Total Uranium Plume Footprint Areas

Year	Area Greater Than 30 µg/L	Area Greater Than 50 µg/L	Area Greater Than 100 µg/L
2021 (acres)	75	48.7	28.3
2022 (acres)	74	49.4	27.8
Change (acres)	−1.0	−0.7	−0.5
Change (%)	−1.3	+1.4	−1.8

Between 2021 and 2022, the acreage mapped for the area of the maximum uranium plume above 50 µg/L increased by 0.7 acre. Periodic concentration fluctuations within the plume are expected and are attributed to dissolved uranium movement in response to active pumping.

Groundwater elevations measured in 2022 continue to indicate that the pumping wells are maintaining capture of the uranium plume by enhancing and modifying natural groundwater flow directions within the aquifer. Appendix A, Attachment A.3, provides additional information concerning capture of the total uranium plume.

Data collected in 2022 show that the mass of uranium removed from the aquifer was more than what the groundwater model predicted. This indicates that the pumping system remains effective in removing uranium from the aquifer, but that the model is underpredicting how much uranium will need to be removed to achieve cleanup. Appendix A, Attachment A.1, provides additional information concerning the mass of uranium removed from the aquifer.

In 2022, the site groundwater model was updated with uranium concentrations measured in the first half of 2021. Updated modeled cleanup date predictions for the South Plume, South Field and Waste Storage Area were determined to be 2025, 2038, and 2045, respectively. These new cleanup time predictions assume that the no wellfield pumping changes are made to the current operational design.

DOE also modeled in 2022 how best to optimize the South Plume extraction wells moving forward, and how to possibly speed up the cleanup of the South plume. The first model runs focused on utilizing the existing South Plume recovery wells. A big risk factored into these modeling runs though was the assumption that the existing extraction wells would continue to operate dependably until they are no longer needed. DOE was successful in prolonging the operational life of recovery well 3927 by lower its target pumping rate. This approach was therefore modeled for the other extraction wells. The modeling results indicated that predicted cleanup of the South Plume could still be achieved in 2025, even with the existing recovery wells pumping at the lower pumping rates.

Modeling was also conducted in 2022 to provide an alternative approach, should one or more of the existing extraction wells fail. The selected model alternative replaces the six existing South

Plume recovery wells (3924 through 3927) with two new recovery wells that are better positioned for capture and remediation of the remaining South Plume. With operation of the two new proposed recovery wells the existing six South plume extraction wells are no longer needed to capture and remediate the remaining portions of the South Plume. This operational alternative, therefore, removes the risk involved with the continued operation of the existing aging South Plume recovery wells. This alternative also provides DOE with the option of continuing to operate remaining South Plume recovery wells at lower pumping rates to provide additional flushing in the South Plume until it is certified clean.

As discussed in Section 3.3.1.2 recovery wells 3927 and 32308 were permanently shut down in 2022 due to operational problems associated with the old age of the wells. DOE is proceeding with the alternative modeling approach discussed above and is installing two new extraction wells in the South Plume to continue with remediation of the remaining South Plume. The two new extraction wells are scheduled to be operational in 2024.

Bulk plume metrics (i.e., plume acres, average plume concentration, and dissolved uranium mass) are also provided in this year's Site Environmental Report to track groundwater remediation progress. Until 2022, these bulk plume metrics were based on Ricker method calculations (Ricker 2008). Beginning with this year's Site Environmental Report, bulk plume metrics are also provided through the use of Earth Volumetric Studio software. Table 7 provides a summary of the Ricker method bulk plume metrics over time, showing an overall decrease for all three metrics between 2006 and 2022.

Table 7. Bulk Plume Metrics (2006 to 2022)

Year	Plume Area (Acres)	Average Plume Concentration (µg/L)	Remaining Dissolved Uranium Mass (lb)
2006	145.7	92.11	306
2010	132.7	89.96	272
2014	108.0	86.41	213
2016	108.0	79.32	195
2017	97.3	79.12	175
2018	95.9	86.23	190
2019	89.2	81.58	166
2020	85.9	80.77	158
2021[a]	81.6	82.46	153
2022	80.7	88.58	163

[a] Average plume concentration and remaining dissolved uranium mass were corrected from data reported in the 2021 Site Environmental Report (DOE 2022b) from 80.85 µg/L and 150 lb, respectively.

As noted in Table 7, during preparation of these metrics for 2022, it was discovered that errors were noted in the 2021 Site Environmental Report (DOE 2022b). The errors involved the average total uranium concentration and the total mass of dissolved uranium. The errors have been corrected and reported in Appendix A, Attachment A.2; the errors were found to have little effect on the overall interpretation provided in Figure A.2-24. Based on the Ricker method, dissolved mass decreased by approximately 47% between 2006 and 2022, decreasing from 306 lb in 2006 to 163 lb in 2022.

Earth Volumetric Studio software determined bulk plume metric for results for October 1, 2006, October 2, 2021, and October 1, 2022, are as follows.

Metric	October 1, 2006	October 1, 2021	October 1, 2022
Dissolved Mass (lb)	159.64	67.21	54.45
Average Concentration (µg/L)	68.44	67.47	59.21
Area (Acres)	136.50	88.87	85.25
Volume (Cubic Feet)	279.55	119.39	110.21
Average Thickness (feet)	22.45	14.73	14.17

Based on Earth Volumetric Studio software, dissolved plume mass decreased by approximately 66% between 2006 and 2022, decreasing from a maximum 159.64 lb in 2006 to 54.45 lb in 2022. It should be noted that the total mass computed by Earth Volumetric Studio software is significantly lower than the mass calculated by the Ricker method. The 2006 plume mass calculated by the Ricker method is 306 lb compared to 160 lb calculated by the software. The Ricker method is a two-dimensional approach, and conservative assumptions are applied to account for the third vertical dimension. A conservative plume thickness of 30 ft is assumed in the Ricker calculations, and the maximum uranium concentration at each sample location is applied to the full plume thickness. These assumptions are not needed when concentration variations are visualized in three dimensions, so Earth Volumetric Studio software provides a more realistic estimate of plume mass. For example, the average plume thickness calculated by the software for October 2006 is 22.5 ft (25% less than the 30 ft plume thickness assumed for the Ricker method), and the average concentration is 68 µg/L (26% less than the 92 µg/L estimated by the Ricker method). If the mass calculated by the Ricker method is adjusted to account for the overestimates of plume thickness and average concentration, then the 2006 Ricker method calculated mass becomes 170 lb, which is very similar to the 160 lb mass calculate by Earth Volumetric Studio software.

Two calculations, plume center-of-mass and total uranium mass remaining in the aquifer, are presented in Appendix A, Attachment A.2. Plume center-of-mass calculations show that the center of mass of each plume area has remained fairly stationary between 2006 and 2022, indicating that the surrounding pumping wells are capturing the plume and not allowing the center of mass to migrate as it would if no pumping was taking place. Of note is that the center of mass has shifted to the north in the South Field. This provides additional support for the determination that uranium concentrations in the South Plume are decreasing, and that progress is being made in achieving the objective of cleaning up the South Plume first.

The Ricker method calculation for mass remaining in the aquifer estimates the dissolved mass present in the groundwater as total aqueous uranium. The estimate for the mass of aqueous uranium is used to estimate the solid uranium mass adsorbed to aquifer sediments (Deutsch 1997). The dissolved mass and solid mass combined provide an estimate of the total uranium mass remaining in the aquifer. Calculation of the pounds of uranium remaining in the aquifer (dissolved and sorbed) for both the Ricker method and through Earth Volumetric Studio software analysis is 3,395.29 lb and 1,134.19 lb, respectively.

National Laboratory Network Recommendations

In early 2021, a DOE National Laboratory Network Collaboration was conducted concerning the Fernald Preserve groundwater remediation. EPA and Ohio EPA participated in the collaboration, with the understanding that any official input or endorsement for any of the recommendations would be reserved for if, and when DOE decides to pursue implementation of a recommendation at the site. The objective of the collaboration was to present recommendations to improve the ongoing aquifer remediation at the Fernald Preserve.

The collaboration involved two focus groups. Focus Group 1 was challenged with developing recommendations on how to maintain and keep an aging well field system operating efficiently. Focus Group 2 was challenged with developing recommendations to improve the efficiency and success of the existing pumping remedy and to improve the aquifer cleanup predictions for planning purposes while considering the following three site priorities:

1. Focus first on the off-property plume.
2. Focus second on the southern South Field plume.
3. Focus third on the recalcitrant areas of the plume in the South Field and former Waste Storage Area.

Results of Focus Group 1: Aging Well Field System

Focus Group 1 did not identify anything that is currently being done to maintain the aging well field system at the Fernald Preserve that should stop being done. Focus Group 1 acknowledged that operating an aging wellfield system efficiently is somewhat of a “art” rather than a “science” in that there is no one proven method or process that seems to always work. Success involves a degree of trial and error to determine the optimal operational practice for any given well. Given the operational challenges at the Fernald Preserve, the current operation and maintenance program was determined to be sound. When the DOE National Laboratory Network Collaboration personnel contacted area experts for information, those familiar with the site’s well field maintenance program emphasized that they often refer to the Fernald Preserve when they need an example of how to approach the challenge. Focus Group 1 presented the following three consensus recommendations:

1. Test the use of automatic biofilm and scale control in the extraction wells.
2. Test the use of carbon dioxide to rehabilitate extraction wells.
3. Enhance rehabilitation contact (i.e., use of satellite wells to deliver treatments).

DOE began implementing these recommendations in 2022 by conducting a small-scale test of the automatic biofilm and scale control recommendation.

The automatic biofilm and scale control recommendation calls for the routine administration of a biocide like peracetic acid instead of the current practice of doing periodic administration of liquid acid descaler. Routine administration of the peracetic acid will require infrastructure modifications to the wellheads of the extraction wells. Before making these wellhead modifications, DOE conducted a manual test on a select couple of extraction wells. The National Laboratory Network recommendation called for the use of a biocide like peracetic acid on a new extraction well. A new extraction well was not available, so two recently rehabilitated extraction wells were selected for the test. With concurrence from EPA and Ohio EPA, the manual test began in November 2021 and lasted 6 months. Specific capacity data collected during the small-scale test indicate that the routine use of peracetic acid on aged wells that were recently rehabilitated brought no improvement in the efficiency of the wells specific capacity compared to the periodic use of liquid acid descaler on a recently rehabilitated well. However, the scenario of doing routine administration of peracetic acid on a brand-new extraction well remains untested. DOE may attempt the test again when a newly installed extraction well is available.

All three National Laboratory Network recommendations from Focus Group 1 pertain to extending the life of an extraction well. Considering the age of the existing extraction wells, rather than trying to prolong their lives further, the best option may be to strategically replace them. DOE will revisit all three Focus Group 1 National Laboratory Network recommendations as deemed appropriate when replacement of an extraction well is being considered.

Results of Focus Group 2: Improve Efficiency of the Aquifer Cleanup

Focus Group 2 did not identify anything that is currently being done to improve efficiency of the aquifer cleanup at the Fernald Preserve that should be stopped. Six recommendations were presented. Four of the six recommendations involved doing things that are *not* being done at the Fernald Preserve. Two of the six recommendations involved things that the Fernald Preserve are being done but that should be supplemented with something that the Fernald Preserve is *not* doing.

What the Fernald Preserve is not doing, but should be doing:

1. Use alternative mathematical expressions to predict cleanup time frames.
2. Conduct targeted data mining of available site information for enhanced understanding of prior fate and transport behavior and improved predictions of future behavior.
3. Prepare three-dimensional visualizations of key hydrogeologic and geochemical parameter distributions over time.
4. Conduct algorithm-based optimization for future remedy operation and design.

What the Fernald Preserve is doing that should be supplemented with something else:

1. Refine plume metric calculations to reduce uncertainty.
2. Continue to port the site groundwater model to a modern hydrologic software platform.

DOE has implemented two of the Focus Group 2 recommendations in 2022: (1) The use of alternative mathematical expressions (discussed in Appendix A, Attachment A.1) and (2) The three-dimensional visualization of key hydrologic and geochemical parameter distributions over time (discussed in Appendix A, Attachment A.2). It is anticipated that full implementation of all the recommendations will take from 1 to 4 more years. Implementation of any National Laboratory Network recommendation is subject to availability of resources, stakeholder coordination (as appropriate) and regulatory approval.

Both of the completed recommendations mentioned add value to the ongoing aquifer remediation by improving the interpretation capabilities and providing more powerful data analysis techniques. The objective of continuing with the implementation of the remaining recommendations noted above is to improve the predicative capability of the site groundwater model and lead to a more efficient and timely remediation of the remaining contaminant plume.

3.5 OSDF Monitoring

Monitoring of the OSDF is conducted in the leachate collection system (LCS), leak detection system (LDS), glacial till (perched water), and Great Miami Aquifer. Figure 20 identifies the OSDF footprint and monitoring well locations for Cells 1 through 8. Flow is monitored within the facility in the LCS and LDS to determine whether the facility is operating as designed. Water quality is monitored in the LCS, LDS, glacial till, and Great Miami Aquifer to identify any potential water quality changes that could have resulted from leakage from the facility.

LCS and LDS flow data collected in 2022 indicate that engineered features within the OSDF continue to perform as designed. Leachate flow continues to diminish as expected, and LDS flow volumes indicate that the cell liners are performing well as designed.

A comparison of water quality data collected in 2022 from within the facility (LCS and LDS) to water quality data collected beneath the facility (perched groundwater in the glacial till and groundwater in the Great Miami Aquifer) indicates that the facility is operating as designed. Table 8 summarizes the groundwater, LCS, and LDS monitoring information for Cells 1 through 8 of the OSDF by providing the range of total uranium concentrations measured in 2022. The majority of total uranium concentrations measured in 2022 fell within the historical range of concentrations previously measured for each monitoring horizon. New high and new low concentrations measured in 2022 are identified in bold in Table 8.

As shown in Table 8, and summarized below, two new high total uranium concentrations were detected in 2022 within the facility (LDS horizon). As reported in Appendix A, Attachment A.5, the uranium concentrations in the LDS horizons have historically increased as the LDSs dry out. Continued monitoring is the recommended action at this time.

- LDS of Cell 4: A new high of 79.8 µg/L was measured. The previous high was 55.9 µg/L.
- LDS of Cell 6: A new high of 160 µg/L was measured. The previous high was 152 µg/L.

Summary statistics and time versus concentration graphs for each of the monitoring horizons listed in this section are provided in subattachments to Appendix A, Attachment A.5. Also provided in subattachments to Attachment A.5 are bivariate plots for each of the eight cells, which demonstrate that mixing between the LCS, LDS, and horizontal till well at each cell is not occurring. The new high concentrations summarized for 2022 are attributed to decreasing flow rates in the LDS. Continued routine sampling is the recommended action.

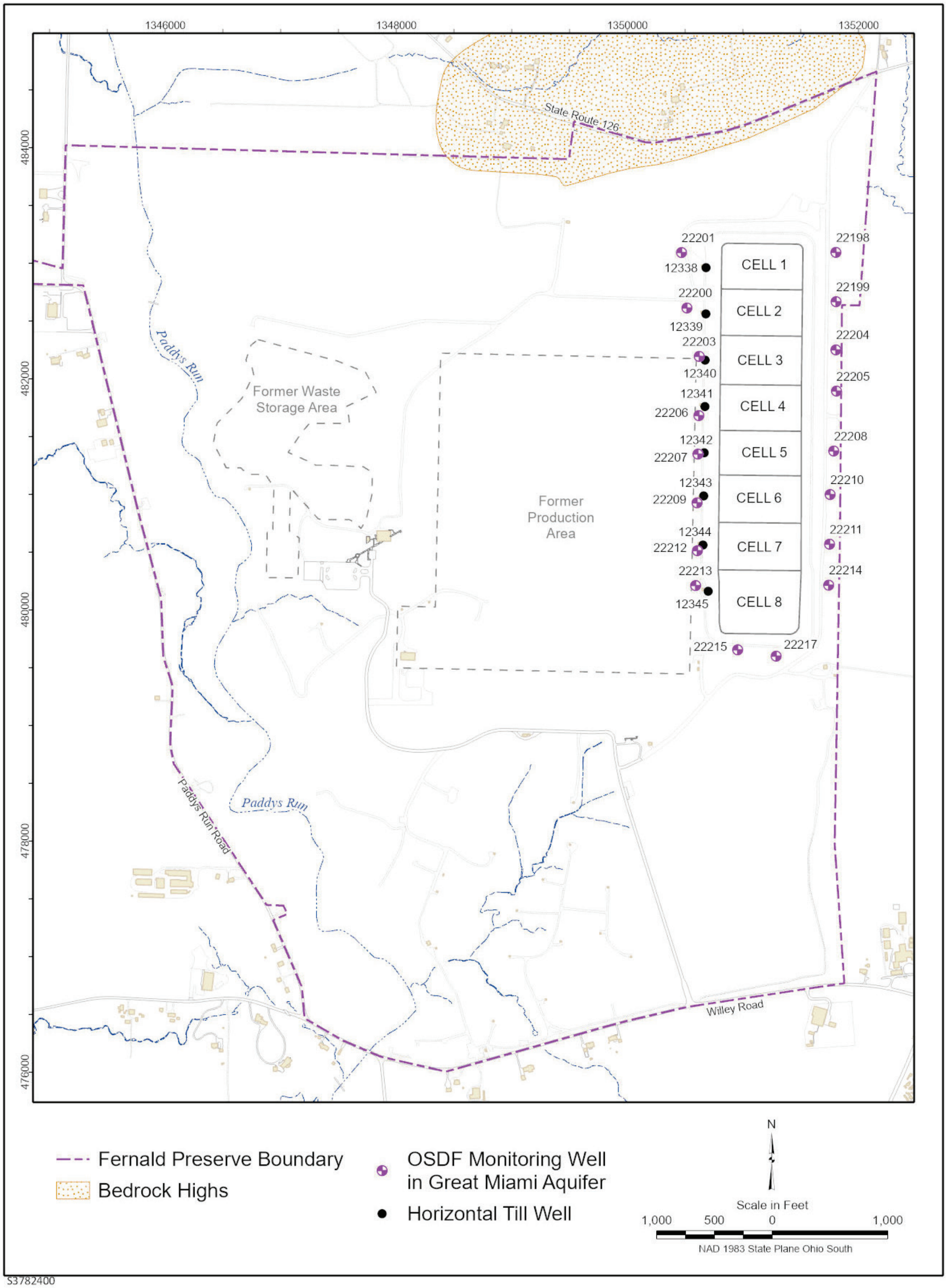


Figure 20. OSDF Footprint and Monitoring Well Locations

Table 8. OSDF Groundwater, Leachate, and LDS Monitoring Summary

Cell (Waste Placement)	Monitoring Location	Monitoring Zone	Date Sampling Started	Total Number of Samples	Range of Total Uranium Concentrations[a,b] (µg/L)	First Half 2022[a,c] (µg/L)	Second Half 2022[a,c] (µg/L)	Historical Trend[d] (Year Last Sampled)
Cell 1 (Dec 1997)	12338C	LCS	Feb 17, 1998	78	ND–206	18.8	10.2	None (2022)
	12338D	LDS	Feb 18, 1998	37	1.50–37.0	DRY	DRY	Up (2011)
	12338	Glacial Till	Oct 30, 1997	87	ND–19	7.12	6.68	Up (2022)
	22201	Great Miami Aquifer	Mar 31, 1997	94	ND–12.4	5.52	6.07	Up (2022)
	22198	Great Miami Aquifer	Mar 31, 1997	143	0.540–15.2	3.08	2.51	Down (2022)
Cell 2 (Nov 1998)	12339C	LCS	Nov 23, 1998	74	4.51–686	45.8	55.9	Up (2022)
	12339D	LDS	Dec 14, 1998	29	4.08–25.8[e]	DRY	DRY	None (2013)
	12339	Glacial Till	Jun 29, 1998	98	ND–36.9	15.8	17.9	Up (2022)
	22200	Great Miami Aquifer	Jun 30, 1997	89	ND–4.69	0.303	1.49	Up (2022)
	22199	Great Miami Aquifer	Jun 25, 1997	120	ND–12.1	0.353	0.513	Down (2022)
Cell 3 (Oct 1999)	12340C	LCS	Oct 13, 1999	72	9.27–206	141	131	Up (2022)
	12340D	LDS	Aug 26, 2002	20	8.90–27.7[e]	DRY	DRY	Down (2007)
	12340	Glacial Till	Jul 28, 1998	91	ND–58.5	16.3	15.2	None (2022)
	22203	Great Miami Aquifer	Aug 24, 1998	84	ND–**23.5**	**23.5**	9.45	Up (2022)
	22204	Great Miami Aquifer	Aug 24, 1998	115	ND–22.9	3.08	1.96	Up (2022)
Cell 4 (Nov 2002)	12341C	LCS	Nov 4, 2002	58	4.41–234	113	86.4	None (2022)
	12341D	LDS	Nov 4, 2002	42	5.74–**79.8**	**79.8**	DRY	Up (2022)
	12341	Glacial Till	Feb 26, 2002	71	3.40–7.91	3.46	3.19	Down (2022)
	22206	Great Miami Aquifer	Nov 6, 2001	75	ND–5.78	0.731	1.14	Up (2022)
	22205	Great Miami Aquifer	Nov 5, 2001	102	0.446–19.7	2.13	2.40	None (2022)
Cell 5 (Nov 2002)	12342C	LCS	Nov 4, 2002	60	3.39–285	131	162	None (2022)
	12342D	LDS	Nov 4, 2002	40	2.93–27.1	DRY	DRY	Down (2013)
	12342	Glacial Till	Feb 26, 2002	72	7.45–21.1	7.64	8.90	Down (2022)
	22207	Great Miami Aquifer	Nov 6, 2001	75	ND–4.48	0.449	0.269	Down (2022)
	22208	Great Miami Aquifer	Nov 5, 2001	101	ND–2.1	0.361	0.254	None (2022)
Cell 6 (Nov 2003)	12343C	LCS	Oct 27, 2003	57	8.03–276	119	103	Down (2022)
	12343D	LDS	Oct 27, 2003	56	3.1–**160**	**160**	133	Up (2022)
	12343	Glacial Till	Mar 14, 2003	64	ND–24.2	8.48	7.80	None (2022)
	22209	Great Miami Aquifer	Dec 16, 2002	70	ND–2.43	0.409	0.447	Down (2022)
	22210	Great Miami Aquifer	Dec 16, 2002	96	ND–1.02	0.638	0.647	None (2022)

Table 8. OSDF Groundwater, Leachate, and LDS Monitoring Summary (continued)

Cell (Waste Placement)	Monitoring Location	Monitoring Zone	Date Sampling Started	Total Number of Samples	Range of Total Uranium Concentrations[a,b] (µg/L)	First Half 2022[a,c] (µg/L)	Second Half 2022[a,c] (µg/L)	Historical Trend[d] (Year Last Sampled)
Cell 7 (Sep 2004)	12344C	LCS	Sep 2, 2004	53	4.72–355	56.2	90.9	Down (2022)
	12344D	LDS	Sep 2, 2004	29	12.2–169[e]	DRY	DRY	Up (2015)
	12344	Glacial Till	Feb 24, 2004	61	0.674–12.1	3.54	3.91	Up (2022)
	22212	Great Miami Aquifer	Jan 21, 2004	63	ND–5.53	0.428	0.385	Down (2022)
	22211	Great Miami Aquifer	Jan 21, 2004	86	ND–4.31	0.369	0.394	None (2022)
Cell 8 (Dec 2004)	12345C	LCS	Oct 18, 2004	50	1.51–335	147	159	None (2022)
	12345D	LDS	Oct 18, 2004	45	9.38–315	DRY	DRY	Up (2021)
	12345	Glacial Till	May 19, 2004	20	3.48–7.3	DRY	DRY	Up (2008)
	22213	Great Miami Aquifer	Mar 31, 2004	62	ND–0.71	0.364	0.354	Up (2022)
	22214	Great Miami Aquifer	Mar 31, 2004	86	ND–2.95	0.469	0.843	Down (2022)
	22215	Great Miami Aquifer	Aug 22, 2005	53	ND–16.4	0.679	0.364	None (2022)
	22217[g]	Great Miami Aquifer	Aug 22, 2005	52	ND–18.3	1.86	5.60	Down (2022)

Note 1: The data on this table represent the raw data from the database; however, data presented in Appendix A, Attachment A.5 have gone through statistical processing and analysis. In regard to the statistical processing, the data were quarterized (normalized to one result per quarter) and outliers removed to arrive at an accurate distribution model. Because of the processing, the total number of samples and range of concentrations on this table may not match the text, tables, and figures in Appendix A, Attachment A.5. The rules used for the statistical processing and analysis in Attachment A.5 are discussed in Appendix A, Attachment A.5, Section A.5.2.1, and summarized in Table A.5-3.

Note 2: Uranium concentration versus time graphs are located in the subattachments to Appendix A, Attachment A.5. See Figures A.5.1-5A and A.5.1-5B for Cell 1; Figures A.5.2-5A and A.5.2-5B for Cell 2; Figures A.5.3-5A and A.5.3-5B for Cell 3; Figures A.5.4-5A and A.5.4-5B for Cell 4; Figures A.5.5-5A and A.5.5-5B for Cell 5; Figures A.5.6-5A and A.5.6-5B for Cell 6; Figures A.5.7-5A and A.5.7-5B for Cell 7; and Figures A.5.8-7A and A.5.8-7B for Cell 8.

[a] **Bold text indicates a new high or low detected in 2022.**
[b] ND = not detected.
[c] Where there are more than two data points for the half year, the higher result is used.
[d] The trends presented here are based on nonparametric Mann-Kendall procedure and come from the tables in Appendix A, Attachment A.5 subattachments for each cell. See Tables A.5.1-1, A.5.2-1, A.5.3-1, A.5.4-1, A.5.5-1, A.5.6-1, A.5.7-1, and A.5.8-1.
[e] Some data are not considered representative of LDS in Cell 2 (December 14, 1998, through May 23, 2000, data set) due to malfunction in Cell 2 leachate pipeline and resulting mixing of individual flows. It is suspected that some November 2004 samples were switched (i.e., 12339C with 12339D, and 12340C with 12340D). If data from these events were included above, maximum total uranium concentrations would be 71 µg/L for 12339D and 72.4 µg/L for 12340D. It is suspected that samples were switched in 2014 (i.e., 12344D with the field duplicate for 12345C). If the data point from this sampling event was not included above, maximum total uranium concentration for 12344D would be 37.6 µg/L.
[f] The Cell 4 LDS was dry, resulting in no data from fourth quarter 2011 through 2016.
[g] Monitoring location 22216 was plugged and abandoned in April 2006. Monitoring location 22217 is its replacement. The results listed for location 22217 also include the results for location 22216.

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4.0 Surface Water and Effluent Pathway

> **Results in Brief: 2022 Surface Water and Effluent Pathway**
>
> **Surveillance Monitoring:** No effluent analytical results from samples collected in 2022 exceeded any surface water FRL.
>
> **Uranium Discharges:** In 2022, 335 lb of uranium were discharged in effluent to the Great Miami River. Approximately 32 lb of uranium were released to the environment through uncontrolled storm water runoff. The estimated total mass of uranium released through the surface water and effluent pathway was approximately 367 lb.
>
> **NPDES Permit Compliance:** There were no instances of noncompliance at any sample location in 2022.

This section presents the 2022 monitoring activities and results for surface water and effluent to determine the effects of site activities on the surface water pathway.

In general, low levels of contaminants enter the surface water pathway at the Fernald Preserve by two primary mechanisms: effluent that is monitored as it is discharged to the Great Miami River and uncontrolled runoff entering the site's drainages from remediated areas that are now certified and restored. Because these discharges have continued through remediation and legacy management, the surface water pathway will continue to be monitored.

4.1 Summary of Surface Water and Effluent Pathway

> To assist in the understanding of this section, the following key definitions are provided:
>
> - **controlled runoff.** Storm water that is collected and, under normal circumstances, treated and discharged to the Great Miami River as effluent. However, currently, the only storm water that is controlled is associated with the footprint of the outdoor processing activities at the wastewater treatment facility.
> - **uncontrolled runoff.** Storm water that is not collected for treatment but enters the site's natural drainages.
> - **effluent.** Primarily untreated groundwater discharged to the Great Miami River via the effluent line. A small amount of groundwater is routed to treatment each month and blended with water from the backwash basin. The small volume of treated water is blended with untreated groundwater and is discharged to the Great Miami River via the outfall line.
> - **surface water.** Water that flows within natural drainage features.

The effluent pathway consists of flows discharged to the Great Miami River via the Parshall Flume, sample location PF 4001. Discharges through this point are considered under the control of wastewater treatment operations. Effluent is currently composed of treated and untreated groundwater, treated leachate from the OSDF, and storm water associated with the footprint of the outdoor processing activities at the wastewater treatment facility. Groundwater is no longer routinely treated to meet discharge limits. A small volume of groundwater is blended with other wastewater stored in the CAWWT backwash basin when basin water is treated. The backwash basin is an above-ground lined impoundment that is used to temporarily store wastewater originating from a variety of sources (i.e., well rehabilitation, CAWWT backwash, OSDF leachate, groundwater sampling, CAWWT laboratory, and CAWWT stormwater drainage).

The volume and flow rate of uncontrolled runoff depend on several tributaries to Paddys Run (e.g., SSOD) as well as the northeast drainage that flows to the Great Miami River. The arrows in Figure 21 indicate the general flow direction of uncontrolled runoff as determined from the topography. Uncontrolled runoff from the Fernald Preserve leaves the property via two drainage pathways: Paddys Run and the northeast drainage ditch.

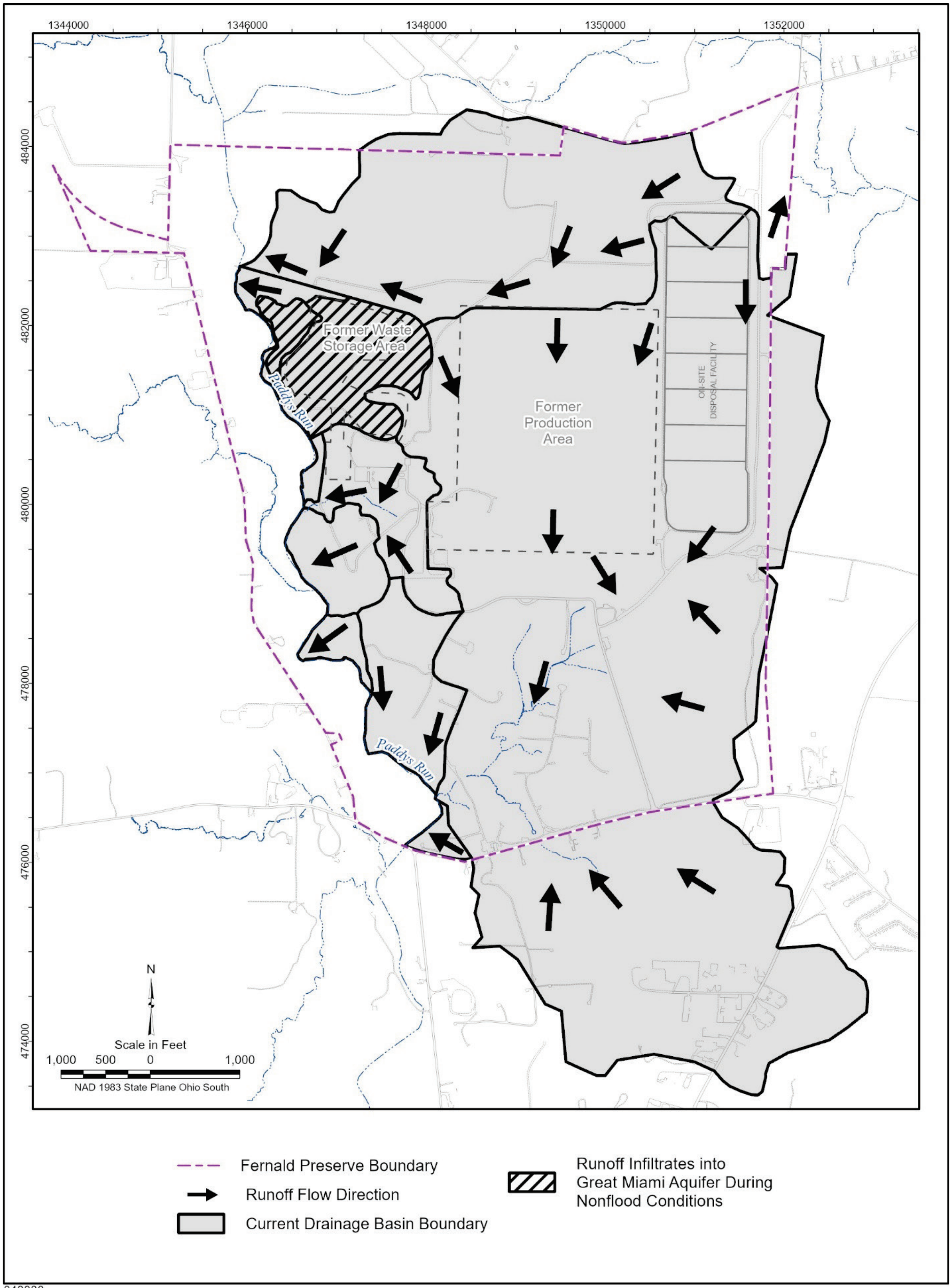

Figure 21. Uncontrolled Surface Water Areas and Runoff Flow Directions

4.2 Remediation Activities Affecting the Surface Water Pathway

Activities that had the potential to affect the surface water pathway included routine operation and maintenance activities of the OSDF and the CAWWT and ecological restoration activities conducted throughout the property, including repairing areas of erosion.

Now that surface remediation has been completed at the Fernald Preserve and the groundwater remedy continues, the restored areas of the site are the primary focus relative to uncontrolled runoff. Controls to mitigate sediment leaving the site are primarily based on the vegetation and stabilization practices (e.g., erosion controls) within the restored areas.

One small area west of the former waste pits, continued to show elevated total uranium concentrations in surface water samples. The location of elevated uranium area is a series of small puddles and drainage ditches due west of the center of former Waste Pit 3, which drain generally south to a depression near the former Waste Storage Area runoff control basin known as the "cement pond." This area does not drain directly to Paddys Run and is not open to the public. A streambank stabilization project was conducted in 2014 and 2015 to ensure that Paddys Run does not erode into this area.

After a limited maintenance activity was completed in the fall of 2007, DOE committed to continue monitoring of the elevated uranium area. Two monitoring points (SWD-05 and SWD-09) were added to the surface water program to fulfill this monitoring commitment (Figure 22). These two locations are sampled weekly when water is present. Surface water volume was sufficient to collect 23 samples at SWD-05 and 31 samples at SWD-09. In 2022, concentrations measured were within the historical range for the area.

4.3 Surface Water and Effluent Monitoring Program

Surface water and effluent are sampled to determine the effect of the Fernald Preserve's activities on the environment. Surface water is sampled at several locations in the site's drainage areas and analyzed for various radiological and nonradiological constituents. Effluent is sampled before discharge into the Great Miami River.

The key elements of the surface water and effluent program design are:

- **Sampling:** Sample locations, frequency, and constituents were selected to address requirements of the NPDES permit, the FFCA, and the OU5 ROD and to provide a comprehensive assessment of surface water quality at key locations, including two background (i.e., offsite) locations (Figure 22). Surface water is monitored for six FRL constituents.
- **Data Evaluation:** The integrated data evaluation process focuses on tracking and evaluating data and comparing analytical results with background and historical ranges, FRLs, and NPDES permit limits. This information is used to assess impacts on surface water due to site remediation activities affecting uncontrolled runoff or effluent to the Great Miami River. The assessment also includes identifying the potential for impacts from surface water to groundwater in the Great Miami Aquifer. The ongoing data evaluation is designed to support remedial action decision making.

- **Reporting:** Surface water and effluent data are reported through the annual Site Environmental Report. Monthly discharge monitoring reports required by the NPDES permit are submitted to Ohio EPA.

Data from samples collected under the IEMP are used to fulfill surveillance and compliance monitoring functions. Surveillance monitoring results of the IEMP surface water and effluent program are used to assess the collective effectiveness of site remediation in preventing unacceptable impacts to the surface water and groundwater. Compliance monitoring includes sampling at stormwater and effluent discharge points and is conducted to comply with provisions in the NPDES permit, the FFCA, and the OU5 ROD. The data are routinely evaluated to identify any unacceptable trends and to trigger corrective actions, when needed to ensure protection of these critical environmental pathways. Figure 22 depicts IEMP and NPDES surface water and effluent sample locations for 2022.

4.3.1 Surveillance Monitoring

Effluent is discharged to the Great Miami River through the effluent line identified in Figure 22. Samples of the effluent are collected at the Parshall flume (PF 4001). The resulting data are used to calculate the concentration of each FRL constituent after the effluent mixes with the water in the Great Miami River.

Surveillance monitoring in 2022 was based on an evaluation of analytical results from samples collected during the year. This evaluation indicated that during 2022, there were no exceedances of total uranium in any of the effluent samples analyzed. Seven of the 31 surface water analytical results (23%) from sample location SWD-09 exceeded the surface water FRL for total uranium (530 µg/L) in 2022. The 2022 high result of 918 µg/L is lower than the highest result of 2,087 µg/L collected in 2016. There were no surface water total uranium FRL exceedances in 23 samples collected at SWD-05 in 2022. Analysis of all results from samples collected at SWD-05 and SWD-09 indicates a downward trend for both locations. Residual uranium in the soil appears to be the cause for the elevated uranium concentrations. The contamination appears localized to the area around SWD-09, and the uranium concentrations measured in water collected from locations SWD-05 and SWD-09 appear to be influenced by seasonal changes. Surface water monitoring locations SWD-05 and SWD-09 were established to monitor the area west of the former Waste Pits Area where elevated uranium concentrations have been detected. Based on the number of years of data collected at SWD-05 and SWD-09, DOE is proposing to reduce the weekly sampling frequency at these locations to semi-annual to align with the frequency of sampling as stated in the LMICP. Appendix B provides additional details.

The following two key sample locations represent points where surface water or effluent leaves the site:

- Paddys Run at the Willey Road property boundary (surface water sample location SWP-03)
- The Parshall Flume (sample location PF 4001) at the entry point of the effluent line leading to the Great Miami River

No total uranium results exceeded the surface water FRL of 530 µg/L during 2022 at these two locations. The total uranium concentration at SWP-03 in the sample collected March 7, 2022, was 2.0 µg/L, well below the surface water total uranium FRL of 530 µg/L. Figure 23 illustrates the decrease of the total uranium concentration in Paddys Run from 1985 through 2022. The large decrease in concentration in 1987 is attributable to the installation of the stormwater retention basin in 1986, which greatly reduced the volume of contaminated runoff flowing into Paddys Run from the Former Production Area.

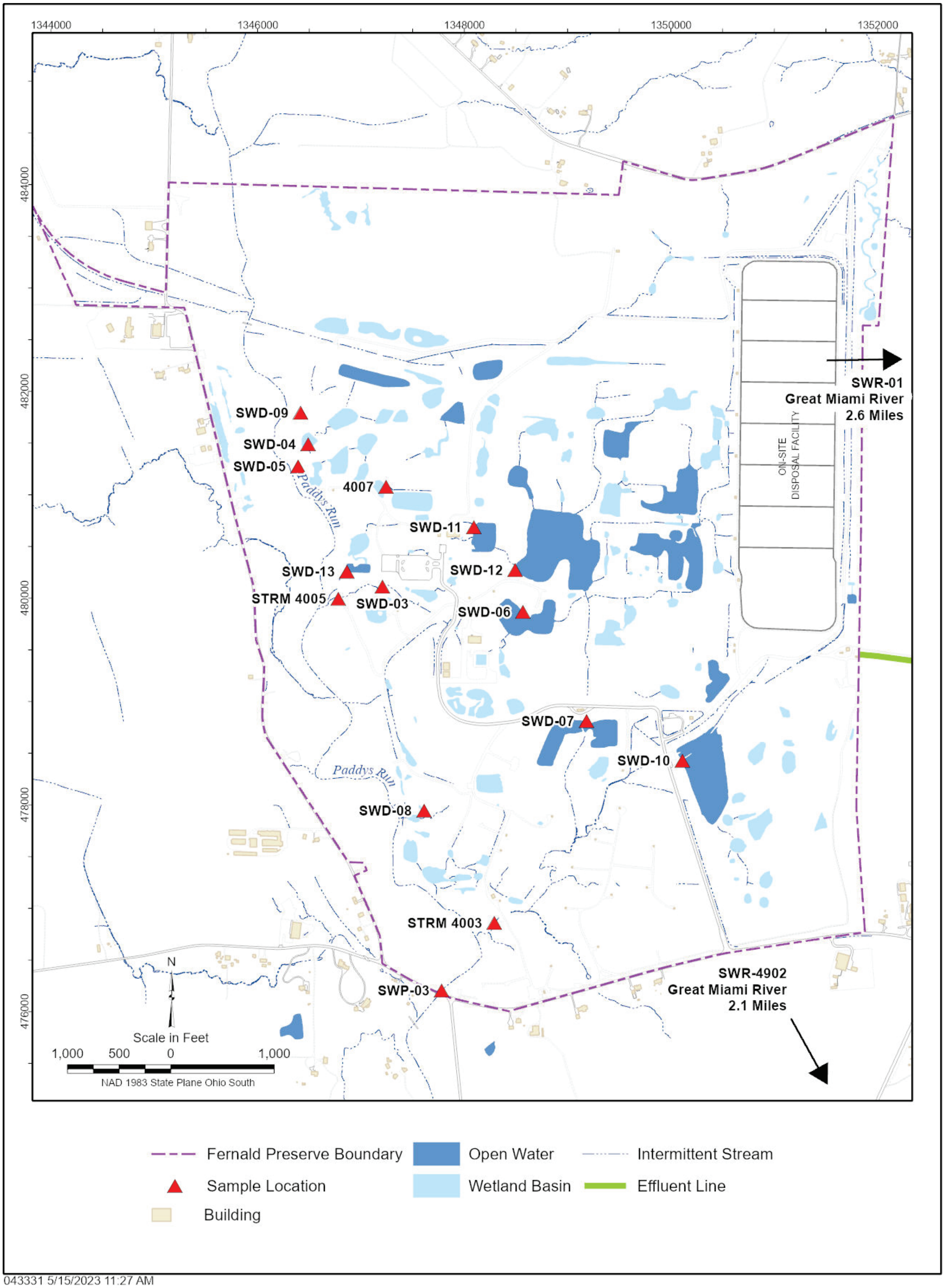

Figure 22. IEMP/NPDES Surface Water and Effluent Sample Locations

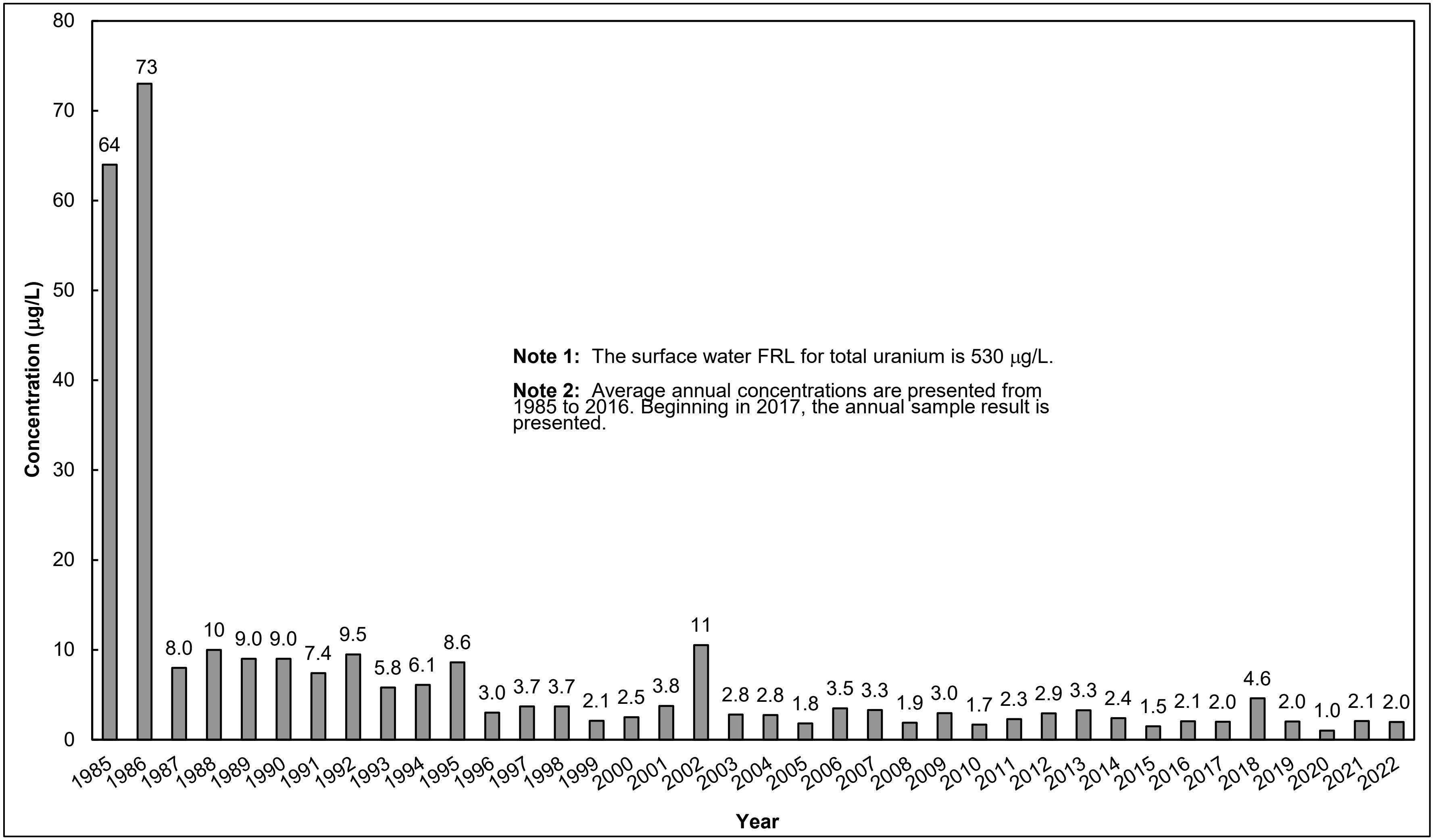

Figure 23. Annual Average Total Uranium Concentrations in Paddys Run at Willey Road (SWP-03 Sample Location)

Samples collected at PF 4001 are used in the surveillance evaluation because this is the last point where effluent is sampled before discharge to the Great Miami River. The maximum daily total uranium concentration at PF 4001 in 2022 was 24.4 µg/L on February 26, 2022. This result is below the drinking water standard (30 µg/L) and far below the surface water total uranium FRL of 530 µg/L. Data collected from this location cannot directly be compared to the surface water FRL without considering the effect of the effluent waters mixing with the Great Miami River. A mixing equation (discussed further in Appendix B) is used to account for the actual flow rate in the Great Miami River and the discharge flow rate at PF 4001 when the maximum uranium concentration was detected. The resulting concentration in the river after mixing was estimated to be 2.30 µg/L for February 26, 2022.

Surface water data are also evaluated to provide an ongoing assessment of the potential for cross-media impacts from surface water to the underlying Great Miami Aquifer. In areas where glacial overburden is absent, a direct pathway exists for contaminants to reach the aquifer. This contaminant pathway to the aquifer was considered in the design of the Fernald Preserve groundwater remedy. The groundwater remedy includes pumping from groundwater extraction wells downgradient of these areas where direct infiltration occurs. This pumping serves to capture and remove contaminated groundwater from the aquifer, mitigating any potential cross-media impacts. To provide this assessment, sample locations were selected to evaluate contaminant concentrations in surface water just upstream or within those areas where site drainages have eroded through the protective glacial overburden. The locations are SWD-03, SWD-04, SWD-05, SWD-07, SWD-08, and STRM 4005.

In 2022, sample results from surface water cross-media impact locations SWD-04 exceeded the total uranium groundwater FRL of 30 µg/L. Location SWD-04 is in the former Waste Storage Area. This location is within the capture zone of the aquifer remediation system. Appendix A, Attachment A.2, provides additional information concerning the impact of surface water infiltrating into the Great Miami Aquifer. Sampling at these locations will continue to provide an assessment of the cross-media impact. Appendix B presents additional details of the FRL exceedances.

In 2015, DOE conducted an assessment of the scope of the surface water quality monitoring program. The assessment concluded that the scope of the program could be reduced. With approval from EPA, Ohio EPA, and local stakeholders, DOE implemented these reductions in 2017. The current surface water program is presented in the IEMP (Attachment D of the LMICP [DOE 2019]). A similar assessment of the surface water quality monitoring program occurred in 2021 and based on this assessment, which was presented in Appendix B of the 2021 Site Environmental Report (DOE 2022b), additional monitoring reductions were warranted. With approval of the 2023 LMICP (DOE 2023), these reductions were incorporated into the surface water program beginning in calendar year 2023.

As stated in Section earlier in this section, based on the number of years of data collected at SWD-05 and SWD-09, DOE is proposing to reduce the frequency of sampling at these locations from weekly to semi-annual to align with the sampling of the remaining surface water locations. With approval from the regulators and stakeholders, this change will be implemented in 2024.

4.3.2 Compliance Monitoring

4.3.2.1 FFCA and OU5 ROD Compliance

The Fernald Preserve is required to monitor effluent discharges at the Parshall Flume (sample location PF 4001) for total uranium mass discharges and total uranium concentrations. This requirement is identified in the July 1986 FFCA and the OU5 ROD (DOE 1996b). The OU5 ROD requires treatment of effluent so that the mass of total uranium discharged to the Great Miami River through PF 4001 does not exceed 600 lb per year. The OU5 ROD and the subsequent *Explanation of Significant Differences for Operable Unit 5* (DOE 2001b) also require that the monthly average total uranium concentration in the effluent not exceed 30 µg/L, the EPA-established drinking water standard.

Figure 24 shows that the cumulative mass of total uranium discharged to the Great Miami River through the Parshall Flume (PF 4001) during 2022 was 335 lb, which is below the annual discharge limit of 600 lb. Figure 25 shows that the monthly average total uranium concentration in water discharged through the Parshall Flume (PF 4001) was below the 30 µg/L discharge limit every month during 2022.

4.3.2.2 NPDES Permit Compliance

Compliance sampling, consisting of sampling for nonradiological pollutants from uncontrolled runoff in the SSOD and effluent discharges from the Fernald Preserve, is regulated under the state-administrated NPDES program. Until June 1, 2022, the site operated under an NPDES permit which took effect on March 1, 2015. A new permit was approved in early 2022 and took effect on June 2, 2022, and will expire on May 31, 2027. There were no instances of noncompliance at any of the permitted outfalls in 2022.

4.3.3 Uranium Discharges in Surface Water and Effluent

As identified in Figure 24, 335 lb of uranium in effluent were discharged to the Great Miami River through the Parshall Flume (PF 4001) in 2022. In addition to the effluent, uncontrolled runoff is also contributing to the amount of uranium entering surface water. Figure 26 presents the mass of uranium from the uncontrolled runoff and controlled discharges from 1993 through 2022.

A loading term is used to estimate the pounds of uranium discharged to Paddys Run via uncontrolled runoff. With the approval of the 2017 Site Environmental Report (DOE 2018a) by EPA and Ohio EPA, the loading term was revised. The revision of the loading term was based on total uranium data from surface water sampling locations, which reflects the decreasing total uranium concentrations measured at points discharging to Paddys Run as a result of significant historical improvements in the capture of contaminated stormwater and remediation of site soil. The current loading term is 0.8 lb of uranium per inch of precipitation. During 2022, 40.5 inches of precipitation fell at the Fernald Preserve; therefore, an estimated 32.4 lb of uranium entered the environment through uncontrolled runoff. The estimated total amount of uranium discharged to the surface water pathway for the year, including controlled effluent discharges and uncontrolled runoff, was approximately 367.4 lb.

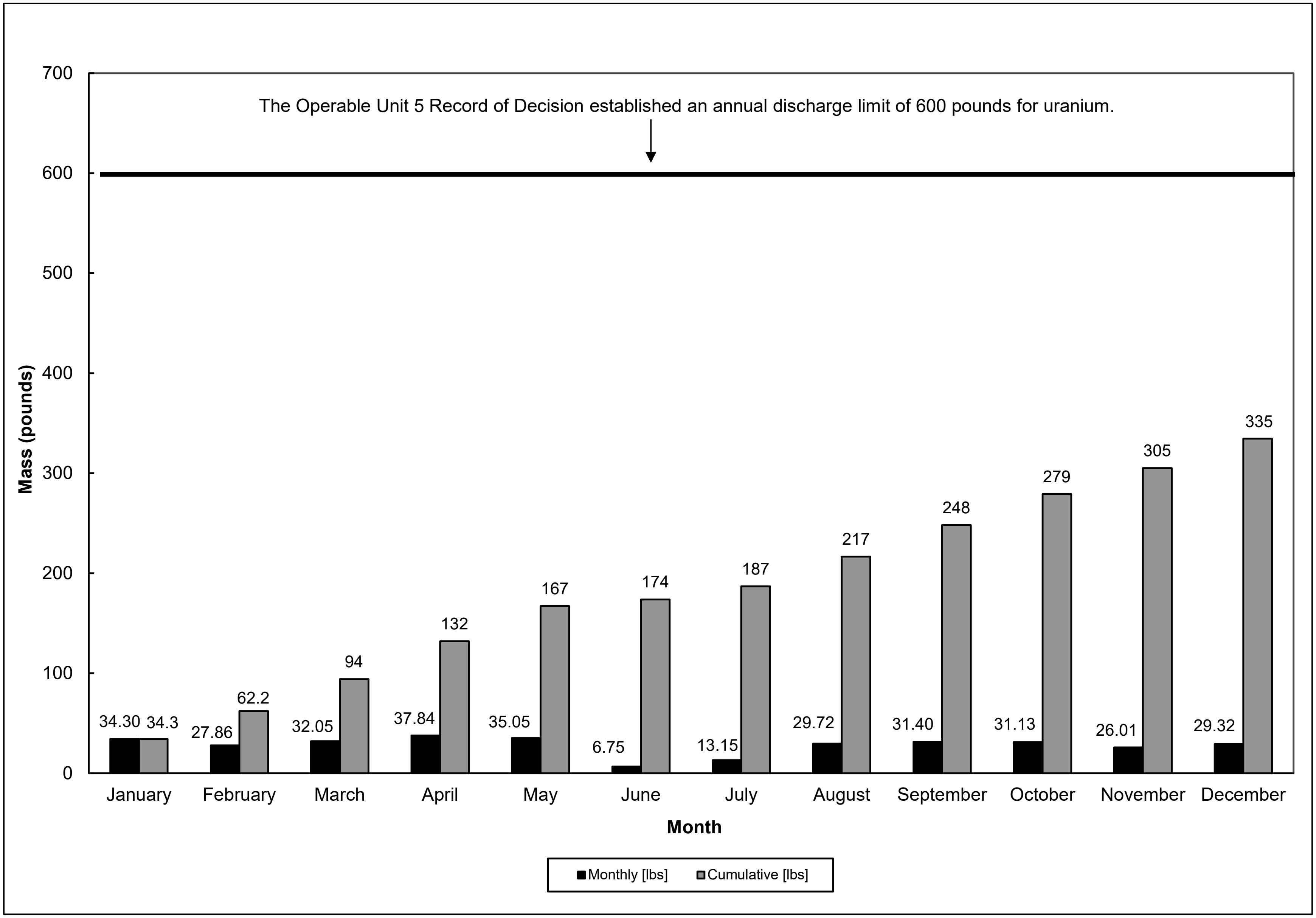

Figure 24. Mass of Uranium Discharged to the Great Miami River Through the Parshall Flume (PF 4001) in 2022

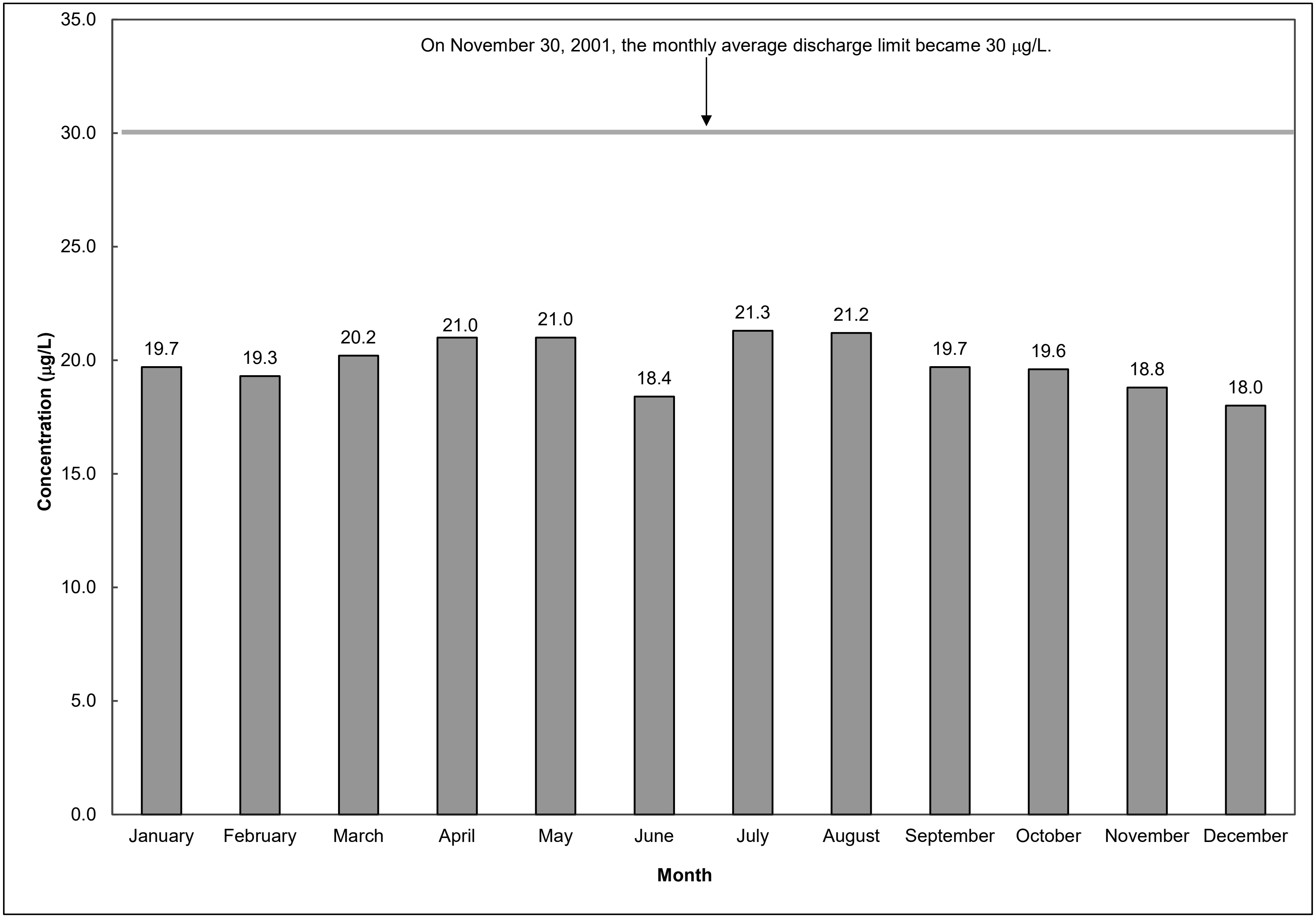

Figure 25. 2022 Monthly Average Total Uranium Concentration in Water Discharged Through the Parshall Flume (PF 4001) to the Great Miami River

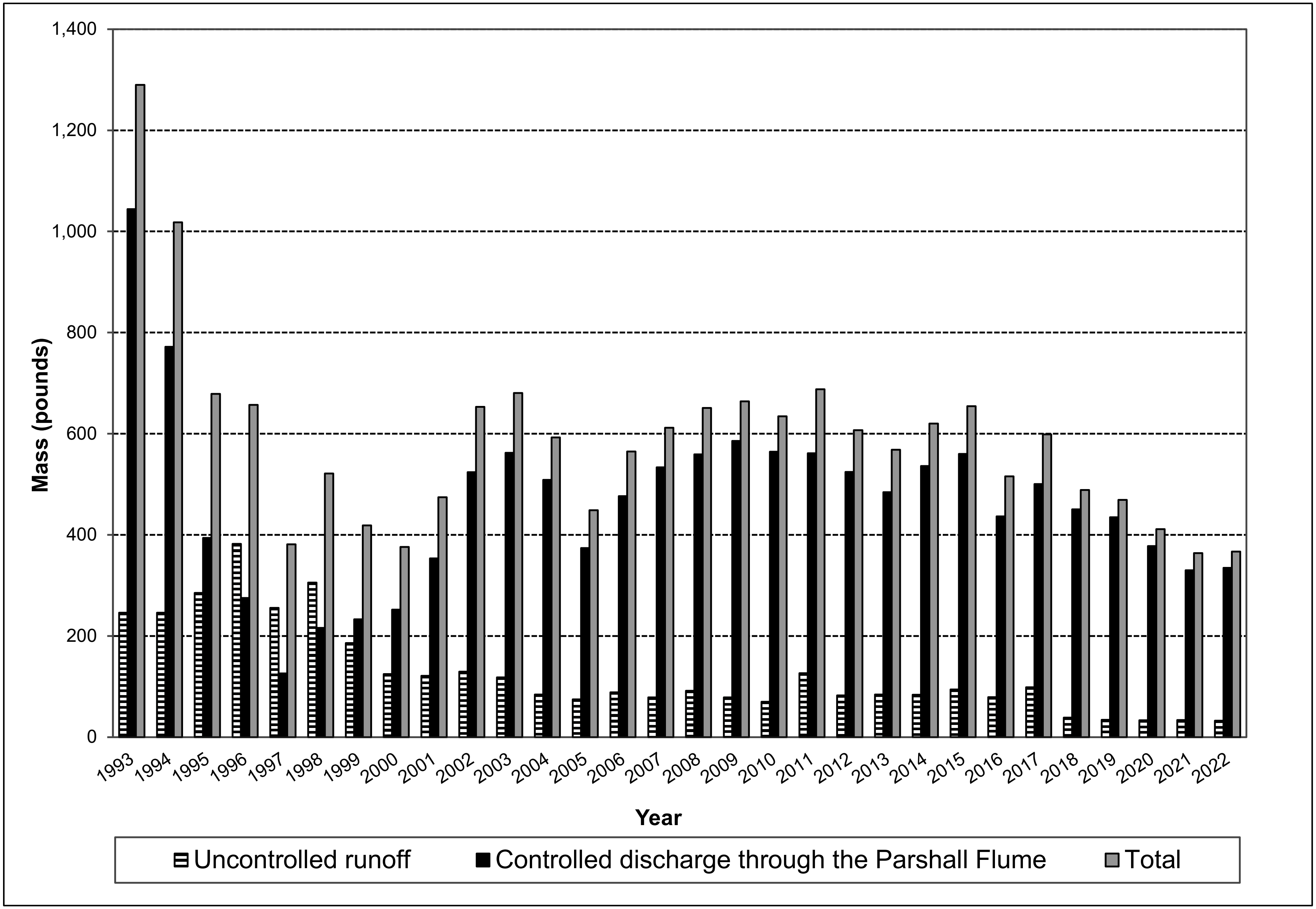

Figure 26. Uranium Discharged via the Surface Water Pathway, 1993−2022

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5.0 Natural Resources

Results in Brief: Ecological Monitoring Activities

In 2022, prairie functional monitoring was conducted using the floristic inventory method implemented in 2021. Restored community-type functional monitoring will continue on a 3-year rotation with the next prairie monitoring event to occur in 2025.

Prescribed burns were completed in two areas in the Former Production Area late in 2022. The post-burn walkdown for the prescribed burn areas was completed in early 2023.

Functional Monitoring

- A floristic inventory of remediation prairie communities across the site indicated results were consistent with previous findings. Remediation prairies are stable and are likely plateauing in their development. Monitoring results indicate that remediation successional communities are in the early stages of transitioning to forest communities.

Implementation Monitoring

- There was no ecological restoration project implementation monitoring in 2022.

Site and OSDF Inspections

- Findings were primarily invasive herbaceous plants and woody vegetation in the restored areas and on the OSDF, as well as the need for repair of deer exclosure fencing. Debris continues to be found, mostly in the Former Production Area and the former Waste Storage Area. During the December 2022 inspection, it was discovered that the Main Drainage Corridor culvert was in need of repair. Concrete had degraded, which caused the grate preventing access to the culvert to become dislodged. Plans are being developed to repair the grating in 2023.
- No major issues were observed with respect to institutional controls or the integrity of the OSDF cap.

This section provides background information on the natural resources associated with the Fernald Preserve and summarizes the activities in 2022 relating to these resources. Included in this section is a discussion of the following:

- Ecological restoration activities
- Site and OSDF inspections
- Affected habitat areas
- Threatened and endangered species
- Cultural resources

Much of the 1,050 acres of the Fernald Preserve property is undeveloped land that provides habitat for a variety of animals and plants. Wetlands, deciduous and riparian (streamside) woodlands, old fields, grasslands, and aquatic habitats are among the site's natural resources. Over 900 acres of the site have undergone ecological restoration. Figure 27 shows the restoration project areas that have been completed. Some of these areas provide habitat for state and federally endangered species. These endangered species are identified in Section 5.4. Cultural resources, such as prehistoric archaeological sites, have also been surveyed. The Fernald Preserve's mission of long-term stewardship under LM includes establishing, managing, and monitoring ecologically restored areas across the site.

Monitoring of these natural and cultural resources is addressed in the "Natural Resource Monitoring Plan," which is included as Appendix A of Attachment D of the LMICP (DOE 2019). The Natural Resource Monitoring Plan presents an approach for monitoring and reporting the status of several priority natural resources to remain in compliance with pertinent regulations and agreements. The approach for the monitoring and maintenance of ecologically restored areas is also addressed. Restoration monitoring has been ongoing following an expanded approach in 2009, when DOE and Ohio EPA signed a Consent Decree in November 2008 that settled a long-standing natural resource damage claim under Section 107 of CERCLA. As part of the settlement, the Fernald Natural Resource Trustees (DOE, Ohio EPA, and the U.S. Department of the Interior) finalized the Natural Resource Restoration Plan (NRRP), which is Appendix B of the *Consent Decree Resolving Ohio's Natural Resource Damage Claim against DOE* (State of Ohio 2008). The NRRP specifies an ecological monitoring program for restored areas at the site. This includes an enhanced wetland mitigation monitoring program and a functional monitoring program that evaluates restored communities. An implementation monitoring program is also in place and is used to determine whether revegetation efforts are successful following construction activities.

The NRRP also specifies creation of a Restored Area Maintenance Plan (RAMP). This document detailed the approach that was used for managing ecologically restored areas across the site through 2020. The RAMP included provisions for planting and seeding, control of invasive species, management of wetland water levels, erosion control, nuisance animal control, and maintenance of public amenities (DOE 2012b). Field personnel used this plan as a basis for management of restored areas described in the annual Site Environmental Report.

The NRRP required that the RAMP be reviewed after 10 years of implementation. DOE, along with the other Natural Resource Trustees, conducted this review in 2020, which resulted in the development of the Natural Resource Management Plan (NRMP). The NRMP outlines the management and evaluation approach for ecologically restored areas, including revised ecological monitoring methods. A 10-year review of ecological monitoring results showed that restored communities have for the most part been successfully established across the site. The revised approach to functional monitoring outlined in the NRMP shifts the focus from management area evaluations to restored community evaluations. These results will be used to help manage restored areas in future years. Figure 28 shows the breakdown of the communities to be evaluated. Select remediation prairie and remediation successional communities were monitored in 2022 using the revised functional monitoring approach. The NRMP was incorporated as Appendix A of Volume I of the 2023 LMICP (DOE 2023). Additional details are provided in Section 5.1.2 and Appendix C.

5.1 Ecological Restoration Activities

Maintenance in ecologically restored areas included mowing; repairing deer exclosure fence; mitigating potential impacts to high quality wetlands caused by beaver activities; and controlling invasive herbaceous plants, shrubs, and trees. Prescribed burning is a prairie management tool used on the site. In 2022, DOE and the U.S. Forest Service entered into an inter-agency agreement to conduct prescribed burns at the site. On December 2, 2022, the U.S. Forest Service conducted two prescribed burns, burning approximately 20 acres of prairie in the Former Production Area. The post-burn walkdown of this area was completed in early 2023. Figure 29 shows the location of 2022 restoration maintenance activities, which are discussed in the following sections.

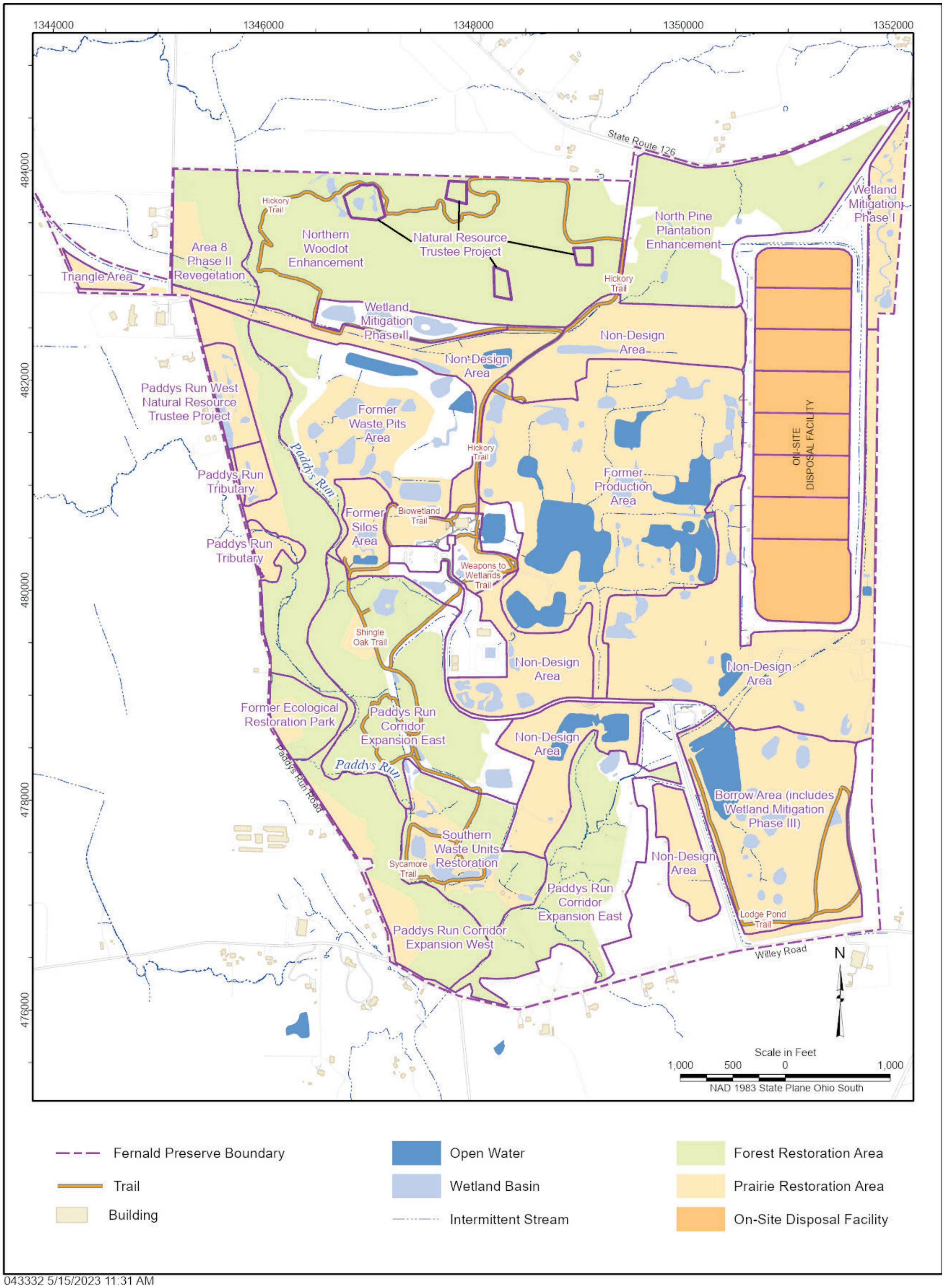

Figure 27. Restoration Project Areas

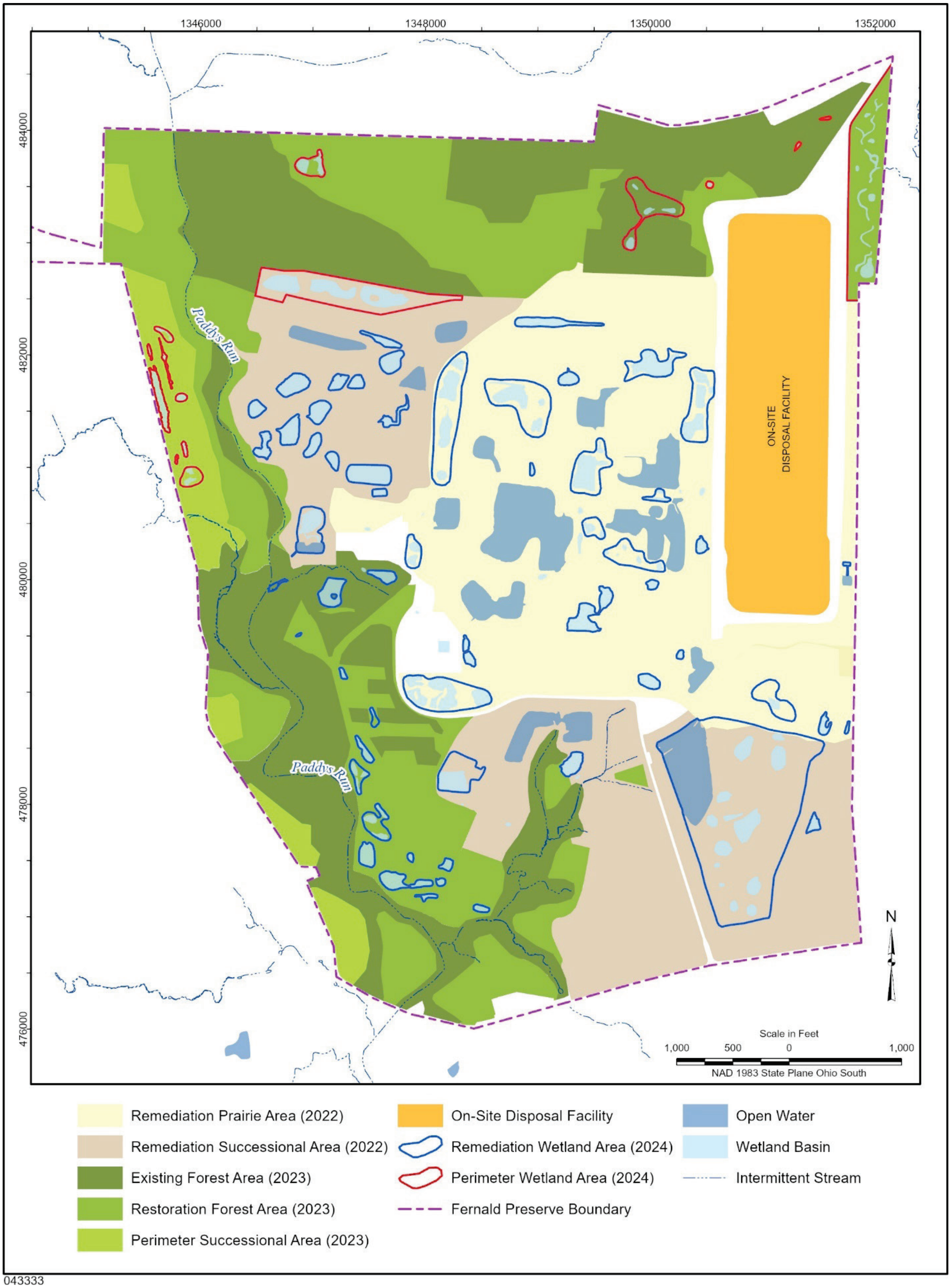

Figure 28. Ecological Community Types

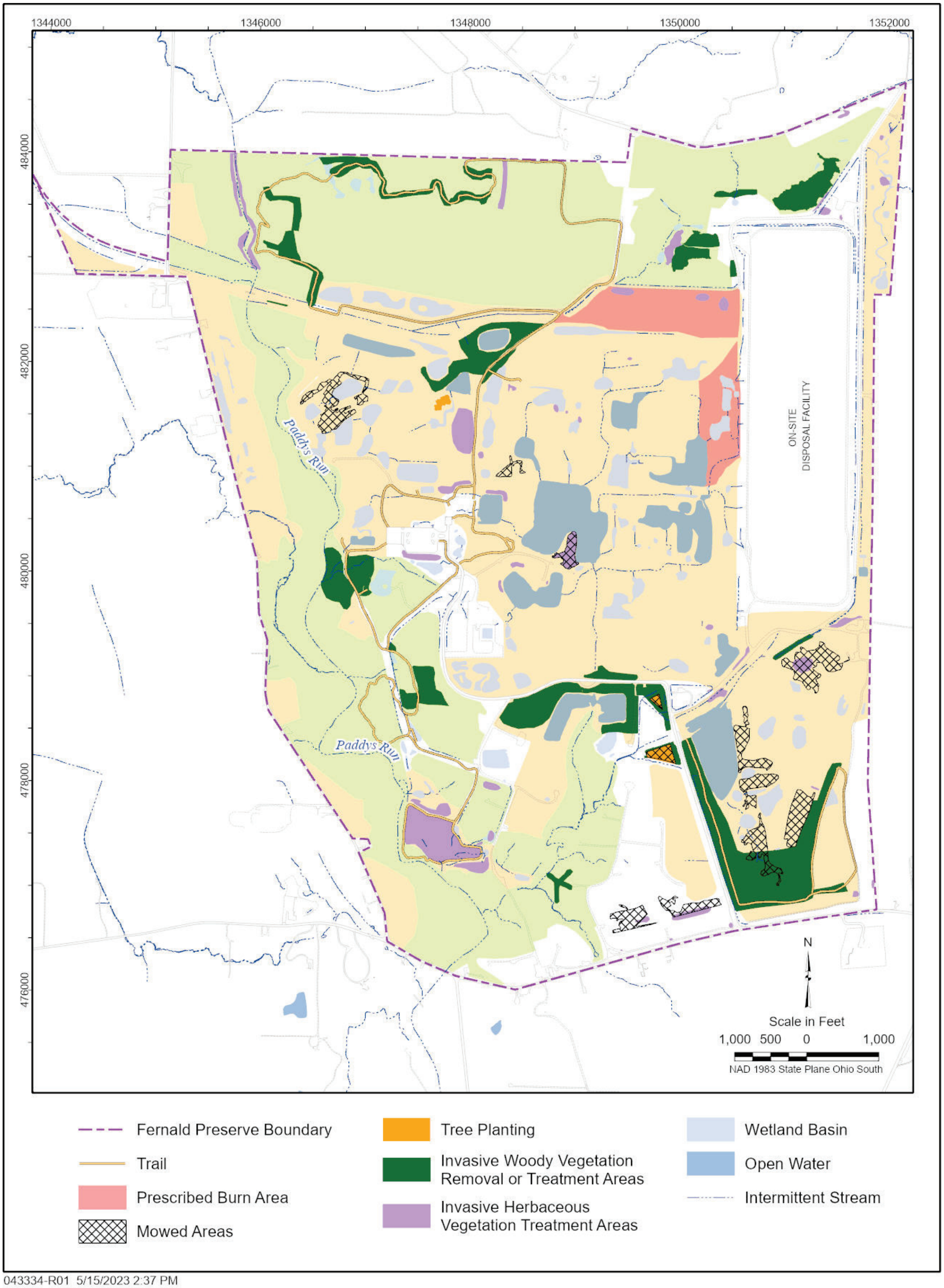

Figure 29. Ecological Restoration Maintenance Activities 2022

5.1.1 Restored Area and OSDF Maintenance and Repair

The primary focus of 2022 restored area maintenance activities (Figure 29) was vegetation management and enhancement, some of which addressed inspection findings identified throughout the year. Appendix C includes summary tables and maps that show the location of specific inspection findings. The goals of restored area maintenance are to combat the invasive species, improve the vegetation quality, and increase species diversity.

Invasive herbaceous species are addressed using a variety of methods including herbicide application, mowing, burning, manual removal, or a combination of these methods. For example, in 2022, several areas with heavy teasel infestations were mowed in late winter then treated with herbicide in the spring. Spot spraying with herbicide to control noxious and invasive herbaceous weeds in restored areas and on the OSDF cap continued in spring 2022. Target herbaceous species are listed on Table 9 and shown on Figure 29. Approximately 272 acres were treated for invasive herbaceous species.

Table 9. Invasive Herbaceous Species Treated in 2022

Common Name	Scientific Name
Teasel species	*Dipsacus sp.*
Canada thistle	*Cirsium arvense*
Chinese bush clover	*Lespedez cuneata*
Giant reed	*Phragmites australis*
Lesser celandine	*Ficaria verna*
Mugwort	*Artemisia vulgaris*
Purple loosestrife	*Lythrum salicaria*
Reed canary grass	*Phalaris arundinacea*

Invasive woody vegetation is physically removed or treated with herbicide across the site and on the OSDF cap and perimeter drainages. Trees and shrubs must not become established on the OSDF cap, so they are removed or treated with herbicide once discovered.

Fall foliar herbicide application to control amur honeysuckle (*Lonicera maackii*) continued in 2022. Dense infestations of honeysuckle will crowd out native species, prevent sunlight from reaching the ground, and prevent seedling development of desirable vegetation. A characteristic of honeysuckle is that it does not go dormant until a few weeks after most other vegetation. Timing herbicide application after nearby plants have gone dormant in the fall allows the use of herbicide to treat honeysuckle while avoiding harm to surrounding vegetation. This technique is widely used and has proven to be an effective means of control. In addition to foliar herbicide application, cutting woody vegetation and painting the cut stumps with herbicide was a technique used to aid in the control of several different invasive woody vegetation species, and is a method that can be used throughout the year. Mechanical removal using equipment to remove the woody vegetation from the ground was also employed in 2022. Approximately 51 acres of invasive woody vegetation was managed using this combination of methods across the site (Table 10).

Table 10. Invasive Woody Vegetation Species Treated in 2022

Common Name	**Scientific Name**
Amur honeysuckle	*Lonicera maackii*
Autumn olive	*Elaeagnus umbellata*
Buckthorn	*Rhamnus cathartica*
Callery pear	*Pyrus calleryana*
Japanese honeysuckle	*Lonicera japonica*
Multiflora rose	*Rosa multiflora*
Tree of heaven	*Ailanthus altissima*

In addition to treatment and removal of invasive vegetation, approximately 120 trees and shrubs were planted in three areas of the site to help increase species diversity, enhance successional development of restored areas, and decrease forest fragmentation

There is a resident population of Canada geese at the Fernald Preserve. Canada geese are considered nuisance animals primarily because of their potential for aggression to humans. However, due to establishment of vegetation and an increase in natural predators, there has not been a population growth, and goose hazing (i.e., scaring and harassing) has not been needed since 2014. Site personnel continue to monitor the Canada goose population each year. The site applies for an ODNR permit to remove nests or addle eggs annually, if necessary.

The mute swan is non-native, invasive, and considered a nuisance species by ODNR; therefore, ODNR grants permission to addle the eggs of the mute swans. No formal permit is required. Reduced site staffing in response to the coronavirus pandemic prevented Fernald Preserve staff from monitoring nesting activities and addling eggs in 2020, which resulted in an increase in the number of mute swans on site. In spring 2021, DOE authorized ODNR to conduct mute swan management activities in support of the ODNR statewide mute swan management program. No mute swan management activities occurred in 2022. Mute swan egg addling by site staff will be employed in 2023, if eggs are present. DOE maintains the agreement with ODNR to allow mute swan management activities on site.

5.1.2 Ecological Restoration Monitoring

> **Ecological Monitoring Parameters**
> There are a number of ways to evaluate the type and quality of habitats within an area. At the Fernald Preserve, ecological monitoring focuses on determining the extent of native plant species composition and calculating a Floristic Quality Assessment Index (FQAI). The FQAI process is described in the *Floristic Quality Assessment Index (FQAI) for Vascular Plants and Mosses for the State of Ohio* (Andreas et al. 2004). The specific parameters used at the Fernald Preserve include the following:
>
> - **Total Species**: The total number of species sampled within a given area.
> - **Native Species**: The total number of species native to Ohio. The updated *Ohio Vascular Plant Database* is used to determine whether a species is native (Gara 2013).
> - **Percent Native Species**: The number of native species divided by the total number of species. Relative frequency of native species is also used. This is calculated by dividing the frequency (or number of times a species is observed) by the total number of observations for a given area.
> - **Average Coefficient of Conservatism (CC)**: The CC is a number between 0 and 10 that has been assigned to virtually every species that may be found in Ohio. The CC value is related to how "tolerant" a species is, as well as its habitat requirements. Nonnative plants have a CC of 0. Common species that can grow in a wide variety of habitats are considered "tolerant" and are scored a CC between 0 and 3. Native plants with very specific habitat requirements are scored high CC values, in the 7–10 range. The updated *Ohio Vascular Plant Database* (Gara 2013) lists the CC for each plant found in Ohio.
> - **Floristic Quality Assessment Index (FQAI)**: The CC values described above are used to calculate the FQAI. The FQAI is the average CC value divided by the square root of the total number of species for a given area.

Before 2021, a two-tier ecological monitoring program was used to assess restoration efforts. Implementation monitoring was used to assess vegetation establishment following seeding and planting projects. Functional monitoring was used to assess the progress of the development of a restored community (prairie, wetland, forest) by comparing floristic quality parameters to those of baseline and reference sites. Reference sites are offsite communities that represent an ideal end-state for site restoration projects. The NRRP states the goals for vegetation establishment were 50% native species and 90% total cover. For woody vegetation, the goal was 80% survival (State of Ohio 2008).

As stated in Section 5.0, the Fernald Preserve Natural Resource Trustees reviewed the ecological monitoring program as part of the 2020 RAMP update. A revised approach to functional monitoring methods and area focus was proposed and subsequently implemented in 2021. This revised method consists of conducting florist inventories and will focus on a specific restored community type each year. Perimeter area and remediation wetland areas were monitored in 2021. Prairie areas and remediation successional areas were monitored in 2022 and existing forest areas, restoration forest areas and perimeter successional areas will be monitored in 2023 (Figure 28).

5.1.2.1 Functional Monitoring

Functional monitoring activities previously conducted compared restored communities to prerestoration "baseline" conditions and high-quality reference sites. Baseline and reference sites were characterized in 2001 and 2002. From 2003 to 2005, restored areas were evaluated. Wetlands were evaluated in 2003, prairie communities in 2004, and forest habitats in 2005. The same 3-year rotation resumed in 2009 and continued through 2014. In 2015, monitoring efforts shifted from sitewide community types to an area-based approach on a 3-year basis. The area-based approach continued through 2020, completing two full cycles of monitoring. In 2021, functional monitoring took place in wetland communities, implementing the new floristic inventory method. In 2022, the floristic inventory method was used to monitor remediation prairie areas and remediation successional areas (Figure 28). For each floristic inventory, the entire monitoring area was examined, and each species observed was recorded. Native and non-native species richness and composition, area mean coefficient of conservatism (CC), and floristic quality assessment index (FQAI) were calculated from the data to assess the condition of the monitoring areas. The latest Ohio FQAI database (Gara 2013) is used to determine nativity status and CC values. Appendix C provides a more detailed discussion regarding ecological monitoring results.

The 2022 functional monitoring results indicate that native vegetation is fully established across all the restored areas monitored. Percent nativity, mean CC and FQAI values are higher in the remediation successional areas than the remediation prairie areas. A historical comparison of these values show results for both remediation prairie areas and remediation successional areas are consistent with previous findings. The remediation prairie areas are stable and have likely plateaued in development, and the remediation successional areas are in the early stages of transitioning to forested areas. Continued vegetation monitoring and management will be required to ensure this successional process continues.

5.2 Fernald Preserve Site, OSDF, and Trail Inspections

The LMICP describes the routine inspection process for both the site and the OSDF. Inspections are conducted quarterly with joint participation from the regulators. Inspections document evidence of unauthorized uses of the site, the effectiveness of institutional controls, and any need for repairs. Inspections are conducted in several phases. Quarterly inspections focus on signs, fencing, gates, site access points, etc. Field walkdowns take place in the winter months when vegetation is dormant, optimizing visibility of site conditions and allowing for easier access to some areas. Ecologically restored areas are evaluated for the presence of noxious weeds, erosion, condition of vegetation, presence of potentially contaminated debris, and signs of damage from nuisance animals. Quarterly inspection reports are posted on the LM public website at https://www.energy.gov/lm/fernald-preserve-ohio-site. The quarterly inspection reports can also be viewed online at the Fernald Preserve Visitors Center or by contacting the site at (513) 648-3330. Appendix C presents inspection findings from all 2022 quarterly site and OSDF inspections. In addition to quarterly inspections, the public trails and overlooks are inspected weekly to ensure that they are safe and usable. Ohio EPA and other regulators are invited to participate in OSDF and site inspections.

5.2.1 Site Inspections

As with recent years, site inspection findings in 2022 consisted mostly of the presence of noxious and invasive weeds and deer exclosure fencing that was damaged by fallen trees and limbs or is deteriorating due to age and weather exposure. Beginning in 2022, inspection findings are detailed in quarterly inspection reports only if the finding is associated with activity and use limitations for the site. As a result, only one inspection finding was reported in the 2022 quarterly inspection reports. The finding was identified during the December 2022 point-specific institutional control inspection and is associated with the Main Drainage Corridor culvert access control grating. The culvert, along with an adjacent 18-inch culvert that is completely buried, was left in place and has fixed radiological contamination. These culverts are located directly below the OSDF leachate conveyance system and the main effluent line running between the CAWWT and the Great Miami River. Because of their location, these culverts could not have been removed without potentially impacting ongoing CAWWT and OSDF operations. Instead, metal grating was installed to prevent access to the 60-inch culvert. Site inspections ensure that the 60-inch culvert grating is in place and is serviceable, and that the 18-inch culvert is not exposed through erosion or other ground disturbance. The last quarterly inspection of 2022 identified that the grate had experienced natural degradation of the concrete which caused the rebar grate to become dislodged. Plans are being developed to repair the grating in 2023. Additional information is provided in Appendix C.

Debris continues to be found, primarily in the Former Production Area and former Waste Storage Area; however, debris finding numbers were lower in 2022 than in previous years. During remediation of the Fernald Preserve, every effort was made to remove and dispose of all debris. However, weather, erosion, and earth-moving activities occasionally reveal small pieces of debris that were not visible during remediation and restoration efforts. Examples of debris include pieces of concrete, rebar, clay tile, asphalt, and metal. Debris is discovered during site inspections and construction activities and by personnel during field activities. In 2022, 128 pieces of debris were discovered. Radiological surveys were conducted of all debris and no debris was observed to have fixed radiological contamination above background levels. All debris was removed from the field and properly disposed. More information regarding debris and other inspection findings is provided in Appendix C.

5.2.2 OSDF Inspections

For inspections of the OSDF, inspectors perform a quarterly walkdown of the perimeter and toe, and an annual walkdown and evaluation of the vegetated cap to verify its integrity. Trees, shrubs, erosion rills, holes from burrowing animals, noxious weeds, settlement cracks, and other indications that there may be an issue with the proper functioning of the cap are flagged and repaired. In 2022, there were no signs that the integrity of the cap had been compromised in any way. Findings consisted mainly of woody vegetation and noxious weeds.

5.2.3 Trail Inspections

Weekly trail inspections continued in 2022 to ensure trails were safe for use. There were no significant findings.

5.3 Affected Habitat Findings

The potential for unanticipated habitat impacts is low, but they can occur during construction or site maintenance activities. The restoration projects described in Section 5.1.1 resulted in minimal impacts. The potential for habitat impacts is considered before site maintenance and construction activities.

Beavers continued to be very active at the site in 2022, resulting in changes to water elevations and vegetation in several wetlands and ponds. An increase in the site beaver population has been observed for the last several years. Beavers are native, and their presence is evidence of continued development of restored plant communities. However, they may alter the landscape by impeding drainages, raising water levels in wetlands, flooding upland areas, and clearing trees. These naturally occurring changes are expected to continue in the future.

5.4 Threatened and Endangered Species and Species Inventories

The Endangered Species Act requires the protection of any federally threatened or endangered species and any habitat critical for the species' existence. Several Ohio laws mandate the protection of state endangered species as well. Since 1993, a number of surveys have been conducted to determine the presence of any threatened or endangered species at the site. As a result of these surveys, the federally endangered Indiana bat and the formerly state threatened Sloan's crayfish (*Orconectes sloanii)* are the only threatened or endangered species observed on the property. As of 2022, Sloan's crayfish was removed from Ohio's threatened or endangered species lists. Suitable habitat exists for the federally endangered Indiana bat, federally threatened northern long-eared bat, the state-threatened spring coral root, and the state-endangered cave salamander. With the exception of an Indiana bat and Sloan's crayfish, none of these species have been found on the site, but their habitat ranges encompass the Fernald Preserve. Figure 30 shows the potential habitats for these species. According to the LMICP (DOE 2019), Section 6.0, "Natural Resource Monitoring Plan," threatened or endangered species habitat will be surveyed as needed before any construction activities. If threatened or endangered species are identified, appropriate avoidance or mitigation efforts will be taken.

Potential Threatened and Endangered Species at the Fernald Preserve

Indiana Bat: The federally endangered Indiana bat (*Myotis sodalis*) forms colonies in hollow trees and under loose tree bark along riparian (streamside) areas during the summer. Excellent habitat for the Indiana bat has been identified at the Fernald Preserve along the wooded banks of the northern reaches of Paddys Run. The habitat provides an extensive mature canopy of older trees and water throughout the year. One Indiana bat was captured and released on the property in August 1999.

Northern Long-Eared Bat: The federally threatened northern long-eared bat (*Myotis septentrionalis*) will roost singly or in colonies in the summer using either live trees with loose bark or dead hollow trees (snags). The Fernald Preserve has been recognized as potential summer roosting habitat for the northern long-eared bat. Although no captures have been recorded at the preserve, a variety of live and dead trees and water sources in the preserve may provide ideal habitat within the known range of this species.

Spring Coral Root: The state-threatened spring coral root (*Corallorhiza wisteriana*) is a white and red orchid that blooms in April and May and grows in partially shaded areas of forested wetlands and wooded ravines. This plant has not been identified at the Fernald Preserve; however, suitable habitat exists in portions of the Northern Woodlot Enhancement area.

Cave Salamander: The state-endangered cave salamander (*Eurycea lucifuga*) is slender and its coloring is red to orange with irregular black dots. It is found in caves, springs, small limestone streams, outcrops, and old springhouses where groundwater is present. It has only been documented in Ohio in Hamilton, Butler, and Adams counties. Suitable habitat within the Fernald Preserve is limited, but populations have been observed just north of the

5.5 Cultural Resources

The Fernald Preserve and surrounding area are in a region of rich soil and many sources of water, such as the Great Miami River. Because of its advantageous location, the area was settled repeatedly throughout prehistoric and historical time, resulting in diverse cultural resources. At a minimum, 148 prehistoric and 40 historic sites have been identified within 1.2 miles of the Fernald Preserve.

Several laws have been established to protect cultural resources. The National Historic Preservation Act requires DOE to consider the effects of its actions on sites that are listed or eligible for listing on the National Register of Historic Places. The Native American Graves Protection and Repatriation Act (Title 43 *Code of Federal Regulations* Section 10 [43 CFR 10]) requires that prehistoric human remains, and associated artifacts, be identified and returned to the appropriate Native American tribe. Compliance with these laws is addressed through a Programmatic Agreement between DOE and the Ohio State Historic Preservation Office (DOE 2012d), which was updated in 2012.

To comply with these laws and the Programmatic Agreement, DOE conducted archaeological surveys before remediation activities in undeveloped areas of the Fernald Preserve. Figure 31 shows the areas of the Fernald Preserve that have been surveyed. These surveys have resulted in the identification of five sites that may be eligible for listing on the National Register of Historic Places. None of these sites were affected by construction activities in 2022.

No archaeological surveys were conducted in 2022, and no unexpected discoveries were encountered during field activities. All ground-disturbing activities took place in previously disturbed or surveyed areas.

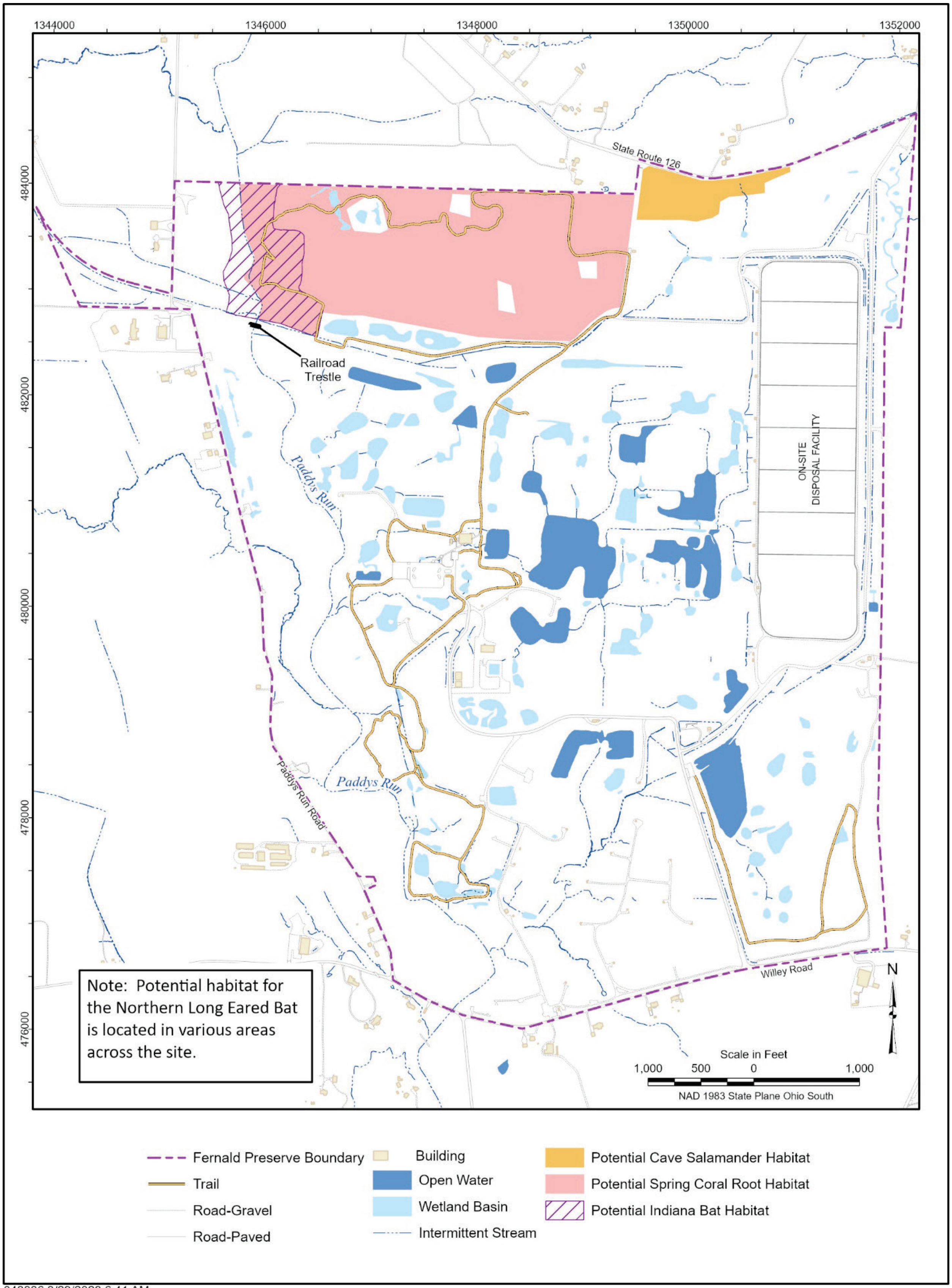

Figure 30. Threatened and Endangered Species Potential Habitat Areas

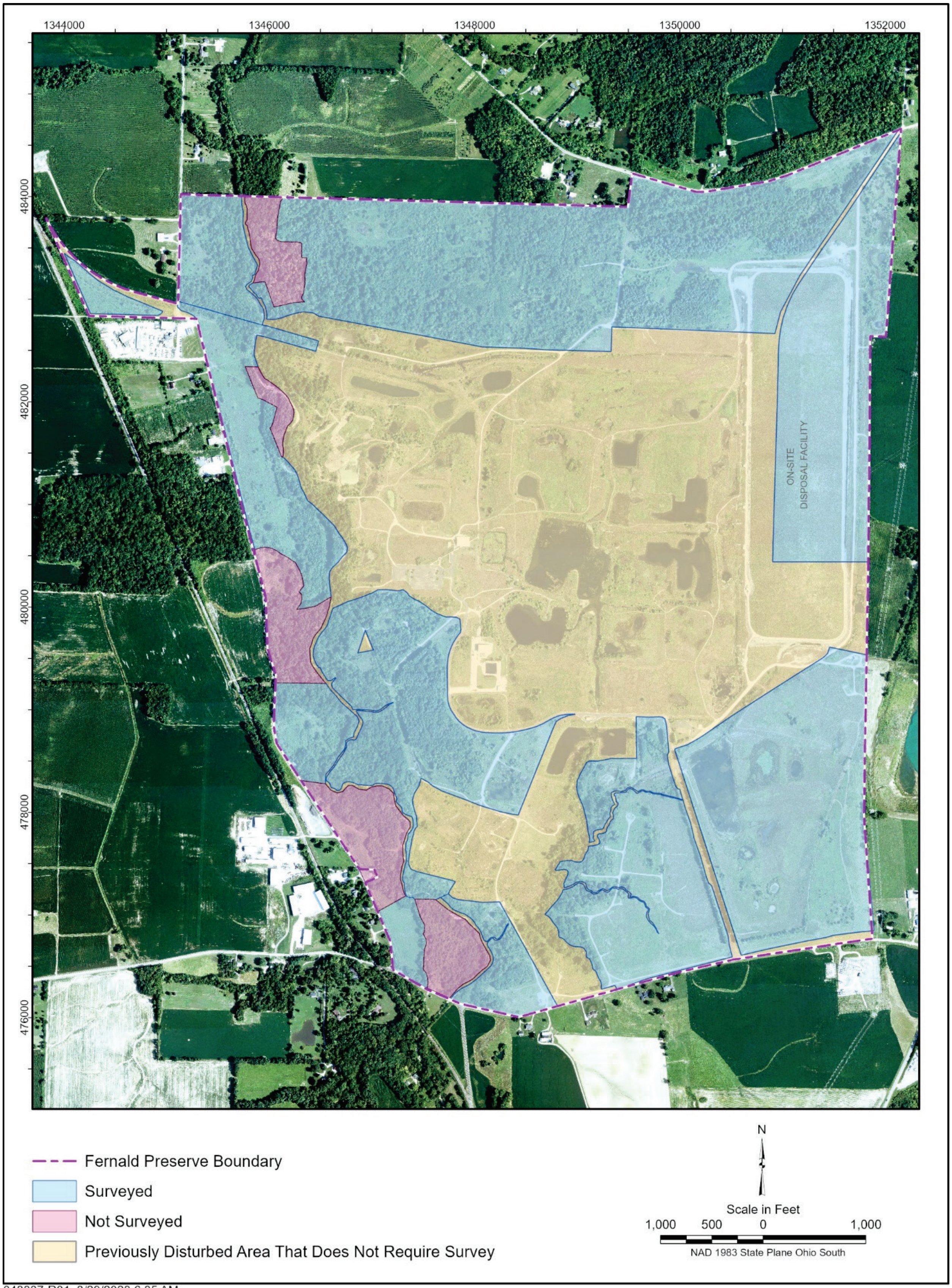

Figure 31. Cultural Resource Survey Areas

6.0 References

7 USC 136 et seq. "Federal Insecticide, Fungicide, and Rodenticide Act", as amended, *United States Code*.

15 USC 2601 et seq. "Toxic Substances Control Act," as amended,

33 USC 1251 et seq. "Clean Water Act" (Federal Water Pollution Control Act), as amended, *United States Code*.

42 USC 6901 et seq. "Resource Conservation and Recovery Act," as amended, *United States Code*.

42 USC 7401 et seq. "Clean Air Act," as amended, *United States Code*.

42 USC 9601 et seq. "Comprehensive Environmental Response, Compensation, and Liability Act of 1980," as amended, *United States Code*.

10 CFR 1021. "National Environmental Policy Act", *Code of Federal Regulations*.

43 CFR 10. "Native American Graves Protection and Repatriation Act," *Code of Federal Regulations.*

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7.0 Glossary

applicable or relevant and appropriate requirements (ARARs). Requirements set forth in regulations that implement environmental and public health laws that a selected remedy must attain unless a waiver is invoked. ARARs are divided into three categories: chemical-specific, location-specific, and action-specific, according to whether the requirement is triggered by the presence or emission of a chemical, by a vulnerable or protected location, or by a particular action.

Aquifer. A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.

capture zone. Estimated area that is being "captured" by the pumping of groundwater extraction wells. The definition of the capture zone is important in ensuring that the total uranium plumes targeted for cleanup are being remediated.

Certification. The process by which a soil remediation area is certified as clean. Samples from the area are collected and analyzed, and then the contaminant levels are compared to the FRLs established in the OU5 ROD. Not all soil remediation areas at the Fernald Preserve require excavation before certification is done.

Contaminant. A substance that when present in air, surface water, sediment, soil, or groundwater above naturally occurring (background) levels causes degradation of the media.

crossvane. A U-shaped structure of boulders built across a stream channel to reduce water velocity and energy along the streambank.

effluent. Water from numerous areas at the site that is routed through the site's wastewater treatment facility and discharged to the Great Miami River.

Floristic Quality Assessment Index (FQAI). A method of evaluating an ecosystem based on the type and quality of plants present.

glacial overburden/glacial till: Silt, sand, gravel, and clay deposited by glacial action on top of the Great Miami Aquifer and surrounding bedrock highs.

Great Miami Aquifer. Sand and gravel deposited by the meltwaters of Pleistocene glaciers within the entrenched ancestral Ohio and Miami rivers. This is also called a buried channel or a sand and gravel aquifer.

groundwater. Water in a saturated zone or stratum beneath the surface of land.

mixed waste. Hazardous waste (as defined by RCRA) that has been contaminated with low-level radioactive materials.

radionuclide. Refers to a radioactive nuclide. There are several hundred known radionuclides that can be artificially produced or naturally occurring. Radionuclides are characterized by the number of neutrons and protons in an atom's nucleus and their characteristic decay processes.

remedial action. The actual construction and implementation phase of a Superfund site cleanup that follows the remedy selection process and remedial design.

remedial investigation/feasibility study. The first major event in the remedial action process that serves to assess site conditions and evaluate alternatives to the extent necessary to select a remedy.

removal action. A short-term cleanup or removal of released hazardous substances from the environment. A removal action is performed in response to a release or the imminent threat of release of hazardous substances into the environment.

surface water. Water that is flowing within natural drainage features.

uncontrolled runoff. Storm water that is not collected by the site for treatment but enters the site's natural drainages.

waste acceptance criteria. A disposal facility's specifications for the types and sizes of materials, the acceptable levels of constituents, and other criteria for all material that can be disposed of in that facility. Offsite disposal facilities such as the Nevada National Security Site (formerly called the Nevada Test Site) that dispose of Fernald Preserve waste have specific waste acceptance criteria. In addition, the OSDF had waste acceptance criteria that were approved by the regulatory agencies.

Appendix A

Supplemental Groundwater Information

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Contents

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Appendix A presents groundwater data and analysis in support of Section 3.0, "Groundwater Pathway." This appendix consists of the following five attachments:

- Attachment A.1 provides operational data for the South Field Module, the South Plume Module, and the Waste Storage Area Module
- Attachment A.2 provides groundwater monitoring total uranium results, including summary statistics and plume maps
- Attachment A.3 provides groundwater elevation data and quarterly water-level maps
- Attachment A.4 provides an analysis of the non-uranium final remediation level exceedances both inside and outside the current Operational Design Remediation Footprint
- Attachment A.5 provides results for the On-Site Disposal Facility leak detection and leachate monitoring program

Groundwater analytical data are available through the U.S. Department of Energy Office of Legacy Management's Geospatial Environmental Mapping System (https://gems.lm.doe.gov/).

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Attachment A.1

Contents

Tables

Figures

Abbreviations

CAWWT	Converted Advanced Wastewater Treatment
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EVS	Earth Volumetric Studio
FRL	Final Remediation Level
GMA	Great Miami Aquifer
Ohio EPA	Ohio Environmental Protection Agency
PRRS	Paddys Run Road Site
WSA	Waste Storage Area

Measurement Abbreviations

95% UCL	95% upper confidence limit
amsl	above mean sea level
ft	feet
gpm	gallons per minute
K_d	partition (or distribution) coefficient
lb	pounds
Mgal	million gallons
Mg/L	milligrams per liter
µg/L	micrograms per liter

A.1.0 Operational Assessment

This attachment provides operational data for the South Field Module, the South Plume Module, and the Waste Storage Area (WSA) Module at the Fernald Preserve, Ohio, Site, including:

- Operational data for the 20 extraction wells pumping in 2022.
- Uranium concentration trends for each extraction well compared to model-predicted concentration trends.
- Uranium concentrations at selected monitoring wells compared to model-predicted concentrations.
- Pounds of uranium removed from the aquifer.
- Estimates of the pounds of uranium remaining to be removed from the aquifer to complete the pumping stage of the aquifer remedy.

From July 1, 2014, through June 2018, extraction wells were operated to achieve a design pumping rate of 5,075 gallons per minute (gpm). The design pumping rate is the pumping rate used in the groundwater model to estimate cleanup times for the aquifer remedy. Beginning in July 2018, the design pumping rate was reduced to 4,975 gpm because of a decreased pumping rate from 200 to 100 gpm in recovery well RW-4 (Section A.1.9). Groundwater modeling predicted that the design pumping rate reduction would have no effect on the estimated cleanup times for the aquifer remedy. Figure A.1-1 depicts the locations of the extraction and former reinjection wells and identifies surrounding monitoring wells. Table A.1-1 provides summaries of gallons of water pumped, total uranium removed, and uranium removal indexes for 2022 and for the duration of the remedy to date (August 1993 through December 2022).

Information in this attachment is organized into the following subsections:

- Operational System Overview (Section A.1.1)
- Wellfield Shutdowns in 2022 (Section A.1.2)
- South Field Module (Section A.1.3)
- South Plume Module (Section A.1.4)
- Waste Storage Area Module (Section A.1.5)
- Total Uranium Data (Section A.1.6)
- Total Uranium Data Discussion (Section A.1.7)
- DOE National Laboratory Network Collaboration (Section A.1.8)
- Pumping Rates (Section A.1.9)
- CAWWT Capacity Reduction and Backwash Basin Replacement (Section A.1.10)

A.1.1 Operational System Overview

The current Operational Design and associated target design pumping rates to achieve cleanup for the groundwater remedy has been in effect since design changes were implemented on

July 1, 2014. Under the 2014 Operational Design, modeling predictions indicated that the pumping stage of the aquifer remedy would be achieved as follows:

- 2022 for the South Plume and Southern South Field
- 2030 for the Northern South Field
- 2035 for the former WSA

As shown below, progress was made in decreasing the South Plume between 2014 and the end of 2022.

Area	Total Uranium Plume Size 2014 (acres)	Total Uranium Plume Size 2022 (acres)	Percent Reduction
South Plume	29.8	14.6	51%
South Field	62.0	47.1	24%

Although progress was made reducing the uranium plume, uranium concentration data measured in the aquifer indicated that model-predicted cleanup goals for the South Plume and southern South Field would not be reached by 2022. In early 2022, the groundwater model was rerun to determine what the new cleanup times would be if uranium concentrations measured in the first half of 2021 were loaded into the model as initial conditions.

As was done for past model runs, modeled-predicted cleanup date uncertainty, due to changes in the elevation of the water table in the aquifer over time, was bracketed by modeling three different sets of boundary conditions for the elevation of the water table (i.e., wet, nominal, and dry). During wet boundary conditions, the water table elevation is at its historic high, and during dry boundary conditions, the water table elevation is at its historic low. Nominal is the average elevation of the water table. The model-predicted cleanup years are as follows:

Plume Area	Wet Boundary Conditions	Nominal Boundary Conditions	Dry Boundary Conditions
South Plume	2024	2025	2024
South Field	2035	2033	2038
Waste Storage Area	2040	2040	2045

As in previous modeling runs, the maximum model-predicted cleanup year for each boundary condition was selected as the new targeted cleanup year, resulting in the following new predicted cleanup years.

- South Plume: 2025
- South Field: 2038
- WSA: 2045

Figure A.1-2 illustrates how the 2022 model run predicts that the cleanup will progress under nominal boundary conditions (the most conservative boundary condition for cleanup of the south plume). Figure A.1-3 illustrates the pounds of uranium removed from the Great Miami Aquifer in 2013 (year before pumping changes) and 2022. More information concerning the new modeling predictions is provided in Sections is provided in Sections A.1.6 and A.1.7.

The current Operational Design (implemented in 2014) is more aggressive than the previous design because the target system design pumping rate is higher. The 2014 design is also more efficient than previous designs because pumping is more concentrated where the pumping is needed and when it is needed. The 2014 design introduced the strategy of decreasing design pumping rates as the remedy progresses.

The more-aggressive pumping rates required more maintenance (due to iron fouling of the pumps and well screens) than earlier less-aggressive pumping rates required. Figure A.1-4 shows the difference between a clean pump and one removed from an active pumping well at the Fernald Preserve after it had been operating for some time. As shown in the bottom photo, the pump pulled from the well is coated with iron, which interfered with operation of the pump and motor.

Operational experience was used to create and refine an aggressive and initially successful well maintenance program to address this iron fouling. Extraction wells are treated with a chemical solution called liquid acid descaler when operational parameters indicate that cleaning is warranted. As shown in the following table, the number of extraction wells decreased from 23 to 20 in 2014, but the number of chemical treatments increased after 2014 as a result of more-aggressive pumping rates and aging well infrastructure.

There were some exceptions to the increase in the number of treatments. The number of treatments was down in 2016, but 2016 was not a normal operating year due to an unplanned wellfield shutdown discussed in the 2016 Site Environmental Report (DOE 2017). The number of treatments was also down in 2018 and 2019. In 2018, it was due to the impact that the Converted Advanced Wastewater Treatment (CAWWT) construction project had on the availability of the backwash basin for wastewater generated by well treatment. In 2019, it was due to a construction project to replace the CAWWT backwash basin.

In 2021, the site began reducing the number of liquid acid descaler treatments due to the realization that the long-term use of liquid acid descaler over time was harmful to metal components of an aging wellfield system. In 2022, the decrease in treatments continued with the realization that the use of liquid acid descaler was causing pitless adaptor problems in the off-property wells. Operating experience also indicated that the wellfield was experiencing other problems that would not be responsive to treatments. For example, the same iron fouling that was occurring in the pumps and well screens was also occurring in the discharge piping. The iron fouling restricted flow through the discharge pipes creating backpressure on the flow from the wells.

Year	Number of Extraction Wells	Number of Chemical Treatments
2022	20	17
2021	20	30
2020	20	43
2019	20	19[a]
2018	20	28[b]
2017	20	35
2016	20	22[c]
2015	20	41
2014	23/20[d]	32
2013	23	38

[a] Number of chemical treatments was affected by replacement of the CAWWT backwash basin.
[b] Number of chemical treatments was affected by the CAWWT construction project.
[c] Number of chemical treatments was affected by an extended unplanned shutdown (DOE 2017).
[d] The number of operating extraction wells was reduced in July 2014.

In 2021, the situation became even more apparent when the seals of the pitless adaptor on South Plume Recovery Well RW-3 were discovered to be weakened by a combination of age and the continued use of liquid acid descaler such that that some of the water being pumped from the well was able to cascade back down into the well. More maintenance and pump replacements will be required in the future.

In 2022, the South Plume recovery wells continued to experience operational challenges. Because of their advanced age, having been continually operated for over 28 years and exposure to liquid acid descaler, during periodic well treatments and rehabilitations damage to the seals and pitless adaptors increased. Recovery wells RW-3, RW-4, and RW-6 experienced operational problems. Operators were able to repair South Plume recovery well RW-3 to be operational again in 2022, but RW-4 and RW-6 were permanently shut down. After repairing RW-3, liquid acid descaler treatments in the off-property wells were discontinued in 2022 to prevent further damage to the wells.

South Plume recovery well RW-4 was able to maintain its design setpoint of 200 gpm from 1993 to 2018. As discussed in Section A.1.9, the target pumping rate of RW-4 was lowered to 100 gpm in 2018. In June 2022, the well was no longer able to maintain 100 gpm and was turned off on June 6, 2022. A new pump and motor replacement was scheduled. In July 2022, a new pump and motor was installed, but the pitless adaptor was not able to be seated on the well screen causing the well to leak. In August 2022, the pump and motor were replaced again, and once again the pitless adaptor would not seat properly. June 6, 2022, is recognized as the official date that this well was permanently turned off.

South Plume recovery well RW-6 was shut down permanently on July 25, 2022, after 23 years of operation. From 1998 to 2022, the well met its design setpoint of 300 gpm. In July 2022, an underground leak developed, and the well was shut down. Groundwater modeling conducted in 2022 demonstrated that the well was no longer located where it was needed to efficiently clean up the remaining South Plume. Given that DOE was already planning a replacement for this well at a more optimal location, U.S. Department of Energy (DOE) decided to direct resources toward the new well rather than investigating the cause of the underground leak and implementing repairs on a well that was in the process of being replaced.

DOE also made efforts to address the iron fouling that extraction wells experience through the choice of equipment. DOE purchased 12 new stainless steel pumps in 2016 to help alleviate some of the maintenance challenges associated with operating the pumps continuously. Installation of the stainless steel pumps occurred as older pumps were removed for maintenance. As of 2021, all 12 of the pumps had been put into service. Based on the maintenance history, the stainless steel pumps have proven to last longer.

DOE continues to work with recognized wellfield maintenance experts to determine whether the well maintenance program can be improved to extend the life of the pumps. The issue of well maintenance was discussed in a DOE National Laboratory Network collaboration that was held in 2021. More information is provided in Section A.1.8.

A.1.2 Wellfield Shutdowns in 2022

The planned annual wellfield shutdown in 2022 lasted 43 days (June 6 to July 18, 2022). During this shutdown, recovery well RW-2 continued to pump at the leading south edge of the uranium plume. The other South Plume recovery wells normally remain on during the shutdown; however, in 2022, wells RW-1, RW-3 and RW-4 were down due to maintenance issues.

In addition to the annual planned wellfield shutdown, the wellfield is shut down whenever the Great Miami River reaches a river stage of 14 feet at the U.S. Geological Survey measurement gauge at Miamitown, Ohio. When flow in the river reaches this level, gravity flow from the site discharge pipe is affected. The wellfield remains off until the river stage falls below 14 feet. This approach was discussed with the U.S. Environmental Protection Agency (EPA) and the Ohio Environmental Protection Agency (Ohio EPA) during the March 14, 2018, regulatory meeting. These temporary wellfield shutdowns have not had a negative impact on remediation progress and could actually be beneficial from a rebound perspective. The total number of days the wellfield was shut down due to high river stage from 2018 to 2022 was as follows:

Year	Wellfield Shut Down Due to River Stage (days)
2018	10
2019	7
2020	4
2021	0
2022	4

A.1.3 South Field Module

Eleven extraction wells were operational in the South Field Module in 2022. The 11 active extraction wells were 31550 (EW-18), 31560 (EW-19), 31561 (EW-20), 33326 (EW-17a), 32276 (EW-22), 32446 (EW-24), 32447 (EW-23), 33061 (EW-25), 33262 (EW-15a), 33264 (EW-30), and 33298 (EW-21a).

The target combined pumping rate for the South Field Module wells in 2022 was 2,875 gpm. Table A.1-1 presents the combined performance data for the South Field Module. Tables A.1-2 through A.1-12 provide individual extraction well performance data for the South Field Module wells in 2022. Target pumping rates are reported on each individual extraction well performance table, and footnotes explain individual extraction well outages of greater than 24 hours.

During 2022, 1,277.30 million gallons (Mgal) of groundwater were pumped from the active extraction wells in the South Field Module, resulting in the removal of 237.13 pounds (lb) of uranium from the Great Miami Aquifer (GMA). Since startup in July 1998, the South Field Module has removed 29.082 billion gallons of water and 9,659.69 lb of uranium from the GMA.

A.1.4 South Plume Module

2022 was a year of operational change for the South Plume Module. In 2022, recovery wells RW-4 and RW-6 were permanently turned off, and the target pumping rate for RW-7 was reduced from 300 gpm to 200 gpm.

Six recovery wells were operational in the South Plume Module at the start of 2022: 3924 (RW-1), 3925 (RW-2), 3926 (RW-3), 3927 (RW-4), 32308 (RW-6), and 32309 (RW-7). These wells are south of Willey Road and north of New Haven Road. The target combined pumping rate for the South Plume Module wells in 2022 was 1,300 gpm.

In June 2022, recovery well RW-4 was no longer able to maintain 100 gpm. It was turned off on June 6, 2022, and a new pump and motor replacement was scheduled. In July 2022, a new pump and motor was installed, but the seal to the pitless adaptor leaked. In August 2022, the pump and motor were replaced again, and once again, the pitless adaptor could not be seated properly. Because the pitless adaptor was leaking, it was decided to leave the well turned off permanently. As discussed in Section A.1-9, RW-4 was no longer needed to capture and remediate the South Plume.

South Plume recovery well RW-6 was shut down permanently on July 25, 2022, after 23 years of operation. From 1998 to 2022, it was capable of meeting its design setpoint of 300 gpm. In July 2022, an underground leak developed and the well was shut down. Groundwater modeling conducted in 2022 demonstrated that RW-6 was no longer located where it was needed to efficiently clean up the remaining South Plume. Given that DOE was already moving forward with a replacement for this well at a more optimal location, DOE decided to direct resources toward the new well rather than investigating the cause of the underground leak and implementing repairs. In 2022, RW-7 could not maintain its target pumping rate of 300 gpm. In 2021, RW-7 was chemically treated, but when the pump and motor were restarted, sand was entering the well screen. This can damage the pump and indicates that there is a hole in the well screen. Using a downhole camera, no visible holes were detected in the screen; therefore, the problem was believed to be with the casing at the bottom of the screen. A cement plug was installed in the base of the screen, which corrected the problem. With the addition of the concrete plug, the well struggled to maintain 300 gpm in 2022, so the target pumping rate was lowered to 200 gpm.

With the shutdown of RW-4 and RW-6, and reduced flow in RW-7, the target combined pumping rate for 2023 will be 800 gpm, which is 500 gpm lower than it was in 2022. As discussed further below, DOE is in the process of installing two new extraction wells that will take the place of all remaining South Plume recovery wells (i.e., RW-1, RW-2, RW-3 and RW-7) once the wells are operational.

Table A.1-1 presents the combined performance data for the South Plume Module. Tables A.1-13 through A.1-18 provide individual extraction well performance data for the South Plume Module wells in 2022. Target pumping rates are reported on each individual extraction well performance table, and footnotes explain individual extraction well outages of greater than 24 hours.

During 2022, 398.11 Mgal of groundwater were pumped from the active extraction wells in the South Plume Module, resulting in the removal of 56.44 lb of uranium from the GMA. Since its startup in August 1993, the South Plume Module has removed 19.207 billion gallons of groundwater and 3,627 lb of uranium from the GMA.

During 2022, the South Plume Module continued to meet the primary objectives of:

- Preventing further southward movement of the total uranium plume while capturing the main lobe of the South Plume without adversely affecting the Paddys Run Road Site (PRRS) plume (wells 3924 [RW-1], 3925 [RW-2], 3926 [RW-3], and 3927 [RW-4]).
- Actively remediating the higher-concentration region of the off-property plume (32308 [RW-6] and 32309 [RW-7]).

Attachment A.3 presents additional details concerning capture, along with supporting data.

A.1.4.1 Current Condition of Recovery Wells RW-1, RW-2, and RW-3

Recovery wells RW-1, RW-2, and RW-3 have been operating for over 28 years. The wells were originally installed downgradient of the leading edge of the South Plume, with the objective of capturing the South Plume before the plume could mix with a downgradient plume associated with other business operations (i.e., PRRS). Data collected over the course of well operation demonstrate that the wells were successful in achieving this objective.

Groundwater modeling conducted in 2022 demonstrates that recovery wells RW-1, RW-2, and RW-3 are no longer needed to remediate and capture the remaining South plume if two new extraction wells are installed further north. Metal components in RW-1, RW-2, and RW-3 have been weakened by the long-term use of liquid acid descaler, and the use of additional treatments will risk permanently damaging the pitless adaptors.

Given that wells RW-1, RW-2, and RW-3 are no longer needed for capture and remediation of the South Plume once two replacement wells are installed to the north and given that additional liquid acid descaler treatments presents the risk of damaging the pitless adaptors rendering the wells inoperable, RW-1, RW-2, and RW-3 will be operated at a target pumping rate of 200 gpm each until they fail. It should be noted that RW-1, RW-2, and RW-3 are 10-inch diameter wells, which require 8-inch diameter pumps and motors. All other wells in the aquifer remediation system use pumps and motors that are larger than 8 inches in diameter. Because continued operation of the existing South Plume wells is no longer needed, DOE does not plan to purchase any additional 8-inch diameter pumps and motors. Efforts will be made to repair the 8-inch diameter pumps and motors, until the supply is exhausted.

A.1.4.2 Current Condition of Recovery Well RW-7

Recovery well RW-7 has been operating for over 23 years. It was installed to support remediation of the South Plume. Data collected over the course of operation demonstrates that it has been successful in helping to remediate the South Plume. Groundwater modeling conducted in 2022 demonstrates that RW-7 is no longer situated in an optimal location to complete remediation of the remaining South Plume. A concrete plug was installed in RW-7 in 2021 to stop sand from entering the screen, resulting in the need to lower the pumping rate from 300 gpm to 200 gpm in 2022. DOE is in the process of replacing RW-7. RW-7 will be operated at a target pumping rate of 200 gpm until it fails, or the replacement well is ready.

A.1.4.3 South Plume Modeling in 2022

Conservative groundwater modeling conducted in 2022 (based just on the movement of groundwater, and the current location of the South Plume) indicates that all of the South Plume wells (RW-1, RW-2, RW-3, RW-4, RW-6, and RW-7) can be shut down approximately 3 years before plume capture is breached. If two replacement wells are installed at locations identified in the 2022 modeling, remediation and capture of the remaining South plume will be achieved without continued operation of RW-1, RW-2, RW-3, and RW-7. DOE is planning to install the two new extraction wells at locations identified by the groundwater model. DOE plans to have the two new wells operational in early 2024, well ahead of 3 years.

A.1.4.4 Operational Path Forward for Existing South Plume Wells

Operational experience has shown that if a rate of 100 gpm can be maintained in the South Plume wells they continue to operate fairly well, but once the pumping rate falls below 100 gpm, the pumping rate deteriorates rapidly and the well needs to be rehabilitated. Because two new replacement wells are planned to be operational in early 2024, there is no need to rehabilitate RW-1, RW-2, RW-3, and RW-7 to extend their operational life should they no longer be able to achieve a pumping rate of 100 gpm. The steps presented below will be taken to operate these wells at or above 100 gpm for as long as possible before they are permanently shut down. It should be noted that all extraction wells develop their own unique operational challenges; therefore, the steps are not intended to be all inclusive, rather focus on the main challenges that have been encountered historically. If a unique challenge is encountered that is not mentioned in these steps, then appropriate action will be taken, short of conducting excavation and well redevelopment.

The following steps will be taken before RW-1, RW-2, RW-3, and RW-7 are permanently turned off. No action will be taken at these wells until the pumping rate falls below 100 gpm. In addition to the operational reasons presented above, this will also provide for seasonal water table changes. If the pumping rate at RW-1, RW-2, RW-3, and RW-7 falls below 100 gpm, the following steps will be taken:

[1] Pull the pump and motor from the well.

[2] Inspect the pitless adaptor.

    [a] If the pitless adaptor is damaged such that it cannot be repaired without excavation, then permanently shut down the well.

[b] If the pitless adaptor is not damaged or can be repaired without excavation, repair the pitless adaptor and proceed to replace the pump or motor, or both.

[3] Replace the pump and motor.

[a] If after replacement of the pump and motor the well cannot maintain 100 gpm, then permanently turn off the well.

A.1.4.5 Paddys Run Road Site

In 2022, as in previous years, PRRS constituents of concern (arsenic, phosphorus, potassium, sodium, and volatile organic compounds) were monitored at 10 monitoring well locations immediately south of the South Plume Module to ensure that the operation of the system does not adversely impact the PRRS plume. The 10 wells monitored were 2128, 2636, 2898, 2899, 2900, 3128, 3636, 3898, 3899, and 3900 (Figure A.1-1).

The Mann-Kendall test for trend was run on PRRS constituent data collected from these wells. As indicated in Table A.1-19, the following two parameters monitored for PRRS constituents of concern in four different wells had “up” trends:

- Potassium in monitoring wells 2898, 2899, 3898, and 3899
- Sodium in monitoring wells 2898, 2899, 3898, and 3899

Figures A.1-5 through A.1-12 provide plots of concentration versus time for these constituents and wells.

Groundwater flow directions are reported in Attachment A.3 in the form of groundwater elevation maps (Figures A.3-1 through A.3-4). The groundwater elevation maps for 2022 indicate that flow to monitoring wells 2898, 2899, 3898, and 3899 was from the northeast to the southwest. This indicates that the increasing concentrations at these locations were moving toward the PRRS plume, not away from it.

The monitoring activity for PRRS constituents of concern also included sampling for volatile organic compounds. These compounds are monitored because they were present in the PRRS plume, which is not of Fernald site origin (ERM Midwest Inc. 1994). No volatile organic compounds were detected in 2022.

Monitoring water levels appears to be more effective than monitoring water quality for determining whether pumping in the South Plume is pulling the PRRS plume toward the South Plume recovery wells.

A.1.5 Waste Storage Area Module

Three extraction wells were operational in the former WSA Module in 2022. The three extraction wells were 32761 (EW-26), 33062 (EW-27), and 33347 (EW-33a).

The target combined pumping rate for the WSA Module wells in 2022 was 800 gpm. The combined performance data for the WSA Module are presented in Table A.1-1. Tables A.1-20 through A.1-22 provide individual extraction well performance data for the WSA Module wells for 2022. Target pumping rates are reported on each individual extraction well performance table, and footnotes explain individual extraction well outages of greater than 24 hours.

During 2022, 332.11 Mgal of groundwater were pumped from extraction wells in the WSA Module, resulting in the removal of 60.26 lb of uranium from the GMA. Since startup in May 2002, the WSA Module has removed 8.771 billion gallons of water and 2,540.23 lb of uranium from the GMA.

A.1.6 Total Uranium Data

In 2022, water samples were collected monthly from the extraction wells and analyzed for total uranium. The total uranium concentrations were used to calculate an annual mass of uranium removed from the well. The data are also used to determine whether a well needs to be routed to treatment.

The current aquifer remedy is able to achieve uranium discharge limits (i.e., average monthly concentration of less than 30 micrograms per liter [µg/L] and 600 lb annually) established in the Operable Unit 5 Record of Decision (DOE 1996) without routine groundwater treatment. Routine groundwater treatment has not been needed since 2010. Since 2010, groundwater was occasionally sent to treatment for very short periods. The reasons for the short periods of treatment varied. For instance, treatment can be needed when wells pumping low uranium concentrations are turned off for maintenance and wells pumping higher uranium concentrations continue pumping. With conversion to the smaller 50 gpm treatment system (which became operational on April 3, 2018), a small amount of groundwater is routed to treatment each month and blended with water from the backwash basin to dilute anion concentrations in the backwash basin water before treatment.

In 2022, 2.008 billion gallons of groundwater were pumped from the GMA, and 4.48 Mgal (0.22%) of groundwater was treated. The following table provides a summary of how much groundwater was treated each month. The minimum and maximum total uranium concentrations provided are for individual wells. The average is for all wells operating that month.

Month	Water Treated (gallons)	Minimum Total Uranium (µg/L)	Maximum Total Uranium (µg/L)	Average Total Uranium (µg/L)
January	867,915	3.8	35.2	20.9
February	554,020	3.0	34.0	20.6
March	138,210	3.3	31.5	20.2
April	229,425	3.9	33.7	22.9
May	303,810	3.3	30.4	19.5
June	310.835	6.0	77.6	23.5
July	212,845	8.7	35.2	17.3
August	320,695	9.6	29.8	17.7
September	288,900	5.7	28.6	17.3
October	415,660	8.3	36.4	20.1
November	386,920	8.9	34.2	18.5
December	450,590	7.7	30.3	16.3
Total	**4,479,825**			

A data assessment exercise is conducted each year and reported in the Site Environmental Report where uranium concentration data collected from the extraction wells are tracked graphically and statistically to assess how the concentrations are trending. Uranium concentrations are plotted over time and fitted with a regression line. In previous years, expressions used for regression of extraction well data included power functions, exponential functions, and polynomials. These functions were fit to uranium concentration data using Microsoft Excel.

The assessment exercise reported for this year is changed from the previous years. A collaborative effort between the DOE and the National Laboratory Network resulted in recommendations to reduce risk involved with the ongoing aquifer remedy. One recommendation was the use of alternative mathematical expressions to project remedial time frames through (1) implementation of new statistical projection methods for uranium concentration data as an alternative to the current methods used, and (2) refining the calculation approach for confidence intervals on the time projections. The objective for making these changes is to improve the accuracy of groundwater cleanup projections, including uranium mass removal projections for extraction wells and remedial time frame projections for the uranium plume. This recommendation was completed in 2022 and a draft report is expected to be issued in 2023.

The report will describe (1) how dual exponential functions were evaluated for use at the Fernald Preserve, and the resulting selection of stretched exponential functions to conduct regression analysis of extraction well datasets each year to project uranium mass removal, and (2) the use of bootstrapping to calculate 95% confidence intervals for the stretched exponential functions. Beginning with this year's Site Environmental Report, National Laboratory Network recommendations were implemented, and stretched exponential functions and the bootstrapping method were used.

Figures A.1-13 through A.1-32 are uranium concentration versus time plots for each extraction well. Each graph displays uranium concentration data measured at the well, a regression trend of the uranium concentration dataset using stretched exponential equations, a 95% confidence level about the stretched exponential trend prepared using a bootstrapping approach, and groundwater model predictions.

The data in Figures A.1-13 through A.1-32 illustrate that as pumping continues, the uranium concentration of the pumped groundwater decreases. The slope of a fitted regression curve through the uranium concentration dataset at each extraction well provides a prediction of how pumping concentrations will continue to decrease and can be used to make uranium mass removal predictions over time for each extraction well.

EPA guidelines found in *General Methods for Remedial Operation Performance Evaluations* (EPA 1992) suggest that a 95% upper confidence level (UCL) of the measured uranium concentration dataset should also be used to help evaluate the uncertainty of the predicted trend. Figures A.1-13 through A.1-32 display both the upper and lower 95% confidence level, with the 95% uncertainty region shaded gray.

The Fernald Preserve aquifer remediation was designed using the Variable Saturated Analysis Model in Three Dimensions (also called VAM-3D). When the site transitioned to the Office of Legacy Management in 2006, the remediation was operating to a design that was established in 2005 called the WSA Phase II Design (DOE 2005). As explained in Section A.1.1, a new design, called the current Operational Design, was implemented in July 2014 (DOE 2014). Groundwater model predictions for both designs assume that an equilibrium linear isotherm adequately describes the partitioning of total uranium between the sorbed and dissolved phases.

The Fernald Preserve groundwater model predicts the future average pounds of uranium that will be removed from the aquifer for each year of the modeled remedy to eventually achieve concentration based final remediation levels (FRL) goals. This prediction (broken down by year) is used to judge how closely the actual remediation is tracking the model predictions. The actual pounds of uranium removed from the aquifer are compared to the model predictions to assess how reasonable the model predictions were. Stretched exponential equations based on measured concentration data collected at the extraction wells are used to provide a prediction of the number of pounds of uranium that will be removed from the aquifer in future years to achieve concentration-based FRL goals. Stretched exponential equations based on uranium concentration data collected at extraction wells through December 31, 2022, are summarized in Table A.1-23.

Changing water levels in the aquifer result in cleanup prediction uncertainty. Modeling is therefore conducted under low water-level conditions, high water-level conditions, and nominal water-level conditions to bracket the uncertainty in model-predicted cleanup times. Until 2021, this tracking exercise used model predictions for high water-level conditions, because they were the most conservative (i.e., presented the longest predicted cleanup times for the overall remedy). As discussed below, new model predictions for 2022 and beyond use nominal boundary conditions because this is the most conservative boundary condition for cleanup of the off-property South Plume (i.e., presented the longest predicted cleanup time for the South Plume).

Every year, the average uranium concentration data used to create the stretched exponential curves for each extraction well are updated with the data for the current reporting year. This results in the equations for each well changing slightly from year to year in response to the incorporation of the new data. At the end of December 2022, data indicated that 15,751 net lb of uranium had been removed from the GMA by the pump-and-treat remedy. Net pounds of uranium includes a small amount of uranium that was reinjected into the aquifer between 1998 and 2004.

Groundwater modeling conducted in 2012 predicted that under the current pumping rates, pumping would continue until 2022 in the South Plume and Southern South Field, 2030 in the northern South field, and 2035 in the former WSA. Annual monitoring results used to track remedy progress indicate that these dates would not be achieved. In early 2022, the groundwater model was re-run to determine what the new cleanup times would be if uranium concentrations measured in the first half of 2021 were loaded into the model as initial conditions.

As was done for past model runs, modeled predicted cleanup date uncertainty due to changes in the elevation of the water table in the aquifer over time was bracketed by modeling three different sets of water table boundary conditions (i.e., wet, nominal, and dry). During wet boundary conditions the water table elevation is at its highest, and during dry boundary conditions the water table elevation is at its lowest. Nominal is the average elevation of the water table. The results were as follows:

Plume Area	Wet Boundary Conditions	Nominal Boundary Conditions	Dry Boundary Conditions
South Plume	2024	2025	2024
South Field	2035	2033	2038
Waste Storage Area	2040	2040	2045

As in previous modeling runs, the maximum model predicted cleanup date for each boundary condition was selected as the new target cleanup date, resulting in the following new predicted cleanup years.

- South Plume: 2025
- South Field: 2038
- WSA: 2045

Since the longest model predicted cleanup date for the South Plume (2025) was determined using nominal boundary conditions, and the immediate objective of the aquifer remedy is to clean up the South Plume first, it was decided to present cleanup predictions for nominal boundary conditions for the 2022 model run in this Site Environmental Report. Table A.1-24 provides a yearly breakdown of the pounds of uranium to be removed from 2023 to 2040 to achieve concentration-based FRL goals, based on three predictions (i.e., uranium concentration data, model predictions, 95% UCL). Figure A.1-33 illustrates the relationship between the three predictions. Each prediction is further discussed below.

A.1.6.1 Total Uranium Concentration Data

Using stretched exponential functions, the estimate of pounds or uranium to be removed from the aquifer between 2023 and 2040 to achieve remediation goals increased from 2,502 pounds to 3,305 lb which is an increase of 803 lb.

A.1.6.2 Model

Modeling conducted in 2022 predicts that from 2023 through 2040 an additional 2,355 lb of uranium will need to be removed from the GMA to achieve concentration-based cleanup goals under nominal boundary conditions. It should be noted that, by loading the 2021 plume concentrations into the groundwater model, the predicted pounds of uranium needing to be removed to achieve remediation goals increased by 1,812 lb over the previous modeling runs (2,890 – 1,078 lb = 1,812 lb).

A.1.6.3 95% UCL

Use of a bootstrapping approach to calculate a 95% confidence interval resulted in an estimate for the upper confidence level that is more reasonable than the previous used method. The previous method estimated that between 2023 and 2040 an additional 9,603 lb of uranium would need to be removed from the aquifer to achieve remediation goals. The new estimate is 4,314 lb, which is more in line with the actual data.

A summary of the three predictions is provided below.

Net pounds of uranium extracted through December 2022	15,751		
	Data	**Model**	**95% UCL**
Predicted pounds of uranium to be extracted between 2023 and the end of the pump-and-treat stage of the aquifer remedy (in accordance with the current Operational Design, nominal boundary conditions)	3,305	2,355	4,314
Total predicted pounds of uranium to be removed to achieve concentration-based FRL goals	**19,056**	**18,106**	**20,065**
Estimated percent complete (based on pounds of uranium to be removed)	**83%**	**87%**	**79%**

Results shown above indicate that as of December 31, 2022, the estimated percent complete (based on pounds of uranium to be removed to achieve concentration-based FRL goals) are 83%, 87%, and 79% for the data, model, and 95% UCL of the data, respectively. Following the EPA guidelines mentioned earlier, the estimated percent complete based on pounds of uranium removed is between 79% and 83%. The groundwater model prediction indicates 87% complete.

Tracking pounds of uranium removed against groundwater modeling predictions provides an indirect status on progress being made to attain cleanup goals. Other methods (mapping Ricker Method and Earth Volumetric Studio [EVS] software) of tracking reduction in the plume size are presented in Attachment A.2.

A.1.7 Total Uranium Data Discussion

In early 2022, the groundwater model was re-run with updated uranium plume concentrations consistent with monitoring results for the first half of 2021. The groundwater model run previously was based on an initial mass loading of 16,000 lb of uranium. As can be seen from Table A.1-24, both monitoring data and modeling now predict that between 18,106 to 19,056 lb of dissolved uranium will need to be pumped from the aquifer in order to achieve cleanup objectives. The 95% UCL estimate is even higher at 20,065 lb.

A comparison of groundwater model-predicted uranium concentrations and the actual uranium concentrations measured at each extraction well is provided in Table A.1-25. The 2021 Site Environmental Report (DOE 2022) marked the seventh year this comparison had been completed for the current Operational Design using model predictions made in 2014. This year, the 2022 model predictions shown in Figure A.1-25 were made with the updated model run that used initial uranium plume concentrations measured in 2021.

The comparison this year shows that the average model-predicted total uranium concentration for 2022 (20.85 µg/L) is higher than the actual average concentration measured in December 2022 (16.3 µg/L). The residual average uranium concentration (actual uranium concentration minus model-predicted uranium concentration) was -4.5 µg/L. The standard deviation for the residual dataset was 27.7. As reported in Section A.1.8, DOE continues to work on ways to improve the predictive capability of the site groundwater model.

A comparison of groundwater model-predicted concentrations and actual observed concentrations measured at selected monitoring wells in 2022 is provided in Table A.1-26. It should be noted that in the 2021 Site Environmental Report, the 2021 model predictions that were shown in Table A.1-26 were made in 2012 when the groundwater model was run to implement the 2014 operational changes. The 2022 model predictions shown in Table A.1-26 were made with the updated model run that used initial uranium plume concentrations measured in 2021.

Actual uranium concentrations measured in the first half of 2022 are compared against model-predicted uranium concentrations for April 2022. Changing water levels in the aquifer result in model-predicted cleanup variations and uncertainty. Modeling is, therefore, conducted under low water-level conditions, high water-level conditions, and nominal water-level conditions. The comparison shown in Table A.1-26 represents nominal water-level conditions. Groundwater modeling conducted under nominal water-level conditions resulted in the longest cleanup time predictions for the South Plume; therefore, they are the most conservative for the South Plume. Comparing observed uranium concentrations against the model-predicted concentrations began in 2016. It should be noted that starting in 2017, the comparison is based on 13 fewer data points as a result of the monitoring reductions implemented in 2017.

As shown in Table A.1-26, the average residual uranium concentration in 2022 was 29.55 µg/L. As was presented in previous years, Table A.1-27 shows the average residual uranium concentration for 2022 with five monitoring wells that were the main contributors to the difference (2049, 2387, 23276, 23281, and 83294_C2) removed. Those five wells are in the South Field. The average residual uranium concentration decreases from 29.55 µg/L (all measured wells) to 6.19 µg/L (five wells removed). These larger discrepancies found at these five wells are indicators that the model predictions are less reasonable for these five locations. As reported below in Section A.1.8, DOE continues to work on ways to improve the predictive capability of the site groundwater model.

Decreasing efficiency in mass removal is a common challenge for pumping operations. Uranium concentration curves are trending asymptotic. It was this trend, in part, that resulted in DOE optimizing the remediation operation and implementing a more aggressive cleanup design in 2014.

As discussed in Attachment A.2, calculations show that more uranium is sorbed to aquifer sediments than is dissolved in the water. The slow desorption process controls how much uranium is dissolved each year into the water and subsequently pumped out of the aquifer by the extraction wells. As the remedy proceeds, the desorption rate becomes slower and the remedy becomes less efficient, regardless of how much water is flushed through the sediments. Finding the right balance between desorption rate and pumping rate is difficult.

Collectively, this information indicates that additional work is needed to optimize the performance of the system again (as was done in 2014). Additional groundwater conceptualization and modeling work is being conducted based on recommendations made during a DOE National Laboratory Collaboration that was conducted in early 2021. More information is provided in Section A.1.8.

It should be recognized that pumping may only progress the remediation to a certain point and there may be recalcitrant areas remaining that will need to be addressed using a different approach. For instance, progress in achieving a concentration-based cleanup is being assessed in part by attributing uranium concentration declines being measured to the pounds of uranium being removed from the aquifer through active pumping. Reducing conditions in the aquifer that caused uranium to sorb to sediments could also contribute to lower dissolved uranium concentrations in the groundwater. Reducing conditions could therefore also be a factor in why some areas of the aquifer might not respond to pump-and-treat as well as other areas. As the aquifer remedy progresses and the plume decreases in size, such that only recalcitrant areas are left, the need to have a better understanding of the geochemical conditions within the recalcitrant areas (such as oxidation-reduction conditions) could become more important for completing cleanup in those areas.

Some recalcitrant areas in the GMA are likely the result of sediment grain size variations that are present within the aquifer and are common to braided stream depositional environments like the GMA. The presence of areas of finer grained sediment may be limiting the success of pumping dissolved uranium from all impacted areas of the aquifer. Uranium will tend to sorb more to finer-grained sediments, because there is more surface area available. Movement of groundwater, due to pumping, will be easier through coarser-grained sediments, and groundwater will tend to move around areas where finer-grained sediments are present. Essentially the finer-grained areas are not flushed as easily as the coarser-grained areas. In effect, uranium slowly de-sorbs from the areas of finer-grained sediments as the water moves past and around them. This slow desorption process lengthens aquifer cleanup times.

As the groundwater remedy progresses, additional work to define the uranium partitioning coefficient (K_d) may also be deemed beneficial to help refine cleanup efforts in recalcitrant areas of the uranium plume. Selecting a K_d for uranium in the groundwater model that reflects actual site conditions everywhere in the uranium plume over the life of the groundwater remediation effort might not be appropriate. Groundwater model predictions for the Fernald Preserve assume that an equilibrium linear isotherm adequately describes the partitioning of total uranium between sorbed and dissolved phases. One K_d value ($K_d = 3$) is used to represent the entire model domain and time frame. This value was determined empirically by the Sandia National Laboratory using core samples of aquifer sediment collected from contaminated areas across the Fernald site (SNL 2004). It is considered to be a good representative K_d value overall, but it might not reflect reality in all areas of the plume.

A.1.8 DOE National Laboratory Network Collaboration

In early 2021, a DOE National Laboratory Network collaboration was conducted concerning the Fernald Preserve Groundwater Remediation. EPA and Ohio EPA participated, with the understanding that any official input or endorsement for any of the recommendations would be reserved for if DOE decides to pursue implementation of a recommendation at the site. The objective of the collaboration was to present recommendations to improve the ongoing aquifer remediation at the Fernald Preserve.

The collaboration involved two focus groups. Focus Group 1 was challenged with developing recommendations on how to maintain and keep an aging wellfield system operating efficiently. Focus Group 2 was challenged with developing recommendations to improve the efficiency and success of the existing pumping remedy and to improve the aquifer cleanup predictions for planning purposes while considering the following three site priorities:

1. Focus first on the off-property plume
2. Focus second on the southern South Field plume
3. Focus third on the recalcitrant areas of the plume in the South Field and former WSA

A.1.8.1 Results of Focus Group 1: Aging Wellfield System

Focus Group 1 did not identify anything that is currently being done to maintain the aging wellfield system at the Fernald Preserve that should stop being done. Focus Group 1 acknowledged that operating an aging wellfield system efficiently is somewhat of an art in that there is no one proven method or process that seems to always work. Success involves a degree of trial and error to determine the optimal operational practice for any given well. Given the operational challenges at the Fernald Preserve, the current operation and maintenance program was determined to be sound. When the DOE National Laboratory Network Collaboration personnel contacted area experts for information, those familiar with the Fernald site’s wellfield maintenance program emphasized that they often refer to the Fernald Preserve when they need an example of how to approach the challenge. Focus Group 1 presented the following three consensus recommendations:

1. Test the use of automated biofilm and scale control in the extraction wells.
2. Test the use of carbon dioxide to rehabilitate extraction wells.
3. Enhance rehabilitation contact (i.e., use of satellite wells to deliver treatments).

Working with EPA, Ohio EPA and stakeholders, DOE moved forward in November 2021 with a small-scale manual test of the biofilm and scale-control recommendation.

Implementation of the automatic biofilm and scale-control recommendation consists of the routine administration of peracetic acid instead of the current practice of doing periodic administration of liquid acid descaler. Routine administration of the peracetic acid would require infrastructure modifications to the wellheads of the extraction wells. Before making these wellhead modifications, DOE conducted a manual test on two wells.

With concurrence from EPA and Ohio EPA, the manual test began in November 2021 and lasted for 6 months. Specific capacity data collected during the 6-month manual test indicated that the routine use of peracetic acid on aged wells (that were recently rehabilitated) resulted in no improvement in the wells' specific capacity compared to the improvement realized through the periodic use of liquid acid descaler. The National Laboratory Network recommendation for the routine use of a biocide like peracetic acid called for starting the routine treatment in a new extraction well that had not yet undergone iron fouling. Therefore, the routine use of a biocide remains a potential option for newly installed extraction wells.

All three National Laboratory Network recommendations from Focus Group 1 pertain to extending the life of an extraction well. Considering the age of the existing extraction wells, rather than trying to prolong their lives further, the best option may be to just begin to strategically replace them. DOE will revisit all three Focus Group 1 National Laboratory Network recommendations as deemed appropriate when replacement of an extraction well is being considered.

A.1.8.2 Results of Focus Group 2: Improve Efficiency of the Aquifer Cleanup

Focus Group 2 did not identify anything that is currently being done to improve efficiency of the aquifer cleanup at the Fernald Preserve that should be stopped. Six recommendations were presented. Four recommendations involved doing things that are *not* currently being done at the Fernald Preserve. Two recommendations involved things that are being done at the Fernald Preserve, but should be supplemented with something that the Fernald Preserve is *not* doing.

What the Fernald Preserve is not doing but should be doing:

1. Use alternative mathematical expressions to predict cleanup time frames.
2. Conduct targeted data mining of available site information for enhanced understanding of prior fate and transport behavior and improved predictions of future behavior.
3. Prepare three-dimensional visualizations of key hydrogeologic and geochemical parameter distributions over time.
4. Conduct algorithm-based optimization for future remedy operation and design.

What the Fernald Preserve is doing that should continue, and should be supplemented with something else:

1. Refine plume metric calculations to reduce uncertainty.
2. Continue to port the site groundwater model to a modern hydrologic software platform.

DOE began implementation of these Focus Group 2 recommendations in 2022, and it is anticipated that full implementation will take from 1 to 4 more years. Implementation of any National Laboratory Network recommendation is subject to availability of resources, stakeholder coordination (as appropriate), and regulatory approval.

DOE completed two of the Group 2 National Laboratory Network recommendations in 2022: (1) Alternative Mathematical Expressions for Projecting Remedial Time Frame, and (2) Four-Dimensional Mapping and Interpretation. The use of alternative mathematical expressions was briefly discussed in Section A.1.6, and Four-Dimensional Mapping and Interpretation is briefly discussed below.

A four-dimensional mapping tool was developed using EVS software. This tool facilitates interpretation and communication of extensive environmental datasets. The tool can be used for both visual, qualitative, and quantitative analysis. A three-dimensional geologic model, a time series of water table surfaces, and a time series of volumetric plume models were generated. Water table mapping and streamline analysis were used to assess the capture influence of the remediation system. This evaluation indicated that the current operational design achieves full containment of the uranium plume. This is discussed further in Attachment A.3. Uranium plume mapping and calculation of bulk metrics was used to assess plume stability. The results demonstrate that the lateral and vertical dimensions of the plume are contracting, the total dissolved uranium mass is decreasing, and the center of mass has not migrated downgradient. These results are further discussed in Attachment A.2. With the four-dimensional mapping implementation complete, incorporating additional site data into the EVS tool is straightforward. DOE plans to update this tool as deemed appropriate and use it for ongoing evaluation and communication of data for the Fernald Preserve site, as well as update the site groundwater model as needed.

A.1.9 Pumping Rates

Target design extraction well pumping rates for 2022 are provided in Table A.1-28. The target design pumping rate has changed over time. From July 1, 2014, through June 2018, the target design pumping rate was 5,075 gpm (DOE 2014). The target design pumping rate is the pumping rate used in the groundwater model to estimate cleanup times for the aquifer remedy. Beginning in July 2018, the target design pumping rate was reduced to 4,975 gpm because of a decreased pumping rate from 200 to 100 gpm in recovery well RW-4.

In 2018, extraction well 3927 (RW-4) was no longer able to maintain its design setpoint of 200 gpm. This well is in the South Plume Module off DOE property (Figure A.1-1), is 26 years old, and has a hole in the screen that has been repaired with a concrete plug. Rehabilitation attempts are no longer effective in getting the pumping rate back up to 200 gpm. Previous modeling had extraction well 3927 (RW-4) pumping until 2022. Given the limited time that this well was projected to be needed, DOE completed modeling to determine whether a replacement well was warranted.

The modeling indicated that extraction well 3927 (RW-4) could be turned off in 2018 without impacting the model-predicted cleanup times and that capture of the remaining uranium plume would be maintained. Particle track maps showed that water supplying extraction well 3927 (RW-4) was coming mostly from outside the remaining uranium plume footprint. Based on the modeling results, DOE took a conservative approach and continues to pump extraction well 3927 (RW-4) at 100 gpm, rather than 200 gpm, and plans to continue to operate the well until it fails. The continued pumping at the lower rate should help to further flush the aquifer in this area. This approach was discussed with EPA and Ohio EPA at an update meeting on July 11, 2018, at the Fernald Preserve. Both EPA and Ohio EPA concurred with this revised operational approach for extraction well 3927 (RW-4).

In June 2022, recovery well RW-4 was no longer able to maintain 100 gpm. It was turned off on June 6, 2022, and a new pump and motor replacement was scheduled. In July 2022, a new pump and motor was installed, but the drillers could not get the pitless adaptor to seat on the well screen causing the well to leak. In August 2022, the pump and motor was replaced again, and once again the drillers could not get the pitless adaptor to seat properly. June 6, 2022, is recognized as the official date that this well was turned off permanently. As reported above, through 2022 the target pumping rate for this well was recognized as 200 gpm. On January 1, 2023, it will be removed from the South Plume Module and removed from Table A.1-28.

Beginning in January 2023, the target design pumping rate for the South Plume on Table A.1-28 will be reduced by an additional 400 gpm due to loss of RW-6 and a decrease in pumping rate at RW-7. The 2023 target design pumping rate will be 4,475 gpm. As the remedy proceeds, pumping rates may change as efforts are made to maximize the effectiveness of each module.

As discussed earlier, RW-6 was permanently shut down in 2022 and the target design pumping rate of RW-7 was decreased from 300 gpm to 200 gpm. Overall, these two pumping adjustments amount to a total decrease of 400 gpm. For operational tracking purposes, the previous target pumping rates (before the changes noted above) are recognized in the report. Beginning January 1, 2023, RW-4 and RW-6 were officially removed from the list of operating wells in the South Plume Module, and the target pumping rate for RW-7 became 200 gpm.

Modeling conducted in 2022 demonstrates that if the six existing South Plume recovery wells are replaced with two new recovery wells (RW-6A and RW-7A) east and northeast of RW-6 and RW-7, then capture of the remaining South Plume will be maintained, and the predicted cleanup time for the South Plume will not increase. The proposed path forward for the operation of remaining South Plume wells was discussed in Section A.1-4. Additional modeling conducted in 2022 demonstrates that all existing South Plume wells can be down for a period of three years before capture of the remaining South Plume is compromised. Using the date when recovery well RW-6 was permanently turned off as the conservative starting point (July 25, 2022), DOE needs to have the new wells operating no later than July 25, 2025. DOE is moving forward with the installation of the two new South Plume recovery wells and anticipates that they will be operational in early 2024.

In September 2012, with concurrence from EPA and Ohio EPA, a pulse pumping exercise was initiated at extraction wells 31550 (EW-18), 31560 (EW-19), 31561 (EW-20), and 33061 (EW-25). At the time, these four wells were equipped with pumps and motors that operated most efficiently at rates of approximately 300 gpm. The WSA Phase II Design called for a target pumping rate of 100 gpm for each of these wells. The 100 gpm rate was being achieved by throttling back on the flow from each of the wells; however, this type of operation was not energy efficient.

With the exception of extraction well 31561 (EW-20), the current Operational Design also calls for a pumping rate of 100 gpm for each of these wells. To be more energy efficient, when weather or temperatures are above freezing, the three wells that remained at 100 gpm under the current Operational Design targets are being pumped at a higher rate for a shorter period each day to remove the daily volume of water prescribed by the current Operational Design. Specifically, the wells are being pumped for 300 gpm for 8 hours a day (a total of

144,000 gallons per day) rather than 100 gpm for 24 hours a day (a total of 144,000 gallons per day). Flow and particle path monitoring predictions indicate that the new pumping schedule will maintain capture of the 30 µg/L uranium plume. Extraction well 31561 (EW-20) has a target pumping rate of 200 gpm under the current Operational Design, so pulse pumping is no longer being used at this well.

A.1.10 CAWWT Capacity Reduction and Backwash Basin Replacement

As presented in the *Fernald Preserve 2015 Site Environmental Report* (DOE 2016), the CAWWT system had become oversized and had reached the end of its useful life. Additionally, equipment corrosion and corrective maintenance had become ongoing issues for facility operations.

In March 2015, a CAWWT Condition Assessment Report was finalized (Whitman, Requardt & Associates LLP 2015) confirming that many of the treatment system components were at or nearing the end of their useful life. A decision was made to replace the CAWWT system with a 50-gpm system inside the CAWWT building. DOE received concurrence on a path forward in July 2015 from EPA and Ohio EPA and in August 2015 from the Fernald Community Alliance. Planning for the project began in August 2015.

The project was initiated in 2016 and implemented in three steps:

1. Treatment media removal and demolition of existing piping and tanks to allow room for the new system in the existing building.
2. Design of the new system.
3. Construction, installation, and commissioning of the new system.

Step 1 was completed in January 2017. Four multimedia filters, four of the six existing ion-exchange vessels, and associated piping were removed to provide space for installation of the new system. Two ion-exchange vessels and associated piping remained to be available to handle treatments needs until the new system was operational. The current CAWWT building remains to house the smaller treatment system, laboratory, operations control room office, and maintenance shop and to provide storage space.

Step 2, design of the new system, was completed in the spring of 2017. The system was designed to meet the site's wastewater treatment needs through 2039.

Step 3, construction, installation, and commissioning of the new system was completed in 2018. The new system became operational on April 3, 2018.

In 2019, the backwash basin (which is used to hold wastewater from the site before being treated) was refurbished. Refurbishment efforts included the removal, shipping, and disposal of approximately 600 cubic yards of low-level radiological waste at a commercial disposal facility in west Texas. While the backwash basin was being refurbished, wellfield maintenance activities were put on hold until the new backwash basin was available to temporarily store spent well maintenance fluids before being treated in the CAWWT system.

A.1.11 References

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Table A.1-1. Aquifer Restoration System Operational Summary

	Reporting Period					
	January 2022 Through December 2022			August 1993 Through December 2022		
	Volume Pumped/ Reinjected (Mgal)	**Total Uranium Removed/ Reinjected (lb)**	**Uranium Removal Index (lb/Mgal)[a]**	**Volume Pumped/ Reinjected (Mgal)**	**Total Uranium Removed/ Reinjected (lb)**	**Uranium Removal Index (lb/Mgal)**
South Field Module	1277.30	237.13	0.19	29,081.58	9,659.69	0.33
Waste Storage Area Module	332.11	60.26	0.18	8,770.68	2,540.23	0.29
South Plume Module	398.11	56.44	0.14	19,206.77	3,627.04	0.19
Reinjection Module[a]	0	0	NA	1,936.48	76.27	Not Applicable
Aquifer Restoration Systems Totals						
Extraction Wells	2,007.52	353.83	0.18	57,059.02	15,826.93	0.28
(Reinjection Wells[a])	0	0	NA	(1,936.48)	(76.27)	Not Applicable
Net	2,007.52	353.83	0.18	55,122.54	15,750.66	Not Applicable

[a] Reinjection Module was shut down in September 2004.

Table A.1-2. Extraction Well 31550 (EW-18) Operational Summary for 2022

Reference Elevation (feet above mean sea level [ft amsl]): 572.11 (top of well)
Northing Coordinate (1983): 477,018.5
Easting Coordinate (1983): 1,348,979.8

Hours in reporting period: 8,760
Hours not pumped: 1,200.0

Hours pumped: 7,560
Operational percent: 86.3

Adjusted operational percent[a]: 97.83

Target pumping rate: 100 gpm

Monthly Measurements at Wellfield							
Month		**Monthly Average Pumping Rate[b] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		110.2		4.918		35.2	0.29
Feb		101.8		4.105		34.0	0.28
Mar		93.9		4.191		31.5	0.26
Apr		111.0		4.797		33.1	0.28
May		107.6		4.801		25.9	0.22
Jun		19.1		0.823		27.6	0.23
Jul		59.2		2.642		24.8	0.21
Aug		128.0		5.715		27.1	0.23
Sep		109.1		4.714		26.3	0.22
Oct		108.5		4.843		32.9	0.27
Nov		111.8		4.828		32.2	0.27
Dec		110.7		4.943		27.9	0.23
	Average	97.6	Total	51.320	Average	29.9	Average 0.25

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-18 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-18 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-18 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-18 was down from June 6 to July 18 for planned wellfield shutdown.
Well EW-18 was down from October 31 to November 1 for liquid acid descaler chemical treatment.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-3. Extraction Well 31560 (EW-19) Operational Summary for 2022

Reference Elevation (ft amsl): 574.93 (top of well)
Northing Coordinate (1983): 477,403.1
Easting Coordinate (1983): 1,349,028.9

Hours in reporting period: 8,760
Hours not pumped: 1,135.5

Hours pumped: 7,624.5
Operational percent: 87.04

Adjusted operational percent[a]: 98.66

Target pumping rate: 100 gpm

Monthly Measurements at Wellfield							
Month	Monthly Average Pumping Rate[b] (gpm)		Volume Pumped (Mgal)		Monthly Total Uranium Concentration[c] (µg/L)		Uranium Removal Index (lb of total uranium removed/Mgal pumped)
Jan	110.6		4.935		19.9		0.17
Feb	99.2		3.998		18.2		0.15
Mar	103.4		4.614		20.2		0.17
Apr	110.5		4.772		22.1		0.18
May	110.3		4.922		18.3		0.15
Jun	18.9		0.817		18.9		0.16
Jul	71.0		3.168		18.5		0.15
Aug	110.7		4.944		19.6		0.16
Sep	110.6		4.778		15.4		0.13
Oct	110.7		4.940		20.5		0.17
Nov	107.9		4.661		19.0		0.16
Dec	111.0		4.955		16.2		0.14
Average	97.9	Total	51.504	Average	18.9	Average	0.16

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-19 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-19 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-19 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-19 was down from June 6 to July 18 for planned wellfield shutdown.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-4. Extraction Well 31561 (EW-20) Operational Summary for 2022

Reference Elevation (ft amsl): 578.77 (top of well)
Northing Coordinate (1983): 477,660.8
Easting Coordinate (1983): 1,349,254.5

Hours in reporting period: 8,760 | Hours pumped: 7,496.5 | Target pumping rate: 200 gpm
Hours not pumped: 1,263.5 | Operational percent: 85.58

Adjusted operational percent[a]: 97.00

Monthly Measurements at Wellfield

Month	Monthly Average Pumping Rate[b] (gpm)	Volume Pumped (Mgal)	Monthly Total Uranium Concentration[c] (µg/L)	Uranium Removal Index (lb of total uranium removed/Mgal pumped)
Jan	263.7	11.771	35.0	0.29
Feb	225.7	9.102	31.4	0.26
Mar	206.3	9.211	29.7	0.25
Apr	218.1	9.424	33.7	0.28
May	190.1	8.487	30.4	0.25
Jun	35.6	1.536	32.6	0.27
Jul	92.1	4.111	29.2	0.24
Aug	216.6	9.671	29.8	0.25
Sep	202.9	8.766	28.6	0.24
Oct	172.8	7.715	36.4	0.30
Nov	167.9	7.251	34.2	0.29
Dec	163.4	7.293	30.3	0.25
	Average 179.6	Total 94.337	Average 31.8	Average 0.27

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-20 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-20 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-20 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-20 was down from May 17 to May 19 for liquid acid descaler chemical treatment.
Well EW-20 was down from June 6 to July 18 for planned wellfield shutdown.
Well EW-20 was down from October 24 to October 25 for a Perasan A chemical treatment.
Well EW-20 was down from October 31 to November 1 for liquid acid descaler chemical treatment.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-5. Extraction Well 33326 (EW-17a) Operational Summary for 2022

Reference Elevation (ft amsl): 574.84 (top of well)
Northing Coordinate (1983): 477,905.5
Easting Coordinate (1983): 1,348,854.1

Hours in reporting period: 8,760
Hours not pumped: 1,289.0

Hours pumped: 7,471.0
Operational percent: 85.29

Adjusted operational percent[a]: 96.67

Target pumping rate: 175 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	189.5	8.457	11.3	0.09
Feb	173.5	6.997	10.4	0.09
Mar	176.9	7.896	10.7	0.09
Apr	190.3	8.220	11.9	0.10
May	186.1	8.308	10.0	0.08
Jun	31.8	1.375	10.4	0.00
Jul	68.8	3.071	11.8	0.10
Aug	194.7	8.692	10.2	0.09
Sep	194.7	8.412	9.5	0.08
Oct	194.8	8.695	11.3	0.09
Nov	191.2	8.258	10.7	0.09
Dec	195.1	8.709	8.7	0.07
	Average 165.6	Total 87.090	Average 10.6	Average 0.08

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-17A was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-17A was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-17A was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-17A was down from June 6 to July 18 for planned wellfield shutdown.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-6. Extraction Well 32276 (EW-22) Operational Summary for 2022

Reference Elevation (ft amsl): 567.14 (top of well)
Northing Coordinate (1983): 476,447.3
Easting Coordinate (1983): 1,348,857.3

Hours in reporting period: 8,760
Hours not pumped: 1,951.0

Hours pumped: 6,809.0
Operational percent: 77.73

Adjusted operational percent[a]: 88.11

Target pumping rate: 300 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	0.0	0.000	0.0	0.00
Feb	286.3	11.544	17.0	0.00
Mar	307.6	13.731	17.8	0.15
Apr	329.8	14.249	20.6	0.17
May	323.1	14.422	18.2	0.15
Jun	55.7	2.408	20.2	0.00
Jul	127.0	5.670	18.9	0.16
Aug	142.4	6.357	21.6	0.18
Sep	329.6	14.237	17.8	0.15
Oct	329.2	14.694	20.2	0.17
Nov	327.4	14.144	20.4	0.17
Dec	329.4	14.703	17.2	0.14
	Average 240.6	Total 126.159	Average 17.5	Average 0.12

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-22 was down from January 1 to February 2 due to bad motor, variable frequency drive, and motor cable.
Well EW-22 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-22 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-22 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-22 was down from June 6 to July 18 for planned wellfield shutdown.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-7. Extraction Well 32446 (EW-24) Operational Summary for 2022

Reference Elevation (ft amsl): 578.37 (top of well)
Northing Coordinate (1983): 476,634.5
Easting Coordinate (1983): 1,349,312.4

Hours in reporting period: 8,760
Hours not pumped: 2,631.0

Hours pumped: 6,129.0
Operational percent: 69.97

Adjusted operational percent[a]: 79.31

Target pumping rate: 400 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	374.6	16.723	27.6	0.23
Feb	38.3	1.544	27.6	0.23
Mar	9.4	0.419	27.6	0.23
Apr	379.7	16.403	27.9	0.23
May	362.6	16.185	23.0	0.19
Jun	62.7	2.710	24.6	0.00
Jul	142.4	6.357	21.6	0.18
Aug	369.4	16.489	21.7	0.18
Sep	344.9	14.900	22.2	0.19
Oct	348.3	15.548	26.7	0.22
Nov	233.0	10.067	25.8	0.22
Dec	438.8	19.588	22.7	0.19
	Average 258.7	Total 136.933	Average 24.9	Average 0.19

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-24 not meeting setpoint in most of 2022 due to high discharge pressure caused by plugged pipes; pipes were cleaned in November.
Well EW-24 was down from February 4 due to a locked pump.
Well EW-24 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-24 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-24 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-24 was down from June 6 to July 18 for planned wellfield shutdown.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-8. Extraction Well 32447 (EW-23) Operational Summary for 2022

Reference Elevation (ft amsl): 574.53 (top of well)
Northing Coordinate (1983): 477,150.2
Easting Coordinate (1983): 1,349,421.2

Hours in reporting period: 8,760
Hours not pumped: 1,240.5

Hours pumped: 7,519.5
Operational percent: 85.84

Adjusted operational percent[a]: 97.30

Target pumping rate: 500 gpm

Monthly Measurements at Wellfield							
Month		**Monthly Average Pumping Rate[b] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[c] (µg/L)**		**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		461.8		20.614		29.1		0.24
Feb		406.8		16.403		27.9		0.23
Mar		439.8		19.631		25.2		0.21
Apr		548.8		23.710		29.7		0.25
May		520.0		23.211		26.3		0.22
Jun		85.5		3.695		28.9		0.24
Jul		211.8		9.454		21.0		0.18
Aug		548.5		24.487		27.9		0.23
Sep		548.8		23.708		25.5		0.21
Oct		545.0		24.330		29.5		0.25
Nov		503.7		21.758		28.2		0.24
Dec		470.6		21.007		24.3		0.20
	Average	440.9	Total	232.006	Average	27.0	Average	0.22

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-23 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-23 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-23 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-23 was down from March 14 to March16 for liquid acid descaler chemical treatment.
Well EW-23 was down from June 6 to July 18 for planned wellfield shutdown and rehabilitation.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-9. Extraction Well 33061 (EW-25) Operational Summary for 2022

Reference Elevation (ft amsl): 575.56 (top of well)
Northing Coordinate (1983): 478,318.8
Easting Coordinate (1983): 1,349,531.0

Hours in reporting period: 8,760
Hours not pumped: 1,388.5

Hours pumped: 7,371.5
Operational percent: 84.15

Adjusted operational percent[a]: 95.39

Target pumping rate: 100 gpm

Monthly Measurements at Wellfield								
Month		**Monthly Average Pumping Rate[b] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[c] (µg/L)**		**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		108.6		4.848		23.8		0.20
Feb		99.5		4.011		20.3		0.17
Mar		96.1		4.288		19.9		0.17
Apr		111.0		4.797		23.2		0.19
May		109.1		4.870		19.2		0.16
Jun		19.1		0.825		19.6		0.00
Jul		52.5		2.345		21.1		0.18
Aug		110.7		4.941		17.8		0.15
Sep		110.8		4.787		18.9		0.16
Oct		110.6		4.937		20.5		0.17
Nov		101.1		4.369		21.4		0.18
Dec		112.2		5.010		19.6		0.16
	Average	95.1	Total	50.028	Average	20.4	Average	0.16

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-25 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-25 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-25 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-25 was down from March 14 to March 16 for liquid acid descaler chemical treatment.
Well EW-25 was down from June 6 to July 18 for planned wellfield shutdown.
Well EW-25 was down from October 25 to October 27 for a liquid acid descaler chemical treatment.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-10. Extraction Well 33262 (EW-15a) Operational Summary for 2022

Reference Elevation (ft amsl): 568.37 (top of well)
Northing Coordinate (1983): 477,799.9
Easting Coordinate (1983): 1,348,150.0

Hours in reporting period: 8,760
Hours not pumped: 1,252.0

Hours pumped: 7,508
Operational percent: 85.71

Adjusted operational percent[a]: 97.15

Target pumping rate: 300 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	328.8	14.676	23.2	0.19
Feb	301.3	12.146	22.8	0.19
Mar	307.6	13.729	24.5	0.20
Apr	329.5	14.236	28.1	0.23
May	322.6	14.402	25.0	0.21
Jun	55.5	2.398	24.9	0.21
Jul	116.4	5.197	29.6	0.25
Aug	329.4	14.703	25.6	0.21
Sep	329.4	14.229	22.3	0.19
Oct	306.5	13.681	23.1	0.19
Nov	327.9	14.164	20.3	0.17
Dec	329.2	14.695	16.1	0.13
	Average 282.0	Total 148.256	Average 23.8	Average 0.20

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-15A was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-15A was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-15A was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-15A was down from June 6 to July 18 for planned wellfield shutdown.
Well EW-15A was down from October 24 to October 26 for a Perasan A chemical treatment.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-11. Extraction Well 33264 (EW-30) Operational Summary for 2022

Reference Elevation (ft amsl): 573.82 (top of well)
Northing Coordinate (1983): 477,200.9
Easting Coordinate (1983): 1,349,751.5

Hours in reporting period: 8,760
Hours not pumped: 2,882.5

Hours pumped: 5,877.5
Operational percent: 67.09

Adjusted operational percent[a]: 76.05

Target pumping rate: 400 gpm

Monthly Measurements at Wellield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	438.5	19.573	12.3	0.10
Feb	402.3	16.220	10.9	0.09
Mar	403.5	18.012	10.8	0.09
Apr	415.1	17.932	11.5	0.10
May	393.7	17.574	9.3	0.08
Jun	74.3	3.209	9.2	0.00
Jul	0.0	0.000	0.0	0.00
Aug	0.0	0.000	0.0	0.00
Sep	332.0	14.344	5.7	0.05
Oct	438.7	19.585	8.3	0.07
Nov	427.4	18.463	8.9	0.07
Dec	202.4	9.033	7.7	0.06
	Average 294.0	Total 153.944	Average 7.9	Average 0.06

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-30 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-30 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-30 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-30 was down from May 3 to May 5 for liquid acid descaler chemical treatment.
Well EW-30 was down from June 6 to July 21 for planned wellfield shutdown and rehabilitation.
Well EW-30 was down from July 18 to September 8 for rehabilitation.
Well EW-30 was down from December 15 to December 31 due to excessive vibration.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-12. Extraction Well 33298 (EW-21a) Operational Summary for 2022

Reference Elevation (ft amsl): 576.21 (top of well)
Northing Coordinate (1983): 477,953.1
Easting Coordinate (1983): 1,349,499.9

Hours in reporting period: 8,760
Hours not pumped: 1,241.5

Hours pumped: 7,518.5
Operational percent: 85.83

Adjusted operational percent[a]: 97.29

Target pumping rate: 300 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	321.7	14.359	28.2	0.24
Feb	294.4	11.870	26.4	0.22
Mar	299.3	13.359	30.3	0.25
Apr	321.8	13.904	32.9	0.27
May	315.0	14.064	28.3	0.24
Jun	54.7	2.363	29.3	0.00
Jul	137.9	6.157	35.2	0.29
Aug	329.9	14.728	28.6	0.24
Sep	321.9	13.908	23.9	0.20
Oct	262.5	11.717	28.7	0.24
Nov	240.1	10.374	25.2	0.21
Dec	236.7	10.565	19.8	0.17
	Average 261.3	Total 137.368	Average 28.1	Average 0.21

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-21A was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-21A was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-21A was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-21A was down from June 6 to July 18 for planned wellfield shutdown.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-13. Extraction Well 3924 (RW-1) Operational Summary for 2022

Reference Elevation (ft amsl): 533.51 (top of well)
Northing Coordinate (1983): 474,219.7
Easting Coordinate (1983): 1,348,314.3

Hours in reporting period: 8,760 | Hours pumped: 6,352.5 | Target pumping rate: 200 gpm
Hours not pumped: 2,407.5 | Operational percent: 72.52

Monthly Measurements at Wellfield								
Month		**Monthly Average Pumping Rate[a] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[b] (µg/L)**		**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		201.7		9.002		12.5		0.10
Feb		194.3		7.833		11.7		0.10
Mar		204.9		9.146		11.9		0.10
Apr		214.2		9.255		12.6		0.11
May		206.0		9.197		9.9		0.08
Jun		35.9		1.551		10.4		0.00
Jul		141.1		6.297		8.7		0.07
Aug		217.6		9.713		9.6		0.08
Sep		218.7		9.449		10.0		0.08
Oct		28.8		1.284		11.4		0.10
Nov		0.0		0.000		0.0		0.00
Dec		217.6		9.715		10.6		0.09
	Average	156.79	Total	82.442	Average	9.9	Average	0.08

[a] Well RW-1 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-1 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well RW-1 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well RW-1 was down from June 6 to June 16 for rehabilitation. The well could not be restarted until July 12, 2022.
Well RW-1 was down from October 5 to December 1 due to a leak in the pitless adaptor.
[b] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-14. Extraction Well 3925 (RW-2) Operational Summary for 2022

Reference Elevation (ft amsl): 542.01 (top of well)
Northing Coordinate (1983): 474,319.7
Easting Coordinate (1983): 1,348,565.4

Hours in reporting period: 8,760
Hours not pumped: 1,043.0
Hours pumped: 7,717.0
Operational percent: 88.9
Target pumping rate: 200 gpm

Monthly Measurements at Wellfield							
Month	Monthly Average Pumping Rate[a] (gpm)		Volume Pumped (Mgal)		Monthly Total Uranium Concentration[b] (µg/L)		Uranium Removal Index (lb of total uranium removed/Mgal pumped)
Jan	194.9		8.702		14.1		0.12
Feb	178.3		7.190		13.7		0.11
Mar	173.1		7.728		13.7		0.11
Apr	151.4		6.541		16.1		0.13
May	145.9		6.512		14.3		0.12
Jun	230.7		9.967		13.3		0.11
Jul	165.2		7.375		12.3		0.10
Aug	163.9		7.318		12.3		0.10
Sep	124.8		5.393		13.0		0.11
Oct	88.1		3.933		15.4		0.13
Nov	4.7		0.203		15.4		0.13
Dec	217.3		9.698		11.1		0.09
Average	153.2	Total	80.560	Average	13.7	Average	0.11

[a] Well RW-2 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-2 was down from February 25 to February 26 due to high river levels in the Great Miami
Well RW-2 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well RW-2 was down from May 17 to May 19 for liquid acid descaler chemical treatment.
Well RW-2 was down from November 3 to December 1 to replace the pump.
[b] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-15. Extraction Well 3926 (RW-3) Operational Summary for 2022

Reference Elevation (ft amsl): 586.73 (top of well)
Northing Coordinate (1983): 474,428.6
Easting Coordinate (1983): 1,348,837.5

Hours in reporting period: 8,760 | Hours pumped: 6,448.5 | Target pumping rate: 200 gpm
Hours not pumped: 2,311.5 | Operational percent: 73.61

Monthly Measurements at Wellfield								
Month		**Monthly Average Pumping Rate[a] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[b] (µg/L)**		**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		189.1		8.441		21.1		0.18
Feb		159.5		6.431		20.9		0.17
Mar		154.4		6.891		21.8		0.18
Apr		117.6		5.082		23.0		0.19
May		0.0		0.000		19.8		0.00
Jun		0.0		0.000		0.0		0.00
Jul		30.5		1.363		28.1		0.23
Aug		225.3		10.058		21.0		0.18
Sep		209.5		9.051		19.4		0.16
Oct		180.7		8.068		21.2		0.18
Nov		155.9		6.736		21.9		0.18
Dec		190.3		8.496		17.2		0.14
	Average	134.4	Total	70.616	Average	19.6	Average	0.15

[a] Well RW-3 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-3 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well RW-3 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well RW-3 was down from April 30 to July 28 due to maintenance problems and annual wellfield shutdown.
[b] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-16. Extraction Well 3927 (RW-4) Operational Summary for 2022

Reference Elevation (ft amsl): 591.84 (top of well)
Northing Coordinate (1983): 474,541.8
Easting Coordinate (1983): 1,349,127.3

Hours in reporting period: 8,760 | Hours pumped: 3,542 | Target pumping rate: 200/100[a] gpm
Hours not pumped: 5,218 | Operational percent: 40.43

Monthly Measurements at Wellfield								
Month		**Monthly Average Pumping Rate[b] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[c] (µg/L)**		**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		124.7		5.568		3.8		0.03
Feb		115.8		4.668		3.0		0.03
Mar		107.1		4.779		3.3		0.03
Apr		84.9		3.667		3.9		0.03
May		103.1		4.603		3.3		0.03
Jun		20.0		0.863		6.0		0.05
Jul		0.0		0.000		0.0		0.00
Aug		0.0		0.000		0.0		0.00
Sep		0.0		0.000		0.0		0.00
Oct		0.0		0.000		0.0		0.00
Nov		0.0		0.000		0.0		0.00
Dec		0.0		0.000		0.0		0.00
	Average	46.3	Total	24.149	Average	1.9	Average	0.03

[a] The target pumping rate changed from 200 to 100 gpm in July 2018.
[b] Well RW-4 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-4 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well RW-4 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well RW-4 was down from May 3 to May 5 for liquid acid descaler chemical treatment.
Well RW-4 was turned off permanently on June 6, 2022.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-17. Extraction Well 32308 (RW-6) Operational Summary for 2022

Reference Elevation (ft amsl): 582.05 (top of casing)
Northing Coordinate (1983): 475,078.8
Easting Coordinate (1983): 1,348,693.9

Hours in reporting period: 8,760
Hours not pumped: 5,007.5

Hours pumped: 3,752.5
Operational percent: 83.28

Adjusted operational percent[a]: 48.56

Target pumping rate: 300 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	202.9	9.058	31.5	0.26
Feb	193.6	7.804	28.5	0.24
Mar	204.2	9.115	28.2	0.24
Apr	202.8	8.762	31.6	0.26
May	186.0	8.303	27.1	0.23
Jun	30.4	1.312	28.5	0.00
Jul	43.1	1.924	12.3	0.10
Aug	0.0	0.000	0.0	0.00
Sep	0.0	0.000	0.0	0.00
Oct	0.0	0.000	0.0	0.00
Nov	0.0	0.000	0.0	0.00
Dec	0.0	0.000	0.0	0.00
	Average 88.6	Total 46.278	Average 15.6	Average 0.11

[a] Adjusted for planned annual wellfield shutdown.
[b] Well RW-6 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-6 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well RW-6 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well RW-6 was down from June 6 to July 18 for planned wellfield shutdown.
Well RW-6 was shut down permanently on July 25 due to an underground leak.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-18. Extraction Well 32309 (RW-7) Operational Summary for 2022

Reference Elevation (ft amsl): 582.05 (top of casing)
Northing Coordinate (1983): 475,109.6
Easting Coordinate (1983): 1,348,366.3

Hours in reporting period: 8,760
Hours not pumped: 1,545.5

Hours pumped: 7,214.5
Operational percent: 27.92

Adjusted operational percent[a]: 93.36

Target pumping rate: 300 gpm

Monthly Measurements at Wellfield							
Month		**Monthly Average Pumping Rate[b] (gpm)**		**Volume Pumped (Mgal)**		**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan		202.3		9.031		23.2	0.19
Feb		193.5		7.800		20.4	0.17
Mar		204.4		9.123		19.8	0.17
Apr		218.5		9.441		22.2	0.19
May		213.7		9.538		19.3	0.16
Jun		36.8		1.591		21.7	0.00
Jul		98.0		4.374		12.3	0.10
Aug		214.0		9.555		18.9	0.16
Sep		218.2		9.428		19.7	0.16
Oct		218.4		9.750		23.3	0.19
Nov		108.4		4.682		19.8	0.17
Dec		218.4		9.750		19.4	0.16
	Average	178.7	Total	94.064	Average	20	Average 015

[a] Adjusted for planned annual wellfield shutdown.
[b] Well RW-7 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well RW-7 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well RW-7 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well RW-7 was down from June 6 to July 18 for planned wellfield shutdown.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-19. PRRS Groundwater Summary Statistics and Trend Analysis

Analyte	Monitoring Well	Number of Samples[a,b,c]	Minimum[a,b,c,d] (mg/L)	Maximum[a,b,c,d] (mg/L)	Average[a,b,c,d] (mg/L)	SD[a,b,c,d,e]	Trend[a,b,c,d,f]
Arsenic	2128	254	0.000195	0.188	0.0108	0.0200	Down
	2636	192	0.0100	0.0939	0.0432	0.0186	Down
	2898	71	0.000147	0.0820	0.00408	0.0104	No Trend[g]
	2899	64	0.000320	0.0283	0.00254	0.00385	No Trend[g]
	2900	253	0.000320	0.0609	0.00485	0.00529	Down
	3128	74	0.000400	0.234	0.00677	0.0272	No Trend
	3636	71	0.000500	0.0233	0.00292	0.00370	No Trend[g]
	3898	71	0.000500	0.0434	0.00423	0.00615	No Trend[g]
	3899	72	0.000147	0.0307	0.00282	0.00444	No Trend[g]
	3900	72	0.000375	0.0208	0.00301	0.00353	No Trend
Phosphorus	2128	80	0.0250	16.2	1.25	2.23	Down
	2636	44	9.60	170	77.2	42.4	Down
	2898	72	0.0050	9.95	0.218	1.19	Down
	2899	63	0.0050	0.831	0.0537	0.108	No Trend
	2900	70	0.0431	4.74	0.429	0.615	Down
	3128	81	0.0050	13.0	0.216	1.44	No Trend
	3636	70	0.0091	1.10	0.0662	0.133	No Trend
	3898	70	0.0075	1.24	0.0905	0.160	Down
	3899	71	0.0050	1.86	0.105	0.252	Down
	3900	72	0.0050	1.38	0.0817	0.218	Down
Potassium	2128	72	0.830	18.0	3.14	3.07	Down
	2636	44	4.60	218	57.0	49.3	Down
	2898	72	1.11	9.64	4.40	1.13	Up
	2899	64	1.36	8.85	4.11	0.898	Up
	2900	71	0.0095	6.00	1.94	1.04	No Trend
	3128	74	1.09	3.70	1.88	0.604	Down
	3636	70	1.09	4.24	2.08	0.568	Down
	3898	71	0.610	4.23	2.73	0.739	Up
	3899	72	0.875	4.55	2.86	0.798	Up
	3900	72	0.975	3.19	1.69	0.372	Down
Sodium	2128	72	12.3	75.2	33.1	11.2	Down
	2636	44	14.4	148	47.6	26.8	Down
	2898	72	4.95	31.0	19.8	4.69	Up
	2899	64	11.2	25.1	17.9	3.33	Up
	2900	71	0.0136	43.3	25.1	7.9	Down
	3128	74	3.52	13.4	5.44	2.44	Down
	3636	70	3.14	13.0	5.59	2.62	Down
	3898	71	7.29	28.8	13.0	5.77	Up
	3899	72	6.24	43.6	14.2	10.1	Up
	3900	72	3.13	10.8	4.72	1.68	Down

[a] The data are based on unfiltered samples from the Operable Unit 5 Remedial Investigation/Feasibility Study dataset (1988–1993) and 1994 through 2022 groundwater data (unfiltered and filtered for 2001–2022).

[b] If more than one sample is collected per well per day (e.g., duplicate), then only one sample is counted for the total number of samples, and the sample with the maximum concentration is used to determine the summary statistics (minimum, maximum, average, standard deviation, and Mann-Kendall test for trend).

[c] Rejected data qualified with an R were not included in this count or the summary statistics.

[d] Where concentrations are below the detection limit, each result used in the summary statistics is set at half the detection limit.

[e] SD = standard deviation.

[f] Trend starts on August 27, 1993, and is based on the startup of the South Plume extraction wells (DOE 1993). This Mann-Kendall test for trend is performed with a 95% confidence interval.
[g] The original statistics indicated an upward trend; however, the upward trend was due to a slight increase in the method detection limit for nondetected concentrations. As a result, “No Trend” is indicated.

Table A.1-20. Extraction Well 32761 (EW-26) Operational Summary for 2022

Reference Elevation (ft amsl): 570.88 (top of casing)
Northing Coordinate (1983): 479,892.4
Easting Coordinate (1983): 1,347,364.0

Hours in reporting period: 8,760
Hours not pumped: 2,198.0

Hours pumped: 6,562
Operational percent: 74.918

Adjusted operational percent[a]: 84.91

Target pumping rate: 300 gpm

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	328.1	14.647	22.1	0.18
Feb	296.8	11.967	21.1	0.18
Mar	285.9	12.764	15.9	0.13
Apr	320.9	13.863	24.6	0.21
May	280.9	12.538	21.1	0.18
Jun	55.4	2.393	22.6	0.19
Jul	0.0	0.000	0.0	0.00
Aug	58.7	2.619	22.6	0.19
Sep	307.1	13.268	20.7	0.17
Oct	319.3	14.255	22.5	0.19
Nov	312.3	13.491	21.3	0.18
Dec	319.2	14.251	18.4	0.15
	Average 240.4	Total 126.057	Average 19.4	Average 0.16

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-26 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-26 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-26 was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-26 was down from March 15 to March 17 for liquid acid descaler chemical treatment.
Well EW-26 was down on May 30 due to overheating variable frequency drive.
Well EW-26 was down from June 6 to July 18 for planned wellfield shutdown.
Well EW-26 was down from July 18 to August 24 for rehabilitation.
Well EW-26 was down from June 1 to July 9 for planned annual wellfield shutdown.
Well EW-26 was down from July 26 to August 5 due to sitewide power outage for substation breaker replacement.
Well EW-26 was down from August 10 to August 19 for rehabilitation.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-21. Extraction Well 33062 (EW-27) Operational Summary for 2022

Reference Elevation (ft amsl): 575.10 (top of casing)
Northing Coordinate (1983): 480,013.0
Easting Coordinate (1983): 1,348,037.2

Hours in reporting period: 8,760
Hours not pumped: 1,040.0

Hours pumped: 7,720.0
Operational percent: 88.13

Adjusted operational percent[a]: 99.89

Target pumping rate: 200 gpm

Month	Monthly Average Pumping Rate[b] (gpm)	Volume Pumped (Mgal)	Monthly Total Uranium Concentration[c] (µg/L)	Uranium Removal Index (lb of total uranium removed/Mgal pumped)
	Monthly Measurements at Wellfield			
Jan	203.6	9.089	22.9	0.19
Feb	201.4	8.122	23.9	0.20
Mar	201.9	9.011	22.9	0.19
Apr	219.9	9.498	25.6	0.21
May	215.3	9.613	21.4	0.18
Jun	93.8	4.052	23.5	0.20
Jul	98.8	4.408	22.1	0.18
Aug	211.5	9.443	22.5	0.19
Sep	197.9	8.551	21.0	0.18
Oct	173.8	7.757	25.5	0.21
Nov	219.0	9.459	22.3	0.19
Dec	219.6	9.802	20.6	0.00
	Average 188.0	Total 98.805	Average 22.85	Average 0.18

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-27 was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-27 was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-27was down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-27 was down from June 6 to July 18 for planned wellfield shutdown.
Well EW-27 was down from October 25 to October 27 for liquid acid descaler chemical treatment.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-22. Extraction Well 33347 (EW-33a) Operational Summary for 2022

Reference Elevation (ft amsl): 574.86 (top of casing)
Northing Coordinate (1983): 481,031.8
Easting Coordinate (1983): 1,346,715.8

Hours in reporting period: 8,760 | Hours pumped: 5,899.0 | Target pumping rate: 300 gpm
Hours not pumped: 2,861.0 | Operational percent: 67.33

Adjusted operational percent[a]: 76.33

Monthly Measurements at Wellfield				
Month	**Monthly Average Pumping Rate[b] (gpm)**	**Volume Pumped (Mgal)**	**Monthly Total Uranium Concentration[c] (µg/L)**	**Uranium Removal Index (lb of total uranium removed/Mgal pumped)**
Jan	300.8	13.429	21.5	0.18
Feb	273.7	11.035	20.9	0.17
Mar	262.9	11.736	17.6	0.15
Apr	304.4	13.150	23.2	0.19
May	192.8	8.608	19.0	0.16
Jun	0.0	0.000	0.0	0.00
Jul	0.0	0.000	0.0	0.00
Aug	3.1	0.139	19.0	0.16
Sep	214.2	9.252	26.4	0.22
Oct	319.2	14.247	24.3	0.20
Nov	295.5	12.766	23.1	0.19
Dec	288.8	12.890	19.0	0.16
	Average 204.6	Total 107.252	Average 17.83	Average 0.15

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-33A was down from February 18 to February 19 due to high river levels in the Great Miami River.
Well EW-33A was down from February 25 to February 26 due to high river levels in the Great Miami River.
Well EW-33Awas down from March 7 to March 9 due to high water levels in the Great Miami River.
Well EW-33A was down from March 15 to March 17 for liquid acid descaler chemical treatment.
Well EW-33A was down from May 24 to May 26 for LAD chemical treatment.
Well EW-33A was down from May 25 due to overheated variable frequency drive.
Well EW-33A was down from May 28 to September 9 due to overheated variable frequency drive, and for rehabilitation.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-23. Stretch Exponential Regression Equations for Uranium Concentration Data Collected at Extraction Wells—Through December 31, 2022

Extraction Well Number	Database Identification	Stretched Exponential Equations
RW-1	3924	$y = 68.91e^{-(x/4259.7)\wedge 0.7382}$
RW-2	3925	$y = 44.97e^{-(x/6560.6)\wedge 0.5112}$
RW-3	3926	$y = 59.52e^{-(x/9760.6)\wedge 0.0001}$
RW-4	3927	$y = 7.88e^{-(x/9983.7)\wedge 0.0001}$
RW-6	32308	$y = 81.1e^{-(x/6174.8)\wedge 0.4924}$
RW-7	32309	$y = 85.16e^{-(x/4640.9)\wedge 0.7716}$
EW-15a	33262	$y = 98.29e^{-(x/2076.9)\wedge 0.3373}$
EW-17a	33326	$y = 42.38e^{-(x/5968.9)\wedge 1}$
EW-18	31550	$y = 500e^{-(x/0.23)\wedge 0.0976}$
EW-19	31560	$y = 155.41e^{-(x/1416.4)\wedge 0.5091}$
EW-20	31561	$y = 109.83e^{-(x/1014.7)\wedge 0.1297}$
EW-21a	33298	$y = 160.79e^{-(x/2485.8)\wedge 0.5148}$
EW-22	32276	$y = 314.35e^{-(x/1087.2)\wedge 0.5478}$
EW-23	32447	$y = 409.67e^{-(x/627.2)\wedge 0.3831}$
EW-24	32446	$y = 111.11e^{-(x/3705.4)\wedge 0.5281}$
EW-25	33061	$y = 59.23e^{-(x/7049.5)\wedge 0.5751}$
EW-30	33264	$y = 163.94e^{-(x/1799.1)\wedge 0.7394}$
EW-26	32761	$y = 164.43e^{-(x/985.4)\wedge 0.401}$
EW-27	33062	$y = 251.58e^{-(x/470.1)\wedge 0.3599}$
EW-33a	33347	$y = 500e^{-(x/0.0001)\wedge 0.067}$

Table A.1-24. Estimate of Pounds of Uranium to Be Removed to Achieve Concentration-Based FRL Goals

Year	Based on Concentration Data and use of Use of Stretched Exponential Equations	Based on Model Predictions	Based on 95% UCL
2023	405	382	492
2024	390	313	481
2025	377	272	471
2026	239	200	301
2027	232	176	296
2028	226	157	292
2029	220	143	287
2030	215	132	284
2031	210	122	280
2032	205	114	276
2033	200	107	273
2034	59	39	86
2035	58	37	85
2036	56	35	84
2037	55	33	83
2038	54	32	82
2039	53	31	81
2040	51	30	80
Estimate of total to be extracted	3,305	2,355	4,314
Actual net pounds extracted through December 31, 2022	*15,751*	*15,751*	*15,751*
Estimate of total pounds to be extracted to achieve concentration-based FRL goals.	19,056	18,106	20,065
Year	**Estimate of Mass Removal Completeness Based on Concentration Data**	**Estimate of Mass Removal Completeness Based on Model Predictions**	**Estimate of Mass Removal Completeness Based on 95% UCL of Concentration Data**
2022	83%	87%	79%

Table A.1-25. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations

Extraction Well	Model-Predicted Total Uranium Concentration December 2022 (µg/L)	Total Uranium Concentration December 2022 (µg/L)	Residual Total Uranium Concentration[a] (µg/L)
3924 (RW-1)	4.78	10.6	5.8
3925 (RW-2)	7.94	11.1	3.2
3926 (RW-3)	7.52	17.2	9.7
3927 (RW-4)	2.25	0.0	–2.3
32308 (RW-6)	14.76	0.0	–14.8
32309 (RW-7)	12.88	19.4	6.5
33262 (EW-15a)	17.33	16.1	–1.2
33326 (EW-17a)	7.77	8.7	0.9
31550 (EW-18)	16.29	27.9	11.6
31560 (EW-19)	27.54	16.2	–11.3
31561 (EW-20)	30.06	30.3	0.2
33298 (EW-21a)	25.51	19.8	–5.7
32276 (EW-22)	11.35	17.2	5.9
32447 (EW-23)	20.5	24.3	3.8
32446 (EW-24)	8.51	22.7	14.2
33061 (EW-25)	33.01	19.6	–13.4
32761 (EW-26)	15.91	18.4	2.5
33062 (EW-27)	10.2	20.6	10.4
33264 (EW-30)	6.83	7.7	0.9
33347 (EW-33a)	136.13	19.0	–117.1
2022 Average	20.85	16.3	–4.5
2022 Standard Deviation	28.49	8.0	27.7
2022 Maximum	136.13	30.3	14.2
2022 Minimum	2.25	0.0	–117.1
2022 Range	133.88	30.3	131.3
2021 Average	13.2	20.2	7.07
2021 Standard Deviation	5.91	7.90	8.0
2021 Maximum	26.28	31.6	18.4
2021 Minimum	3.23	2.80	–13.3
2021 Range	23.05	28.8	31.7
2020 Average	14.1	20.7	6.66
2020 Standard Deviation	6.8	7.90	8.0
2020 Maximum	29.8	32.3	18.6
2020 Minimum	3.23	2.90	–13.0
2020 Range	26.6	29.4	31.6
2019 Average	15.3	19.9	4.70
2019 Standard Deviation	7.8	8.20	9.10
2019 Maximum	34.0	34.8	20.5
2019 Minimum	3.23	2.80	–14.6
2019 Range	30.8	32.0	35.1
2018 Average	16.8	21.1	4.3

Table A.1-25. Comparison of Model-Predicted Versus Actual Total Uranium Concentration (continued)

Extraction Well	Model-Predicted Total Uranium Concentration December 2022 (µg/L)	Total Uranium Concentration December 2022 (µg/L)	Residual Total Uranium Concentration[a] (µg/L)
2018 Standard Deviation	9.0	8.5	9.7
2018 Maximum	39.5	37.2	20.9
2018 Minimum	3.22	2.80	–16.6
2018 Range	36.3	34.4	37.6
2017 Average	18.5	22.0	3.5
2017 Standard Deviation	10.4	8.70	11.4
2017 Maximum	46.5	40.9	22.0
2017 Minimum	3.20	2.60	–26.8
2017 Range	43.3	38.3	48.8
2016 Average	20.5	23.5	2.99
2016 Standard Deviation	15.1	8.50	14.3
2016 Maximum	55.84	44.4	21.7
2016 Minimum	3.18	3.80	–35.4
2016 Range	52.7	40.6	57.1
2015 Average	23.1	22.6	–0.48
2015 Standard Deviation	15.1	8.50	15.4
2015 Maximum	69.2	41.0	14.7
2015 Minimum	3.16	3.60	–50.4
2015 Range	66.0	37.4	65.1

[a] Residual total uranium concentration = actual total uranium concentration – model-predicted total uranium concentration.

