Appendix A

Supplemental Groundwater Information

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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

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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
VAM-3D	Variable Saturated Analysis Model in Three Dimensions
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 18 extraction wells pumping in 2023.
- 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.

In 2023, three extraction wells were shut down permanently in the South Plume Module [3925 (RW-2), 3926 (RW-3), and 32309 (RW-7)]. With the permanent shutdown of South Plume extraction wells 3927 (RW-4) and 32308 (RW-6) in 2022, only one of the original six South Plume recovery wells [3924 (RW-1)] remained operational at the end of 2023. As discussed in this attachment, these operational changes reflect a transition in the South Plume Module from an aging system of six extraction wells to an updated module comprised of two new replacement wells.

The design pumping rate, the pumping rate used in the groundwater model to estimate cleanup times for the aquifer remedy, has changed and will change again in the future as the remedy progresses. The current cleanup operation is based on a 2005 modeling design (DOE 2005). From 2005 to 2014, the design pumping rate was 4,775 gallons per minute (gpm) (DOE 2014). From July 1, 2014, through June 2018, the design pumping rate was 5,075 gpm. Beginning in July 2018, the design pumping rate was 4,975 gpm. Beginning in 2023 the design pumping rate was 4,475 gpm (DOE 2022a). As discussed in this attachment, groundwater modeling predicted that the design pumping rate reductions in 2018 and 2023 would have no effect on the estimated cleanup times for the aquifer remedy. The design pumping rate is scheduled to change again in 2024 when two replacement wells become operational, and the design pumping rate from modeling conducted in 2022 is implemented.

Figure A.1-1 depicts the locations of the active 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 2023 and for the duration of the remedy to date (August 1993 through December 2023).

Information in this attachment is organized into the following subsections:

- Operational System Overview (Section A.1.1)
- Wellfield Shutdowns in 2023 (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 was implemented on July 1, 2014. A main objective of the 2014 design was to remediate the South Plume area first. 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 and South Field between 2014 and the end of 2023.

Area	Total Uranium Plume Size 2014 (acres)	Total Uranium Plume Size 2023 (acres)	Percent Reduction
South Plume	29.8	13.13	55.9%
South Field	62.0	46.5	25.0%

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 (GMA) in 2013 (year before pumping changes) and 2023. More information concerning the new modeling predictions 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 (2005) 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 in the 2014 design 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. In more recent years, the number of treatments has decreased due to realization that the long-term use of liquid acid descaler over time was harmful to metal components of an aging wellfield system.

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 2023, 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
2023	18[a]	11
2022	20	17
2021	20	30
2020	20	43
2019	20	19[b]
2018	20	28[c]
2017	20	35
2016	20	22[d]
2015	20	41
2014	23/20[e]	32
2013	23	38

[a] The number of operating extraction wells was reduced in 2022 (i.e., RW-4 and RW-6 were turned off).
[b] Number of chemical treatments was affected by replacement of the CAWWT backwash basin.
[c] Number of chemical treatments was affected by the CAWWT construction project.
[d] Number of chemical treatments was affected by an extended unplanned shutdown (DOE 2017).
[e] 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 3926 (RW-3) were discovered to be weakened by a combination of age and the continued use of liquid acid descaler such that some of the water being pumped from the well was able to cascade back down into the well.

In 2022, the South Plume recovery wells continued to experience operational challenges. Because of their advanced age, and exposure to liquid acid descaler during periodic well treatments and rehabilitations, damage to the seals and pitless adaptors increased. Recovery wells 3926 (RW-3), 3927 (RW-4), and 32308 (RW-6) experienced operational problems. Operators were able to repair South Plume recovery well 3926 (RW-3) to be operational again in 2022, but 3927 (RW-4) and 32308 (RW-6) were permanently shut down. After repairing 3926 (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 3926 (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 the U.S. Department of Energy (DOE) was already planning a replacement for this well at a more optimal location, it was decided that resources would be directed 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 2023

The planned annual wellfield shutdown in 2023 lasted 40 days (May 31 to July 9, 2023). During this shutdown, recovery well RW-1 and RW-2 continued to pump at the southern edge of the uranium plume with the exception of a 2 day shutdown (June 19 to June 20) due to composite sampler issues. RW-3 was permanently shut down on June 12, 2023.

A second 2023 wellfield shutdown occurred between August 2 and August 23 to clean the inside surfaces of the wellfield discharge pipes. Over years of operation, iron deposits had accumulated on the inside surfaces of the discharge pipes restricting flow. Pipes from 13 onsite wells were cleaned. Following the cleaning, 4 of the 13 wells showed significant improvement in flow rate; 5 of the 13 wells were also rehabilitated and had new pumps installed. All five showed significant improvements in flow rate, which was attributed to the combination of clean pipes, rehabbed well screens, and new pumps. Cleaning the well pipes resulted in at least some reduction in discharge pressure for all the wells and significant improvements in flow rates at several wells. DOE is planning to repeat the cleanings approximately every 5 years with the next cleaning planned for 2028.

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 (ft) 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 ft. 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 2023 was as follows:

Year	Wellfield Shut Down Due to River Stage (days)
2018	10
2019	7
2020	4
2021	0
2022	4
2023	4

A.1.3 South Field Module

Eleven extraction wells were operational in the South Field Module in 2023. 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 2023 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 2023. 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 2023, 1,1149.81 million gallons (Mgal) of groundwater were pumped from the active extraction wells in the South Field Module, resulting in the removal of 185.46 pounds (lb) of uranium from the GMA. Since startup in July 1998, the South Field Module has removed 30.231 billion gallons of water and 9,845.15 lb of uranium from the GMA.

A.1.4 South Plume Module

During the years 2022 and 2023, five of the original six South Plume extraction wells were permanently shut down due to age and maintenance problems (RW-2, RW-3, RW-4, RW-6, and RW-7). At the end of 2023 only extraction well RW-1 remained operational. At the end of 2023, the remaining recovery well [3924 (RW-1)] continued to operate, but struggled to maintain its operational setpoint. Additional information is provided in Section A.1.9

Four recovery wells were operational in the South Plume Module at the start of 2023: 3924 (RW-1), 3925 (RW-2), 3926 (RW-3), 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 2023 was 800 gpm.

Two of the original six South Plume recovery wells were permanently shut down in 2022. Recovery well RW-4 was permanently turned off on June 6, 2022, after 29 years of operation (1998 to 2022). The decision to turn off 3927 (RW-4) permanently began in June 2022, when 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 32308 (RW-6) was shut down permanently on July 25, 2022, after 23 years of operation (1998 to 2022). 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.

Three of the original six South Plume recovery wells were permanently shut down in 2023. These three wells were 32309 (RW-7), 3926 (RW-3), and 3925 (RW-2). RW-7 was permanently shut down on October 24, 2023, after 24 years of operation (1998 to 2023). 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 could indicate 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. On October 24, 2023, RW-7 shut down due to a motor malfunction. RW-7 was scheduled to be shut down permanently the week of November 20, 2023, to facilitate drilling and installation of two new extraction wells. The decision was made to leave RW-7 permanently shut down rather than replace the motor for one additional month of service.

Recovery well 3925 (RW-2) was permanently shut down on October 31, 2023, after 30 years of operation (1993 to 2023). The pumping rate in RW-2 had fallen to 80 gpm and the pitless adaptor was too corroded to be repaired without extensive excavation. The metal port was also too corroded to administer liquid acid descaler for treatment (i.e., threads on the metal port were too badly corroded, and attempts to administer liquid acid descaler through another, smaller port did not significantly increase the flow rate). As discussed in Section A.1-9, RW-4 was no longer needed to capture and remediate the South Plume.

Recovery well 3926 (RW-3) was permanently shut down on June 12, 2023, after 30 years of operation (1993 to 2023). The flow rate had decreased to approximately 60 gpm, and similar to RW-2, the metal components of the well were too badly corroded to implement liquid acid descaler treatments. As discussed in Section A.1-9, RW-3 was no longer needed to capture and remediate the South Plume.

With the shutdown of five of the original six South Plume extraction wells, the target pumping rate for the South Plume Module will be approximately 200 gpm for the remaining well (RW-1). As discussed below, DOE is in the process of installing two new extraction wells to take the place of all six of the original South Plume recovery wells.

Table A.1-1 presents the combined performance data for the South Plume Module. Tables A.1-13 through A.1-16 provide individual extraction well performance data for the South Plume Module wells in 2023. 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 2023, 276.14 Mgal of groundwater were pumped from the active extraction wells in the South Plume Module, resulting in the removal of 31.19 lb of uranium from the GMA. Since its startup in August 1993, the South Plume Module has removed 19.483 billion gallons of groundwater and 3,658 lb of uranium from the GMA.

During 2023, several original South Plume Module wells were permanently shut down. Conservative groundwater modeling conducted in 2022 (based just on the movement of groundwater and the current location of the South Plume) indicated that all of the original 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 and operational at the locations identified in the 2022 modeling, remediation and capture of the remaining South Plume will be achieved without continued operation of any of the original South Plume wells. The first original South Plume well to be shut down permanently was RW-4 on June 6, 2022. Defining this date as the start of the 3-year window to avoid breach of capture, results in the two new wells needing to be operational before June 2025. The new wells will be operational in spring 2024, well ahead of the 3-year window, which results in the continued achievement of the two main objectives of the South Plume Module:

- 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.
- Actively remediating the higher-concentration region of the off-property plume.

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

A.1.4.1 Current Condition of Recovery Well RW-1

As reported in the previous section, at the end of 2023 only one of the original South Plume recovery wells (RW-1) remained operating at the end of 2023. Recovery well RW-1 has been operating for 30 years. The well was originally installed downgradient of the leading edge of the South Plume along with three other wells, 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 South Plume wells were successful in achieving this objective.

Groundwater modeling conducted in 2022 demonstrates that the original South Plume recovery wells RW-1, RW-2, RW-3, and RW-4 are no longer needed to remediate and capture the remaining South Plume if two new extraction wells are installed further north. Metal components in the original South Plume wells 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 well RW-1 is 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 well inoperable, RW-1 will be operated at a target pumping rate of 200 gpm until it fails. It should be noted that RW-1 is a 10-inch diameter well, which requires an 8-inch diameter pump and motor. 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 Operational Path Forward for the Remaining Original South Plume Well

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 to extend its operational life should it no longer be able to achieve a pumping rate of 100 gpm. The steps presented below will be taken to operate the well at or above 100 gpm for as long as possible before it is 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 they 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 is permanently turned off. No action will be taken at the well 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 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, if available.

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

A.1.4.3 Paddys Run Road Site

In 2023, 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.1-17, 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 (milligrams per liter [mg/L]) 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 2023 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 2023.

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 2023. 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 2023 was 800 gpm. The combined performance data for the WSA Module are presented in Table A.1-1. Tables A.1-18 through A.1-20 provide individual extraction well performance data for the WSA Module wells for 2023. 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 2023, 339.57 Mgal of groundwater were pumped from extraction wells in the WSA Module, resulting in the removal of 53.90 lb of uranium from the GMA. Since startup in May 2002, the WSA Module has removed 9.110 billion gallons of water and 2,594.13 lb of uranium from the GMA.

A.1.6 Total Uranium Data

In 2023, 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 2023, 1.766 billion gallons of groundwater were pumped from the GMA, and 3.46 Mgal (0.20%) 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	322,210	7.68	28.6	18.3
February	377,995	7.7	31.8	19.1
March	271,950	8.1	33.8	18.3
April	281,660	6.8	26.2	18.5
May	280,210	7.4	29.7	17.3
June	257,945	10.0	20.0	12.2
July	221,540	9.1	33.1	17.5
August	248,430	8.1	25.9	17.2
September	293,365	9.7	36.9	18.8
October	298,425	9.0	33.3	16.9
November	314,705	7.3	31.4	15.6
December	290,305	6.1	29.2	16.3
Total	**3,458,740**			

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. Until 2022, 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 changed in 2022. A collaborative effort between 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 was 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 implemented in the 2022 Site Environmental Report (DOE 2023).

For the implementation, dual exponential functions were evaluated and from that stretched exponential functions were selected to conduct regression analysis of yearly extraction well datasets to project uranium mass removal. A bootstrapping approach was used to calculate 95% confidence intervals for the stretched exponential functions.

Figures A.1-13 through A.1-27 are uranium concentration versus time plots for each extraction well operating in 2023. 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.1-27 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 limit (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.1-27 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 level (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, 2023, are summarized in Table A.1-21.

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 2023, data indicated that 16,021 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 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 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.1-22 provides a yearly breakdown of the pounds of uranium to be removed from 2024 to 2040 to achieve concentration-based FRL goals, based on three predictions (i.e., uranium concentration data, model predictions, 95% UCL). Figure A.1-28 illustrates the relationship between the three predictions. Each prediction is further discussed below.

The estimated pounds of uranium to be removed for this year's report (as shown in Table A.1-22) were adjusted due to the permanent shutdown of some of the South Plume recovery wells. As explained earlier, at the end of 2023, only RW-1 remained operating. Stretched exponential predictions and 95% UCL predictions shown in Table A.1-22 do not include South Plume recovery wells RW-2 through RW-7; however, the model predictions for 2024 and 2025 still include RW-2 through RW-7. Once the two new wells are operational in 2024, the modeling run that includes those two wells and no other South Plume wells will be used for future predicted pounds of uranium to be removed from the aquifer.

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 2024 and 2040 to achieve remediation goals is 2,895 lb.

A.1.6.2 Model

Modeling conducted in 2022 predicts that from 2024 through 2040 an additional 1,973 lb of uranium will need to be removed from the GMA to achieve concentration-based cleanup goals under nominal boundary conditions. These modeling predictions include South Plume recovery wells RW-1 through RW-7 for 2024 and 2025. Once the two new South Plume recovery wells are operational in 2024, the modeling run that includes the two new wells and not the other South Plume wells will be used to make future predictions of the pounds of uranium to be removed from the aquifer.

A.1.6.3 95% UCL

Use of a bootstrapping approach to calculate a 95% confidence interval resulted in an estimate that between 2024 and 2040 an additional 3,518 lb, of uranium will need to be removed from the aquifer to achieve concentration-based cleanup goals.

A summary of the three predictions is provided below.

Net pounds of uranium extracted through December 2023	16,021		
	Data	**Model**	**95% UCL**
Predicted pounds of uranium to be extracted between 2024 and the end of the pump-and-treat stage of the aquifer remedy (in accordance with the current Operational Design, nominal boundary conditions)	2,895	1,973	3,518
Total predicted pounds of uranium to be removed to achieve concentration-based FRL goals	18,916	17,994	19,539
Estimated percent complete (based on pounds of uranium to be removed)	85%	89%	82%

Results shown above indicate that as of December 31, 2023, the estimated percent complete (based on pounds of uranium to be removed to achieve concentration-based FRL goals) are 85%, 89%, and 82% 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 82% and 85%. The groundwater model prediction indicates 89% 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 (DOE 2022a) was rerun 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 shown in Table A.1-22 both monitoring data and modeling now predict that between 17,994 to 18,916 lb of dissolved uranium will need to be pumped from the aquifer in order to achieve concentration-based cleanup objectives. The 95% UCL estimate is higher at 19,539 lb.

A comparison of groundwater model-predicted uranium concentrations and the actual uranium concentrations measured at each extraction well is provided in Table A.1-23. For 7 years (2015 to 2021) this comparison was made using model predictions made in 2012 and implemented in 2014. Beginning with the 2022 Site Environmental Report (DOE 2023), model predictions shown in Figure A.1-28 were made with an updated model run that used initial uranium plume concentrations measured in 2021. The 2022 model run had all South Plume wells operating.

The comparison this year does not include recovery wells RW-2 through RW-7 because those wells were permanently turned off before December 2023. The comparison this year shows that the average model-predicted total uranium concentration for 2023 was (16.50 µg/L). The actual average measured concentration in December 2023 was (16.55 µg/L). The residual average uranium concentration (actual uranium concentration minus model-predicted uranium concentration) was −0.5 µg/L. The standard deviation for the residual dataset was 12.88. 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 2023 is provided in Table A.1-24. It should be noted that in the 2021 Site Environmental Report, the 2021 model predictions that were shown in Table A.1-24 were made in 2012 when the groundwater model was run to implement the 2014 operational changes. Beginning in 2022, model predictions shown in Table A.1-24 were made with the updated model run that used initial uranium plume concentrations measured in 2021. This is expected to change again for next year’s report when the 2022 modeling run that includes the two new South Plume extraction wells, and none of the original South Plume Extraction wells will be used.