Table A.1-26. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations in Selected Monitoring Wells

Well Number	Observed Total Uranium Concentrations 1st Half 2022 (µg/L)	Predicted Total Uranium Concentrations[a] April 1, 2022 (µg/L)	Total Uranium Concentration Residuals (µg/L)
2045	51.1	24.80	26.30
2046	18.8	24.00	–5.20
2049	278	14.12	263.88
2093	3.62	2.63	0.99
2385	16.4	26.22	–9.82
2386	146	108.22	37.78
2387	144	44.47	99.53
2821	7.36	6.18	1.18
23271	53.6	29.00	24.60
23273	79.2	55.91	23.29
23274	67.9	82.36	–14.46
23275	76.6	37.41	39.19
23276	90.7	37.80	52.90
23278	24.2	13.87	10.33
23280	24.8	31.90	–7.10
23281	133	41.77	91.23
82433_C2	3.38	10.64	–7.26
83117_C2	19.9	31.34	–11.44
83124_C2	20.5	53.08	–32.58
83293_C2	2.42	3.77	–1.35
83294_C2	116	55.29	60.71
83295_C2	60.4	27.19	33.21
83296_C2	23.6	19.87	3.73
2022 Average	63.54	33.99	29.55
2022 Standard Deviation	65.71	25.12	61.02
2022 Maximum	278.00	108.22	263.88
2022 Minimum	2.42	2.63	–32.58
2022 Range	275.58	105.59	296.46

[a] Model predictions based on nominal water levels.

Table A.1-27. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations with Select Wells Removed

Well Number[a]	Observed Total Uranium Concentrations 1st Half 2022 (µg/L)	Predicted Total Uranium Concentrations April 1, 2022[b] (µg/L)	Total Uranium Concentration Residuals (µg/L)
2045	51.1	13.0	46.8
2046	18.8	18.8	–4.52
2093	3.62	2.63	0.99
2385	16.4	60.0	–9.82
2386	146.0	108.22	37.78
2821	7.36	6.18	1.18
23271	53.6	29.00	24.60
23273	79.2		
23274	67.9	82.36	–14.46
23275	76.6	37.41	39.19
23278	24.2	13.87	10.33
23280	24.8	31.90	–7.10
82433_C2	3.38	10.64	–7.26
83117_C2	19.9	31.34	–11.44
83124_C2	20.5	53.08	–32.58
83293_C2	2.42	3.77	–1.35
83295_C2	60.4	27.19	33.21
83296_C2	23.6	19.87	3.73
2022 Average	38.88	32.69	6.19
2022 Standard Deviation	37.00	27.46	20.25
2022 Maximum	146.00	108.22	39.19
2022 Minimum	2.42	2.63	–32.58
2022 Range	143.58	105.59	71.77

[a] Data from monitoring wells 2386, 2387, 23273, 23275, 23281, and 83294_C2 are not presented.
[b] Model predictions are based on nominal water levels.

Table A.1-28. Extraction Well Target Pumping Rates

Extraction Well	Target Pumping Rate (gpm)
South Plume	
3924 (RW-1)	200
3925 (RW-2)	200
3926 (RW-3)	200
3927 (RW-4)	200/100[a]
32308 (RW-6)	300
32309 (RW-7)	300
Subtotal	1,300
Waste Storage Area	
32761 (EW-26)	300
33062 (EW-27)	200
33347 (EW-33a)	300
Subtotal	800
South Field Extraction	
31550 (EW-18)	100
31560 (EW-19)	100
31561 (EW-20)	200
33298 (EW-21a)	300
33326 (EW-17a)	175
32276 (EW-22)	300
32446 (EW-24)	400
32447 (EW-23)	500
33061 (EW-25)	100
33264 (EW-30)	400
33262 (EW-15a)	300
Subtotal	2,875
Total Pumping	4,975[a]

[a] Pumping rate was changed from 200 gpm to 100 gpm in July 2018.

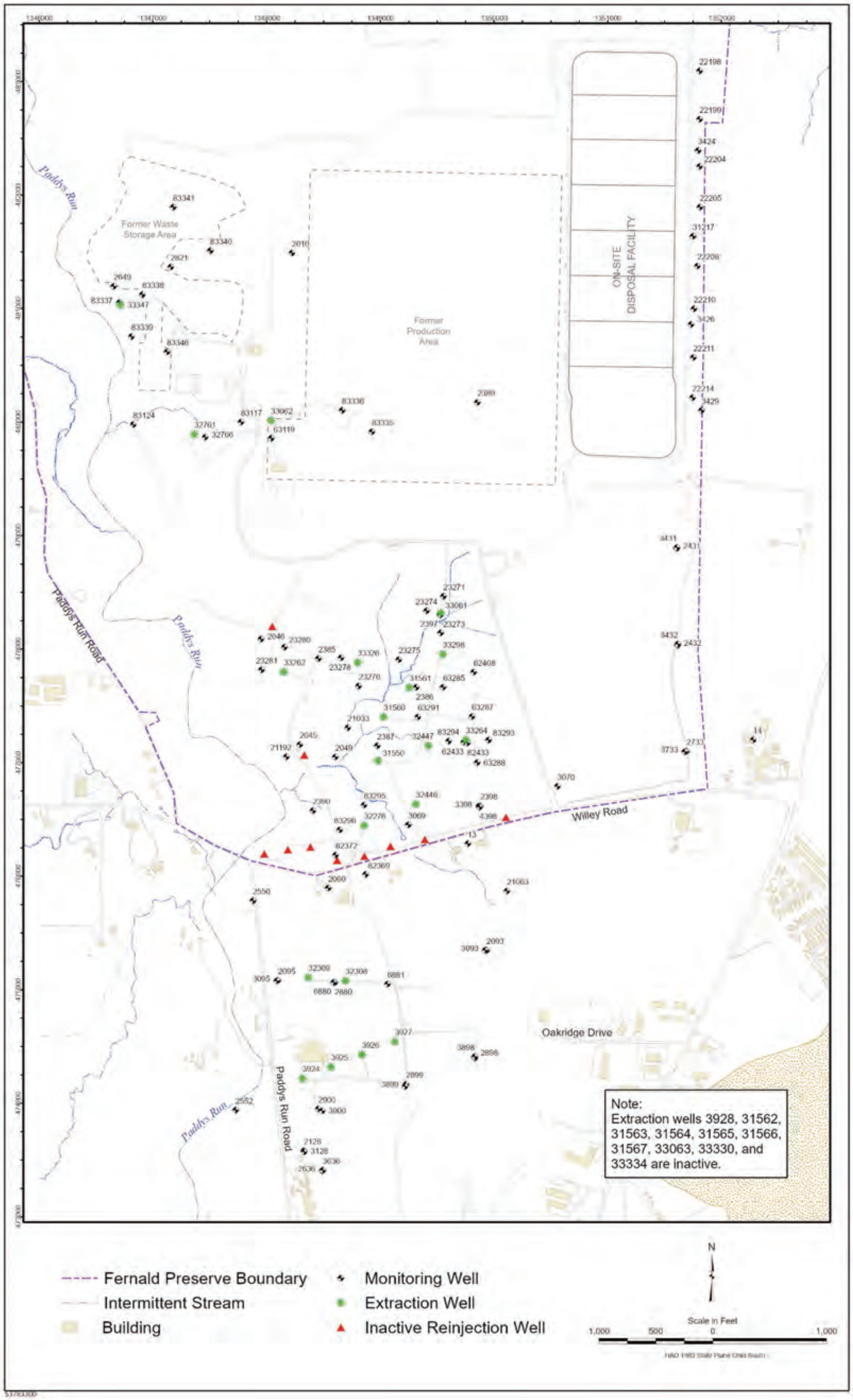

Figure A.1-1. Well Locations for South Plume, South Field, WSA, and PRRS Monitoring Activities

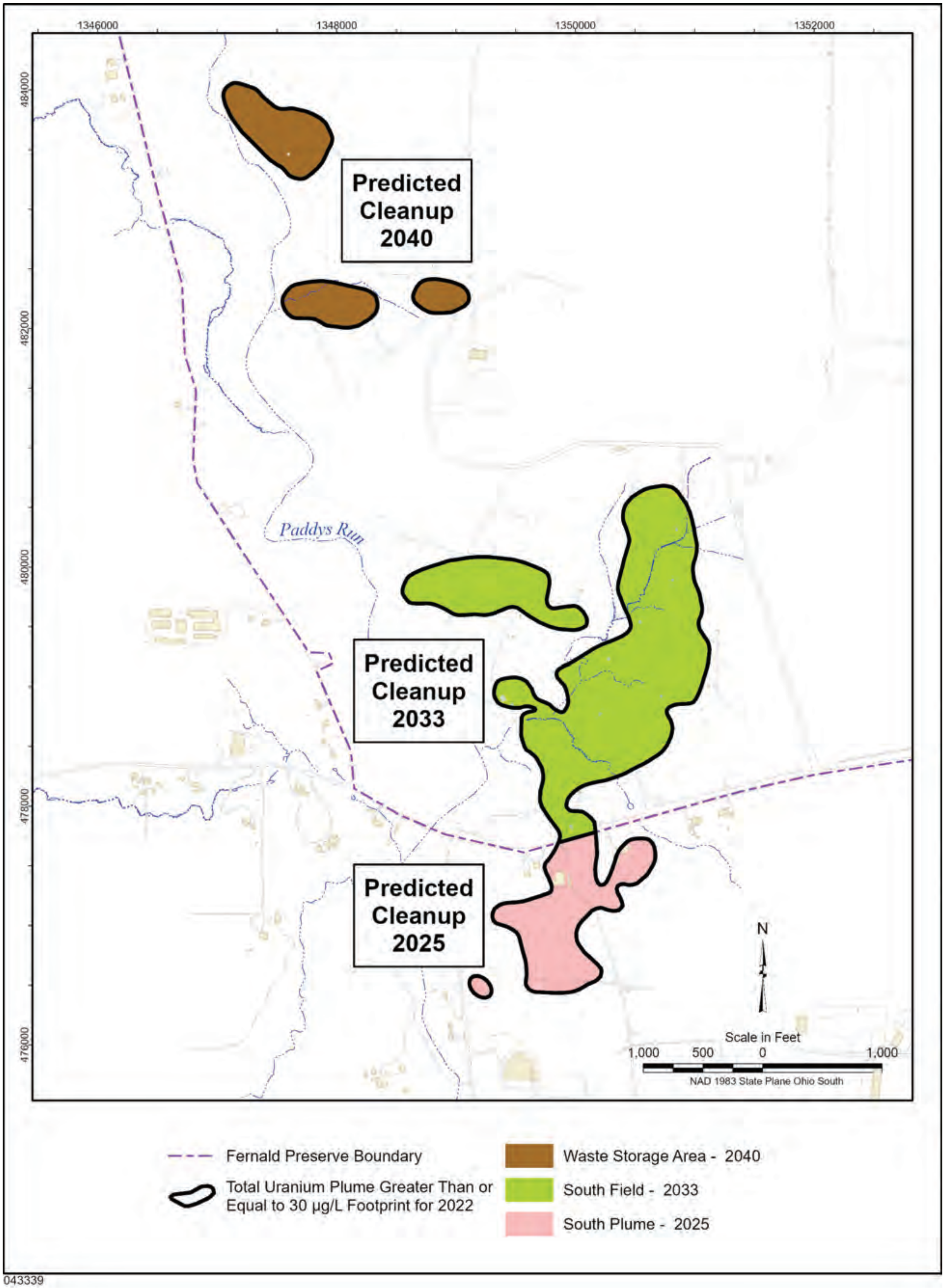

Figure A.1-2. Operational Design

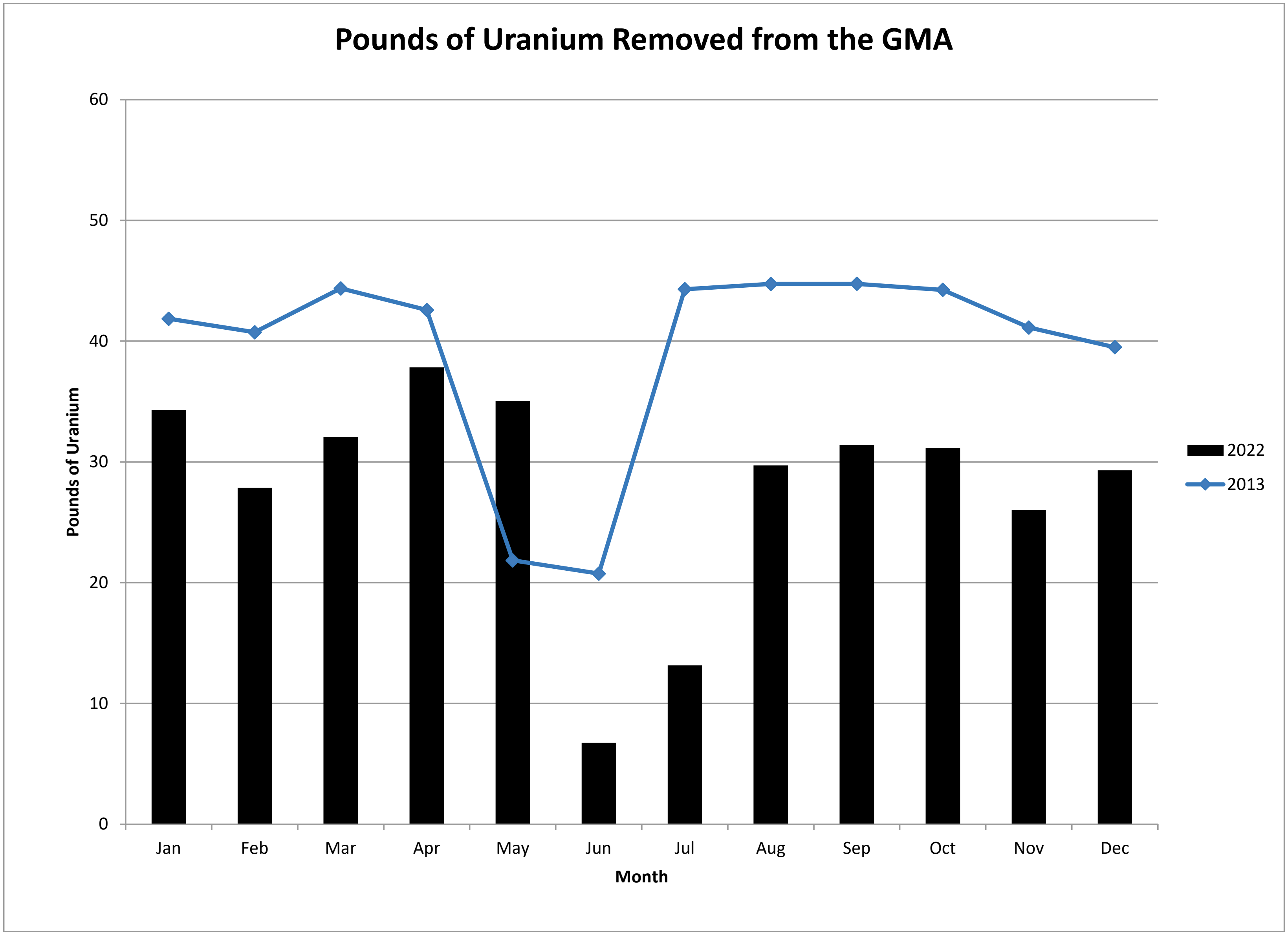

Figure A.1-3. Pounds of Uranium Removed from the GMA

Figure A.1-4. Clean Pump (Top) Versus Iron-Fouled Pump (Bottom)

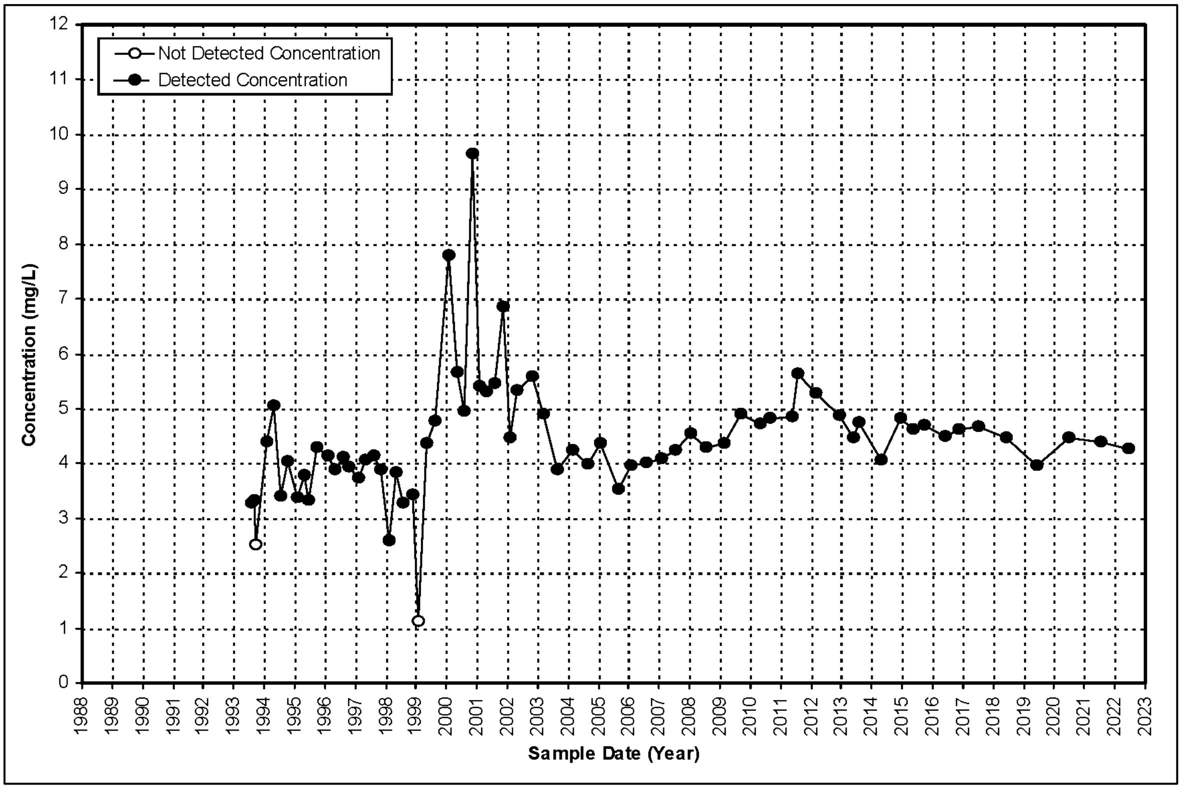

Figure A.1-5. Potassium Concentration Versus Time Plot for Monitoring Well 2898

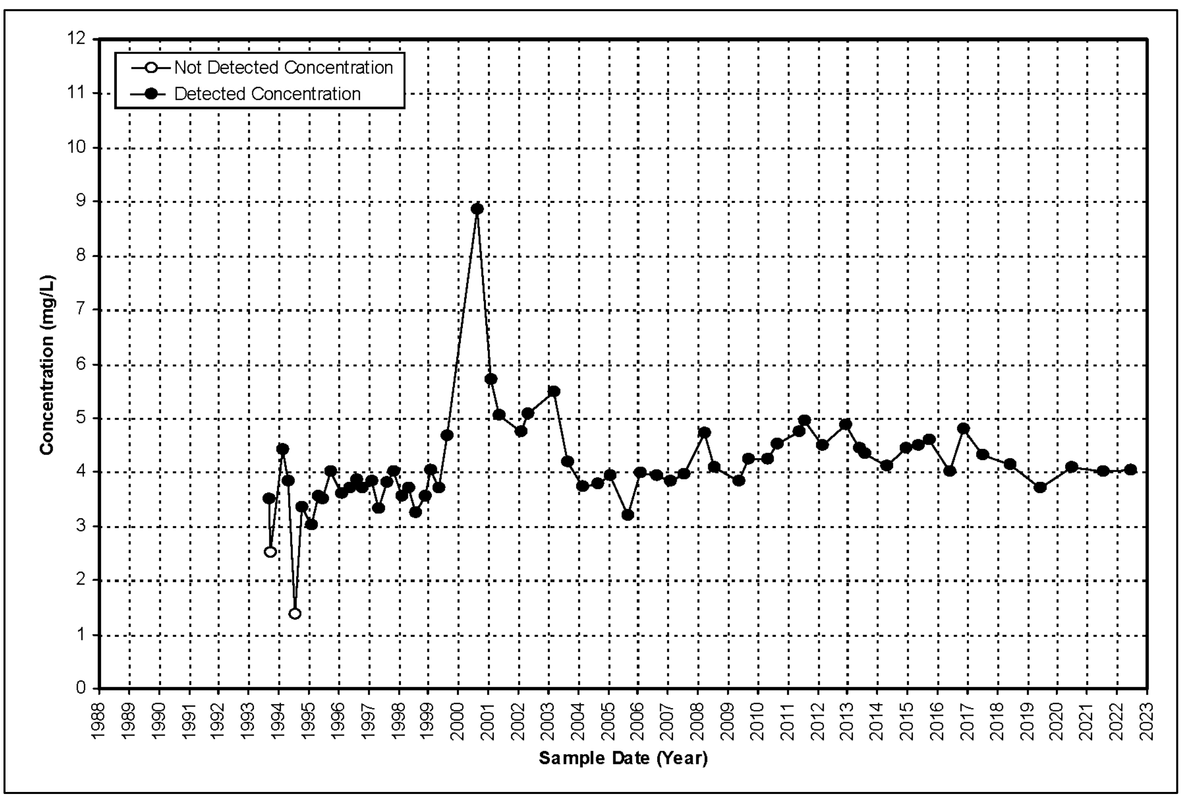

Figure A.1-6. Potassium Concentration Versus Time Plot for Monitoring Well 2899

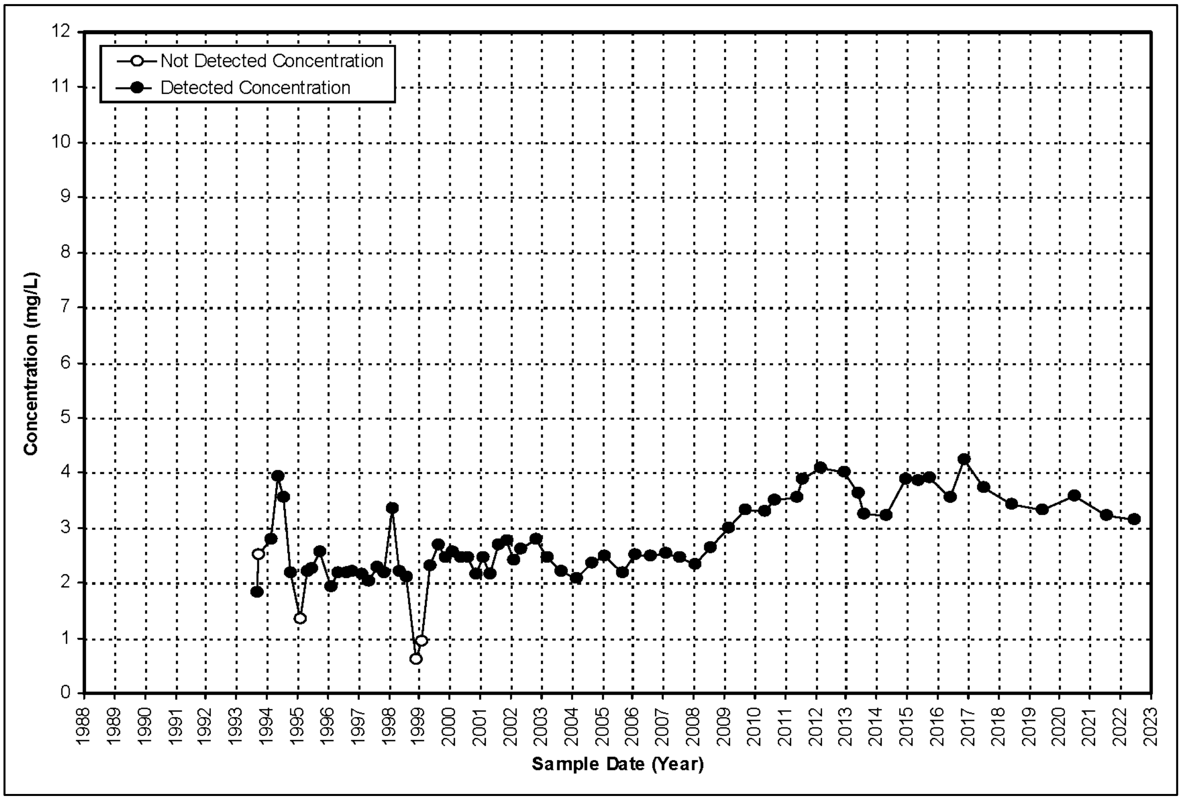

Figure A.1-7. Potassium Concentration Versus Time Plot for Monitoring Well 3898

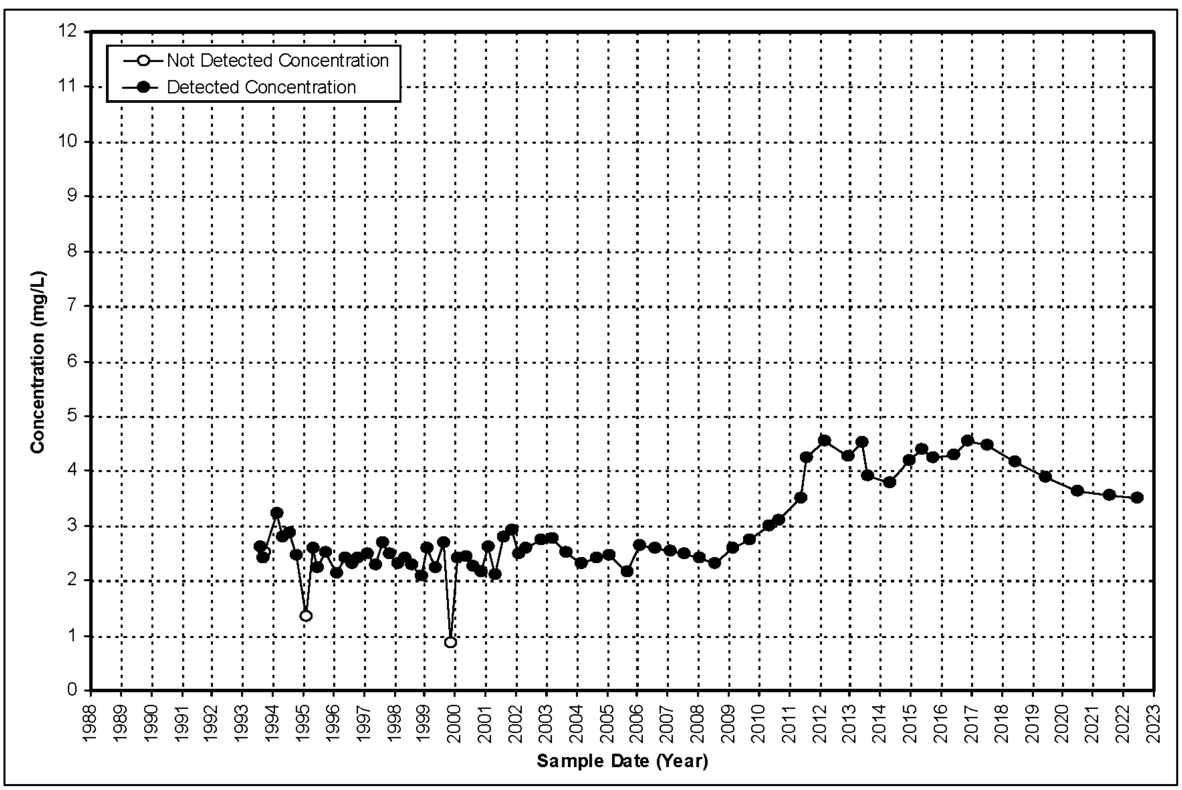

Figure A.1-8. Potassium Concentration Versus Time Plot for Monitoring Well 3899

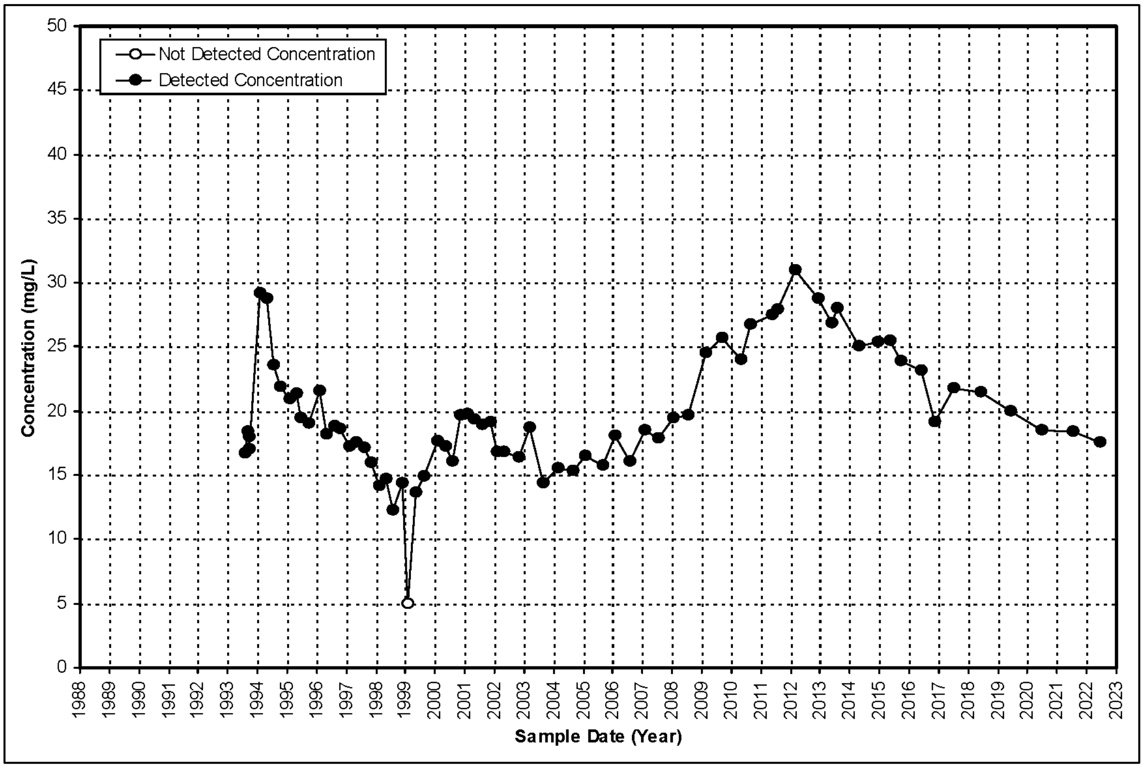

Figure A.1-9. Sodium Concentration Versus Time Plot for Monitoring Well 2898

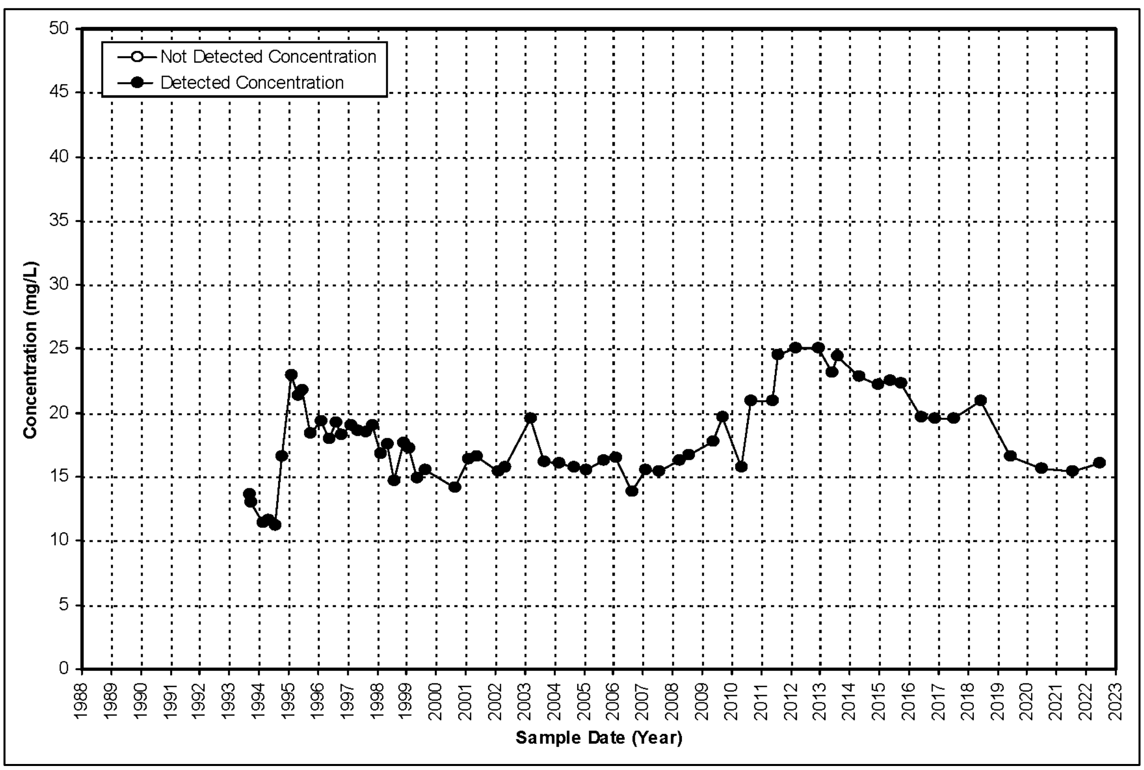

Figure A.1-10. Sodium Concentration Versus Time Plot for Monitoring Well 2899

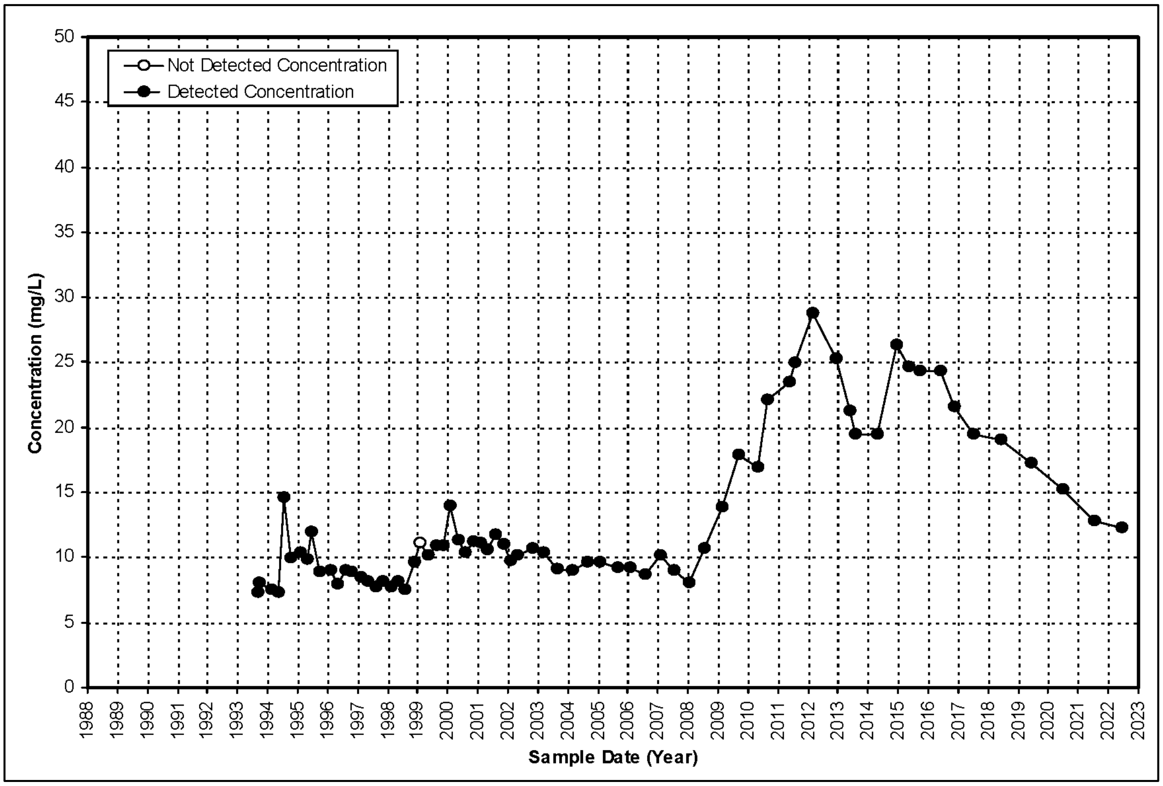

Figure A.1-11. Sodium Concentration Versus Time Plot for Monitoring Well 3898

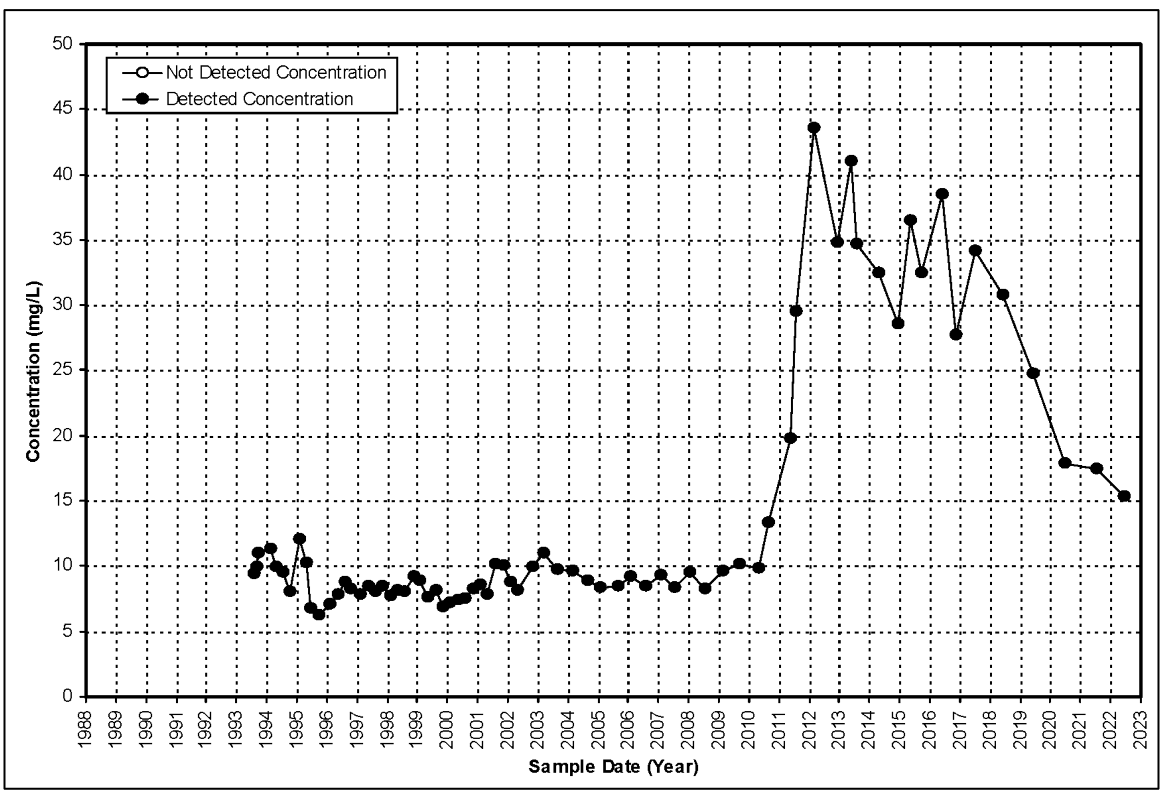

Figure A.1-12. Sodium Concentration Versus Time Plot for Monitoring Well 3899

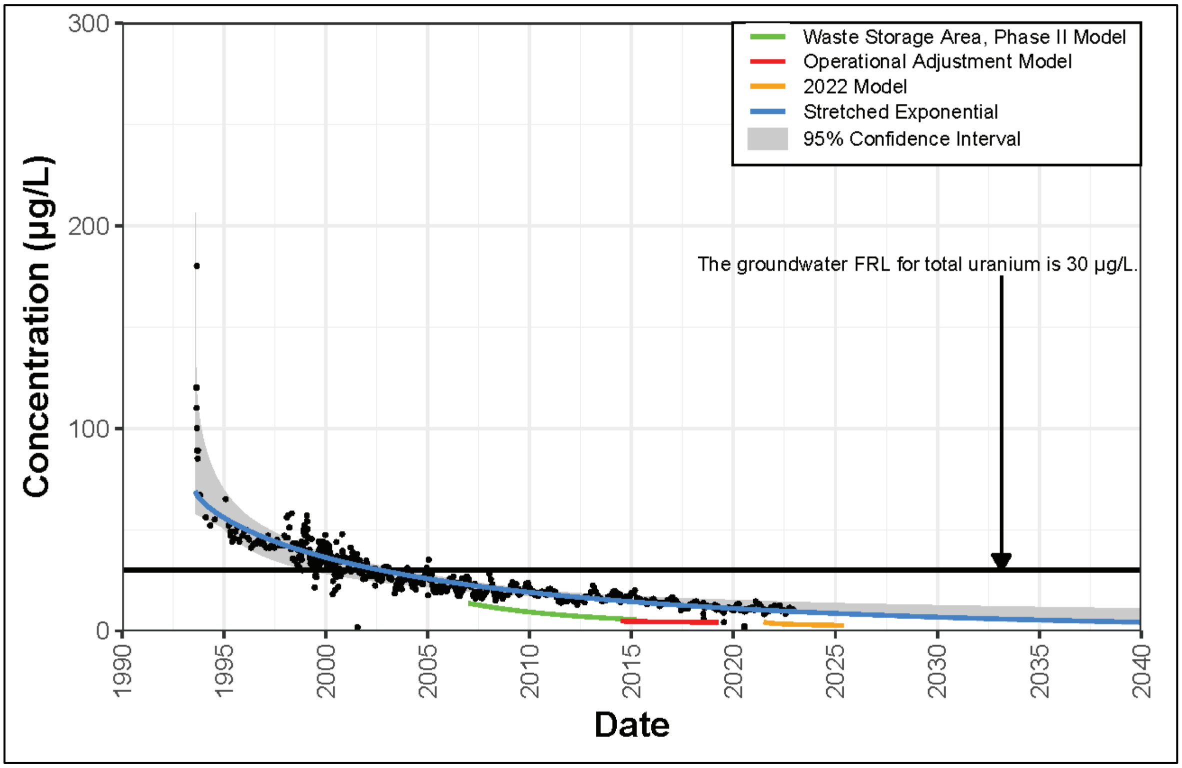

Figure A.1-13. Total Uranium Concentration Versus Time Plot for Extraction Well 3924 (RW-1) with Regression Analysis

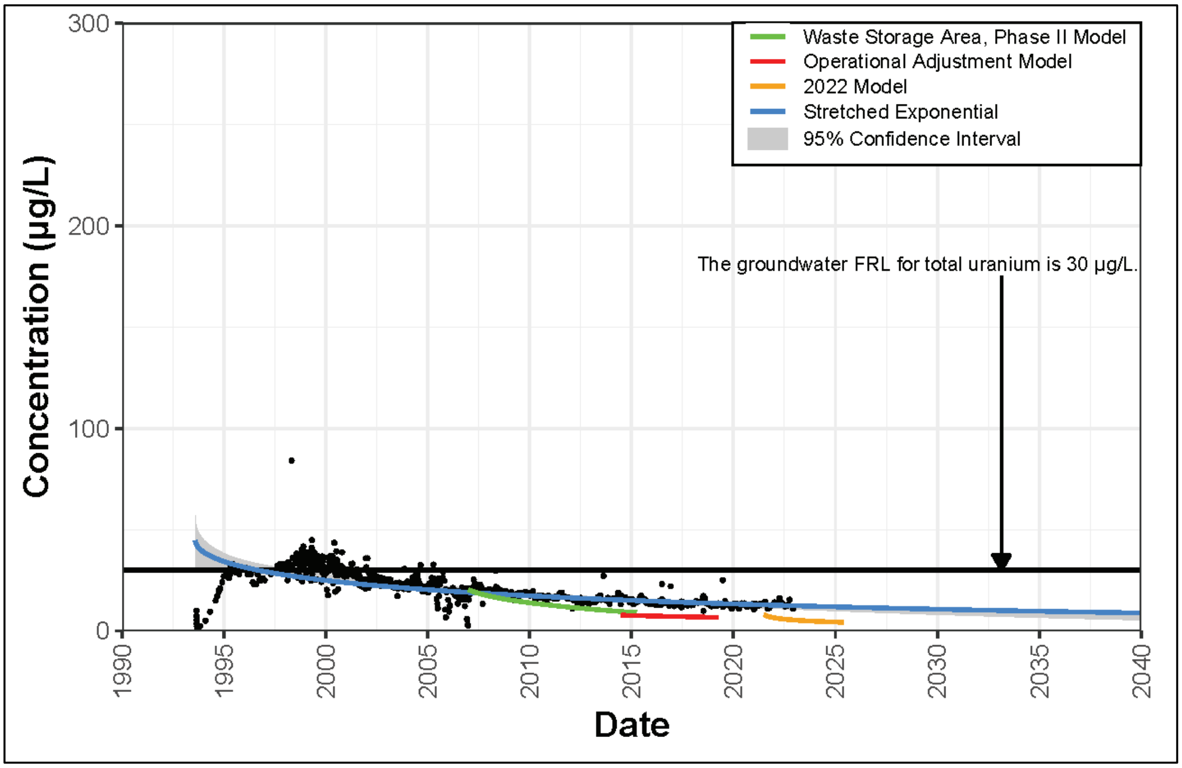

Figure A.1-14. Total Uranium Concentration Versus Time Plot for Extraction Well 3925 (RW-2) with Regression Analysis

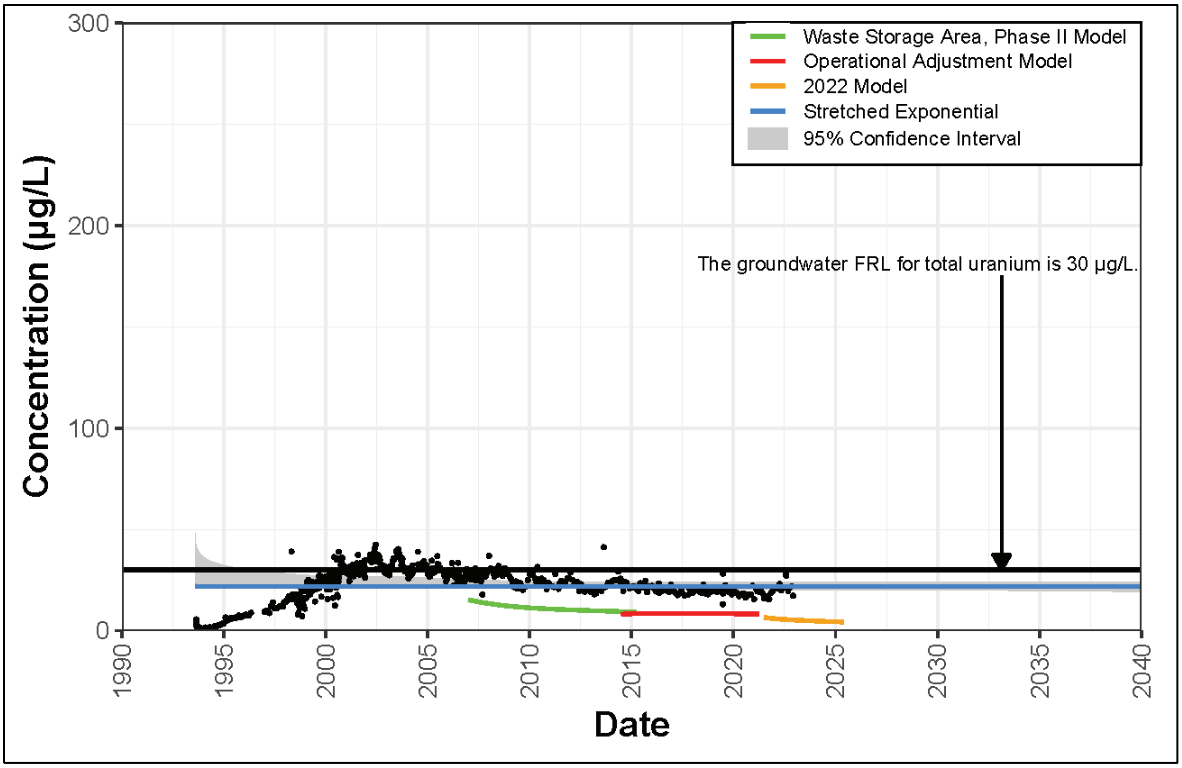

Figure A.1-15. Total Uranium Concentration Versus Time Plot for Extraction Well 3926 (RW-3) with Regression Analysis

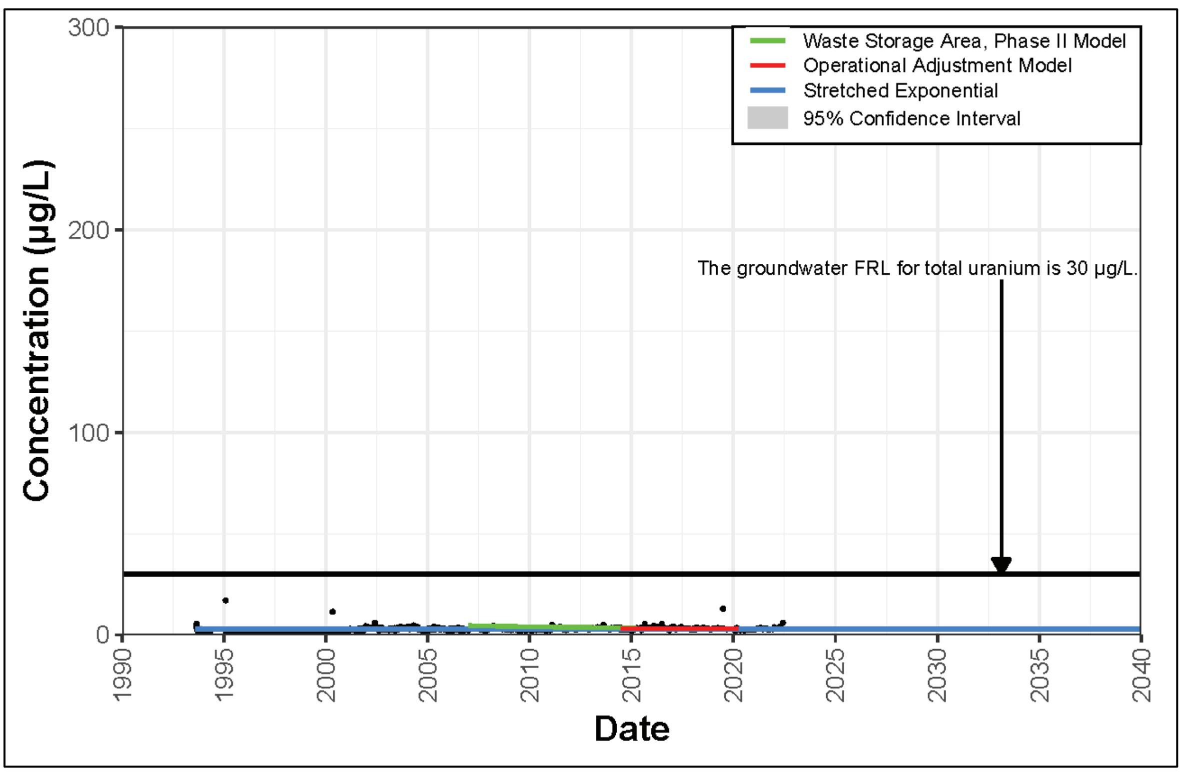

Figure A.1-16. Total Uranium Concentration Versus Time Plot for Extraction Well 3927 (RW-4) with Regression Analysis

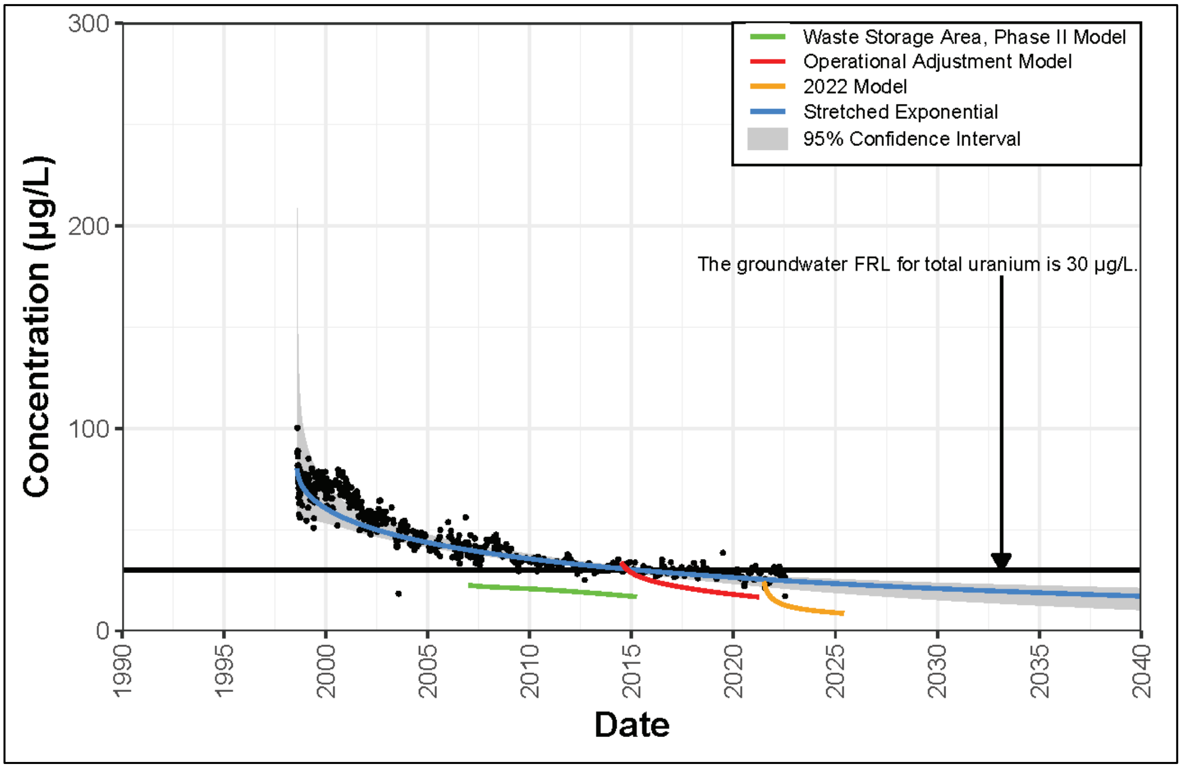

Figure A.1-17. Total Uranium Concentration Versus Time Plot for Extraction Well 32308 (RW-6) with Regression Analysis

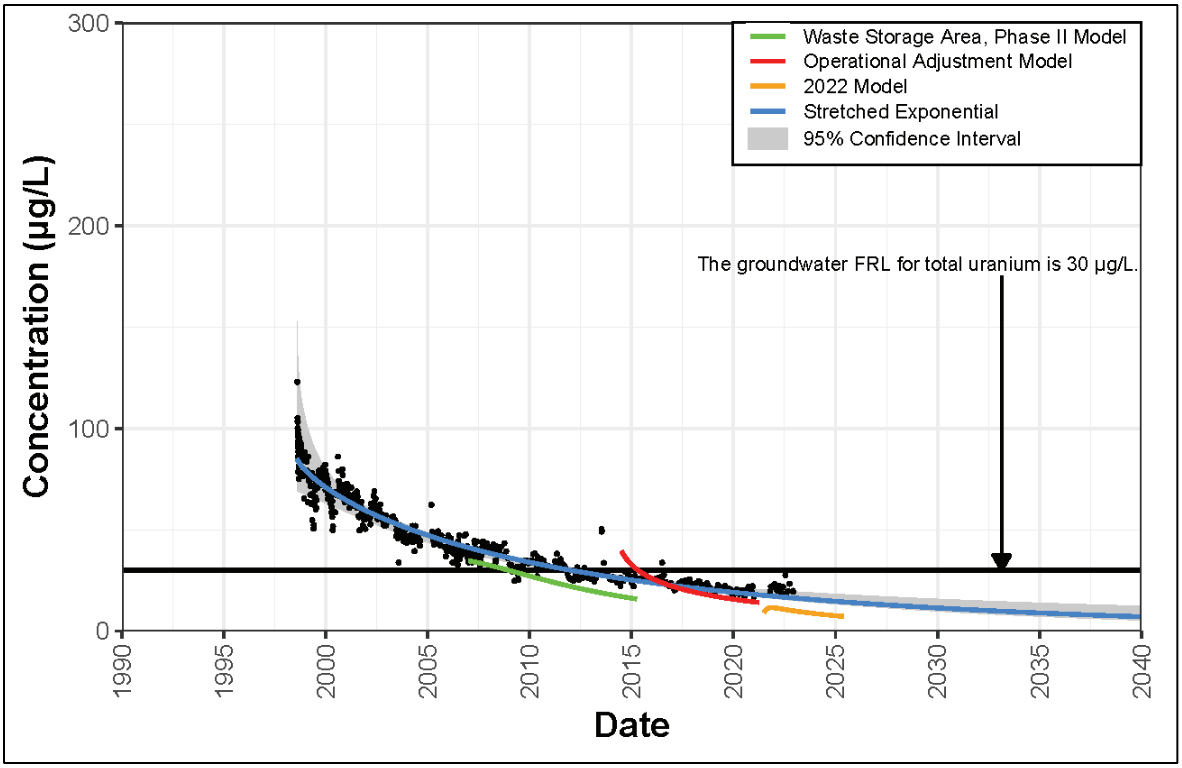

Figure A.1-18. Total Uranium Concentration Versus Time Plot for Extraction Well 32309 (RW-7) with Regression Analysis

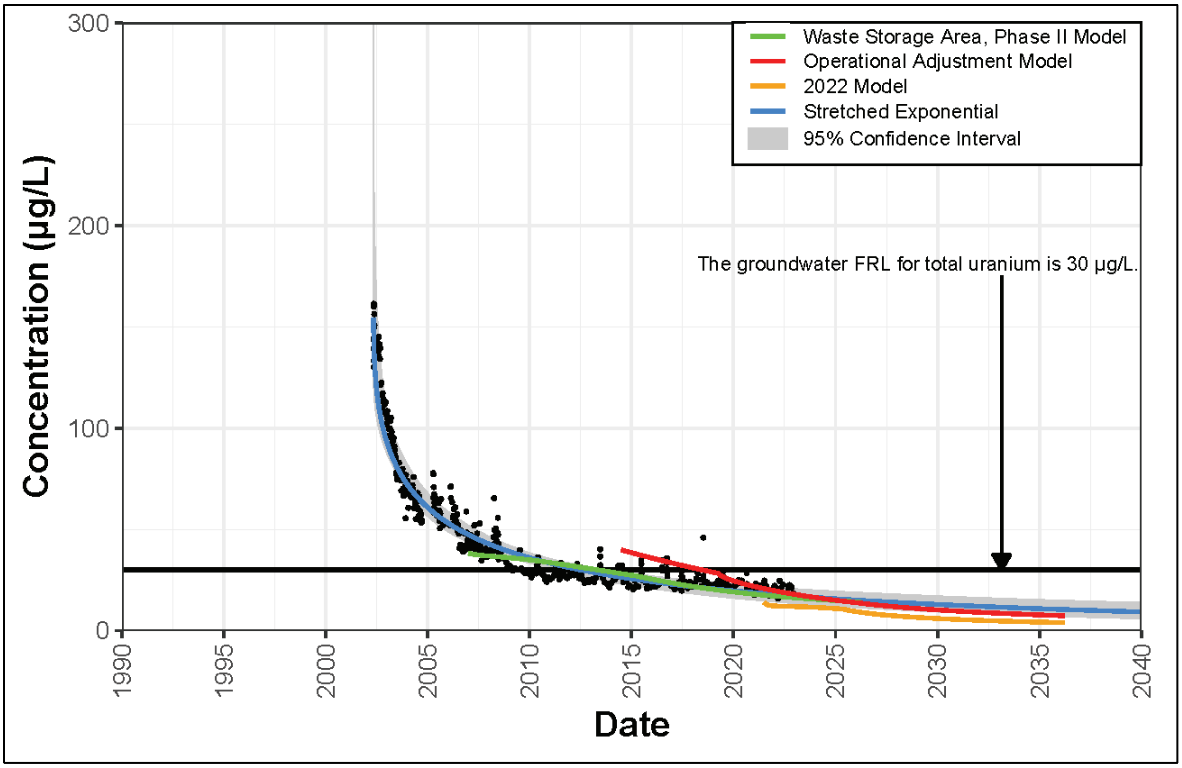

Figure A.1-19. Total Uranium Concentration Versus Time Plot for Extraction Well 32761 (EW-26) with Regression Analysis

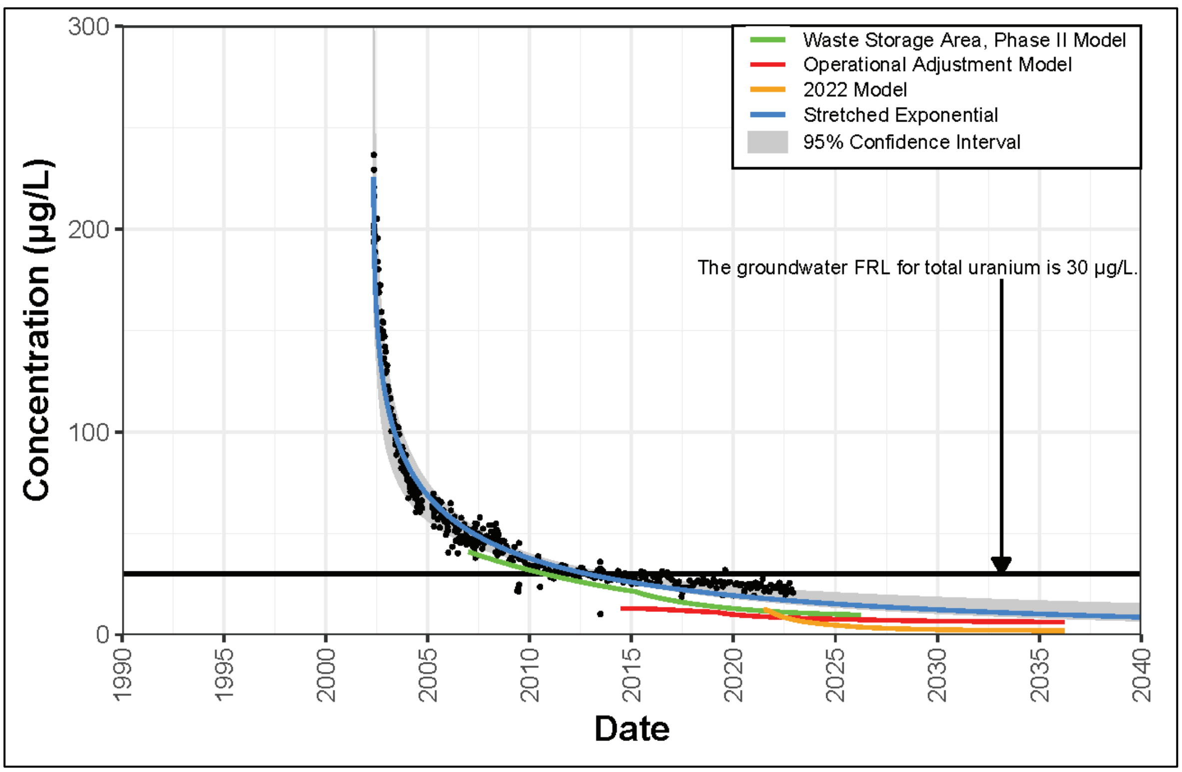

Figure A.1-20. Total Uranium Concentration Versus Time Plot for Extraction Well 33062 (EW-27) with Regression Analysis

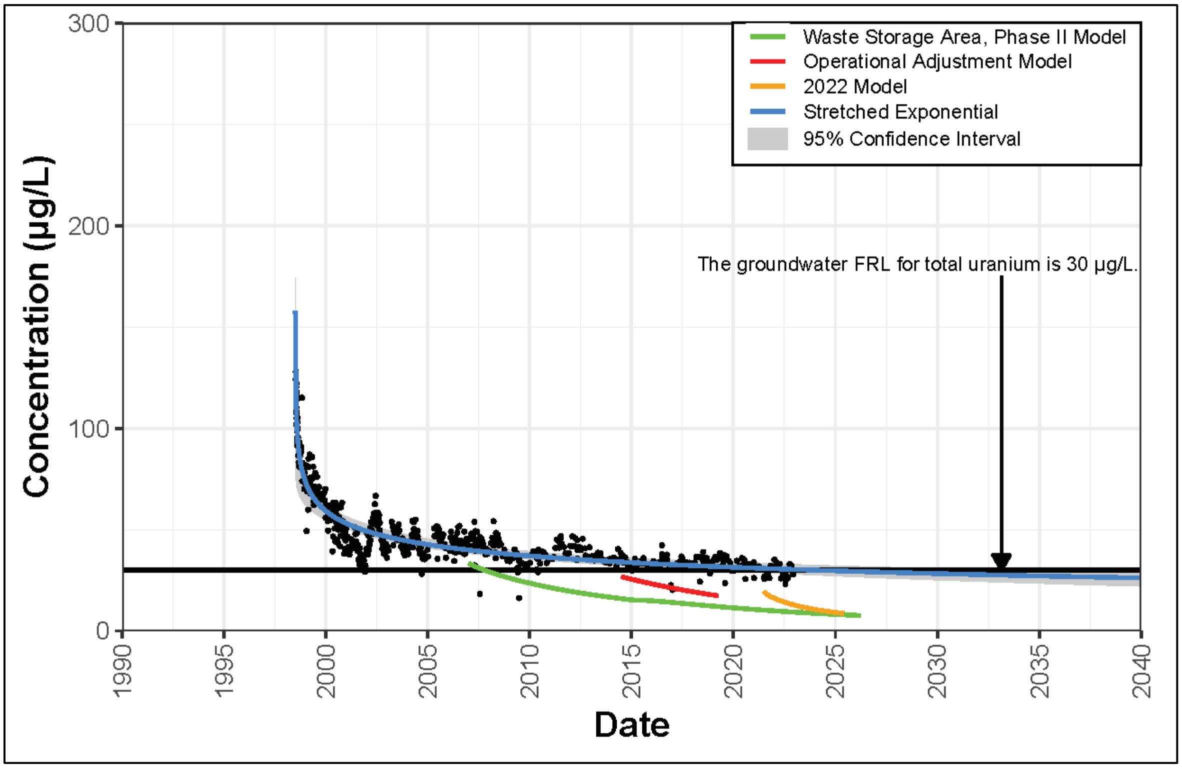

Figure A.1-21. Total Uranium Concentration Versus Time Plot for Extraction Well 31550 (EW-18) with Regression Analysis

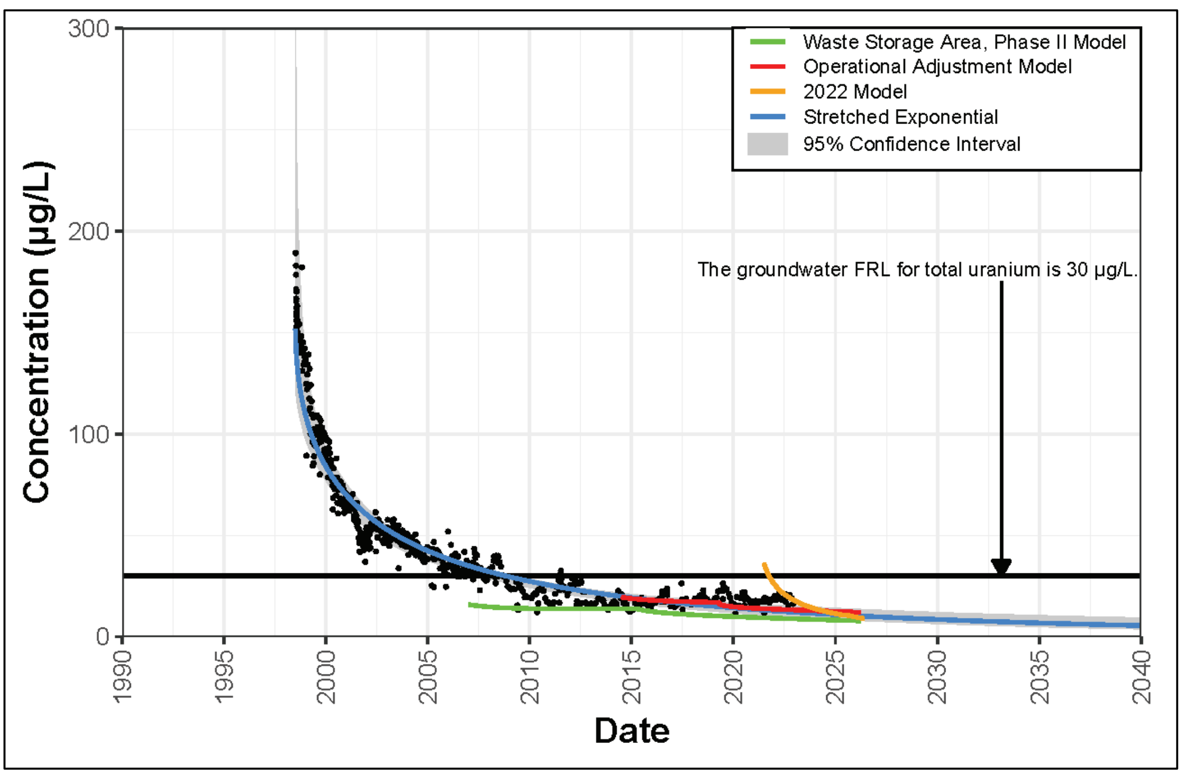

Figure A.1-22. Total Uranium Concentration Versus Time Plot for Extraction Well 31560 (EW-19) with Regression Analysis

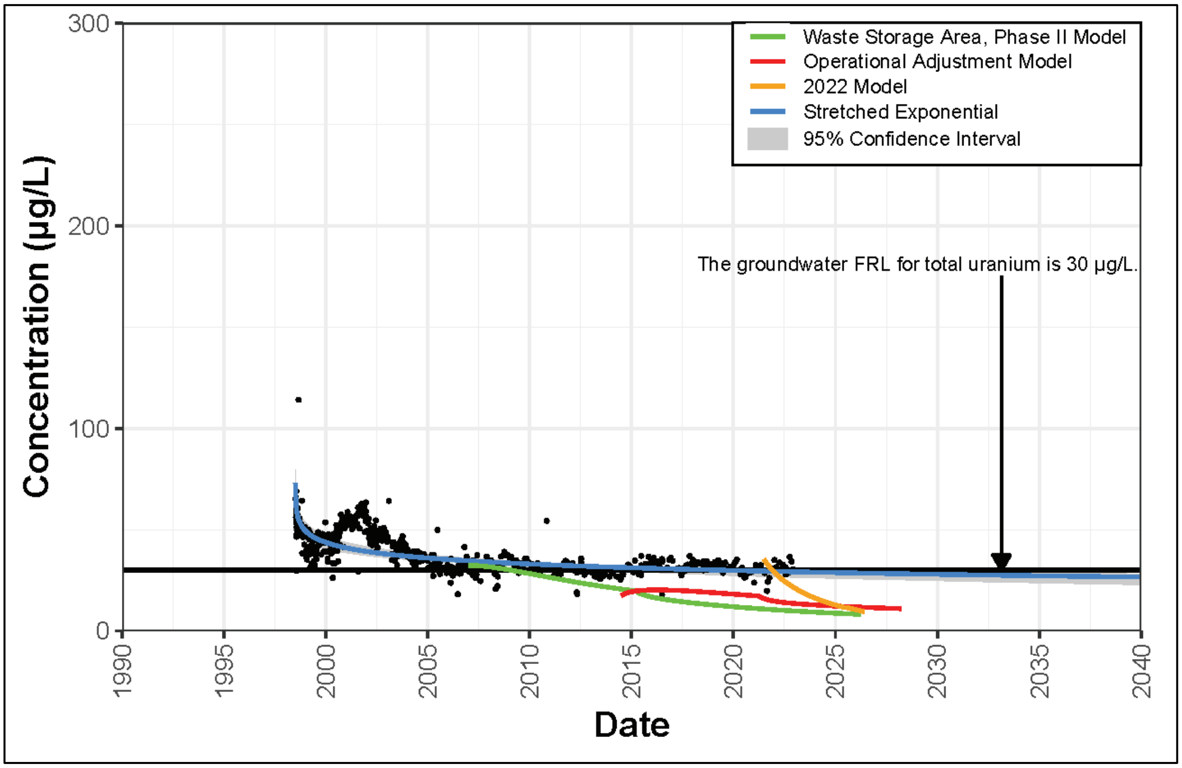

Figure A.1-23. Total Uranium Concentration Versus Time Plot for Extraction Well 31561 (EW-20) with Regression Analysis

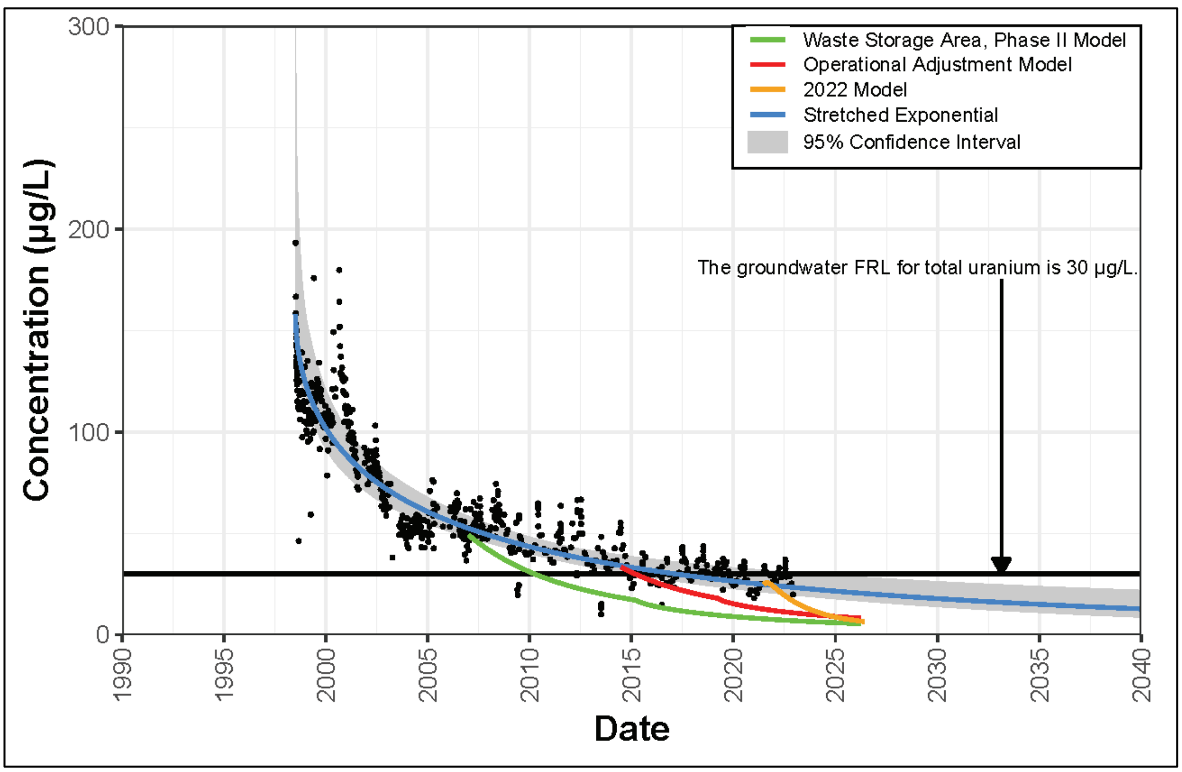

Figure A.1-24. Total Uranium Concentration Versus Time Plot for Extraction Wells 31562 (EW-21) and 33298 (EW-21a) with Regression Analysis

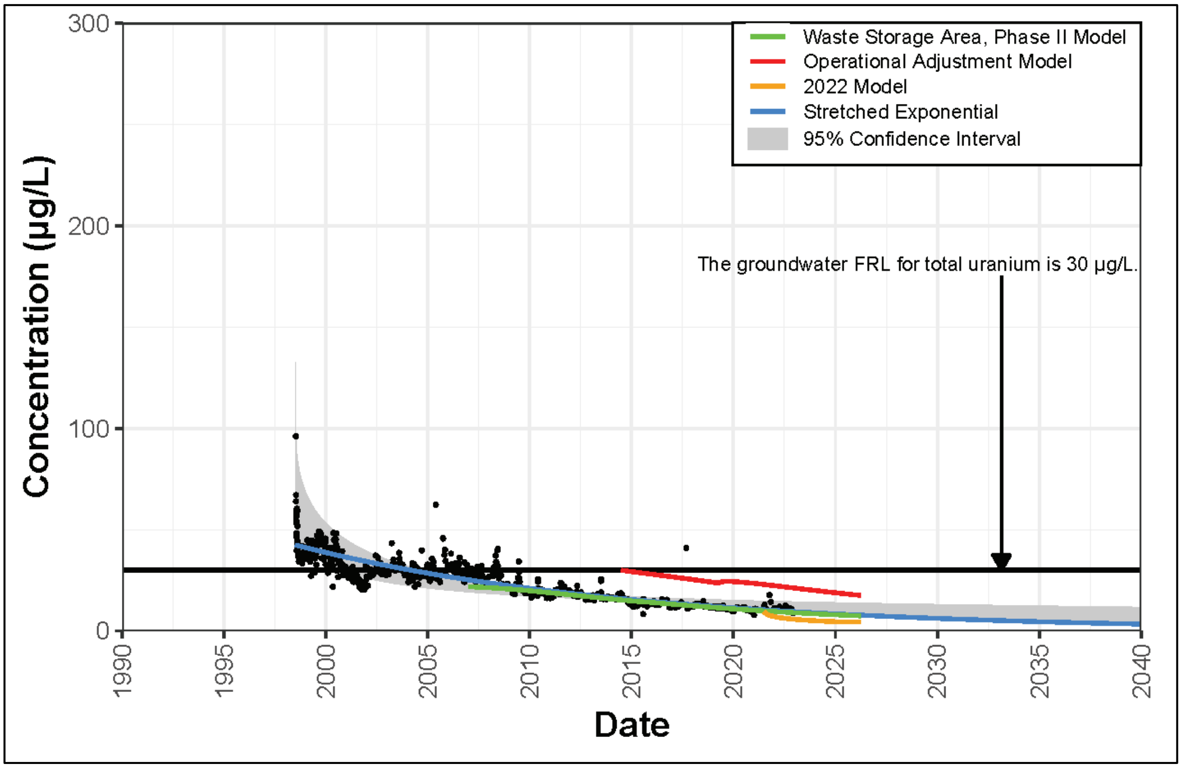

Figure A.1-25. Total Uranium Concentration Versus Time Plot for Extraction Wells 31567 (EW-17) and 33326 (EW-17a) with Regression Analysis

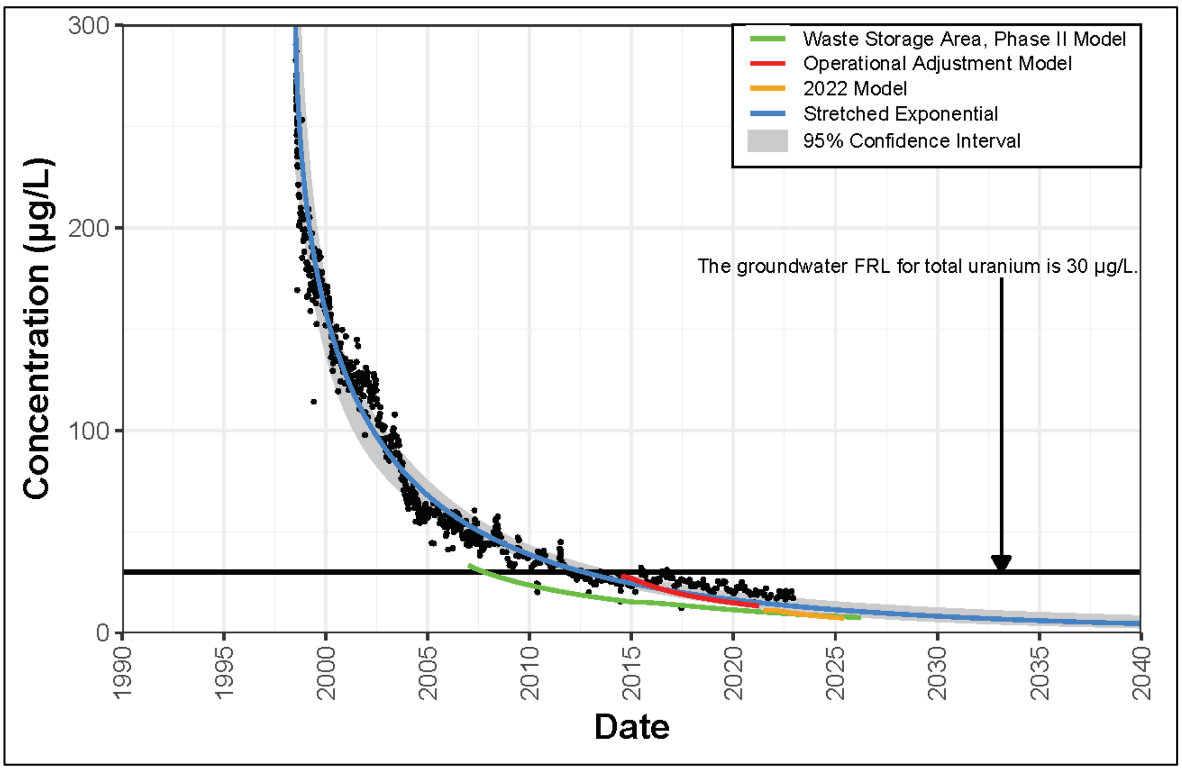

Figure A.1-26. Total Uranium Concentration Versus Time Plot for Extraction Well 32276 (EW-22) with Regression Analysis

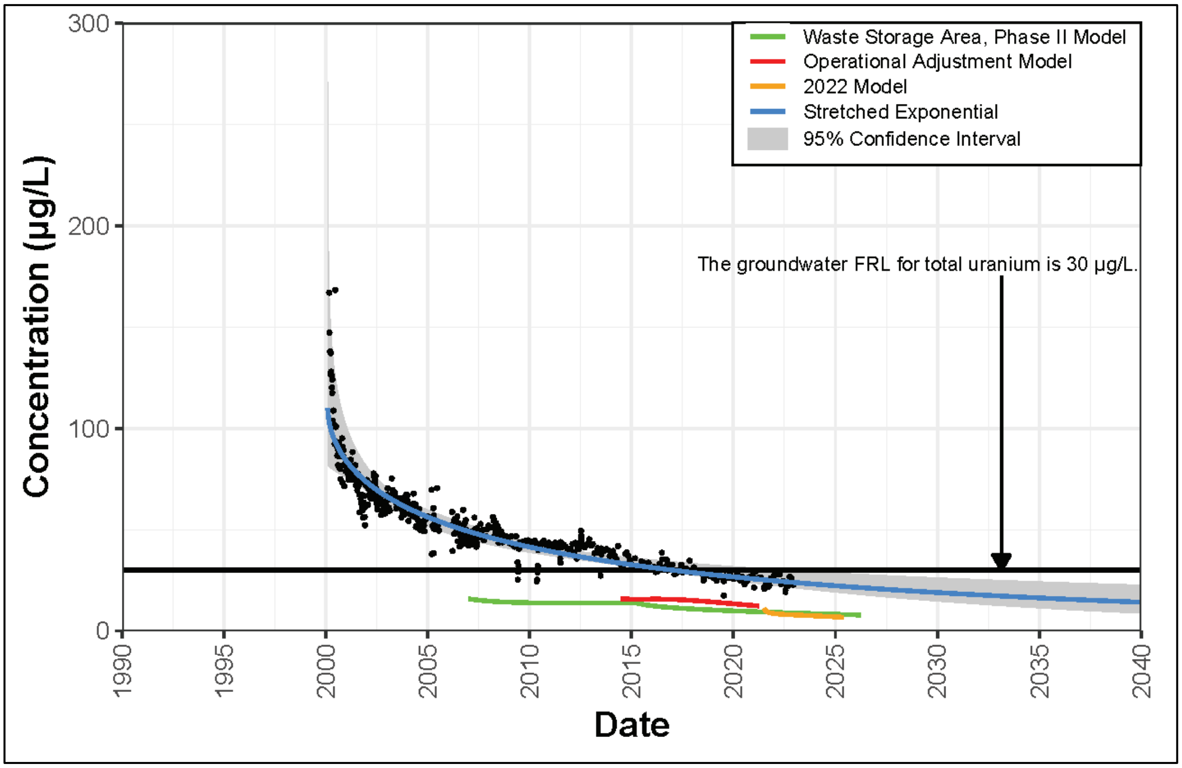

Figure A.1-27. Total Uranium Concentration Versus Time Plot for Extraction Well 32446 (EW-24) with Regression Analysis

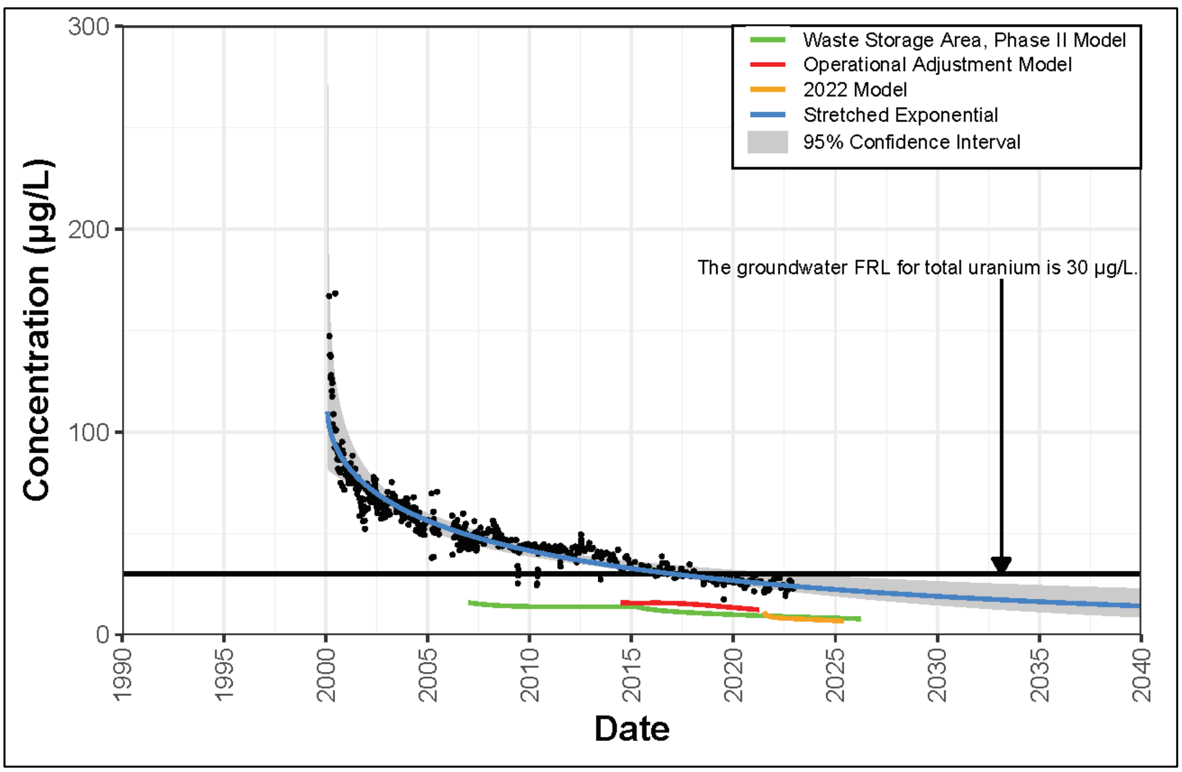

Figure A.1-28. Total Uranium Concentration Versus Time Plot for Extraction Well 32447 (EW-23) with Regression Analysis

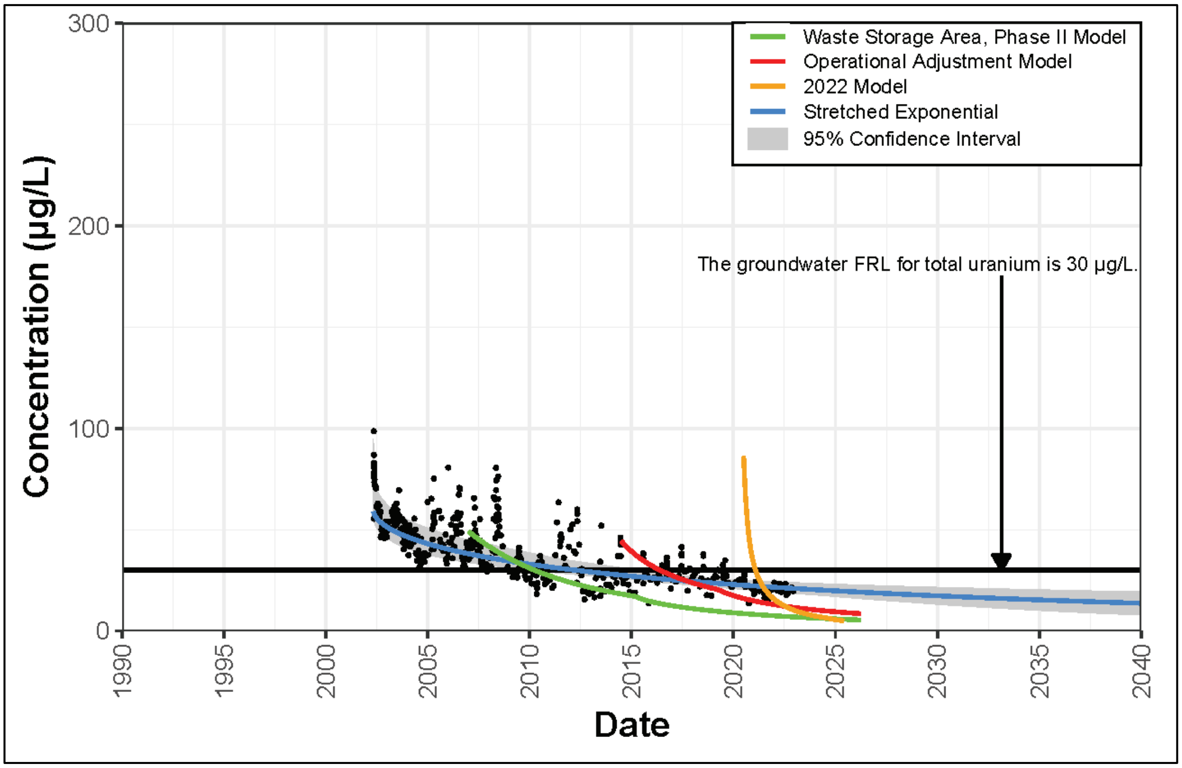

Figure A.1-29. Total Uranium Concentration Versus Time Plot for Extraction Well 33061 (EW-25) with Regression Analysis

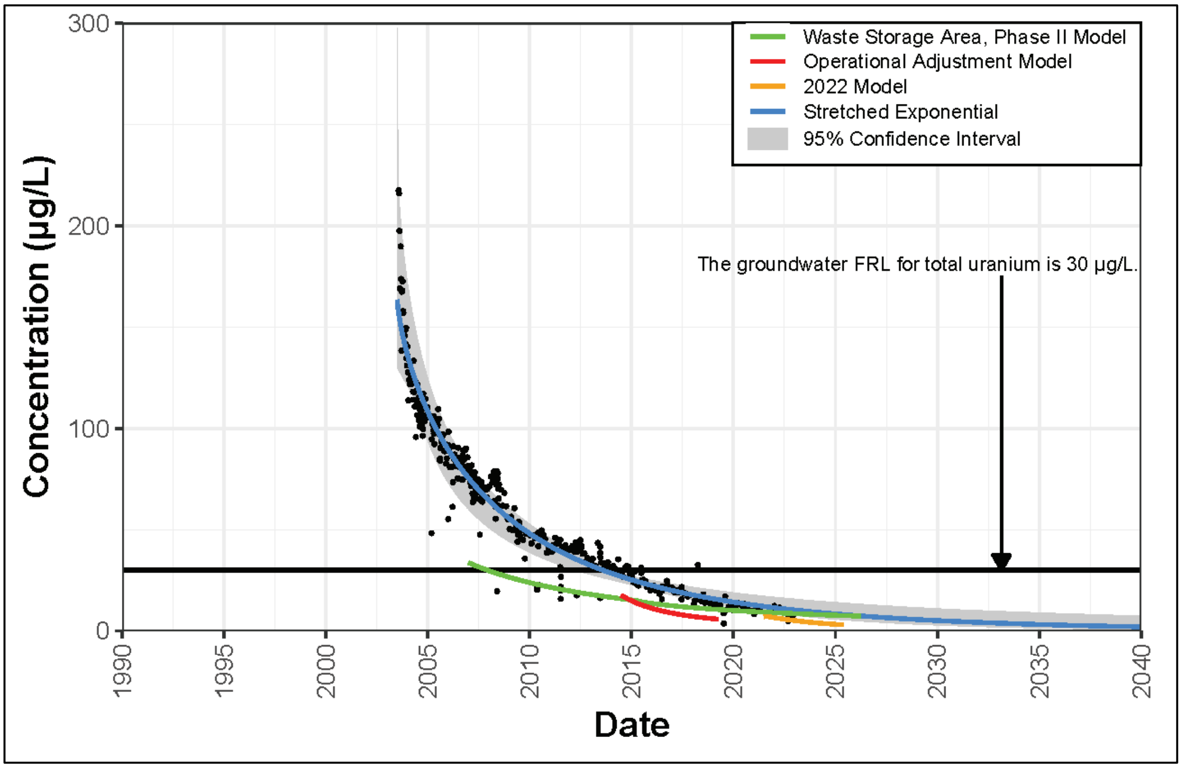

Figure A.1-30. Total Uranium Concentration Versus Time Plot for Extraction Well 33264 (EW-30) with Regression Analysis

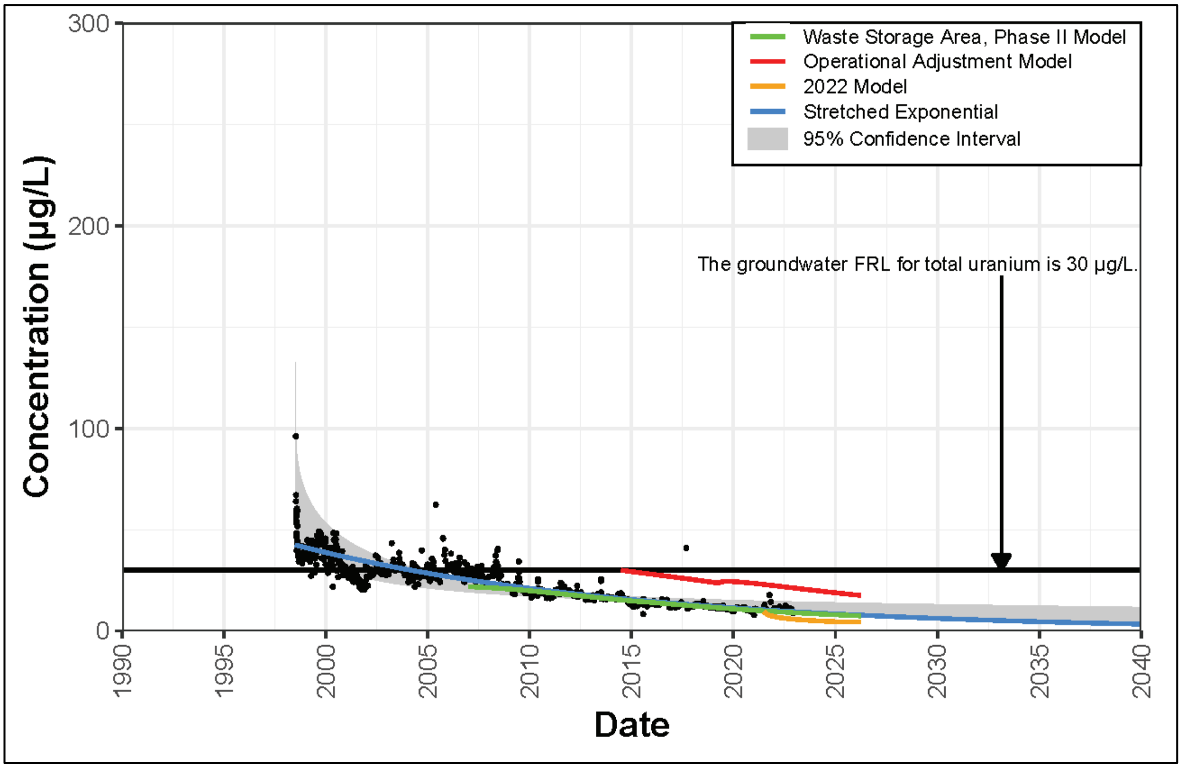

Figure A.1-31. Total Uranium Concentration Versus Time Plot for Extraction Well 33262 (EW-15a) with Regression Analysis

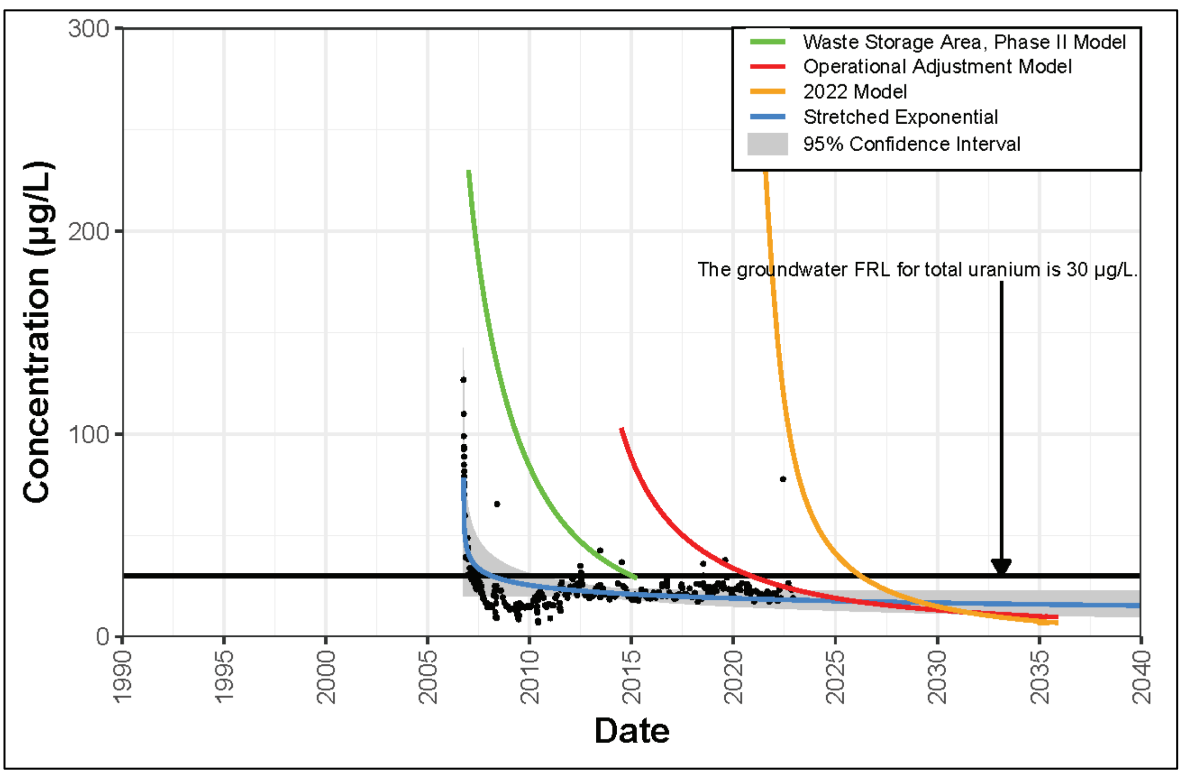

Figure A.1-32. Total Uranium Concentration Versus Time Plot for Extraction Well 33347 (EW-33a) with Regression Analysis

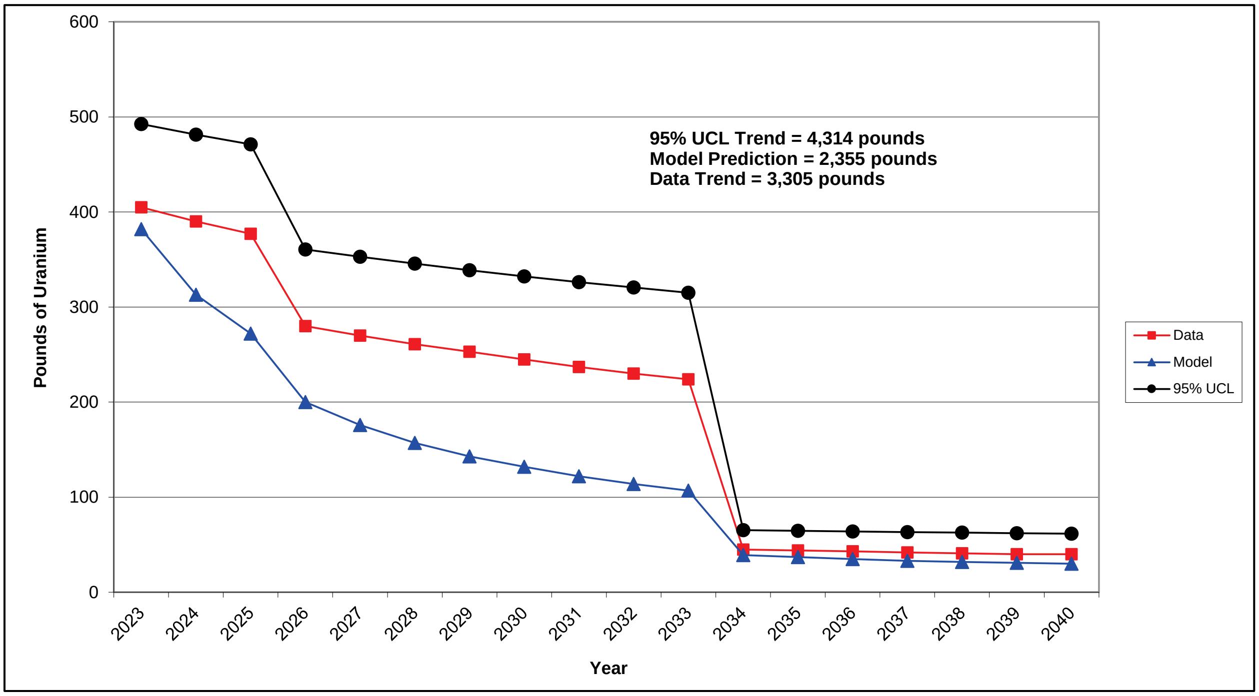

Figure A.1-33. Estimate of Yearly Pounds of Uranium to Be Pumped from Aquifer to Achieve Concentration-Based FRL Goals (Model Predictions Versus Measured Concentration Trends) Data Collected Through 2022

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Attachment A.2

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Contents

Tables

Figures

Abbreviations

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EVS	Earth Volumetric Studio
FRL	final remediation level
IEMP	Integrated Environmental Monitoring Plan
K_d	distribution coefficient
Ohio EPA	Ohio Environmental Protection Agency
PPDD	Pilot Plant Drainage Ditch
WSA	Waste Storage Area

Measurement Abbreviations

amsl	above mean sea level
bgs	below ground surface
ft	feet
g/cm^3	grams per cubic centimeter
L	liters
lb	pounds
L/kg	liters per kilogram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
µg/L	micrograms per liter
mS/cm	millisiemens per centimeter
NTU	nephelometric turbidity unit
SU	standard unit

A.2.0 Assessment of Total Uranium Results

This attachment provides groundwater monitoring total uranium results through 2022, including summary statistics and plume maps, at the Fernald Preserve, Ohio, Site. The groundwater remediation at the Fernald Preserve is a concentration-based cleanup. The *Record of Decision for Remedial Actions at Operable Unit 5* (DOE 1996) states that "areas of the Great Miami Aquifer exceeding final remediation levels (FRLs) will be restored through extraction methods." Uranium is the primary constituent of concern for groundwater. The groundwater FRL for total uranium is 30 micrograms per liter (µg/L). The background total uranium concentration for unfiltered groundwater samples from the Great Miami Aquifer near the Fernald Preserve is 1.2 µg/L. This background value is based on the 95th percentile of unfiltered samples (*Remedial Investigation Report for Operable Unit 5* [DOE 1995], Section 4, Table 4-8). Both the area of the aquifer targeted for remediation and the statistical procedures that will be used to verify that aquifer cleanup objectives have been achieved are described in the *Fernald Groundwater Certification Plan* (DOE 2006).

Groundwater total uranium sampling requirements are presented in the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (DOE 2019a). IEMP groundwater monitoring and extraction well locations are shown in Figure A.2-1. For integration purposes, locations of the On-Site Disposal Facility monitoring wells used to monitor the Great Miami Aquifer are also shown in Figure A.2-1.

In addition to the routine well monitoring specified in the IEMP, 27 locations were sampled using a direct-push sampling tool (Geoprobe) in 2022. This direct push sampling focused on the South Plume and South Field areas, with emphasis on the South Plume. Direct-push sampling results for the 27 locations (12196C, 13229I, 13233C, 13239G, 13267D, 13477E, 13510A, 13513C, 13533A, 13535A, 13538A, 13542A, 13601, 13602, 13603, 13604, 13605, 13606, 13607, 13608, 13609, 13610, 13611, 13612, 13613, 13614, and 13615) are presented in Tables A.2-1 through A.2-27.

Direct-push sampling locations are often sampled several times over the course of the remediation. When a direct-push location is resampled, the convention is to identify the new sample with the same location number but with an alphabetical extension to differentiate the earlier sample (e.g., 12230, 12230A, 12230B). If a resample location is moved more than 50 feet (ft) from the original location, a new number is assigned.

Figures A.2-2 and A.2-3, show maximum total uranium plume maps for 2022. Figure A.2-2 shows direct-push data. Figure A.2-3 shows monitoring well and extraction well data. Data collected from the aquifer are used to progressively update the maximum total uranium plume maps in the following conservative manner:

- Total uranium concentration data are posted on a map with the contours from the previous map. The highest representative total uranium value at a monitoring well location is posted. The highest concentration associated with each direct-push location is also posted.
- If a recently measured concentration from a well is greater than the previous concentration contour value at that location, then the plume is recontoured using the higher value.

- If the most recent concentration measurement from a well is less than the previous contour value for that location, then the new data are posted, but the plume contours are not adjusted using the new data until confirmatory direct-push sampling can be conducted.
- If direct-push data or multilevel monitoring well data are available, and a complete vertical profile of an area indicates that concentrations have changed, then the map is recontoured using the new direct-push data or multilevel well data. Under this strategy, a reduction in the size of the mapped plume is based on vertical profile data.
- If a monitoring well has a history of intermittent exceedances and the well location appears to be isolated from the main plume, then the well location is identified on the maximum uranium plume map as a location with intermittent exceedances. This serves to keep track of the locations with intermittent exceedances so that their presence can be carried forward into the certification stage of the remediation project.

Until 2020, the Site Environmental Report contained both a first half and a second half of the year total uranium plume map. Experience has shown that routinely producing an annual first half total uranium plume map provided little benefit to the annual Site Environmental Report. Yearly comparisons of remedy progress reported in the Site Environmental Report are based on the second half total uranium plume map. Beginning with the 2021 Site Environmental Report (DOE 2022), the U.S. Department of Energy (DOE) no longer routinely presented a first half total uranium plume map in the Site Environmental Report each year. Uranium concentration data continue to be collected in the first half of the year as prescribed by the IEMP, but the data are no longer reported in a first half total uranium plume map. If uranium concentration data ever indicates that a first half total uranium plume map would provide benefit to the reporting presented in the Site Environmental Report, then a first half map will be added on a case-by-case basis, as deemed appropriate.

Table A.2-28 lists the monitoring wells where total uranium concentrations exceeded the 30 µg/L FRL during 2022. Included in the table are total uranium statistical summaries for each well, which include Mann-Kendall trend analyses. Table A.2-29 provides total uranium statistical summaries for the extraction wells, including Mann-Kendall trend analyses. Extraction well trends are discussed in Attachment A.1. Figure A.2-4 illustrates the statistics presented in Table A.2-28, showing where total uranium concentrations have an upward trend, downward trend, or no trend. Monitoring wells with an upward trend based on the Mann-Kendall analysis are discussed further.

Tracking the acreage of the maximum total uranium plume footprint provides a means for assessing progress in achieving remediation goals. Figure A.2-5 shows the footprint of the 30 µg/L total uranium plume from the second half of 2021 compared to the footprint of the 30 µg/L total uranium plume from 2022. The 2021 plume is highlighted yellow, indicating areas where the plume was reduced for mapping purposes in 2022. Acreage changes within the 30 µg/L footprint (i.e., area above 50 µg/L and area above 100 µg/L) are also tracked and reported. A breakdown for the past 2 years is provided below.

Comparison of 2021 and 2022 Maximum Total Uranium Plume Footprint Area

Year	Area Greater Than 30 µg/L	Area Greater Than 50 µg/L	Area Greater Than 100 µg/L
2021 (acres)	75.0	48.7	28.3
2022 (acres)	74.0	49.4	27.8
Change (acres)	1	−0.7	0.5
Change (percent)	−1.3	1.4	−1.8

Between 2021 and 2022, the acreage mapped for the area of the maximum uranium plume above 50 µg/L increased by 0.7 acre. Periodic concentration fluctuations within the plume are expected and are attributed to dissolved uranium movement in response to active pumping.

Since 1997, the footprint of the total uranium plume being targeted for cleanup has decreased 163.6 acres. Table A.2-30 provides a tabulation of plume area from 1997 through 2022.

Monitoring results are presented in the following three sections:

- Section A.2.1, "Former Waste Storage Area," including the Pilot Plant Drainage Ditch (PPDD) Area
- Section A.2.2, "Former Plant 6 Area"
- Section A.2.3, "South Field and Off-Property South Plume Total Uranium Plumes"

For each of the three sections, information is presented concerning:

- New direct-push sampling data.
- Intermittent total uranium FRL exceedance locations.
- Monitoring wells with increasing total uranium concentration trends.

The remainder of the attachment is organized as follows:

- Section A.2.4 presents information concerning monitoring well inspection and maintenance
- Section A.2.5 presents information concerning center-of-mass plume calculations for the total uranium plumes
- Section A.2.6 presents total uranium cross sections

A.2.1 Former Waste Storage Area

A.2.1.1 Former Waste Storage Area Maximum Total Uranium Plume

The size of the mapped footprint of the 30 µg/L maximum total uranium plume in the former Waste Storage Area (WSA) between 2021 and 2022 remained unchanged at 6.7 acres.

A.2.1.1.1 New Direct-Push Sampling Data in the Former WSA

No direct-push sampling was conducted in 2022 in the former WSA.

A.2.1.1.2 Intermittent Total Uranium FRL Exceedance Locations in the Former WSA

Four monitoring wells (83339, 83340, 83341, and 83346) are identified on the maximum total uranium plume map for 2022 in the former WSA (Figure A.2-3) as being monitoring locations with intermittent total uranium FRL exceedances.

Figure A.2-6 is a time versus concentration graph for monitoring well 83339. The graph shows that the total uranium concentrations for two of the channels (channels 2 and 3) have always been below 30 µg/L. Channel 1 has had one exceedance of the uranium FRL since 2013, and that was in 2019. The sample collected in the first half of 2022 was below the uranium FRL. Channel 1 was dry during the second half of 2022.

Figure A.2-7 is a time versus concentration graph for monitoring well 83340. The graph shows that the total uranium concentrations for two of the channels (channels 2 and 3) have always been below 30 µg/L. The total uranium concentration for channel 1 was above 30 µg/L between 2018 and 2021. Since 2021, the first half sample has been very near or slightly below 30 µg/L.

Figure A.2-8 is a time versus concentration graph for monitoring well 83341. The graph shows that the total uranium concentrations for two of the channels (channels 2 and 3) have always been below 30 µg/L. Channel 1 of monitoring well 83341 was dry between 2014 and 2017. The uranium concentrations of the samples collected in 2017 and 2018 were below 30 µg/L. The uranium concentration of the sample collected in the second half of 2019 was above 30 µg/L. The uranium concentration collected in the first half of 2020 in channel 1 was below 30 µg/L. Channel 1 was dry during the second half of 2020. The uranium concentration measured in the first half of 2021 and 2022 in channel 1 was below 30 µg/L. Channel 1 was dry during the second half of 2021 and 2022.

Figure A.2-9 is a time versus concentration graph for monitoring well 83346. The graph shows that the total uranium concentrations for two of the channels (channels 2 and 3) have always been below 30 µg/L. The total uranium concentration for channel 1 was above 30 µg/L in 2018 and 2019. It has been below 30 µg/L since 2019.

All four of these monitoring wells will continue to be monitored. If future monitoring indicates that the intermittent total uranium FRL exceedances are continuing or increasing, additional direct-push sampling may be conducted in the areas when water levels are high to determine whether a plume can be defined. These four wells will continue to be identified on maximum total uranium plume maps as locations where intermittent total uranium FRL exceedances have been measured so that their presence will be carried forward into the certification stage of the aquifer remediation.

A.2.1.1.3 Monitoring Wells with Increasing Total Uranium Concentration Trends in the Former WSA

As shown in Figure A.2-4, two monitoring wells (83340 and 2649) had an increasing total uranium concentration trend in the former WSA. Monitoring well 83340 is discussed in the previous section. Monitoring well 2649 was reported in the 2013 through 2019 Site Environmental Reports (DOE 2014; DOE 2015; DOE 2016; DOE 2017a; DOE 2018; DOE 2019b; DOE 2020; DOE 2021) as having increasing concentration trends. Table A.2-28 provides summary statistics for the well. Monitoring well 2649 is within capture of the groundwater remediation system.

Figure A.2-10 is a total uranium concentration versus time plot for monitoring well 2649. The figure shows an increase in uranium concentration in 2007. The increase is attributed to pumping in nearby extraction well 33347, which began in late 2006. As is shown in Figure A.2-10, the concentration of uranium in monitoring well 2649 has exceeded 1,000 µg/L in 2013, 2018, and 2022. This is an area of the plume where uranium contamination is known to be sorbed to aquifer sediments in the vadose zone. When this sediment is saturated or flushed due to high water levels in the aquifer, the uranium can desorb into the water, resulting in the high concentration measurements. Multichannel well 83337 is near monitoring well 2649. The shallowest channel in well 83337 is channel 1. As shown in Figure A.2-11, the uranium concentration of channel 1 in monitoring well 83337 has also been above 1,000 µg/L, while the other two deeper channels in that well have not. In 2022, concentration was again above 1,000 µg/L.

A.2.1.1.4 Former WSA Summary

The following two groundwater remediation issues present challenges in the former WSA:

- Uranium contamination sorbed to sediments in the vadose zone beneath former source areas
- High surface water uranium concentrations occur in a swale located between the former Waste Pits and Paddys Run

Uranium Contamination Sorbed to Sediments in the Vadose Zone Beneath Former Source Areas: High total uranium concentrations that correspond to high water levels continue to be a concern for the former WSA plume. Located beneath a former source area, total uranium contamination is sorbed to aquifer sediments in the vadose zone. When pumping is stopped and the water level rises, dissolved total uranium concentrations in the groundwater may increase (rebound) enough to exceed groundwater FRLs.

This issue is being somewhat alleviated each year by conducting a planned well field shutdown to allow water levels to rise and desorb some of the contamination in these areas. The confirmation that this issue has been addressed will be documented as described in the *Fernald Groundwater Certification Plan* (DOE 2006) after the pumping phase of the remediation ends. Certification monitoring will be conducted once the pumping wells are turned off to verify that concentrations above FRLs are not rebounding.

High Surface Water Uranium Concentrations Occur in a Swale located Between the Former Waste Pits and Paddys Run: Intermittent puddles of surface water occur in a swale bounded by Paddys Run to the west and the former waste pits to the east. As presented in Appendix B, the total uranium concentrations of many of the surface water samples collected from this area exceed the groundwater FRL.

Surface water that collects in the swale is sampled at surface water sampling locations SWD-05 and SWD-09. The uranium concentration measured at SWD-09 has exceeded the surface water FRL (530 µg/L). The highest uranium concentration reported was 2,087 µg/L in December 2016. The uranium contamination appears to be localized to the area around SWD-09, and the uranium concentrations measured in the surface water from SWD-09 appear to be influenced by seasonal changes.

During normal flow conditions, surface water from the swale area infiltrates into the ground. This is also the case in the former Waste Pit 3 area, where water infiltrates into the ground and serves as a source of recharge to the aquifer. The uranium concentration in the aquifer beneath this infiltration area is above the uranium groundwater FRL (30 µg/L). Surface water from much of the former WSA drains into the former Waste Pit 3. The area of infiltration in the swale and former WSA is within capture of the groundwater remediation system. Because the area is within capture, there is currently no risk to the public from the infiltrating surface water. Continued monitoring will document whether the concentration in the infiltrating surface water decreases over time.

In 2014, groundwater modeling was conducted to determine the potential impact to model-predicted aquifer cleanup times if uranium-contaminated surface water is infiltrating into the aquifer from the swale. A modeled worst-case scenario was based on the highest total uranium concentration measured in ponded water within the swale and high infiltration rates. The conservative groundwater modeling scenario:

- Took no credit for attenuation of uranium in glacial till or alluvium.
- Used input infiltration rates of 50 inches per year rather than 6 inches per year.
- Used an input infiltrating total uranium concentration of 1,900 µg/L, which was the highest total uranium concentration measured in ponded water within the swale between 2007 and 2014.

Modeling under these extremely conservative conditions had no impact to model-predicted cleanup times for the aquifer in this area. If infiltrating surface water with high uranium concentrations continues toward the end of the pumping operation, DOE will work with the U.S. Environmental Protection Agency (EPA) and the Ohio Environmental Protection Agency (Ohio EPA) to determine the best path forward for remediation of the aquifer in this area.

A.2.1.2 PPDD Maximum Total Uranium Plume

The mapped footprint of the 30 µg/L maximum total uranium plume in the PPDD area between 2021 and 2022 remained unchanged at 5.8 acres (Figure A.2-5).

A.2.1.2.1 New Direct-Push Sampling Data in the PPDD Area

No direct-push sampling was conducted in 2022 in the PPDD area.

A.2.1.2.2 Intermittent Total Uranium FRL Exceedance Locations in the PPDD Area

One monitoring well, 83335, is identified on the maximum total uranium plume map for 2022 in the former PPDD area (Figure A.2-3) as being a monitoring location with intermittent total uranium FRL exceedances.

Figure A.2-12 provides a time versus total uranium concentration plot for monitoring well 83335. The figure shows that total uranium concentrations measured from 2013 through the first half of 2019 have been below the total uranium groundwater FRL for all monitoring channels. In the second half of 2019, channel 2 had a concentration of 32.4 µg/L. Since 2019, the uranium concentration of both collected samples were below the total uranium groundwater

FRL. Channel 1 has always been dry. This well will continue to be identified on maximum total uranium plume maps as being a location where intermittent total uranium FRL exceedances have been measured so that its presence will be carried forward into the certification stage of the aquifer remediation.

A.2.1.2.3 Monitoring Wells with Increasing Total Uranium Concentration Trends in the PPDD Area

As shown in Table A.2-28 and Figure A.2-4, one monitoring well (83124_C4) had an increasing total uranium concentration trend in 2022 in the PPDD Area. Figure A.2-13 is a total uranium concentration versus time plot for monitoring well 83124. This monitoring well is upgradient of extraction well 33062. The increase in uranium concentration in channel 1 is attributed to uranium contamination sorbed to aquifer sediments in the vadose zone.

A.2.2 Former Plant 6 Area

A.2.2.1 New Direct-Push Sampling Data in the Plant 6 Area

No direct-push sampling was conducted in 2022 in the Plant 6 Area.

A.2.2.2 Intermittent Total Uranium FRL Exceedance Locations and Monitoring Wells with Increasing Total Uranium Concentration Trends

Plans for a groundwater restoration module in the former Plant 6 Area were abandoned in 2001 based on the outcome of the *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas* (DOE 2001). The data in this design indicated that the total uranium plume in the former Plant 6 Area was no longer present. EPA and Ohio EPA concurred with this decision.

Monitoring well 2389 is the only groundwater monitoring well remaining in the area where Plant 6 was in the Former Production Area (Figure A.2-1). This well is identified as a location with intermittent total uranium FRL exceedances on the maximum total uranium plume map (Figure A.2-3). It is also identified as a monitoring location where total uranium concentrations are trending up (Figure A.2-4 and Table A.2-28).

Figure A.2-14 is a total uranium concentration versus time plot for monitoring well 2389 and shows that sporadic total uranium FRL exceedances were detected at this well between 2002 and 2007, but exceedances have been constant since 2011. As discussed below, FRL exceedances are detected in this area when the sample is approximately 515 ft amsl or higher. Since 2011, water levels have been at or near 515 ft above mean sea level (amsl), and the uranium FRL exceedances have been consistent. In 2022, total uranium concentrations were above 30 µg/L. As shown in Figure A.2-14, the water level during both 2022 sampling events was at or above 515 ft amsl.

Previous direct-push sampling in this area indicates that the total uranium FRL exceedances are associated with high water-table conditions. The former Plant 6 Area is targeted for direct-push sampling when the water-table elevation is at or above 515 ft amsl. As shown below, unless the water table is above an elevation of 515 ft amsl, total uranium FRL exceedances are normally not detected. The last direct-push sample was collected in 2019 (13360E). The elevation of the collected sample was the highest ever recorded (517 ft amsl). The concentration measured was also the highest ever measured at 63.0 µg/L.

Year	Location	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)
2007	13360	<1.00	512
2008	13360A	37.2	515
2010	13360B	4.40	510
2011	13360C	37.7	515
2018	13360D	12.2	513
2019	13360E	63.0	517

Monitoring well 2389 will continue to be identified on the maximum total uranium plume map as being a location where intermittent total uranium FRL exceedances have been measured so that its presence will be carried forward into the certification stage of the aquifer remediation. This well is within capture of the groundwater remediation system.

A.2.3 South Field and Off-Property South Plume Total Uranium Plumes

The mapped footprint of the 30 µg/L maximum total uranium plume in the South Field and off-property South Plume decreased in size between 2021 and 2022. The size of the footprint was 62.52 acres in 2021 and 61.53 acres in 2022, a decrease of 1.0 acres (1.6%) (Figure A.2-5).

The mapped footprint of the 50 µg/L area of the plume increased in size between 2021 and 2022. The size of the area was 38.86 acres in 2021 and 39.499 acres in 2022, an increase of 0.64 acres (1.6%).

The mapped footprint 100 µg/L area of the plume decreased between 2021 and 2022. The size of the area was 20.41 acres in 2021 and 20.0 acres in 2022, a decrease 0.41 acres (2.1%).

A.2.3.1 South Field

In 2022, direct-push sampling was conducted at five locations in the South Field (locations 13533A, 13601, 13602, 13603, and 13604). Figure A.2-2 shows the locations and the 2022 total uranium results. All five locations are located in the southwest area of the South Field Plume.

Location 13533A

Location 13533A is west of the South Field uranium plume, in the southern half of the South Plume. Direct-push sampling results for location 13533A are provided in Table A.2-1. The location is identified in Figure A.2-2.

This location has been sampled twice in 2021 and 2022. The location sampled in 2021 was identified as location 13533. The location sampled in 2022 was identified as location 13533A. The following table provides total uranium concentrations from the two sampling events.

Location 13533 (2021)		Location 13533A (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
510	31.8	511	45.4
500	3.6	501	8.5
490	6.7	491	6.1
480	3.3	481	< 1.0
470	5.4	471	3.4

The maximum total uranium concentration measured in 2021 was 31.8 µg/L (elevation of 510 ft amsl). The maximum total uranium concentration measured in 2022 was 45.4 µg/L (elevation 511 ft amsl). The 30 µg/L contour on the 2021 maximum uranium plume map did not need to be adjusted to honor the 2022 concentration.

<u>Location 13601</u>
Location 13601 is in the southwest area of the South Field. Direct-push sampling results for location 13601 are provided on Table A.2-2, and the location is identified on Figure A.2-2.

As shown in Table A.2-2, the maximum total uranium concentration measured in 2022 was 38.4 µg/L (elevation 514 ft amsl). The maximum uranium plume map was not adjusted to honor the 2022 measurement because a 2022 sample from the nearby monitoring well 2045 was 66. 4 µg/L resulting in the location being located within the 50 µg/L contour on Figure A.2-2

<u>Location 13602</u>
Location 13602 is in the southwest area of the South Field. Direct-push sampling results for location 13602 are provided on Table A.2-3, and the location is identified on Figure A.2-2.

As shown in Table A.2-3, the maximum total uranium concentration measured in 2022 was 21.1 µg/L (elevation 513 ft amsl). The maximum uranium plume map was adjusted to honor the 2022 measurement.

<u>Location 13603</u>
Location 13603 is in the southwest area of the South Field. Direct-push sampling results for location 13603 are provided on Table A.2-4, and the location is identified on Figure A.2-2.

As shown in Table A.2-4, the maximum total uranium concentration measured in 2022 was 106 µg/L (elevation 516 ft amsl). The maximum uranium plume map was adjusted to honor the 2022 measurement.

<u>Location 13604</u>
Location 13604 is in the southwest area of the South Field. Direct-push sampling results for location 13604 are provided on Table A.2-5, and the location is identified on Figure A.2-2.

As shown in Table A.2-5, the maximum total uranium concentration measured in 2022 was 12.8 µg/L (elevation 504 ft amsl). The maximum uranium plume map was adjusted to honor the 2022 measurement.

A.2.3.1.1 Intermittent Total Uranium FRL Exceedance Locations and Monitoring Wells with Increasing Total Uranium Concentration Trends

No intermittent total uranium FRL exceedance locations are identified for the South Field.

A.2.3.1.2 Monitoring Wells with Increasing Total Uranium Concentration Trends in the South Field

As Table A.2-28 shows, four monitoring wells in the South Field—21033, 2386, 2387, and 83294_C1—had upward trends for total uranium concentrations in 2022. The locations are shown in Figure A.2-4. Figures A.2-15 through A.2-18 provide time versus total uranium concentration plots for these four wells. The total uranium concentration increases are attributed to changes in the plume caused by the active groundwater remediation. Uranium contamination is being pulled toward the extraction wells.

A large increase in uranium concentration was measured in monitoring well 2049 in 2022. As shown in Figure A.2-19, in the first half of 2022 the uranium concentration increased from being below 30 µg/L in 2021 to a new all-time high for the well of 278 µg/L. In the second half of 2022, the result was 207 µg/L. As shown in Table A.2-28 the uranium data set from this well is trending down statistically. The cause for this sudden increase in uranium concentration is being attributed to a slug of dissolved uranium in this area.

DOE will continue to monitor these wells but plans no action at this time in response to the increasing concentration trends. All these wells are within the capture zone of the groundwater remediation system.

A.2.3.2 South Plume

A.2.3.2.1 New Direct-Push Sampling Data in the South Plume

In 2022, direct-push sampling was conducted at 22 locations in the South Plume (12196C, 13229I, 13233C, 13239G, 13267D, 13477E, 13510A, 13513C, 13535A, 13538A, 13542A, 13605, 13606, 13607, 13608, 13609, 13610, 13611, 13612, 13613, 13614, and 13615). Sampling locations are shown in Figure A.2-2. Sampling results are discussed below.

Location 12196C

Location 12196C is situated in the northeast lobe of the South Plume. Direct-push sampling results for location 12196C are provided in Table A.2-6. The location is identified in Figure A.2-2.

This location has been sampled four times: 1996, 2005, 2007, and 2022. The samples collected in 1996 were identified as location 12196. The samples collected in 2022 were identified as location 12196C. Total uranium concentration data from all four sampling events are provided below.

12196 (1996)		12196A (2005)		12196B (2007)		12196C (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
518	0.4	514	4.3	517	6.7	514	33.7
509	0.3	505	87.5	507	59.6	504	40.3
499	0.7	495	100.7	497	103.7	494	<1.0
489	0.5	485	14.4	487	3.2	484	20.0
479	0.3	475	37.4	477	9.0	474	2.8
469	0.5	465	18.7	467	3.0		
459	0.7						
449	0.4						
439	1.6						

As shown above, the maximum uranium concentration decreased from 103.7 µg/L (elevation 497 ft amsl) in 2007 to 40.3 µg/L (elevation 504 ft amsl) in 2022. Because a close direct-push sample in 2022 at location 13477E (southeast of location 12196C) was above 50.0 µg/L the contour map was not adjusted to honor the 40.3 µg/L.

Location 13229I

Location 13229I is located on the west edge of the South Plume. Direct-push sampling results for location 13229I are provided in Table A.2-7. The location is identified in Figure A.2-2.

This location has been sampled ten times: 2002, 2003, 2008, 2013, 2015, 2017, 2018, 2019, 2020, and 2022. The samples collected in 2002 were identified as location 13229. The samples collected in 2022 were identified as location 13229I. Total uranium concentration data from all ten sampling events are provided below.

Location 13229 (2002)		Location 13229A (2003)		Location 13229B (2008)		Location 13229C (2013)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
517	58.0	515	81.8				
508	101	506	89.3	509	72.7	510	61.2
498	47.0	496	92.7	499	65.3	500	40.8
488	29.0	486	51.2	489	42.2	490	41.2
478	19.0	476	11.3	479	37.4	480	15.2
468	15.0	466	4.50	469	17.8	470	5.9
458	3.20	456	1.20			460	3.4
448	<1.0						

Location 13229D (2015)		Location 13229E (2017)		Location 13229F (2018)		Location 13229G (2019)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
511	47.1	512	49.8	511	58.2	516	58.8
501	49.8	502	32.2	501	36.3	506	37.2
491	39.8	492	14.0	491	24.7	496	32.9
481	26.7	482	13.5	481	21.5	486	17.5
471	11.6	472	5.3	471	14.9		
		462	3.7				

Location 13229H (2020)		Location 13229I (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
515	46.7	512	52.8
505	20.8	502	33.1
495	18.1	492	19.9
485	12.5	482	20.0
		472	13.0

Between 2015 and 2022, the six samples collected from this location show that the maximum uranium concentration has ranged between 58.8 µg/L in 2019 (elevation 511 ft amsl) and 46.7 µg/L in 2020 (elevation 515 ft amsl). In 2022, the concentration was back up above 50.0 µg/L (elevation 512 ft amsl). The total uranium plume map was adjusted to honor the 52.8 µg/L concentration.

Location 13233C

Location 13233C is located northeast of extraction well 32308 in the South Plume. Direct-push sampling results for location 13233C are provided in Table A.2-8. The location is identified in Figure A.2-2.

This location has been sampled four times: 2002, 2013, 2015, and 2022. The samples collected in 2002 were identified as location 13233. The samples collected in 2022 were identified as location 13233C. Total uranium concentration data from all four sampling events are provided below.

Location 13233 (2002)		Location 13233A (2013		Location 13233B (2015)		Location 13233C (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
513	20.0	511	44.8	510	39.0	515	44.1
505	54.0	501	20.4	500	41.1	505	31.5
495	55.0	491	16.7	490	28.1	495	29.2
485	38.0	481	10.2	480	20.3	485	21.5
475	33.0	471	<1.0			475	11.0
465	4.20	461	<1.0				
455	1.30	451	3.10				

These data show that the uranium concentration at this location was 44.1 µg/L in 2022 (elevation 515 ft amsl). No change was required on the total uranium plume map.

<u>Location 13239G</u>

Location 13239G is situated north of extraction well 32309 in the approximate center of the South Plume. Direct-push sampling results for location 13239G are provided in Table A.2-9. The location is identified in Figure A.2-2.

This location has been sampled eight times: 2002, 2013, 2015, 2016, 2017, 2019, 2020, and 2022. The samples collected in 2002 were identified as location 13239. The samples collected in 2022 was identified as location 13239G. Total uranium concentration data from all eight sampling events are provided below.

Location 13239 (2002)		Location 13239A (2013)		Location 13239B (2015)		Location 13239C (2016)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
515	65.0						
507	49.0	511	64.0	511	62.0	511	58.5
497	69.0	501	43.5	501	50.6	501	54.3
487	32.0	491	25.5	491	30.9	491	38.7
477	12.0	481	5.70	481	10.9	481	15.1
467	4.90	471	2.00	471	4.8	471	9.3
457	1.90						
447	1.20						

Location 13239D (2017)		Location 13239E (2019)		Location 13239F (2020)		Location 13239G (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
511	46.5	514	59.5	512	53.6	512	74.3
501	40.5	504	45.5	502	46.4	502	29.4
491	34.7	494	40.6	492	33.2	492	18.5
481	3.0	484	12.3	482	11.7	482	10.6
471	4.8	474	14.6	472	6.9	472	2.5

The maximum uranium concentration sample collected in 2022 (74.3 µg/L at an elevation of 512 ft amsl) shows that the location remains above 50 µg/L. No change to the plume was required to honor the 2022 concentration.

Location 13267D

Location 13267D is in the southeast corner of the South Plume. Direct-push sampling results for location 13267D are provided in Table A.2-10. The location is identified in Figure A.2-2.

This location has been sampled five times: 2002, 2013, 2020, 2021, and 2022. The samples collected in 2002 were identified as location 13267. The samples collected in 2022 were identified as location 13267D. Total uranium concentration data from all five sampling events are provided below.

Location 13267 (2002)		Location 13267A (2013)		Location 13267B (2020)		Location 13267C (2021)		Location 13267D (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
517	5.8			514	8.3	513	57.4	513	15.6
508	64.0	511	16.3	504	52.2	503	32.1	503	22.3
498	60.0	501	18.8	494	34.5	493	30.9	493	8.6
488	54.0	491	16.8	484	12.4	483	14.6	483	10.9
478	30.0	481	18.2	474	8.7	473	3.4	473	1.7
468	3.6	471	7.7	464	7.6			463	<1.0
458	0.9	461	0.5						
448	0.8								

The maximum total uranium concentration at this location has fluctuated between a high of 64.0 µg/L in 2002 (elevation 508 ft amsl) and 18.8 µg/L in 2013 (elevation 501 ft amsl). In 2020 the concentration was once again above 50 µg/L (52.2 µg/L at an elevation of 504 ft amsl). A 50 µg/L contour was added around this location on the 2020 total uranium plume map to honor the 2020 result. The result in 2022 was 22.3 µg/L (503 ft amsl). The 2022 total uranium plume map was revised based on the 2022 result.

Location 13477E

Location 13477E is in the northeast corner of the South Plume. Direct-push sampling results for location 13477E are provided in Table A.2-11. The location is identified in Figure A.2-2.

This location has been sampled six times: 2014, 2015, 2018, 2019, 2021, and 2022. The samples collected in 2014 were identified as location 13477. The samples collected in 2022 were identified as location 13477E. Total uranium concentrations from all sixe sampling events are provided below.

Location 13477 (2014)		Location 13477A (2015)		Location 13477B (2018)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
512	1.4	511	<1.0	515	< 1.0
502	31.8	501	18.4	505	< 1.0
492	58.6	491	52.0	495	65.0
482	2.6	481	3.6	485	13.5
472	2.7	471	5.7	475	16.7

Location 13477C (2019)		Location 13477D (2021)		Location 13477E (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
518	<1.0	513	<1.0	512	<1.0
508	<1.0	503	32.0	502	59.4
498	56.5	493	59.3	492	9.4
488	13.0	483	13.7	482	8.4
478	8.2	473	8.8	472	2.1

The maximum uranium concentration at this location in 2022 remained above 50 µg/L. The 2022 total uranium plume map did not need to be adjusted to honor the 2022 concentration.

Location 13510A

Location 13510A is in the east side of the South Plume. Direct-push sampling results for location 13510A are provided in Table A.2-12. The location is identified on Figure A.2-2.

This location has been sampled two times: 2018 and 2022. The samples collected in 2018 were identified as location 13510. The samples collected in 2022 were identified as location 13510A. Total uranium concentrations from both sampling events are provided below.

Location 13510 (2018)		Location 13510A (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
513	7.2	512	12.7
503	26.9	502	24.7
493	46.7	492	5.7
483	48.1	482	12.5
		472	3.8
		462	1.2

The highest uranium concentration measured at this location in 2022 was 24.7 µg/L (elevation 502 ft amsl). The 2022 uranium plume map was not adjusted to honor this concentration. Additional direct-push data will be collected around this area next year to further define how to adjust the plume.

Location 13513C

Location 13513C is in the southeast corner of the South Plume. Direct-push sampling results for location 13513C are provided in Table A.2-13. The location is identified on Figure A.2-2.

This location has been sampled four times: 2018, 2020, 2021, and 2022. The samples collected in 2018 were identified as location 13513. The samples collected in 2021 were identified as location 13513C. Total uranium concentrations from all four sampling events are provided below.

Location 13513 (2018)		Location 13513A (2020)		Location 13513B (2021)		Location 13513C (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
513	10.1	515	10.3	514	38.0	515	23.2
503	26.4	505	19.3	504	25.7	505	46.4
493	43.5	495	45.3	494	28.6	495	32.2
483	33.0	485	10.8	484	22.7	485	16.1
473	<1.0	475	1.4	474	2.2	475	3.2

The maximum total uranium concentration at this location remains above 30 ug/L. No change was made to the maximum total uranium plume map based on the 2022 result.

Location 13535A

Location 13535A is in the northeastern corner of the South Plume. Direct-push results are provided in Table A.2-14. This location is identified on Figure A.2-2.

This location has been sampled two times: 2021 and 2022. The samples collected in 2021 were identified as location 13535. The samples collected in 2022 were identified as location 13535A. Total uranium concentrations from the two sampling events are provided below.

Location 13535 (2021)		Location 13535A (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
511	<1.0	513	1.1
501	76.1	503	36.6
491	6.1	493	16.0
481	2.4	483	2.9
471	2.4	473	<1.0

The maximum total uranium concentration measured in 2021 was 76.1 µg/L (elevation 501 ft amsl). The maximum total uranium concentration measured in 2022 was 36.6 µg/L (elevation 503 ft amsl). The 2022 maximum total uranium plume map was revised to honor the 2022 concentration.

Location 13538A

Location 13538A is in the northwest portion of the South Plume. Direct-push results are provided in Table A.2-15. This location is identified on Figure A.2-2.

This location has been sampled two times: 2021 and 2022. The samples collected in 2021 were identified as location 13538. The samples collected in 2022 were identified as location 13538A. Total uranium concentrations from the two sampling events are provided below.

Location 13538 (2021)		Location 13538A (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
511	35.5	514	42.7
501	31.7	504	4.9
491	10.3	494	21.3
481	6.1	484	7.4
471	2.6	474	6.4

The maximum total uranium concentration measured in 2022 was 42.7 µg/L (elevation 514 ft amsl). The 2022 maximum total uranium plume map did not need to be adjusted for the 2022 result.

Location 13542A

Location 13542A is on the southwest corner of the South Plume. Direct-push results are provided in Table A.2-16. This location is identified on Figure A.2-2.

Location 13542 was sampled three times in 2021 and again in 2022. The first samples collected in 2021 were identified as location 13542. The samples collected in 2022 were identified as 13542A. Results for both years are provided in the table below.

Location 13542 (7/20/2021)		Location 13542 (7/28/2021)		Location 13542 (8/6/2021)		Location 13542A (2022)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
509	32.2	509	21.1	509	21.9	512	40.4
499	5.4	499	4.8	499	2.7	502	5.9
489	8.9	489	6.1	489	6.8	492	5.4
479	22.7	479	17.2	479	9.7	482	11.4
469	40.9	469	20.2	469	19.8	472	23.6
		459	10.2	459	15.4	462	20.5
		449	3.9	449	8.0	452	18.5
		439	1.4	439	1.0	442	1.6

The first sampling was conducted on July 20, 2021, and resulted in a maximum uranium concentration of 40.9 µg/L (elevation 469 ft amsl). In 2021, monitoring well 3095, located just north of location 13542, had a maximum uranium concentration of 39.8 µg/L. This indicates that there is a deep lens of contamination in this area below the water table. It was decided to do a confirmatory sampling on July 28, 2021, and results were different enough from the results on July 20, 2021, that it was decided to do a third confirmatory sampling on August 6, 2021. As shown in the table above, no uranium concentrations above 30 µg/L were measured in the July 28, 2021, and August 6, 2021, samples. To be conservative, sample results from July 20, 2021, the highest total uranium concentrations measured, were selected for the 2021 maximum total uranium plume map. The 2021 uranium plume map showed a plume above 30 µg/L based on the July 20, 2021, samples from location 13542 and 2021 monitoring results from monitoring well 3095. Location 13542 was sampled again in 2022. The maximum uranium concentration measured in 2022 was 40.4 µg/L (elevation 469 ft amsl). No changes were needed on the 2022 total uranium plume map to honor the 2022 result.

Location 13605

Location 13605 is located on the northwest corner of the South Plume, just south of Willey Road. Direct-push results are provided in Table A.2-17. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 26.8 µg/L (elevation 513 ft amsl). The 2022 maximum total uranium plume map was revised to honor the 2022 concentration.

Location 13606
Location 13606 is located on the west side of the South Plume. Direct-push results are provided in Table A.2-18. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 56.1 µg/L (elevation 513 ft amsl). The 2022 maximum total uranium plume map was revised to honor the 2022 concentration.

Location 13607
Location 13607 is located in the center of the South Plume. Direct-push results are provided in Table A.2-19. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 26.4 µg/L (elevation 511 ft amsl). The 2022 maximum total uranium plume map was not revised to honor the 2022 concentration. Additional sampling will be conducted in this area in 2023 to determine how best to revise the plume map in this area.

Location 13608
Location 13608 is located on the east side of the South Plume. Direct-push results are provided in Table A.2-20. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 37.8 µg/L (elevation 501 ft amsl). Before sampling in this area, it was assumed that the uranium concentration data from this location would be below 30 µg/L. Because it was above 30 µg/L, the 2022 maximum total uranium plume map was revised to honor the 2022 concentration. This location was a farm field that was immediately planted following sampling. It could not be resampled until the crops were harvested in the fall. Following crop harvest, an attempt was made to resample, but equipment and weather did not cooperate. A second sample in 2022 was not collected. Additional sampling will be conducted in this area in 2023.

Location 13609
Location 13609 is located on the west side of the South Plume. Direct-push results are provided in Table A.2-21. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 50.8 µg/L (elevation 513 ft msl). The 2022 maximum total uranium plume map was revised to honor the 2022 concentration.

Location 13610
Location 13610 is located in the center of the South Plume. Direct-push results are provided in Table A.2-22. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 26.5 µg/L (elevation 492 ft amsl). The 2022 maximum total uranium plume map was not revised to honor the 2022 concentration. Additional sampling will be conducted in this area in 2023 to determine how best to revise the plume map in this area.

Location 13611

Location 13611 is located in the center of the South Plume. Direct-push results are provided in Table A.2-23. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 25.1 µg/L (elevation 512 ft amsl). The 2022 maximum total uranium plume map was not revised to honor the 2022 concentration. Additional sampling will be conducted in this area in 2023 to determine how best to revise the plume map in this area.

Location 13612

Location 13612 is located in the center of the South Plume. Direct-push results are provided in Table A.2-24. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 38.8 µg/L (elevation 502 ft amsl). The 2022 maximum total uranium plume map was not revised to honor the 2022 concentration. Additional sampling will be conducted in this area in 2023 to determine how best to revise the plume map in this area.

Location 13613

Location 13613 is located in the center of the South Plume. Direct-push results are provided in Table A.2-25. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 33.6 µg/L (elevation 503 ft amsl). The 2022 maximum total uranium plume map was not revised to honor the 2022 concentration. Additional sampling will be conducted in this area in 2023 to determine how best to revise the plume map in this area.

Location 13614

Location 13614 is located in the center of the South Plume. Direct-push results are provided in Table A.2-26. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 71.9 µg/L (elevation 514 ft amsl). The 2022 maximum total uranium plume map did not need to be revised to honor the 2022 concentration.

Location 13615

Location 13615 is located in the southeast corner of the South Plume. Direct-push results are provided in Table A.2-27. The 2022 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

The maximum total uranium concentration measured in 2022 was 26.4 µg/L (elevation 503 ft amsl). The 2022 maximum total uranium plume map was revised to honor the 2022 concentration.

A.2.3.2.2 Intermittent Total Uranium FRL Exceedance Locations in the South Plume

Two monitoring wells (2552 and 2900) are identified on the maximum total uranium plume maps for 2022 in the South Plume (Figure A.2-3) as being monitoring locations with intermittent total uranium FRL exceedances. Beginning in 2017, monitoring well 2900 is sampled only once a year, during the first half of the year.

A time versus total uranium concentration plot for monitoring well 2552 is provided in Figure A.2-20. The figure shows that no total uranium FRL exceedances have been measured since 2016.

A time versus total uranium concentration plot for monitoring well 2900 is provided in Figure A.2-21. The figure indicates that no total uranium FRL exceedances occurred in 2022. Only two total uranium FRL exceedances have been measured at this well since 1993. The last one occurred in 2012.

These wells will continue to be identified on maximum total uranium plume maps as locations where intermittent total uranium FRL exceedances have been measured so that their presence will be carried forward into the certification stage of the aquifer remediation.

A.2.3.2.3 Monitoring Wells with Increasing Total Uranium Concentration Trends in the South Plume

As shown in Figure A.2-4 and Table A.2-28, three monitoring wells (2880, 82369_C2, and 82369_C3) had upward trends for total uranium concentration in the South Plume in 2022. Time versus concentration graphs for these wells are provided in Figures A.2-22 and A.2-23. Both wells are located within the capture zone of the extraction wells and, as such, the increasing concentration trends are not considered to be a threat to human health or the environment.

A.2.4 Monitoring Well Inspection and Maintenance

All monitoring wells were inspected in 2022 with particular emphasis on those wells that are not routinely used for sampling or water level measurements. The main concern noted for wells not routinely sampled was that protective casings on some of them need to be painted and have identification markings reapplied. Additional minor findings include:

- Some protective casing lids were hard to open.
- Some wells need to have vegetation or branches removed from around them to improve access.
- Uneven surfaces were noted around some wells.

Many of the inspection findings noted above were corrected immediately (e.g., vegetation removal). Deficiencies that could not be corrected immediately (e.g., removal of overhanging trees) will be corrected as time permits.

Annual visual inspections of all monitoring wells will continue in future years with any deficiencies documented and corrected. Additionally, camera surveys of monitoring wells that are not routinely sampled will be conducted every 5 years. The last camera survey was conducted in 2017 and 2018. The most recent camera survey began in 2022 and will continue into 2023. In 2022, issues were identified in seven monitoring wells. DOE will determine the path forward when the camera surveys are completed in 2023; wells with issues will most likely be properly plugged and abandoned unless it can be determined that the issue can be corrected.

Well Number	Date of Installation	Program Use	Issue Identified
2008	1988	None	Leaking well riser joints
2043	1987	Groundwater Elevations Only	Bent riser and leaking well riser joints
2044	1988	Groundwater Elevations Only	Leaking well riser joints
2051	1987	Groundwater Elevations Only	Leaking well riser joints
2383	1990	Groundwater Elevations Only	Leaking well riser joints
2881	1993	Groundwater Elevations Only	Leaking well riser joints
2935	1993	None	Leaking well riser joints
3011	1987	Groundwater Elevations Only	Leaking well riser joints

A.2.5 Plume Metrics

Uranium plume area, center of mass, and remaining uranium mass calculations were first reported in the 2015 Site Environmental Report (DOE 2016), in response to a request from Ohio EPA. Those calculations follow the approach presented by Joseph A. Ricker in “A Practical Method to Evaluate Ground Water Contaminant Plume Stability” (Ricker 2008).

Using the Ricker method calculations supplements other remedy tracking metrics (i.e., maximum uranium plume maps, model predictions, and uranium concentration data regressions) that are also being reported. The other metrics were developed over many years of interaction with EPA and Ohio EPA, have proven to be reasonable and useful, and are considered to be good for measuring the extraction system’s effectiveness. The Ricker method provides an additional good assessment tool.

Starting with this year’s Site Environmental Report, Earth Volumetric Studio (EVS) software was also used to assist in determining plume metrics (i.e., volume, footprint area, average plume thickness, and center of mass). This additional assessment stems from a recommendation made during a collaborative effort with the DOE National Laboratory Network. The National Laboratory Network recommended a four-dimensional mapping exercise (i.e., three spatial dimensions with time as the fourth dimension). The result of the additional assessment supports the Ricker results and demonstrates that the lateral and vertical dimensions of the uranium plume are contracting, the total dissolved uranium mass is decreasing, and the center of mass has not migrated downgradient. These results also indicate that the pumping system is successfully containing the contamination, preventing plume expansion, and reducing uranium concentrations throughout the contaminated aquifer.

A.2.5.1 Ricker Method Results

As reported in the 2016 Site Environmental Report (DOE 2017a), plume area calculations based on the Ricker method compared reasonably well with plume area calculations made by conservatively mapping the maximum uranium plume each year. However, the Ricker method calculation of uranium mass remaining in the aquifer was reported as being an order of magnitude lower than predictions presented in Attachment A.1 (based on groundwater modeling predictions and a regression of monitoring data). As discussed below, refinement of the calculation methodology since 2017 indicates that the calculations are in closer agreement when the difference between the mass of uranium in the groundwater and the mass of uranium sorbed to aquifer sediments is recognized and considered in the calculation.

As reported in the 2016 Site Environmental Report (DOE 2017a), a notable difference between the Ricker method and the other metrics being used was that the Ricker method did not include the results of groundwater samples collected using the Geoprobe, while the other metrics did include these data. The groundwater data collected using the Geoprobe were not included in the Ricker calculation because the Ricker calculation requires a dataset that is consistent in location over time; the annual Geoprobe effort does not sample the same locations every year. Ohio EPA requested that future calculations include Geoprobe results to see if the included data improve estimates of the uranium mass remaining (DOE 2017b).

The analysis presented in this year's report uses the annual maximum concentration in 2006, 2010, 2014, 2016 through 2022 and a consistent set of monitoring well data that span all 10 selected years. The most recent maximum total uranium results available at Geoprobe locations were also included. Surfer software (version 15.5.382) was used for kriging the data and mapping the results. Until 2017, the analysis was conducted for three separate plume areas: the PPDD, the South Field and South Plume, and the former WSA. With the addition of Geoprobe data, the analysis in 2017 changed to being applied to the entire plume. A homogenous effective porosity equal to that modeled for the aquifer (28%) was assumed, and a plume thickness of 30 ft was used.

Figure A.2-24 provides a uranium plume map that identifies the calculated center of mass for each year (2006, 2010, 2014, and 2016 through 2022). As shown in Figure A.2-24, the center of mass in each plume area has remained fairly stationary (i.e., in the same general area) over this period, indicating that the surrounding pumping wells are capturing the plume and not allowing the center of mass to migrate as it would if no pumping were taking place. In the former WSA, the center of mass has shifted slightly to the northwest over time. This is attributed to the higher uranium results in the northwest area as a result of additional Geoprobe sampling in the area. In the PPDD Area, the center of mass has shifted slightly to the west. This is attributed to cleanup of the east portion of the PPDD plume. In the South Field and South Plume, the center of mass has shifted slightly to the north. This is attributed to continuing uranium concentration reductions in the South Plume and southern South Field as cleanup proceeds. With inclusion of the Geoprobe data beginning in 2017, the dataset includes more samples collected near and outside plume boundaries, which helps better define the boundaries of the plume.

DOE plans to continue presenting these plume metrics in future Site Environmental Reports and will include Geoprobe data. With the addition of Geoprobe data, the analysis lends itself better to being applied to the entire plume, rather than dividing the plume into three different areas (i.e., WSA, PPDD, and the combined South Field and South Plume). Including the Geoprobe data also provides plume maps that appear to be better defined at the plume boundaries.

Figure A.2-25 provides 2022 Ricker method results for the total uranium plume area, the average total uranium concentration within the plume, and the total dissolved uranium mass remaining within the plume area. These trends are useful in illustrating remediation progress. As shown in Figure A.2-25, for 2022, the Ricker method calculations indicate that the total uranium plume area was 80.7 acres, the average uranium plume concentration was 88.58 µg/L, and the total uranium plume dissolved mass was 163 pounds (lb).

It should be noted that during preparation of these metrics for 2022, it was discovered that an error had been made in what was reported in the 2021 Site Environmental Report (DOE 2022). The error involved the average total uranium concentration and the total mass of dissolved uranium. The errors have little effect on the overall interpretation provided in Figure A.2-25. Data reported in error in the 2021 Site Environmental Report along with the corrected value is provided below.

	2021 Incorrect Data	2021 Corrected Data
Average Total Uranium Concentration (µg/L)	80.85	82.46
Mass of Total Uranium Dissolved (lb)	150	153

A.2.5.2 Earth Volumetric Studio Software Mapping Assessment

As mentioned above, the EVS analysis is new to the Site Environmental Report starting this year. To address the National Laboratory Network recommendation, an EVS data assessment exercise was conducted using data collected through 2021.

The footprint of the 2021 total uranium plume generated through EVS is very similar to the 2021 total uranium plume footprint provided in the 2021 Site Environmental Report. This shows that the interpretation obtained from the EVS mapping is consistent with previous plume interpretations. For this report, a footprint of the 2022 uranium plume generated through EVS and the bulk plume metrics (i.e., uranium plume dissolved mass, average concentration, volume, footprint area, and average thickness) for the 2022 plume interpretation are presented in Figures A.2-26 and A.2-27, respectively.

The bulk plume metrics provided in Figure A.2-27 were calculated for the combined plume and for four separate plume areas: the South Plume, the South Field Plume, WSA, and the PPDD. Trends in plume metrics observed through the EVS exercise are similar to trends calculated for the site by the Ricker method, with a downward trend in both mass and footprint areas.

Dissolved plume mass decreased by approximately 66% between 2007 and 2022, decreasing from 160 lb in 2006 to less than 54 lb in 2022 (Figure A.2-27). It should be noted that the total mass computed by EVS is significantly lower than the mass calculated by the Ricker method. The 2006 plume mass calculated by the Ricker method is 306 lb compared to 160 lb calculated by EVS. The Ricker method is a two-dimensional approach, and conservative assumptions are applied to account for the third vertical dimension. A conservative plume thickness of 30 ft is assumed in the Ricker calculations, and the maximum uranium concentration at each sample location is applied to the full plume thickness. These assumptions are not needed when concentration variations are visualized in three dimensions, so EVS provides a more realistic estimate of plume mass. For example, the average plume thickness calculated by EVS for October 2006 is 22.5 ft (25% less than the 30 ft plume thickness assumed for the Ricker method), and the average concentration is 68 µg/L (26% less than the 92 µg/L estimated by the Ricker method). If the mass calculated by the Ricker method is adjusted to account for the overestimates of plume thickness and average concentration, then the 2006 mass becomes 170 lb, which is very similar to the 160 lb mass calculate by EVS.

EVS-determined bulk plume metric for the results from October 1, 2006, October 2, 2021, and October 1, 2022, for the entire uranium plume are as follows.

Metric	October 1, 2006	October 1, 2021	October 1, 2022
Dissolved Mass (lb)	159.64	67.21	54.45
Average Concentration (µg/L)	68.44	67.47	59.21
Area (acres)	136.50	88.87	85.25
Volume (cubic feet)	279.55	119.39	110.21
Average Thickness (feet)	22.45	14.73	14.17

A.2.5.3 Total Uranium Plume Area

Table A.2-31 presents a comparison of the 2022 plume size interpretations (Figure A.2-2 and A.2-3) to the Ricker method calculation. Previous years are also presented. The comparison indicates that between 2014 and 2022, the percent difference for Ricker method has ranged between 2.6% and 9.1%. The percent difference in 2022 was 9.1%. For 2021 and 2022, the percent difference for the EVS method was 18.5% and 15.3%, respectively.

A.2.5.4 Total Mass of Uranium Remaining in the Aquifer

As has been done in previous Site Environmental Reports a calculation of the total mass of uranium remaining in the aquifer is presented. This year, the calculation is presented for dissolved mass determined using the both the Ricker method and the EVS interpretation.

<u>Ricker Method</u>
The value of 163 lb for the total mass of uranium remaining in the aquifer based on the Ricker method presented in Figure A.2-25 represents the dissolved mass of total uranium remaining in the aquifer based on 2022 data. As shown below, this result can be put into the context of the aquifer remediation by using the relationship of the contaminant distribution coefficient (K_d).

The distribution coefficient is the ratio of the concentration of a contaminant sorbed on the surfaces of the aquifer sediments to the concentration of the contaminant dissolved in groundwater and is represented as follows:

$$K_d = C_s/C_{aq}$$

where:

K_d = distribution coefficient, liters per kilogram (L/kg)

C_s = concentration of total uranium sorbed to aquifer sediments, milligrams per kilogram (mg/kg)

C_{aq} = concentration of total uranium dissolved in groundwater, milligrams per liter (mg/L)

The site-specific K_d for uranium used in the groundwater model is 3 L/kg (DOE 2003), which indicates that the concentration of uranium sorbed to aquifer sediments is three times the concentration of uranium in the groundwater. However, as discussed below, the sorbed mass of uranium is actually greater than three times the dissolved mass in solution because of the units used for K_d (Deutsch 1997).

The mass of aquifer solid in contact with 1 liter (L) of groundwater under saturated conditions can be defined as the bulk density of the solid (ρ_b) divided by the porosity of the aquifer (η). In the groundwater model, the bulk density is 1.85 grams per cubic centimeter (g/cm^3) and aquifer porosity is 28%; therefore, ρ_b/η = 6.61 g/cm^3.

The total uranium mass in the aquifer can be estimated by adding both the aqueous mass and solid mass using the following formula (Deutsch 1997):

$$\text{Total mass} = [(C_{aq})(1\text{ L})] + [(\rho_b/\eta)(C_s)(1\text{ L})]$$

where:

C_{aq} = concentration of total uranium dissolved in groundwater, mg/L

ρ_b = bulk density of aquifer sediments, g/cm^3

η = porosity of aquifer, percent

C_s = concentration of total uranium sorbed to aquifer sediments, mg/kg

This equation is solved below for a 1 L aquifer volume with an assumed C_{aq} of 1 mg/L. Site-specific values defined in the groundwater model for bulk density (1.85 g/cm^3) and aquifer porosity (28%) are used. A K_d of 3 L/kg is used to define a C_s of 3 mg/kg.

$$\text{Total Mass} = [(C_{aq})(1\text{ L})] + [(\rho_b/\eta)(C_s)(1\text{ L})]$$

$$\text{Total Mass} = [(1\text{ mg}_{aq}/\text{L})(1\text{ L})] + \{[(1.85\text{ g/cm}^3)/0.28][(3\text{ mg/kg})(1\text{ L})]\}$$

$$\text{Total Mass} = (1\text{ mg}_{aq}) + \{(6.61\text{ g/cm}^3)[(3\text{ mg/kg})(1\text{ L})]\}$$

Unit Conversions

$(6.61 \text{ g/cm}^3)(1{,}000 \text{ cm}^3\text{/L}) = 6{,}610 \text{ g/L}$

$(6{,}610 \text{ g/L})(1{,}000 \text{ mg/g}) = 6{,}610{,}000 \text{ mg/L})$

$$\text{Total Mass} = (1 \text{ mg}_{aq}) + [(6{,}610{,}000 \text{ mg/L})(3 \text{ mg/kg})(1 \text{ L})]$$

Unit Conversion

$(3 \text{ mg/kg})(1 \text{ kg}/1{,}000{,}000 \text{ mg}) = 0.000003$

$$\text{Total Mass} = 1 \text{ mg}_{aq} + (6{,}610{,}000 \text{ mg/L})[(0.000003)(1 \text{ L})]$$

$$\text{Total Mass} = 1 \text{ mg}_{aq} + 19.83 \text{ mg}_{s}$$

This total mass calculation shows that the uranium mass sorbed in a 1 L volume of aquifer is 19.83 times greater than the uranium mass dissolved. This relationship can be combined with the result of the Ricker dissolved mass estimate to determine a total uranium mass for the aquifer. The Ricker method estimated a dissolved uranium mass of 163 lb (Figure A.2-25); therefore, the estimated total mass in the aquifer (based on 2022 data) was 3,395.29 pounds.

$$3{,}395.29 \text{ lb total} = 163 \text{ lb}_{aq} + (163 \text{ lb}_{aq})(19.83)$$

$$3{,}395.29 \text{ lb total} = 163 \text{ lb} + 3{,}232.29 \text{ lb}$$

The result of 3,395.29 lb of uranium mass total from the Ricker method can be compared to the predicted dissolved mass removal estimates presented in Attachment A.1 to achieve an estimate of the dissolved mass required to be removed from the aquifer to achieve a concentration-based cleanup of 30 µg/L. The estimate will also show how much sorbed uranium mass will remain in the aquifer when the concentration-based cleanup is achieved.

As shown in Table A.1-24 in Attachment A.1, two estimates are provided for the estimated total pounds of dissolved uranium mass to be removed from the aquifer to achieve the concentration-based cleanup FRL of 30 µg/L:

- 2,355 lb dissolved mass (based on new 2022 model predictions)
- 3,466 lb dissolved mass (based on regression of concentration data)

The range in the predicted mass of dissolved uranium that needs to be removed indicates that between 1,040.29 and negative 79.71 lb of uranium will remain sorbed to aquifer sediments when the concentration-based cleanup of 30 µg/L is achieved:

- 3,395.29 lb – 2,355 lb = 1,040.29 lb sorbed uranium mass remains
- 3,395.29 lb – 3,466 lb = -79.71 lb sorbed uranium mass remains

The use of stretched exponential equations to trend uranium concentration data (new this year) resulted in a prediction that more dissolved uranium mass (3,466 lb) will need to be removed from the aquifer than was determined to be present in the aquifer (3,395.29 lb) by the Ricker method.

EVS Interpretation

As presented earlier, through EVS analysis, the dissolved uranium mass present in the aquifer in October 2022 was determined to be 54.45 lb (considerably lower than the 163 lb determined through the Ricker method). Using 54.45 lb and a multiplier of 19.83 (as shown below), results in an estimated mass remaining of 1,134.19 lb. This is considerably lower than the 3,395.29 lb determined previously.

$$1{,}134.19 \text{ lb total} = 54.45 \text{ lb}_{aq} + (54.45 \text{ lb}_{aq})(19.83)$$

$$1{,}134.19 \text{ lb total} = 54.45 \text{ lb} + 1{,}079.74 \text{ lb}$$

In Table A.1-24 in Attachment A.1, two estimates are provided for the total pounds of dissolved uranium mass to be removed from the aquifer to achieve the concentration-based cleanup FRL of 30 µg/L:

2,355 lb dissolved mass (based on new 2022 model predictions)

3,466 lb dissolved mass (based on regression of concentration data)

As shown below, subtracting the predicted dissolved mass removal estimates presented in Table A.1-24 from the EVS interpreted result of 1,134.19 pounds remaining in the aquifer results in negative numbers.

1,134.19 lb – 2,355 lb = -1,220.81 lb sorbed uranium mass remains

1,134.19 lb – 3,466 lb = -2,3331.81 lb sorbed uranium mass remains

<u>Summary</u>

The estimated range for dissolved mass of uranium remaining in the aquifer is 54.45 lb (EVS) to 163 lb (Ricker). These dissolved mass estimates were put into the context of the aquifer remediation by using the contaminant distribution coefficient (Kd) relationship presented in Deutsch 1997.

The Deutsch relationship indicates that the uranium mass sorbed in a 1 L volume of aquifer is 19.83 times greater than the uranium mass dissolved. Using this multiplier, the estimated range of mass remaining in the aquifer (both dissolved and sorbed) was determined to be 1,134.19 lb (EVS) to 3,395.29 lb (Ricker).

Of the two estimates, the Ricker method estimate (3,395.29 lb) is closer to the estimates of the total pounds of dissolved uranium mass left to be removed from the aquifer to achieve the concentration based cleanup FRL of 30 ug/L reported in Attachment A.1, Table A.1-24 (i.e., 2,355 lb based on 2022 model predictions, and 3,466 lb based on stretched exponential regression of concentration data).

DOE will continue to refine these interpretation methods. For instance, as more EVS interpretation work is conducted, a better understanding of actual plume dimensions and volume will evolve. Additional work to better understand how Kd varies in the braided stream deposits found in the aquifer could result in better cleanup time predictions and better remediation results in recalcitrant areas.

A.2.6 Total Uranium Plume Cross Sections

Five total uranium plume cross sections are presented to provide a vertical interpretation of the total uranium plume. The locations of each cross section are shown in Figures A.2-28, A.2-29, and A.2-30. These three figures also display the maximum total uranium plume interpretation 2022. The cross sections (A–A′, B–B′, C–C′, D–D′, and E–E′) are provided in Figures A.2-31A through A.2-35A, respectively.

New to this year’s Site Environmental Report, in addition to creating cross sections using Surfer software (as described below), DOE has produced the same five cross section using EVS software. Figures A.2-31A through A.2-35A presents the Surfer version, Figure A.2-31B through Figure A.2-35B presents the EVS version. DOE intends to transition to only using EVS generated cross sections for future Site Environmental Reports. Both are shown in this year’s Site Environmental Report to illustrate the similarity between the two methods.

Surfer software (Version 15.5.382) was used to krige the total uranium concentration datasets and produce the plume cross sections. Point kriging of the data for all total uranium cross sections was performed using the Surfer default settings with the exception of the anisotropy ratio. For anisotropy, a ratio of 10 to 1 (vertical to horizontal) was used.

The plume interpretations shown in the cross sections provide a less conservative plume interpretation of area than the maximum total uranium plume maps presented in Figures A.2-2, and A.2-3. The cross sections, therefore, do not correlate directly with the maximum total uranium plume interpretations presented in those figures. The cross sections provide an additional interpretation of the total uranium concentration data that were used to develop the maximum total uranium plume maps.

Each cross section depicts the ground surface, the base of the glacial till (clay overburden), the top of the unconsolidated sand and gravel Great Miami Aquifer, and the average water-table elevation. Monitoring well data are the maximum total uranium concentrations measured at the water table elevation recorded at the time that the sample was collected. The midpoint of the monitoring well screen or Geoprobe screen is shown for each location with a “+” symbol. Vertical depth total uranium profiles are provided for each Geoprobe location. Extraction well screen locations and depths are also shown in the cross sections, if applicable.

As illustrated in the cross sections, the top of the 30 µg/L total uranium plume is normally situated at the water table, but in a few areas of the aquifer the top of the 30 µg/L total uranium plume is located beneath the water table. Some of the plume areas depicted in the maximum total uranium plume maps appear as smaller, separated plume areas in the cross sections. The separate areas help to point out where most of the total uranium concentrations are located based on the kriging results. Tracking the location and size of the plume areas beneath the water table should prove helpful in making operational decisions as the remedy progresses.

A.2.7 Split Sampling Program

In 2022 the scope of this program was reduced from three wells to one well. Since 1987, DOE has participated in a split sampling program with Ohio EPA. Split samples are obtained when technicians alternately add portions of a sample to two individual sample containers. This collection method helps ensure that both samples are as close as possible to being identical. The split samples are then submitted to two analytical laboratories; this allows for an independent comparison of data to ascertain quality assurance for laboratory analysis and field sampling methods. Ohio EPA occasionally performs independent sampling in addition to split sampling.

The split sampling program at private homeowner wells is the longest running groundwater monitoring effort at the site. The program was initiated in 1982 in response to monitoring results indicating above background concentrations of uranium in private wells near the site. By 1984, the site had officially established the program with the monthly sampling of 19 privately-owned wells. In 1996, the private well program had grown to 32 private wells. At a property owner’s request, any drinking water well near the site was sampled for uranium, and the one-time results were reported to the well owner. If any special request sample showed a questionable or significant total uranium concentration, or if the private well was determined to provide critical groundwater information in an area, the property owner had the option to participate in the routine sampling program. These private wells were sampled monthly or quarterly depending upon location, and sampling results were reported annually in the Site Environmental Report. Three private wells (13, 14, and 2060) were included in the monitoring effort (DOE 1997). These three private wells continued to be sampled through 2022.

In 1997, with implementation of the IEMP, the private well program was modified to include only private wells 13, 14, and 2060, which included the private well where off-property contamination was initially reported in 1981. Other private wells that had been previously monitored were not carried forward into the IEMP program because a public water supply was made available to the surrounding properties who had been affected by the off-property groundwater contamination (DOE 1998). Data from these three remaining private wells have been used to produce the total uranium plume presented in Attachment A.2.

As shown in Figures A.2-36 and A.2-37, the historical sampling results for total uranium at wells 13 and 14 are well below the 30 µg/L FRL. Well 13 has been below the FRL since 2002 and well 14 has been below the FRL since this well was first sampled in 1988. These wells are located off-site and are outside of the uranium plume boundary and have been below the FRL for over 20 years. For these reasons, beginning in 2023, with concurrence from EPA and Ohio EPA, DOE will stop monitoring in these two private wells which occur outside the current plume (wells13 and 14) and will continue monitoring uranium in well 2060. The time versus concentration graph for well 2060 is provided in Figures A.2-38. This well will continue to be monitored as part of the IEMP program.

A.2.8 Uranium Concentration Trends at Select Monitoring Wells

New to this year’s Site Environmental Report is an additional prediction of when cleanup goals will be achieved at individual monitoring wells, which is independent of the groundwater model. These new predictions were made by applying dual exponential mathematical functions to uranium concentration data at groundwater monitoring wells that had uranium FRL exceedances in 2022 and show downward trending concentrations in 2022. This work was completed as part of the National Laboratory Network mathematical model recommendation discussed earlier. A brief summary of the results of the exercise is provided below. A more detailed presentation of the work is provided in the following report: *Alternative Mathematical Expressions for Projecting Remedial Time Frame Report*, *Fernald Preserve, Ohio Site* (DOE 2023).

The results of the exercise are provided in Table A.2-32. The results help identify how individual monitoring wells are responding to the aquifer remedy. For instance, in the South Plume, the current uranium concentration trend at monitoring well 6880 indicates that based on the current data trend, remediation goals at this well may not be achieved until sometime between 2027 and 2045. The 2022 groundwater modeling prediction for achievement of remediation goals in the South Plume through pumping is between 2024 and 2025. The two new extraction wells (expected to be operational in 2024) in this area should help accelerate the decreasing trend observed at this well. Table A.2-32 provides similar results for the South Field, PPDD, and former WSA.

In summary, the assessment of the trend of uranium concentration data shown in Table A.2-32 at individual monitoring wells through the application of dual exponential mathematical functions will continue to be used to help track remediation progress, identify recalcitrant areas, and be compared to modeling predictions to determine how the remedy is progressing.

A.2.9 References

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Table A.2-1. Geoprobe Location 13533A

Easting '83:	1348683	feet
Northing '83:	476268	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	515.81	feet AMSL
Work Completed:	6/6/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	511	65	0 - 10	45.4	17.7	7.37	0.820	>999	109	6.70
2	501	75	10 - 20	8.5	17.0	7.83	1.76	>999	35.0	9.49
3	501	75	10 - 20	4.9	17.0	7.83	1.76	>999	35.0	9.49
4	491	85	20 - 30	6.1	16.8	7.73	0.790	>999	>999	5.40
5	481	95	30 - 40	1.0	16.4	7.73	0.820	>999	39.7	5.87
6	471	105	40 - 50	3.4	15.3	7.70	0.83	>999	946	5.39

[a]Samples are filtered through a 5 micron filter.

Table A.2-2. Geoprobe Location 13601

Easting '83:	1348347	feet
Northing '83:	477158	feet
Ground Elevation:	543	feet above mean sea level (AMSL)
Depth to Water Table:	24.00	feet below ground surface (BGS)
Water Table Elevation:	519.27	feet AMSL
Work Completed:	6/13/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	514	29	0 - 10	38.4	21.7	7.57	0.720	>999	91.1	6.47
2	504	39	10 - 20	15.9	17.2	7.68	0.620	>999	50.3	7.03
3	504	39	10 - 20	15.9	17.2	7.68	0.620	>999	50.3	7.03
4	494	49	20 - 30	4.5	16.9	7.91	0.620	>999	39.1	6.25
5	484	59	30 - 40	4.0	15.1	7.87	0.595	>999	10.2	7.39
6	474	69	40 - 50	1.0	17.9	7.99	0.670	>999	13.1	4.55

[a]Samples are filtered through a 5 micron filter.

Table A.2-3. Geoprobe Location 13602

Easting '83:	1348456	feet
Northing '83:	477035	feet
Ground Elevation:	542	feet above mean sea level (AMSL)
Depth to Water Table:	24.00	feet below ground surface (BGS)
Water Table Elevation:	517.84	feet AMSL
Work Completed:	6/8/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	29	0 - 10	21.1	15.2	7.29	0.790	>999	918	7.50
2	503	39	10 - 20	5.0	18.2	7.97	0.750	>999	47.0	6.82
3	503	39	10 - 20	4.8	18.2	7.97	0.750	>999	47.0	6.82
4	493	49	20 - 30	2.4	15.0	7.83	0.680	>999	52.3	5.01
5	483	59	30 - 40	2.0	15.0	7.91	0.630	>999	16.1	6.38
6	473	69	40 - 50	2.4	14.9	7.88	0.607	>999	19.4	6.50

[a]Samples are filtered through a 5 micron filter.

Table A.2-4. Geoprobe Location 13603

Easting '83:	1348652	feet
Northing '83:	476573	feet
Ground Elevation:	572	feet above mean sea level (AMSL)
Depth to Water Table:	51.00	feet below ground surface (BGS)
Water Table Elevation:	520.76	feet AMSL
Work Completed:	6/14/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	516	56	0 - 10	106	19.8	7.35	0.720	>999	108	7.06
2	506	66	10 - 20	12.9	18.9	7.78	0.630	>999	57.0	6.35
3	506	66	10 - 20	10.0	18.9	7.78	0.630	>999	57.0	6.35
4	496	76	20 - 30	16.8	18.7	7.64	0.720	>999	32.3	5.58
5	486	86	30 - 40	16.9	19.0	7.58	0.810	>999	20.7	4.60
6	476	96	40 - 50	9.1	17.6	7.50	0.800	>999	20.8	4.86

[a]Samples are filtered through a 5 micron filter.

Table A.2-5. Geoprobe Location 13604

Easting '83:	**1348970**	feet
Northing '83:	**476481**	feet
Ground Elevation:	**561**	feet above mean sea level (AMSL)
Depth to Water Table:	**42.50**	feet below ground surface (BGS)
Water Table Elevation:	**518.69**	feet AMSL
Work Completed:	**6/15/2022**	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	514	48	0 - 10	6.6	18.5	7.46	0.670	>999	>999	7.90
2	504	58	10 - 20	11.4	22.1	7.88	0.750	>999	31.9	5.48
3	504	58	10 - 20	12.8	22.1	7.88	0.750	>999	31.9	5.48
4	494	68	20 - 30	4.1	21.2	7.96	0.720	>999	>999	5.97
5	484	78	30 - 40	9.3	16.6	7.74	0.800	>999	29.6	4.43
6	474	88	40 - 50	8.6	17.1	7.69	0.740	>999	>999	5.65

[a]Samples are filtered through a 5 micron filter.

Table A.2-6. Geoprobe Location 12196C

Easting '83:	1349174	feet
Northing '83:	475881	feet
Ground Elevation:	582	feet above mean sea level (AMSL)
Depth to Water Table:	63.00	feet below ground surface (BGS)
Water Table Elevation:	518.90	feet AMSL
Work Completed:	5/24/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	514	68	0 - 10	33.7	16.6	7.75	0.930	>999	263	7.92
2	504	78	10 - 20	40.3	15.3	7.68	0.780	>999	369	6.20
3	504	78	10 - 20	39.4	15.3	7.68	0.780	>999	369	6.20
4	494	88	20 - 30	<1.0	15.2	7.73	0.680	>999	22.4	5.94
5	484	98	30 - 40	20.0	15.1	7.67	0.680	>999	>999	7.38
5	474	108	40 - 50	2.8	17.0	8.05	0.600	>999	311	8.56

[a]Samples are filtered through a 5 micron filter.

Table A.2-7. Geoprobe Location 13229I

Easting '83:	1348246	feet
Northing '83:	475529	feet
Ground Elevation:	572	feet above mean sea level (AMSL)
Depth to Water Table:	55.00	feet below ground surface (BGS)
Water Table Elevation:	516.65	feet AMSL
Work Completed:	5/10/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	60	0 - 10	52.8	17.0	7.41	0.740	>999	368	8.00
2	502	70	10 - 20	33.1	16.0	7.65	0.720	>999	>999	7.97
3	502	70	10 - 20	30.9	16.0	7.65	0.720	>999	>999	7.97
4	492	80	20 - 30	19.9	15.6	7.65	0.640	>999	25.9	5.30
5	482	90	30 - 40	20.0	15.6	7.66	0.602	>999	11.7	4.50
6	472	100	40 - 50	13.0	15.2	7.69	0.640	>999	213	4.98

[a]Samples are filtered through a 5 micron filter.

Table A.2-8. Geoprobe Location 13233C

Easting '83:	1348644	feet
Northing '83:	475199	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	520.38	feet AMSL
Work Completed:	4/19/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	515	66	0 - 10	44.1	12.3	7.50	0.720	>999	472	8.35
2	505	76	10 - 20	30.4	12.1	7.72	0.680	>999	>999	7.85
3	505	76	10 - 20	31.5	12.1	7.72	0.680	>999	>999	7.85
4	495	86	20 - 30	29.2	11.5	7.56	0.700	>999	>999	6.49
5	485	96	30 - 40	21.5	11.2	7.69	0.680	>999	492	6.51
6	475	106	40 - 50	11.0	11.7	7.74	0.680	>999	>999	6.90

[a]Samples are filtered through a 5 micron filter.

Table A.2-9. Geoprobe Location 13239G

Easting '83:	1348459	feet
Northing '83:	475398	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.16	feet AMSL
Work Completed:	3/30/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	67	0 - 10	74.3	14.0	7.30	0.800	>999	694	8.06
2	502	77	10 - 20	29.0	13.7	7.48	0.740	>999	37.1	6.02
3	502	77	10 - 20	29.4	13.7	7.48	0.740	>999	37.1	6.02
4	492	87	20 - 30	18.5	16.8	7.83	0.720	>999	>999	8.50
5	482	97	30 - 40	10.6	13.6	7.59	0.800	>999	>999	6.05
6	472	107	40 - 50	2.5	14.0	7.71	0.710	>999	>999	5.41

[a]Samples are filtered through a 5 micron filter.

Table A.2-10. Geoprobe Location 13267D

Easting '83:	1348841	feet
Northing '83:	475194	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	518.27	feet AMSL
Work Completed:	4/28/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	67	0 - 10	15.6	13.6	7.47	0.750	>999	46.2	6.28
2	503	77	10 - 20	22.3	13.8	7.73	0.650	>999	101	5.56
3	503	77	10 - 20	20.2	13.8	7.73	0.650	>999	101	5.56
4	493	87	20 - 30	8.6	14.2	7.89	0.730	>999	132	6.62
5	483	97	30 - 40	10.9	13.5	7.74	0.750	>999	>999	5.55
6	473	107	40 - 50	1.7	13.9	7.56	0.820	>999	77.4	5.17
7	463	117	50 - 60	<1	13.7	7.57	0.830	>999	92.0	5.08

[a]Samples are filtered through a 5 micron filter.

Table A.2-11. Geoprobe Location 13477E

Easting '83:	1349240	feet
Northing '83:	475822	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	63.00	feet below ground surface (BGS)
Water Table Elevation:	516.88	feet AMSL
Work Completed:	5/9/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	68	0 - 10	<1.0	16.0	7.02	0.900	>999	550	7.02
2	502	78	10 - 20	59.4	15.4	7.63	0.760	>999	77.6	5.48
3	502	78	10 - 20	58.5	15.4	7.63	0.760	>999	77.6	5.48
4	492	88	20 - 30	9.4	15.8	7.90	0.770	>999	33.7	6.73
5	482	98	30 - 40	8.4	16.2	7.64	0.810	>999	722	5.48
6	472	108	40 - 50	2.1	15.7	7.66	0.860	>999	67.3	3.95

[a]Samples are filtered through a 5 micron filter.

Table A.2-12. Geoprobe Location 13510A

Easting '83:	1348848	feet
Northing '83:	475584	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.16	feet AMSL
Work Completed:	5/2/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	67	0 - 10	12.7	16.5	7.46	0.870	>999	>999	6.91
2	502	77	10 - 20	22.2	15.2	7.71	0.690	>999	361	6.45
3	502	77	10 - 20	24.7	15.2	7.71	0.690	>999	361	6.45
4	492	87	20 - 30	5.7	15.8	7.91	0.700	>999	34.0	4.95
5	482	97	30 - 40	12.5	16.1	7.83	0.690	>999	13.7	4.98
6	472	107	40 - 50	3.8	15.5	7.71	0.790	>999	272	4.95
7	462	117	50 - 60	1.2	15.2	7.56	0.860	>999	13.8	4.41

[a]Samples are filtered through a 5 micron filter.

Table A.2-13. Geoprobe Location 13513C

Easting '83:	1348891	feet
Northing '83:	475083	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	520.14	feet AMSL
Work Completed:	5/4/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	515	66	0 - 10	23.2	13.6	7.39	0.920	>999	59.6	6.70
2	505	76	10 - 20	46.4	13.2	7.72	0.710	>999	>999	5.41
3	505	76	10 - 20	36.9	13.2	7.72	0.710	>999	>999	5.41
4	495	86	20 - 30	32.2	12.9	7.66	0.680	>999	36.5	5.41
5	485	96	30 - 40	16.1	12.8	7.66	0.740	>999	6.07	3.72
6	475	106	40 - 50	3.2	12.9	7.68	0.810	>999	>999	6.84

[a]Samples are filtered through a 5 micron filter.

Table A.2-14. Geoprobe Location 13535A

Easting '83:	1349334	feet
Northing '83:	475922	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	58.00	feet below ground surface (BGS)
Water Table Elevation:	517.92	feet AMSL
Work Completed:	5/31/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	63	0 - 10	1.1	21.6	7.65	0.890	>999	829	4.63
2	503	73	10 - 20	36.6	17.6	7.68	0.760	>999	24.3	4.52
3	503	73	10 - 20	34.0	17.6	7.68	0.760	>999	24.3	4.52
4	493	83	20 - 30	16.0	17.9	7.74	0.760	>999	16.3	3.52
5	483	93	30 - 40	2.9	18.6	7.79	0.790	>999	>999	4.01
6	473	103	40 - 50	<1.0	17.1	7.60	0.830	>999	327	2.81

[a]Samples are filtered through a 5 micron filter.

Table A.2-15. Geoprobe Location 13538A

Easting '83:	1348356	feet
Northing '83:	475537	feet
Ground Elevation:	575	feet above mean sea level (AMSL)
Depth to Water Table:	56.00	feet below ground surface (BGS)
Water Table Elevation:	518.98	feet AMSL
Work Completed:	5/16/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	514	61	0 - 10	42.7	15.4	7.45	0.730	>999	411	7.12
2	504	71	10 - 20	4.5	14.9	7.73	0.730	>999	127	4.93
3	504	71	10 - 20	4.9	14.9	7.73	0.730	>999	127	4.93
4	494	81	20 - 30	21.3	14.6	7.74	0.650	>999	71.2	5.87
5	484	91	30 - 40	7.4	14.9	7.74	0.400	>999	158	5.96
6	474	101	40 - 50	6.4	15.4	7.70	0.750	>999	>999	5.71

[a]Samples are filtered through a 5 micron filter.

Table A.2-16. Geoprobe Location 13542A

Easting '83:	1348155	feet
Northing '83:	474985	feet
Ground Elevation:	540	feet above mean sea level (AMSL)
Depth to Water Table:	23.00	feet below ground surface (BGS)
Water Table Elevation:	516.57	feet AMSL
Work Completed:	5/17/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	28	0 - 10	40.4	13.1	7.39	1.03	>999	27.3	9.44
2	502	38	10 - 20	5.9	15.3	7.60	0.630	>999	49.6	6.82
3	502	38	10 - 20	5.5	15.3	7.60	0.630	>999	49.6	6.82
4	492	48	20 - 30	5.4	15.6	7.52	0.770	>999	19.4	5.92
5	482	58	30 - 40	11.4	15.0	7.38	0.840	>999	6.71	4.73
6	472	68	40 - 50	23.6	14.6	7.39	0.850	>999	160	4.62
7	462	78	50 - 60	20.5	14.9	7.44	0.870	>999	>999	5.55
8	452	88	60 - 70	18.5	14.3	7.48	0.850	>999	>999	4.65
9	442	98	70 - 80	1.6	14.9	7.45	0.770	>999	130	3.96

[a]Samples are filtered through a 5 micron filter.

Table A.2-17. Geoprobe Location 13605

Easting '83:	1348591	feet
Northing '83:	476000	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.86	feet AMSL
Work Completed:	5/23/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	67	0 - 10	26.8	14.7	7.47	0.830	>999	382	10.55
2	503	77	10 - 20	3.9	15.0	8.00	0.670	>999	55.6	5.76
3	503	77	10 - 20	2.7	15.0	8.00	0.670	>999	55.6	5.76
4	493	87	20 - 30	6.4	14.5	8.06	0.680	>999	>999	5.68
5	483	97	30 - 40	1.5	14.7	8.08	0.700	>999	114	4.40
6	473	107	40 - 50	2.1	14.6	7.72	0.870	>999	111	4.64

[a]Samples are filtered through a 5 micron filter.

Table A.2-18. Geoprobe Location 13606

Easting '83:	1348494	feet
Northing '83:	475628	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	517.55	feet AMSL
Work Completed:	3/28/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	65	0 - 10	56.1	10.0	7.56	0.700	>999	>999	9.32
2	503	75	10 - 20	23.5	11.0	7.86	0.683	>999	>999	7.75
3	503	75	10 - 20	22.8	11.0	7.86	0.683	>999	>999	7.75
4	493	85	20 - 30	17.3	10.4	7.85	0.658	>999	>999	9.70
5	483	95	30 - 40	10.5	10.6	7.66	0.810	>999	342	6.22
6	473	105	40 - 50	8.9	11.3	7.72	0.810	>999	>999	6.56

[a]Samples are filtered through a 5 micron filter.

Table A.2-19. Geoprobe Location 13607

Easting '83:	1348607	feet
Northing '83:	475630	feet
Ground Elevation:	577	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	515.80	feet AMSL
Work Completed:	4/12/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	511	66	0 - 10	26.4	15.2	7.60	0.650	>999	>999	7.45
2	501	76	10 - 20	14.5	14.6	7.80	0.690	>999	983	5.23
3	501	76	10 - 20	15.4	14.6	7.80	0.690	>999	983	5.23
4	491	86	20 - 30	12.8	14.5	7.69	0.740	>999	248	6.09
5	481	96	30 - 40	6.5	13.8	5.36	0.760	>999	>999	7.40
6	471	106	40 - 50	1.6	13.9	6.78	0.830	>999	397	5.61

[a]Samples are filtered through a 5 micron filter.

Table A.2-20. Geoprobe Location 13608

Easting '83:	1349115	feet
Northing '83:	475614	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	63.00	feet below ground surface (BGS)
Water Table Elevation:	516.27	feet AMSL
Work Completed:	5/5/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	511	68	0 - 10	4.3	13.7	7.46	0.990	>999	111	6.24
2	501	78	10 - 20	34.7	14.0	7.71	0.770	>999	257	5.54
3	501	78	10 - 20	37.8	14.0	7.71	0.770	>999	257	5.54
4	491	88	20 - 30	14.2	13.9	7.74	0.690	>999	43.1	5.34
5	481	98	30 - 40	22.3	14.1	7.57	0.670	>999	23.7	5.30
6	471	108	40 - 50	1.9	13.9	7.56	0.810	>999	13.6	4.59

[a]Samples are filtered through a 5 micron filter.

Table A.2-21. Geoprobe Location 13609

Easting '83:	1348482	feet
Northing '83:	475548	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	517.86	feet AMSL
Work Completed:	3/29/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	65	0 - 10	50.8	13.2	7.66	0.750	>999	102	7.20
2	503	75	10 - 20	32.0	12.8	7.76	0.760	>999	525	7.15
3	503	75	10 - 20	31.1	12.8	7.76	0.760	>999	525	7.15
4	493	85	20 - 30	11.1	12.2	7.88	0.730	>999	>999	7.68
5	483	95	30 - 40	5.1	11.9	7.78	0.880	>999	>999	6.52
6	473	105	40 - 50	6.3	11.8	7.76	0.800	>999	348	5.91

[a]Samples are filtered through a 5 micron filter.

Table A.2-22. Geoprobe Location 13610

Easting '83:	1348604	feet
Northing '83:	475547	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	516.59	feet AMSL
Work Completed:	4/20/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (µg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	66	0 - 10	17.7	13.1	7.42	0.710	>999	>999	8.89
2	502	76	10 - 20	22.7	12.4	7.94	0.630	>999	>999	8.48
3	502	76	10 - 20	20.9	12.4	7.94	0.630	>999	>999	8.48
4	492	86	20 - 30	26.5	11.8	7.76	0.622	>999	>999	8.55
5	482	96	30 - 40	7.1	12.3	7.78	0.750	>999	>999	6.50
6	472	106	40 - 50	5.0	11.9	7.70	0.700	>999	>999	7.60

[a]Samples are filtered through a 5 micron filter.

Table A.2-23. Geoprobe Location 13611

Easting '83:	1348716	feet
Northing '83:	475549	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	516.94	feet AMSL
Work Completed:	4/26/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	66	0 - 10	25.1	12.3	7.40	0.780	>999	805	8.50
2	502	76	10 - 20	21.5	12.4	7.80	0.622	>999	>999	8.12
3	502	76	10 - 20	25.0	12.4	7.80	0.622	>999	>999	8.12
4	492	86	20 - 30	20.2	11.9	7.72	0.650	>999	40.0	6.54
5	482	96	30 - 40	14.3	12.0	7.65	0.690	>999	41.3	6.50
6	472	106	40 - 50	2.5	12.4	7.63	0.840	>999	60.6	5.83

[a]Samples are filtered through a 5 micron filter.

Table A.2-24. Geoprobe Location 13612

Easting '83:	1348602	feet
Northing '83:	475412	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	516.83	feet AMSL
Work Completed:	4/25/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	512	67	0 - 10	28.8	15.8	7.34	0.730	>999	33.3	7.24
2	502	77	10 - 20	38.8	15.4	7.43	0.680	>999	>999	6.56
3	502	77	10 - 20	37.1	15.4	7.43	0.680	>999	>999	6.56
4	492	87	20 - 30	10.0	16.0	7.67	0.750	>999	691	6.81
5	482	97	30 - 40	4.9	15.2	7.36	0.770	>999	219	4.81
6	472	107	40 - 50	2.8	15.3	5.96	0.800	>999	451	5.75

[a]Samples are filtered through a 5 micron filter.

Table A.2-25. Geoprobe Location 13613

Easting '83:	1348708	feet
Northing '83:	475333	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	518.01	feet AMSL
Work Completed:	4/27/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	67	0 - 10	29.5	14.4	7.99	0.660	>999	>999	8.03
2	503	77	10 - 20	33.6	14.5	7.71	0.650	>999	750	6.53
3	503	77	10 - 20	32.6	14.5	7.71	0.650	>999	750	6.53
4	493	87	20 - 30	31.5	13.9	7.67	0.710	>999	548	5.99
5	483	97	30 - 40	11.3	14.5	7.82	0.770	>999	>999	7.46
6	473	107	40 - 50	11.9	14.1	7.55	0.780	>999	761	6.15

[a]Samples are filtered through a 5 micron filter.

Table A.2-26. Geoprobe Location 13614

Easting '83:	1348501	feet
Northing '83:	475269	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	518.66	feet AMSL
Work Completed:	4/4/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	514	67	0 - 10	71.9	13.1	7.38	0.800	>999	119	8.30
2	504	77	10 - 20	34.6	12.5	7.66	0.760	>999	248	7.12
3	504	77	10 - 20	33.7	12.5	7.66	0.760	>999	248	7.12
4	494	87	20 - 30	27.1	12.5	7.73	0.710	>999	>999	6.83
5	484	97	30 - 40	6.1	13.0	7.86	0.740	>999	5.01	5.88
6	474	107	40 - 50	<1	12.8	7.82	0.637	>999	>999	5.82

[a]Samples are filtered through a 5 micron filter.

Table A.2-27. Geoprobe Location 13615

Easting '83:	1349024	feet
Northing '83:	475084	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	63.00	feet below ground surface (BGS)
Water Table Elevation:	518.31	feet AMSL
Work Completed:	5/11/2022	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered[a] (μg/L)	Temperature Filtered[a] (°C)	pH Filtered[a] (SU)	Specific Conductance Filtered[a] (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered[a] (NTU)	Dissolved Oxygen Filtered[a] (mg/L)
1	513	68	0 - 10	16.7	16.5	7.31	0.930	>999	57.1	7.10
2	503	78	10 - 20	26.4	16.3	7.57	0.830	>999	38.3	5.88
3	503	78	10 - 20	23.3	16.3	7.57	0.830	>999	38.3	5.88
4	493	88	20 - 30	15.0	15.8	7.54	0.680	>999	219	5.20
5	483	98	30 - 40	2.7	16.0	7.52	0.720	>999	232	5.82
6	473	108	40 - 50	1.9	15.7	7.43	0.790	>999	>999	6.12

[a]Samples are filtered through a 5 micron filter.

Table A.2-28. Summary Statistics and Trend Analysis of Monitoring Wells for Total Uranium with 2022 Results Above FRLs

Well	No. of Samples	Minimum (µg/L)[a,b,c,d]	Maximum (µg/L)[a,b,c,d]	Average (µg/L)[a,b,c,d,e]	Standard Deviation (µg/L)[a,b,c,d,e]	Trend[a,b,c,d,e,f]
2045	95	12.0	462	109	92.8	No Trend
2049	71	3.00	278	69.4	53	Down
2095	84	15.7	208	85.5	52.1	Down
21033	62	7.34	43.2	22.0	7.96	Up
23271	42	34.6	144	67.9	30.1	Down
23273	42	79.2	421	210	80.1	Down
23274	63	58.8	384	153	63.4	Down
23275	41	76.6	349	154	55.7	Down
23276	42	3.56	115	78.2	19.1	Down
23281	42	16.1	366	117	75	Down
2386	65	6.67	146	36.9	33.8	Up
2387	65	18.1	492	153	74.1	Up
2389	54	0.899	120	33.2	21.2	Up
2397	51	135	737	341	127	Down
2649	61	6.01	1,250	287	339	Up
2880	65	0.400	71.8	29.3	26.3	Up
3095	85	2.00	94.0	28.6	16.8	No Trend
63285	42	57.3	277	158	66.4	Down
6880	52	35.7	145	74.9	25.5	Down
82369_C1	20	12.1	210	124	41.4	No Trend
82369_C2	13	25.1	50.6	35.1	7.05	Up
82369_C3	11	24.0	41.3	32.3	5.07	Up
83117_C1	43	1.28	1,620	680	318	Down
83117_C4	23	37.6	111	71.6	20.1	Down
83124_C1	66	102	1,070	480	201	No Trend
83124_C2	39	20.5	103	42.6	18.0	Down
83124_C4	22	25.4	62.2	42.8	8.91	Up
83124_C5	22	24.4	61.4	45.7	9.1	Down
83294_C1	36	98.5	340	218	0.6	Up
83294_C2	57	1.24	575	290	123	Down
83295_C2	37	53.1	178	109	39.9	Down
83295_C3	27	39.1	175	102	46.2	Down
83296_C1	21	49.3	135	75.3	21.0	Down
83337_C1	39	255	2,660	1,340	578	Down
83337_C2	56	2.40	835	118	162	No Trend
83338_C1	28	282	1,100	509	149	Down
83338_C2	34	14	648	85.3	135	Down
83340_C1	30	13.2	72.7	31.4	10.5	Up

[a] Summary statistics and Mann-Kendall test for trend are primarily based on unfiltered samples with some filtered samples from the Operable Unit 5 Remedial Investigation/Feasibility Study dataset (1988 through 1993) and 1994 through 2022 groundwater data.
[b] If more than one sample is collected per well per day (e.g., duplicate), then only one sample is counted for the number of samples, and the sample with the maximum representative concentration is used for determining the summary statistics (minimum, maximum, average, and standard deviation) and Mann-Kendall test for trend.
[c] Rejected data qualified with an R were not included in this count, the summary statistics, or Mann-Kendall test for trend.
[d] If the number of samples is greater than or equal to four, then all of the summary statistics and the Mann-Kendall test for trend are reported. If the total number of samples is equal to three, then the minimum, maximum, and average are reported. If the total number of samples is equal to two, then the minimum and maximum are reported. If the total number of samples is equal to one, then the data point is reported as the minimum.
[e] For results where the concentrations are below the detection limit, the results used in the summary statistics and Mann-Kendall test for trend are each set at half the detection limit.
[f] The Mann-Kendall test for trend is performed with a 95% confidence interval, using data from third quarter 1998 through 2022.