Actual uranium concentrations measured in the first half of 2023 are compared against model-predicted uranium concentrations for April 2023. 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.1-24 represents nominal water-level conditions. Groundwater modeling conducted in 2022 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.1-24, the average residual uranium concentration in 2023 was 33.62 µg/L. As was presented in previous years, Table A.1-25 shows the average residual uranium concentration for 2023 with five monitoring wells that were the main contributors to the difference (2049, 2386, 2387, 23273, and 83295_C2) removed. Those five wells are in the South Field. The average residual uranium concentration decreases from 33.62 µg/L (all measured wells) to 15.74 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 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 currently 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 Network 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 desorbs from the areas of finer-grained sediments as the water moves past and around them. This slow desorption process lengthens aquifer cleanup times by hindering uranium transport and mobility in the aquifer.

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 when and 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 2 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.

In 2023, DOE began working on comparing the VAM-3D modeling code to the MODFLOW modeling code for running the Fernald site groundwater model. The objective is to see if MODFLOW can be used in order to be more user friendly and transparent for running future algorithm-based optimization codes. A decision on which code the site plans to move forward with should be available in 2024. Any decision to move forward with either VAM-3D or MODFLOW will be discussed with both EPA and Oho EPA before being implemented.

A.1.9 Pumping Rates

Target design extraction well pumping rates for 2023 are provided in Table A.1-26. The target design pumping rate is the pumping rate used in the groundwater model to estimate cleanup times for the aquifer remedy. The target design pumping rate has changed over time. From 2005 to July 1, 2014, the target design pumping rate was 4,775 gpm. From July 1, 2014, through June 2018, the target design pumping rate was 5,075 gpm (DOE 2014). 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 2023, the target design pumping rate was reduced to 4,475 gpm due to RW-4 and RW-6 being permanently turned off in 2022, and the target pumping rate of RW-7 being reduced from 300 to 200 gpm. A brief discussion of each reduction (RW-4, RW-6, and RW-7) is provided below.

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), and had a hole in the screen that had been repaired with a concrete plug. Rehabilitation attempts were 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 continued to operate the well until it failed on June 6, 2022. The continued pumping at the lower rate helped 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 were replaced again, and once again the drillers could not get the pitless adaptor to seat properly. As reported above, through 2022 the target pumping rate for this well was recognized as 200 gpm. On January 1, 2023, it was removed from the South Plume Module and removed from Table A.1-26.

Beginning in January 2023, the target design pumping rate for the South Plume on Table A.1-26 was 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 was 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. 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.

As discussed in Section A.1 4, three more original South Plume wells (RW-3, RW-7, and RW-2) were permanently shut down in 2023. Only one original South Plume well remained operating at the end of 2023 (RW-1, at a target rate of 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 3 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. In 2023, DOE began installing the two new South Plume recovery wells and the wells are scheduled to be operational in spring2024.

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

DOE (U.S. Department of Energy), 1993. *South Plume Groundwater Recovery System Design, Monitoring, and Evaluation Program Plan*, Fluor Environmental Management Project, Fernald Area Office, Cincinnati, Ohio, April.

DOE (U.S. Department of Energy), 1996. *Record of Decision for Remedial Actions at Operable Unit 5*, 7478 U 007 501.4, Final, Fluor Fernald, Cincinnati, Ohio, January.

DOE (U.S. Department of Energy), 2005. *Waste Storage Area Phase II Design Report*, 52424-RP-0004, Revision A, Draft Final, Fluor Fernald, Fernald Area Office, Cincinnati, Ohio, June.

DOE (U.S. Department of Energy), 2014. *Operational Design Adjustments-1, WSA Phase-II Groundwater Remediation Design, Fernald Preserve*, LMS/FER/S10798, Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2016. *Fernald Preserve 2015 Site Environmental Report*, LMS/FER/S13591, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2022a. *2022 Groundwater Modeling Report, Fernald Preserve, Ohio, Site*, Revision 1, LMS/FER/40875, Office of Legacy Management, November.

DOE (U.S. Department of Energy), 2022b. *Fernald Preserve 2021 Site Environmental Report*, LMS/FER/S37811, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2023. *Fernald Preserve 2022 Site Environmental Report*, LMS/FER/S43783, Office of Legacy Management, May.

EPA (U.S. Environmental Protection Agency), 1992. *General Methods for Remedial Operation Performance Evaluations*, Environmental Research Laboratory, Ada, Oklahoma, January.

ERM Midwest Inc., 1994. *Remedial Investigation and Risk Assessment, Paddys Run Road Site*, Revision 1, Volumes 1–5, Crosby Township, Hamilton, Ohio.

SNL (Sandia National Laboratories), 2004. *Results of Uranium Adsorption/Desorption Experiments and Microanalytical Studies Characterizing Sediment Samples from the Great Miami Aquifer, Fernald DOE Site, Ohio*, SAND2004-4085, Albuquerque, New Mexico, August.

Whitman, Requardt & Associates LLP, 2015. *Fernald Preserve Site Converted Advanced Wastewater Treatment Current Condition Assessment Report*, Final, March.

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

	Reporting Period					
	January 2023 Through December 2023			August 1993 Through December 2023		
	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	1,149.81	185.46	0.16	30,231.39	9,845.15	0.33
Waste Storage Area Module	339.57	53.90	0.16	9,110.25	2,594.13	0.28
South Plume Module	276.14	31.19	0.11	19,482.91	3,658.23	0.19
Reinjection Module[a]	0	0	NA	1,936.48	76.27	Not Applicable
Aquifer Restoration Systems Totals						
Extraction Wells	1,765.52	270.55	0.15	58,824.54	16,097.48	0.27
(Reinjection Wells[a])	0	0	NA	(1,936.48)	(76.27)	Not Applicable
Net	1,765.52	270.55	0.15	56,688.07	16,021.21	Not Applicable

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

Table A.1-2. Extraction Well 31550 (EW-18) Operational Summary for 2023

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: 1,677

Hours pumped: 7,083
Operational percent: 80.86

Adjusted operational percent[a]: 90.81

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	110.3	4.923	24.7	0.21
Feb	106.4	4.292	22.1	0.18
Mar	92.1	4.111	29.8	0.25
Apr	110.5	4.775	26.2	0.22
May	103.7	4.628	29.7	0.25
Jun	0.0	0.000	0.0	0.00
Jul	84.5	3.771	26.6	0.22
Aug	39.8	1.776	25.9	0.22
Sep	110.8	4.787	33.4	0.28
Oct	110.9	4.952	29.6	0.25
Nov	111.1	4.798	26.6	0.22
Dec	111.1	4.960	24.4	0.20
	Average 90.9	Total 47.773	Average 24.9	Average 0.23

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-18 was down from March 4 to March 6 due to high river levels.
Well EW-18 was down from March 24 to March 27 due to high river levels.
Well EW-18 was down from May 31 to July 9 for planned wellfield shutdown.
Well EW-18 was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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: 1,674

Hours pumped: 7,086
Operational percent: 80.89

Adjusted operational percent[a]: 90.85

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	111.0		4.957		14.0		0.12
Feb	109.6		4.421		18.1		0.15
Mar	92.1		4.111		17.2		0.14
Apr	110.8		4.785		16.0		0.13
May	101.6		4.534		15.5		0.13
Jun	0.0		0.000		0.0		0.00
Jul	88.9		3.971		15.1		0.13
Aug	39.9		1.779		15.1		0.13
Sep	110.8		4.787		16.1		0.13
Oct	110.8		4.948		16.4		0.14
Nov	111.3		4.808		14.4		0.12
Dec	110.9		4.949		12.6		0.11
Average	91.5	Total	48.049	Average	14.2	Average	0.12

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-19 was down from March 4 to March 6 due to high river levels.
Well EW-19 was down from March 24 to March 27 due to high river levels.
Well EW-19 was down from May 31 to July 9 for planned wellfield shutdown.
Well EW-19 was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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 not pumped: 2,504

Hours pumped: 6,256
Operational percent: 71.42

Adjusted operational percent[a]: 80.21

Target pumping rate: 200 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		156.9		7.004		28.6		0.24
Feb		161.9		6.528		31.8		0.27
Mar		152.1		6.790		33.8		0.28
Apr		166.2		7.180		31.6		0.26
May		0.0		0.000		0.0		0.00
Jun		0.0		0.000		0.0		0.00
Jul		170.0		7.588		31.5		0.26
Aug		73.9		3.300		25.1		0.21
Sep		225.1		9.725		36.9		0.31
Oct		220.1		9.824		33.3		0.28
Nov		219.1		9.467		31.4		0.26
Dec		199.0		8.882		29.2		0.24
	Average	145.4	Total	76.287	Average	26.1	Average	0.22

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-20 was down from March 4 to March 6 due to high river levels.
Well EW-20 was down from March 24 to March 27 due to high river levels.
Well EW-20 was down from April 29 to July 9 for rehabilitation and planned wellfield shutdown.
Well EW-20 was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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: 2,303.5

Hours pumped: 6,457.0
Operational percent: 73.70

Adjusted operational percent[a]: 82.78

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	183.5	8.191	7.6	0.06
Feb	151.5	6.110	10.0	0.08
Mar	119.5	5.333	10.4	0.09
Apr	194.0	8.383	9.4	0.08
May	143.3	6.396	9.4	0.08
Jun	0.0	0.000	0.0	0.00
Jul	0.0	0.000	0.0	0.00
Aug	55.9	2.493	9.4	0.08
Sep	194.2	8.390	10.0	0.08
Oct	194.8	8.698	9.0	0.08
Nov	195.1	8.426	7.3	0.06
Dec	185.9	8.300	6.6	0.06
	Average 134.8	Total 70.721	Average 7.4	Average 0.06

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-17A was down from March 4 to March 6 due to high river levels.
Well EW-17A was down from March 20 to March 22 for liquid acid descaler chemical treatment.
Well EW-17A was down from March 24 to March 27 due to high river levels.
Well EW-17A was down from May 26 to August 2 for power outage, planned wellfield shutdown, rehabilitation.
Well EW-17A was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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: 1,685

Hours pumped: 7,075
Operational percent: 80.76

Adjusted operational percent[a]: 90.70

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		329.6		14.711		15.3		0.13
Feb		329.1		13.271		17.8		0.00
Mar		274.9		12.270		17.1		0.14
Apr		329.4		14.231		17.3		0.14
May		273.0		12.185		17.8		0.15
Jun		0.0		0.000		0.0		0.00
Jul		234.7		10.479		17.9		0.15
Aug		284.5		12.699		19.1		0.16
Sep		329.9		14.250		20.6		0.17
Oct		329.8		14.722		18.8		0.16
Nov		329.9		14.250		15.9		0.13
Dec		329.3		14.699		14.4		0.12
	Average	281.2	Total	147.767	Average	16.0	Average	0.12

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-22 was down from March 4 to March 6 due to high river levels.
Well EW-22 was down from March 24 to March 27 due to high river levels.
Well EW-22 was down from May 26 to July 9 due to power outage and planned wellfield shutdown.
Well EW-22 was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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: 1,723

Hours pumped: 7,037
Operational percent: 80.33

Adjusted operational percent[a]: 90.22

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	438.3	19.566	21.6	0.18
Feb	423.0	17.054	23.5	0.20
Mar	367.7	16.412	22.2	0.19
Apr	430.7	18.608	22.3	0.19
May	378.5	16.894	22.0	0.18
Jun	0.0	0.000	0.0	0.00
Jul	284.5	12.699	19.1	0.16
Aug	132.5	5.915	19.3	0.16
Sep	438.2	18.929	24.0	0.20
Oct	402.4	17.961	22.8	0.19
Nov	357.2	15.432	22.0	0.18
Dec	413.7	18.467	19.7	0.16
	Average 338.9	Total 177.939	Average 19.9	Average 0.17

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-24 was down from March 4 to March 6 due to high river levels.
Well EW-24 was down from March 24 to March 27 due to high river levels.
Well EW-24 was down from May 31 to July 9 for planned wellfield shutdown.
Well EW-24 was down from August 2 to August 23 for well pipe cleaning.
Well EW-24 was down from November 13 to November 16 for liquid acid descaler chemical treatment.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-8. Extraction Well 32447 (EW-23) Operational Summary for 2023

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: 3,475

Hours pumped: 5,285
Operational percent: 60.33

Adjusted operational percent[a]: 67.75

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	439.1	19.602	24.5	0.20
Feb	404.2	16.297	26.1	0.22
Mar	323.7	14.448	24.4	0.20
Apr	484.2	20.916	23.6	0.20
May	434.8	19.410	24.7	0.21
Jun	0.0	0.000	0.0	0.00
Jul	0.0	0.000	0.0	0.00
Aug	3.9	0.173	41.7	0.35
Sep	0.0	0.000	0.0	0.00
Oct	336.5	15.020	23.5	0.20
Nov	500.1	21.605	24.1	0.20
Dec	528.7	23.599	22.0	0.18
	Average 287.9	Total 151.069	Average 19.6	Average 0.16

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-23 was down from March 4 to March 6 due to high river levels.
Well EW-23 was down from March 24 to March 27 due to high river levels.
Well EW-23 was down from March 27 to March 29 for liquid acid descaler chemical treatment.
Well EW-23 was down from May 31 to August 29 for planned wellfield shutdown and variable frequency drive malfunction.
Well EW-23 was down from August 31 to October 12 to replace variable frequency drive.
Well EW-23 was down from November 13 to November 15 for liquid acid descaler chemical treatment.
.[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-9. Extraction Well 33061 (EW-25) Operational Summary for 2023

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: 1,800

Hours pumped: 6.960
Operational percent: 79.45

Adjusted operational percent[a]: 89.23

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		109.1		4.870		17.6		0.15
Feb		105.6		4.259		18.8		0.16
Mar		86.2		3.849		18.1		0.15
Apr		111.0		4.794		15.0		0.13
May		96.7		4.318		17.9		0.15
Jun		0.0		0.000		0.0		0.00
Jul		81.8		3.653		16.4		0.14
Aug		40.7		1.817		16.5		0.14
Sep		112.1		4.844		19.8		0.17
Oct		113.5		5.066		17.0		0.14
Nov		114.7		4.955		19.3		0.16
Dec		110.5		4.932		21.1		0.18
	Average	90.2	Total	47.359	Average	16.5	Average	0.14

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-25 was down from March 4 to March 6 due to high river levels.
Well EW-25 was down from March 21 to March 23 for liquid acid descaler chemical treatment.
Well EW-25 was down from March 24 to March 27 due to high river levels.
Well EW-25 was down from May 12 to May 13 due to variable frequency drive malfunction.
Well EW-25 was down from May 31 to July 9 for planned wellfield shutdown.
Well EW-25 was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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: 1,936

Hours pumped: 6,824
Operational percent: 77.89

Adjusted operational percent[a]: 87.48

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	328.2	14.651	14.6	0.12
Feb	314.1	12.663	18.2	0.15
Mar	208.4	9.305	21.1	0.18
Apr	311.0	13.435	23.3	0.19
May	256.2	11.439	20.7	0.17
Jun	0.0	0.000	0.0	0.00
Jul	205.7	9.182	24.9	0.21
Aug	100.0	4.463	19.3	0.16
Sep	298.9	12.910	23.9	0.20
Oct	329.7	14.718	18.1	0.15
Nov	328.5	14.190	14.4	0.12
Dec	322.5	14.397	12.1	0.10
	Average 250.3	Total 131.352	Average 17.5	Average 0.15

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-15A was down from March 4 to March 6 due to high river levels.
Well EW-15A was down from March 14 to March 16 for liquid acid descaler chemical treatment.
Well EW-15A was down from March 20 to March 23 for liquid acid descaler chemical treatment.
Well EW-15A was down from March 24 to March 27 due to high river levels.
Well EW-15A was down from May 26 to July 9 due to power outage and planned wellfield shutdown.
Well EW-15A was down from August 2 to August 23 for well pipe cleaning.
Well EW-15A was down from August 12 to September 14 for liquid acid descaler 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 2023

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 pumped: 5,652 | Target pumping rate: 400 gpm
Hours not pumped: 3,108 | Operational percent: 64.52

Adjusted operational percent[a]: 72.46

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		26.7		1.077		7.7		0.06
Mar		367.9		16.425		8.1		0.07
Apr		439.4		18.981		6.8		0.06
May		411.1		18.353		7.4		0.06
Jun		0.0		0.000		0.0		0.00
Jul		298.5		13.324		12.3		0.10
Aug		140.5		6.270		8.1		0.07
Sep		407.7		17.612		9.7		0.08
Oct		439.3		19.610		9.1		0.08
Nov		439.6		18.991		7.4		0.06
Dec		408.6		18.241		6.1		0.05
	Average	281.6	Total	148.883	Average	6.9	Average	0.06

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-30 was down from January 1 to February 27 due to pump replacement and variable frequency drive malfunction.
Well EW-30 was down from March 4 to March 6 due to high river levels.
Well EW-30 was down from March 24 to March 27 due to high river levels.
Well EW-30 was down from May 31 to July 9 for planned wellfield shutdown.
Well EW-30 was down from August 2 to August 23 for well pipe cleaning.
Well EW-30 was down from August 12 to September 14 for liquid acid descaler treatment.
Well EW-30 was down from December 12 to December 14 for liquid acid descaler treatment.
[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 2023

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: 1,696

Hours pumped: 7,064
Operational percent: 80.64

Adjusted operational percent[a]: 90.56

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	203.2	9.069	17.9	0.15
Feb	204.3	8.239	23.5	0.20
Mar	184.1	8.219	25.2	0.21
Apr	259.5	11.211	25.5	0.21
May	232.3	10.370	25.3	0.21
Jun	0.0	0.000	0.0	0.00
Jul	223.1	9.958	33.1	0.28
Aug	105.3	4.703	25.4	0.21
Sep	329.5	14.235	32.0	0.27
Oct	318.5	14.218	22.7	0.19
Nov	254.6	10.999	16.4	0.14
Dec	209.6	9.358	15.5	0.13
	Average 210.3	Total 110.578	Average 21.9	Average 0.18

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-21A was down from March 4 to March 6 due to high river levels.
Well EW-21A was down from March 14 to March 16 for liquid acid descaler treatment.
Well EW-21A was down from March 24 to March 27 due to high river levels.
Well EW-21A was down from May 31 to July 9 for planned wellfield shutdown and rehabilitation.
Well EW-21A was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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: 8,072 | Target pumping rate: 200 gpm
Hours not pumped: 688 | Operational percent: 92.15

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		218.5		9.755		8.9		0.07
Feb		195.4		7.878		10.3		0.09
Mar		182.9		8.164		10.1		0.08
Apr		214.8		9.278		10.2		0.09
May		212.5		9.484		10.4		0.09
Jun		220.7		9.533		10.0		0.00
Jul		223.0		9.956		9.7		0.08
Aug		69.9		3.122		9.3		0.08
Sep		174.9		7.557		11.0		0.09
Oct		205.3		9.164		11.6		0.10
Nov		195.0		8.424		9.8		0.08
Dec		184.1		8.217		8.8		0.07
	Average	191.4	Total	100.532	Average	10.0	Average	0.08

[a] Well RW-1 was down from March 4 to March 6 due to high river levels.
Well RW-1 was down from March 24 to March 27 due to high river levels.
Well RW-1 was down from June 19 to June 20 due to Parshall Flume composite sampler not working.
Well RW-1 was down from August 2 to August 23 for well pipe cleaning.
[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 2023

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 pumped: 6,440.5 | Target pumping rate: 200 gpm
Hours not pumped: 2,319.5 | Operational percent: 73.52

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	218.7	9.764	10.1	0.08
Feb	164.3	6.626	12.5	0.10
Mar	184.6	8.239	12.8	0.11
Apr	212.6	9.183	12.0	0.10
May	198.1	8.842	11.6	0.10
Jun	186.5	8.058	12.1	0.10
Jul	154.3	6.886	12.3	0.10
Aug	43.4	1.937	12.2	0.10
Sep	108.1	4.669	14.9	0.12
Oct	102.7	4.583	13.8	0.12
Nov	0.0	0.000	0.0	0.00
Dec	0.0	0.000	0.0	0.00
	Average 131.1	Total 68.786	Average 12.4	Average 0.10

[a] Well RW-2 was down from February 16 to February 24, due to a variable frequency drive malfunction.
Well RW-2 was down from March 4 to March 6 due to high river levels.
Well RW-2 was down from March 24 to March 27 due to high river levels.
Well RW-2 was down from June 19 to June 20 due to Parshall Flume composite sampler not working.
Well RW-2 was down from August 2 to August 23 for well pipe cleaning.
Well RW-2 was down from September 25 to September 27 for liquid acid descaler chemical treatment.
Well RW-2 was shut down permanently on October 31, 2023.

[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 2023

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: 374.8 | Target pumping rate: 200 gpm
Hours not pumped: 5,012 | Operational percent: 42.79

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		182.9		8.165		16.2		0.14
Feb		157.4		6.346		19.1		0.16
Mar		118.4		5.286		19.2		0.16
Apr		118.0		5.098		19.0		0.16
May		85.8		3.831		19.1		0.16
Jun		26.5		1.146		11.6		0.10
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	114.8	Total	29.873	Average	17.4	Average	0.14

[a] Well RW-3 was down from March 4 to March 6 due to high river levels.
Well RW-3 was down from March 24 to March 27 due to high river levels.
Well RW-3 was shut down permanently on June 12, 2023.
[b] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-16. Extraction Well 32309 (RW-7) Operational Summary for 2023

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: 3,568

Hours pumped: 5,192
Operational percent: 59.27

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	155.0	6.919	17.9	0.15
Feb	231.8	9.346	19.2	0.16
Mar	175.8	7.848	18.1	0.15
Apr	218.5	9.440	16.8	0.14
May	204.1	9.110	17.2	0.14
Jun	0.0	0.000	0.0	0.00
Jul	159.2	7.105	12.3	0.10
Aug	105.9	4.728	15.6	0.13
Sep	297.1	12.835	19.0	0.16
Oct	215.5	9.618	19.7	0.16
Nov	0.0	0.000	0.0	0.00
Dec	0.0	0.000	0.0	0.00
	Average 176.3	Total 76.949	Average 15.6	Average 0.13

[a] Adjusted for planned annual wellfield shutdown.
[b] Well RW-7 was down from January 10 to January 19 for preventive maintenance valve check, and new pump.
Well RW-7 was down from March 4 to March 6 due to high river levels.
Well RW-7 was down from March 24 to March 27 due to high river levels.
Well RW-7 was down from May 31 to July 9 for planned wellfield shutdown.
Well RW-7 was down from August 2 to August 23 for well pipe cleaning.
Well RW-7 was shut down permanently on October 24, 2023.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-17. 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	255	0.000195	0.188	0.0108	0.0200	Down
	2636	193	0.0100	0.0939	0.0431	0.0187	Down
	2898	72	0.000147	0.0820	0.00406	0.0103	No Trend[g]
	2899	65	0.000320	0.0283	0.00254	0.00382	No Trend[g]
	2900	254	0.000320	0.0609	0.00484	0.00528	Down
	3128	75	0.000400	0.234	0.00671	0.0270	No Trend
	3636	72	0.000500	0.0233	0.00291	0.00367	No Trend[g]
	3898	72	0.000500	0.0434	0.00420	0.00611	No Trend[g]
	3899	73	0.000147	0.0307	0.00281	0.00441	No Trend[g]
	3900	73	0.000375	0.0208	0.00301	0.00351	No Trend
Phosphorus	2128	81	0.0250	16.2	1.23	2.22	Down
	2636	45	9.60	170	76.2	42.4	Down
	2898	73	0.0050	9.95	0.215	1.18	Down
	2899	64	0.0050	0.831	0.0532	0.107	No Trend
	2900	71	0.0431	4.74	0.425	0.611	Down
	3128	82	0.0050	13.0	0.213	1.43	No Trend
	3636	71	0.0091	1.10	0.0654	0.132	No Trend
	3898	71	0.0075	1.24	0.0904	0.159	Down
	3899	72	0.0050	1.86	0.103	0.250	Down
	3900	73	0.0050	1.38	0.0807	0.216	Down
Potassium	2128	73	0.830	18.0	3.12	3.06	Down
	2636	45	4.60	218	56.3	48.9	Down
	2898	73	1.11	9.64	4.40	1.12	Up
	2899	65	1.36	8.85	4.11	0.892	Up
	2900	72	0.0095	6.00	1.93	1.03	No Trend
	3128	75	1.09	3.70	1.87	0.604	Down
	3636	71	1.09	4.24	2.06	0.572	Down
	3898	72	0.610	4.23	2.73	0.734	Up
	3899	73	0.875	4.55	2.87	0.793	Up
	3900	73	0.975	3.19	1.69	0.370	Down

Table A.1-17. PRRS Groundwater Summary Statistics and Trend Analysis (continued)

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]
Sodium	2128	73	12.3	75.2	32.9	11.3	Down
	2636	45	14.4	148	46.9	26.8	Down
	2898	73	4.95	31.0	19.8	4.66	Up
	2899	65	11.2	25.1	18.0	3.32	Up
	2900	72	0.0136	43.3	24.9	8.00	Down
	3128	75	3.52	13.4	5.42	2.43	Down
	3636	71	3.14	13.0	5.56	2.61	Down
	3898	72	7.29	28.8	13.0	5.74	Up
	3899	73	6.24	43.6	14.1	10.0	Up
	3900	73	3.13	10.8	4.71	1.67	Down

[a] The data are based on unfiltered samples from the Operable Unit 5 Remedial Investigation/Feasibility Study dataset (1988–1993) and 1994 through 2023 groundwater data (unfiltered and filtered for 2001–2023).

[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.1-18. Extraction Well 32761 (EW-26) Operational Summary for 2023

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: 2,290

Hours pumped: 6,470
Operational percent: 73.85

Adjusted operational percent[a]: 82.94

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		318.9		14.237		16.2		0.14
Feb		291.6		11.758		18.9		0.16
Mar		244.7		10.922		18.4		0.15
Apr		315.5		13.631		19.3		0.16
May		262.3		11.707		18.9		0.16
Jun		0.0		0.000		0.0		0.00
Jul		0.0		0.000		0.0		0.00
Aug		102.3		4.567		25.7		0.21
Sep		329.7		14.242		22.6		0.19
Oct		329.9		14.726		19.5		0.16
Nov		329.9		14.252		17.0		0.14
Dec		329.6		14.711		26.0		0.22
	Average	237.9	Total	124.753	Average	16.9	Average	0.14

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-26 was down from March 4 to March 6 due to high river levels.
Well EW-26 was down from March 24 to March 27 due to high river levels.
Well EW-26 was down from May 26 to May 31 due to power outage.
Well EW-26 was down from May 31 to August 23 for planned wellfield shutdown, rehabilitation, and pipe cleaning.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-19. Extraction Well 33062 (EW-27) Operational Summary for 2023

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: 2,166

Hours pumped: 6,549
Operational percent: 75.27

Adjusted operational percent[a]: 84.54

Target pumping rate: 200 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	218.3	9.745	17.3	0.14
Feb	208.1	8.392	19.5	0.16
Mar	155.7	6.951	19.7	0.16
Apr	219.5	9.484	19.4	0.16
May	186.3	8.315	20.1	0.17
Jun	79.7	3.443	20.0	0.17
Jul	21.3	0.950	17.5	0.15
Aug	58.0	2.591	18.0	0.15
Sep	219.6	9.487	24.2	0.20
Oct	219.4	9.795	20.7	0.17
Nov	202.8	8.763	14.4	0.12
Dec	186.3	8.316	16.0	0.00
	Average 164.6	Total 86.233	Average 18.90	Average 0.15

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-27 was down from March 4 to March 6 due to high river levels.
Well EW-27 was down from March 24 to March 27 due to high river levels.
Well EW-27 was down from March 27 to March 29 for liquid acid descaler chemical treatment.
Well EW-27 was down from May 26 to July 9 due to power outage and planned wellfield shutdown.
Well EW-27 was down from July 15 to August 23 for rehabilitation and pipe cleaning.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-20. Extraction Well 33347 (EW-33a) Operational Summary for 2023

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 not pumped: 1,863

Hours pumped: 6.897
Operational percent: 78.73

Adjusted operational percent[a]: 88.42

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		302.2		13.492		18.1		0.15
Feb		304.2		12.267		20.0		0.17
Mar		235.7		10.523		18.3		0.15
Apr		305.0		13.174		20.5		0.17
May		242.4		10.823		19.4		0.16
Jun		0.0		0.000		0.0		0.00
Jul		184.0		8.213		18.3		0.15
Aug		100.5		4.488		16.6		0.14
Sep		309.8		13.383		20.1		0.17
Oct		309.7		13.826		17.5		0.15
Nov		317.1		13.697		16.6		0.14
Dec		329.3		14.698		13.8		0.12
	Average	245.0	Total	128.584	Average	16.60	Average	0.14

[a] Adjusted for planned annual wellfield shutdowns.
[b] Well EW-33A was down from March 4 to March 6 due to high river levels.
Well EW-33A was down from March 24 to March 27 due to high river levels.
Well EW-33A was down from March 28 to March 30 for liquid acid descaler treatment.
Well EW-33A was down from May 26 to July 9 due to power outage and planned wellfield shutdown.
Well EW-33A was down from August 2 to August 23 for well pipe cleaning.
[c] Average is used if more than one concentration measurement is available for a particular month.