Table A.2-29. Summary Statistics and Trend Analysis of Extraction Wells for Total Uranium

Well	Number of Samples[a,b]	Minimum (µg/L)[a,b,c]	Maximum (µg/L)[a,b,c]	Average (µg/L)[a,b,c]	Standard Deviation (µg/L)[a,b,c]	Trend[a,b,c,d]
South Plume Module (August 27, 1993, through December 31, 2022)						
3924	741	1.2	180	26.7	15.1	Down
3925	745	0.5	84.0	22.2	8.2	Down
3926	731	1.5	42.4	24.3	7.7	Down
3927	722	1.0	17.0	2.7	1.1	Up
South Plume Optimization Module (August 9, 1998, through December 31, 2022)						
32308	656	17.1	100	48.5	17.1	Down
32309	663	15.6	123	48.3	21.3	Down
South Field Module (July 13, 1998, through December 31, 2022)						
31550	693	16.2	128	47.2	18.1	Down
31560	720	11.2	183	50.7	37.3	Down
31561	693	17.7	114[e]	38.4	10.0	Down
32276	733	12.3	290	85.1	63.8	Down
32446	586	17.4	168	52.6	21.8	Down
32447	611	9.4	302	89.7	55.6	Down
33061	490	13.6	98.5	40.0	15.6	Down
33262	449	16.1	110	40.0	14.9	Down
33264	449	3.6	364	61.7	44.8	Down
33298	397	10.1	76.2	44.6	13.2	Down
33326	348	7.8	62.2	20.5	8.4	Down
Waste Storage Area Module (May 8, 2002, through December 31, 2022)						
32761	475	15.9	161	50.1	32.0	Down
33062	495	10.2	236	56.0	42.3	Down
33347	299	7.0	126	25.2	15.5	No Trend

[a] If more than one sample is collected per well per day (e.g., duplicate), then only one sample is counted for the number of samples, and the sample with the maximum representative concentration is used for determining the summary statistics (minimum, maximum, average, and standard deviation) and Mann-Kendall test for trend.

[b] Rejected data qualified with an R were not included in this count, the summary statistics, or Mann-Kendall test for trend.

[c] For results where the concentrations are below the detection limit, the results used in the summary statistics and Mann-Kendall test for trend are each set at half the detection limit.

[d] Mann-Kendall test for trend is performed with a 95% confidence interval.

[e] This result (sampled August 31, 1998) appears to be an outlier. It is suspected that the sample for this well was switched with the sample from extraction well 31562, which is no longer active as an extraction well.

Table A.2-30. Plume Size 1997 Through 2022

Year	Area Greater Than 30 µg/L Total Uranium (acres)
1997	237.6[a]
1998	216.9[a]
1999	228.9[a]
2000	233.4[a]
2001	171.1
2002	176.0
2003	179.1
2004	195.2
2005	196.1
2006	189.3
2007	186.0
2008	186.9
2009	186.0
2010	184.0
2011	144.3
2012	130.3
2013	127.3
2014	110.9
2015	109.5
2016	105.0
2017	94.4
2018	89.3
2019	86.5
2020	81.5
2021	75.0
2022	74.0

[a] Plume size based on 20 µg/L total uranium.

Table A.2-31. Comparison of Plume Size Interpretation and Ricker Method Plume Size Calculation

Year	Maximum Uranium Plume Size Interpretation (acres)	Ricker Method Plume Size Calculation (acres)	Ricker Relative Percent Difference[a]	EVS Method Plume Size Calculation (acres)	EVS Relative Percent Difference[b]
2006	189.3	145.7	23.0%		
2010	184.0	132.7	27.9%		
2014	110.9	108.0	2.6%		
2016	105.0	108.0	2.9%		
2017	94.4	97.3	3.1%		
2018	89.3	95.9	7.4%		
2019	86.5	89.2	3.1%		
2020	81.5	85.9	5.4%		
2021	75.0	81.6	8.8%	88.9	18.5%
2022	74.0	80.7	9.1%	85.3	15.3%

[a] Relative percent difference = [(maximum-Ricker)/maximum] X 100.

[b] Relative percent difference = [(maximum-EVS)/maximum] X 100.

Table A.2-32. Predicted Cleanup Date Range using Dual Exponential Equation

Well	Predicted Cleanup Date Range
South Plume	
2095	2013–2018
6880	2027–2045
South Field	
2045	2038–Not Determined[a]
2049	2013–2017
2397	2050–2103
23271	2024–Not Determined[a]
23273	2040–Not Determined[a]
23274	2036–2060
23275	2046–Not Determined[a]
23281	2017–Not Determined[a]
63285	2030–2046
83294_C2	2036–2053
83295_C2	2028–2039
83295_C3	2023–2028
83296_C1	2031–2086
Pilot Plant Drainage Ditch	
83117_C1	2059–2171
83117_C4	2025–2045
83124_C2	2016–2023
83124_C5	2022–2035
Waste Storage Area	
83337_C1	2066–2997
83338_C1	2081–2168

[a]Not determined because the trend went flat (i.e.,asymptotic).

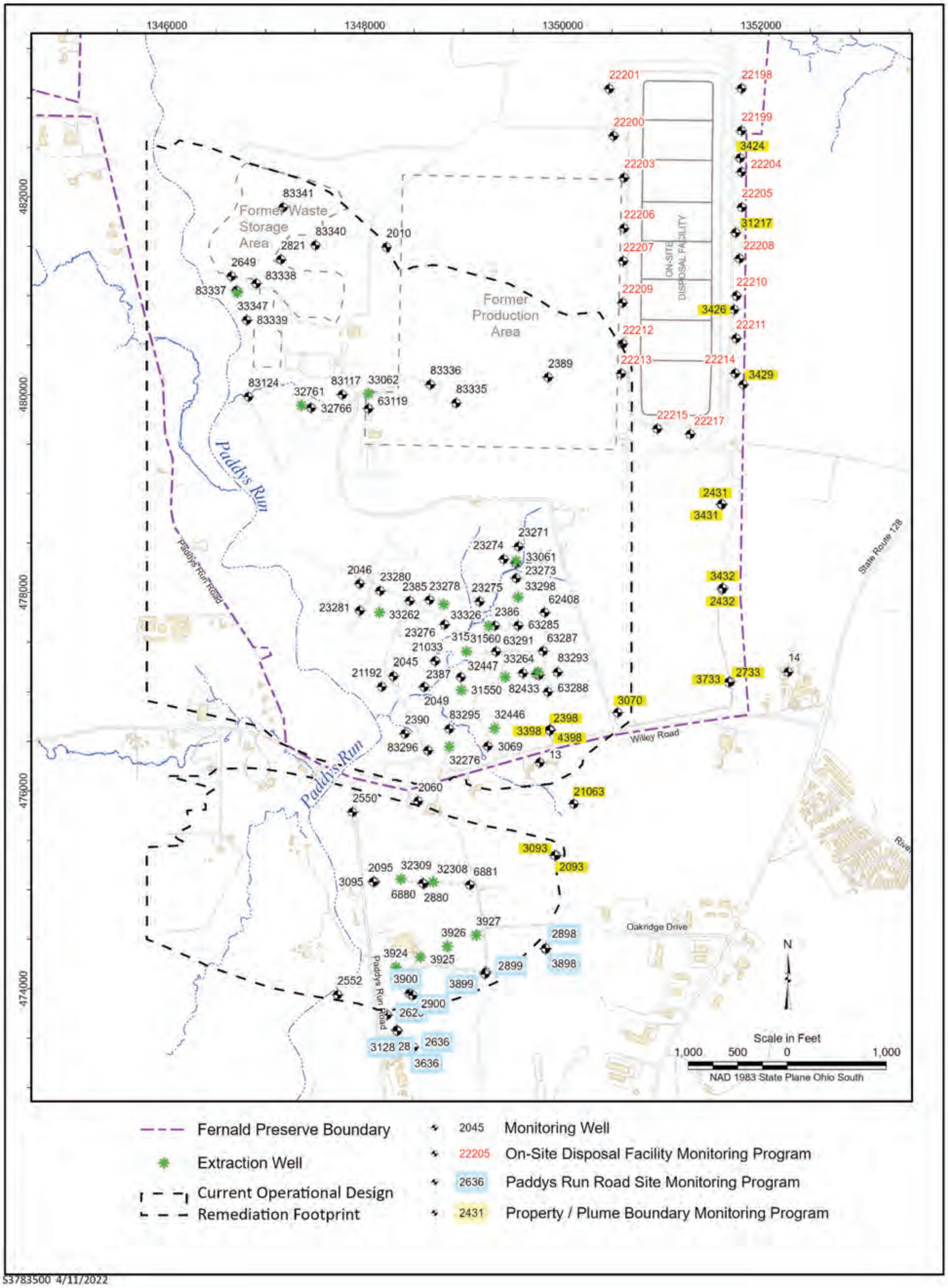

Figure A.2-1. IEMP Water Quality Monitoring Wells and Extraction Wells

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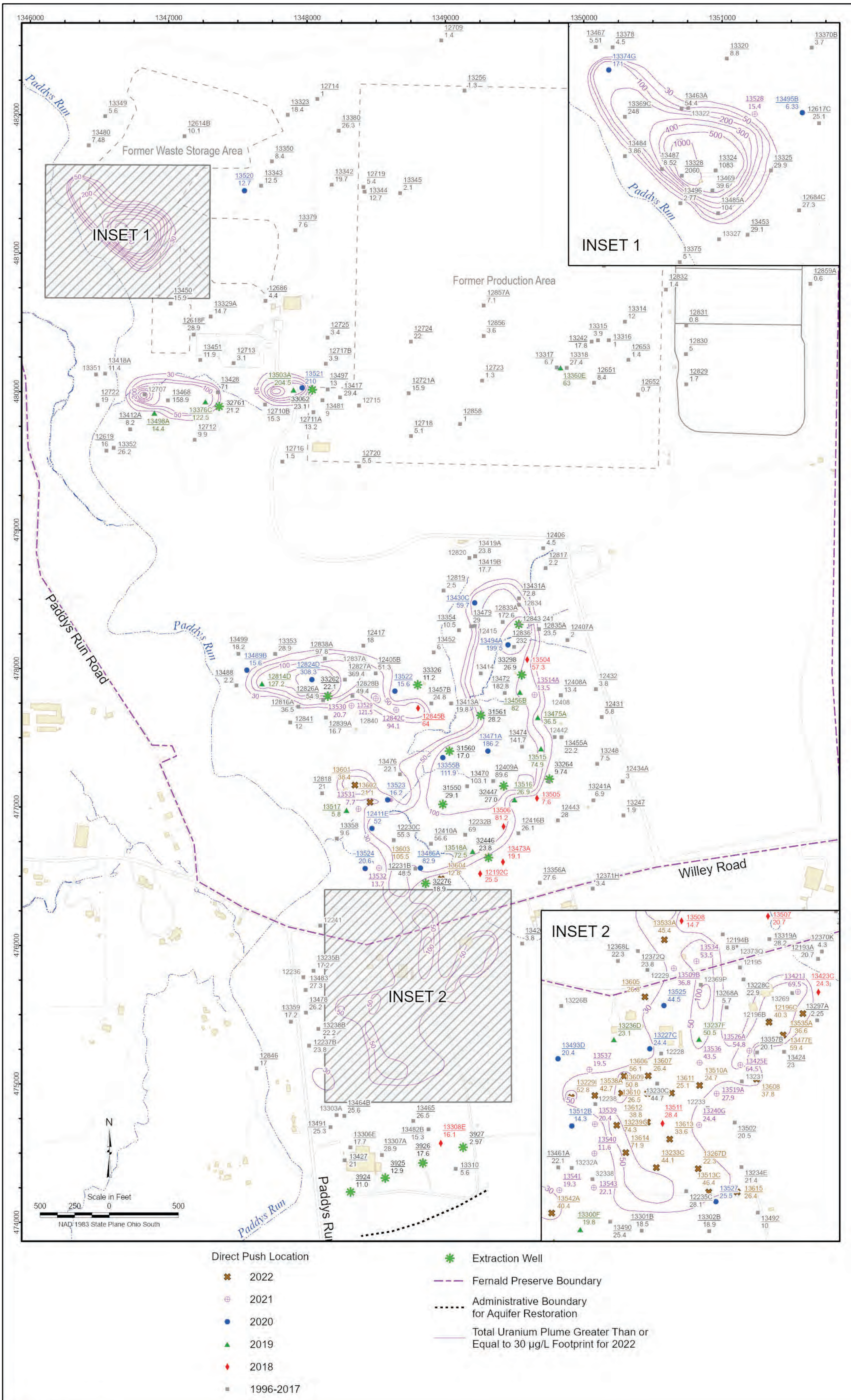

Figure A.2-2. Direct-Push Data and Maximum Total Uranium Plume for 2022

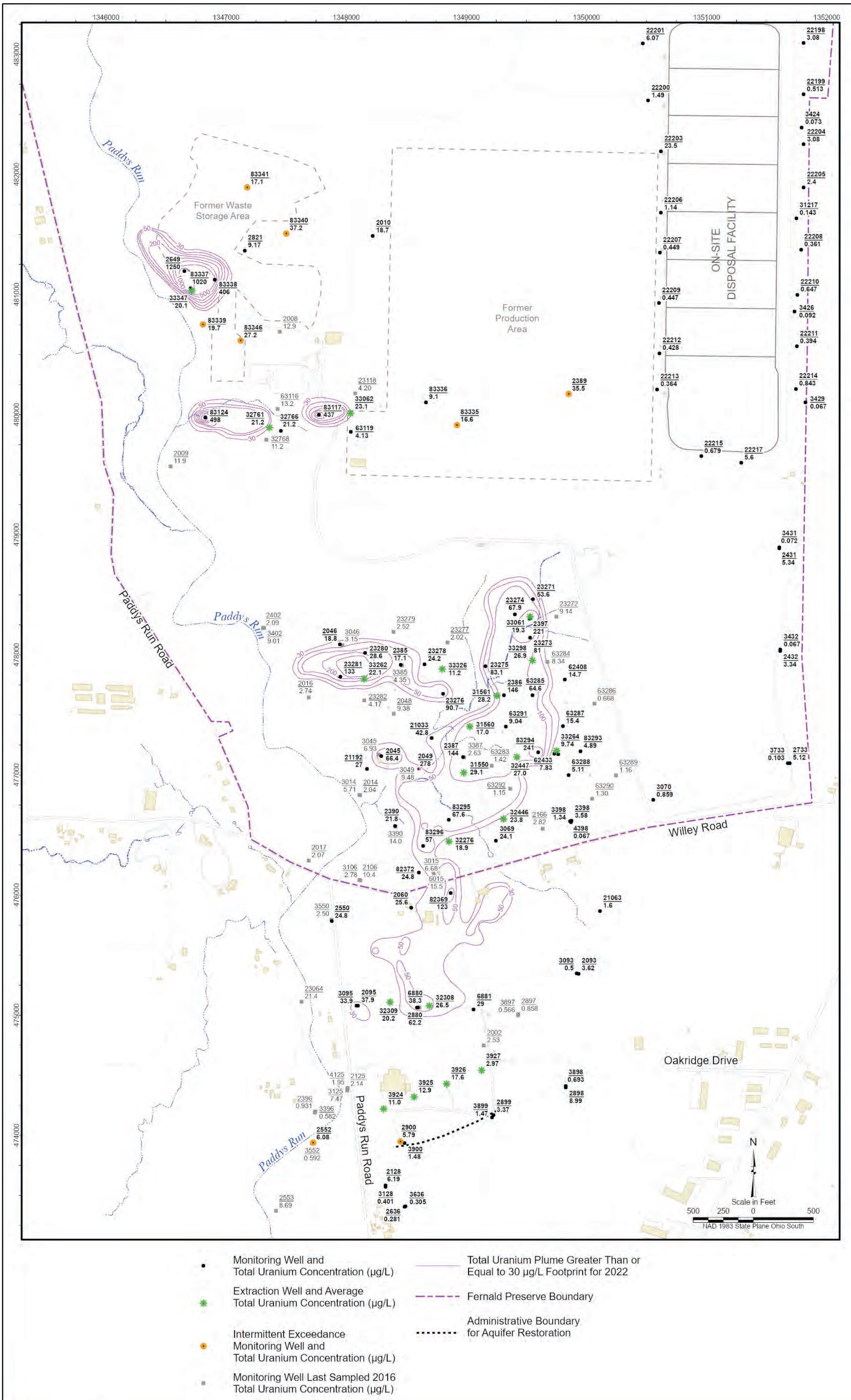

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Figure A.2-3. Monitoring Well Data and Maximum Total Uranium Plume for 2022

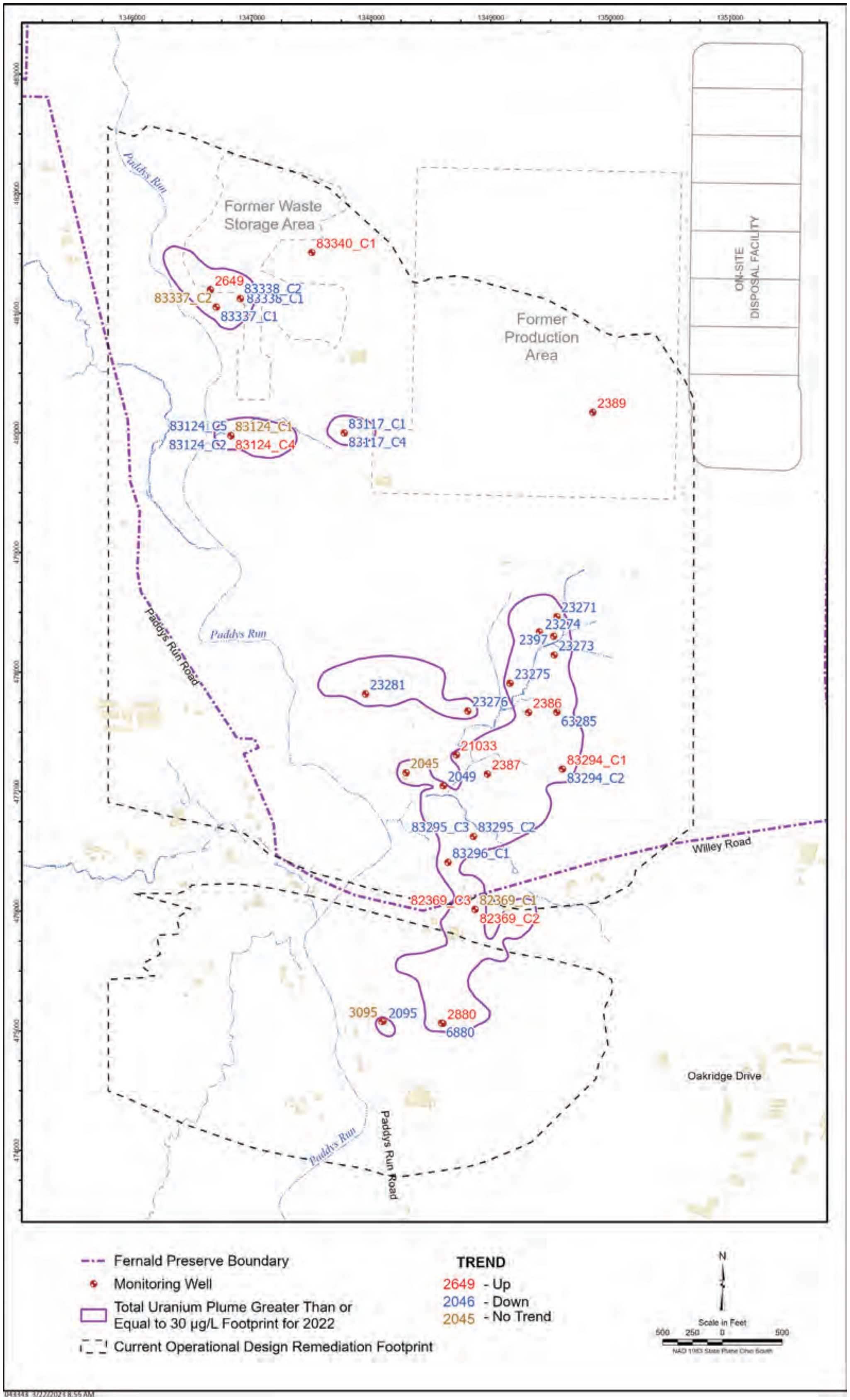


Figure A.2-4. Monitoring Wells with 2022 Exceedances for Total Uranium with Up, Down, or No Significant Trends

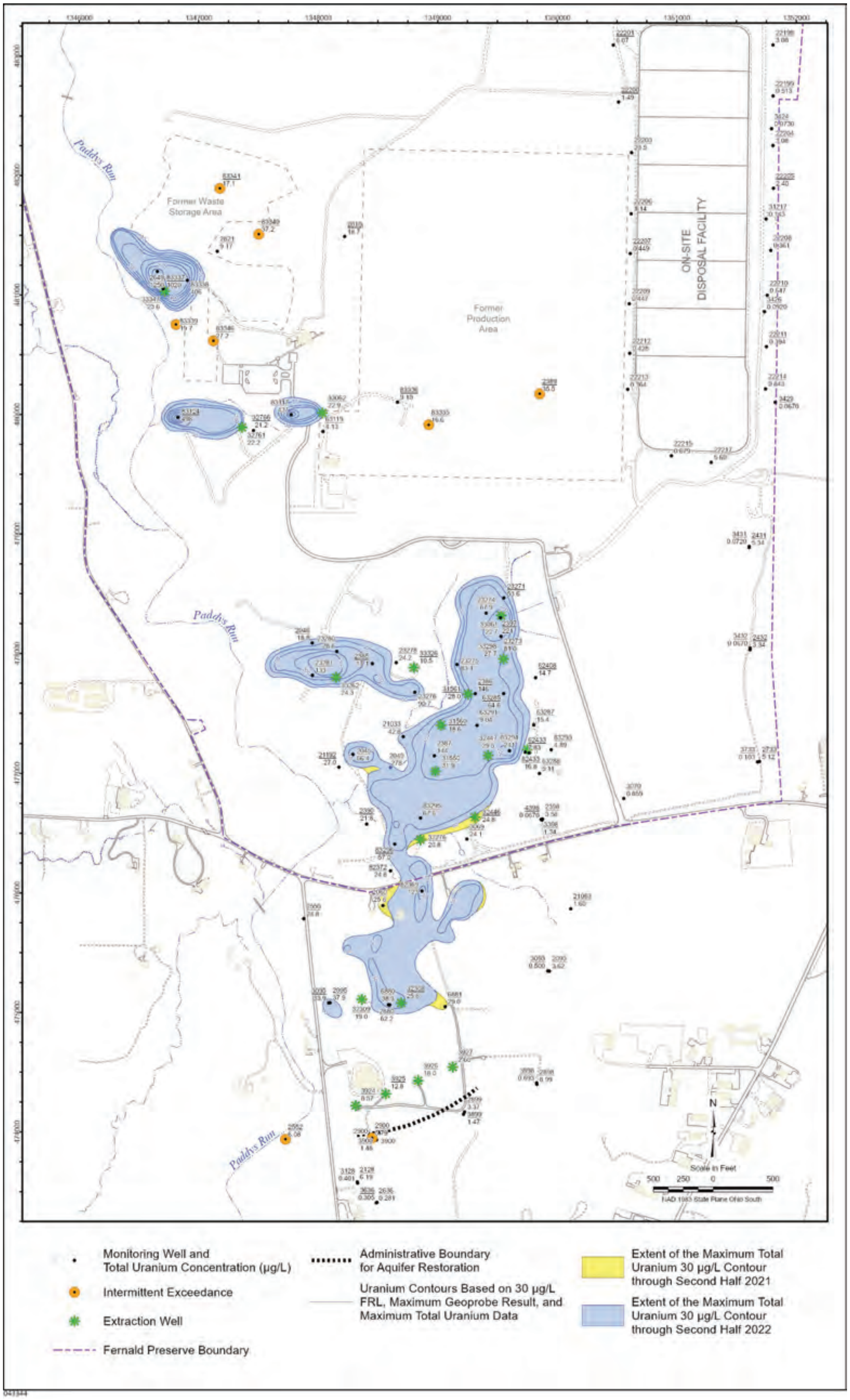


Figure A.2-5. Monitoring Well Data from 2022 Comparison to Maximum Total Uranium Footprint at end of 2021

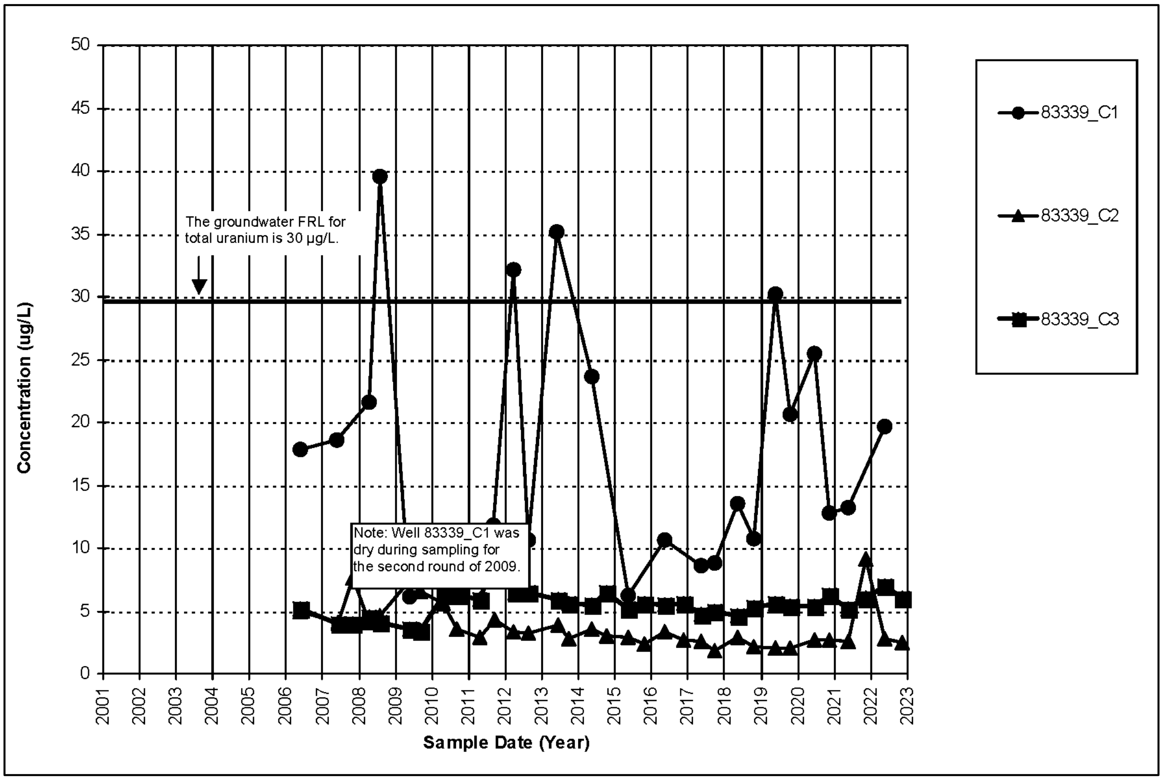


Figure A.2-6. Total Uranium Concentration Versus Time Plot for Monitoring Well 83339

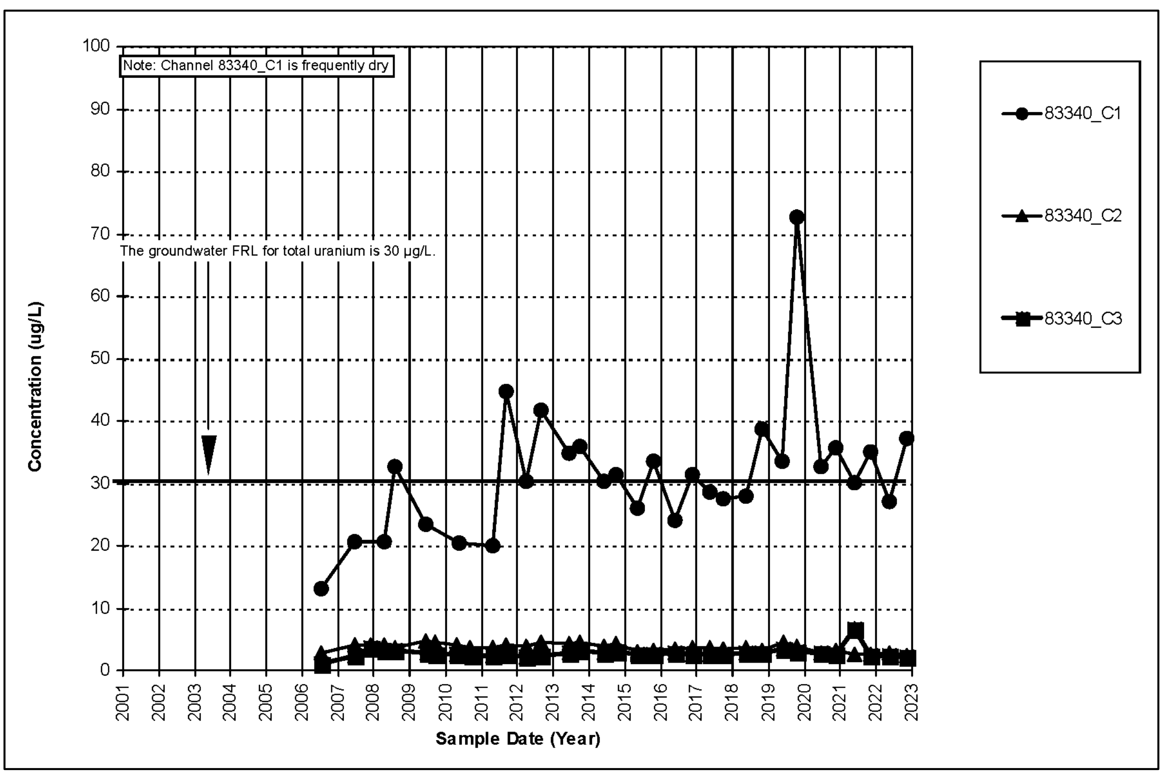


Figure A.2-7. Total Uranium Concentration Versus Time Plot for Monitoring Well 83340

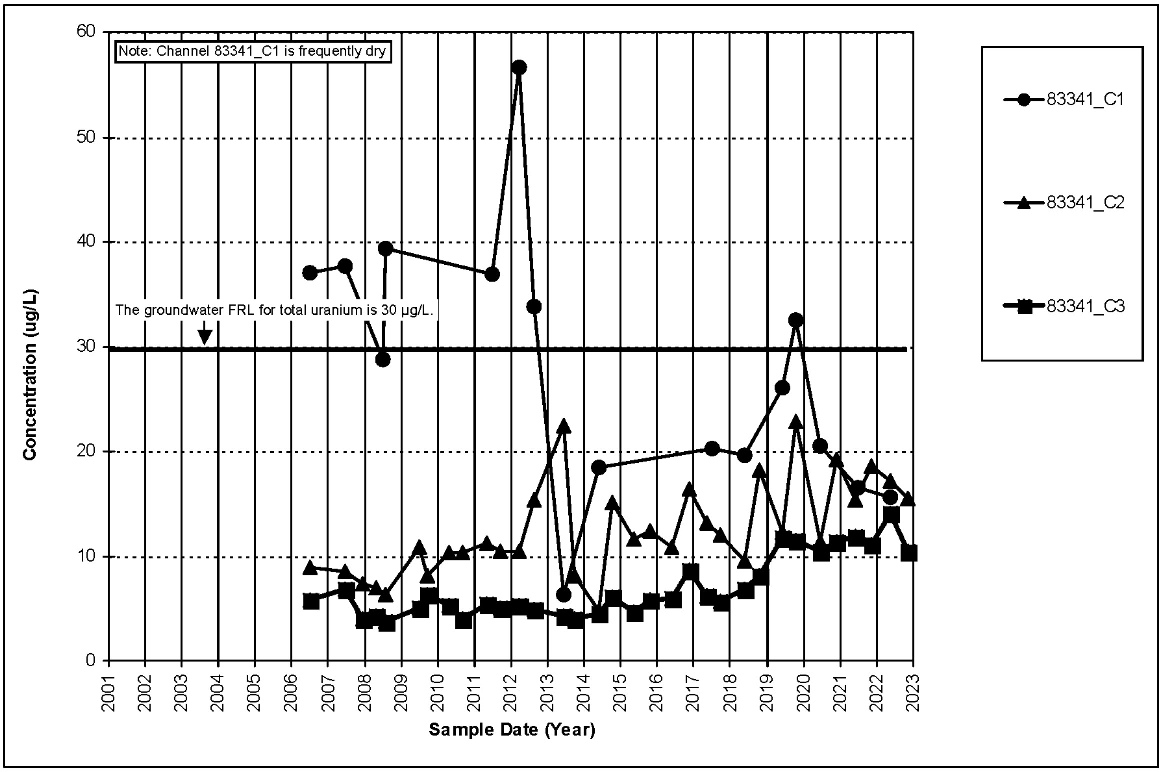


Figure A.2-8. Total Uranium Concentration Versus Time Plot for Monitoring Well 83341

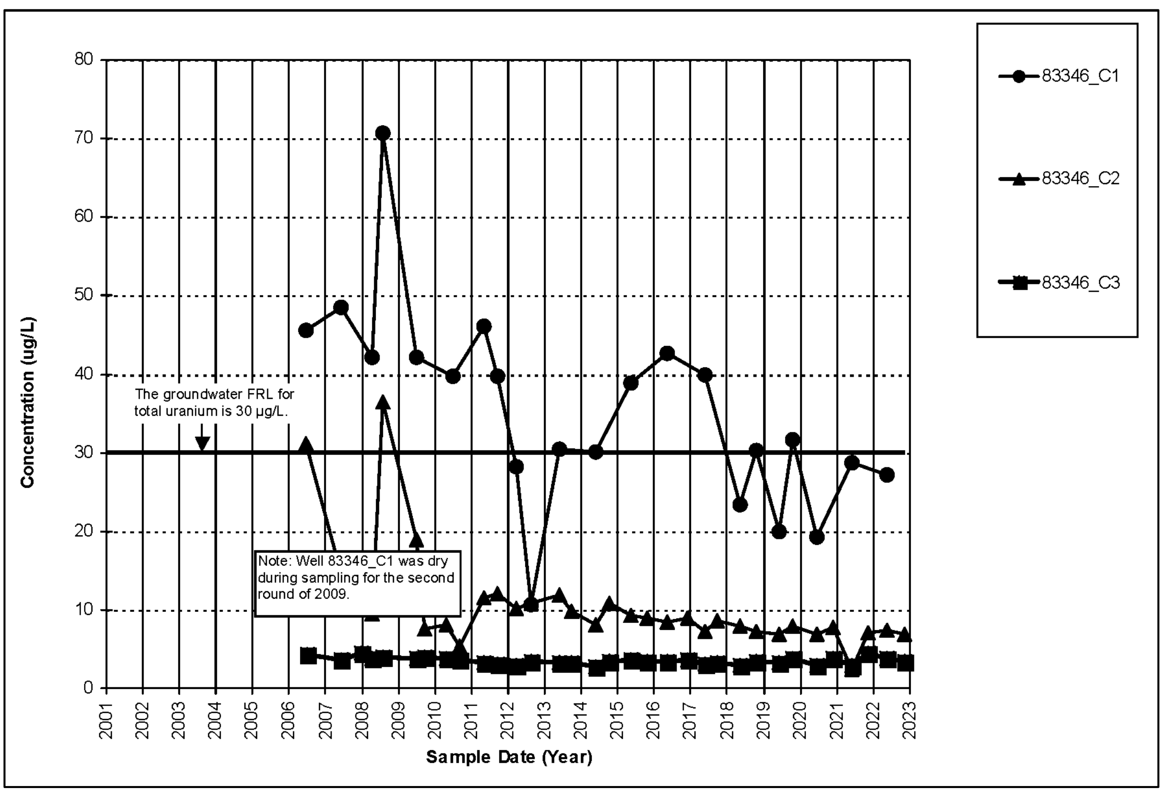


Figure A.2-9. Total Uranium Concentration Versus Time Plot for Monitoring Well 83346

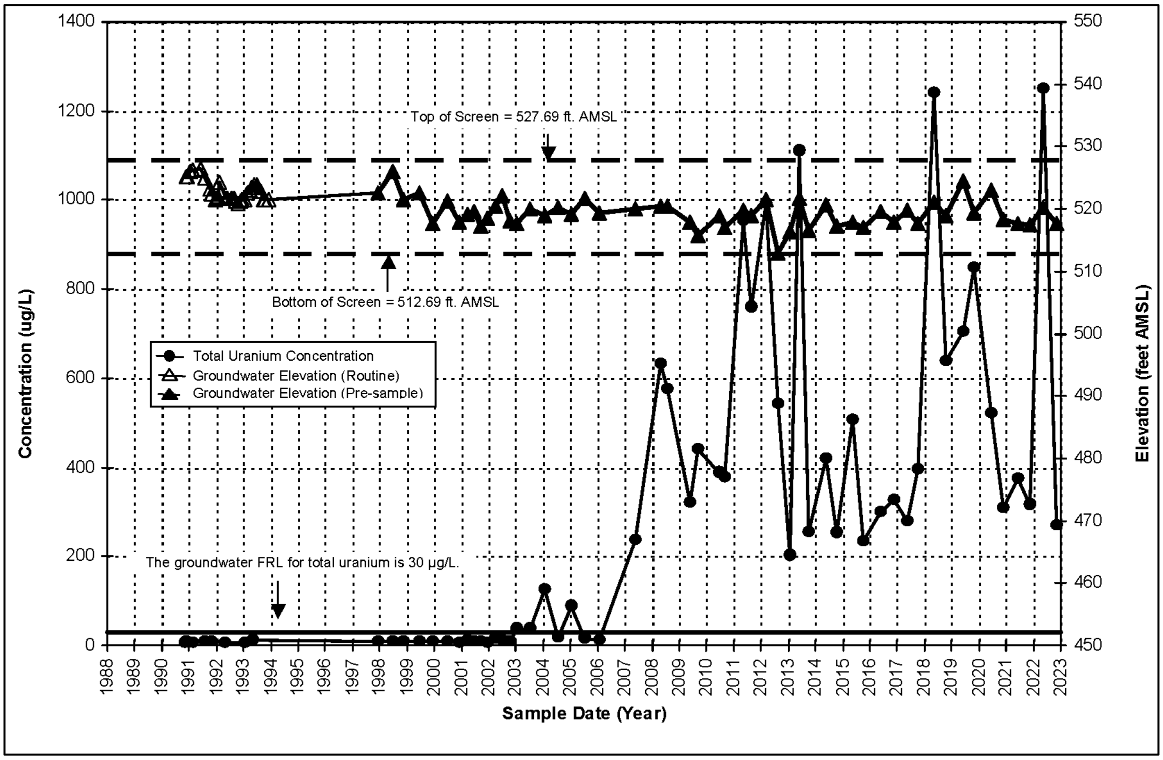


Figure A.2-10. Total Uranium Concentration Versus Time Plot for Monitoring Well 2649

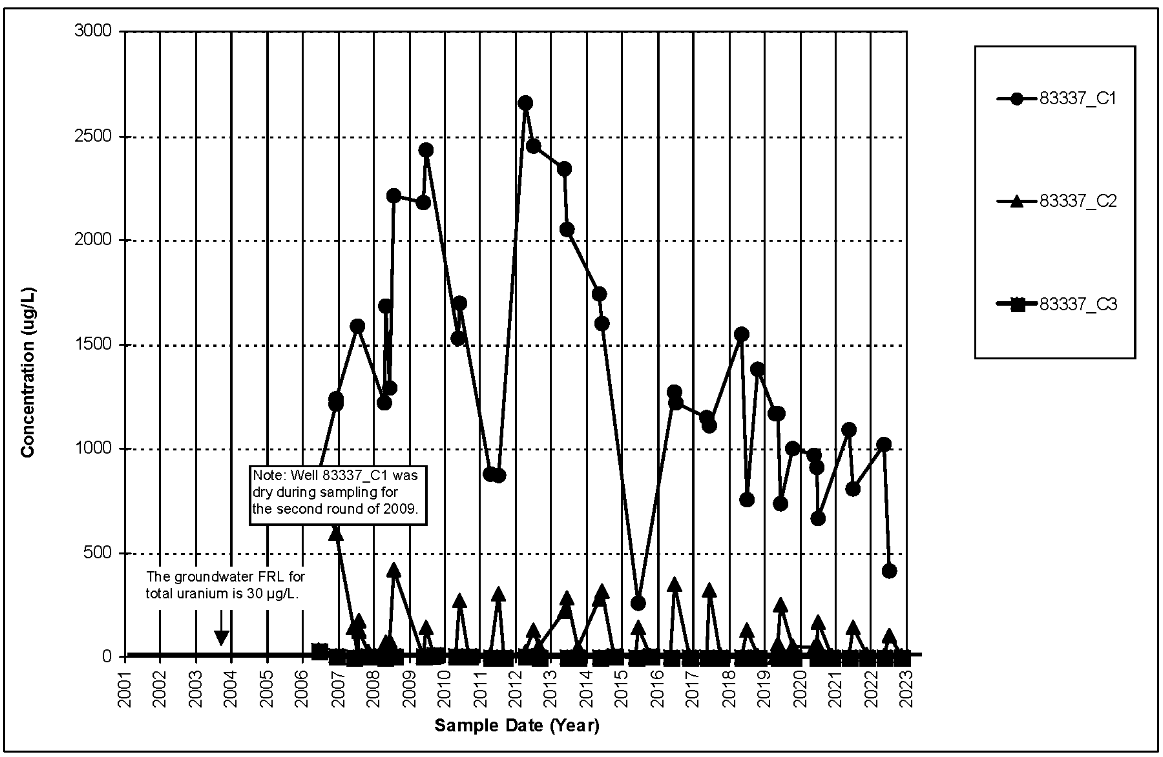


Figure A.2-11. Total Uranium Concentration Versus Time Plot for Monitoring Well 83337

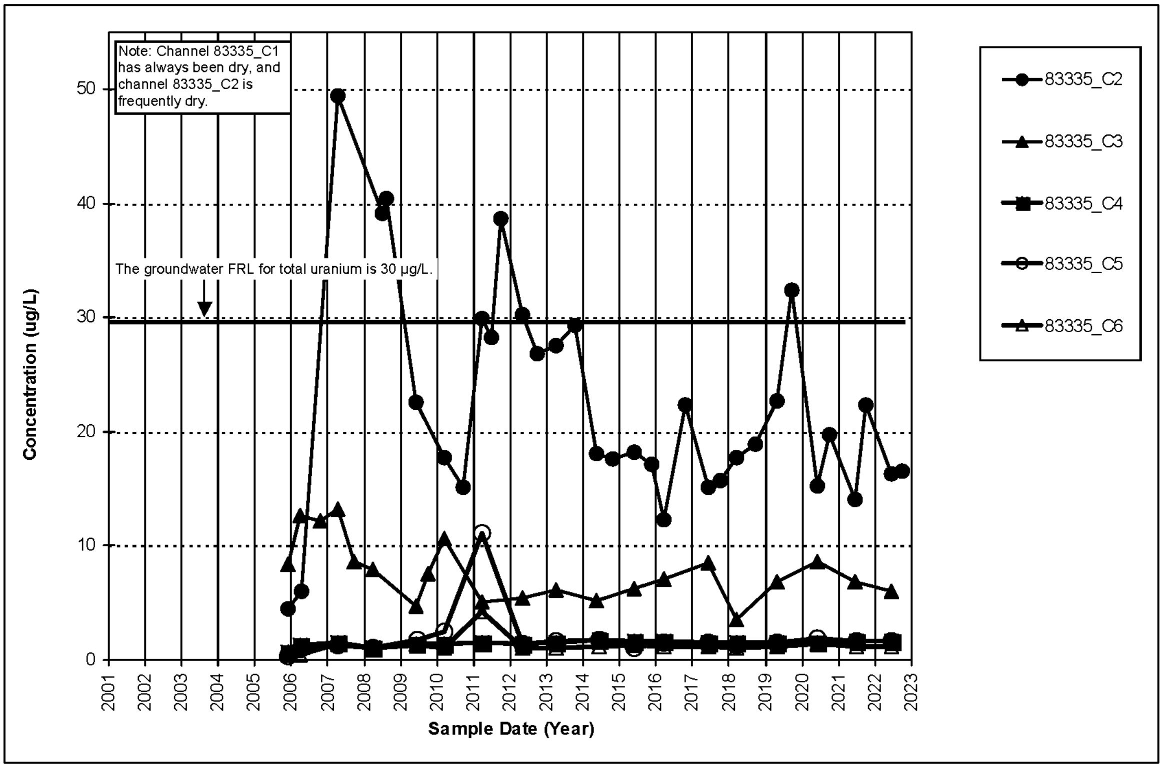


Figure A.2-12. Total Uranium Concentration Versus Time Plot for Monitoring Well 83335

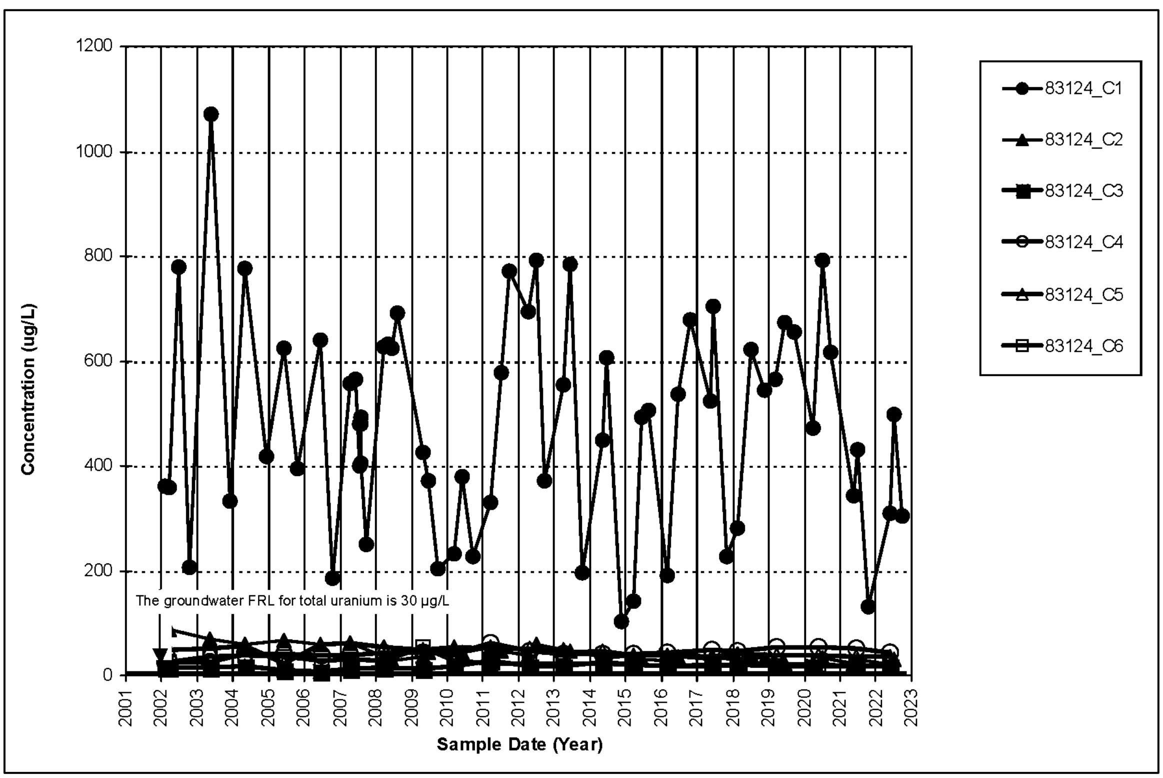


Figure A.2-13. Total Uranium Concentration Versus Time Plot for Monitoring Well 83124

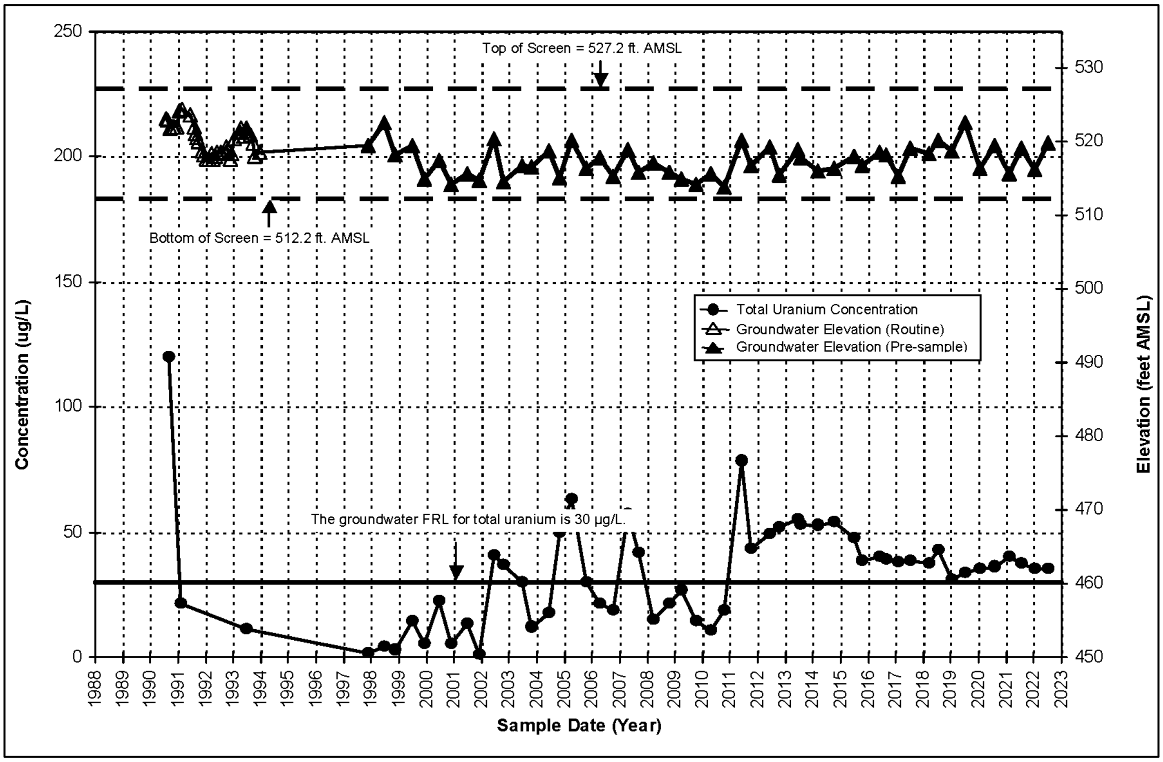


Figure A.2-14. Total Uranium Concentration Versus Time Plot for Monitoring Well 2389

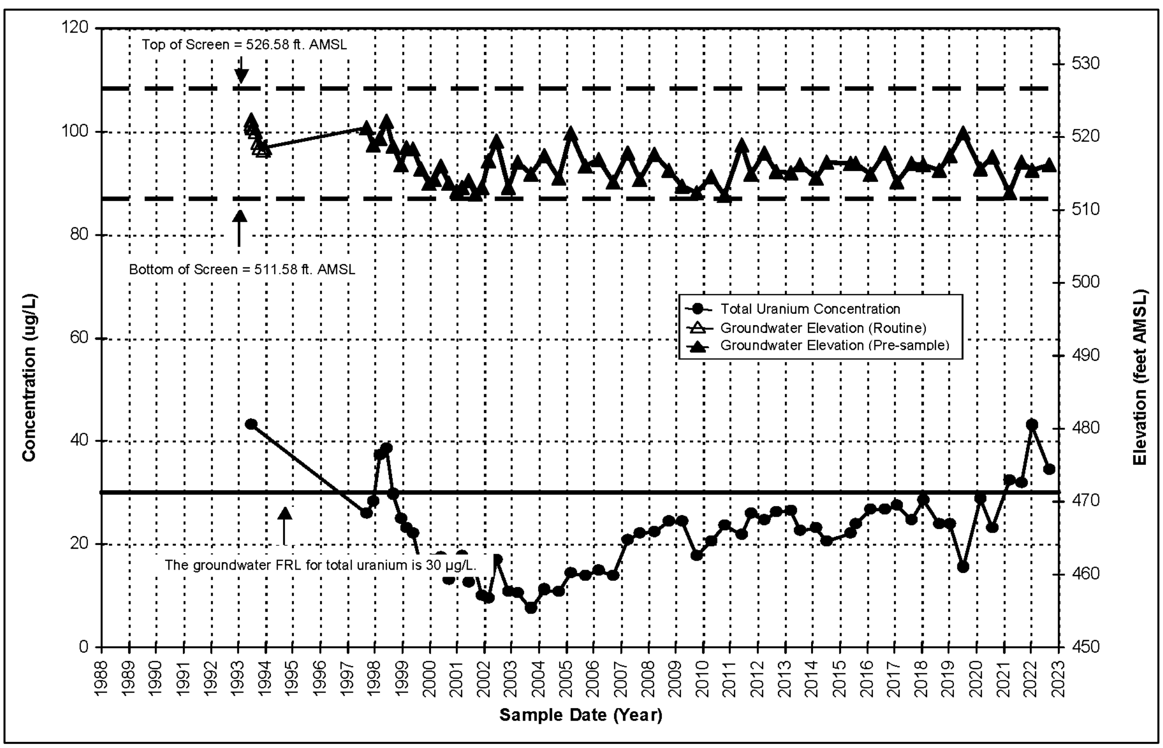


Figure A.2-15. Total Uranium Concentration Versus Time Plot for Monitoring Well 21033

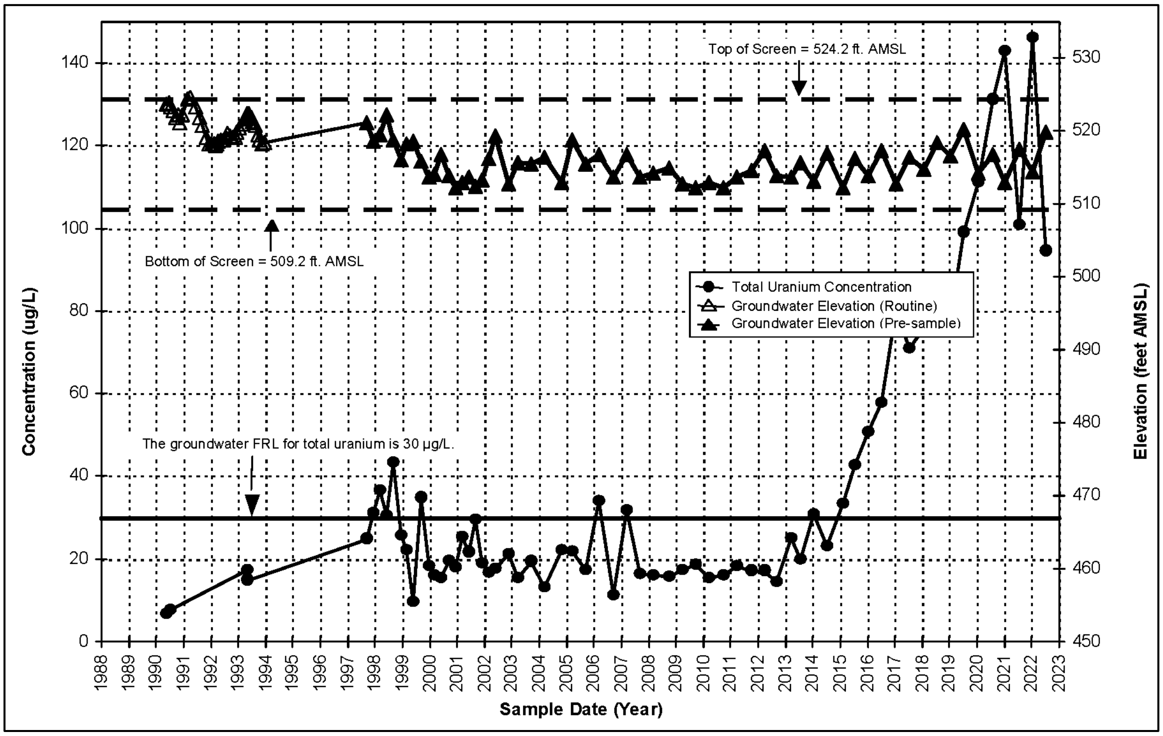


Figure A.2-16. Total Uranium Concentration Versus Time Plot for Monitoring Well 2386

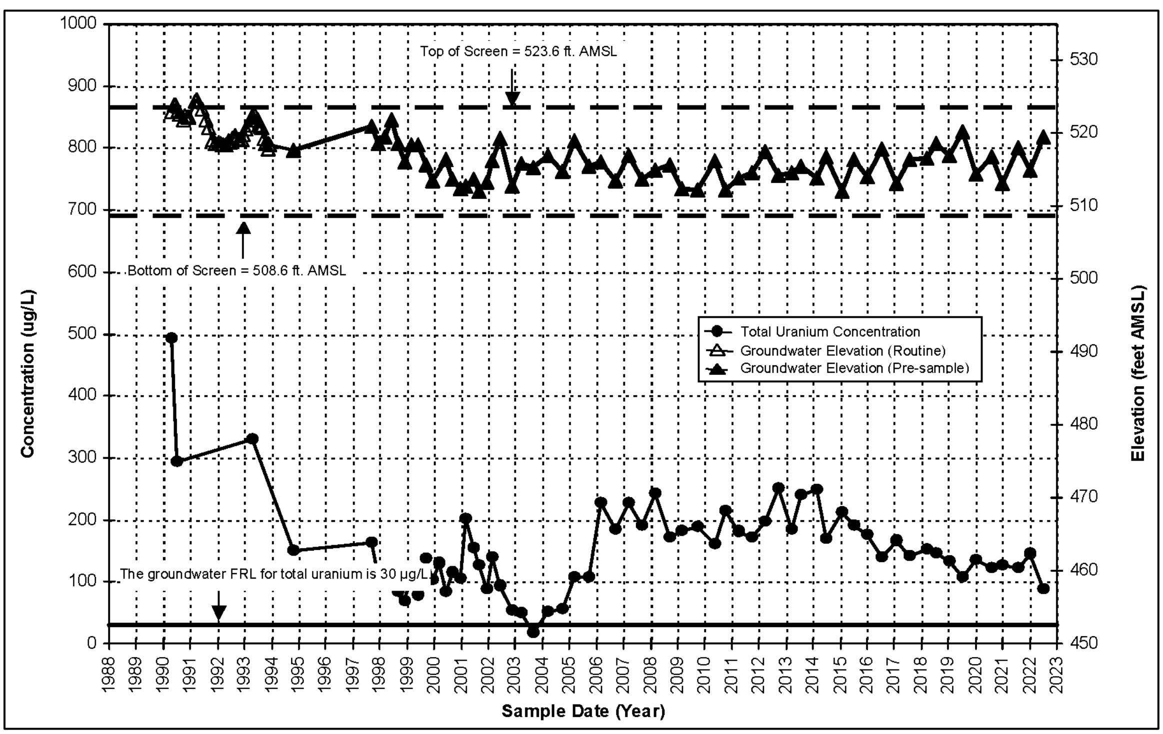


Figure A.2-17. Total Uranium Concentration Versus Time Plot for Monitoring Well 2387

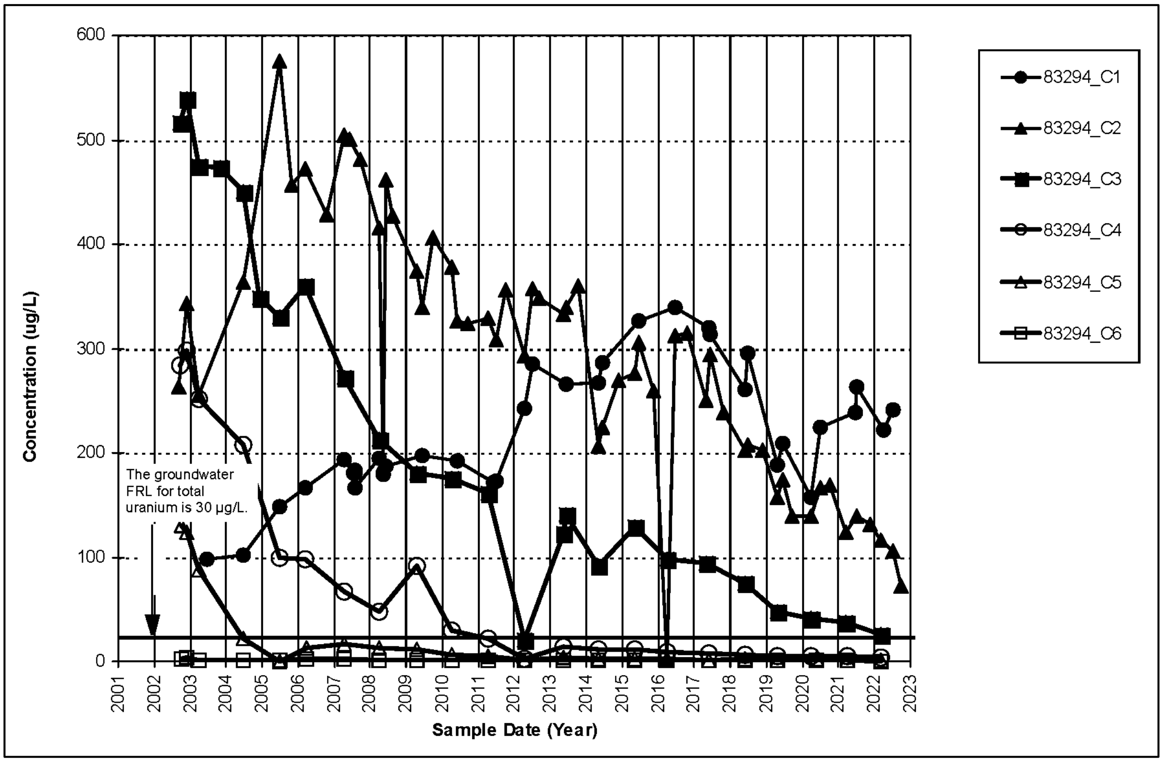


Figure A.2-18. Total Uranium Concentration Versus Time Plot for Monitoring Well 83294

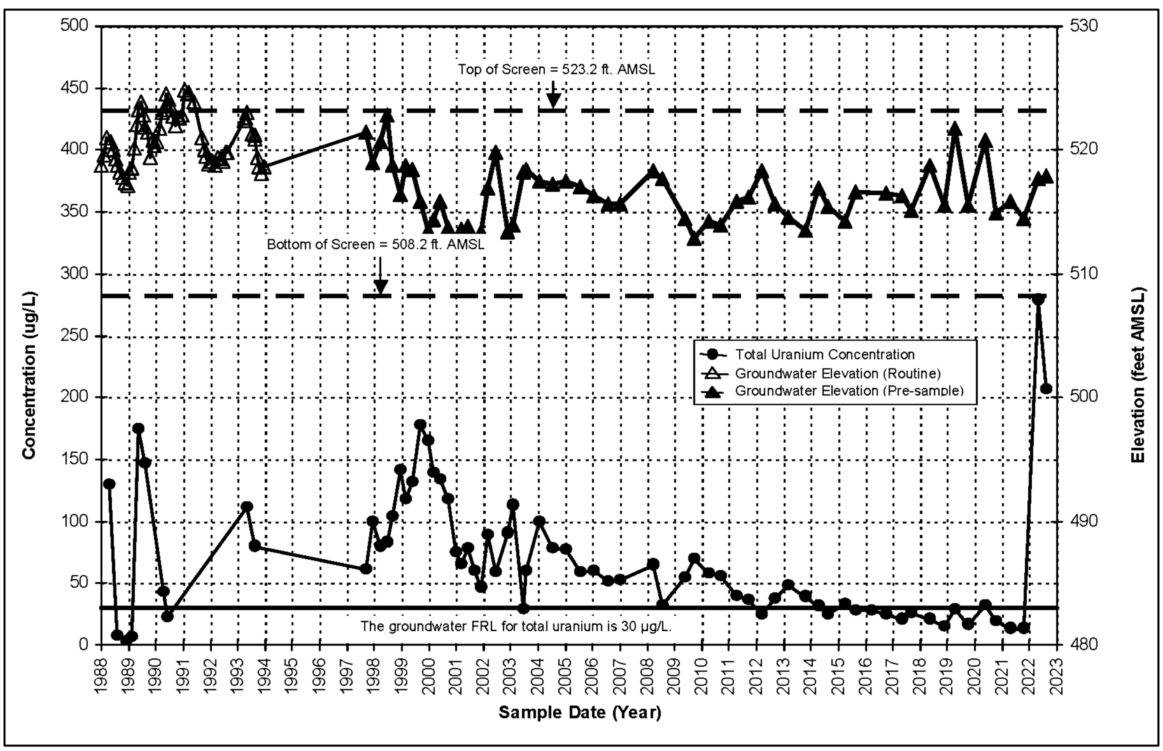


Figure A.2-19. Total Uranium Concentration Versus Time Plot for Monitoring Well 2049

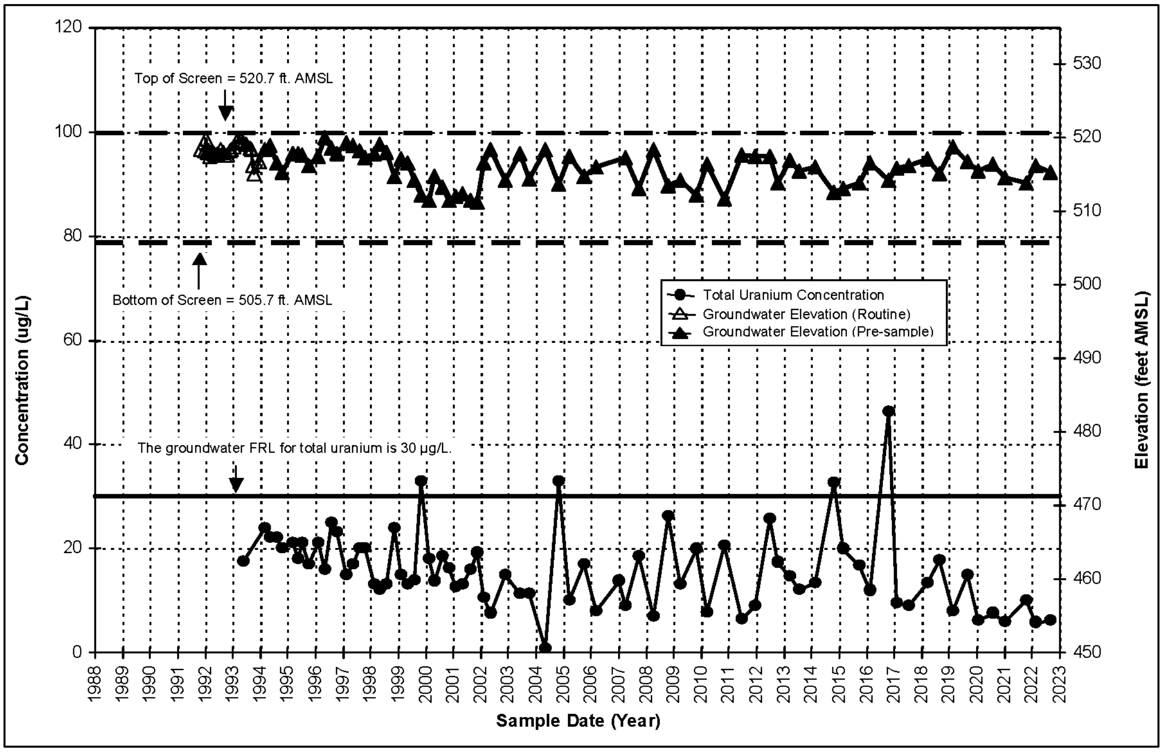


Figure A.2-20. Total Uranium Concentration Versus Time Plot for Monitoring Well 2552

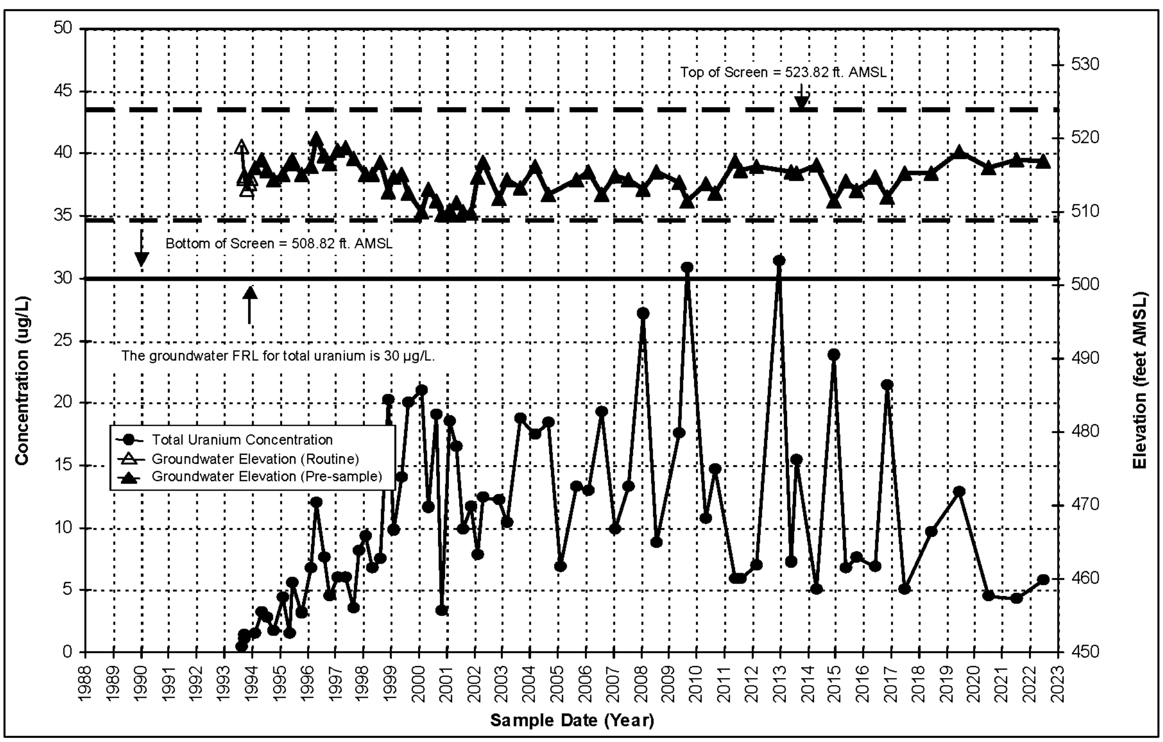


Figure A.2-21. Total Uranium Concentration Versus Time Plot for Monitoring Well 2900

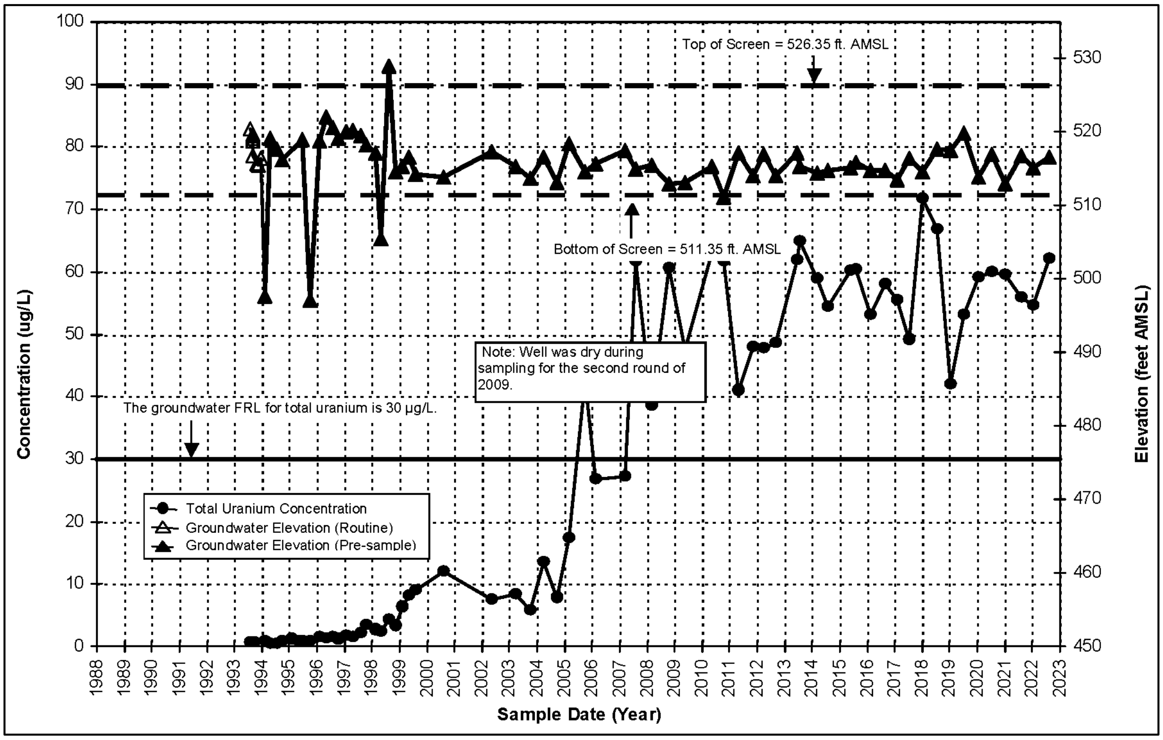


Figure A.2-22. Total Uranium Concentration Versus Time Plot for Monitoring Well 2880

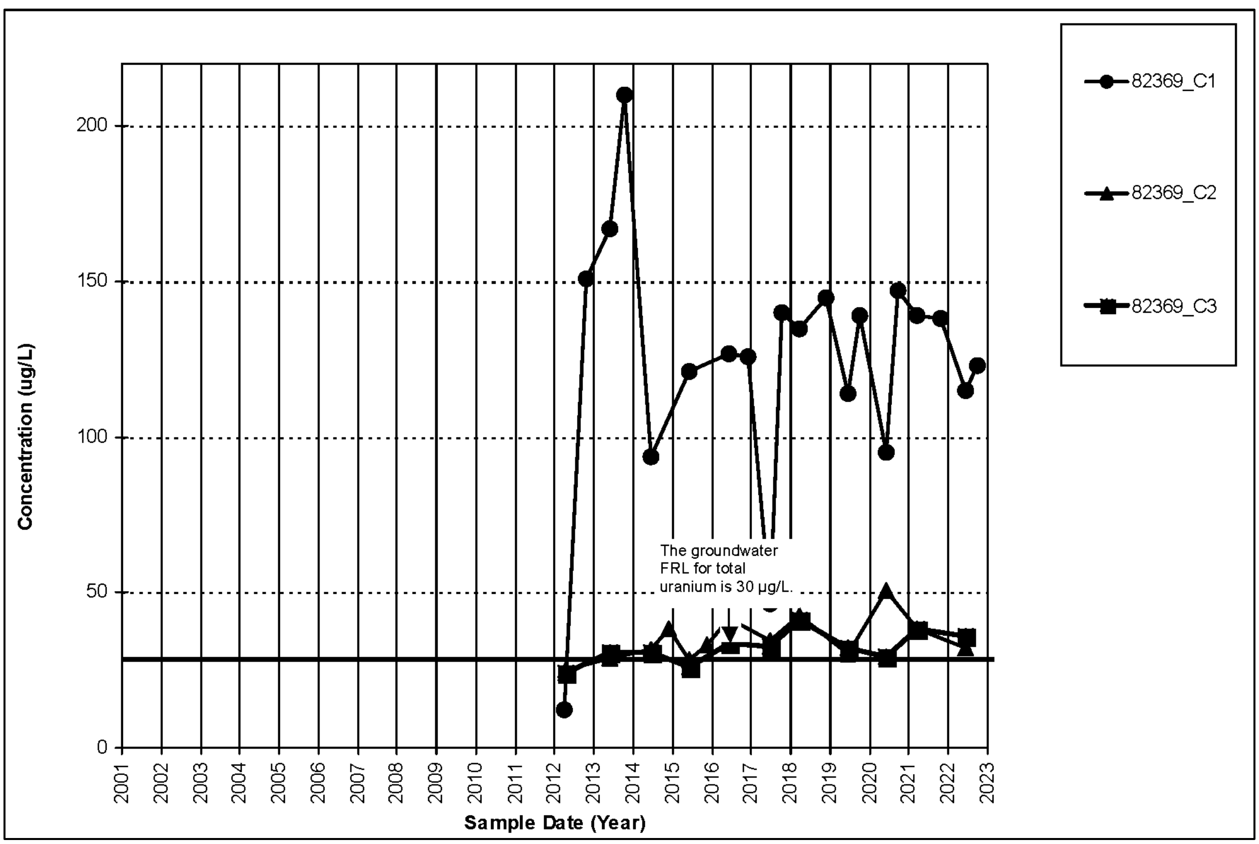


Figure A.2-23. Total Uranium Concentration Versus Time Plot for Monitoring Well 82369

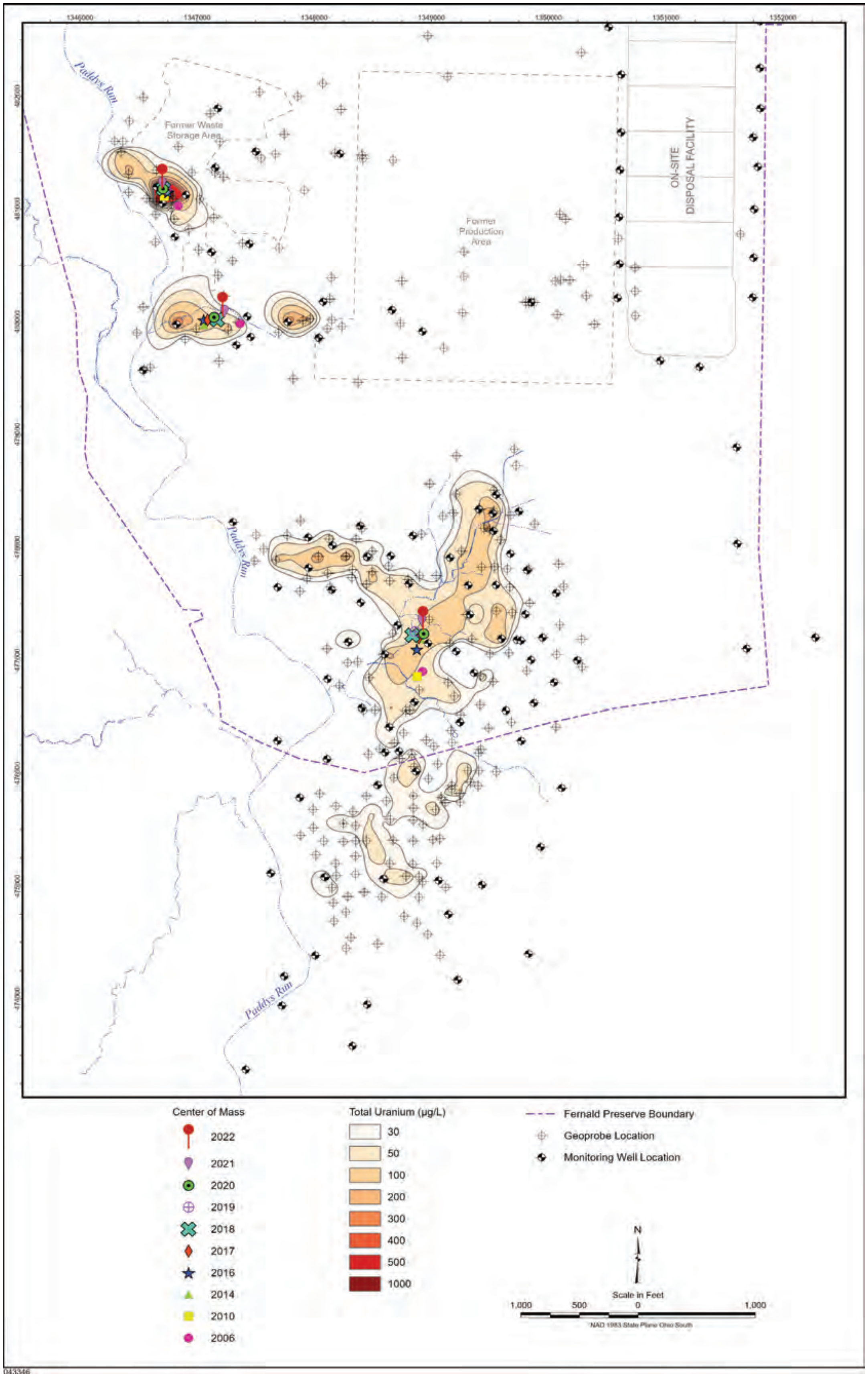


Figure A.2-24. Ricker Method Center of Mass

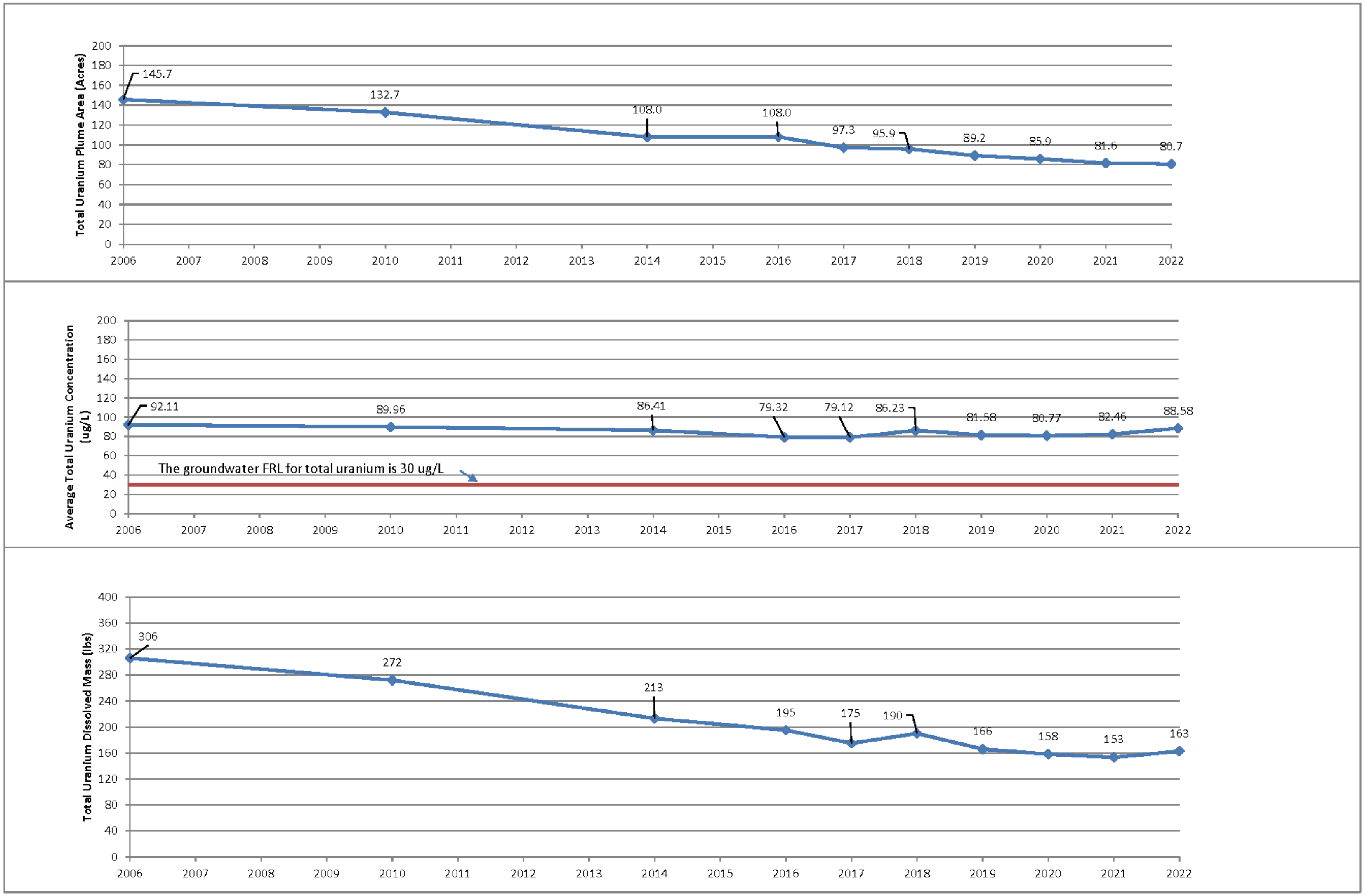


Figure A.2-25. Ricker Method Total Uranium Plume Calculations

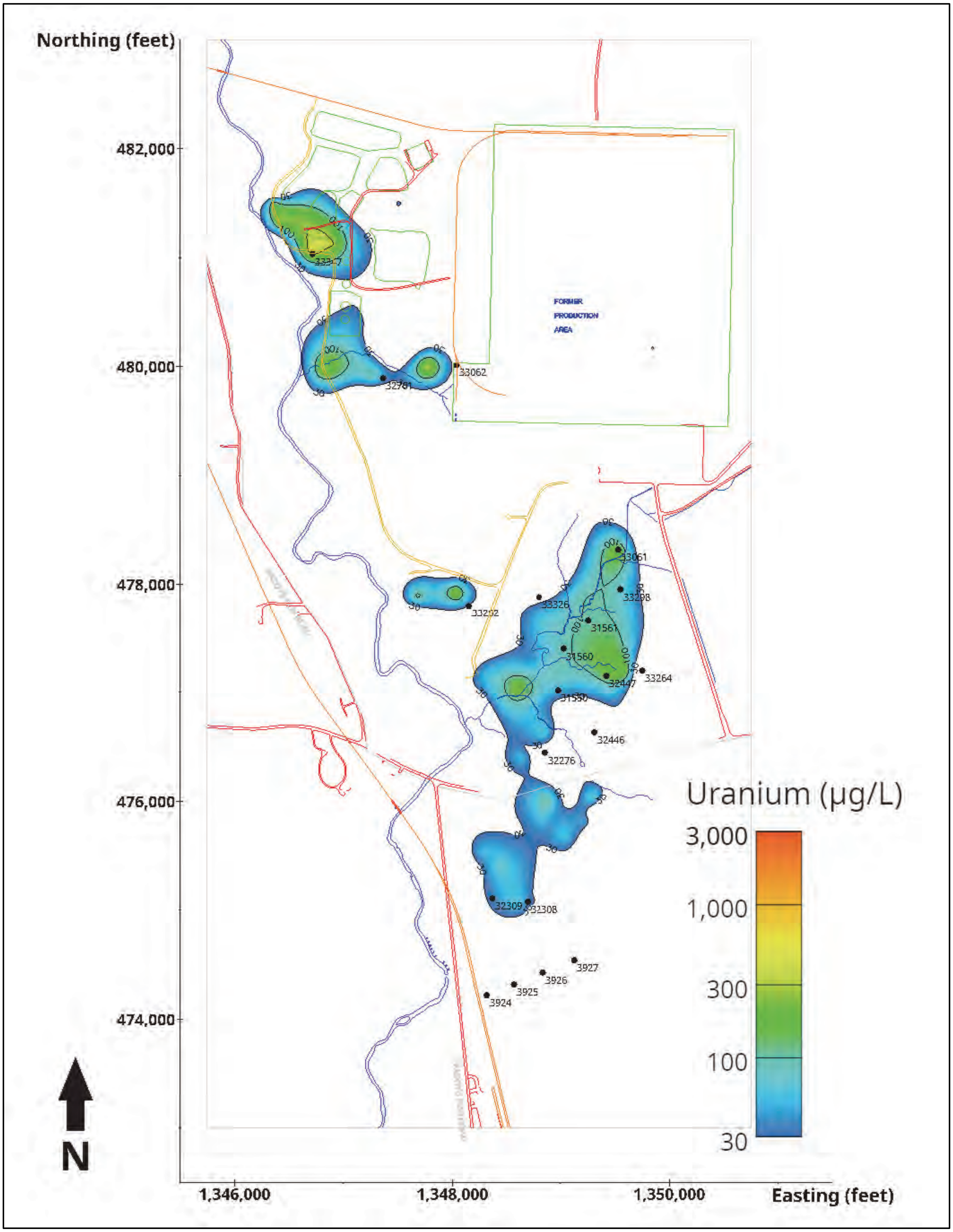


Figure A.2-26. EVS 2022 Plume Interpretation

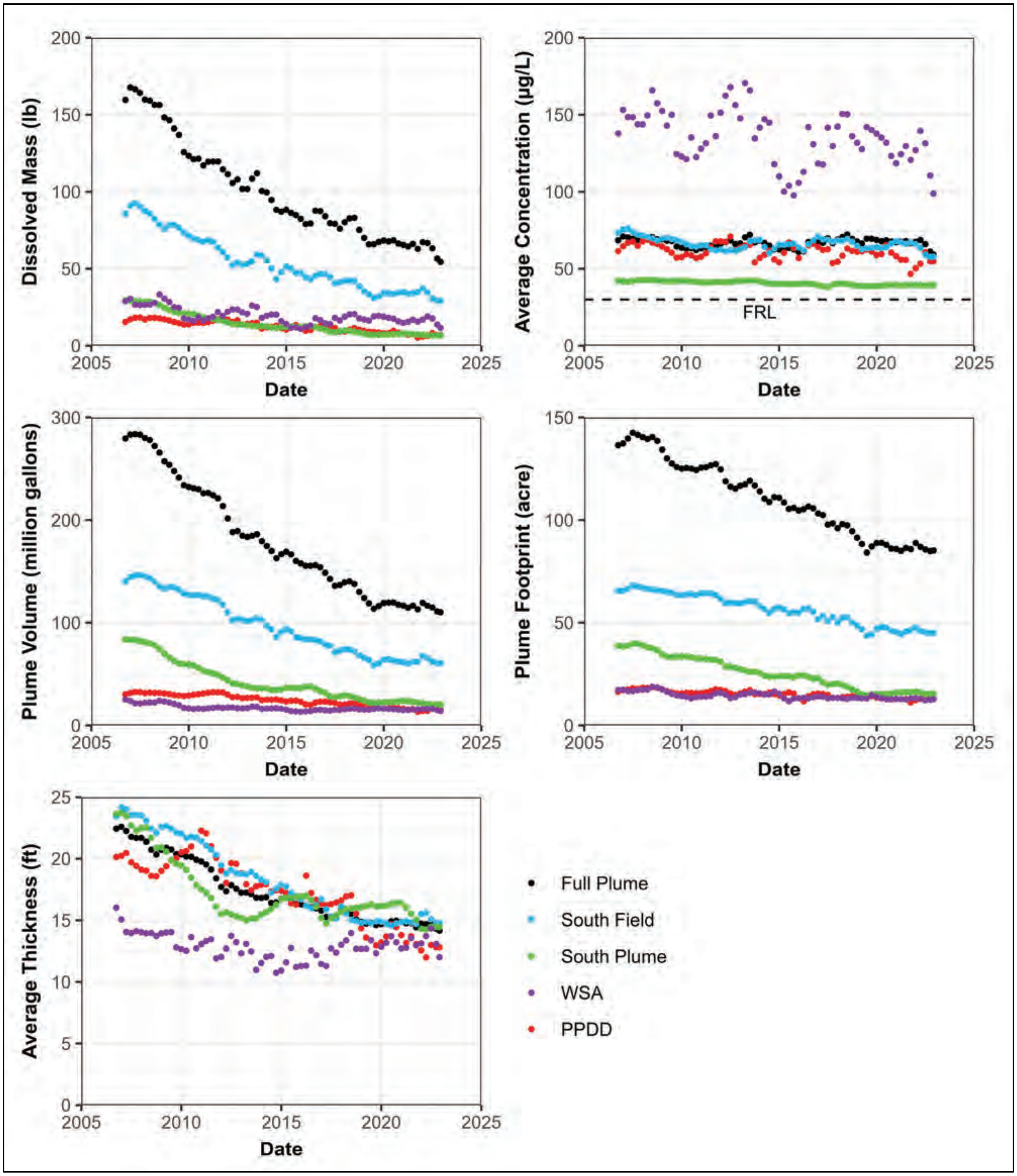


Figure A.2-27. EVS 2022 Plume Metrics

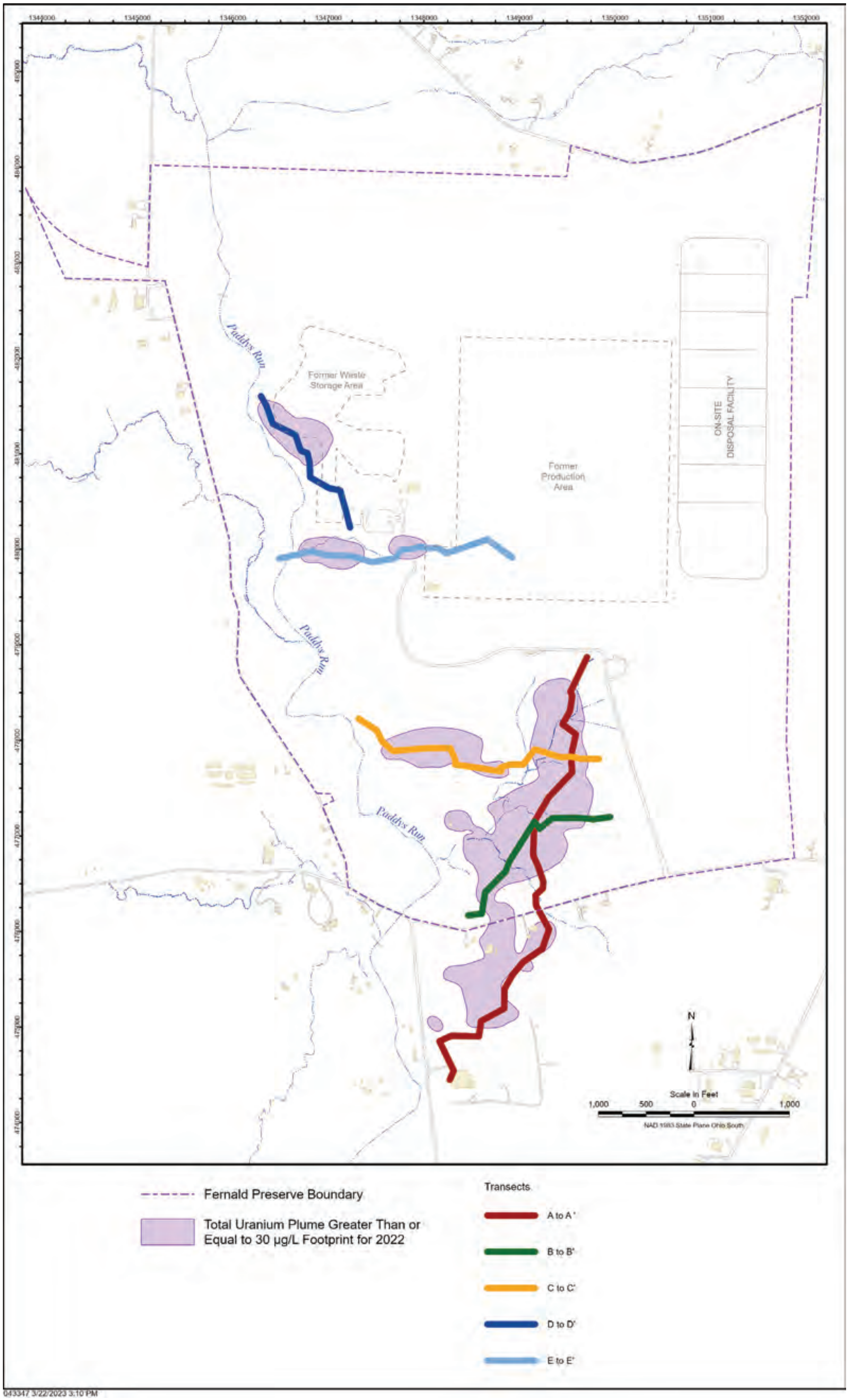


Figure A.2-28. Uranium Plume Cross Section Overview Map

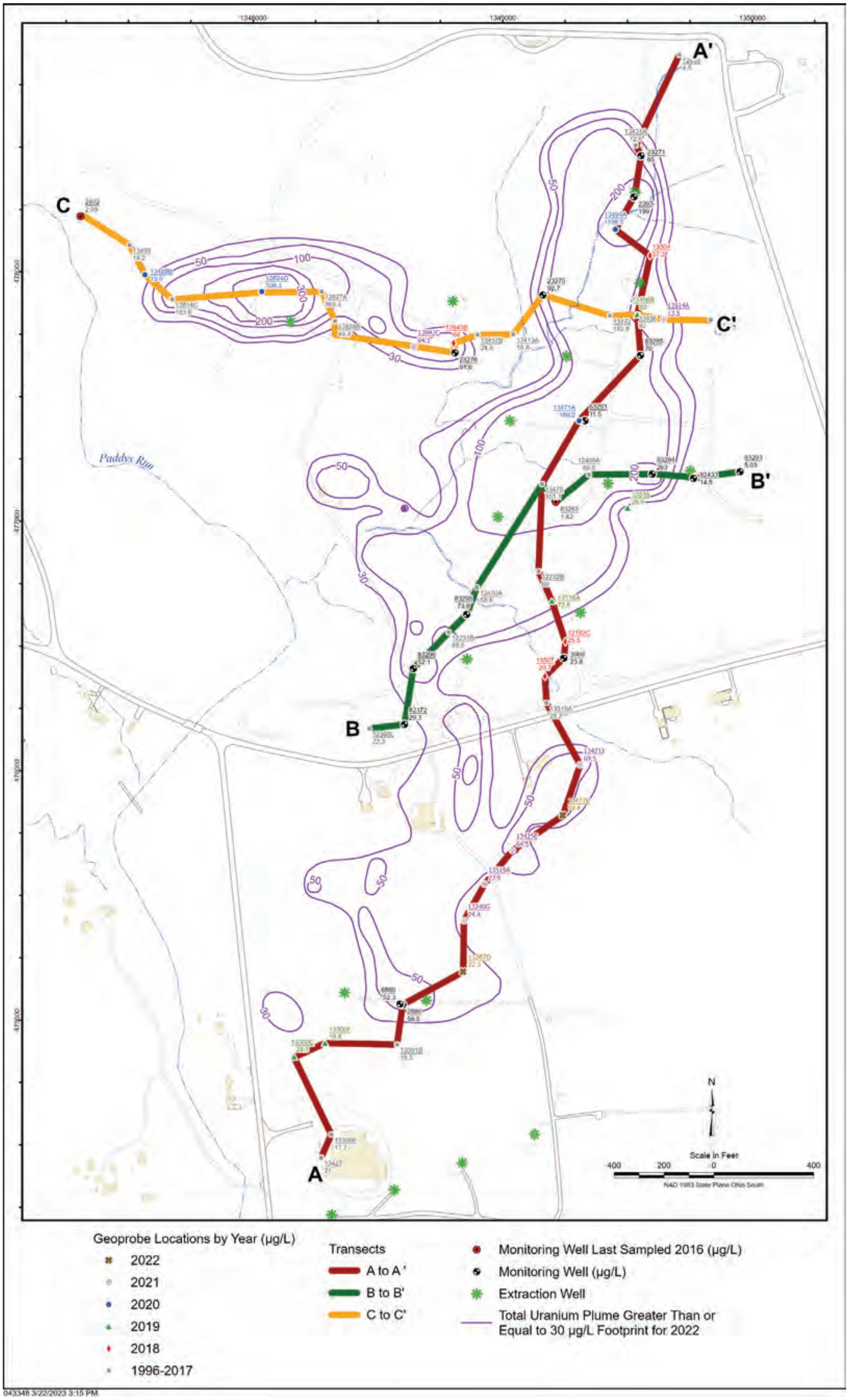


Figure A.2-29. Uranium Plume South Cross Section Location Map

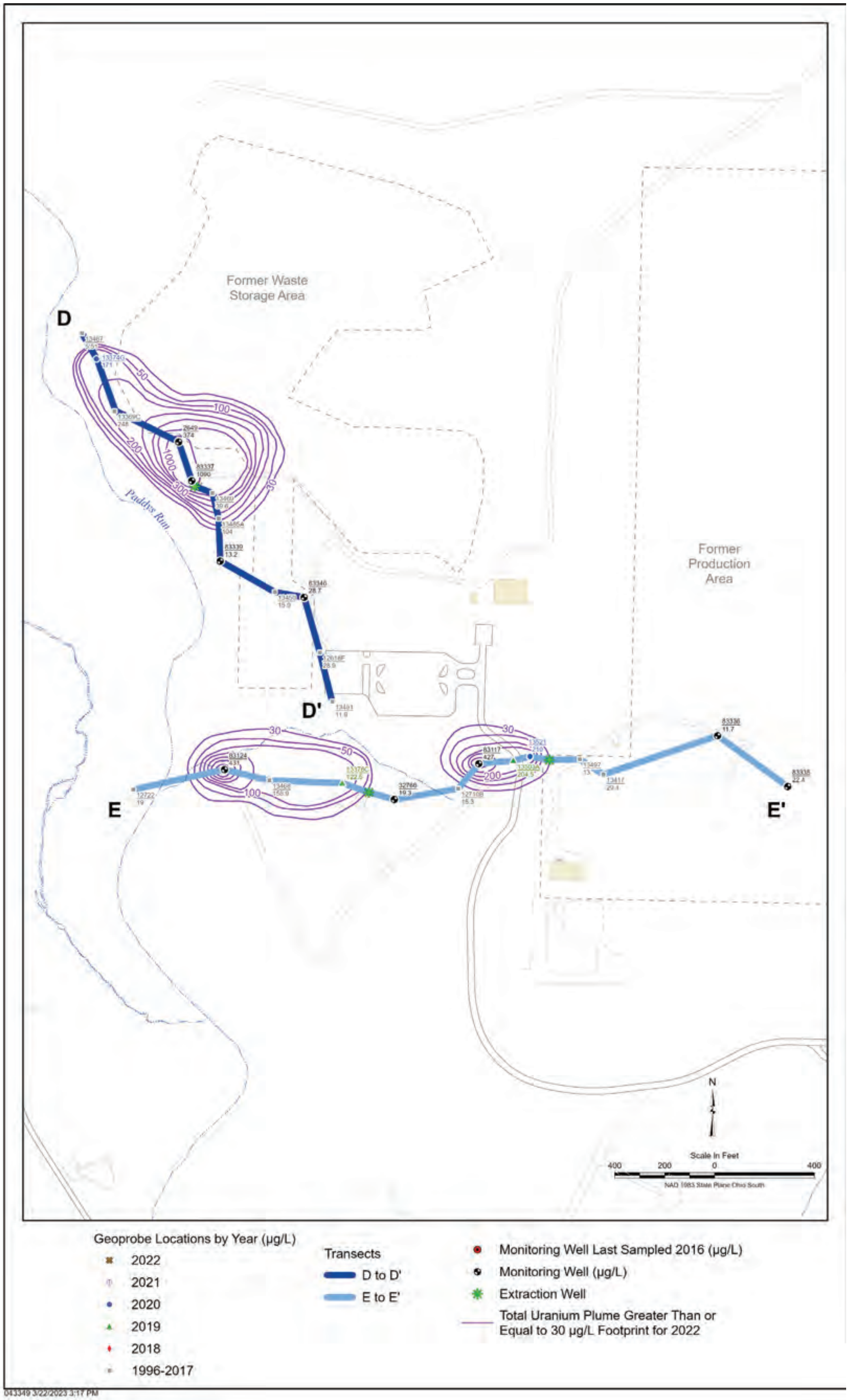
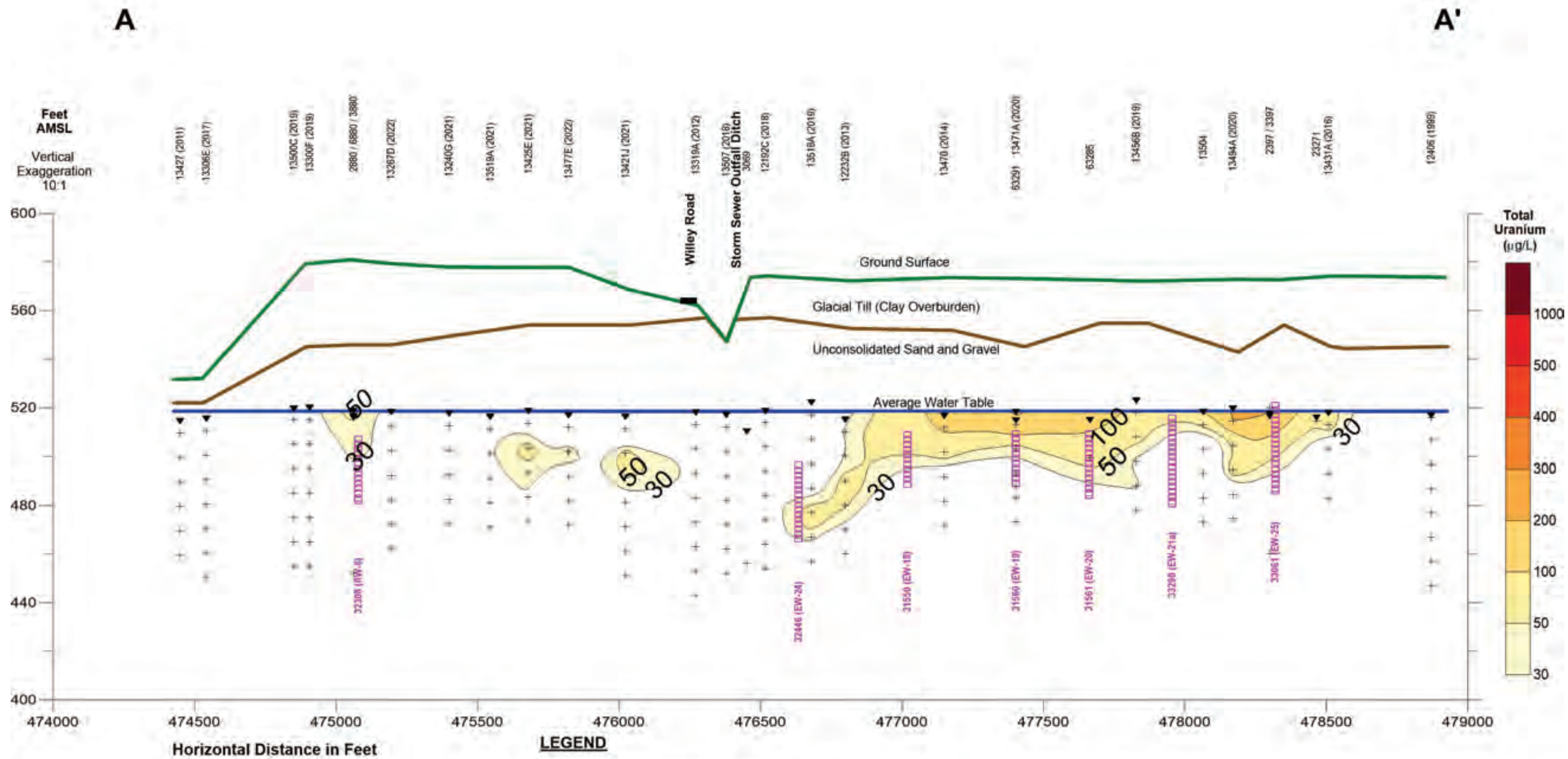


Figure A.2-30. Uranium Plume North Cross Section Location Map



LEGEND

3069 - Monitoring well
12232 (2013) - Direct-push location (Year sampled with Geoprobe)
▼ - Water level on sampling date
+ - Mid-point of well/sampler screen
□ - Extraction well screened interval

Figure A. 2-31A. Total Uranium Plume Cross Section A–A'

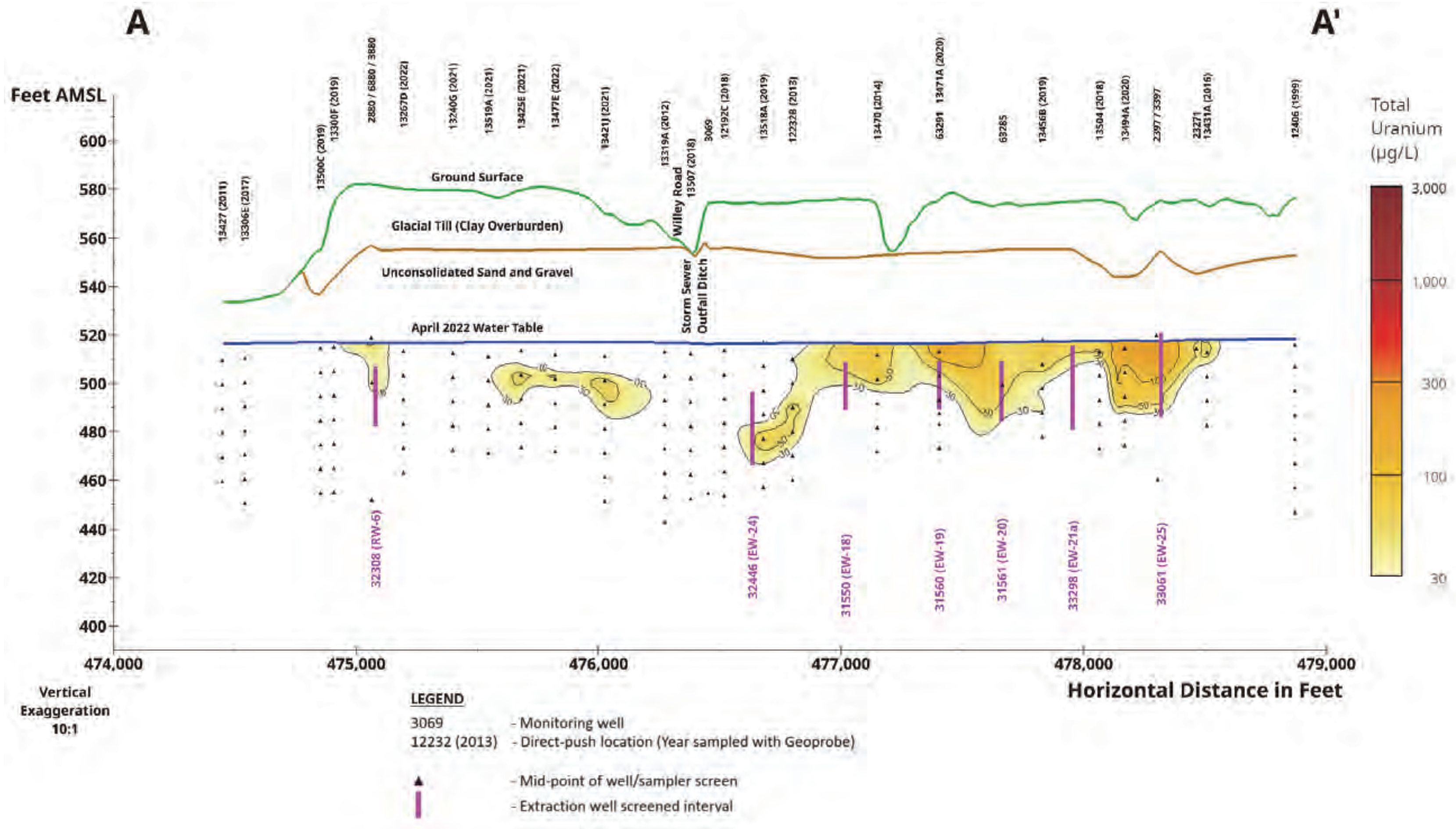


Figure A. 2-31B. EVS Total Uranium Plume Cross Section A–A′

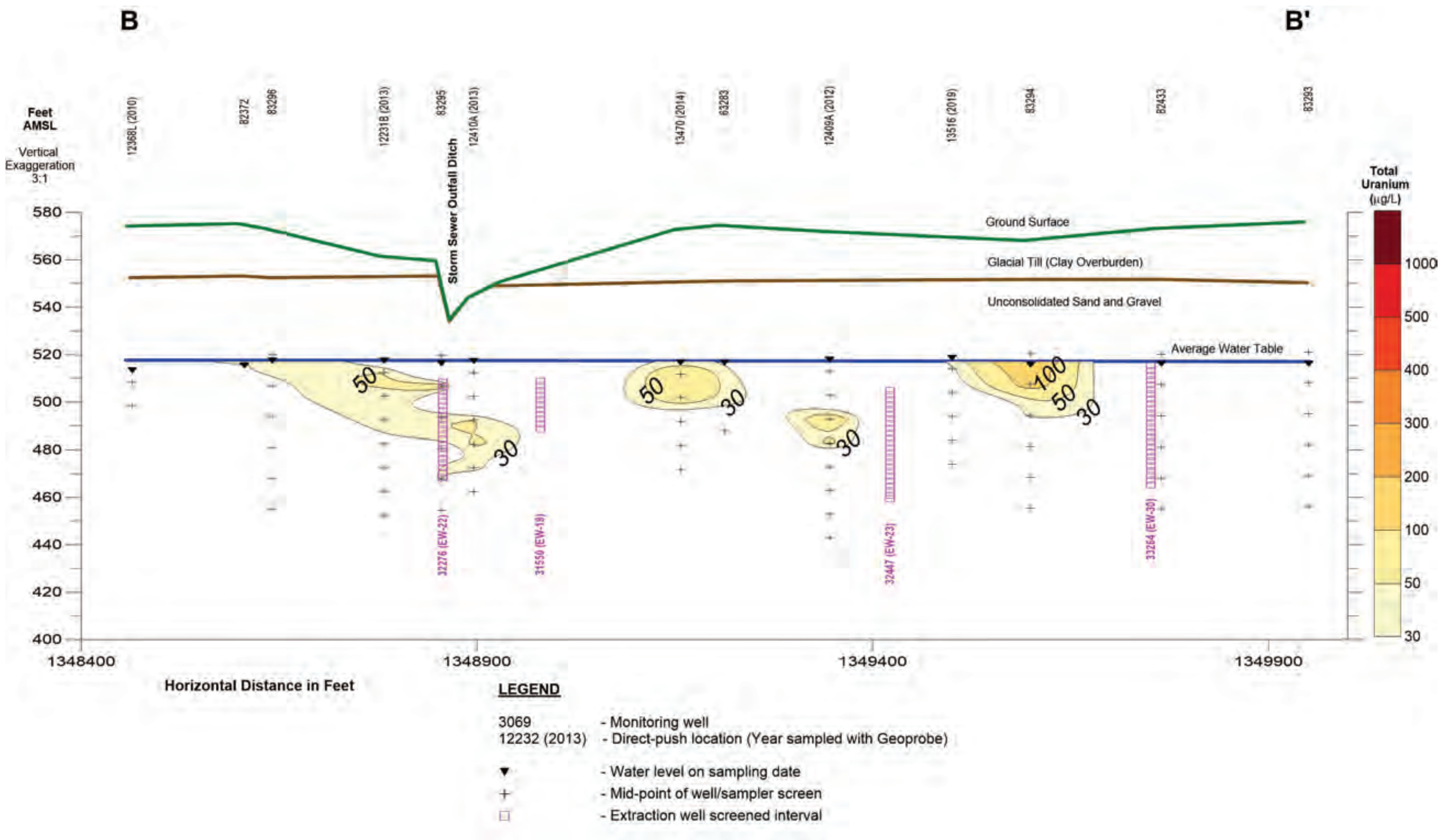


Figure A.2-32A. Total Uranium Plume Cross Section B–B'

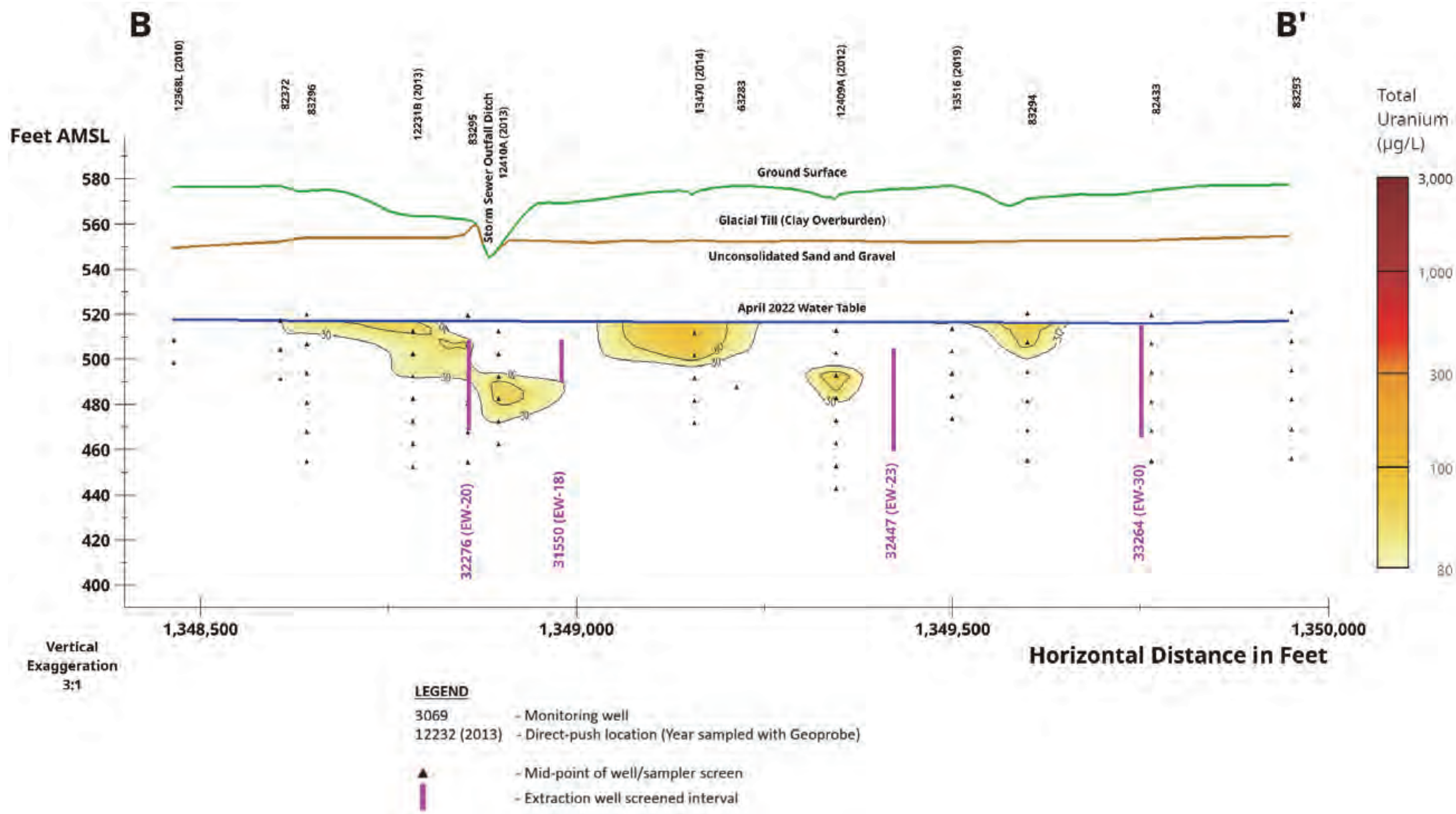


Figure A.2-32B. EVS Total Uranium Plume Cross Section B–B'

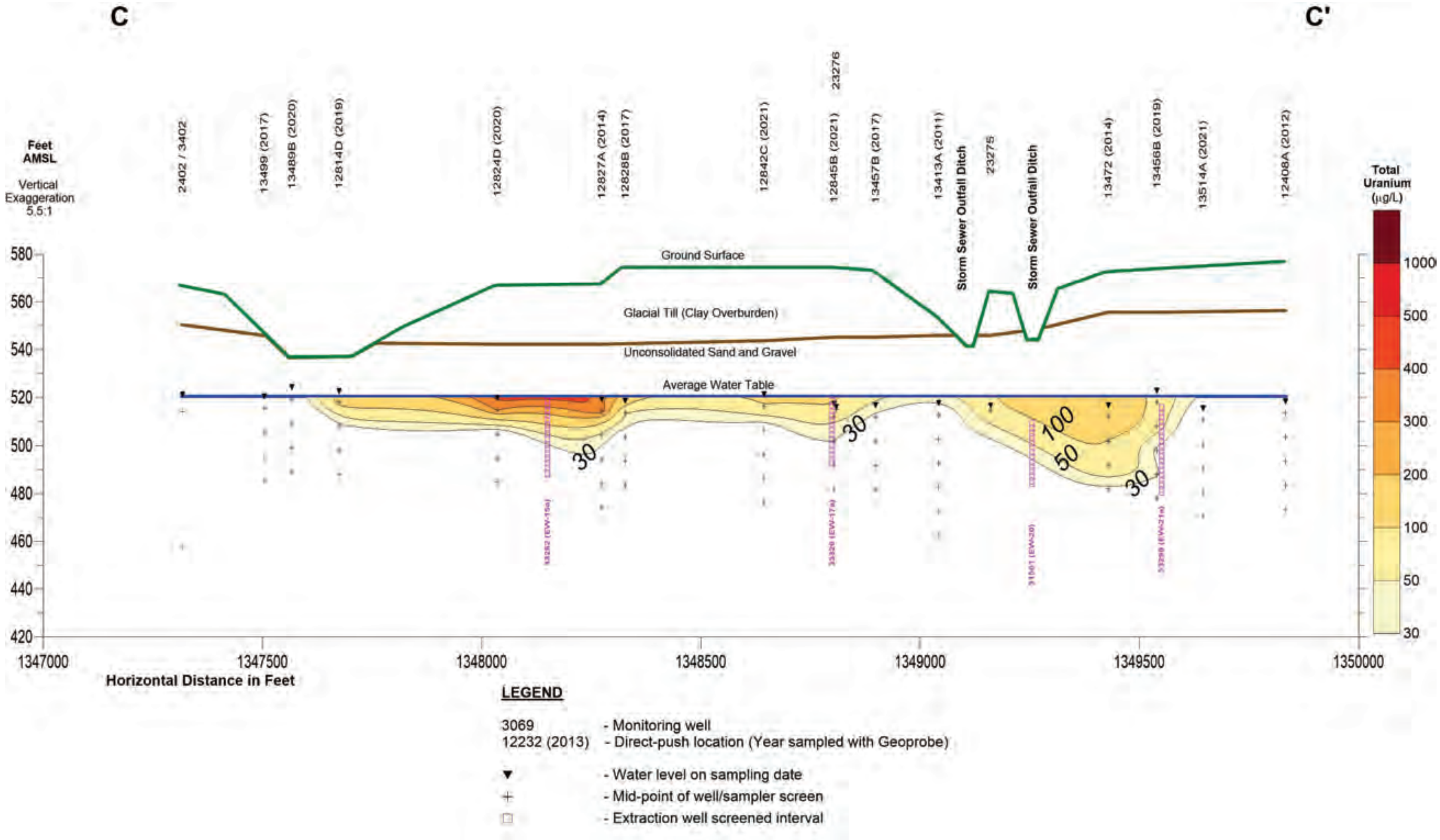


Figure A.2-33A. Total Uranium Plume Cross Section C–C'

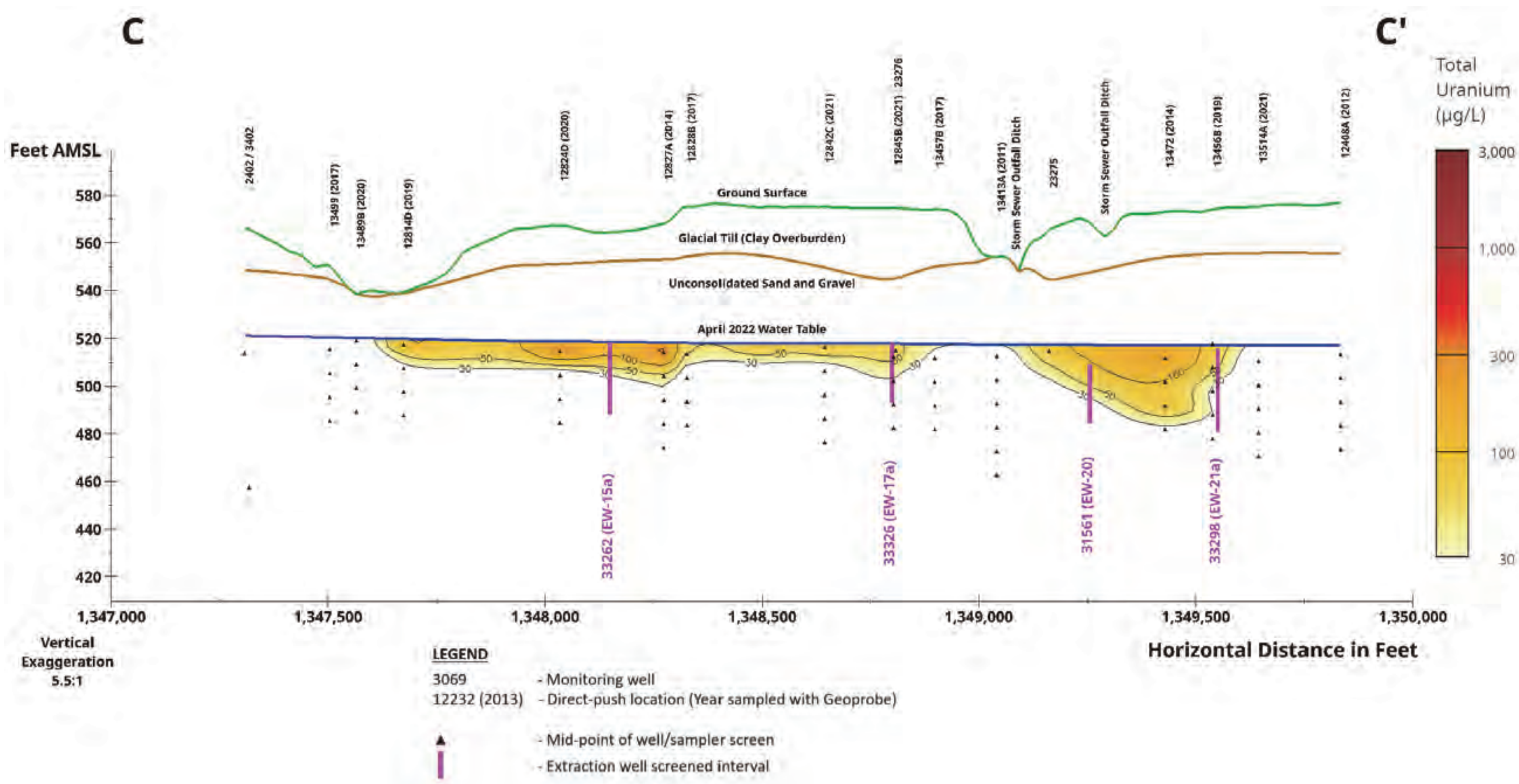


Figure A.2-33B. EVS Total Uranium Plume Cross Section C–C'

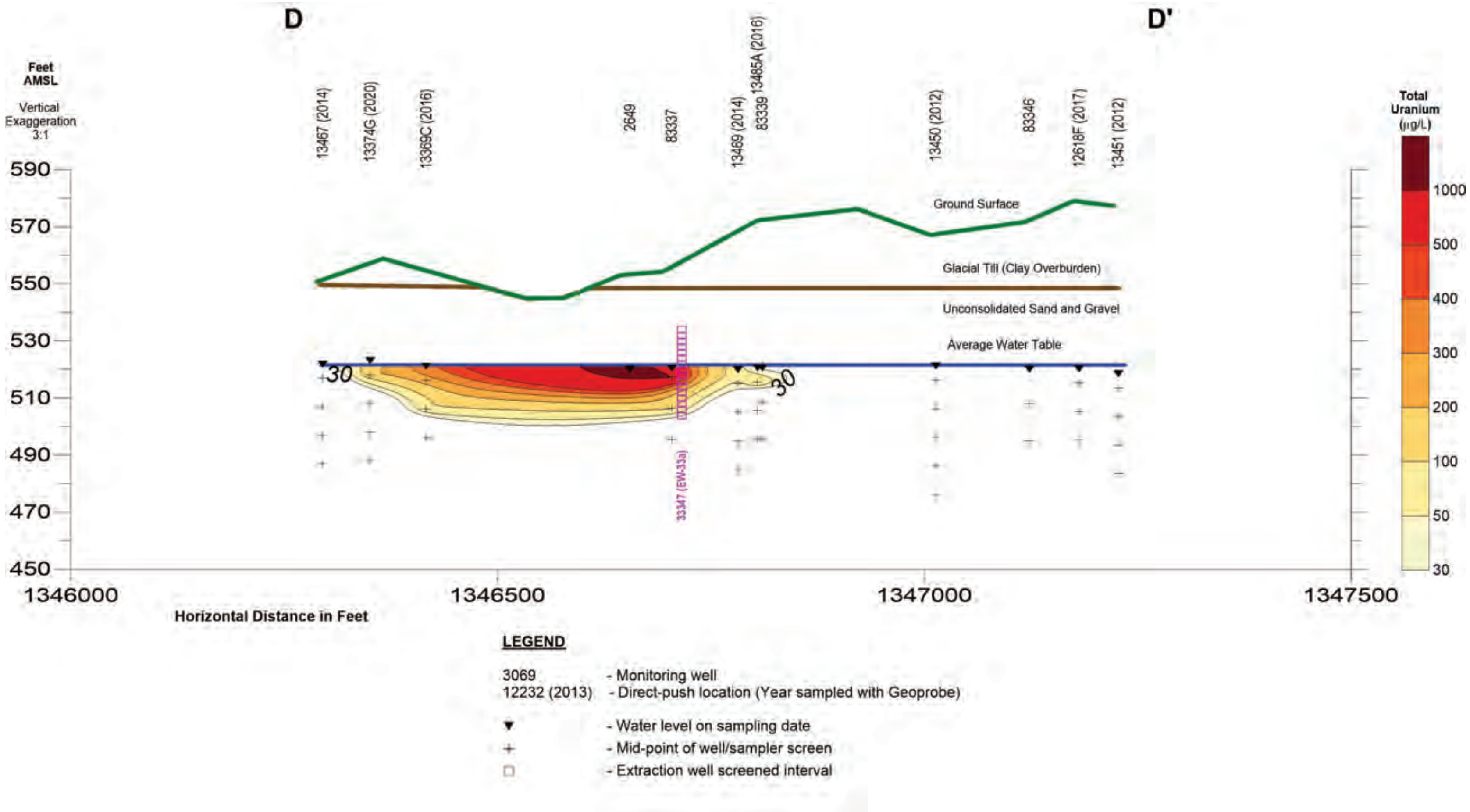


Figure A.2-34A. Total Uranium Plume Cross Section D–D′

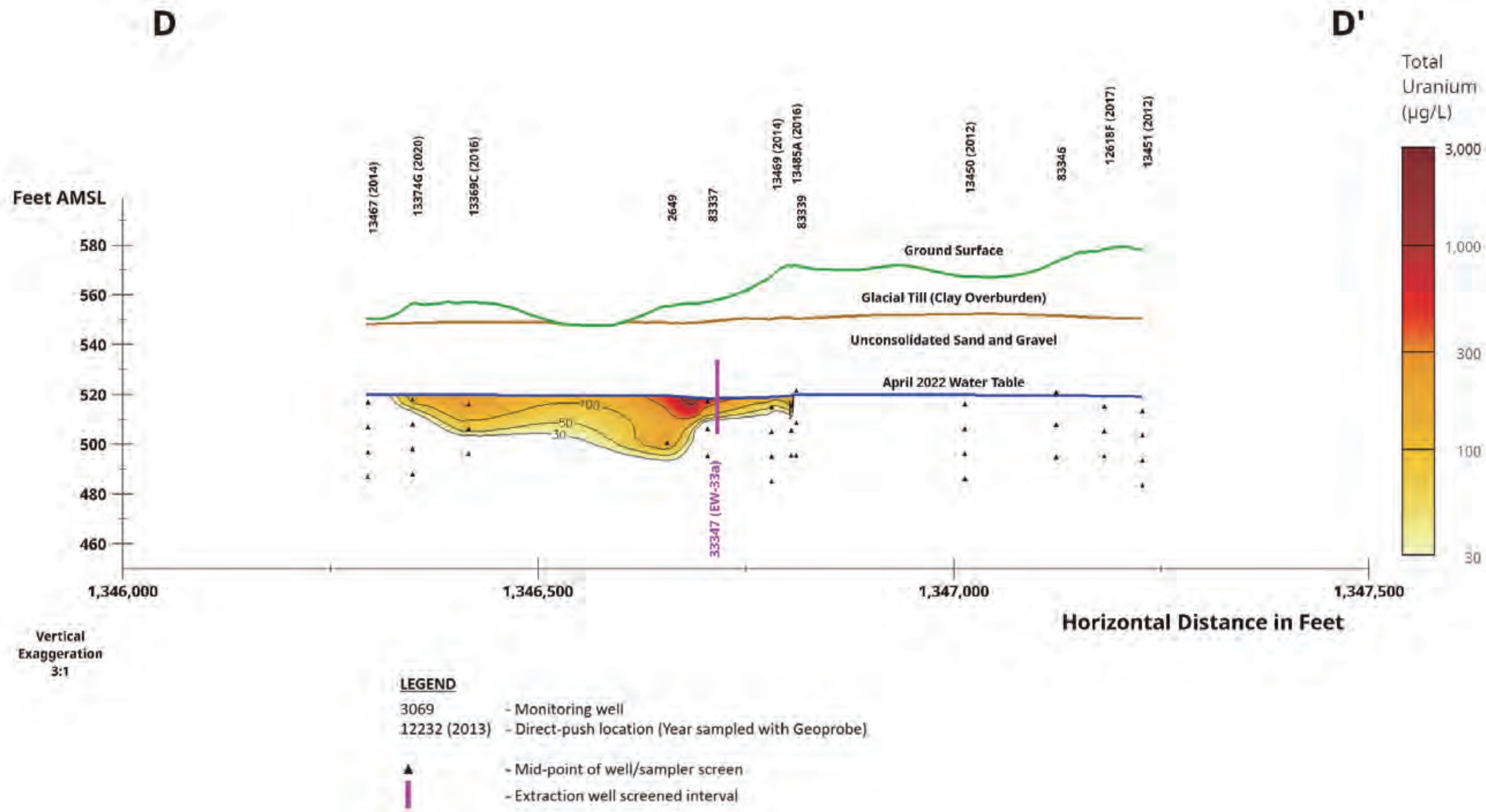


Figure A.2-34B. EVS Total Uranium Plume Cross Section D–D'

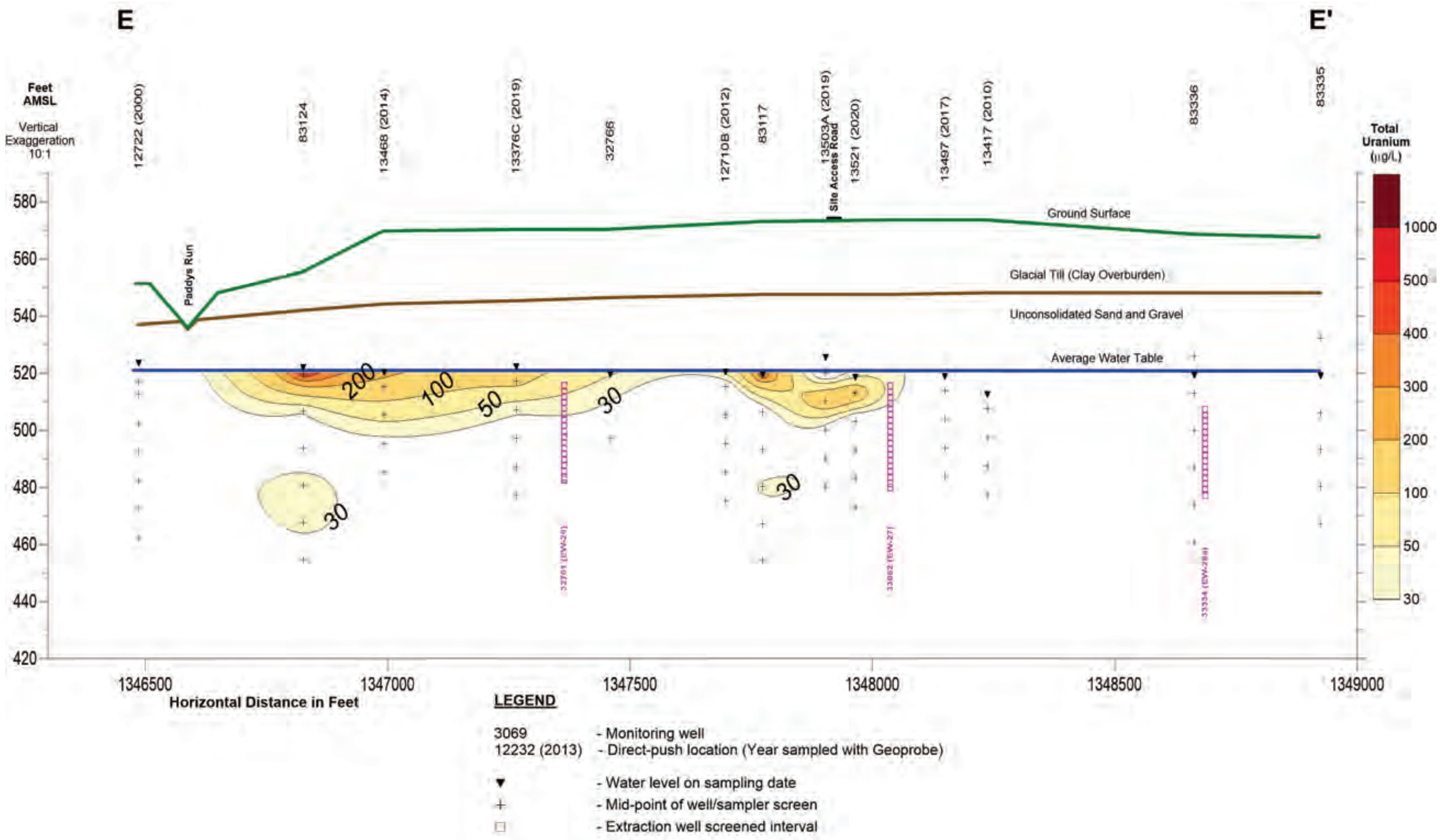


Figure A.2-35A. Total Uranium Plume Cross Section E–E'

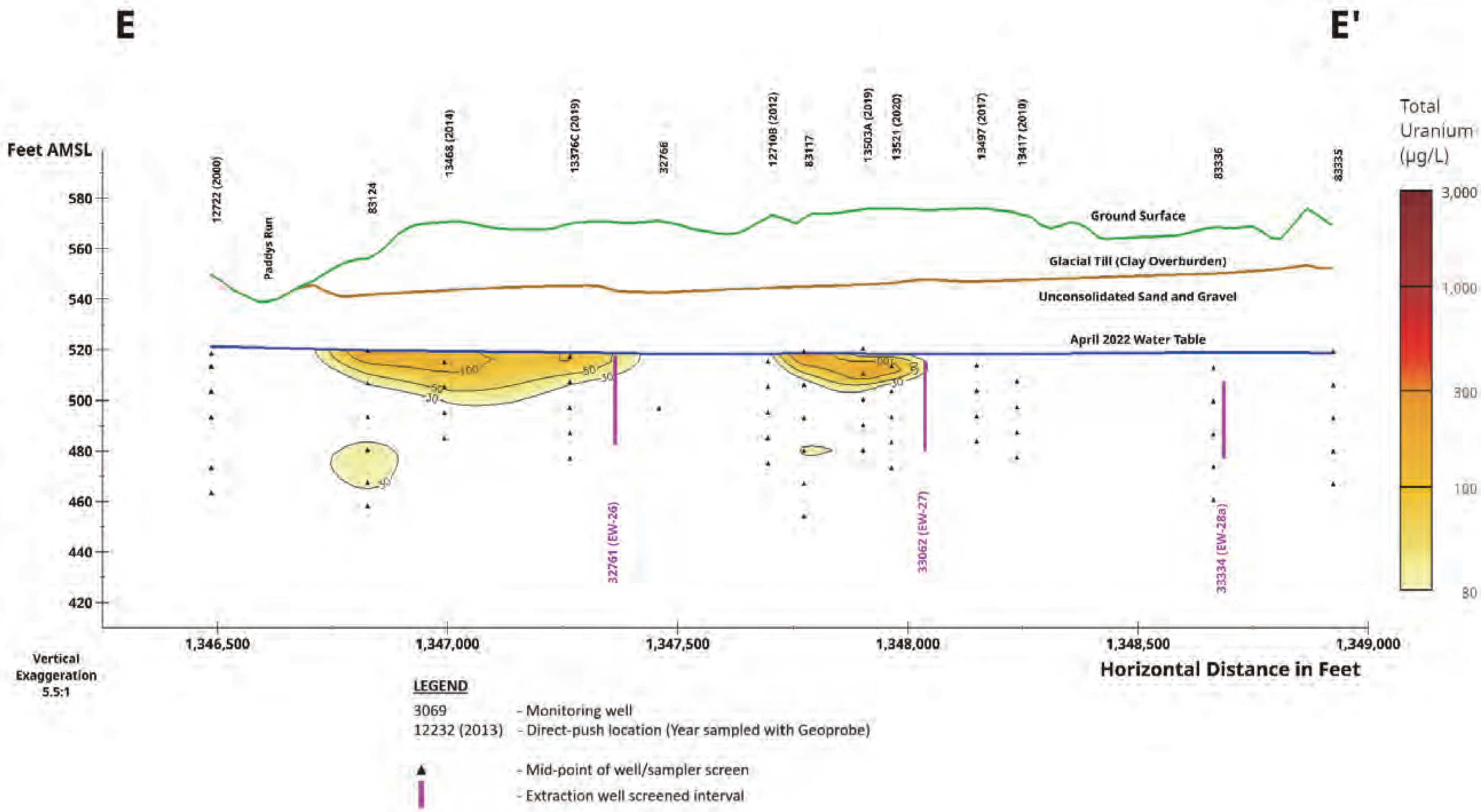


Figure A.2-35B. EVS Total Uranium Plume Cross Section E–E'

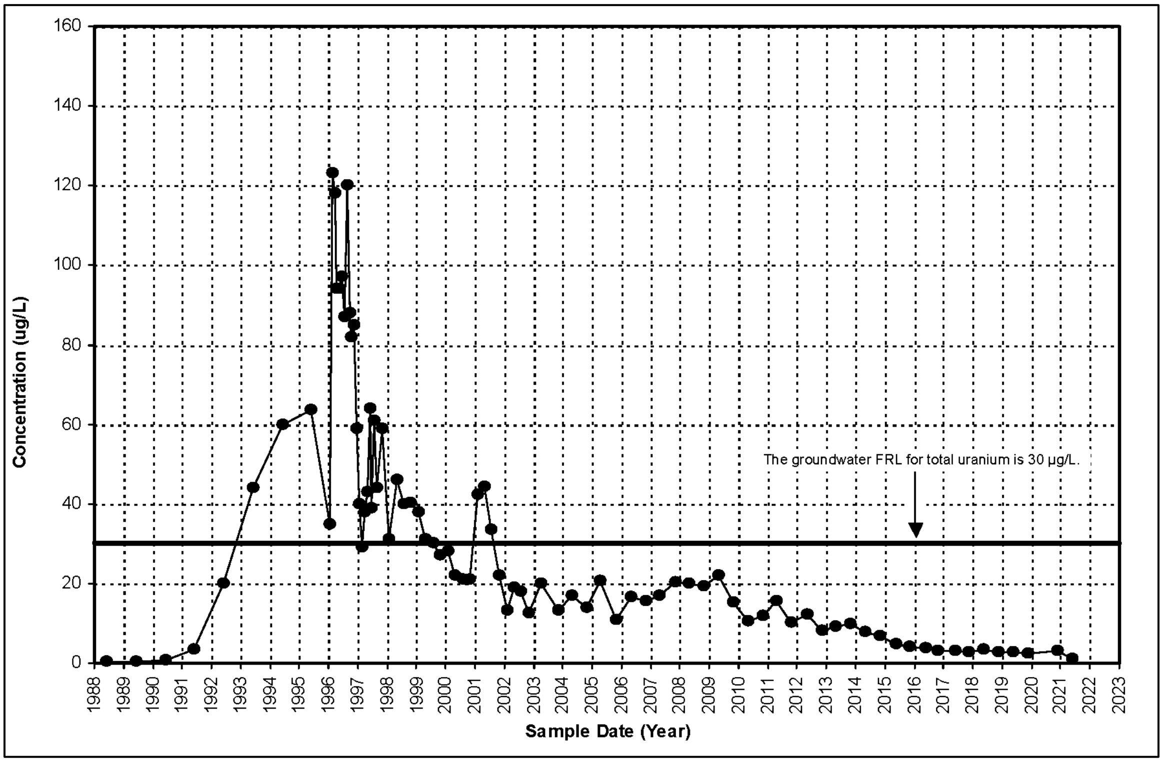


Figure A.2-36. Total Uranium Concentration Versus Time Plot for Monitoring Well 13

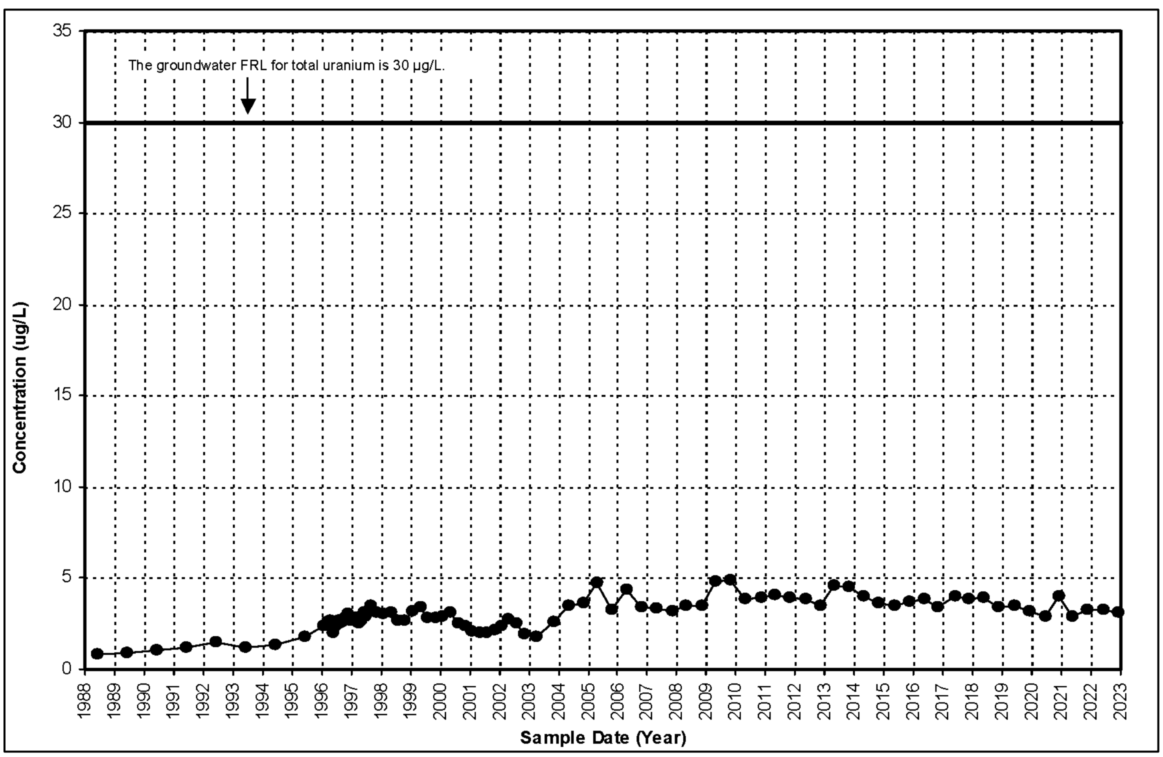


Figure A.2-37. Total Uranium Concentration Versus Time Plot for Monitoring Well 14

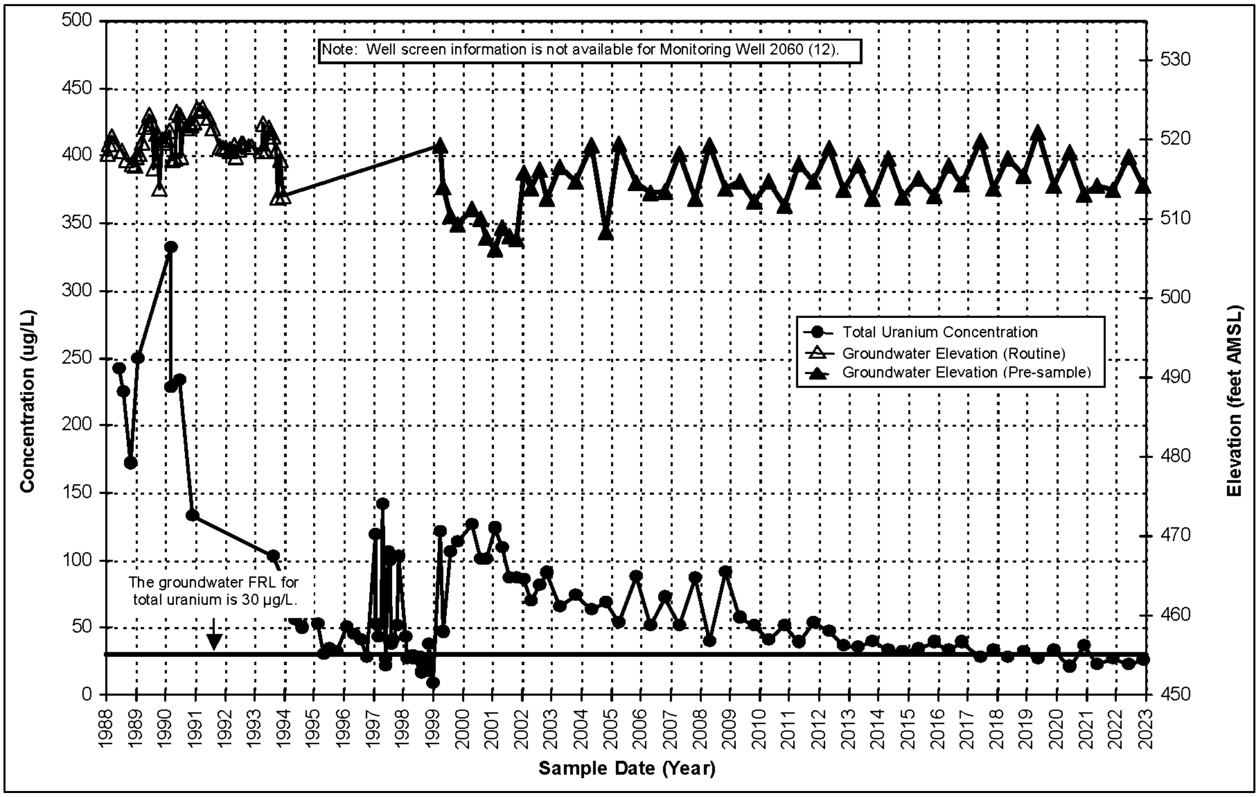


Figure A.2-38. Total Uranium Concentration Versus Time Plot for Monitoring Well 2060

Attachment A.3

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Contents

Tables

Figures

Abbreviations

DOE	U.S. Department of Energy
IEMP	Integrated Environmental Monitoring Plan
OSDF	On-Site Disposal Facility
VAM-3D	Variable Saturated Analysis Model in Three Dimensions
WSA	Waste Storage Area

Measurement Abbreviations

amsl	above mean sea level
ft	feet
gpm	gallons per minute
µg/L	micrograms per liter

A.3.0 Groundwater Elevations and Capture Assessment

A.3.1 Groundwater Elevations and Capture Assessment

Quarterly groundwater elevation maps for 2022 are provided in Figures A.3-1 through A.3-4. Each groundwater elevation map contains the following quarter-specific information:

- Groundwater elevation data
- Interpreted water-table contours, capture zones, and flow divides
- Bedrock highs
- Model-predicted current Operational Design Remediation Footprint (based on particle tracks)
- Extent of the maximum 30 micrograms per liter (μg/L) total uranium plume
- Number of extraction wells in each module and the module-specific pumping rates during the period in which the groundwater elevations were measured

Water levels in 2022 were measured as specified in the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (DOE 2019). A total of 172 monitoring wells were available for measurement. As required by the IEMP, during the second quarter of 2022, all 172 wells were targeted for water level measurements. During the other three quarters, 99 of the 172 available wells were targeted for measurement. A summary of the results is shown below.

Quarter	Measurement Dates (2022)	Number of Days	Average Water Level (ft amsl)[a]
1	January 3 to January 5	3	516.13
2	April 4 to April 7	4	518.03
3	August 29 to August 31	3	517.40
4	December 5 to 6	2	514.88

[a]ft amsl = feet above mean sea level.

Five monitoring wells and the uppermost channel in eight multichannel wells were dry at various times of the year. A summary is provided below.

Well	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
2014	DRY			DRY
2384	DRY		DRY	DRY
2636				DRY
22192	DRY	DRY	DRY	DRY
22303				DRY
83293_C1	DRY			DRY
83295_C1				DRY
83335_C1	DRY	DRY	DRY	DRY
83336_C1	DRY	DRY	DRY	DRY
83337_C1	DRY			DRY
83340_C1	DRY			
83341_C1	DRY			DRY
83346_C1				DRY

Quarterly groundwater elevation maps for 2022 are provided in Figures A.3-1 through A.3-4. Water level measurements are generally collected during times when all extraction wells are pumping; however, due to certain conditions (e.g., well maintenance), individual wells might be shut down during the measurement period. Any specific well shutdowns during the elevation measurement period are noted in Figures A.3-1 through A.3-4. The maps for 2022 illustrate capture of the maximum total uranium plume using groundwater elevation contours derived from quarterly water level measurements and model-predicted capture. The pumping rates reported in Figures A.3-1 through A.3-4 are averages of the actual pumping rates during the measurement period.

Model-predicted capture (called the current Operational Design Remediation Footprint) is based on particle tracks that were created using target system pumping rates defined in the current Operational Design. The current Operational Design Remediation Footprint used in this report was constructed using reverse, nonretarded, particle path interpretations from the Variable Saturated Analysis Model in Three Dimensions (VAM-3D) Zoom Groundwater Model that was updated in 2014 to reflect capture during the time period modeled for the 2014 Operational Design Adjustment (DOE 2014). Figure A.3-5 shows the resulting particle tracks that were used to define the remediation footprint. Model particles were seeded at each extraction well. The resulting particle tracks represent the individual path that each particle traveled in 10 years during each of the three pumping stages modeled for the cleanup. The limits of most of the particle tracks are truncated because the particles reached the edge of the VAM-3D Zoom Groundwater Model domain.

The times of travel used to define the particle paths considered the pumping changes that are predicted to occur when different portions of the uranium plume achieve cleanup goals. The following three pumping stages were defined:

- **Stage 1:** 20 wells at a system rate of 5,075 gallons per minute (gpm)
- **Stage 2:** 10 wells at a system rate of 3,075 gpm
- **Stage 3:** 3 wells at a system rate of 1,100 gpm

A groundwater flow divide between Paddys Run Outlet and the New Baltimore Outlet is not readily distinguishable. Groundwater flow diverges around the bedrock high that separates the Paddys Run Outlet from the New Baltimore Outlet, but without additional measurement locations in the New Baltimore Outlet, the location where flow is dividing is not apparent. However, additional measurement locations in the New Baltimore Outlet are not needed for capture assessment purposes.

During the first two quarters of 2022, flow in the vicinity of the On-Site Disposal Facility (OSDF) was generally from the northeast. During the last two quarters of 2022 flow in the vicinity of the OSDF was more from the north to northwest. Flow direction is influenced by seasonal fluctuations in the aquifer and by the active pumping taking place for the groundwater remediation, which is predicted to last until the end of the remediation. Before the start of pumping for the groundwater remediation, flow in the vicinity of the OSDF was generally west to east. It is anticipated that when pumping stops, flow in the vicinity of the OSDF will return to a generally west-to-east direction.

Figure A.3-6 shows cumulative annual precipitation levels for 2004 through 2022, as recorded at the Butler County Regional Airport. Cumulative precipitation in 2022 was 40.50 inches. Between 2004 and 2022, the annual precipitation level has been as low as 33.20 inches (2010) and as high as 60.20 inches (2011).

Average annual water-table fluctuations and yearly ranges for 2006 through 2022 are as follows.

Year	Average Fluctuation (feet)	Fluctuation Range (feet)
2022	3.46	1.2 to 5.73
2021	4.14	1.4 to 7.24
2020	4.35	2.1 to 5.97
2019	3.82	0.21 to 7.09
2018	3.92	1.0 to 7.57
2017	3.80	0.15 to 4.83
2016	2.50	0.20 to 4.93
2015	4.64	0.35 to 4.99
2014	5.14	1.21 to 6.35
2013	3.45	0.35 to 4.28
2012	4.70	1.1 to 6.79
2011	7.50	7.4 to 14.5
2010	3.78	0.06 to 12.1
2009	2.46	0.1 to 5.5
2008	5.70	1.0 to 10.46
2007	4.45	1.7 to 7.7
2006	3.40	2.0 to 7.1

Capture zone interpretations for 2022 coupled with the particle track interpretations and contoured water-table gradients indicate that the 30 µg/L total uranium plume was being captured in 2022.

During 2020, the U.S. Department of Energy (DOE) collaborated with the DOE National Laboratory Network to determine what could be done to improve the Fernald Preserve groundwater remediation effort. One recommendation was to utilize available software to conduct four-dimensional mapping exercises: three spatial dimensions with time as the fourth dimension. Earth Volumetric Software was utilized to carry out the recommendation. As part of that exercise, water table mapping was conducted using quarterly water level data collected from August 2014 through April 2022. A total of 30 different quarterly water level events were used for the analysis. Water table interpretation was performed using kriging with external drift, following the methodology of Tonkin and Larson (2002). The kriging results were imported into the software for visualizing and streamline analyses. The streamline capture fraction was used to assess whether full containment is being achieved by the current Operational Design. Results indicated that the current Operational Design achieves full containment of the uranium plume, consistent with previous evaluations reported in this and past Site Environmental Reports.

A.3.2 Annual Planned Well Field Shutdown

The entire well field (excluding the South Plume recovery well RW-2) was shut down from June 6 to July 18, 2022, as planned to allow water levels to recover to nonpumping elevations.

Quarterly measurement of water levels in 2022 was planned so that measurements were not collected during the planned shutdown.

Uranium is bound to sediments in the unsaturated zone of the Great Miami Aquifer in former contamination source areas. This contamination will remain bound unless water levels in the aquifer rise and saturate the contaminated sediments, allowing the bound uranium to dissolve into the groundwater.

This presents a challenge to a pump-and-treat remedy, because pumping lowers the water level. In a pump-and-treat remedy, only the dissolved uranium is removed by the pumping action. Sorbed uranium in the vadose zone is not removed. The concern is that once pumping ends, water levels will rise and provide a means for additional uranium to dissolve into the water, potentially raising dissolved contaminant levels above final remediation goals. This process is referred to as “concentration rebound” and is a concern for pump-and-treat groundwater remedies. Planned annual well field shutdowns have been conducted since 2007 to allow water levels in the aquifer to rise as high as possible to saturate aquifer material that is not normally saturated. To achieve the highest water level rise possible, the well field shutdowns are planned to coincide with seasonal high water levels in the aquifer.

A.3.2.1 Water Level Results

Pressure transducers, which automatically record water levels, are installed in 11 groundwater monitoring wells (2045, 2046, 2095, 2649, 3881, 23274, 62433, 32763, 22301, 22302, and 63119) for the shutdown (Figure A.3-7). Water level measurements were recorded twice each day at midnight and noon.

The zero hour transducer readings (midnight) were used to track water level changes in the transducer wells during the shutdown periods. The maximum water level rise at each well, measured during the shutdown period in 2022, is presented below.

Planned Shutdown: June 6 to July 12, 2022

Location	Elevation at Midnight Prior to Shutdown June 6, 2022 (ft amsl)	Elevation at Midnight Prior to Restart July 12, 2022 (ft amsl)	Water Level Rise (ft)
2045	518.27	519.84	1.57
2046	518.91	519.99	1.08
2649	521.80	522.14	0.34
23274	517.74	520.08	2.34
63119[a]	Not recorded	Not recorded	Not recorded
22302	516.82	519.23	2.41
3881	517.15	518.80	1.65
22301	517.42	519.52	2.10
2095	517.60	518.85	1.25
32763	518.99	521.33	2.34
62433	515.83	519.44	3.61

[a] Data not collected due to dead battery in datalogger.

The water level rise measurements indicate that during the shutdown, the water level rise ranged from 0.34 feet (ft) (well 2649) to 3.61 ft (well 62433).

Figure A.3-8 shows water levels versus precipitation from May 25, 2007, through January 5, 2023. Three wells are shown in the figure: well 2649 (former Waste Storage Area [WSA]), well 2046 (west side of South Field Area), and well 62433 (east side of South Field Area). The combination of the shutdown and seasonal water level rise in 2022 resulted in the following water level rises:

- 5.04 ft in the former WSA (monitoring well 2649)
- 5.27 ft in the west side of the South Field (monitoring well 2046)
- 7.26 ft in the east side of the South Field (monitoring well 62433)

A.3.2.2 Uranium Concentration Results

Consistent with previous years, total uranium concentrations were measured in six groundwater monitoring wells (2045, 2046, 23274, 83124, 83294, and 83337 [Figure A.3-9]) before, during, and after the 2022 shutdown. The results of the 2022 IEMP first-half uranium sampling are used to represent uranium concentrations in the well before the shutdown. Groundwater samples collected in June 2022 represent concentrations during the shutdown. The results of the 2022 IEMP second-half uranium sampling are used to represent uranium concentrations in the well after the shutdown exercise was completed. Due to a miscommunication between the project lead and the sampling crew post-shutdown samples at monitoring wells 2046, 23274, and 83124_C2 were not collected. The second half of the 2022 post-shutdown sample was incorrectly applied as being the pre-start sample and a true post-shutdown sample was not collected. The two shallowest channels (channels 1 and 2) of the type-8 monitoring wells were sampled with the exception of well 83124_C2 (as explained previously) or if the channel was dry. Uranium concentration measurements at the six monitoring wells before, during, and after the 2022 shutdown are provided in Table A.3-1.

A comparison of pre-shutdown uranium concentrations to pre-startup uranium concentrations in the monitoring wells indicated that concentrations increased in four of the six wells during the shutdown: 2045, 83124, 83294_C1, 83294_C2, and 83337_C2. As stated in the IEMP, during the second half of the year, the channel with the highest uranium concentration (as measured during the first half of the year) is sampled if it is not dry. If the targeted channel is dry, the next deeper channel is sampled. In the second half of 2022, 83294_C1 and 83337_C1 were dry.

As prescribed in the IEMP, uranium concentrations were also measured at the extraction wells before and daily for 4 days after the wells were restarted. After each well was restarted, the first water sample was collected after the well had been pumping for approximately 5 minutes. Results for the shutdown are provided in Table A.3-2. Recovery well RW-2 continued to run during the shutdown.

The last column of Table A.3-2 provides the difference between the maximum uranium concentration measured after the wells were restarted and the average uranium concentration measured within a month prior to the shutdown at each extraction well. As the data indicate, approximately half of the wells showed an increase in uranium concentrations. The largest increase in uranium concentration was measured in recovery well RW-3 (8.9 µg/L).

A.3.3 Continued Transducer Monitoring

Although not required by the IEMP, pressure transducers installed in 2007 to support the first annual well field shutdown remain in the wells and continue to operate so that daily changes in water levels can be recorded on a continuous, routine basis at key points in the aquifer. The transducers are programmed to record a water level measurement twice daily, at noon and midnight. Data from three of the six locations (former WSA [2649], west side of the South Field Area [2046], and east side of the South Field Area [62433]) are shown in Figure A.3-7 and are plotted in Figure A.3-8 along with precipitation data collected through January 5, 2023. The transducers will continue to record data to provide a more complete record of seasonal and short-term water-table fluctuations and continue to be used to plan the timing of future well field shutdowns.

A.3.4 References

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Table A.3-1. Uranium Concentrations at Monitoring Wells Before, During, and After the 2022 Well Field Shutdown

Uranium Concentrations at Monitoring Wells Before, During, and After the 2022 Wellfield Shut Down

Well	Easting	Northing	First Half 2022 Pre-Shutdown Concentrations		Pre-Start-Up Concentrations July 2022		Second Half 2022 Post-Shutdown Concentrations	
			Date	Uranium (µg/L)	Date	Uranium (µg/L)	Date	Uranium (µg/L)
2045	1348291	477158.9	4/26/2022	51.1	7/13/2022	66.4	8/11/2022	55.9
2046	1347950	478087.8	2/9/2022	18.8	7/11/2022	16.5	Not Sampled	Not Sampled
23274	1349406	478337	1/19/2022	67.9	7/11/2022	58.8	Not Sampled	Not Sampled
83124_C1	1346826	479977.2	5/24/2022	309.0	7/12/2022	498.0	9/29/2022	304.0
83124_C2	1346826	479977.2	5/24/2022	20.5	7/12/2022	31.7	Not Sampled	Not Sampled
83294_C1	1349599	477189.5	3/8/2022	222.0	7/12/2022	241.0	Dry	Dry
83294_C2	1349599	477189.5	3/2/2022	116.0	7/12/2022	102.0	10/3/2022	72.5
83337_C1	1346704	481051.9	5/17/2022	1,020	7/12/2022	411.0	Dry	Dry
83337_C2	1346704	481051.9	5/17/2022	5.7	7/12/2022	106.0	11/7/2022	3.7

Table A.3-2. Total Uranium Concentration at Extraction Wells During 2022 Well Field Shutdown

Extraction Well	June 6, 2022 Total Uranium Concentration (ug/L)	Date of Well Restart	Total Uranium Concentration (ug/L) After Well Field Re-Start							Maximum Post Re-Start Minus June 6, 2022 Concentration[a]
			1st Restart Sample	2nd Restart Sample	3rd Restart Sample	4th Restart Sample	Minimum	Maximum	Range	
RW-1	10.4	7/12/2022	9.3	8.4	8.7	8.3	8.3	9.3	1.0	-1.1
RW-2[b]	13.3	NA[b]	12.1	12.1	12.3	12.6	12.1	12.6	0.5	-0.7
RW-3	19.8	7/28/2022	28.7	28.6	28.0	27.1	27.1	28.7	1.6	8.9
RW-4[c]	6.0	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
RW-6	28.5	7/18/2022	17.1	26.0	26.4	25.9	17.1	26.4	9.3	-2.1
RW-7	21.7	7/18/2022	27.6	17.1	17.5	17.6	17.1	27.6	10.5	5.9
EW-15A	24.9	7/21/2022	31.2	33.7	26.5	26.9	26.5	33.7	7.2	8.8
EW-17A	10.4	7/21/2022	11.3	11.9	12.5	11.4	11.3	12.5	1.2	2.1
EW-18	27.6	7/19/2022	23.0	23.8	24.5	28.0	23.0	28.0	5.0	0.4
EW-19	18.9	7/19/2022	17.6	17.9	17.4	21.0	17.4	21.0	3.6	2.1
EW-20	32.6	7/19/2022	28.5	29.2	2.8	31.4	2.8	31.4	28.6	-1.2
EW-21A	29.3	7/19/2022	37.1	34.8	32.4	36.4	32.4	37.1	4.7	7.8
EW-22	20.2	7/20/2022	16.6	18.1	20.7	20.0	16.6	20.7	4.1	0.5
EW-23	28.9	7/20/2022	15.9	19.5	23.9	24.6	15.9	24.6	8.7	-4.3
EW-24	24.6	7/20/2022	19.2	19.9	23.4	23.7	19.2	23.7	4.5	-0.9
EW-25	19.6	7/21/2022	19.4	23.2	19.7	21.9	19.4	23.2	3.8	3.6
EW-26	22.6	8/24/2022	22.6	20.7	22.5	21.3	20.7	22.6	1.9	0
EW-27[d]	23.5	7/18/2022	19.7	23.0	22.2	23.6	19.7	23.6	3.9	0.1
EW-30	9.2	9/8/2022	6.2	4.8	5.2	6.4	4.8	6.4	1.6	-2.8
EW-33A	77.6	8/24/2022	19.0	26.4	24.3	23.1	19.0	26.4	7.4	-51.2

Shading indicates uranium concentration after well field re-start was greater than June 6, 2022, uranium concentration.

[a] Shutdown began on June 6, 2022, at 7:00 a.m. and ended on July 12, 2022, for a duration of 36 days.

[b] NA= not applicable; leading edge well continued operating during the shutdown.

[c] NA=not applicable; well not restarted.

[d] Well operated during shutdown as necessary for treatment.

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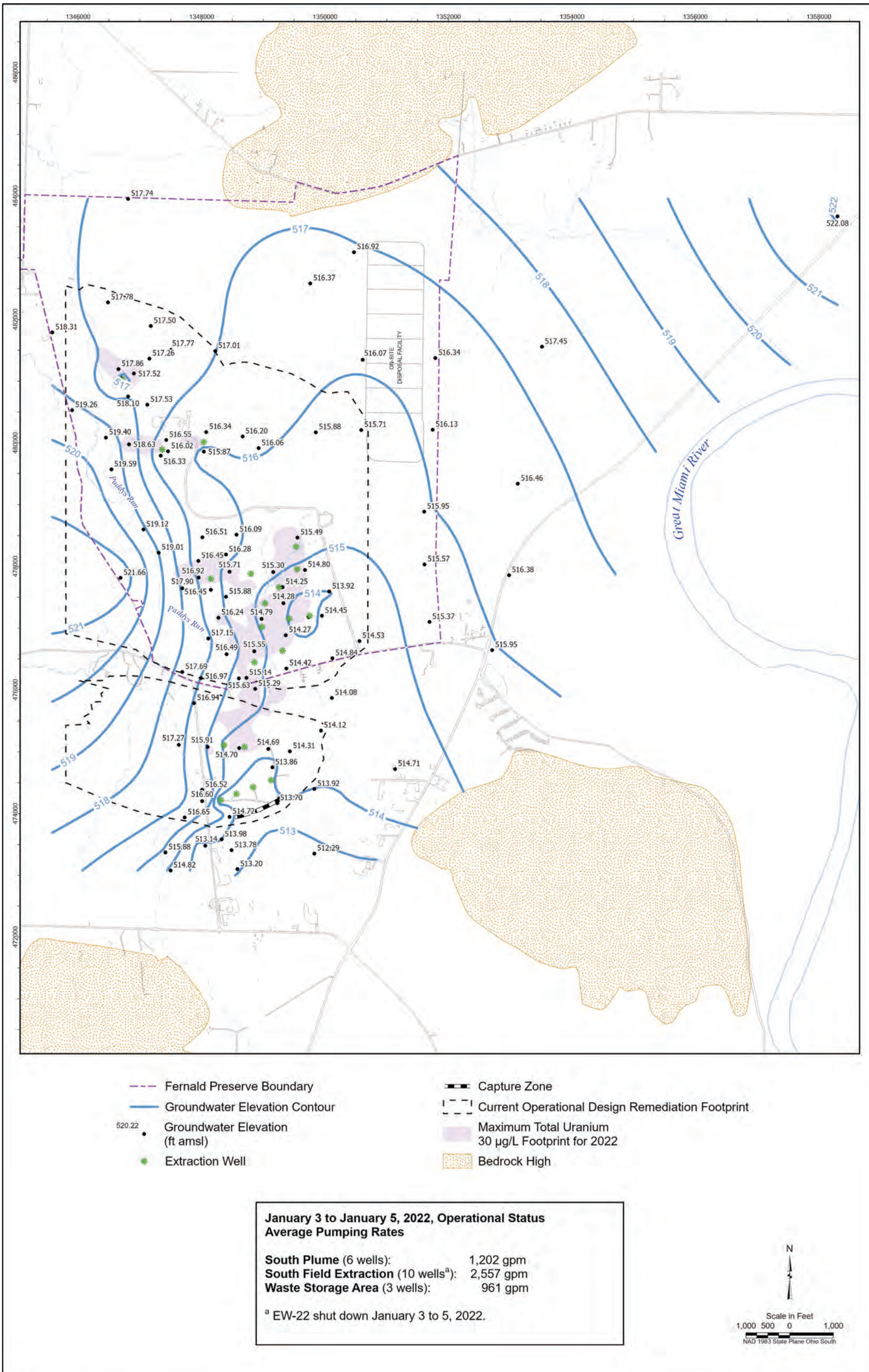

Figure A.3-1. Routine Groundwater Elevation Map, First Quarter 2022 (January 3 Through January 5, 2022)

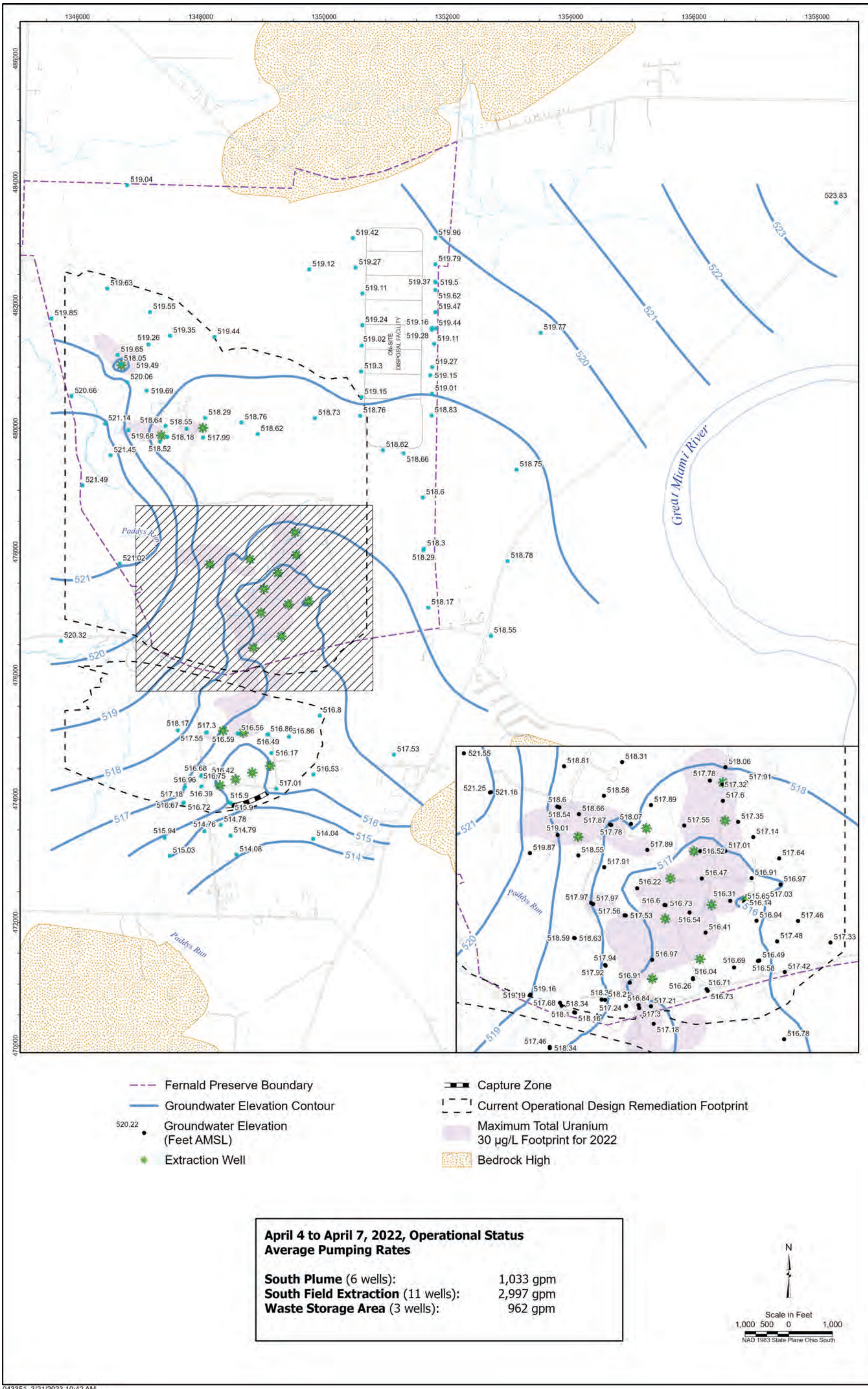

Figure A.3-2. Routine Groundwater Elevation Map, Second Quarter 2022 (April 4 Through April 7, 2022)

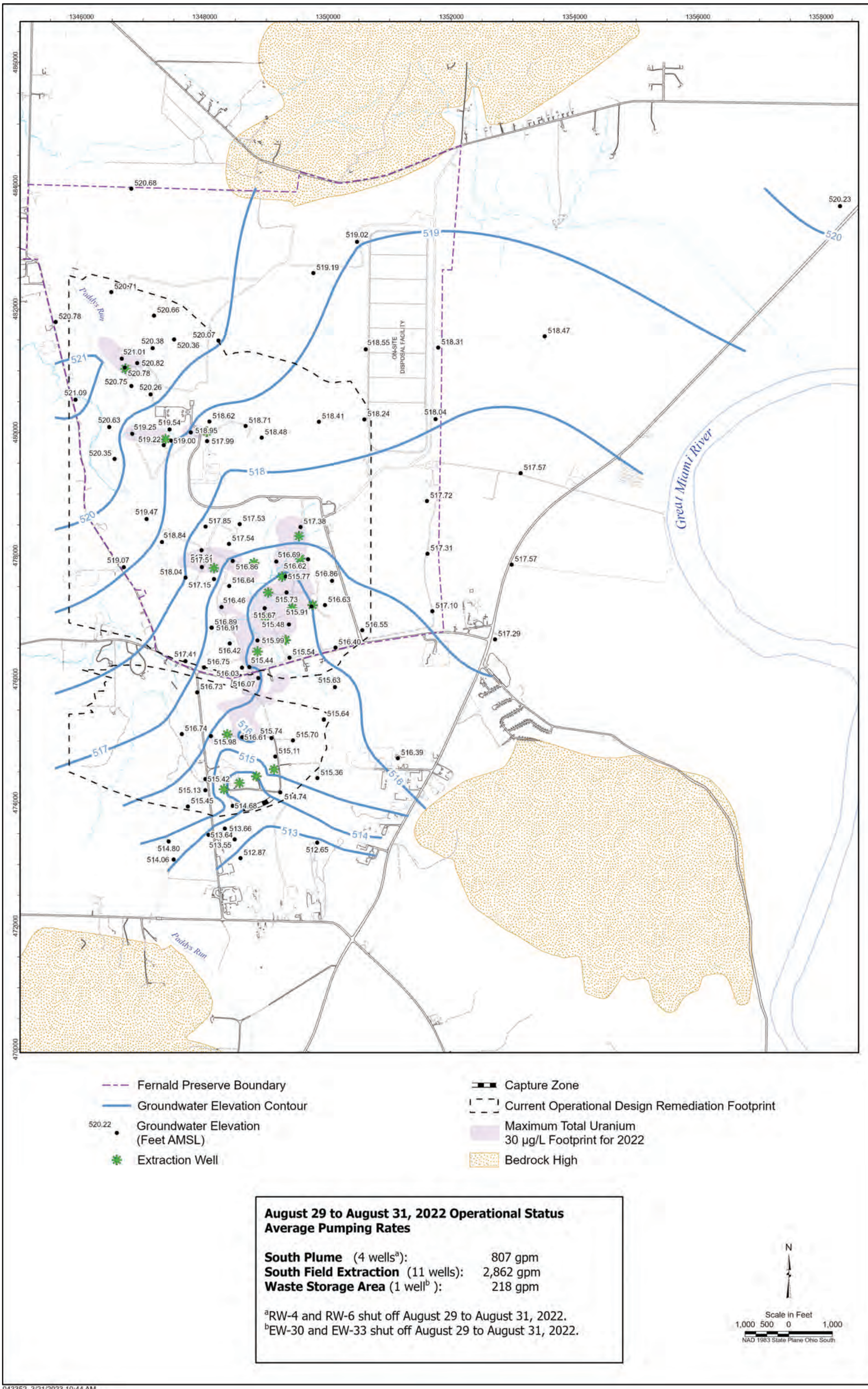

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Figure A.3-3. Routine Groundwater Elevation Map, Third Quarter 2022 (August 29 Through August 31, 2022)

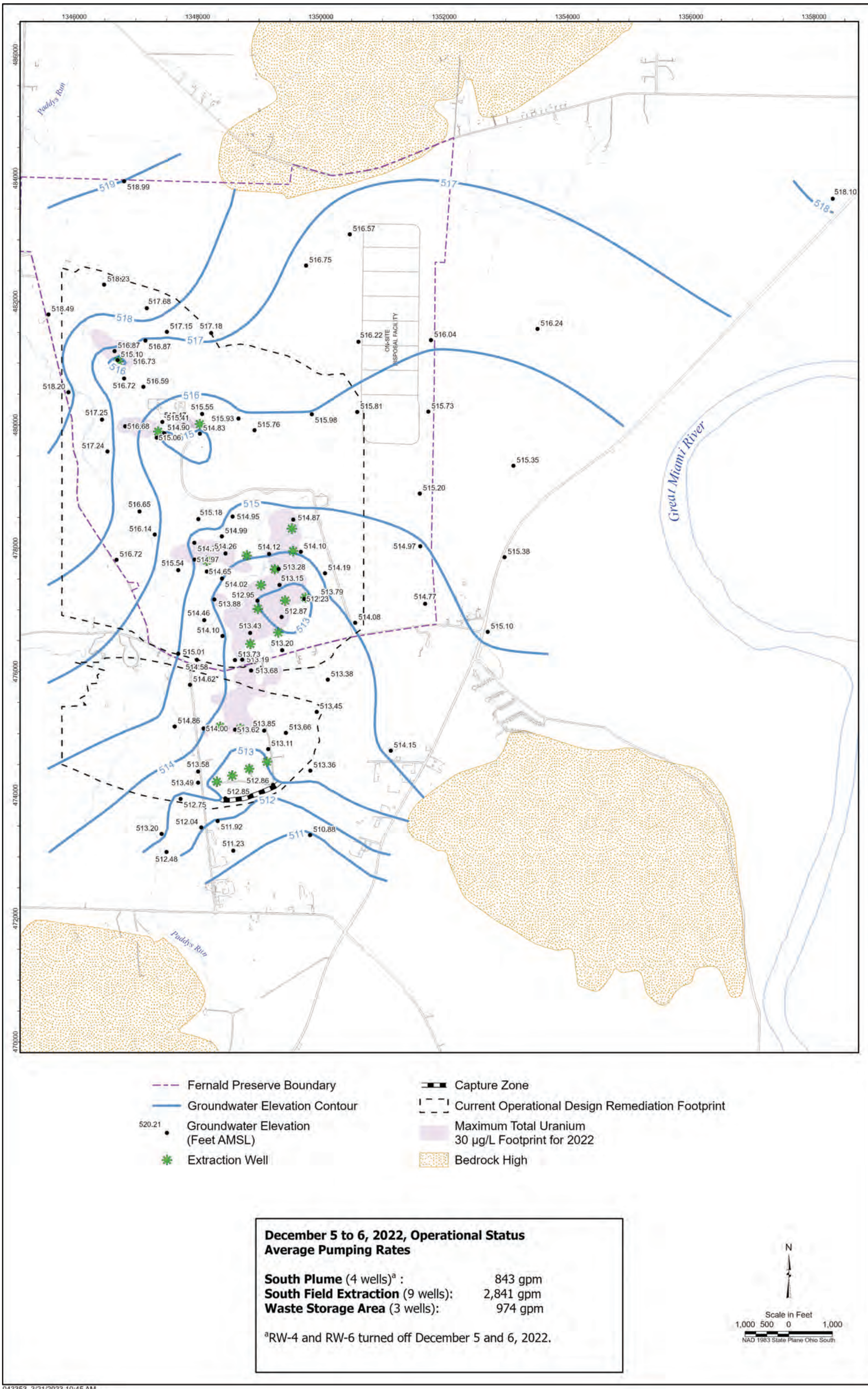

Figure A.3-4. Routine Groundwater Elevation Map, Fourth Quarter 2022 (December 5 to December 6, 2022)

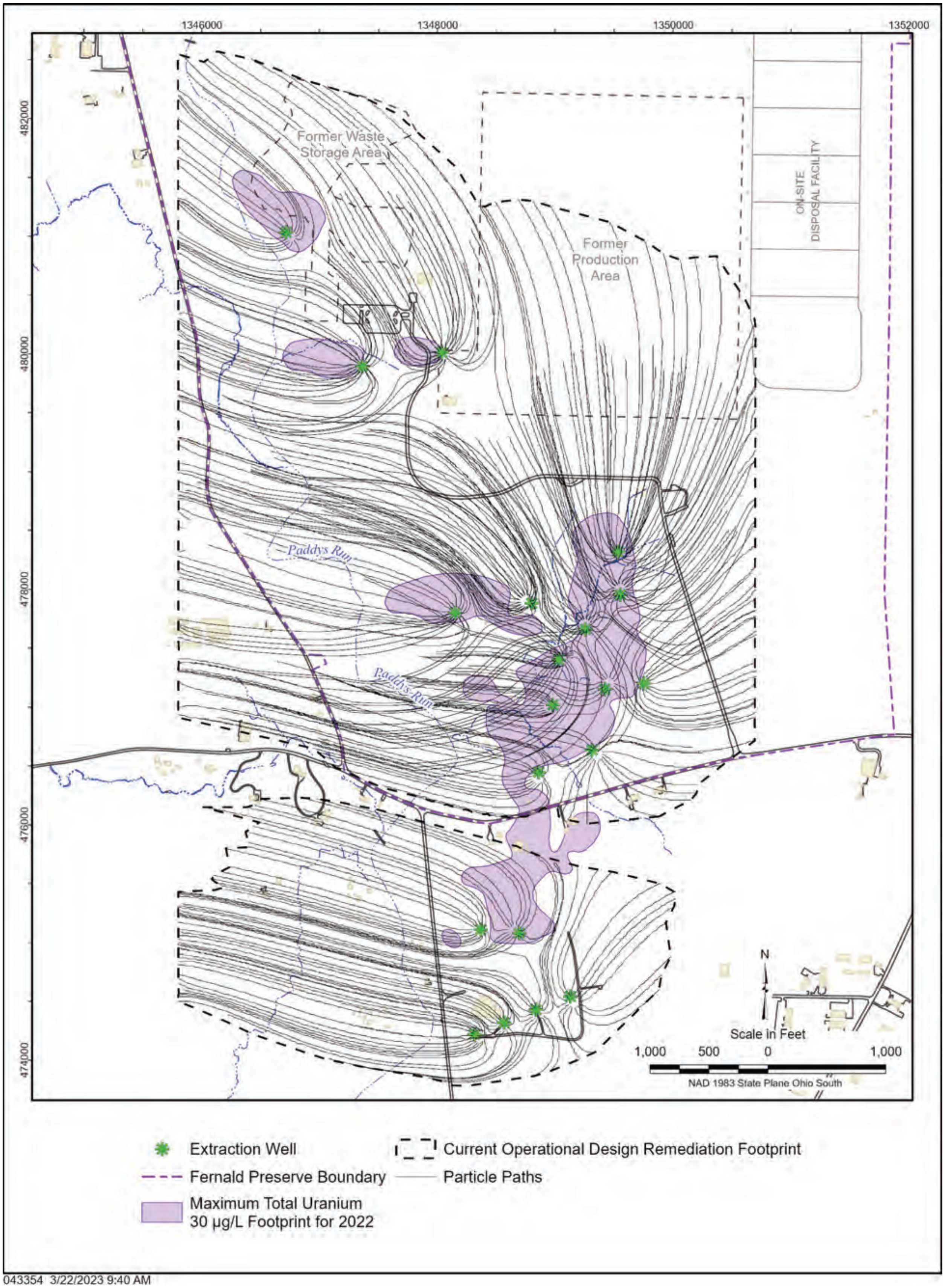

Figure A.3-5. Current Operational Design Remediation Footprint

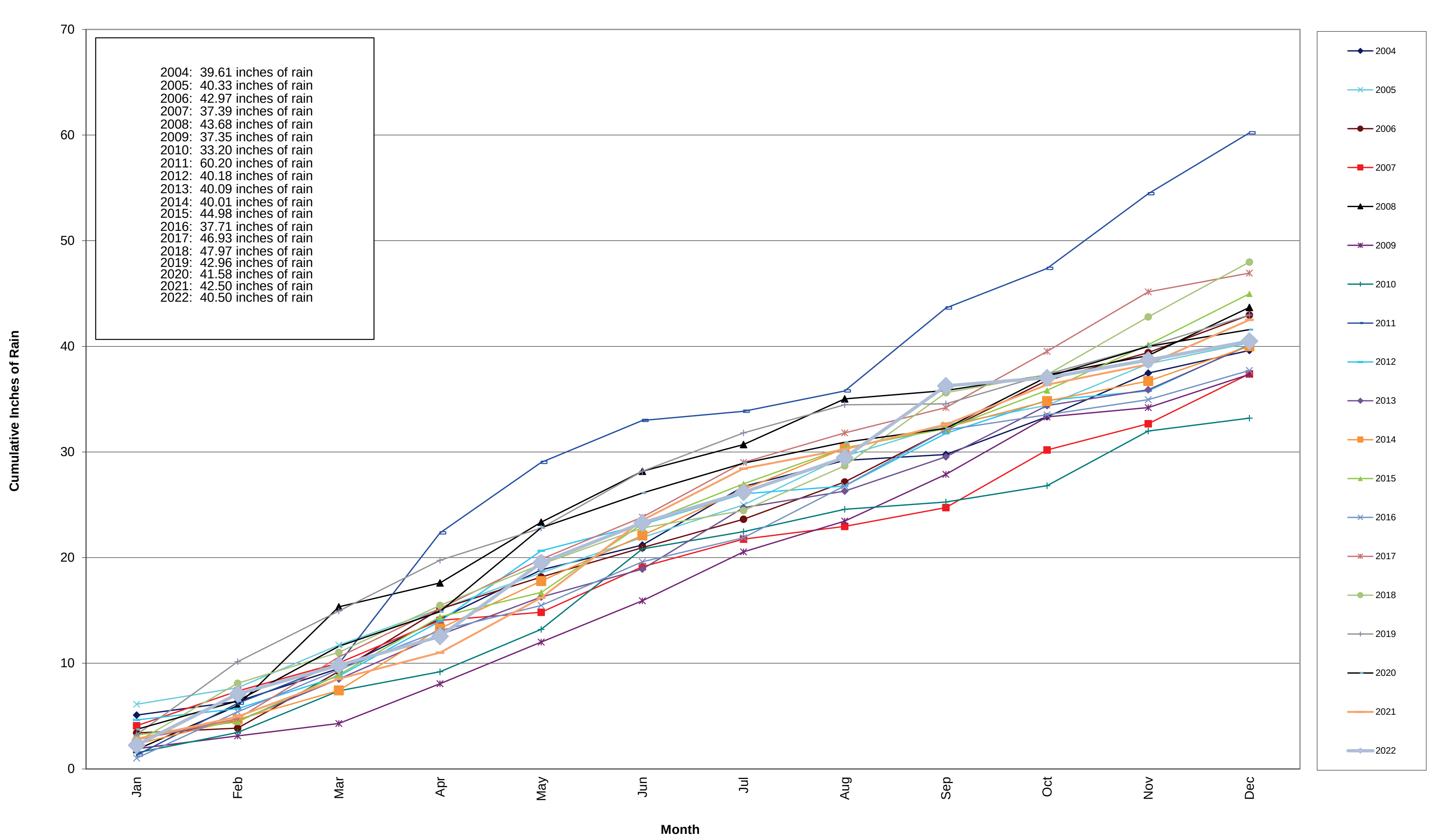

Figure A.3-6. Cumulative Annual Precipitation: 2004 Through 2022 as Recorded at the Butler County Regional Airport

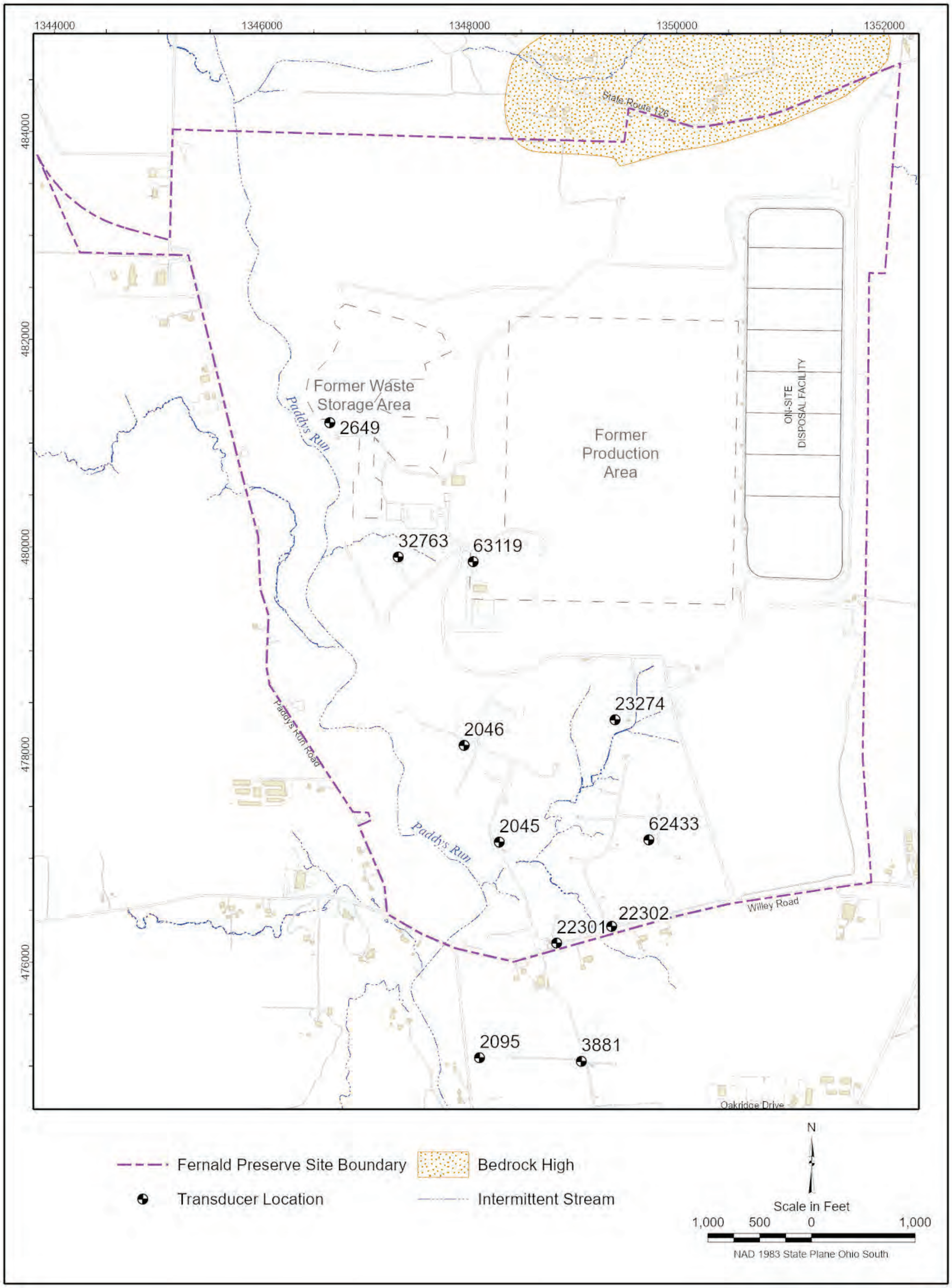

Figure A.3-7. Transducer Locations for the 2022 Operational Shutdown

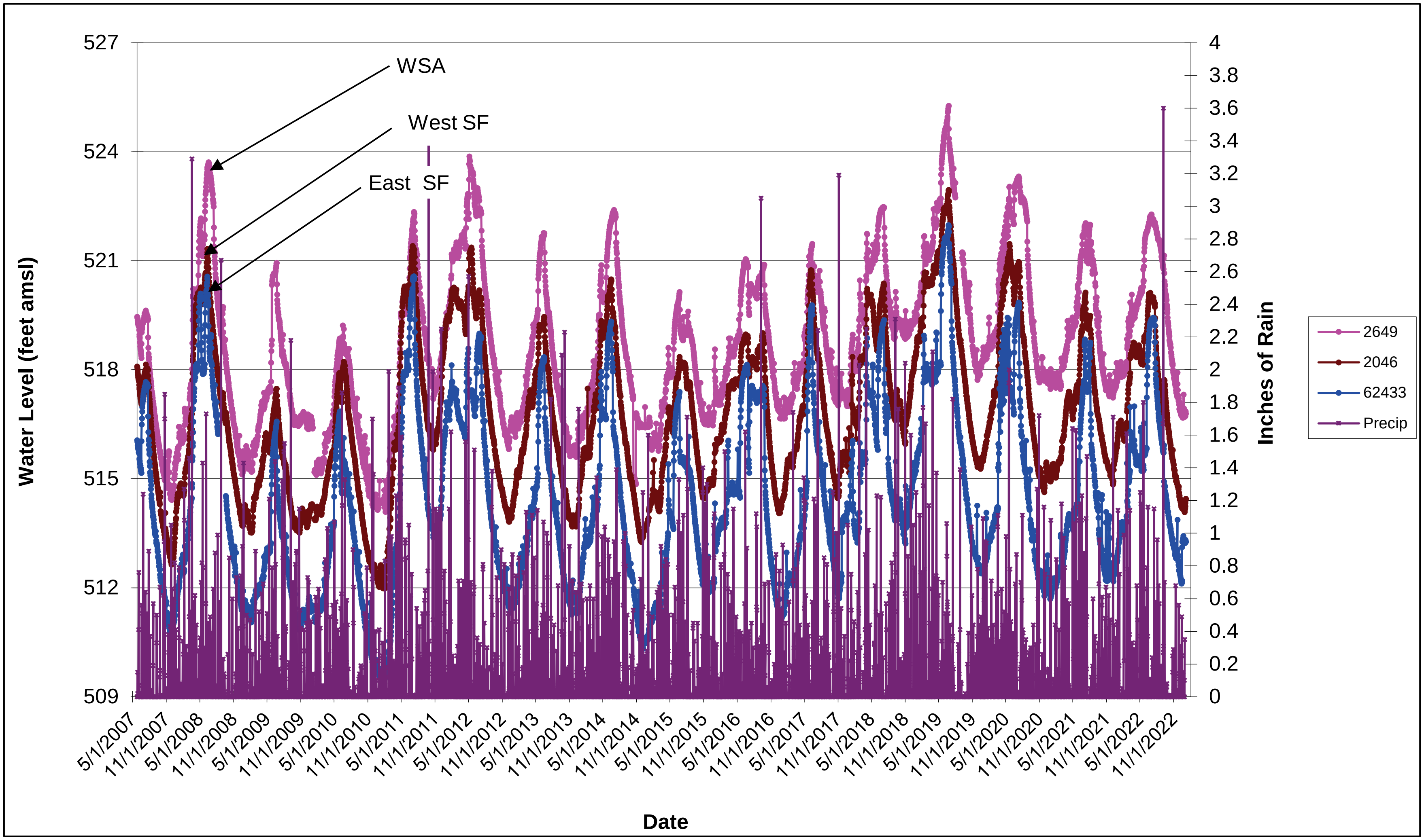

Figure A.3-8. Water Levels Versus Precipitation May 25, 2007, Through December 31, 2022

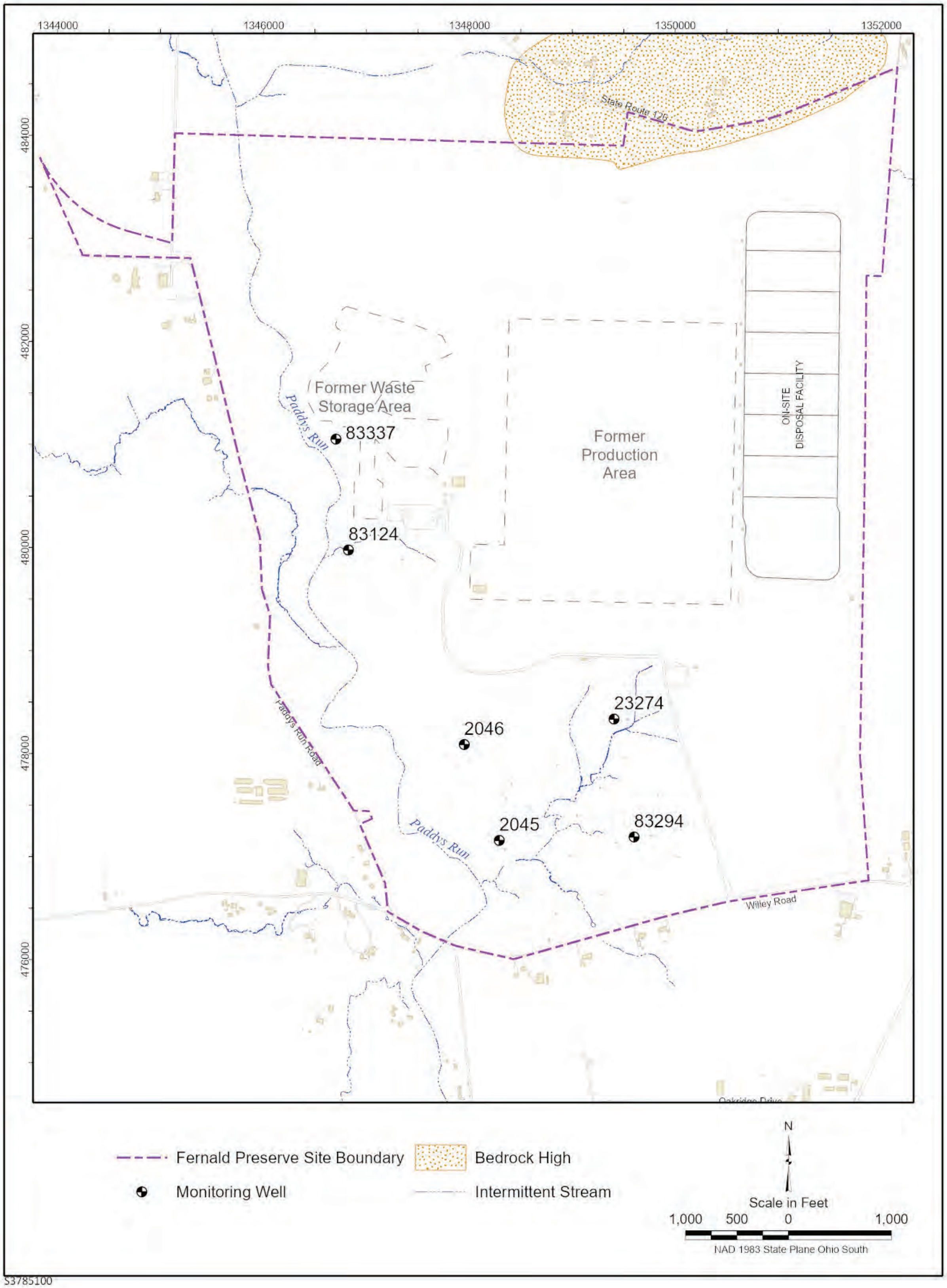

Figure A.3-9. Monitoring Well Locations for the 2022 Operational Shutdowns

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Attachment A.4

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Contents

Tables

Figures

Abbreviations

FRL	final remediation level
GMA	Great Miami Aquifer
IEMP	Integrated Environmental Monitoring Plan
LMICP	*Comprehensive Legacy Management and Institutional Controls Plan*
OSDF	On-Site Disposal Facility
WSA	Waste Storage Area

Measurement Abbreviations

mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

A.4.0 Non-Uranium Final Remediation Level Results

This attachment provides an analysis of the non-uranium final remediation level (FRL) exceedances both inside and outside the current Operational Design Remediation Footprint at the Fernald Preserve, Ohio, Site. This attachment evaluates non-uranium FRL results for 2022 collected under the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP) (DOE 2019). The purpose of the evaluation is to:

- Identify 2022 non-uranium FRL exceedances (Section A.4.1).
- Determine the persistence of non-uranium FRL exceedances outside the current Operational Design Remediation Footprint (Section A.4.2).
- Describe the evaluation of 2022 non-uranium FRL exceedances outside the current Operational Design Remediation Footprint (Section A.4.2).
- Present conclusions (Section A.4.3).