Table A.1-21. Stretch Exponential Regression Equations for Uranium Concentration Data Collected at Extraction Wells—Through December 31, 2023

Extraction Well Number	Database Identification	Stretched Exponential Equations
RW-1	3924	$y = 178.04e^{-(x/436.7)\text{^}0.3159}$
RW-7	32309	$y = 89.50e^{-(x/4249.4)\text{^}0.7016}$
EW-15a	33262	$y = 90.66e^{-(x/2876.8)\text{^}0.4050}$
EW-17a	33326	$y = 42.69e^{-(x/5899.1)\text{^}0.9796}$
EW-18	31550	$y = 500.00e^{-(x/0.24)\text{^}0.0981}$
EW-19	31560	$y = 204.75e^{-(x/731.3)\text{^}0.4089}$
EW-20	31561	$y = 116.66e^{-(x/604.8)\text{^}0.1203}$
EW-21a	33298	$y = 217.06e^{-(x/1275.9)\text{^}0.4092}$
EW-22	32276	$y = 330.62e^{-(x/891.5)\text{^}0.4881}$
EW-23	32447	$y = 453.21e^{-(x/413.3)\text{^}0.3356}$
EW-24	32446	$y = 121.71e^{-(x/3062.5)\text{^}0.4928}$
EW-25	33061	$y = 58.24e^{-(x/6907.1)\text{^}0.6267}$
EW-30	33264	$y = 233.97e^{-(x/1071.7)\text{^}0.5916}$
EW-26	32761	$y = 176.96e^{-(x/798.4)\text{^}0.3748}$
EW-27	33062	$y = 332.38e^{-(x/169.0)\text{^}0.2765}$
EW-33a	33347	$y = 64.54e^{-(x/484.3)\text{^}0.0644}$

Table A.1-22. Estimate of Pounds of Uranium to Be Removed to Achieve Concentration-Based FRL Goals

Year	Based on Concentration Data and Use of Stretched Exponential Equations	Based on Model Predictions	Based on 95% UCL
2024	323	313	384
2025	312	272	376
2026	246	200	294
2027	240	176	289
2028	234	157	284
2029	229	143	280
2030	223	132	275
2031	218	122	271
2032	214	114	268
2033	209	107	264
2034	68	39	79
2035	66	37	78
2036	65	35	77
2037	64	33	76
2038	63	32	75
2039	62	31	74
2040	61	30	73
Estimate of total to be extracted	2,895	1,973	3,518
Actual net pounds extracted through December 31, 2023	*16,021*	*16,021*	*16,021*
Estimate of total pounds to be extracted to achieve concentration-based FRL goals	18,916	17,994	19,539
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**
2023	85%	89%	82%

Table A.1-23. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations

Extraction Well	Model-Predicted Total Uranium Concentration December 2023 (µg/L)	Total Uranium Concentration December 2023 (µg/L)	Residual Total Uranium Concentration[a] (µg/L)
3924 (RW-1)	3.76	8.8	–5.04
33262 (EW-15a)	14.76	12.1	–2.66
33326 (EW-17a)	8.09	6.6	–1.49
31550 (EW-18)	14.72	24.4	9.68
31560 (EW-19)	25.34	12.6	–12.74
31561 (EW-20)	22.97	29.2	6.23
33298 (EW-21a)	16.34	15.5	–0.84
32276 (EW-22)	10.21	14.4	4.19
32447 (EW-23)	19.75	22.0	2.25
32446 (EW-24)	7.50	19.7	12.20
33061 (EW-25)	19.63	21.1	1.47
32761 (EW-26)	19.33	26.0	6.67
33062 (EW-27)	7.41	16.0	8.59
33264 (EW-30)	2.80	6.1	3.30
33347 (EW-33a)	54.90	13.8	–41.10
2023 Average	16.50	16.55	0.05
2023 Standard Deviation	12.69	7.01	12.88
2023 Maximum	54.90	29.20	12.20
2023 Minimum	2.80	6.10	–41.10
2023 Range	52.10	23.10	53.30
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

Table A.1-23. Comparison of Model-Predicted Versus Actual Total Uranium Concentration (continued)

Extraction Well	Model-Predicted Total Uranium Concentration December 2023 (µg/L)	Total Uranium Concentration December 2023 (µg/L)	Residual Total Uranium Concentration[a] (µg/L)
2018 Average	16.8	21.1	4.3
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.1-24. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations in Selected Monitoring Wells

Well Number	Observed Total Uranium Concentrations First Half 2023 (µg/L)	Predicted Total Uranium Concentrations[a] April 1, 2023 (µg/L)	Total Uranium Concentration Residuals (µg/L)
2045	57.4	20.38	37.02
2046	12.3	15.93	–3.63
2049	143	11.83	131.17
2093	3.54	2.18	1.36
2385	26.7	18.45	8.25
2386	176	72.02	103.98
2387	114	27.79	86.21
2821	5.89	6.05	-0.16
23271	37.36	17.58	19.72
23273	130	32.48	97.52
23274	88.7	45.50	43.20
23275	92.6	25.21	67.39
23276	72.7	26.93	45.77
23278	21.9	10.59	11.31
23280	17.58	21.95	–4.45
23281	92.8	24.12	68.68
82433_C2	3.04	9.45	–6.41
83117_C2	22.6	30.11	–7.51
83124_C2	25.0	46.02	–21.02
83293_C2	2.2	4.01	–1.81
83294_C2	63.1	44.80	18.30
83295_C2	92.2	21.22	70.98
83296_C2	24.5	17.15	7.35
2023 Average	57.61	23.99	33.62
2023 Standard Deviation	50.43	16.19	42.72
2023 Maximum	176.00	72.02	131.17
2023 Minimum	2.20	2.18	–21.02
2023 Range	173.80	69.84	152.19
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.1-25. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations with Select Wells Removed

Well Number[a]	Observed Total Uranium Concentrations First Half 2023 (µg/L)	Predicted Total Uranium Concentrations April 1, 2023[b] (µg/L)	Total Uranium Concentration Residuals (µg/L)
2045	57.4	20.38	37.02
2046	12.3	15.93	–3.63
2093	3.54	2.18	1.36
2385	26.7	18.45	8.25
2821	5.89	6.05	-0.16
23271	37.36	17.58	19.72
23274	88.7	45.50	43.20
23275	92.6	25.21	67.39
23276	72.7	26.93	45.77
23278	21.9	10.59	11.31
23280	17.58	21.95	–4.45
23281	92.8	24.12	68.68
82433_C2	3.04	9.45	–6.41
83117_C2	22.6	30.11	–7.51
83124_C2	25.0	46.02	–21.02
83293_C2	2.2	4.01	–1.81
83294_C2	63.1	44.80	18.30
83296_C2	24.5	17.15	7.35
2023 Average	37.21	21.47	15.74
2023 Standard Deviation	32.11	13.51	26.21
2023 Maximum	92.80	46.02	68.68
2023 Minimum	2.20	2.18	–21.02
2023 Range	90.60	43.84	89.71
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.1-26. Extraction Well Target Design Pumping Rates

Extraction Well	Target Pumping Rate (gpm)
South Plume	
3924 (RW-1)	200
3925 (RW-2)	200
3926 (RW-3)	200
32309 (RW-7)	200
Subtotal	800
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	4,475[a]

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

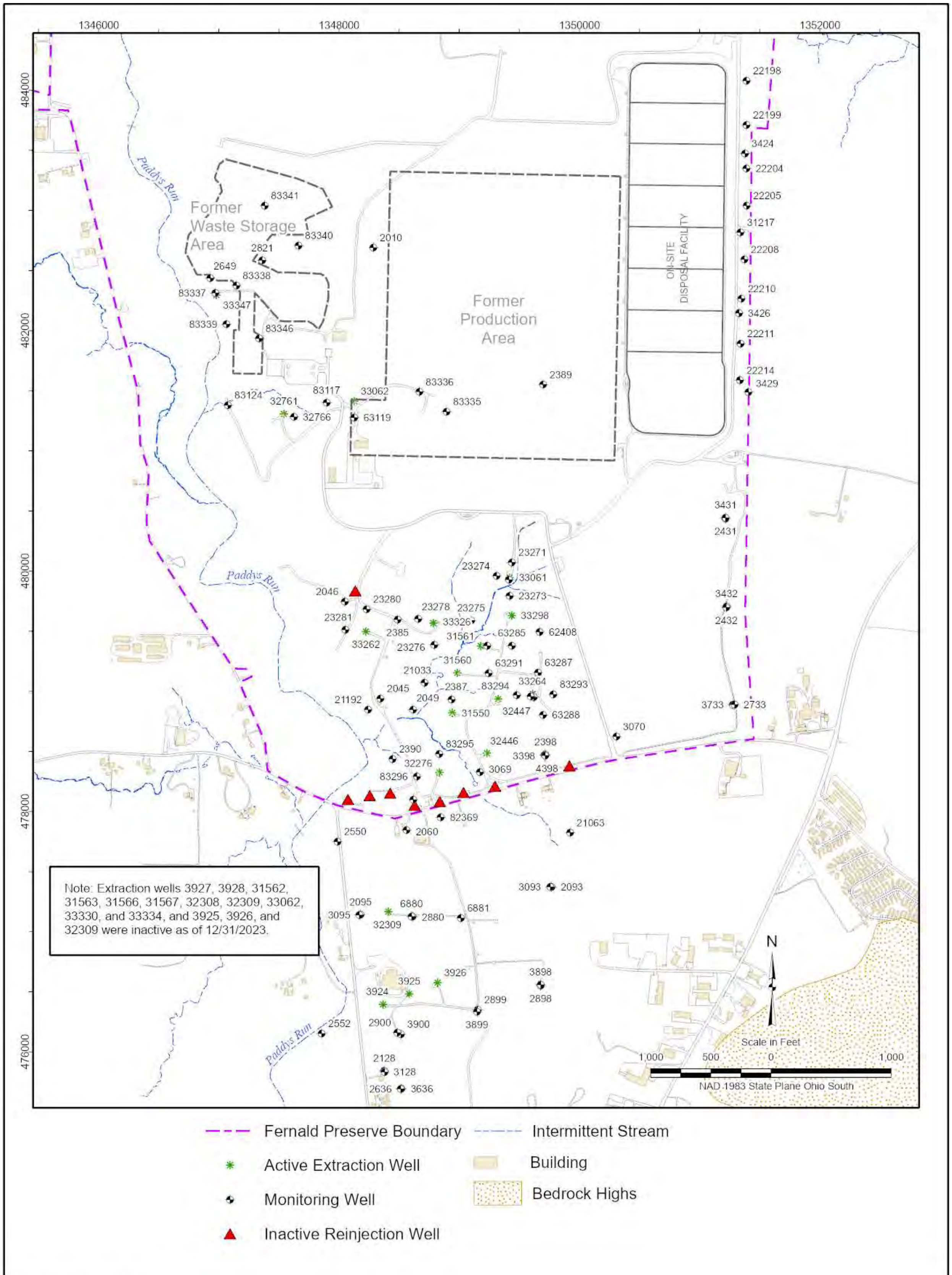

Figure A.1-1. Well Locations for South Plume, South Field, WSA, and PRRS Monitoring Activities

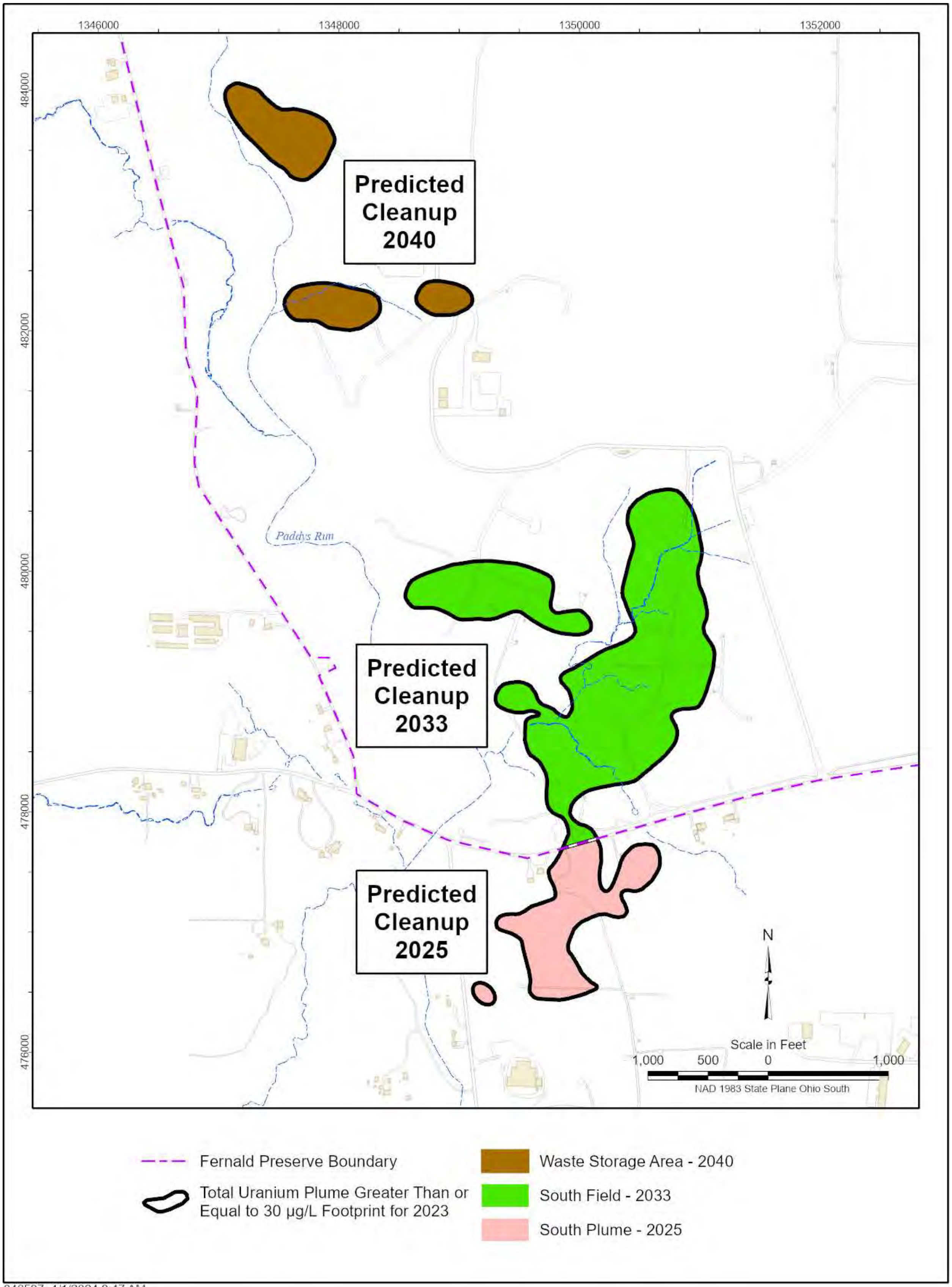

Figure A.1-2. Operational Design

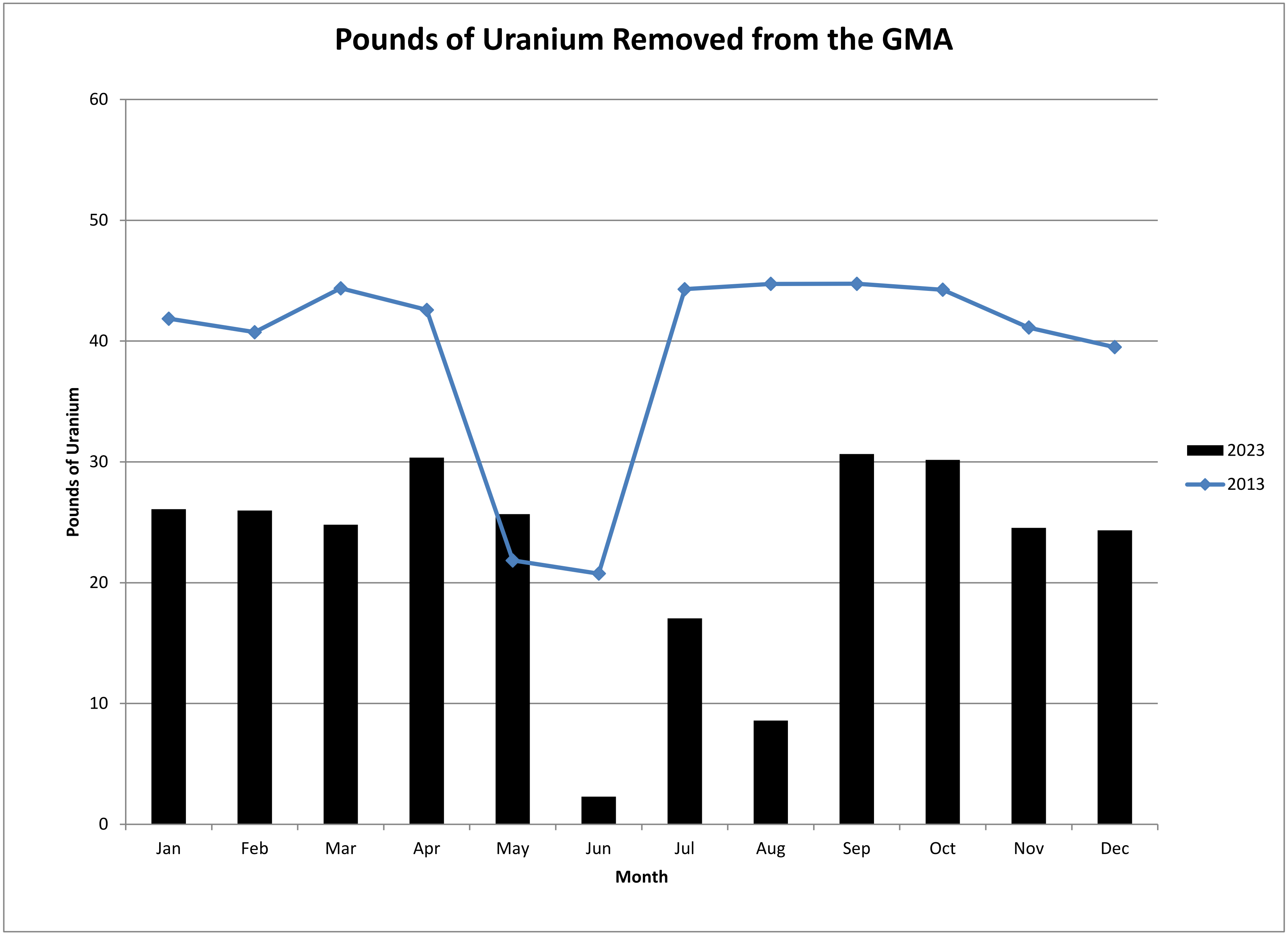

Figure A.1-3. Pounds of Uranium Removed from the GMA

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

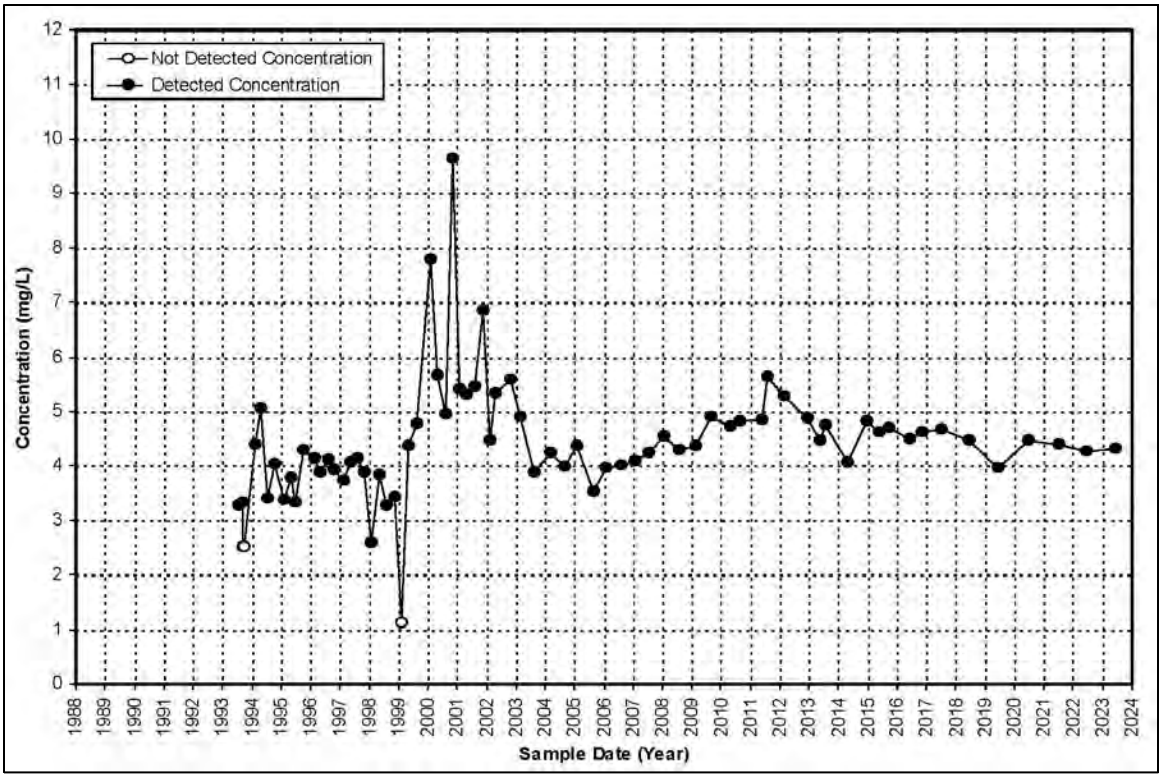

Figure A.1-5. Potassium Concentration Versus Time Plot for Monitoring Well 2898

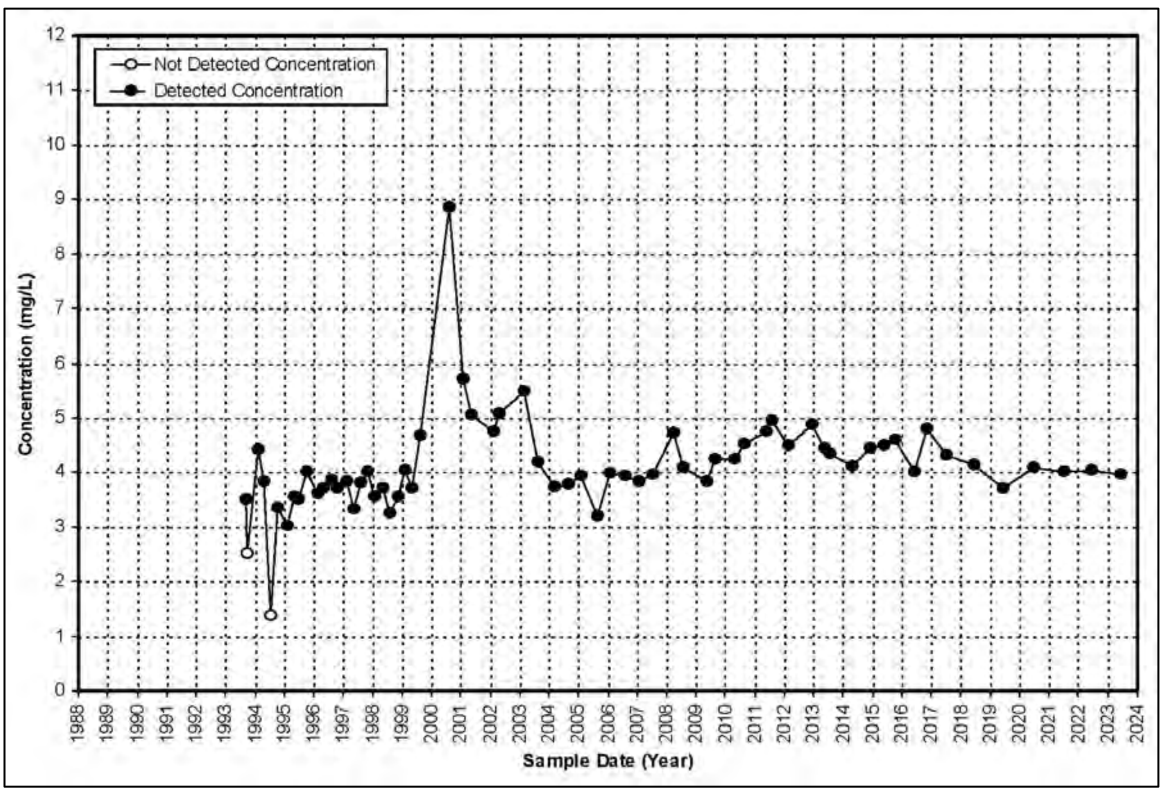

Figure A.1-6. Potassium Concentration Versus Time Plot for Monitoring Well 2899

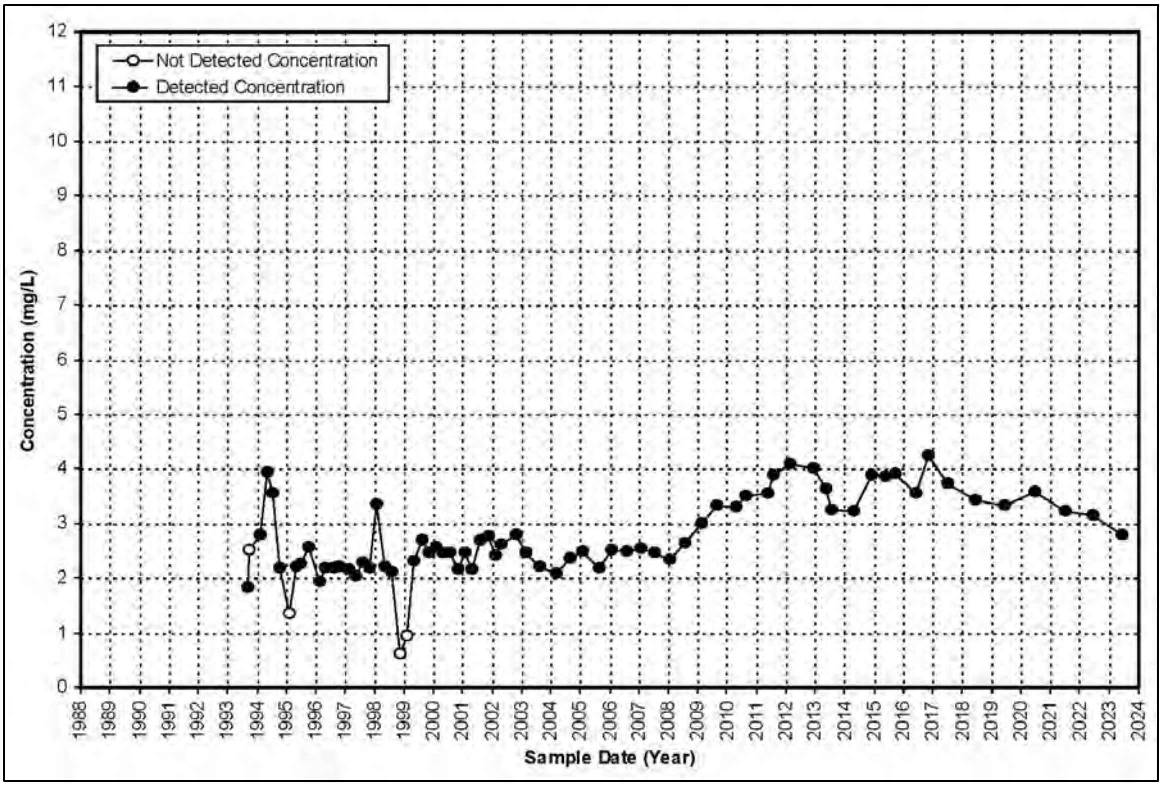

Figure A.1-7. Potassium Concentration Versus Time Plot for Monitoring Well 3898

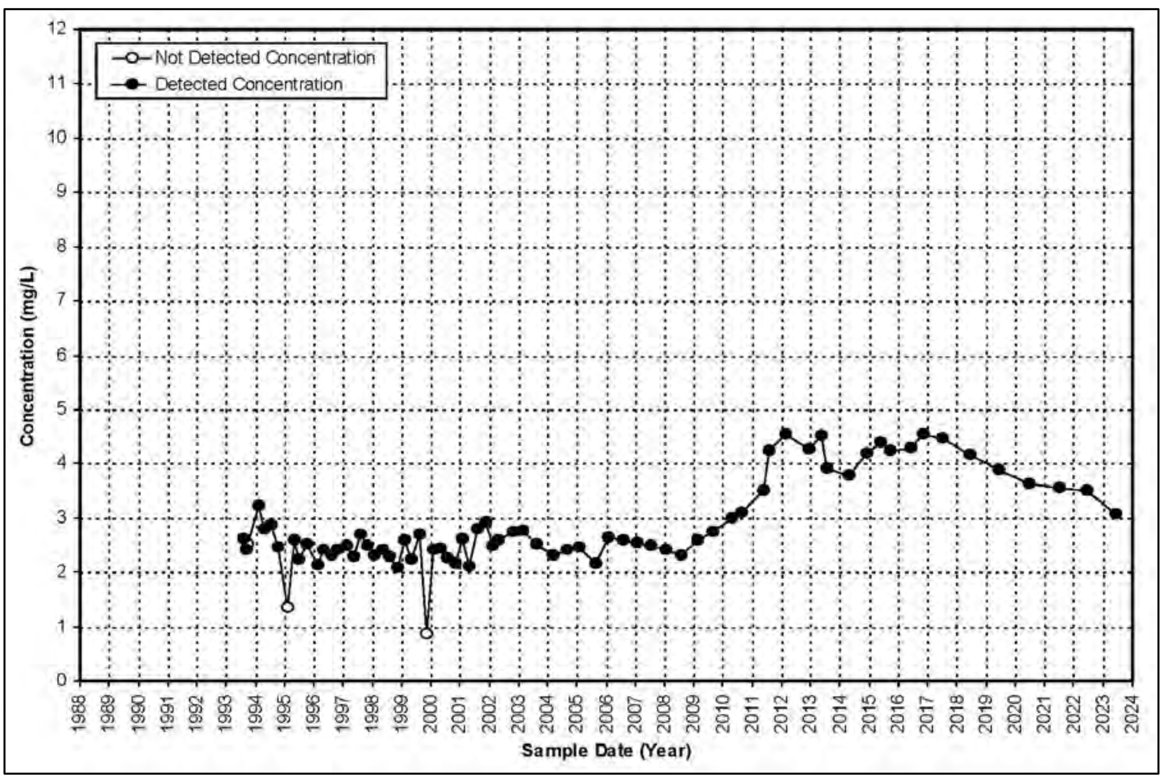

Figure A.1-8. Potassium Concentration Versus Time Plot for Monitoring Well 3899

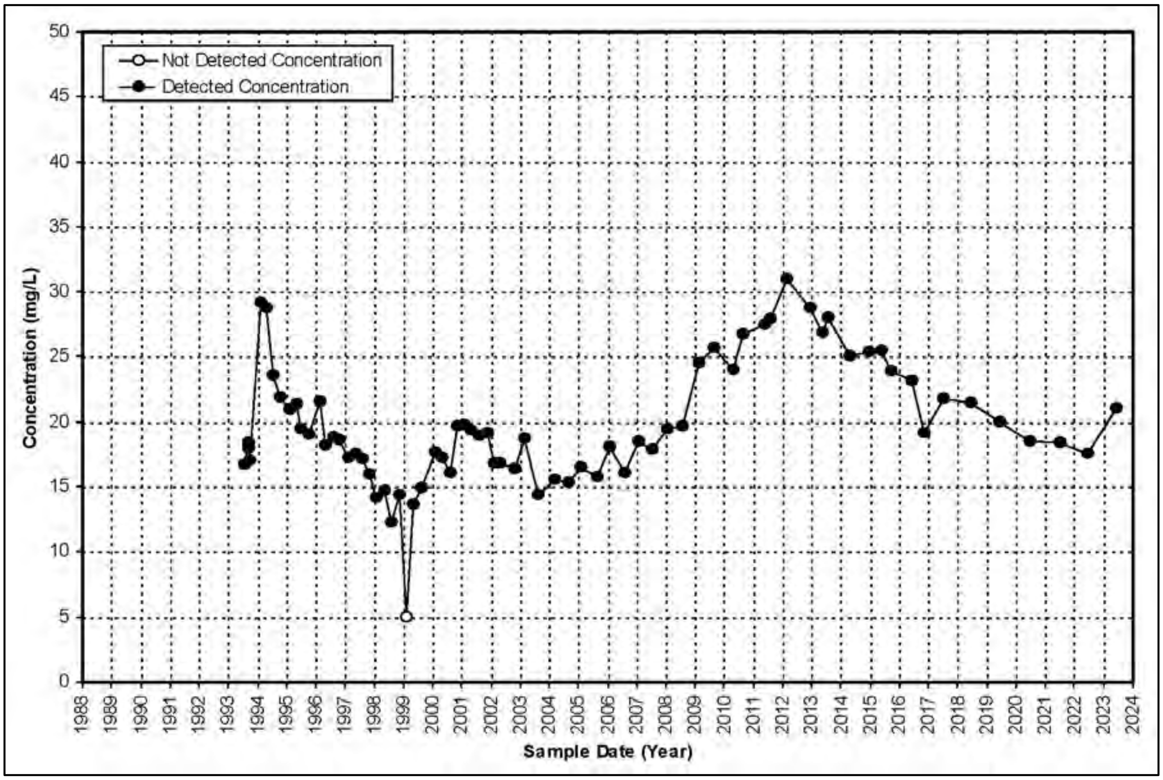

Figure A.1-9. Sodium Concentration Versus Time Plot for Monitoring Well 2898