Consistent with past Site Environmental Reports, non-uranium groundwater monitoring results from wells monitored in the Great Miami Aquifer (GMA) for performance of the On-Site Disposal Facility (OSDF) are included in the data evaluation presented in this section of the Site Environmental Report. Beginning in 2017, the number of non-uranium constituents being sampled in the OSDF monitoring program was reduced. Data presented and discussed in the *Fernald Preserve 2015 Site Environmental Report* (DOE 2016) supported making the changes to the OSDF monitoring program. The proposed changes were approved by the U.S. Environmental Protection Agency, the Ohio Environmental Protection Agency, and stakeholders during the routine review and approval process of the 2017 LMICP (DOE 2017a).

As a result of the OSDF monitoring changes, the following nine non-uranium constituents are no longer being routinely sampled for in the GMA as part of the OSDF monitoring program: total organic carbon, iron, sodium, cobalt, total alkalinity, barium, chloride, copper, and chromium. The non-uranium constituents currently being sampled in the GMA as part of the IEMP are provided in Table 6 in Attachment D of the LMICP (DOE 2019). A list of the constituents routinely sampled in the GMA as part of the OSDF monitoring program can be found in Section 3.2.1.3 in Attachment C of the LMICP. Tables and data analyses presented below reflect the current combined sampling effort.

A.4.1 Non-Uranium FRL Exceedances for 2022

Table A.4-1 shows the summary statistics and trend analysis for the 2022 non-uranium FRL exceedances from monitoring wells both inside and outside the current Operational Design Remediation Footprint. Five non-uranium FRL constituents had one or more FRL exceedances during 2022. Figure A.4-1 identifies the locations of these exceedances.

Figure A.4-1 shows that the non-uranium FRL exceedances in 2022 were in the former Waste Storage Area (WSA), with one exceedance along the eastern property boundary. The exceedances in the WSA are within the current Operational Design Remediation Footprint. The exceedance along the eastern property boundary was located outside the current Operational

Design Remediation Footprint. Specific discussion regarding exceedances and persistence outside the footprint is provided in Section A.4.2.

Table A.4-2 identifies the locations and constituents that have had non-uranium FRL exceedances since 1997 for constituents monitored in 2022. The first column in Table A.4-2 lists the groundwater FRL constituents monitored in 2022. As discussed above, Table A.4-2 reflects the current monitoring effort. The 2016 Site Environmental Report (DOE 2017b) provides a discussion concerning the changes implemented in 2017. The second column in Table A.4-2 identifies the wells monitored that have had an exceedance since 1997 for each constituent. The third column identifies the associated aquifer zone monitored. The fourth column identifies the associated monitoring program for each well or constituent. The remaining columns show monitoring years that reflect a semiannual sampling frequency; a "1" denotes an exceedance for one of the two samples, and a "2" denotes an exceedance for both samples. Beginning in 2017, the sampling frequency of several of the wells that had been sampled quarterly through 2013 was reduced from a semiannual to annual frequency. Data presented and discussed in the 2015 Site Environmental Report (DOE 2016) supported making the sampling frequency change.
Table A.4-2 also indicates whether exceedances occurred inside or outside the remediation footprint (shading indicates the well is located outside the footprint).

As specified in Table 4 in the IEMP (DOE 2019), there were 13 non-uranium constituents monitored in 2022; as stated above, five constituents had exceedances during 2022. The following table summarizes the 2022 non-uranium monitoring information.

Constituent (units)	Groundwater Final Remediation Level	2022 Monitoring Summary	2022 Maximum Exceedance
Antimony (mg/L)	0.0060	No exceedances	Not applicable
Arsenic (mg/L)	0.050	No exceedances	Not applicable
Boron (mg/L)	0.33	No exceedances	Not applicable
Carbon disulfide (mg/L)	5.5	No exceedances	Not applicable
Fluoride (mg/L)	4	No exceedances	Not applicable
Lead (mg/L)	0.015	No exceedances	Not applicable
Manganese (mg/L)	0.90	No exceedances	Not applicable
Molybdenum (mg/L)	0.10	Exceedances in former WSA wells	0.601
Nickel (mg/L)	0.10	No exceedances	Not applicable
Nitrate + nitrite, as nitrogen (mg/L)	11	Exceedances in former WSA wells	46.8
Technetium-99 (pCi/L)	94	Exceedances in former WSA wells	347
Trichloroethene (µg/L)	5	Exceedances in former WSA wells	8.53
Zinc (mg/L)	0.021	Exceedance in the Property Plume Boundary Wells	0.0370

A.4.1.1 Non-Uranium Direct-Push Sampling Results for 2022

In 2022, no direct-push sampling was conducted in the former WSA.

A.4.2 Evaluation of 2022 Non-Uranium FRL Exceedances Outside the Current Operational Design Remediation Footprint

This section presents an evaluation of the persistence of non-uranium FRL exceedances outside the current Operational Design Remediation Footprint.

A.4.2.1 Background

The *Restoration Area Verification Sampling Program Summary Report* (DOE 1998) states that any FRL exceedance detected at the property boundary during routine monitoring outside the 10-year uranium-based restoration footprint (DOE 1997a) would also be evaluated for persistence. The evaluation would be performed using the same conservative data evaluation method approved in the *Restoration Area Verification Sampling Program Project-Specific Plan* (DOE 1997b) to determine whether a change in the aquifer restoration remedy is required. This evaluation was expanded, beginning with the *2000 Integrated Site Environmental Report* (DOE 2001), to include all non-uranium FRL exceedances detected outside the 10-year uranium-based restoration footprint, not just those detected at the property boundary. In the 2003 Site Environmental Report (DOE 2004), the 10-year uranium-based restoration footprint was replaced with a 10-year time-of-travel remediation footprint based on 2003 target pumping rates and using the Variable Saturated Analysis Model in Three Dimensions Zoom Groundwater Model. The footprint was updated in 2005 to reflect capture during the period modeled for the WSA (Phase II) remediation design. The footprint was updated in 2014 to reflect capture during the time period modeled for the 2014 Operational Design Adjustment (DOE 2014) (Figure A.4-1).

Analytical data from samples collected immediately following an FRL exceedance are evaluated to determine whether the exceedance is persistent. In accordance with the approved *Restoration Area Verification Sampling Program Project-Specific Plan* (DOE 1997b), if two or more consecutive sampling events following an FRL exceedance indicate that the concentration has decreased below the groundwater FRL, then the exceedance is not considered persistent. If an FRL exceedance outside the current Operational Design Remediation Footprint is determined to not be persistent, then no additional action is required beyond the routine groundwater monitoring specified in the current IEMP. If an FRL exceedance is determined to be persistent, then the cause of the persistent exceedance will be identified and its effect on the aquifer remedy design assessed. Ultimately, the cause needs to be addressed either through a modification of the aquifer remedy or by other means. It is recognized that some non-uranium constituents can be oxidation-reduction sensitive, and their stability is controlled in large measure by the oxidation-reduction state of the groundwater, which can vary, perhaps causing transient FRL exceedances to come and go.

A.4.2.2 Evaluation and Discussion

Figure A.4-1 and the shaded portion of Table A.4-1 identify the 2022 non-uranium FRL exceedances outside the current Operational Design Remediation Footprint. In 2022, there was one FRL exceedance outside the current Operational Design Remediation Footprint: zinc in monitoring well 22205.

Table A.4-3 addresses possible persistent FRL exceedances that occurred outside the current Operational Design Remediation Footprint in 2022. If the results of two or more sampling events immediately following an FRL exceedance indicate that the concentration decreased below the FRL, then the exceedance is identified as not persistent in Table A.4-3.

The following is a summary of results presented in Table A.4-3:

- The zinc FRL exceedance at monitoring well 3128, identified as being potentially persistent in 2021, was shown to be not persistent in 2022.
- The zinc FRL exceedance at monitoring well 22205, identified as being potentially persistent in 2021, requires that additional data be collected to determine if it is persistent.

Figures A.4-2 and A.4-3 present individual graphs of time versus concentration for the wells listed in Table A.4-3. Semiannual sampling results from OSDF monitoring activities are included in the evaluation of property boundary wells.

The year 2022 marks 26 years that an evaluation for persistence of non-uranium FRL exceedances in wells outside the current Operational Design Remediation Footprint has been conducted, as part of the IEMP. In the past, many exceedances identified as persistent became not persistent in later years. As of 2022, no persistent exceedances are identified outside the remediation footprint.

A.4.3 Conclusions

From the information provided in this attachment, the following conclusions can be made:

- Non-uranium FRL exceedances occurring in the former WSA were taken into consideration for the current Operational Design and are within capture of the groundwater remediation system.
- In 2022, a zinc FRL exceedance in monitoring well 22205 requires that additional routine data be collected to determine whether it is persistent.
- In 2022, a zinc FRL exceedance in monitoring well 3128 (detected in 2021) was determined to be non-persistent.

A.4.4 References

DOE (U.S. Department of Energy), 1996. *Record of Decision for Remedial Actions at Operable Unit 5*, 7478 U 007 501.4, Fluor Fernald, Cincinnati, Ohio, January.

DOE (U.S. Department of Energy), 1997a. *Baseline Remedial Strategy Report, Remedial Design for Aquifer Restoration*, 2505-RP-0003, Revision 0, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio, June.

DOE (U.S. Department of Energy), 1997b. *Restoration Area Verification Sampling Program Project-Specific Plan*, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio.

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DOE (U.S. Department of Energy), 2017a. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 10, Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2017b. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2019. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 12, Office of Legacy Management, January.

Table A.4-1. Summary Statistics and Trend Analysis for Non-Uranium Constituents with 2022 Results Above FRLs

Constituent (FRL)[a]	Monitoring Well	No. of Samples[b,c,d]	No. of Samples Above FRL[b,c,d]	No. of Samples Above FRL for 2022[b,c,d]	Maximum Exceedance for 2022[b,c,d,e,f]	Minimum[b,c,d,e,f]	Maximum[b,c,d,e,f]	Average[b,c,d,e,f]	Standard Deviation[b,c,d,e,f]	Trend[b,c,d,e,f,g]
					(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Molybdenum (0.10 mg/L)	2649	45	45	2	0.601	0.175	1.26	0.473	0.236	No Trend
Nitrate + nitrite as nitrogen (11 mg/L)[h]										
	83338_C1	27	22	2	46.8	0.404	73.8	39.8	20.6	No Trend
	83340_C1	29	20	1	16.6	0.470	761	43.9	139	Down
	83340_C2	32	31	2	17.4	2.93	86.7	39.5	24.1	Down
	83340_C3	32	27	1	17.9	1.13	133	38.7	32.4	Down
	83341_C1	15	11	1	37.2	0.265	56.3	22.0	19.0	Up
	83341_C2	32	9	1	11.6	0.090	258	19.1	45.7	No Trend
					(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	
Technetium-99 (94 pCi/L)	2649	53	49	1	347	55.2	1660	479	429	Down
	83338_C1	27	22	2	328	10.1	515	237	132	Up
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	
Trichloroethene (5 µg/L)	2649	45	28	1	8.53	0.12	120	25.3	30.2	Down
					(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Zinc (0.021 mg/L)	22205	59	2	1	0.0370	0.001	0.0370	0.00616	0.00699	Up

Note: Shading indicates well is outside the current Operational Design Remediation Footprint.
[a] From *Record of Decision for Remedial Actions at Operable Unit 5* (DOE 1996), Table 9-4.
[b] Based on samples from August 1997 through 2022.
[c] If more than one sample is collected per well per day (e.g., duplicate), then only one sample is counted for the total number of samples, and the sample with the maximum representative concentration is used for determining the summary statistics (minimum, maximum, average, and standard deviation) and Mann-Kendall test for trend.
[d] Rejected data qualified with an R were not included in the count, the summary statistics, or Mann-Kendall test for trend.
[e] If the number of samples is greater than or equal to four, then the Mann-Kendall test for trend and all of the summary statistics are reported. If the total number of samples is equal to three, then the minimum, maximum, and average are reported. If the total number of samples is equal to two, then the minimum and maximum are reported. If the total number of samples is equal to one, then the data point is reported as the minimum.
[f] For results where the concentrations are below the detection limit, the results used in the summary statistics and Mann-Kendall test for trend are each set at half the detection limit.
[g] Mann-Kendall test for trend is performed with a 95% confidence interval, using data from third quarter 1998 through 2022.
[h] FRL based upon nitrate from *Record of Decision for Remedial Actions at Operable Unit 5* (DOE 1996), Table 9–4.

Table A.4-2. Groundwater FRL Exceedances from 1997 Through 2022

Constituent	Well[a]	Aquifer Zone	Project[b]	1997	1998		1999		2000		2001		2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012		2013		2014		2015		2016[d]		2017[e]		2018[e]		2019[e]		2020[e]		2021[e]		2021[e]	
				2[c]	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Antimony																																																						
	22198	0	P/PB																									1	1																									
	22199	0	P/PB																									1																											
	22204	0	P/PB																									1																											
	22205	0	P/PB																									1																											
	22208	0	P/PB													1												1																											
	2398	2	P/PB																				1																														
	2431	0	P/PB													1												1																											
	2432	0	P/PB																				1					1																											
	2636	4	PRRS														1		1				1						1			1										1													
	2733	0	P/PB																				1																														
	3070	2	P/PB																				1					1																											
	31217	0	P/PB																									1																											
	3398	2	P/PB																				1																														
	3424	0	P/PB																				1					1																											
	3426	0	P/PB																				1																														
	3431	0	P/PB																									1																											
	3432	0	P/PB																				1					1																											
	4398	2	P/PB																				1					1																											
Arsenic																																																						
	2636	4	PRRS	1	1		2						1				1													1																									
	2898	4	PRRS						1																																														
	2900	4	PRRS						1																																														
Boron																																																						
	2045	2	SF				1	1	1																																														
	2049	2	SF	2		2	2	2	2	1				1																																							
Carbon disulfide																																																						
	2649	1	WSA			1																																															
	3821	1	WSA					1										1																																				
Fluoride																																																						
	2431	0	P/PB			1																																															
Lead																																																						
	22198	0	P/PB																										1																										
	2431	0	P/PB						1																																														
	3733	0	P/PB	1						1																																													
Manganese																																																						
	2010	1	WSA						1		1				1	1	1	1		1	1	1	1	1	1	1		1			1	1	1	1	2	1	1						1						1		1			
	22198	0	P/PB											1																																							
	22203	0	P/PB																																							1											
	22204	0	P/PB												1			1	1	1	1	1	1	1	1	1	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2	1											
	22205	0	P/PB																	1										1																								
	22214	0	P/PB																													1																					
	2431	0	P/PB		2																																																
	2432	0	P/PB							1		2	1		1																																						
	2648	1	WSA	1		1		1	1		1		1					1	1		1																																	
	2733	0	P/PB																																1																		
	3093	4	P/PB																								1																										
	3821	1	WSA					1	1		1		1		1	1	1			1	1		1	1	1	1	1	1	1	1	1	1	1	1																					
	83337_C1	1	WSA																						1	1																											
	83337_C2	1	WSA																							1																											
	83337_C3	1	WSA																							1		1																									
	83338_C2	1	WSA																				1		1		1						1																				
	83339_C1	1	WSA																				1		1	1																											
	83339_C2	1	WSA																								1																										
	83339_C3	1	WSA																						1						1																					
	83341_C1	1	WSA																				1		1	1							1															1	1					
	83341_C2	1	WSA																				1	1						1				1							1						1					
	83346_C1	1	WSA																				1		1	1	1																											
	83346_C2	1	WSA																				1	1		1	1																											
Molybdenum																																																						
	2649	1	WSA	1		1		1	1		1		1		1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nickel																																																						
	22198	0	P/PB					1																																													
	2398	2	P/PB	1	2	2		2																																													
	4398	2	P/PB				1																																														
	83346_C1	1	WSA																							1																											
	83346_C2	1	WSA																							1	1																										
Nitrate/Nitrite																																																						
	2648	1	WSA		1			1	1		1					1	1	1			1																																	
	2649	1	WSA	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1		1	1		1		1	1					1		1		1																				
	2821	1	WSA					1						1				1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1		1	1	1	1	1	1		1	1	1			
	3821	1	WSA							1										1				1			1	1	1	1	1	1																							
	83338_C1	1	WSA																										1		1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
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	83338_C3	1	WSA																					1			1	1	1	1	1	1				1																			
	83340_C1	1	WSA																				1		1	1	1		1		1	1	1	1	1		1	1						1	1	1	1		1	1	1		1	
	83340_C2	1	WSA																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
	83340_C3	1	WSA																				1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1		1	
	83341_C1	1	WSA																				1										1	1	1								1		1		1	1	1		1		1	
	83341_C2	1	WSA																							1								1				1				1				1	1	1	1					1
	83341_C3	1	WSA																				1			1																1					1	1					
Selenium																																																						
	22198	0	P/PB																																																	1	
	22199	0	P/PB																																																	1	
	22203	0	P/PB																																																	1	
	22206	0	P/PB																																																	1	
	22209	3	P/PB																																																	1	
	22212	3	P/PB																																																	1	
Technetium-99																																																						
	2648	1	WSA					1			2				1																																						
	2649	1	WSA	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1	
	2821	1	WSA					1						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	2	1												1		1			
	83338_C1	1	WSA																										1		1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
	83338_C2	1	WSA																					1				1	1	1	1	1	1	1	1	1	1		1															
	83338_C3	1	WSA																					1			1	1	1	1	1			1	1	1																	
	83340_C1	1	WSA																				1		1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1				
	83340_C2	1	WSA																				1	1	1	1	1	1																									
	83340_C3	1	WSA																				1	1	1	1	1	1				1		1																					
Trichloroethene																																																						
	2649	1	WSA			1		1	1		1		1		1	1	1	1	1	1	1		1			1	1				1	1	1	1	1	1								1	1	1	1	1	1				1	
	2821	1	WSA																				1	1		1	1	1	1	1	1	1	1	1	2																				
Zinc																																																						
	22198	0	P/PB																										1																										
	22199	0	P/PB												1																																						
	22204	0	P/PB												1									1				1																										
	22205	0	P/PB																																												1						1	
	22210	0	P/PB																1		1					1																										
	2398	2	P/PB		1																																																
	2431	0	P/PB			2			1																																												
	2432	0	P/PB				1		1	1																																											
	2625	4	PRRS																						1	1					1	1	1		1	1	1			1	1	1													
	2636	4	PRRS																						1	1																											
	2733	0	P/PB				1																												1																		
	2900	4	PRRS							1						1							1																													
	3128	4	PRRS																1																																1	
	3426	0	P/PB				1	1																															1												
	3429	0	P/PB				2																																				1								
	3431	0	P/PB										1																																								
	3733	0	P/PB												1																																						
	3899	4	PRRS								1																																										

Note: Shading indicates well is outside the current Operational Design remediation footprint.

[a] A "1" denotes an exceedance for the time period; a "2" denotes two exceedances during the time period due to quarterly sampling frequency or multiple sampling projects.

[b] WSA = Waste Storage Area

SF = South Field

P/PB = Property/Plume Boundary for FRL Exceedances

PRRS = Property/Plume Boundary for Paddys Run Road Site

[c] Sampling for the IEMP was initiated in August 1997.

[d] Prior to 2017, P/PB included OSDF monitoring results for some constituents.

[e] Beginning in 2017, monitoring frequency for P/PB and PRRS projects changed from semi-annual to annual.

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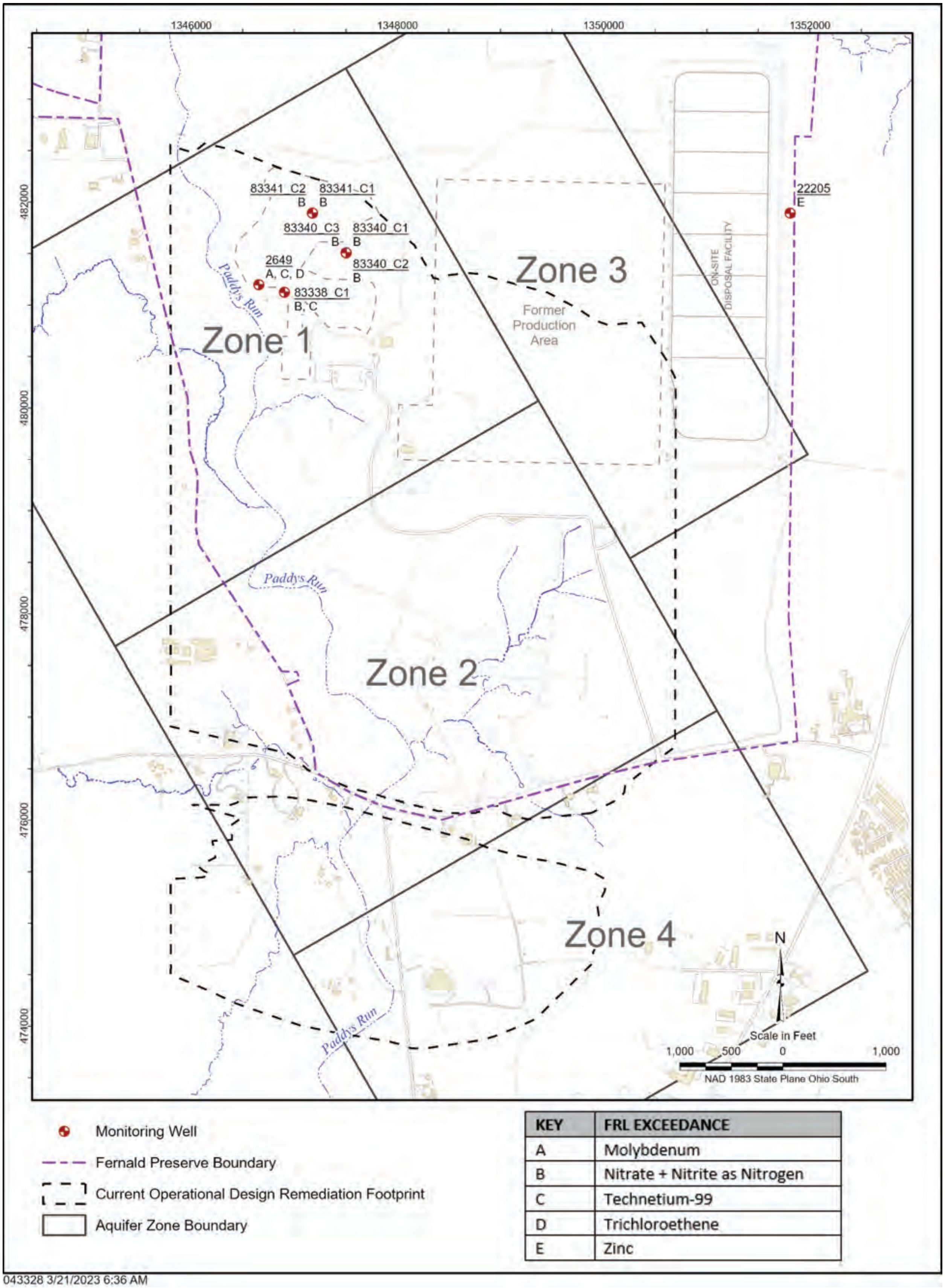
Table A.4-3. Summary of Persistence Evaluation of Non-Uranium FRL Exceedances Outside the Current Operational Design Remediation Footprint

Constituent	Monitoring Well	Monitoring Program	Pertinent 2021 Results	2022 FRL Exceedance	Evaluation Results for 2022	Figure Number
Zinc	22205	Property/Plume Boundary	Additional routine data required	Yes	Additional routine data required	A.4-2
Zinc	3128	Property/Plume Boundary	Not applicable	No	Not persistent	A.4-3



KEY	FRL EXCEEDANCE
A	Molybdenum
B	Nitrate + Nitrite as Nitrogen
C	Technetium-99
D	Trichloroethene
E	Zinc

Figure A.4-1. Non-Uranium Constituent Locations with 2022 Results Above FRLs

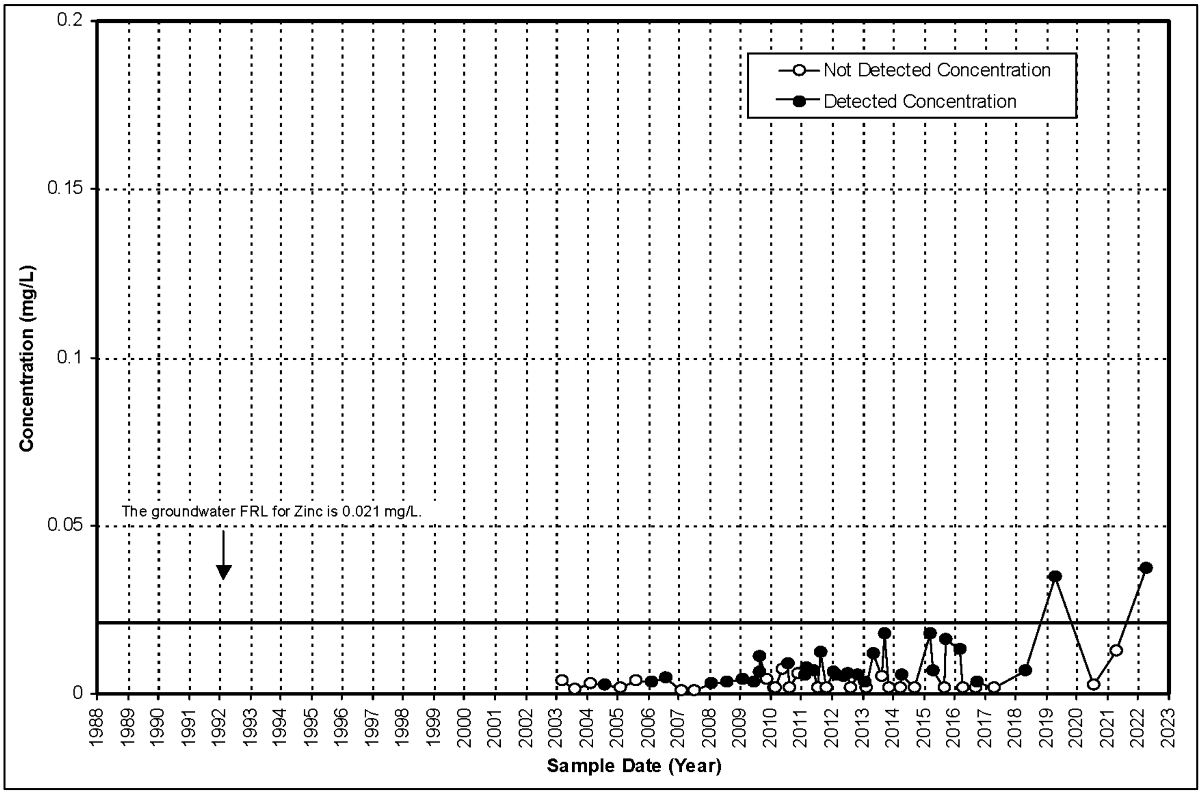


Figure A.4-2. Zinc Concentration Versus Time Plot for Monitoring Well 22205

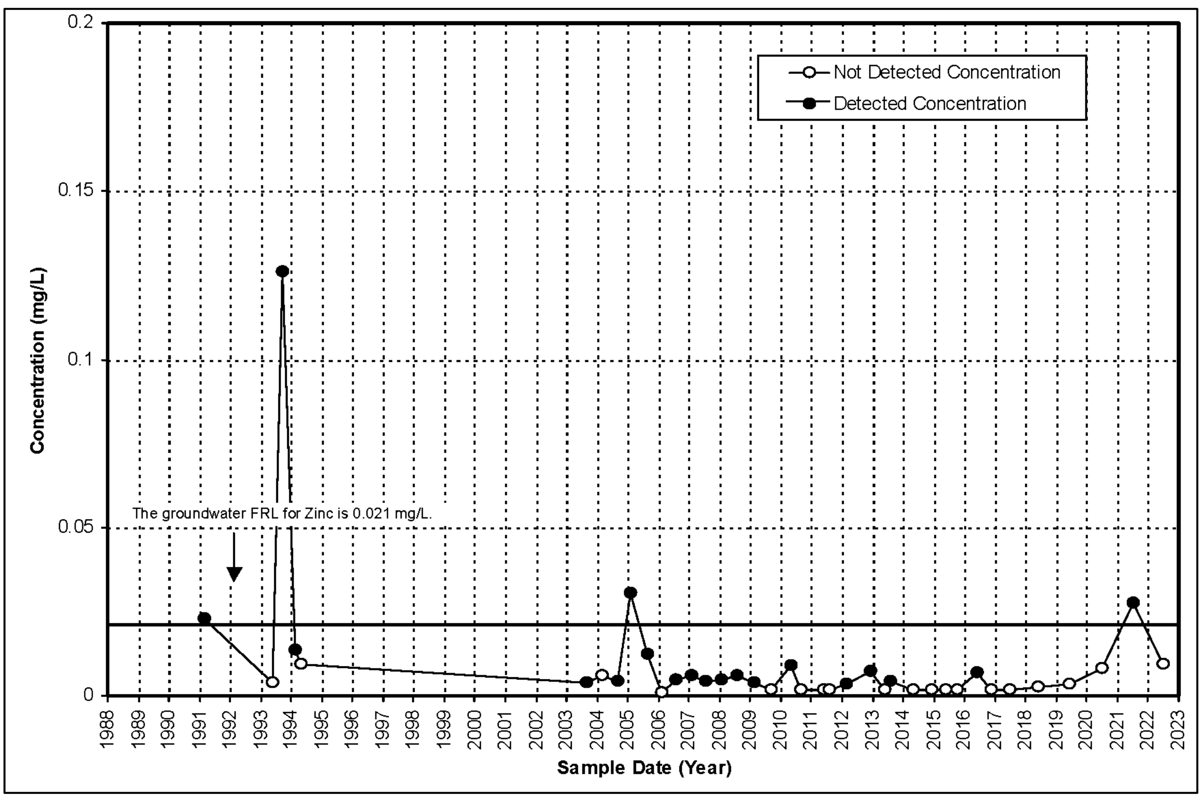


Figure A.4-3. Zinc Concentration Versus Time Plot for Monitoring Well 3128

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Attachment A.5

Contents

Tables

Figures

Abbreviations

CAWWT	Converted Advanced Wastewater Treatment
CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GWLMP	Groundwater/Leak Detection and Leachate Monitoring Plan
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
LMICP	*Comprehensive Legacy Management and Institutional Controls Plan*
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

ft	feet
gpad	gallons per acre per day
µg/L	micrograms per liter

A.5.0 On-Site Disposal Facility Monitoring Results

This attachment provides results for the On-Site Disposal Facility (OSDF) leak detection and leachate monitoring program at the Fernald Preserve, Ohio, Site. Monitoring and sampling were conducted in accordance with the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP), Attachment C, “Groundwater/Leak Detection and Leachate Monitoring Plan” (GWLMP) (DOE 2019a). The objective of the GWLMP is to meet regulatory requirements for groundwater detection monitoring in the Great Miami Aquifer (GMA) and perched groundwater system and to provide leachate monitoring information.

Facility Description

The OSDF is in the northeast area of the Fernald Preserve. It has a capacity of 2.96 million cubic yards and a maximum height of approximately 65 feet (ft). A security fence surrounds the OSDF and defines a footprint that occupies approximately 100 acres. The facility consists of eight individual cells. All eight cells were completely full and capped by October 2006.

Protection of the GMA and the overlying perched groundwater system includes the following measures for each of the eight cells (refer to Figure A.5-1 for a cross section of the liner system):

- Multilayer composite cap system
- Leachate collection system (LCS)
- Leak detection system (LDS)
- Multilayer composite liner system

The LCS consists of a gravel layer installed beneath the encapsulated waste to collect rainwater that came in contact with the waste during cell construction and additional moisture that is draining from the waste following capping. The LDS is located beneath both the LCS and the primary geosynthetic liner system and provides a mechanism for collecting and monitoring leakage through the primary liner layer of the OSDF before any releases to the environment. Both systems drain to the west and extend beyond the synthetic liner systems into valve houses, where leachate is collected in tanks for sampling.

The base of each cell liner also slopes toward the centerline of the cell, and the centerline of the base is sloped toward the west. Leachate moving along the top of a liner would first travel toward the centerline and then west along the centerline to be drained from the cell via piping at the penetration box, which is the lowest elevation point of the cell.

Each cell is monitored below the penetration box with a horizontal till well (HTW), which represents the first monitoring point for a potential release from a cell. HTWs provide monitoring of the perched groundwater quality beneath the point where the LCS and LDS pipes exit the liner system. The GMA is monitored by both an upgradient and a downgradient monitoring well for each cell. Figure A.5-2 identifies the well locations associated with the OSDF. Table A.5-1 identifies specific dates for the following cell activities:

- Sample initiation for each monitoring horizon
- Waste placement initiation

- LDS volume measurement initiation
- Cap geomembrane layer completion
- Cap completion (through seeding)

A construction quality assurance and quality control program was executed for each cell of the OSDF. The synthetic liners and caps of each cell were inspected and tested for defects at the time of installation. Given the attention to quality assurance and quality control during the installation of the OSDF liner system, it is doubtful that a breach in the liner would have gone unnoticed, but it is possible that a breach could develop. Such a breach would provide a potential pathway for leachate migration, but adequate hydraulic head is needed to drive leachate through the breach and clay liner into the underlying horizon.

The GWLMP summarizes the principal geologic, hydrogeologic, and subsurface contaminant conditions in the OSDF area that had a direct bearing on the development of the monitoring program for the OSDF facility. As discussed in the GWLMP, the conceptual flow path or migration pathway for a leak from the facility involves understanding:

- How each cell was constructed and how a cell transmits leachate from the facility.
- The impact of hydraulic head within the facility in the LDS and the design action leakage rate.
- The nature, thickness, and hydraulic conductivity of glacial clay beneath the facility.
- Residual soil contamination beneath the facility and its possible impact to HTW water quality results.
- The groundwater model evaluations of transport times and modeled flow paths for use in placing monitoring wells for the monitoring network in the GMA.
- Modeled breakthrough travel times through the glacial clay for uranium (the main contaminant of concern) and for technetium-99 (the most mobile contaminant).

Information Organization

The 2022 OSDF leak detection and leachate monitoring information is organized into the following sections:

- Flow and Hydraulic Performance (Section A.5.1)
- Water Quality: Data Presentations and Evaluations (Section A.5.2)
- Cell Cap Inspections (Section A.5.3)
- Summary of Overall Performance and Findings and Recommendations (Section A.5.4)

Subattachments A.5.1 through A.5.8 provide cell-specific information for Cells 1 through 8.

A.5.1 Flow and Hydraulic Performance

A.5.1.1 Overall LCS Volumes

Capacitance probes are used to measure water levels in each LCS tank. The water levels in the tanks are communicated to the Converted Advanced Wastewater Treatment (CAWWT) facility via radio signal. When the water level in the tank reaches 1.86 ft, the tank is approximately 80% full, and the pump automatically starts to pump water from the tank to the leachate lift station. The water in the lift station is pumped to the CAWWT facility backwash basin. To determine the volume of leachate pumped, the change in water level after pumping is converted to gallons using an equation from the tank manufacturer. If communication to the CAWWT facility is not functioning, tanks are pumped manually when tanks are between 40% and 80% full of water. In this case, volumes pumped are recorded manually on the leachate round sheet. Tanks are also pumped manually after each sampling event.

Leachate volumes have been measured since waste placement began. Figure A.5-3 is a graph showing monthly leachate volumes from October 2006 through December 2022. Figure A.5-4 is a graph that shows the annual leachate volume from 2007 through 2022.

Leachate volumes shown in both figures are impacted by leachate line closures beginning in 2016 and continuing into 2019. Additional information concerning these closures is summarized in the following table. Contingencies for closing the valves are provided in the GWLMP in the 2019 LMICP (DOE 2019a). No line closures have occurred since 2019.

From an operational perspective, when the leachate line valves are closed, water begins to collect on the liner of each cell. By design, 1 ft of water should not be allowed to accumulate on the liner. As discussed in the LMICP, 156 days is the current estimated minimum number of days required to accumulate 1 ft of hydraulic head on the primary liner. As shown below, none of the closures between 2016 and 2019 exceeded 156 days.

Leachate Line Closure		Reason for Leachate Line Closure	Days Closed During Calendar Year
Shut Date	Open Date		
July 05, 2016	September 23, 2016[a]	Unplanned power outage	79
September 20, 2017	February 6, 2018[b]	CAWWT facility construction	103 (2017) and 37 (2018)
March 14, 2018	April 15, 2018	CAWWT facility construction	33
August 13, 2019	December 3, 2019[c]	CAWWT backwash basin refurbishment	112

[a] Valves were opened beginning September 23 and ending on September 30, 2016. Days reported are the maximum number of days for any cell.
[b] Valves were opened beginning February 2 and ending on February 6, 2018. Days reported are the maximum number of days for any cell.
[c] Valves were opened beginning December 3 and ending on December 6, 2019. Days reported are the maximum number of days for any cell.

Shutting the valves impacts the volume recorded for the facility over the calendar year. As reported in each annual Site Environmental Report for the year affected by valve closure, the reported leachate volumes either reflect a period that is less than a year, as in 2017, or the volume reported reflects more than a year, as in 2018. The effect of the relatively long period of leachate line closure that extended into the next reporting year affected the reporting of the leachate volumes for both 2017 and 2018. Leachate accumulation for 2017 reflected approximately 9 months of accumulation (75% of the year), whereas 2018 leachate accumulation reflected approximately 15 months (125% of the year). In 2019, the valves were closed for a planned shutdown to support the CAWWT backwash basin refurbishment as discussed in Appendix A, Attachment A.1. The valves were shut for a period within the calendar year and did not affect the reporting of the volume in the same way as in 2017 and 2018.

Leachate volumes reported for 2019 reflect accumulation over the entire calendar year with the leachate valves being open 253 days (January 1 through August 13, and December 3 through December 31, 2019), during which time a total of 113,350 gallons of leachate were collected and pumped to the CAWWT backwash basin for subsequent treatment at the CAWWT facility.

Leachate volumes for 2022 reflect the entire calendar year with the valves open, during which time a total of 105,198 gallons of leachate were collected and pumped to the CAWWT backwash basin for subsequent treatment at the CAWWT facility. No additional closures of the OSDF leachate lines are planned in the next several years. Continued monitoring is expected to show that the annual leachate volume continues to decrease.

The volume of precipitation that fell on the OSDF in 2022 was approximately 59.5 million gallons (40.5 inches over 54.1 acres). The facility cap was designed to inhibit water from infiltrating the OSDF. Leachate collected in 2022 (105,198 gallons) represents approximately 0.18% of the 59.5 million gallons. This value indicates that in 2022 the cap was performing as designed to reduce infiltration.

The GWLMP identifies that trend analysis of the LCS flow-monitoring measurements will be conducted for capped cells to provide an indication of changes in system performance. Monthly accumulation volumes for Cells 1 through 8 are plotted and provided in Subattachments A.5.1 through A.5.8. The semilog plots indicate that leachate volumes from the capped cells continue to decline over time, but the rate of decline is decreasing.

A.5.1.2 LDS Accumulation Rates and Volumes

Quantitative measurement of the volumes accumulating in and pumped from the LDS tanks was initiated according to the various dates in Table A.5-1. These measurements began using the same methodology as described above for the LCS. These data are used to determine both accumulation rates (in gallons per acre per day [gpad]) and accumulation volumes (in gallons) for each cell's LDS. As explained below, the method of measuring flow in the LDS (for those cells that still have flow) has changed in response to the decreasing flow.

The GWLMP states that trend analysis of the LDS flow monitoring measurements will be conducted for capped cells to provide an indication of changes in system performance. Monthly accumulation volumes for Cells 1 through 8 are provided and graphically displayed in Subattachments A.5.1 through A.5.8. The graphs indicate that LDS flows are trending asymptotic at or near zero.

Through 2017, capacitance probes were used in the tank of each LDS to measure the water level within the tank. The capacitance probes can measure within hundredths of a foot of water in the bottom of the tank. Measured water levels were used to calculate the accumulation rate for each cell. Although water may register via the probes, there may not be enough water present to physically obtain a sample. Pump out of the tank can occur automatically if an LDS tank water level reaches 80% of its capacity (1.86 ft of water). Pump out also occurs after semiannual sampling is completed to remove any water that remains after sampling, to ensure newer water is sampled for the next semiannual sampling event.

In 2022, LDS tanks for Cells 1, 2, 3, 5, 7, and 8 were too dry to collect semiannual samples, so no pump out occurred in these LDS tanks, resulting in an accumulation rate of 0.0 gpad. While no pump outs occurred in the LDS tanks for Cells 4 and 6, the LDS tanks in Cells 4 and 6 accumulated enough water to collect routine semiannual samples in 2022. However, the amount of water accumulated in each of those LDS tanks in 2022 was very low, so accumulation rates are estimated by tracking the volume of water manually pumped out of each LDS tank and the amount of time between pump outs. To be conservative, a volume of 1 gallon was assumed for each sampling event. The calculation for estimated maximum accumulation rates based on tank pump outs is summarized in the following table.

Cell	Estimated Volume Pumped from LDS (gallons)	Estimated Maximum Accumulation Rate (gpad)
4	1	0.00086
6	2	0.00084

The *On-Site Disposal Facility Final Design Calculation Package* (DOE 1997) defines an initial response leakage rate for individual cells of 200 gpad. As a best management practice, the U.S. Department of Energy (DOE) imposed two lower leakage rates:

1. Initial response leakage rate of 20 gpad.
2. Low-flow response leakage rate of 2 gpad.

The highest estimated maximum accumulation rate determined for 2022 (0.00086 gpad in Cell 4) is only 0.04% of the low-flow response leakage rate of 2 gpad.

The 2022 estimated maximum LDS accumulation rates, the percent of the initial response leakage rate, and the percent of the low-flow response leakage rate for each cell are as follows.

Cell	2022 Estimated Maximum LDS Accumulation Rate Calculated from Tank Pump Outs (gpad)	Percent of Initial Response Leakage Rate	Percent of Low-Flow Response Leakage Rate
1	0.00	0.0	0.0
2	0.00	0.0	0.0
3	0.00	0.0	0.0
4	0.00086	0.004	0.04
5	0.00	0.0	0.0
6	0.00084	0.004	0.04
7	0.00	0.0	0.0
8	0.00	0.0	0.0

These estimated LDS accumulation rates indicate that the liner systems for the cells are performing well and within the specifications outlined in the approved OSDF design, as illustrated in Figure A.5-5. The initial response leakage rate of 20 gpad and the low-flow response leakage rate of 2 gpad are administrative criteria for commencing an investigation into the possibility that the cell is not performing as designed. They are one-tenth and one-hundredth of the design criterion of 200 gpad, respectively. Because all the cells are closed and capped, it is expected that LDS accumulation rates will continue to diminish over time. Rates will continue to be closely tracked to document that the primary liner systems continue to perform as designed.

The estimated maximum accumulation rate measured for the two cells that had flow in the LDS in 2022 (Cell 4 and 6) was only 0.00086 gpad. The current LDS tanks hold approximately 300 gallons of water, making them oversized for current LDS flow conditions. In the 2018 Site Environmental Report (DOE 2019b), DOE reported plans to install tubing at an existing sampling port upstream of the LDS tank to provide a means to divert any future flow into a 5-gallon container. The thought was that the smaller container would better facilitate future sampling events and LDS flow measurement capabilities. Given that the LDS systems continue to dry up, DOE decided not to install the sampling ports.

Over the years, several small, very minor leaks have occurred in the valve house piping that so far have been easily repaired. The liquid is being contained within the valve house. The leaks are the result of galvanic corrosion between two different types of metal components of the piping system. Rather than wait for more leaks to develop, and with concurrence from the U.S. Environmental Protection Agency (EPA) and the Ohio Environmental Protection Agency (Ohio EPA), DOE began replacing the metal pipes in the valve hoses with plastic piping in late 2022. Sampling ports described above on the LDS lines were also installed so that a sample from the LDS could be collected in a smaller 5-gallon container. Pipe replacements and the installation of sampling ports on the LDS lines are scheduled for completion in early 2023.

In late 2021, a small amount of water was observed in valve house 7 in the area where the LCS piping penetrates the valve house wall and enters the valve house. The LCS and LDS pipes enter the valve houses through the east wall of the valve houses. The LCS is a double-walled pipe; the secondary containment system contained no liquid, indicating that the liquid was not coming from the LCS. The amount of liquid in the valve house increased after precipitation events. Sampling of the liquid entering the valve house revealed that the uranium concentration

(8.2 µg/L) matched the very low historical total uranium concentrations in the perched groundwater in the area (2.0 µg/L – 8.61 µg/L); therefore, the liquid in the valve house is attributed to water leaking into the valve house from outside the valve house at the point where the LCS line system penetrates through the valve house wall. Any liquid that entered the valve house via this pathway was directed to the LCS tank within the valve house until repairs could be made. The small amount of liquid entering the LCS tanks via this pathway prior to repair temporarily impacted the volume and quality of water collected from the Cell 7 LCS tank. The impact was minimal. DOE repaired the leak in valve house 7 in summer 2022. Unfortunately, additional small leaks occurred along the inner surface of the same wall in valve house 7 following the repair. The repaired area in valve house 7 did not leak, but other leaks along the east wall developed. It is believed that once the initial leak was fixed, water building up on the outside of the valve house wall found other entry points through the wall. Based on the nature of the leaks observed, it is assumed that water is collecting around the base of the east side of the valve house. During heavy precipitation events, water collects and rises on the outside of the valve house wall until it finds a way to either go around or through the walls. DOE plans to continue investigating this potential cause for the leaks in late summer or early fall 2023 when seasonal precipitation is lowest and the soil outside of the valve house wall should be the driest. If this is determined to be the cause of the leaks, potential repairs will be evaluated (e.g., French drain, sump pump).

A.5.1.3 Liner Efficiencies

Cell-specific apparent liner hydraulic efficiencies are calculated using the following equation:

$$\text{Hydraulic efficiency} = [1 - (\text{Volume}_{\text{LDS}}/\text{Volume}_{\text{LCS}})] \times 100$$

Apparent liner hydraulic efficiency is a measure of how a cell's liner is performing. This equation considers *all* the LDS volume to be leakage through the primary liner, which is a conservative measure. In the *Report on the 1995 Workshop on Geosynthetic Clay Liners* (EPA 1996), several sources of flow from leak detection layers were identified. These sources include:

- Top liner leakage.
- Construction water and compression water.
- Consolidation water.
- Water from groundwater infiltration.

As stated previously, the LDSs in Cells 1, 2, 3, 5, 7, and 8 were dry in 2022, and no pump outs occurred in any of the eight LDS tanks resulting in an LDS volume equal to 0 for the purposes of calculating the liner efficiency. Since 2019, liner efficiencies of only those cells that had LDS volumes greater than 0 are reported (Cells 4 and 6 for 2022). In the following table, Cells 4 and 6 are reported at 100% in 2022 because, although a sample was collected, no pumping occurred from the tanks.

Apparent Liner Efficiency (Percent), Quarterly for 2022

Quarter	Cell 4	Cell 6
First	100.00	100.00
Second	100.00	100.00
Third	100.00	100.00
Fourth	100.00	100.00

A.5.1.4 HTW Water Yields

HTW water yields are monitored at each cell to document trends in perched-water purge volumes. In 2022, the HTWs were purged twice (March and September). Average annual purge water yields from the HTWs ranged from 0 gallons beneath Cell 8 to 1,050 gallons beneath Cell 5 as shown in the table. The HTW water yields will continue to be tracked and factored into the OSDF leak detection evaluation, where appropriate. Further information (total volumes pumped, number of months purged, and the average monthly purge volume) is provided in each cell's subattachment.

Horizontal Till Well Purge Events for 2022

Location ID	Cell	First Half Purge March 9, 2022 (gallons)	Second Half Purge September 12, 2022 (gallons)	Annual Total (gallons)	Annual Average (gallons)
12338	Cell 1	555	225	780	390
12339	Cell 2	790	830	1,620	810
12340	Cell 3	690	710	1,400	700
12341	Cell 4	570	550	1,120	560
12342	Cell 5	1,050	1,050	2,100	1,050
12343	Cell 6	440	280	720	360
12344	Cell 7	1,050	780	1,830	915
12345	Cell 8	Dry	Dry	Dry	Dry
	Totals	5,145	4,425	9,570	Not applicable

A.5.2 Water Quality: Data Presentations and Evaluations

The water quality and data presentations and evaluations presented in this report are as follows:

- Semiannual Monitoring Summary Statistics (Section A.5.2.1)
- Concentration Plots (Section A.5.2.2)
  - LCS, LDS, and HTW of each cell
  - HTW and GMA wells of each cell
- Control Charts (Section A.5.2.3)

- Bivariate Plots (Section A.5.2.4)
- Upward Concentration Trends in the HTW and GMA Wells (Section A.5.2.5)

A.5.2.1 Semiannual Monitoring Summary Statistics

Water quality within each cell is sampled in the LCS and LDS. Water quality beneath each cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present results. Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell. With EPA and Ohio EPA concurrence, monitoring changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017 (total uranium, boron, sodium, sulfate, calcium, lithium, magnesium, nitrate + nitrite as nitrogen, potassium, selenium, technetium-99, total dissolved solids, and total organic halogens). All 13 parameters are sampled in the GMA wells; 4 of the 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW for each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was eliminated beginning in January 2017 with EPA and Ohio EPA concurrence.

Summary statistics for all the parameters monitored semiannually are provided in Subattachments A.5.1 through A.5.8 (Tables A.5.1-1 through A.5.8-1). The information provided in each summary table is based on a standardized quarterly sampling frequency. Baseline data are included in the summary statistics. A discussion of data collected for the OSDF is provided in the GWLMP (Attachment C of the LMICP).

A summary of the statistical process used is illustrated in Figure A.5-6. Table A.5-2 lists the rules that are used to report the data provided in Tables A.5.1-1 through A.5.8-1 in each subattachment. For analytical results below the detection limit, one-half the detection limit was used in calculations of the average, standard deviation, distribution, trend, serial correlation, and outliers. One objective in conducting the summary statistics is to identify the parameters that meet the requirements for control charts (i.e., greater than eight samples, normal or lognormal distribution, no trend, and no serial correlation).

Data used in the summary statistics were “quarterized” (i.e., normalized to quarterly data). The rationale is that during different periods, data were collected at varying time intervals. For example, from October 30, 1997, through December 8, 1997, 15 samples were collected for total uranium from HTW 12338. In all of 1998, only four were collected; in 1999, there were seven; in 2000, there were six; and four each were collected in 2001 through 2003. To summarize, in a 5- to 6-week period in 1997, nearly as much data were collected as were collected from 1998 to 2000. Without normalizing the data, the periods with more sampling activity would carry more weight and, therefore, with respect to the calculations, would be considered more important. Additionally, sampling the same well at too short of an interval (often just 1 day apart in 1997) also violated the statistical assumption of independence. Well data that are collected too closely in time are serially correlated and can distort the statistics underlying the control charts. Even with quarterly sampling, there is often an issue with serial correlation.

Statistical calculations were conducted using ChemStat version 6.3 (a Starpoint Software program, www.pointstar.com). ChemStat software is also used to perform the statistical analysis of groundwater monitoring data at Resource Conservation and Recovery Act facilities.

Dataset distributions were checked using the Shapiro-Wilk test (95% confidence interval) for datasets with fewer than 50 samples and the Shapiro-Francia test (95% confidence interval) for datasets with 50 samples or more. The Mann-Kendall test for trend (95% confidence interval) was used to determine the presence of either an upward or downward concentration trend over time. The rank Von Neumann test (confidence interval of 99%) was used to check for serial correlation.

As discussed in the *Fernald Preserve 2015 Site Environmental Report* (DOE 2016), low flow rates, coupled with LDS collection tanks that are open to the atmosphere, can bias analytical results high for some constituents and low for others. Because of the low-flow conditions, it is uncertain whether an LDS sample collected from a valve house tank truly represents the composition of an LDS sample from within the facility. Collecting water quality samples from the LDS and using the data to statistically demonstrate that the facility is operating as designed does not appear to be the best approach for complying with Ohio Solid Waste Regulations (Ohio Administrative Code 3745-27-19[M][5]) for the OSDF. As stated in the GWLMP of the 2019 LMICP (DOE 2019a), monitoring accumulation rates from the LDS against established design and agreed-to administrative action rates is a much better approach. It should be noted that the installation of sampling ports on the LDS lines in late 2022 through early 2023 so that a sample can be directed into a 5-gallon container will improve the sample collection process for the LDS beginning in 2023. But it should also be noted that the LDS lines continue to dry up, and in 2022, only Cells 4 and 6 had enough water present to collect a sample.

A.5.2.2 Concentration Plots

Concentration plots for the parameters monitored semiannually in 2022 are presented in Subattachments A.5.1 through A.5.8. The plots are presented with a common vertical *y* scale based on the parameter. Outliers identified in Subattachments A.5.1 through A.5.8 in Tables A.5.1-1 through A.5.8-1 are not plotted on the concentration plots.

Table A.5-3 provides an OSDF groundwater, leachate, and LDS monitoring summary. As shown in Table A.5-3 and listed below, three sampling locations had new high total uranium concentrations in 2022; two were in the LDS and one was in the GMA.

- **GMA of Cell 3:** A new high of 23.5 micrograms per liter (µg/L) was measured in the first half of 2022 in the upgradient GMA well (22203). The previous high was 18.5 µg/L. The concentration measured in the second half of 2022 was 9.45 µg/L.
- **LDS of Cell 4:** A new high of 79.8 µg/L was measured in the first half of 2022 in the LDS of Cell 4. The previous high was 55.9 µg/L. The LDS for Cell 4 was dry in the second half of 2022.
- **LDS of Cell 6:** A new high of 160 µg/L was measured in the first half of 2022. The previous high was 152 µg/L. The concentration measured in the second half of 2022 was 133 µg/L.

Bivariate plot results reported in Section A.5.2.4 continue to support the interpretation that chemical signatures for the different monitoring horizons are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, new high uranium concentrations measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

The new high uranium concentrations measured in the LDS of Cells 4 and 6 in 2022 are not attributed to communication with the LCS. A new high uranium concentration measured in the LDS is attributed to the impact that decreasing flow can have on the uranium concentration left in fluid remaining in the LDS as the LDS dries up. Uranium concentration versus time plots for each cell are provided in Subattachments A.5.1 through A.5.8. As shown in those figures, with the exception of Cell 3 LDS, an increasing uranium concentration trend was clearly observed in the LDS of other cells as they were drying up (Cells 1, 2, 5, and 7). For Cell 3, the last sample collected showed an increasing uranium concentration, but the overall trend in the Cell 3 LDS leading up to the last sample was not increasing. The LDS of each cell is expected to dry up over time, and this indicates that the facility continues to operate as designed.

Figures A.5-7 through A.5-8 illustrate the trends observed at the two cells that had enough fluid left in the LDS to sample in 2022. Each figure shows three graphs with a general trend line. The upper graph is the total uranium concentration versus time in the LDS fluid. The middle graph is the accumulation of fluid in gallons in the LDS, and the lower graph is the mass of uranium contained within the accumulated volume of fluid. The graphs illustrate that as the LDS dries up (decreasing accumulation volume), the uranium concentrations increase, while the mass of uranium in the accumulated fluid does not show an overall increasing trend.

A.5.2.3 Control Charts

Intrawell control charts employ historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared “not in control” if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to interpret control charts: the decision value (h) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with at least eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (h) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM (*h*) limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit (*h*) on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit (*h*). This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit (*h*).

Eighteen Shewhart-CUSUM control charts were prepared in 2022 and are presented in Subattachments A.5.1 through A.5.8 for parameters monitored semiannually in the HTW and GMA wells in 2022 that had datasets that achieved control chart criteria (i.e., more than eight samples, normal or lognormal distribution, no trend, and no serial correlation). All of the 18 control charts exhibited “in control” conditions.

A.5.2.4 Bivariate Plots

Bivariate plots are used in an Alternate Source Determination capacity to show that water quality changes observed beneath the facility in HTW and GMA wells are not attributed to facility performance. Sodium and total uranium were selected because this combination provides a good distinction between LCS, LDS, and HTW. This combination was discovered during the Common Ion Study (DOE 2008). Although the sodium–uranium bivariate plot for Cell 8 provides a distinction between the LDS and HTW, the separation shown between the LDS and HTW is not as distinct as it is for the other seven cells; therefore, a sulfate–uranium bivariate plot is also provided for Cell 8. In 2020, the uranium concentration in the LCS of Cell 1 decreased enough to place it in the area of the bivariate plot occupied by HTW samples. The LDS of Cell 1 has been too dry to collect a sample from since 2011. An additional bivariate plot of sodium–sulfate is provided for Cell 1 to illustrate that the sodium and sulfate concentrations indicate that the LCS and HTW zones are not mixing. Other combinations may be added in the future, if deemed appropriate.

Bivariate plots are presented for each cell in Subattachments A.5.1 through A.5.8. The bivariate plots illustrate the concentration signatures in each monitoring horizon. Distinct clustering of horizon concentrations indicates that the fluids in the different horizons are not mixing. In response to an Ohio EPA comment on the *Fernald Preserve 2009 Site Environmental Report* (DOE 2010) (Ohio EPA Comment Number 35), the closest points between monitoring horizons were dated until 2018. Beginning with the *Fernald Preserve 2018 Site Environmental Report* (DOE 2019b), an arrow is provided on the plots from the first to most recent sample result for each monitoring horizon. The dates of the first and most recent sample plotted are also posted for each sampling horizon.

An additional bivariate plot for sodium–sulfate is presented for Cell 1 in Subattachment A.5.1. The additional sodium–sulfate bivariate plot provides supporting information concerning the water chemistry signatures present in the LCS and HTW of Cell 1—specifically, that they are separate and distinct.

An additional bivariate plot for uranium–sulfate is presented for Cell 8 in Subattachment A.5.8. The additional uranium–sulfate bivariate plot provides supporting information concerning the water chemistry signatures present in the LDS and HTW of Cell 8—specifically, that they are separate and distinct.

The bivariate plots for 2022 continue to support the interpretation that chemical signatures for the different monitoring horizons are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in 2022 (HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell not related to cell performance.

In light of the water quality sampling challenges discussed in the 2016 Site Environmental Report (DOE 2017), DOE conducted an assessment to determine whether the continued use of bivariate plots with data from the LDS is still warranted. Assessment results indicated that bivariate plots continue to be a valuable tool for assessing whether the monitoring zones are mixing (Geochemical Consultants 2016).

A.5.2.5 Upward Concentration Trends in the HTW and GMA Wells

The HTW is located beneath the liner penetration box of each cell by design. This area of the liner penetration box is the lowest elevation point of each cell and potentially the weakest point in the cell design. If a leak were to develop, it should be detected beneath the liner penetration box first. Therefore, the water quality in the HTW represents the first line of evidence that a potential leak from the cell might be occurring. A leak would be indicated by an increasing concentration trend in the HTW.

GMA monitoring wells are positioned (and identified) for pre-aquifer-remediation flow conditions defined in the Operable Unit 5 Remedial Investigation Report (DOE 1995). Water level data reported in the Operable Unit 5 Remedial Investigation Report indicate that, before the start of pumping for the groundwater remediation, groundwater flow directions in the vicinity of the OSDF were generally from west to east.

Groundwater flow beneath the OSDF is currently being influenced by active pumping taking place for the groundwater remediation southwest of the OSDF. Water beneath the OSDF is generally moving in response to this pumping from northeast to southwest. When pumping for the groundwater remedy stops, groundwater flow in the vicinity of the OSDF should once again return to a direction that is generally from west to east. Trends are therefore being tracked in all GMA wells at this time.

An increasing concentration trend in a HTW or GMA monitoring well could be attributed to a possible leak from the OSDF. In addition, increasing concentration trends in the HTW or GMA wells could also be caused by fluctuating ambient concentrations beneath the cells, and not connected to the operation of the facility.

As presented in Subattachments A.5.1 through A.5.8, several parameter datasets have upward concentration trends beneath the OSDF (i.e., HTW and GMA wells). Bivariate plots (uranium–sodium, uranium–sulfate, and sodium–sulfate) indicate separate and distinct chemical signatures for the LCS, LDS, and HTW of all eight cells. This indicates that water is not mixing from inside the facility to outside the facility, leading to the conclusion that the facility is not leaking. Therefore, concentration increases observed in the HTW and GMA wells are attributed to fluctuating ambient concentrations beneath the cells and not to cell performance. Additional information is provided in Subattachments A.5.1 through A.5.8.

A.5.3 Cell Cap Inspections

OSDF cell cap inspections are conducted quarterly and include the toe of the side slopes, the drainage features around the base of the cell cap, and the fence line. In 2022, inspections were conducted in March, June, September, and December. A complete inspection of the cell cap is conducted annually. The inspection team typically includes representatives from Ohio EPA, Ohio Department of Health, and the site contractor. Issues identified during inspections typically include rocks that surface as topsoil settles, animal burrows and digging, the presence of woody vegetation, and noxious herbaceous species.

The issues are addressed as follows:

- Rocks greater than 4 inches in diameter that surface are removed, especially if they will interfere with mowing activities or may be a source location for erosion.
- Animal burrows and holes are filled in and reseeded, if necessary.
- Woody vegetation is cut and stumps are treated with herbicide.
- Herbicide is applied to noxious weeds.

In 2022, there were no visual signs that the integrity of the cap had been compromised. Appendix C provides additional information regarding the OSDF cap inspections.

A.5.4 Summary of Overall Performance and Findings and Recommendations

Based on LCS and LDS flow data, the engineered cap, liners, and drainage features within the OSDF continue to perform as designed. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of each cell (total uranium and sulfate in Cell 8, sodium sulfate in Cell 1) indicate that waters from the different horizons are not mixing, and, therefore, it can be inferred that the primary and secondary liners are not leaking. Water quality constituent concentration increases noted in the HTW and GMA wells are attributed to fluctuating ambient concentrations beneath the OSDF and not to OSDF performance. Surface inspections conducted in 2022 showed no visual signs that the integrity of the cap had been compromised in any way. It is therefore recommended that the only action to take at this time concerning the OSDF is to continue monitoring the facility as prescribed in the GWLMP.

Specific Findings:

- LCS volumes continue to diminish with time. Total facility leachate volume in 2022 was 0.64% less than in 2021 (approximately 105,198 gallons in 2022 compared with 105,874 gallons in 2021).
- In 2022, there was not enough water in the LDS of Cells 1, 2, 3, 5, 7, and 8 to collect a water sample.

- LDS accumulation rate for 2022 in Cell 4 and Cell 6 indicates that the liner systems are performing as designed. The largest estimated LDS maximum accumulation rate calculated in 2022 was 0.00086 gpad in Cell 4, approximately 0.004% of the initial response leakage rate of 20 gpad, and 0.04% of the low-flow response leakage rate of 2 gpad.
- Quarterly apparent liner efficiencies were 100% for all cells in 2022.
- Three sampling locations had new high total uranium concentrations in 2022. Two were in the LDS, and one was in the GMA.
  - **GMA of Cell 3:** A new high of 23.5 µg/L was measured in the first half of 2022 in the upgradient GMA well (22203). The previous high was 18.5 µg/L. The concentration measured in the second half of 2022 was 9.45 µg/L.
  - **LDS of Cell 4:** A new high of 79.8 µg/L was measured in the first half of 2022 in the LDS of Cell 4. The previous high was 55.9 µg/L. The LDS of Cell 4 was dry in the second half of 2022.
  - **LDS of Cell 6:** A new high of 160 µg/L was measured in the first half of 2022. The previous high was 152 µg/L. The concentration measured in the second half of 2022 was 133 µg/L.
- Bivariate plots continue to show that the chemical signatures for uranium, sulfate, and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that:
  - Mixing between the horizons is not occurring; therefore, concentration changes measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.
  - New high uranium concentrations measured in the LDS are not attributed to communication with the LCS. The new high uranium concentrations measured in the LDS are attributed to the impact that decreasing flow can have on the uranium concentration left in water remaining in the LDS as the LDS dries up.
- In 2022, 18 datasets met the criteria for Shewhart-CUSUM control charts. All control charts exhibited “in control” conditions.
- In 2022, quarterly physical inspections of the OSDF revealed no visual signs that the integrity of the OSDF cap had been compromised.

A.5.5 References

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Table A.5-1. OSDF Initiation and Completion Dates

Cell	Sample Initiation per Horizon[a]	Waste Placement Initiation	LDS Volume Measurement Initiation[b]	Cap Geomembrane Layer Completion[c]	Cap Completion[d]
1	LCS: February 17, 1998 LDS: February 18, 1998 HTW: October 30, 1997 GMA-U: March 31, 1997 GMA-D: March 31, 1997	December 23, 1997	May 1999	August 17, 2001	December 20, 2001
2	LCS: November 23, 1998 LDS: December 14, 1998 HTW: June 29, 1998 GMA-U: June 30, 1997 GMA-D: June 25, 1997	November 12, 1998	May 1999	July 17, 2003	November 12, 2003
3	LCS: October 13, 1999 LDS: August 26, 2002 HTW: July 28, 1998 GMA-U: August 24, 1998 GMA-D: August 24 1998	October 26, 1999	October 1999	July 16, 2004	September 20, 2004
4	LCS: November 4, 2002 LDS: November 4, 2002 HTW: February 26, 2002 GMA-U: November 6, 2001 GMA-D: November 5, 2001	November 08, 2002	November 2002	December 18, 2004	April 29, 2005
5	LCS: November 4, 2002 LDS: November 4, 2002 HTW: February 26, 2002 GMA-U: November 6, 2001 GMA-D: November 5, 2001	November 19, 2002	November 2002	June 22, 2005	August 29, 2005
6	LCS: October 27, 2003 LDS: October 27, 2003 HTW: March 14, 2003 GMA-U: December 16, 2002 GMA-D: December 16, 2002	November 18, 2003	January 2004	October 28, 2005	January 12, 2006

Table A.5-1. OSDF Initiation and Completion Dates (continued)

Cell	Sample Initiation per Horizon[a]	Waste Placement Initiation	LDS Volume Measurement Initiation[b]	Cap Geomembrane Layer Completion[c]	Cap Completion[d]
7	LCS: September 2, 2004 LDS: September 2, 2004 HTW: February 24, 2004 GMA-U: January 21, 2004 GMA-D: January 21, 2004	September 9, 2004	September 2004	July 2006	October 25, 2006
8	LCS: October 18, 2004 LDS: October 18, 2004 HTW: May 19, 2004 GMA-U: March 31, 2004 GMA-D: March 31, 2004 GMA-SW: August 22, 2005 GMA-SE: August 22, 2005	December 2, 2004	December 2004	September 24, 2006	October 25, 2006

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer; GMA-SW = southwest Great Miami Aquifer; and GMA-SE = southeast Great Miami Aquifer
[b]Prior to 1999, overall LDS volumes were measured. From 1999 on, LDS volumes were measured by cell.
[c]The cap geomembrane layer is made of high density polyethylene.
[d]Cap completion includes seeding.

Table A.5-2. Rules for Summary Statistics for Cells 1 Through 8

Rules	No. of Detected Samples	Total No. of Samples	Percent of Detects	Minimum [a,b]	Maximum[a,b]	Average	Standard Deviation	Distribution Type	Trend	Serial Correlation	Outliers
Include outliers	Yes	Yes	Yes	No	No	No	No	No	No	No	
Only one result	Yes	Yes	Yes	report "NA"	report value	report "Insufficient"	report "Insufficient"	report "Insufficient"	report "Insufficient"	report "Insufficient"	
Only two results	Yes	Yes	Yes	report value	report value	report "Insufficient"	report "Insufficient"	report "Insufficient"	report "Insufficient"	report "Insufficient"	
All non-detects	Yes	Yes	Yes	report "ND"	report "NA"	report "Insufficient"	report "Insufficient"	report "Insufficient"	report "Insufficient"	report "Insufficient"	
Other rules						Need 3 detections otherwise report "Insuff"	Need 4 detections otherwise report "Insuff"	Need at least 3 samples to report distriburtion	Need at least 4 detects to report trend	Need at least 6 samples to report serial correlation	Need at least 4 samples to report outliers
Other rules						If distribution is "Lognormal," substitute "LogMean"					
Other rules						If distribution is "Undefined," substitute "Median"					

[a]NA=not applicable; ND=not detected
[b]If reported value is a nondetected result, report ND.

Table A.5-3. OSDF Groundwater, Leachate, and LDS Monitoring Summary

Cell (Waste Placement)	Monitoring Location	Monitoring Zone	Date Sampling Started	Total Number of Samples	Range of Total Uranium Concentrations[a,b] (µg/L)	First Half 2022[a,c] (µg/L)	Second Half 2022[a,c] (µg/L)	Historical Trend[d] (Year Last Sampled)
Cell 1 (Dec 1997)	12338C	LCS	Feb 17, 1998	76	ND–206	18.8	10.2	None (2022)
	12338D	LDS	Feb 18, 1998	37	1.50–37.0	DRY	DRY	Up (2011)
	12338	Glacial Till	Oct 30, 1997	85	ND–19	7.12	6.68	Up (2022)
	22201	Great Miami Aquifer	Mar 31, 1997	92	ND–12.4	5.52	6.07	Up (2022)
	22198	Great Miami Aquifer	Mar 31, 1997	140	0.540–15.2	3.08	2.51	Down (2022)
Cell 2 (Nov 1998)	12339C	LCS	Nov 23, 1998	72	4.51–686	45.8	55.9	Up (2022)
	12339D	LDS	Dec 14, 1998	29	4.08–25.8[e]	DRY	DRY	None (2013)
	12339	Glacial Till	Jun 29, 1998	96	ND–36.9	15.8	17.9	Up (2022)
	22200	Great Miami Aquifer	Jun 30, 1997	87	ND–4.69	0.303	1.49	Up (2022)
	22199	Great Miami Aquifer	Jun 25, 1997	117	ND–12.1	0.353	0.513	Down (2022)
Cell 3 (Oct 1999)	12340C	LCS	Oct 13, 1999	70	9.27–206	141	131	Up (2022)
	12340D	LDS	Aug 26, 2002	20	8.90–27.7[e]	DRY	DRY	Down (2007)
	12340	Glacial Till	Jul 28, 1998	89	ND–58.5	16.3	15.2	None (2022)
	22203	Great Miami Aquifer	Aug 24, 1998	82	ND–**23.5**	**23.5**	9.45	Up (2022)
	22204	Great Miami Aquifer	Aug 24, 1998	112	ND–22.9	3.08	1.96	Up (2022)
Cell 4 (Nov 2002)	12341C	LCS	Nov 04, 2002	56	4.41–234	113	86.4	None (2022)
	12341D	LDS	Nov 04, 2002	41	5.74–**79.8**	**79.8**	DRY	Up (2022)[f]
	12341	Glacial Till	Feb 26, 2002	69	**3.40**–7.91	3.46	3.19	Down (2022)
	22206	Great Miami Aquifer	Nov 06, 2001	73	ND–5.78	0.731	1.14	Up (2022)
	22205	Great Miami Aquifer	Nov 05, 2001	99	0.446–19.7	2.13	2.40	None (2022)
Cell 5 (Nov 2002)	12342C	LCS	Nov 04, 2002	58	3.39–285	131	162	None (2022)
	12342D	LDS	Nov 04, 2002	40	2.93–27.1	DRY	DRY	Down (2013)
	12342	Glacial Till	Feb 26, 2002	70	7.45–21.1	7.64	8.90	Down (2022)
	22207	Great Miami Aquifer	Nov 06, 2001	73	ND–4.48	0.449	0.269	Down (2022)
	22208	Great Miami Aquifer	Nov 05, 2001	98	ND–2.1	0.361	0.254	None (2022)

Table A.5-3. OSDF Groundwater, Leachate, and LDS Monitoring Summary (continued)

Cell (Waste Placement)	Monitoring Location	Monitoring Zone	Date Sampling Started	Total Number of Samples	Range of Total Uranium Concentrations[a,b] (µg/L)	First Half 2022[a,c] (µg/L)	Second Half 2022[a,c] (µg/L)	Historical Trend[d] (Year Last Sampled)
Cell 6 (Nov 2003)	12343C	LCS	Oct 27, 2003	55	8.03–276	119	103	Down (2022)
	12343D	LDS	Oct 27, 2003	54	3.1–**160**	**160**	133	Up (2022)
	12343	Glacial Till	Mar 14, 2003	62	ND–24.2	8.48	7.80	None (2022)
	22209	Great Miami Aquifer	Dec 16, 2002	68	ND–2.43	0.409	0.447	Down (2022)
	22210	Great Miami Aquifer	Dec 16, 2002	93	ND–1.02	0.638	0.647	None (2022)
Cell 7 (Sep 2004)	12344C	LCS	Sep 02, 2004	51	4.72–355	56.2	90.9	Down (2022)
	12344D	LDS	Sep 02, 2004	29	12.2–169[e]	DRY	DRY	Up (2015)
	12344	Glacial Till	Feb 24, 2004	59	0.674–12.1	3.54	3.91	Up (2022)
	22212	Great Miami Aquifer	Jan 21, 2004	61	ND–5.53	0.428	0.385	None (2022)
	22211	Great Miami Aquifer	Jan 21, 2004	83	ND–4.31	0.369	0.394	None (2022)
Cell 8 (Dec 2004)	12345C	LCS	Oct 18, 2004	48	1.51–335	147	159	None (2022)
	12345D	LDS	Oct 18, 2004	45	9.38–**315**	DRY	DRY	Up (2021)
	12345	Glacial Till	May 19, 2004	20	3.48–7.3	DRY	DRY	Up (2008)
	22213	Great Miami Aquifer	Mar 31, 2004	60	ND–0.71	0.364	0.354	Up (2022)
	22214	Great Miami Aquifer	Mar 31, 2004	83	ND–2.95	0.469	0.843	Down (2022)
	22215	Great Miami Aquifer	Aug 22, 2005	51	ND–16.4	0.679	0.364	None (2022)
	22217[g]	Great Miami Aquifer	Aug 22, 2005	50	ND–18.3	1.86	5.60	Down (2022)

Note: The data on this table represent the raw data from the database. However, data presented in the Attachment A.5 subattachments have gone through a statistical processing and analysis. In regard to the statistical processing, the data were quarterized (normalized to one result per quarter) and outliers were removed to arrive at an accurate distribution model. Because of the processing, the total number of samples and range of concentrations on this table might not match the text, tables, and figures in Attachment A.5. The rules used for the statistical processing and analysis in Attachment A.5 are discussed in Section A.5.2.1, and the results are summarized in Table A.5-2.

Note: Uranium concentration versus time graphs can be found in the Attachment A.5 subattachments. See Figures A.5.1-5A and A.5.1-5B for Cell 1; Figures A.5.2-5A and A.5.2-5B for Cell 2; Figures A.5.3-5A and A.5.3-5B for Cell 3; Figures A.5.4-5A and A.5.4-5B for Cell 4; Figures A.5.5-5A and A.5.5-5B for Cell 5; Figures A.5.6-5A and A.5.6-5B for Cell 6; Figures A.5.7-5A and A.5.7-5B for Cell 7; and Figures A.5.8-7A and A.5.8-7B for Cell 8.

[a] **Bold text indicates a new high or low detected in 2021**.
[b] ND = not detected.
[c] Where there are more than two data points for the half year, the higher result is used.
[d] The trends presented here are based on nonparametric Mann-Kendall procedure and come from the tables in Attachment A.5 subattachments for each cell. See Tables A.5.1-1, A.5.2-1, A.5.3-1, A.5.4-1, A.5.5-1, A.5.6-1, A.5.7-1, and A.5.8-1.
[e] Some data are not considered representative of LDS in Cell 2 (December 14, 1998, through May 23, 2000, dataset) due to malfunction in Cell 2 leachate pipeline and resulting mixing of individual flows. It is suspected that some November 2004 samples were switched (i.e., 12339C with 12339D, and 12340C with 12340D). If data from these events were included above, maximum total uranium concentrations would be 71 µg/L for 12339D and 72.4 µg/L for 12340D. It is suspected that samples were switched in 2014 (i.e., 12344D with the field duplicate for 12345C). If the data point from this sampling event was not included above, maximum total uranium concentration for 12344D would be 37.6 µg/L.
[f] The Cell 4 LDS was dry, resulting in no data from fourth quarter 2011 through 2016.
[g] Monitoring location 22216 was plugged and abandoned in April 2006. Monitoring location 22217 is its replacement. The results listed for location 22217 also include the results for location 22216.

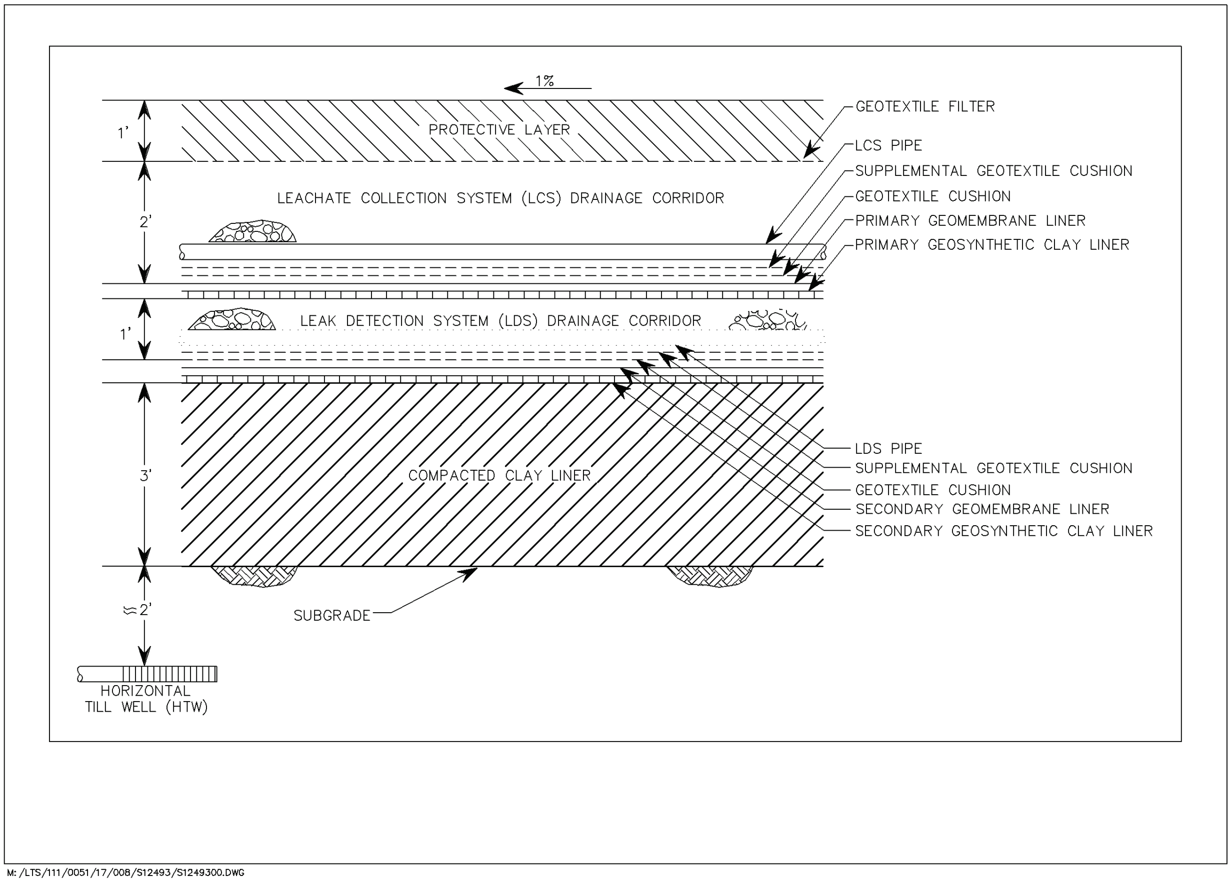

Figure A.5-1. Cross Section of OSDF Liner System with HTW at the Drainage Corridor

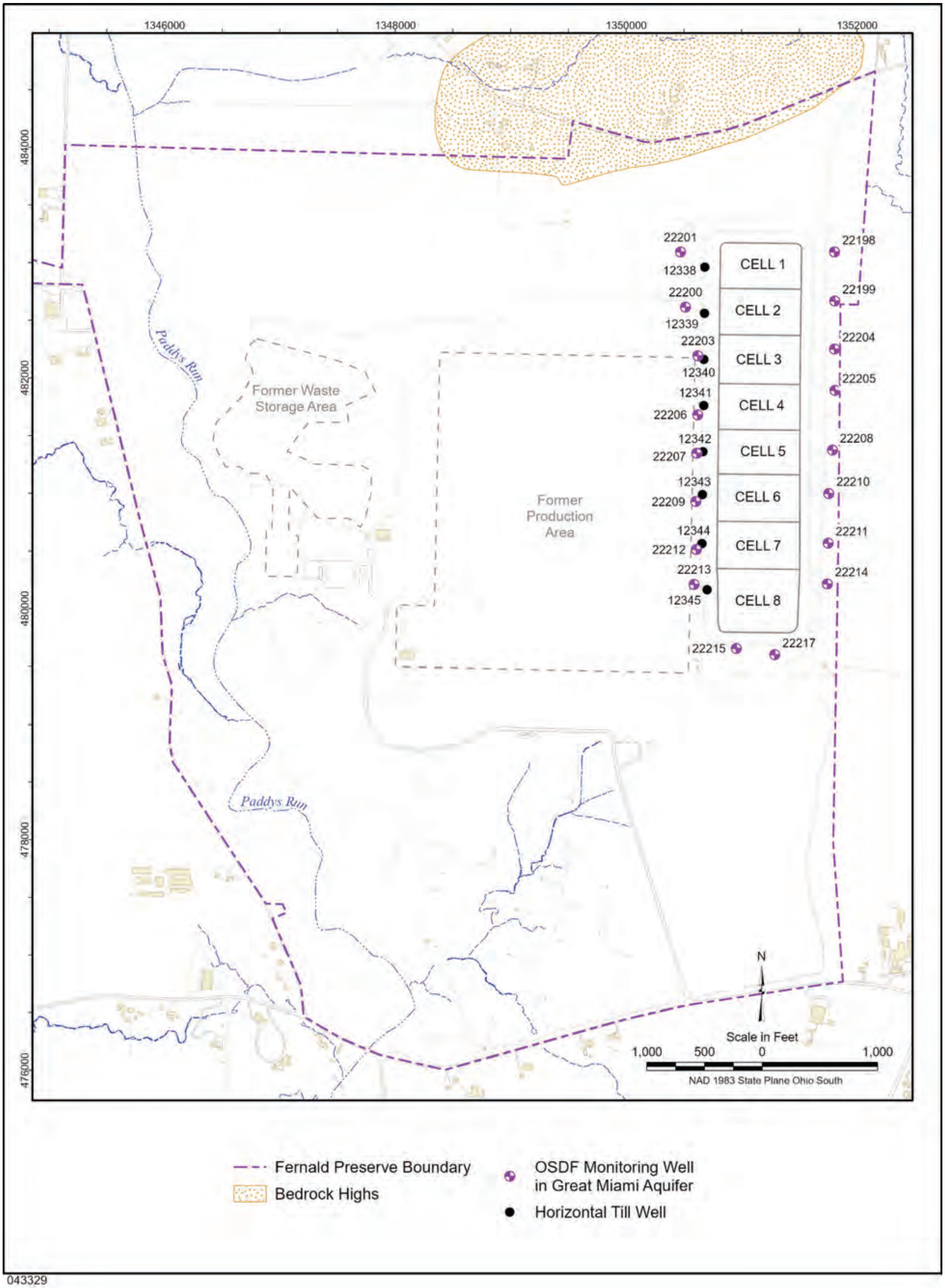

Figure A.5-2. OSDF Footprint and Monitoring Well Locations

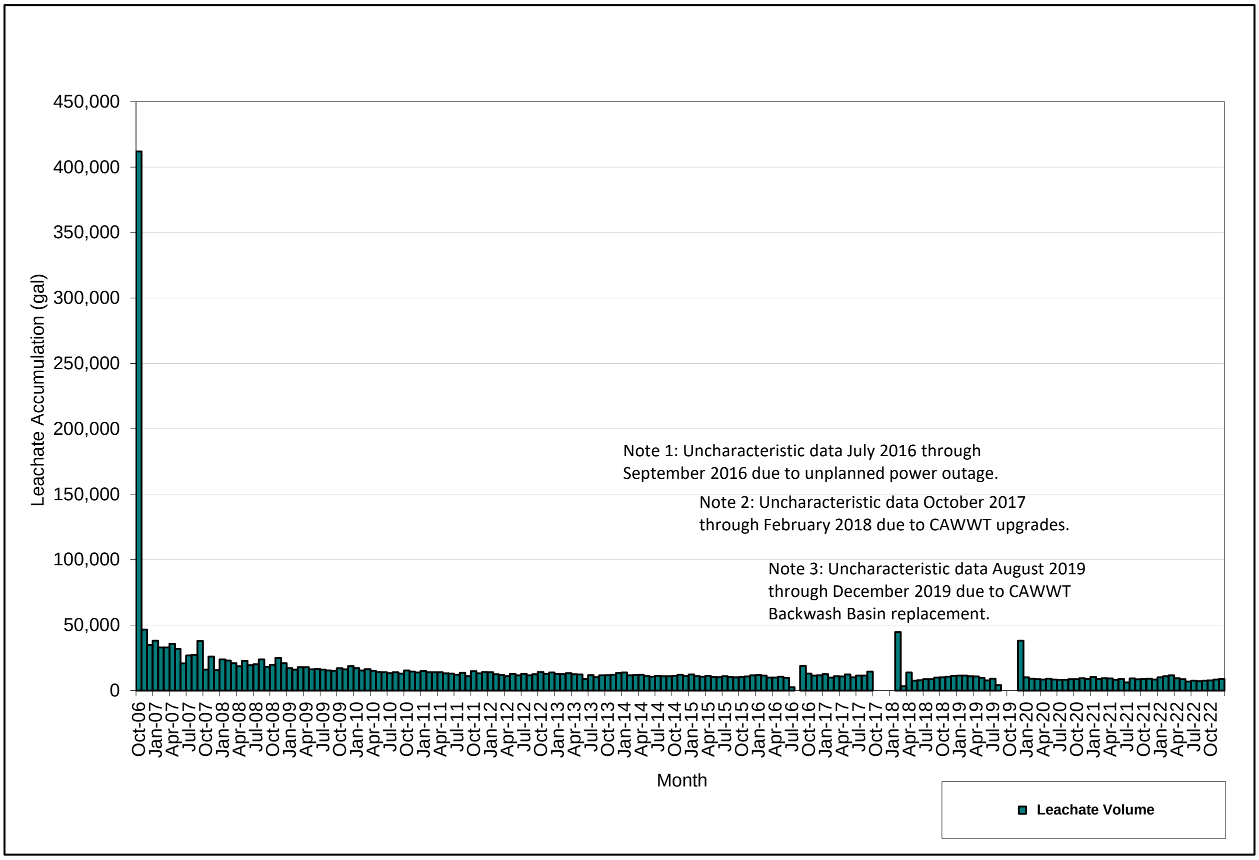

Figure A.5-3. OSDF Monthly LCS Flow (October 2006 Through December 2022)

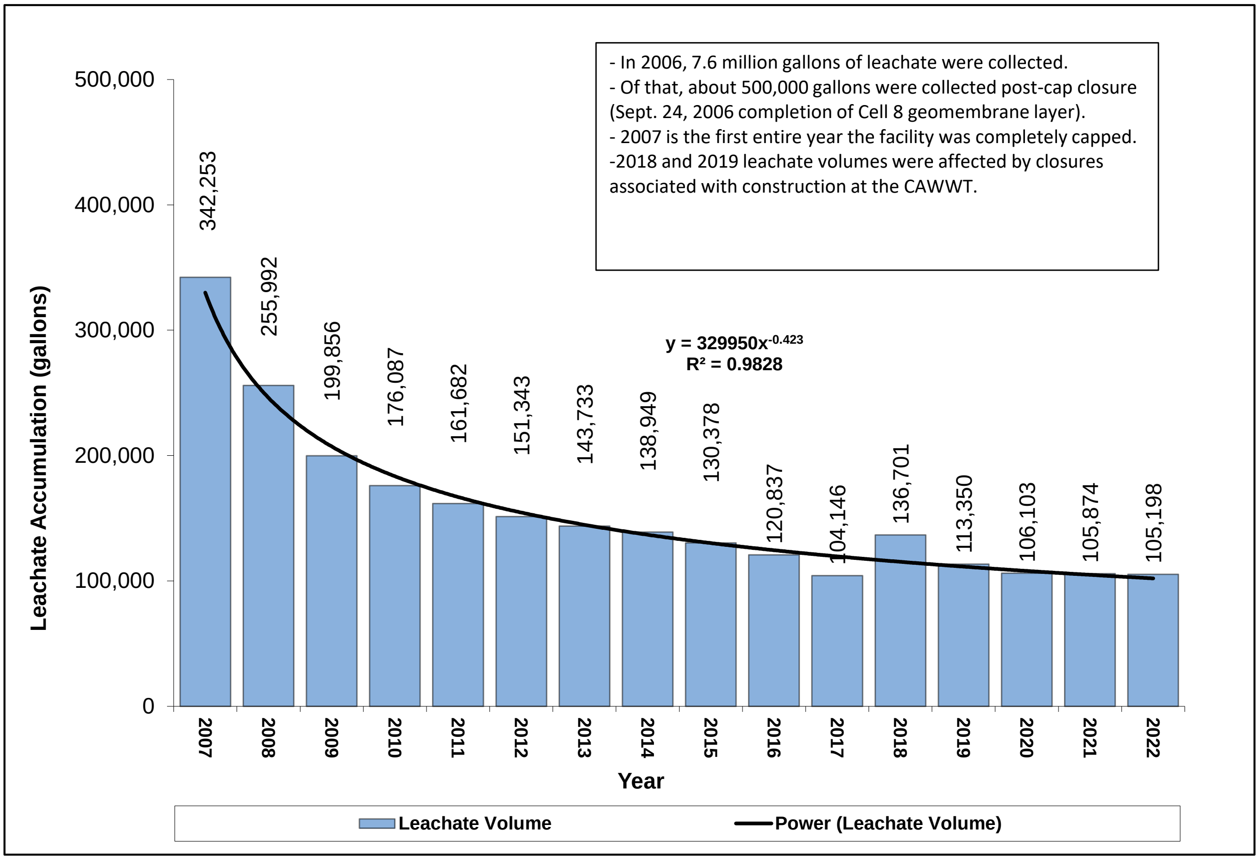

Figure A.5-4. OSDF Annual LCS Flow (2007 Through 2022)

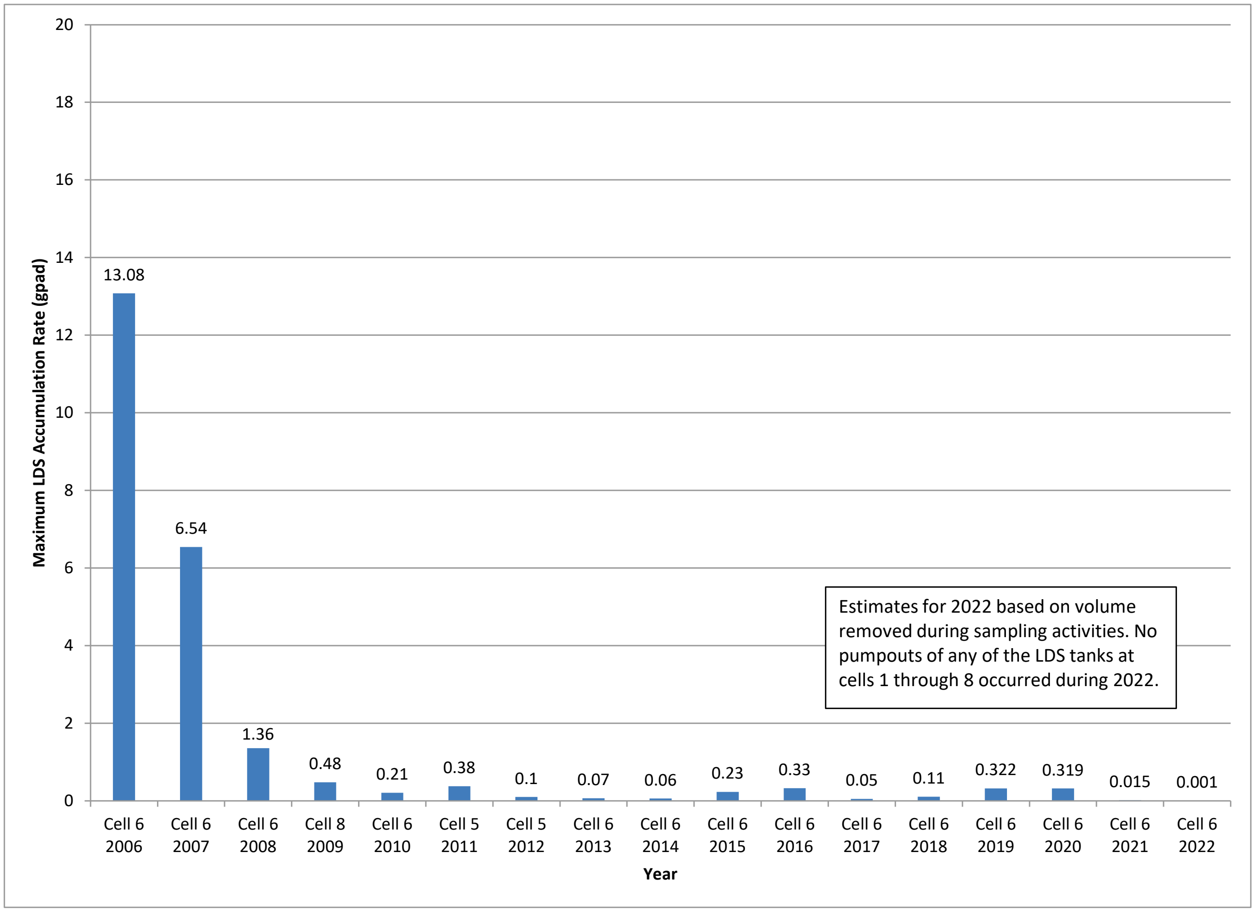

Figure A.5-5. Maximum LDS Accumulation Rate Between 2006 and 2022

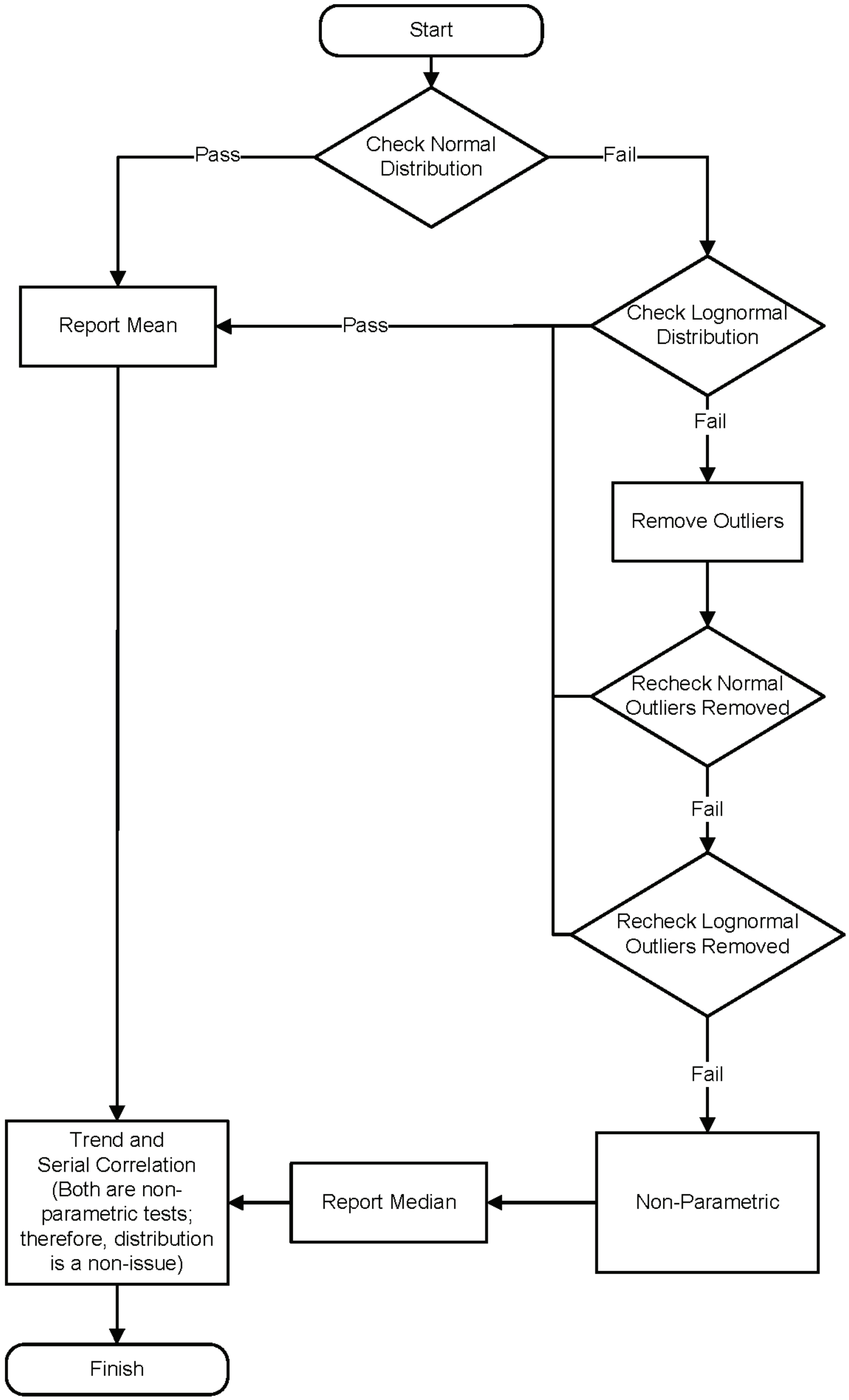

Figure A.5-6. OSDF Statistical Evaluation Process

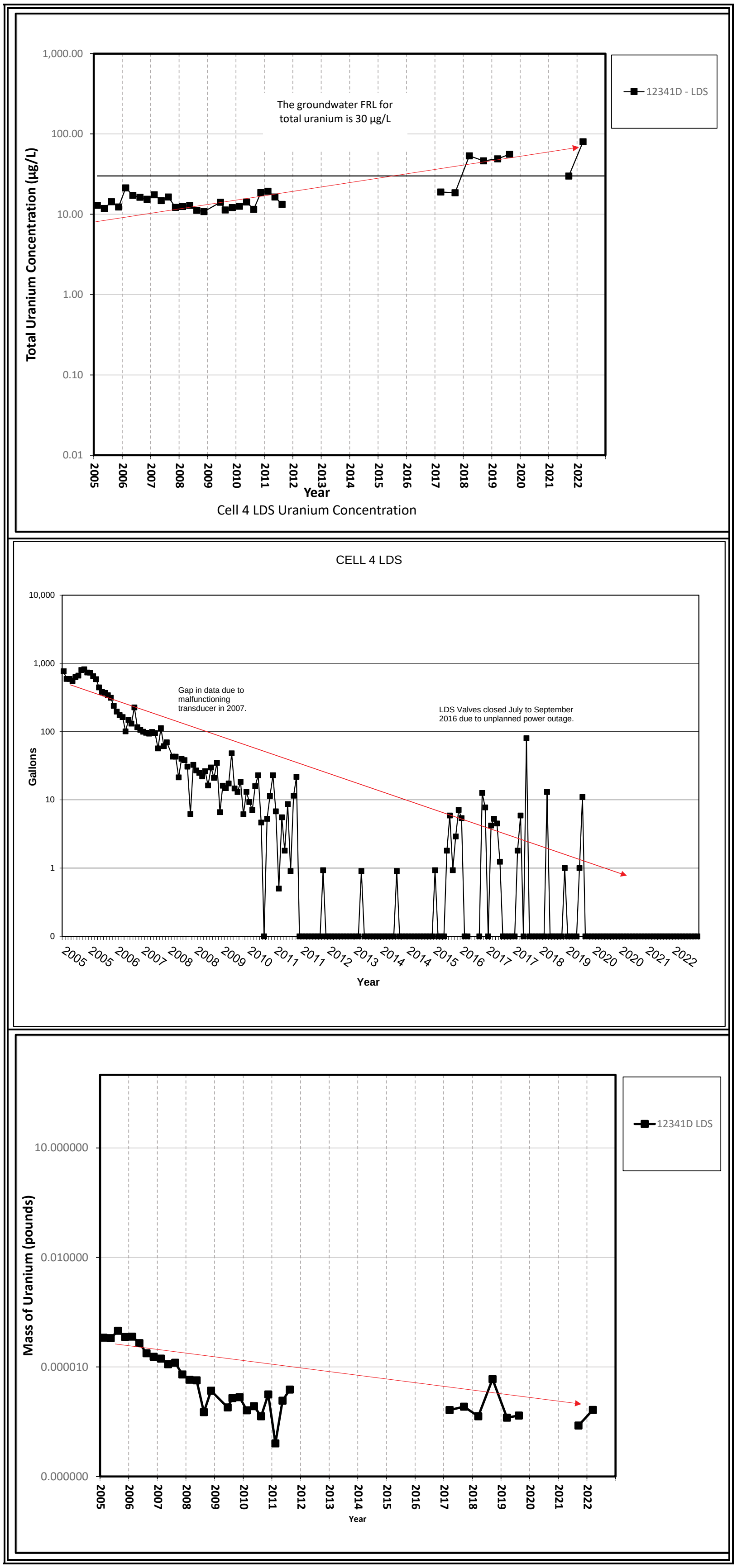

Figure A.5-7. Cell 4 LDS Concentration, Accumulation Rate, and Uranium Mass Comparison

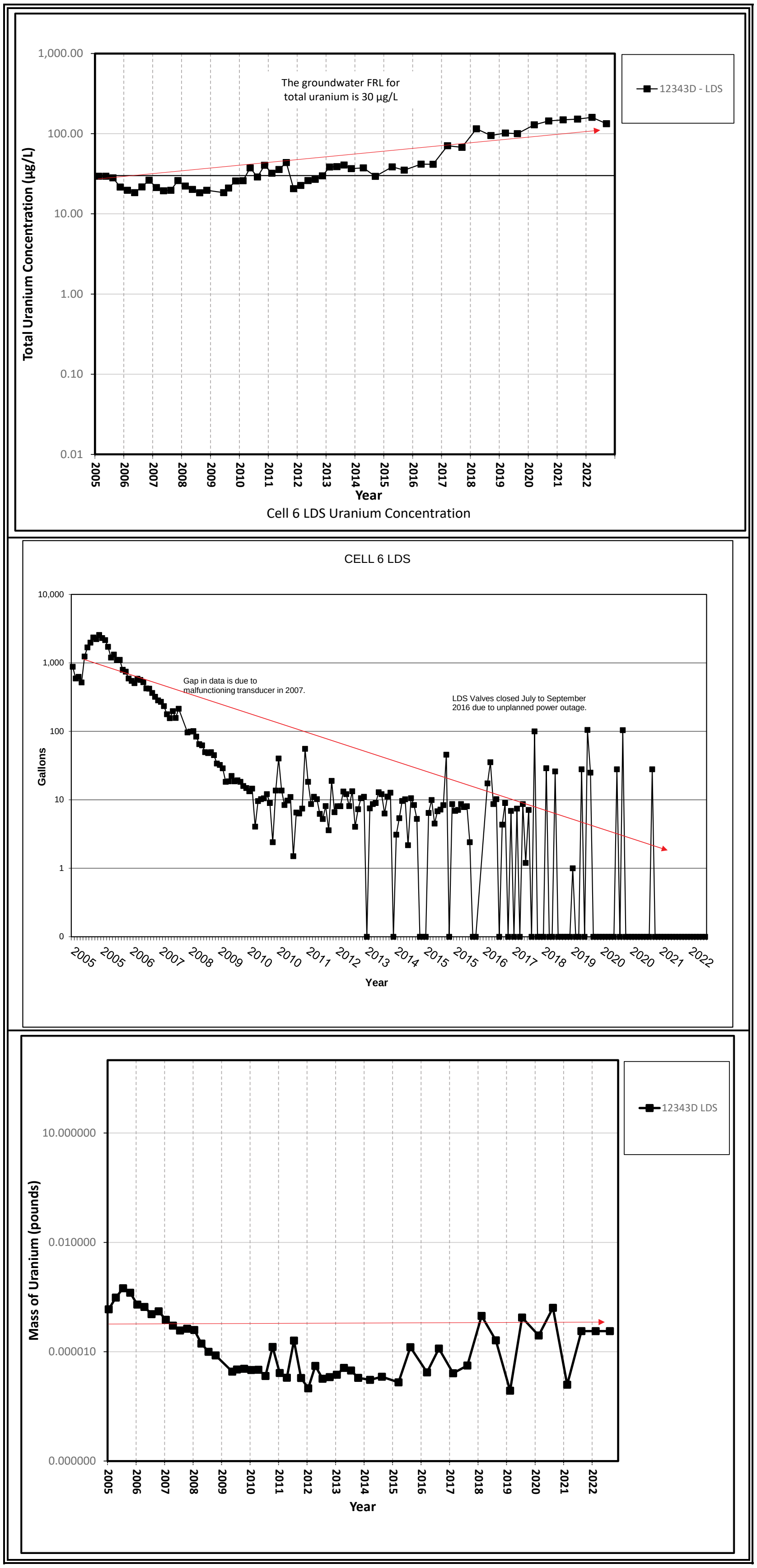

Figure A.5-8. Cell 6 LDS Concentration, Accumulation Rate, and Uranium Mass Comparison

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Subattachment A.5.1

Cell 1

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	upgradient Great Miami Aquifer
GMA-U	downgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about On-Site Disposal Facility (OSDF) Cell 1:

- Semiannual monitoring summary statistics (Table A.5.1-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.1-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.1-2)
- OSDF horizontal till well (HTW) 12338 water yield (Table A.5.1-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.1-3 and A.5.1-4)
- Plots of concentration versus time (Figures A.5.1-5A through A.5.1-17)
- A bivariate plot for total uranium-sodium (Figure A.5.1-18)
- A bivariate plot for sodium-sulfate (Figure A.5.1-19)
- Control chart (Figure A.5.1-20)

A.5.1.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and the LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining whether the OSDF was operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW for each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.1.1.1 LCS and LDS Results

As shown in Table A.5.1-1 and summarized below, two parameters in 2022 (sodium and sulfate) have upward trends in the LCS based on the Mann-Kendall test for trend. No new high concentrations were measured in the LCS of Cell 1 in 2022. The volume of water in the LDS tank of Cell 1 has been insufficient to collect a sample since 2011.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 1

Parameter	LCS 12338C 2022 Trend	LDS 12338D Trend (Year Last Sampled)
Sodium	Up	Up (2011)
Sulfate	Up	Up (2011)

A.5.1.1.2 HTW and Monitoring Well Results

As shown in Table A.5.1-1 and summarized below, five parameters (total uranium, boron, magnesium, nitrate + nitrite as nitrogen, and selenium) have upward trends in the HTW or the GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 1

Parameter	HTW 12338[a]	GMA-U[a,b] 22201	GMA-D[a,b] 22198
Total Uranium	Up	Up	
Boron		Up	
Magnesium		Up	
Nitrate + Nitrite as Nitrogen		Up	
Selenium			Up

Notes:
[a] No entry indicates that the trend was not upward.
[b] GMA-U = upgradient Great Miami Aquifer, GMA-D = downgradient Great Miami Aquifer.

A.5.1.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 1 LCS, LDS, and HTW is provided in Figure A.5.1-18. On the figure, the first sample ever collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. The plot for 2022 shows that the uranium concentrations measured in the LCS were 18.8 micrograms per liter (µg/L) and 10.2 µg/L. These uranium concentrations in the LCS are similar to uranium concentrations measured in the HTW in 2022. In 2022, the uranium concentrations measured in the HTW were 7.12 µg/L and 6.68 µg/L. An additional sodium-sulfate bivariate plot for Cell 1 LCS and HTW is provided in Figure A.5.1-19 for the period April 2014 to August 2022. Because the LDS has been dry since 2011, it is not shown in Figure A.5.1-19. Figure A.5.1-19 shows that the chemical signatures for sodium and sulfate in the LCS and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.1.2 Control Charts

Intrawell control charts employ historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared "not in control" if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits: the decision value (h) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (h) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, a "not in control" condition should be based on the CUSUM (h) limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit (h). This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit (h).

As shown in Table A.5.1-1 in gray and summarized below, one parameter in the HTW and GMA wells of Cell 1 meets the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in one control chart (Figure A.5.1-20). The one control chart for Cell 1 indicates "in control" conditions for lithium.

Parameter	Monitoring Point[a]	Well Number	Assessment	Figure Number
Lithium	GMA-U	22201	In Control	A.5.1-20

[a] GMA-U = upgradient Great Miami Aquifer.

A.5.1.3 Summary and Conclusions

- Two parameters monitored semiannually within the facility in 2022 have an upward concentration trend in the LCS of Cell 1: sodium and sulfate.
- No new high concentrations were measured in the LCS of Cell 1 in 2022. The volume of water in the LDS tank of Cell 1 has been insufficient to collect a sample since 2011.
- Five parameters have an upward concentration trend beneath the facility in the HTW and GMA wells: total uranium, boron, magnesium, nitrate + nitrite as nitrogen, and selenium. Separate and distinct chemical signatures for sodium and sulfate in the LCS and HTW of Cell 1 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 1 (i.e., HTW and GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- One control chart was constructed for Cell 1 parameters for monitoring horizons beneath the facility (HTW and GMA wells). The control chart for Cell 1 indicates “in control” conditions for lithium.

A.5.1.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. “Ground Water Monitoring Program for a Sanitary Landfill Facility,” *Ohio Administrative Code.*

Table A.5.1-1. Summary Statistics for Cell 1

	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12338C	79	80	98.8	ND	159	76.2	37.7	Normal	None (2022)	Detected	206 (Q1-10)
	LDS	12338D	37	37	100	1.5	37.0	10.8	6.8	Undefined	Up (2011)	Detected	
	HTW	12338	76	78	97.4	ND	12.7	8.00	3.44	Undefined	Up (2022)	Detected	
	GMA-U	22201	81	85	95.3	ND	12.4	5.10	3.31	Undefined	Up (2022)	Detected	
	GMA-D	22198	93	93	100	0.574	15.2	4.69	2.50	Undefined	Down (2022)	Detected	
Boron (mg/L)	LCS	12338C	80	81	98.8	ND	1.72	0.977	0.313	Undefined	Down (2022)	Detected	2.80(Q1-99), 2.53(Q3-04), 2.81(Q3-05), 2.33(Q4-07)
	LDS	12338D	37	38	97.4	0.169	0.345	0.243	0.043	Ln Normal	None (2011)	Not Detected	0.001(Q3-00), 0.0296(Q1-98)
	HTW	12338	58	61	95.1	ND	0.271	0.140	0.061	Normal	None (2022)	Detected	
	GMA-U	22201	83	85	97.6	ND	0.158	0.122	0.027	Undefined	Up (2022)	Detected	
	GMA-D	22198	80	84	95.2	ND	0.131	0.055	0.016	Ln Normal	Down (2022)	Detected	
Sodium (mg/L)	LCS	12338C	54	54	100	11.7	22.0	18.5	2.6	Undefined	Up (2022)	Detected	29.3(Q3-05)
	LDS	12338D	9	9	100	335	896	571	216	Normal	Up (2011)	Not Detected	
	HTW	12338	46	46	100	8.72	23.8	13.1	3.7	Undefined	Down (2022)	Detected	
	GMA-U	22201	37	37	100	11.1	65.5	42.3	14.2	Normal	Down (2022)	Detected	
	GMA-D	22198	38	38	100	9.93	18.6	13.3	2.1	Normal	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12338C	66	66	100	707	3,360	1,800	670	Undefined	Up (2022)	Detected	
	LDS	12338D	19	19	100	675	3,500	1,590	780	Ln Normal	Up (2011)	Detected	
	HTW	12338	56	56	100	376	907	620	130	Normal	Down (2022)	Detected	
	GMA-U	22201	61	61	100	91.8	735	255	146	Ln Normal	None (2022)	Detected	1,980(Q4-04)
	GMA-D	22198	61	61	100	101	506	158	90	Undefined	Down (2022)	Detected	
Calcium (mg/L)	GMA-U	22201	30	30	100	140	334	202	42	Ln Normal	Down (2022)	Not Detected	
	GMA-D	22198	30	30	100	133	192	153	14	Normal	Down (2022)	Not Detected	
Lithium (mg/L)	GMA-U	22201	37	37	100	0.00665	0.0153	0.0108	0.0025	Normal	None (2022)	Not Detected	
	GMA-D	22198	37	37	100	0.00624	0.0107	0.00926	0.00081	Undefined	None (2022)	Not Detected	
Magnesium (mg/L)	GMA-U	22201	30	30	100	36.1	82.2	49.5	9.4	Ln Normal	Up (2022)	Not Detected	
	GMA-D	22198	30	30	100	36.2	47.8	40.3	3.0	Normal	Down (2022)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22201	24	30	80.0	ND	1.44	0.270	0.478	Undefined	Up (2022)	Not Detected	
	GMA-D	22198	9	50	18.0	ND	0.55	0.0125	0.174	Undefined	Down (2022)	Not Detected	
Potassium (mg/L)	GMA-U	22201	30	30	100	1.33	3.97	2.85	0.53	Normal	Down (2022)	Not Detected	
	GMA-D	22198	31	31	100	1.15	3.30	1.58	0.39	Undefined	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22201	3	37	8.1	ND	0.0289	0.0049	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22198	5	57	8.8	ND	0.0153	0.0031	0.0029	Undefined	Up (2022)	Detected	
Technetium-99 (pCi/L)	GMA-U	22201	1	34	2.9	ND	3.86	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22198	2	35	5.7	ND	8.30	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22201	37	37	100	594	1600	919	197	Ln Normal	Down (2022)	Not Detected	
	GMA-D	22198	37	37	100	559	805	617	64	Undefined	Down (2022)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22201	37	85	43.5	ND	0.0319	0.0064	0.0068	Undefined	Down (2022)	Not Detected	0.078(Q1-97), 0.308(Q2-00)
	GMA-D	22198	19	84	22.6	ND	0.0235	0.0018	0.0053	Undefined	None (2022)	Detected	0.0473(Q2-98), 0.092(Q2-00), 0.100(Q2-10)

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b]ND = not detected; NA = not applicable

[c]Averages were determined based on the distribution assumption.

[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e]Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f]Trend based on nonparametric Mann-Kendall procedure.

[g]Serial correlation based on Rank Von Neumann test.

[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i]Q = quarter

Table A.5.1-2. OSDF Horizontal Till Well 12338 (Cell 1) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
1999	5,655	9	628
2000	6,000	6	1,000
2001	4,060	4	1,015
2002	4,060	4	1,015
2003	4,325	4	1,081
2004	3,950	4	988
2005	4,250	4	1,063
2006	4,350	4	1,088
2007	3,625	4	906
2008	3,625	4	906
2009	2,750	4	917
2010	3,405	4	851
2011	3,675	4	919
2012	1,850	4	463
2013	1,235	4	309
2014	1,770	2	885
2015	650	2	325
2016	575	2	288
2017	785	2	393
2018	495	2	248
2019	950	2	475
2020	1,050	2	525
2021	1,100	2	550
2022	780	2	390

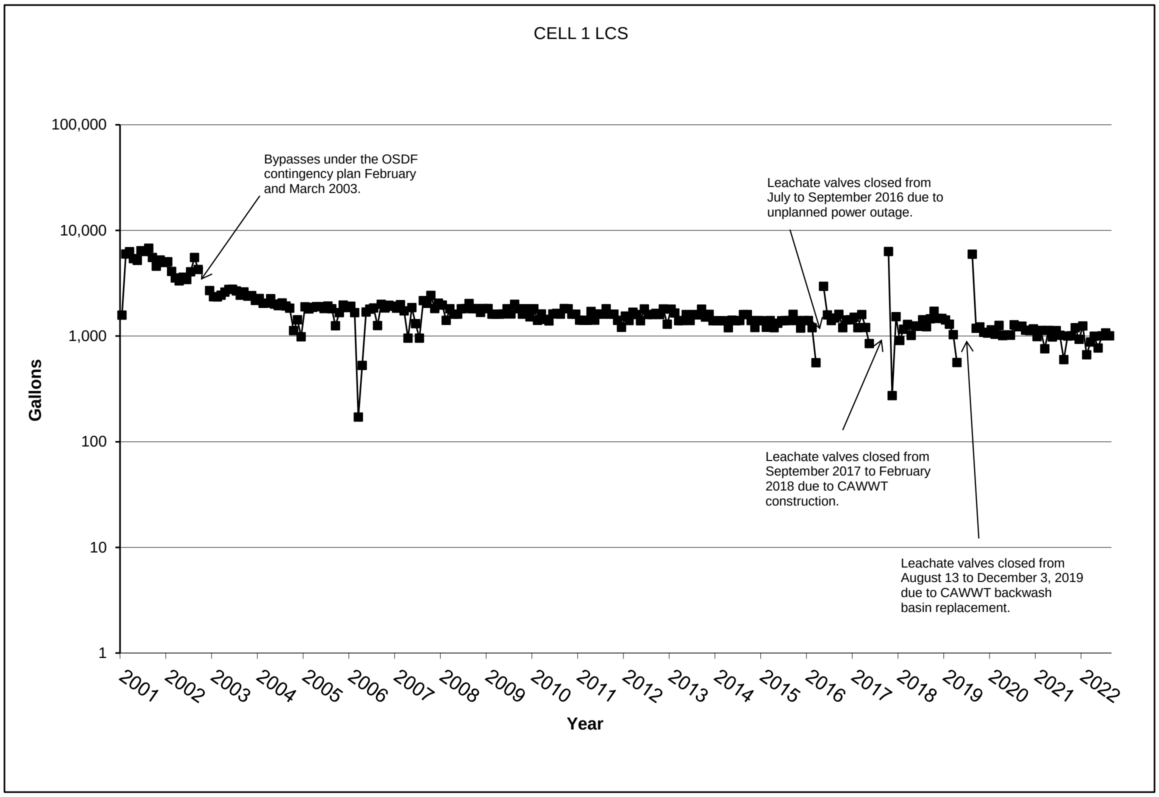

Figure A.5.1-1. Monthly Accumulation Volumes for Cell 1 LCS

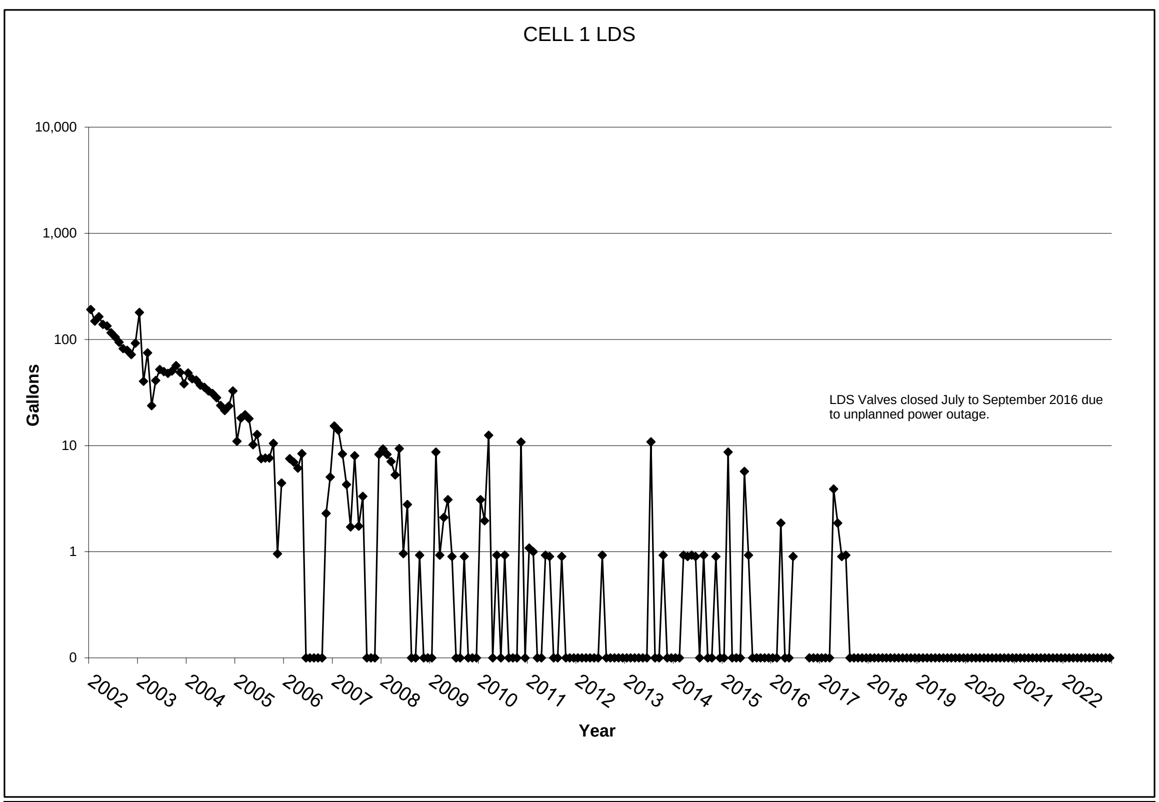

Figure A.5.1-2. Monthly Accumulation Volumes for Cell 1 LDS

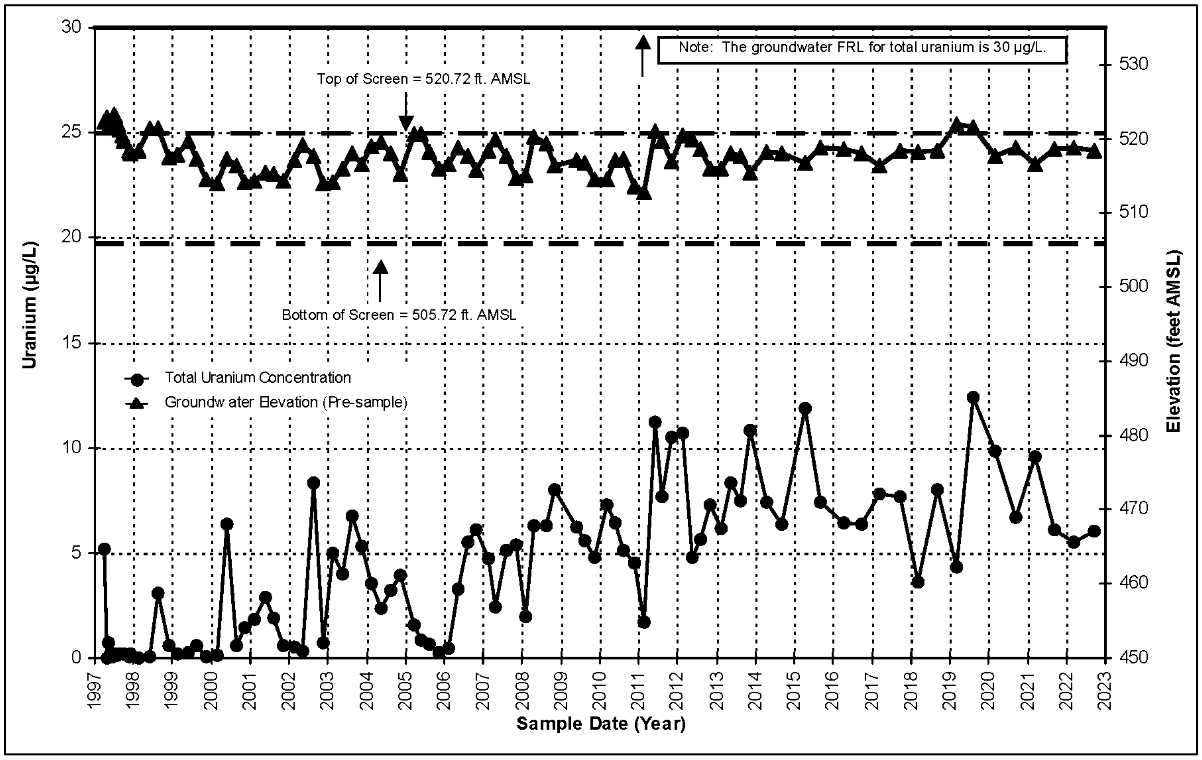

Figure A.5.1-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 1 Upgradient Monitoring Well 22201

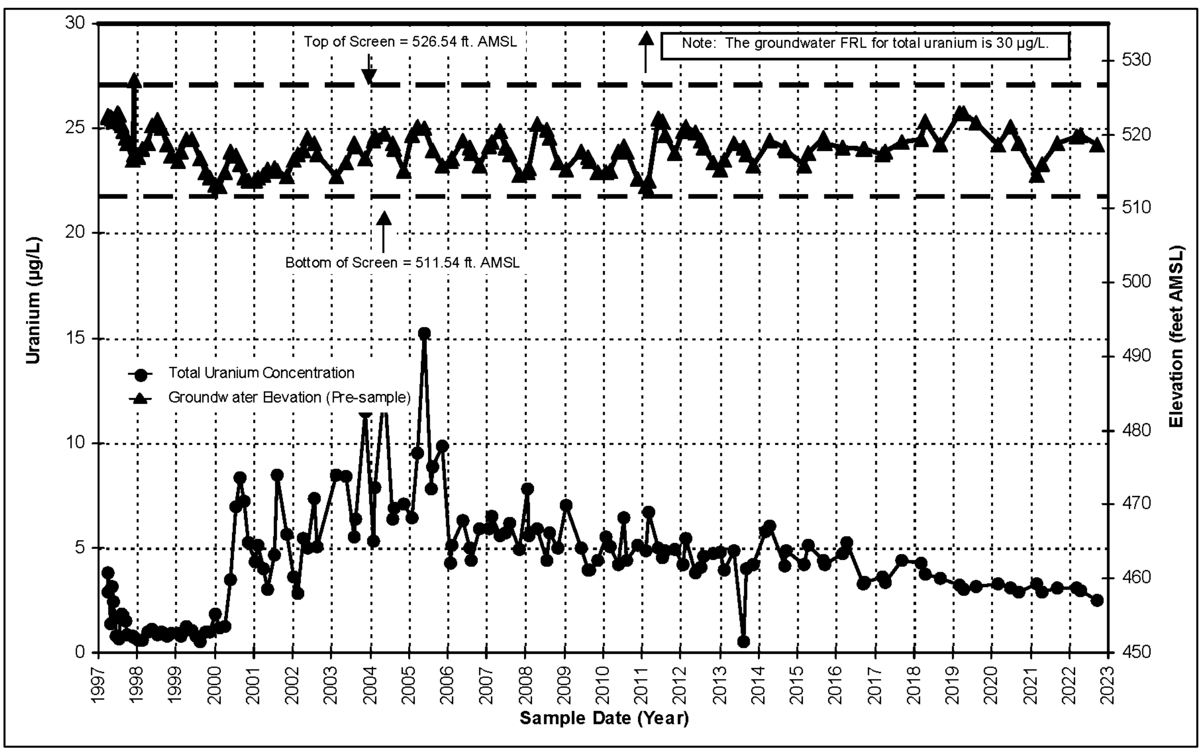

Figure A.5.1-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 1 Downgradient Monitoring Well 22198

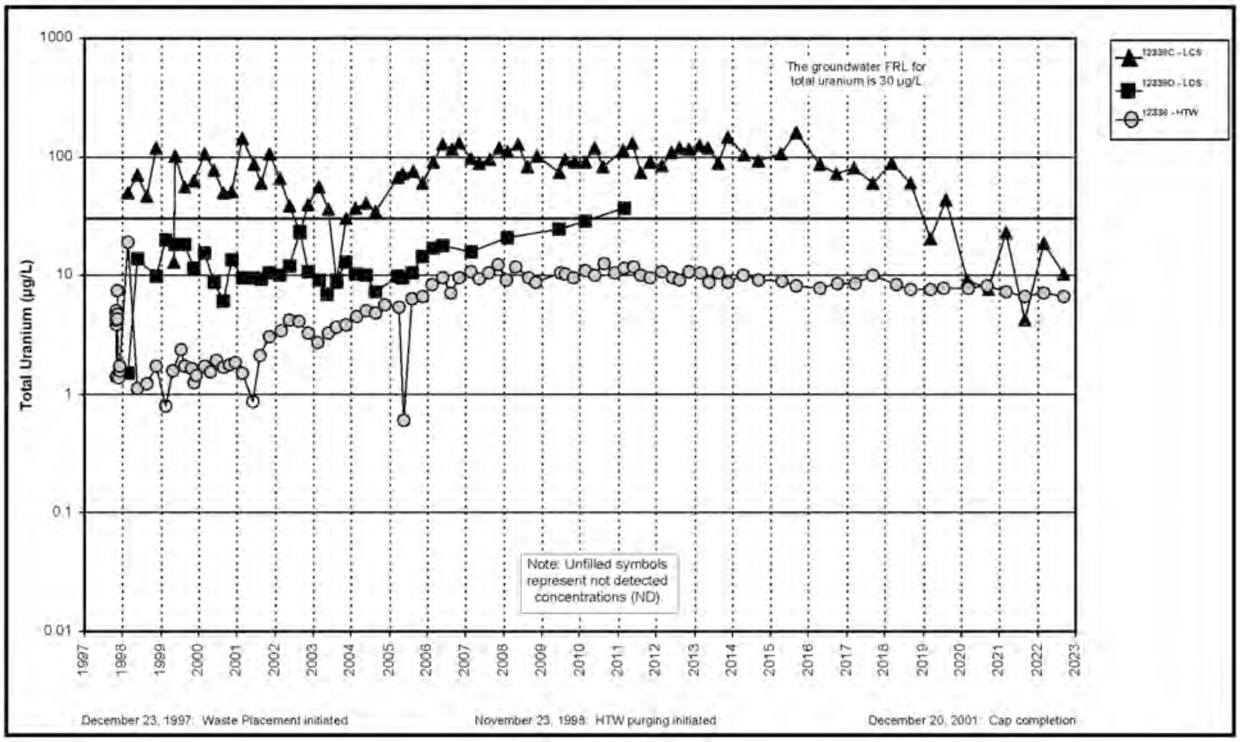

Figure A.5.1-5A. Cell 1 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

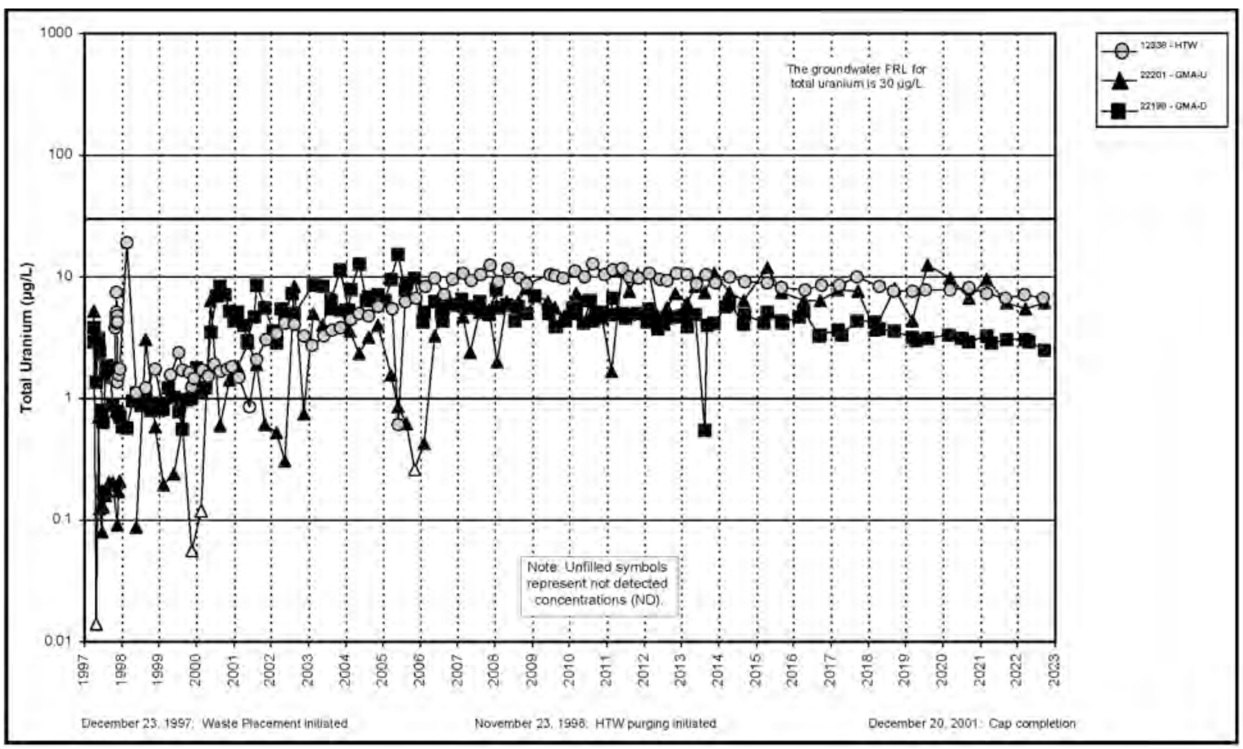

Figure A.5.1-5B. Cell 1 Total Uranium Concentration Versus Time Plot for HTW, upgradient GMA Well, and downgradient GMA Well

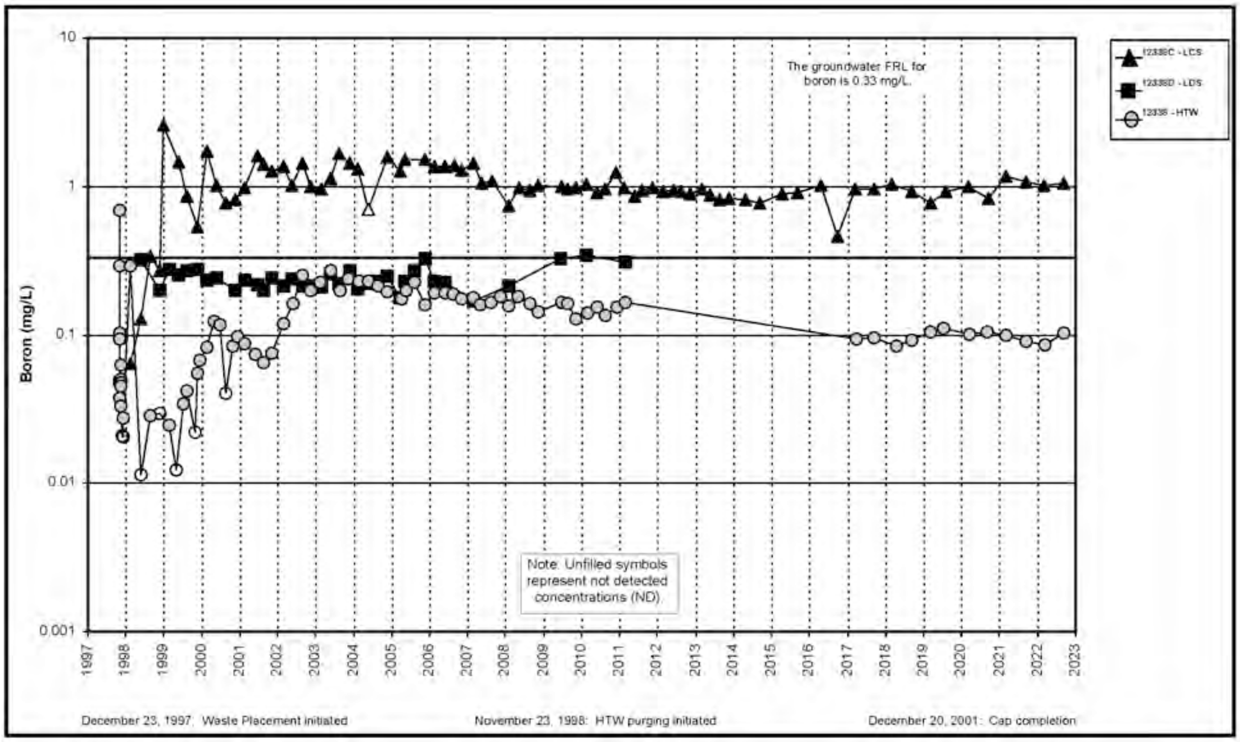

Figure A.5.1-6A. Cell 1 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

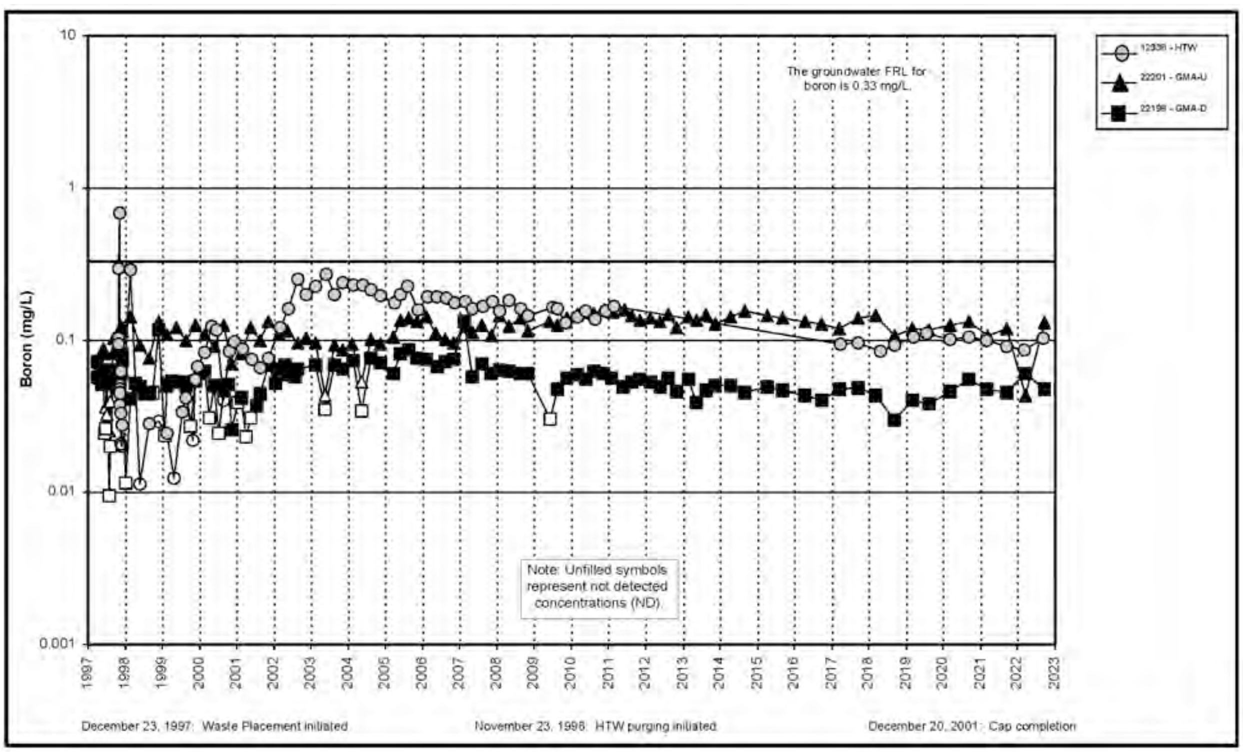

Figure A.5.1-6B. Cell 1 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

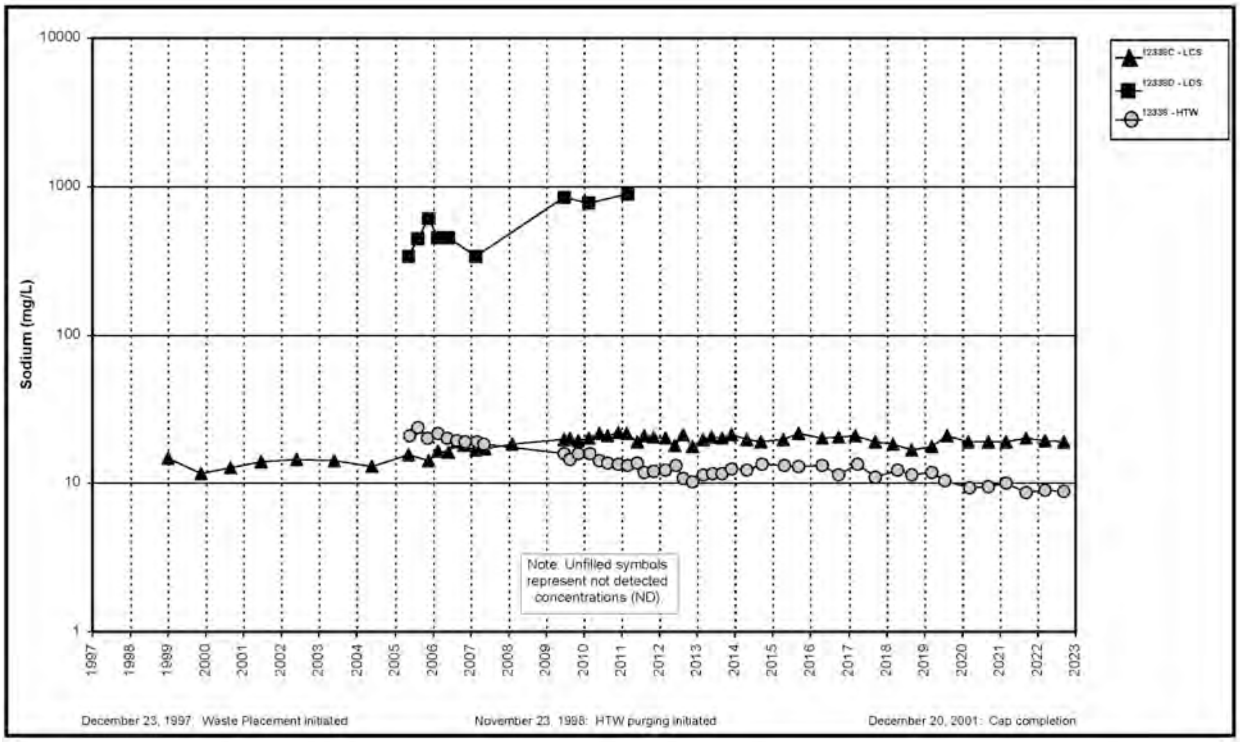

Figure A.5.1-7A. Cell 1 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

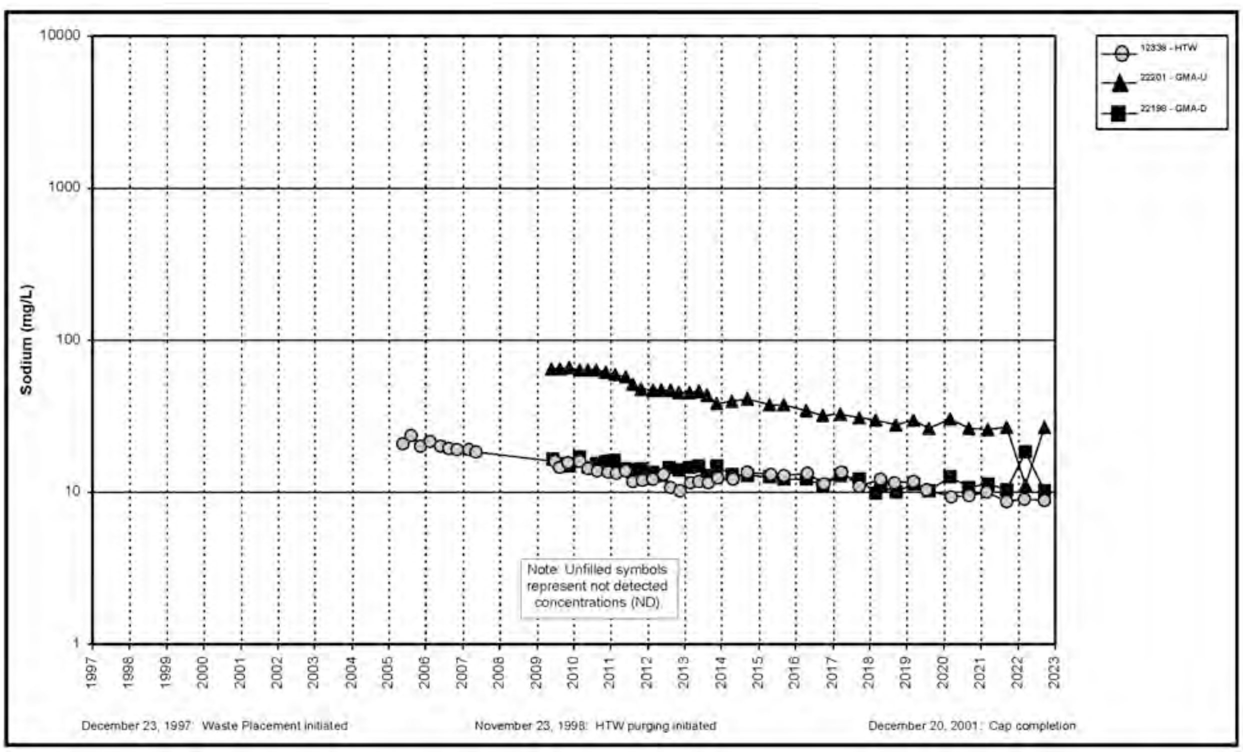

Figure A.5.1-7B. Cell 1 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

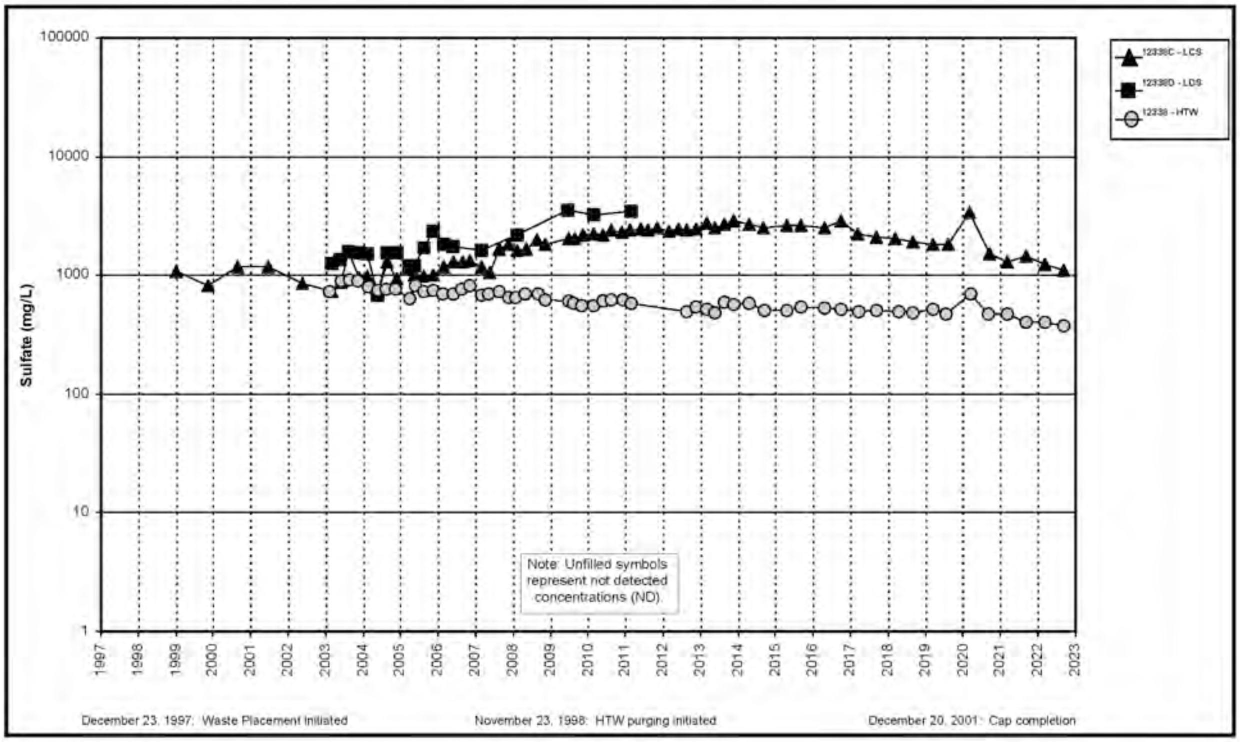

Figure A.5.1-8A. Cell 1 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

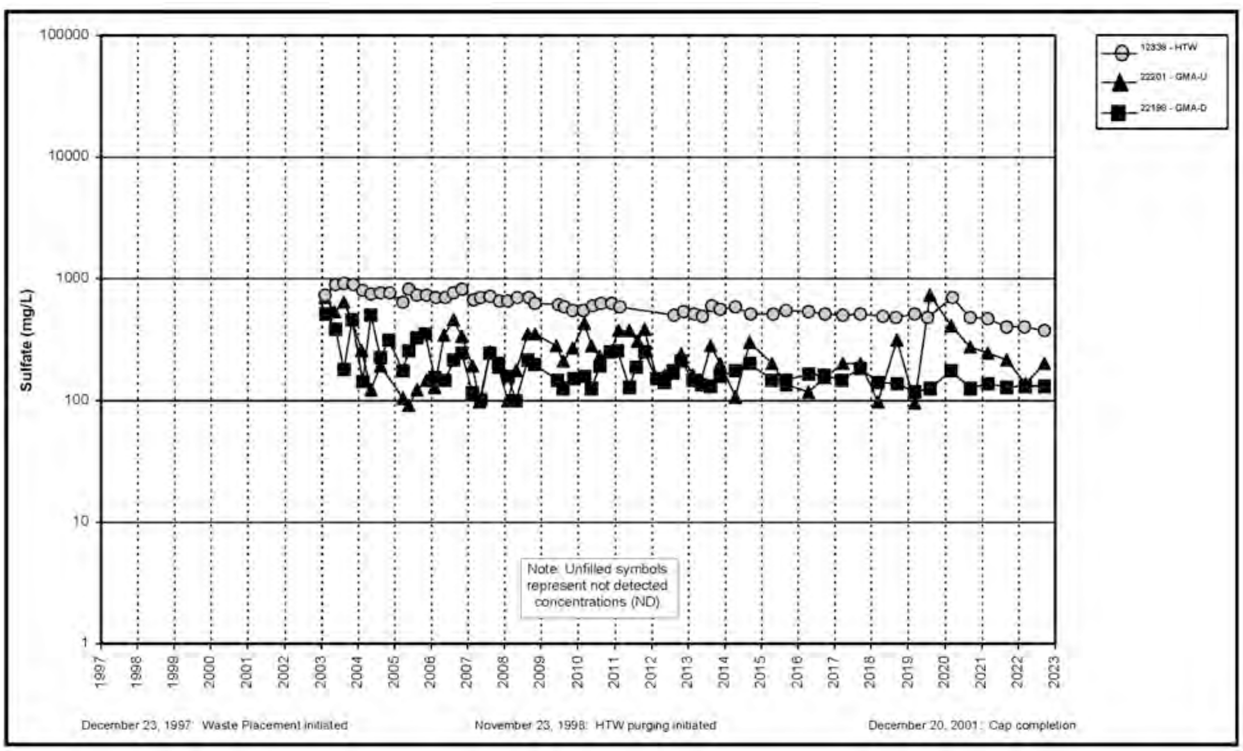

Figure A.5.1-8B. Cell 1 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

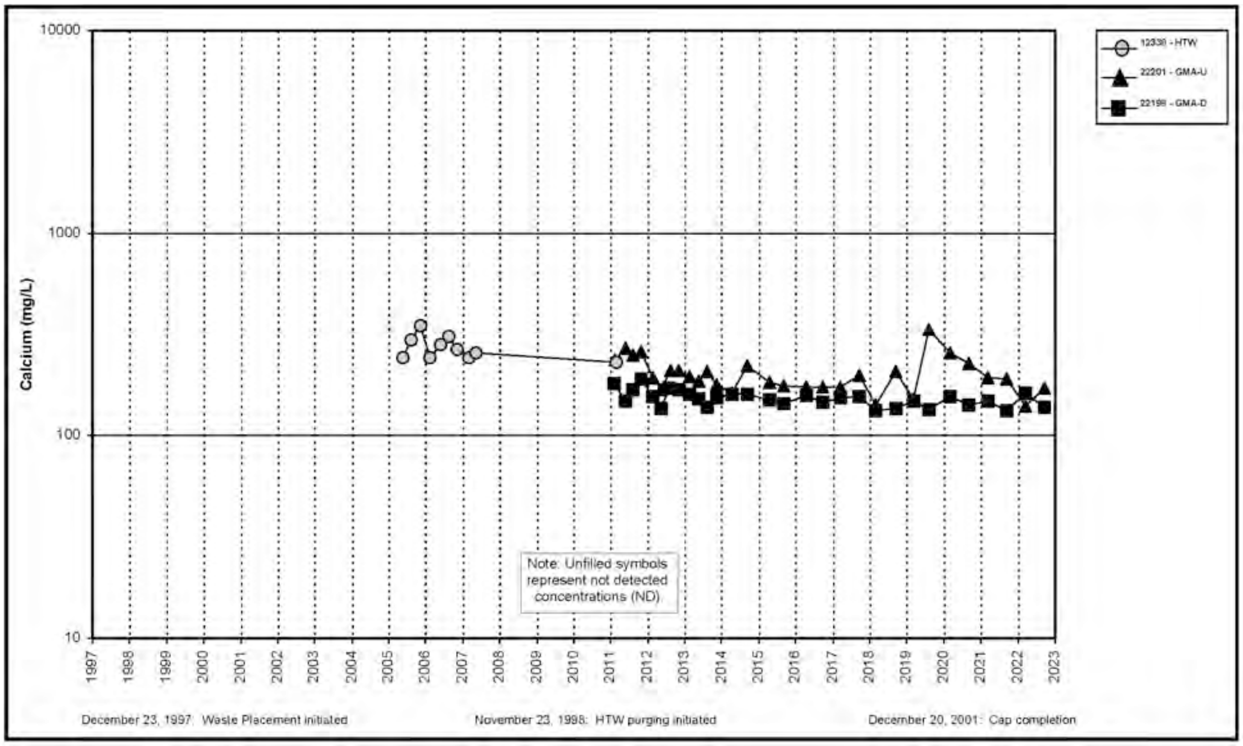

Figure A.5.1-9. Cell 1 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

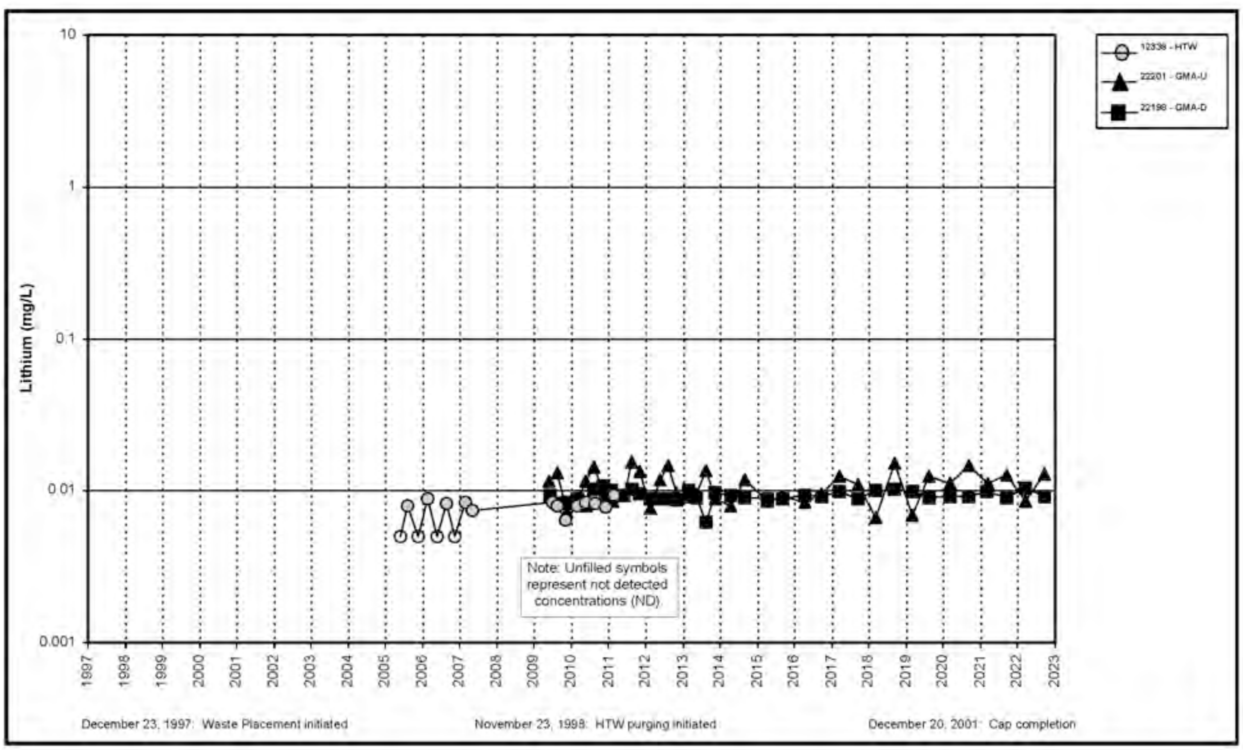

Figure A.5.1-10. Cell 1 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

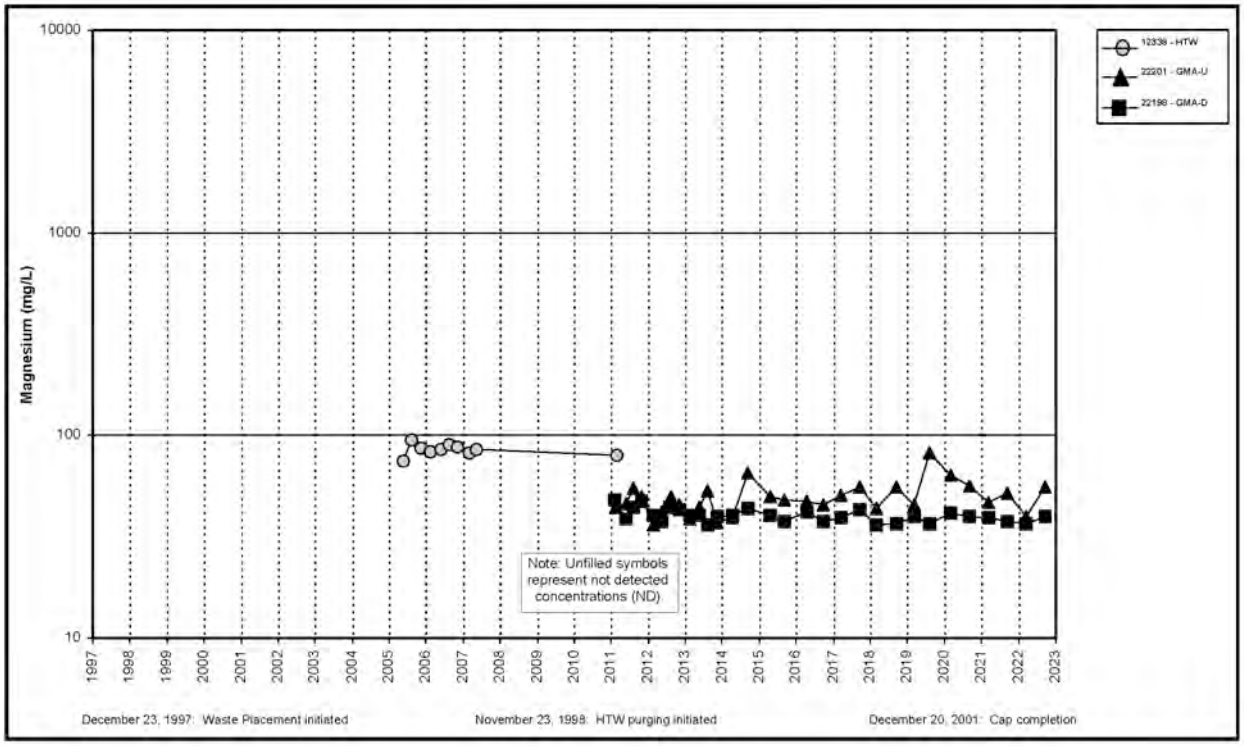

Figure A.5.1-11. Cell 1 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

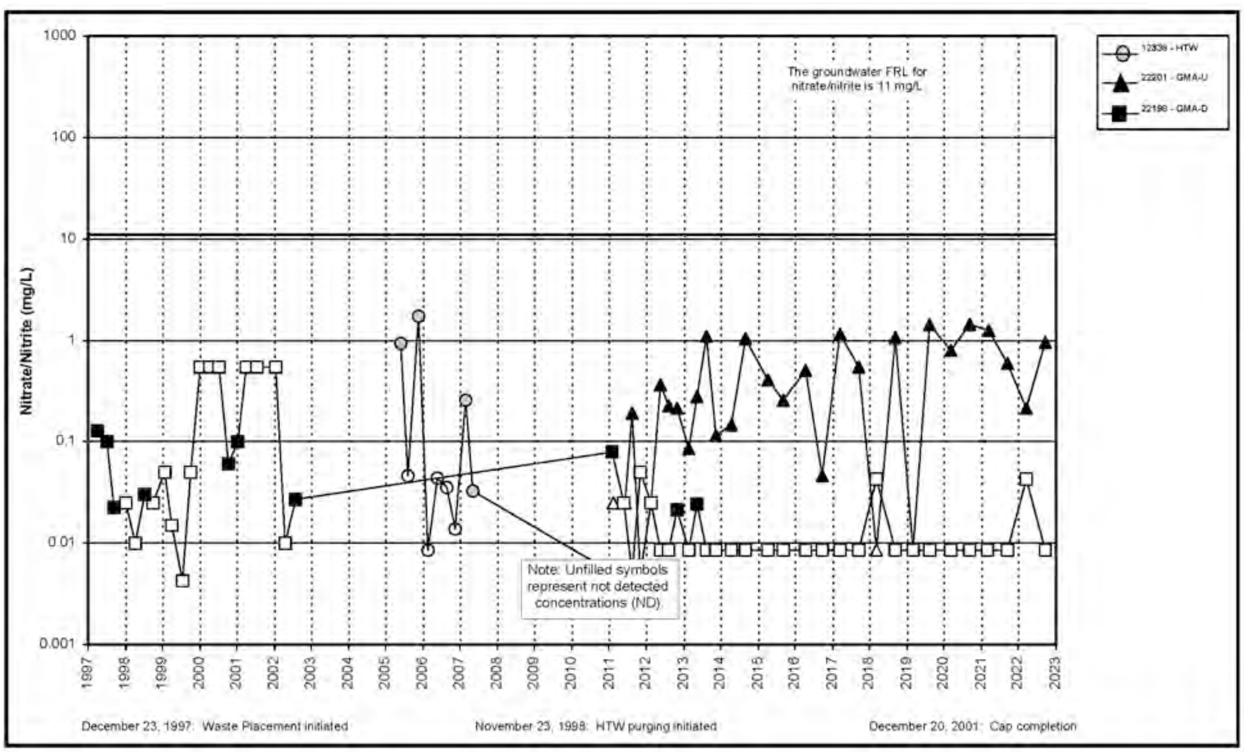

Figure A.5.1-12. Cell 1 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

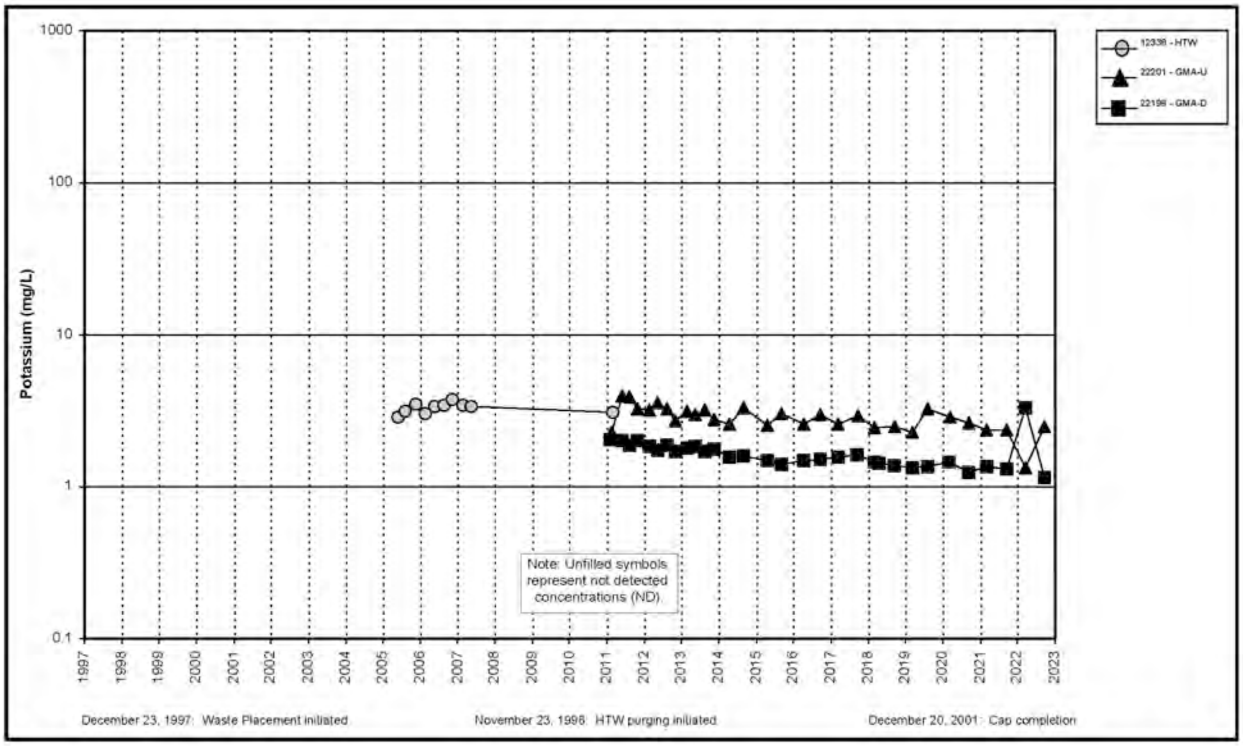

Figure A.5.1-13. Cell 1 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

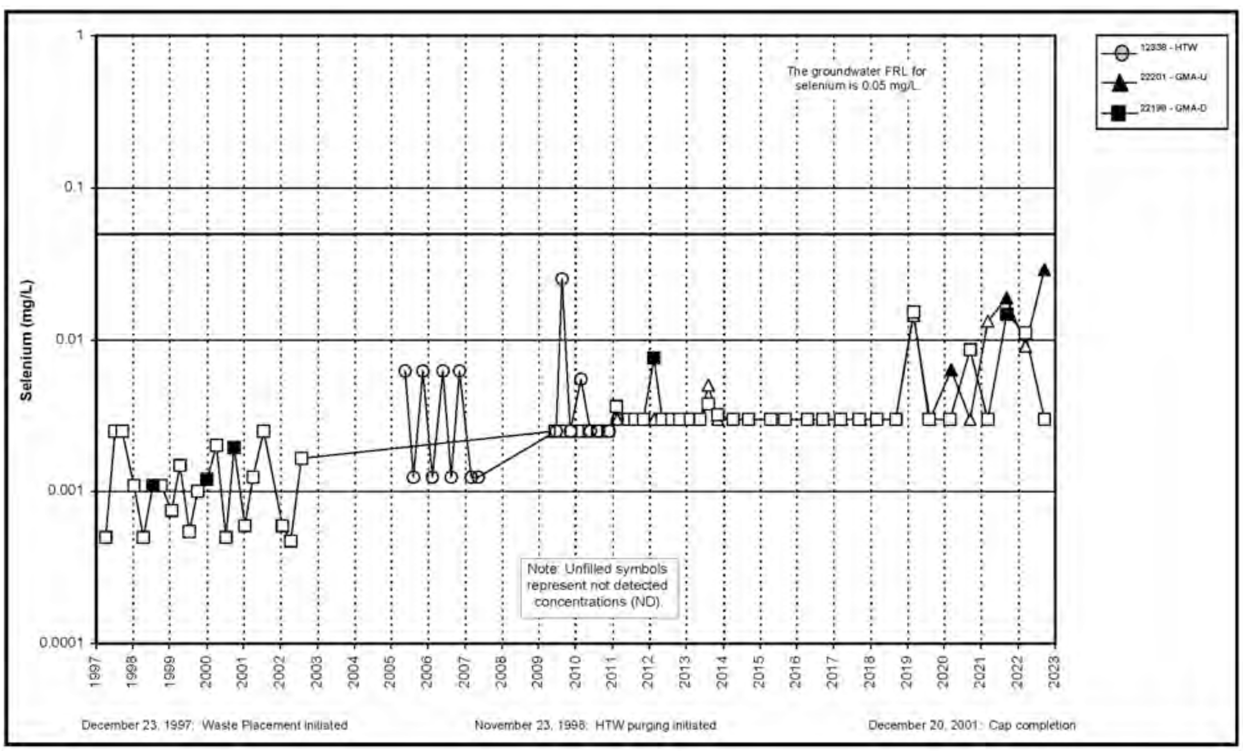

Figure A.5.1-14. Cell 1 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

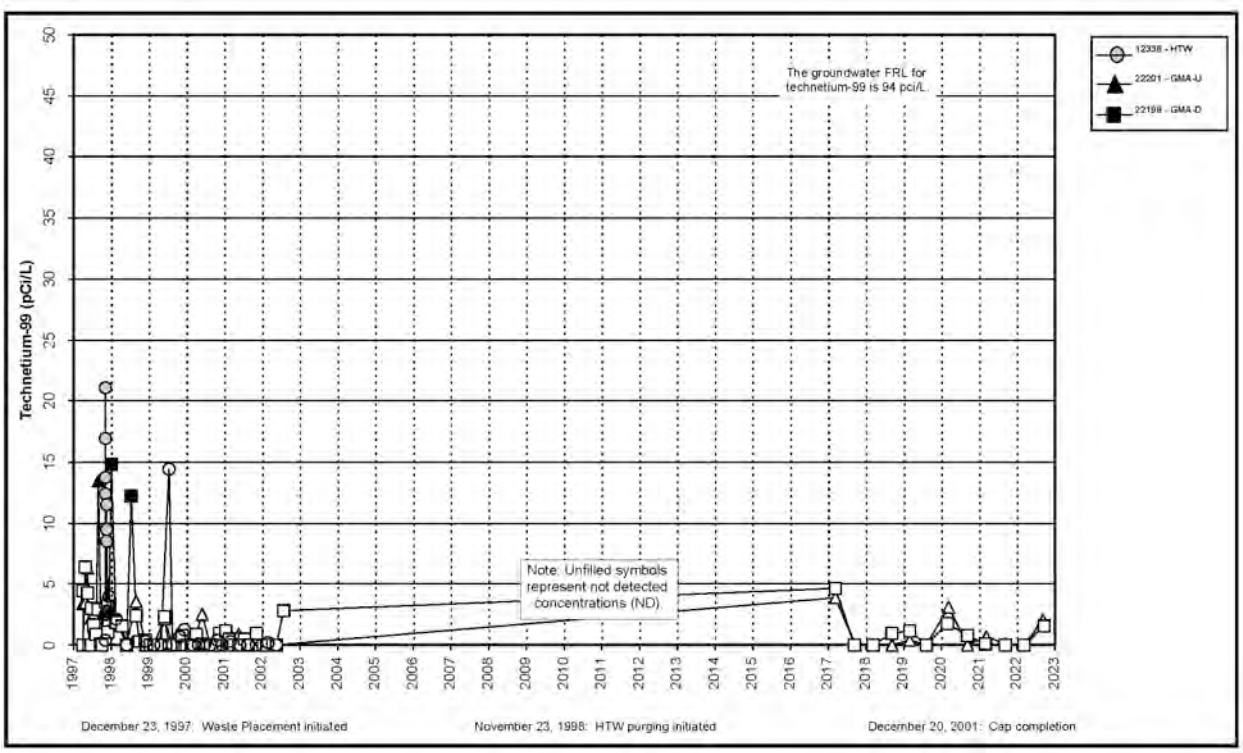

Figure A.5.1-15. Cell 1 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

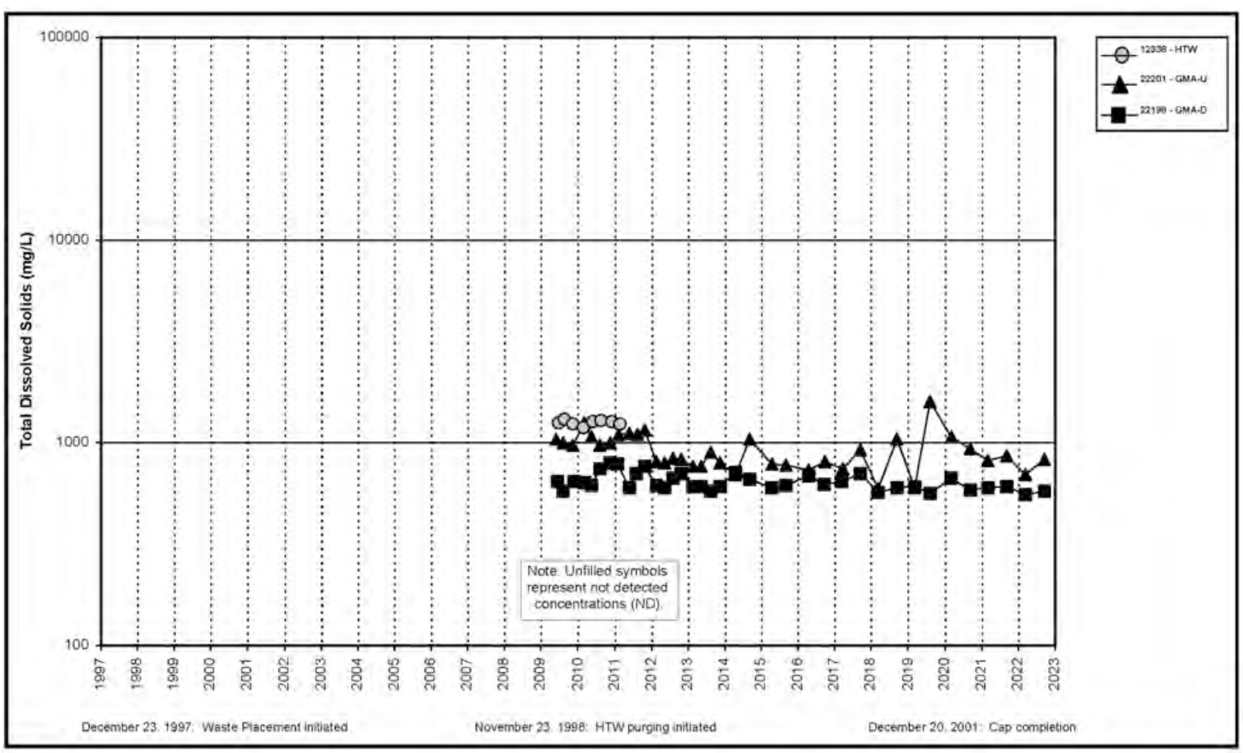

Figure A.5.1-16. Cell 1 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

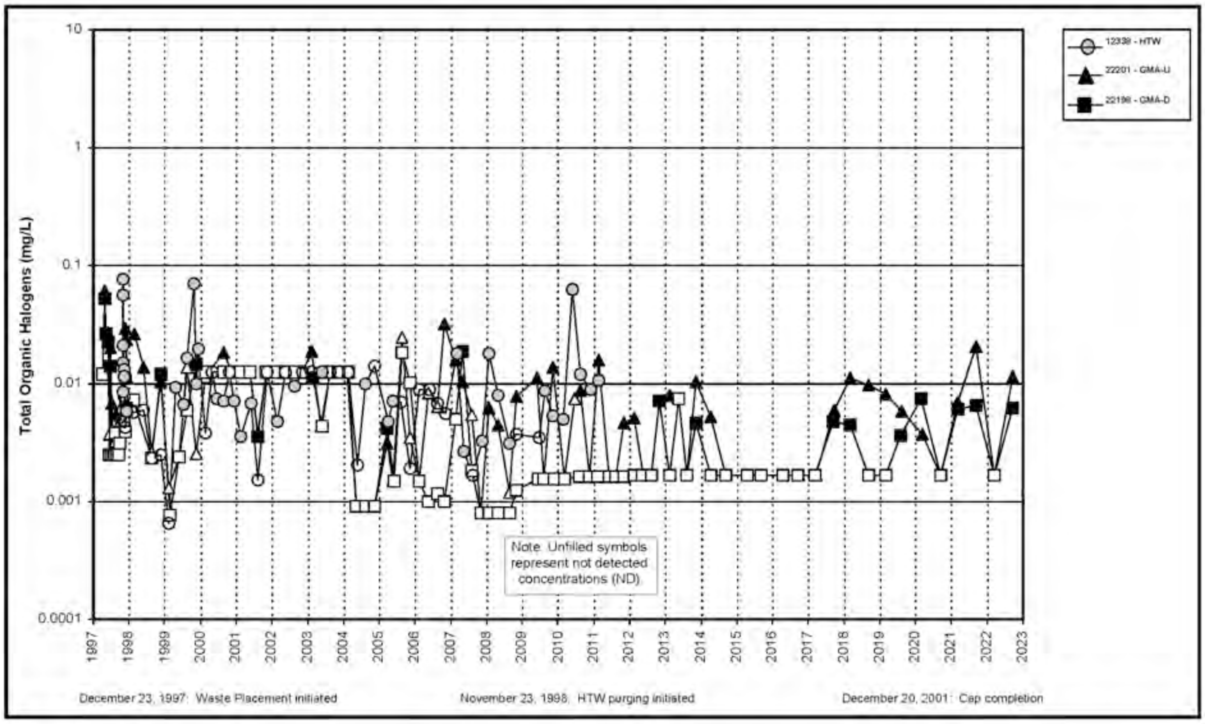

Figure A.5.1-17. Cell 1 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

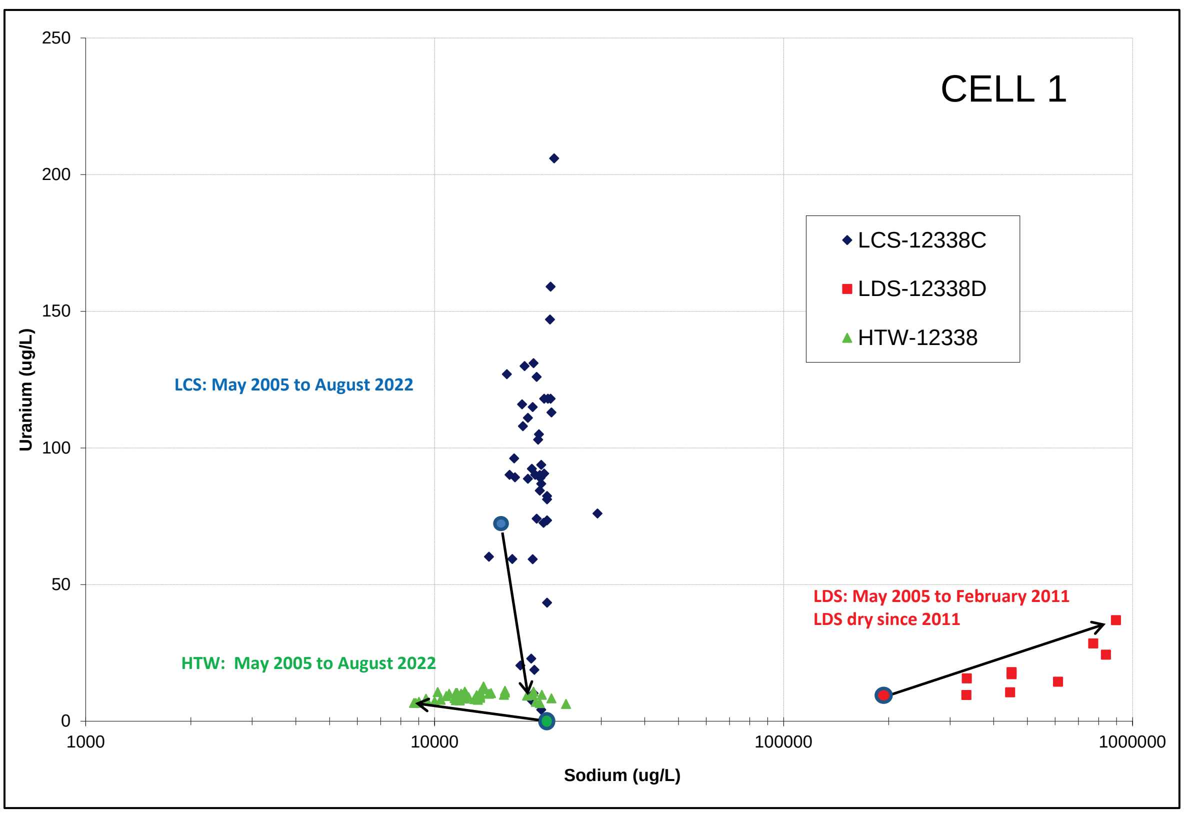

Figure A.5.1-18. Cell 1 Bivariate Plot for Uranium and Sodium

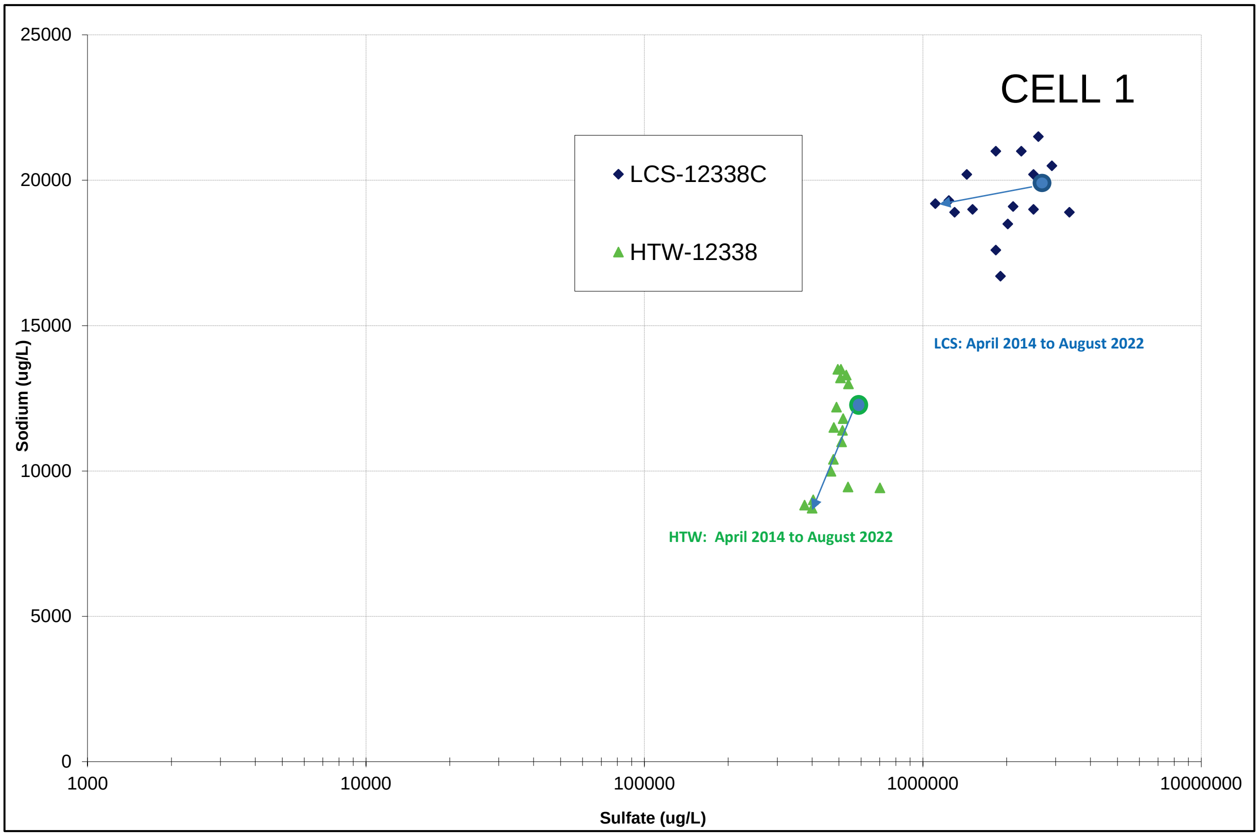

Figure A.5.1-19. Cell 1 Bivariate Plot for Sodium and Sulfate

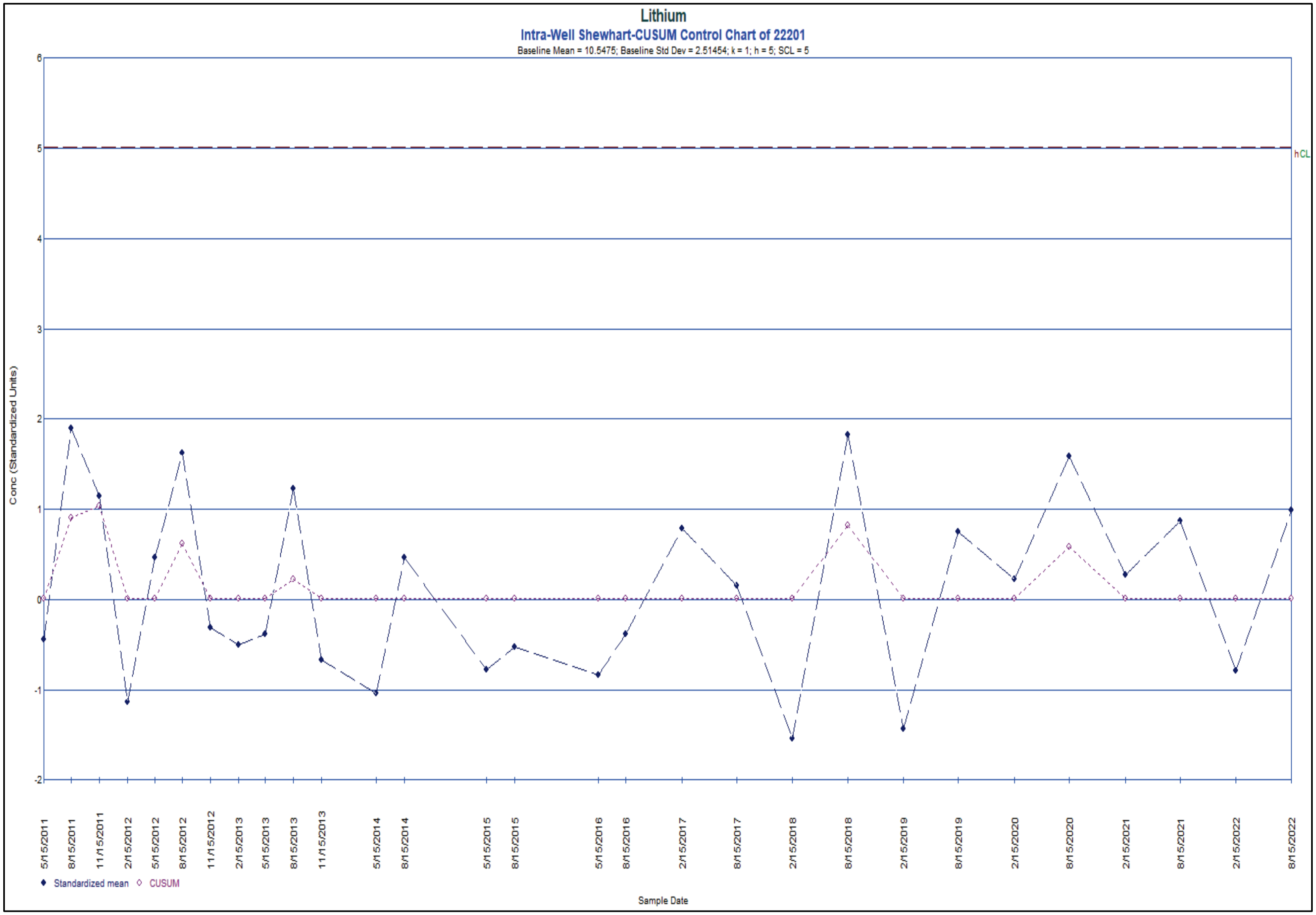

Figure A.5.1-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22201

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Subattachment A.5.2

Cell 2

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about On-Site Disposal Facility (OSDF) Cell 2:

- Semiannual monitoring summary statistics (Table A.5.2-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.2-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.2-2)
- OSDF horizontal till well (HTW) 12339 water yield (Table A.5.2-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.2-3 and A.5.2-4)
- Plots of concentration versus time (Figures A.5.2-5A through A.5.2-17)
- A bivariate plot for uranium-sodium (Figure A.5.2-18)
- Control chart (Figure A.5.2-19)

A.5.2.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining whether the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells: 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW for each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.2.1.1 LCS and LDS Results

As shown in Table A.5.2-1 and summarized below, four parameters (total uranium, boron, sodium, and sulfate) in 2022 have upward trends in the LCS or LDS based on the Mann-Kendall test for trend. No new high concentrations were measured in the LCS of Cell 2 in 2022. The volume of water in the LDS tank of Cell 2 has been insufficient to collect a sample since 2013.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 2[a]

Parameter	LCS 12339C 2022 Trend	LDS 12339D Trend (Year Last Sampled)[a]
Total Uranium	Up	
Boron	Up	Up (2013)
Sodium	Up	Up (2013)
Sulfate	Up	Up (2013)

[a] No entry indicates that the trend was not up.

A.5.2.1.2 HTW and Monitoring Well Results

As shown in Table A.5.2-1 and summarized below, five parameters in 2022 (total uranium, boron, lithium, potassium, and selenium) have upward trends in the HTW or the GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 2

Parameter	HTW 12339[a]	GMA-U[b] 22200	GMA-D[a,b] 22199
Total Uranium	Up	Up	
Boron	Up	Up	Up
Lithium		Up	Up
Potassium		Up	
Selenium		Up	

[a] No entry indicates that the trend was not up.
[b] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer.

A.5.2.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 2 LCS, LDS, and HTW is provided in Figure A.5.2-18. On the figure, the first sample ever collected from the monitoring horizon are circled. An arrow leads from the first sample to the location of the most recent sample. The plot shows that the chemical signatures for uranium and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.2.2 Control Charts

Intrawell control charts use historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared “not in control” if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (*h*) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.2-1 in gray and summarized below, one parameter in the HTW or GMA wells of Cell 2 meet the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in one control chart (Figure A.5.2-19). The control chart for Cell 2 indicates “in control” conditions for total dissolved solids.

Parameter	Monitoring Point[a]	Well Number	Assessment	Figure Number
Total Dissolved Solids	GMA-D	22199	In Control	A.5.2-19

[a] GMA-D = downgradient Great Miami Aquifer.

A.5.2.3 Summary and Conclusions

- Four parameters monitored semiannually have an upward concentration trend in the LCS of Cell 2 in 2022: total uranium, boron, sodium, and sulfate. No new high concentrations were measured in the LCS of Cell 2 in 2022.
- The volume of water in the LDS tank of Cell 2 has been insufficient to collect a sample since 2013.

- Five parameters monitored semiannually in 2022 have an upward concentration trend in the HTW or GMA wells of Cell 2: total uranium, boron, lithium, potassium, and selenium. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 2 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 2 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- One control chart was constructed for Cell 2 parameters. The control chart exhibits “in control” conditions.