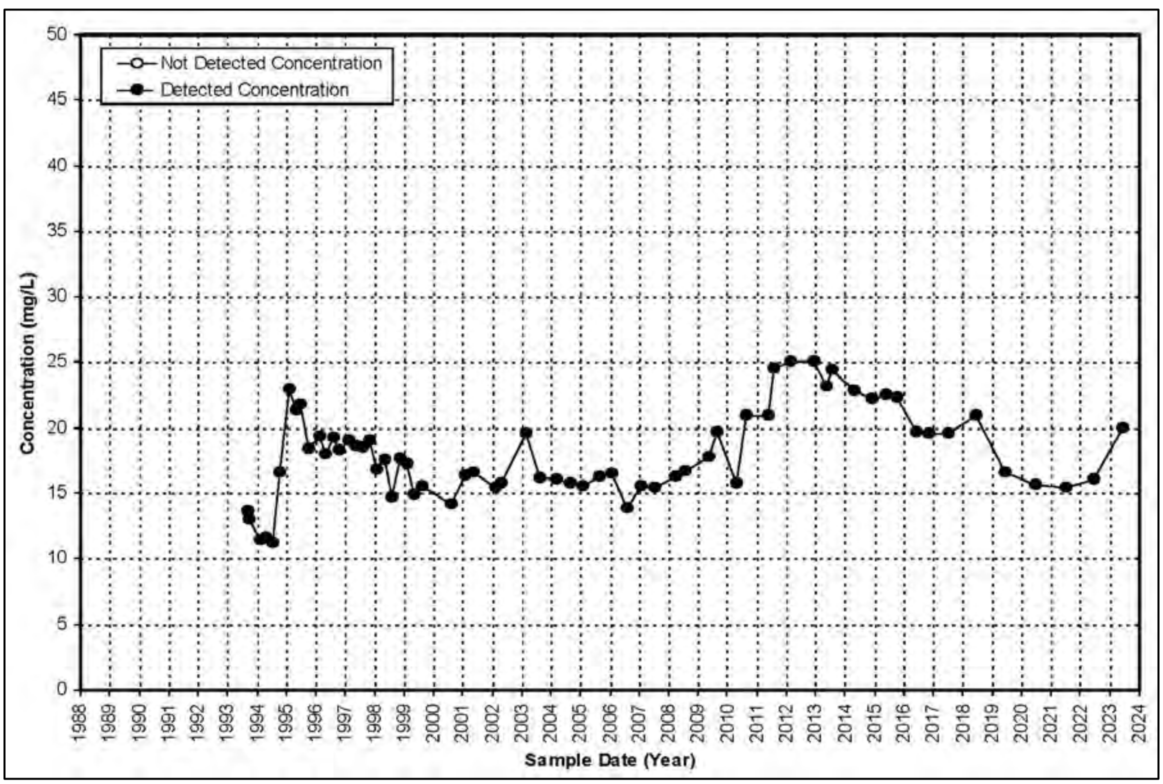

Figure A.1-10. Sodium Concentration Versus Time Plot for Monitoring Well 2899

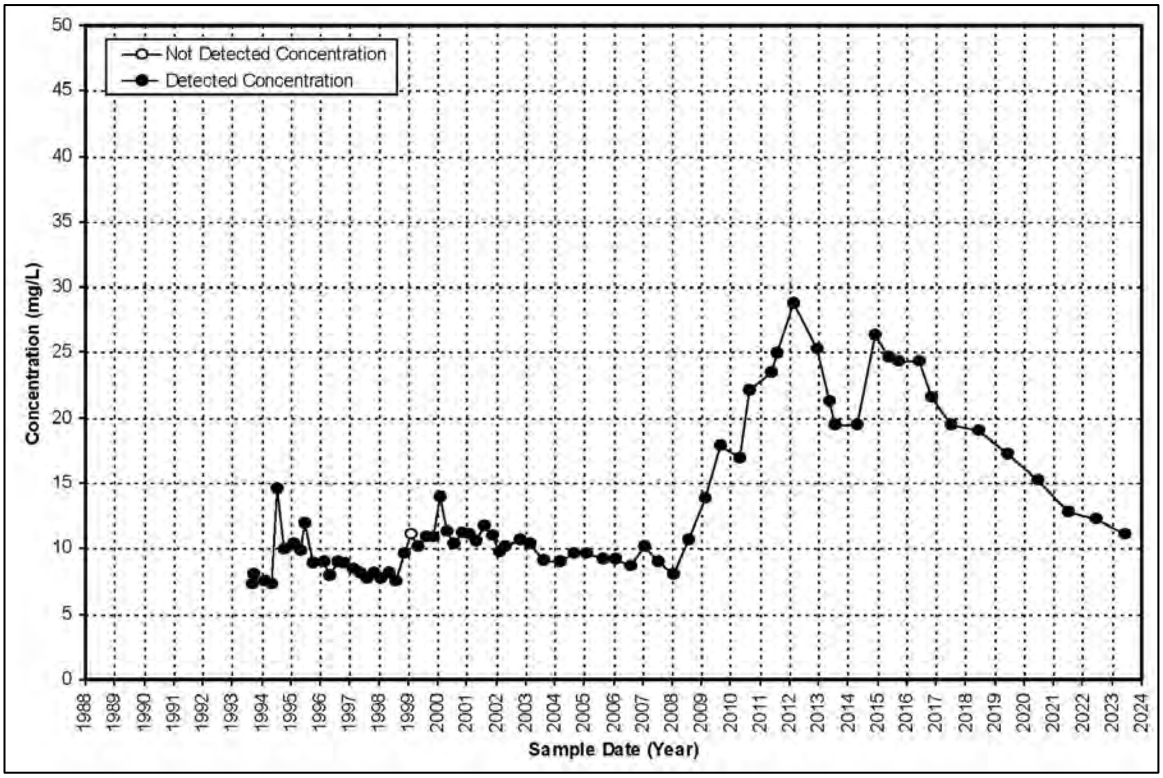

Figure A.1-11. Sodium Concentration Versus Time Plot for Monitoring Well 3898

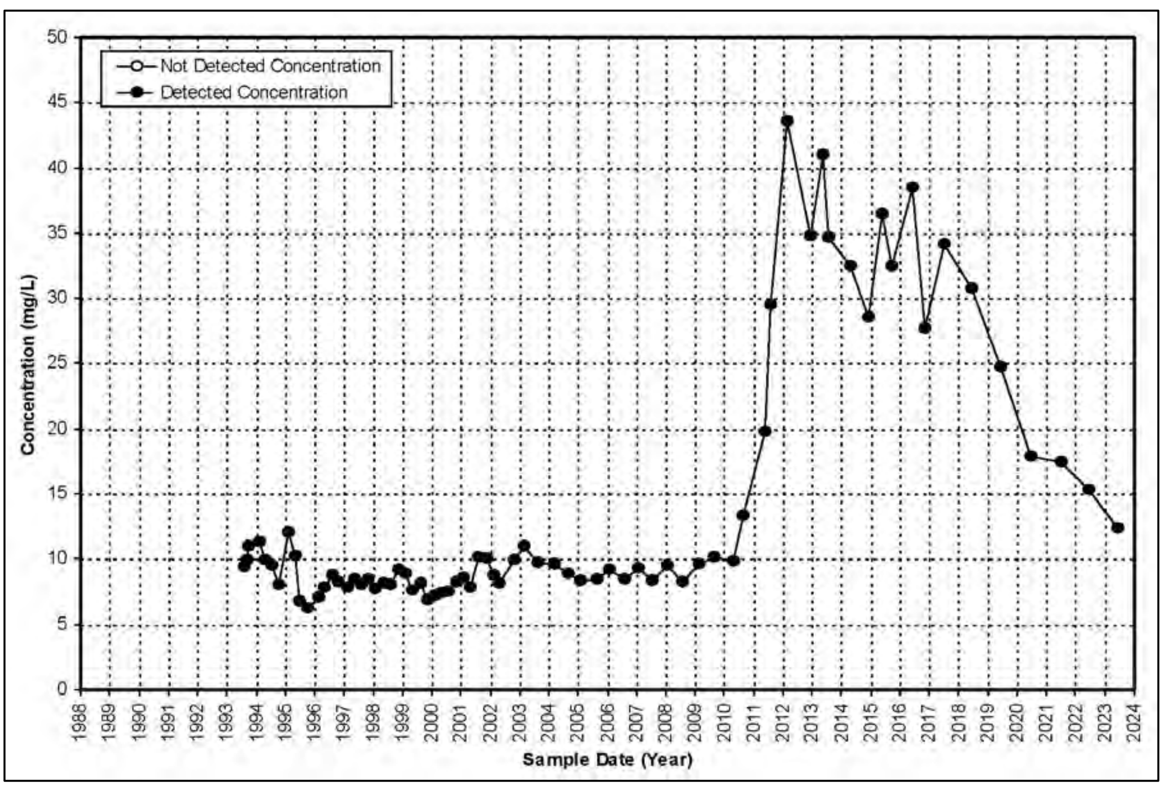

Figure A.1-12. Sodium Concentration Versus Time Plot for Monitoring Well 3899

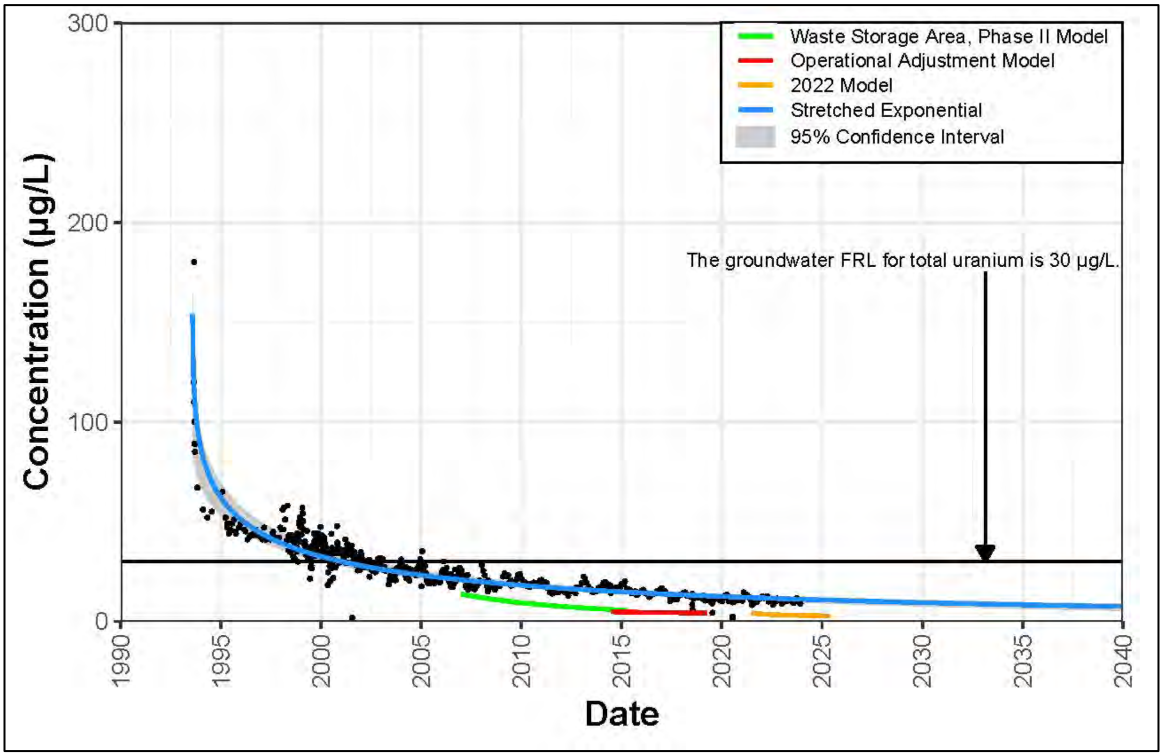

Figure A.1-13. Total Uranium Concentration Versus Time Plot for Extraction Well 3924 (RW-1) with Regression Analysis

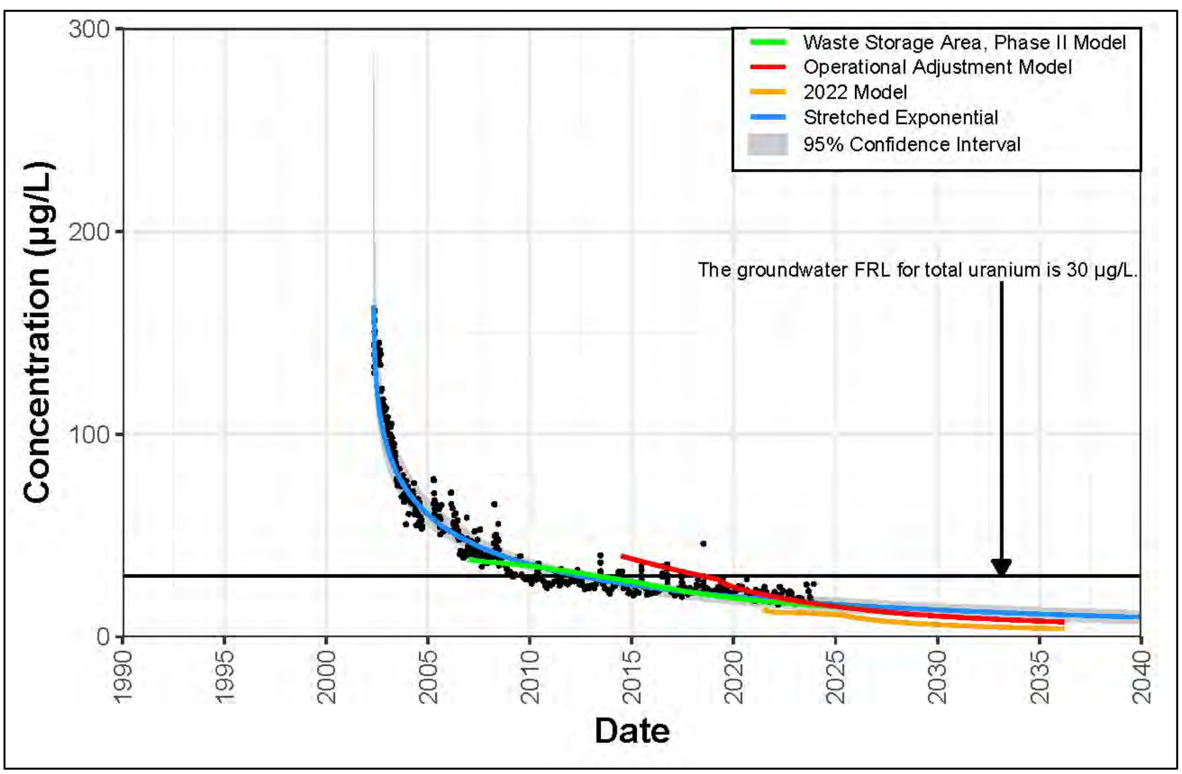

Figure A.1-14. Total Uranium Concentration Versus Time Plot for Extraction Well 32761 (EW-26) with Regression Analysis

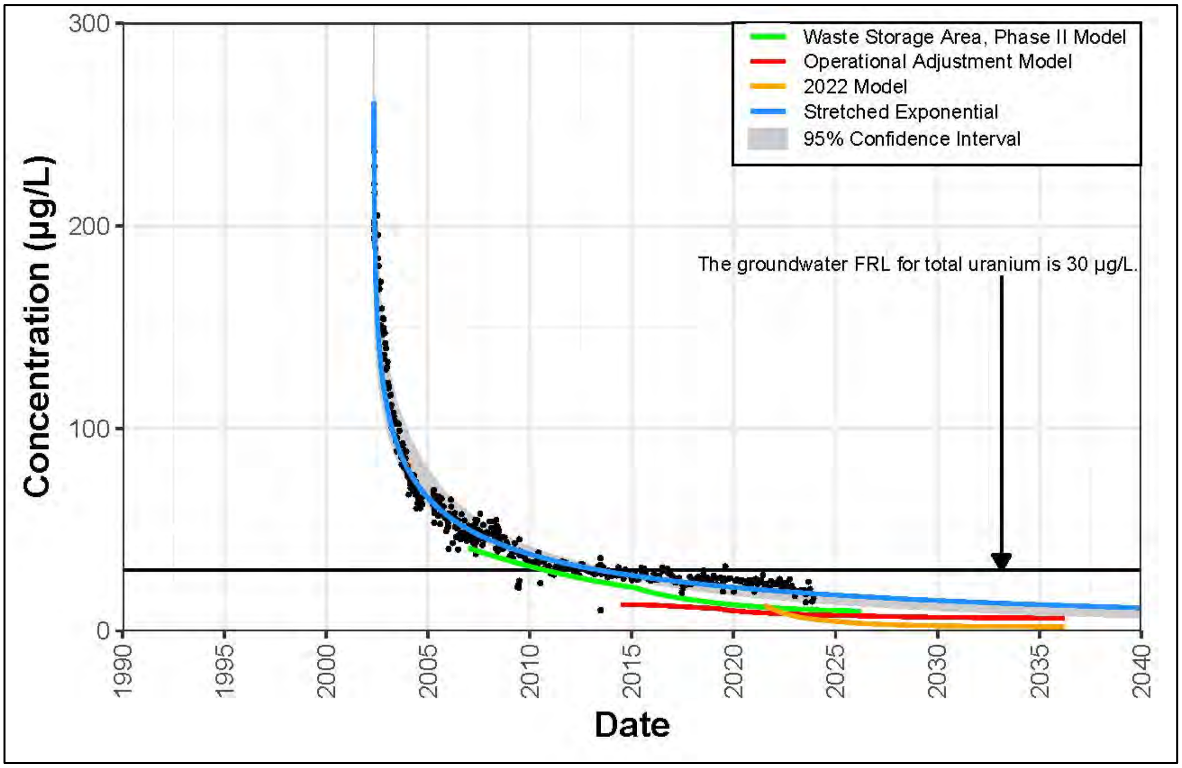

Figure A.1-15. Total Uranium Concentration Versus Time Plot for Extraction Well 33062 (EW-27) with Regression Analysis