A.5.2.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. “Ground Water Monitoring Program for a Sanitary Landfill Facility,” *Ohio Administrative Code.*

Table A.5.2-1. Summary Statistics for Cell 2

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12339C	76	76	100	4.51	686	127	114	Ln Normal	Up (2022)	Detected	
	LDS	12339D	35	35	100	4.08	71.0	14.5	13.2	Undefined	None (2013)	Detected	
	HTW	12339	77	78	98.7	ND	36.9	11.4	6.6	Undefined	Up (2022)	Detected	
	GMA-U	22200	64	84	76.2	ND	4.69	0.303	0.586	Undefined	Up (2022)	Not Detected	
	GMA-D	22199	88	93	94.6	ND	12.1	0.608	2.15	Undefined	Down (2022)	Not Detected	
Boron (mg/L)	LCS	12339C	77	77	100	0.207	4.78	2.60	1.09	Ln Normal	Up (2022)	Detected	
	LDS	12339D	35	35	100	0.289	2.22	0.422	0.371	Undefined	Up (2013)	Detected	
	HTW	12339	58	61	95.1	ND	0.213	0.102	0.052	Undefined	Up (2022)	Detected	
	GMA-U	22200	72	84	85.7	ND	0.105	0.0586	0.0238	Undefined	Up (2022)	Detected	
	GMA-D	22199	75	84	89.3	ND	0.0899	0.0499	0.0147	Normal	Up (2022)	Detected	
Sodium (mg/L)	LCS	12339C	53	53	100	3.32	42.8	20.4	6.5	Undefined	Up (2022)	Detected	
	LDS	12339D	10	10	100	664	2,450	1,230	540	Normal	Up (2013)	Detected	
	HTW	12339	46	46	100	29.5	119	43.8	23.4	Undefined	Down (2022)	Detected	
	GMA-U	22200	37	37	100	20.4	32.9	26.4	3.4	Normal	Down (2022)	Detected	
	GMA-D	22199	38	38	100	7.94	19.5	13.1	3.4	Normal	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12339C	65	65	100	155	1,960	1,590	310	Undefined	Up (2022)	Detected	
	LDS	12339D	18	18	100	2,290	13,000	4,800	2,680	Ln Normal	Up (2013)	Detected	
	HTW	12339	56	56	100	344	850	549	128	Normal	Down (2022)	Detected	
	GMA-U	22200	61	61	100	61.1	434	130	93	Undefined	Down (2022)	Not Detected	
	GMA-D	22199	61	61	100	101	540	165	85	Undefined	None (2022)	Not Detected	
Calcium (mg/L)	GMA-U	22200	30	30	100	115	205	136	23	Undefined	Down (2022)	Not Detected	
	GMA-D	22199	30	30	100	125	193	144	18	Undefined	None (2022)	Not Detected	
Lithium (mg/L)	GMA-U	22200	37	37	100	0.00345	0.00587	0.00439	0.00055	Ln Normal	Up (2022)	Not Detected	
	GMA-D	22199	37	37	100	0.00650	0.0101	0.00771	0.00076	Normal	Up (2022)	Detected	
Magnesium (mg/L)	GMA-U	22200	30	30	100	33.1	54.9	39.6	4.8	Undefined	None (2022)	Not Detected	
	GMA-D	22199	30	30	100	36.2	54.8	40.5	4.5	Undefined	None (2022)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22200	4	30	13.3	ND	0.200	0.0085	0.0407	Undefined	None (2022)	Not Detected	
	GMA-D	22199	2	30	6.7	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22200	30	30	100	1.50	2.14	1.87	0.19	Normal	Up (2022)	Detected	
	GMA-D	22199	31	31	100	1.23	1.75	1.45	0.12	Normal	Down (2022)	Not Detected	
Selenium (mg/L)	GMA-U	22200	6	37	16.2	ND	0.0134	0.0030	0.0031	Undefined	Up (2022)	Detected	
	GMA-D	22199	1	37	2.7	ND	0.0186	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22200	0	33	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22199	0	33	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22200	37	37	100	497	857	611	95	Undefined	None (2022)	Not Detected	
	GMA-D	22199	37	37	100	520	820	648	72	Normal	None (2022)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22200	32	84	38.1	ND	0.177	0.00453	0.0241	Undefined	Down (2022)	Detected	
	GMA-D	22199	19	84	22.6	ND	0.0775	0.00250	0.0116	Undefined	Down (2022)	Detected	

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.
Note 2: Data used in this table have been standardized to quarterly.
[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer
[b]ND = not detected; NA = not applicable
[c]Averages were determined based on the distribution assumption.
[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.
[e]Data distribution based on the Shapiro-Wilk statistic.
Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.
Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the normal assumption.
Undefined: Normal and Ln Normal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.
[f]Trend based on nonparametric Mann-Kendall procedure.
[g]Serial correlation based on Rank Von Neumann test.
[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).
[i]Q = quarter

Table A.5.2-2. OSDF Horizontal Till Well 12339 (Cell 2) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
1999	5,725	7	818
2000	5,750	6	958
2001	3,395	4	849
2002	3,625	4	906
2003	3,370	4	843
2004	3,220	4	805
2005	3,275	4	819
2006	3,175	4	1,088
2007	3,325	4	831
2008	3,050	4	763
2009	2,400	4	800
2010	3,275	4	819
2011	3,200	4	800
2012	3,110	4	778
2013	2,945	4	736
2014	1,605	2	803
2015	1,450	2	725
2016	1,535	2	768
2017	1,600	2	800
2018	1,605	2	803
2019	1,580	2	790
2020	1,645	2	823
2021	1,610	2	805
2022	1,620	2	810

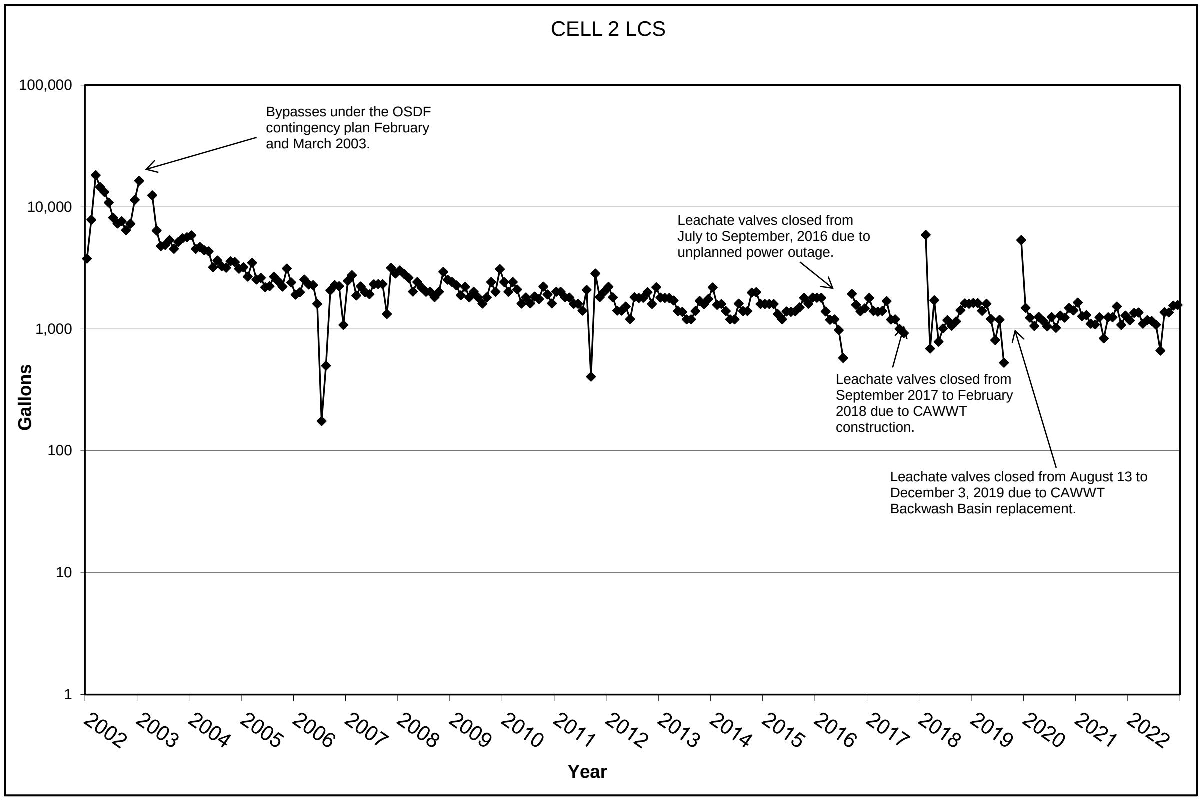

Figure A.5.2-1. Monthly Accumulation Volumes for Cell 2 LCS

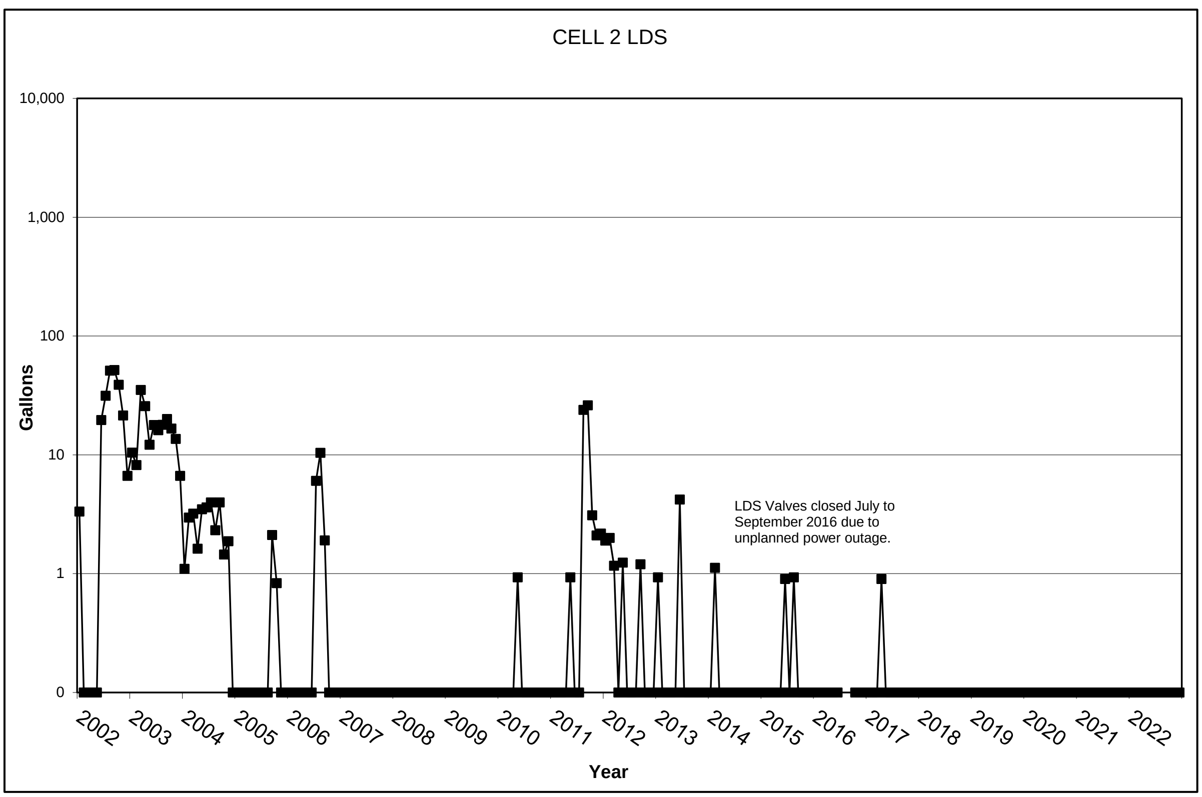

Figure A.5.2-2. Monthly Accumulation Volumes for Cell 2 LDS

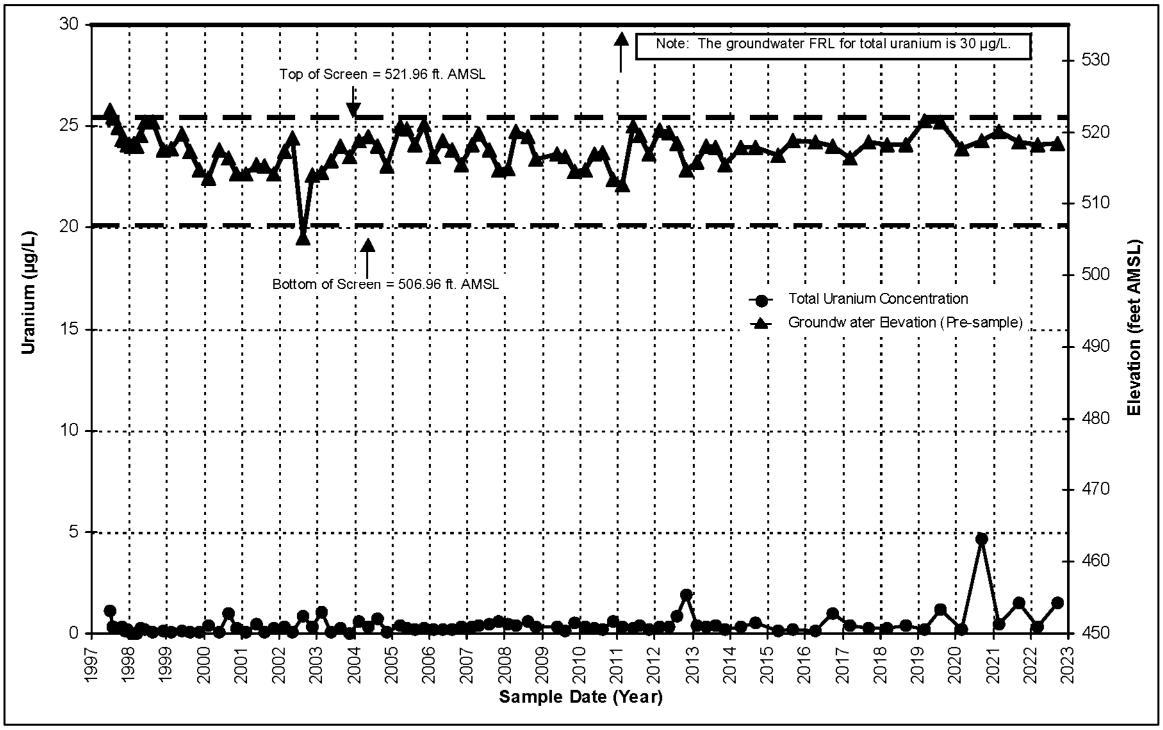

Figure A.5.2-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 2 Upgradient Monitoring Well 22200

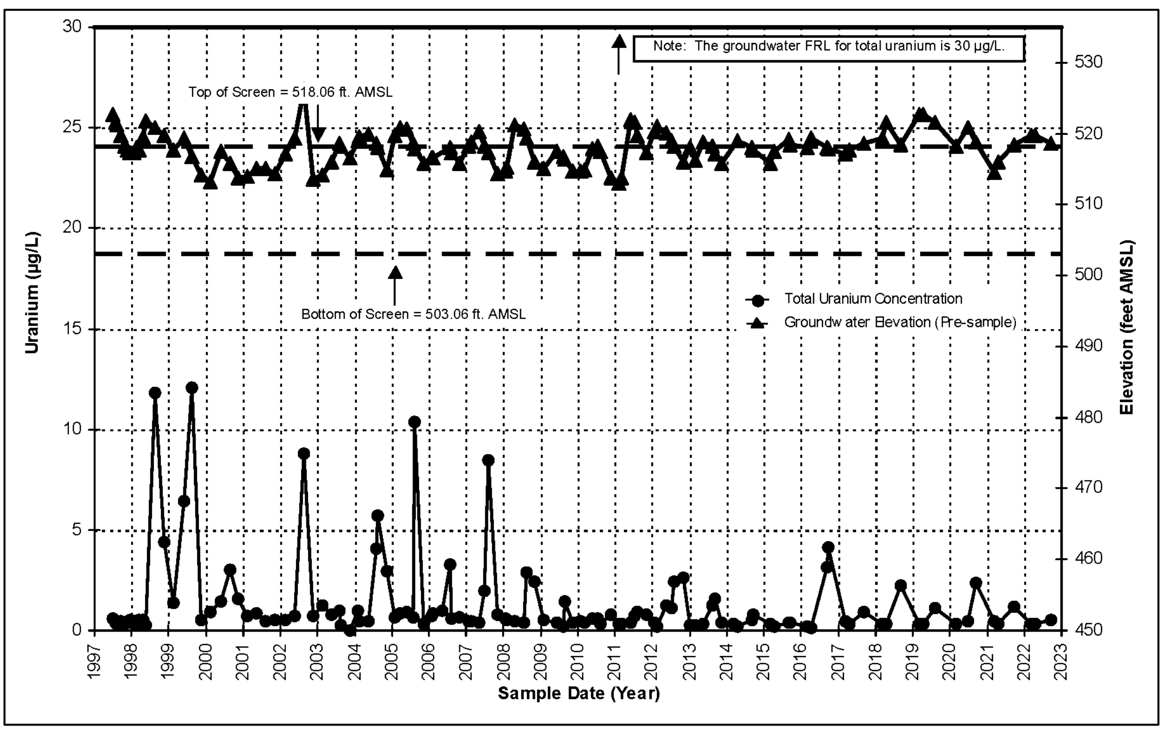

Figure A.5.2-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 2 Downgradient Monitoring Well 22199

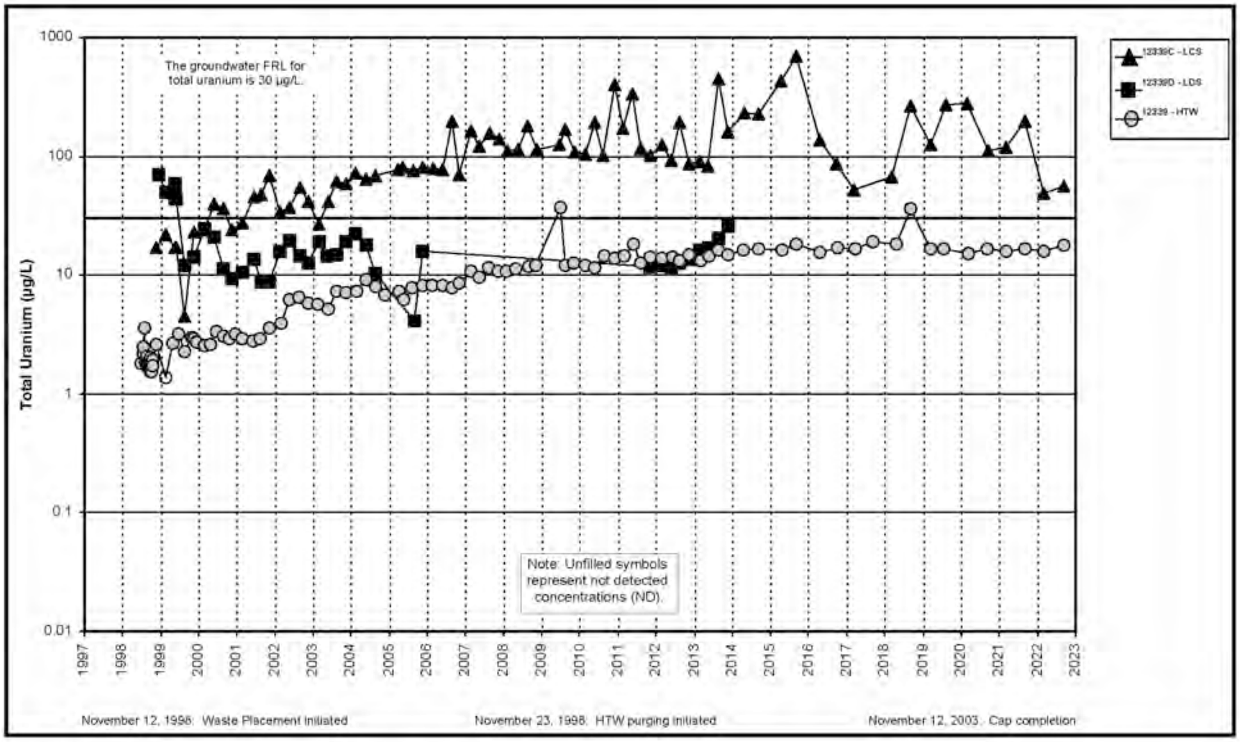

Figure A.5.2-5A. Cell 2 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

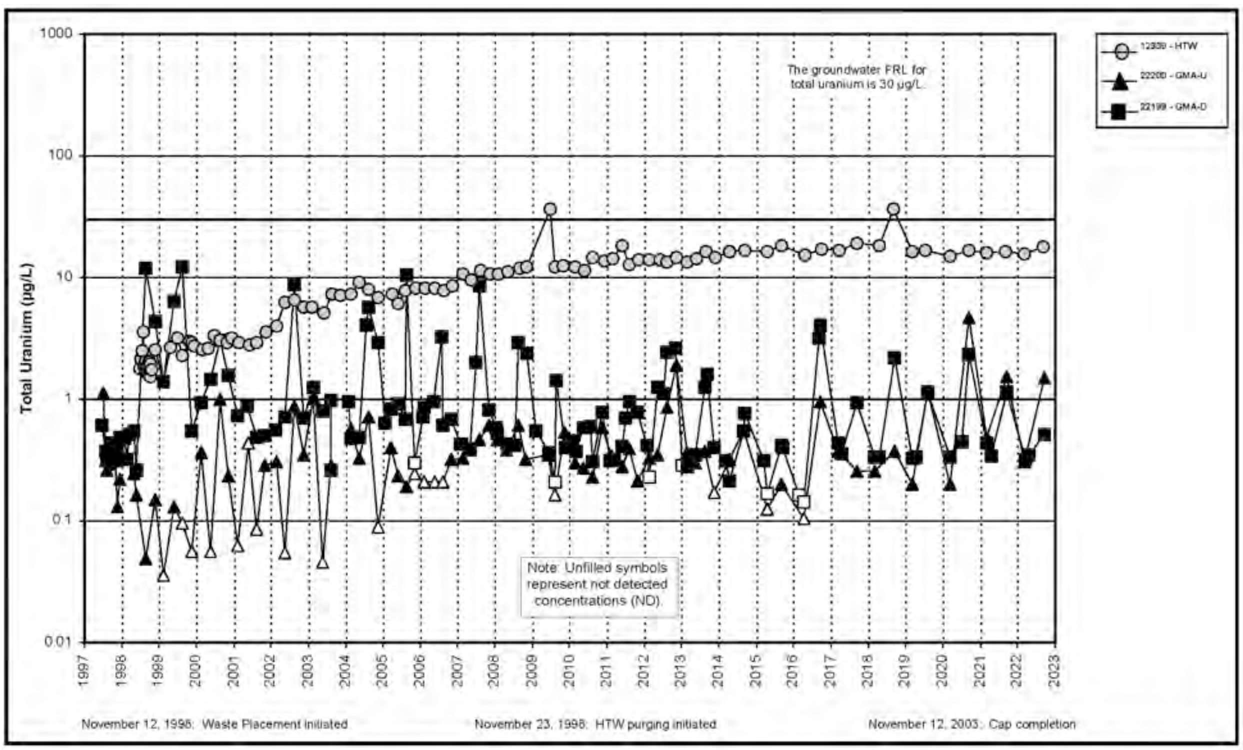

Figure A.5.2-5B. Cell 2 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

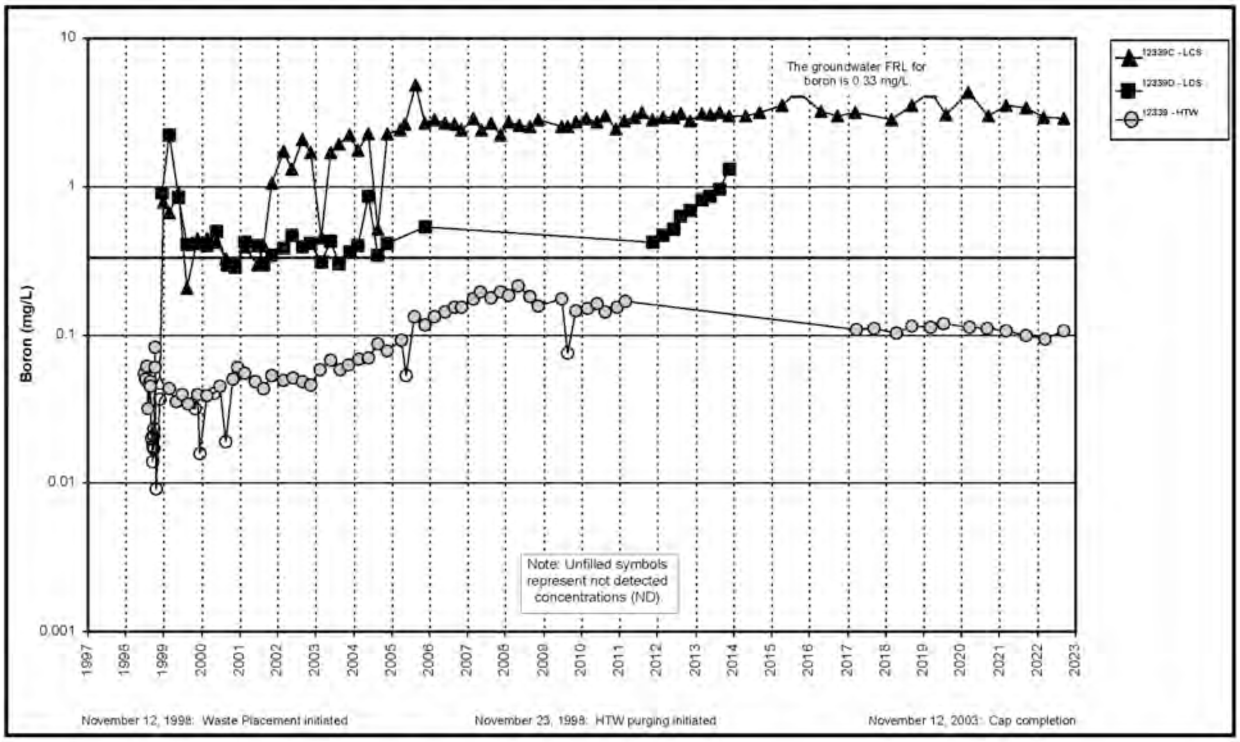

Figure A.5.2-6A. Cell 2 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

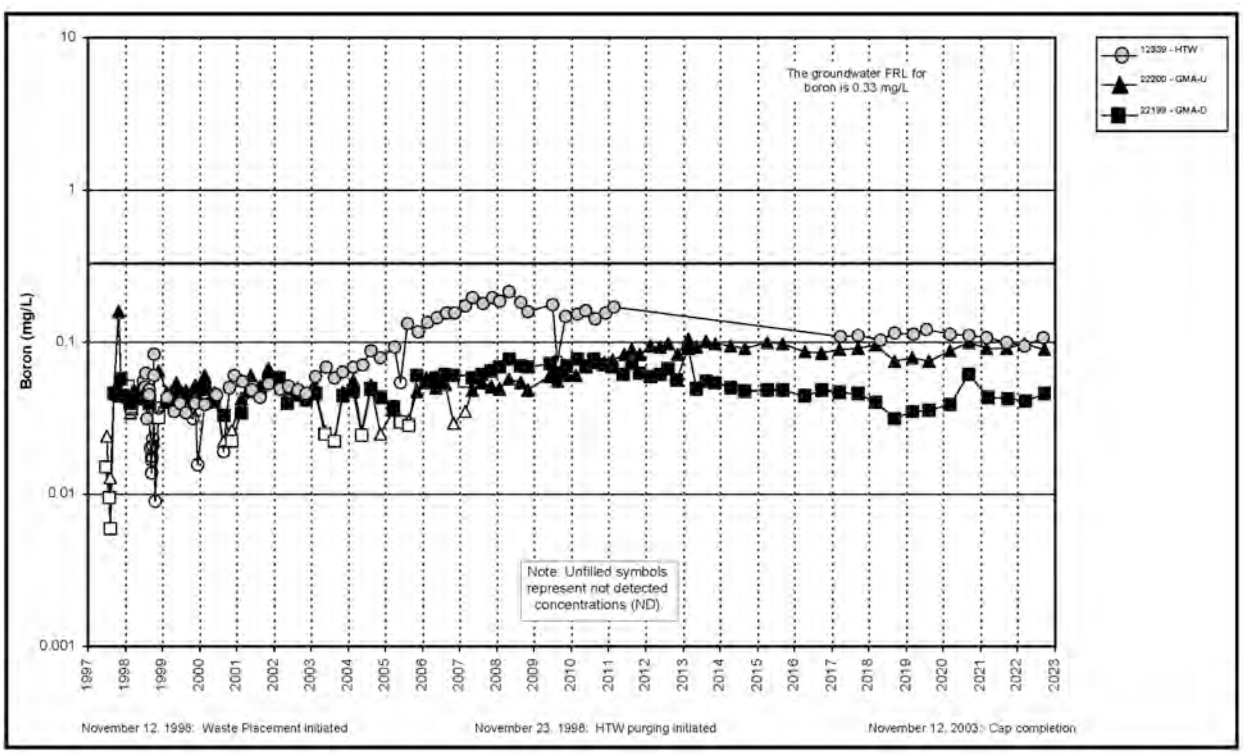

Figure A.5.2-6B. Cell 2 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

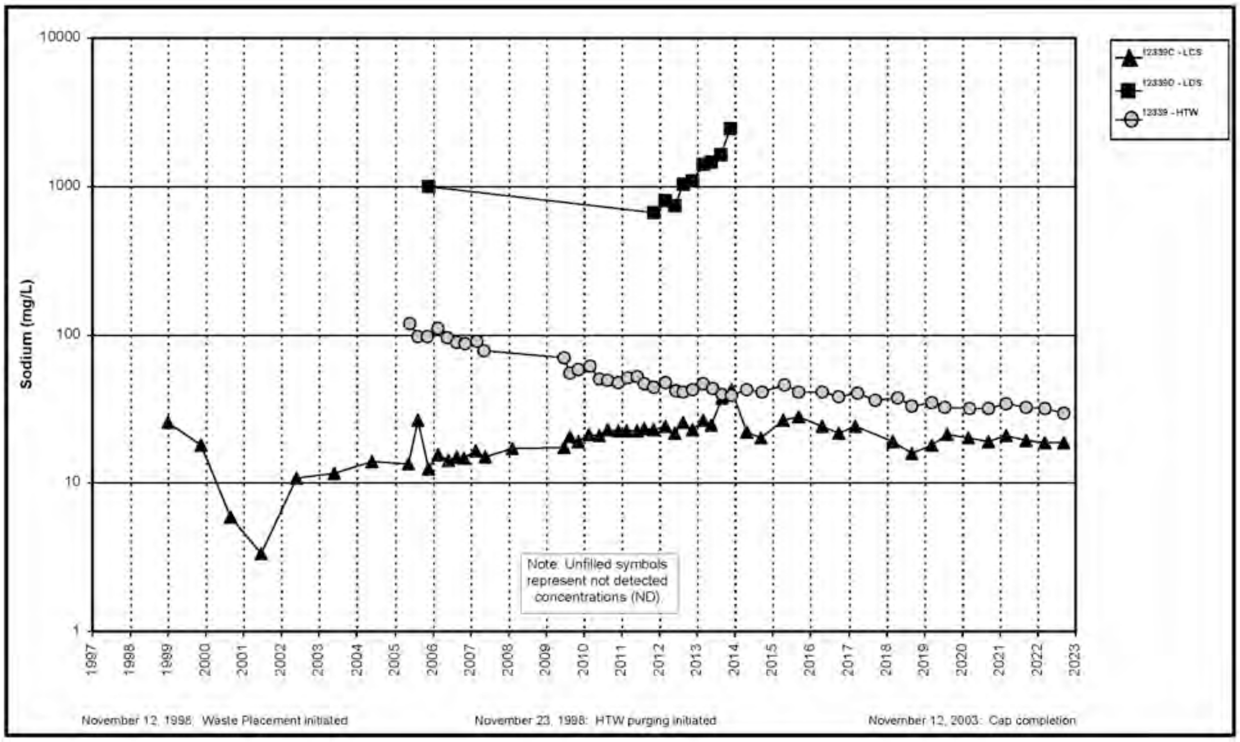

Figure A.5.2-7A. Cell 2 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

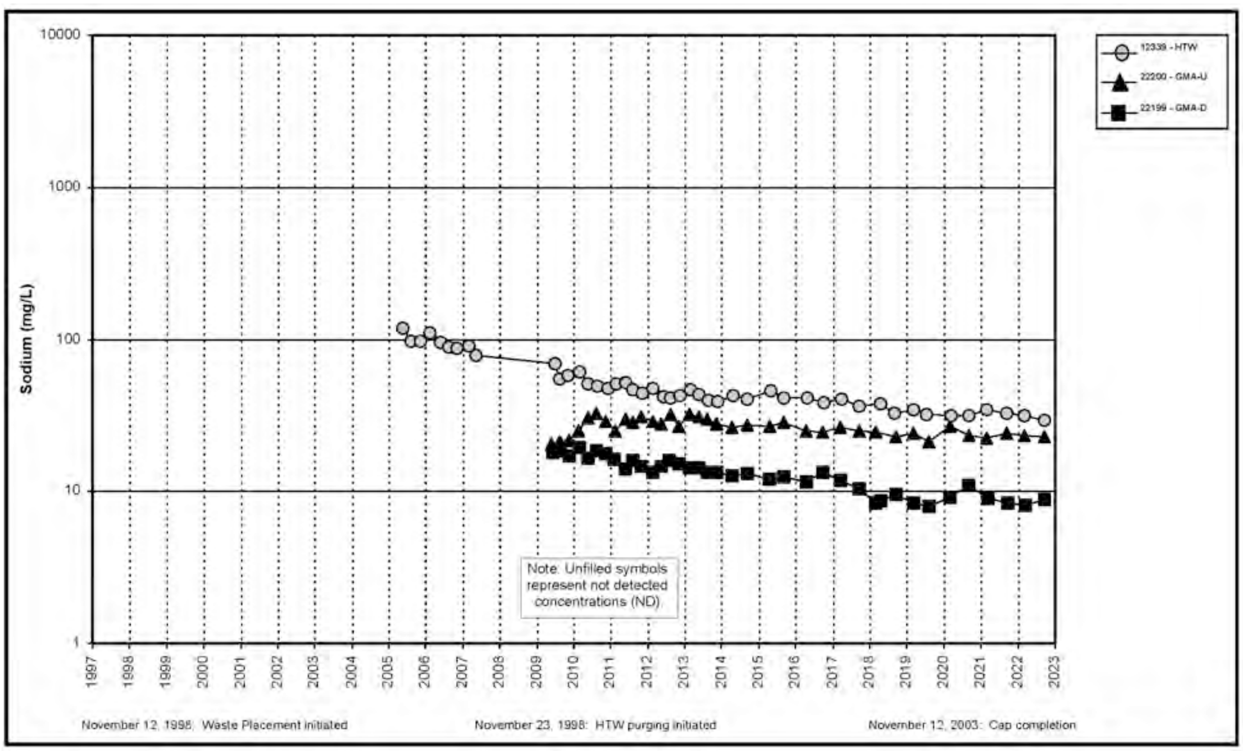

Figure A.5.2-7B. Cell 2 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

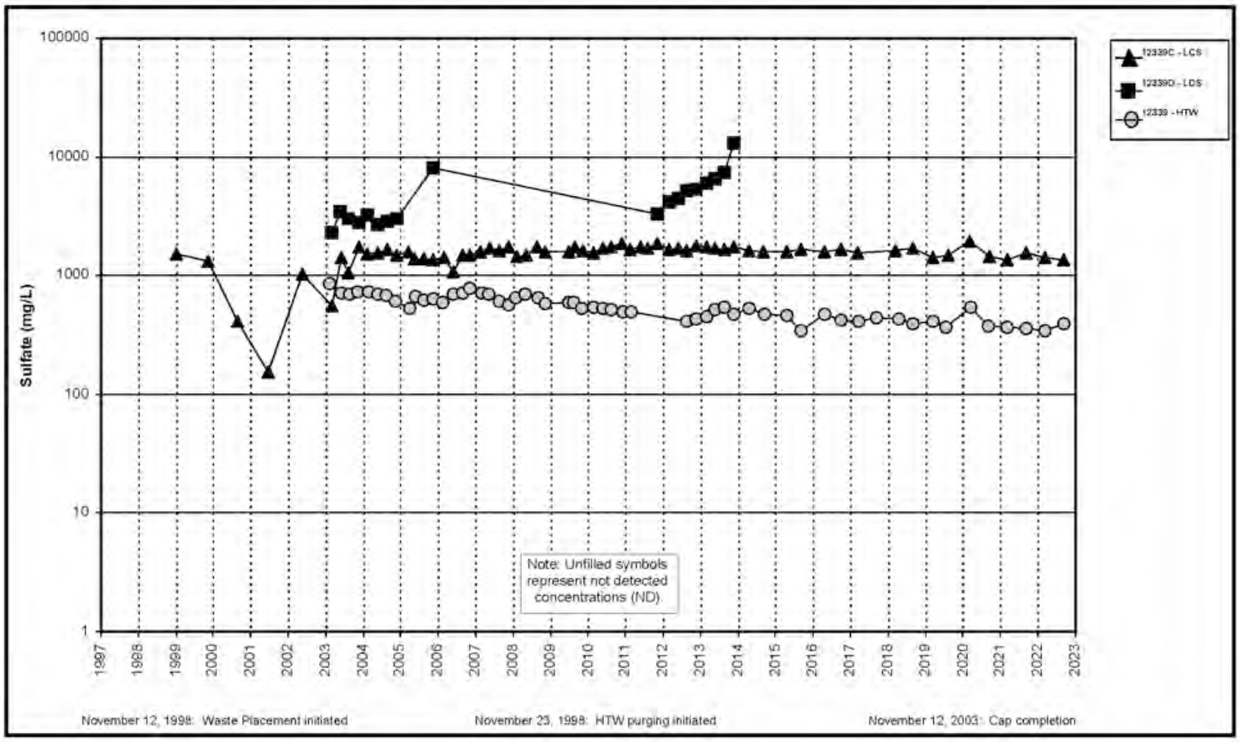

Figure A.5.2-8A. Cell 2 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

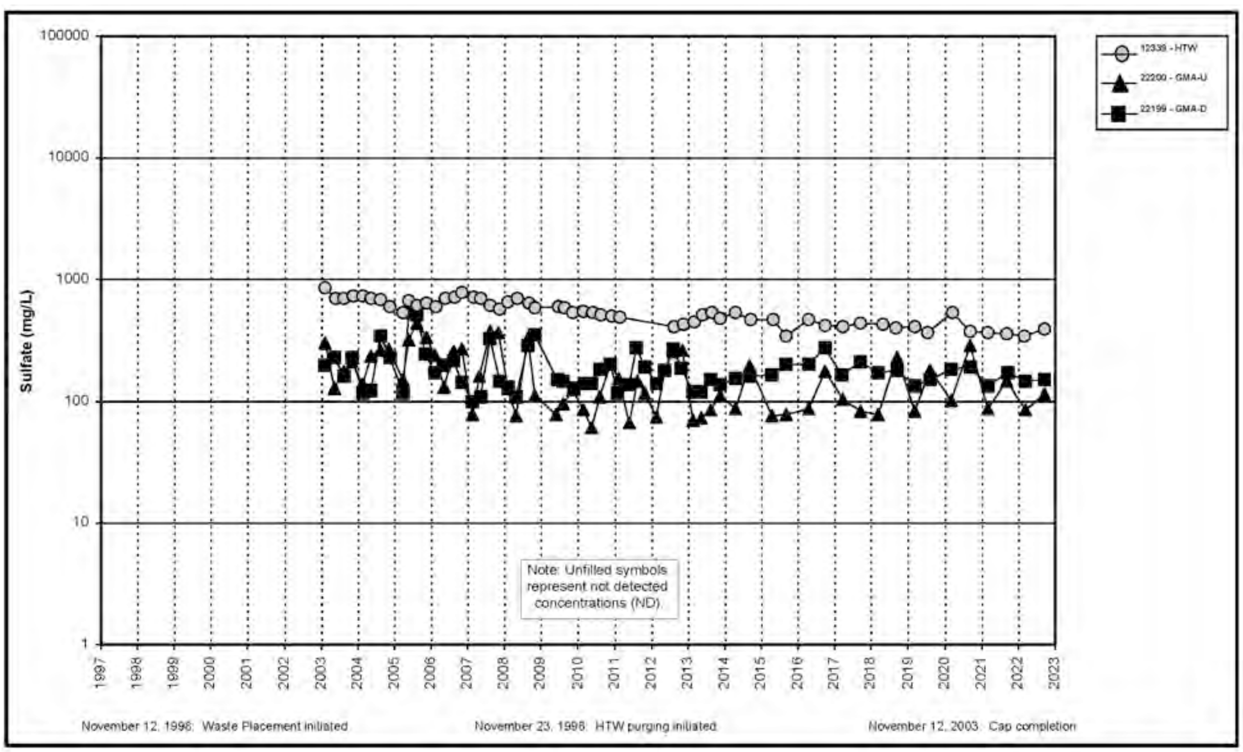

Figure A.5.2-8B. Cell 2 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

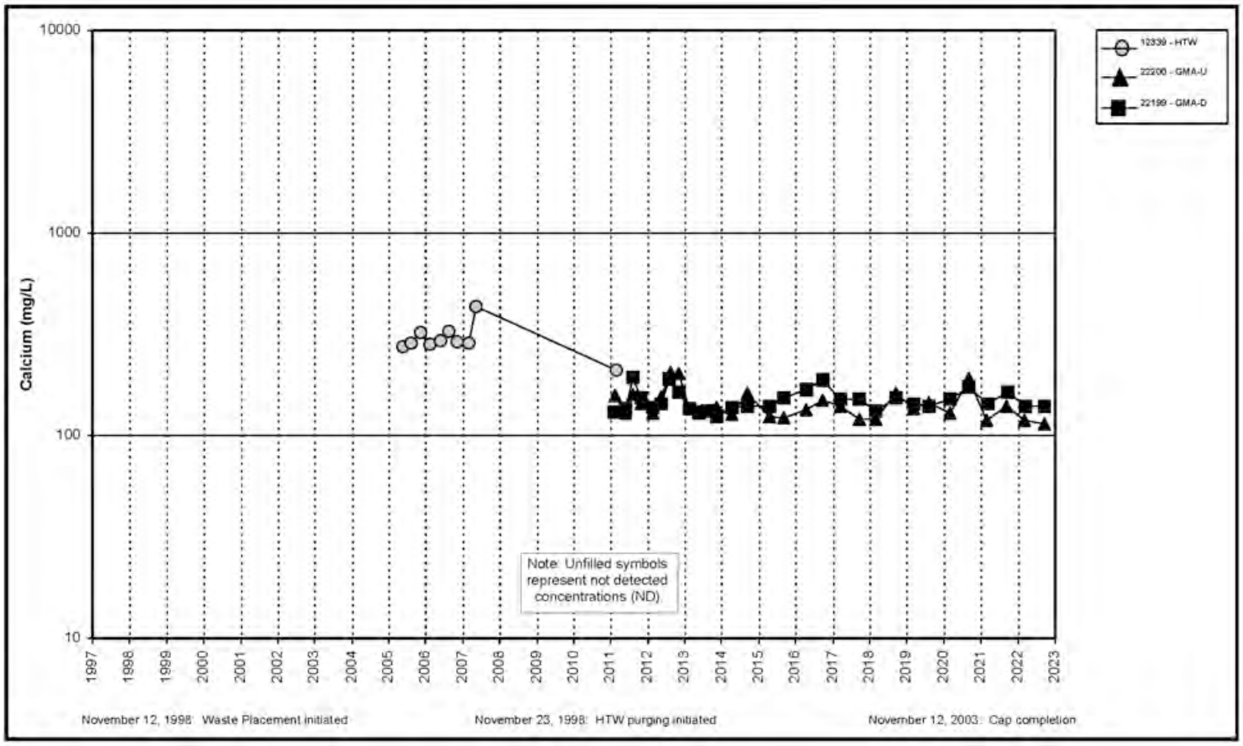

Figure A.5.2-9. Cell 2 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

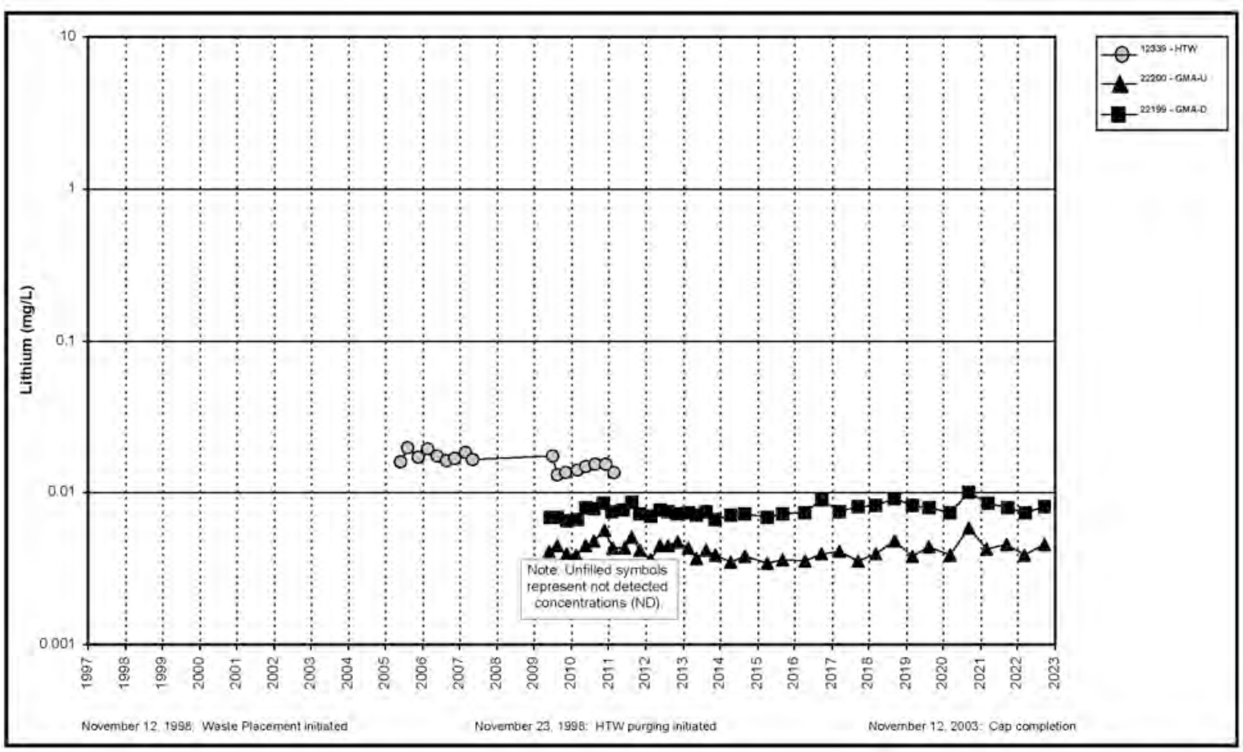

Figure A.5.2-10. Cell 2 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

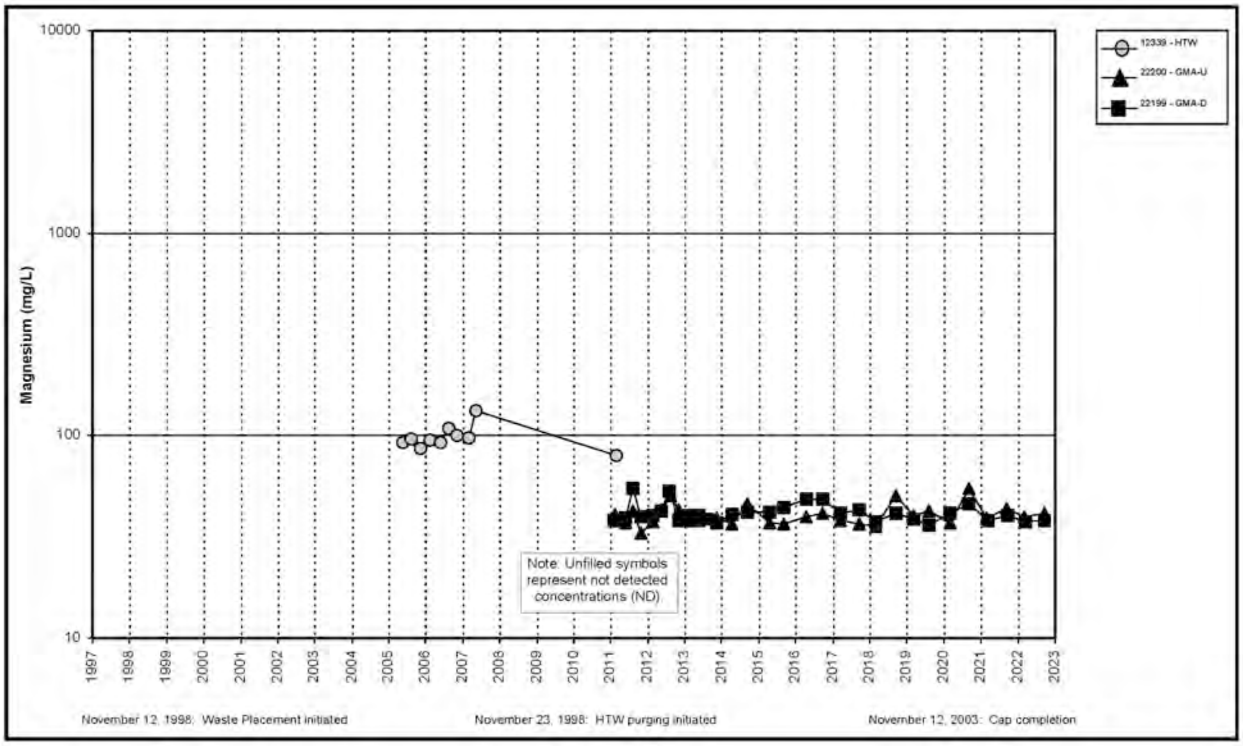

Figure A.5.2-11. Cell 2 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

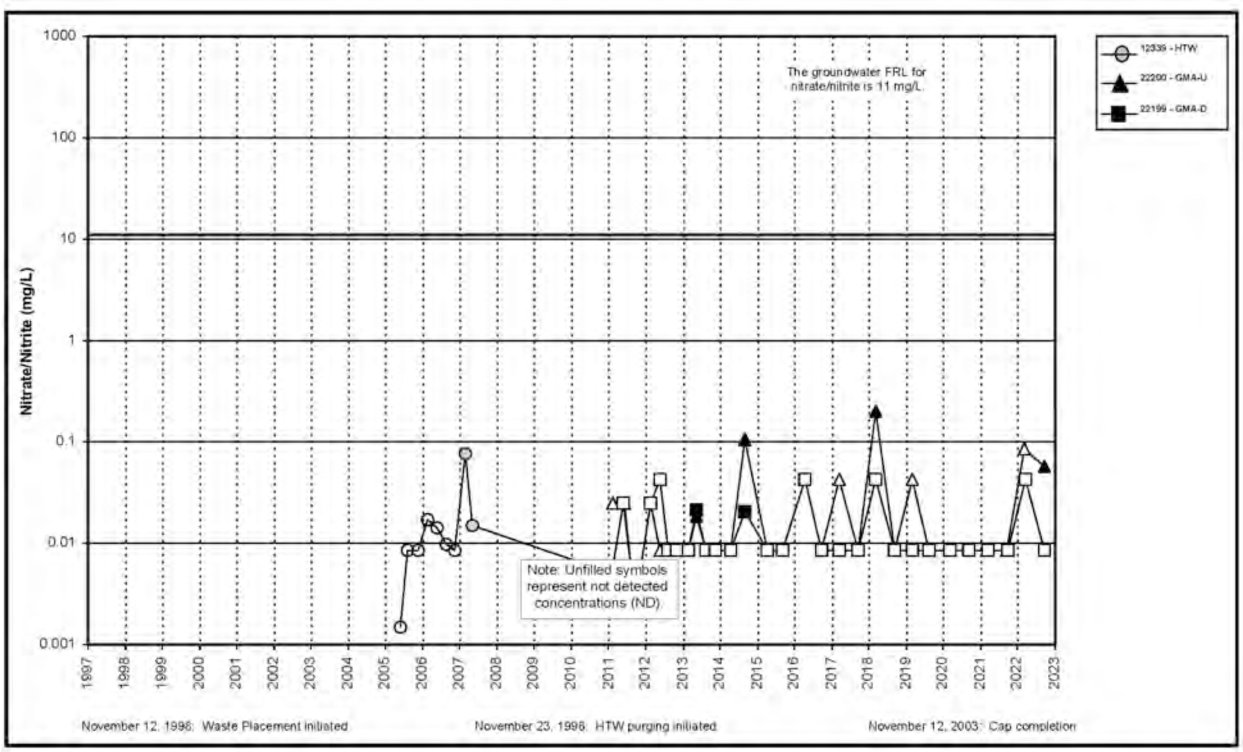

Figure A.5.2-12. Cell 2 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

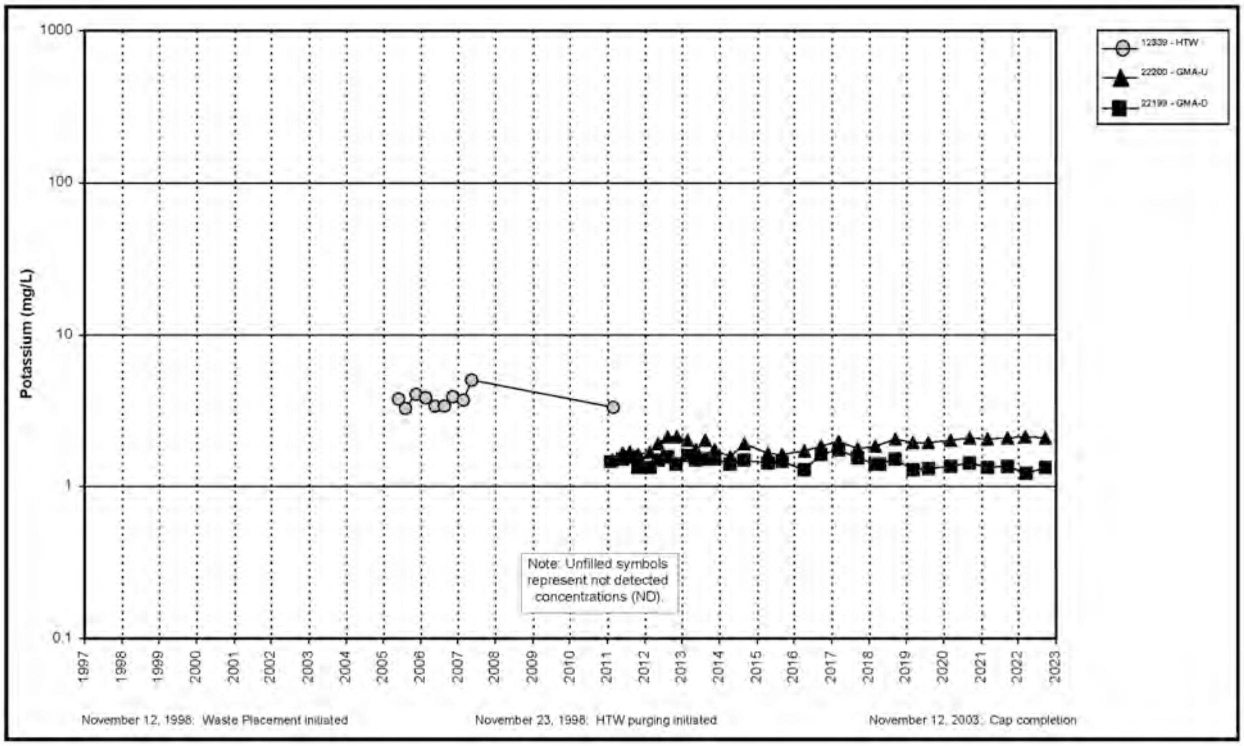

Figure A.5.2-13. Cell 2 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

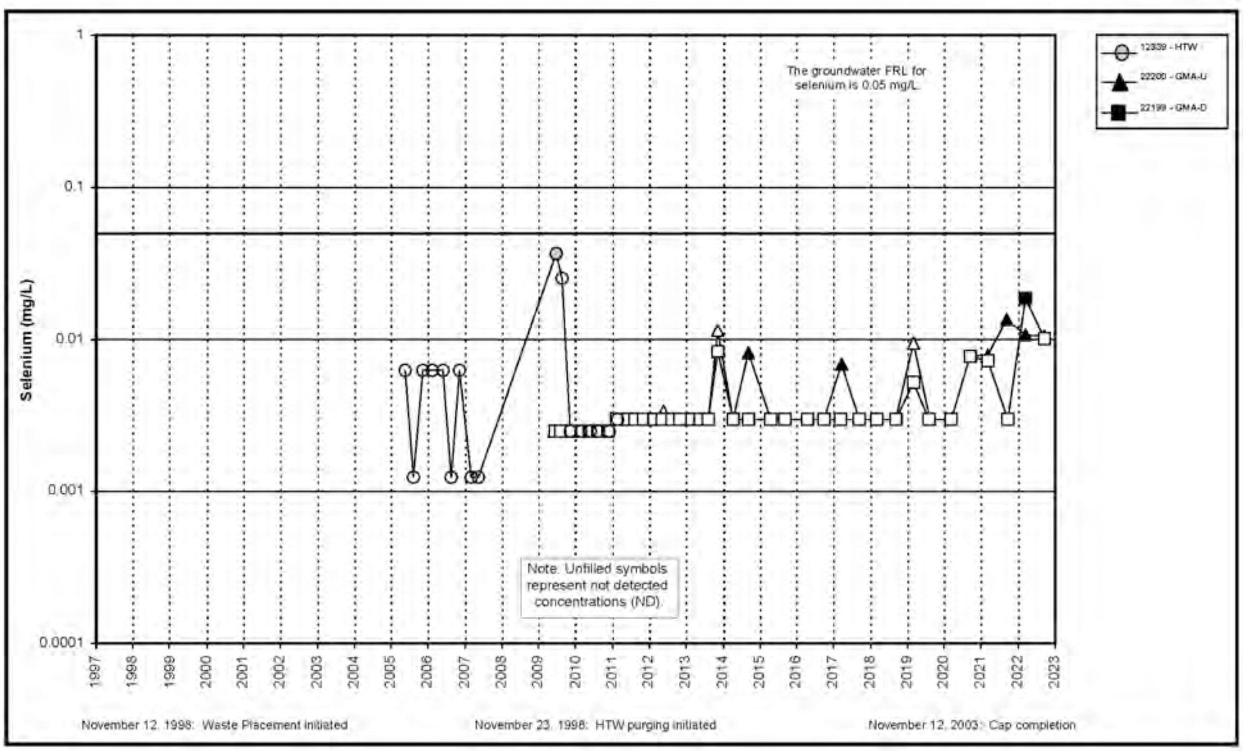

Figure A.5.2-14. Cell 2 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

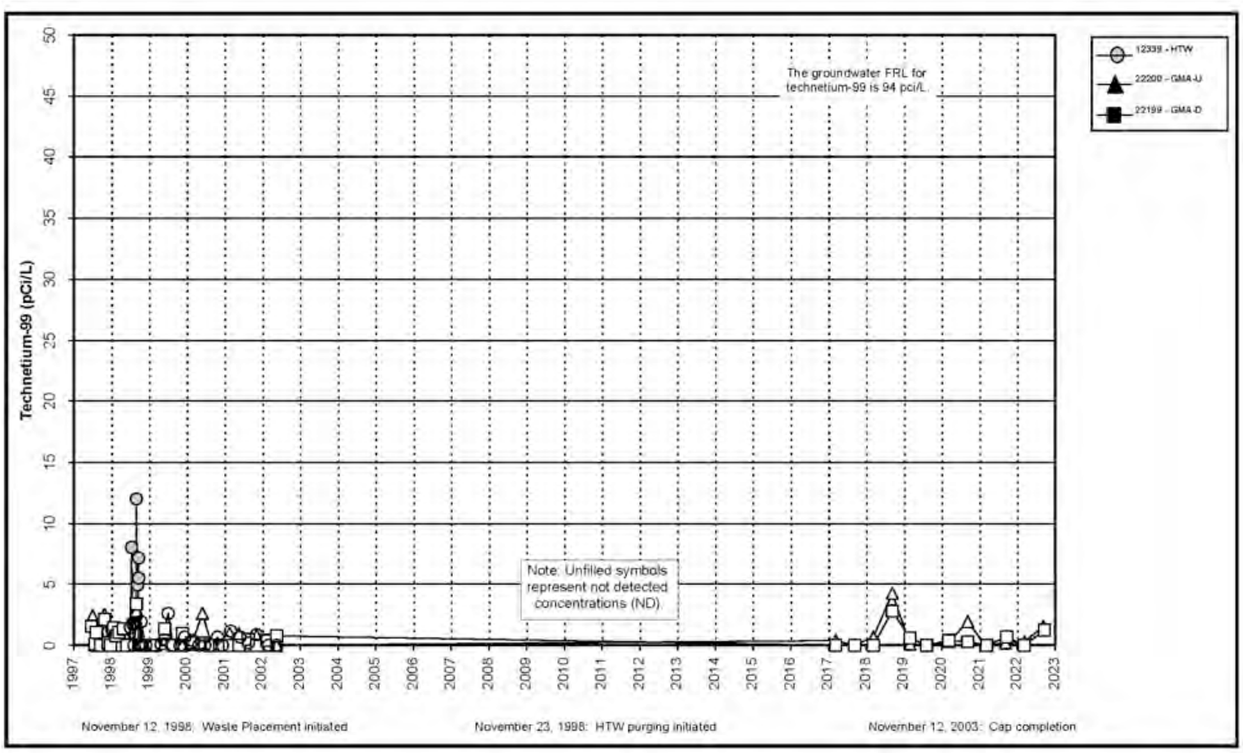

Figure A.5.2-15. Cell 2 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

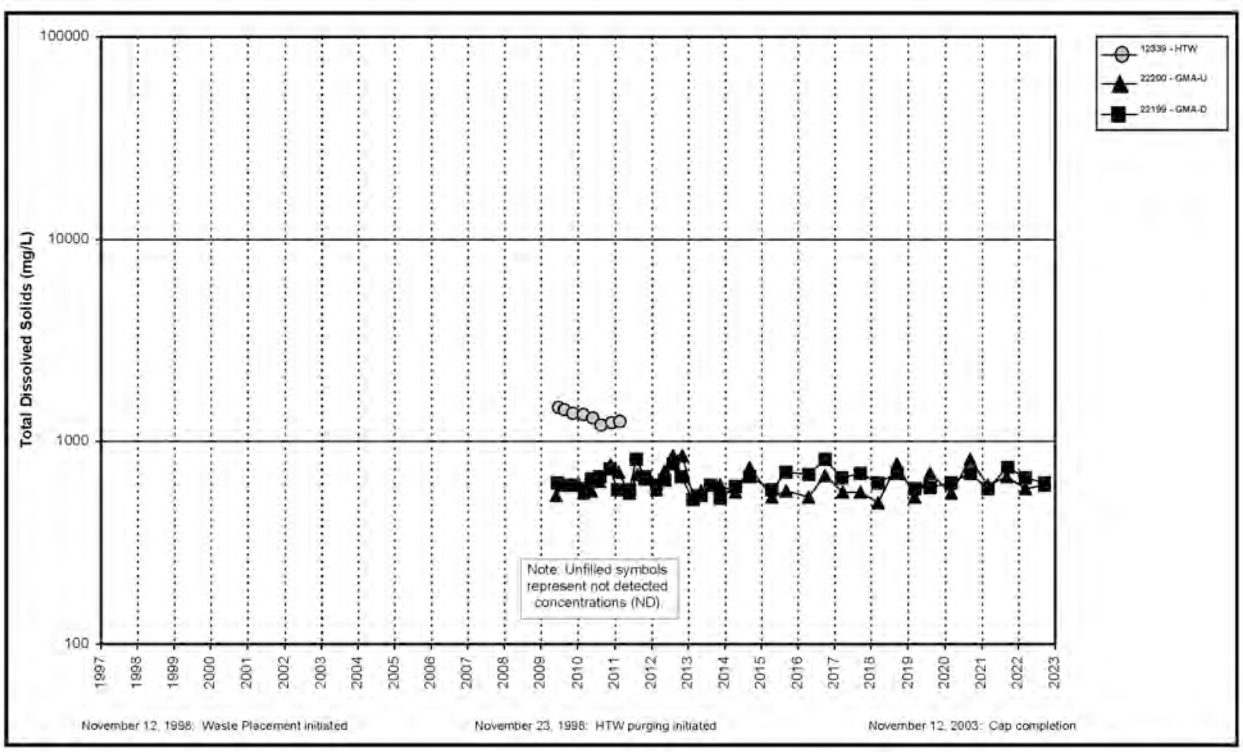

Figure A.5.2-16. Cell 2 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

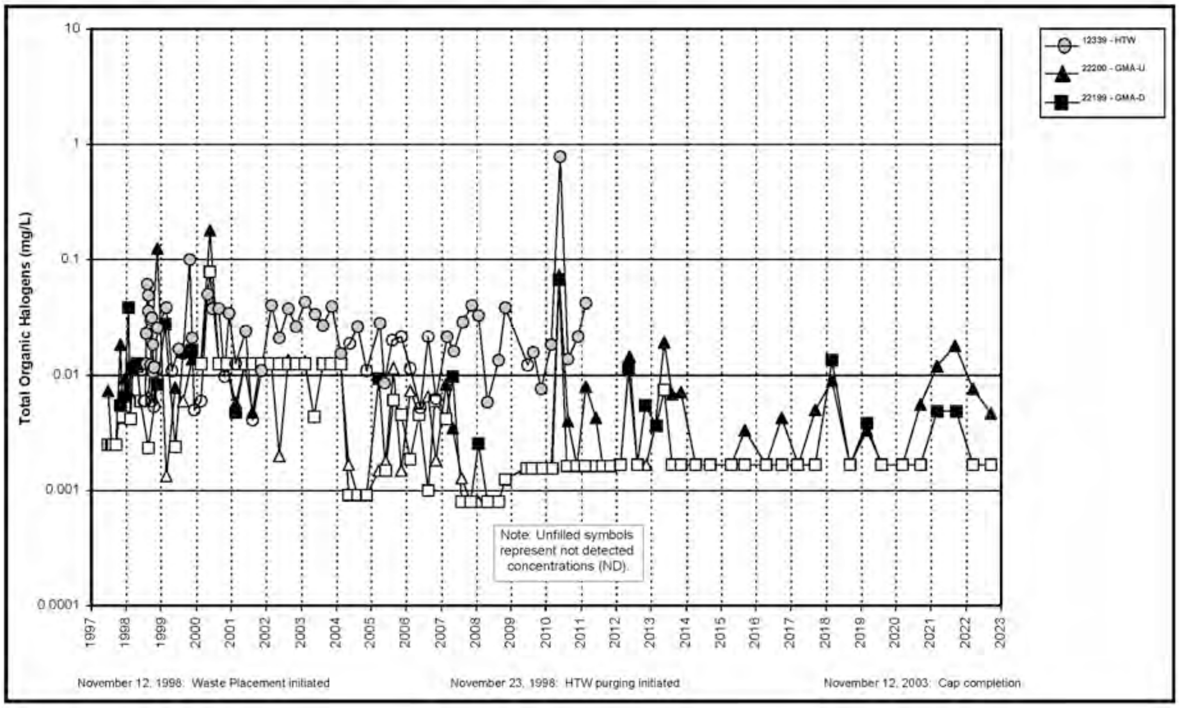

Figure A.5.2-17. Cell 2 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

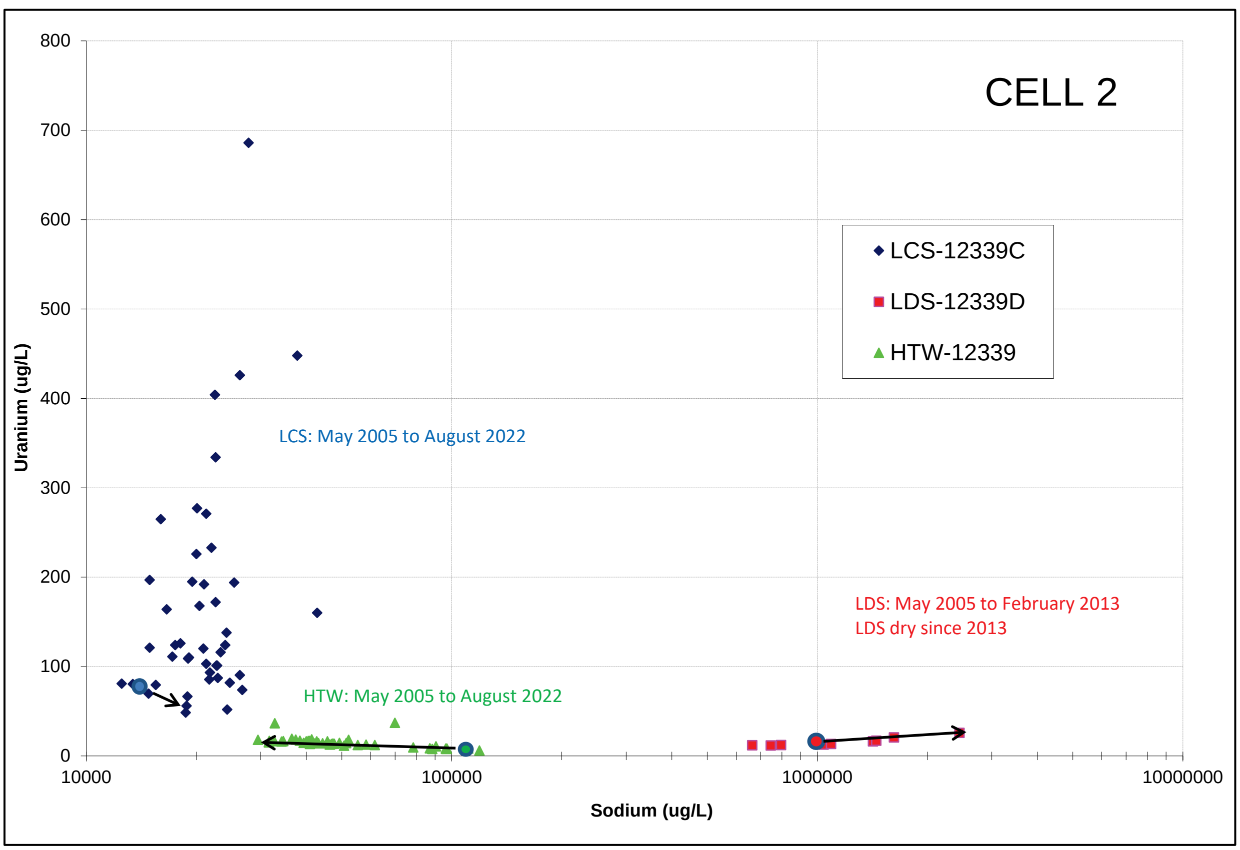

Figure A.5.2-18. Cell 2 Bivariate Plot for Uranium and Sodium

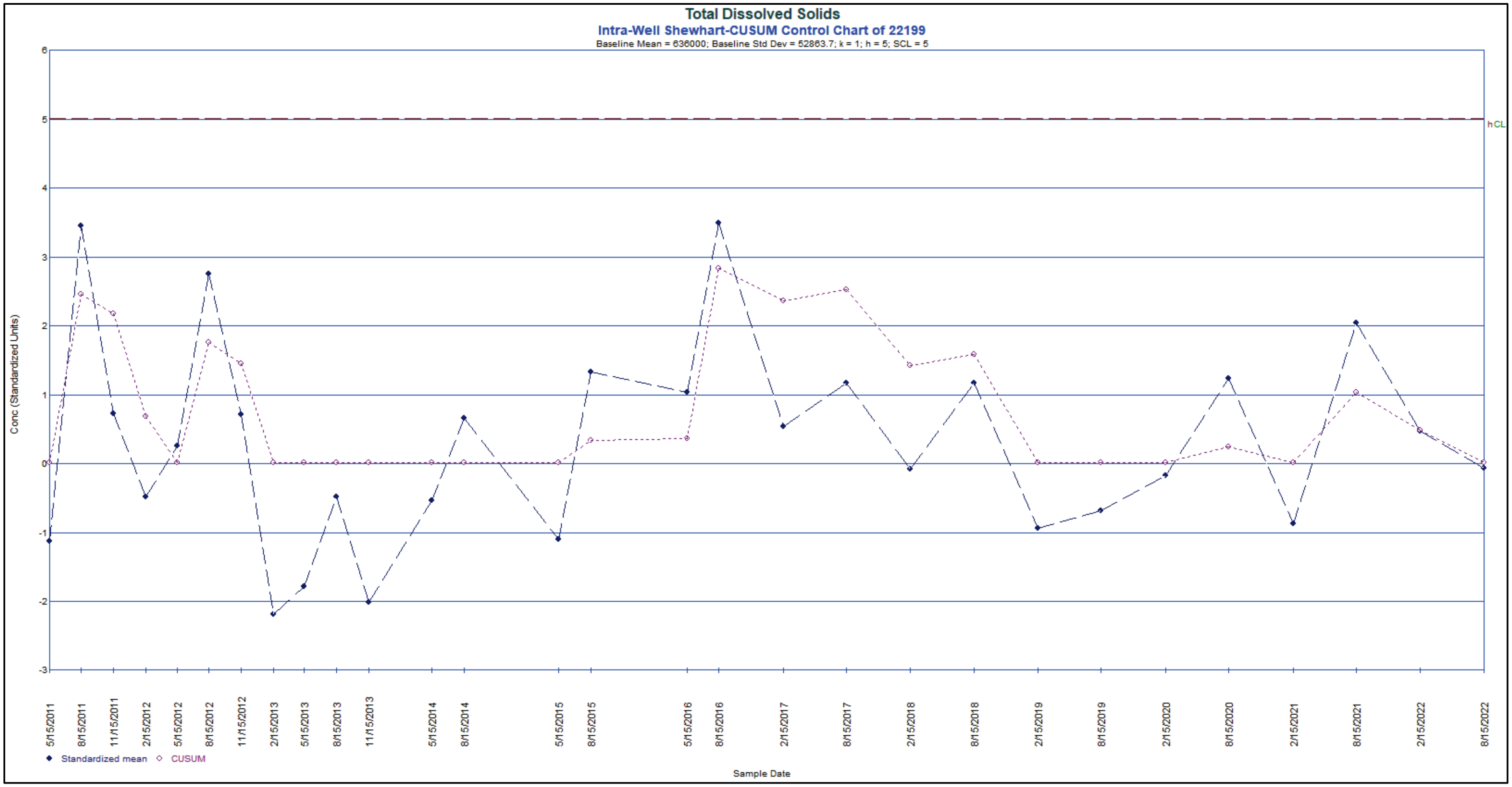

Figure A.5.2-19. Intrawell Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22199

Subattachment A.5.3

Cell 3

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 3:

- Semiannual monitoring summary statistics (Table A.5.3-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.3-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.3-2)
- OSDF horizontal till well (HTW) 12340 water yield (Table A.5.3-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.3-3 and A.5.3-4)
- Plots of concentration versus time (Figures A.5.3-5A through A.5.3-17)
- A bivariate plot for uranium-sodium (Figure A.5.3-18)
- Control charts (Figures A.5.3-19 through A.5.3-21)

A.5.3.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.3.1.1 LCS and LDS Results

As shown in Table A.5.3-1 and summarized below, four parameters (total uranium, boron, sodium, and sulfate) in 2022 have upward trends in the LCS based on the Mann-Kendall test for trend. No new high concentrations were measured in the LCS of Cell 3 in 2022. Since 2007, the volume of water in the LDS tank of Cell 3 has been insufficient to collect a sample.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 3

Parameter	LCS 12340C 2022 Trend	LDS 12340D Trend (Year Last Sampled)[a]
Total Uranium	Up	Down (2007)
Boron	Up	
Sodium	Up	Down (2007)
Sulfate	Up	Down (2007)

[a] No entry indicates that the trend was not up.

A.5.3.1.2 HTW and Monitoring Well Results

As shown in Table A.5.3-1 and summarized here, seven parameters (total uranium, boron, lithium, magnesium, nitrate + nitrite as nitrogen, selenium, and total dissolved solids) have upward trends in the HTW or the GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 3

Parameter	HTW 12340[a]	GMA-U 22203[b]	GMA-D 22204[a,b]
Total Uranium		Up	Up
Boron	Up	Up	Up
Lithium		Up	
Magnesium		Up	
Nitrate + Nitrite as Nitrogen		Up	
Selenium		Up	Up
Total Dissolved Solids		Up	

[a] No entry indicates that the trend was not up.
[b] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer.

A.5.3.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 3 LCS, LDS, and HTW is provided in Figure A.5.3-18. On the figure, the first sample ever collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. The plot shows that the chemical signatures for uranium and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.3.2 Control Charts

Intrawell control charts use historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart.

Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared "not in control" if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (*h*) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.3-1 in gray shading and as summarized below, two parameter in the HTW and GMA wells of Cell 3 meet the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in two control charts (Figures A.5.3-19 and A.5.3-20). Both control chart for Cell 3 exhibited "in control" conditions.

Parameter	Monitoring Point[a]	Well Number	Assessment	Figure Number
Calcium	GMA-U	22203	In Control	A.5.3-19
Lithium	GMA-D	22204	In Control	A.5.3-20

[a] GMA-D = downgradient Great Miami Aquifer; GMA-U = upgradient Great Miami Aquifer.

A.5.3.3 Summary and Conclusions

- Four parameters monitored semiannually in 2022 have an upward concentration trend in the LCS of Cell 3: total uranium, boron, sodium, and sulfate. No new high concentrations were measured in the LCS of Cell 3 in 2022.
- The volume of water in the LDS tank of Cell 3 has been insufficient to collect a sample since 2007.

- Seven parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 3: total uranium, boron, lithium, magnesium, nitrate + nitrite as nitrogen, selenium, and total dissolved solids. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 3 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 3 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- Two control charts were constructed for Cell 3 parameters. Both control charts exhibit "in control" conditions.

A.5.3.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. "Ground Water Monitoring Program for a Sanitary Landfill Facility," *Ohio Administrative Code.*

Table A.5.3-1. Summary Statistics for Cell 3

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12340C	74	74	100	9.35	206	85.0	40.3	Normal	Up (2022)	Detected	
	LDS	12340D	21	21	100	8.90	27.7	19.7	13.0	Normal	Down (2007)	Not Detected	72.4 (Q4-04)
	HTW	12340	77	77	100	3.89	29.3	18.0	7.8	Undefined	None (2022)	Detected	58.5 (Q3-09), 42.1 (Q3-16)
	GMA-U	22203	76	79	96.2	ND	23.5	2.33	4.62	Ln Normal	Up (2022)	Detected	
	GMA-D	22204	87	88	98.9	ND	22.9	3.79	4.58	Undefined	Up (2022)	Detected	
Boron (mg/L)	LCS	12340C	74	75	98.7	ND	9.19	4.47	1.81	Undefined	Up (2022)	Detected	
	LDS	12340D	20	21	95.2	ND	0.557	0.128	0.149	Undefined	Down (2007)	Not Detected	
	HTW	12340	60	60	100	0.0481	0.259	0.141	0.051	Normal	Up (2022)	Detected	0.960 (Q3-06)
	GMA-U	22203	68	79	86.1	ND	0.0870	0.0499	0.0170	Normal	Up (2022)	Detected	
	GMA-D	22204	71	79	89.9	ND	0.0887	0.0457	0.0150	Normal	Up (2022)	Detected	
Sodium (mg/L)	LCS	12340C	54	54	100	4.35	49.9	27.4	7.6	Undefined	Up (2022)	Detected	
	LDS	12340D	9	9	100	263	344	315	27	Normal	None (2007)	Not Detected	
	HTW	12340	46	46	100	10.2	74.1	34.7	17.4	Ln Normal	Down (2022)	Detected	
	GMA-U	22203	37	37	100	15.9	30.7	21.0	3.8	Ln Normal	Down (2022)	Detected	
	GMA-D	22204	38	38	100	7.88	20.5	13.2	3.8	Ln Normal	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12340C	66	66	100	26.1	2,650	1,860	520	Undefined	Up (2022)	Detected	
	LDS	12340D	19	19	100	112	2,510	1,250	700	Undefined	Down (2007)	Not Detected	
	HTW	12340	56	56	100	352	958	627	157	Normal	Down (2022)	Detected	
	GMA-U	22203	61	61	100	64.2	738	253	147	Ln Normal	None (2022)	Detected	4,020 (Q3-12)
	GMA-D	22204	61	61	100	186	779	427	159	Normal	Down (2022)	Detected	
Calcium (mg/L)	GMA-U	22203	30	30	100	135	290	180	38	Ln Normal	None (2022)	Not Detected	
	GMA-D	22204	30	30	100	134	365	222	58	Ln Normal	Down (2022)	Detected	
Lithium (mg/L)	GMA-U	22203	37	37	100	0.00577	0.0229	0.00980	0.00535	Undefined	Up (2022)	Not Detected	
	GMA-D	22204	37	37	100	0.00694	0.0102	0.00864	0.00088	Normal	None (2022)	Not Detected	
Magnesium (mg/L)	GMA-U	22203	30	30	100	32.5	65.6	48.0	9.5	Normal	Up (2022)	Not Detected	
	GMA-D	22204	30	30	100	37.2	66.6	48.7	8.1	Normal	Down (2022)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22203	17	30	56.7	ND	0.0360	0.0876	0.090253	Undefined	Up (2022)	Not Detected	
	GMA-D	22204	1	30	3.3	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22203	30	30	100	2.07	3.50	2.56	0.35	Ln Normal	Down (2022)	Not Detected	
	GMA-D	22204	31	31	100	1.17	3.07	2.00	0.54	Normal	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22203	5	37	13.5	ND	0.0130	0.00300	0.00291	Undefined	Up (2022)	Detected	
	GMA-D	22204	5	37	13.5	ND	0.0178	0.00300	0.00335	Undefined	Up (2022)	Detected	
Technitium-99 (pCi/L)	GMA-U	22203	1	28	3.6	ND	8.44	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22204	0	28	0	ND	NA	Insufficient	insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22203	37	37	100	524	1,410	720	195	Undefined	Up (2022)	Detected	
	GMA-D	22204	37	37	100	487	1,530	945	233	Normal	Down (2022)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22203	42	79	53.2	ND	0.213	0.00524	0.0250	Undefined	None (2022)	Detected	
	GMA-D	22204	17	79	21.5	ND	0.0270	0.0075	0.0187	Undefined	Down (2022)	Detected	0.165 (Q2-00)

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b]ND = not detected; NA = not applicable

[c]Averages were determined based on the distribution assumption.

[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e]Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f]Trend based on nonparametric Mann-Kendall procedure.

[g]Serial correlation based on Rank Von Neumann test.

[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i]Q = quarter

Table A.5.3-2. OSDF Horizontal Till Well 12340 (Cell 3) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
1999	4,880	11	444
2000	1,090	6	182
2001	1,050	4	263
2002	1,200	4	300
2003	1,770	4	443
2004	2,875	4	719
2005	3,330	4	833
2006	3,115	4	779
2007	2,895	4	724
2008	2,875	4	719
2009	2,100	4	700
2010	2,650	4	663
2011	2,600	4	650
2012	2,150	4	538
2013	2,725	4	681
2014	1,455	2	728
2015	1,050	2	525
2016	1,445	2	723
2017	1,425	2	713
2018	1,400	2	700
2019	1,475	2	738
2020	1,550	2	775
2021	1,435	2	718
2022	1,400	2	700

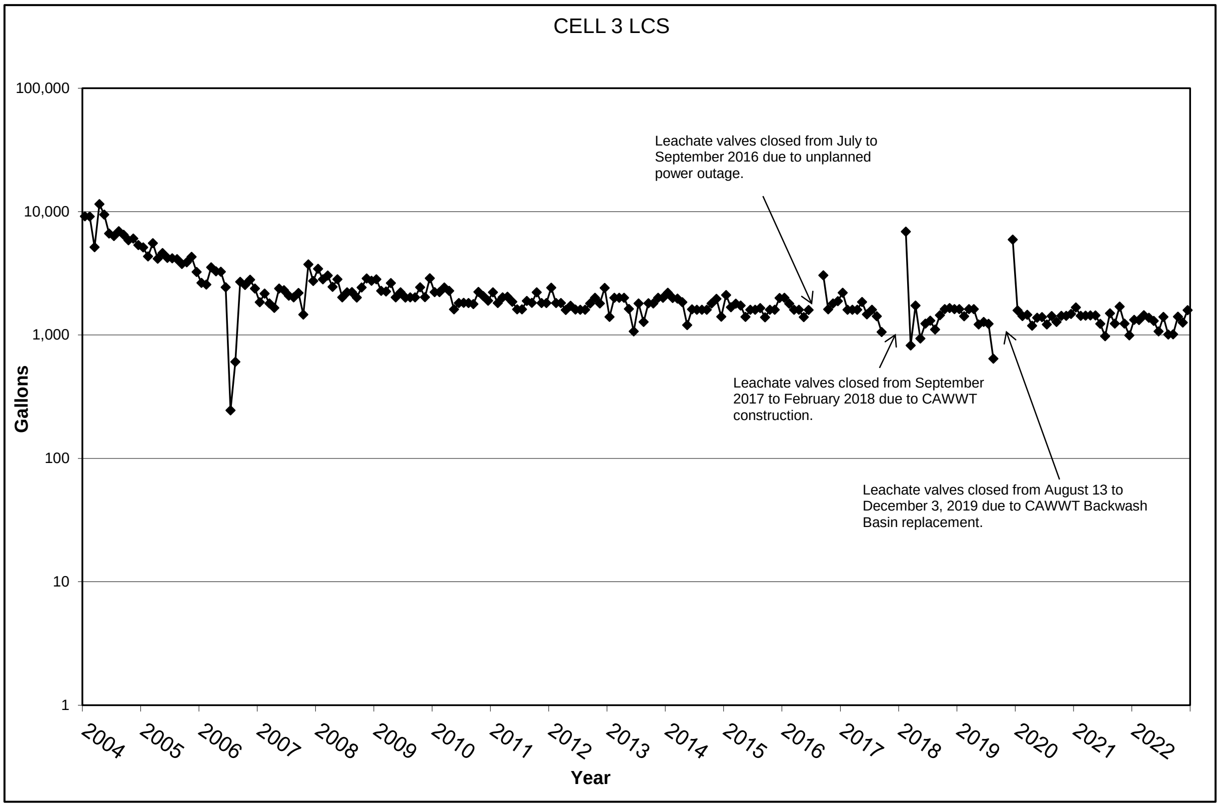

Figure A.5.3-1. Monthly Accumulation Volumes for Cell 3 LCS

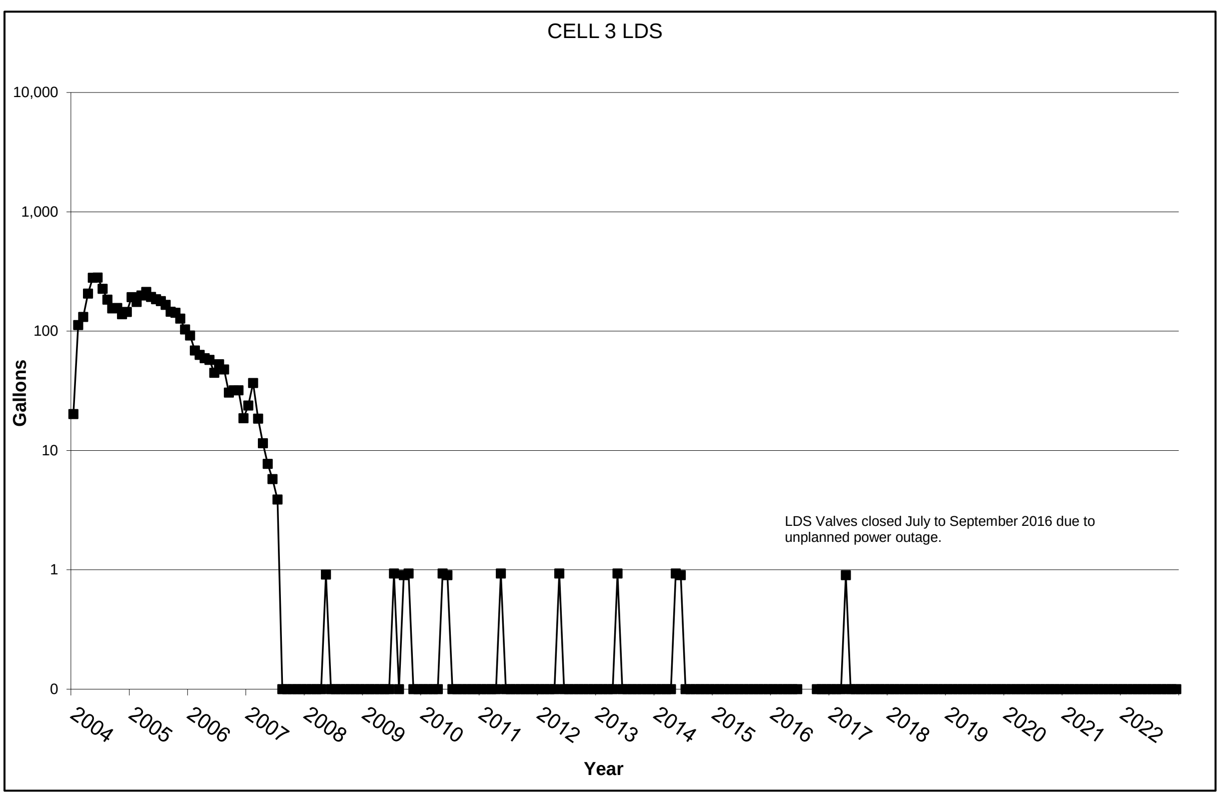

Figure A.5.3-2. Monthly Accumulation Volumes for Cell 3 LDS

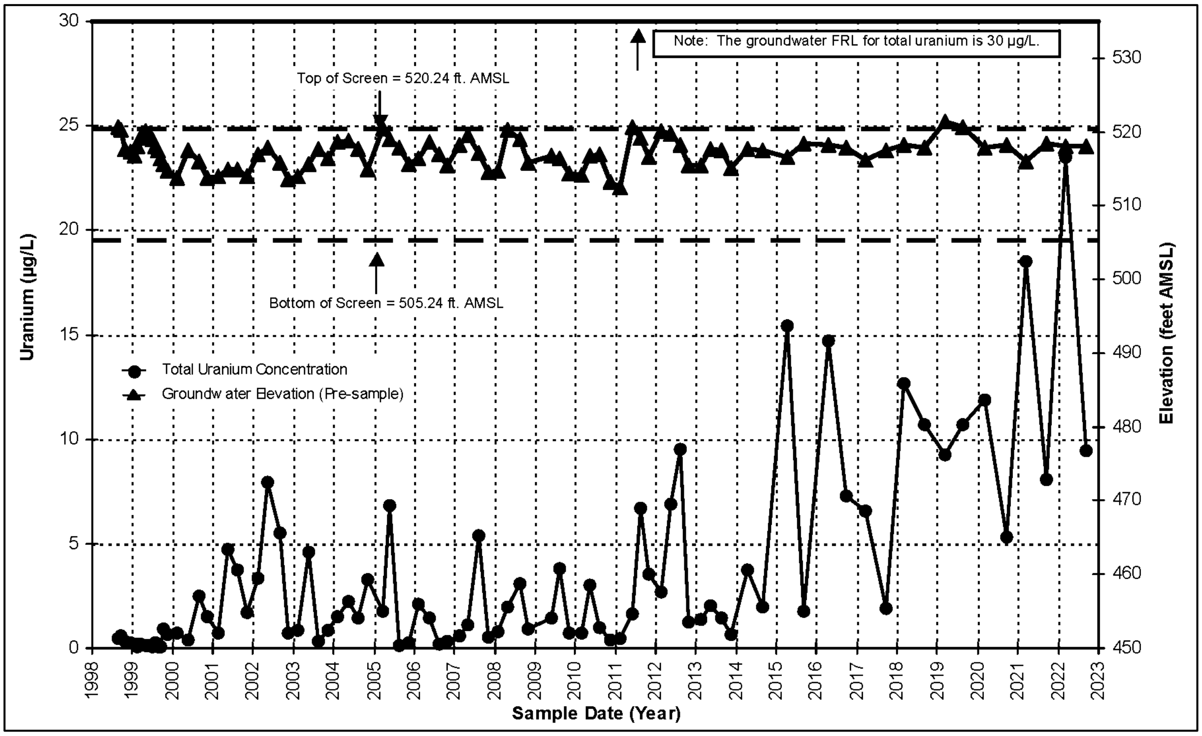

Figure A.5.3-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 3 Upgradient Monitoring Well 22203

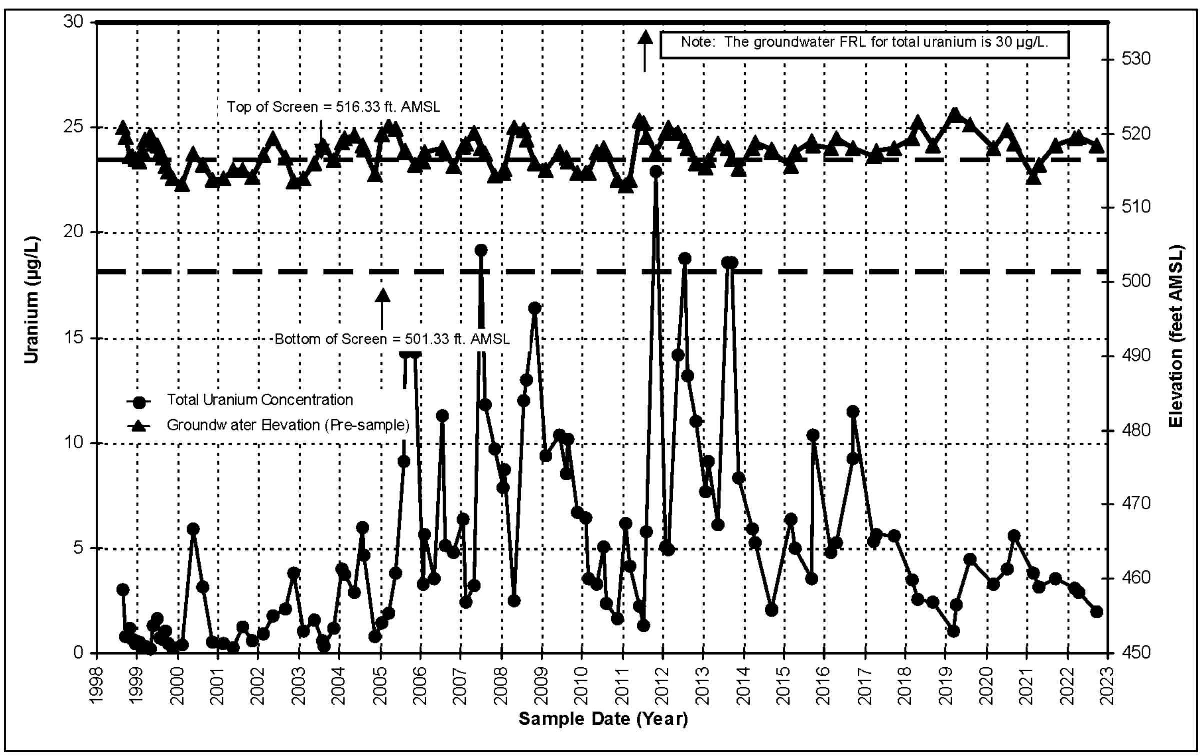

Figure A.5.3-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 3 Downgradient Monitoring Well 22204

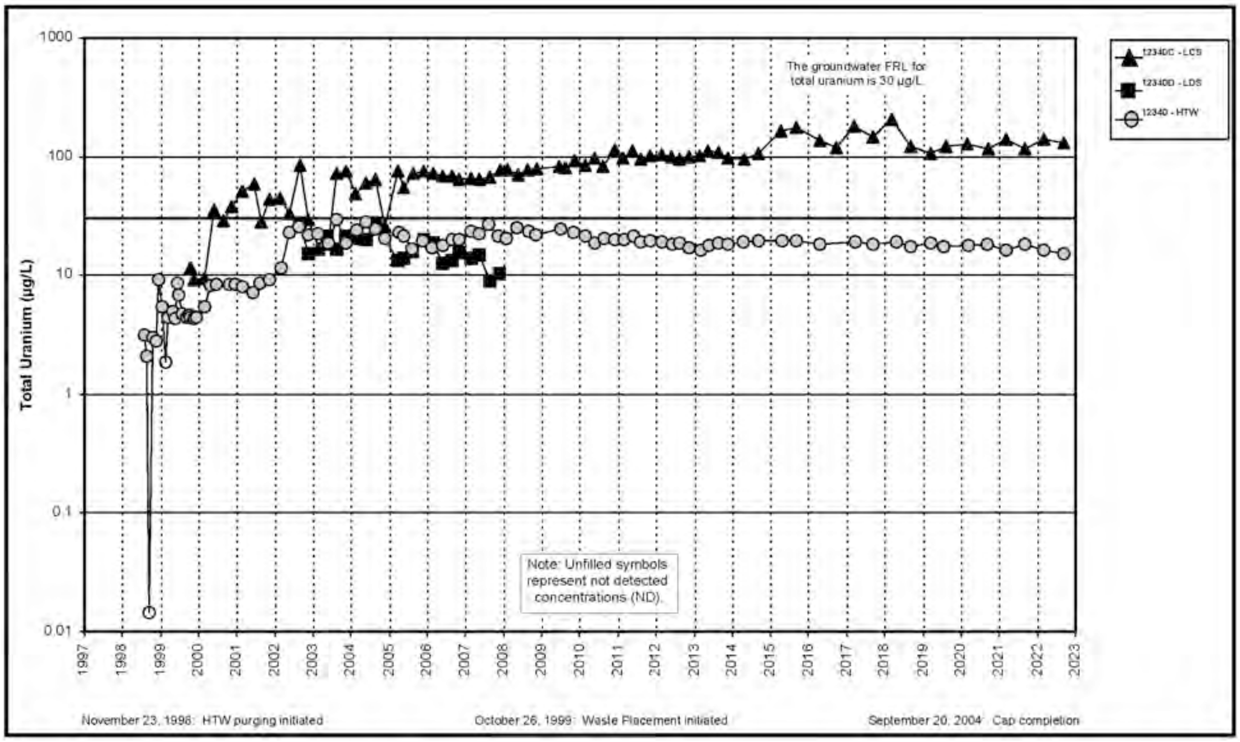

Figure A.5.3-5A. Cell 3 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

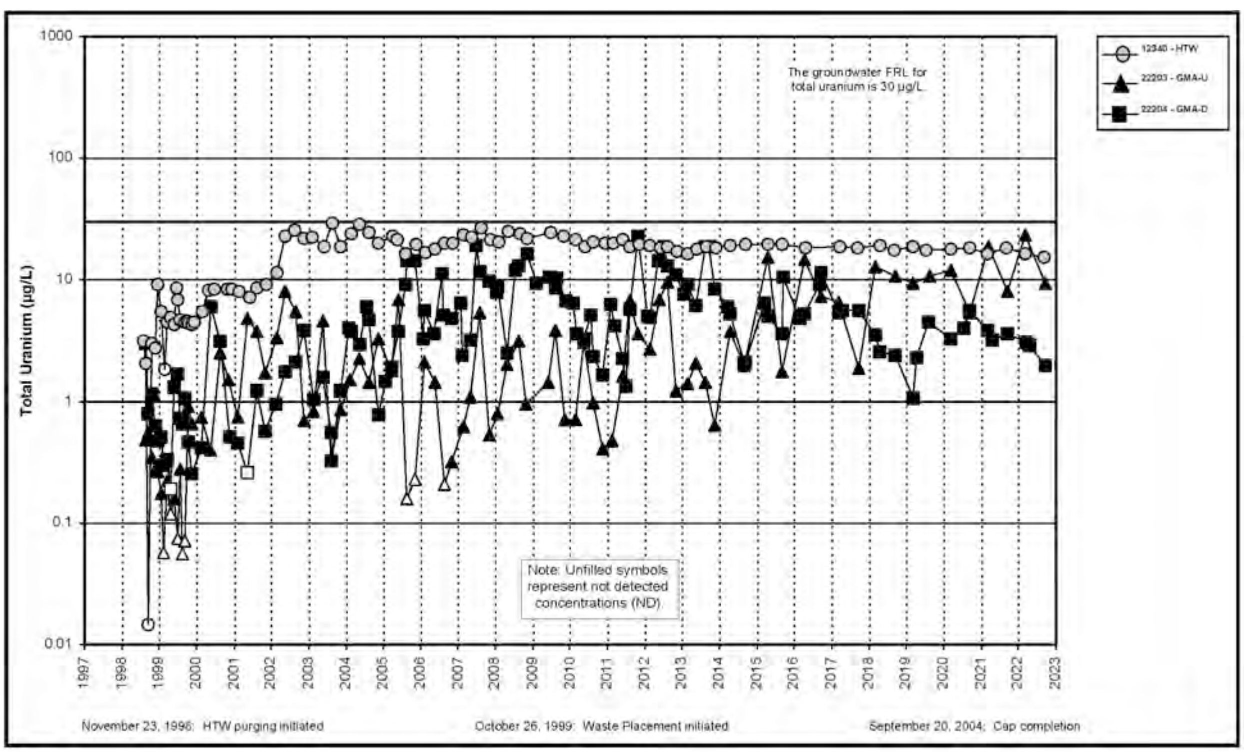

Figure A.5.3-5B. Cell 3 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

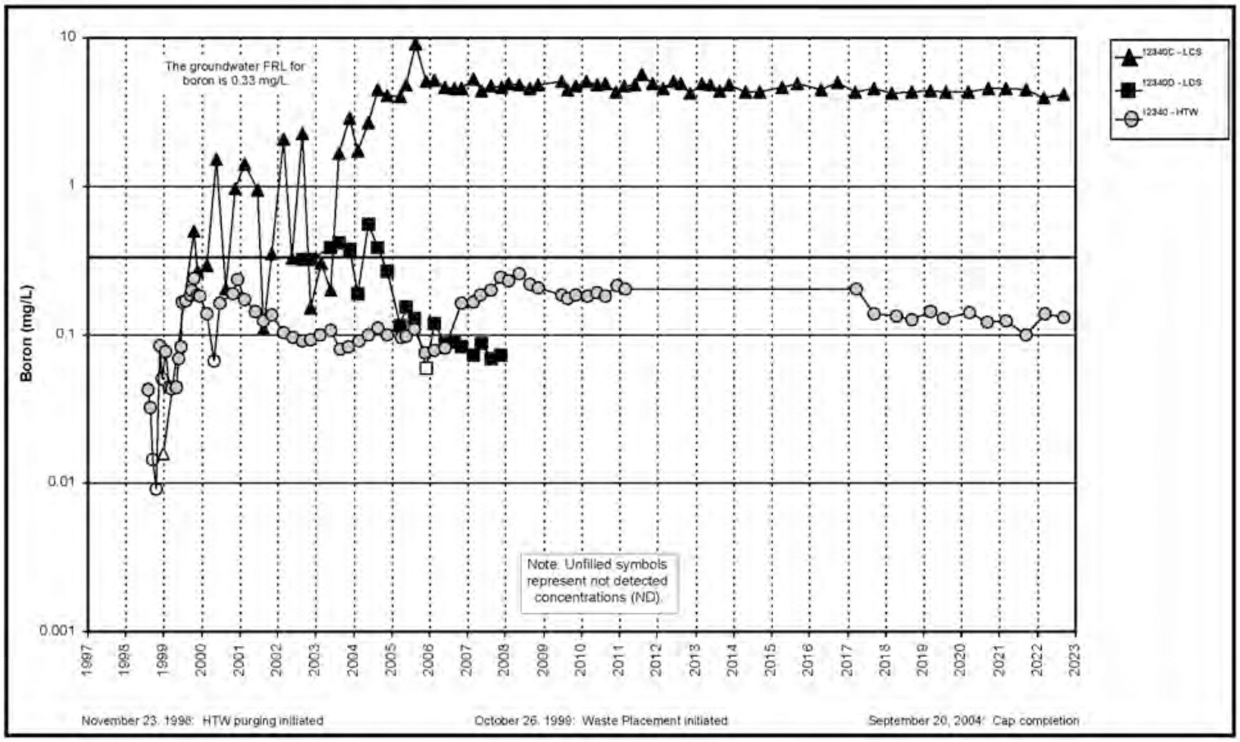

Figure A.5.3-6A. Cell 3 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

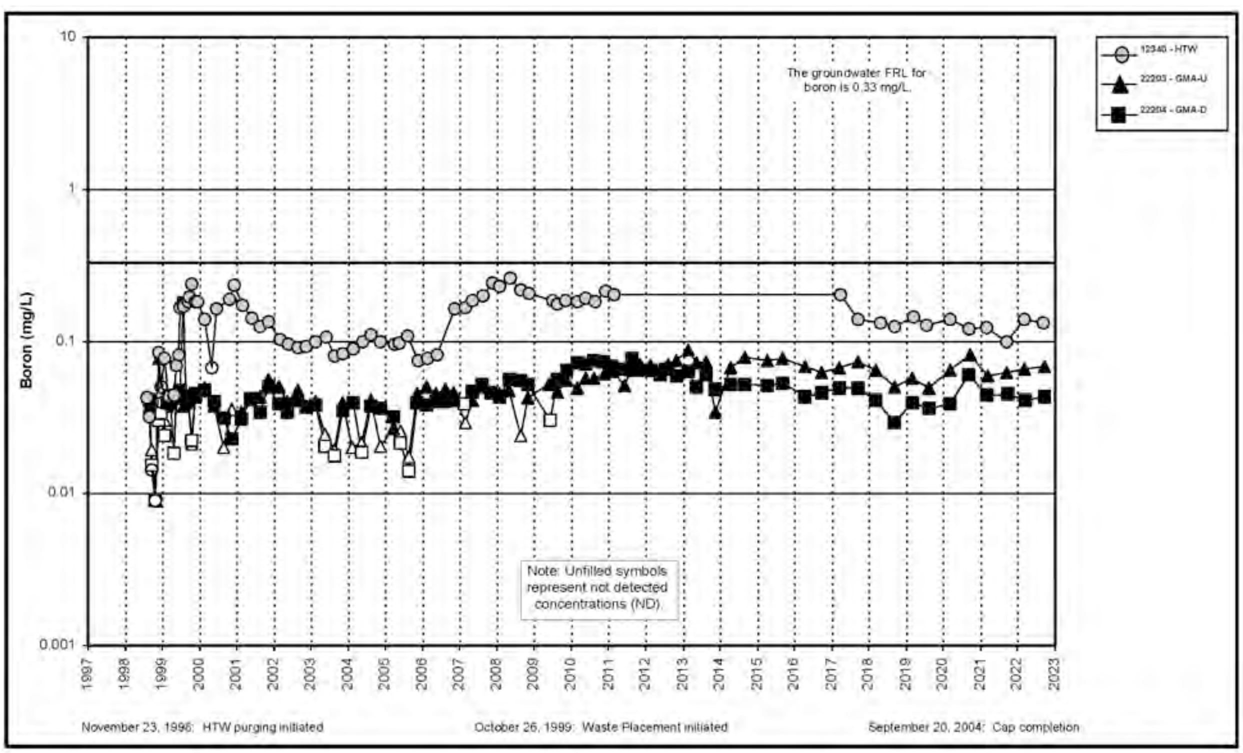

Figure A.5.3-6B. Cell 3 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

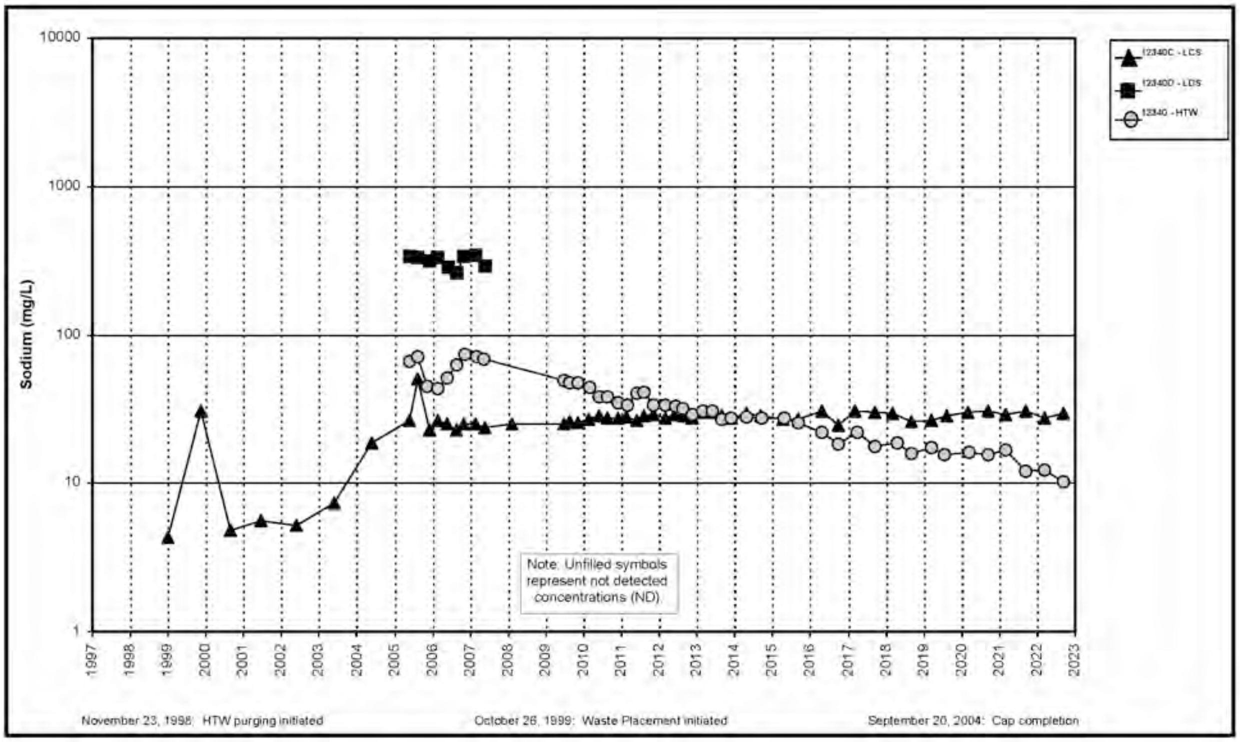

Figure A.5.3-7A. Cell 3 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

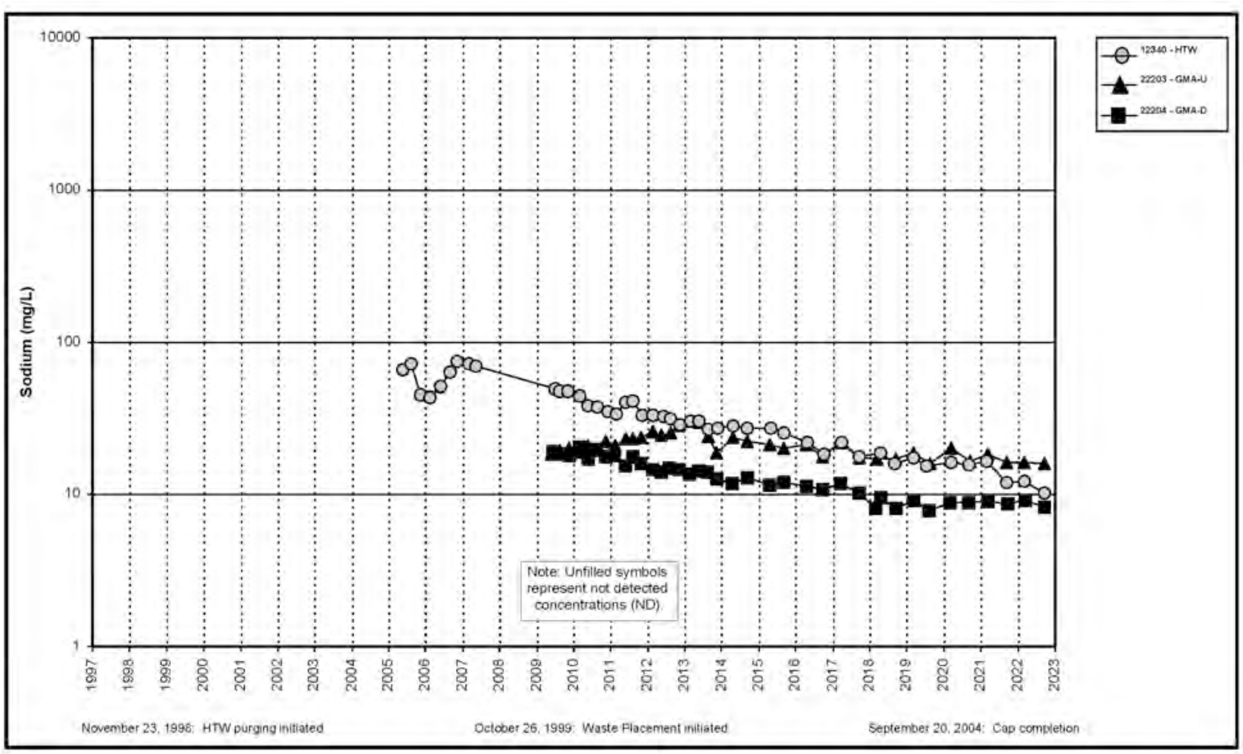

Figure A.5.3-7B. Cell 3 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

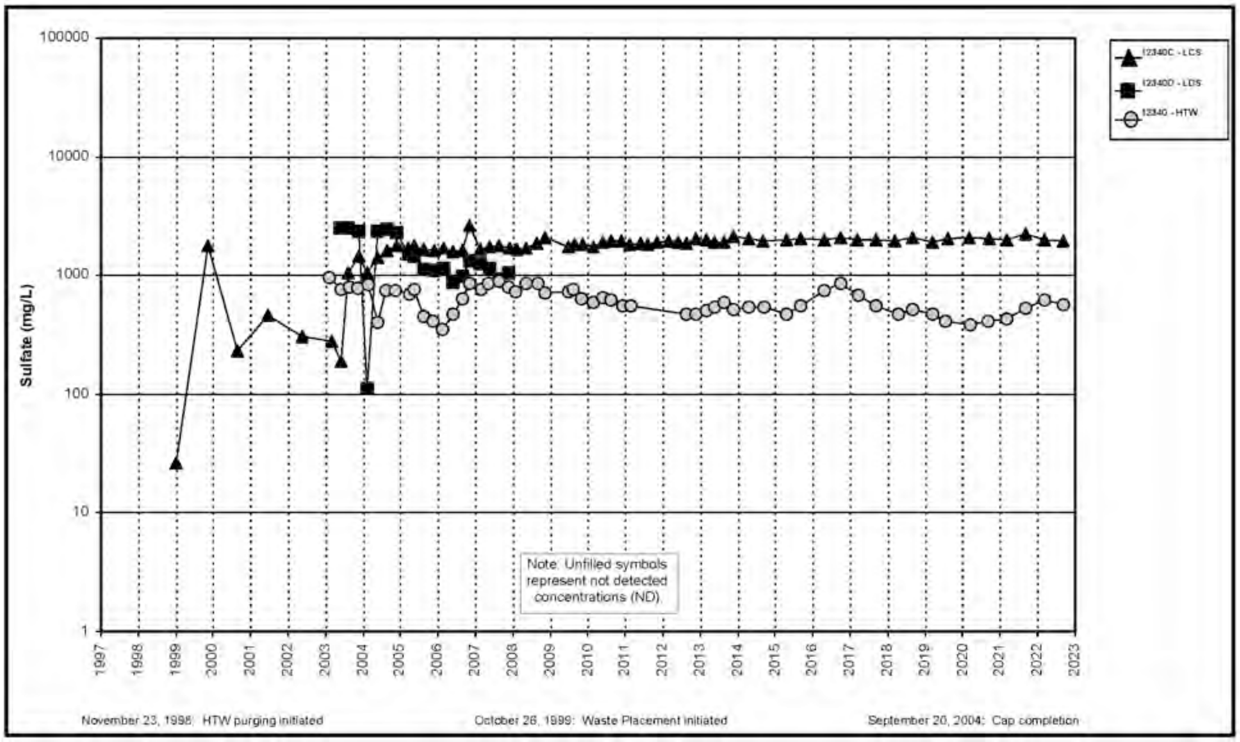

Figure A.5.3-8A. Cell 3 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

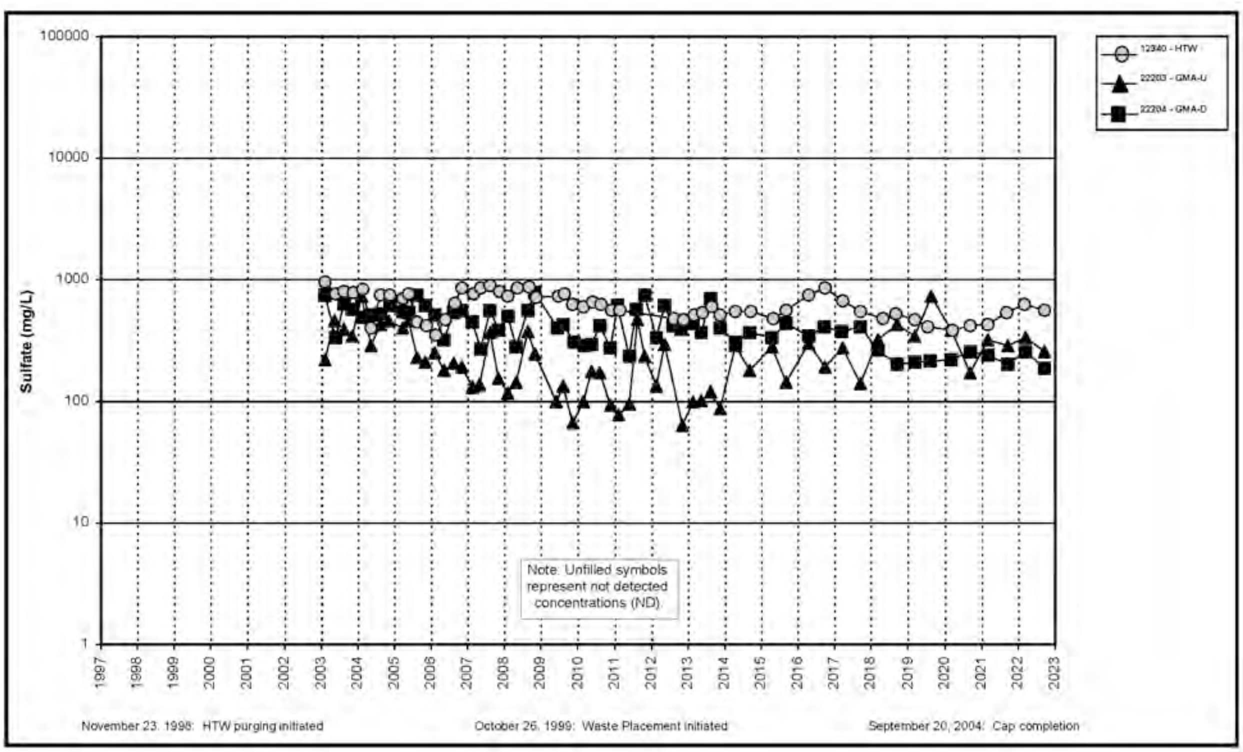

Figure A.5.3-8B. Cell 3 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

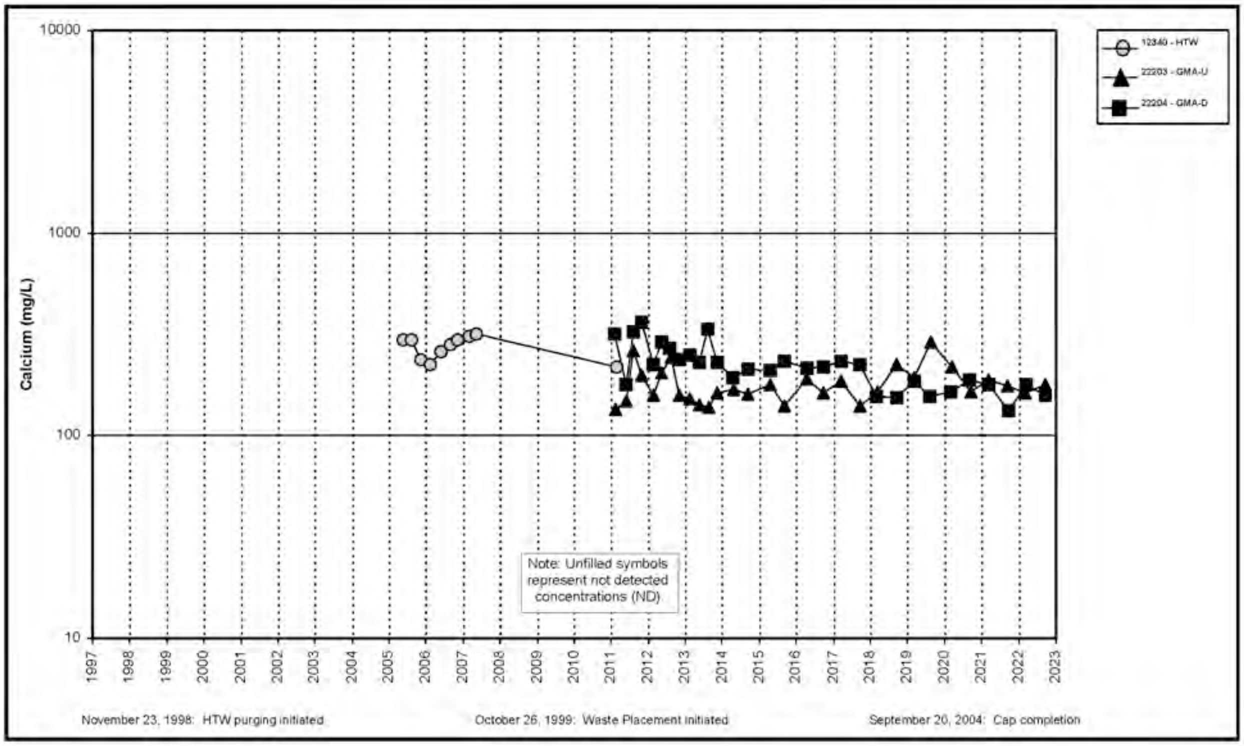

Figure A.5.3-9. Cell 3 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

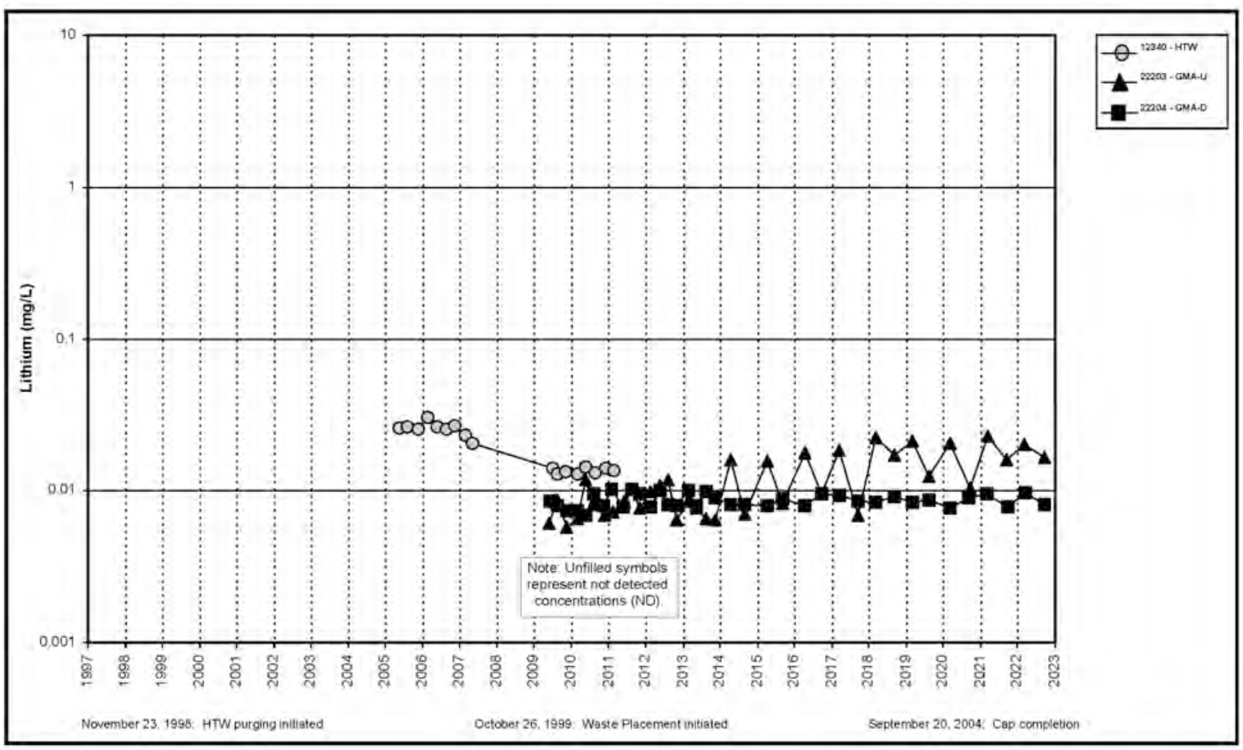

Figure A.5.3-10. Cell 3 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

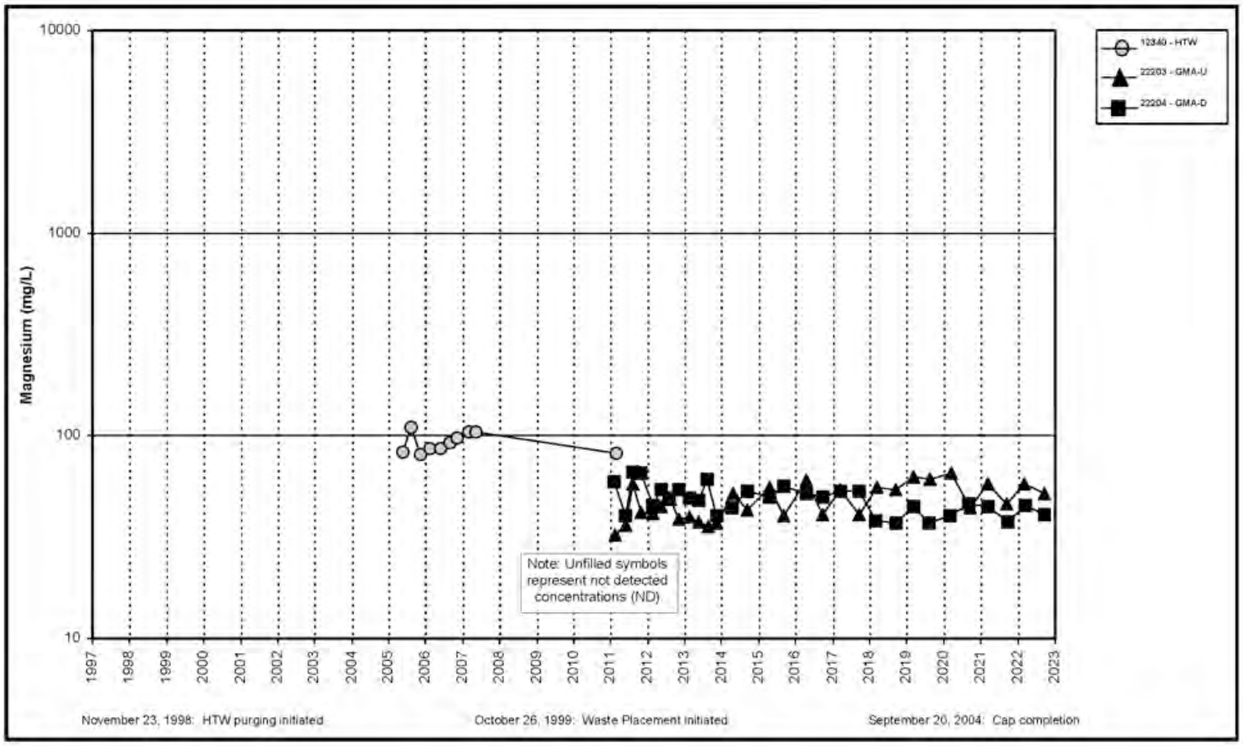

Figure A.5.3-11. Cell 3 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

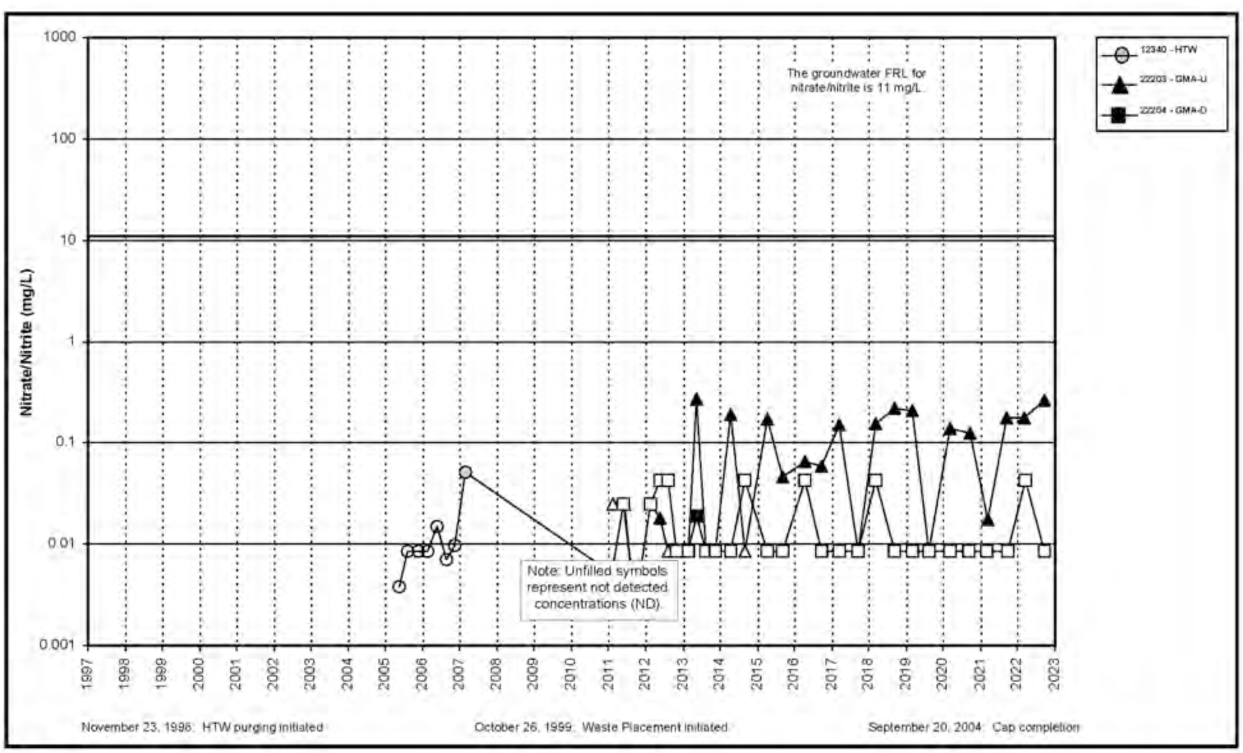

Figure A.5.3-12. Cell 3 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

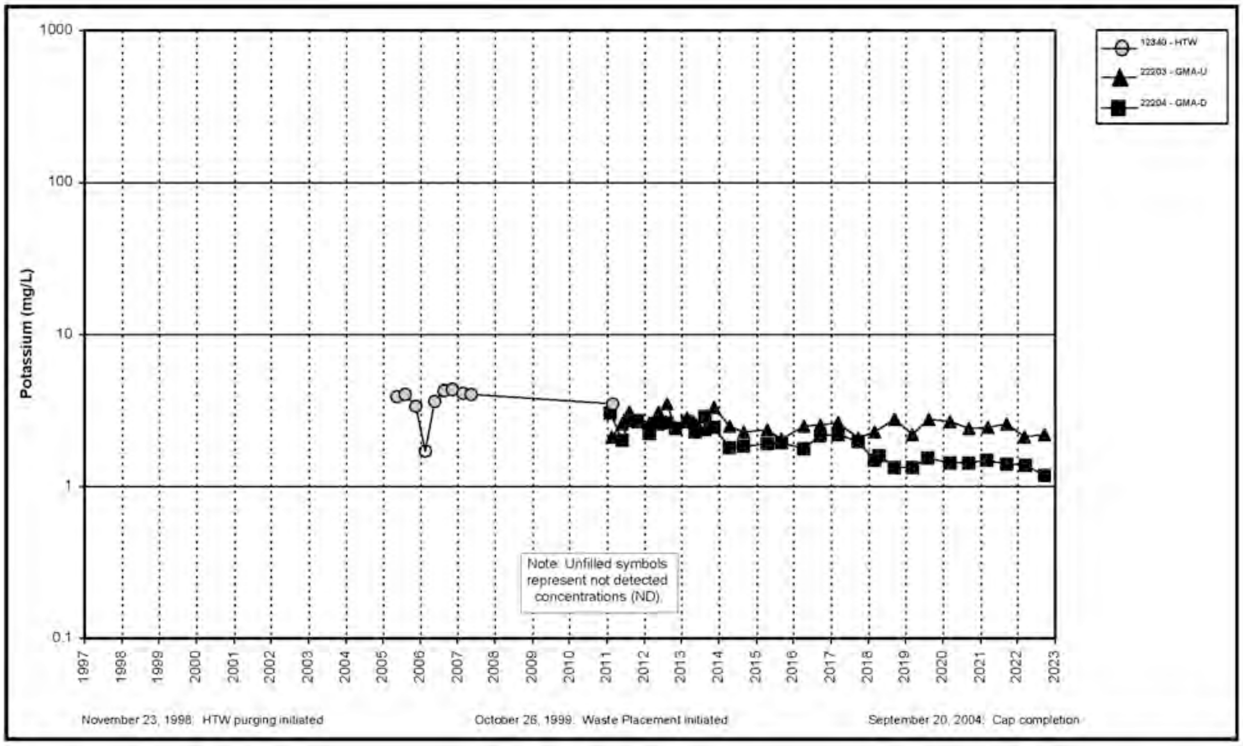

Figure A.5.3-13. Cell 3 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

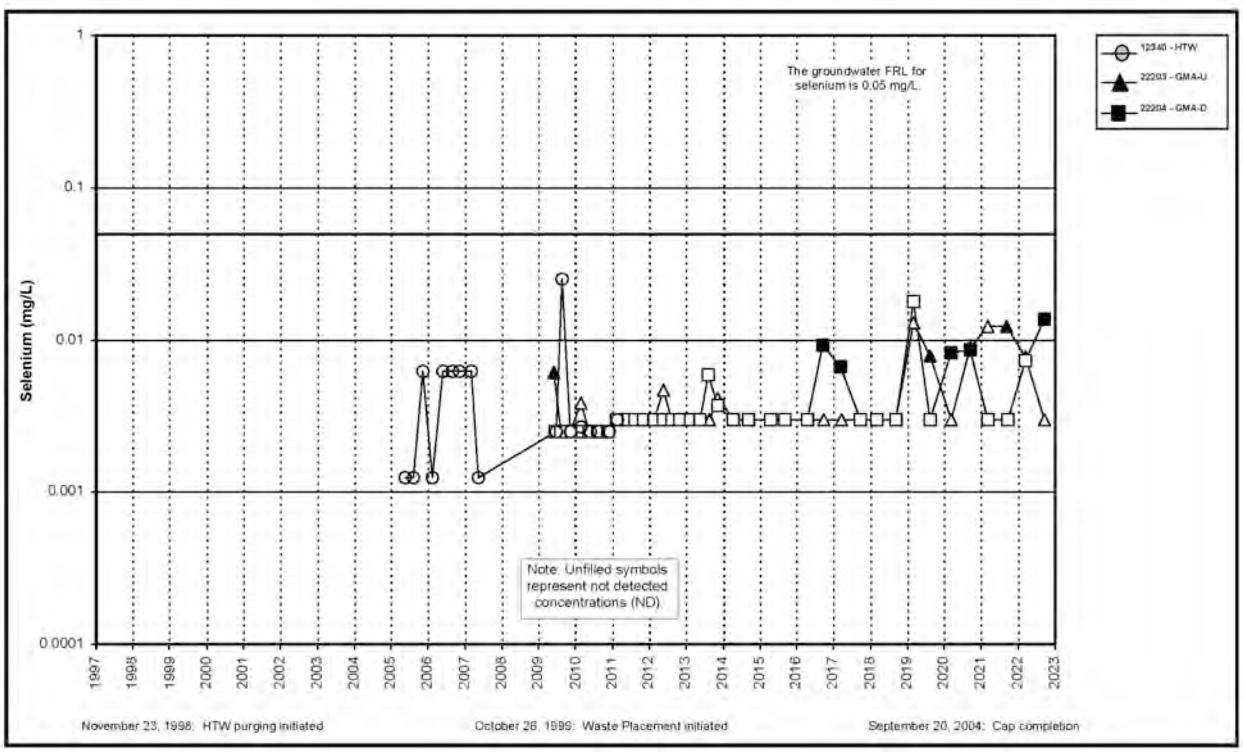

Figure A.5.3-14. Cell 3 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

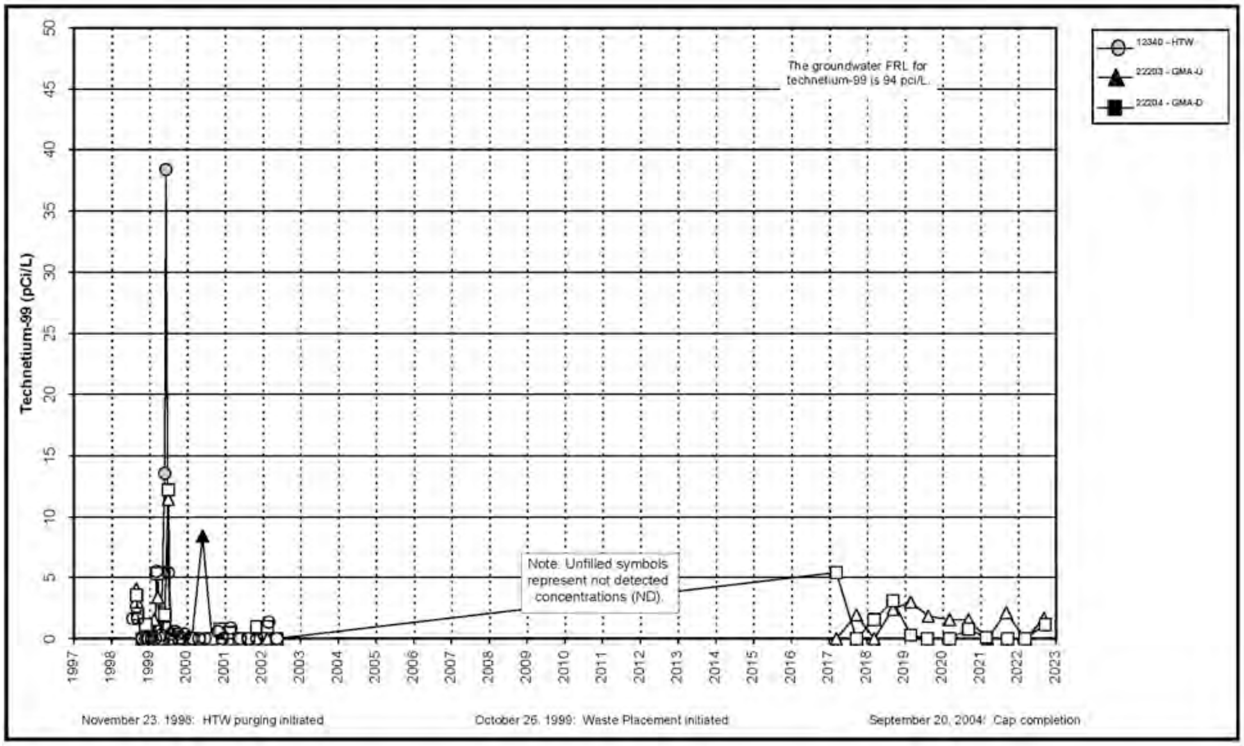

Figure A.5.3-15. Cell 3 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

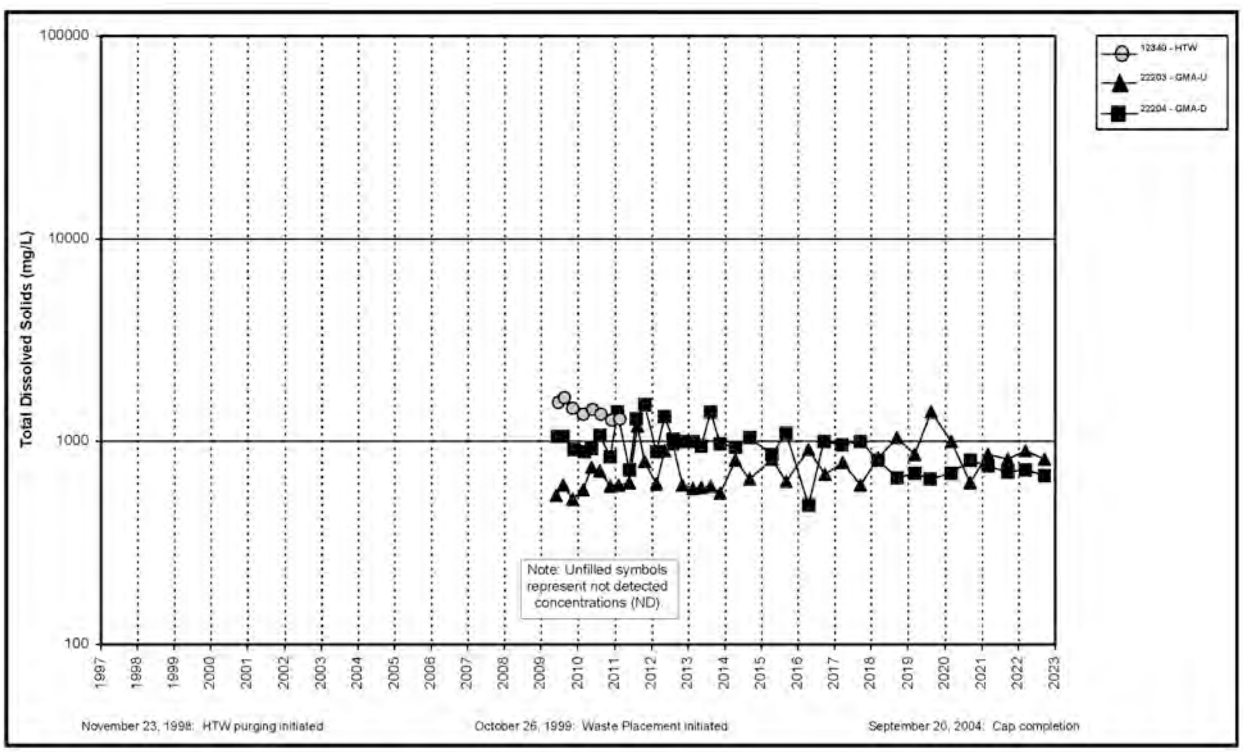

Figure A.5.3-16. Cell 3 Total Dissolved Solid Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

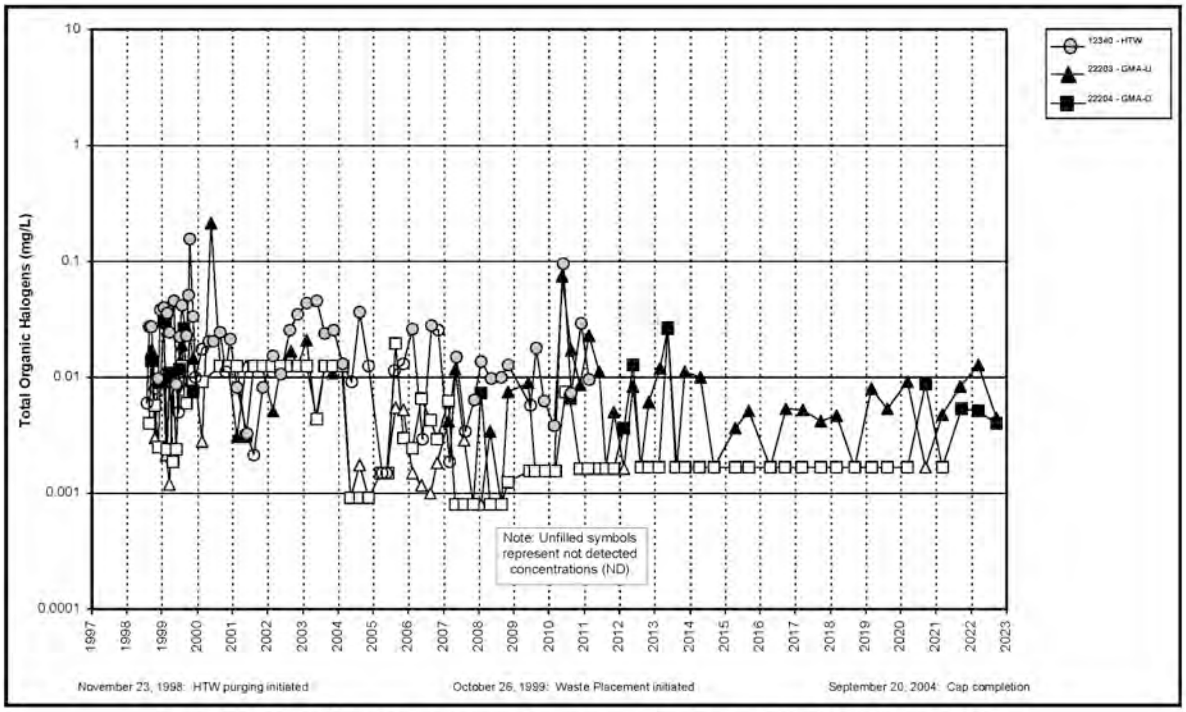

Figure A.5.3-18B. Cell 3 Total Organic Halogens Concentration vs. Time Plot for HTW, GMA-U Well, and GMA-D Well

Figure A.5.3-17. Cell 3 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

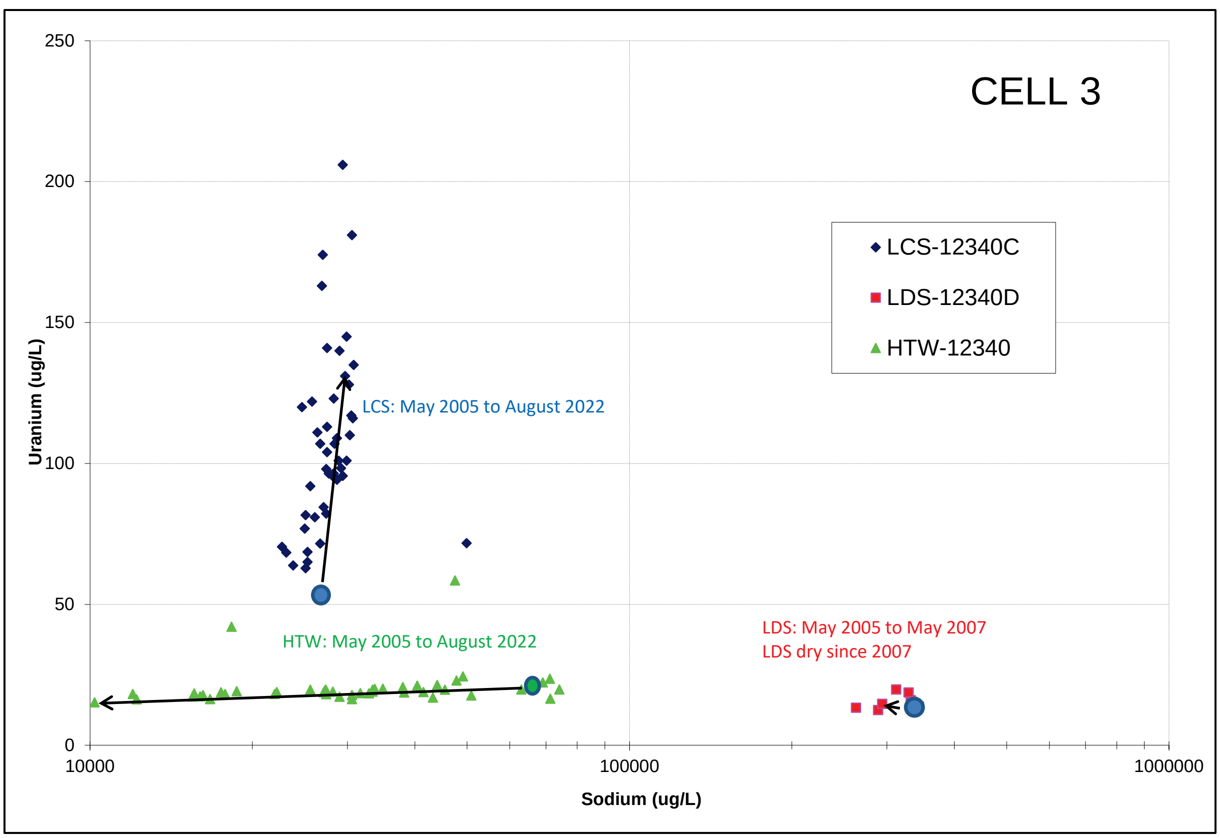

Figure A.5.3-18. Cell 3 Bivariate Plot for Uranium and Sodium

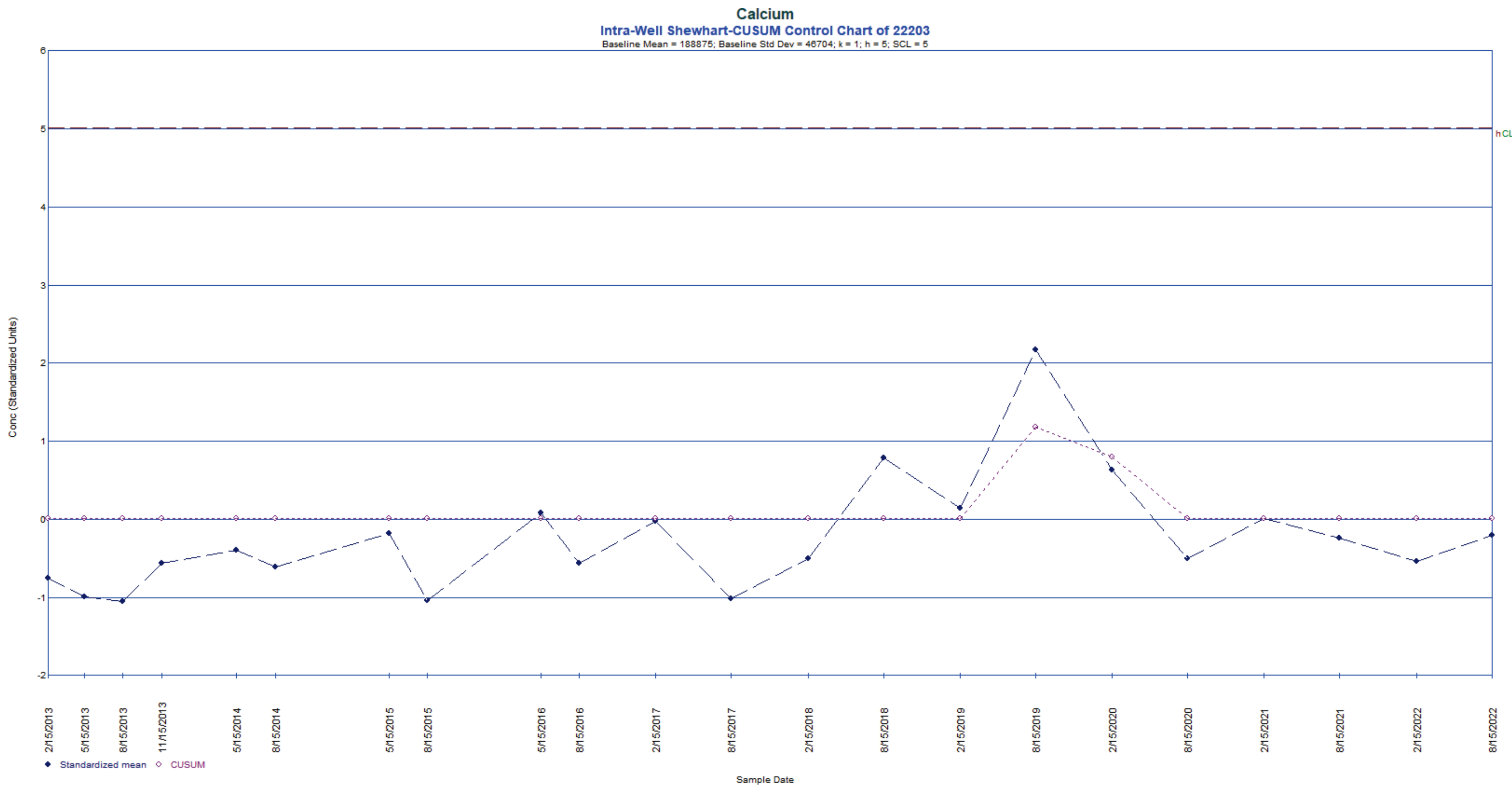

Figure A.5.3-19. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22203

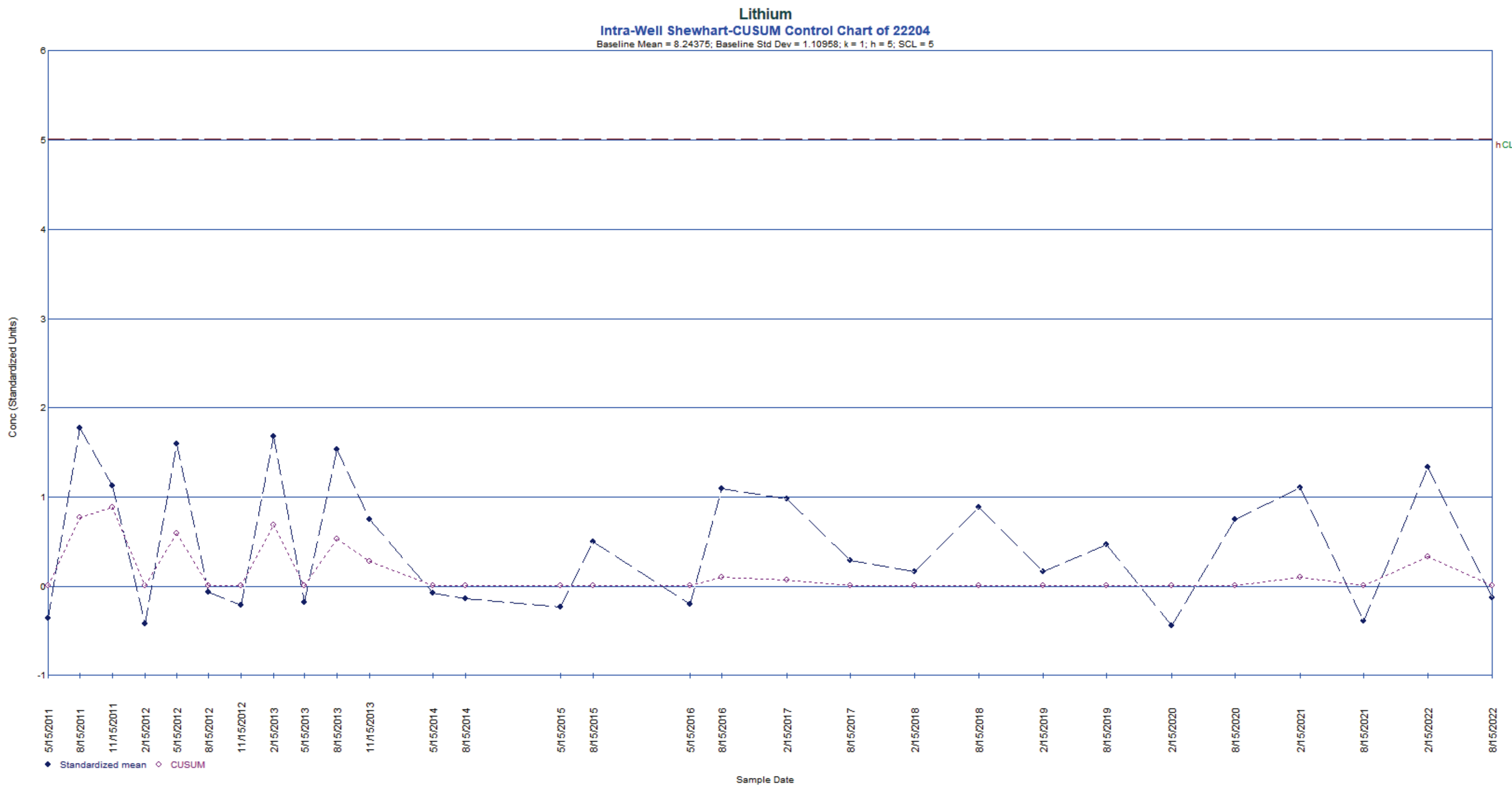

Figure A.5.3-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22204

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Subattachment A.5.4

Cell 4

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 4:

- Semiannual monitoring summary statistics (Table A.5.4-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.4-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.4-2)
- OSDF horizontal till well (HTW) 12341 water yield (Table A.5.4-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.4-3 and A.5.4-4)
- Plots of concentration versus time (Figures A.5.4-5A through A.5.4-17)
- A bivariate plot for uranium-sodium (Figure A.5.4-18)
- Control charts (Figures A.5.4-19 through A.5.4-23)

A.5.4.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.4.1.1 LCS and LDS Results

As shown in Table A.5.4-1 and summarized below, four parameters (total uranium, boron, sodium, and sulfate) have upward trends in the LCS or LDS based on the Mann-Kendall test for trend.

From 2012 to 2016, the volume of water in the LDS tank of Cell 4 was insufficient to collect a sample. From 2016 to 2019, enough water was present in the LDS tank of Cell 4 to sample it twice a year. The volume of water in the LDS tank of Cell 4 was insufficient to collect a sample in 2020. In 2021, enough water was present in the LDS tank of Cell 4 to collect a sample in the second half of the year. In 2022, enough water was present in the LDS tank of Cell 4 to collect a sample in the first half of 2022. New high concentrations of uranium (79.8 micrograms per liter [µg/L]), boron (3.74 milligrams per liter [mg/L]), sodium (4,440 µg/L)], and sulfate (25,500 µg/L) were measured in the LDS of Cell 4 in 2022. The previous highs for uranium, boron, sodium, and sulfate were 55.9 µg/L, 2.89 mg/L, 1,750 mg/L, and 11,600 mg/L, respectively.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 4

Parameter	LCS 12341C 2021 Trend[a]	LDS 12341D Trend (Year Last Sampled)
Total Uranium		Up (2022)
Boron		Up (2022)
Sodium	Up	Up (2022)
Sulfate	Up	Up (2022)

[a] No entry indicates that the trend was not up.

A.5.4.1.2 HTW and Monitoring Well Results

As shown in Table A.5.4-1 and summarized below, six parameters (total uranium, boron, sodium, sulfate, lithium, and selenium) have upward trends in the HTW or GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 4

Parameter	HTW 12341[a]	GMA-U 22206[a,b]	GMA-D 22205[a,b]
Total Uranium		Up	
Boron	Up	Up	Up
Sodium		Up	
Sulfate	Up	Up	
Lithium			Up
Selenium		Up	Up

[a] No entry indicates that the trend was not up.
[b] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer; HTW = Horizontal Till Well.

A.5.4.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 4 LCS, LDS, and HTW is provided in Figure A.5.4-18. On the figure, the first sample ever collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. The plot shows that the chemical signatures for uranium and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.4.2 Control Charts

Intrawell control charts use historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared “not in control” if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (*h*) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.4-1 in gray shading and as summarized below, four parameters in the HTW or GMA wells of Cell 4 meet the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in five control charts (A.5.4-19 through A.5.4-23).

All of the control charts for Cell 4 exhibit “in control” conditions.

Parameter	Monitoring Point[a]	Well Number	Assessment	Figure Number
Uranium	GMA-D	22205	In Control	A.5.4-19
Sulfate	GMA-D	22205	In Control	A.5.4-20
Magnesium	GMA-U	22205	In Control	A.5.4-21
Magnesium	GMA-D	22206	In Control	A.5.4-22
Total Dissolved Solids	GMA-D	22205	In Control	A.5.4-23

[a] GMA-U = upgradient Great Miami Aquifer, GMA-D = downgradient Great Miami Aquifer

A.5.4.3 Summary and Conclusions

- Four parameters in 2022 (total uranium, boron, sodium, and sulfate) have upward trends in the LCS or LDS based on the Mann-Kendall test for trend.
- New high concentrations of uranium (79.8 µg/L), boron (3.74 mg/L), sodium (4,440 µg/L), and sulfate (25,500 µg/L) were measured in the LDS of Cell 4 in 2022. The previous highs for uranium, boron, sodium, and sulfate were 55.9 µg/L, 2.89 mg/L, 1,750 mg/L, and 11,600 mg/L, respectively.
- Six parameters monitored semiannually have an upward concentration in the HTW or GMA wells of Cell 4: total uranium, boron, sodium, sulfate, lithium, and selenium. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 4 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 4 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- Five control charts were constructed for Cell 4 parameters. All control charts exhibit “in control” conditions.

A.5.4.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. “Ground Water Monitoring Program for a Sanitary Landfill Facility,” *Ohio Administrative Code.*

Table A.5.4-1. Summary Statistics for Cell 4

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12341C	60	60	100	4.41	234	88.2	35.0	Undefined	None (2022)	Detected	
	LDS	12341D	42	42	100	5.74	79.8	15.1	14.8	Undefined	Up (2022)	Detected	
	HTW	12341	65	65	100	3.19	7.89	5.34	1.09	Normal	Down (2022)	Detected	
	GMA-U	22206	62	66	93.9	ND	4.67	1.35	0.96	Ln Normal	Up (2022)	Not Detected	
	GMA-D	22205	75	75	100	0.525	12.1	2.48	2.27	Ln Normal	None (2022)	Not Detected	
Boron (mg/L)	LCS	12341C	60	60	100	0.0626	1.93	0.848	0.264	Undefined	Down (2022)	Detected	
	LDS	12341D	42	42	100	0.415	3.74	0.708	0.777	Undefined	Up (2022)	Detected	
	HTW	12341	45	48	93.8	ND	1.24	0.0937	0.207	Undefined	Up (2022)	Detected	
	GMA-U	22206	61	66	92.4	ND	0.0817	0.0471	0.0137	Normal	Up (2022)	Detected	
	GMA-D	22205	59	66	89.4	ND	0.0807	0.0461	0.0141	Normal	Up (2022)	Detected	
Sodium (mg/L)	LCS	12341C	50	50	100	22.0	117	54.6	12.7	Undefined	Up (2022)	Detected	
	LDS	12341D	28	28	100	307	4,440	504	799	Undefined	Up (2022)	Detected	
	HTW	12341	46	46	100	13.7	18.1	15.2	1.0	Ln Normal	Down (2022)	Detected	
	GMA-U	22206	37	37	100	12.3	22.3	17.1	2.9	Normal	Up (2022)	Detected	
	GMA-D	22205	38	38	100	8.53	22.2	14.9	4.3	Undefined	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12341C	60	60	100	140	3,940	2,780	760	Undefined	Up (2022)	Detected	
	LDS	12341D	42	42	100	1,470	25,500	2,660	4,100	Undefined	Up (2022)	Detected	
	HTW	12341	56	56	100	153	531	294	119	Undefined	Up (2022)	Detected	
	GMA-U	22206	61	61	100	90.4	559	211	105	Ln Normal	Down (2022)	Detected	3,720 (Q3-12)
	GMA-D	22205	61	61	100	199	535	334	75	Normal	None (2022)	Not Detected	
Calcium (mg/L)	GMA-U	22206	30	30	100	137	217	149	22	Undefined	None (2022)	Not Detected	
	GMA-D	22205	30	30	100	163	268	216	24	Normal	Down (2022)	Not Detected	
Lithium (mg/L)	GMA-U	22206	37	37	100	0.00729	0.0175	0.0118	0.0025	Normal	Down (2022)	Detected	
	GMA-D	22205	37	37	100	0.00665	0.0167	0.00843	0.00219	Undefined	Up (2022)	Detected	
Magnesium (mg/L)	GMA-U	22206	30	30	100	30.2	43.8	35.9	3.5	Normal	None (2022)	Not Detected	
	GMA-D	22205	30	30	100	40.1	63.2	51.9	5.6	Normal	None (2022)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22206	3	30	10.0	ND	0.0850	0.0193	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	4	30	13.3	ND	0.0818	0.0085	0.0174	Undefined	None (2022)	Not Detected	
Potassium (mg/L)	GMA-U	22206	30	30	100	2.69	4.39	3.62	0.41	Normal	Down (2022)	Detected	
	GMA-D	22205	31	31	100	1.64	3.22	2.29	0.43	Normal	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22206	4	37	10.8	ND	0.0294	0.00300	0.00558	Undefined	Up (2022)	Detected	
	GMA-D	22205	6	37	16.2	ND	0.0180	0.00300	0.00393	Undefined	Up (2022)	Detected	
Technitium-99 (pCi/L)	GMA-U	22206	1	27	3.7	ND	8.54	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	0	27	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22206	37	37	100	551	877	624	81	Undefined	None (2022)	Not Detected	
	GMA-D	22205	37	37	100	726	1180	929	106	Normal	None (2022)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22206	23	66	34.8	ND	0.0640	0.00341	0.00946	Undefined	Down (2022)	Detected	
	GMA-D	22205	15	66	22.7	ND	0.0142	0.00166	0.00388	Undefined	Down (2022)	Detected	0.0340 (Q2-13)

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b]ND = not detected; NA = not applicable

[c]Averages were determined based on the distribution assumption.

[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e]Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f]Trend based on nonparametric Mann-Kendall procedure.

[g]Serial correlation based on Rank Von Neumann test.

[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i]Q = quarter

Table A.5.4-2. OSDF Horizontal Till Well 12341 (Cell 4) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
2002	21,115	9	2,346
2003	3,950	6	658
2004	2,935	5	587
2005	2,500	4	625
2006	2,475	4	619
2007	2,425	4	606
2008	2,220	4	555
2009	2,150	4	717
2010	2,575	4	644
2011	2,350	4	588
2012	2,240	4	560
2013	2,460	4	615
2014	1,140	2	570
2015	975	2	488
2016	1,025	2	513
2017	1,175	2	588
2018	1,155	2	578
2019	1,045	2	523
2020	1,000	2	500
2021	1,160	2	580
2022	1,120	2	560

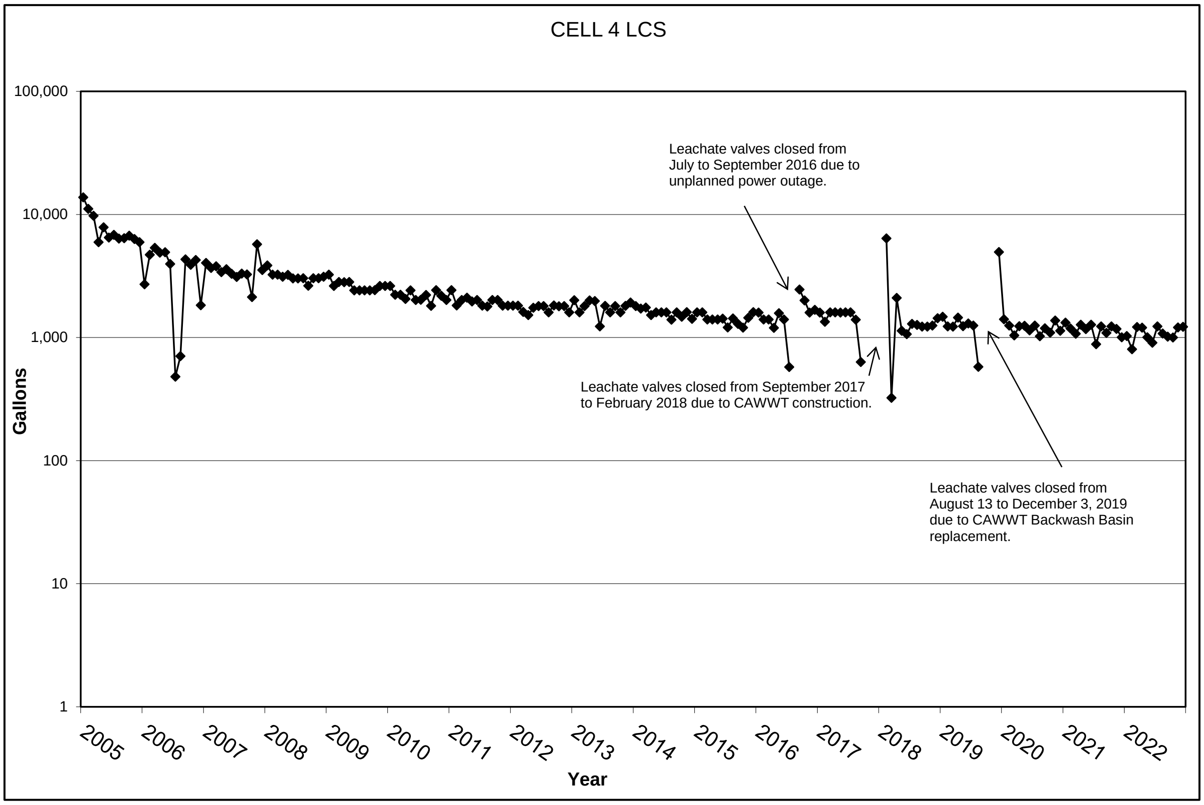

Figure A.5.4-1. Monthly Accumulation Volumes for Cell 4 LCS

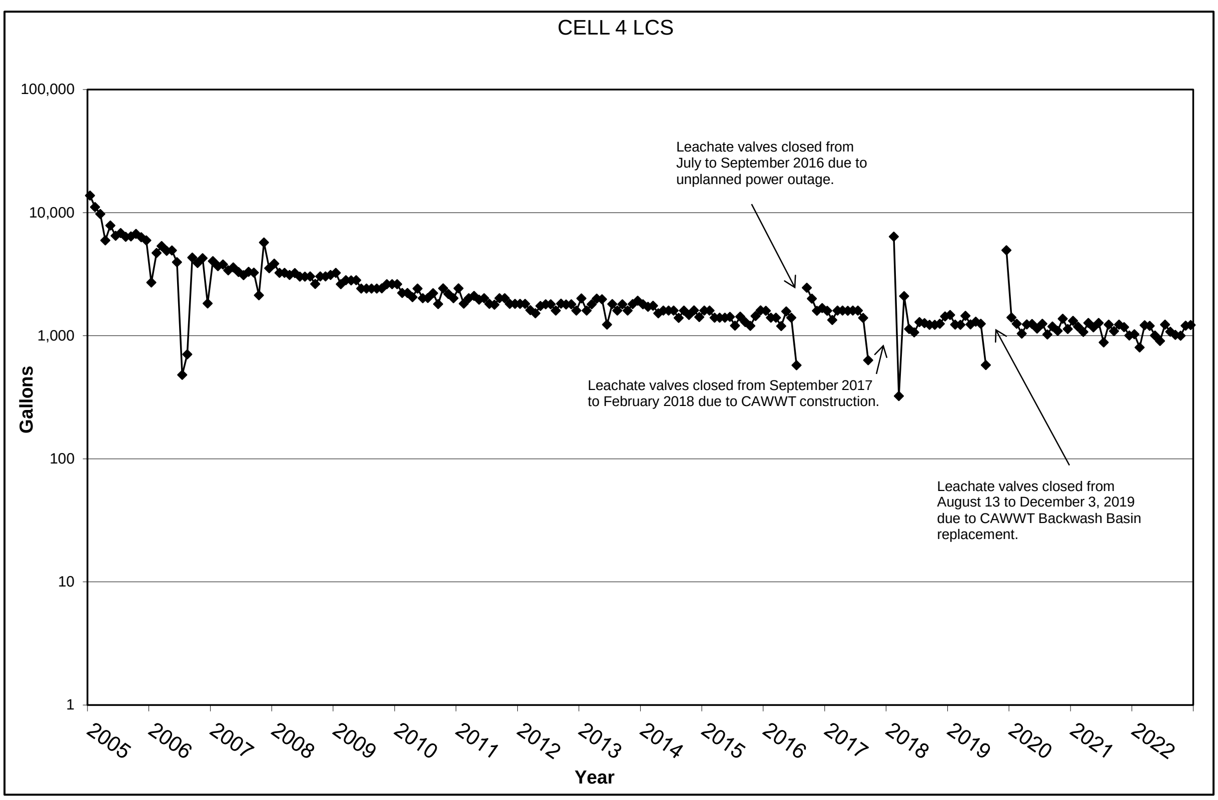

Figure A.5.4-2. Monthly Accumulation Volumes for Cell 4 LDS

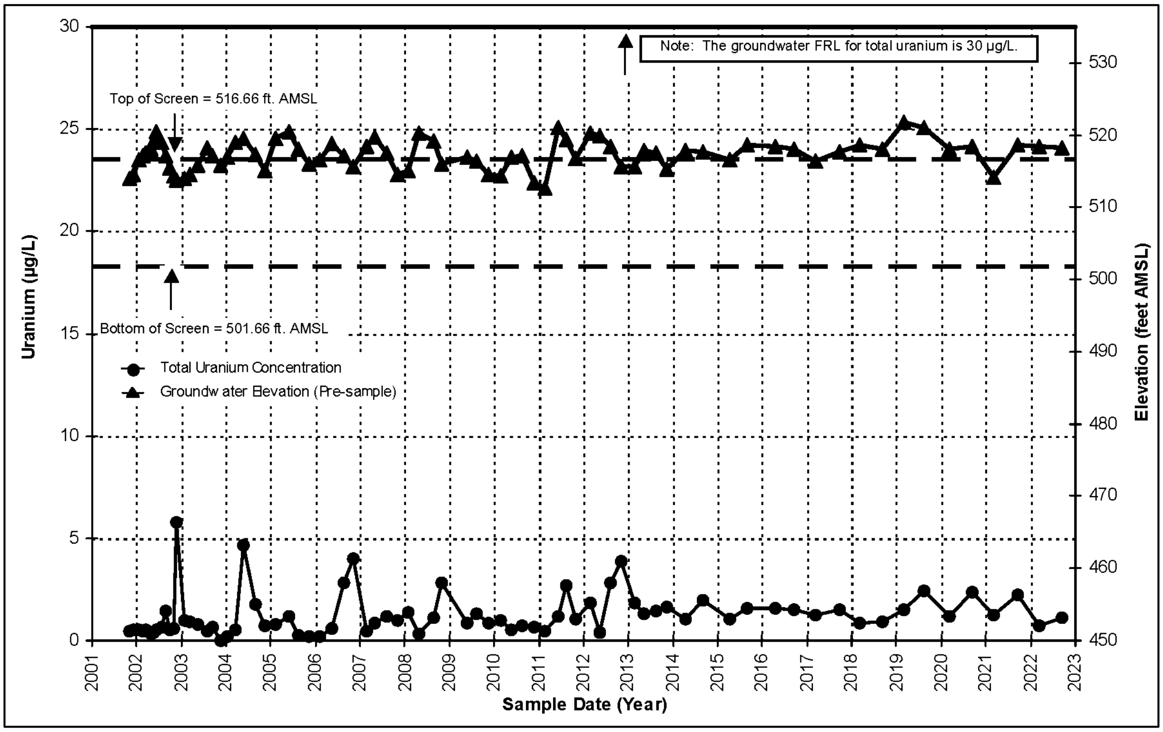

Figure A.5.4-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 4 Upgradient Monitoring Well 22206

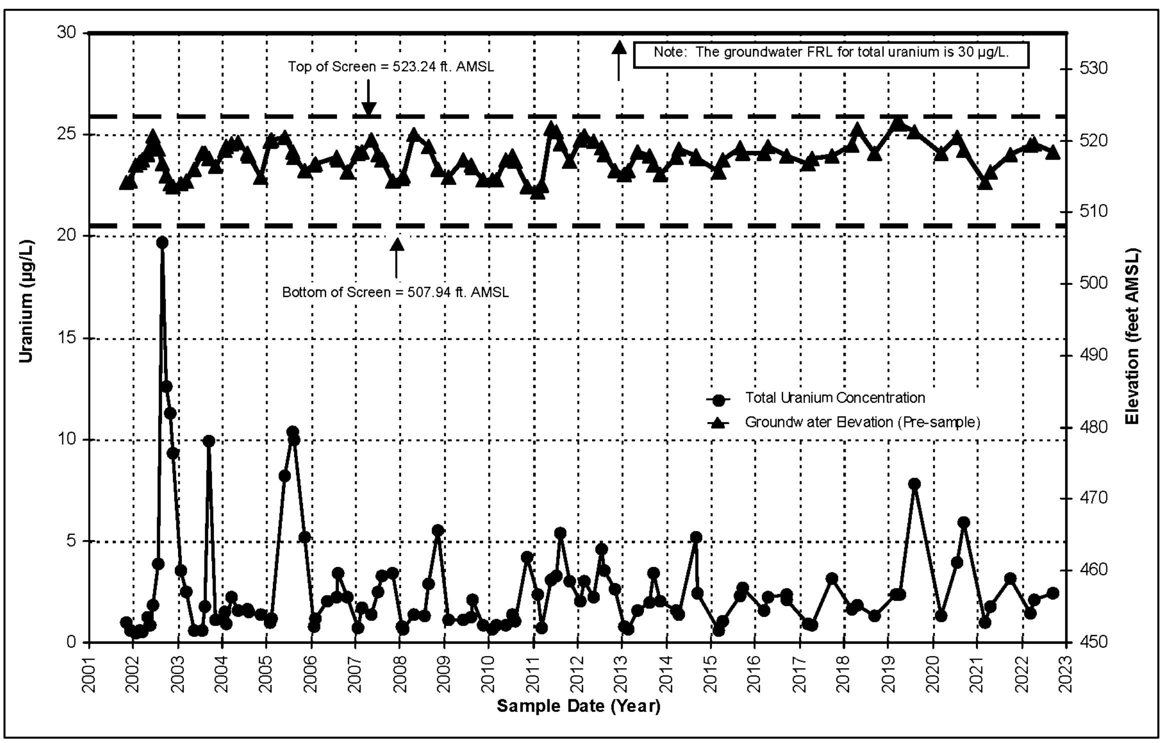

Figure A.5.4-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 4 Downgradient Monitoring Well 22205

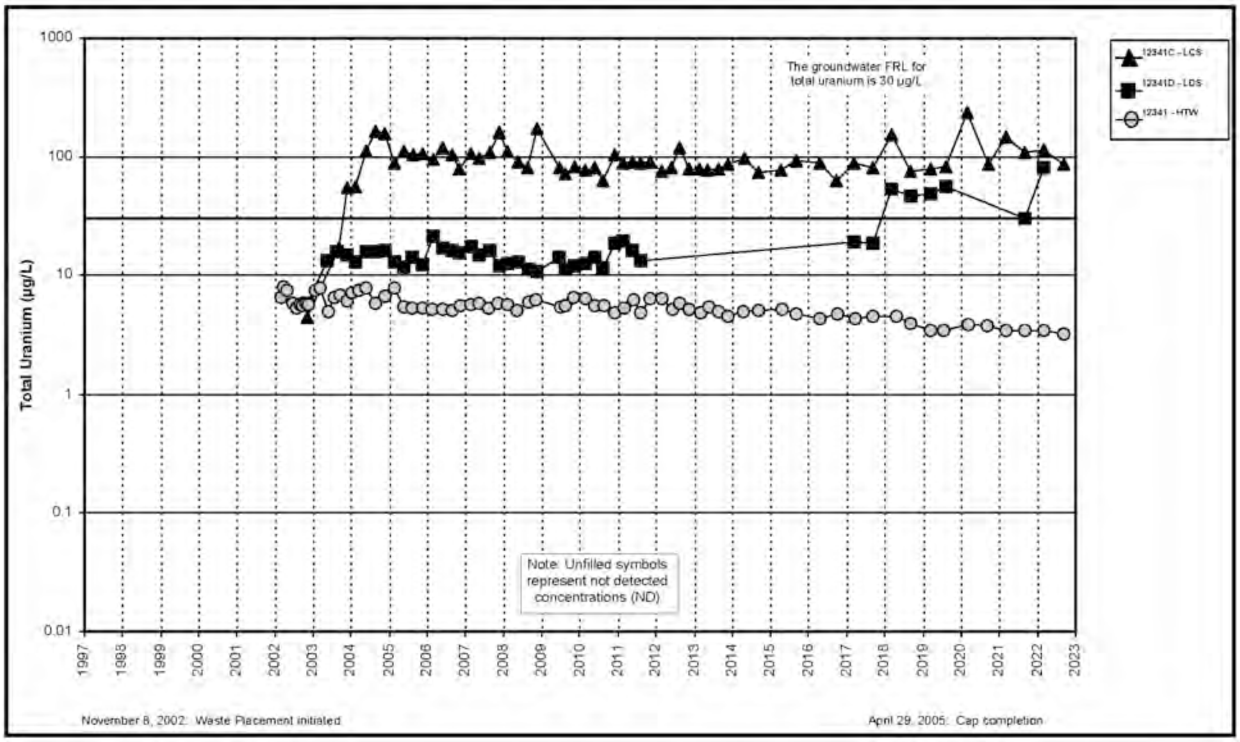

Figure A.5.4-5A. Cell 4 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

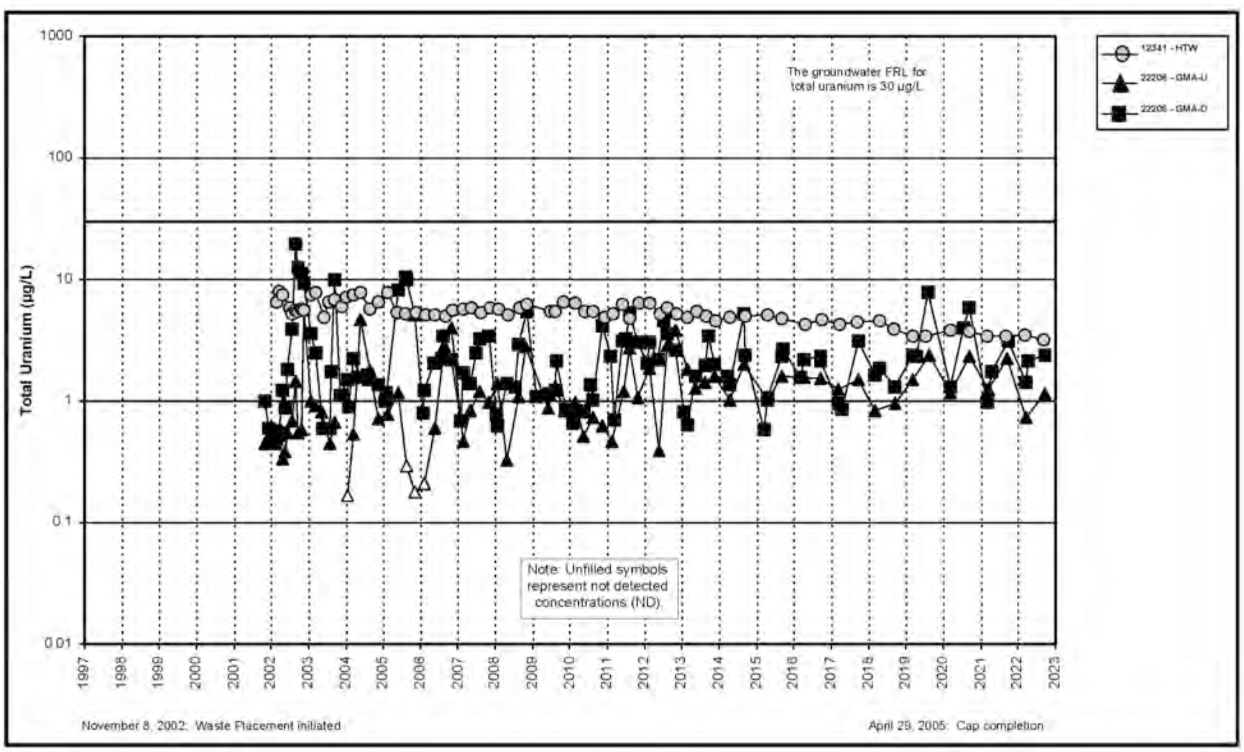

Figure A.5.4-5B. Cell 4 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

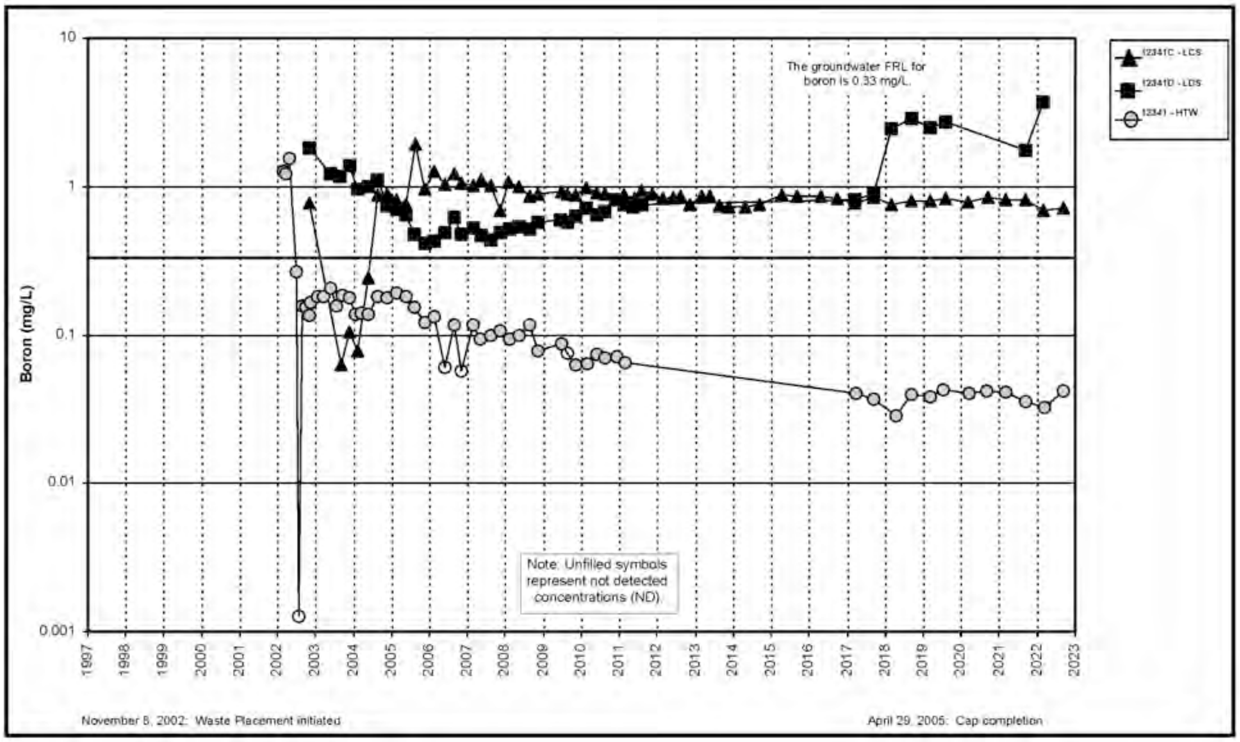

Figure A.5.4-6A. Cell 4 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

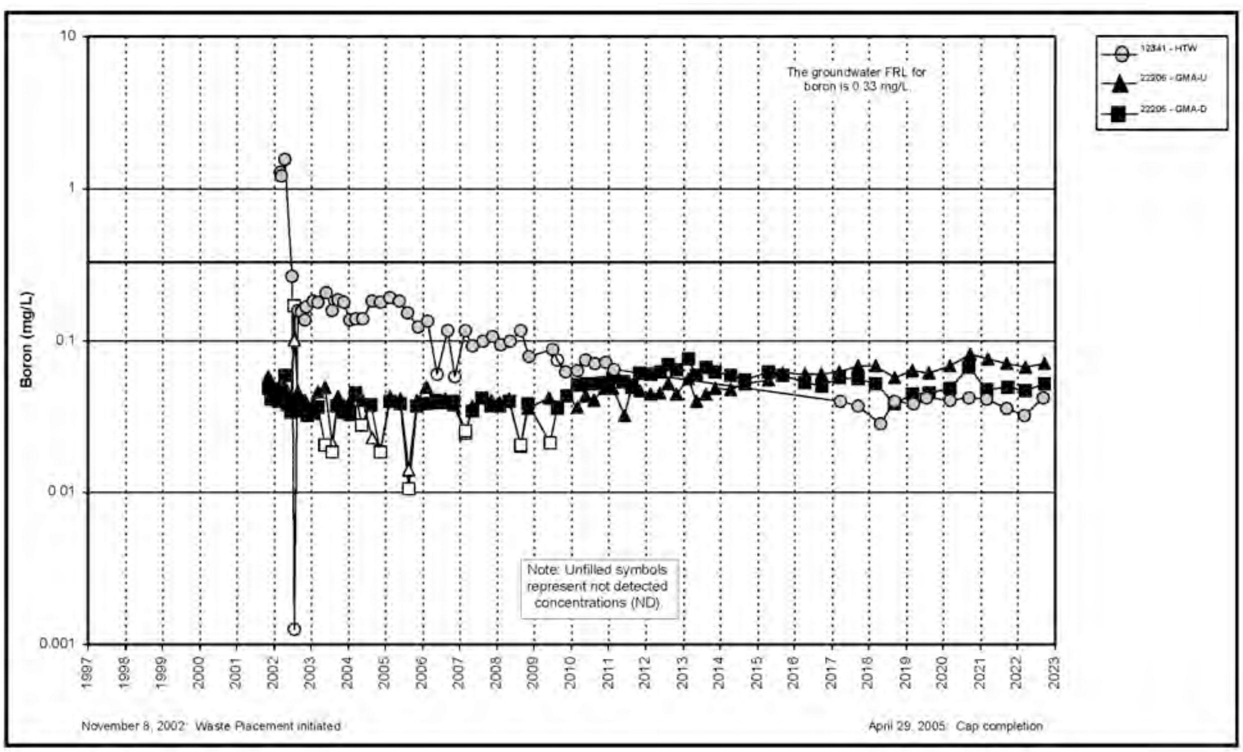

Figure A.5.4-6B. Cell 4 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

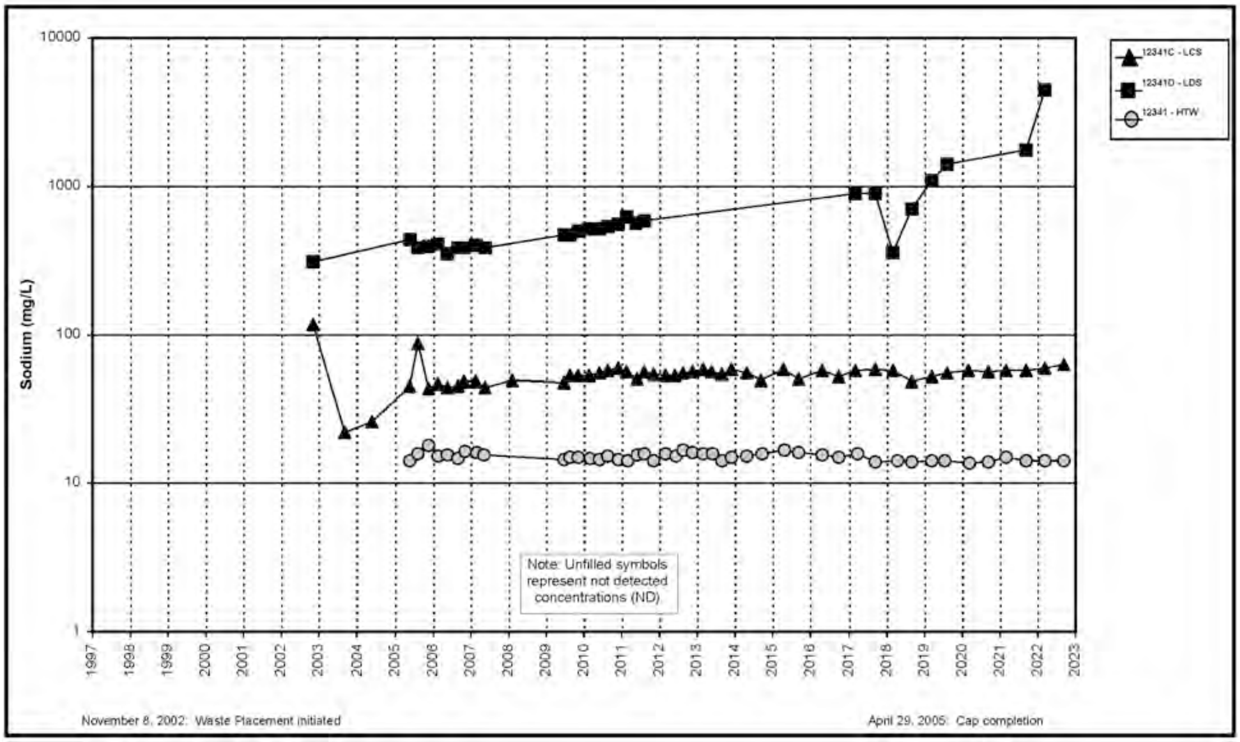

Figure A.5.4-7A. Cell 4 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

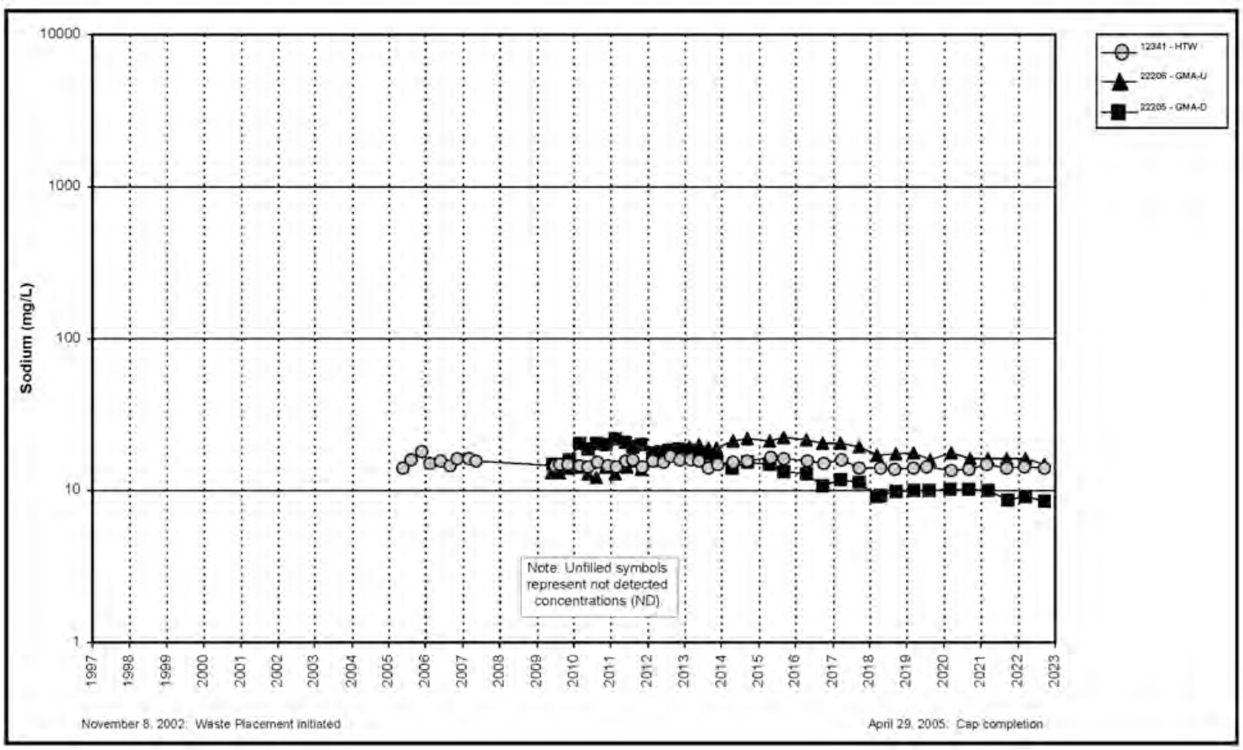

Figure A.5.4-7B. Cell 4 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

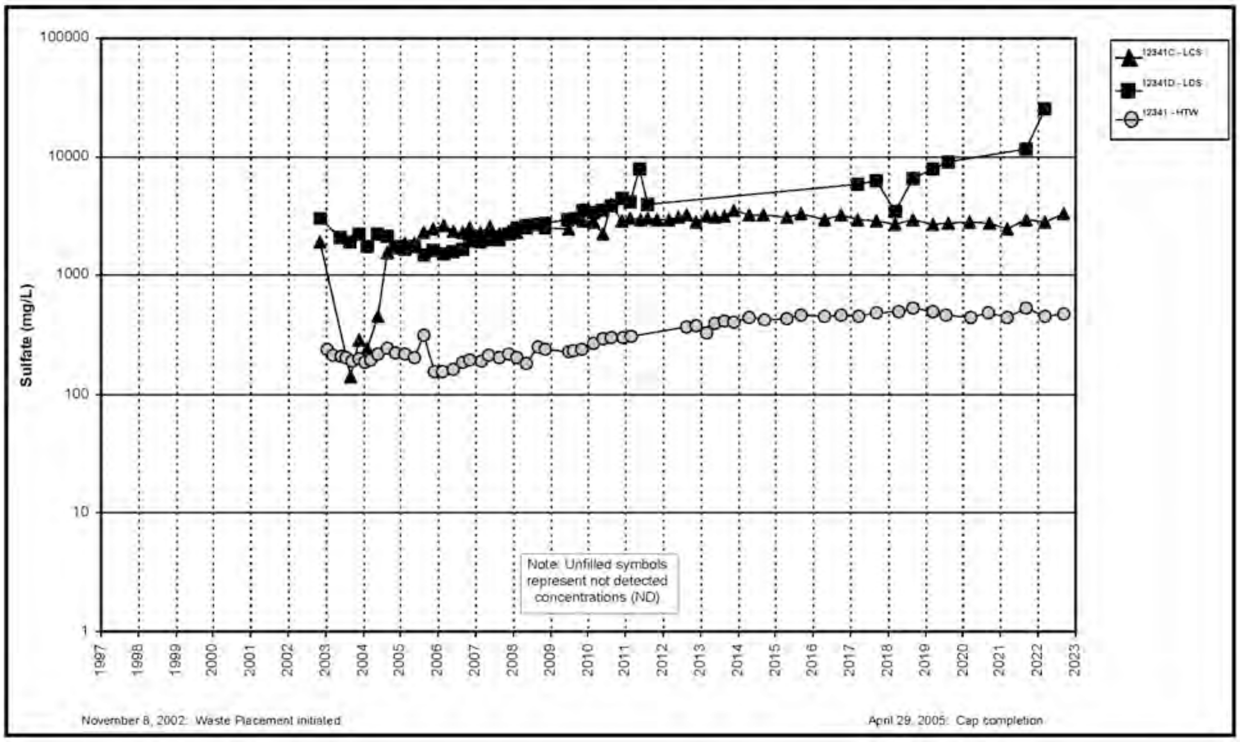

Figure A.5.4-8A. Cell 4 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

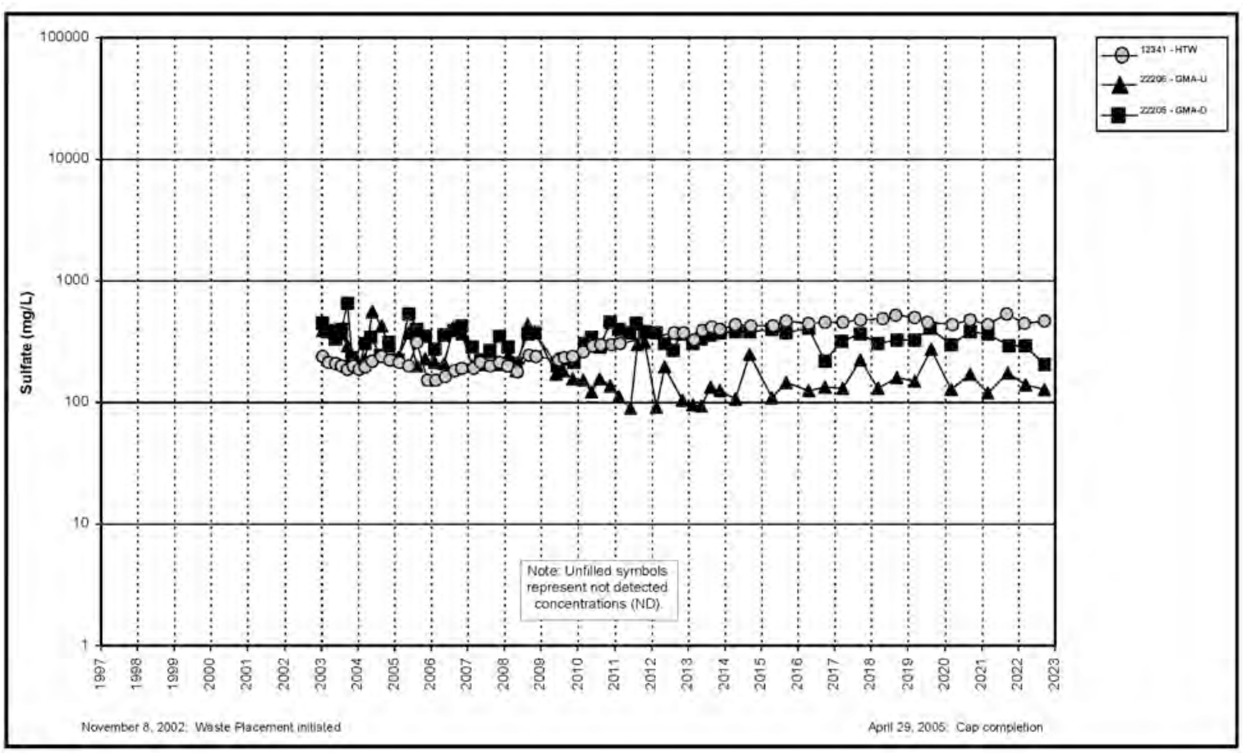

Figure A.5.4-8B. Cell 4 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

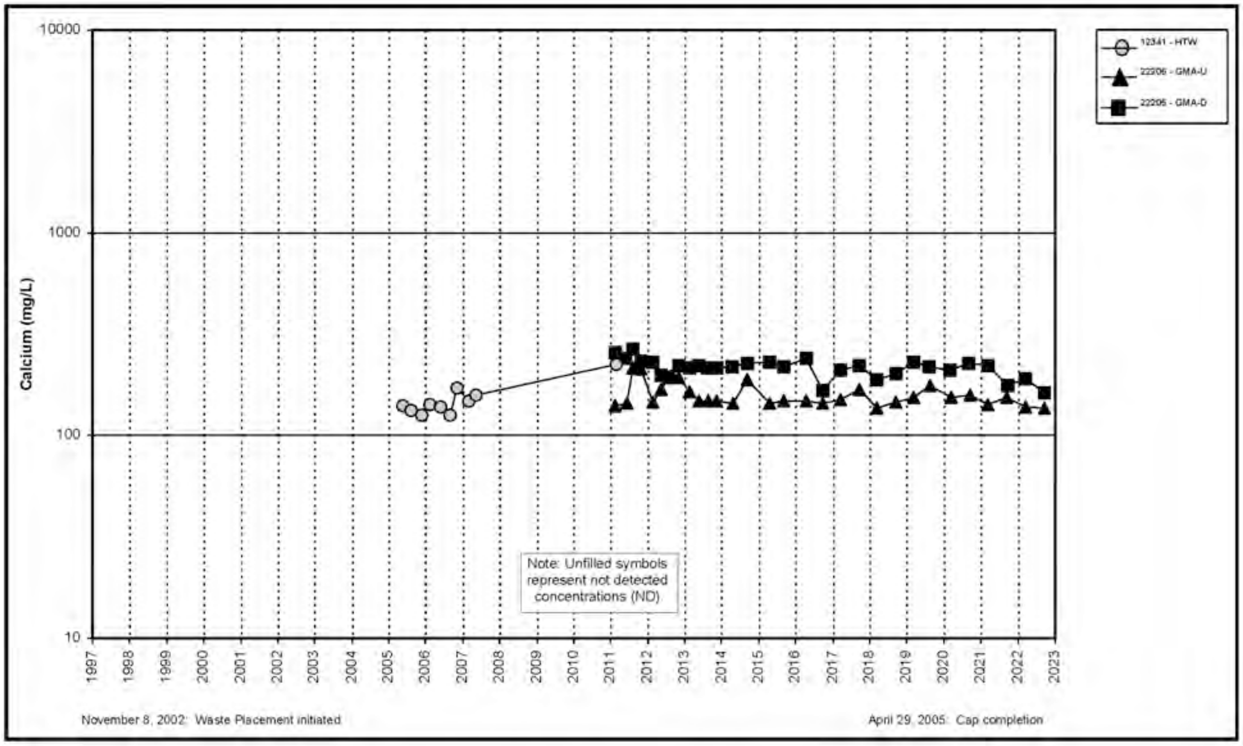

Figure A.5.4-9. Cell 4 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

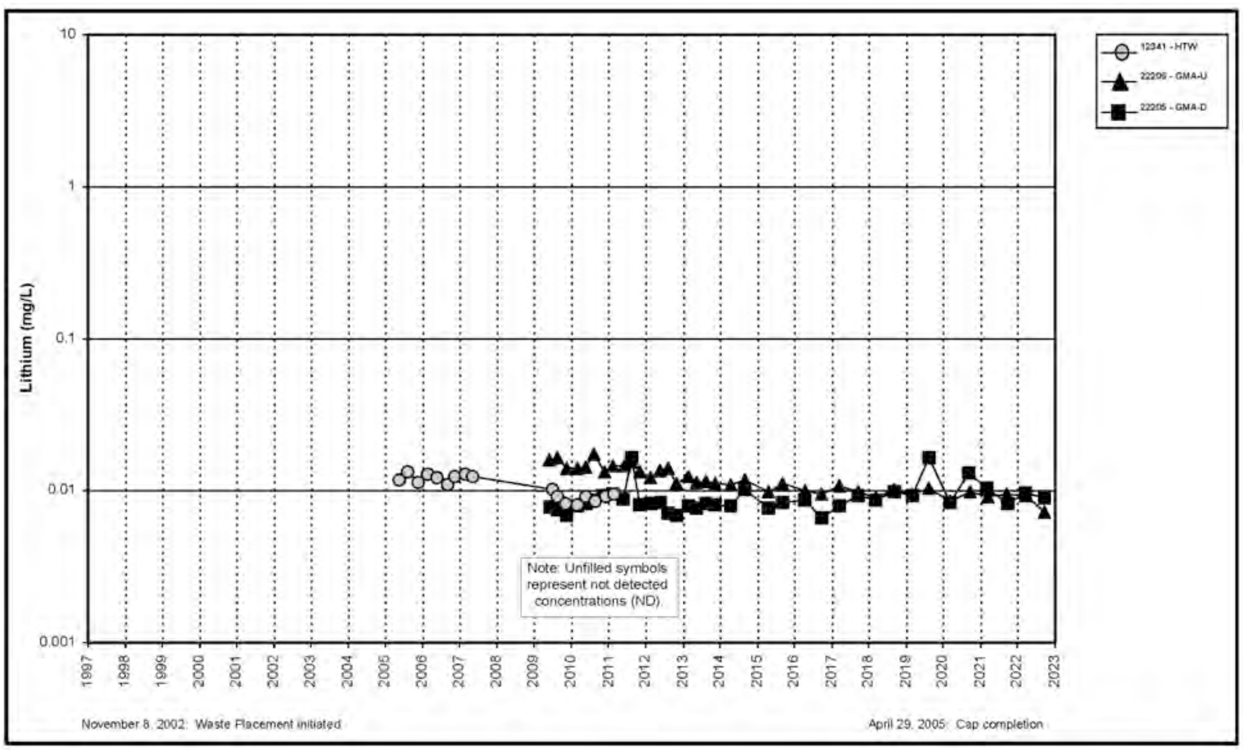

Figure A.5.4-10. Cell 4 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

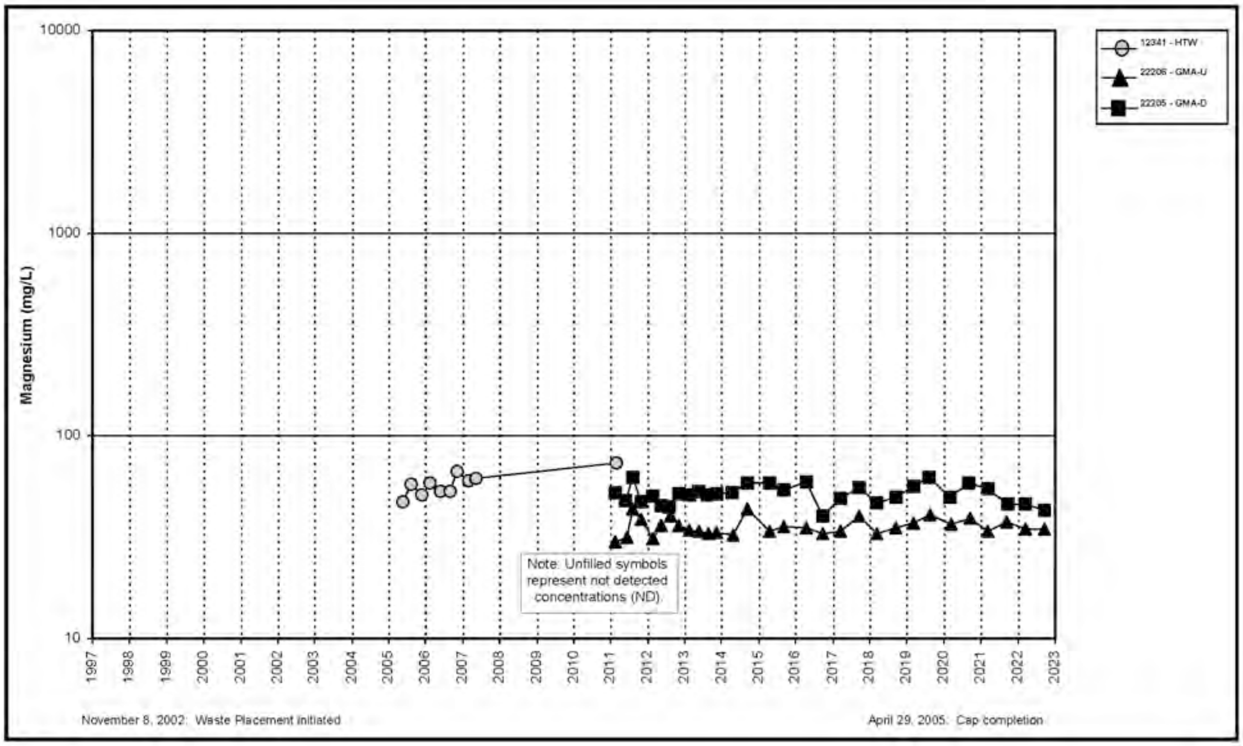

Figure A.5.4-11. Cell 4 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

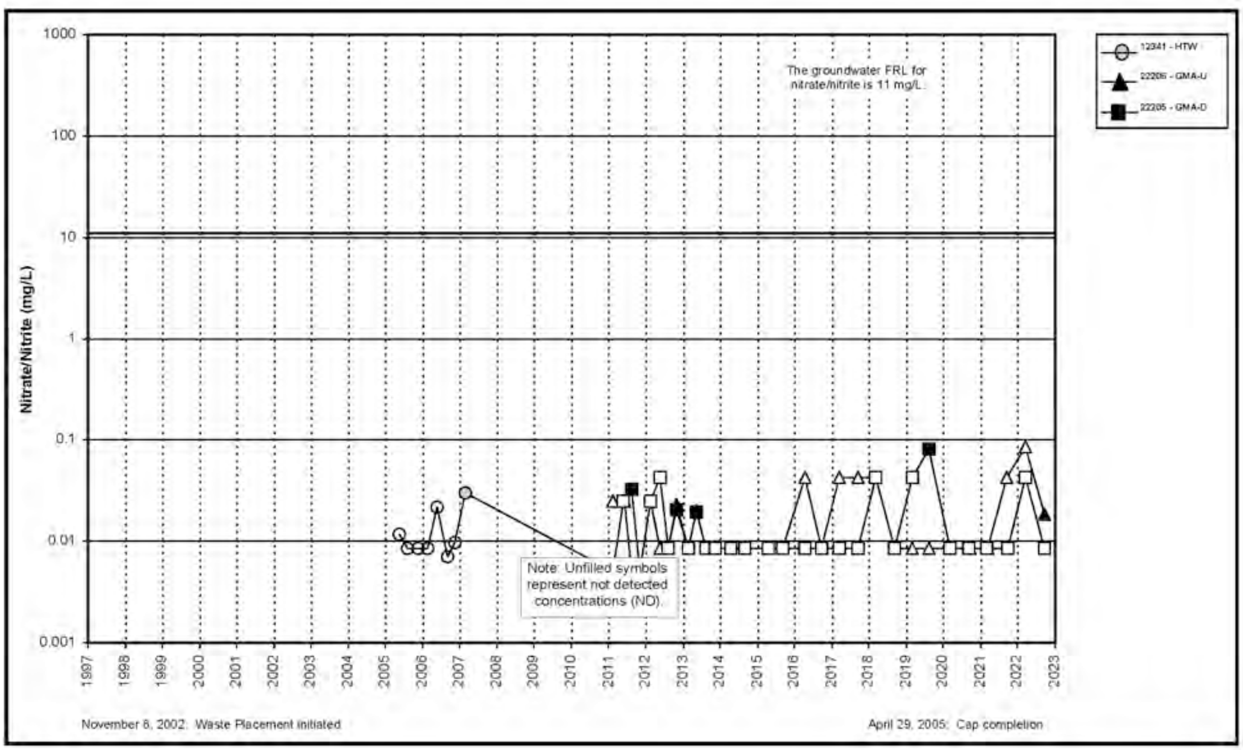

Figure A.5.4-12. Cell 4 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

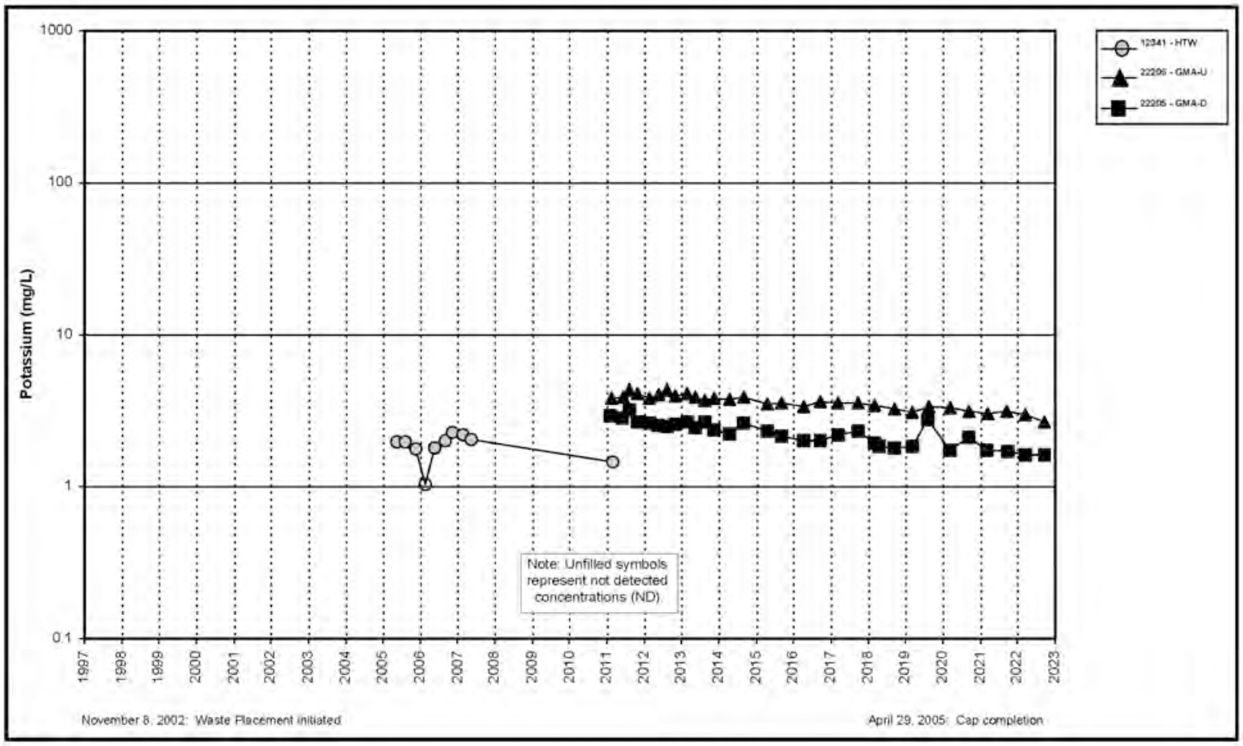

Figure A.5.4-13. Cell 4 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

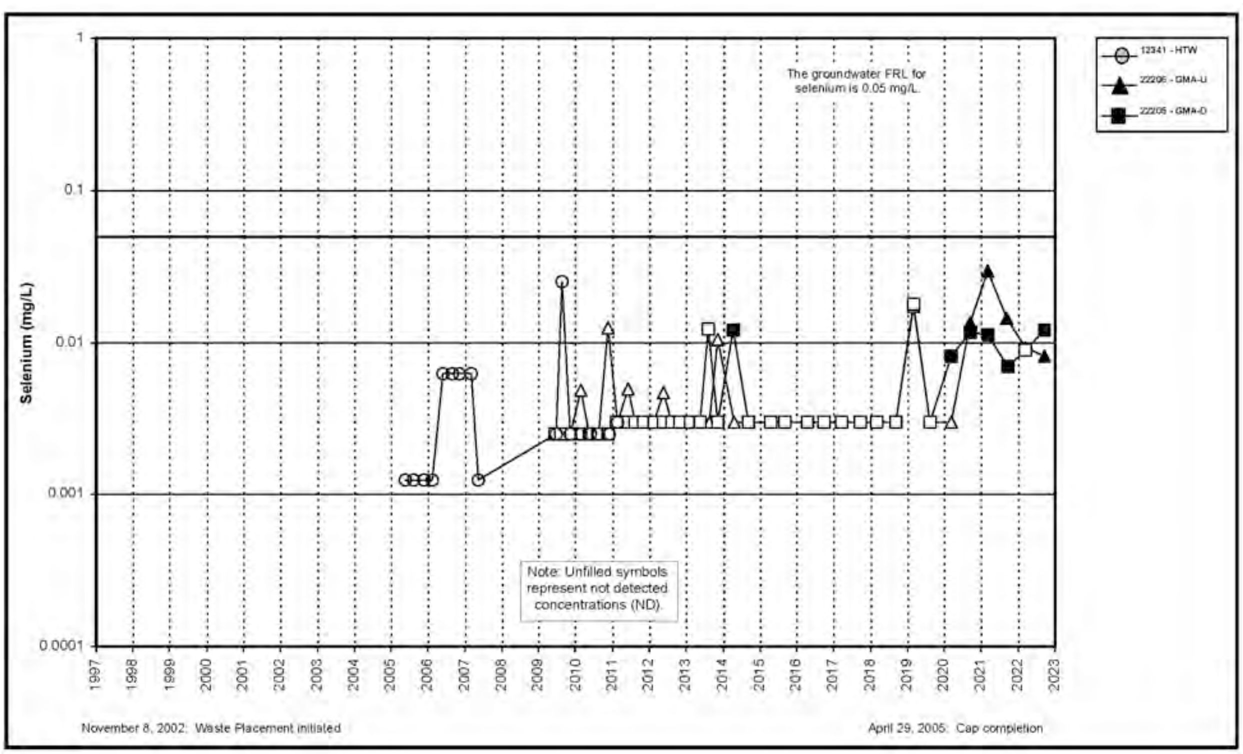

Figure A.5.4-14. Cell 4 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

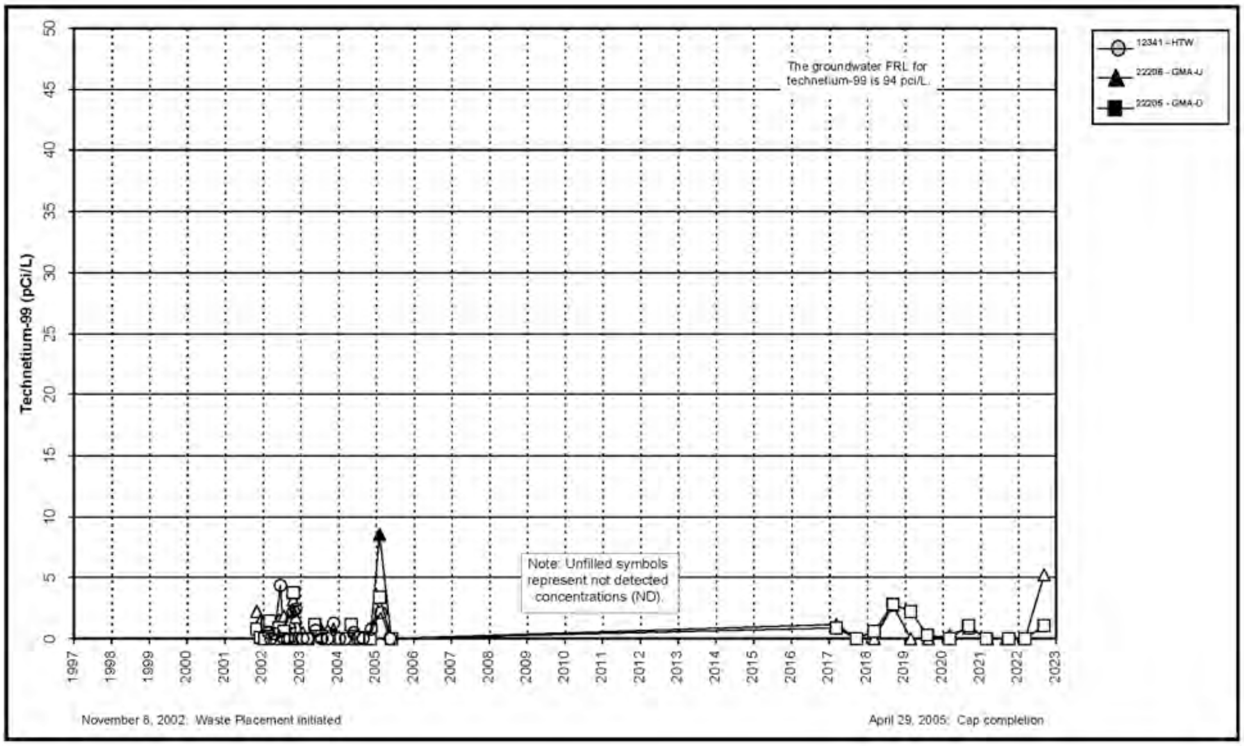

Figure A.5.4-15. Cell 4 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

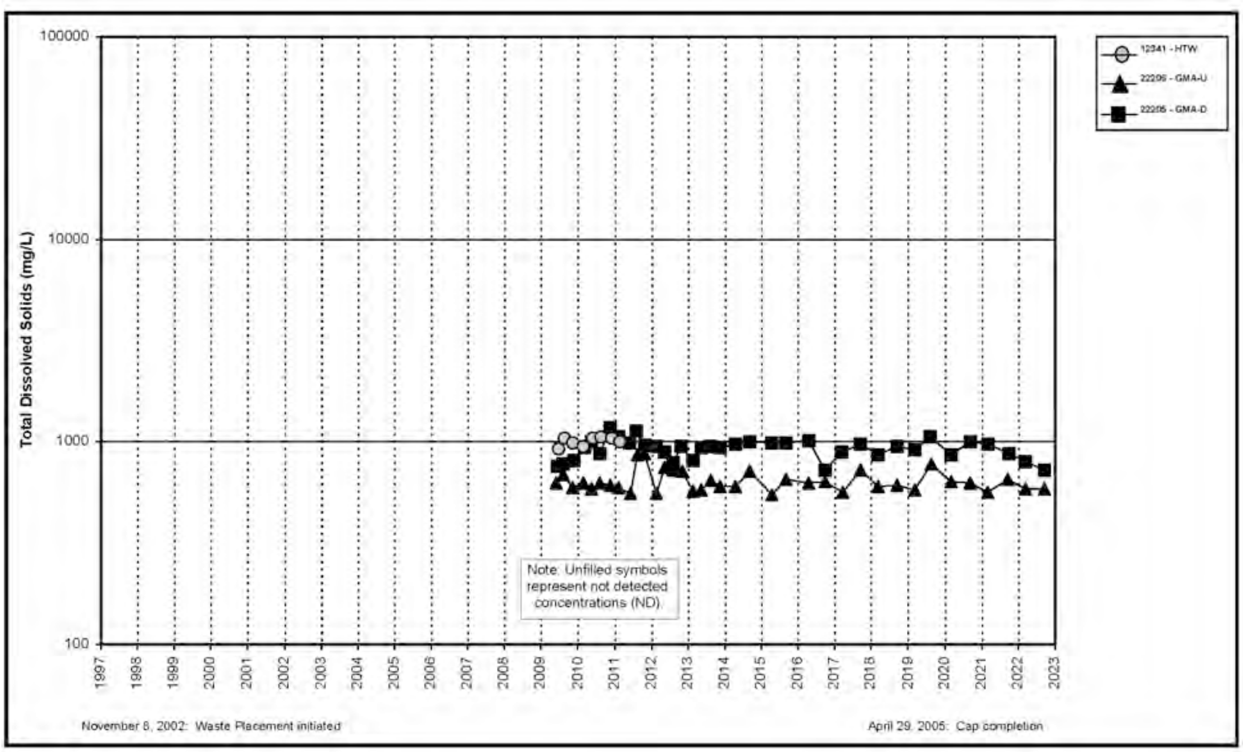

Figure A.5.4-16. Cell 4 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

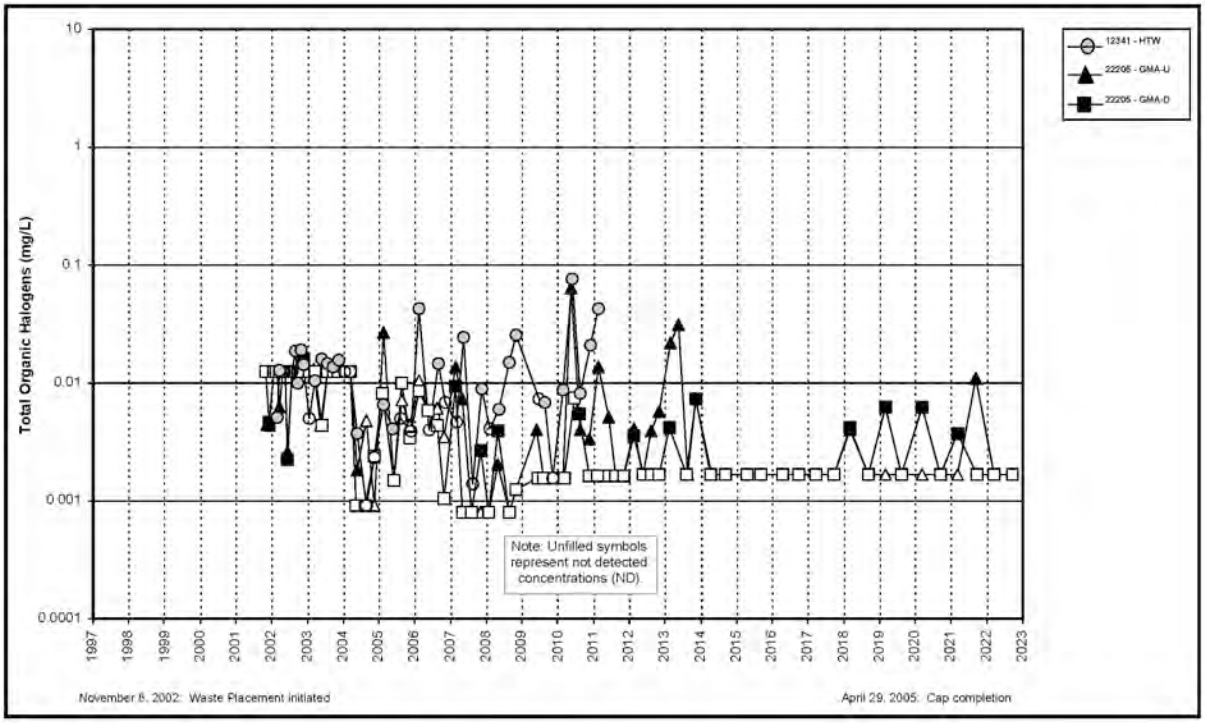

Figure A.5.4-17. Cell 4 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

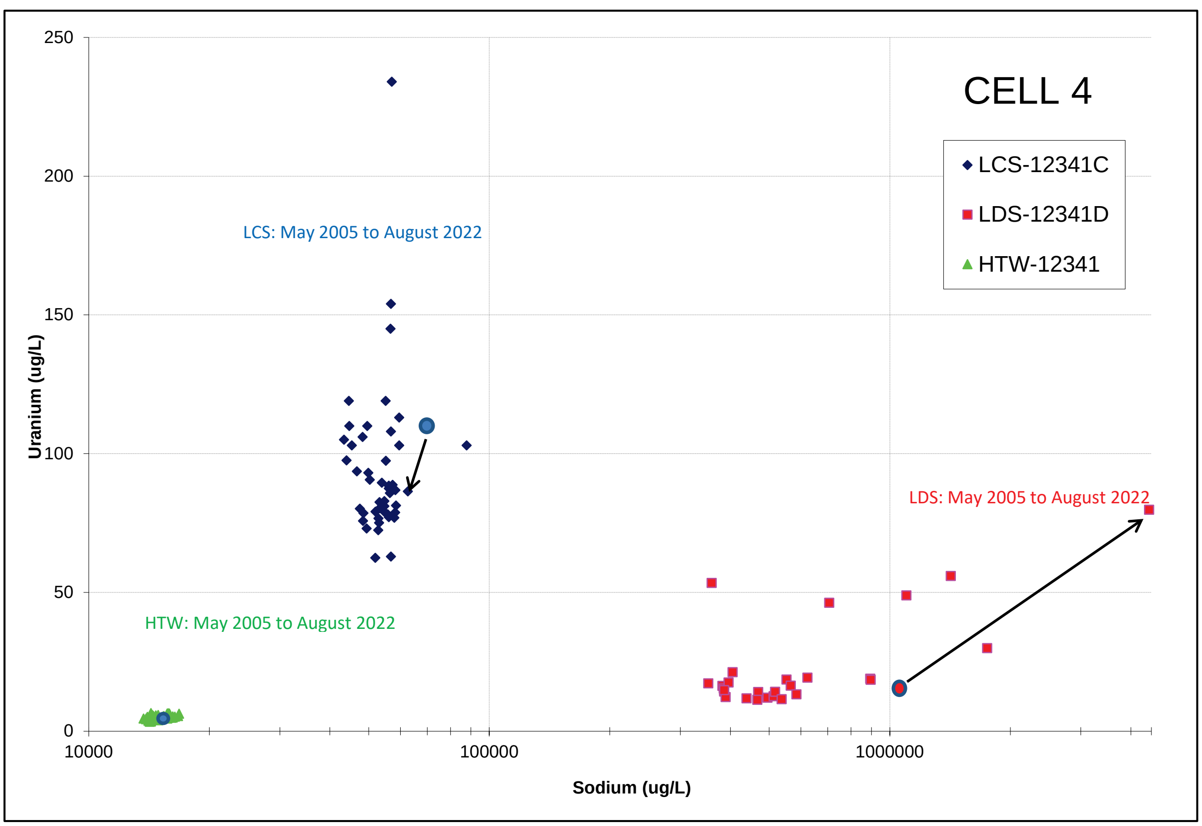

Figure A.5.4-18. Cell 4 Bivariate Plot for Uranium and Sodium

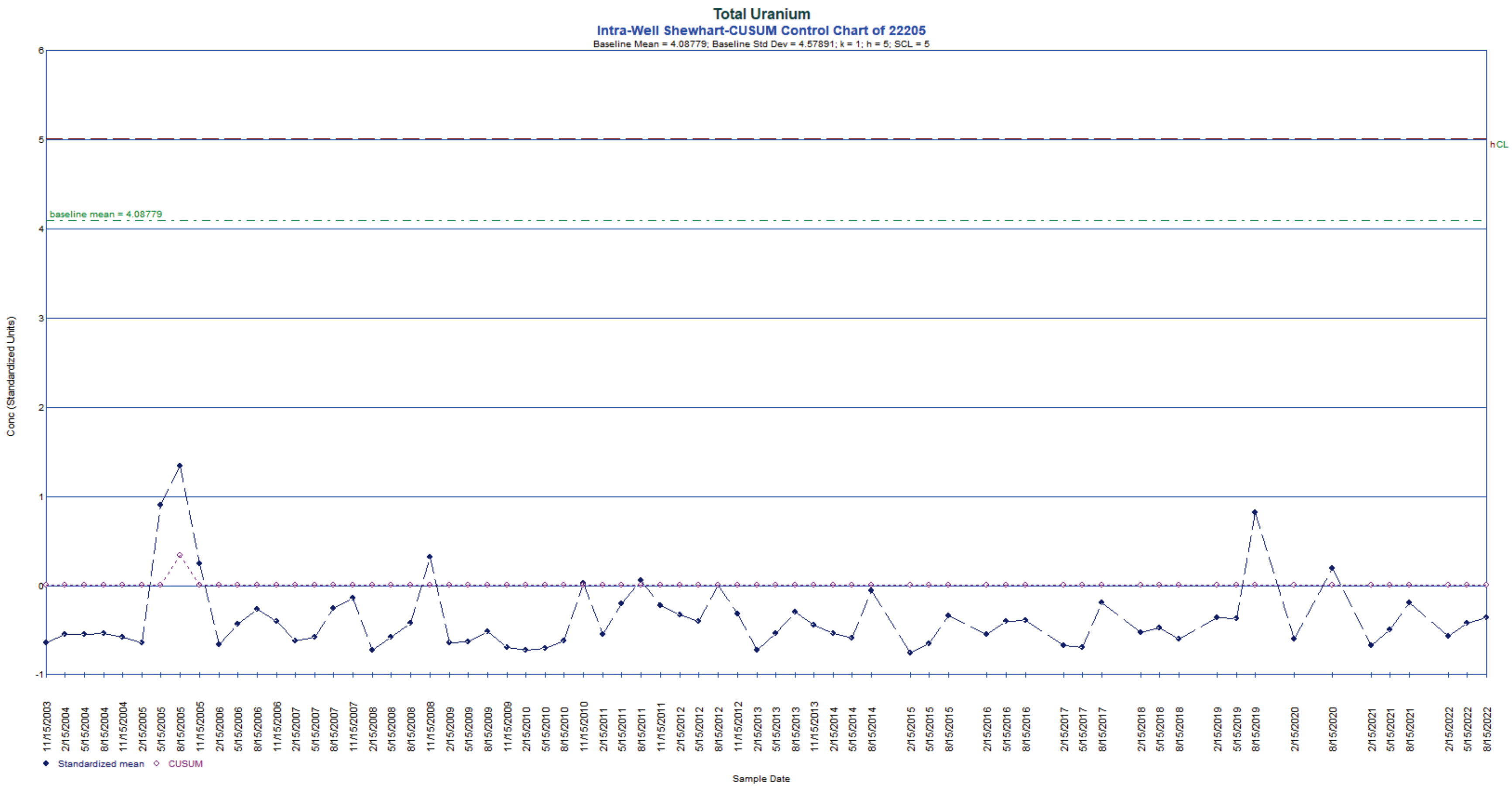

Figure A.5.4-19. Intrawell Shewhart-CUSUM Control Chart for Total Uranium in Monitoring Well 22205

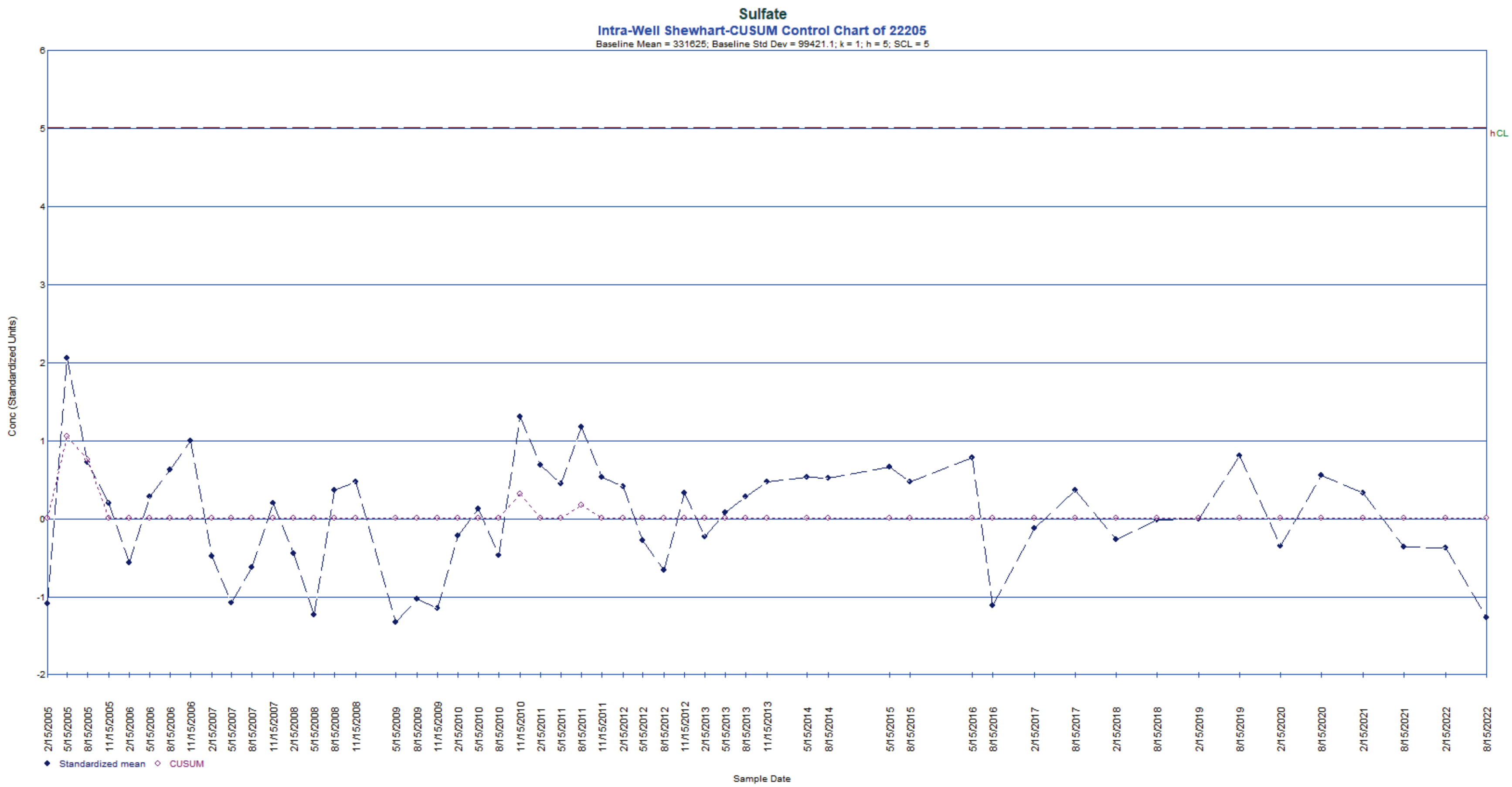

Figure A.5.4-20. Intrawell Shewhart-CUSUM Control Chart for Sulfate in Monitoring Well 22205

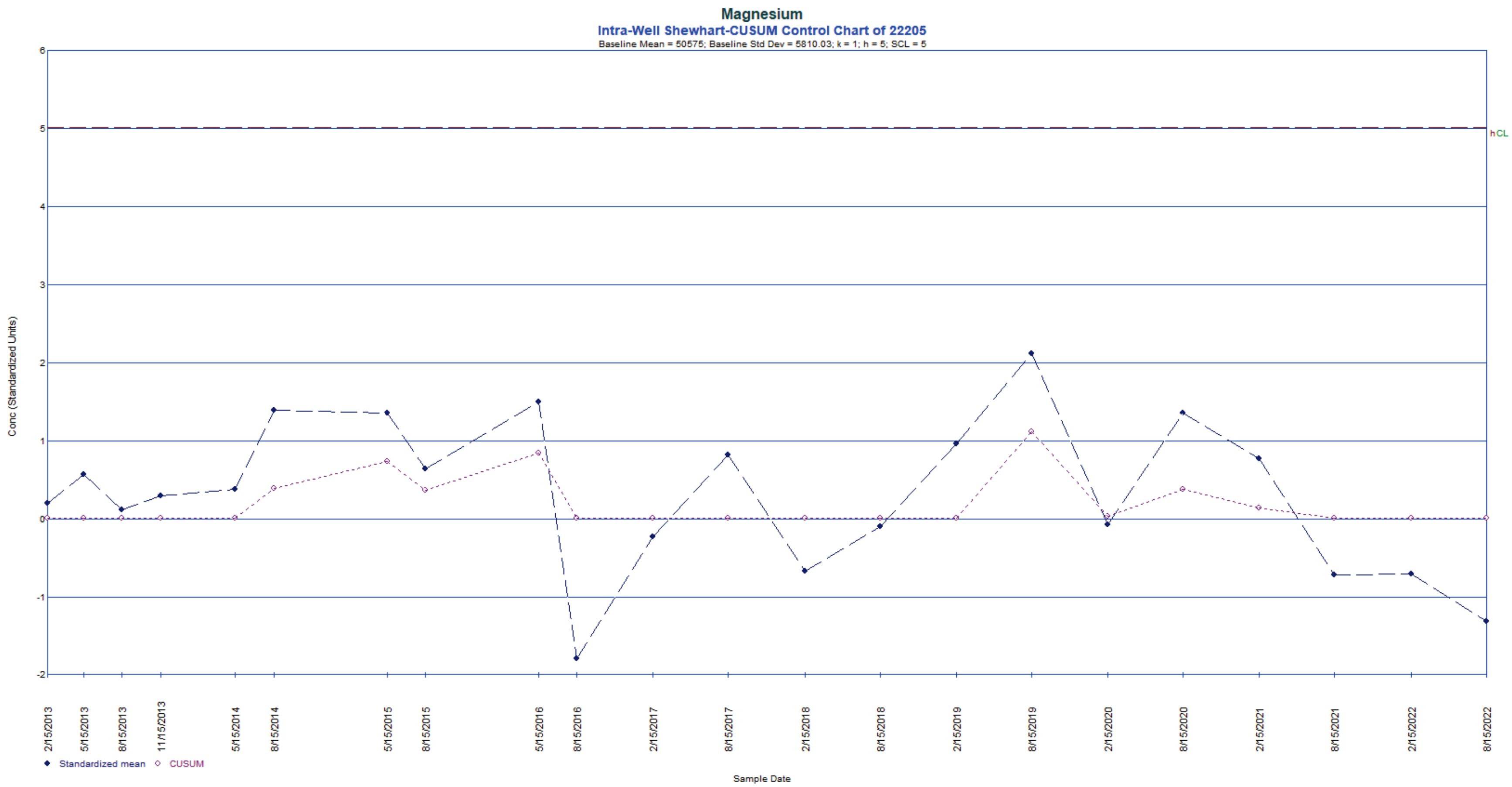

Figure A.5.4-21. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22205

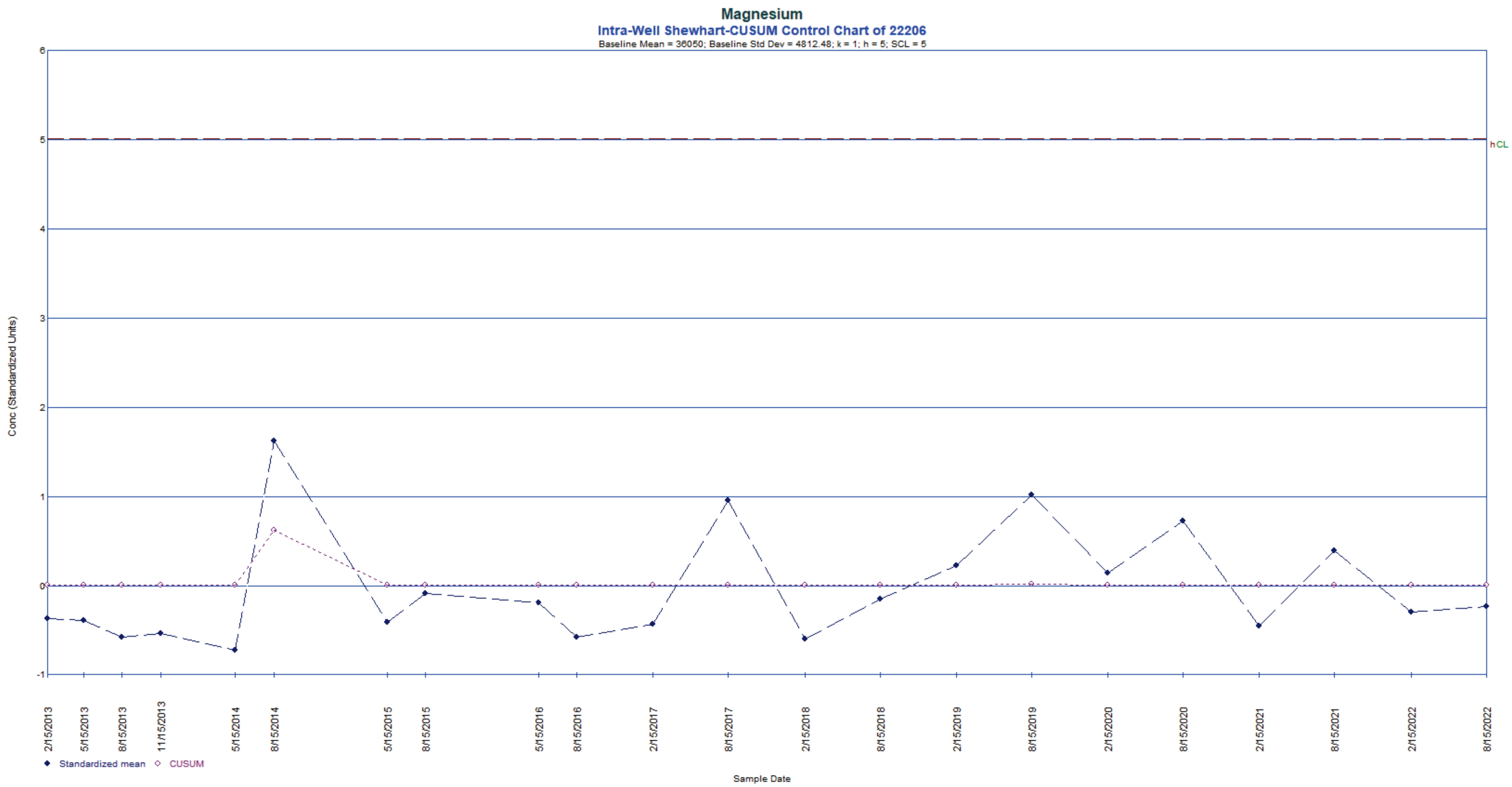

Figure A.5.4-22. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22206

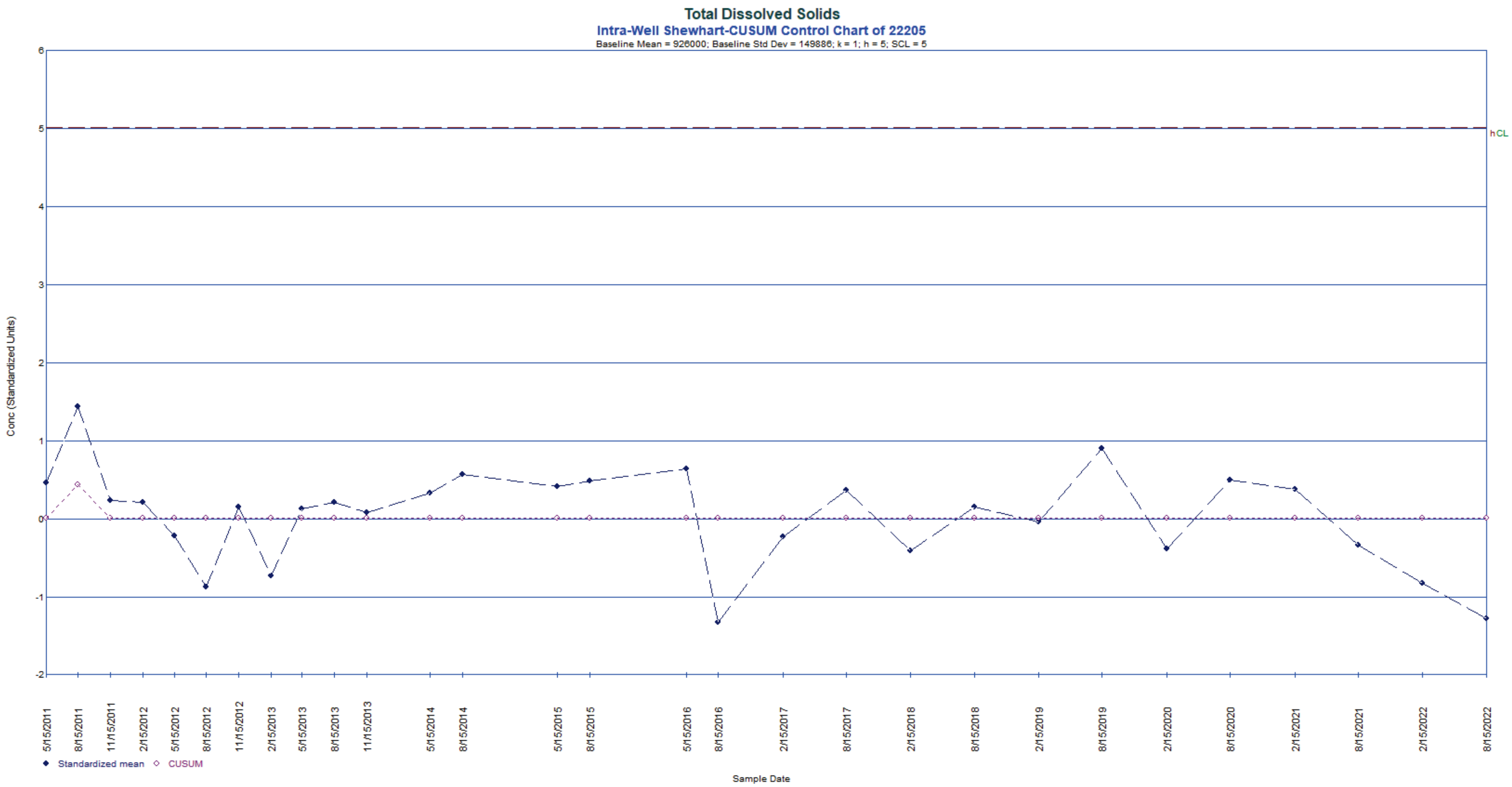

Figure A.5.4-23. Intrawell Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22205

Subattachment A.5.5

Cell 5

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 5:

- Semiannual monitoring summary statistics (Table A.5.5-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.5-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.5-2)
- OSDF horizontal till well (HTW) 12342 water yield (Table A.5.5-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.5-3 and A.5.5-4)
- Plots of concentration versus time (Figures A.5.5-5A through A.5.5-17)
- A bivariate plot for uranium-sodium (Figure A.5.5-18)
- Control chart (Figure A.5.5-19 through A.5.5-20)

A.5.5.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF was operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.5.1.1 LCS and LDS Results

As shown in Table A.5.5-1 and summarized below, one parameter (sulfate) had an upward trend in the LCS based on the Mann-Kendall test for trend in 2022. The volume of water in the LDS tank of Cell 5 was insufficient to collect a sample in 2022.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 5

Parameter	LCS 12342C 2022 Trend	LDS 12342D Trend (Year Last Sampled)
Sulfate	Up	Up (2013)

A.5.5.1.2 HTW and Monitoring Well Results

As shown in Table A.5.5-1 and summarized below, five parameters (boron, sodium, sulfate, lithium, potassium, and selenium) have upward trends in the HTW or GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 5

Parameter	HTW 12342 [a]	GMA-U 22207[a,b]	GMA-D 22208[a,b]
Boron		Up	Up
Sodium		Up	
Sulfate	Up		
Lithium		Up	
Potassium		Up	
Selenium			Up

[a] No entry indicates that the trend was not up.
[b] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer; HTW = horizontal till well.

A.5.5.1.3 Discussion

The uranium-sodium bivariate plot for the Cell 5 LCS, LDS, and HTW is provided in Figure A.5.5-18. On the figure, the first sample ever collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. The plot shows that the chemical signatures for uranium and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.5.2 Control Charts

Intrawell control charts use historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared “not in control” if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (h) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.5-1 in gray shading and as summarized below, two parameters in the HTW or GMA wells of Cell 5 met the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in two control charts (Figures A.5.5-19 and A.5-20) which exhibits “in control” conditions.

Parameter	Monitoring Point	Well Number	Assessment	Figure Number
Calcium	GMA-U	22207	In Control	A.5.5-19
Uranium	GMA-D	22208	In Control	A.5.5-20

[a] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer.

A.5.5.3 Summary and Conclusions

- One parameter (sulfate) had an upward trend in the LCS in 2022 based on the Mann-Kendall test for trend.
- The volume of water in the LDS tank of Cell 5 was insufficient to collect a sample in 2022.
- Six parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 5: boron, sodium, sulfate, lithium, potassium, and selenium. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 5 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 5 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- Two control charts were constructed for Cell 5 parameters. Both exhibit “in control” conditions.

A.5.5.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. "Ground Water Monitoring Program for a Sanitary Landfill Facility," *Ohio Administrative Code.*

Table A.5.5-1. Summary Statistics for Cell 5

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12342C	62	62	100	3.39	285	125	45	Undefined	None (2022)	Detected	
	LDS	12342D	40	40	100	2.93	27.1	15.6	5.2	Normal	Down (2013)	Detected	
	HTW	12342	65	65	100	7.45	19.2	8.99	2.15	Undefined	Down (2022)	Detected	
	GMA-U	22207	55	66	83.3	ND	0.631	0.313	0.125	Ln Normal	Down (2022)	Not Detected	2.39 (Q3-02)
	GMA-D	22208	64	75	85.3	ND	0.540	0.339	0.090	Normal	None (2022)	Not Detected	2.10 (Q2-04); 0.800 (Q1-05); 0.006 (Q2-05); 0.710 (Q2-08)
Boron (mg/L)	LCS	12342C	60	62	96.8	ND	1.59	0.764	0.261	Undefined	None (2022)	Detected	
	LDS	12342D	40	40	100	0.202	1.20	0.398	0.272	Undefined	None (2013)	Detected	
	HTW	12342	46	48	95.8	ND	0.221	0.0862	0.0421	Undefined	Down (2022)	Detected	
	GMA-U	22207	61	66	92.4	ND	0.0912	0.0418	0.0141	Undefined	Up (2022)	Detected	
	GMA-D	22208	60	66	90.9	ND	0.0618	0.0369	0.0116	Normal	Up (2022)	Detected	
Sodium (mg/L)	LCS	12342C	49	50	98.0	57.0	79.7	68.1	4.9	Normal	Down (2022)	Detected	16.4 (Q2-03), 19.7 (Q2-04), 22.2 (Q2-05), 108 (Q3-05)
	LDS	12342D	27	27	100	84.6	808	432	137	Normal	Up (2013)	Detected	
	HTW	12342	46	46	100	17.0	33.6	25.9	4.7	Undefined	Down (2022)	Detected	
	GMA-U	22207	37	37	100	13	23.1	16.7	2.6	Normal	Up (2022)	Detected	
	GMA-D	22208	38	38	100	8.99	17.9	15.2	2.7	Undefined	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12342C	62	62	100	218	5910	3,570	1,240	Undefined	Up (2022)	Detected	
	LDS	12342D	40	40	100	1130	6100	2,160	1,030	Ln Normal	Up (2013)	Detected	
	HTW	12342	56	56	100	101	578	370	128	Undefined	Up (2022)	Detected	
	GMA-U	22207	61	61	100	97.8	552	186	98	Undefined	Down (2022)	Detected	770 (Q2-05)
	GMA-D	22208	61	61	100	98.1	671	358	103	Normal	Down (2022)	Detected	
Calcium (mg/L)	GMA-U	22207	30	30	100	124	187	153	11	Normal	None (2022)	Not Detected	
	GMA-D	22208	30	30	100	107	285	211	36	Normal	Down (2022)	Detected	
Lithium (mg/L)	GMA-U	22207	37	37	100	0.00642	0.0165	0.0141	0.0031	Undefined	Up (2022)	Detected	
	GMA-D	22208	37	37	100	0.00659	0.00985	0.00808	0.00068	Normal	None (2022)	Detected	0.00425 (Q1-17)
Magnesium (mg/L)	GMA-U	22207	30	30	100	26.1	38.5	33.7	3.1	Normal	Up (2022)	Detected	
	GMA-D	22208	30	30	100	43.9	66.4	53.1	6.2	Normal	Down (2022)	Detected	24.3 (Q1-17)
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22207	2	30	6.7	ND	0.425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	3	30	10.0	ND	0.05	0.0182	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22207	30	30	100	2.75	4.82	3.75	0.60	Normal	Up (2022)	Detected	
	GMA-D	22208	31	31	100	2.15	3.53	2.95	0.36	Normal	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22207	3	37	8.1	ND	0.018	0.004	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	5	37	13.5	ND	0.0157	0.00300	0.00359	Undefined	Up (2022)	Detected	
Technitium-99 (pCi/L)	GMA-U	22207	0	27	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	1	27	3.7	ND	6.40	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22207	37	37	100	552	770	636	47	Normal	None (2022)	Detected	987 (Q4-09)
	GMA-D	22208	37	37	100	456	1290	933	154	Normal	Down (2022)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22207	22	66	33.3	ND	0.047	0.00207	0.00729	Undefined	None (2022)	Detected	
	GMA-D	22208	18	66	27.3	ND	0.026	0.00259	0.00519	Undefined	Down (2022)	Detected	

Note 1: Shading indentifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trends (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a] LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b] ND = not detected; NA = not applicable

[c] Averages were determined based on the distribution assumption.

[d] Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e] Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f] Trend based on nonparametric Mann-Kendall procedure.

[g] Serial correlation based on Rank Von Neumann test.

[h] Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i] Q = quarter

Table A.5.5-2. OSDF Horizontal Till Well 12342 (Cell 5) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
2002	35,815	10	3,582
2003	6,200	6	1,033
2004	5,425	5	1,085
2005	4,270	4	1,068
2006	3,710	4	928
2007	4,250	4	1,063
2008	4,225	4	1,056
2009	3,225	4	1,075
2010	4,325	4	1,081
2011	4,225	4	1,056
2012	4,200	4	1,050
2013	4,200	4	1,050
2014	2,100	2	1,050
2015	2,100	2	1,050
2016	2,100	2	1,050
2017	2,100	2	1,050
2018	2,100	2	1,050
2019	2,100	2	1,050
2020	2,100	2	1,050
2021	2,100	2	1,050
2022	2,100	2	1,050

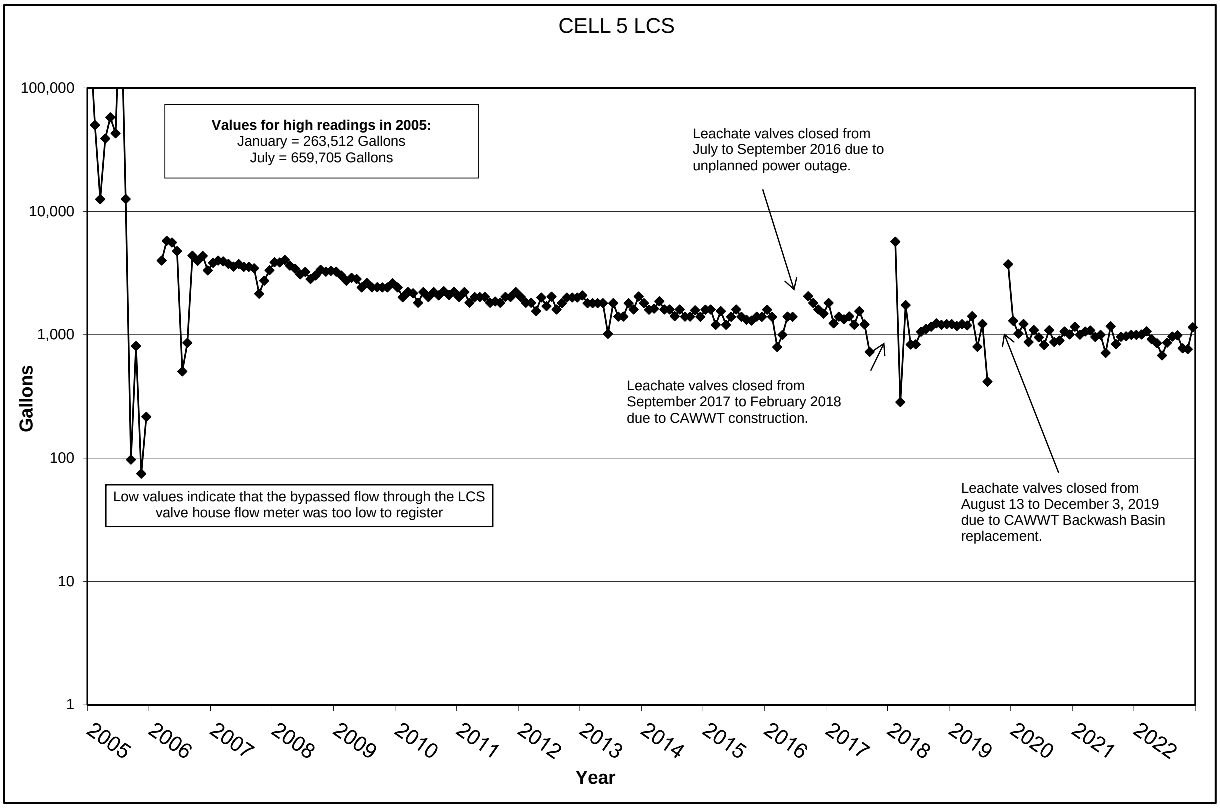

Figure A.5.5-1. Monthly Accumulation Volumes for Cell 5 LCS

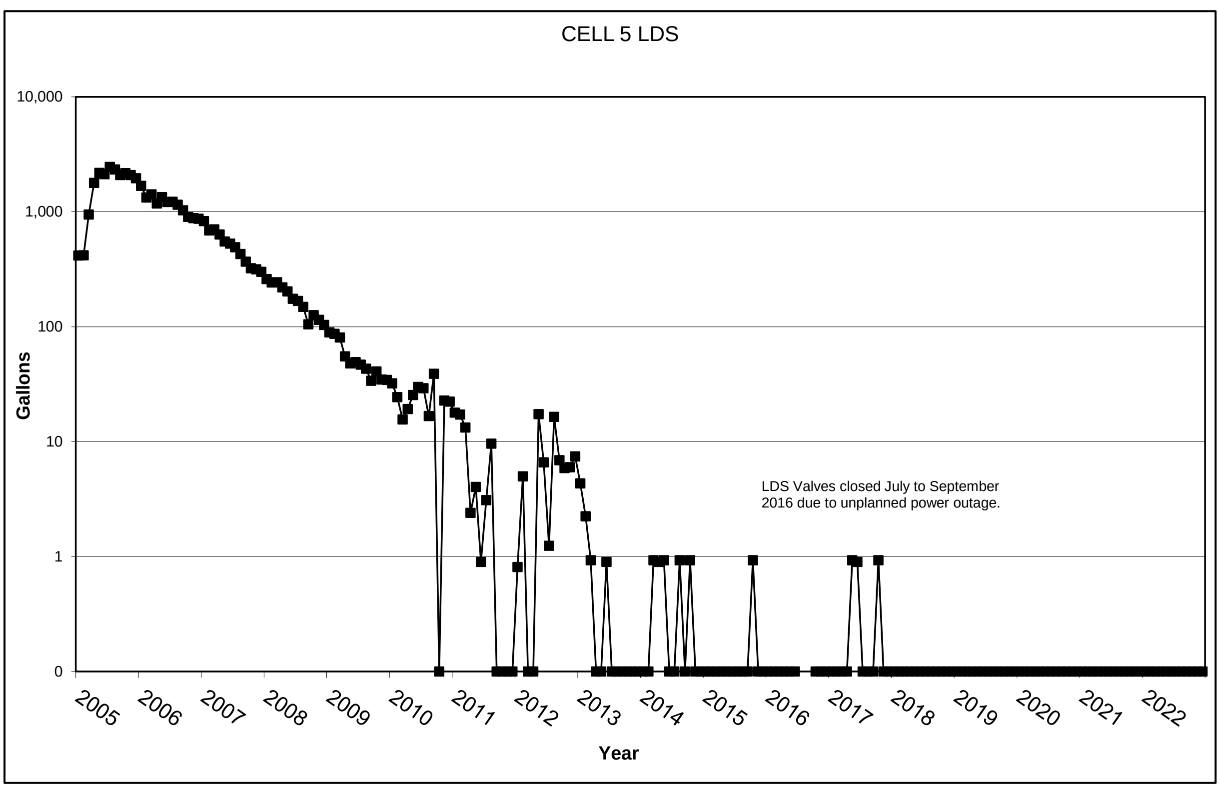

Figure A.5.5-2. Monthly Accumulation Volumes for Cell 5 LDS

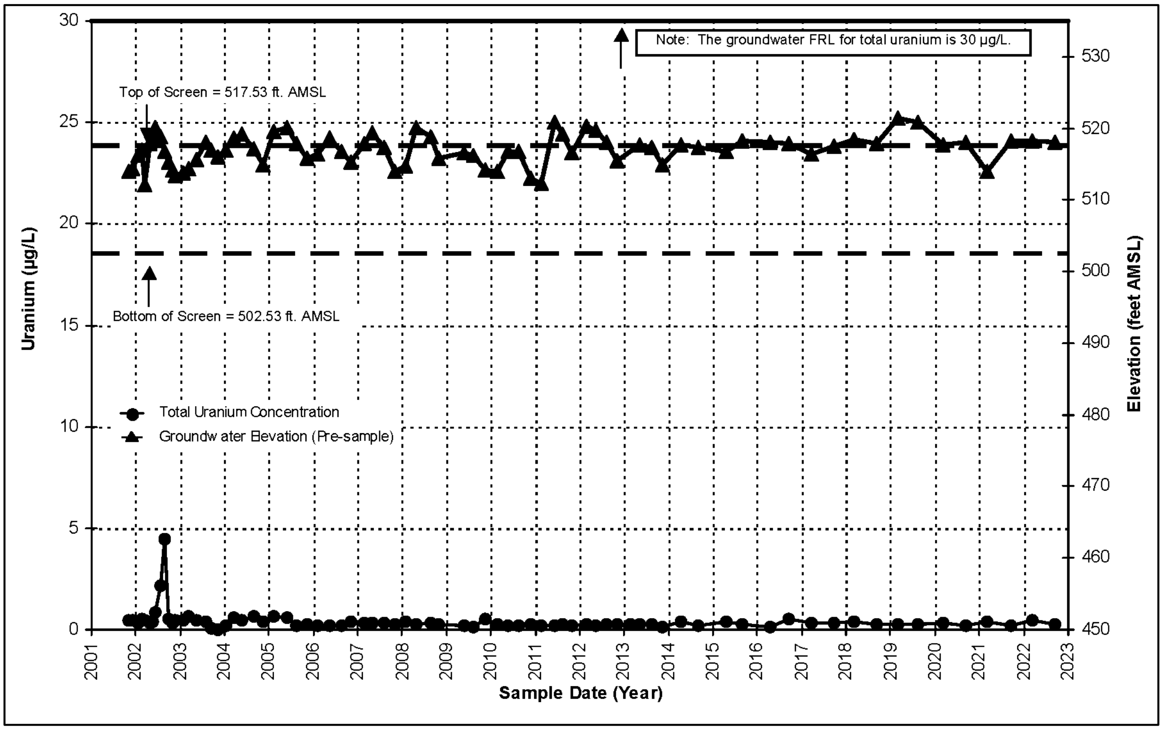

Figure A.5.5-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 5 Upgradient Monitoring Well 22207

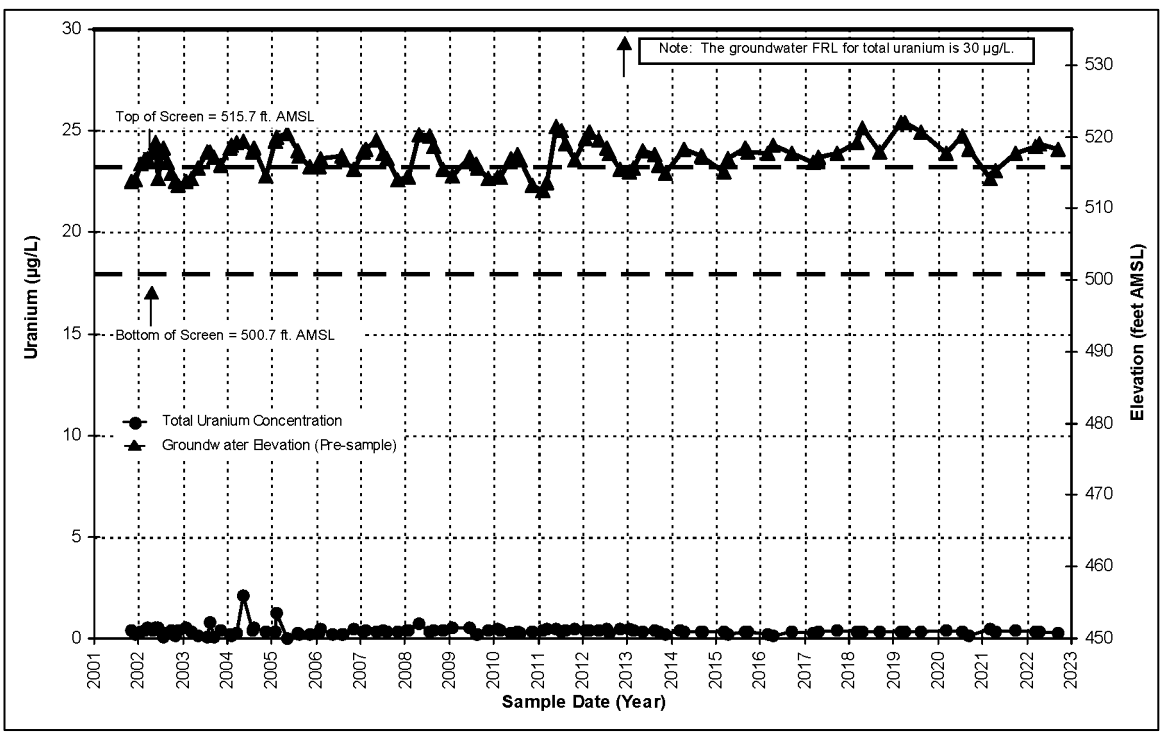

Figure A.5.5-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 5 Downgradient Monitoring Well 22208

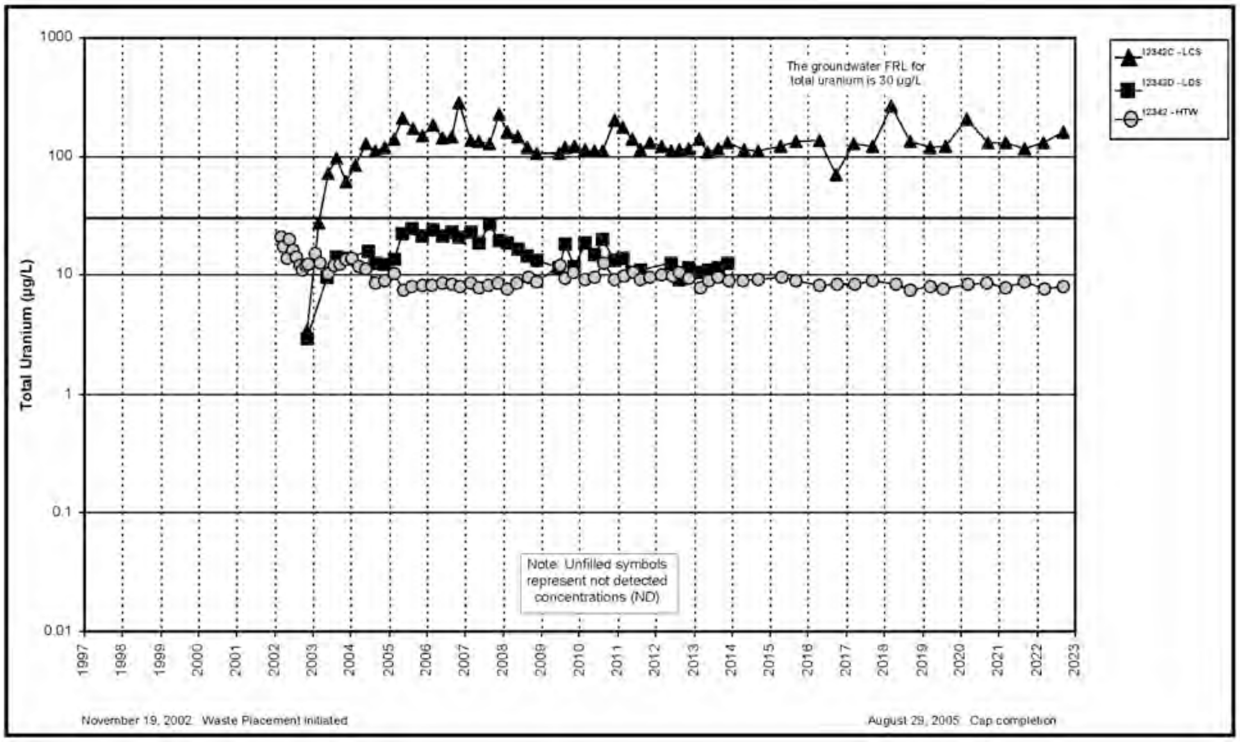

Figure A.5.5-5A. Cell 5 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

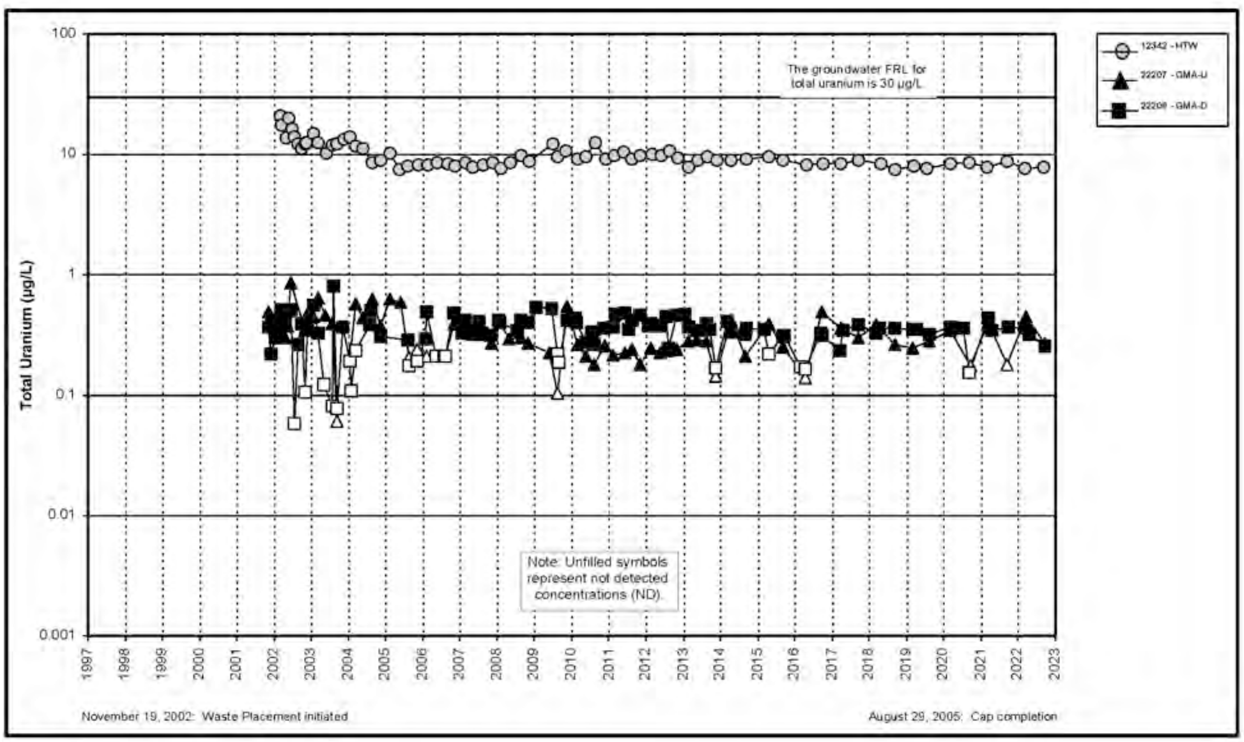

Figure A.5.5-5B. Cell 5 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

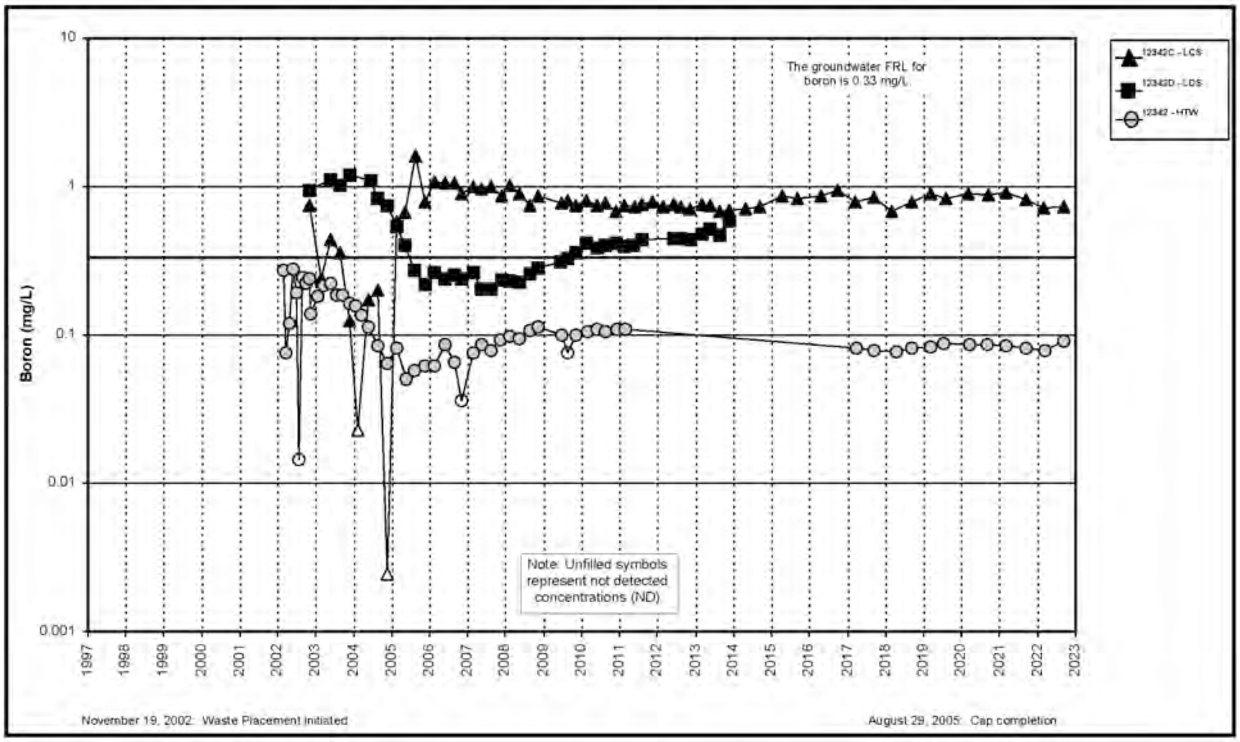

Figure A.5.5-6A. Cell 5 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

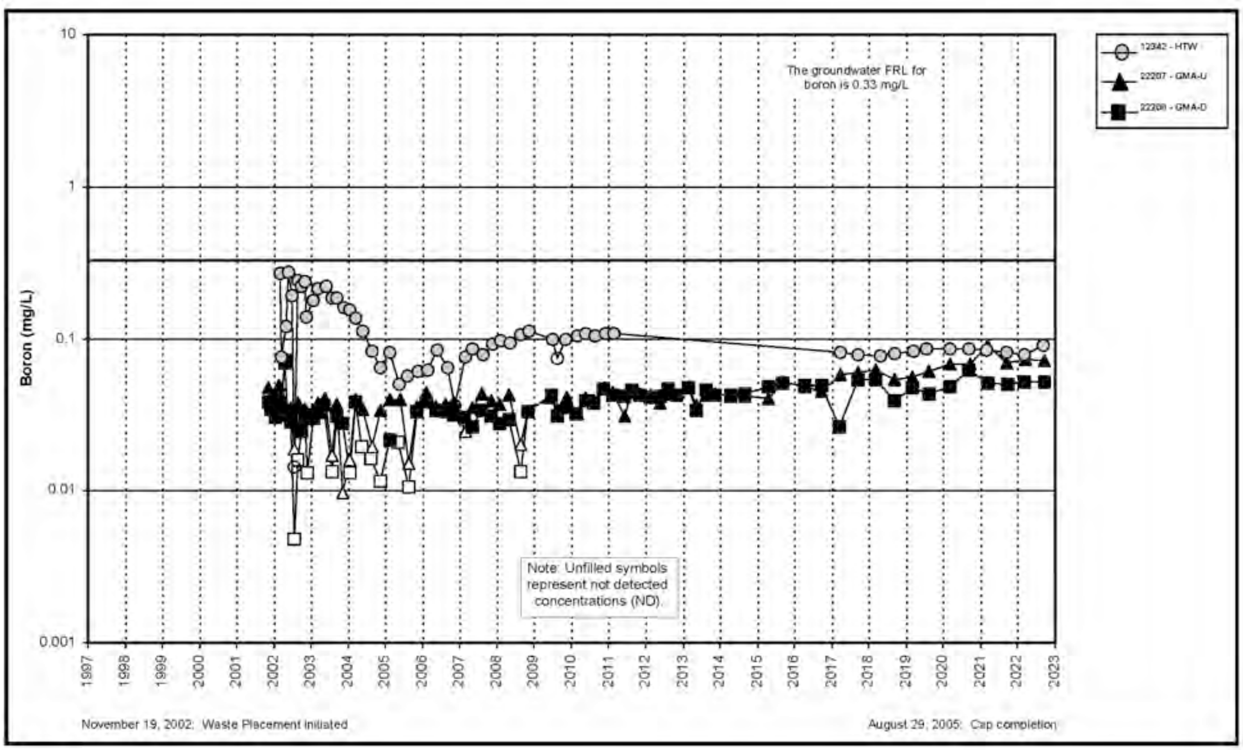

Figure A.5.5-6B. Cell 5 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

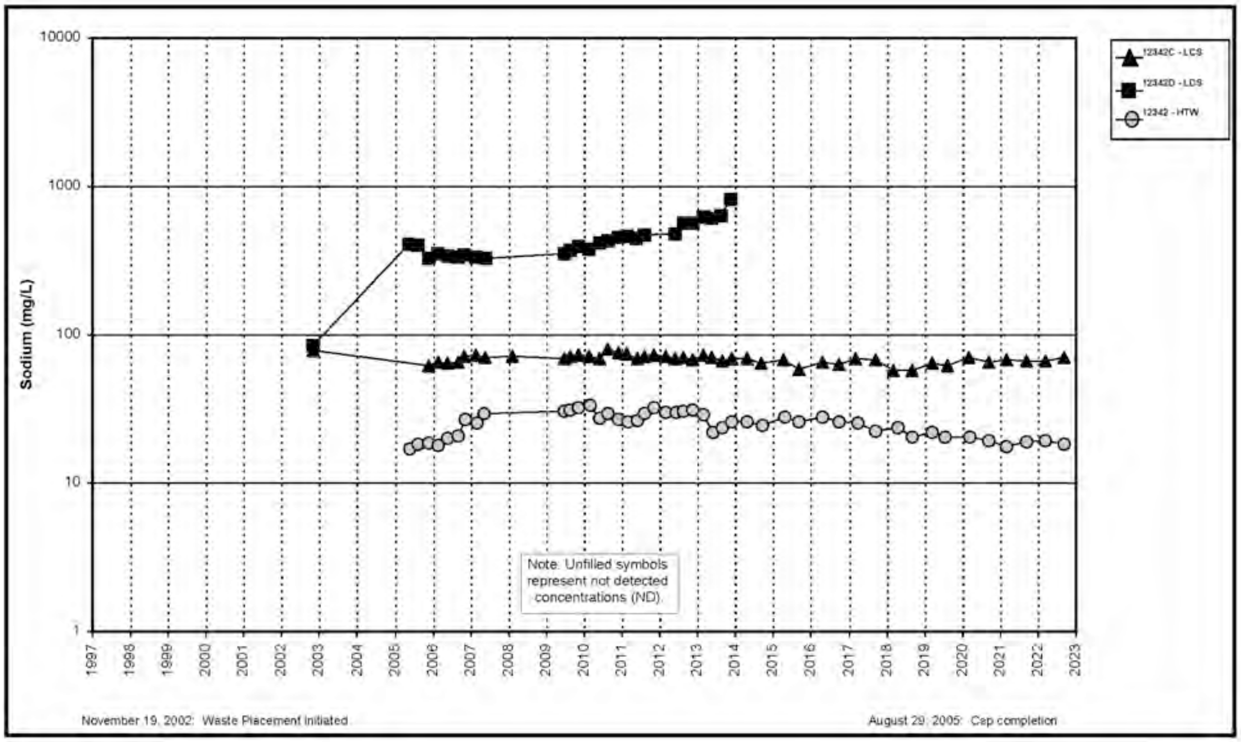

Figure A.5.5-7A. Cell 5 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

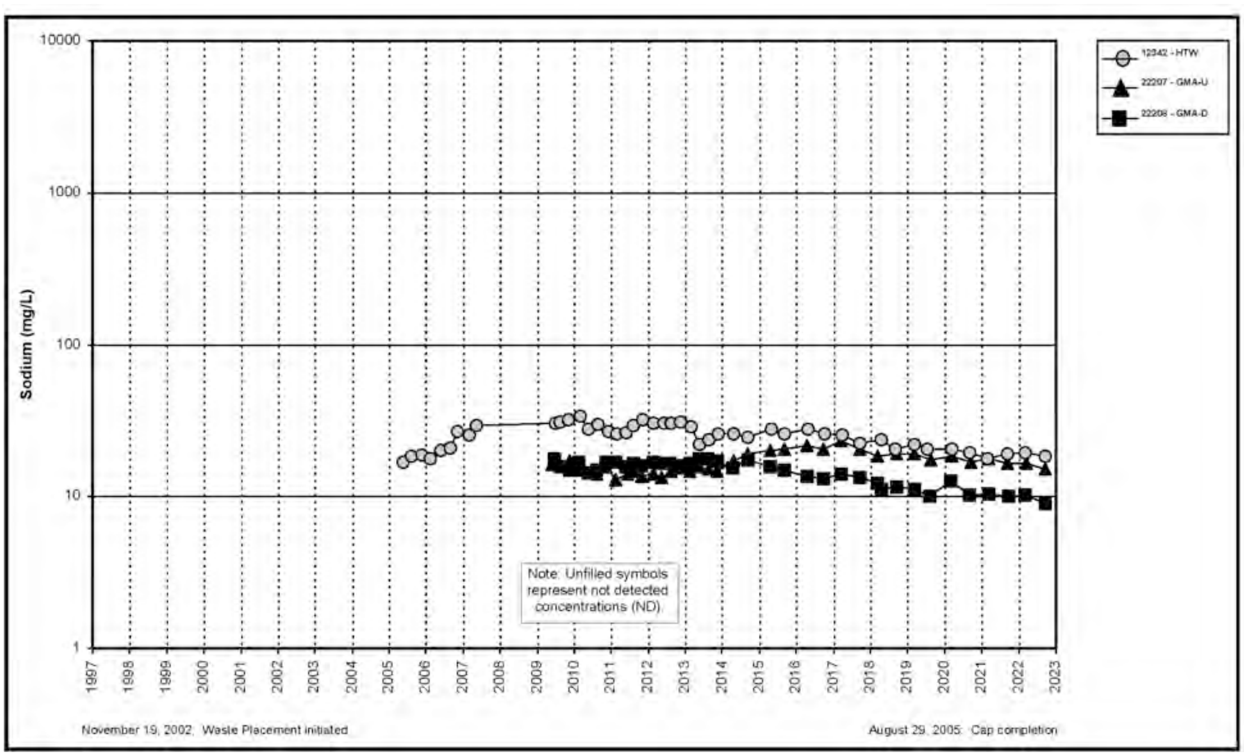

Figure A.5.5-7B. Cell 5 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

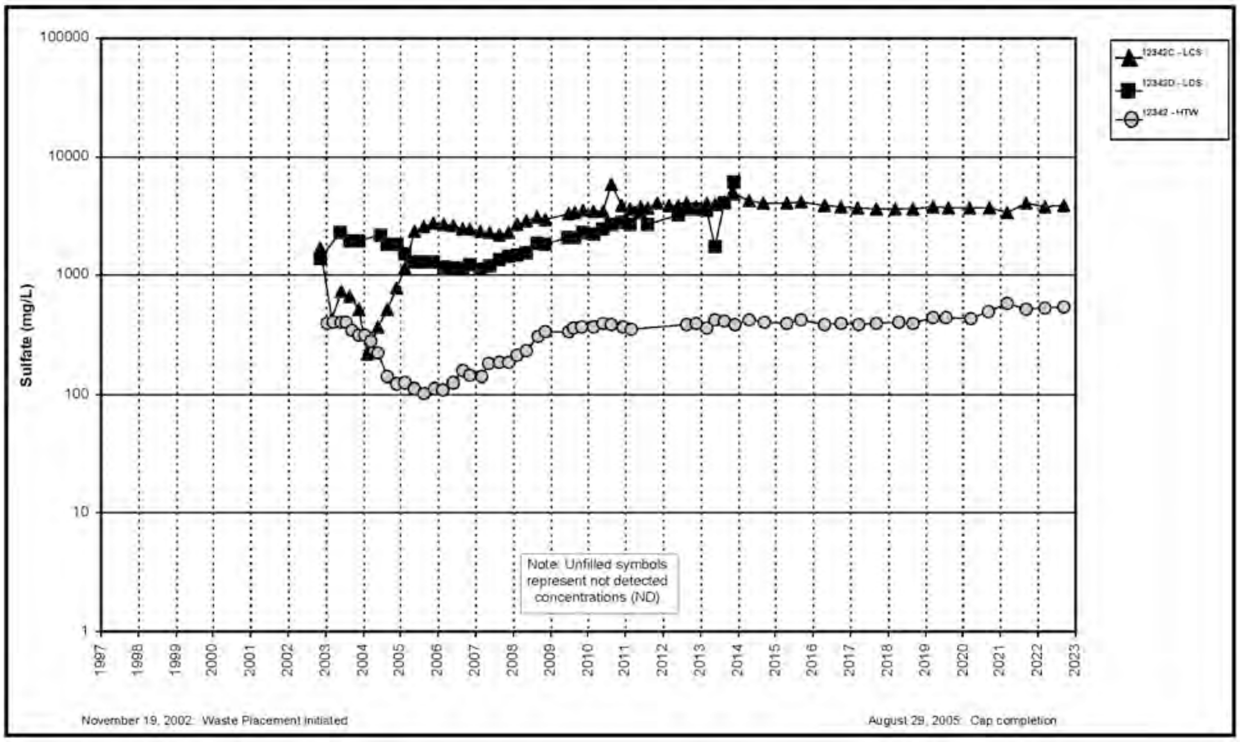

Figure A.5.5-8A. Cell 5 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

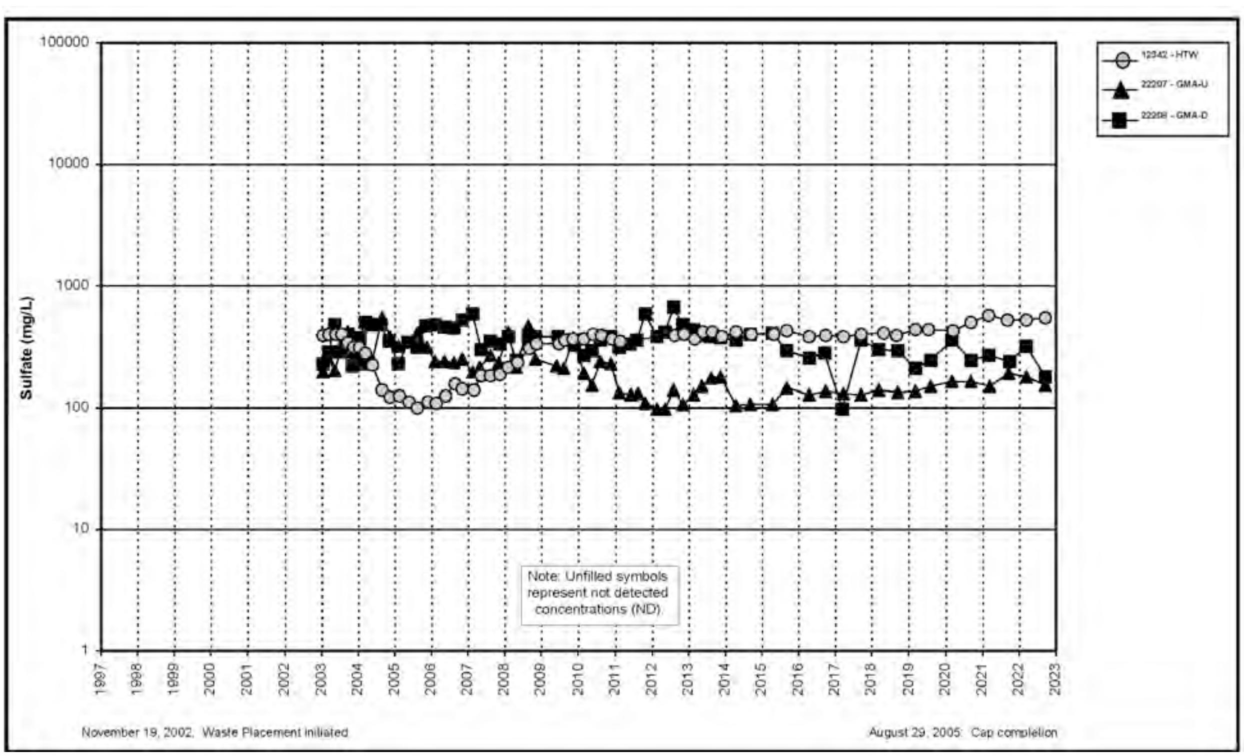

Figure A.5.5-8B. Cell 5 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

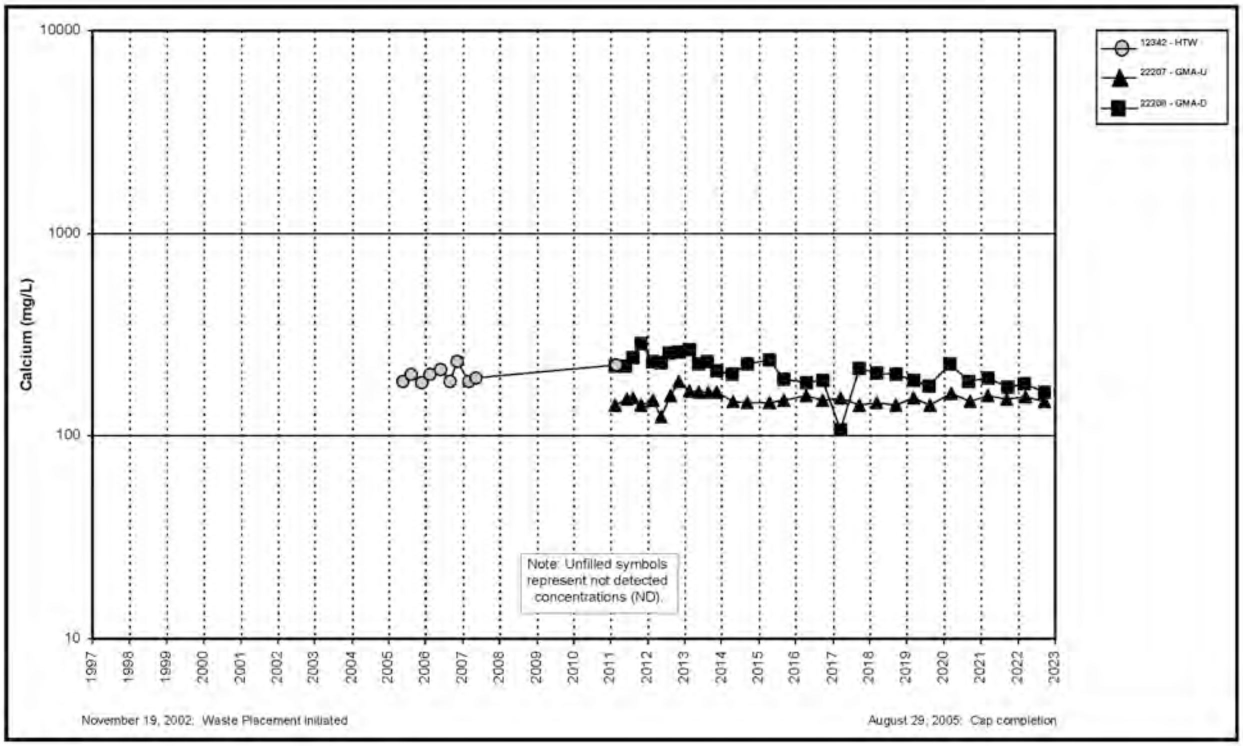

Figure A.5.5-9. Cell 5 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

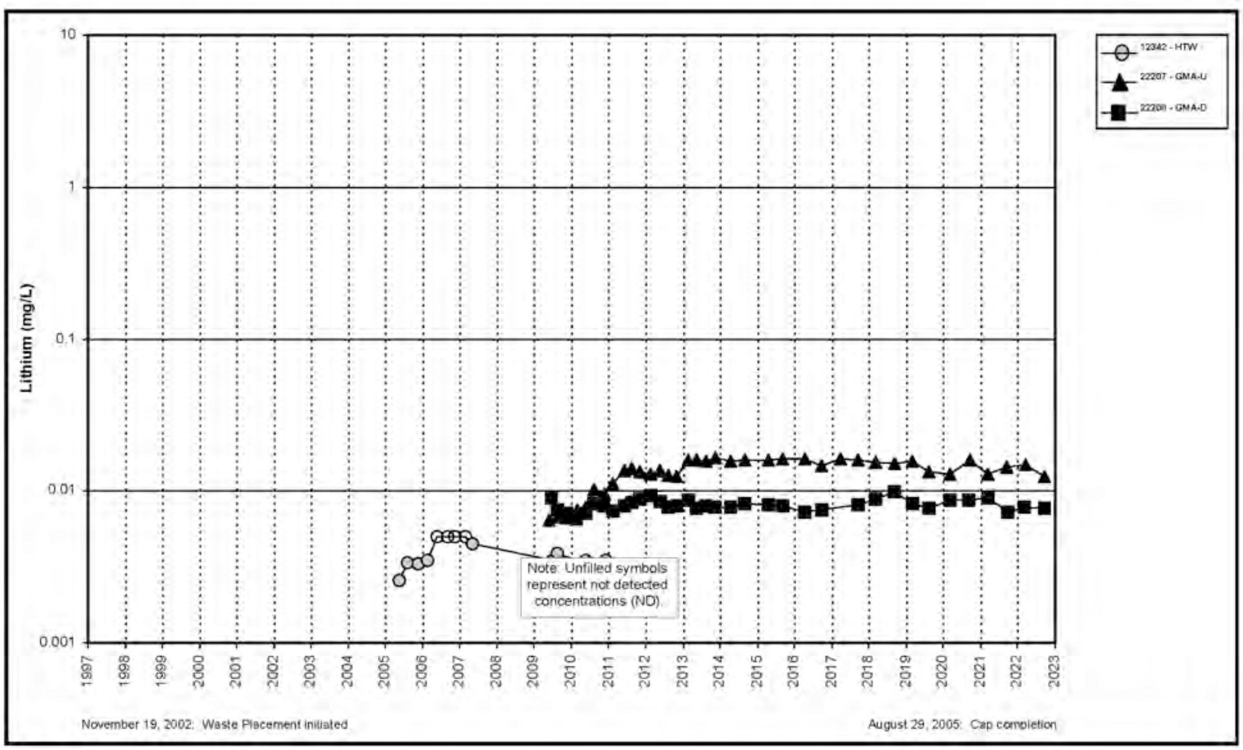

Figure A.5.5-10. Cell 5 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

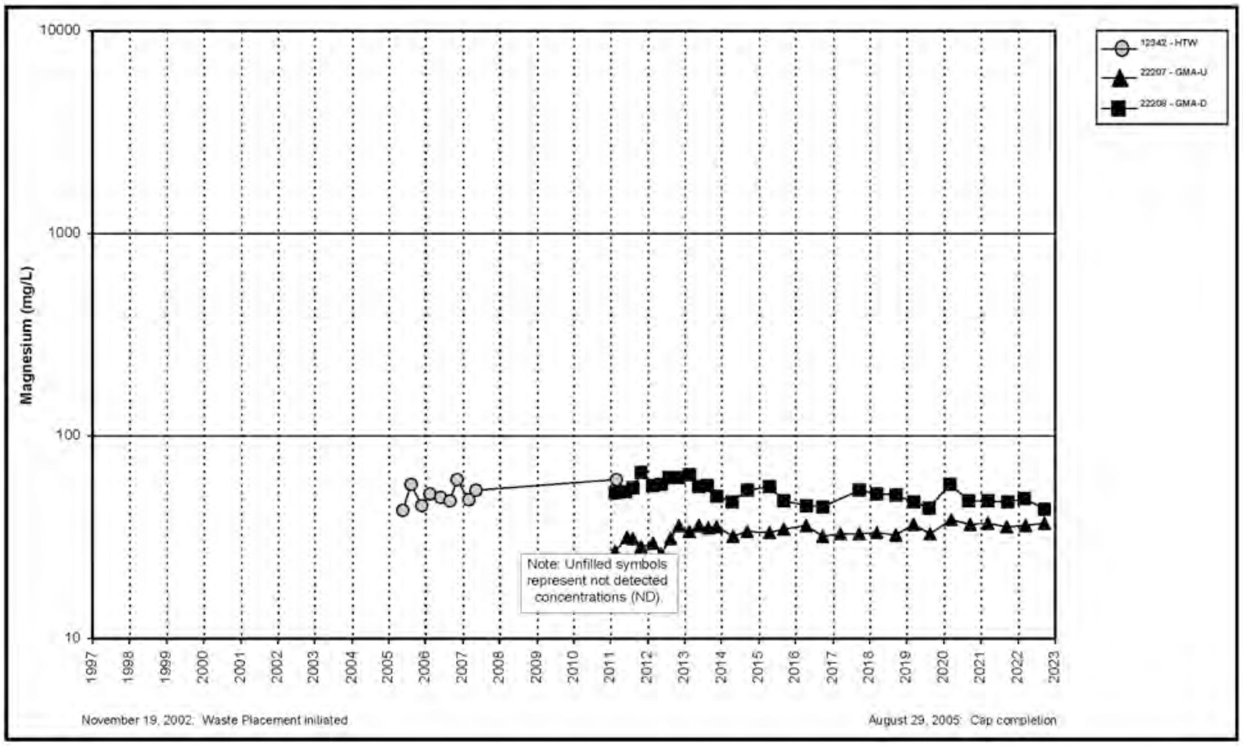

Figure A.5.5-11. Cell 5 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

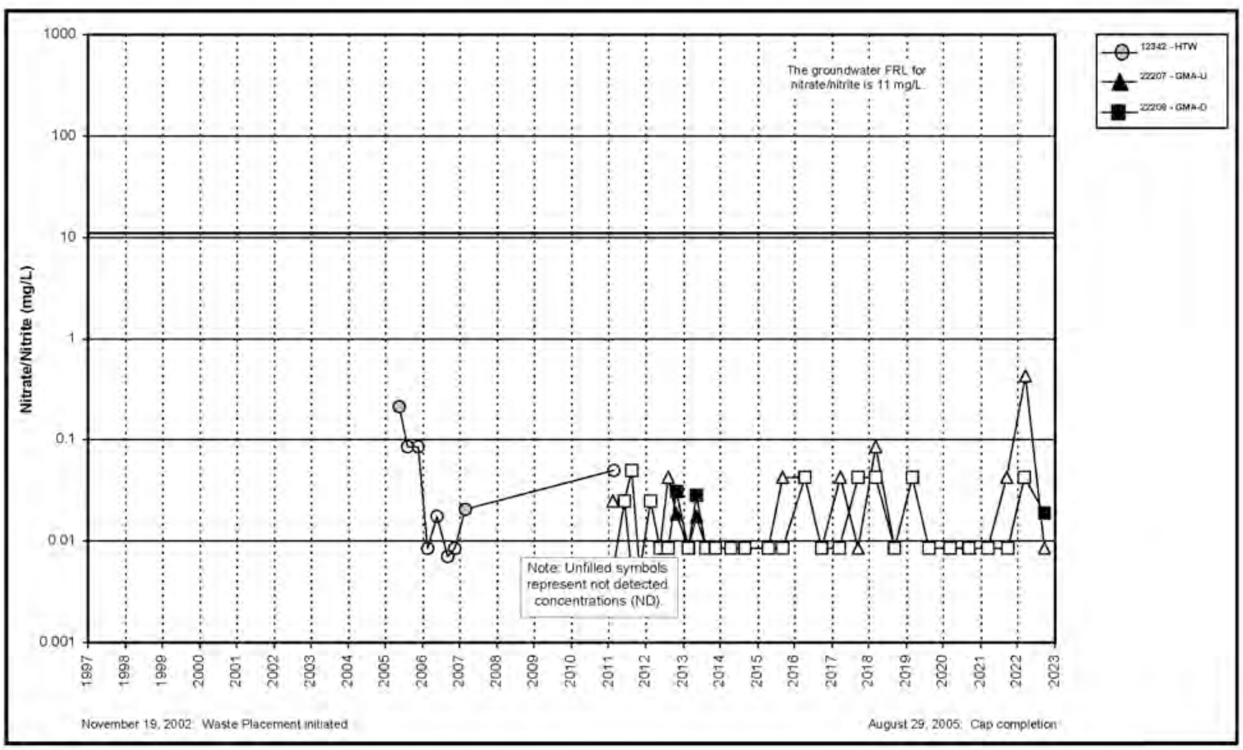

Figure A.5.5-12. Cell 5 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

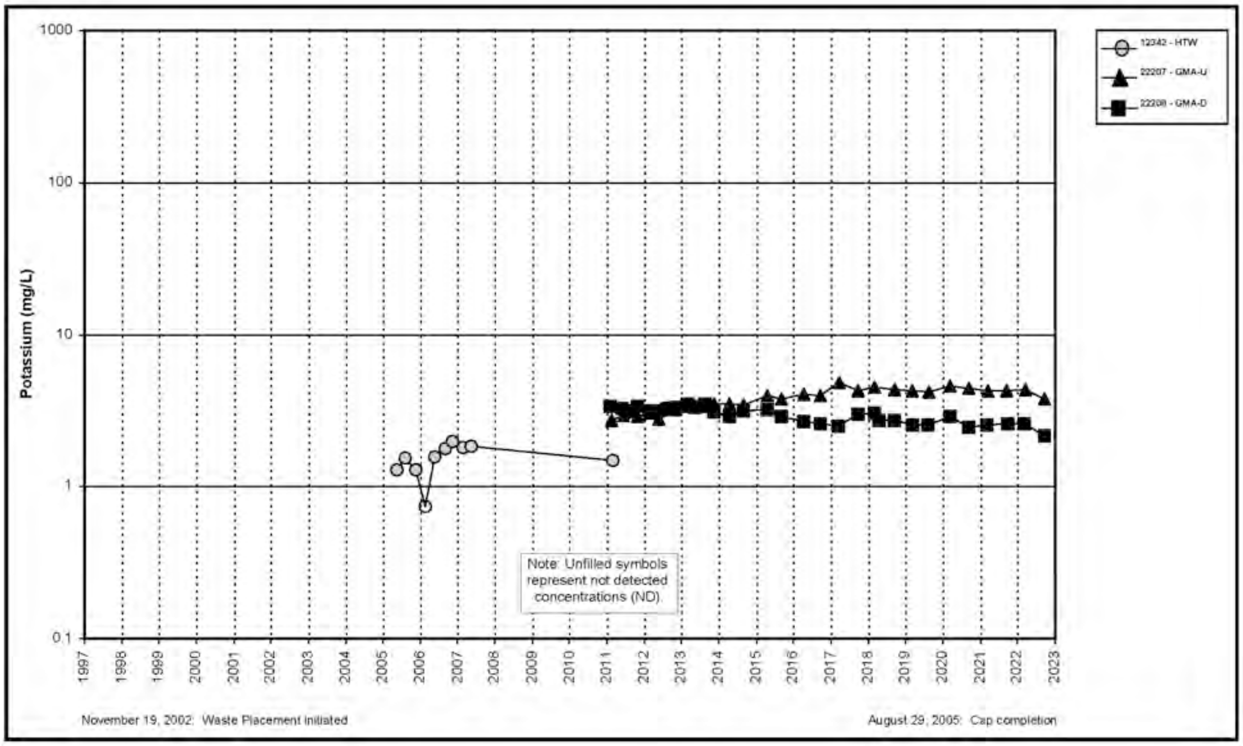

Figure A.5.5-13. Cell 5 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

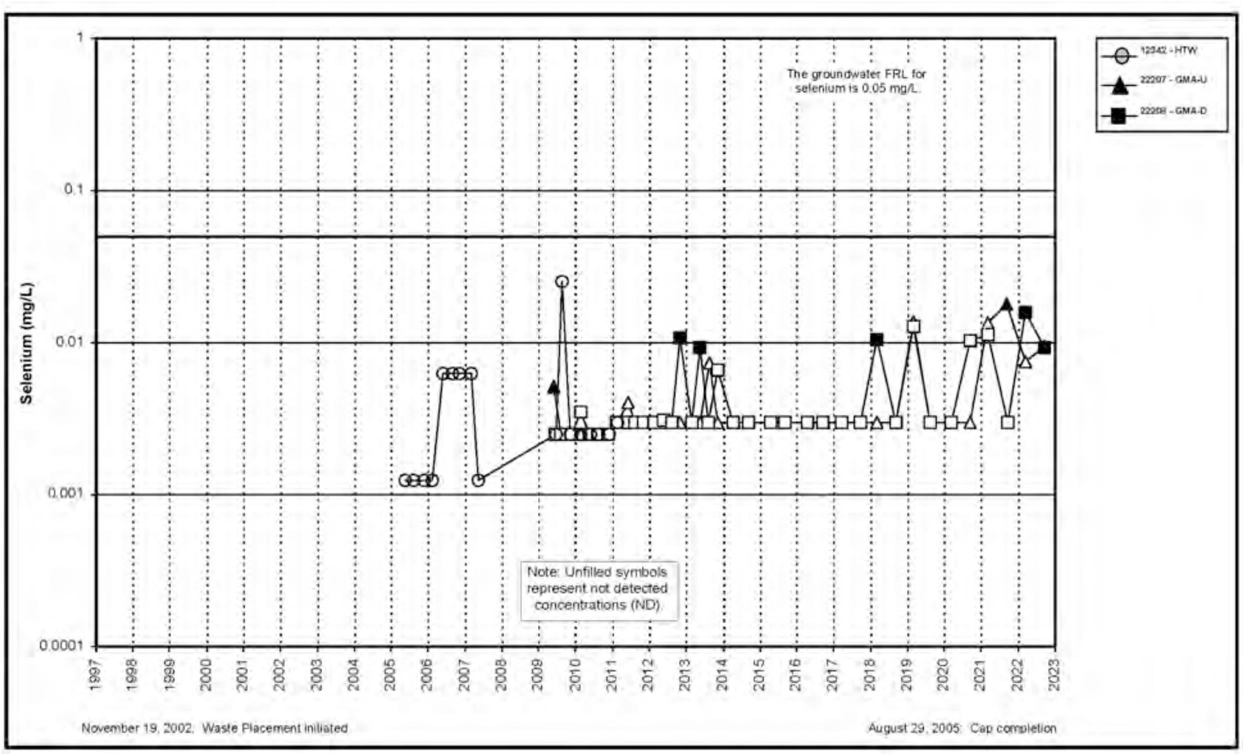

Figure A.5.5-14. Cell 5 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

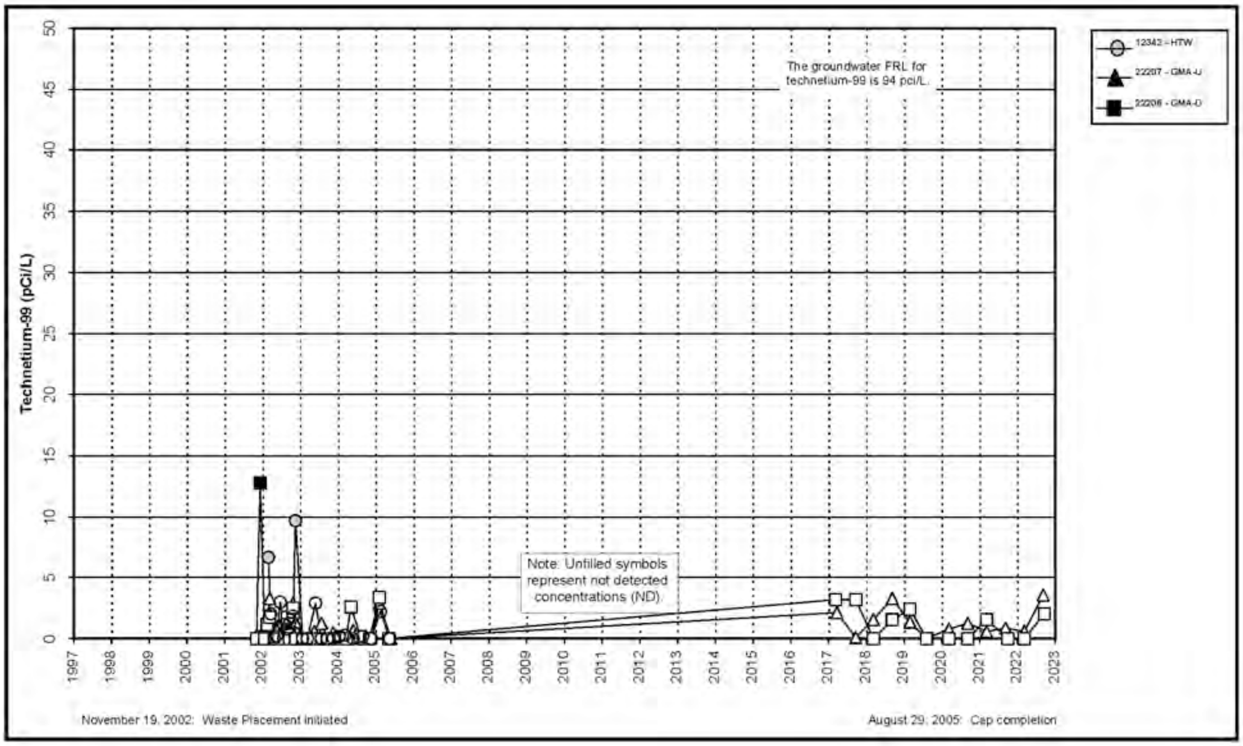

Figure A.5.5-15. Cell 5 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

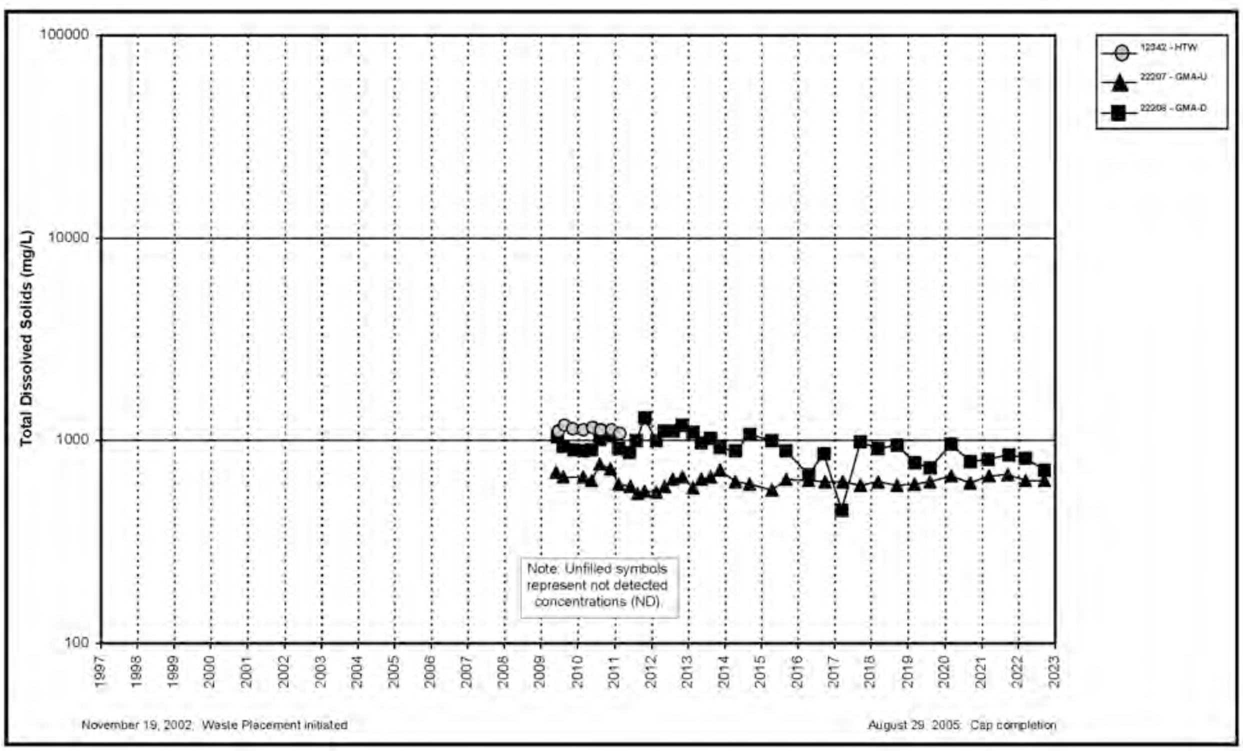

Figure A.5.5-16. Cell 5 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

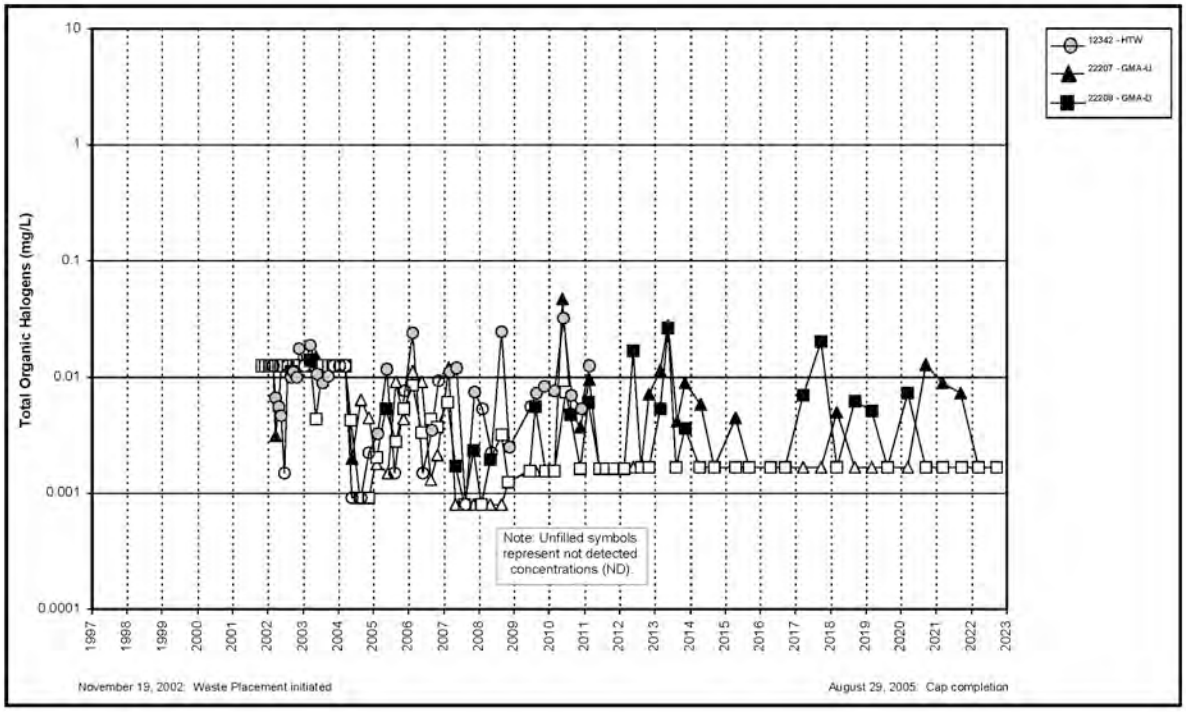

Figure A.5.5-17. Cell 5 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

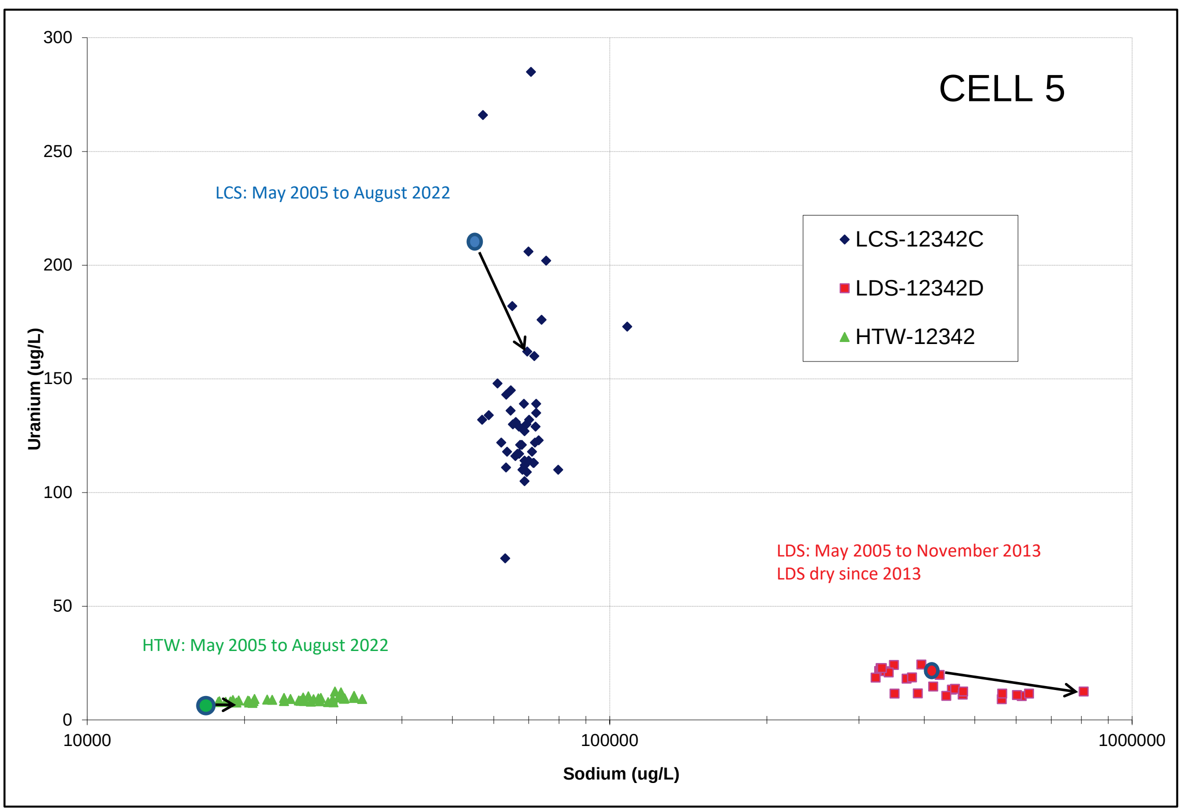

Figure A.5.5-18. Cell 5 Bivariate Plot for Uranium and Sodium

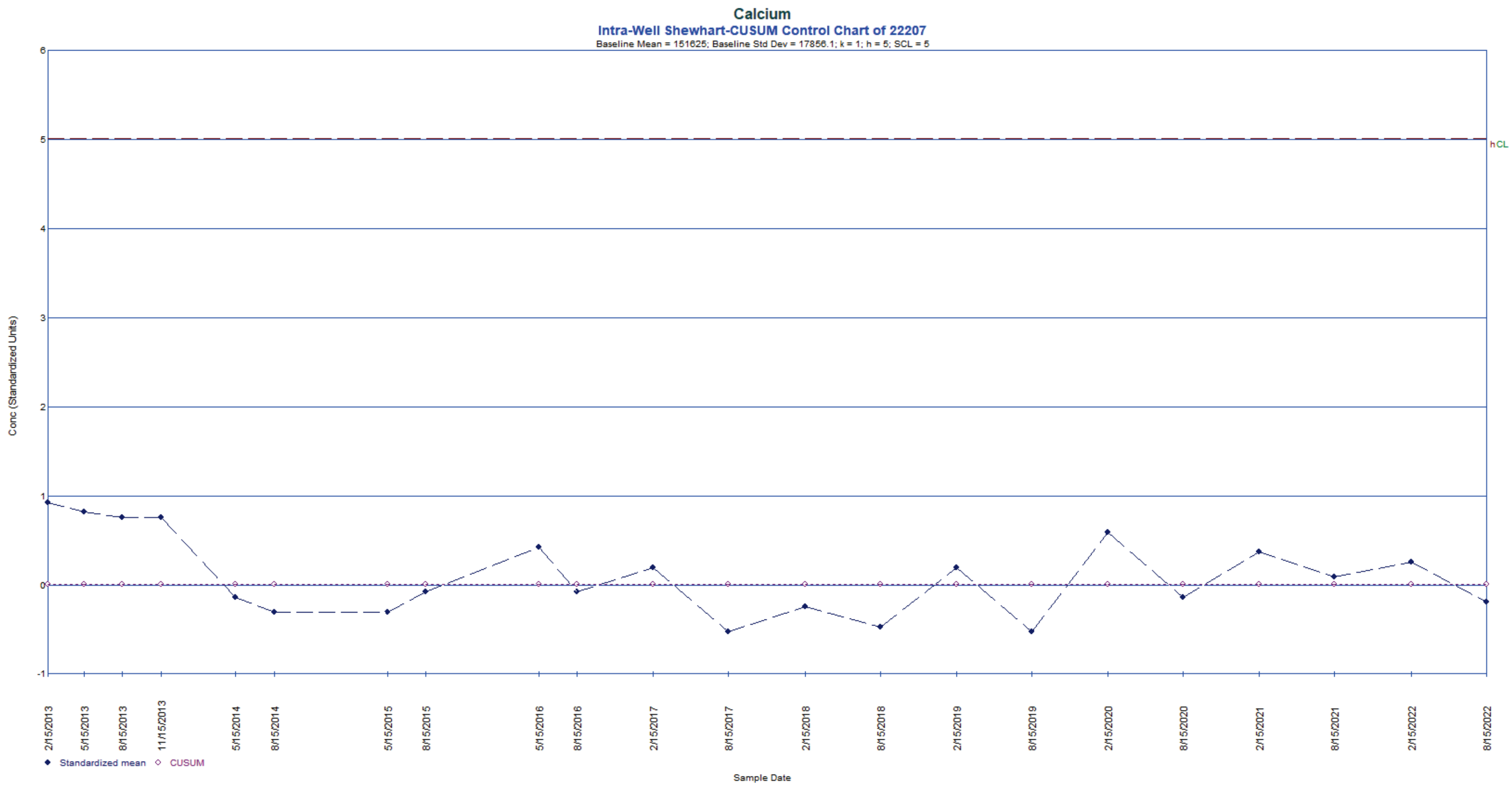

Figure A.5.5-19. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22207

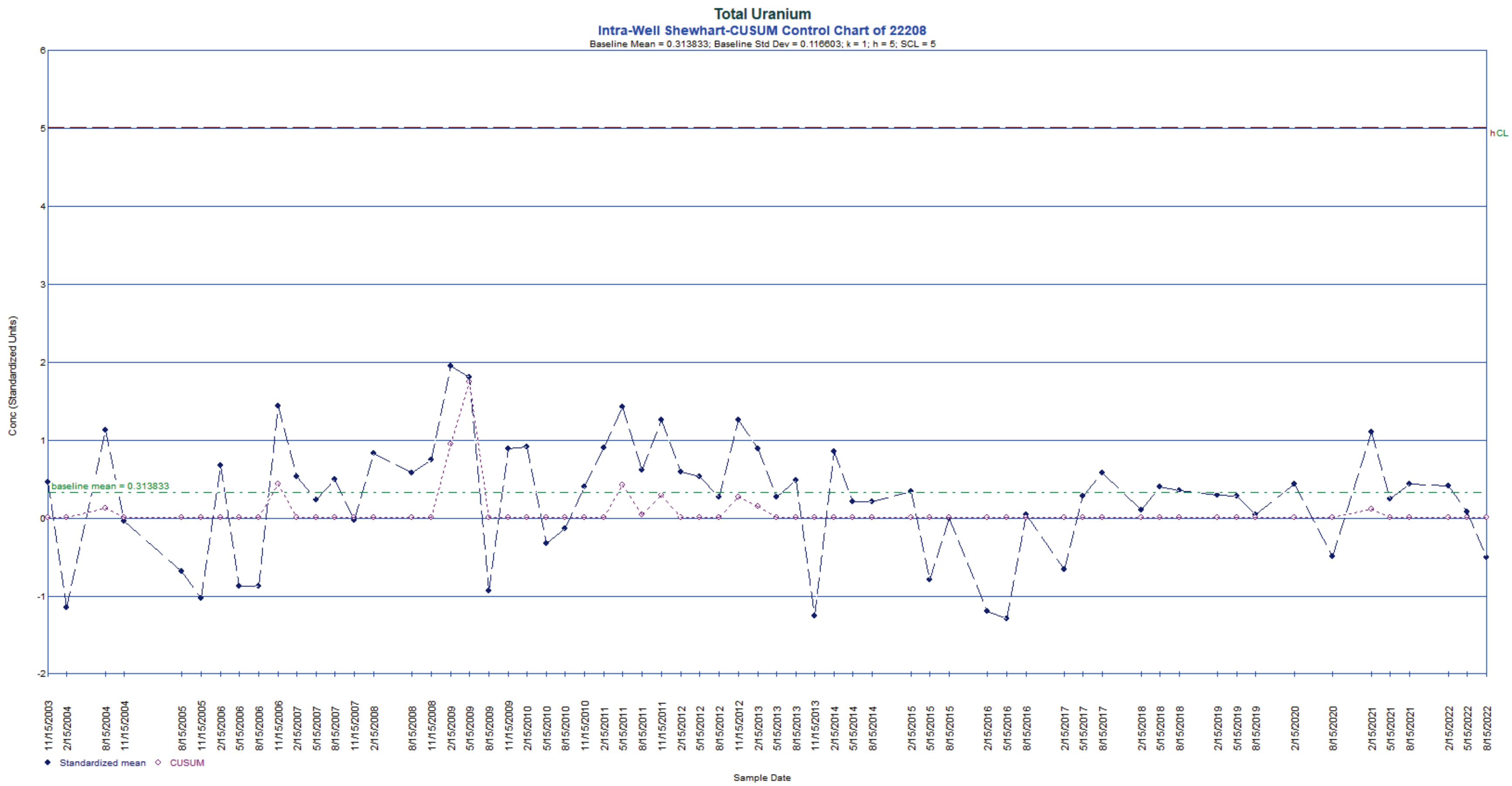

Figure A.5.5-20. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22208

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Subattachment A.5.6

Cell 6

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 6:

- Semiannual monitoring summary statistics (Table A.5.6-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.6-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.6-2)
- OSDF horizontal till well (HTW) 12343 water yield (Table A.5.6-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.6-3 and A.5.6-4)
- Plots of concentration versus time (Figures A.5.6-5A through A.5.6-17)
- A bivariate plot for uranium-sodium (Figure A.5.6-18)
- Control charts (Figures A.5.6-19 through A.5.6-21)

A.5.6.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF was operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.6.1.1 LCS and LDS Results

As shown in Table A.5.6-1 and summarized below, four parameters (total uranium, boron, sodium, and sulfate) in 2022 have upward trends in the LCS or LDS based on the Mann-Kendall test for trend. In 2022, sufficient water was present in the LDS tank of Cell 6 to sample the tank twice.

One new high concentration (sulfate) was measured in the LCS of Cell 6 in 2022. The new high for sulfate was 5,200 milligrams per liter (mg/L). The previous high was 4,800 mg/L. Three new concentration highs were measured in the LDS tank of Cell 6 in 2022 (uranium, sodium, and sulfate). The new high for uranium in the LDS was 160 micrograms per liter (µg/L). The previous high was 152 µg/L. The new high for sodium in the LDS was 1,190 mg/L. The previous high was 856 mg/L. The new high for sulfate in the LDS was 10,800 mg/L. The previous high was 8,470 mg/L.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 6

Parameter	LCS 12343C 2022 Trend[a]	LDS 12343D 2022 Trend
Total Uranium		Up
Boron		Up
Sodium	Up	Up
Sulfate	Up	Up

[a] No entry indicates that the trend was not up.

A.5.6.1.2 HTW and Monitoring Well Results

As shown in Table A.5.6-1 and summarized below, eight parameters (boron, sulfate, calcium, lithium, magnesium, nitrate + nitrite as nitrogen, potassium, and selenium) have upward trends in the HTW or GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 6

Parameter	HTW 12343[a]	GMA-U[b] 22209[a,b]	GMA-D 22210[a,b]
Boron		Up	Up
Sulfate	Up		Up
Calcium		Up	
Lithium		Up	
Magnesium		Up	
Nitrate + Nitrite, as Nitrogen		Up	
Potassium		Up	
Selenium		Up	Up

[a] No entry indicates that the trend was not up.
[b] GMA-U = upgradient Great Miami Aquifer, GMA-D = downgradient Great Miami Aquifer, HTW = horizontal till well.

A.5.6.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 6 LCS, LDS, and HTW is provided in Figure A.5.6-18. On the figure, the first sample ever collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. The plot shows that the chemical signatures for uranium and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

The new high uranium, sodium, and sulfate concentrations measured in the LDS are not attributed to communication with the LCS. They are attributed to the impact that decreasing flow can have on the concentrations left in water remaining in the LDS as the LDS dries up. An additional discussion of this is presented in Attachment A.5, Section A.5.2.2.

A.5.6.2 Control Charts

Intrawell control charts use historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared “not in control” if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (*h*) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.6-1 in gray shading and as summarized below, three parameters in the HTW or GMA wells of Cell 6 (total uranium, lithium, and total dissolved solids) meet the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in three control charts (Figures A.5.6-19 through A.5.6-21). All of the control charts exhibit “in control” conditions.

Parameter	Monitoring Point[a]	Well Number	Assessment	Figure Number
Total Uranium	GMA-D	22210	In Control	A.5.6-19
Lithium	GMA-D	22210	In Control	A.5.6-20
Total Dissolved Solids	GMA-U	22209	In Control	A.5.6-21

[a] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer.

A.5.6.3 Summary and Conclusions

- Four parameters monitored semiannually have an upward concentration trend in the LCS or LDS of Cell 6: total uranium, boron, sodium, and sulfate. One new high concentration was measured in the LCS tank of Cell 6 in 2022 (sulfate). The new high for sulfate was 5,200 mg/L. The previous high was 4,800 mg/L.
- Sufficient water was present in the LDS tank of Cell 6 to sample the tank twice in 2022. Three new concentration highs were measured in the LDS tank of Cell 6 in 2022 (i.e., uranium, sodium, and sulfate). The new high for uranium in the LDS was 160 µg/L. The previous high was 152 µg/L. The new high for sodium in the LDS was 1,190 mg/L. The previous high was 856 mg/L. The new high for sulfate in the LDS was 10,800 mg/L. The previous high was 8,470 mg/L. The new high uranium sodium, and sulfate concentrations measured in the LDS are not attributed to communication with the LCS. They are attributed to the impact that decreasing flow can have on the concentrations left in water remaining in the LDS as the LDS dries up. An additional discussion of this is presented in Attachment A.5, Section A.5.2.2.
- Eight parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 6: boron, sulfate, calcium, lithium, magnesium, nitrate + nitrite as nitrogen, potassium, and selenium. Separate and distinct chemical signatures for uranium and sodium in the LCS, LDS, and HTW of Cell 6 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 6 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- Three control charts were constructed for Cell 6 parameters. All control charts exhibit "in control" conditions.

A.5.6.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. "Ground Water Monitoring Program for a Sanitary Landfill Facility," *Ohio Administrative Code.*

Table A.5.6-1. Summary Statistics for Cell 6

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12343C	58	58	100	43.3	276	124	33	Undefined	Down (2022)	Detected	
	LDS	12343D	58	58	100	3.10	160	29.4	40.8	Undefined	Up (2022)	Detected	
	HTW	12343	58	58	100	6.32	16.9	11.2	2.2	Normal	None (2022)	Detected	24.2 (Q1-07); 21.4 (Q2-11)
	GMA-U	22209	56	62	90.3	ND	0.928	0.480	0.377	Undefined	Down (2022)	Not Detected	2.43(Q2-06), 2.1(Q3-08), 1.64(Q3-11)
	GMA-D	22210	69	71	97.2	ND	0.994	0.658	0.135	Ln Normal	None (2022)	Not Detected	
Boron (mg/L)	LCS	12343C	58	58	100	0.0566	1.37	0.734	0.197	Undefined	Down (2022)	Detected	
	LDS	12343D	58	58	100	0.289	1.22	0.417	0.161	Undefined	Up (2022)	Detected	2.38 (Q3-04)
	HTW	12343	37	41	90.2	ND	0.124	0.0899	0.0149	Normal	None (2022)	Detected	0.0409 (Q2-06); 0.0360 (Q4-06)
	GMA-U	22209	57	62	91.9	ND	0.113	0.0384	0.0139	Undefined	Up (2022)	Detected	
	GMA-D	22210	59	62	95.2	ND	0.0616	0.0370	0.0092	Undefined	Up (2022)	Detected	
Sodium (mg/L)	LCS	12343C	49	49	100	44.5	107	70.8	12.2	Normal	Up (2022)	Detected	23.6 (Q2-04); 23.1 (Q2-05)
	LDS	12343D	47	47	100	109	1190	497	177	Undefined	Up (2022)	Detected	
	HTW	12343	45	45	100	16.3	66.0	37.0	14.6	Undefined	Down (2022)	Detected	
	GMA-U	22209	37	37	100	14.5	26.8	18.8	2.6	Normal	None (2022)	Detected	
	GMA-D	22210	38	38	100	11.1	20.4	17.0	2.5	Undefined	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12343C	58	58	100	491	5200	3500	1080	Undefined	Up (2022)	Detected	
	LDS	12343D	57	57	100	1,300	10,800	3,640	1,890	Ln Normal	Up (2022)	Detected	
	HTW	12343	52	53	98.1	ND	716	495	94	Normal	Up (2022)	Detected	
	GMA-U	22209	61	61	100	2.07	406	162	66	Undefined	Down (2022)	Detected	
	GMA-D	22210	61	61	100	127	392	273	73	Normal	Up (2022)	Detected	578 (Q1-07)
Calcium (mg/L)	GMA-U	22209	30	30	100	136	184	152	11	Normal	Up (2022)	Not Detected	242 (Q3-11); 231 (Q3-13)
	GMA-D	22210	30	30	100	162	239	205	21	Normal	Down (2022)	Detected	
Lithium (mg/L)	GMA-U	22209	37	37	100	0.00486	0.0107	0.00678	0.00144	Ln Normal	Up (2022)	Detected	
	GMA-D	22210	37	37	100	0.00631	0.00865	0.00738	0.00055	Normal	None (2022)	Not Detected	
Magnesium (mg/L)	GMA-U	22209	30	30	100	27	43.4	33.8	3.4	Normal	Up (2022)	Detected	55.4 (Q3-13)
	GMA-D	22210	30	30	100	41.5	58.3	50.2	4.7	Normal	Down (2022)	Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22209	4	31	12.9	ND	0.500	0.0085	0.0877	Undefined	Up (2022)	Not Detected	
	GMA-D	22210	1	30	3.3	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22209	30	30	100	2.31	3.78	3.28	0.26	Undefined	Up (2022)	Not Detected	
	GMA-D	22210	31	31	100	2.54	3.62	3.15	0.26	Normal	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22209	6	37	16.2	ND	0.0236	0.00300	0.00416	Undefined	Up (2022)	Detected	
	GMA-D	22210	5	37	13.5	ND	0.0122	0.00300	0.00258	Undefined	Up (2022)	Detected	
Technitium-99 (pCi/L)	GMA-U	22209	1	23	4.4	ND	8.61	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22210	1	23	4.4	ND	6.61	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22209	37	37	100	550	720	635	41	Normal	None (2022)	Not Detected	876 (Q3-11)
	GMA-D	22210	37	37	100	680	1,020	906	89	Undefined	Down (2022)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22209	19	62	30.6	ND	0.0208	0.00166	0.00482	Undefined	None (2022)	Detected	0.0365 (Q3-06); 0.0377 (Q1-11); 0.0432 (Q1-13)
	GMA-D	22210	18	62	29.0	ND	0.0230	0.00190	0.00450	Undefined	None (2022)	Detected	0.0590 (Q2-10)

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b]ND = not detected; NA = not applicable

[c]Averages were determined based on the distribution assumption.

[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e]Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f]Trend based on nonparametric Mann-Kendall procedure.

[g]Serial correlation based on Rank Von Neumann test.

[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i]Q = quarter

Table A.5.6-2. OSDF Horizontal Till Well 12343 (Cell 6) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
2003	9,940	10	994
2004	760	6	127
2005	925	5	185
2006	565	4	141
2007	355	4	89
2008	510	4	128
2009	550	4	183
2010	935	4	234
2011	1,175	4	294
2012	1,065	4	266
2013	1,130	4	283
2014	475	2	238
2015	725	2	363
2016	600	2	300
2017	720	2	360
2018	815	2	408
2019	690	2	345
2020	740	2	370
2021	690	2	345
2022	720	2	360

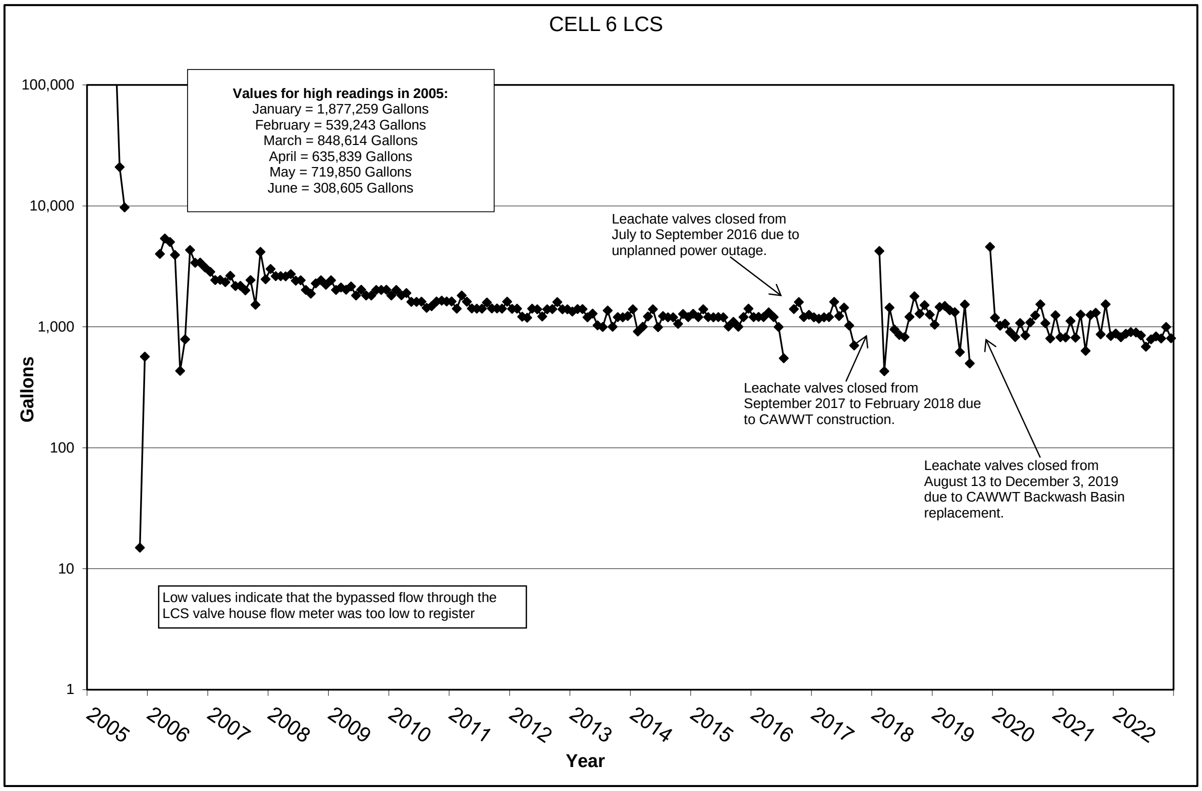

Figure A.5.6-1. Monthly Accumulation Volumes for Cell 6 LCS

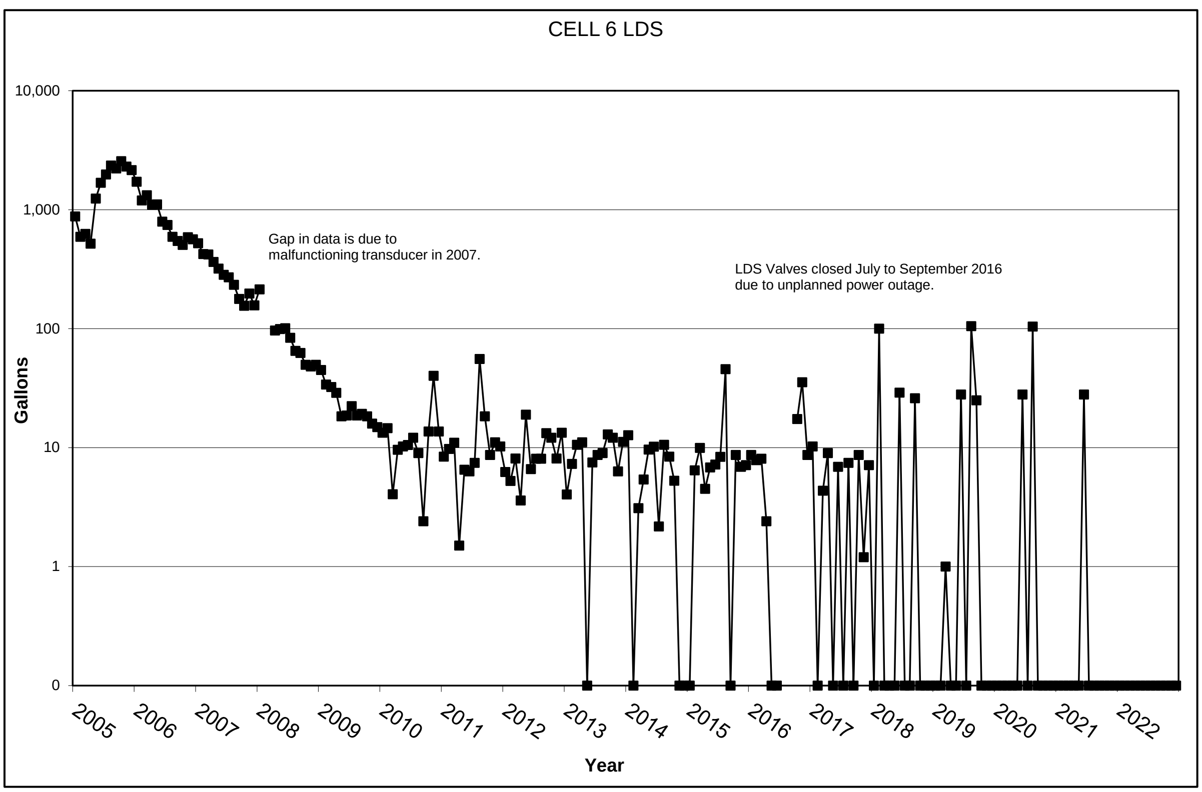

Figure A.5.6-2. Monthly Accumulation Volumes for Cell 6 LDS

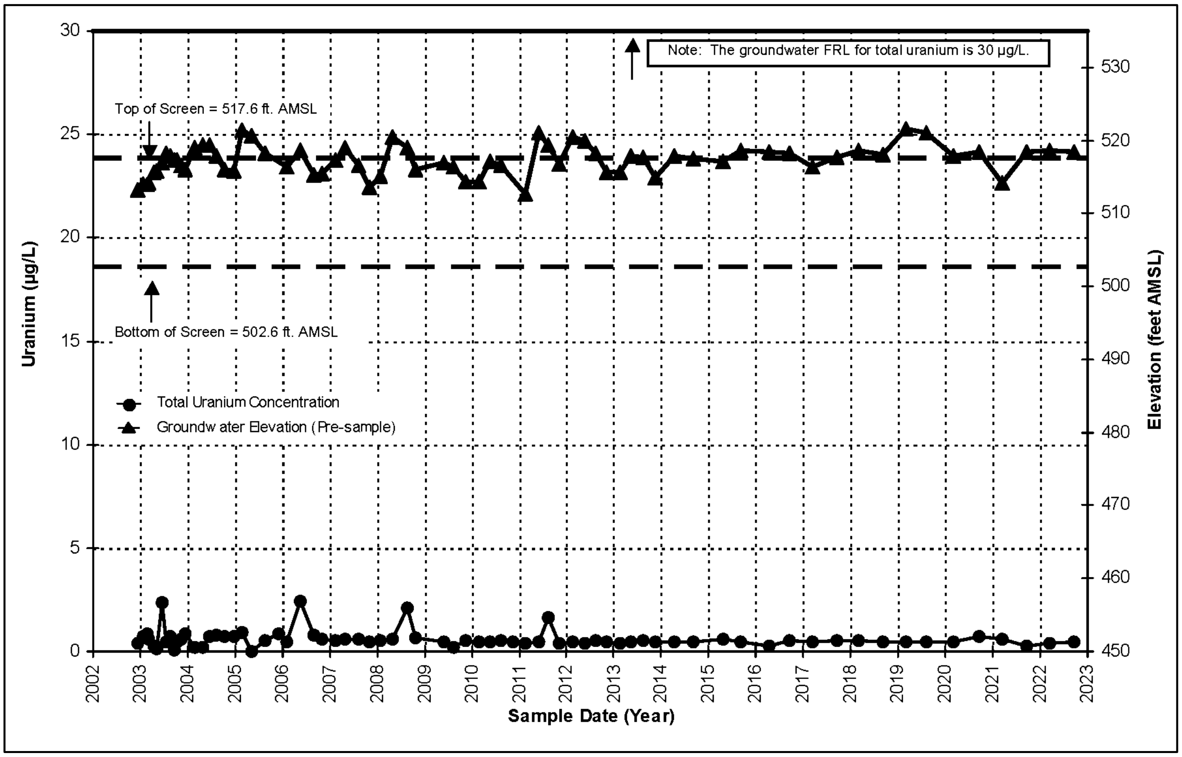

Figure A.5.6-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 6 Upgradient Monitoring Well 22209

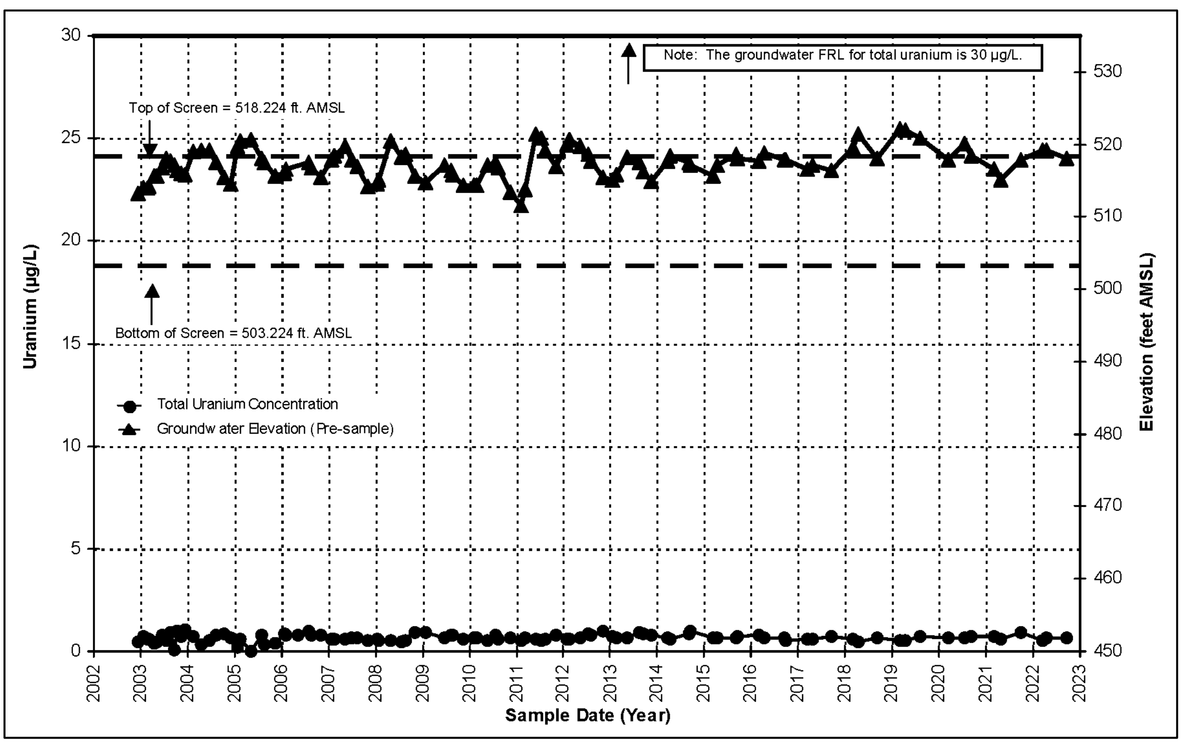

Figure A.5.6-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 6 Downgradient Monitoring Well 22210

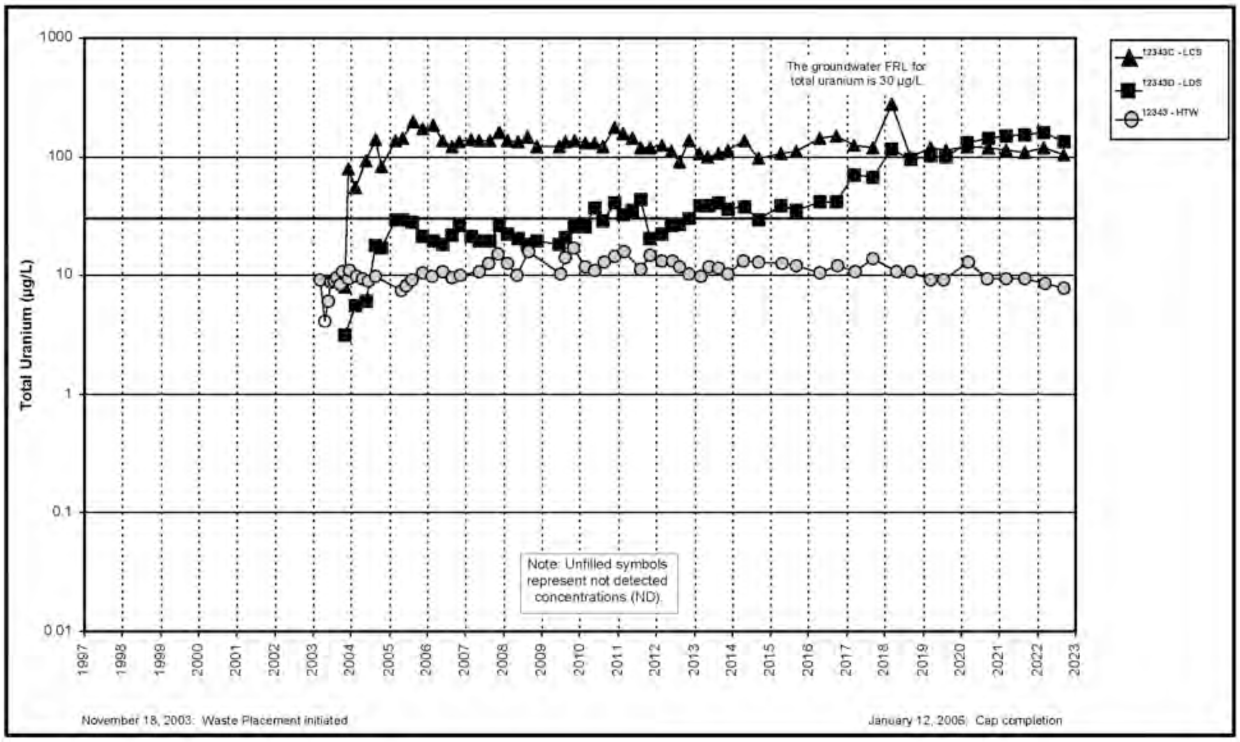

Figure A.5.6-5A. Cell 6 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

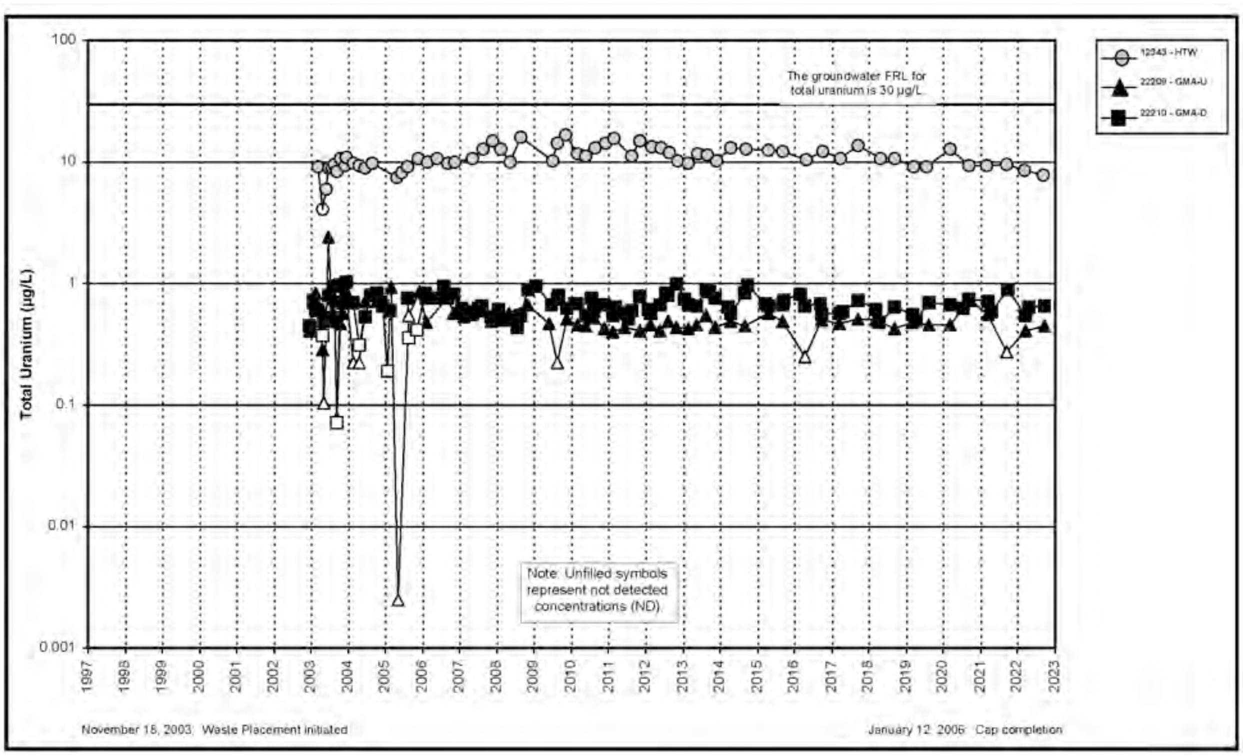

Figure A.5.6-5B. Cell 6 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

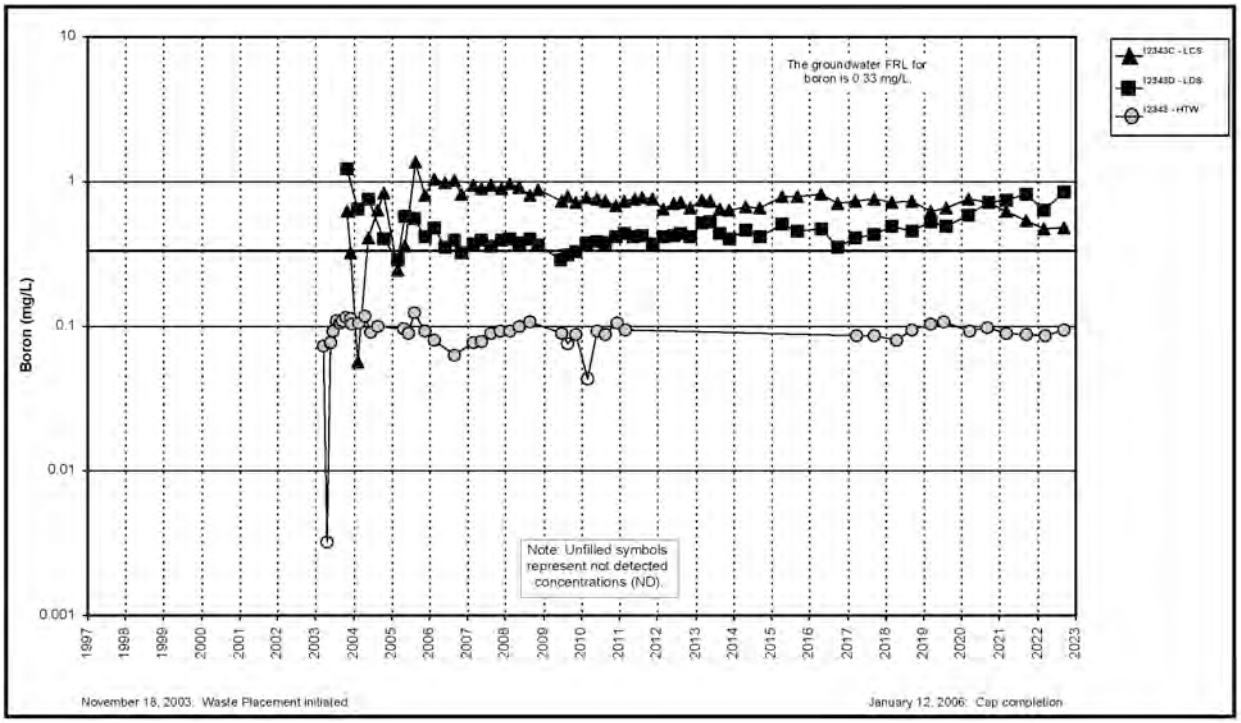

Figure A.5.6-6A. Cell 6 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

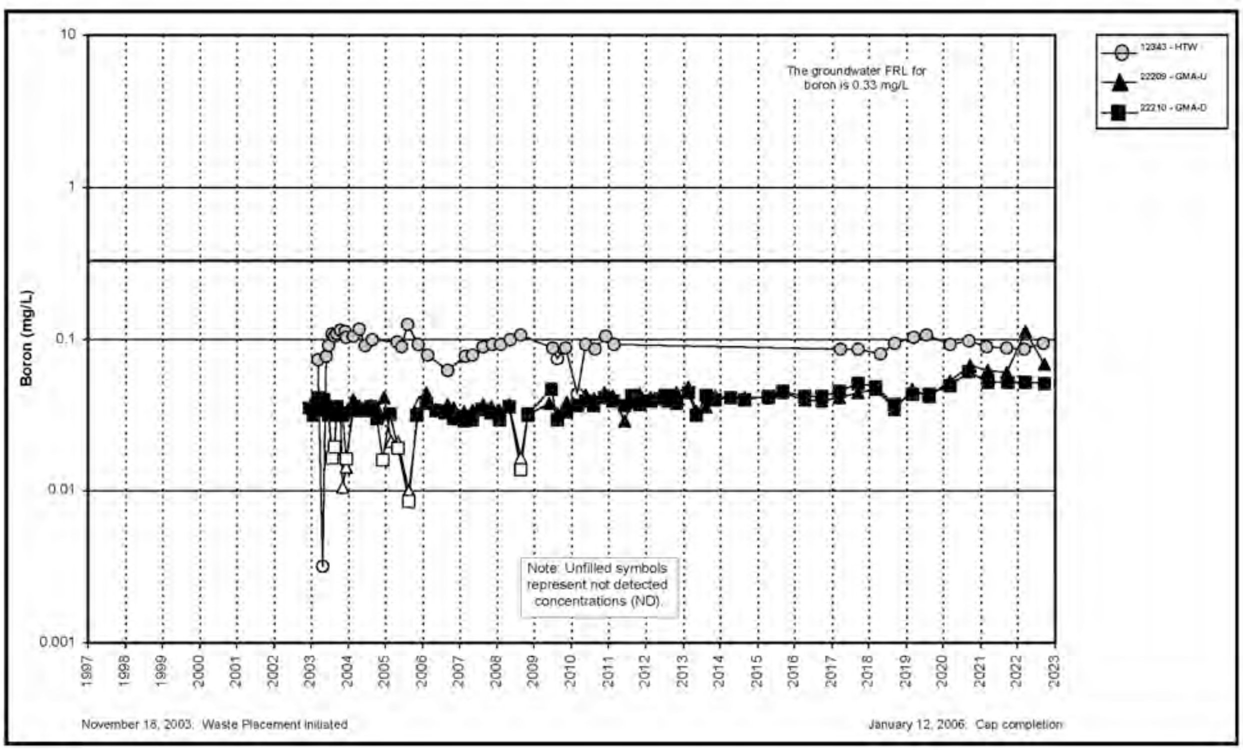

Figure A.5.6-6B. Cell 6 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

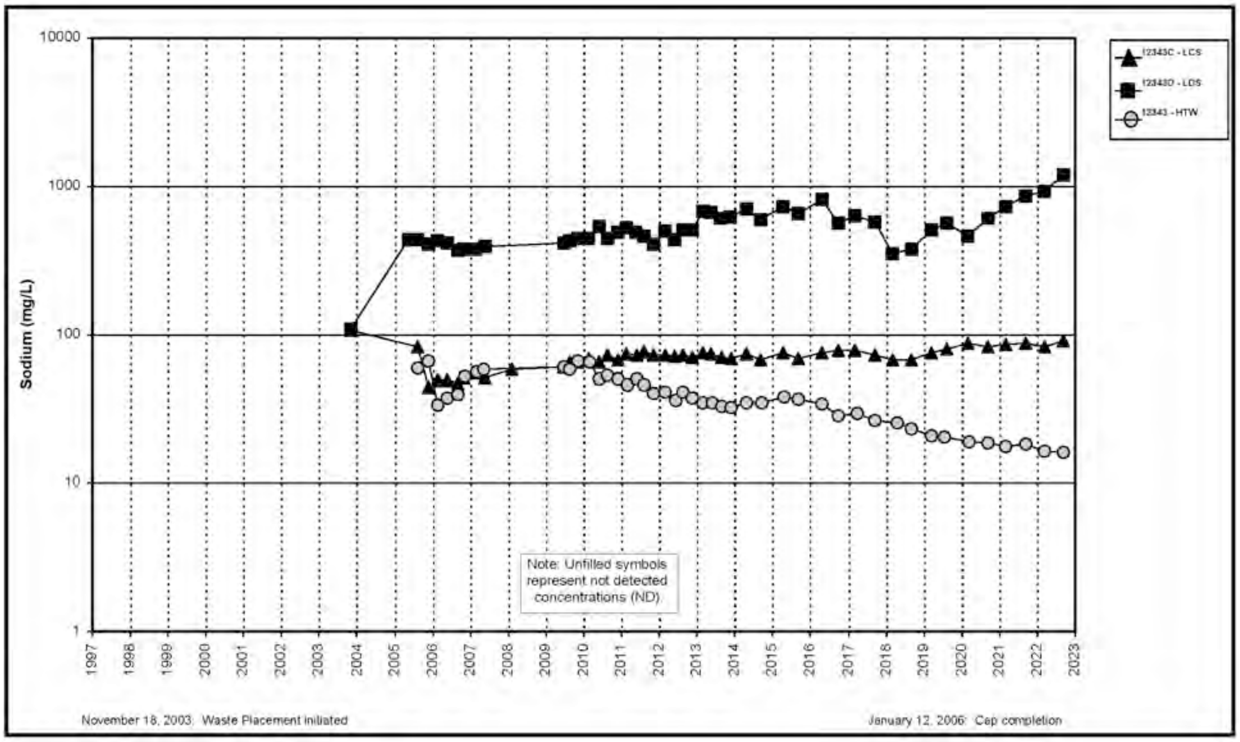

Figure A.5.6-7A. Cell 6 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

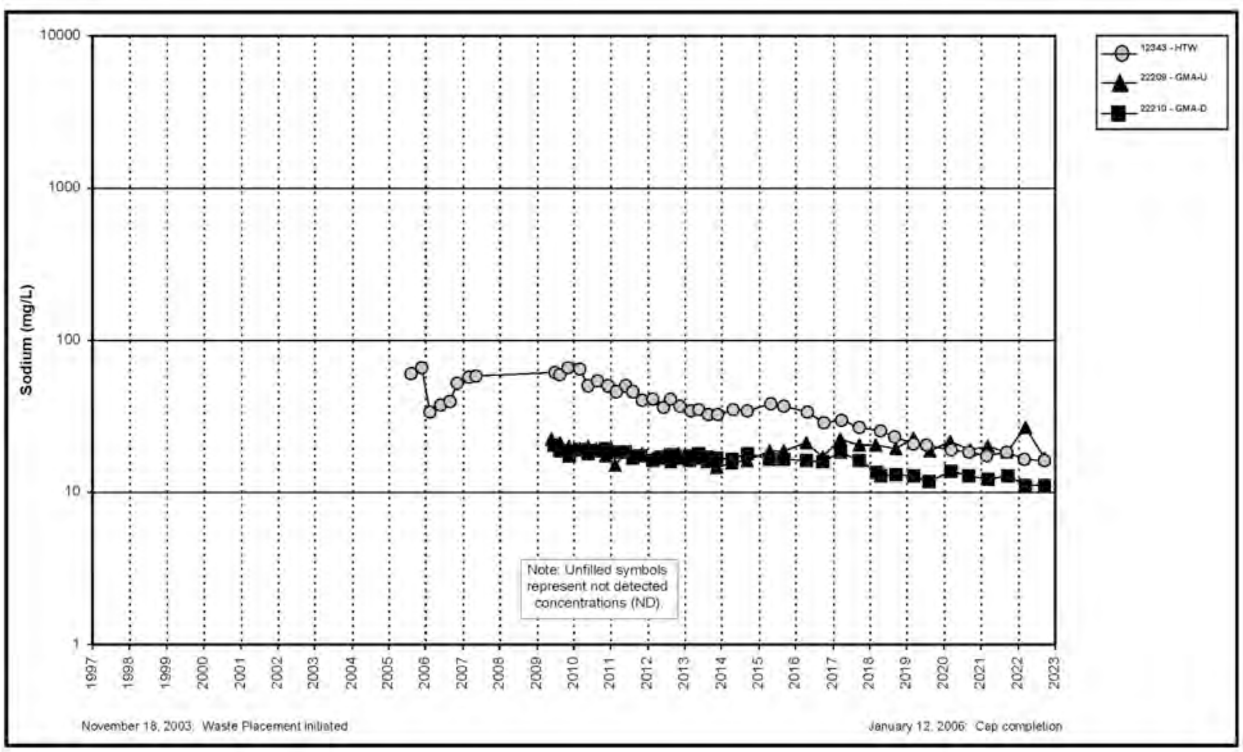

Figure A.5.6-7B. Cell 6 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

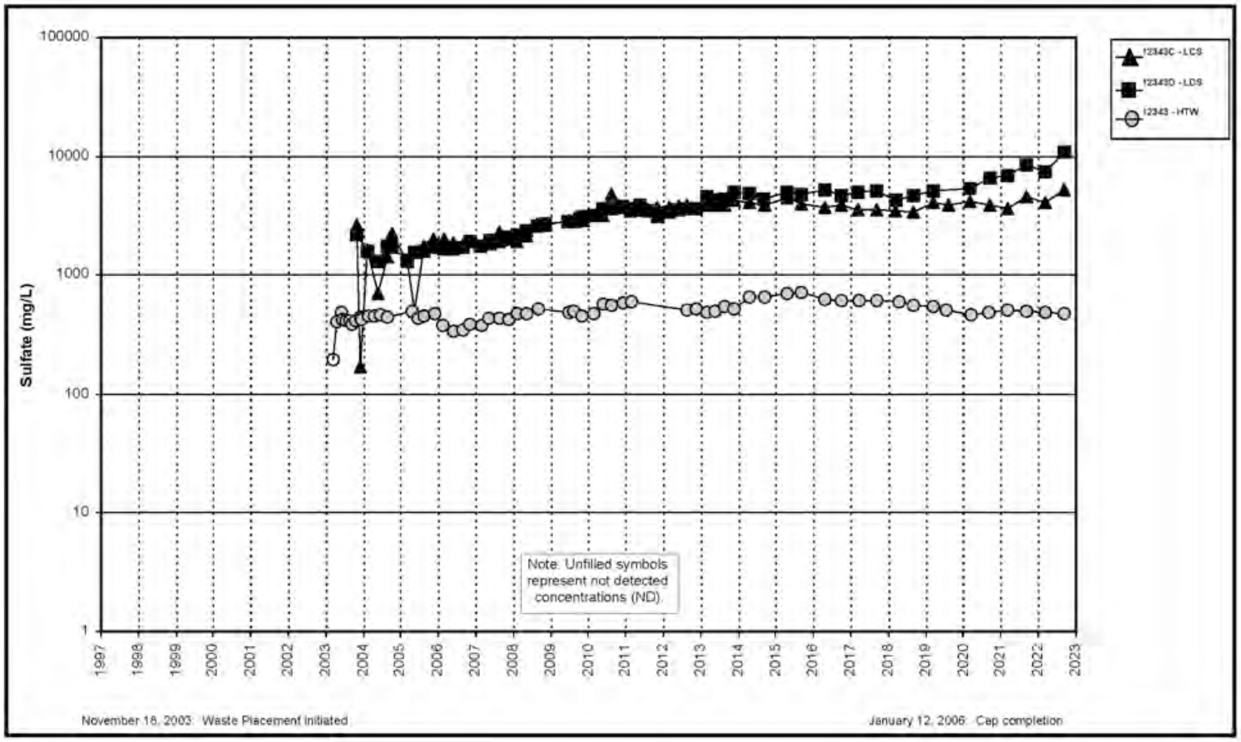

Figure A.5.6-8A. Cell 6 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

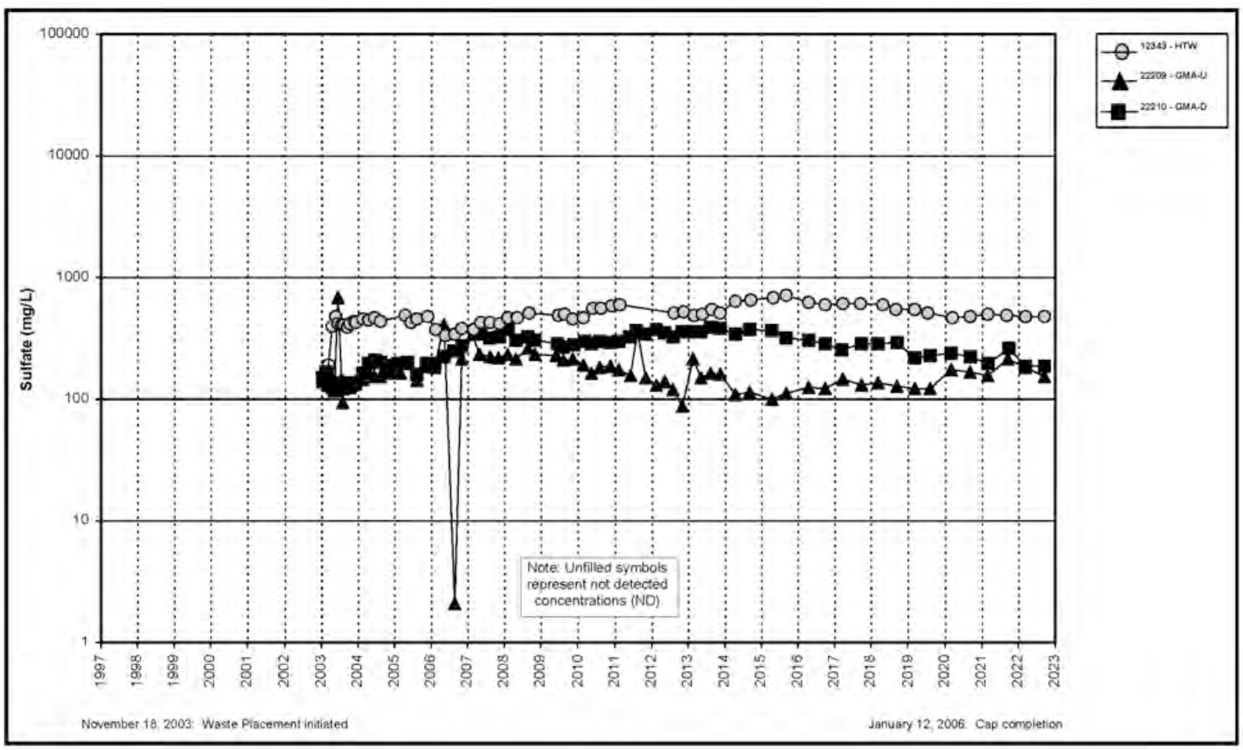

Figure A.5.6-8B. Cell 6 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

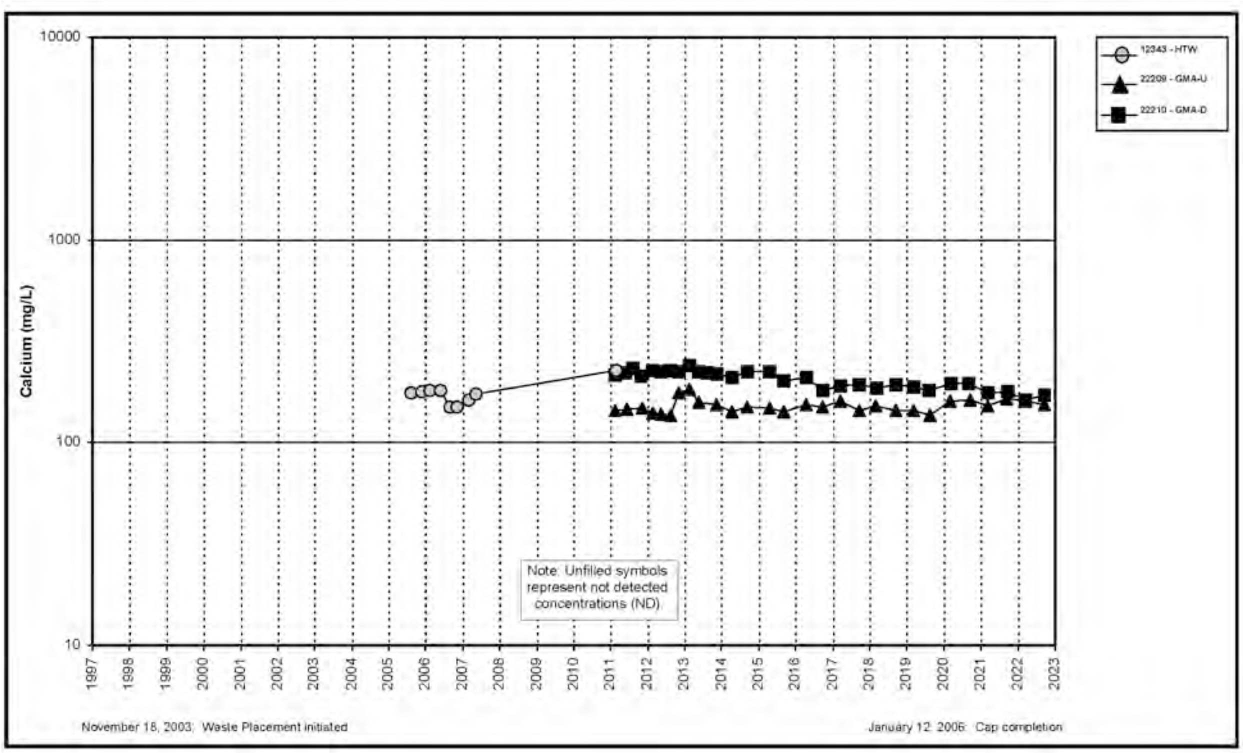

Figure A.5.6-9. Cell 6 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

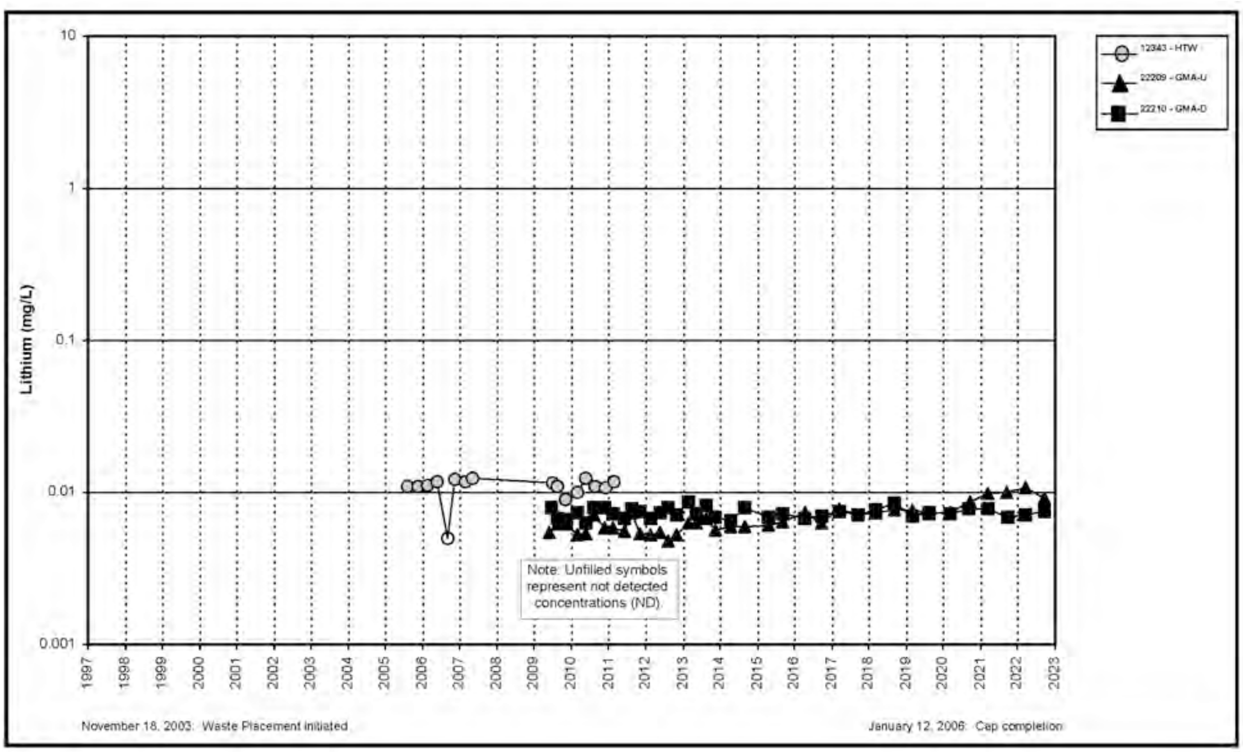

Figure A.5.6-10. Cell 6 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

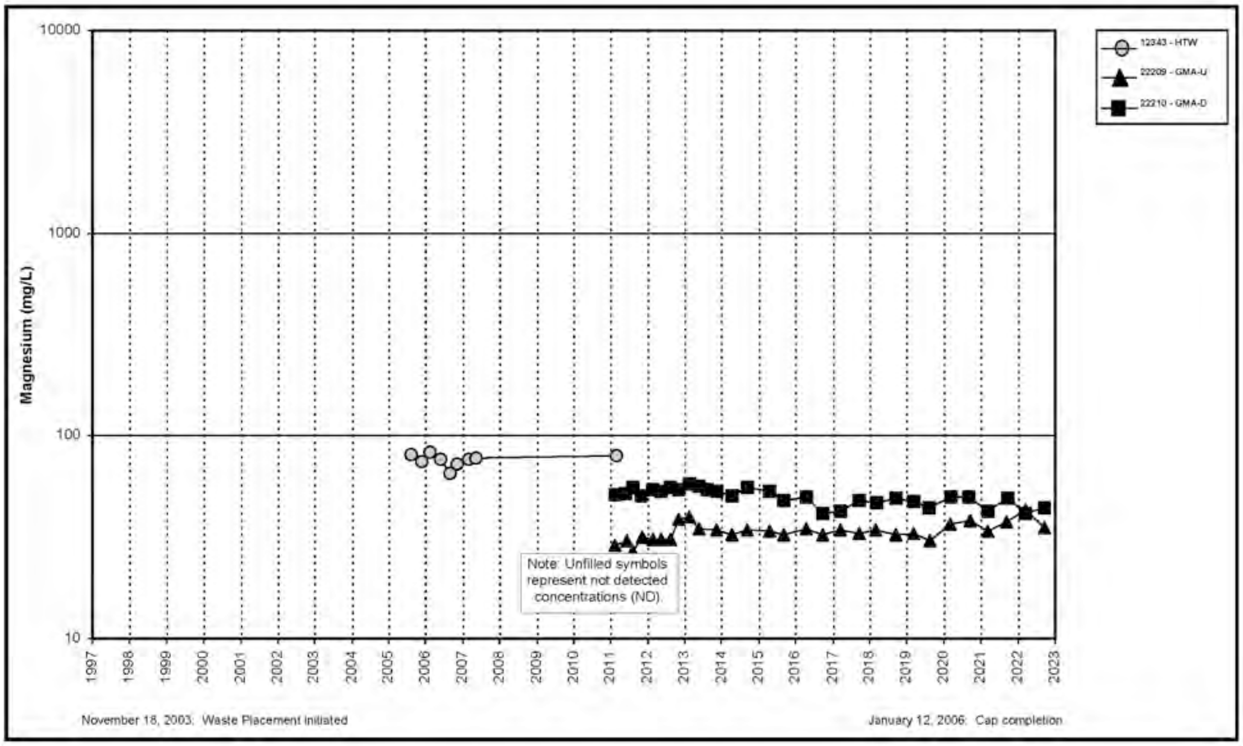

Figure A.5.6-11. Cell 6 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

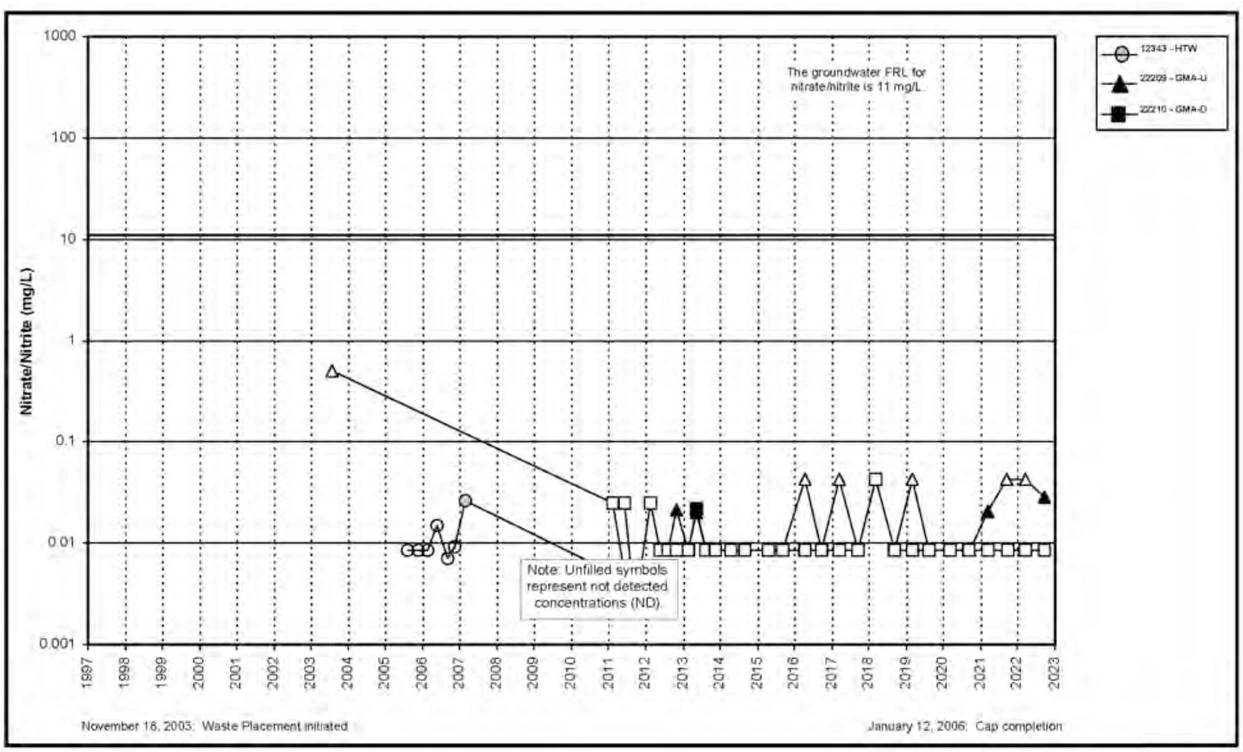

Figure A.5.6-12. Cell 6 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

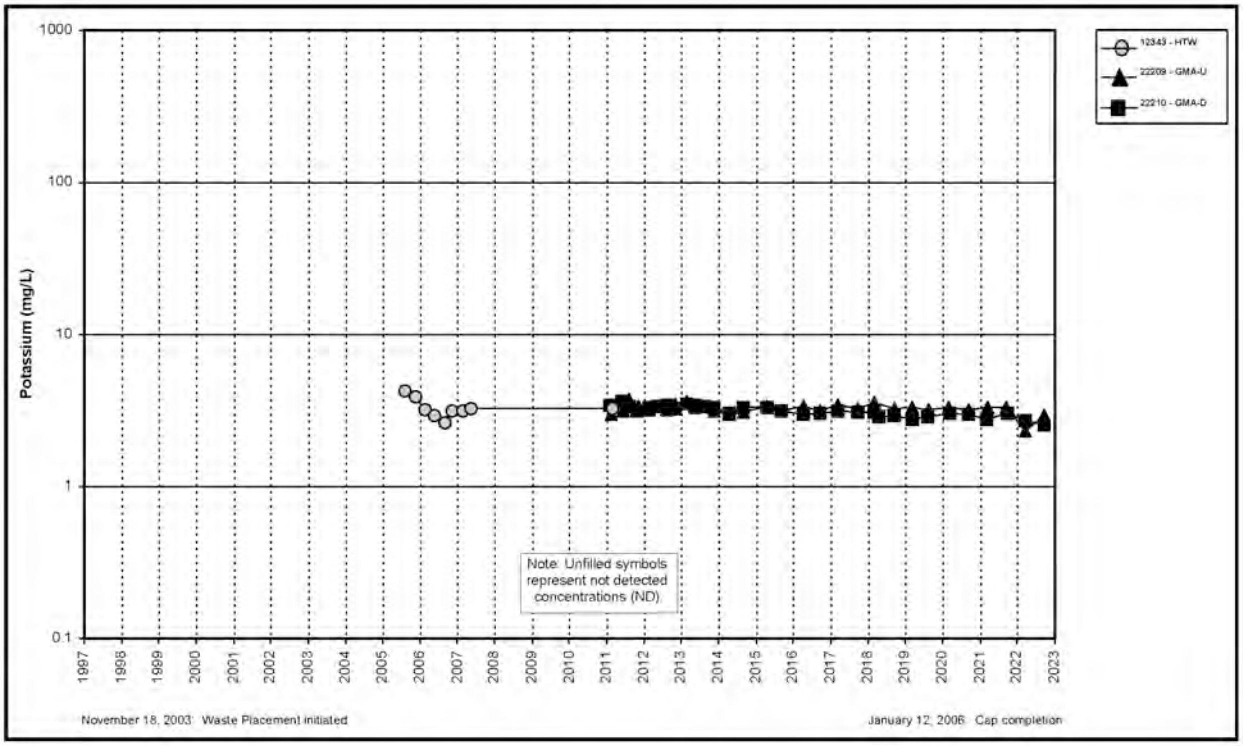

Figure A.5.6-13. Cell 6 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

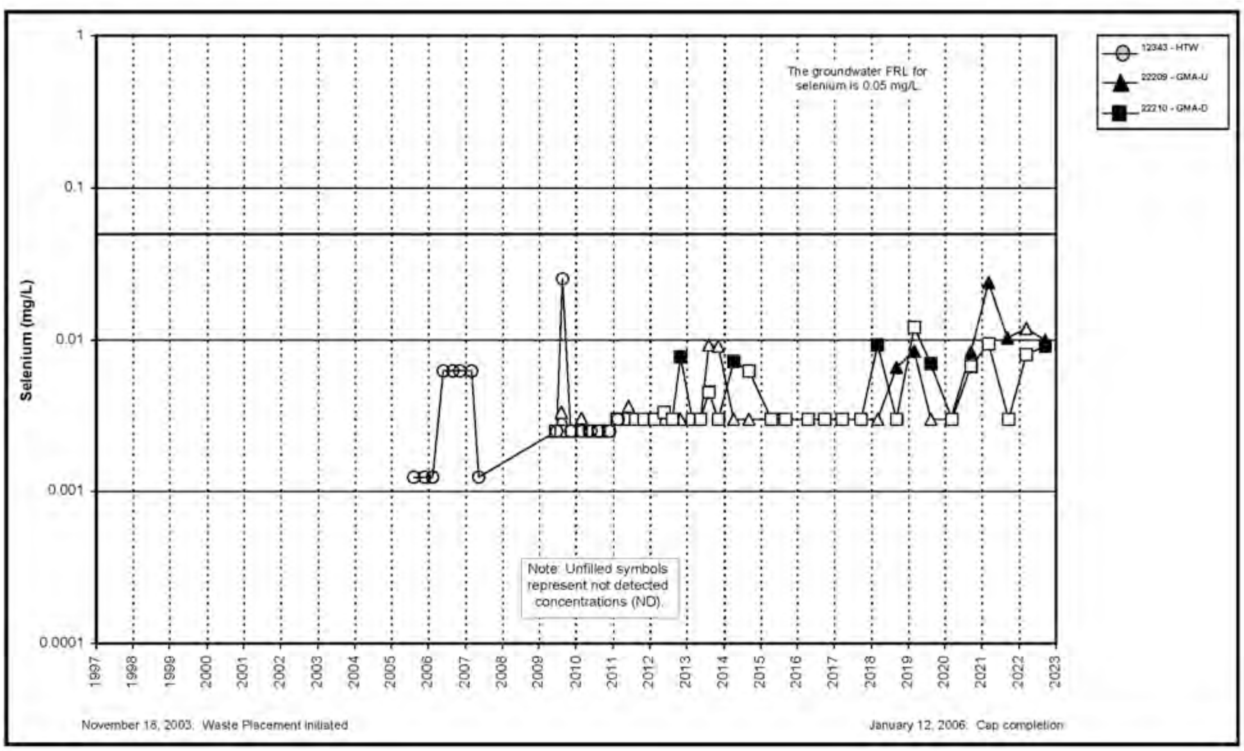

Figure A.5.6-14. Cell 6 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

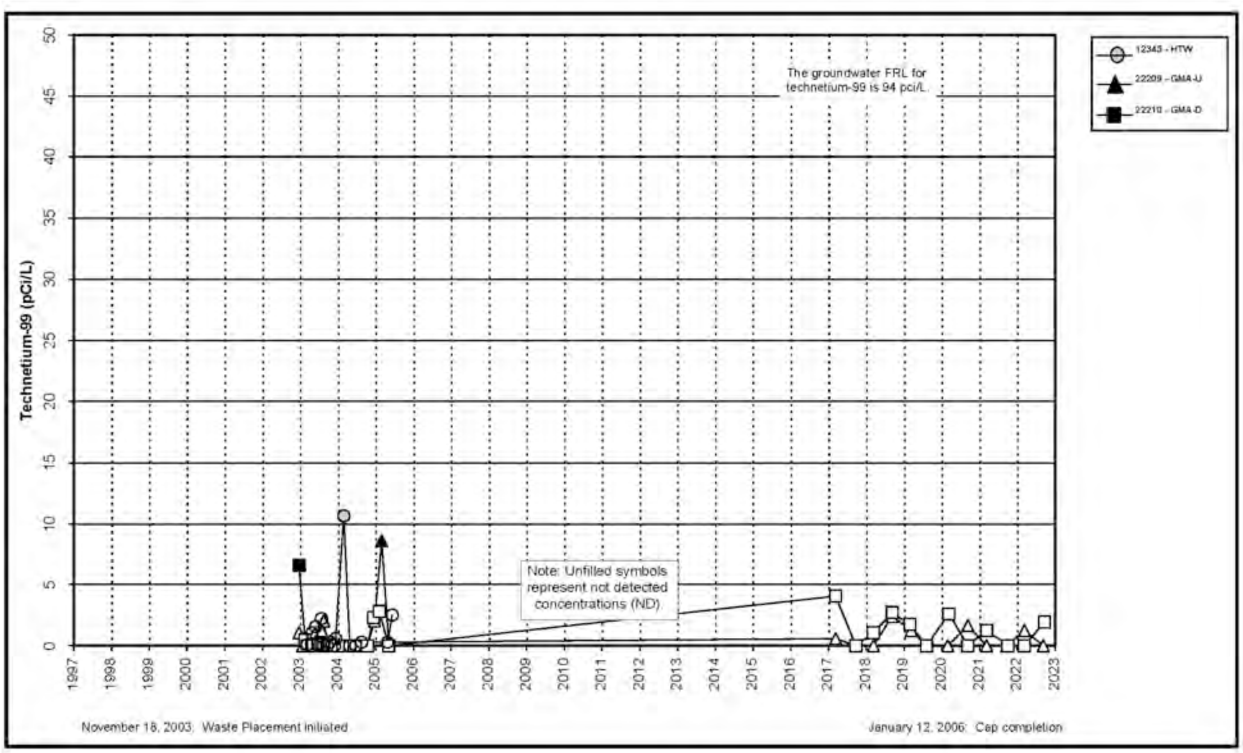

Figure A.5.6-15. Cell 6 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

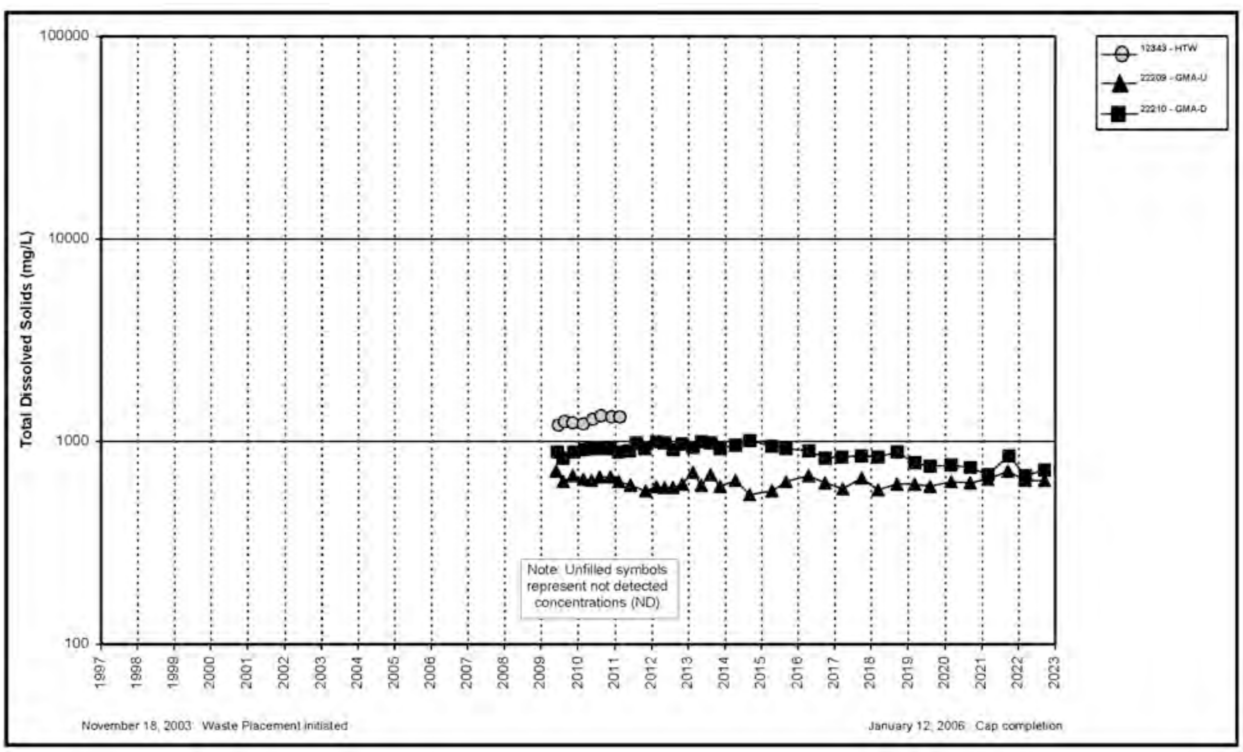

Figure A.5.6-16. Cell 6 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

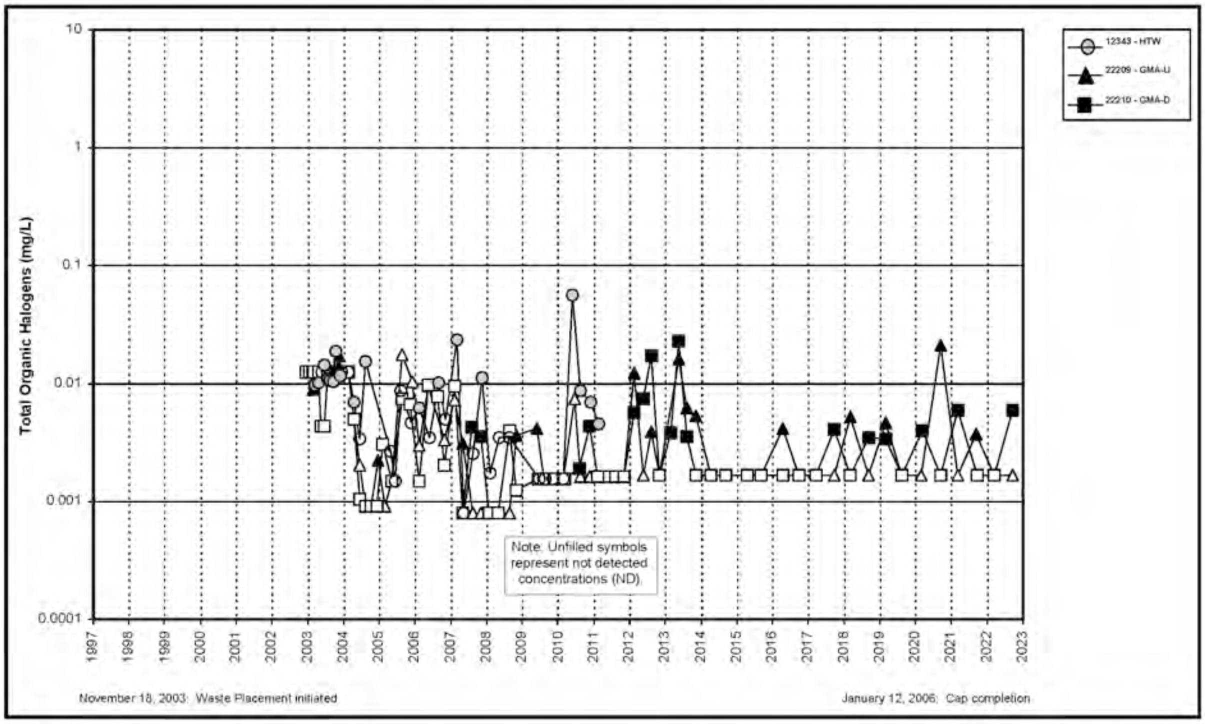

Figure A.5.6-17. Cell 6 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

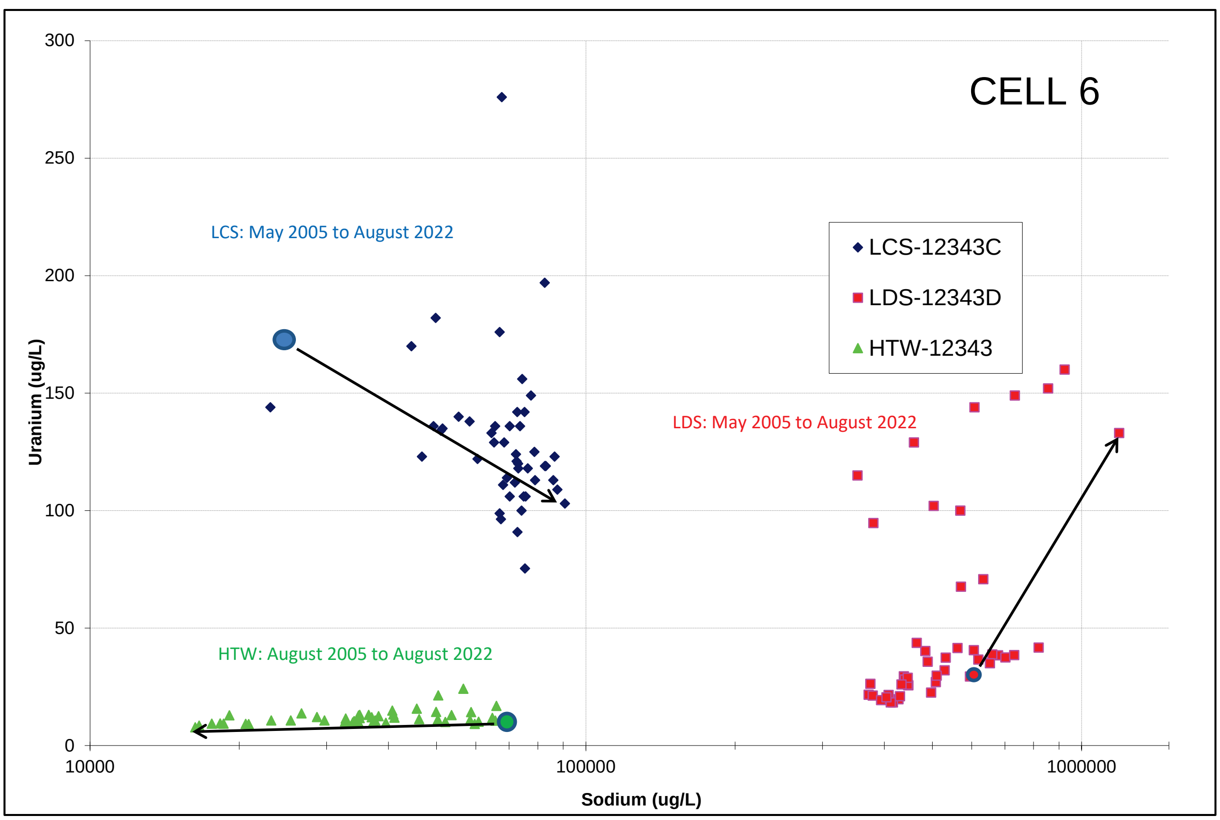

Figure A.5.6-18. Cell 6 Bivariate Plot for Uranium and Sodium

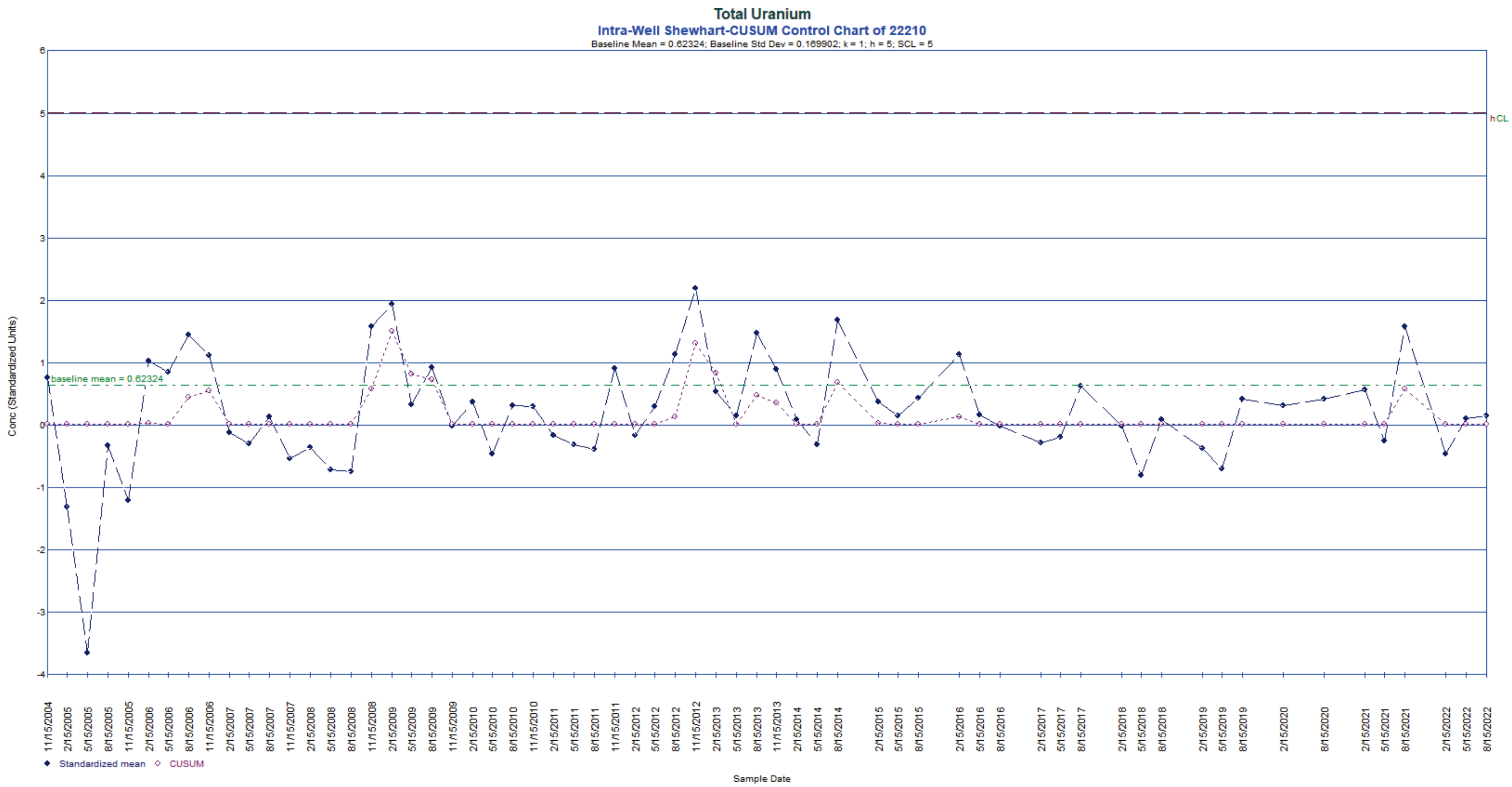

Figure A.5.6-19. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22210

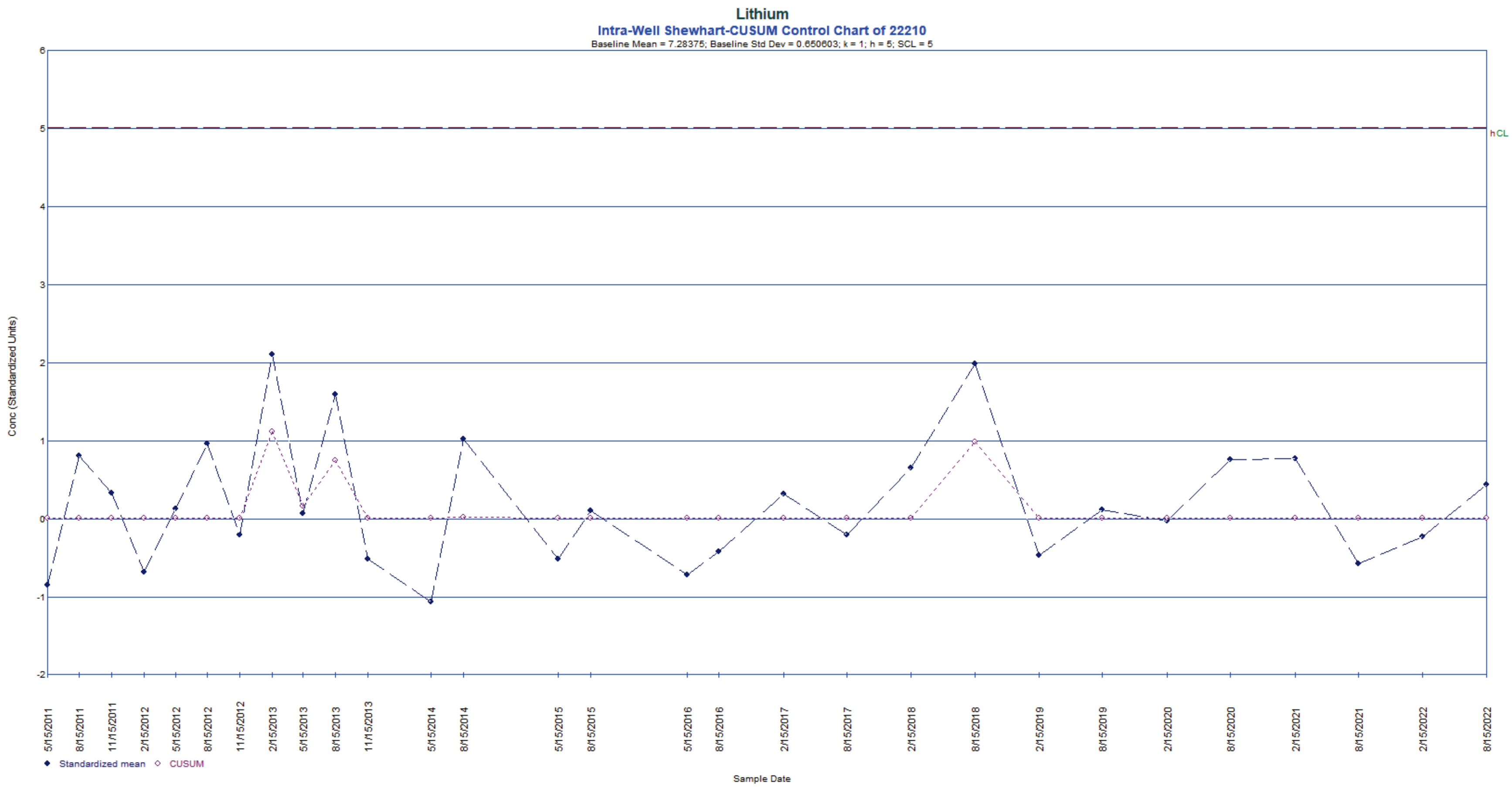

Figure A.5.6-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22210

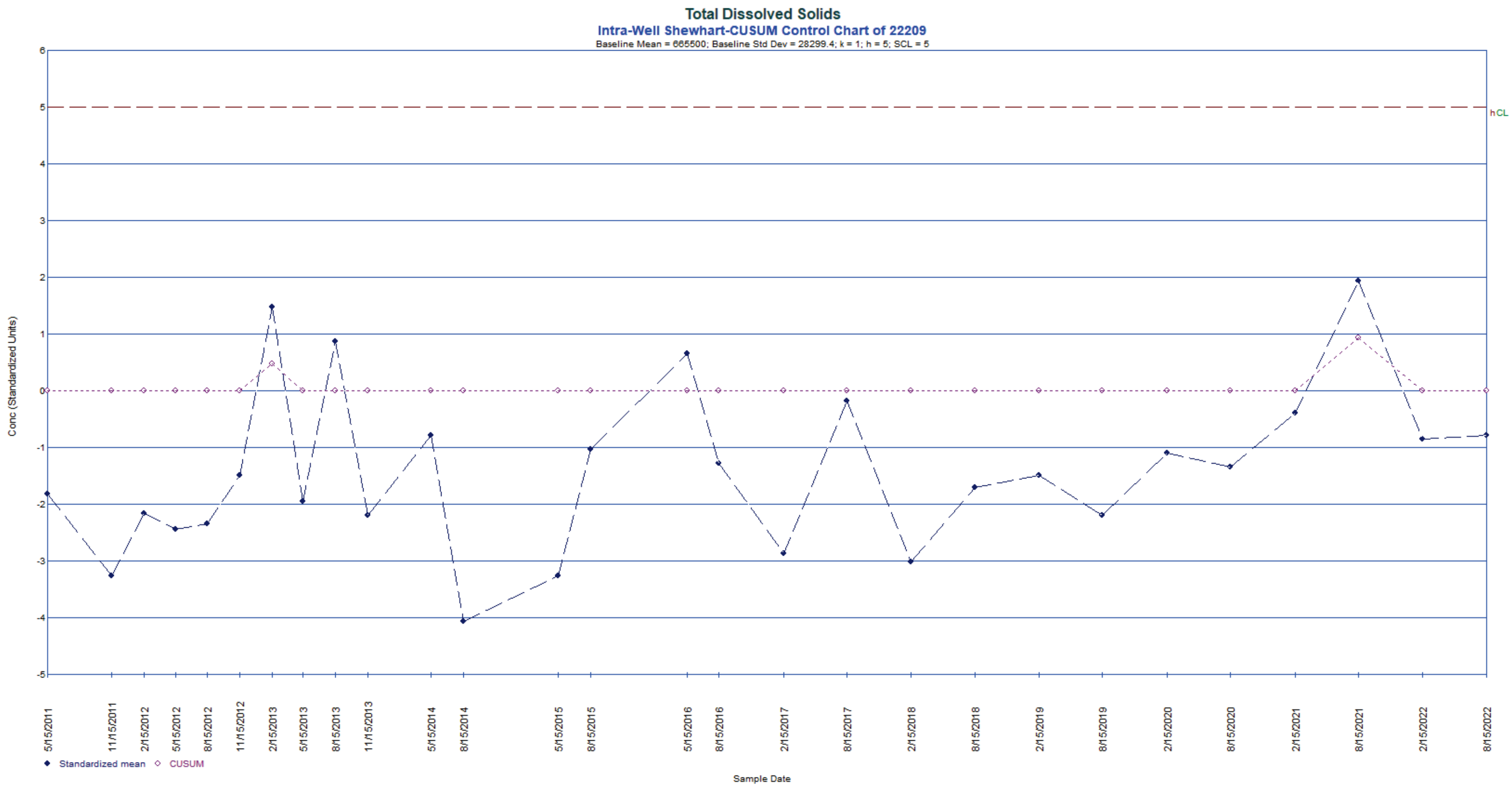

Figure A.5.6-21. Intrawell Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22209

Subattachment A.5.7

Cell 7

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 7:

- Semiannual monitoring summary statistics (Table A.5.7-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.7-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.7-2)
- OSDF horizontal till well (HTW) 12344 water yield (Table A.5.7-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.7-3 and A.5.7-4)
- Plots of concentration versus time (Figures A.5.7-5A through A.5.7-17)
- A bivariate plot for uranium–sodium (Figure A.5.7-18)
- Control charts (Figures A.5.7-19 through A.5.7-21)

A.5.7.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.7.1.1 LCS and LDS Results

As shown in Table A.5.7-1 and summarized below, two parameters (sodium, and sulfate) in 2022 have upward concentration trends in the LCS and/or LDS based on the Mann-Kendall test for trend. No new high concentrations were measured in the LCS of Cell 7 in 2022. The volume of water in the LDS tank of Cell 7 was insufficient to collect a sample in 2012 and 2013. Enough water was present to collect a sample in 2014 and 2015, but since 2015, the volume of water in the LDS tank of Cell 7 has been insufficient to collect a sample.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 7

Parameter	LCS 12344C 2022 Trend	LDS 12344D Trend (Year Last Sampled)
Sodium	Up	Up (2015)
Sulfate	Up	Up (2015)

A.5.7.1.2 HTW and Monitoring Well Results

As shown in Table A.5.7-1 and summarized below, six parameters (total uranium, boron, sodium, sulfate, nitrate + nitrite as nitrogen, and selenium) have upward concentration trends in the HTW or GMA wells based on the Mann-Kendall test for trend.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 7

Parameter	HTW 12344[a]	GMA-U 22212[a,b]	GMA-D 22211[a,b]
Total Uranium	Up		
Boron	Up	Up	Up
Sodium	Up		
Sulfate	Up		
Nitrate, Nitrite as Nitrogen			Up
Selenium		Up	Up

[a] No entry indicates that the trend was not up.
[b] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer.