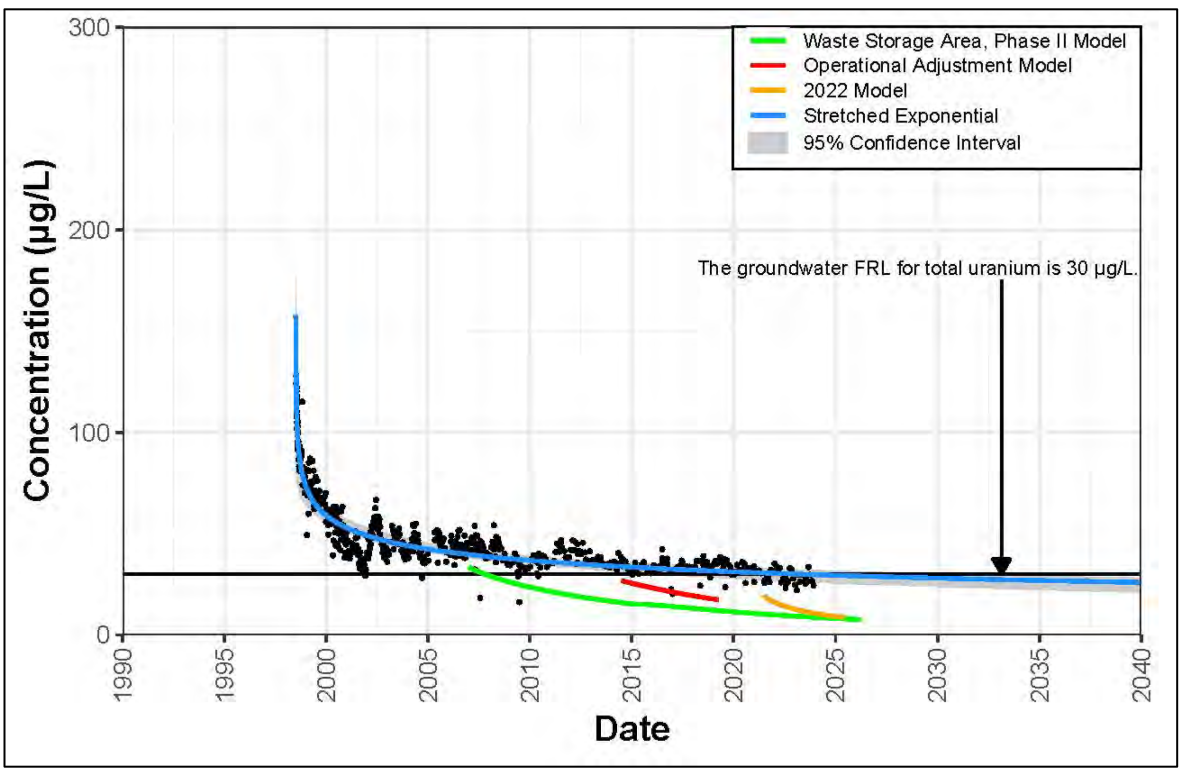

Figure A.1-16. Total Uranium Concentration Versus Time Plot for Extraction Well 31550 (EW-18) with Regression Analysis

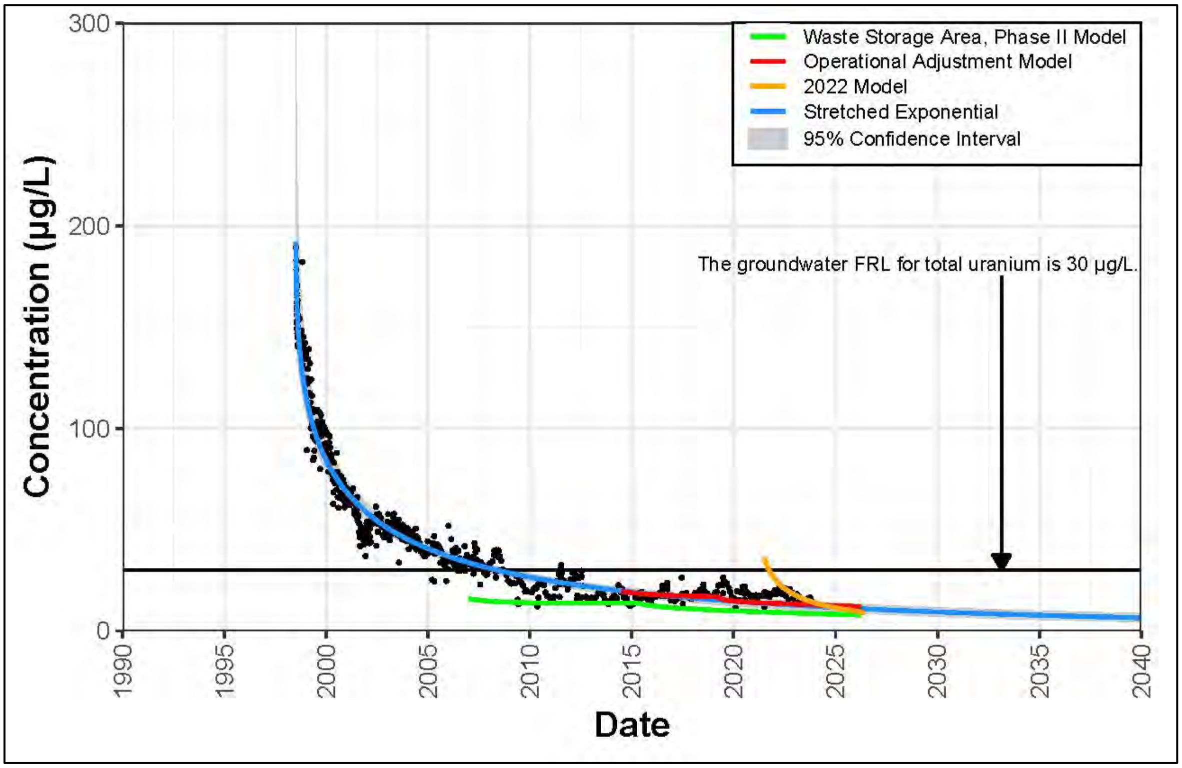

Figure A.1-17. Total Uranium Concentration Versus Time Plot for Extraction Well 31560 (EW-19) with Regression Analysis

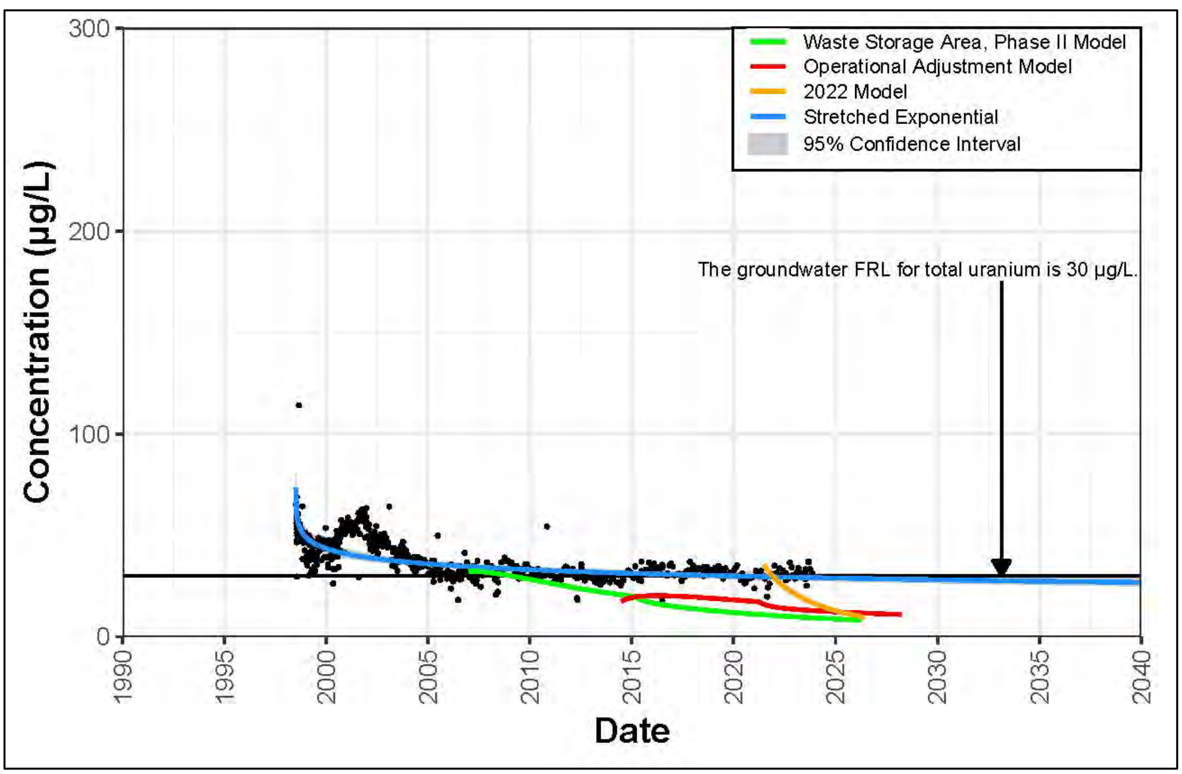

Figure A.1-18. Total Uranium Concentration Versus Time Plot for Extraction Well 31561 (EW-20) with Regression Analysis

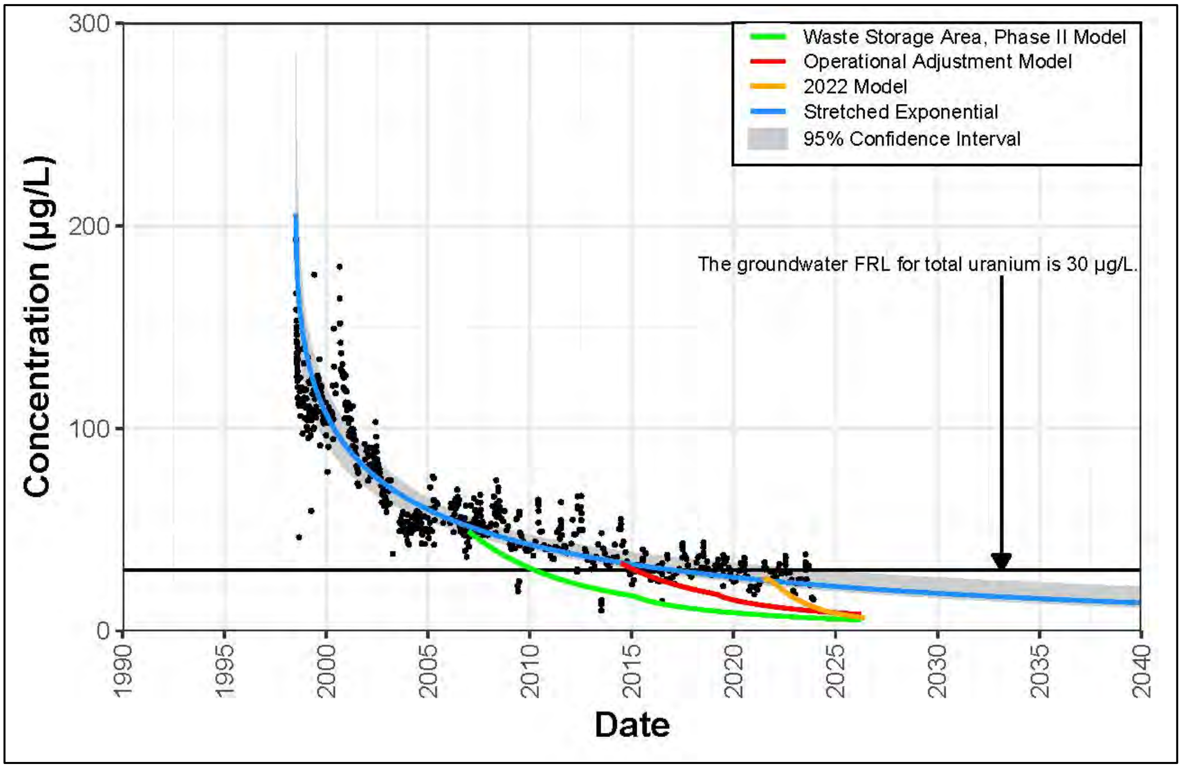

Figure A.1-19. Total Uranium Concentration Versus Time Plot for Extraction Wells 31562 (EW-21) and 33298 (EW-21a) with Regression Analysis

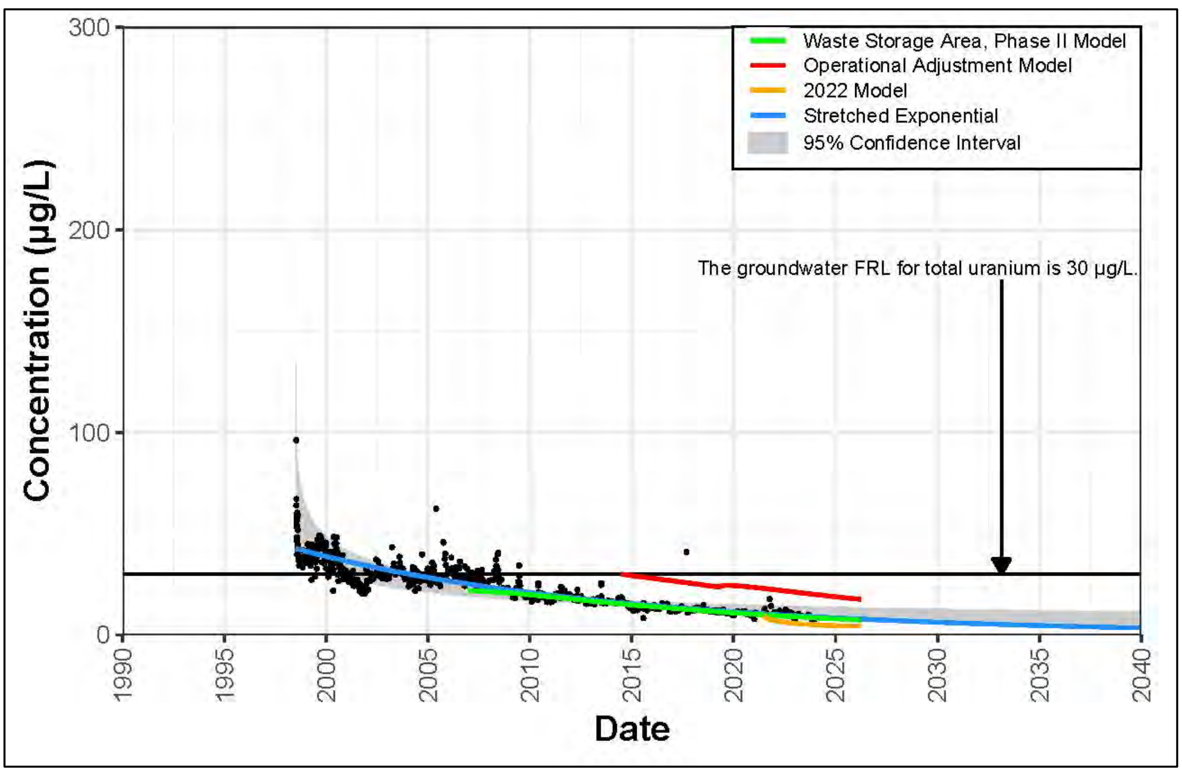

Figure A.1-20. Total Uranium Concentration Versus Time Plot for Extraction Wells 31567 (EW-17) and 33326 (EW-17a) with Regression Analysis