A.5.7.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 7 LCS, LDS, and HTW is provided in Figure A.5.7-18. On the figure, the first sample ever collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. The plot shows that the chemical signatures for uranium and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, upward concentration trends measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.7.2 Control Charts

Intrawell control charts use historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared "not in control" if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (*h*) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.7-1 in gray shading and as summarized below, three parameters in the HTW or GMA wells of Cell 7 (lithium, magnesium, and potassium) meet the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in three control charts (Figures A.5.7-19 through A.5.7-21). All of the control charts exhibit "in control" conditions.

Parameter	Monitoring Point[a]	Monitoring Well	Assessment	Figure Number
Lithium	GMA-D	22211	In Control	A.5.7-19
Magnesium	GMA-U	22212	In Control	A.5.7-20
Potassium	GMA-U	22212	In Control	A.5.7-21

[a] GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer, HTW = Horizontal Till Well.

A.5.7.3 Summary and Conclusions

- Two parameters monitored semiannually in 2022 have an upward concentration trend in the LCS of Cell 7: sodium and sulfate. No new high concentrations were measured in the LCS of Cell 7 in 2022.
- The volume of water in the LDS tank of Cell 7 was insufficient to collect a sample in 2022.

- Six parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 7: total uranium, boron, sodium, sulfate, nitrate, nitrite as nitrogen and selenium. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 7 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 7 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- Three control charts were constructed for Cell 7 parameters. All control charts exhibit "in control" conditions.

A.5.7.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance,* EPA 530/R-09-007, March.

OAC 3745-27-10. "Ground Water Monitoring Program for a Sanitary Landfill Facility," *Ohio Administrative Code.*

Table A.5.7-1. Summary Statistics for Cell 7

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12344C	55	55	100	4.72	355	160	60	Undefined	Down (2022)	Detected	
	LDS	12344D	31	31	100	12.2	37.6	25.7	6.2	Normal	Up (2015)	Detected	169 (Q2-14)
	HTW	12344	55	55	100	2	12.1	3.81	1.83	Undefined	Up (2022)	Detected	
	GMA-U	22212	51	57	89.5	ND	0.634	0.422	0.102	Undefined	Down (2022)	Not Detected	1.64 (Q1-04); 4.46 (Q1-05); 1.70 (Q1-07); 1.73 (Q3-10); 5.53 (Q3-11)
	GMA-D	22211	62	66	93.9	ND	4.065	0.347	0.650	Undefined	None (2022)	Not Detected	
Boron (mg/L)	LCS	12344C	55	55	100	0.0625	1.35	1.09	0.36	Undefined	Down (2022)	Detected	
	LDS	12344D	31	31	100	0.168	2.10	0.360	0.425	Undefined	Up (2015)	Detected	
	HTW	12344	31	39	79.5	ND	0.075	0.0260	0.0118	Ln Normal	Up (2022)	Not Detected	
	GMA-U	22212	55	57	96.5	ND	0.0613	0.0395	0.0086	Undefined	Up (2022)	Detected	
	GMA-D	22211	54	57	94.7	ND	0.0622	0.0330	0.0101	Undefined	Up (2022)	Detected	
Sodium (mg/L)	LCS	12344C	48	48	100	18.1	131	97.8	27.1	Undefined	Up (2022)	Detected	
	LDS	12344D	24	24	100	186	1,590	587	374	Undefined	Up (2015)	Detected	
	HTW	12344	43	43	100	19.8	39.6	34.3	6.0	Undefined	Up (2022)	Detected	
	GMA-U	22212	37	37	100	15.5	27	20.2	2.9	Normal	Down (2022)	Detected	
	GMA-D	22211	38	38	100	10.1	19.2	14.0	2.6	Ln Normal	Down (2022)	Detected	
Sulfate (mg/L)	LCS	12344C	55	55	100	122	5,470	3,630	1,310	Undefined	Up (2022)	Detected	
	LDS	12344D	31	31	100	1,280	7,370	1,770	1,880	Undefined	Up (2015)	Detected	
	HTW	12344	50	50	100	80.4	765	454	261	Undefined	Up (2022)	Detected	
	GMA-U	22212	57	57	100	96.6	731	174	110	Undefined	None (2022)	Detected	
	GMA-D	22211	57	57	100	117	572	293	119	Ln Normal	Down (2022)	Detected	3,640 (Q3-12)
Calcium (mg/L)	GMA-U	22212	30	30	100	140	177	153	10	Undefined	None (2022)	Not Detected	377 (Q3-11)
	GMA-D	22211	30	30	100	136	263	185	37	Ln Normal	Down (2022)	Detected	
Lithium (mg/L)	GMA-U	22212	37	37	100	0.00474	0.00892	0.00566	0.00101	Undefined	None (2022)	Not Detected	
	GMA-D	22211	37	37	100	0.00555	0.0093	0.00700	0.00084	Normal	None (2022)	Not Detected	
Magnesium (mg/L)	GMA-U	22212	30	30	100	28.6	41.5	34.7	2.5	Ln Normal	None (2022)	Not Detected	54.6 (Q3-11)
	GMA-D	22211	30	30	100	34.6	64.7	46.5	8.2	Ln Normal	Down (2022)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22212	3	30	10.0	ND	0.0431	0.0168	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22211	4	30	13.3	ND	0.119	0.0209	0.0232	Normal	Up (2022)	Not Detected	
Potassium (mg/L)	GMA-U	22212	30	30	100	3.05	3.81	3.51	0.299662	Normal	None (2022)	Not Detected	4.81 (Q3-11)
	GMA-D	22211	31	31	100	2.34	3.65	2.88	0.33	Normal	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22212	8	37	21.6	ND	0.0292	0.00300	0.00556	Undefined	Up (2022)	Detected	
	GMA-D	22211	3	37	8.1	ND	0.0125	0.00401	Insufficient	Undefined	Up (2022)	Detected	
Technitium-99 (pCi/L)	GMA-U	22212	1	22	4.6	ND	11	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22211	1	22	4.6	ND	9.38	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22212	37	37	100	519	854	653	59	Ln Normal	None (2022)	Detected	1,130 (Q2-10); 1,270 (Q3-10); 1,510 (Q3-11)
	GMA-D	22211	37	37	100	583	1350	876	213	Ln Normal	Down (2022)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22212	22	57	38.6	ND	0.0125	0.00313	0.00294	Undefined	None (2022)	Not Detected	0.0500 (Q2-10); 0.0190 (Q2-13)
	GMA-D	22211	20	57	35.1	ND	0.0230	0.00168	0.00435	Undefined	None (2022)	Not Detected	0.0540 (Q2-10)

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b]ND = not detected; NA = not applicable

[c]Averages were determined based on the distribution assumption.

[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e]Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

LN Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f]Trend based on nonparametric Mann-Kendall procedure.

[g]Serial correlation based on Rank Von Neumann test.

[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i]Q = quarter

Table A.5.7-2. OSDF Horizontal Till Well 12344 (Cell 7) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
2004	2,380	6	264
2005	2,475	5	495
2006	2,375	4	594
2007	1,300	4	325
2008	2,800	4	700
2009	825	4	275
2010	675	4	169
2011	675	4	169
2012	815	4	204
2013	1,125	4	281
2014	455	2	228
2015	650	2	325
2016	665	2	333
2017	720	2	360
2018	955	2	478
2019	1520	2	760
2020	960	2	480
2021	960	2	480
2022	1,830	2	915

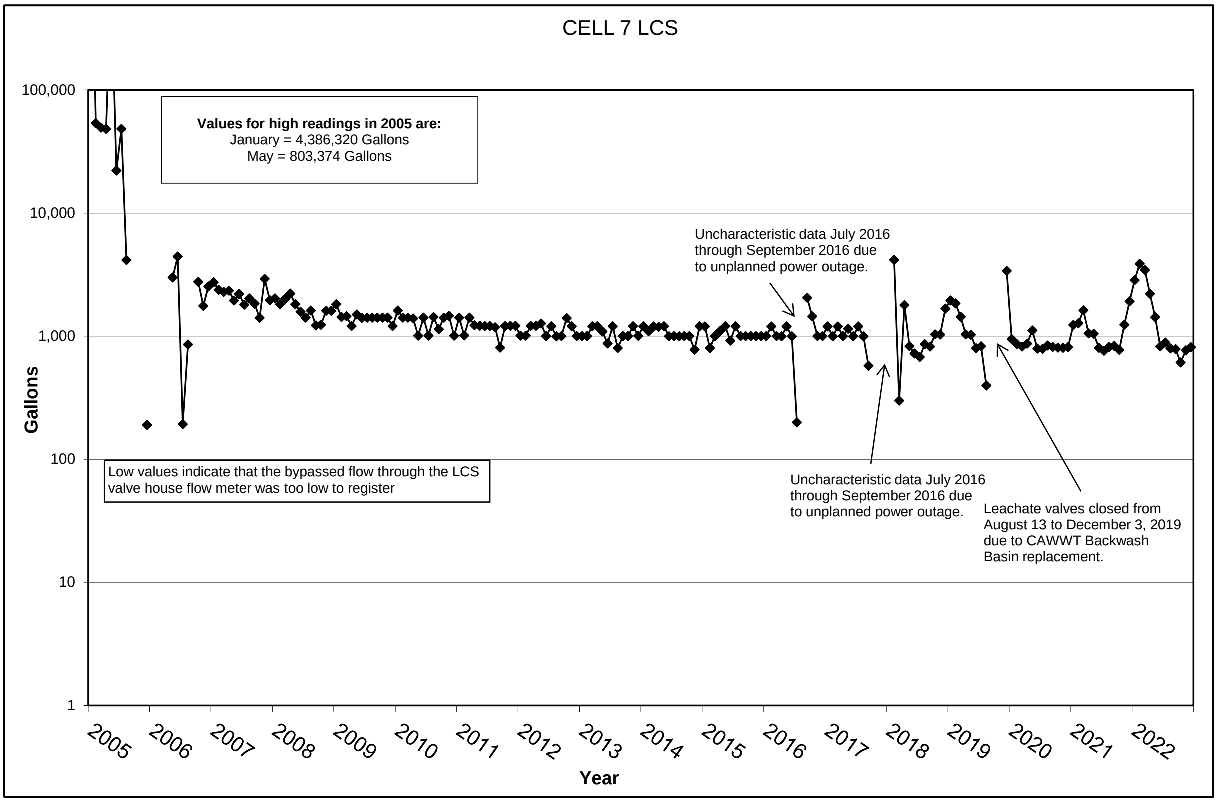

Figure A.5.7-1. Monthly Accumulation Volumes for Cell 7 LCS

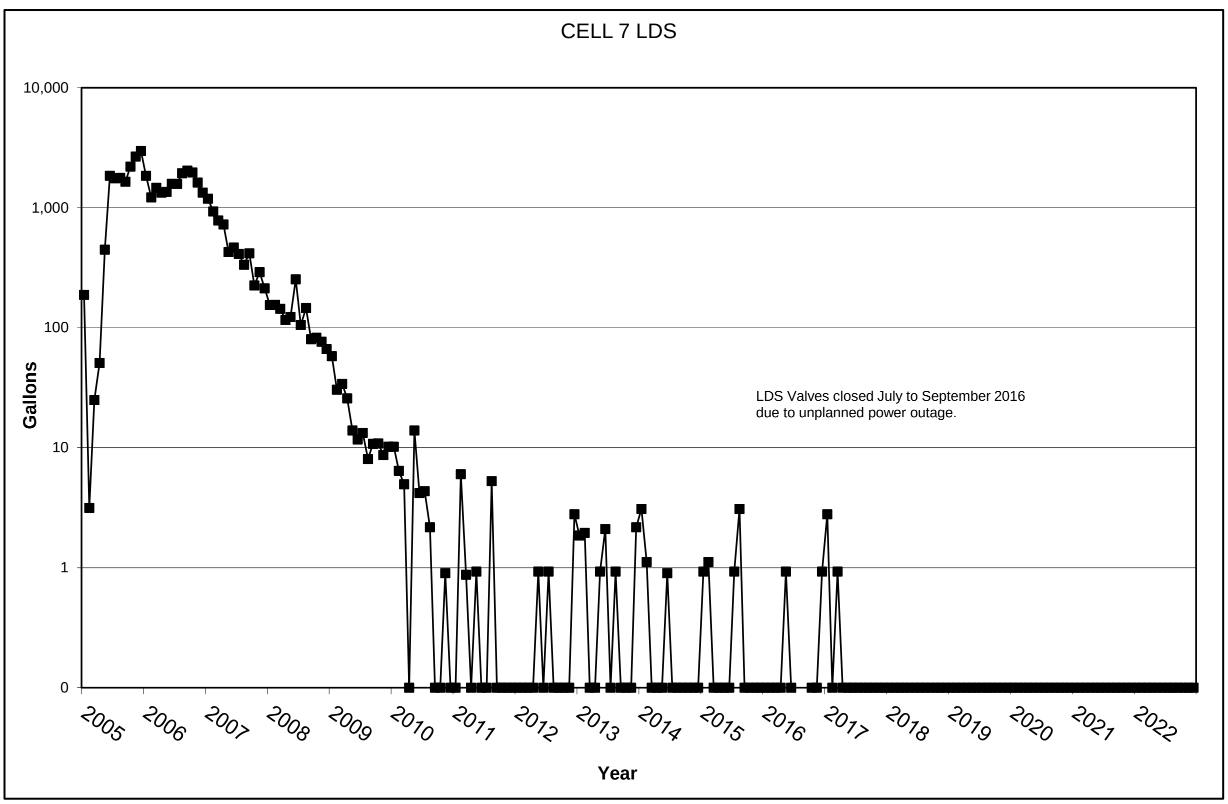

Figure A.5.7-2. Monthly Accumulation Volumes for Cell 7 LDS

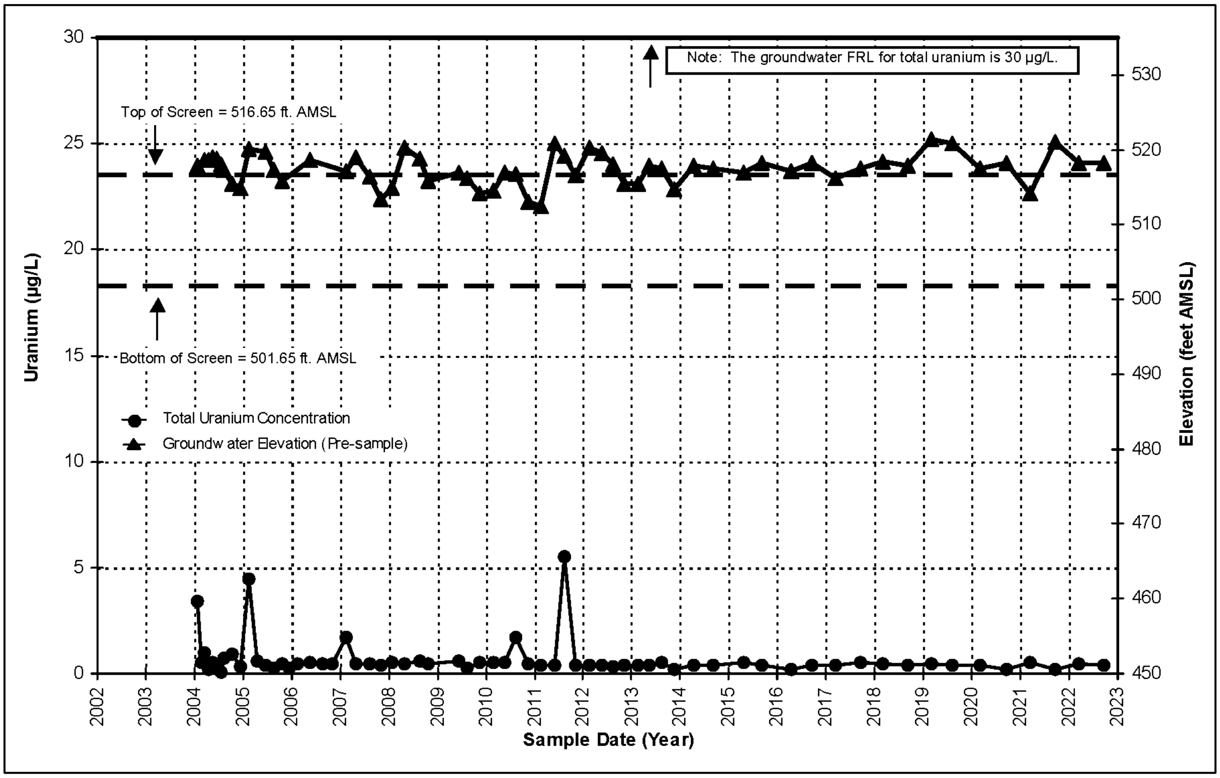

Figure A.5.7-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 7 Upgradient Monitoring Well 22212

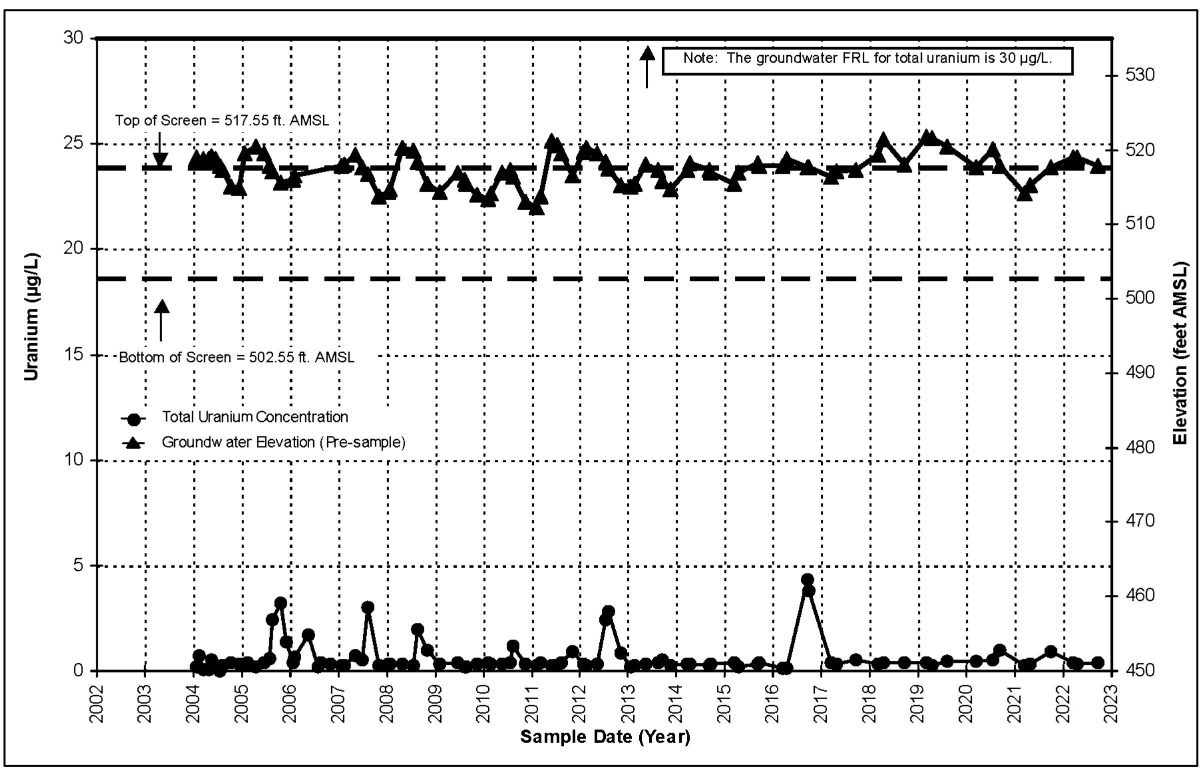

Figure A.5.7-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 7 Downgradient Monitoring Well 22211

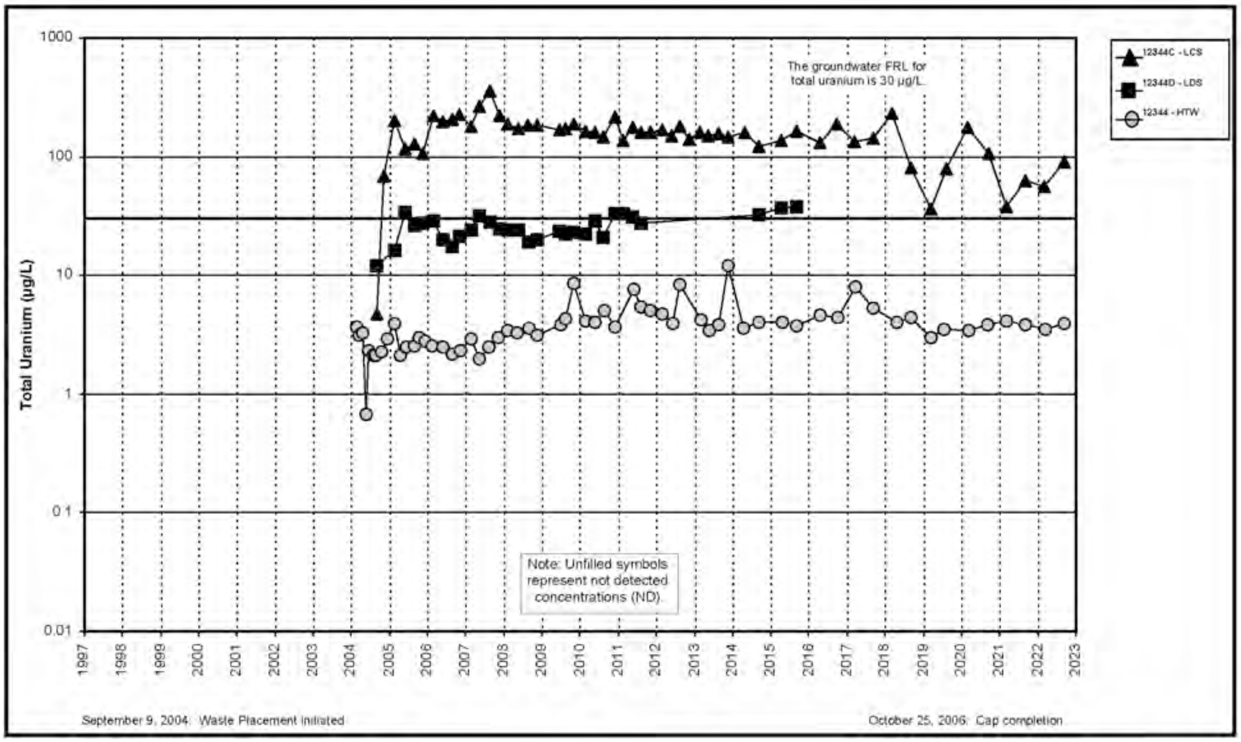

Figure A.5.7-5A. Cell 7 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

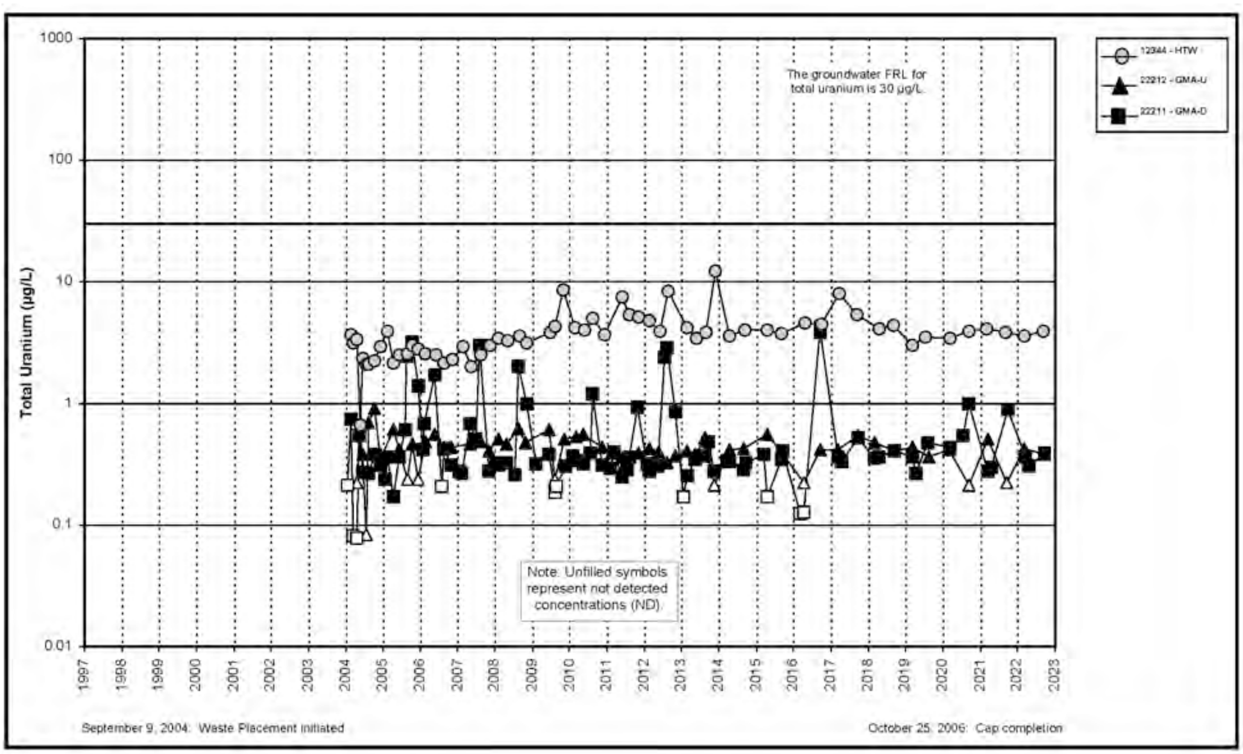

Figure A.5.7-5B. Cell 7 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

Figure A.5.7-6A. Cell 7 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

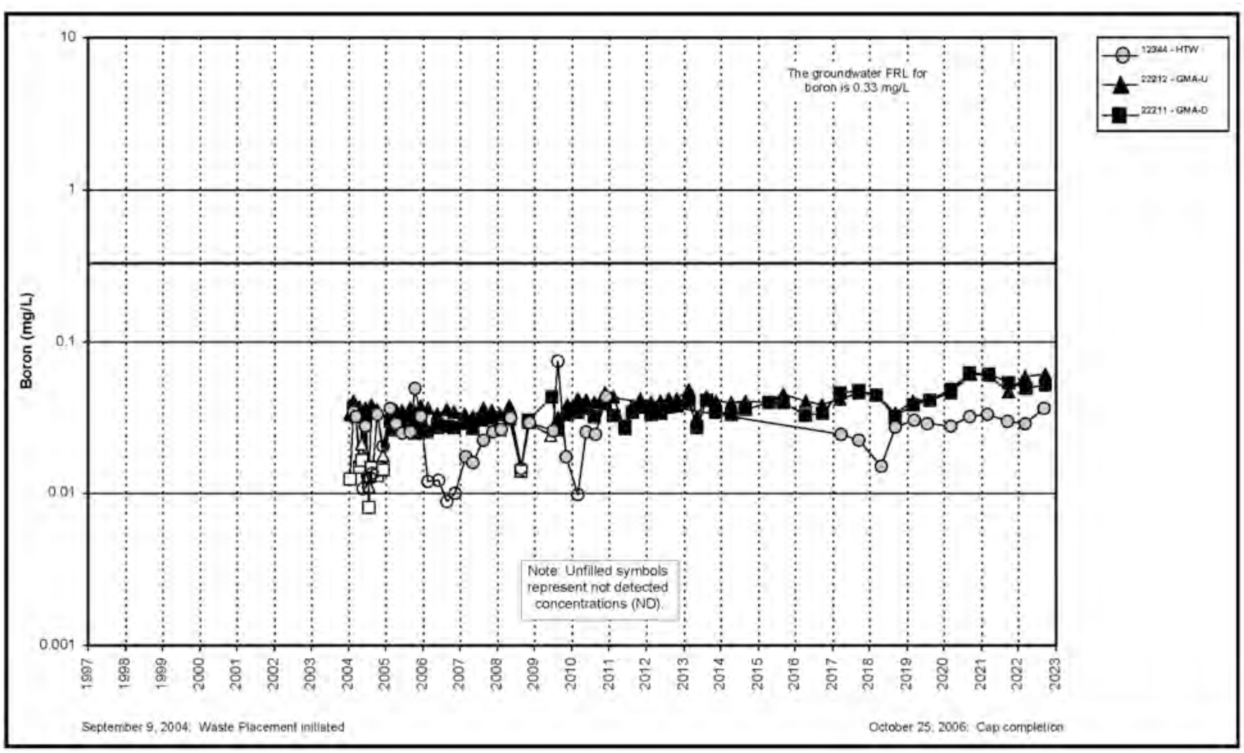

Figure A.5.7-6B. Cell 7 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

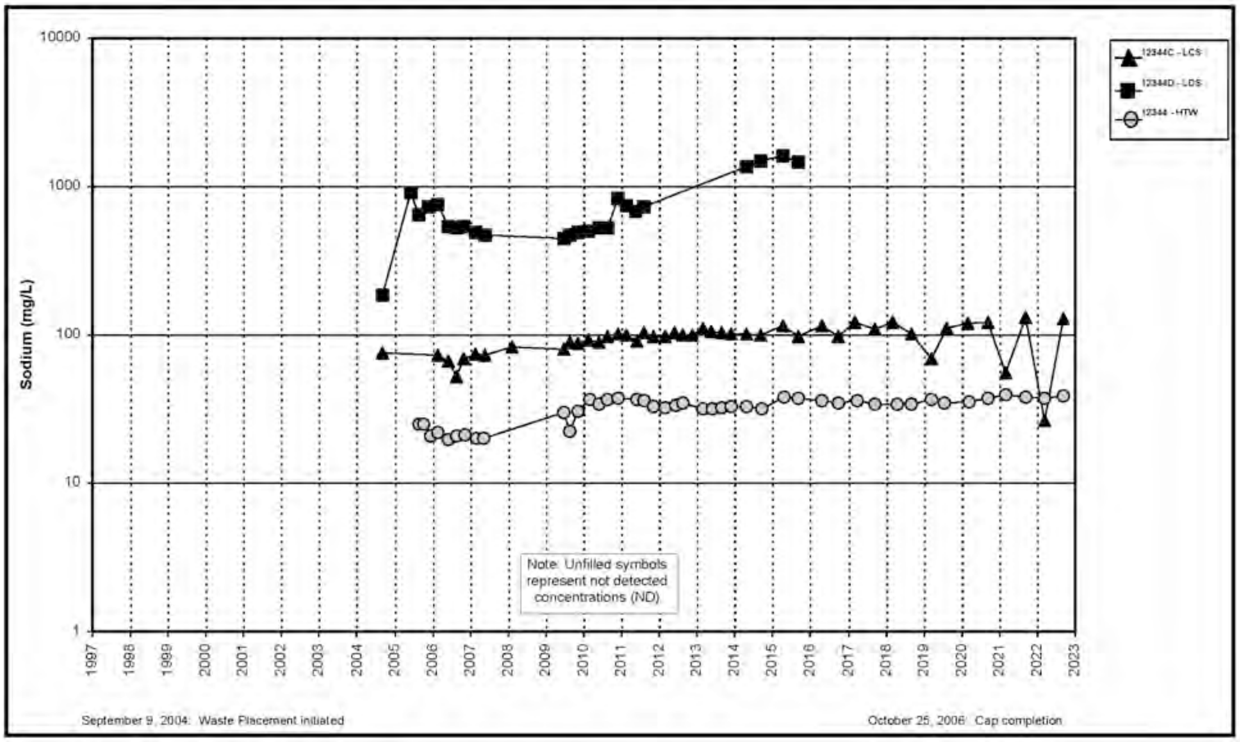

Figure A.5.7-7A. Cell 7 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

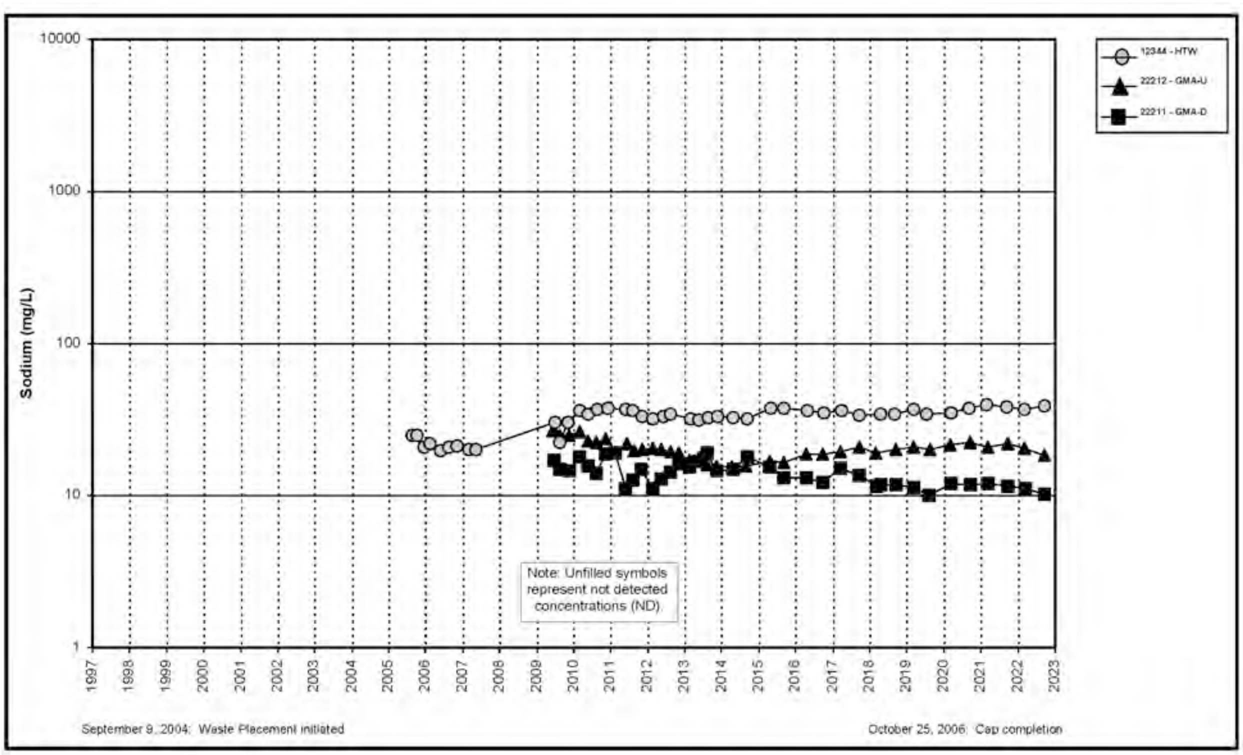

Figure A.5.7-7B. Cell 7 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

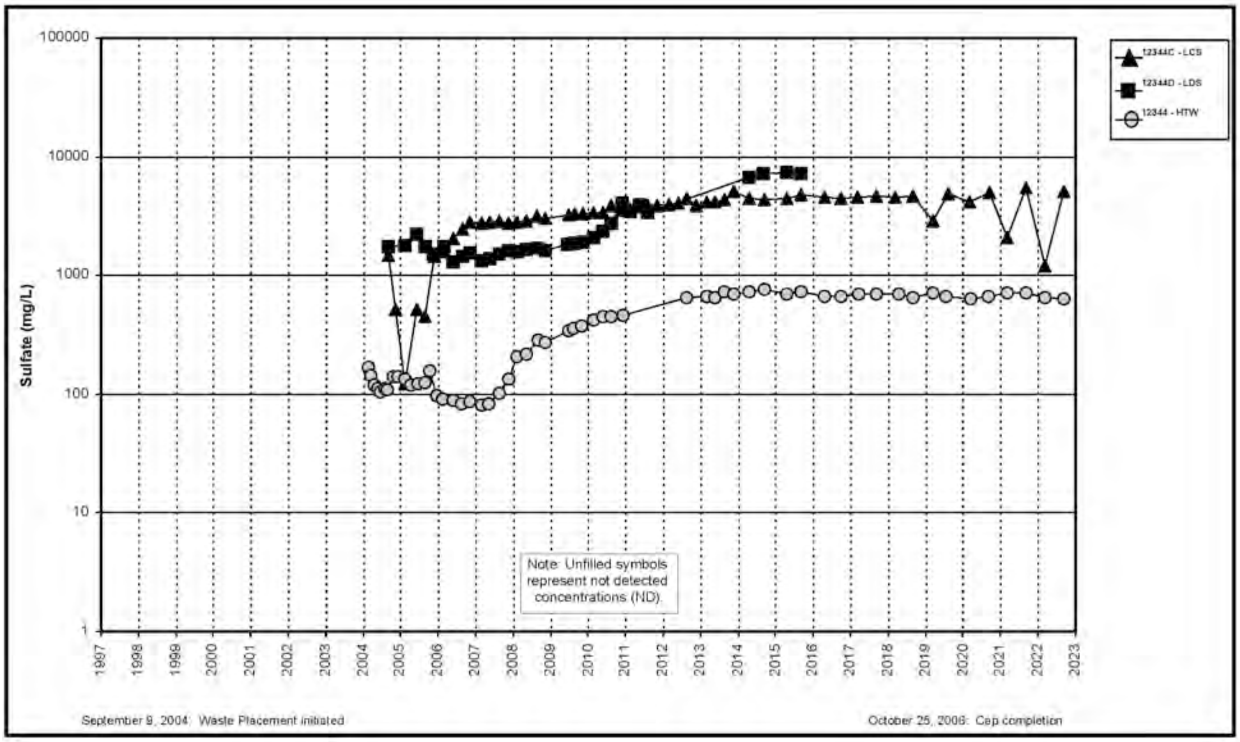

Figure A.5.7-8A. Cell 7 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

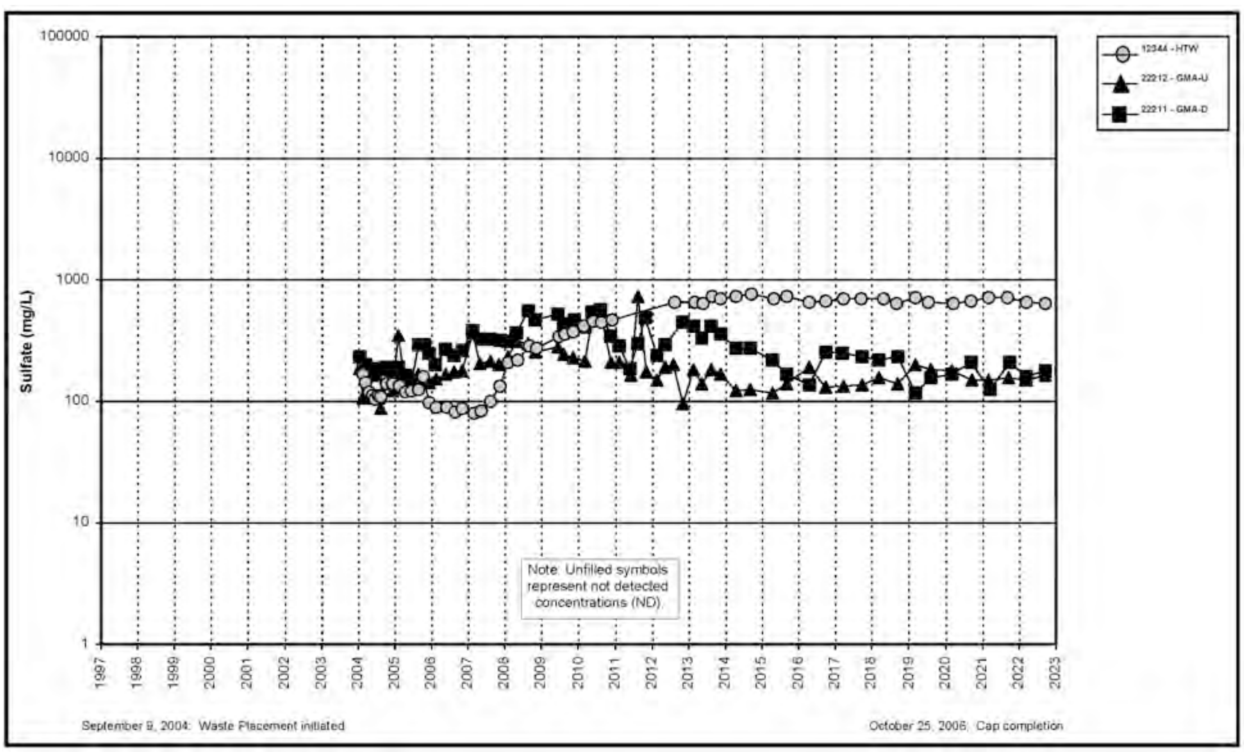

Figure A.5.7-8B. Cell 7 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

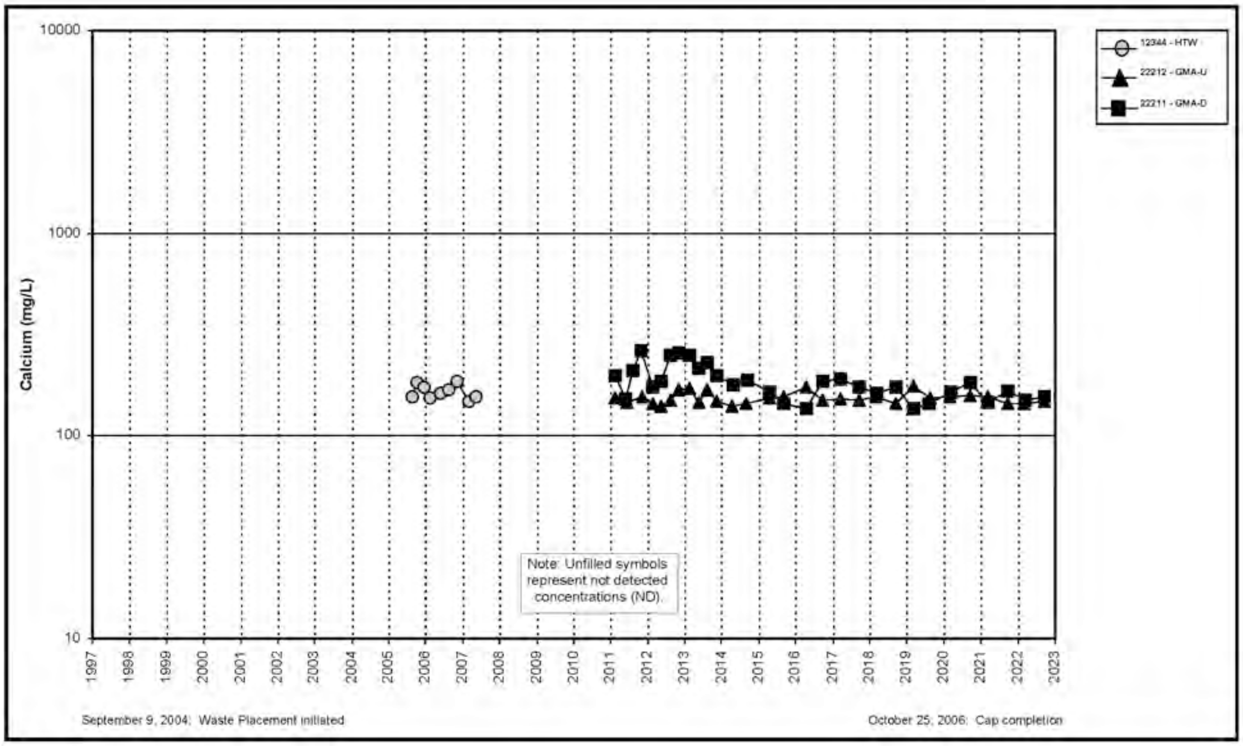

Figure A.5.7-9. Cell 7 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

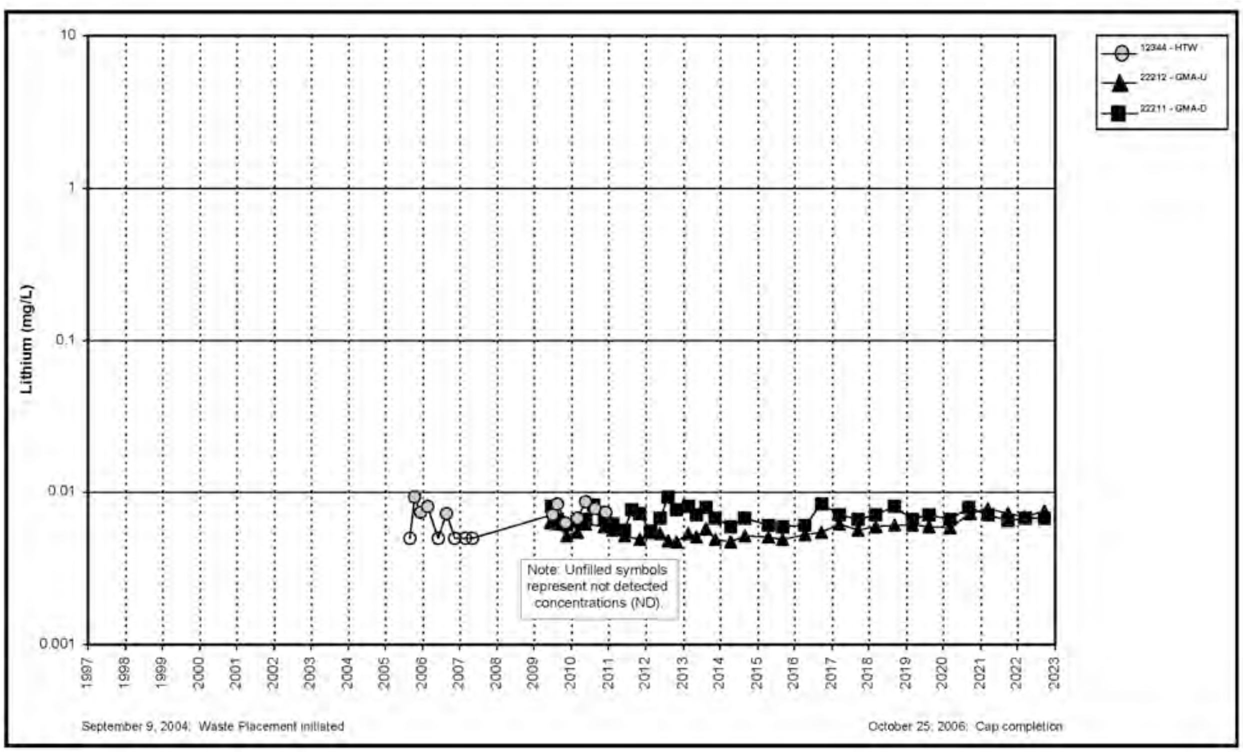

Figure A.5.7-10. Cell 7 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

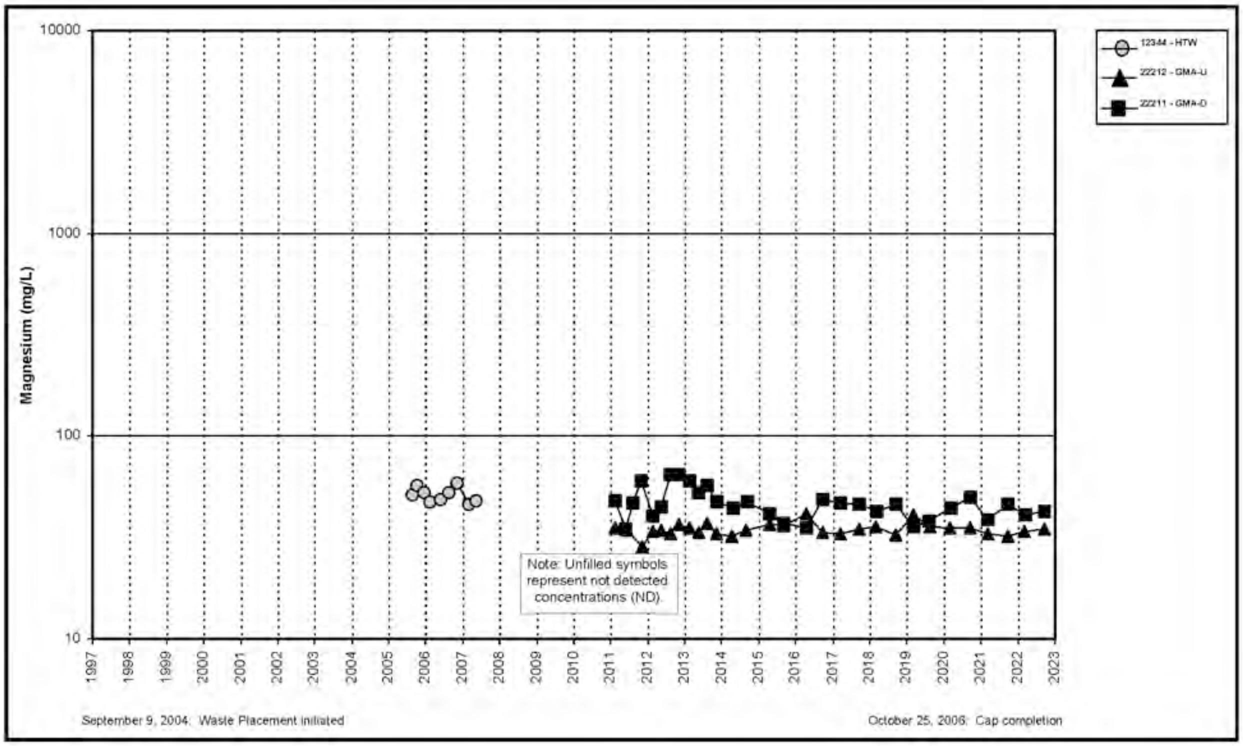

Figure A.5.7-11. Cell 7 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

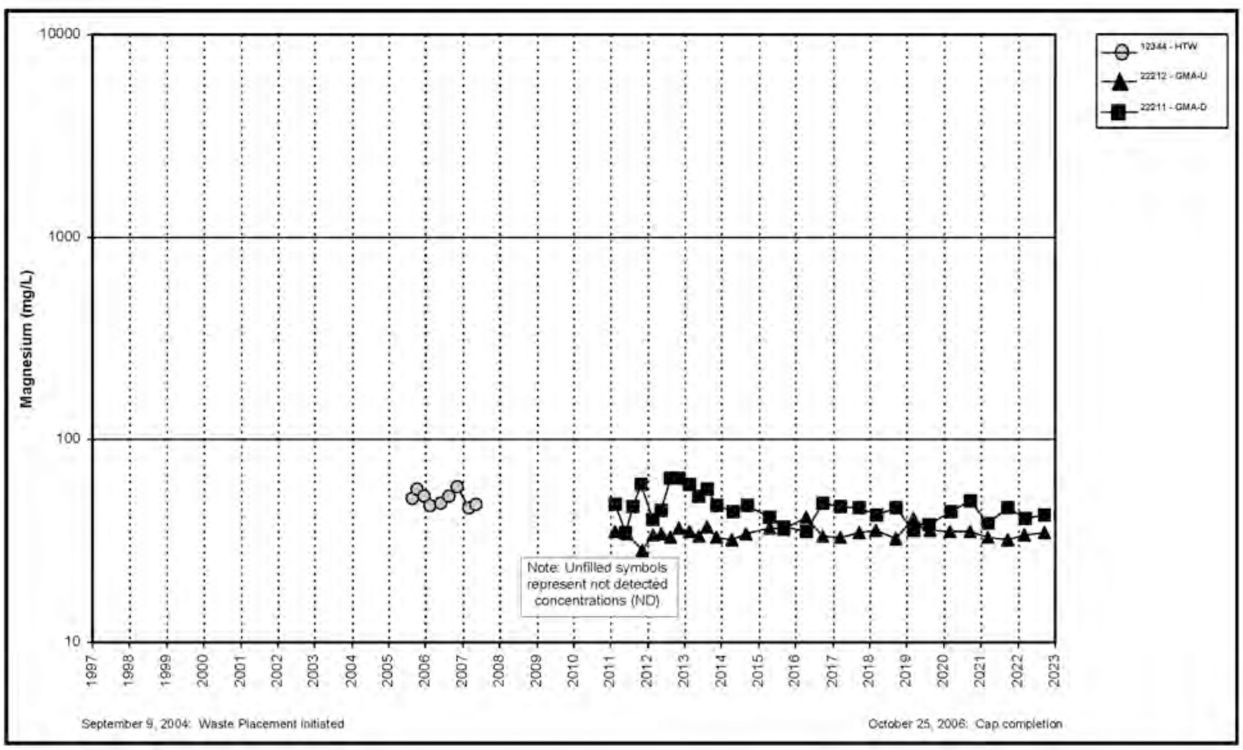

Figure A.5.7-12. Cell 7 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

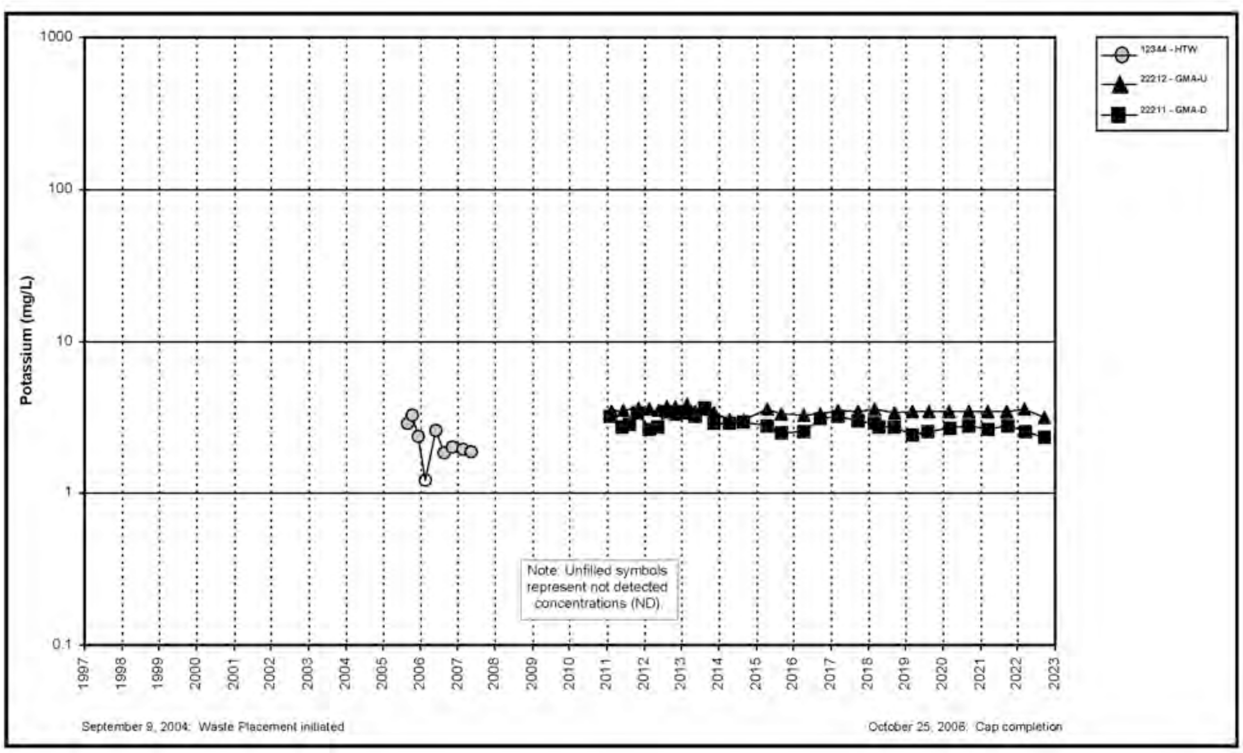

Figure A.5.7-13. Cell 7 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

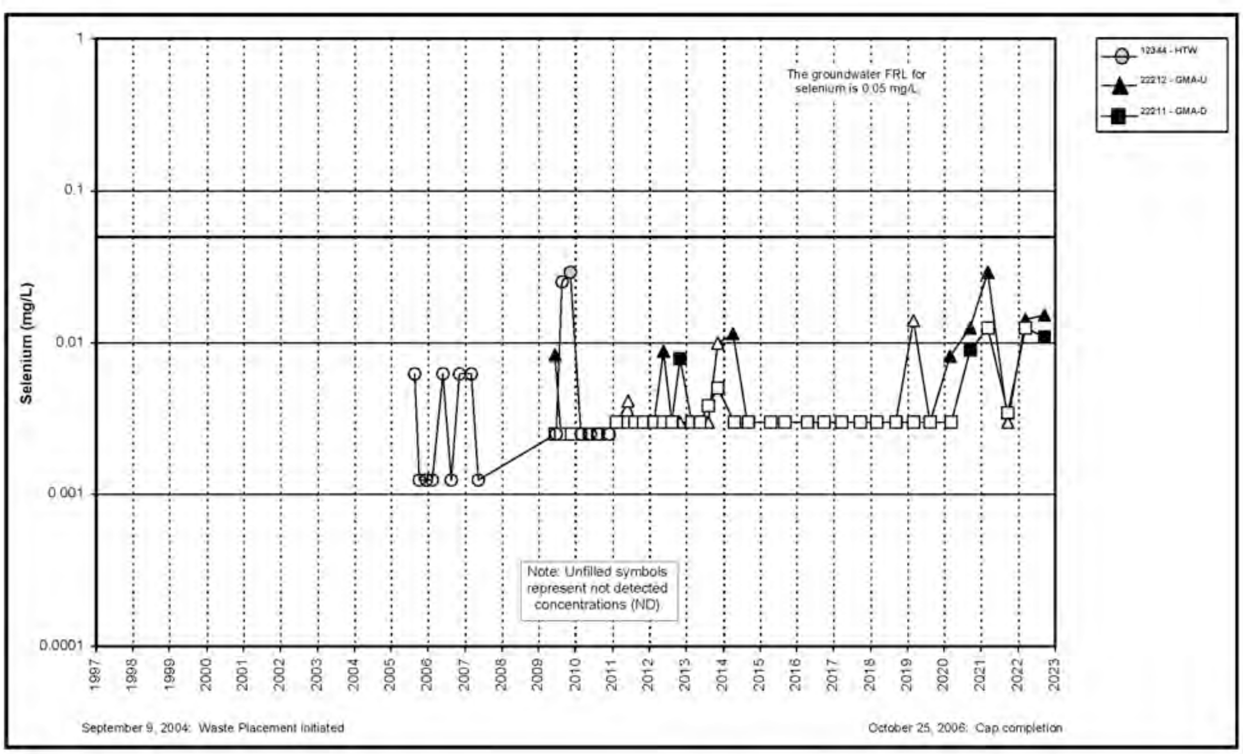

Figure A.5.7-14. Cell 7 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

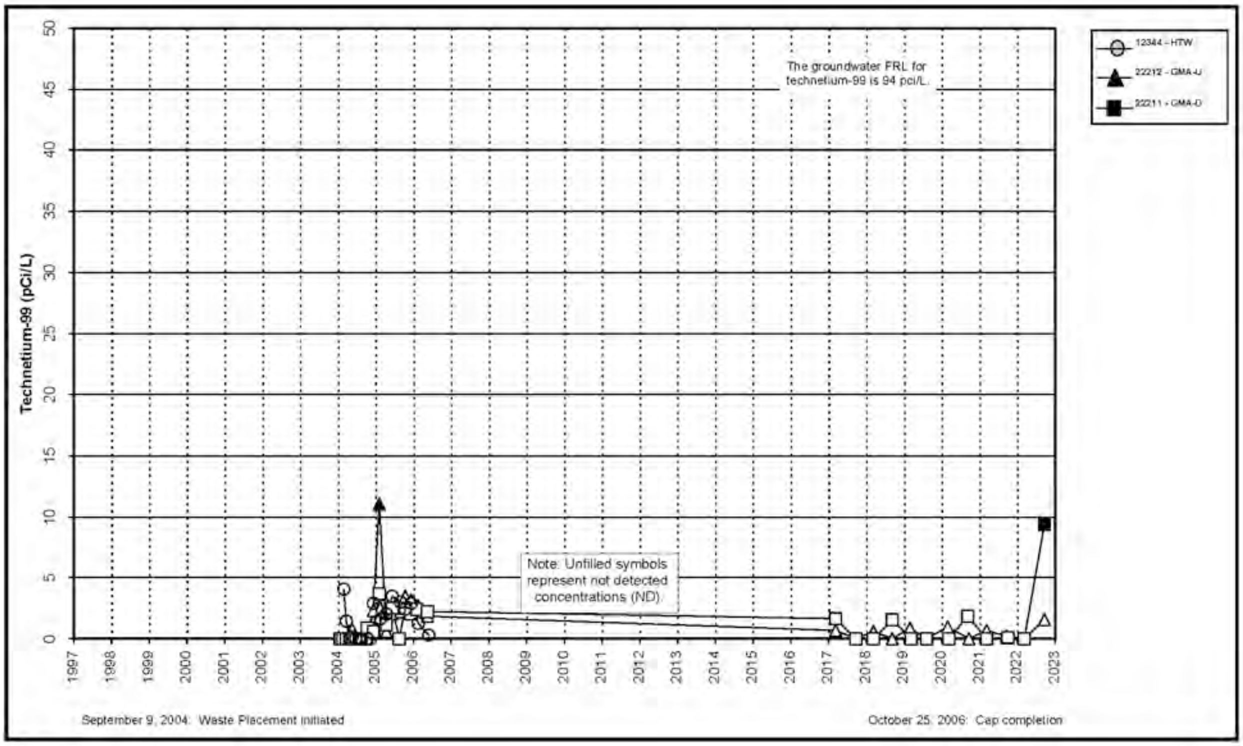

Figure A.5.7-15. Cell 7 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

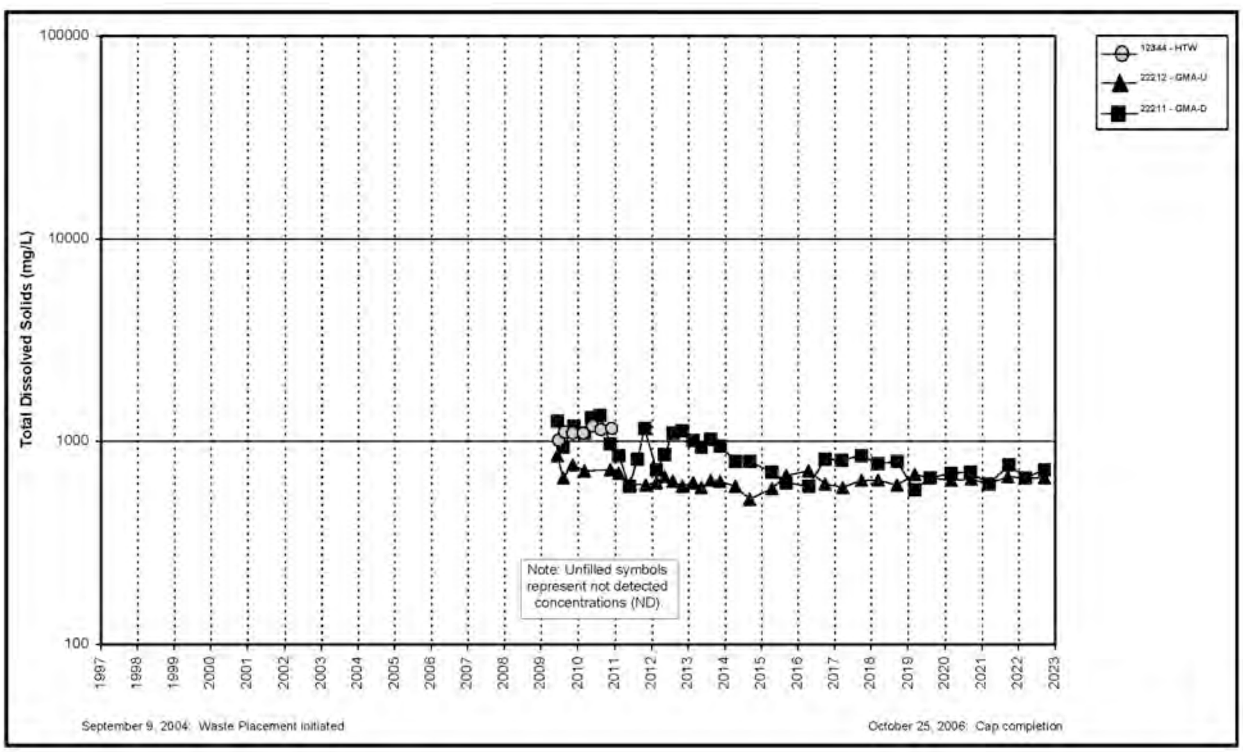

Figure A.5.7-16. Cell 7 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

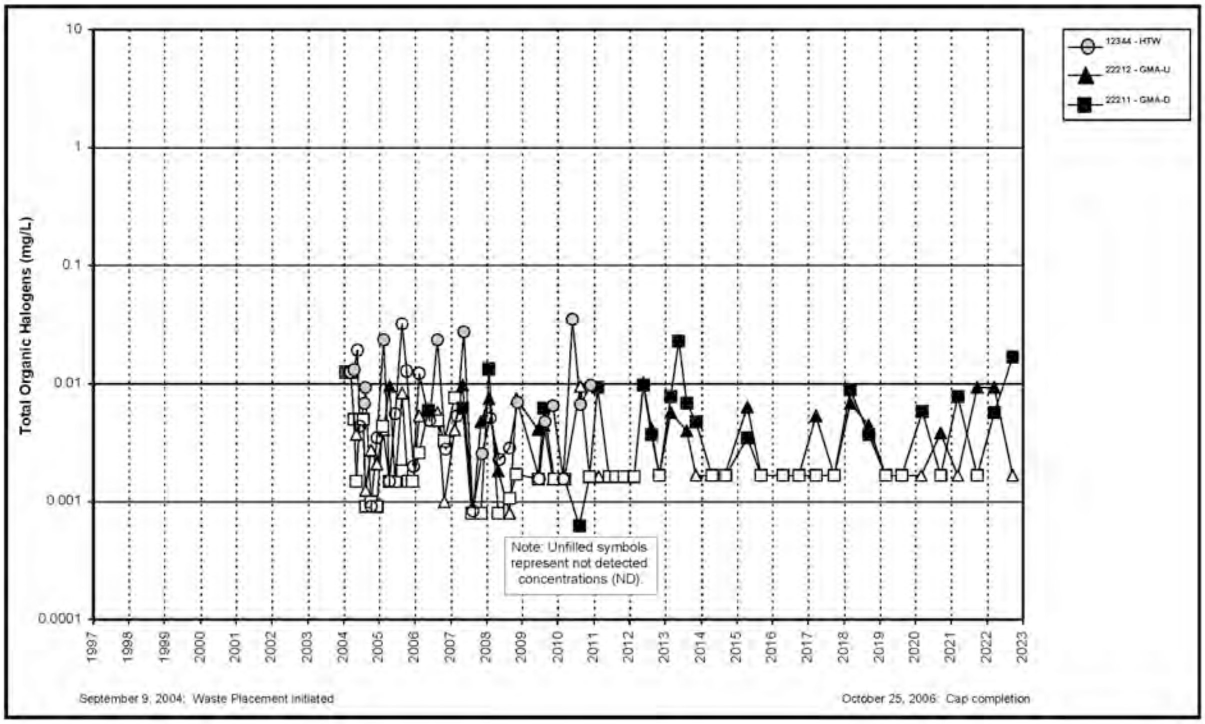

Figure A.5.7-17. Cell 7 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

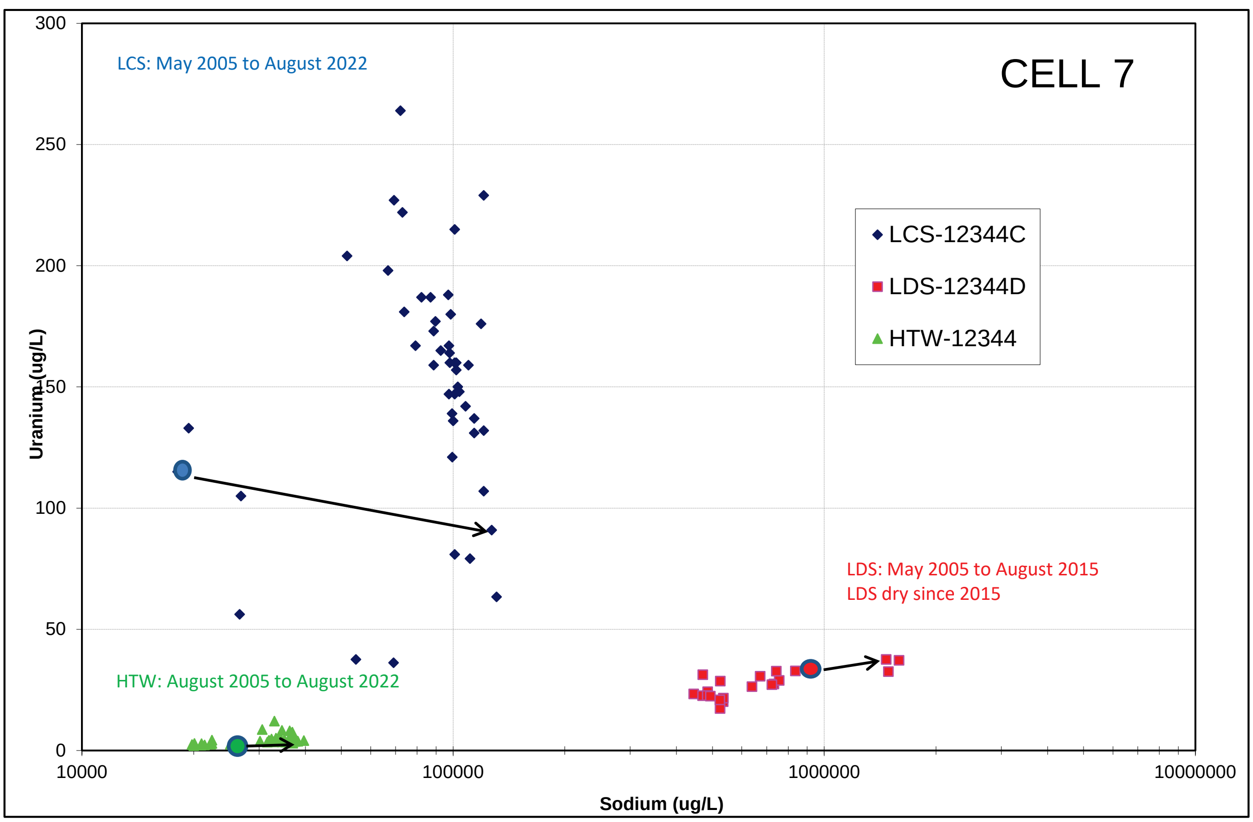

Figure A.5.7-18. Cell 7 Bivariate Plot for Uranium and Sodium

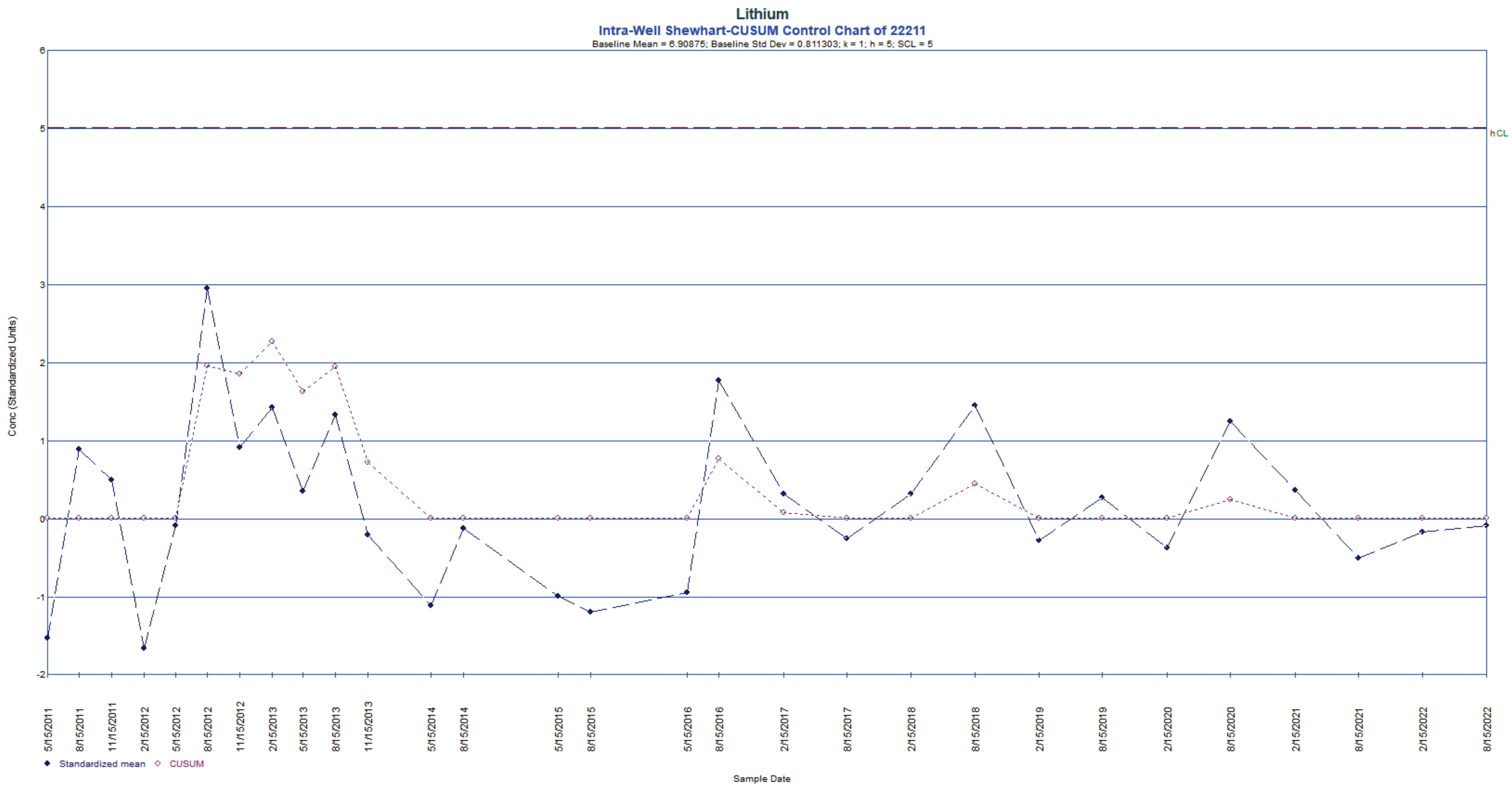

Figure A.5.7-19. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22211

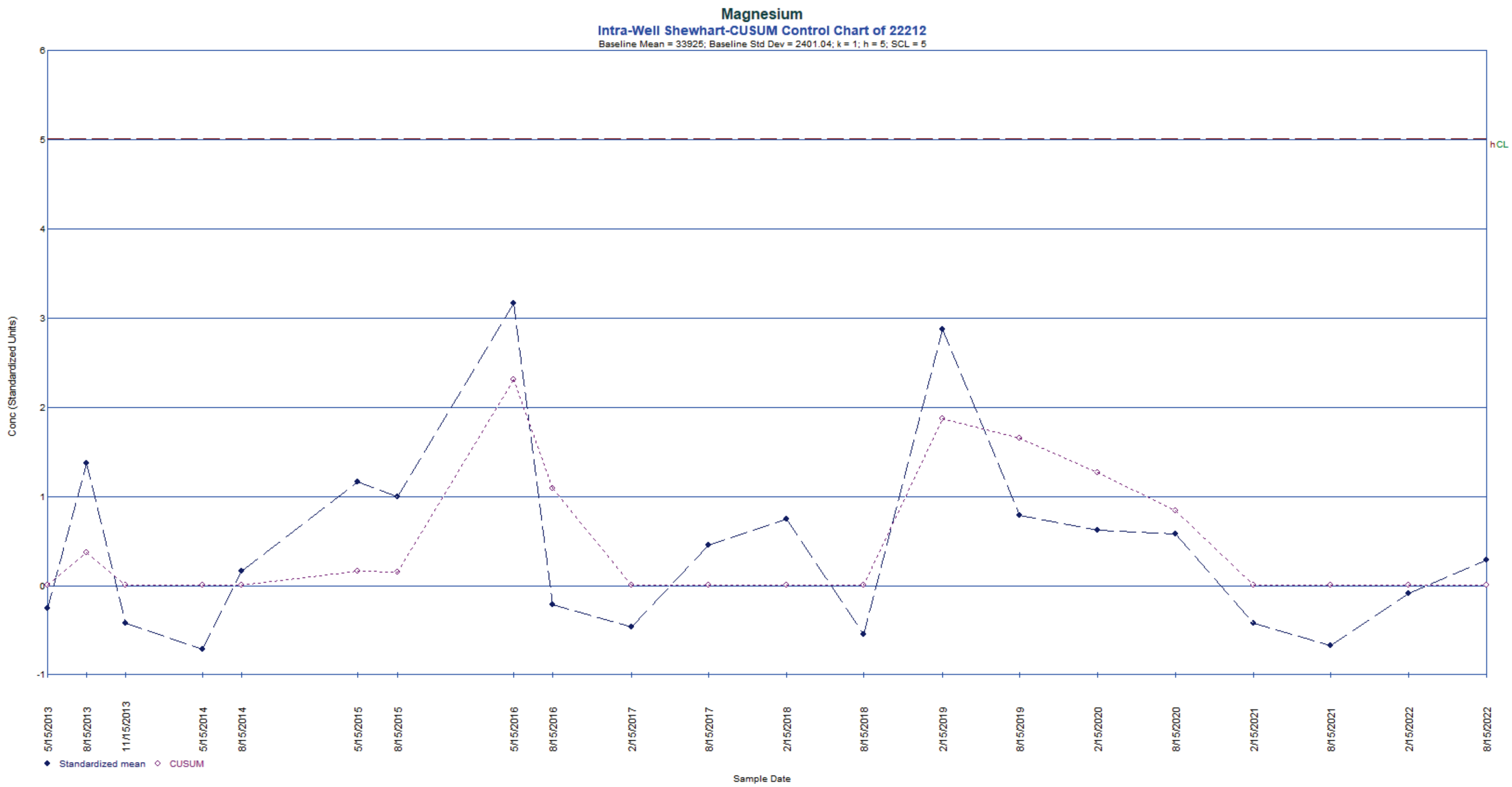

Figure A.5.7-20. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22212

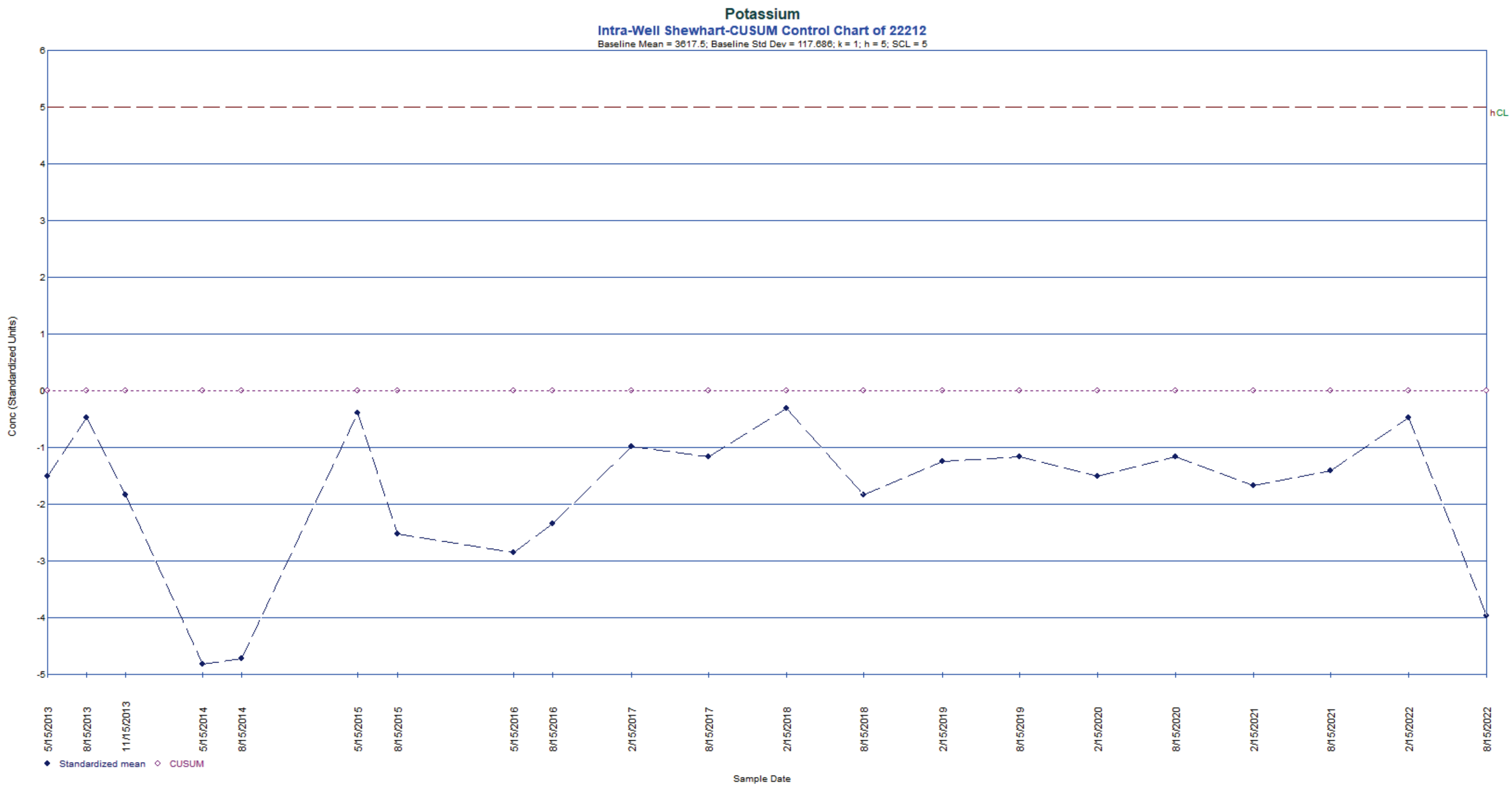

Figure A.5.7-21. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22212

Subattachment A.5.8

Cell 8

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Contents

Tables

Figures

Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	downgradient Great Miami Aquifer
GMA-SE	southeast Great Miami Aquifer
GMA-SW	southwest Great Miami Aquifer
GMA-U	upgradient Great Miami Aquifer
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 8:

- Semiannual monitoring summary statistics (Table A.5.8-1)
- Leachate collection system (LCS) monthly accumulation volumes (Figure A.5.8-1)
- Leak detection system (LDS) monthly accumulation volumes (Figure A.5.8-2)
- OSDF horizontal till well (HTW) 12345 water yield (Table A.5.8-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (Figures A.5.8-3 through A.5.8-6)
- Plots of concentration versus time (Figures A.5.8-7A through A.5.8-19)
- Bivariate plots for uranium-sodium and uranium-sulfate (Figure A.5.8-20 and A.5.8-21)
- Control charts (Figure A.5.8-22 and Figure A.5.8-23)

A.5.8.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration versus time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.8.1.1 LCS and LDS Results

As shown in Table A.5.8-1, and summarized below, four parameters (total uranium, boron, sodium, and sulfate) in 2022 have upward concentration trends in the LCS or LDS based on the Mann-Kendall test for trend. There was not enough water present in the LDS of Cell 8 to collect samples in 2022. One new high concentration was measured in the LCS of Cell 8 in 2022 (sodium). The new high sodium concentration measured in the LCS of Cell 8 in 2022 was 154 milligrams per liter (mg/L), up from 150 mg/L.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 8

Parameter	LCS 12345C 2022 Trend[a]	LDS 12345D 2022 Trend
Total Uranium		Up
Boron		Up
Sodium	Up	Up
Sulfate	Up	Up

[a] No entry indicates that the trend was not up.

A.5.8.1.2 HTW and Monitoring Well Results

As shown in Table A.5.8-1 and summarized below, nine parameters sampled in 2022 (total uranium, boron, sodium, sulfate, lithium, magnesium, selenium, total dissolved solids, and total organic halogens) have upward concentration trends in the HTW or GMA wells based on the Mann-Kendall test for trend. Cell 8 is unique in that it has four GMA wells (upgradient GMA [GMA-U], downgradient GMA [GMA-D], southwest GMA [GMA-SW], and southeast GMA [GMA-SE]). The Cell 8 HTW did not contain enough water to collect a sample in 2022.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 8

Parameter	HTW 12345 Trend (Year Last Sampled)	GMA-U 22213[a,b]	GMA-D 22214[a,b]	GMA-SW 22215[a,b]	GMA-SE 22217[a,b]
Total Uranium	Up (2008)	Up			
Boron		Up		Up	
Sodium			Up	Up	
Sulfate	Up (2008)			Up	
Lithium				Up	
Magnesium				Up	
Selenium		Up	Up	Up	Up
Total Dissolved Solids				Up	
Total Organic Halogens		Up			Up

Notes:

[a] No entry indicates that the trend was not up. Magnesium, selenium, total dissolved solids, and total organic halogen are not HTW parameters.

[b] GMA-U = upgradient Great Miami Aquifer, GMA-D = downgradient Great Miami Aquifer; GMA-SW = southwest Great Miami Aquifer; GMA-SE = southeast Great Miami Aquifer, HTW = horizontal till well.

A.5.8.1.3 Discussion

Two bivariate plots are used to illustrate that the LCS, LDS, and HTW of Cell 8 have separate and distinct chemical signatures. A uranium–sodium bivariate plot for the Cell 8 LCS, LDS, and HTW is provided in Figure A.5.8-20, and a uranium–sulfate bivariate plot for the Cell 8 LCS, LDS, and HTW is provided in Figure A.5.8-21. On the figures, the first sample collected from the monitoring horizon is circled. An arrow leads from the first sample to the location of the most recent sample. Both plots show that the chemical signatures for uranium and sodium and for uranium and sulfate in the LCS are separate and distinct from the signatures seen in the LDS and HTW. The uranium–sulfate plot illustrates more clearly than the uranium–sodium plot that the chemical signatures in the LDS and HTW are also separate and distinct. Separate and distinct chemical signatures in the LCS, LDS, and HTW indicate that water is not mixing between the horizons. Therefore, the increasing concentrations measured beneath Cell 8 (i.e., HTW and GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

A.5.8.2 Control Charts

Intrawell control charts employ historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared "not in control" if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to compute standardized limits—the decision value (*h*) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with greater than eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (*h*) and an SCL on the control chart. The software recommends a value of 5 for the CUSUM control limit and a value of 4.5 for the SCL.

EPA Statistical Analysis Unified Guidance (EPA 2009) suggests that, to simplify the interpretation of the control chart, an out-of-control condition should be based on the CUSUM *(h)* limit alone. Plotting the SCL is not needed. However, the ChemStat software, by default, plots both the SCL and CUSUM control limit *(h)* on the charts. To address this issue, the SCL was defined as 5 to equal the recommended CUSUM control limit *(h)*. This combined limit is identified as *h*CL on the control charts. For interpretation purposes, the *h*CL value will be regarded as the CUSUM control limit *(h)*.

As shown in Table A.5.8-1 in gray shading and as summarized below, two parameters in the HTW or GMA wells of Cell 8 met the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in two control charts (Figure A.5.8-22 and Figure A.5.8-23) that exhibit "in control" conditions.

Parameter	Monitoring Point[a]	Monitoring Well	Assessment	Figure Number
Boron	HTW	12345	In Control	A.5.8-22
Potassium	GMA-SW	22215	In Control	A.5.8-23

[a] GMA-SW = southwest Great Miami Aquifer, HTW = horizontal till well.

A.5.8.3 Summary and Conclusions

- Four parameters monitored semiannually have an upward concentration trend in the LCS or LDS of Cell 8: total uranium, boron, sodium, and sulfate.
- One new high concentration was measured in the LCS of Cell 8 in 2022 (sodium). The new high sodium concentrations measured in the LCS of Cell 8 in 2022 was 154 mg/L, up from 148 mg/L in 2021.
- The Cell 8 HTW did not contain enough water to collect a sample in 2022.
- Nine parameters monitored semiannually are increasing in either the HTW or GMA wells of Cell 8 (total uranium, boron, sodium, sulfate, lithium, magnesium, selenium, total dissolved solids, and total organic halogens). The chemical signatures for uranium–sodium and uranium–sulfate in the LCS of Cell 8 are separate and distinct from the signatures seen in the LDS and HTW. The signature for uranium–sodium in the HTW is also separate and distinct from the LDS signature, but low total uranium concentrations in both horizons have the clusters closer than what is seen in the other seven cells. The signature for uranium–sulfate in the HTW is separate and distinct from the LDS signature. Separate and distinct chemical signatures in the LCS, LDS, and HTW indicate that water is not mixing between the horizons. Concentration increases in the HTW and GMA wells of Cell 8 are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance. The HTW of Cell 8 has been dry since the third quarter of 2008, providing additional evidence that the secondary liner is not leaking.
- Two control charts were constructed for Cell 8 parameters. Both control charts exhibited “in control” conditions.

A.5.8.4 References

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, Cincinnati, Ohio, May.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

OAC 3745-27-10. “Ground Water Monitoring Program for a Sanitary Landfill Facility,” *Ohio Administrative Code.*

Table A.5.8-1. Summary Statistics for Cell 8

Parameter	Horizon[a]	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum[b]	Maximum[b]	Average[c,d]	Standard Deviation[d]	Distribution Type[d,e]	Trend[d,f] (Year Last Sampled)	Serial Correlation[d,g]	Outliers[h,i]
Total Uranium (µg/L)	LCS	12345C	54	54	100	1.51	335	166	57	Undefined	None (2022)	Detected	
	LDS	12345D	47	47	100	9.38	315	25.1	57.4	Undefined	Up (2021)	Detected	
	HTW	12345	16	16	100	3.67	7.30	5.02	0.99	Normal	Up (2008)	Not Detected	
	GMA-U	22213	49	57	86.0	ND	0.717	0.404	0.118	Undefined	Up (2022)	Detected	
	GMA-D	22214	63	66	95.4	ND	2.37	0.417	0.483	Undefined	Down (2022)	Not Detected	
	GMA-SW	22215	46	51	90.2	ND	16.4	0.480	2.48	Undefined	None (2022)	Not Detected	
	GMA-SE	22217	47	47	100	0.898	18.3	6.78	4.17	Normal	Down (2022)	Detected	
Boron (mg/L)	LCS	12345C	54	54	100	0.0681	0.776	0.608	0.162	Undefined	None (2022)	Detected	
	LDS	12345D	47	47	100	0.582	9.20	1.37	1.70	Undefined	Up (2021)	Detected	
	HTW	12345	15	15	100	0.0683	0.0978	0.0834	0.0079	Normal	None (2008)	Not Detected	
	GMA-U	22213	54	57	94.7	ND	0.0583	0.0392	0.0079	Undefined	Up (2022)	Detected	
	GMA-D	22214	55	57	96.5	ND	0.0524	0.0294	0.0076	Undefined	None (2022)	Detected	
	GMA-SW	22215	49	51	96.1	ND	0.0746	0.0354	0.0090	Undefined	Up (2022)	Detected	
	GMA-SE	22217	45	47	95.7	ND	0.0447	0.0283	0.0064	Normal	None (2022)	Detected	
Sodium (mg/L)	LCS	12345C	46	46	100	16.8	154	116	36	Undefined	Up (2022)	Detected	
	LDS	12345D	38	38	100	72.8	4,590	736	775	Ln Normal	Up (2021)	Detected	
	HTW	12345	7	7	100	277	385	334	45	Normal	Down (2008)	Not Detected	
	GMA-U	22213	37	37	100	18.3	30.3	21.5	3.6	Undefined	Down (2022)	Detected	
	GMA-D	22214	38	38	100	9.83	16.8	12.4	1.5	Normal	Up (2022)	Detected	
	GMA-SW	22215	37	37	100	13.5	26.0	18.5	2.5	Normal	Up (2022)	Detected	
	GMA-SE	22217	37	37	100	11	17.6	13.7	1.8	Undefined	None (2022)	Detected	
Sulfate (mg/L)	LCS	12345C	54	54	100	146	4,190	2,930	1,020	Undefined	Up (2022)	Detected	
	LDS	12345D	47	47	100	1,730	36,300	3,940	6,410	Undefined	Up (2021)	Detected	
	HTW	12345	15	15	100	95.5	152	116	18	Normal	Up (2008)	Detected	
	GMA-U	22213	57	57	100	90.2	284	180	53	Normal	None (2022)	Detected	
	GMA-D	22214	57	57	100	76.1	457	213	92	Ln Normal	Down (2022)	Detected	
	GMA-SW	22215	50	51	98.0	ND	870	241	138	Ln Normal	Up (2022)	Detected	911 (Q2-11)
	GMA-SE	22217	47	47	100	113	1,320	353	207	Ln Normal	Down (2022)	Detected	
Calcium (mg/L)	GMA-U	22213	30	30	100	141	186	159	11	Normal	Down (2022)	Detected	
	GMA-D	22214	30	30	100	89.8	230	142	38	Ln Normal	Down (2022)	Detected	
	GMA-SW	22215	30	30	100	127	446	192	68	Undefined	None (2022)	Detected	
	GMA-SE	22217	30	30	100	121	334	192	50	Ln Normal	Down (2022)	Detected	
Lithium (mg/L)	GMA-U	22213	37	37	100	0.00434	0.00728	0.00544	0.00059	Normal	None (2022)	Detected	
	GMA-D	22214	37	37	100	0.00372	0.00858	0.00516	0.00103	Ln Normal	None (2022)	Detected	
	GMA-SW	22215	37	37	100	0.00467	0.00828	0.00595	0.00082	Normal	Up (2022)	Detected	
	GMA-SE	22217	37	37	100	0.00432	0.00799	0.00592	0.00096	Normal	Down (2022)	Detected	
Magnesium (mg/L)	GMA-U	22213	30	30	100	31.7	42.0	36.2	2.6	Normal	None (2022)	Detected	
	GMA-D	22214	30	30	100	22.0	53.2	34.0	8.3	Normal	Down (2022)	Detected	
	GMA-SW	22215	30	30	100	32.5	66.8	43.9	7.4	Ln Normal	Up (2022)	Not Detected	74.5 (Q2-11)
	GMA-SE	22217	30	30	100	27.5	63.3	42.3	8.6	Normal	Down (2022)	Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22213	0	30	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22214	1	30	3.3	ND	0.0500	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SW	22215	3	30	10.0	ND	0.0850	0.0225	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SE	22217	6	30	20.0	ND	0.0850	0.00850	0.0182	Undefined	None (2022)	Not Detected	
Potassium (mg/L)	GMA-U	22213	30	30	100	3.3	4.14	3.67	0.18	Normal	Down (2022)	Detected	
	GMA-D	22214	31	31	100	2.1	3.23	2.52	0.28	Normal	Down (2022)	Detected	
	GMA-SW	22215	30	30	100	3.09	3.87	3.48	0.20	Normal	None (2022)	Not Detected	4.73 (Q2-11); 5.01 (Q3-11); 2.30 (Q4-13)
	GMA-SE	22217	30	30	100	2.4	4.09	3.01	0.41	Normal	Down (2022)	Detected	
Selenium (mg/L)	GMA-U	22213	4	37	10.8	ND	0.0260	0.00300	0.00524	Undefined	Up (2022)	Detected	
	GMA-D	22214	6	37	16.2	ND	0.0249	0.00300	0.00509	Undefined	Up (2022)	Detected	
	GMA-SW	22215	9	37	24.3	ND	0.0278	0.00300	0.00514	Undefined	Up (2022)	Detected	
	GMA-SE	22217	4	37	10.8	ND	0.0201	0.00300	0.00449	Undefined	Up (2022)	Detected	
Technitium-99 (pCi/L)	GMA-U	22213	6	48	12.5	ND	24.8	0.450	4.20	Undefined	Down (2022)	Detected	
	GMA-D	22214	4	48	8.3	ND	11.8	0.015	2.37	Undefined	None (2022)	Not Detected	
	GMA-SW	22215	0	42	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SE	22217	0	38	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22213	37	37	100	429	843	671	82	Undefined	Down (2022)	Detected	
	GMA-D	22214	37	37	100	386	1,020	621	156	Normal	Down (2022)	Detected	
	GMA-SW	22215	37	37	100	457	1,800	821	261	Undefined	Up (2022)	Detected	
	GMA-SE	22217	37	37	100	514	1,550	878	248	Ln Normal	Down (2022)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22213	15	57	26.3	ND	0.056	0.00166	0.00822	Undefined	Up (2022)	Not Detected	
	GMA-D	22214	13	57	22.8	ND	0.059	0.00166	0.00881	Undefined	None (2022)	Not Detected	
	GMA-SW	22215	15	51	29.4	ND	0.046	0.00166	0.00773	Undefined	None (2022)	Not Detected	
	GMA-SE	22217	16	47	34.0	ND	0.073	0.00166	0.0109	Undefined	Up (2022)	Not Detected	

Note 1: Shading identifies a horizontal till well or Great Miami Aquifer well, with at least eight samples, Normal or Ln Normal distribution, no trend (None), and no serial correlation (Not Detected). These wells achieve control chart criteria.

Note 2: Data used in this table have been standardized to quarterly.

[a]LCS = leachate collection system; LDS = leak detection system; HTW = horizontal till well; GMA-U = upgradient Great Miami Aquifer; and GMA-D = downgradient Great Miami Aquifer

[b]ND = not detected; NA = not applicable

[c]Averages were determined based on the distribution assumption.

[d]Insufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

[e]Data distribution based on the Shapiro-Wilk statistic.

Normal: Normal assumption could not be rejected at the 5 percent level and has a higher probability value than the Ln Normal assumption.

Ln Normal: Lognormal assumption could not be rejected at the 5 percent level and has a higher probability value than the Normal assumption.

Undefined: Normal and Lognormal Distribution assumptiions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

[f]Trend based on nonparametric Mann-Kendall procedure.

[g]Serial correlation based on Rank Von Neumann test.

[h]Outliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

[i]Q = quarter

Table A.5.8-2. OSDF Horizontal Till Well 12345 (Cell 8) Water Yield

Year	Total Volume Purged (gallons)	Number of Months Purged	Average Volume Purged (gallons)
2004	4,020	5	804
2005	1,050	6	175
2006	3,375	4	844
2007	1,000	4	250
2008	135	4	34
2009	0	2	0
2010	0	2	0
2011	0	2	0
2012	0	2	0
2013	0	2	0
2014	0	2	0
2015	0	2	0
2016	0	2	0
2017	0	2	0
2018	0	2	0
2019	0	2	0
2020	0	2	0
2021	0	2	0
2022	0	2	0

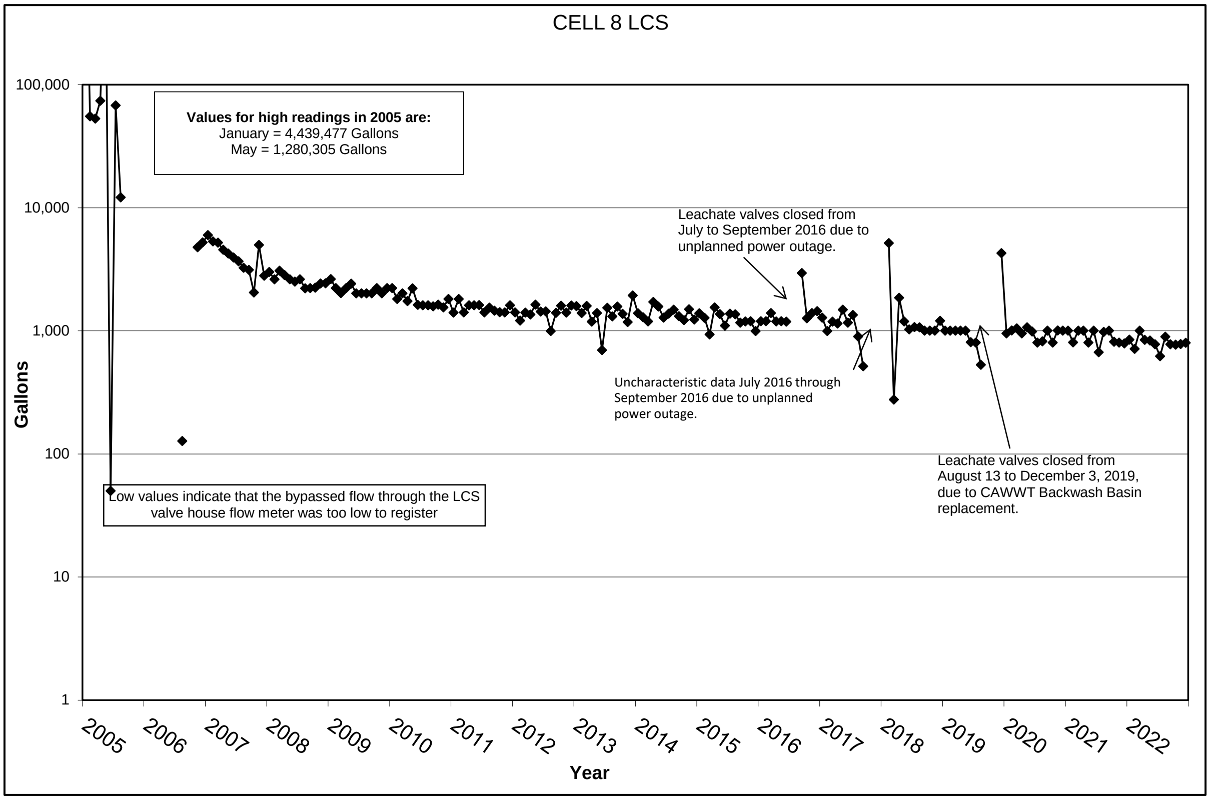

Figure A.5.8-1. Monthly Accumulation Volumes for Cell 8 LCS

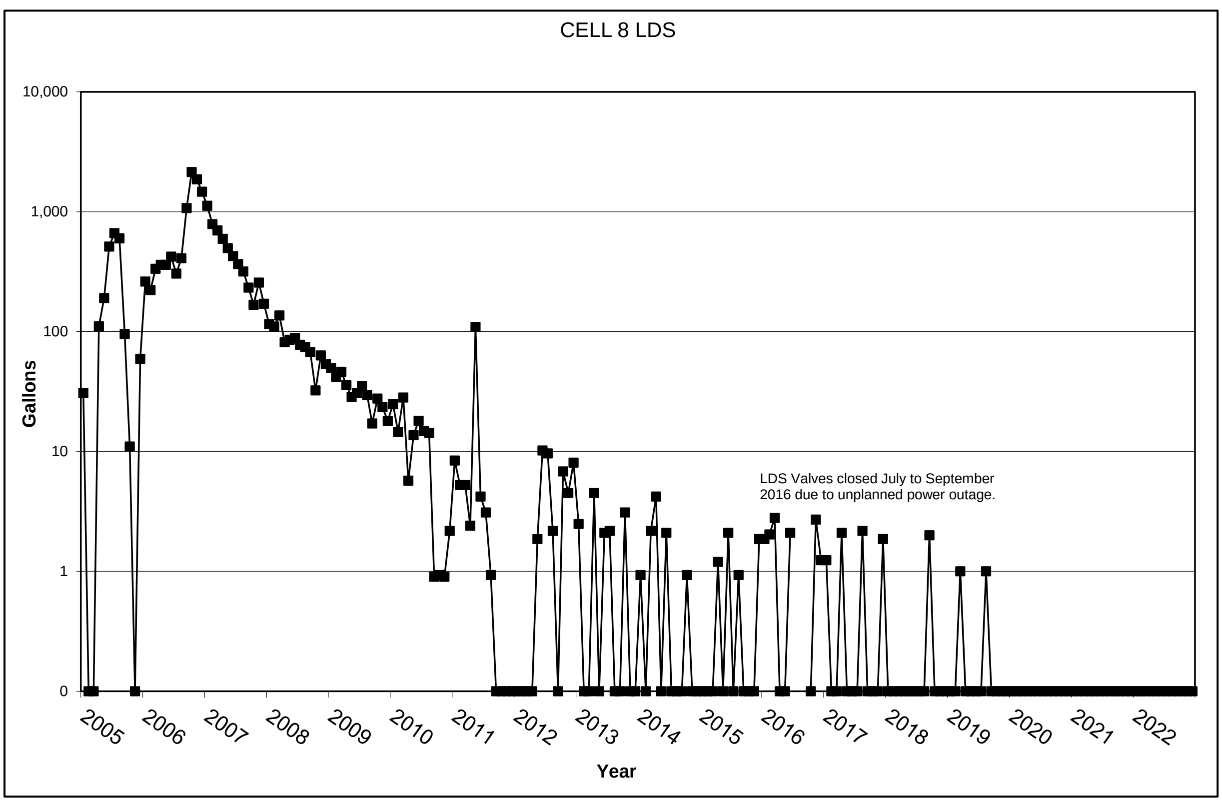

Figure A.5.8-2. Monthly Accumulation Volumes for Cell 8 LDS

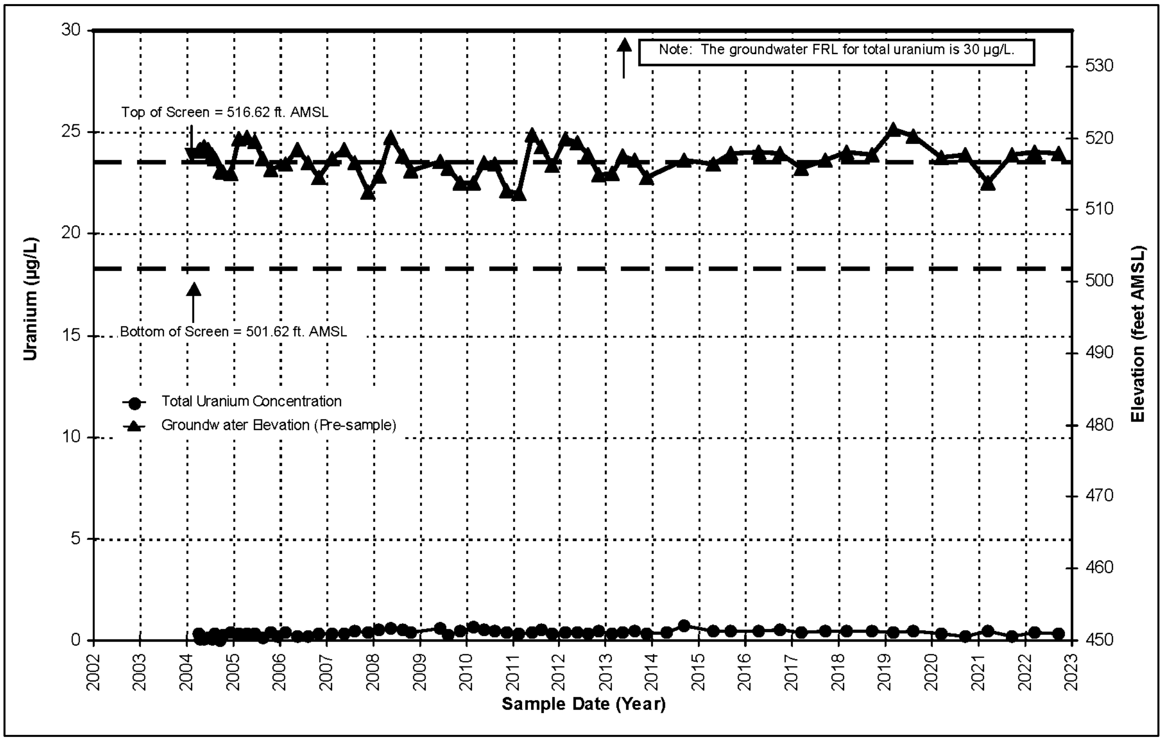

Figure A.5.8-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Upgradient Monitoring Well 22213

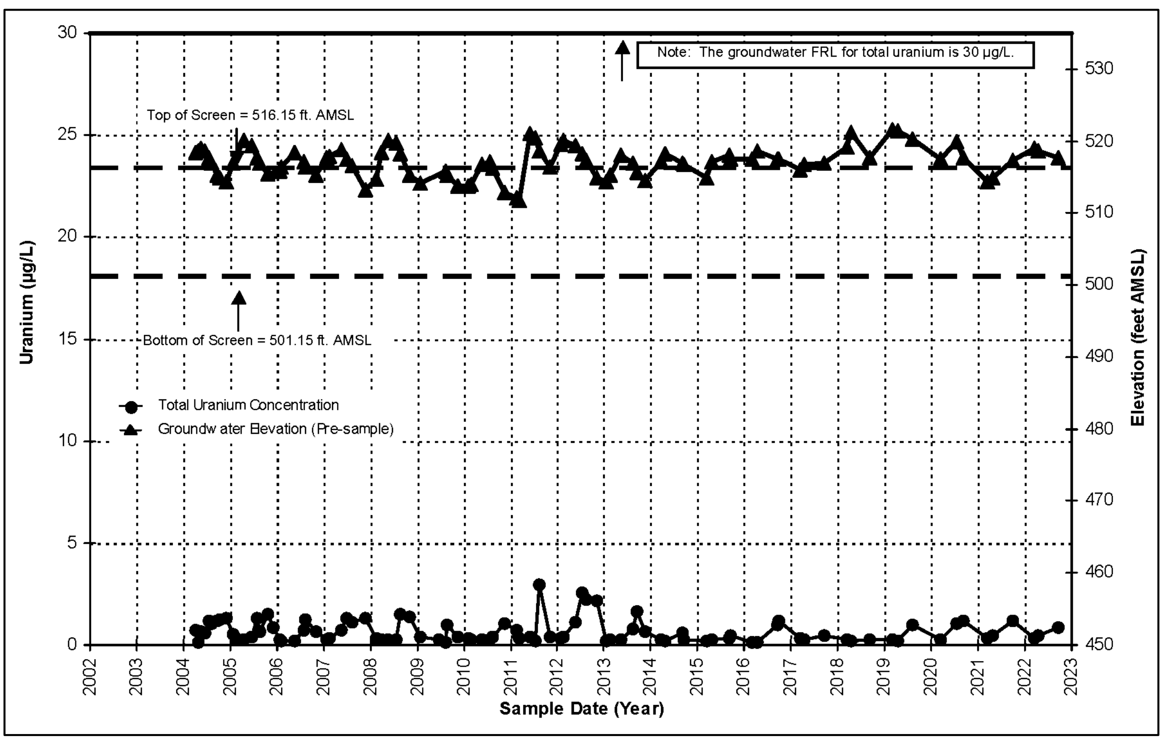

Figure A.5.8-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22214

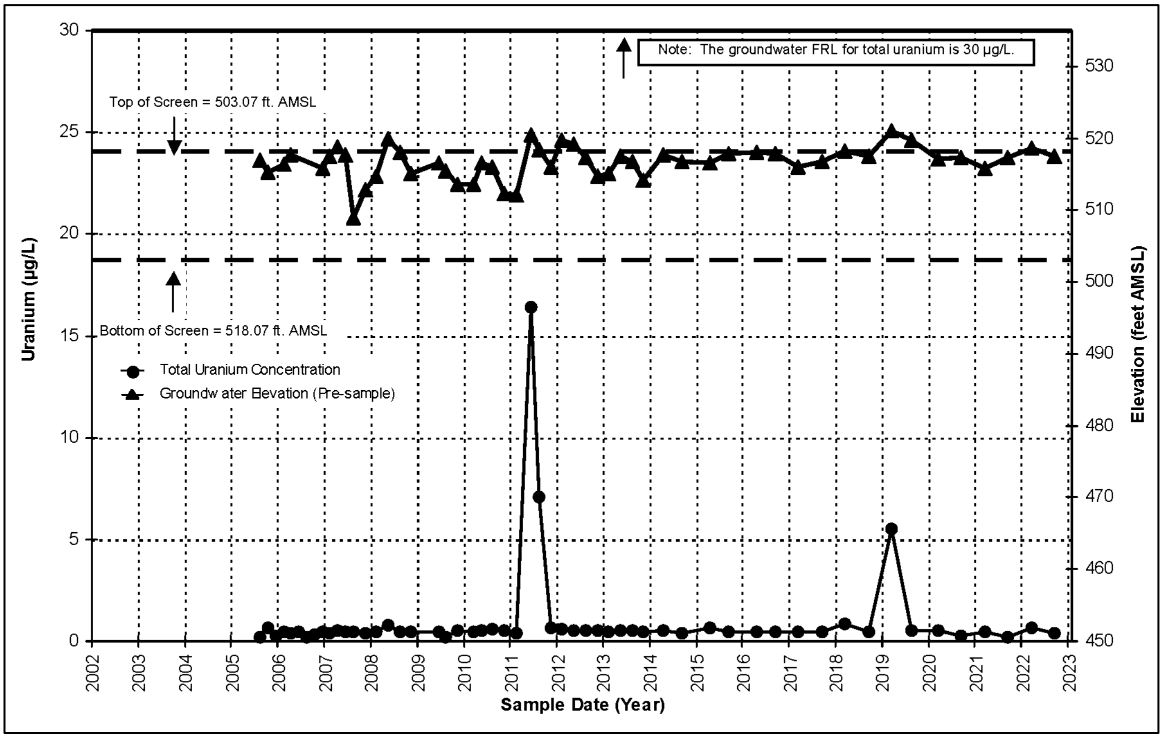

Figure A.5.8-5. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22215

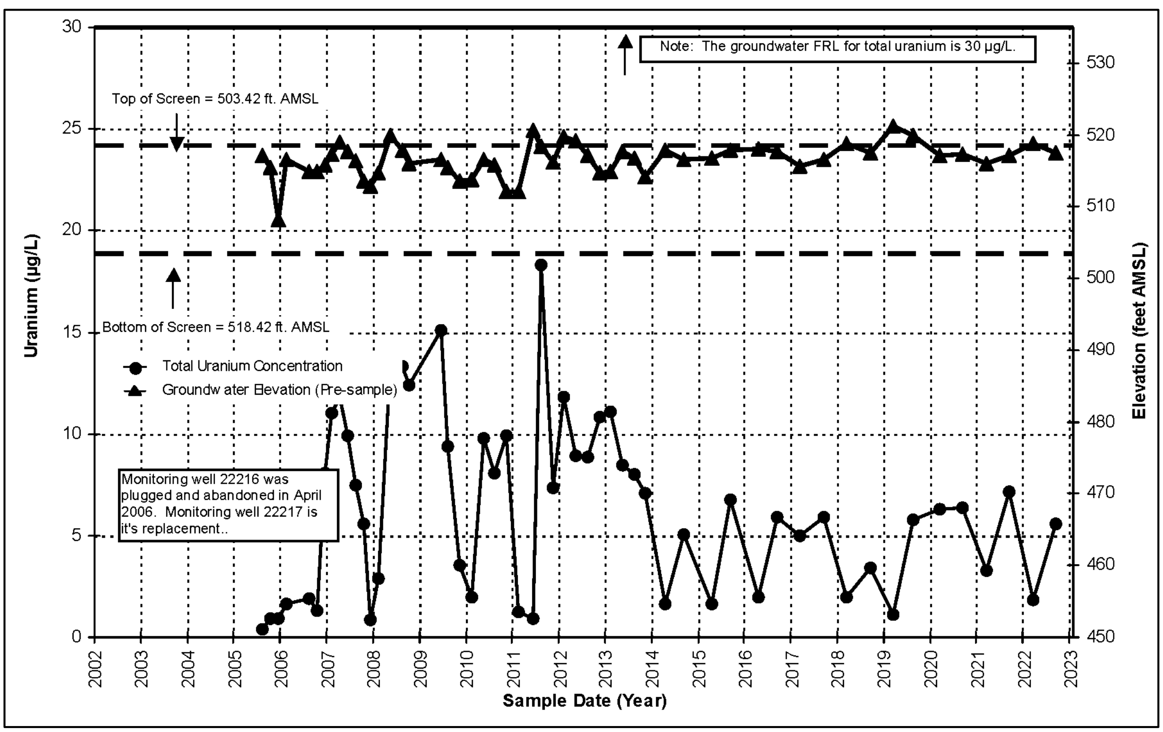

Figure A.5.8-6. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22216/22217

Figure A.5.8-7A. Cell 8 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

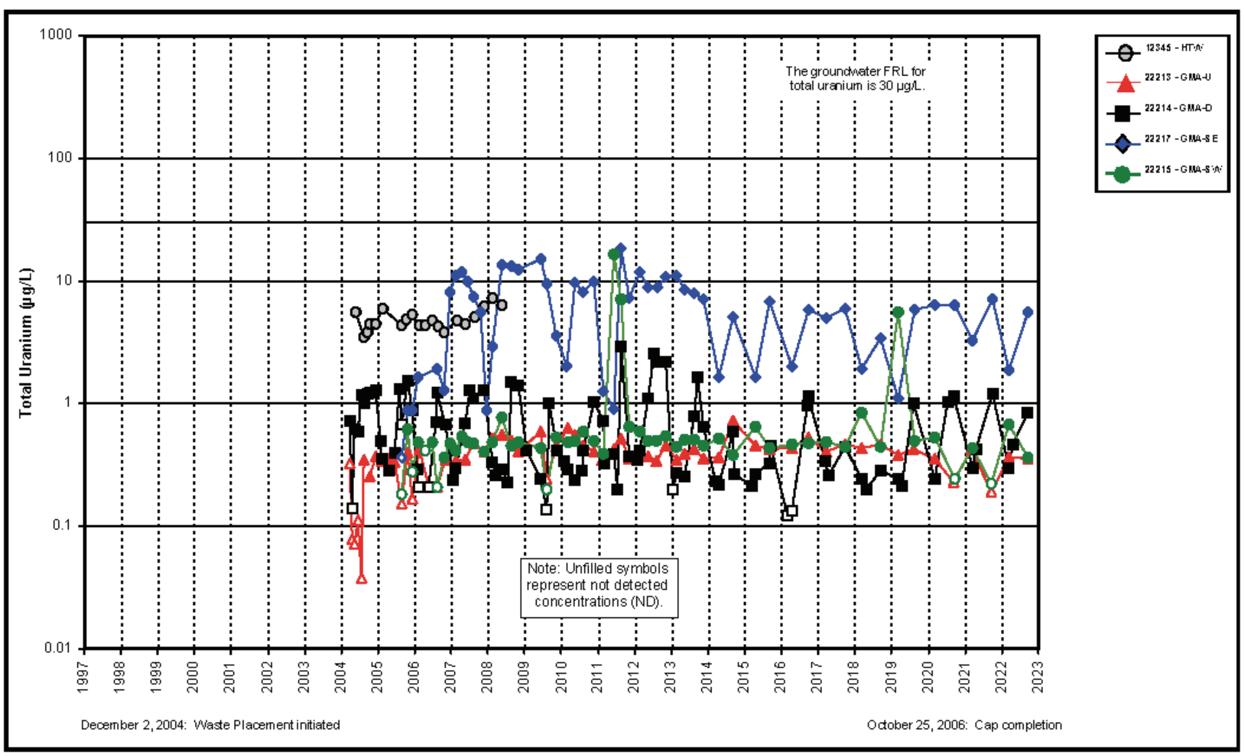

Figure A.5.8-7B. Cell 8 Total Uranium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

Figure A.5.8-8A. Cell 8 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

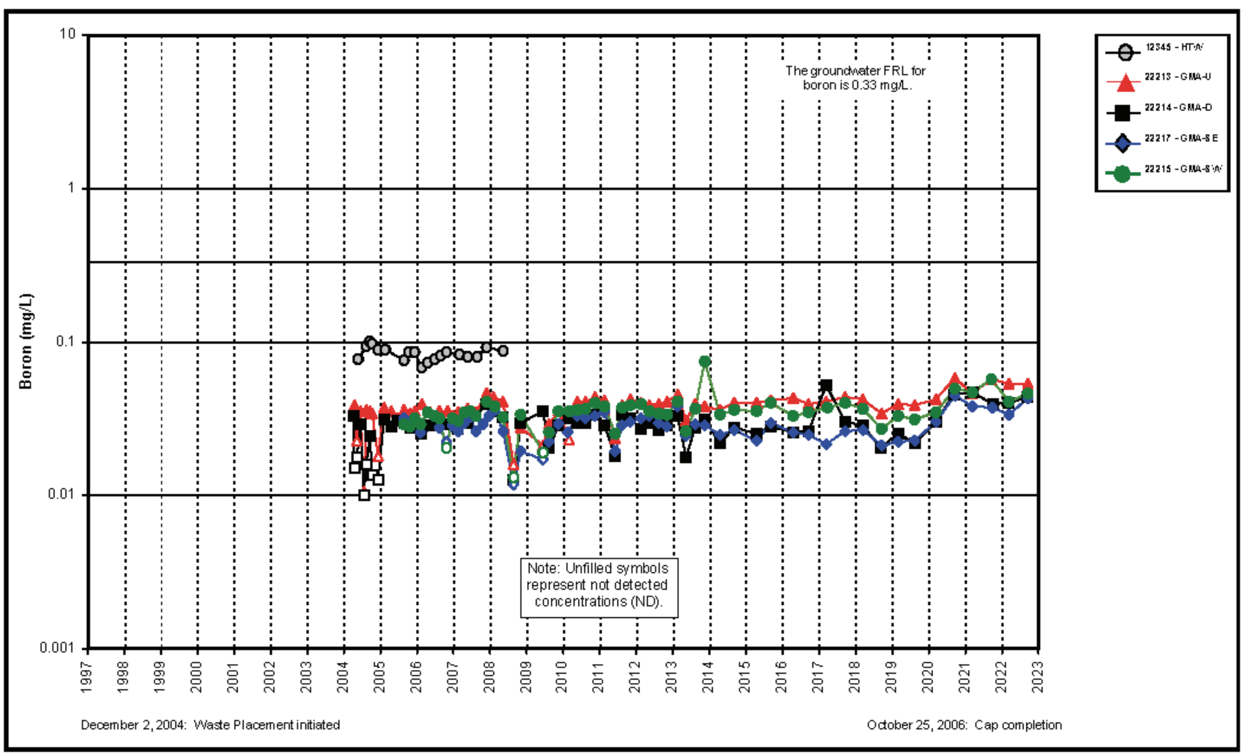

Figure A.5.8-8B. Cell 8 Boron Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

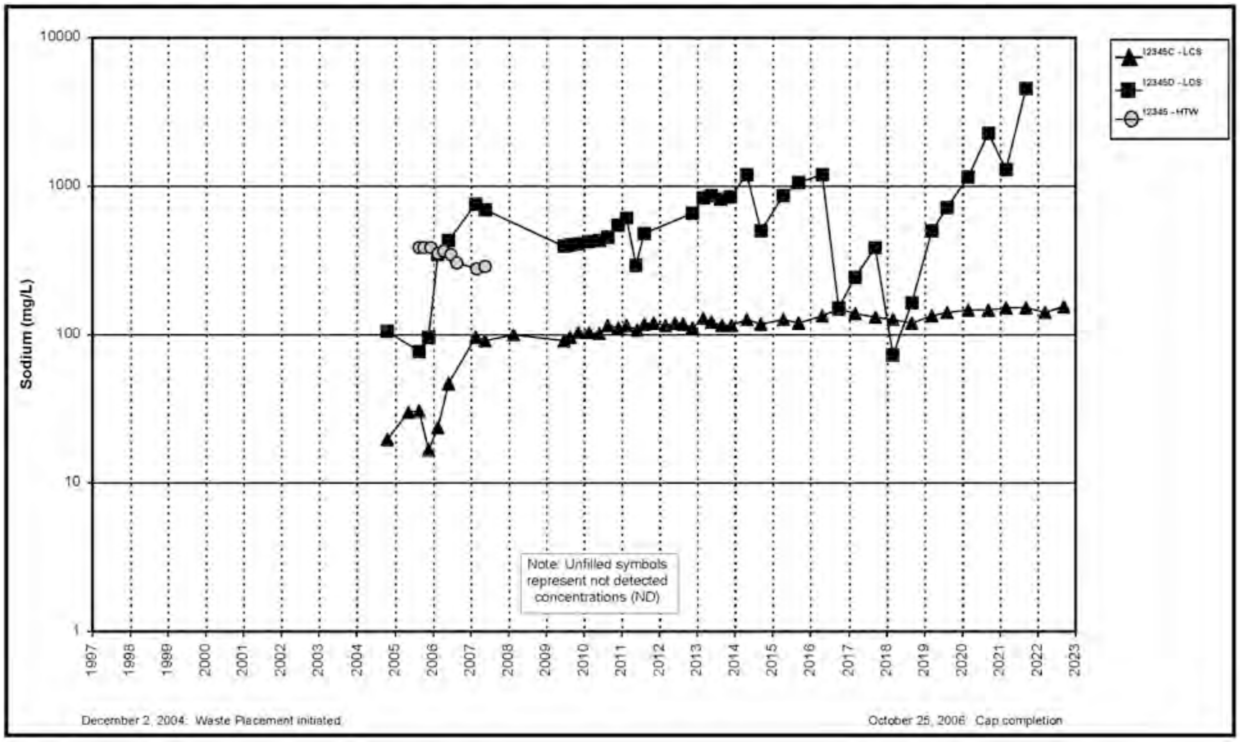

Figure A.5.8-9A. Cell 8 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

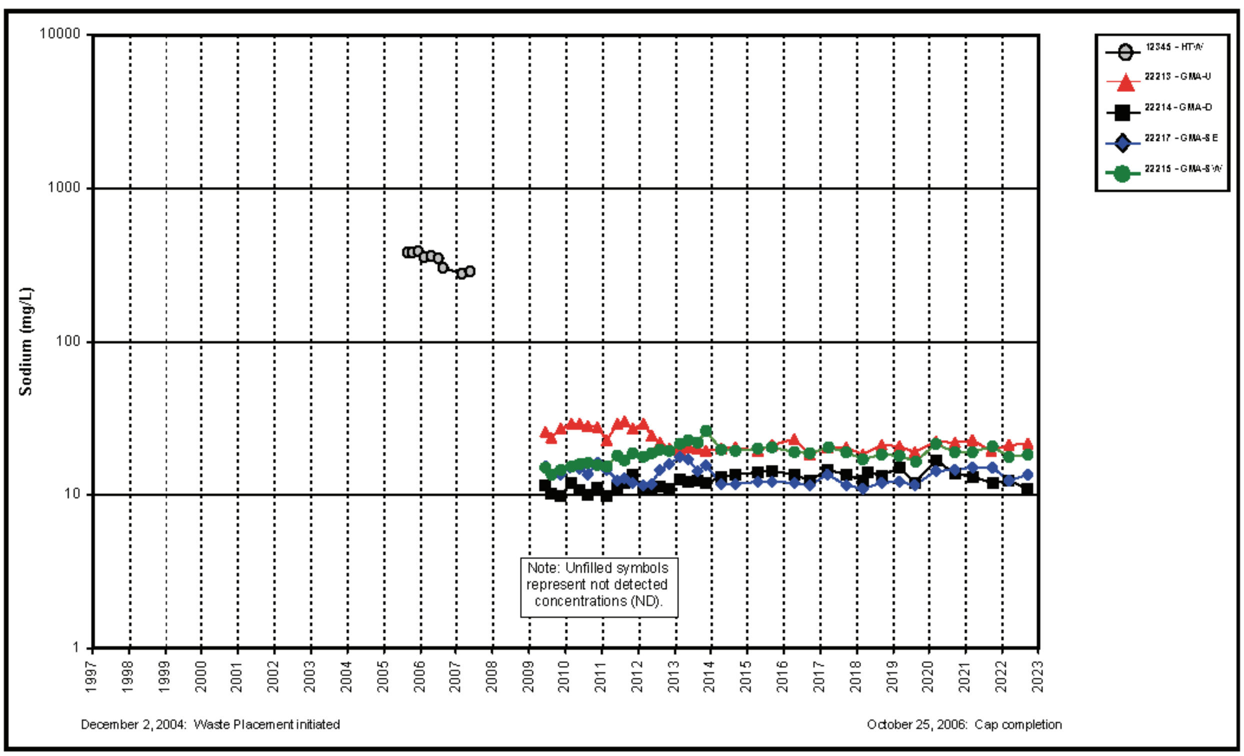

Figure A.5.8-9B. Cell 8 Sodium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

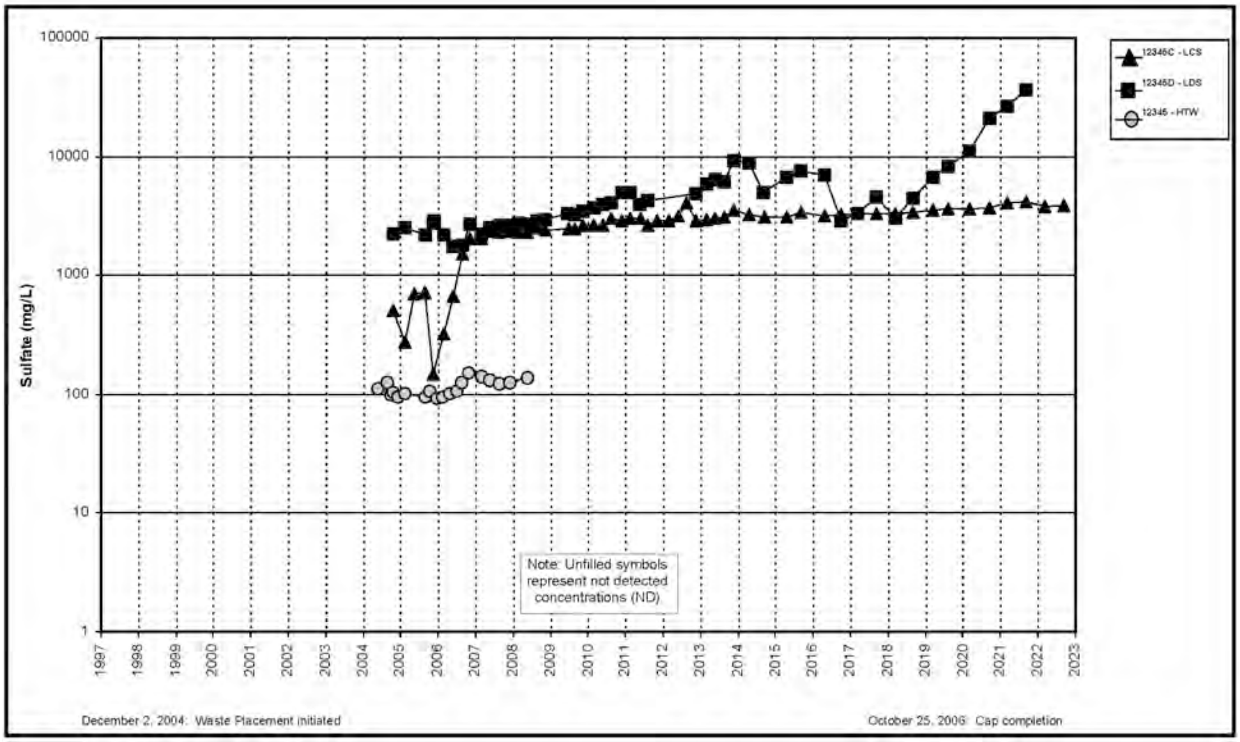

Figure A.5.8-10A. Cell 8 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

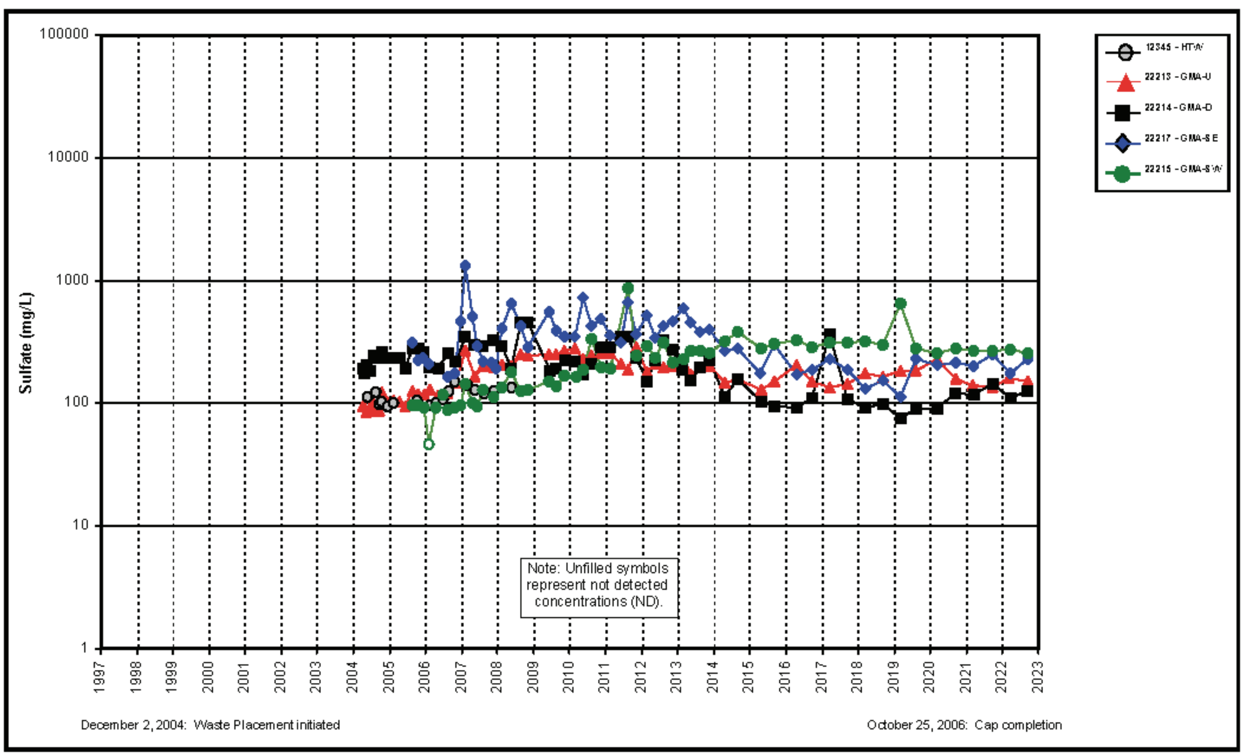

Figure A.5.8-10B. Cell 8 Sulfate Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

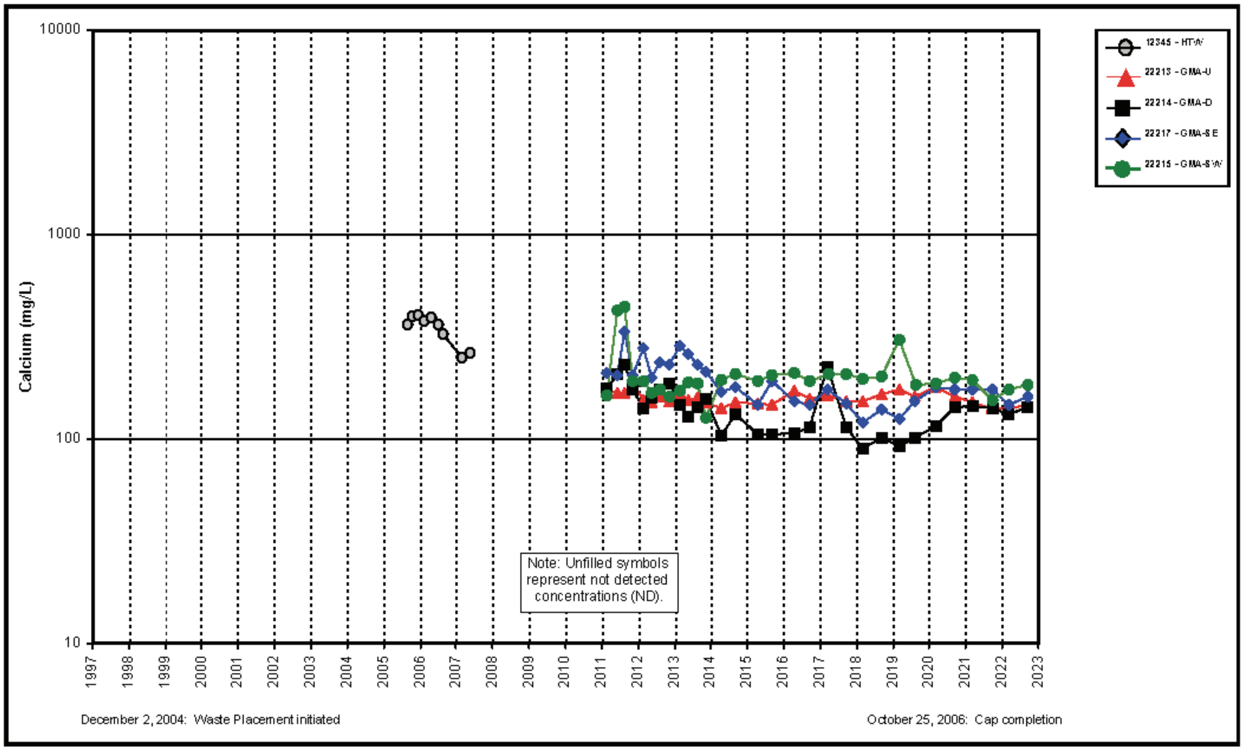

Figure A.5.8-11. Cell 8 Calcium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

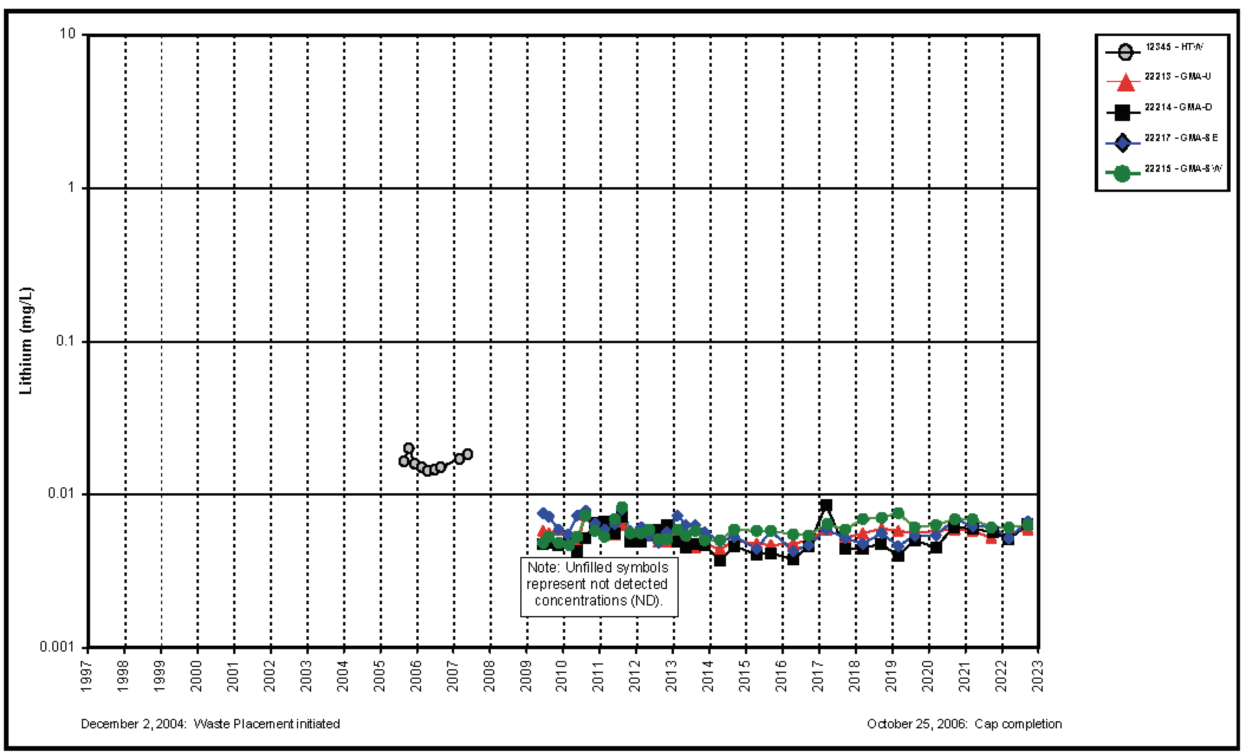

Figure A.5.8-12. Cell 8 Lithium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

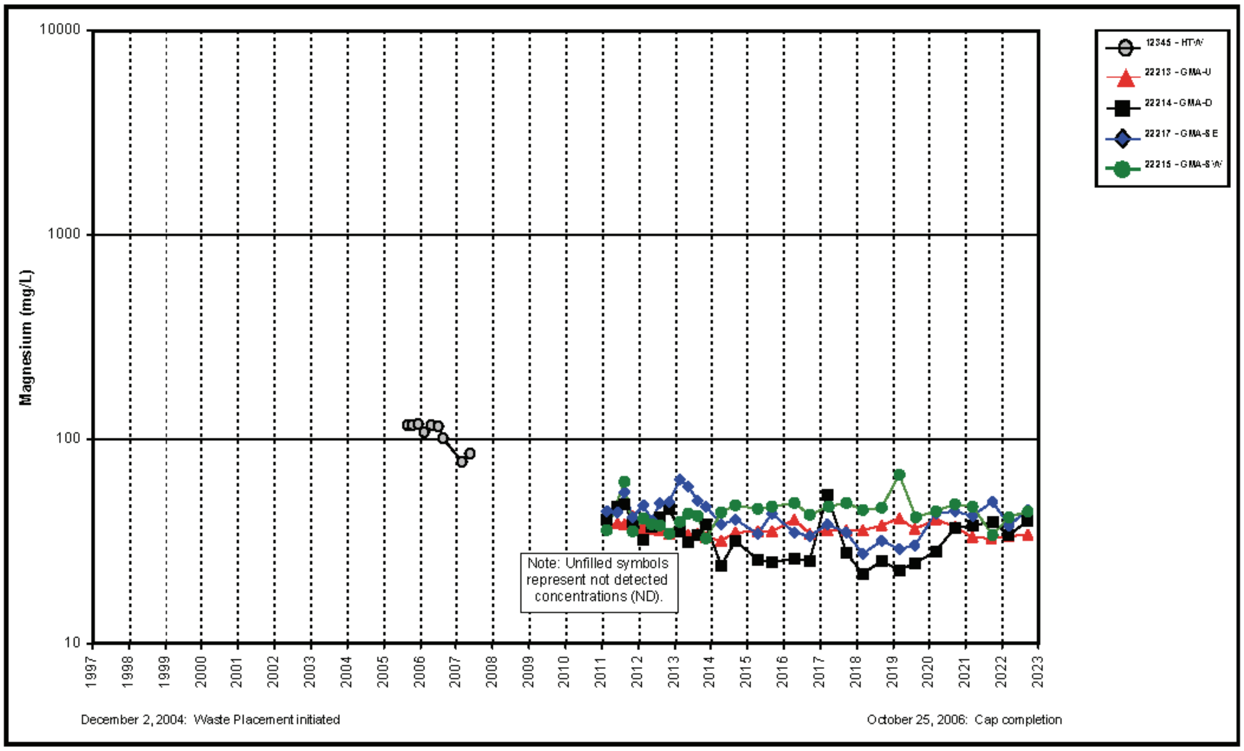

Figure A.5.8-13. Cell 8 Magnesium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

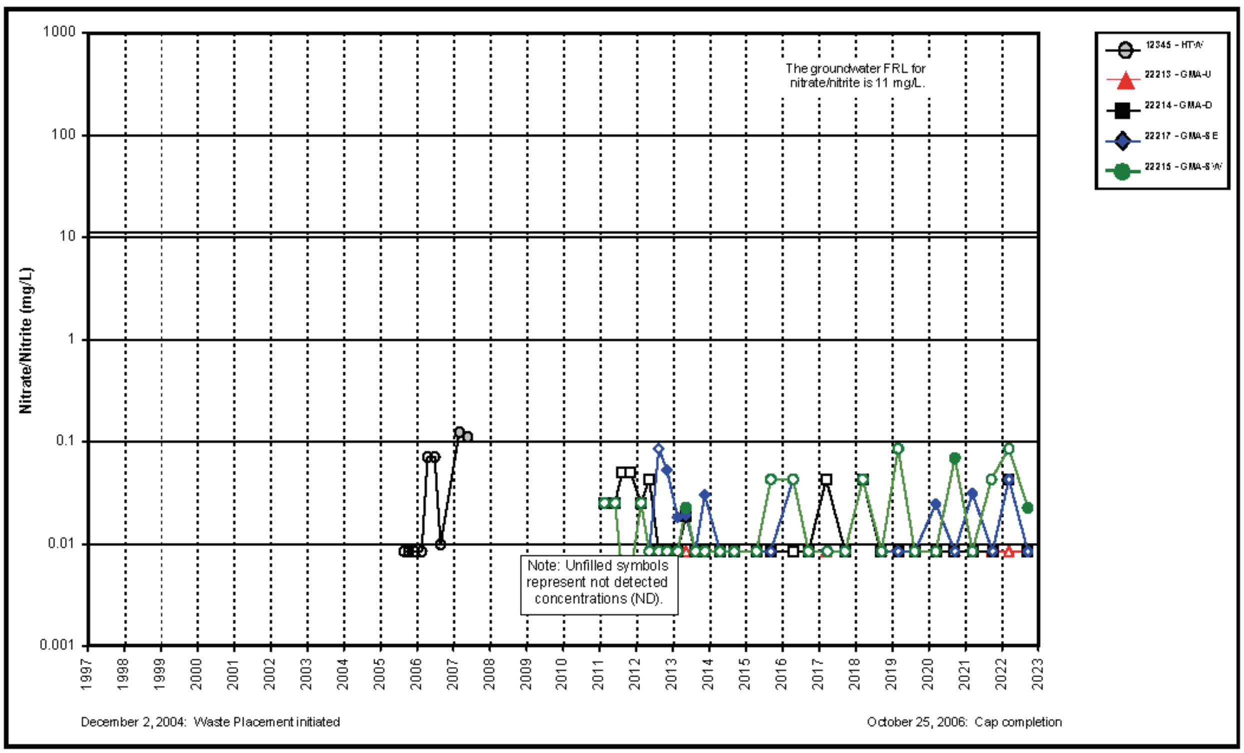

Figure A.5.8-14. Cell 8 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

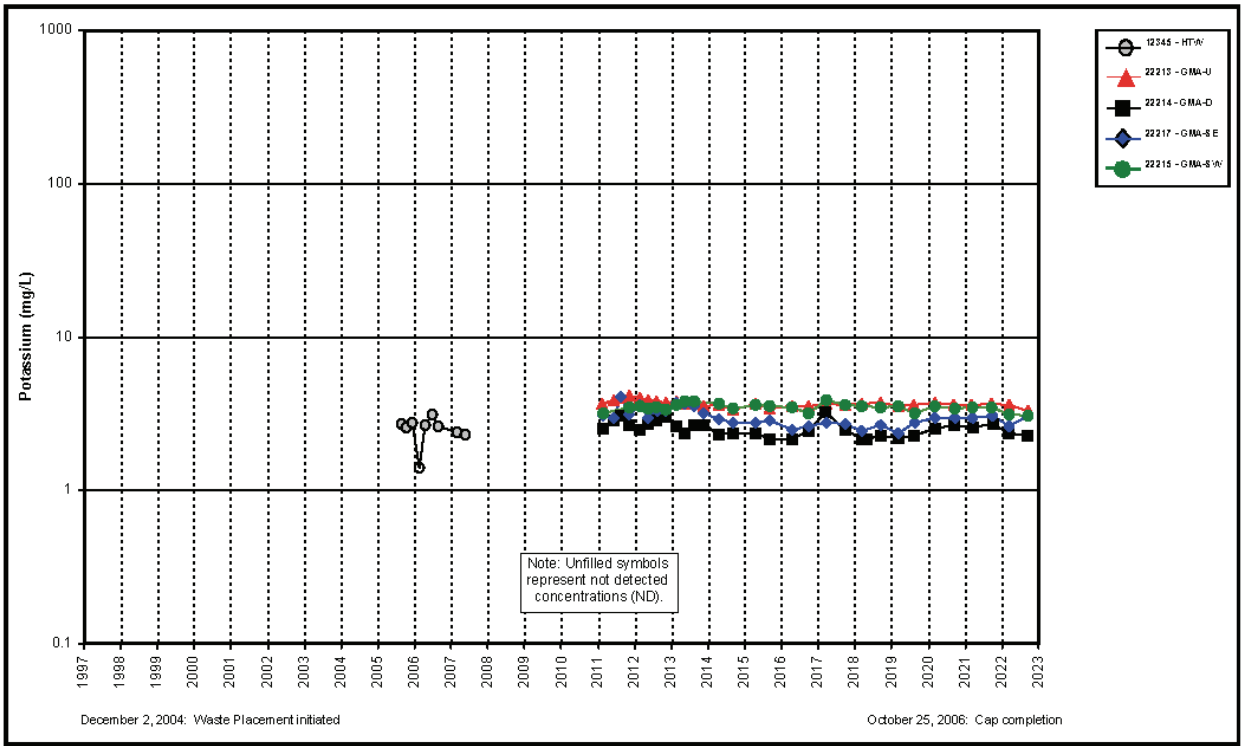

Figure A.5.8-15. Cell 8 Potassium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

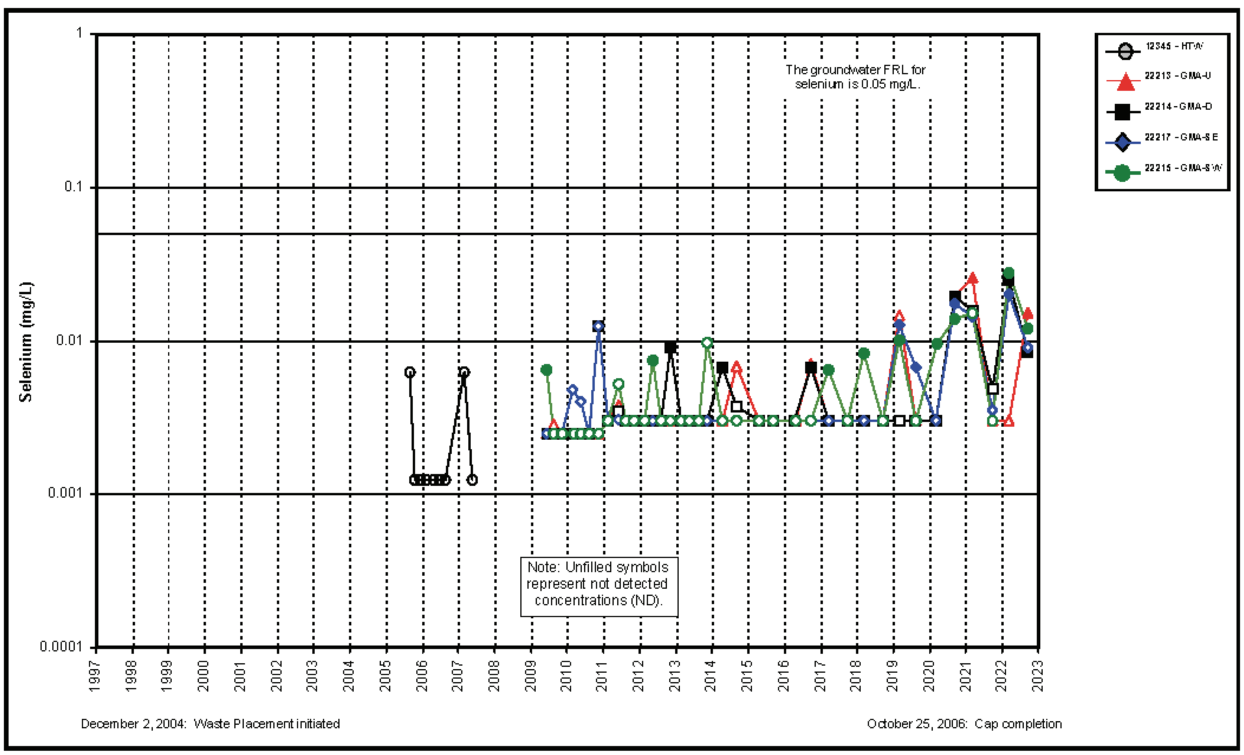

Figure A.5.8-16. Cell 8 Selenium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

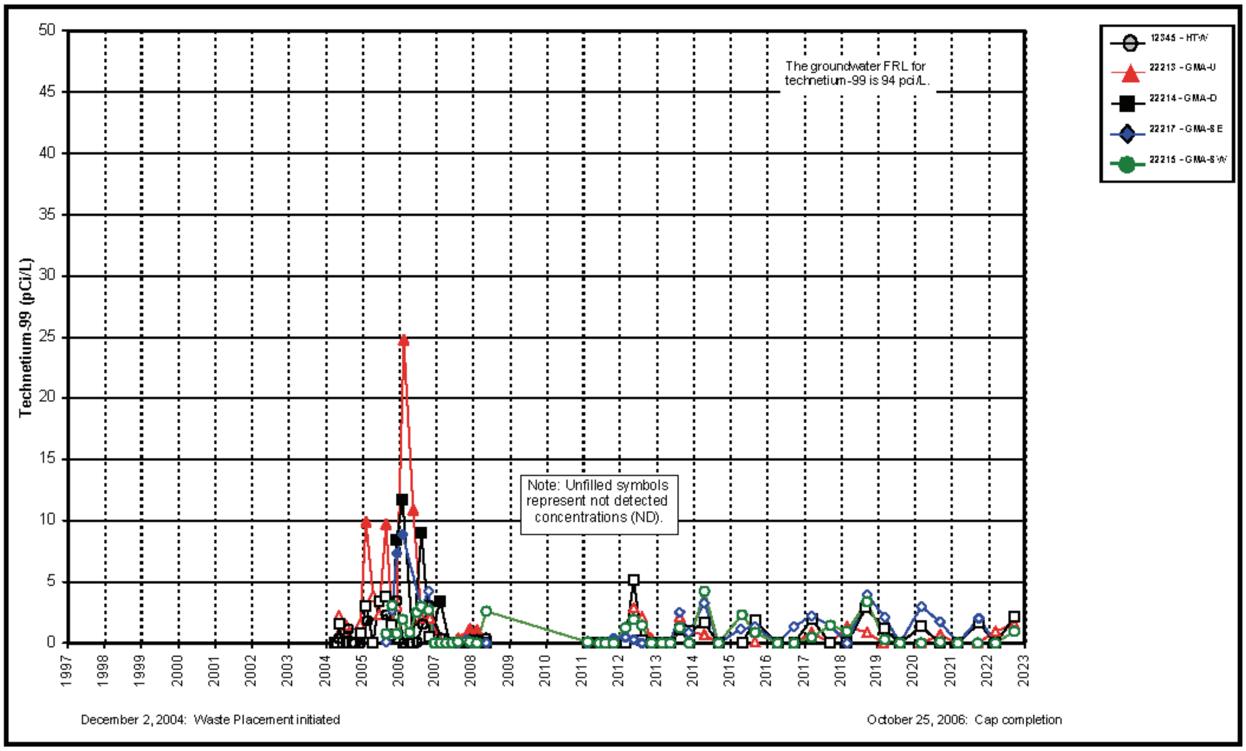

Figure A.5.8-17. Cell 8 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

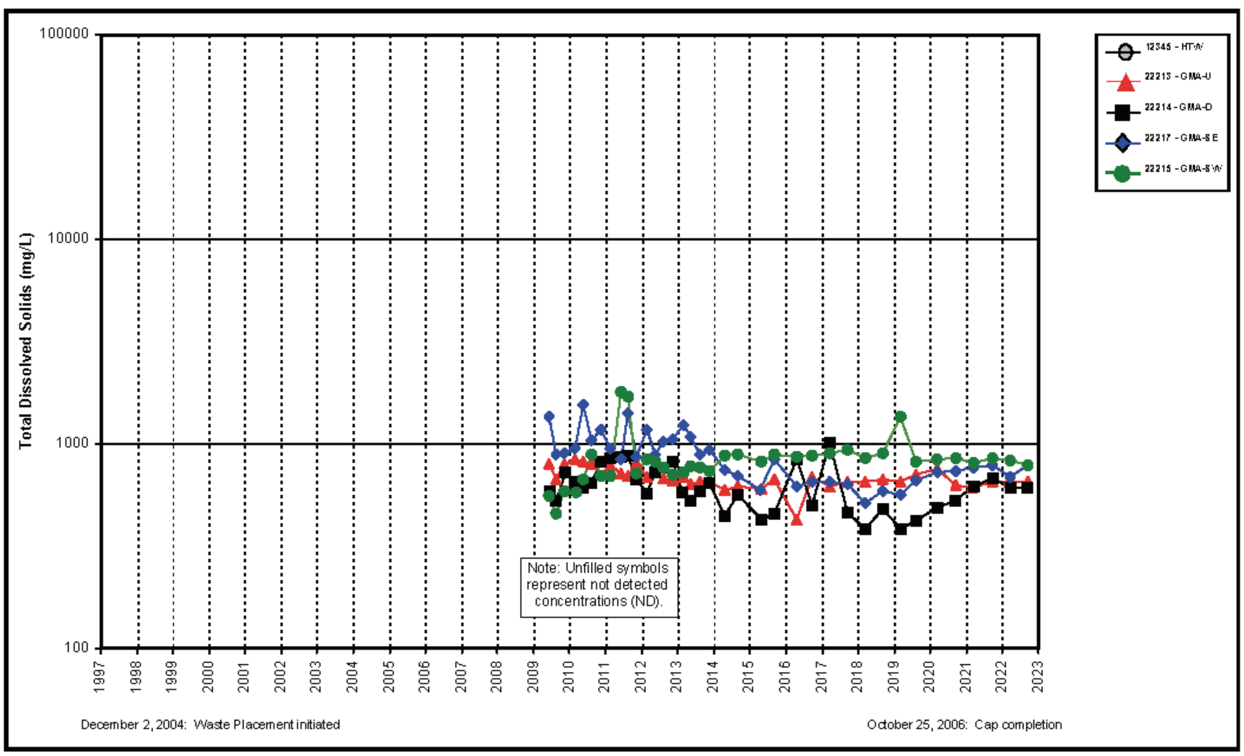

Figure A.5.8-18. Cell 8 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

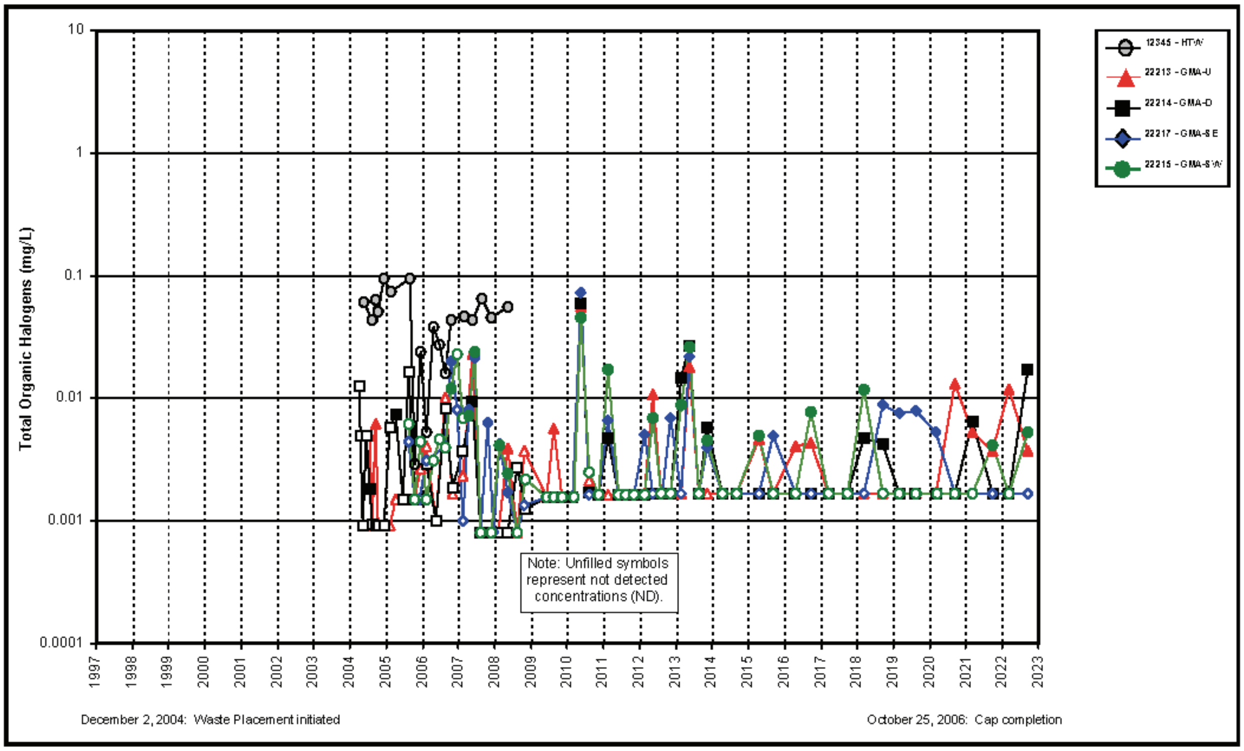

Figure A.5.8-19. Cell 8 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

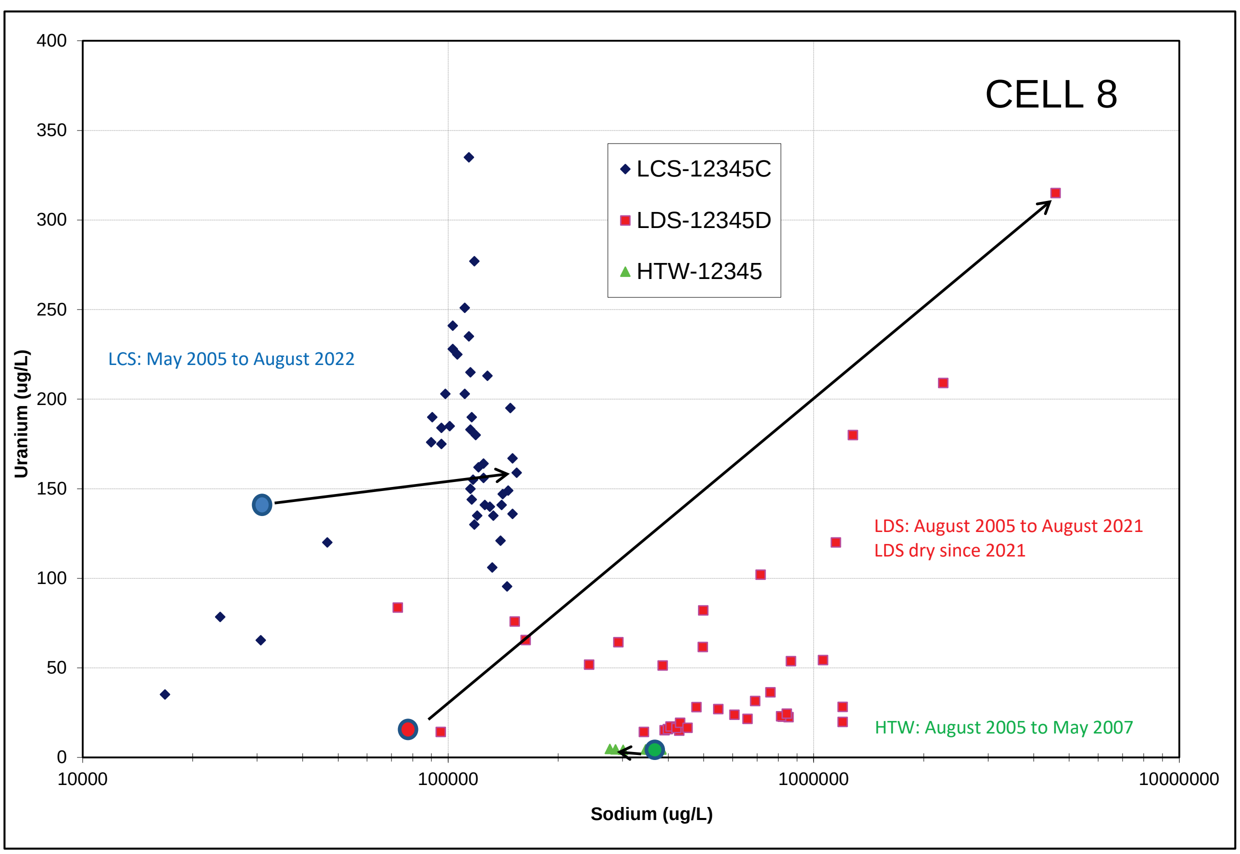

Figure A.5.8-20. Cell 8 Bivariate Plot for Uranium and Sodium

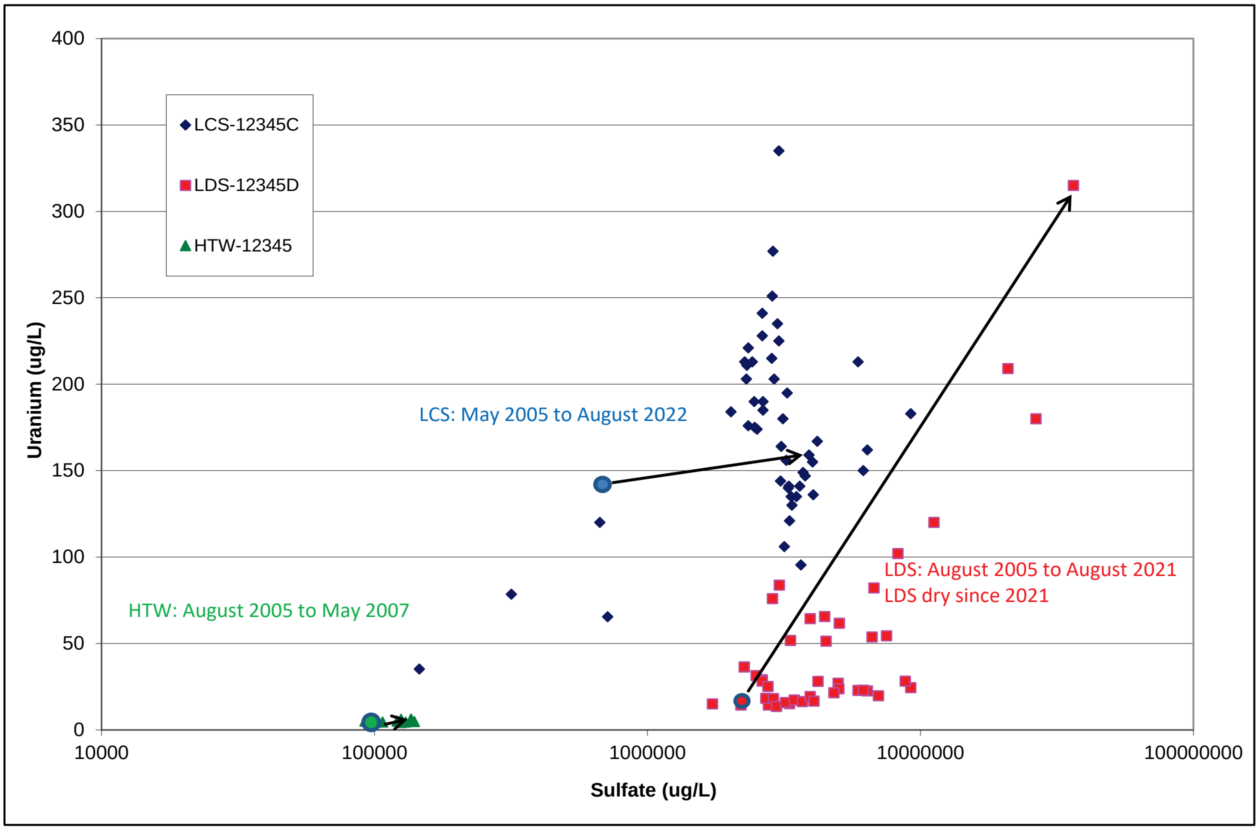

Figure A.5.8-21. Cell 8 Bivariate Plot for Uranium and Sulfate

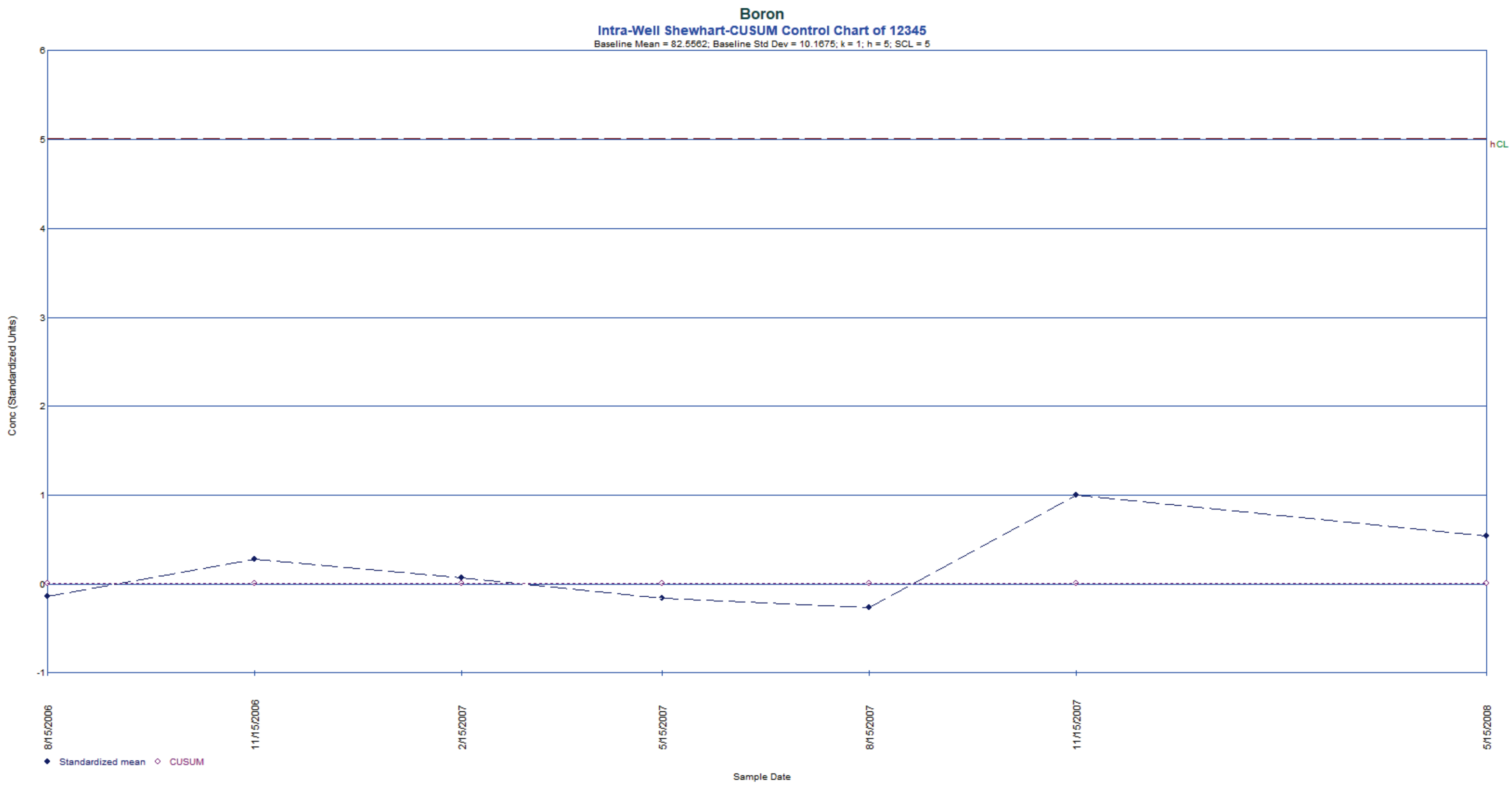

Figure A.5.8-22. Intrawell Shewhart-CUSUM Control Chart for Boron in Monitoring Well 12345

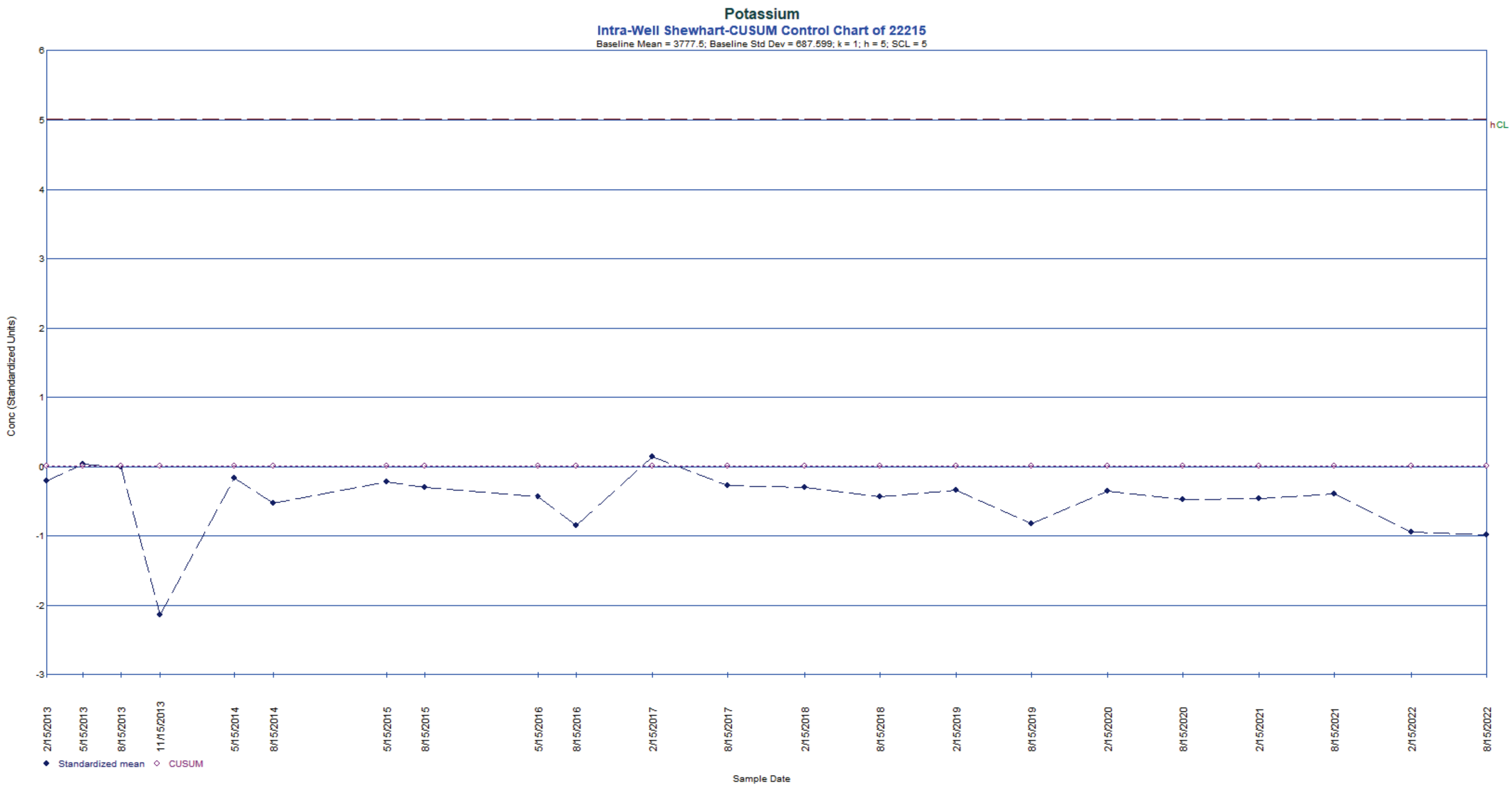

Figure A.5.8-23. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22215

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Appendix B

Supplemental Surface Water and Effluent Information

Contents

Tables

Figures

Abbreviations

DOE	U.S. Department of Energy
FFCA	Federal Facility Compliance Agreement
FRL	final remediation level
GMA	Great Miami Aquifer
IEMP	Integrated Environmental Monitoring Plan
LMICP	*Comprehensive Legacy Management and Institutional Controls Plan*
NPDES	National Pollutant Discharge Elimination System
Ohio EPA	Ohio Environmental Protection Agency
OU5 ROD	Operable Unit 5 Record of Decision

Measurement Abbreviations

cfs	cubic feet per second
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picocuries per liter

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B.1.0 Surface Water and Effluent

This appendix presents additional surface water and effluent data in support of Section 4.0 of this *Fernald Preserve 2022 Site Environmental Report* and provides an evaluation of the final remediation level (FRL) exceedances for surface water and effluent at the Fernald Preserve, Ohio, Site, including an assessment of potential cross-media impacts to the groundwater exposure pathway. Surface water data are available through the U.S. Department of Energy (DOE) Office of Legacy Management's Geospatial Environmental Mapping System (GEMS) database at https://gems.lm.doe.gov/#.

Surface water and effluent samples are collected as required by the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP) (DOE 2019). Figure B-1 shows all IEMP surface water monitoring locations. The following information is discussed in this appendix:

- Surveillance monitoring (Section B.1.1)
- Federal Facility Compliance Agreement (FFCA)/*Final Record of Decision for Remedial Actions at Operable Unit 5* (OU5 ROD) (DOE 1996) compliance (Section B.1.2)
- Controlled and uncontrolled areas (Section B.1.3)
- Surface water monitoring reductions (Section B.1.4)

Routine National Pollutant Discharge Elimination System (NPDES) permit sampling is not discussed in this appendix because it is discussed in detail in Section 4.0, "Surface Water and Effluent Pathway," of this 2022 Site Environmental Report.

B.1.1 Surveillance Monitoring

Surveillance monitoring is the comparison of surface water and effluent analytical results to the surface water FRLs to determine the effects of remediation activities on the surface water exposure pathway. Surveillance monitoring also includes an assessment of the effects surface water may have on the groundwater pathway (referred to as cross-media impacts).

All 2022 data were compared to surface water FRLs. Concentration versus time plots are presented in Figures B-2 through B-25. Samples collected at the Parshall Flume (PF 4001) are used in the surveillance evaluation because this is the last point effluent is sampled before discharge to the Great Miami River.

Water discharges to the Great Miami River are required to be below the FRLs at the point where discharged water is completely mixed with water in the Great Miami River (i.e., outside the mixing zone). In cases where the Parshall Flume data are already below the FRLs, no further action is taken. When the Parshall Flume data are above the FRLs, to determine each constituent's concentration at this point in the Great Miami River, the following calculation is applied. No samples collected at PF 4001 exceeded the surface water FRLs in 2022.

$$C_{PF\,4001} = \frac{[Q_{10}][C_{GMR}] + [Q_{PF}][C_{PF}]}{[Q_{10}] + [Q_{PF}]}$$

where:

C_{PF4001} = Flow-weighted average concentration outside the mixing zone in the Great Miami River, picocuries per liter (pCi/L), micrograms per liter (µg/L), or milligrams per liter (mg/L)

Q_{10} = 7-day, 10-year low flow, 280.58 cubic feet per second (cfs)

C_{GMR} = Background concentration in the Great Miami River from Table 11 in Attachment D of the LMICP, measured in pCi/L, µg/L, or mg/L; (zero was used when no background concentration was available)

Q_{PF} = Daily flow at PF 4001, cfs

C_{PF} = Daily concentration at PF 4001, pCi/L, µg/L, or mg/L

Note

Flow conditions at the Hamilton Dam gauge are periodically reviewed to determine whether there is a lower flow than the 7-day, 10-year low flow of 280.58 cfs. The low flow of 280.58 cfs went into effect during the NPDES permit renewal process using information provided in the NPDES permit fact sheet finalized in 2022. The lowest daily flow measured at the Hamilton Dam gauge (if lower than 280.58 cfs) is used in the equation to see whether an exceedance could potentially occur. The lowest daily flow recorded during 2022 was 594 cfs, which occurred on December 25, 2022.

B.1.1.1 Evaluation of Constituents Above FRLs for 2022

As shown in Table B-1, there were 7 exceedances of the total uranium surface water FRL in 2022. Figures B-2 through B-14 are plots of the total uranium concentration versus time for all surface water sampling locations sampled in 2022. The seven total uranium surface water FRL exceedances (530 µg/L) occurred at sampling location SWD-09. Figure B-2 is a plot of the total uranium concentration versus time for sampling location SWD-09. Concentrations display a cycle of high to low each year. The historical high was 2,087 µg/L, measured in December 2016. The highest total uranium concentration in 2022, 917.8 µg/L, was at this location. The overall statistical trends (Mann-Kendall) with a 95% confidence interval at SWD-09 is “Down.”

As discussed in Section 4.0 of this Site Environmental Report, surface water monitoring currently conducted in a small swale area west of the former waste pits continues to show elevated but slowly diminishing uranium concentrations. After a limited maintenance activity was completed in fall 2007, DOE committed to continued monitoring of the swale area. Two monitoring points (SWD-05 and SWD-09) were added to the surface water program to fulfill this monitoring commitment. These two locations are sampled weekly, when water is present.

Location SWD-05 has been sampled 288 times and location SWD-09 has been sampled 485 times between January 2007 and December 2022. As shown in Table B-1, 284 of the 485 samples collected at SWD-09 (59%) have exceeded the total uranium surface water FRL. As discussed in Appendix A, Attachment A.2, the swale is isolated from surface drainage features, so water entering the swale either evaporates or infiltrates into the ground. If the surface water with elevated total uranium concentration infiltrates into the aquifer beneath the swale, it is quickly captured by nearby extraction well 33347 and poses no threat to human health or the environment. Additional information concerning the impact to groundwater is provided in Section A.2.1.1.4.

B.1.1.2 Evaluation of Cross-Media Impacts for 2022

One of the objectives of the IEMP surveillance monitoring program is to provide an ongoing assessment of the potential for cross-media impacts from surface water to the underlying Great Miami Aquifer (GMA). To conduct this assessment, sampling locations were selected to evaluate contaminant concentrations in surface water just upstream from those areas where site drainages have eroded through the protective glacial overburden (e.g., the Storm Sewer Outfall Ditch, Pilot Plant Drainage Ditch, and certain reaches of Paddys Run). In areas where the glacial overburden is absent, a direct pathway exists for contaminants to reach the aquifer. Key sampling locations associated with these areas of direct infiltration are SWD-03, SWD-04, SWD-05, SWD-07, SWD-08, and STRM 4005 (Figures B-3 through B-8).

Because it is the primary contaminant at the site, total uranium is used as an indicator to evaluate the impact of surface water on the GMA. A conservative assumption is used in this assessment, which considers the total uranium concentration (and all other constituent concentrations) in the surface water to be at the same concentration when the water reaches the GMA through infiltration. However, the more likely scenario is that the total uranium concentration (and all other constituent concentrations) would decrease through dilution and adsorption to sediment particles as the water infiltrates through the ground and mixes with the groundwater in the GMA. The groundwater total uranium FRL of 30 µg/L is used in this cross-media impact assessment.

The results of the cross-media impact assessment for 2022 indicate that one of the six surface water locations evaluated (SWD-04) had results that exceeded the total uranium groundwater FRL of 30 µg/L. The impact SWD-04 has on the aquifer is similar to SWD-09's impact discussed in Section B.1.1.1. All locations are within capture of the groundwater remediation system. Sampling at these locations will continue, and results of these samples will continue to provide an assessment of the cross-media impacts.

B.1.2 FFCA/OU5 ROD Compliance

The OU5 ROD and subsequent *Explanation of Significant Differences for Operable Unit 5* (DOE 2001) stipulate compliance with a monthly flow-weighted average total uranium concentration discharge limit of 30 µg/L at the Great Miami River via PF 4001. In addition to the concentration limitation, the OU5 ROD stipulated that the total mass discharged during a year not exceed 600 pounds.

During 2022, the total uranium concentrations were monitored daily at PF 4001 to demonstrate compliance with these limitations. The Fernald Preserve was in compliance with the total mass limitation, as uranium discharges totaled 335 pounds, which is below the 600-pound limit. The Fernald Preserve was in compliance with the monthly flow-weighted concentration limit every month in 2022, as identified in Figure B-26.

B.1.3 Controlled and Uncontrolled Stormwater Runoff Areas

In 2022, there were no previously uncontrolled areas that were added to the Fernald Preserve controlled storm water system (Figure B-27). At the conclusion of remediation in October 2006, control of storm water runoff was no longer required. The only storm water collected for treatment is that which falls on the controlled pad of the Converted Advanced Wastewater Treatment facility.

B.1.4 Proposed Surface Water Monitoring Reductions

As stated in the *Fifth CERCLA Five Year Review Report for the Fernald Preserve* (DOE 2021), based on an initial review of the surface water results, it may be appropriate to stop monitoring several locations where FRLs have not been exceeded during the 5-year period. This review, which was to also take into account cross-media impact issues, was discussed in the 2021 Site Environmental Report (DOE 2022). Additional surface water monitoring program reductions were documented in the 2015 and 2017 Site Environmental Reports (DOE 2016 and DOE 2018, respectively). The 2021 assessment was completed due to the number of years of data that had been collected without FRL exceedances at many locations. Concentration versus time graphs were reviewed for the 2021 Site Environmental Report for each location and evaluated against the following criteria:

- The surface water location has never had a surface water FRL exceedance
- The cross-media impact surface water location has never had a groundwater FRL exceedance
- It has been at least 10 years since the surface water (all locations) or groundwater (cross-media impact locations) FRL exceedance has occurred

Table B-2 provides a list of surface water locations that met these criteria. The first column identifies the location number and general location. General locations indicate whether the location is in Paddys Run, a drainage to Paddys Run, or a water body internal to the site. The second column identifies the monitored analyte. The third column identifies the current sample collection frequency. The fourth column identifies the figure that presents the concentration versus time graph. The fifth column presents the number of years that the location has been sampled updated to include the sampling year 2022. The sixth column provides the criteria met, as defined above. The seventh column of the table provided the reduction recommendation presented in the 2021 Site Environmental Report. The last column presents the data from 2022.

As shown in Table B-2, it has been determined that reductions in surface water monitoring were warranted. Although total uranium collected at SWP-03 (the point where Paddys Run flows off the Fernald Preserve property) meets the criteria listed above, collection of total uranium at SWP-03 will not be eliminated. Data from samples collected in 2022 are similar to results from previous years and confirm reductions are warranted. With approval from the U.S. Environmental Protection Agency and Ohio Environmental Protection Agency, DOE documented these changes to the IEMP surface water monitoring program in the 2023 LMICP. 2022 was the last year these locations will be monitored and reported.

For 2022, DOE proposes to discontinue weekly sampling at SWD-05 and SWD-09 to align with the semi-annual frequency as stated in the LMICP. As discussed in Section B.1.1.1, from 2007 to

2022, SWD-05 (Figure B-5) and SWD-09 (Figure B-2) have been sampled for uranium 284 and 485 times, respectively. The data indicates that the locations continue to trend down. DOE will implement these changes with stakeholder approval beginning in calendar year 2024.

B.2.0 References

DOE (U.S. Department of Energy), 1996. *Final Record of Decision for Remedial Actions at Operable Unit 5*, 7478 U-007-501.4, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio, January.

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DOE (U.S. Department of Energy), 2021. *Fifth Five-Year Review Report for the Fernald Preserve*, LMS/FER/S33442, Office of Legacy Management, September.

DOE (U.S. Department of Energy), 2022. Fernald Preserve 2021 Site Environmental Report, LMS/FER/S37811, Office of Legacy Management, May.

Table B-1. Summary Statistics and Trend Analysis for Constituents with 2022 Results Above Surface Water FRLs

Location[a]	Constituent	Number of Samples[b,c,d]	Number of Samples Above FRL[b,c,d]	Number of Samples Above FRL for 2022[c,d]	FRL[e] (µg/L)	Maximum FRL Exceedance 2022 (µg/L)	Minimum[b,c,d,f,g] (µg/L)	Maximum[b,c,d,f,g] (µg/L)	Average[b,c,d,f,g] (µg/L)	Standard Deviation[b,c,d,f,g] (µg/L)	Trend[b,c,d,f,g] (µg/L)
SWD-09	Uranium	485	284	7	530	918	3.40	2,087	647	368	Down

[a] Refer to Figure B-1.
[b] Based on samples collected from January 3, 2007, through December 31, 2022.
[c] If more than one sample is collected per surface water location per day (e.g., duplicate, grab, composite), then only one sample is counted for the number of samples, and the sample with the maximum concentration is used for determining the summary statistics (minimum, maximum, average, and standard deviation), the Mann-Kendall test for trend with a 95% confidence interval, and in determining FRL exceedances.
[d] Rejected data qualified with laboratory qualifiers R or Z were not included in the count, the summary statistics, or Mann-Kendall test for trend.
[e] FRL = Final Remediation Level. From OU5 ROD, Table 9−5.
[f] For results where the concentrations are below the detection limit, the results used in the summary statistics and Mann-Kendall test for trend are each set at half the method detection limit.
[g] If the number of samples is greater than or equal to four, then all of the summary statistics and the Mann-Kendall test for trend are reported. If the total number of samples is equal to three, then the minimum, maximum, and average are reported. If the total number of samples is equal to two, then the minimum and maximum are reported. If the total number of samples is equal to one, then the data point is reported as the minimum.

Table B-2. Update of Surface Water Monitoring Reductions

Location	Constituent	IEMP Requirements (Reason for Selection)[a]	Figure Number	Years of Data[b]	Criteria[v]	Approved Recommendation	2022 Result (Surface Water FRL)
SWD-03 (Waste Storage Area)[c]	Uranium, Total	Semiannual (PC)	B-3	25	3	Stop Monitoring	1.99 µg/L (530 µg/L)
SWD-07 (Storm Sewer Outfall Ditch)[c]	Uranium, Total	Semiannual (PC)	B-6	15	3	Stop Monitoring	16.2 µg/L (530 µg/L)
SWD-08 (Former Southern Waste Units Area)[c]	Radium-226	Annual (C)	B-21	14	1, 2	Stop Monitoring	<0.260 (38 pCi/L)
	Radium-228	Annual (C)	B-22	14	1, 2	Stop Monitoring	<0.166 (47 pCi/L)
	Thorium-228	Annual (C)	B-23	14	1, 2	Stop Monitoring	<0.00154 (830 pCi/L)
	Thorium-230	Annual (C)	B-24	14	1, 2	Stop Monitoring	<0.169 (3,500 pCi/L)
SWD-06 (Former Pilot Plant)	Uranium, Total	Semiannual (PC)	B-9	15	1	Stop Monitoring	17.7 µg/L (530 µg/L)
SWD-10 (Lodge Pond)	Uranium, Total	Annual (PC)	B-10	13	1	Stop Monitoring	4.5 µg/L (530 µg/L)
SWD-11 (Former Lime Sludge Pond)	Uranium, Total	Annual (PC)	B-11	13	1	Stop Monitoring	20.8 µg/L (530 µg/L)
SWD-12 (Former Area 4B)	Uranium, Total	Annual (PC)	B-12	13	1	Stop Monitoring	12.5 µg/L (530 µg/L)
SWD-13 (Former Silos Area)	Uranium, Total	Annual (PC)	B-13	13	1	Stop Monitoring	8.89 µg/L (530 µg/L)
SWP-03 (Paddys Run at Downstream Property Boundary)	Uranium, Total	Annual (PC)	B-14	25	1	No Change	1.97 µg/L (530 µg/L)
SWD-04 (Former Waste Pit 3)[c]	Radium-226	Annual (C)	B-15	14	1, 2	Stop Monitoring	0.513 pCi/L (38 pCi/L)
SWD-05 (Former Waste Storage Area)[c]	Radium-226	Annual (C)	B-16	14	1, 2	Stop Monitoring	0.657 pCi/L (38 pCi/L)
	Radium-228	Annual (C)	B-17	14	1, 2	Stop Monitoring	<0.255 pCi/L (47 pCi/L)
	Thorium-230	Annual (C)	B-19	14	1, 2	Stop Monitoring	0.609 pCi/L (3,500 pCi/L)

[a] C = DOE response to Ohio Environmental Protection Agency comment, 2008 LMICP; PC = primary constituent of concern.
[b] 1 = Surface water location — no surface water FRL exceedance.
2 = Cross-media impact location — no groundwater FRL exceedance.
3 = Surface water location — minimum of 10 years since surface water or groundwater FRL exceedance.
[c] Cross-media impact location. Groundwater FRLs are as follows: total uranium, 30 µg/L; radium-226, 20 pCi/L; radium-228, 20 pCi/L; thorium-228, 4.0 pCi/L; thorium-230, 15 pCI/L.

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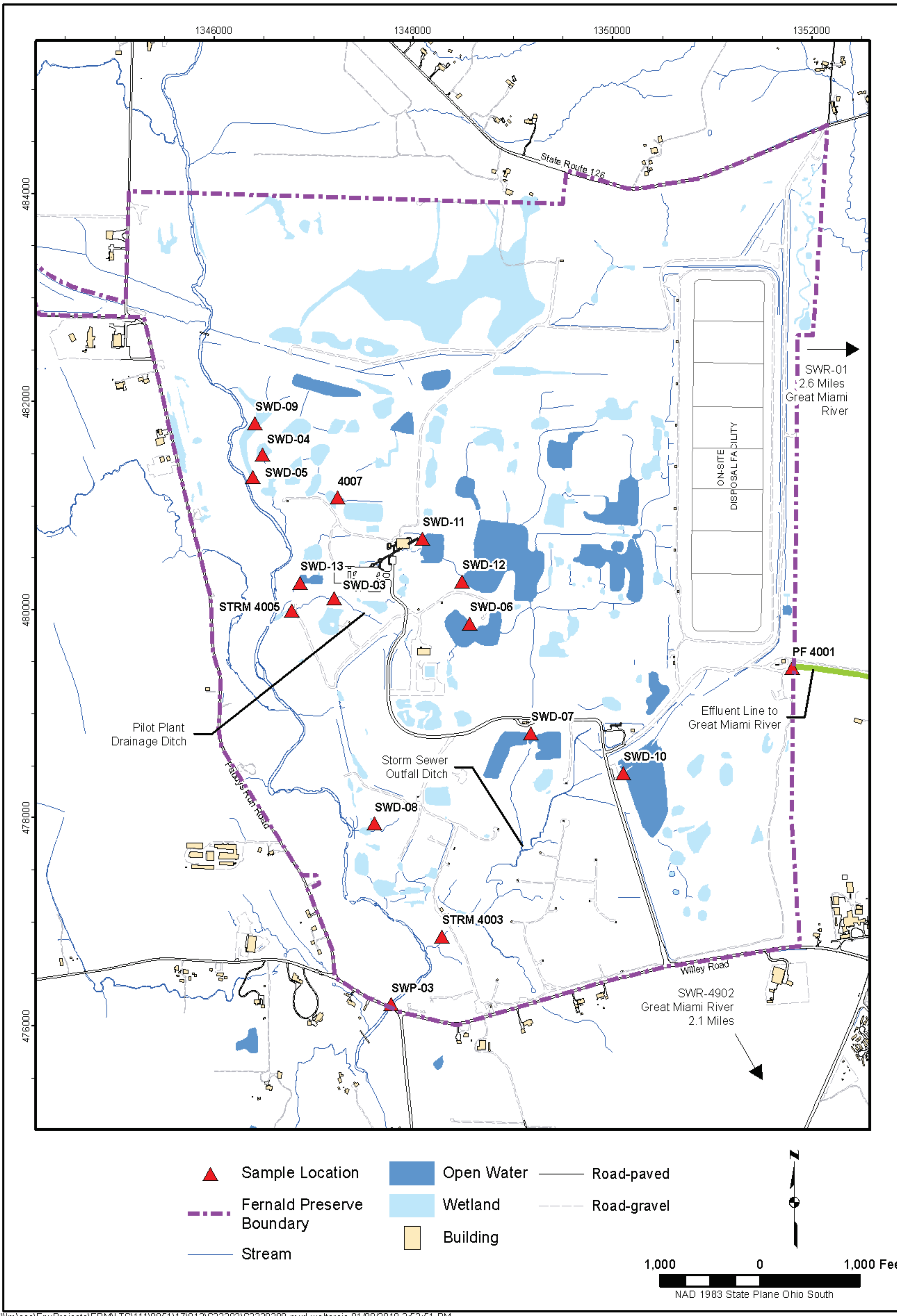

Figure B-1. IEMP/NPDES Surface Water and Effluent Sample Locations

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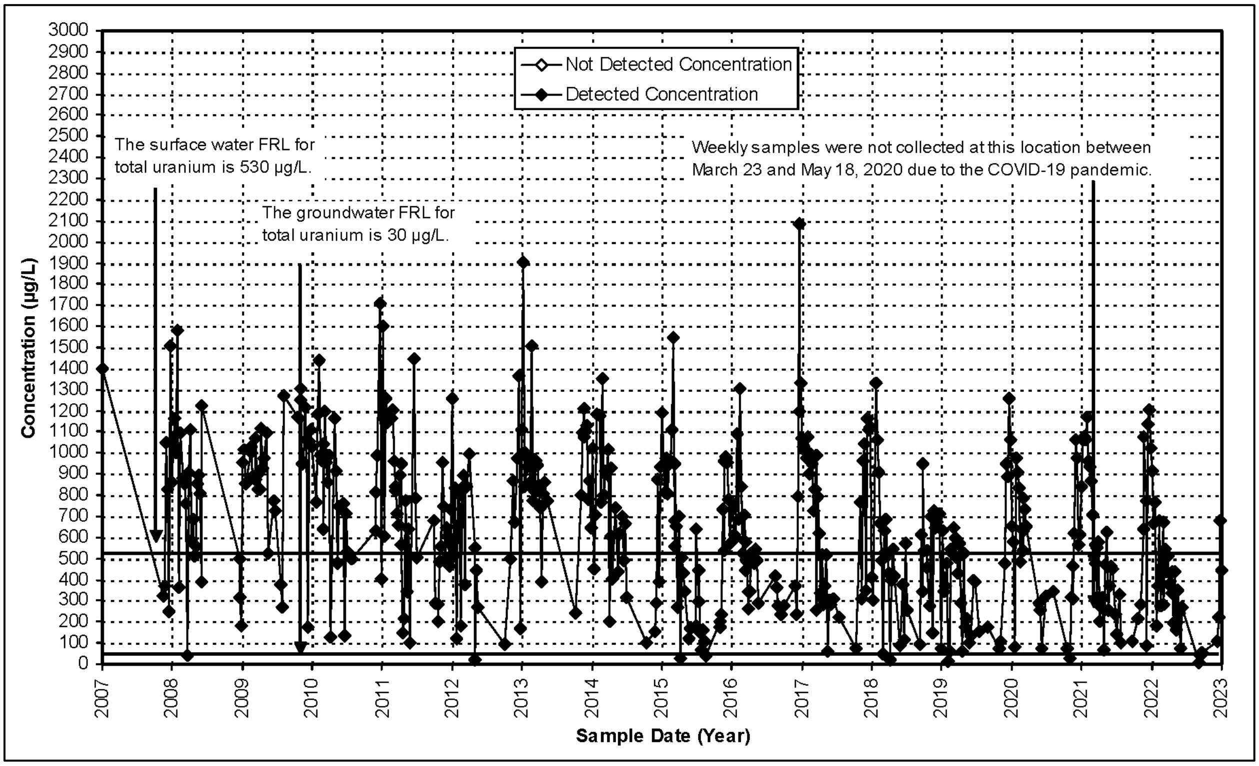

Figure B-2. Total Uranium Concentration Versus Time Plot for Location SWD-09 (Former Waste Storage Area)

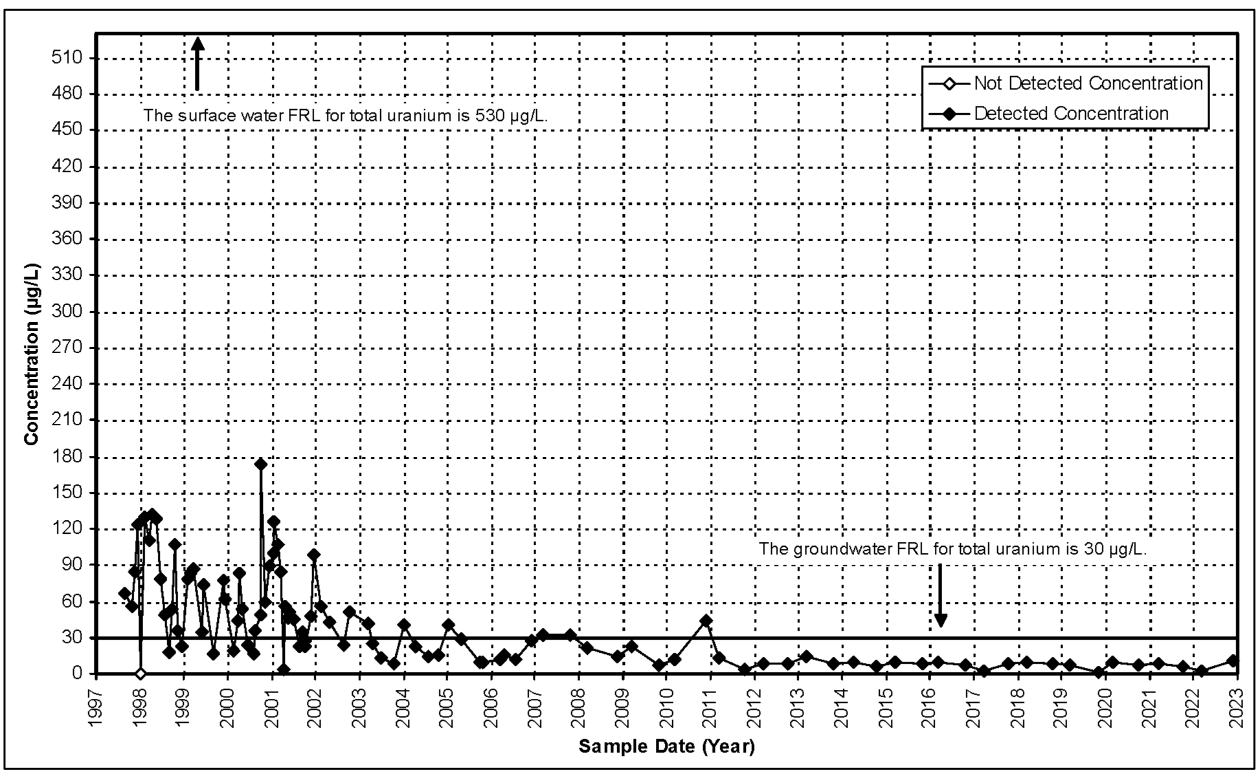

Figure B-3. Total Uranium Concentration Versus Time Plot for Location SWD-03 (Former Waste Storage Area) for Cross-Media Impact Evaluation

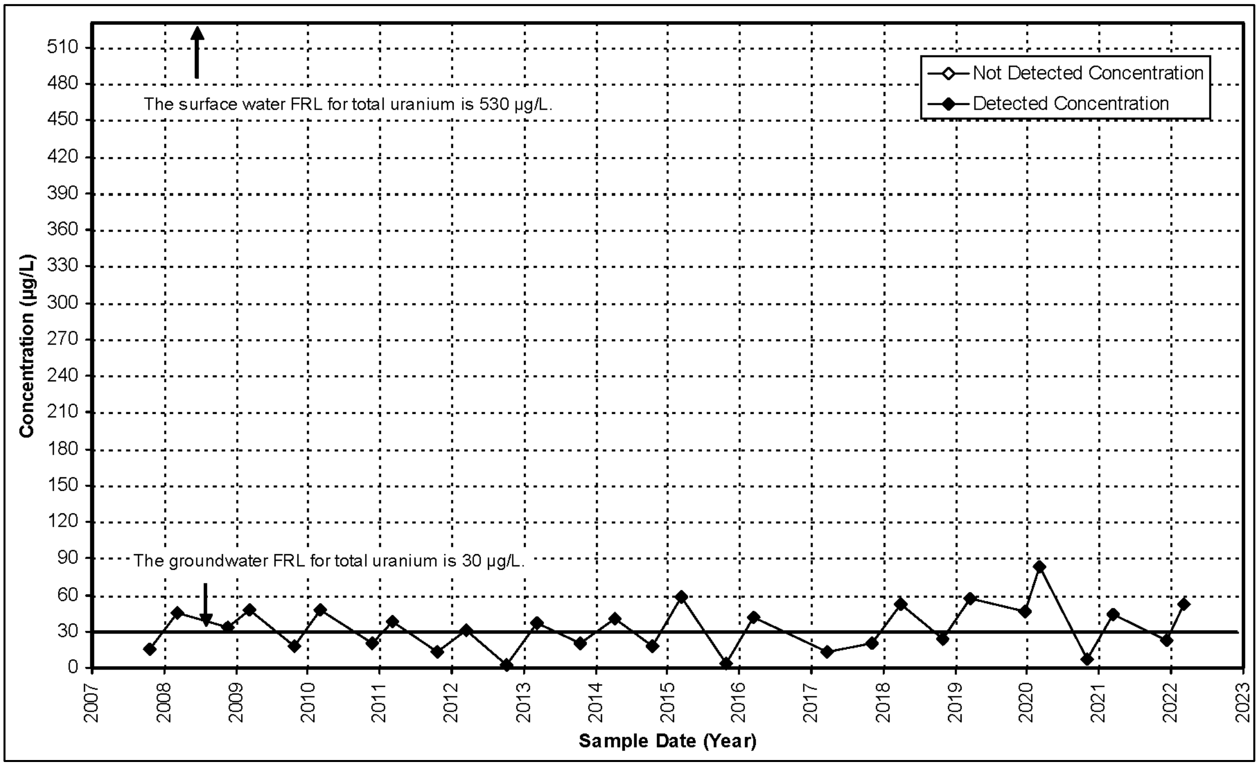

Figure B-4. Total Uranium Concentration Versus Time Plot for Location SWD-04 (Former Waste Pit 3) for Cross-Media Impact Evaluation

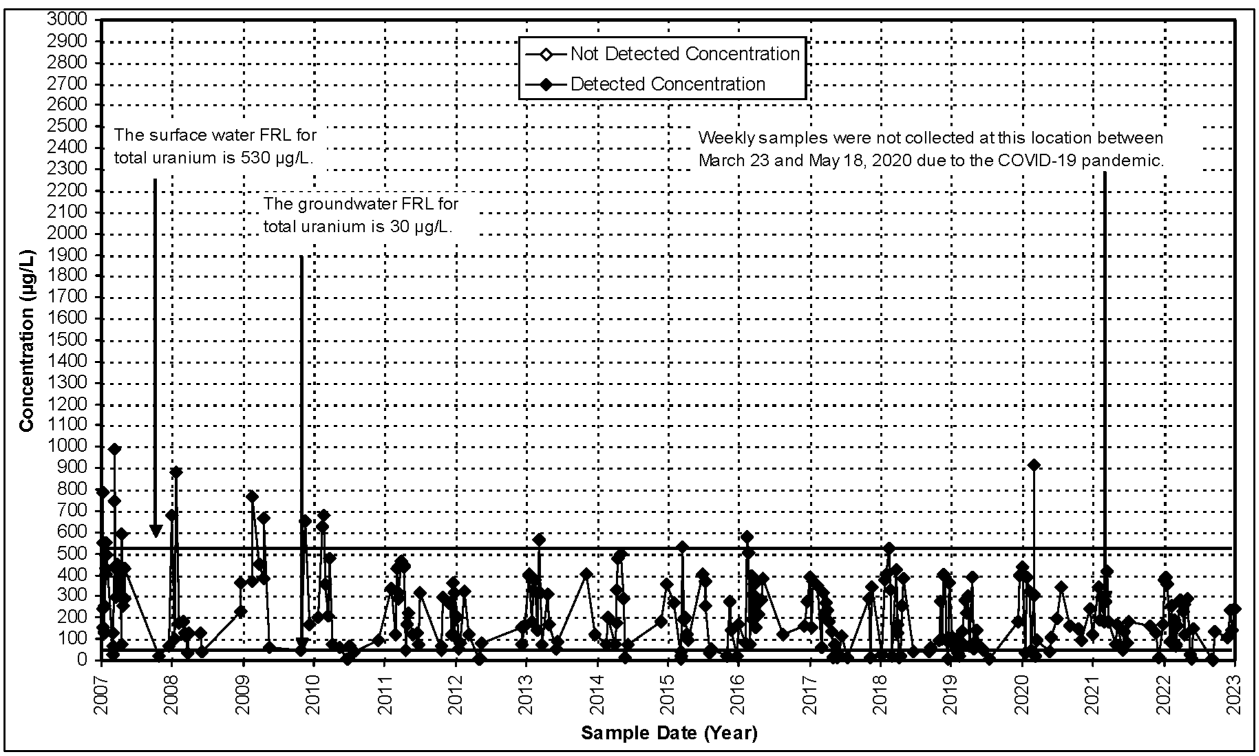

Figure B-5. Total Uranium Concentration Versus Time Plot for Location SWD-05 (Former Waste Storage Area) for Cross-Media Impact Evaluation

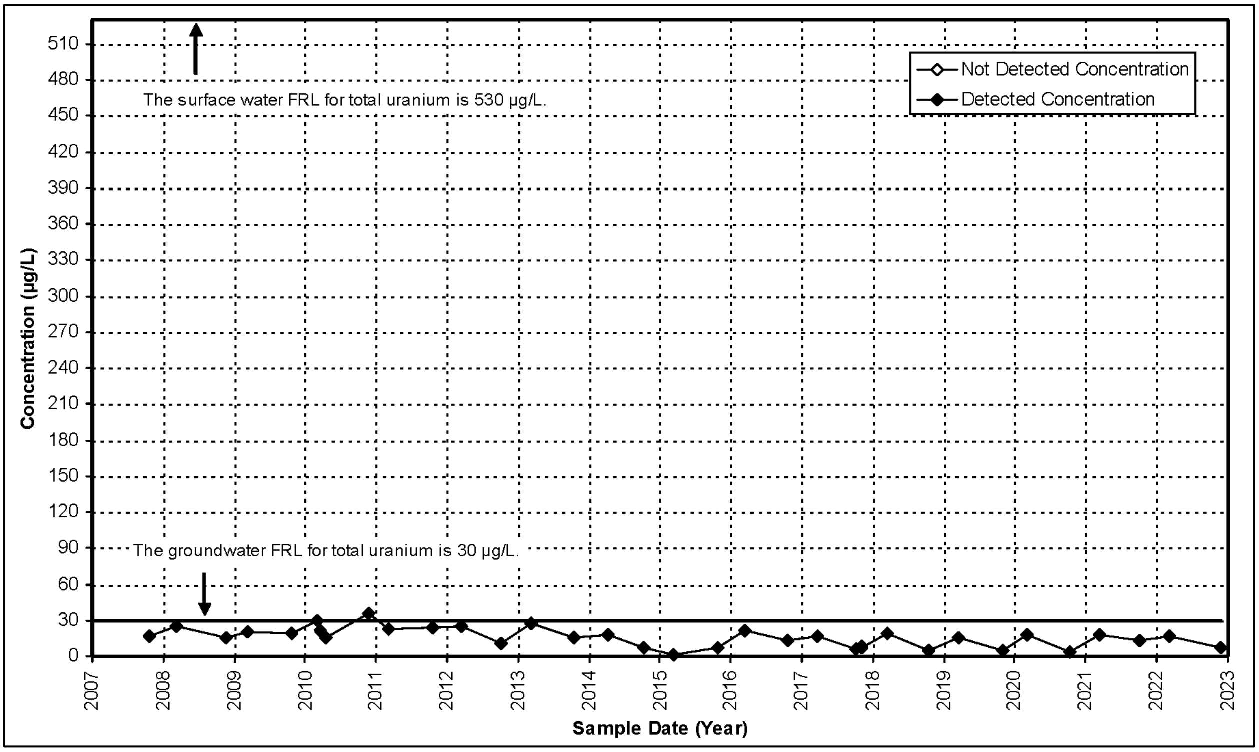

Figure B-6. Total Uranium Concentration Versus Time Plot for Location SWD-07 (Former Production Area Drainage) for Cross-Media Impact Evaluation

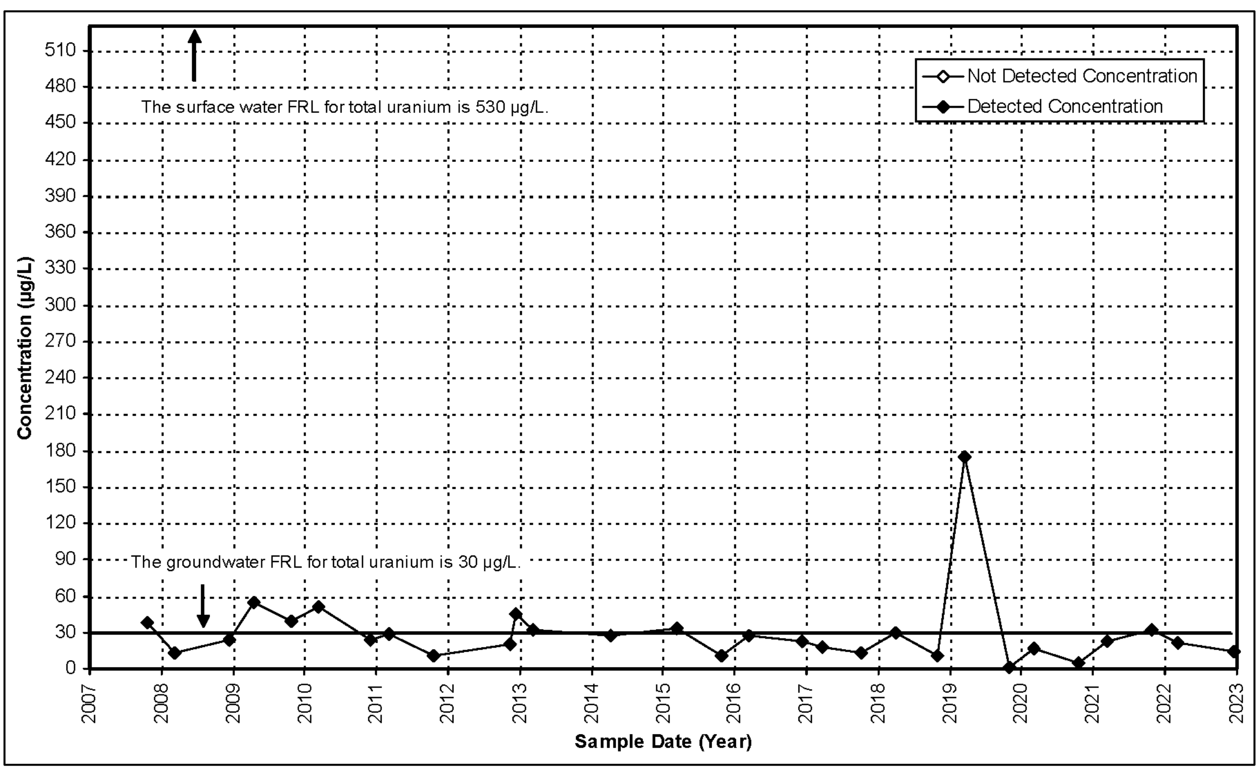

Figure B-7. Total Uranium Concentration Versus Time Plot for Location SWD-08 (Former Southern Waste Units) for Cross-Media Impact Evaluation

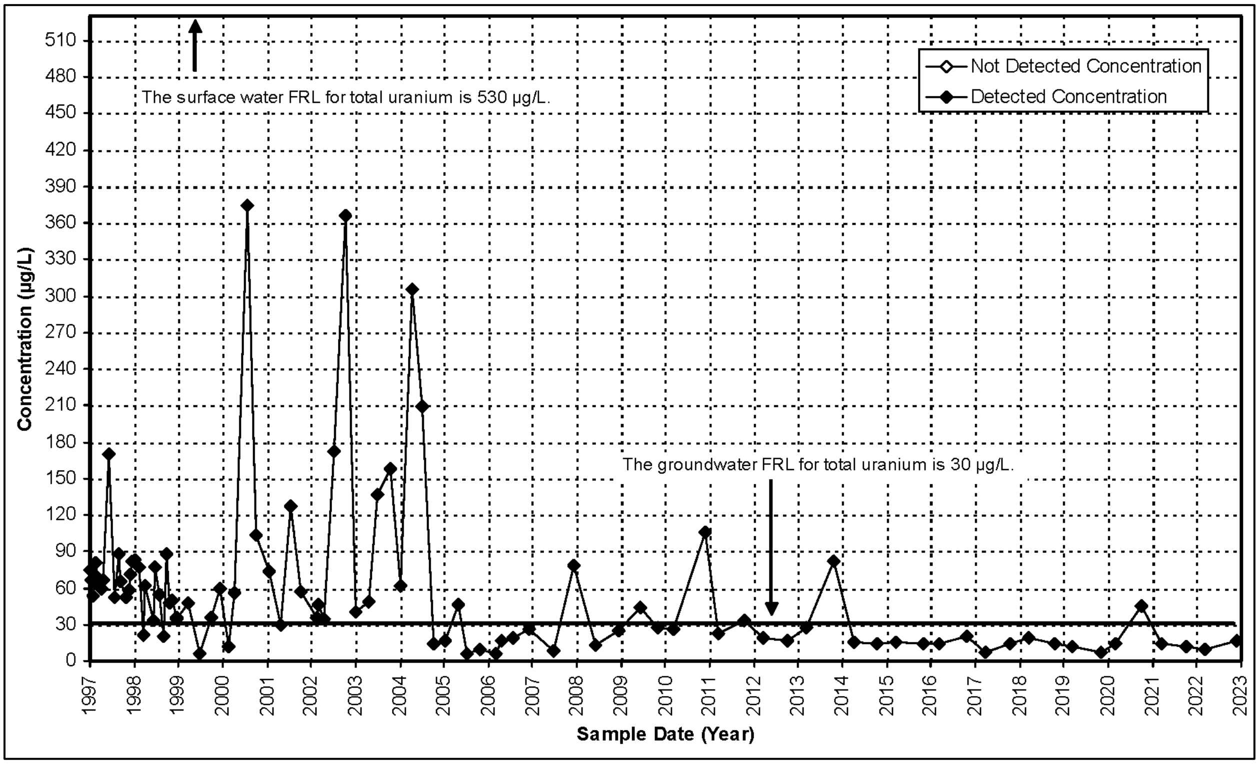

Figure B-8. Total Uranium Concentration Versus Time Plot for Location STRM 4005 (Drainage to Paddys Run) for Cross-Media Impact Evaluation

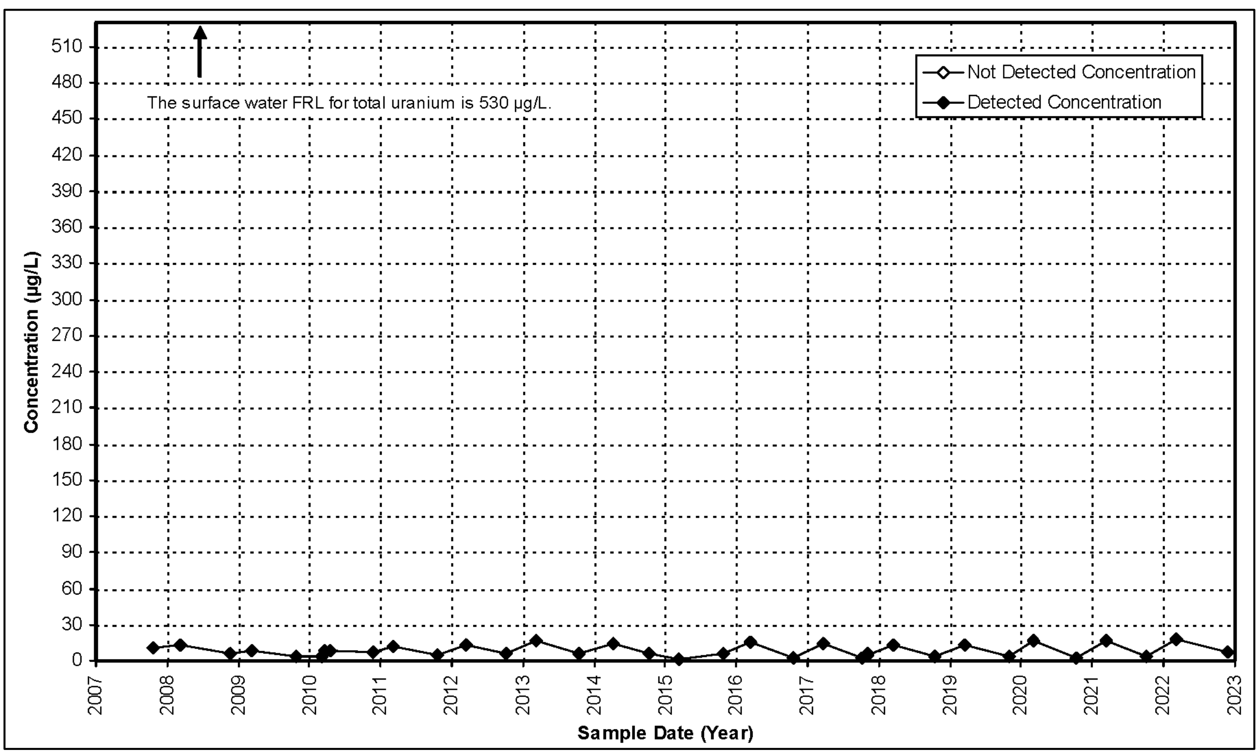

Figure B-9. Total Uranium Concentration Versus Time Plot for Location SWD-06 (Former Pilot Plant)

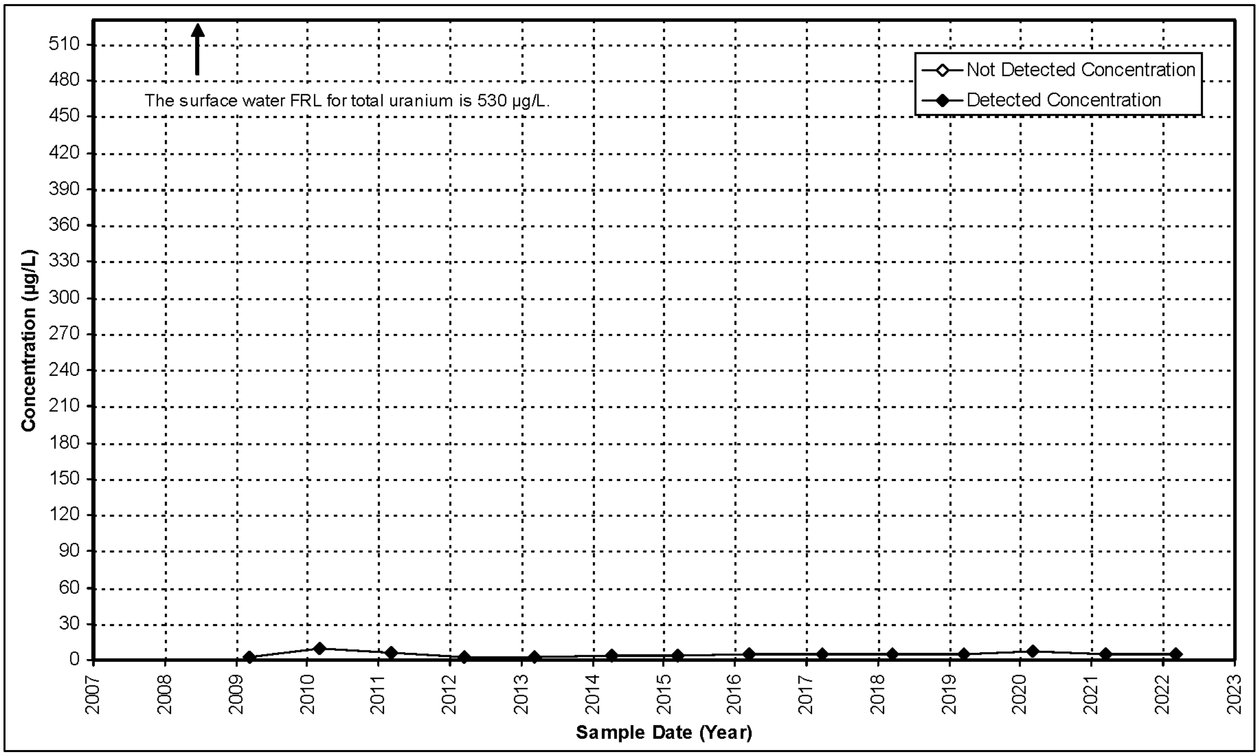

Figure B-10. Total Uranium Concentration Versus Time Plot for Location SWD-10 (Lodge Pond)

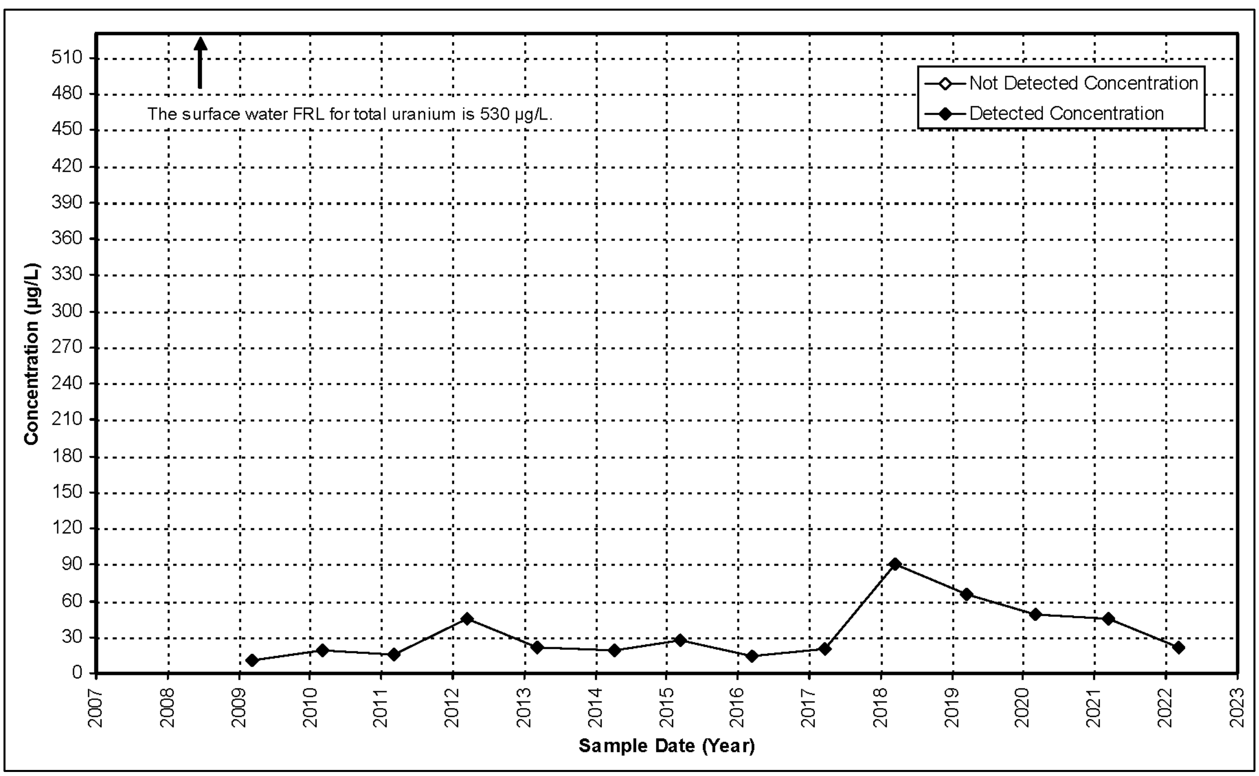

Figure B-11. Total Uranium Concentration Versus Time Plot for Location SWD-11 (Former Lime Sludge Pond)

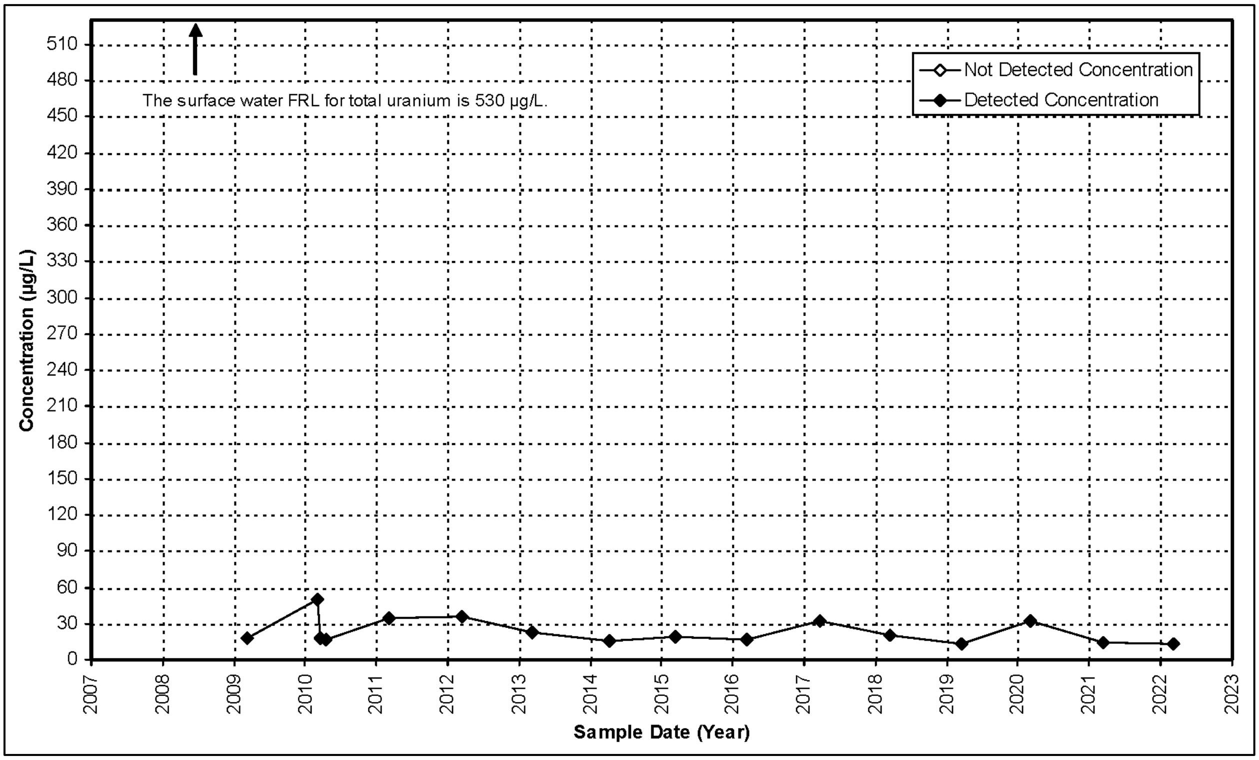

Figure B-12. Total Uranium Concentration Versus Time Plot for Location SWD-12 (Former Area 4B)

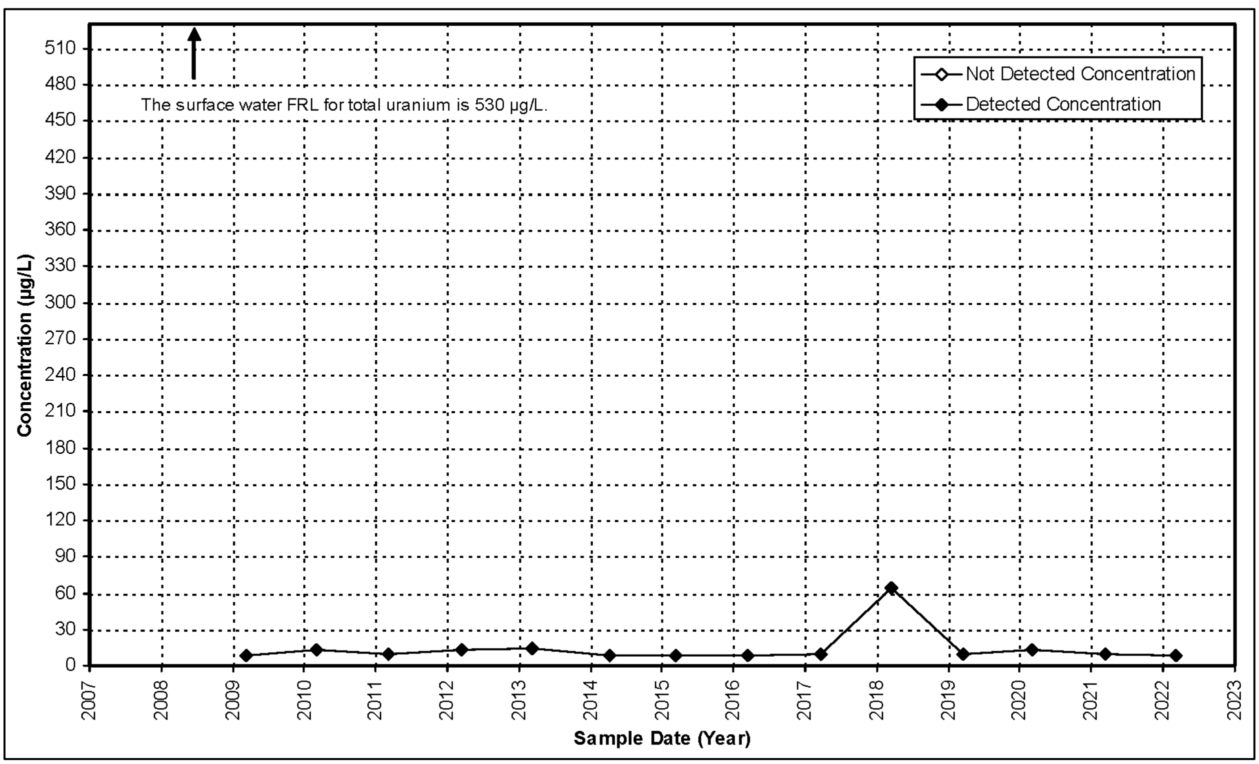

Figure B-13. Total Uranium Concentration Versus Time Plot for Location SWD-13 (Former Silos Area)

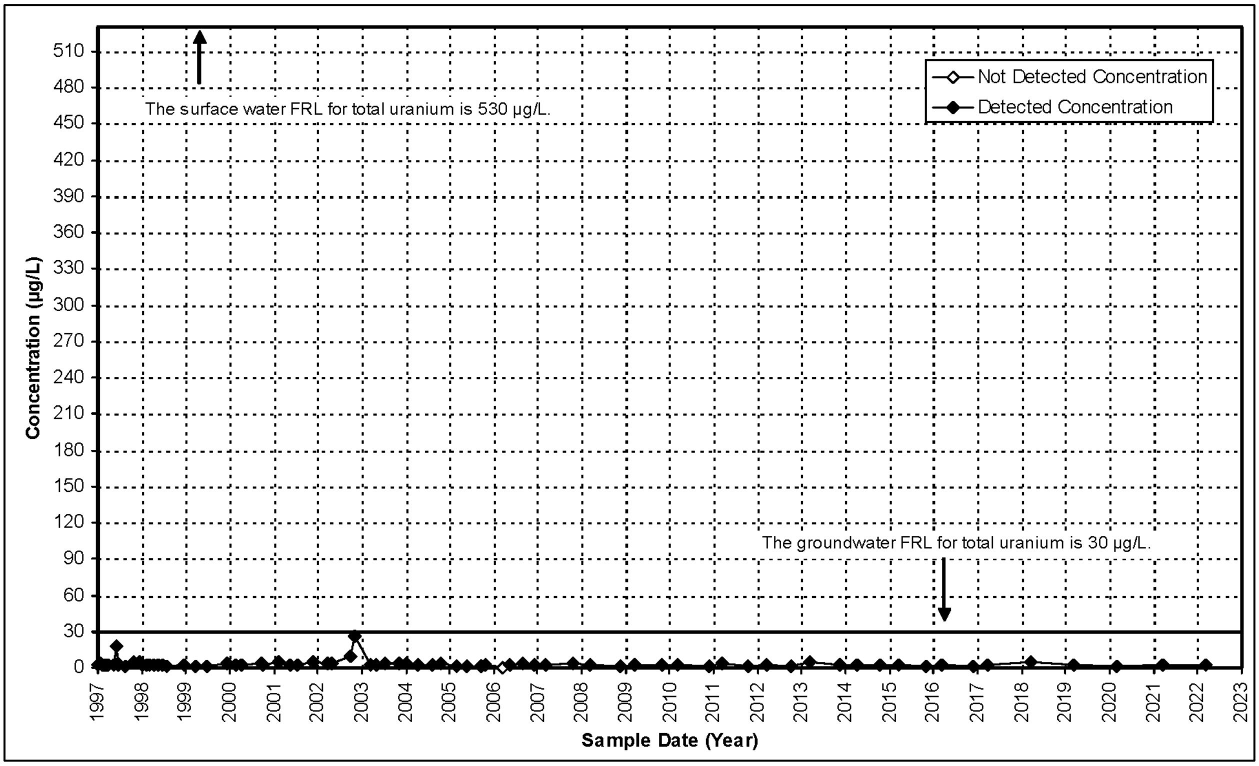

Figure B-14. Total Uranium Concentration Versus Time Plot for Location SWP-03 (Paddys Run at Downstream Property Boundary)

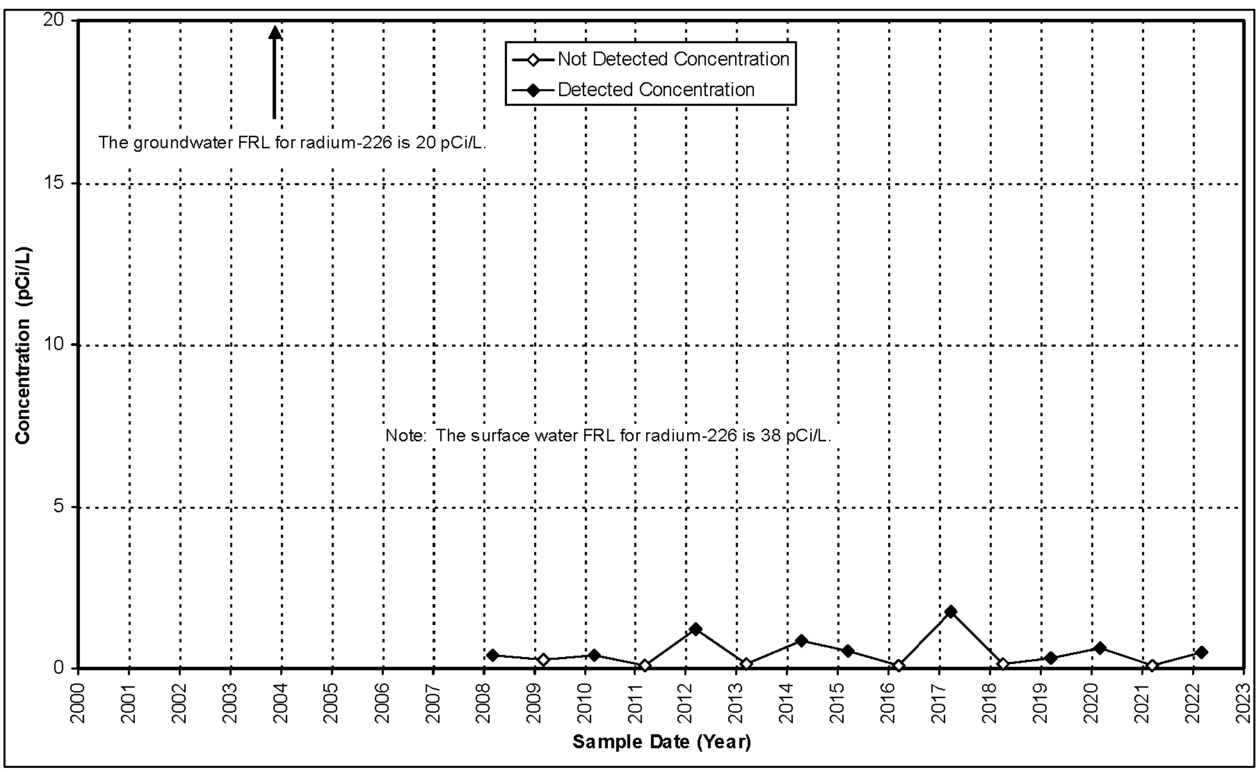

Figure B-15. Radium-226 Concentration Versus Time Plot for Location SWD-04 (Former Waste Pit 3) for Cross-Media Impact Evaluation

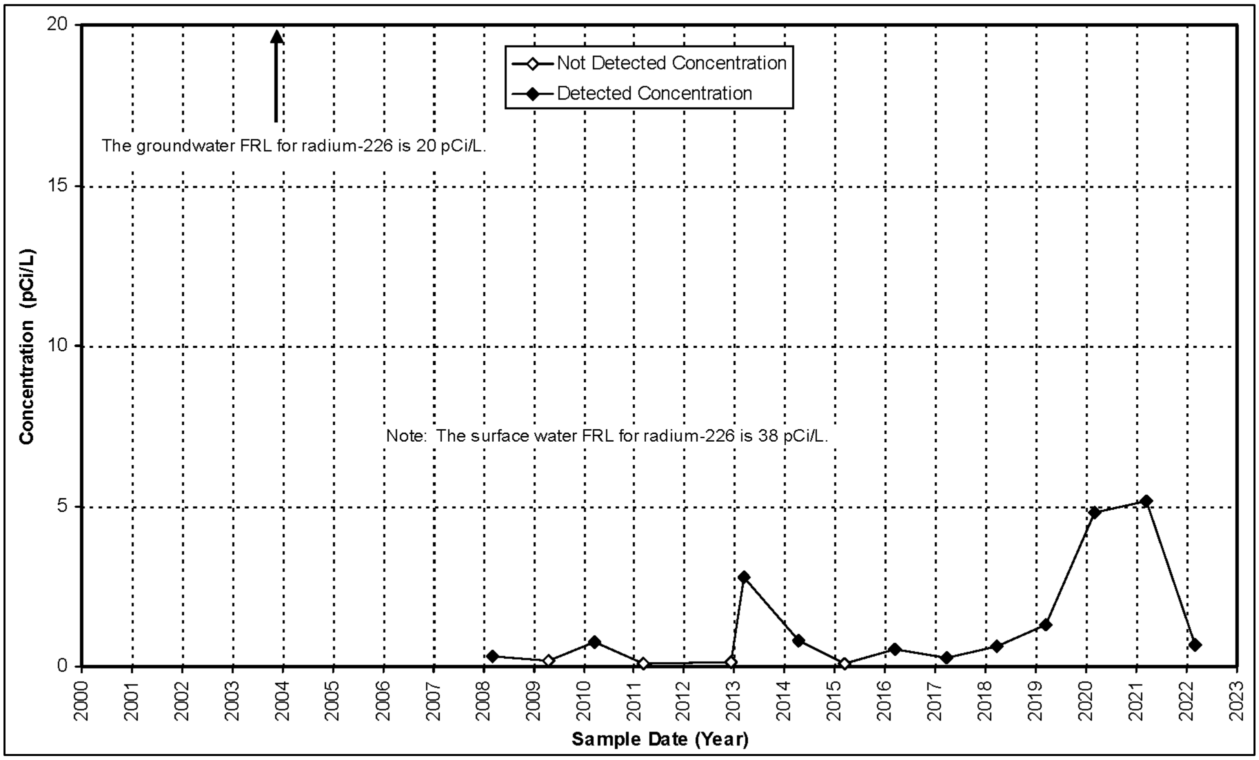

Figure B-16. Radium-226 Concentration Versus Time Plot for Location SWD-05 (Former Waste Storage Area) for Cross-Media Impact Evaluation

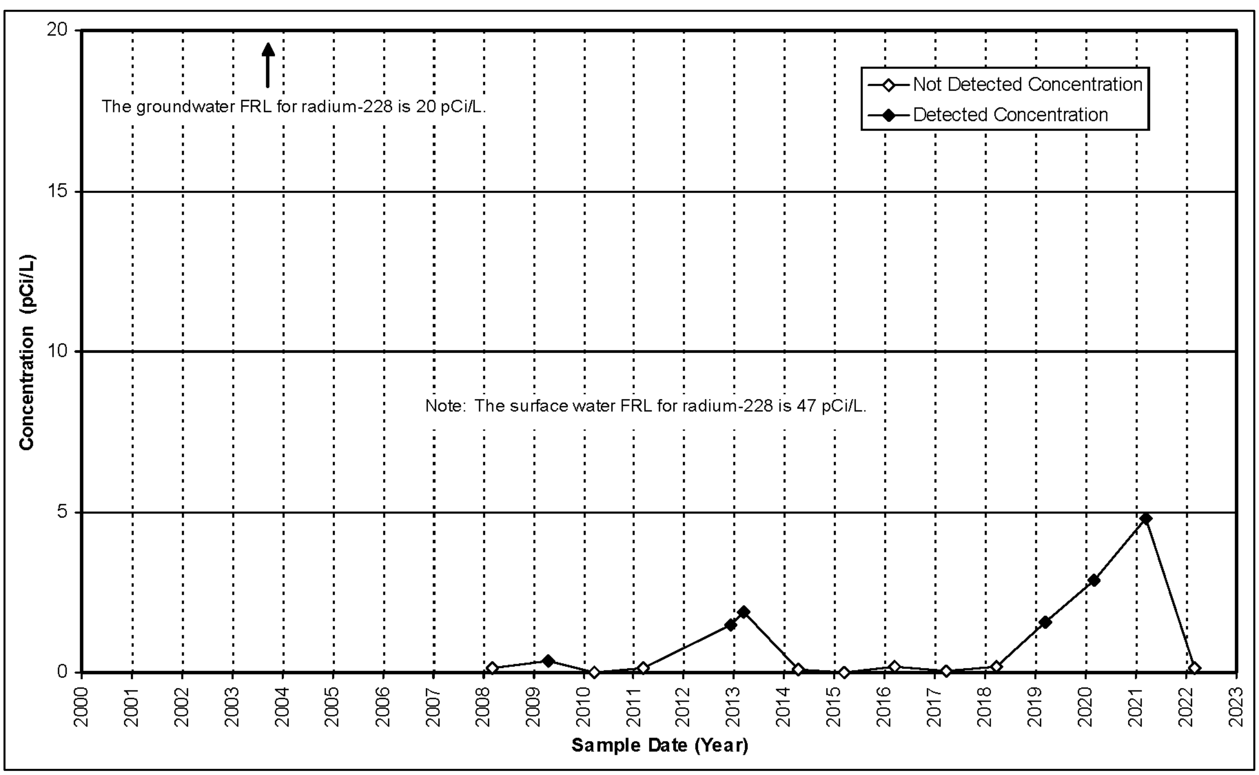

Figure B-17. Radium-228 Concentration Versus Time Plot for Location SWD-05 (Former Waste Storage Area) for Cross-Media Impact Evaluation

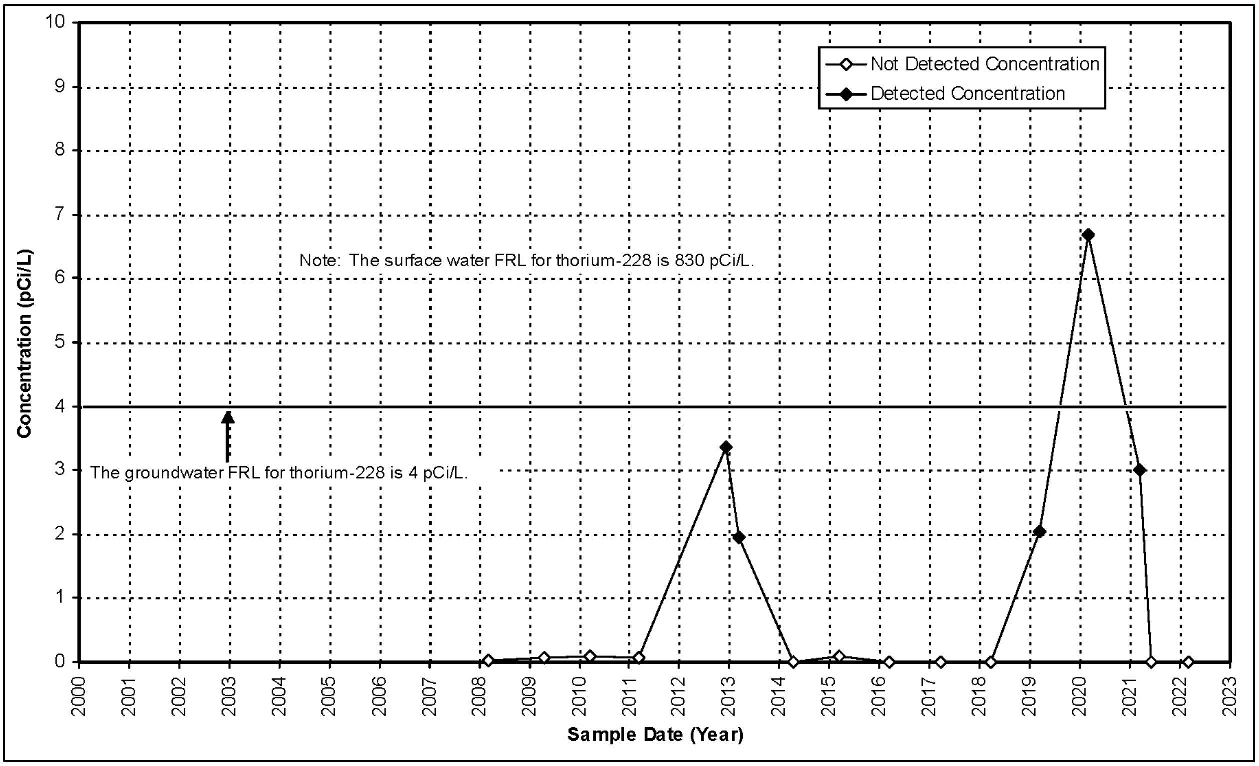

Figure B-18. Thorium-228 Concentration Versus Time Plot for Location SWD-05 (Former Waste Storage Area) for Cross-Media Impact Evaluation

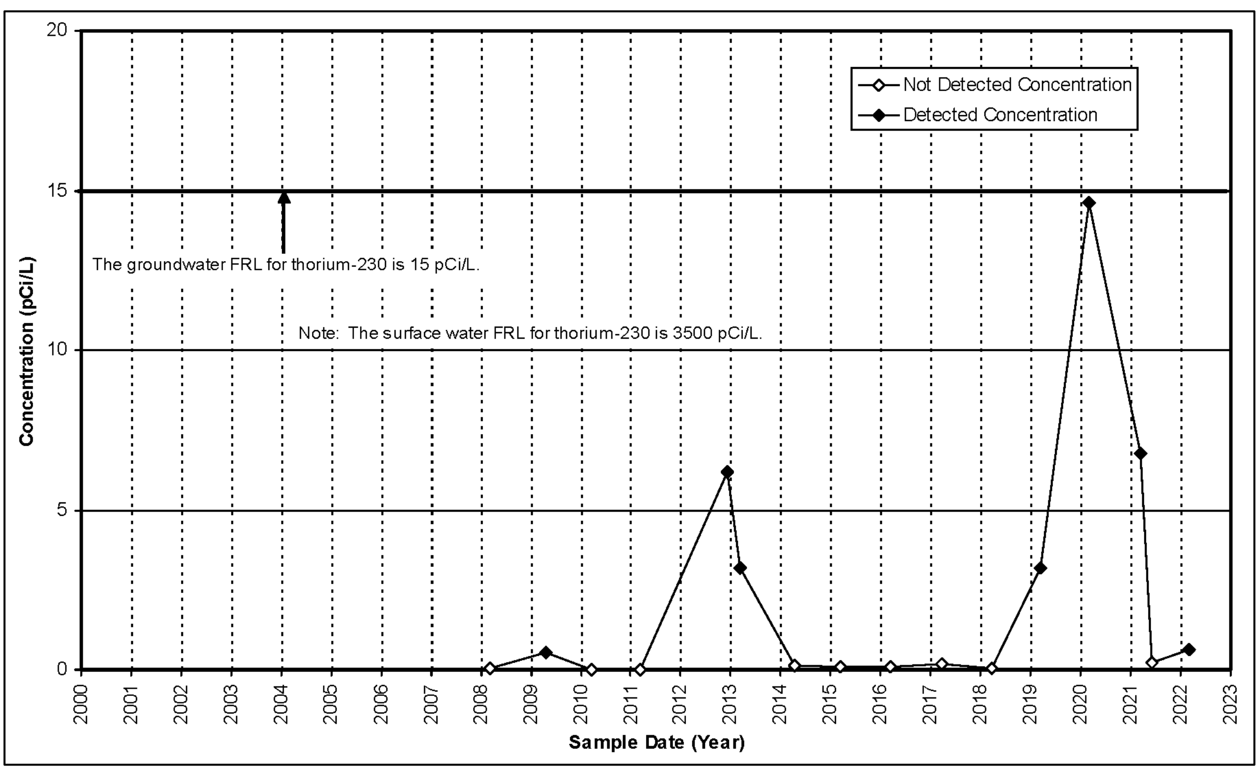

Figure B-19. Thorium-230 Concentration Versus Time Plot for Location SWD-05 (Former Waste Storage Area) for Cross-Media Impact Evaluation

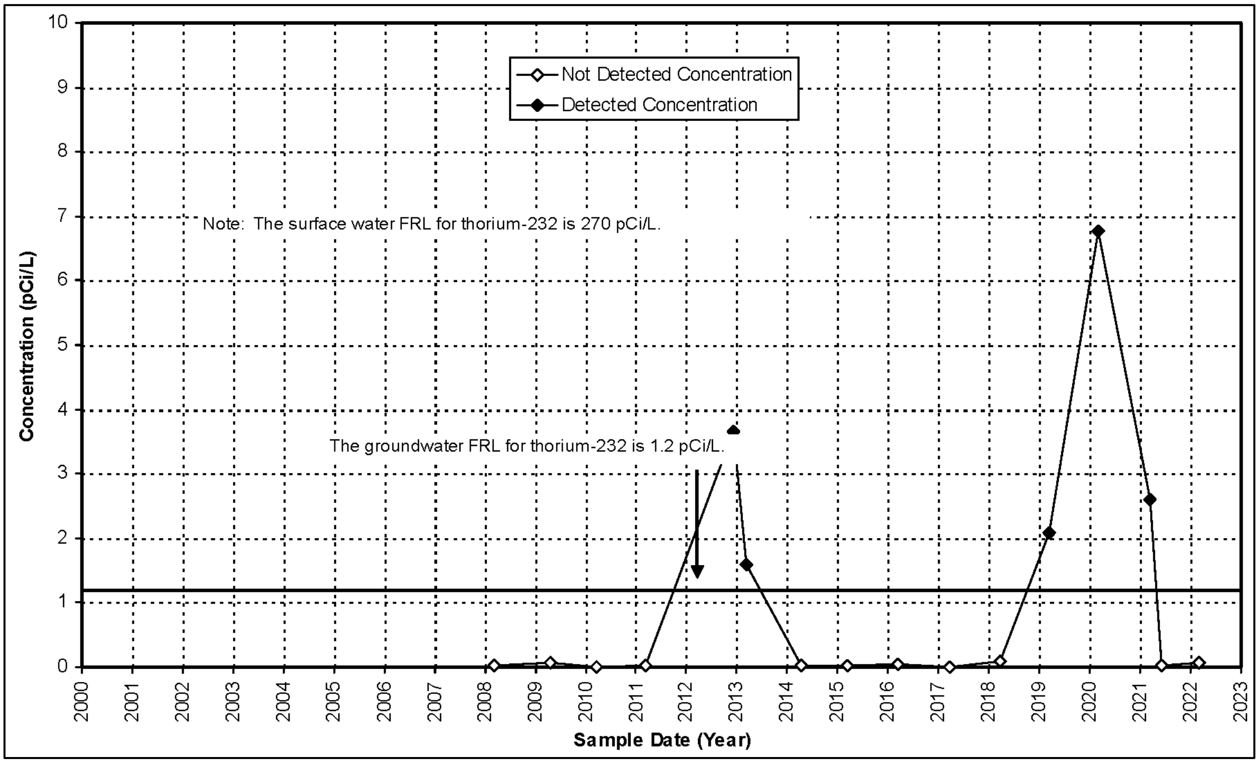

Figure B-20. Thorium-232 Concentration Versus Time Plot for Location SWD-05 (Former Waste Storage Area) for Cross-Media Impact Evaluation

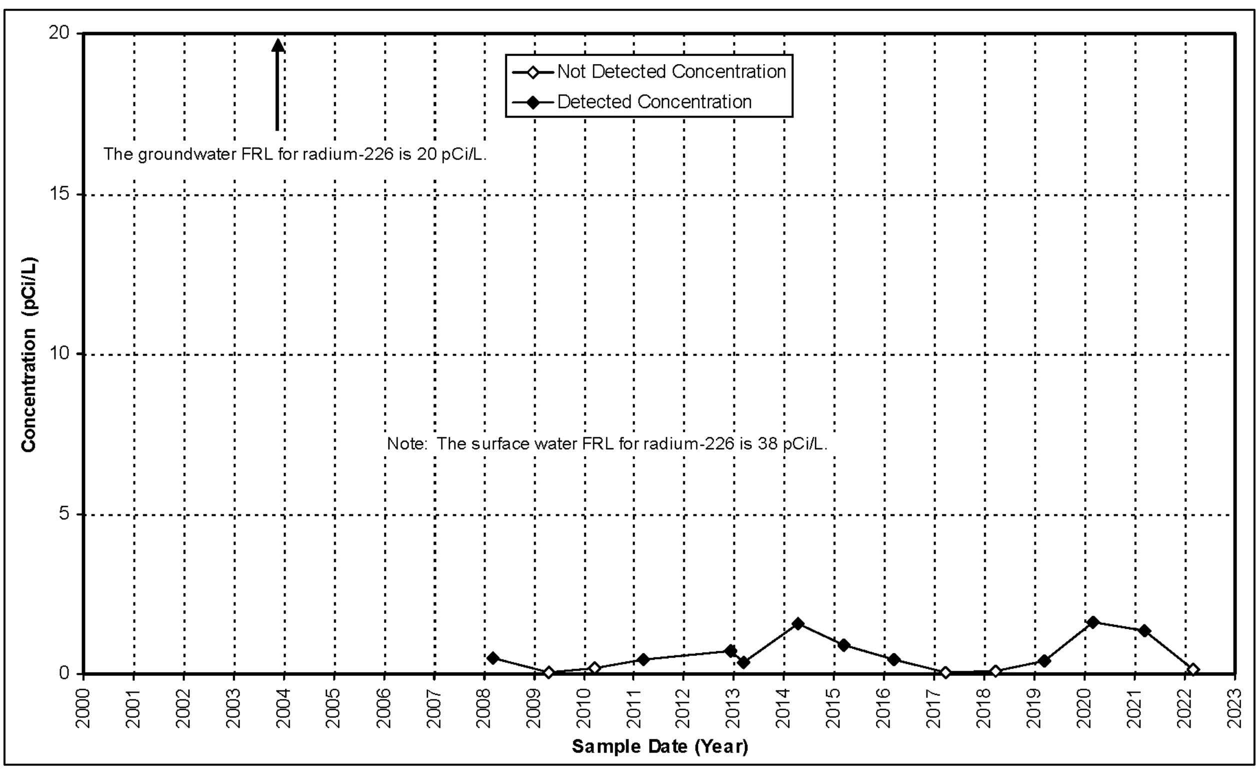

Figure B-21. Radium-226 Concentration Versus Time Plot for Location SWD-08 (Former Southern Waste Units) for Cross-Media Impact Evaluation

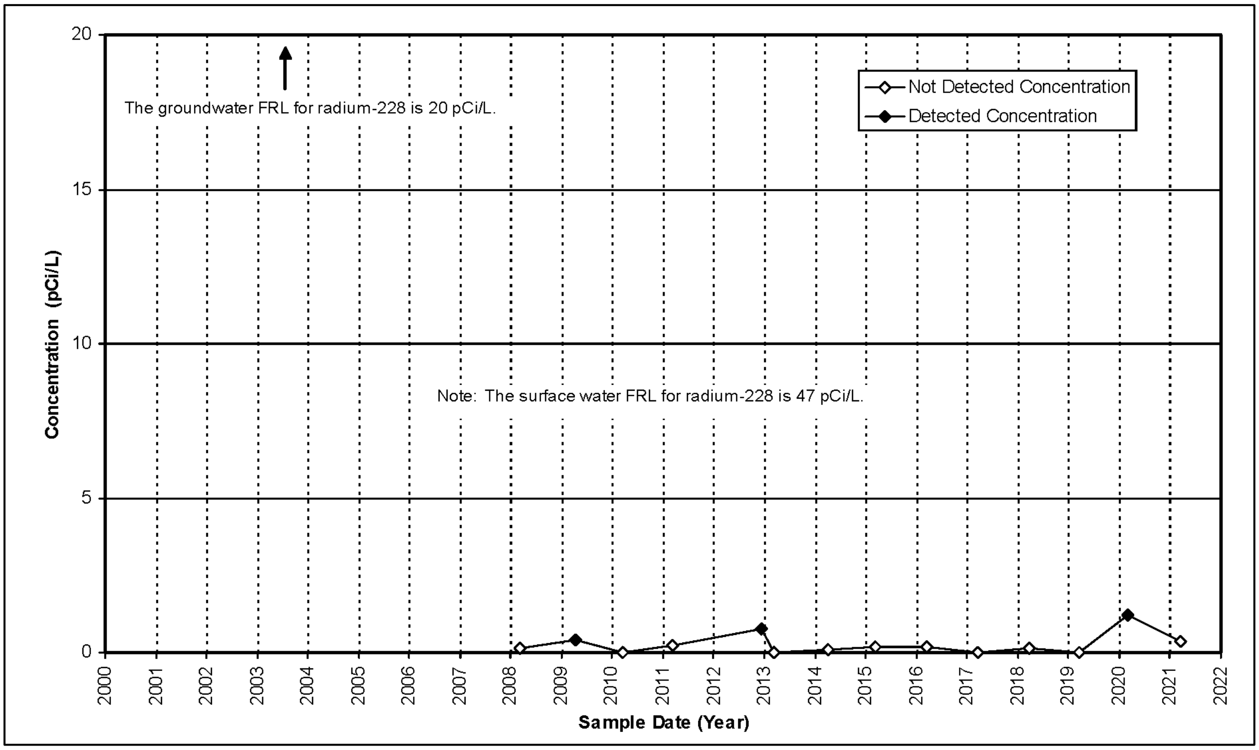

Figure B-22. Radium-228 Concentration Versus Time Plot for Location SWD-08 (Former Southern Waste Units) for Cross-Media Impact Evaluation

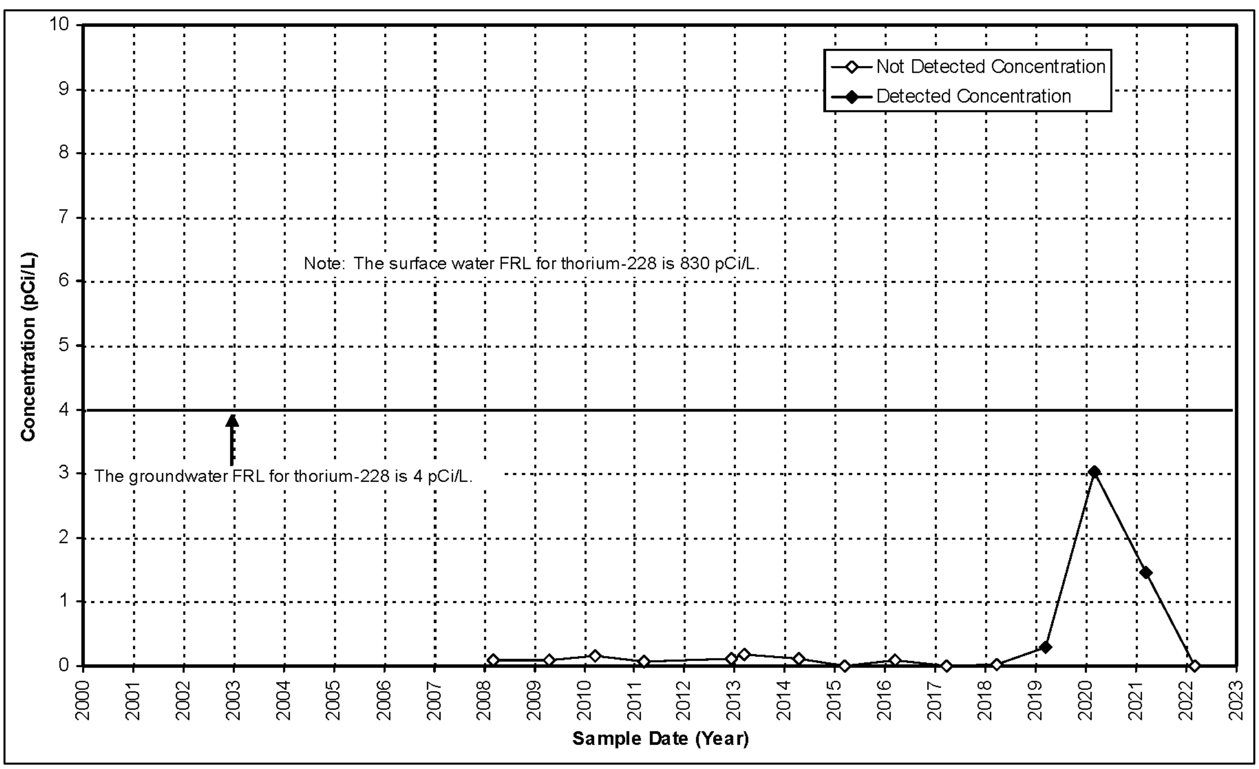

Figure B-23. Thorium-228 Concentration Versus Time Plot for Location SWD-08 (Former Southern Waste Units) for Cross-Media Impact Evaluation

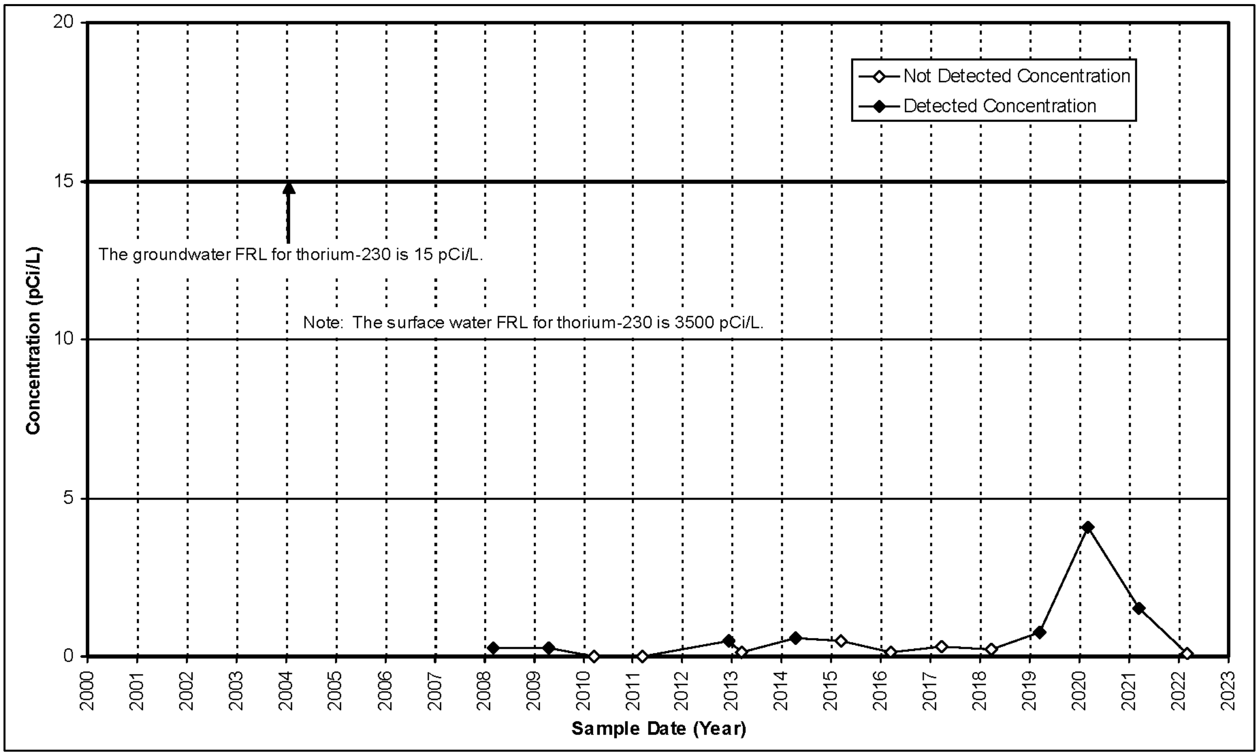

Figure B-24. Thorium-230 Concentration Versus Time Plot for Location SWD-08 (Former Southern Waste Units) for Cross-Media Impact Evaluation

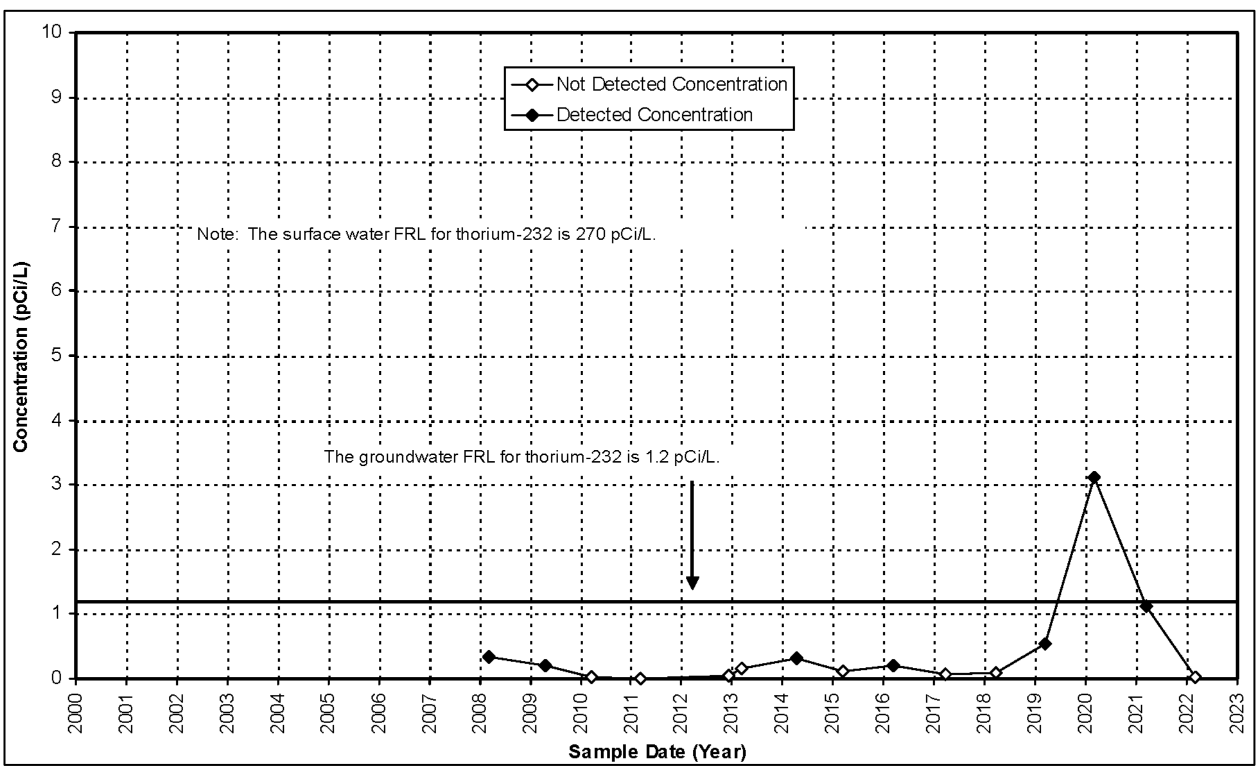

Figure B-25. Thorium-232 Concentration Versus Time Plot for Location SWD-08 (Former Southern Waste Units) for Cross-Media Impact Evaluation

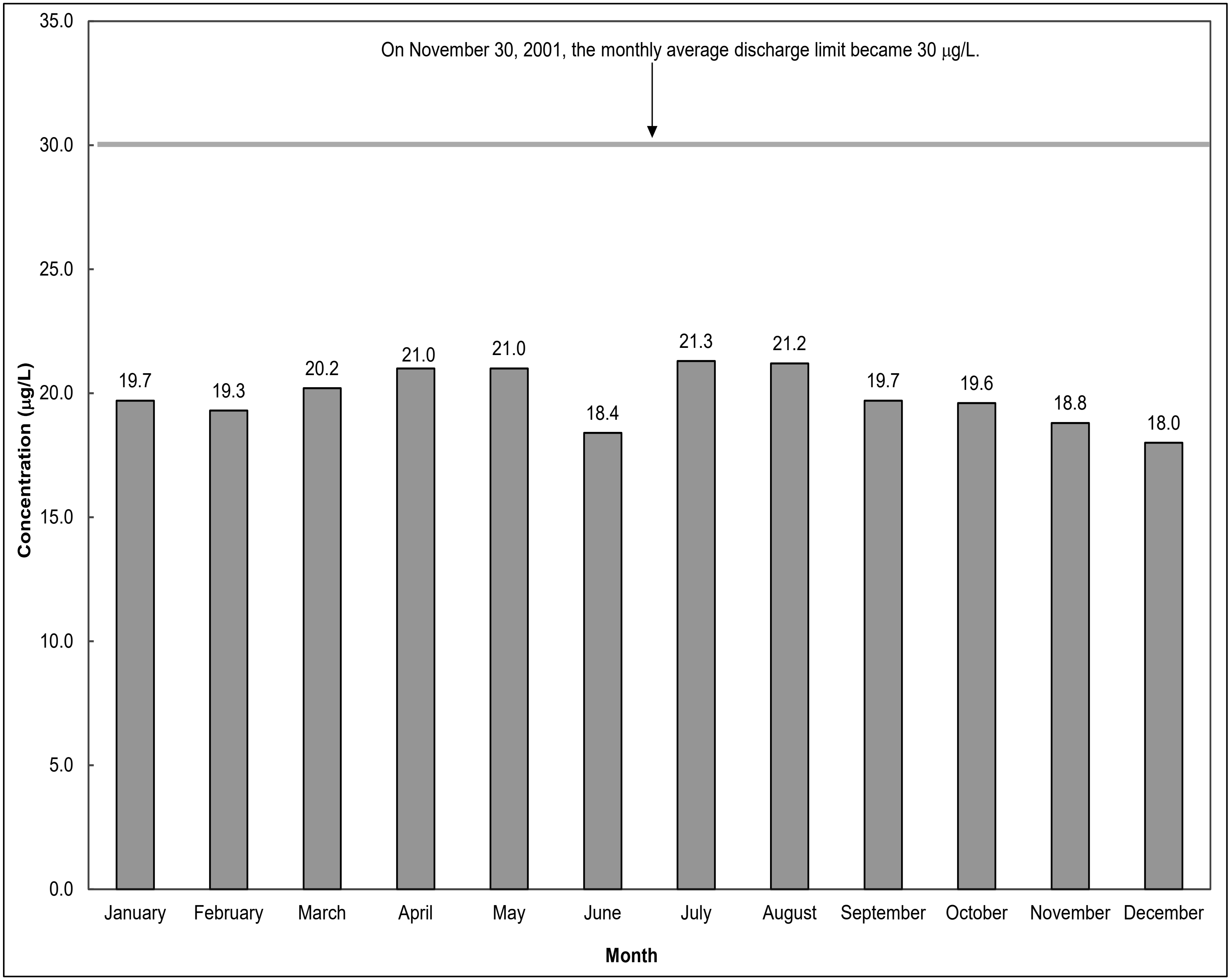

Figure B-26. 2022 Monthly Average Total Uranium Concentration in Water Discharged from PF 4001 to the Great Miami River

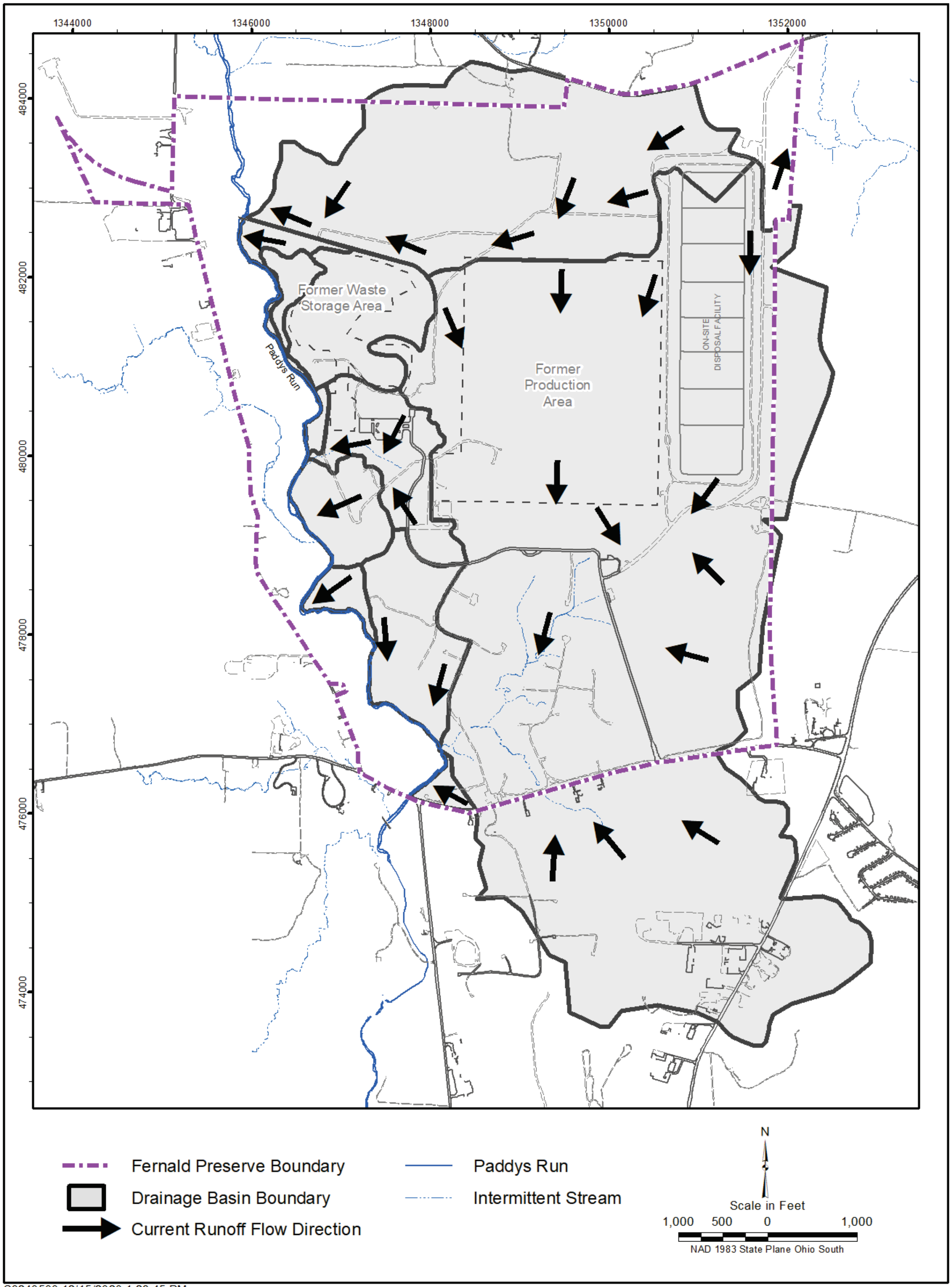

Figure B-27. Current Surface Water Basins and Runoff Flow Direction

Appendix C

Ecological Restoration

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Contents

Tables

Figures

Abbreviations

CC	coefficient of conservatism
DOE	U.S. Department of Energy
FQAI	Floristic Quality Assessment Index
GEMS	Geospatial Environmental Mapping System
LMICP	*Comprehensive Legacy Management and Institutional Controls Plan*
NRRP	Natural Resource Restoration Plan
OSDF	On-Site Disposal Facility
RAMP	Restored Area Maintenance Plan

Measurement Abbreviation

m^2	square meters

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C.1.0 Ecological Restoration Monitoring

This appendix presents data collected as part of ecological restoration monitoring activities at the Fernald Preserve, Ohio, Site, along with results from routine inspections of the site and the On-site Disposal Facility (OSDF). Ecological restoration monitoring in 2022 included an evaluation of prairie and successional communities across the site.

Ecological restoration monitoring is required as part of the natural resource damage settlement among the U.S. Department of Energy (DOE), the Ohio Environmental Protection Agency, and the U.S. Department of the Interior. The Fernald Preserve Natural Resource Restoration Plan (NRRP) (State of Ohio 2008) specifies ecological restoration monitoring requirements.

Vegetation goals for restored areas were established in the NRRP. These include 50% native species composition and 90% total cover. This document established the ecological restoration monitoring program at the Fernald site. The *Fernald Preserve, Ohio, Restored Area Maintenance Plan* (RAMP, DOE 2012) is an additional document that was required by the NRRP. The RAMP established a maintenance program for ecologically restored areas across the site. The NRRP called for a 10-year review of the RAMP by the Fernald Natural Resource Trustees. That review was conducted in 2020 and resulted in the development of the draft final *Fernald Preserve, Ohio, Site Natural Resource Management Plan.* The Fernald Natural Resource Trustees agreed that requirements in the RAMP could be refined to include an evaluation component, since both monitoring and evaluation help to direct maintenance activities. As a result, the Natural Resource Management Plan includes not only refinements to maintenance requirements for restored areas but also refinements to ongoing monitoring requirements. Beginning in 2023, the Natural Resource Management Plan is included as Appendix A of Volume I of the Fernald Preserve *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP) (DOE 2023). Further detail regarding the revised monitoring approach is provided below.

Prior to 2021, a two-tier ecological monitoring program was used to assess restoration efforts. Implementation monitoring was used to evaluate vegetation establishment following seeding and planting projects. Functional monitoring was used to assess the progress of the development of a restored community (prairie, wetland, forest) by comparing floristic quality parameters to those of baseline and reference sites (DOE 2002). Reference sites are offsite communities that represent an ideal end-state for site restoration projects. In 2020, a review of 10 years of data showed that NRRP goals for native species were mostly met, there had been much improvement over baseline conditions, and comparison to reference sites were sometimes met. Based on this review, the Fernald Natural Resource Trustees agreed that a shift from project-specific functional monitoring to a community-based approach for ecological monitoring is more appropriate.

The community-based monitoring involves the development of floristic inventories for each restoration community. Floristic inventories are compiled by conducting a series of walkdowns within a particular community type throughout the growing season. The result is a comprehensive list of vascular plant species for each monitoring area. Figure C-1 shows the breakdown of community types for which floristic inventories are completed. Remediation wetland areas, remediation prairie areas, and remediation successional areas are areas of the site where extensive ground disturbance took place. They are characterized by having little to no topsoil or nearby established vegetation in place when ecological restoration efforts began.

Perimeter wetland areas, perimeter successional areas, restoration forest areas, and existing forest areas are areas where little or no ground disturbance took place. Topsoil was usually still in place at the time ecological restoration efforts began. Each community type will be evaluated on a 3-year rotation. The rotation was implemented in 2021 beginning with perimeter and remediation wetland areas. Remediation prairie areas and remediation successional areas were monitored in 2022; results of that monitoring are presented in this report. Existing forest areas, restoration forest areas and perimeter successional areas will be monitored in 2023. In 2024, the monitoring cycle will repeat with monitoring of perimeter and remediation wetland areas.

Vegetation monitoring of the OSDF is required in accordance with Volume II of the LMICP (DOE 2019a). Monitoring to determine the percentage of native cover on one-third of the OSDF cap is completed annually so that the entire cap is monitored over a 3-year period. DOE and the regulatory agencies agree that the goal is not necessarily to establish a functioning prairie on the OSDF cap, but having 90% total cover and 50% native cover are goals established for the vegetated cap. Vegetation on OSDF cell caps 7 and 8 were monitored in 2022, and the results were presented in the September 2022 quarterly inspection report. Results indicate that the vegetative total cover of both cells is greater than 98%. Native cover for OSDF cell caps 7 and 8 were 65% and 67%, respectively. With approval from the regulators and stakeholders, DOE is planning to provide results of the OSDF vegetation monitoring in the annual Site Environmental Report rather than the OSDF quarterly inspection reports beginning in 2023. This will include a map showing the monitoring location and a summary of the results compared to the goals.

C.2.0 Functional Monitoring

Prior to 2015, functional monitoring was conducted on a sitewide community basis, with wetland monitoring completed one year, prairie monitoring the next, and forest monitoring the third year. From 2015 through 2020, a management-area approach was implemented to ensure that restored areas were maintained on a 3-year rotation (Figure C-2). Functional monitoring in prairie and woodland areas consisted of establishing 15 random 1 square meter (m^2) quadrats that were surveyed for herbaceous vegetation during the growing season (April through September). Surveys were divided into three rounds of five quadrats to ensure coverage throughout the growing season. For each quadrat, species richness and cover data were recorded for herbaceous vegetation. Additional 1,000 m^2 plots were used to collect woody data from each forest community. Species abundance and size data using diameter at breast height measurements were collected for woody vegetation in forest communities. Wetland communities were surveyed via fixed grids as described in the *Fernald Preserve Wetland Mitigation Monitoring Plan* (DOE 2009).

In 2021, wetland communities were evaluated through the revised approach to functional monitoring using the new floristic inventory method. In 2022, remediation area communities across the site were evaluated through this revised approach to functional monitoring. Remediation areas were divided into remediation successional areas, where the long-term management goal is to allow natural forest succession to take place, and remediation prairie areas, where restored prairies will be maintained as prairie communities through vegetation management.

The monitoring areas were surveyed in three rounds to ensure that data were collected through the entire growing season. For each round, the entire monitoring area was examined, and each species observed was recorded. Native and non-native species richness and species composition, average coefficient of conservatism (CC), and Floristic Quality Assessment Index (FQAI) were calculated from the data. Processes for calculating monitoring parameters for all communities are described in the *Fernald Preserve, Fernald, Ohio, Ecological Monitoring Methods Plan and Procedures* (DOE 2021). The latest Ohio FQAI database (Gara 2013) was used to determine nativity status and CC values. The floristic inventory results presented in Table C-1 allow for comparison of the two communities. A total of 266 species were observed with slightly more species identified in remediation successional areas than remediation prairie areas, 222 and 209 species, respectively. Remediation successional areas also had higher native species percent, mean CC, and FQAI scores (Table C-1).

Table C-2 provides a multiyear comparison of mean CC value, FQAI, and percent native species for areas surveyed in 2022. For data presented in Table C-2 from 2010 to 2020, a species list was compiled from previous ecological monitoring data and used to calculate mean CC, FQAI and percent native species for the current floristic inventory areas (Figure C-1). While FQAI is included in Table C-2, this value is influenced by the size of the surveyed area. The new floristic inventory method requires surveys of much larger areas than those previously surveyed for functional monitoring. Because of this, FQAI will be more useful for comparisons of future floristic inventories. Mean CC is a more appropriate index for historical comparisons using previous methods. Spyreas (2016) has shown that mean CC values are useful for comparison when there is variability in plot size and sampling intensity, as well as species misidentification. Mean CC will also be useful for comparisons to future floristic inventories. Species nativity will have value for historical comparisons; however, this could also be influenced slightly by the larger survey areas. This metric will also be useful for future comparisons. It should also be noted that for the remediation successional areas, the 2022 monitoring activities were the most extensive to date. Some remediation successional areas monitored in 2022 have never been monitored or were not consistently monitored. This reinforces the need to use mean CC and native species percent for historical comparison rather than FQAI, which is affected by survey area size.

Table C-2 shows a slight increase in mean CC for remediation successional areas since 2010. For remediation prairie areas, the highest mean CC value was recorded in 2022; however, remediation prairie areas have remained relatively stable since 2010. FQAI scores for both monitoring areas have continued to increase since monitoring began in 2010. Increases in the 2022 FQAI scores were anticipated due to the larger areas surveyed using the new functional monitoring method. Conclusions cannot be drawn from the 2022 FQAI scores alone. Future surveys will be required for comparison. Native species percent continues to increase in both remediation prairie areas and remediation successional areas to 67% and 70%, respectively. In 2022, 155 of the 222 species identified in remediation successional areas are native species. Of these, 18 species of *Carex* sedges were identified (Table C-1). *Carex* sedges are of particular interest due to their high diversity and the many sensitive species in the genus. Several species of interest were observed in remediation successional areas in 2022. Narrow-leaved ladies' tresses (*Spiranthes vernalis*) and rosepink (*Sabatia angularis*) were observed for the first time at the Fernald Preserve. Several high CC value species observed included blue and white false indigo (*Baptisia australis* and *Baptisia lactea*), sideoats grama grass (*Bouteloua curtipendula*), fescue sedge (*Carex festucacea*), Muhlenberg's sedge (*Carex muhlenbergii*), purple coneflower

(*Echinacea purpurea*), Canada wildrye (*Elymus canadensis*), rattlesnake master (*Eryngium yuccifolium*), winged monkeyflower (*Mimulus alatus*), compass plant (*Silphium laciniatum*), prairie dock (*Silphium terebinthinaceum*), cup plant (*Silphium perfoliatum*), lesser ladies' tresses (*Spiranthes ovalis*), and stiff goldenrod (*Solidago rigida*). Additionally, several high CC value species indicative of wooded habitats were observed, including sweetgum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*), white oak (*Quercus alba*), swamp white oak (*Quercus bicolor*), bur oak (*Quercus macrocarpa*), chinquapin oak (*Quercus muehlenbergii*), northern red oak (*Quercus rubra*), and American basswood (*Tilia americana*). The presence of these tree species is encouraging as the long-term management goal for the remediation successional areas is forest development. The presence of high CC woody and prairie species is evidence that while these areas are still dominated by prairie habitats, forest succession is underway. The extensive soil disturbance from restoration activities throughout these areas may slow the successional process, which in undisturbed conditions can take decades, or even centuries. Continued monitoring and management for invasive species will be needed to achieve this goal.

Of the 209 species identified in remediation prairie areas in 2022, 140 are native species and 15 species of *Carex* sedges were observed. Several high CC species were observed in the remediation prairie areas, including sessile toothcup (*Ammannia robusta*), blue and white false indigo (*Baptisia australis* and *Baptisia lactea*), sideoats grama grass (*Bouteloua curtipendula*), purple coneflower (*Echinacea purpurea*), Canada wildrye (*Elymus canadensis*), rattlesnake master (*Eryngium yuccifolium*), spotted joe pye weed (*Eutrochium maculatum*), compass plant (*Silphium laciniatum*), prairie dock (*Silphium terebinthinaceum*), cup plant (*Silphium perfoliatum*), and stiff goldenrod (*Solidago rigida*). Relatively few high CC woody species were observed. These included buttonbush (*Cephalanthus occidentalis*), sycamore (*Platanus occidentalis*), and northern red oak (*Quercus rubra*). In total, 28 woody species were observed in the remediation prairie areas compared to 41 in the remediation successional areas (Table C-1). Two factors are likely contributing to the difference in woody species richness in these areas. First, the remediation prairie areas have had frequent use of prescribed fire as a management tool in the years since restoration activities were completed. The remediation successional areas have seen little to no prescribed burn activity. Another factor is that only small portions of the remediation prairie areas are adjacent to existing wooded areas, while a large part of the remediation successional areas have contact with existing wooded areas and, therefore, seed sources for woody species (Figure C-1). The difference in the woody species composition is desirable for the long-term management goals of these areas. The somewhat lower total species richness in the remediation prairie areas may also be related to prescribed burns, as the burns keep successional species suppressed, and create disturbances that may favor some species like Canada goldenrod (*Solidago canadensis*), which can quickly dominate recently disturbed areas. Continued monitoring and management activities, including mowing, prescribed burns, and invasive species control will be necessary to maintain these remediation prairie areas as prairies.

C.3.0 Site and On-Site Disposal Facility Inspections

The Fernald Preserve LMICP (DOE 2019a) identifies the inspection process for the site and the OSDF. Inspections are conducted quarterly with participation from regulators. Site inspections also include quarterly point-specific institutional control inspections as well as weekly trail inspections. Inspections document evidence of unauthorized uses of the site, the effectiveness of institutional controls, and the need for repairs. Additional inspections are also completed following prescribed burns.

Site inspection finding locations are identified on Figure C-3; OSDF finding locations are identified on Figures C-4A and C-4B. Follow-up maintenance activities are conducted to address findings from site and OSDF inspections. For some findings, it is determined that continued monitoring or no action is required. Some 2022 inspection findings remain to be addressed. DOE continues to resolve older findings even as new ones are generated.

Through calendar year 2021, inspection reports that included the specific findings of the site and OSDF inspections were submitted to the regulators on a quarterly basis, posted on the internet, and summarized in the annual Site Environmental Report. Beginning with calendar year 2022, a more streamlined reporting process was implemented. A report documenting completion of the inspections will continue to be submitted to the regulators on a quarterly basis; however, inspection finding details will only be reported in the annual Site Environmental Report, with one exception. If inspection findings indicate that activity and use limitations for the site are not in compliance, these findings will be discussed with the regulators during routine site meetings with timely notifications as necessary, and the finding details will be included in that quarter's inspection report. Inspection reports are also posted at https://www.energy.gov/lm/fernald-preserve-ohio-site. Additional requirements concerning notifications of significant OSDF findings to the regulators are discussed in Attachment B, "OSDF Post-Closure Care and Inspection Plan" of the LMICP. The only inspection finding reported in the 2022 quarterly inspection reports is discussed in Section C.3.1.

C.3.1 Site Inspections Findings

To manage the site inspections more easily, the site was divided into four quadrants: central, south, east, and west. The field walkdowns are conducted by quadrant. Inspection of the west quadrant, originally scheduled for December 2022, was delayed until early 2023 due to inclement weather. As discussed in Section 5.1, two prescribed burns of approximately 20 acres of prairie were completed on December 2, 2022. The required post-burn walkdown of these areas was completed in January 2023. The results of both inspections will be reported in the 2023 Site Environmental Report.

The 2022 quarterly site inspection findings, resolution detail, and date of resolution are presented by quadrant in Tables C-3 through C-5. The approximate location of each finding for which a location was identified during the inspection is presented in Figure C-3. Similar to the findings from recent years, site inspection findings for 2022 consisted mainly of the presence of noxious and invasive vegetation and damage to deer exclosure fencing. Only one inspection finding was reported in the 2022 quarterly inspection reports. The finding was identified during the December 2022 point-specific institutional control inspection and is associated with the main drainage corridor culvert access control grating. The culvert, along with an adjacent 18-inch culvert that is completely buried, was left in place even though it has fixed radiological contamination. These culverts are located directly below the OSDF leachate conveyance system and the main effluent line running between the Converted Advanced Wastewater Treatment facility and the Great Miami River. Because of their location, these culverts could not have been removed without potentially impacting ongoing Converted Advanced Wastewater Treatment and OSDF operations. Instead, metal grating was installed to prevent access to the 60-inch culvert.

Site inspections ensure that the 60-inch culvert grating is in place and is serviceable and that the 18-inch culvert is not exposed through erosion or other ground disturbance. The approximate location of the main drainage corridor grating is identified on Figure C-2. The last quarterly inspection of 2022 identified that the grate had experienced natural degradation of the concrete which caused the rebar grate to become dislodged. Plans are being developed to repair the grating in 2023.

C3.1.1 Debris

Debris (e.g., asphalt, tile, and concrete) continues to be identified, primarily in the Former Production Area and former Waste Storage Area located in the central quadrant. The site radiological control technician performs a radiological scan of all debris identified. Table C-6 provides a comparison of debris quantities by year. Debris is discovered through the site inspection process as well as during construction activities, site maintenance, and casual observation. In 2022, 128 pieces of debris were identified, radiological surveyed, and removed. None of the debris had fixed radiological contamination above background levels. It is often the case that when one piece of debris is observed during an inspection, additional debris is discovered nearby when returning to remove the debris. Beginning in 2022, a GPS unit will be used to document the location of debris that is above background radiological levels. This information will be presented in the annual Site Environmental Report. No radiologically contaminated debris was identified in 2022.

C3.1.2 Annual Site and OSDF Inspection Photographs

Annual site inspection photographs have been taken across the site (Figure C-5) since 2007. The 2018 Site Environmental Report (DOE 2019b) was the first time these photos were included as part of the Site Environmental Report. Before that, they were made available through the Geospatial Environmental Mapping System (GEMS), an internet-based interface that allows for public access to monitoring and inspection data. Due to changes in the internal review process for posting to this public interface, annual site photographs have not been posted on GEMS since 2015. The 2022 photo set is provided in this report. The first photograph taken at each location along with photographs from 2022 are provided in Figures C-5A through C-73. Note that the angle and perspective at some locations has shifted slightly over the years. The series of photographs show significant vegetation growth and development and generally stable conditions across the site. The annual site inspection photograph process was established to document the restoration following the extensive soil remediation completed in 2006. Additional photographs have been added over the years as newer restoration projects were completed. Because of the successful establishment of vegetation throughout the site, these annual site inspection photographs are less useful in documenting changing conditions.

In the 2021 Site Environmental Report (DOE 2022), DOE proposed to reduce the annual site inspection photographs to include only those required for the OSDF in accordance with Attachment B, "Post-Closure Care and Inspection Plan" of the LMICP. In 2022, the photographs required in accordance with the Post-Closure Care and Inspection Plan were included in the quarterly inspection reports. Beginning in 2023, these photographs will be included only in the annual Site Environmental Report.

C.3.2 OSDF Inspection Findings

OSDF inspections consist of a quarterly walkdown around the perimeter of the OSDF and an annual walkdown of the vegetated cap. Erosion rills, animal burrows, noxious weeds, woody vegetation, settlement cracks, and other indications that there may be an issue with the proper functioning of the cap are identified and repaired. Tables C-7 through C-10 provide the 2022 OSDF findings, resolution detail, and date of resolution. Figure C-4A identifies the approximate location of each listed finding for the March, June, and September inspections. Figure C-4B identifies the approximate location of each listed finding for the December inspection, which was the annual vegetated cap walkdown. In 2022, there were no signs that the integrity of the cap had been compromised. As in previous years, findings consisted mainly of woody vegetation and noxious weeds. Callery pear (*Pyrus calleryana*) and other woody vegetation continue to invade the OSDF cap. Field personnel physically remove or apply herbicide to woody vegetation to keep trees from becoming established on the cap.

C.3.3 Proposed Changes to Site and OSDF Inspection Reporting

As in previous years, site inspection findings for 2022 have consisted mainly of noxious or invasive vegetation and deer exclosure fence damage; 2022 OSDF findings are predominantly woody vegetation. With approval from the regulators and stakeholders, beginning in 2023, DOE will no longer include the tables detailing each inspection finding, but will report the findings in map format. The maps will include the location of each finding identified, the type of finding, and the finding resolution, if the finding has been resolved.

Site inspection findings will generally be grouped by category of most common findings as follows:

- Bio-intrusion (i.e., animal burrow)
- Trash
- Debris (e.g., concrete, asphalt, graphite)
- Debris with fixed contamination above background levels
- Drainage
- Erosion
- Fencing
- Signage
- Structure
- Unauthorized use
- Noxious or invasive vegetation

OSDF inspection findings will also include the following:

- Presence of rocks
- Settlement

As required by the Institutional Controls Plan, which is Volume II of the LMICP (DOE 2023), findings associated with activity and use limitation issues will be discussed with the regulators, reported in the quarterly inspection reports, and discussed in the annual Site Environmental Report. Photographs of the issue may also be included. Requirements associated with additional reporting related to OSDF findings is included in the Post-Closure Care and Inspection Plan, Attachment B of the LMICP.

C.4.0 Monitoring and Inspection Activities in 2023

The revised approach to functional monitoring using floristic inventories implemented in 2021 will continue in 2023 for perimeter successional, remediation forest, and existing forest areas (Figure C-1). Herbaceous monitoring of the OSDF cap will continue. Cell caps 1, 2, and 3 will be evaluated in 2023. DOE suggests that beginning in 2023, OSDF vegetation data be reported in the Site Environmental Report rather than the quarterly inspection reporting process.

Quarterly site inspections will continue to be used to identify issues that need to be addressed through restored area maintenance. To better access remote areas of the site, the timing of field walkdowns is focused in the winter months. This allows for greater visibility and access in densely vegetated areas. Post-burn walkdowns in the central quadrant and the OSDF will also be conducted.

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Table C-1. 2022 Remediation Area Functional Monitoring Summary

	Remediation Prairie Areas	Remediation Successional Areas
Total Species	209	222
Native Species	140	155
Non-Native Species	69	67
Native Species (percent)	67%	70%
Average Coefficient of Conservatism (CC), range between 0-10	1.9	2.3
Floristic Quality Assessment Index	28.0	33.6

				Species Identified	
Species	**Common Name**	**Type**	**CC**	**Remediation Prairies**	**Remediation Successional Areas**
Acalypha rhomboidea	RHOMBIC THREE-S. MERCURY	forb	0	X	X
Acer negundo	BOX ELDER	tree	3	X	X
Acer rubrum	RED MAPLE	tree	2		X
Acer saccharinum	SILVER MAPLE	tree	3	X	
Achillea millefolium	YARROW	forb	1	X	X
Agrimonia parviflora	SMALL-FLOWERED AGRIMONY	forb	2	X	X
Alisma subcordatum	SOUTHERN WATER-PLANTAIN	forb	2	X	X
Ambrosia artemisiifolia	COMMON RAGWEED	forb	0	X	X
Ammannia robusta	SESSILE TOOTH-CUP	forb	7	X	
Amorpha fruticosa	FALSE INDIGO	forb	3		X
Andropogon gerardii	BIG BLUESTEM	grass	5	X	X
Andropogon virginicus	COMMON BROOM-SEDGE	grass	3	X	
Apocynum cannabinum	INDIAN HEMP	forb	1	X	X
Asclepias incarnata	SWAMP MILKWEED	forb	4	X	X
Asclepias syriaca	COMMON MILKWEED	forb	1	X	X
Asclepias tuberosa	BUTTERFLY-WEED	forb	4	X	X
Asplenium platyneuron	EBONY SPLEENWORT	fern	3		X
Aster ericoides	WHITE HEATH ASTER	forb	2		X
Aster lanceolatus	EASTERN LINED ASTER	forb	3		X
Aster lateriflorus	CALICO ASTER	forb	2	X	X
Aster novae-angliae	NEW ENGLAND ASTER	forb	2	X	X
Aster pilosus	AWL ASTER	forb	1	X	X
Aster racemosus	SMALL-HEADED ASTER	forb	2	X	X
Baptisia australis	BLUE FALSE INDIGO	forb	6	X	X
Baptisia lactea	WHITE FALSE INDIGO	forb	8	X	X
Bidens connata	PURPLE-STEMMED BEGGAR'S-TICK	forb	3	X	
Bidens frondosa	DEVIL'S BEGGAR'S-TICK	forb	2	X	X
Bouteloua curtipendula	SIDE-OATS GRAMA GRASS	grass	8	X	X
Calamagrostis canadensis	CANADA BLUEJOINT	grass	4	X	X
Calystegia sepium	HEDGE BINDWEED	forb	1	X	X
Carex amphibola	E. NARROW-LEAVED SEDGE	sedge	5		X
Carex annectens	YELLOW FOX SEDGE	sedge	3	X	X
Carex blanda	COMMON WOOD SEDGE	sedge	1	X	X
Carex cephalophora	OVAL-HEADED SEDGE	sedge	5	X	
Carex comosa	BEARDED SEDGE	sedge	2	X	X
Carex cristatella	CRESTED SEDGE	sedge	3	X	X
Carex festucacea	FESCUE SEDGE	sedge	7		X
Carex frankii	FRANK'S SEDGE	sedge	2	X	X
Carex granularis	MEADOW SEDGE	sedge	3	X	X
Carex grisea	NARROW-LEAVED SEDGE	sedge	4		X
Carex lupulina	HOP SEDGE	sedge	3	X	X
Carex lurida	BOTTLEBRUSH SEDGE	sedge	3	X	
Carex molesta	TROUBLESOME SEDGE	sedge	3		X
Carex muhlenbergii	MUHLENBERG'S SEDGE	sedge	7		X
Carex normalis	LARGE STRAW SEDGE	sedge	4	X	X
Carex scoparia	POINTED BROOM SEDGE	sedge	3	X	X
Carex shortiana	SHORT'S SEDGE	sedge	2	X	X
Carex stipata	CROWDED SEDGE	sedge	2	X	X
Carex tribuloides	BLUNT BROOM SEDGE	sedge	4	X	X
Carex vulpinoidea	FOX SEDGE	sedge	1	X	X
Carya ovata	SHAGBARK HICKORY	tree	6		X
Cephalanthus occidentalis	BUTTONBUSH	shrub	6	X	
Cercis canadensis	REDBUD	small tree	3	X	X

Chamaecrista fasciculata	PARTRIDGE-PEA	forb	3	X	X
Cirsium discolor	FIELD THISTLE	forb	4	X	X
Claytonia virginica	SPRING-BEAUTY	forb	2		X
Conyza canadensis	HORSEWEED	forb	0	X	X
Cornus racemosa	GRAY DOGWOOD	shrub	1	X	
Crataegus crus-galli	COCKSPUR HAWTHORN	small tree	3	X	
Cuscuta gronovii	COMMON DODDER	forb	3	X	
Cyperus esculentus	YELLOW NUT-SEDGE	sedge	0	X	X
Cyperus strigosus	STRAW-COLORED UMBRELLA-S.	sedge	1	X	
Desmodium canadense	CANADA TICK-TREFOIL	forb	4	X	X
Desmodium canescens	HOARY TICK-TREFOIL	forb	4	X	X
Desmodium paniculatum	SHOWY TICK-TREFOIL	forb	3		X
Diospyros virginiana	PERSIMMON	small tree	4		X
Echinacea purpurea	PURPLE CONEFLOWER	forb	6	X	X
Eleocharis erythropoda	RED-FOOTED SPIKE-RUSH	sedge	4	X	X
Eleocharis obtusa	BLUNT SPIKE-RUSH	sedge	1	X	X
Elymus canadensis	CANADA WILD RYE	grass	6	X	X
Epilobium coloratum	PURPLE-LEAVED WILLOW-HERB	forb	1	X	X
Equisetum hyemale	SCOURING-RUSH	fern	2	X	X
Erechtites hieracifolia	PILEWORT	forb	2	X	X
Erigeron annuus	DAISY FLEABANE	forb	0	X	X
Erigeron philadelphicus	PHILADELPHIA FLEABANE	forb	2	X	
Erigeron strigosus	ROUGH FLEABANE	forb	1	X	X
Eryngium yuccifolium	RATTLESNAKE-MASTER	forb	7	X	X
Eupatorium altissimum	TALL BONESET	forb	0	X	X
Eupatorium coelestinum	MISTFLOWER	forb	3		X
Eupatorium maculatum	SPOTTED JOE-PYE WEED	forb	6	X	
Eupatorium perfoliatum	COMMON BONESET	forb	3	X	X
Eupatorium purpureum	PURPLE JOE-PYE WEED	forb	5		X
Eupatorium rugosum	WHITE SNAKEROOT	forb	3	X	X
Eupatorium serotinum	LATE-FLOWERING BONESET	forb	2	X	X
Euphorbia nutans	EYEBANE	forb	0	X	
Euthamia graminifolia	FLAT-TOPPED GOLDENROD	forb	2	X	X
Fraxinus pennsylvanica	GREEN ASH	tree	3	X	X
Galium aparine	CLEAVERS	forb	0	X	X
Geranium carolinianum	CAROLINA CRANE'S-BILL	forb	3	X	X
Geum canadense	WHITE AVENS	forb	2		X
Geum laciniatum	ROUGH AVENS	forb	2	X	
Gleditsia triacanthos	HONEY LOCUST	tree	4	X	X
Hackelia virginiana	VIRGINIA STICKSEED	forb	2		X
Helianthus grosseserratus	SAWTOOTH SUNFLOWER	forb	4		X
Heliopsis helianthoides	SMOOTH OXEYE	forb	5	X	X
Hibiscus moscheutos	SWAMP ROSE-MALLOW	forb	4	X	
Juglans nigra	BLACK WALNUT	tree	5		X
Juncus dudleyi	DUDLEY'S RUSH	forb	3	X	X
Juncus tenuis	PATH RUSH	forb	1	X	X
Juncus torreyi	TORREY'S RUSH	forb	3	X	X
Juniperus virginiana	EASTERN RED CEDAR	tree	3	X	X
Lactuca canadensis	WILD LETTUCE	forb	1	X	X
Leersia oryzoides	RICE CUT GRASS	grass	1	X	X
Lespedeza capitata	ROUND-HEADED BUSH-CLOVER	forb	5	X	
Leucospora multifida	LEUCOSPORA	forb	5	X	
Lindernia dubia	FALSE PIMPERNEL	forb	2		X
Liquidambar styraciflua	SWEETGUM	tree	6		X
Liriodendron tulipifera	TULIP TREE	tree	6		X
Lobelia inflata	INDIAN-TOBACCO	forb	1		X
Lobelia siphilitica	GREAT BLUE LOBELIA	forb	3	X	
Ludwigia palustris	WATER-PURSLANE	forb	3	X	X
Lycopus americanus	AMERICAN WATER-HOREHOUND	forb	3	X	X
Mentha arvensis	FIELD MINT	forb	2	X	
Mimulus alatus	WINGED MONKEY-FLOWER	forb	6		X
Mimulus ringens	COMMON MONKEY-FLOWER	forb	4	X	X
Monarda fistulosa	WILD BERGAMOT	forb	3	X	X
Oenothera biennis	COMMON EVENING-PRIMROSE	forb	1	X	
Oxalis stricta	COMMON YELLOW WOOD-SORREL	forb	0	X	X
Panicum capillare	WITCH GRASS	grass	1	X	X
Panicum clandestinum	DEER'S-TONGUE PANIC GRASS	grass	2	X	
Panicum virgatum	SWITCH GRASS	grass	4	X	X

Parthenocissus quinquefolia	VIRGINIA CREEPER	vine	2	X	X
Penstemon digitalis	FOXGLOVE BEARD-TONGUE	forb	2	X	X
Phyla lanceolata	FOG-FRUIT	forb	3	X	X
Physalis longifolia	SMOOTH GROUND-CHERRY	forb	1		X
Phytolacca americana	POKEWEED	forb	1	X	X
Pinus strobus	WHITE PINE	tree	6		X
Platanus occidentalis	SYCAMORE	tree	7	X	X
Populus deltoides	EASTERN COTTONWOOD	tree	3	X	X
Prunella vulgaris	SELF-HEAL	forb	0	X	X
Prunus americana	AMERICAN PLUM	small tree	3	X	
Prunus munsoniana	MUNSON'S PLUM	small tree	3		X
Pycnanthemum tenuifolium	NARROW-LEAVED MOUNTAIN-MINT	forb	4	X	X
Quercus alba	WHITE OAK	tree	6		X
Quercus bicolor	SWAMP WHITE OAK	tree	7		X
Quercus imbricaria	SHINGLE OAK	tree	5		X
Quercus macrocarpa	BUR OAK	tree	6		X
Quercus muehlenbergii	CHINQUAPIN OAK	tree	7		X
Quercus rubra	RED OAK	tree	6	X	X
Ranunculus sceleratus	CURSED CROWFOOT	forb	1	X	
Ratibida pinnata	GRAY-HEADED CONEFLOWER	forb	5	X	X
Rhus aromatica var. aromatica	FRAGRANT SUMAC	shrub	3	X	X
Rhus glabra	SMOOTH SUMAC	shrub	2	X	
Rhus typhinia	STAGHORN SUMAC	shrub	2		X
Robinia pseudoacacia	BLACK LOCUST	tree	0	X	
Rosa palustris	SWAMP ROSE	shrub	5		X
Rubus allegheniensis	COMMON BLACKBERRY	shrub	1	X	X
Rubus occidentalis	BLACK RASPBERRY	shrub	1		X
Rudbeckia hirta	BLACK-EYED SUSAN	forb	1	X	X
Ruellia strepens	SMOOTH RUELLIA	forb	5		X
Sabatia angularis	ROSE-PINK	forb	4		X
Salix exigua	SANDBAR WILLOW	shrub	1	X	X
Salix nigra	BLACK WILLOW	tree	2	X	X
Sambucus canadensis	COMMON ELDERBERRY	shrub	3		X
Schizachyrium scoparium	LITTLE BLUESTEM	grass	5	X	X
Schoenoplectus tabernaemontani	SOFT-STEMMED BULRUSH	sedge	2	X	X
Scirpus atrovirens	GREEN BULRUSH	sedge	1	X	X
Scirpus cyperinus	WOOL-GRASS	sedge	1	X	
Scirpus pendulus	DROOPING BULRUSH	sedge	2	X	X
Senna hebecarpa	NORTHERN WILD SENNA	forb	4	X	
Silphium laciniatum	COMPASS PLANT	forb	8	X	X
Silphium perfoliatum	CUP-PLANT	forb	6	X	X
Silphium terebinthinaceum	PRAIRIE DOCK	forb	8	X	X
Sisyrinchium angustifolium	STOUT BLUE-EYED-GRASS	forb	2		X
Solidago canadensis	CANADA GOLDENROD	forb	1	X	X
Solidago juncea	PLUME GOLDENROD	forb	2		X
Solidago rigida	STIFF GOLDENROD	forb	8	X	X
Sorghastrum nutans	INDIAN GRASS	grass	5	X	X
Sparganium eurycarpum	GIANT BUR-REED	forb	4	X	
Spartina pectinata	PRAIRIE CORD GRASS	grass	5	X	X
Spiranthes ovalis	LESSER LADIES TRESSES	forb	6		X
Spiranthes vernalis	NARROW-LEAVED LADIES'-TR.	forb	7		X
Symphoricarpos orbiculatus	CORALBERRY	shrub	3	X	X
Teucrium canadense	AMERICAN GERMANDER	forb	3		X
Tilia americana	AMERICAN BASSWOOD	tree	6		X
Toxicodendron radicans	POISON-IVY	vine	1	X	X
Tradescantia ohiensis	OHIO SPIDERWORT	forb	5	X	X
Ulmus americana	AMERICAN ELM	tree	2		X
Ulmus rubra	SLIPPERY ELM	tree	3	X	X
Valerianella umbilicata	BEAKED CORN-SALAD	forb	2	X	
Verbena hastata	BLUE VERVAIN	forb	4	X	X
Verbena stricta	HOARY VERVAIN	forb	3	X	
Verbena urticifolia	WHITE VERVAIN	forb	3	X	X
Vernonia gigantea	TALL IRONWEED	forb	2	X	X
Viburnum prunifolium	BLACK-HAW	shrub	4	X	X
Vitis riparia	RIVERBANK GRAPE	vine	3		X
Vitis vulpina	FROST GRAPE	vine	3	X	
Alliaria petiolata	**GARLIC MUSTARD**	forb	0	X	X
Allium vineale	**FIELD GARLIC**	forb	0	X	X

Alopecurus pratensis	**MEADOW FOXTAIL**	grass	0	X	X
Amaranthus cruentus	**RED AMARANTH**	forb	0		X
Anagallis arvensis	**SCARLET PIMPERNEL**	forb	0	X	
Artemsia vulgaris	**COMMON MUGWORT**	forb	0		X
Barbarea vulgaris	**YELLOW ROCKET**	forb	0	X	X
Bromus inermis	**HUNGARIAN BROME**	grass	0		X
Cardamine hirsuta	**HOARY BITTER CRESS**	forb	0		X
Carduus nutans	**NODDING THISTLE**	forb	0	X	X
Catalpa speciosa	**NORTHERN CATALPA**	tree	0	X	X
Chrysanthemum leucanthemum	**OX-EYE DAISY**	forb	0	X	
Cichorium intybus	**CHICORY**	forb	0	X	X
Cirsium arvense	**CANADA THISTLE**	forb	0	X	X
Cirsium vulgare	**BULL THISTLE**	forb	0	X	X
Conium maculatum	**POISON-HEMLOCK**	forb	0	X	X
Convolvulus arvensis	**FIELD BINDWEED**	forb	0	X	
Coronilla varia	**CROWN-VETCH**	forb	0	X	X
Dactylis glomerata	**ORCHARD GRASS**	grass	0		X
Daucus carota	**QUEEN-ANNE'S-LACE**	forb	0	X	X
Dianthus armeria	**DEPTFORD-PINK**	forb	0	X	X
Dipsacus fullonum	**WILD TEASEL**	forb	0	X	X
Dipsacus laciniatus	**CUT-LEAVED TEASEL**	forb	0	X	X
Echinacea pallida	**PALE PURLPE CONEFLOWER**	forb	0	X	X
Echinochloa crusgalli	**BARNYARD GRASS**	grass	0	X	X
Elaeagnus umbellata	**AUTUMN-OLIVE**	small tree	0		X
Elytrigia repens	**QUACKGRASS**	grass	0	X	
Festuca elatior	**TALL FESCUE**	grass	0	X	X
Glechoma hederacea	**GROUND IVY**	forb	0	X	X
Hordeum jubatum	**SQUIRREL-TAIL BARLEY**	grass	0	X	
Lactuca saligna	**WILLOW-LEAVED LETTUCE**	forb	0	X	
Lactuca serriola	**PRICKLY LETTUCE**	forb	0		X
Lamium purpuream	**PURPLE DEAD-NETTLE**	forb	0	X	X
Lepidium campestre	**FIELD PEPPER-GRASS**	forb	0	X	X
Lespedeza cuneata	**CHINESE BUSH-CLOVER**	forb	0	X	X
Lolium multiflorum	**ITALIAN RYEGRASS**	grass	0	X	X
Lonicera japonica	**JAPANESE HONEYSUCKLE**	vine	0	X	X
Lonicera maackii	**AMUR HONEYSUCKLE**	shrub	0	X	X
Lotus corniculatus	**BIRD'S-FOOT TREFOIL**	forb	0	X	X
Medicago lupulina	**BLACK MEDICK**	forb	0	X	X
Melilotus alba	**WHITE SWEET-CLOVER**	forb	0	X	X
Melilotus officinalis	**YELLOW SWEET-CLOVER**	forb	0	X	X
Morus alba	**WHITE MULBERRY**	tree	0	X	X
Narcissus pseudonarcissus	**DAFFODIL**	forb	0		X
Pastinaca sativa	**WILD PARSNIP**	forb	0		X
Phalaris arundinacea	**REED CANARY GRASS**	grass	0	X	X
Phleum pratense	**TIMOTHY**	grass	0		X
Phragmites australis subsp. australis	**GIANT REED**	grass	0	X	
Pinus nigra	**AUSTRIAN PINE**	tree	0	X	X
Plantago lanceolata	**ENGLISH PLANTAIN**	forb	0	X	X
Plantago major	**COMMON PLANTAIN**	forb	0	X	X
Poa annual	**ANNUAL BLUEGRASS**	grass	0	X	X
Polygonum persicaria	**LADY'S THUMB**	forb	0	X	X
Pyrus callieryana	**CALLIERY PEAR**	small tree	0	X	X
Rosa multiflora	**MULTIFLORA ROSE**	shrub	0	X	X
Rumex crispus	**CURLY DOCK**	forb	0	X	X
Saponaria officinalis	**SOAPWORT**	forb	0	X	X
Schoenoplectus mucronatus	**RICEFIELD BULRUSH**	sedge	0	X	
Senecio glabellus	**BUTTERWEED**	forb	0	X	X
Setaria faberi	**GIANT FOXTAIL GRASS**	grass	0	X	X
Setaria glauca	**YELLOW FOXTAIL GRASS**	grass	0	X	X
Setaria viridis	**GREEN FOXTAIL GRASS**	grass	0	X	
Solanum carolinense	**HORSE NETTLE**	forb	0	X	X
Sorghum halepense	**JOHNSON GRASS**	grass	0	X	
Stellaria media	**COMMON CHICKWEED**	forb	0	X	X
Taraxacum officinale	**COMMON DANDELION**	forb	0	X	X
Thlaspi arvense	**FIELD PENNY CRESS**	forb	0	X	X
Torilis arvensis	**FIELD HEDGE-PARSLEY**	forb	0	X	X
Trifolium hybridum	**ALSIKE CLOVER**	forb	0	X	X
Trifolium pratense	**RED CLOVER**	forb	0	X	X

Table C-1. 2022 Remediation Area Functional Monitoring Summary (continued)

Trifolium repens	**WHITE CLOVER**	forb	0	X	X
Typha angustifolia	**NARROW-LEAVED CAT-TAIL**	forb	0	X	X
Typha x glauca	**HYBRID CAT-TAIL**	forb	0	X	X
Valerianella locusta	**EUROPEAN CORN-SALAD**	forb	0	X	
Verbascum blattaria	**MOTH MULLEIN**	forb	0	X	X
Verbascum thapsus	**COMMON MULLEIN**	forb	0	X	X
Veronica arvensis	**CORN SPEEDWELL**	forb	0	X	X
Viola arvensis	**EUROPEAN FIELD-PANSY**	forb	0	X	
Xanthium strumarium	**COMMON COCKLEBUR**	forb	0	X	X

Highlighted species are non-native, X indicates the species is present in the monitoring area.

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Table C-2. Comparison of Remediation Prairie and Remediation Successional Area Ecological Monitoring Metrics

Time Period	Mean Coefficient of Conservatism		Floristic Quality Assessment Index		Native Species	
	Remediation Prairie Areas	Remediation Successional Areas	Remediation Prairie Areas	Remediation Successional Areas	Remediation Prairie Areas	Remediation Successional Areas
2010	1.8	1.5	20.0	14.7	64%	52%
2013	1.7	1.4	20.1	13.6	60%	49%
2015 to 2017[a]	1.5	1.8	15.6	21.7	59%	61%
2018 to 2020[a]	1.6	1.7	14.3	20.7	59%	63%
2022[b]	1.9	2.2	28.0	33.2	67%	70%

[a] Monitoring rotated among site management areas over a 3-year period.
[b] Revised functional monitoring approach implemented using floristic inventories.

Table C-3. Central Quadrant Site Inspection Findings, February 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Teasel	Herbicide applied	6/27/2022
2	Culvert blocked	Removed blockage	2/23/2022
3	Animal burrows and slumping	To be determined	To be determined
4	Top missing from barn owl box	No action required	12/29/2022
5	Pear trees	Herbicide applied	3/15/2023
6	Mugwort rosettes	Herbicide applied	6/16/2022
7	Phragmites	No action required	6/28/2022
8	Concrete	Free released and disposed[a]	3/15/2022
9	Asphalt	Free released and disposed[a]	3/15/2022
10	Rubber	Free released and disposed[a]	3/15/2022
11	Plastic	Removed plastic	4/6/2022
12	Hard black plastic embedded in turf	Removed plastic	4/6/2022

[a] 10 CFR 835, "Occupational Radiation Protection."

Table C-4. South Quadrant Site Inspection Findings, March 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Phragmites	No action required	6/29/2022
2	Concrete	Free released and disposed[a]	3/15/2022
3	Tree protection cages and metal posts	To be determined	To be determined
4	Transite	Free released and disposed[b]	3/15/2022
5	Bundle of silt fence	Silt fence discarded	4/6/2022
6	Blue surveyor flag	No action required	4/1/2022
7	Hole in deer fence	Deer fence repaired	4/13/2022
8	Unvegetated area	No action required	4/6/2022
9	Hole in deer fence	Deer fence repaired	4/28/2022

Table C-4. South Quadrant Site Inspection Findings, March 2022 (continued)

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
10	Erosion and exposed landscape fabric	To be determined	To be determined
11	Geotextile exposed	No action required	12/29/2022
12	Hole in deer fence	Deer fence repaired	4/7/2022
13	Hole in deer fence	Deer fence repaired	4/7/2022
14	Section of deer fence down	Deer fence repaired	4/28/2022
15	Deer fence torn and down	Deer fence repaired	4/14/2022
16	Deer fence gate open	Deer fence gate repaired	4/6/2022
17	Honeysuckle	Herbicide applied	11/8/2022
18	Honeysuckle	Herbicide applied	11/2/2022
19	Concrete	Free released and disposed[a]	3/15/2022

[a] 10 CFR 835, "Occupational Radiation Protection."

Table C-5. East Quadrant Site Inspection Findings, March 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Holes in deer fence	Deer fence repaired	4/14/2022
2	Broken drainpipe and erosion	No action required	4/14/2022
3	Pears and honeysuckle	Herbicide applied	1/11/2023
4	Pear trees	To be determined	To be determined
5	Teasel	To be determined	To be determined
6	Corrugated plastic on tree	Removed plastic	4/11/2022
7	Pear trees	To be determined	To be determined
8	Teasel	To be determined	To be determined
9	Corrugated plastic	Removed plastic	4/11/2022
10	White corrugated material	Removed material	4/11/2022
11	Pear trees and honeysuckle	To be determined	To be determined
12	Tree protection cage buried in grasses	Removed deer cages	4/13/2022
13	Deer fence post	Removed deer fence post	4/13/2022
14	Pear trees	Herbicide applied	4/21/2022
15	Pear trees	Herbicide applied	4/21/2022
16	Pear trees	Herbicide applied	10/27/2022
17	Pear trees	Herbicide applied	10/27/2022
18	Pear trees	To be determined	To be determined
19	Teasel	Herbicide applied	6/8/2022
20	Teasel	To be determined	To be determined
21	Poison hemlock	To be determined	To be determined
22	Pear trees	To be determined	To be determined
23	Bottom falling out of kestrel box	Repaired kestrel box	4/14/2022
24	Pear trees and honeysuckle	To be determined	To be determined
25	Honeysuckle and autumn olive	To be determined	To be determined

Table C-5. East Quadrant Site Inspection Findings, March 2022 (continued)

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
26	Honeysuckle, pear trees, autumn olive trees	To be determined	To be determined
27	Pear trees and honeysuckle	To be determined	To be determined
28	Honeysuckle	To be determined	To be determined
29	Phragmites	Herbicide Applied	6/28/2022
30	Asphalt	Free released and disposed[a]	3/15/2022
31	Pear trees and honeysuckle	To be determined	To be determined
32	Honeysuckle	To be determined	To be determined
33	Honeysuckle and pear trees	To be determined	To be determined
34	Honeysuckle	To be determined	To be determined

[a] 10 CFR 835, "Occupational Radiation Protection."

Table C-6. Annual Debris Quantities

Year	Free-Release Debris Count[a,b]	Contaminated Debris Count[a]	Percent Contaminated[a,b]
2007	-	108	-
2008	-	128	-
2009	-	36	-
2010	-	21	-
2011	204	4	1.9%
2012	1,480	12	0.8%
2013	391	8	2.0%
2014	814	8	1.0%
2015	453	13	2.8%
2016	261	9	3.3%
2017	574	3	0.5%
2018	294	3	1.0%
2019	925	0	0.0%
2020	241	1	0.4%
2021	143	6	4.0%
2022	128	0	0.0%

[a] 10 CFR 835, "Occupational Radiation Protection."
[b] DOE began recording free-release debris counts in 2011.

Table C-7. OSDF Inspection Findings, March 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Cedar tree	Removed	4/4/2022
2	Cedar tree	Removed	4/4/2022
3	Cedar trees	Removed	4/4/2022
4	Cedar trees	Removed	4/4/2022
5	Cedar tree	Removed	4/4/2022
6	Cedar tree	Removed	4/4/2022
7	Cedar tree	Removed	4/4/2022
8	Cedar tree	Removed	4/4/2022
9	Cedar tree	Removed	4/4/2022
10	Cedar tree	Removed	4/4/2022
11	Asphalt pieces	Unable to locate	3/2/2023
12	Blackberry	Herbicide applied	9/1/2022
13	Cedar trees	Removed	4/4/2022
14	Pear tree	Herbicide applied	3/20/2023
15	Cedar trees	Removed	4/4/2022
16	Cedar trees	Removed	4/4/2022
17	Cedar trees	Removed	4/4/2022
18	Cedar tree	Removed	4/4/2022
19	Cedar tree	Removed	4/4/2022
20	Burrows and sand	To be determined	To be determined
21	Cedar trees	Removed	4/4/2022

Table C-8. OSDF Inspection Findings, June 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Vegetation disturbance due to vehicle travel	No action required; vegetation recovered	12/6/2022
2	Woody vegetation	Herbicide applied	10/27/2022
3	Woody vegetation	Herbicide applied	10/27/2022
4	Woody vegetation	Herbicide applied	10/27/2022
5	Woody vegetation	Herbicide applied	10/27/2022
6	Woody vegetation	Herbicide applied	10/27/2022
7	Woody vegetation	Herbicide applied	10/27/2022

Table C-9. OSDF Inspection Findings, September 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Sycamore trees	Herbicide applied	9/13/2022
2	Woody vegetation	Herbicide applied	9/13/2022
3	Callery pear tree	Herbicide applied	9/13/2022
4	Callery pear tree	Herbicide applied	9/13/2022
5	Callery pear trees	Herbicide applied	9/13/2022
6	Callery pear trees	No action required	9/13/2022
7	Callery pear trees	Herbicide applied	9/13/2022
8	Cedar tree	Herbicide applied	11/21/2022
9	Woody vegetation	Herbicide applied	9/21/2022
10	Woody vegetation	Herbicide applied	9/21/2022
11	Woody vegetation	Herbicide applied	9/21/2022
12	Pear tree	Herbicide applied	9/21/2022
13	Pear, rose, and honeysuckle	Herbicide applied	9/21/2022
14	Mulberry and honeysuckle	Herbicide applied	9/21/2022
15	Pear tree	Herbicide applied	9/21/2022
16	Hole under fence	To be determined	To be determined
17	Fence bent	No action required, no integrity issues	1/23/2023
18	Pear trees	Herbicide applied	10/27/2022
19	Erosion on south edge of gravel road	Erosion repair	10/4/2022
20	Pear trees	Herbicide applied	2/23/2023

Table C-10. OSDF Inspection Findings, December 2022

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
1	Callery pear	Herbicide applied	3/22/2023
2	Callery pear	Herbicide applied	3/20/2023
3	Callery pear	Herbicide applied	3/20/2023
4	Callery pear	Herbicide applied	3/20/2023
5	Callery pear	Herbicide applied	3/20/2023
6	Callery pear	Herbicide applied	3/20/2023
7	Cedar tree	Herbicide applied	3/22/2023
8	Callery pear	Herbicide applied	3/20/2023
9	Callery pear	Herbicide applied	3/20/2023
10	Callery pear	Herbicide applied	3/20/2023
11	Callery pear	Herbicide applied	3/16/2023
12	Callery pear	Herbicide applied	3/16/2023
13	Callery pear	Herbicide applied	3/16/2023
14	Woody vegetation	Herbicide applied	3/22/2023
15	Callery pear	Herbicide applied	3/20/2023

Table C-10. OSDF Inspection Findings, December 2022 (continued)

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
16	Callery pear	Herbicide applied	3/20/2023
17	Callery pear	Herbicide applied	3/20/2023
18	Callery pear	Herbicide applied	3/20/2023
19	Cedar tree	Herbicide applied	3/20/2023
20	Callery pear	Herbicide applied	3/20/2023
21	Callery pear	Herbicide applied	3/20/2023
22	Teasel	Herbicide applied	4/26/2023
23	Callery pear	Herbicide applied	3/20/2023
24	Honeysuckle	Herbicide applied	3/20/2023
25	Callery pear	Herbicide applied	3/20/2023
26	Callery pear	Herbicide applied	3/20/2023
27	Callery pear	Herbicide applied	3/22/2023
28	Callery pear	Herbicide applied	3/16/2023
29	Callery pear	Herbicide applied	3/16/2023
30	Callery pear	Herbicide applied	3/16/2023
31	Callery pear	Herbicide applied	3/22/2023
32	Teasel	Herbicide applied	3/14/2023
33	Callery pear	Herbicide applied	3/16/2023
34	Callery pear	Herbicide applied	3/14/2023
35	Callery pear	Herbicide applied	3/20/2023
36	Callery pear	Herbicide applied	3/16/2023
37	Callery pear	Herbicide applied	3/16/2023
38	Callery pear	Herbicide applied	3/20/2023
39	Callery pear	Herbicide applied	3/16/2023
40	Callery pear	Herbicide applied	3/20/2023
41	Callery pear	Herbicide applied	3/20/2023
42	Callery pear	Herbicide applied	3/20/2023
43	Callery pear	Herbicide applied	3/20/2023
44	Callery pear	Herbicide applied	3/16/2023
45	Callery pear	Herbicide applied	3/16/2023
46	Callery pear	Herbicide applied	3/16/2023
47	Callery pear	Herbicide applied	3/16/2023
48	Callery pear	Herbicide applied	3/16/2023
49	Callery pear	Herbicide applied	3/16/2023
50	Callery pear	Herbicide applied	3/14/2023
51	Callery pear	Herbicide applied	3/14/2023
52	Callery pear	Herbicide applied	3/14/2023
53	Callery pear	Herbicide applied	3/14/2023
54	Callery pear	Herbicide applied	3/14/2023
55	Callery pear	Herbicide applied	3/14/2023

Table C-10. OSDF Inspection Findings, December 2022 (continued)

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
56	Callery pear	Herbicide applied	3/13/2023
57	Callery pear	Herbicide applied	3/20/2023
58	Callery pear	Herbicide applied	3/20/2023
59	Callery pear	Herbicide applied	3/20/2023
60	Callery pear	Herbicide applied	3/20/2023
61	Callery pear	Herbicide applied	3/20/2023
62	Callery pear	Herbicide applied	3/20/2023
63	Callery pear	Herbicide applied	3/20/2023
64	Callery pear	Herbicide applied	3/20/2023
65	Cedar tree	Herbicide applied	3/20/2023
66	Callery pear	Herbicide applied	3/20/2023
67	Callery pear	Herbicide applied	3/20/2023
68	Callery pear	Herbicide applied	3/20/2023
69	Callery pear	Herbicide applied	3/20/2023
70	Callery pear	Herbicide applied	3/20/2023
71	Callery pear	Herbicide applied	3/20/2023
72	Callery pear	Herbicide applied	3/20/2023
73	Callery pear	Herbicide applied	3/20/2023
74	Callery pear	Herbicide applied	3/20/2023
75	Callery pear	Herbicide applied	3/13/2023
76	Callery pear	Herbicide applied	3/13/2023
77	Callery pear	Herbicide applied	3/13/2023
78	Callery pear	Herbicide applied	3/13/2023
79	Callery pear	Herbicide applied	3/14/2023
80	Callery pear	Herbicide applied	3/9/2023
81	Callery pear	Herbicide applied	3/16/2023
82	Callery pear	Herbicide applied	3/9/2023
83	Callery pear	Herbicide applied	3/9/2023
84	Callery pear	Herbicide applied	3/16/2023
85	Callery pear	Herbicide applied	3/9/2023
86	Callery pear	Herbicide applied	3/16/2023
87	Callery pear	Herbicide applied	3/9/2023
88	Callery pear	Herbicide applied	3/16/2023
89	Callery pear	Herbicide applied	3/13/2023
90	Callery pear	Herbicide applied	3/9/2023
91	Honeysuckle	Herbicide applied	3/9/2023
92	Honeysuckle	Herbicide applied	3/16/2023
93	Honeysuckle	Herbicide applied	3/16/2023
94	Callery pear	Herbicide applied	3/16/2023
95	Callery pear	Herbicide applied	3/16/2023

Table C-10. OSDF Inspection Findings, December 2022 (continued)

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
96	Callery pear	Herbicide applied	3/16/2023
97	Callery pear	Herbicide applied	3/16/2023
98	Callery pear	Herbicide applied	3/9/2023
99	Callery pear	Herbicide applied	3/16/2023
100	Honeysuckle	Herbicide applied	3/16/2023
101	Callery pear	Herbicide applied	3/16/2023
102	Honeysuckle	Herbicide applied	3/16/2023
103	Callery pear	Herbicide applied	3/16/2023
104	Callery pear	Herbicide applied	3/16/2023
105	Callery pear	Herbicide applied	3/16/2023
106	Callery pear	Herbicide applied	3/16/2023
107	Callery pear	Herbicide applied	3/16/2023
108	Honeysuckle	Herbicide applied	3/16/2023
109	Callery pear	Herbicide applied	3/16/2023
110	Callery pear	Herbicide applied	3/16/2023
111	Callery pear	Herbicide applied	3/16/2023
112	Honeysuckle	Herbicide applied	3/16/2023
113	Callery pear	Herbicide applied	3/16/2023
114	Callery pear	Herbicide applied	3/16/2023
115	Callery pear	Herbicide applied	3/9/2023
116	Honeysuckle	Herbicide applied	2/23/2023
117	Callery pear	Herbicide applied	2/23/2023
118	Callery pear	Herbicide applied	2/23/2023
119	Callery pear	Herbicide applied	2/23/2023
120	Callery pear	Herbicide applied	2/23/2023
121	Callery pear	Herbicide applied	2/23/2023
122	Callery pear	Herbicide applied	2/23/2023
123	Callery pear	Herbicide applied	2/23/2023
124	Callery pear	Herbicide applied	2/23/2023
125	Callery pear	Herbicide applied	2/23/2023
126	Callery pear	Herbicide applied	2/23/2023
127	Callery pear	Herbicide applied	2/23/2023
128	Callery pear	Herbicide applied	2/23/2023
129	Honeysuckle	Herbicide applied	2/23/2023
130	Callery pear	Herbicide applied	2/23/2023
131	Callery pear	Herbicide applied	2/23/2023
132	Honeysuckle	Herbicide applied	2/23/2023
133	Callery pear	Herbicide applied	2/23/2023
134	Callery pear	Herbicide applied	2/23/2023
135	Callery pear	Herbicide applied	3/9/2023

Table C-10. OSDF Inspection Findings, December 2022 (continued)

Map Number	Inspection Finding	Finding Resolution or Path Forward	Date Resolved
136	Callery pear	Herbicide applied	3/9/2023
137	Callery pear	Herbicide applied	3/9/2023
138	Callery pear	Herbicide applied	3/9/2023
139	Callery pear	Herbicide applied	3/9/2023
140	Callery pear	Herbicide applied	3/9/2023
141	Callery pear	Herbicide applied	3/9/2023
142	Callery pear	Herbicide applied	3/9/2023
143	Callery pear	Herbicide applied	2/23/2023
144	Callery pear	Herbicide applied	3/9/2023
145	Callery pear	To be determined	To be determined
146	Callery pear	Herbicide applied	2/23/2023
147	Honeysuckle	To be determined	To be determined
148	Callery pear	Herbicide applied	2/23/2023
149	Honeysuckle	Herbicide applied	3/20/2023
150	Erosion	To be determined	To be determined

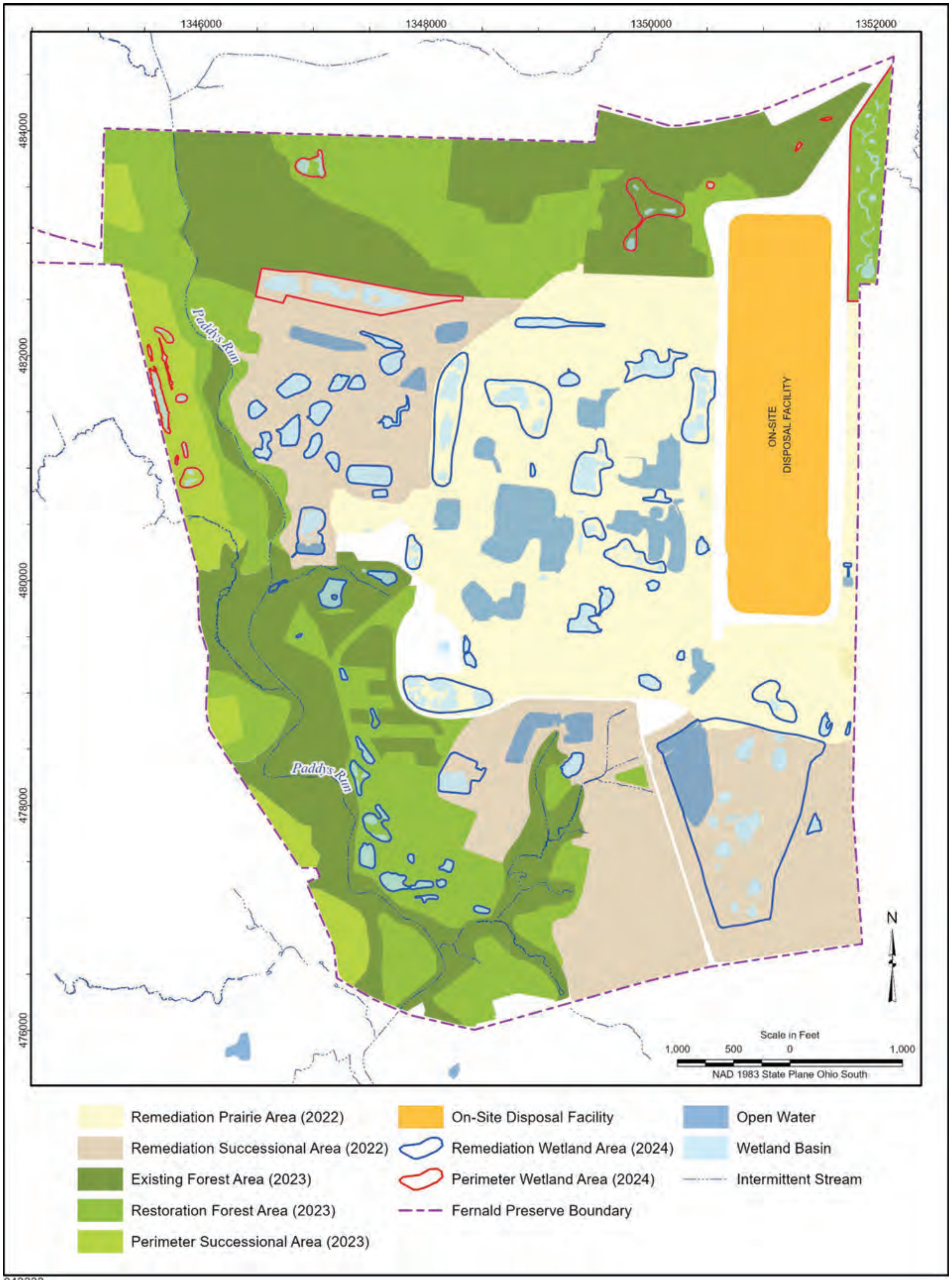

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Figure C-1. Ecological Restoration Management Areas

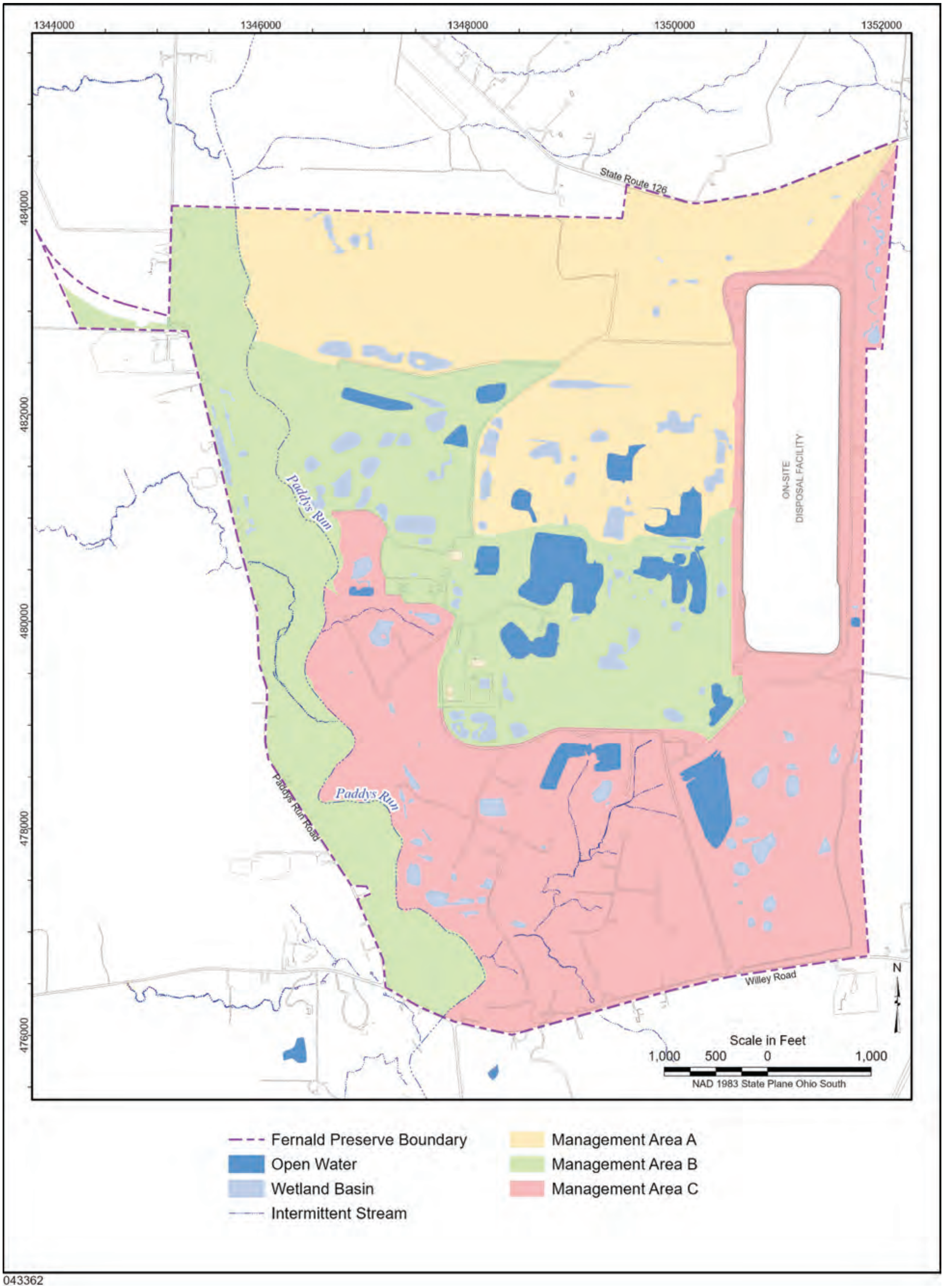

Figure C-2. Area-Based Approach Ecological Management Areas

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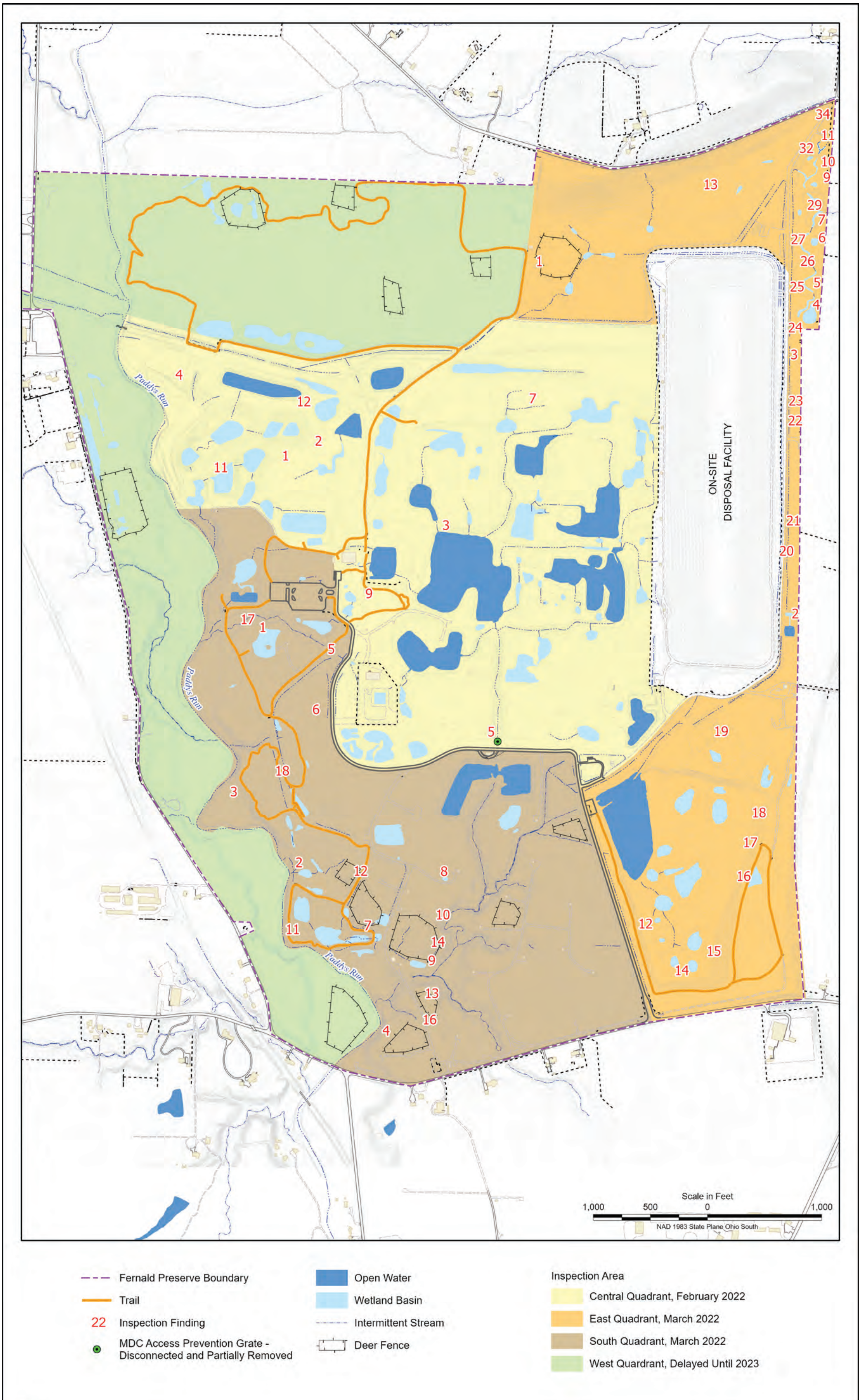


Figure C-3. Site Inspection Findings, 2022

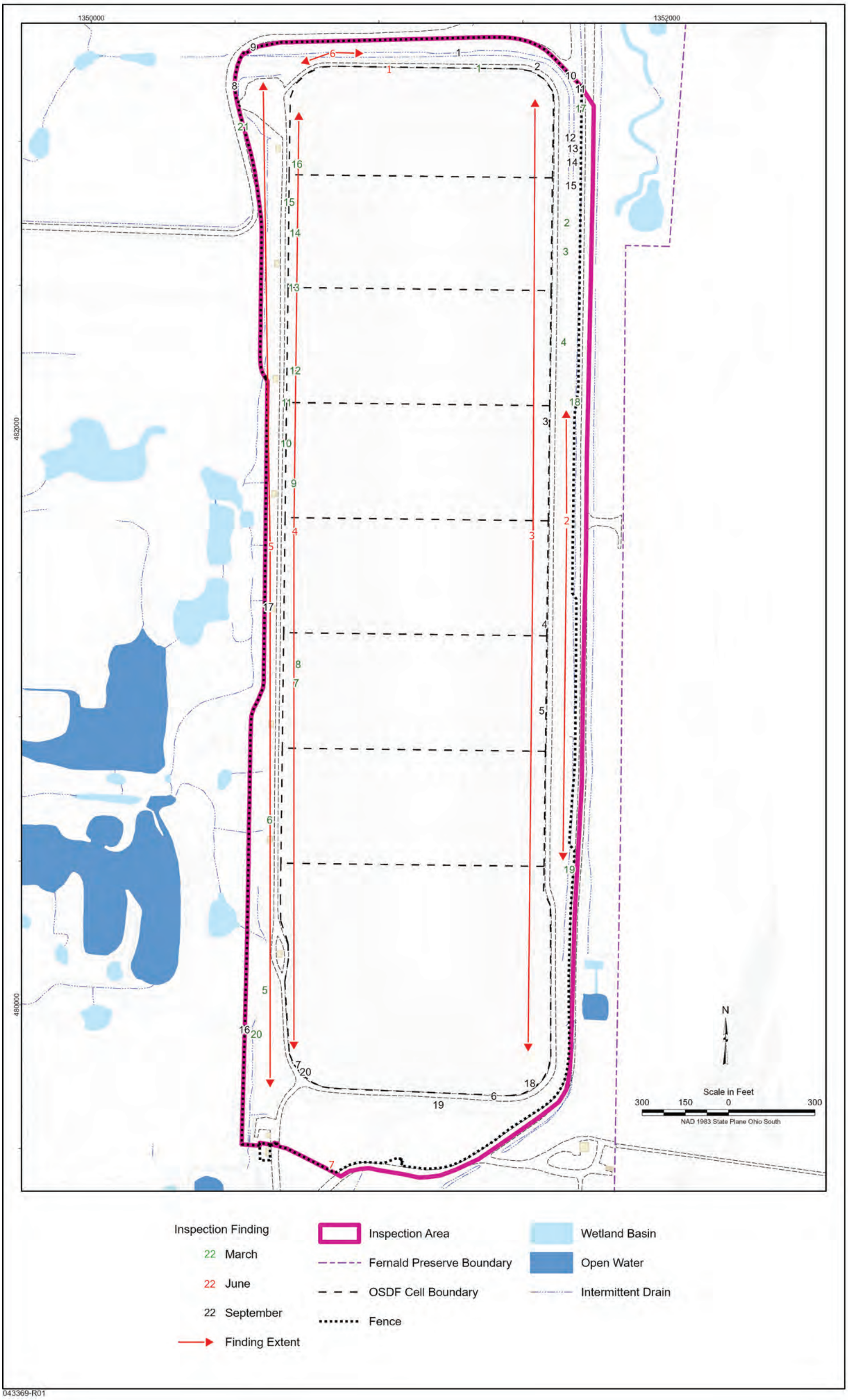


Figure C-4A. OSDF Inspection Findings, March, June, and September 2022

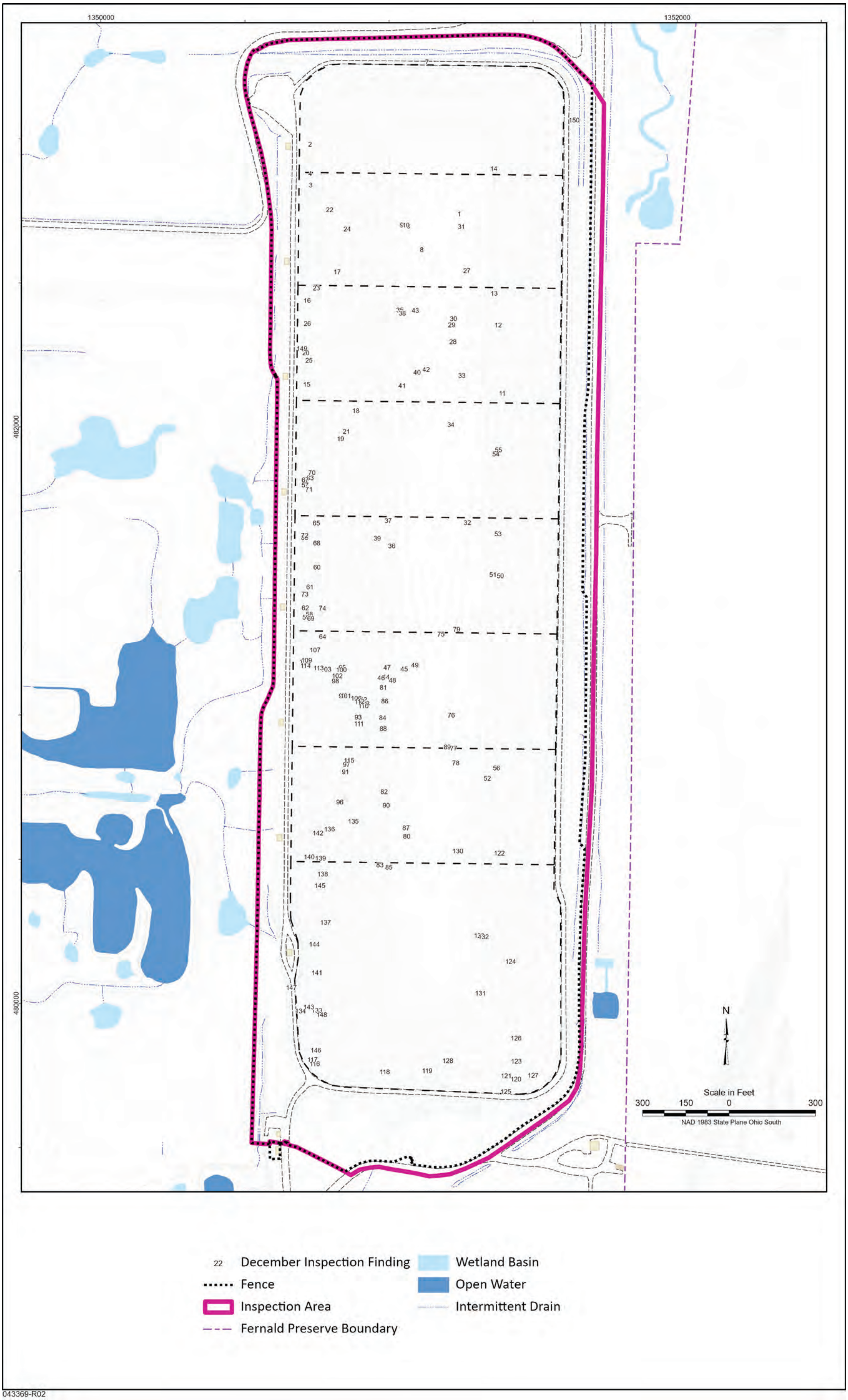


Figure C-4B. OSDF Inspection Findings, December 2022

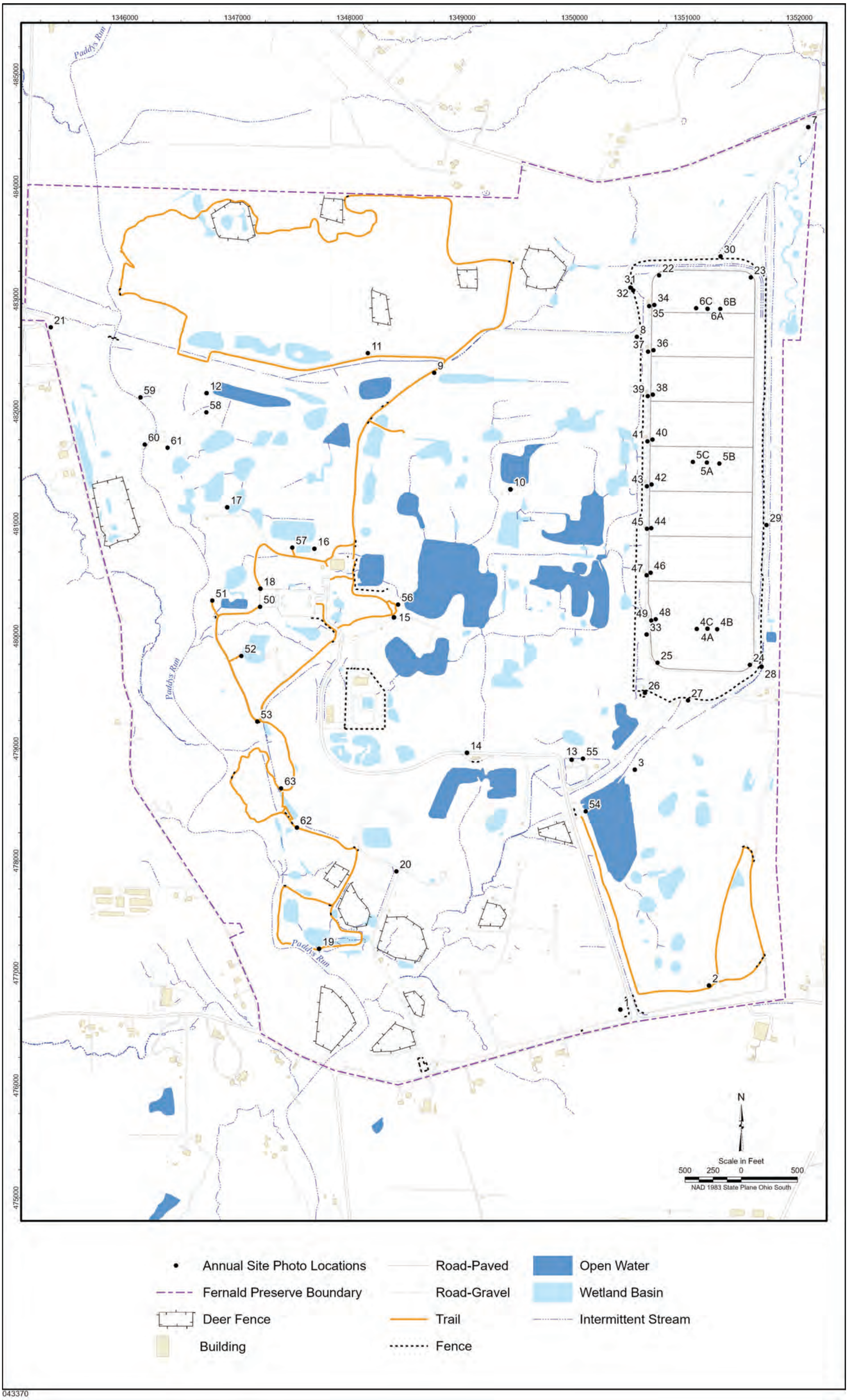


Figure C-5. Location of Site Inspection Photographs

2007

2022

Figure C-5A. Location 1, South Well Field, West Perspective

2007

2022

Figure C-5B. Location 1, South Well Field, North Perspective

2007

2022

Figure C-6A. Location 2, Borrow Area, West Perspective

2007

2022

Figure C-6B. Location 2, Borrow Area, West-Northwest Perspective

2007

2022

Figure C-6C. Location 2, Borrow Area, North Perspective

2007

2022

Figure C-7A. Location 3, Borrow Area, South Perspective

2007

2022

Figure C-7B. Location 3, Borrow Area, West Perspective

2007

2022

Figure C-8A. Location 4A, Top of OSDF Cell 8, South Perspective

2007

2022

Figure C-8B. Location 4A, Top of OSDF Cell 8, North Perspective

2007

2022

Figure C-9. Location 4B, Top of OSDF Cell 8, East Perspective

2007

2022

Figure C-10. Location 4C, Top of OSDF Cell 8, West Perspective

2007

2022

Figure C-11A. Location 5A, Top of OSDF Cell 5, South Perspective

2007

2022

Figure C-11B. Location 5A, Top of OSDF Cell 5, North Perspective

2007

2022

Figure C-12. Location 5B, Top of OSDF Cell 5, East Perspective

2007 **2022**

Figure C-13. Location 5C, Top of OSDF Cell 5, West Perspective

2007 **2022**

Figure C-14A. Location 6A, Top of OSDF Cell 1, South Perspective

2007 **2022**

Figure C-14B. Location 6A, Top of OSDF Cell 1, North Perspective

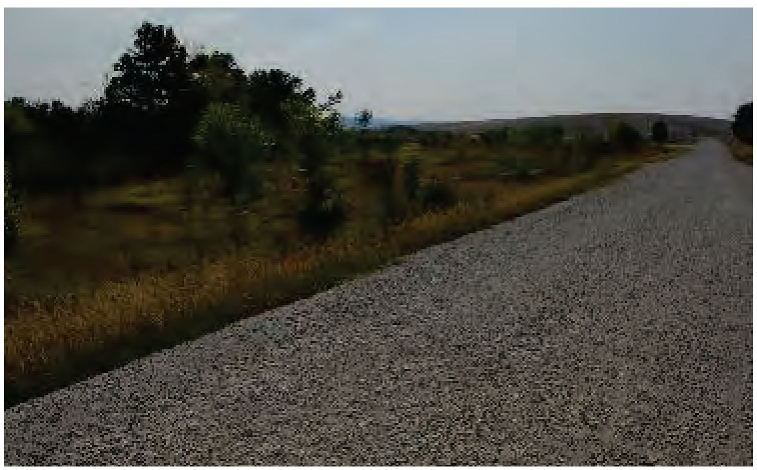
2007 **2022**

Figure C-15. Location 6B, Top of OSDF Cell 1, East Perspective

2007

2022

Figure C-16. Location 6C, Top of OSDF Cell 1, West Perspective



2007

2022

Figure C-17A. Location 7, Northeast Property Corner, South Perspective

2007 **2022**

Figure C-17B. Location 7, Northeast Property Corner, South-Southwest Perspective

2007 **2022**

Figure C-18. Location 8, Former Production Area, Southwest Perspective

2007

2022

Figure C-19. Location 9, Former Production Area, Southeast Perspective

2007

2022

Figure C-20A. Location 10, Former Production Area, South Perspective

2007 **2022**

Figure C-20B. Location 10, Former Production Area, Southwest Perspective

2007 **2022**

Figure C-20C. Location 10, Former Production Area, West Perspective

2007

2022

Figure C-20D. Location 10, Former Production Area, Northwest Perspective

2007

2022

Figure C-20E. Location 10, Former Production Area, North Perspective

2007 **2022**

Figure C-20F. Location 10, Former Production Area, Northeast Perspective

2007 **2022**

Figure C-20G. Location 10, Former Production Area, East Perspective

2007 **2022**

Figure C-20H. Location 10, Former Production Area, Southeast Perspective

2007 **2022**

Figure C-21. Location 11, Wetland Mitigation Phase II, West Perspective

2007 **2022**

Figure C-22A. Location 12, Former Waste Pits Area, East Perspective

2007 **2022**

Figure C-22B. Location 12, Former Waste Pits Area, Southeast Perspective

2007

2022

Figure C-22C. Location 12, Former Waste Pits Area, South Perspective

2007

2022

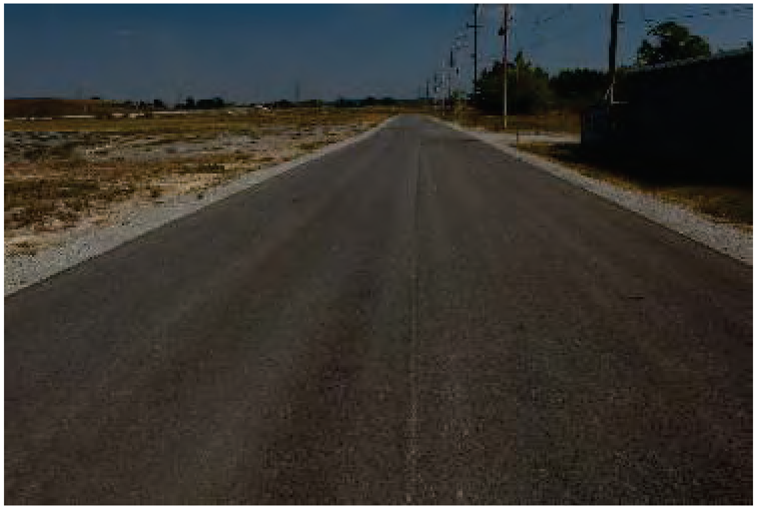
Figure C-23A. Location 13, Former Production Area, Northwest Perspective

2007 **2022**

Figure C-23B. Location 13, Former Production Area, Northeast Perspective

2007 **2022**

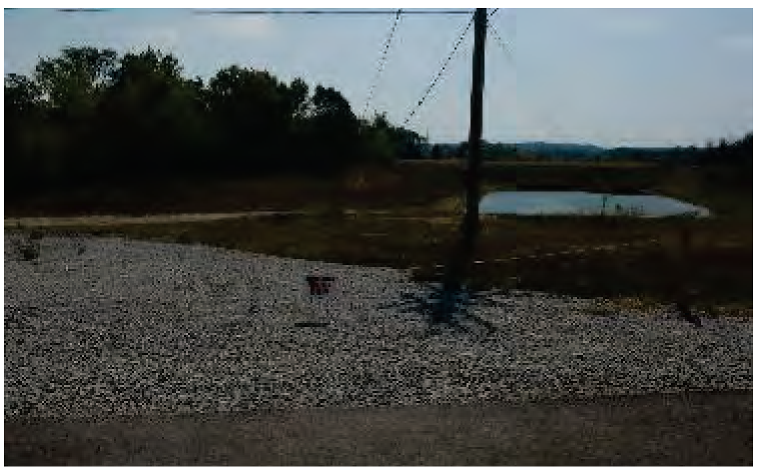
Figure C-24A. Location 14, Former Production Area, North Perspective



2007

2022

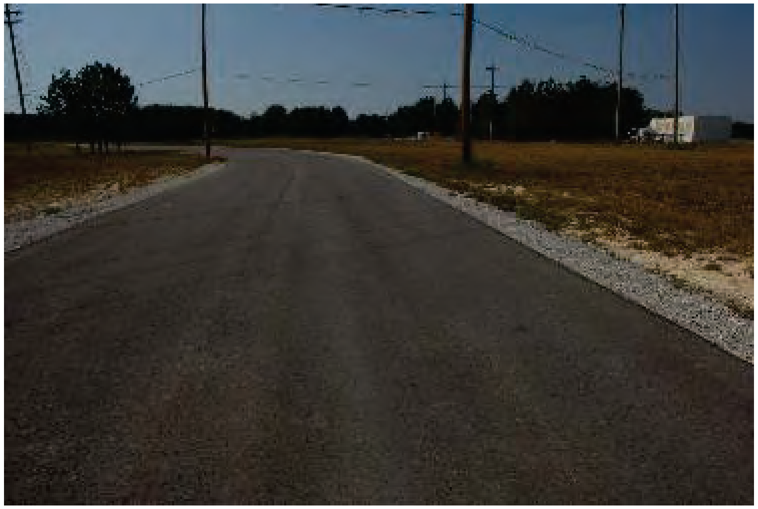
Figure C-24B. Location 14, Former Production Area, East Perspective



2007

2022

Figure C-24C. Location 14, Former Production Area, South Perspective



2007

2022

Figure C-24D. Location 14, Former Production Area, West Perspective

2007

2022

Figure C-25A. Location 15, Former Production Area, North Perspective

2007 **2022**

Figure C-25B. Location 15, Former Production Area, Northeast Perspective

2007 **2022**

Figure C-25C. Location 15, Former Production Area, East Perspective

2007 **2022**

Figure C-25D. Location 15, Former Production Area, Southeast Perspective

2007 **2022**

Figure C-25E. Location 15, Former Production Area, South Perspective

2007

2022

Figure C-25F. Location 15, Former Production Area, Southwest Perspective

2007

2022

Figure C-25G. Location 15, Former Production Area, West Perspective

2007

2022

Figure C-25H. Location 15, Former Production Area, Northwest Perspective

2007

2022

Figure C-26A. Location 16, Biowetland, West-Northwest Perspective

2007 **2022**

Figure C-26B. Location 16, Biowetland, West Perspective

2007 **2022**

Figure C-27A. Location 17, Former Waste Pits Area, West Perspective

2007

2022

Figure C-27B. Location 17, Former Waste Pits Area, Northwest Perspective

2007

2022

Figure C-27C. Location 17, Former Waste Pits Area, North Perspective

2007

2022

Figure C-28A. Location 18, Former Silos Area, West-Southwest Perspective

2007

2022

Figure C-28B. Location 18, Former Silos Area, West-Northwest Perspective

2007 **2022**

Figure C-28C. Location 18, Former Silos Area, North Perspective

2007 **2022**

Figure C-28D. Location 18, Former Silos Area, East Perspective

2007

2022

Figure C-29A. Location 19, Southern Waste Units Area, North-Northwest Perspective

2007

2022

Figure C-29B. Location 19, Former Southern Waste Units Area, North-Northeast Perspective

2007

2022

Figure C-29C. Location 19, Former Southern Waste Units Area, East-Southeast Perspective

2007

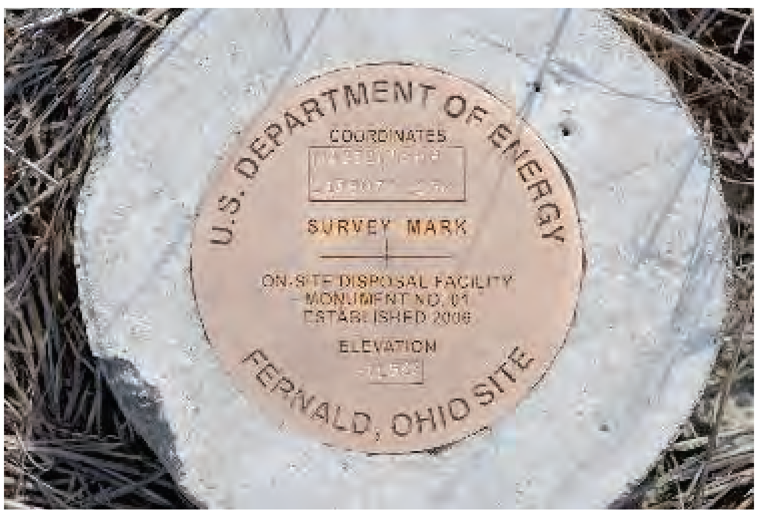
2022

Figure C-30. Location 20, Former Southern Waste Units Area, West-Southwest Perspective

2007

2022

Figure C-31. Location 21, Western Paddys Run Corridor, South-Southeast Perspective



2007

2022

Figure C-32. Location 22, OSDF Survey Marker No. 01 (Northwest Corner)

2007

2022

Figure C-33. Location 23, OSDF Survey Marker No. 02 (Northeast Corner)

2007

2022

Figure C-34. Location 24, OSDF Survey Marker No. 03 (Southeast Corner)

2007

2022

Figure C-35. Location 25, OSDF Survey Marker No. 04 (Southwest Corner)

2007

2022

Figure C-36. Location 26, OSDF Southwest Gate, North-Northeast Perspective

2007 **2022**

Figure C-37. Location 27, OSDF South Gate, North-Northeast Perspective

2007 **2022**

Figure C-38A. Location 28, OSDF East Fence, North Perspective

2007

2022

Figure C-38B. Location 28, OSDF East Fence, North Perspective

2007

2022

Figure C-38C. Location 28, OSDF East Fence Signage, West Perspective

2007

2022

Figure C-38D. Location 28, OSDF East Fence Signage, North-Northwest Perspective

2007

2022

Figure C-39. Location 29, OSDF East Fence, North Perspective

2007 **2022**

Figure C-40A. Location 30, OSDF North Gate, Southwest Perspective

2007 **2022**

Figure C-40B. Location 30, OSDF North Fence, West Perspective

2007 **2022**

Figure C-41. Location 31, OSDF Northwest Gate, North-Northeast Perspective

2007 **2022**

Figure C-42. Location 32, OSDF West Fence, South-Southeast Perspective

2007

2022

Figure C-43A. Location 33, OSDF Valve Houses 7 Through 1, North Perspective

2007

2022

Figure C-43B. Location 33, OSDF Valve Houses 8 Through 1, North Perspective

2007 **2022**

Figure C-44. Location 34, OSDF Valve House 1, West-Northwest Perspective

2007 **2022**

Figure C-45. Location 35, OSDF Cell 1 Wells, Northeast Perspective

2007 **2022**

Figure C-46. Location 36, OSDF Valve House 2, West-Northwest Perspective

2007 **2022**

Figure C-47. Location 37, OSDF Cell 2 Wells, Northeast Perspective

2007 **2022**

Figure C-48. Location 38, OSDF Valve House 3, West-Northwest Perspective

2007 **2022**

Figure C-49. Location 39, OSDF Cell 3 Wells, Northeast Perspective

2007 **2022**

Figure C-50. Location 40, OSDF Valve House 4, West-Northwest Perspective

2007 **2022**

Figure C-51. Location 41, OSDF Cell 4 Wells, Northeast Perspective

2007

2022

Figure C-52. Location 42, OSDF Valve House 5, West-Northwest Perspective

2007

2022

Figure C-53. Location 43, OSDF Cell 5 Wells, Northeast Perspective

2007

2022

Figure C-54. Location 44, OSDF Valve House 6, West-Northwest Perspective

2007

2022

Figure C-55. Location 45, OSDF Cell 6 Wells, Northeast Perspective

2007

2022

Figure C-56. Location 46, OSDF Valve House 7, West-Northwest Perspective

2007

2022

Figure C-57. Location 47, OSDF Cell 7 Wells, Northeast Perspective

2007

2022

Figure C-58. Location 48, OSDF Valve House 8, West-Northwest Perspective

2007

2022

Figure C-59. Location 49, OSDF Cell 8 Wells, Northeast Perspective

2008

2022

Figure C-60. Location 50, Shingle Oak Trail, West Perspective at Trailhead

2008

2022

Figure C-61. Location 51, Shingle Oak Trail, North Perspective at Paddys Run Overlook

2008 **2022**

Figure C-62. Location 52, Shingle Oak Trail, East Perspective at Wildlife Viewing Area

2008 **2022**

Figure C-63. Location 53, Shingle Oak Trail, North Perspective at Southernmost Trail Section

2007

2022

Figure C-64. Location 54, Lodge Pond Deck, East Perspective

2010

2022

Figure C-65. Location 55, Overlook Deck, North Perspective

2010 **2022**

Figure C-66. Location 56, Weapons-to-Wetlands Deck, East Perspective

2010 **2022**

Figure C-67. Location 57, Biowetland Deck, North Perspective

2014

2022

Figure C-68. Location 58, Paddys Run, Streambank Stabilization Area, West Perspective

2014

2022

Figure C-69A. Location 59, Paddys Run, Downstream View

2014

2022

Figure C-69B. Location 59, Paddys Run, Upstream View

2014

2022

Figure C-70. Location 60, Paddys Run, Streambank Stabilization Area, Upstream View of Crossvane

2014

2022

Figure C-71. Location 61, Paddys Run, Streambank Stabilization Area, Northwest Perspective

2014

2022

Figure C-72A. Location 62, South End of Boardwalk, North Perspective

2014

2022

Figure C-72B. Location 62, South End of Boardwalk, South Perspective

2014

2022

Figure C-73. Location 63, North End of Boardwalk, South Perspective