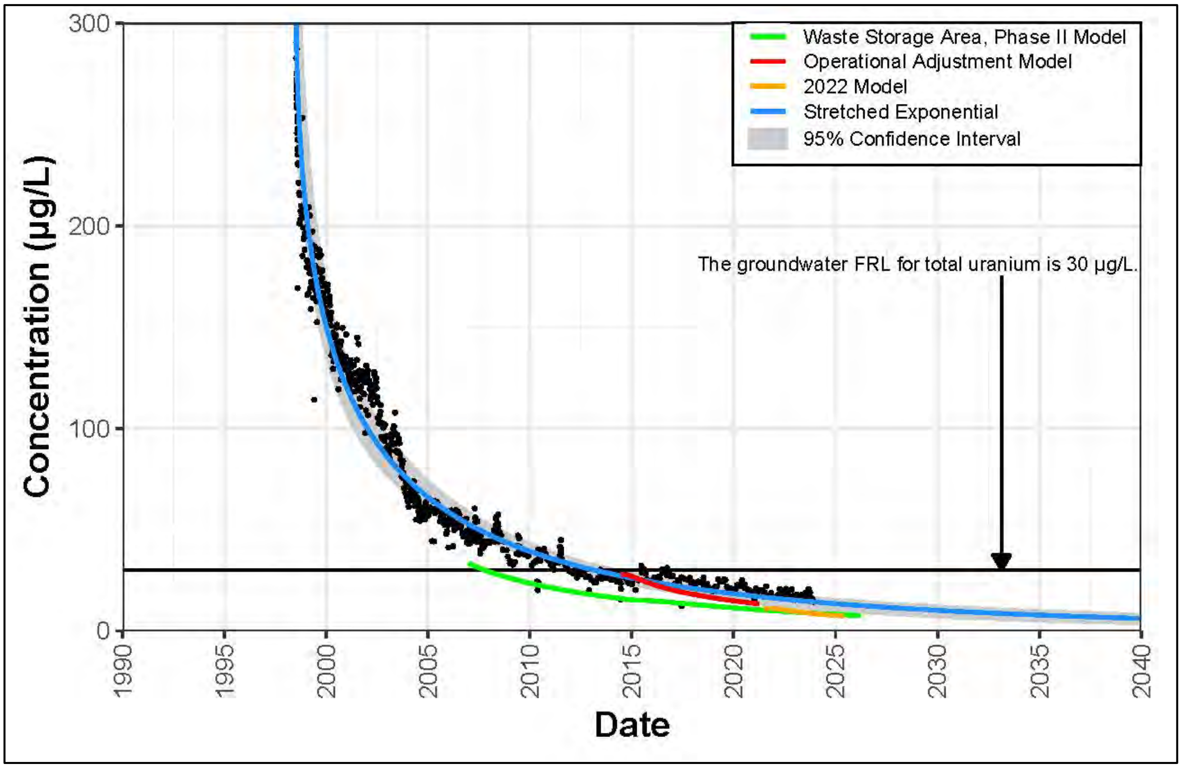

Figure A.1-21. Total Uranium Concentration Versus Time Plot for Extraction Well 32276 (EW-22) with Regression Analysis

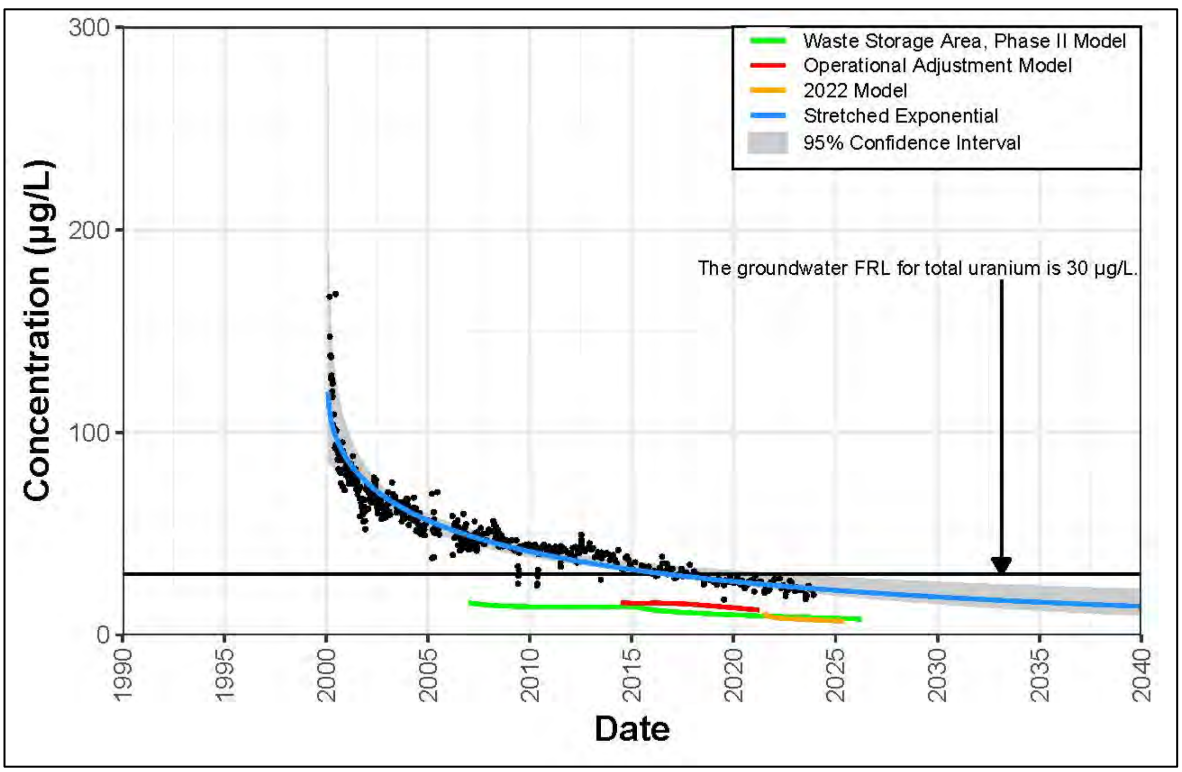

Figure A.1-22. Total Uranium Concentration Versus Time Plot for Extraction Well 32446 (EW-24) with Regression Analysis

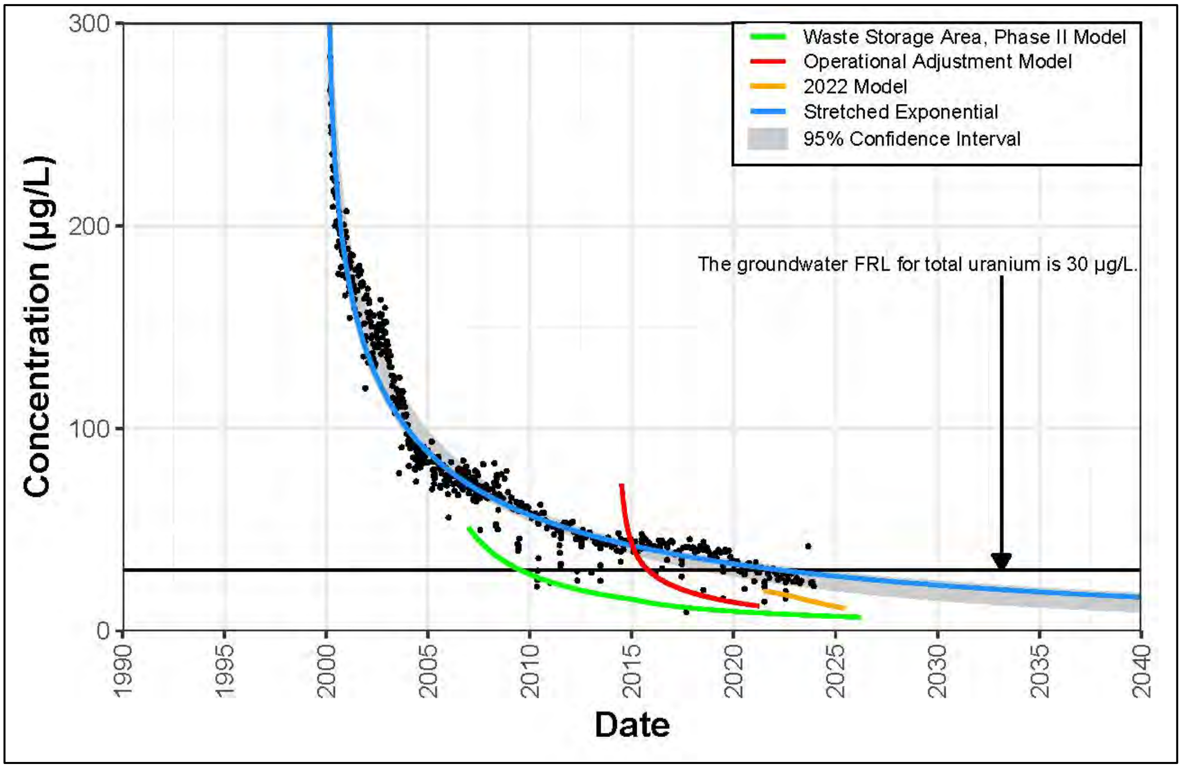

Figure A.1-23. Total Uranium Concentration Versus Time Plot for Extraction Well 32447 (EW-23) with Regression Analysis

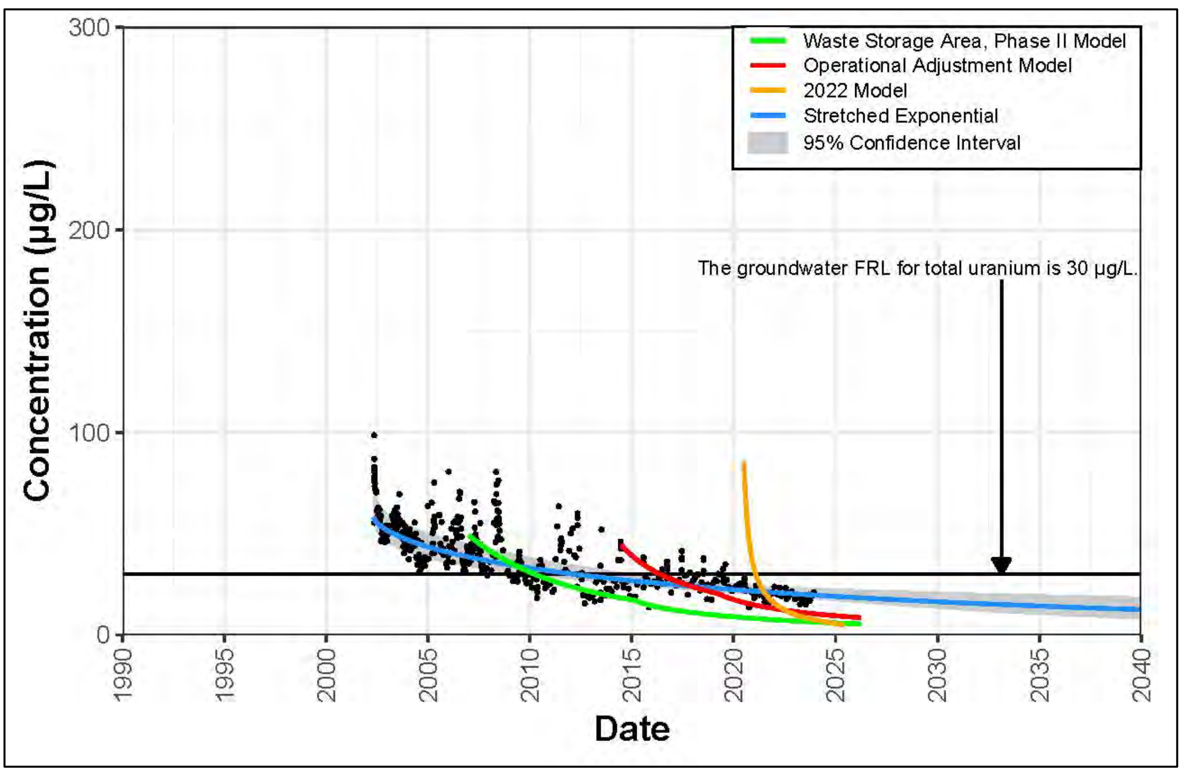

Figure A.1-24. Total Uranium Concentration Versus Time Plot for Extraction Well 33061 (EW-25) with Regression Analysis

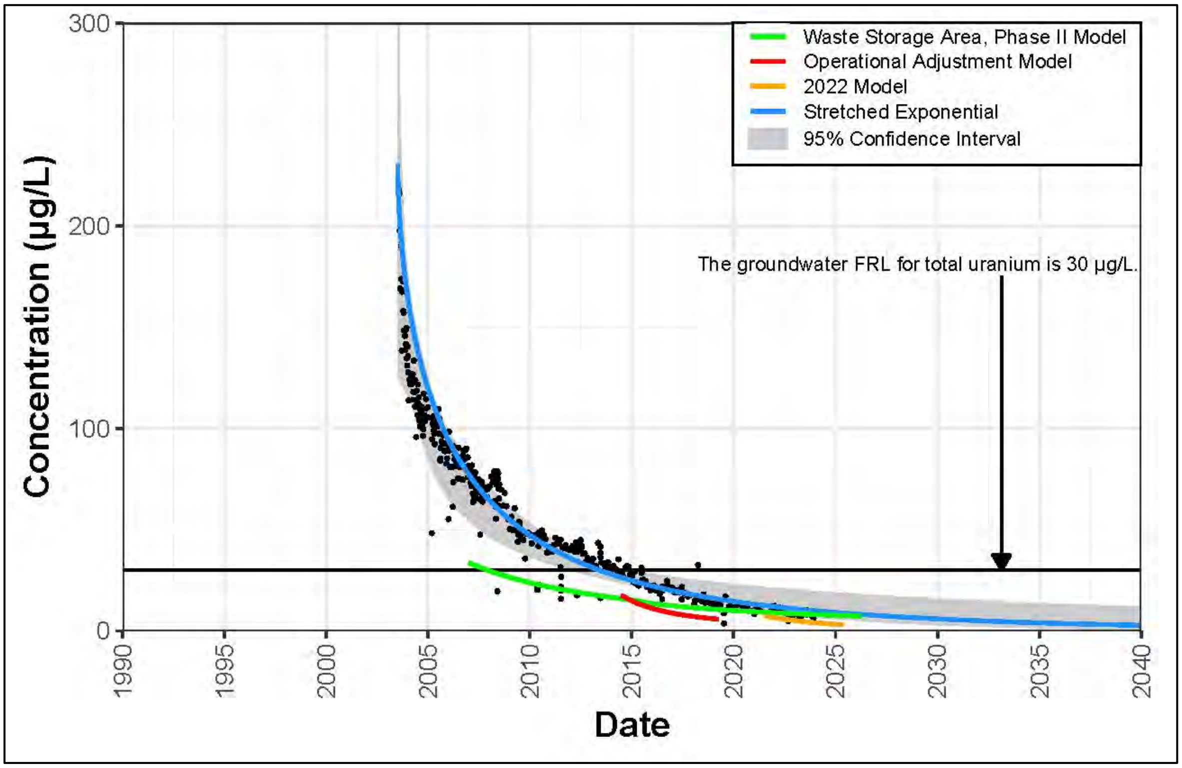

Figure A.1-25. Total Uranium Concentration Versus Time Plot for Extraction Well 33264 (EW-30) with Regression Analysis

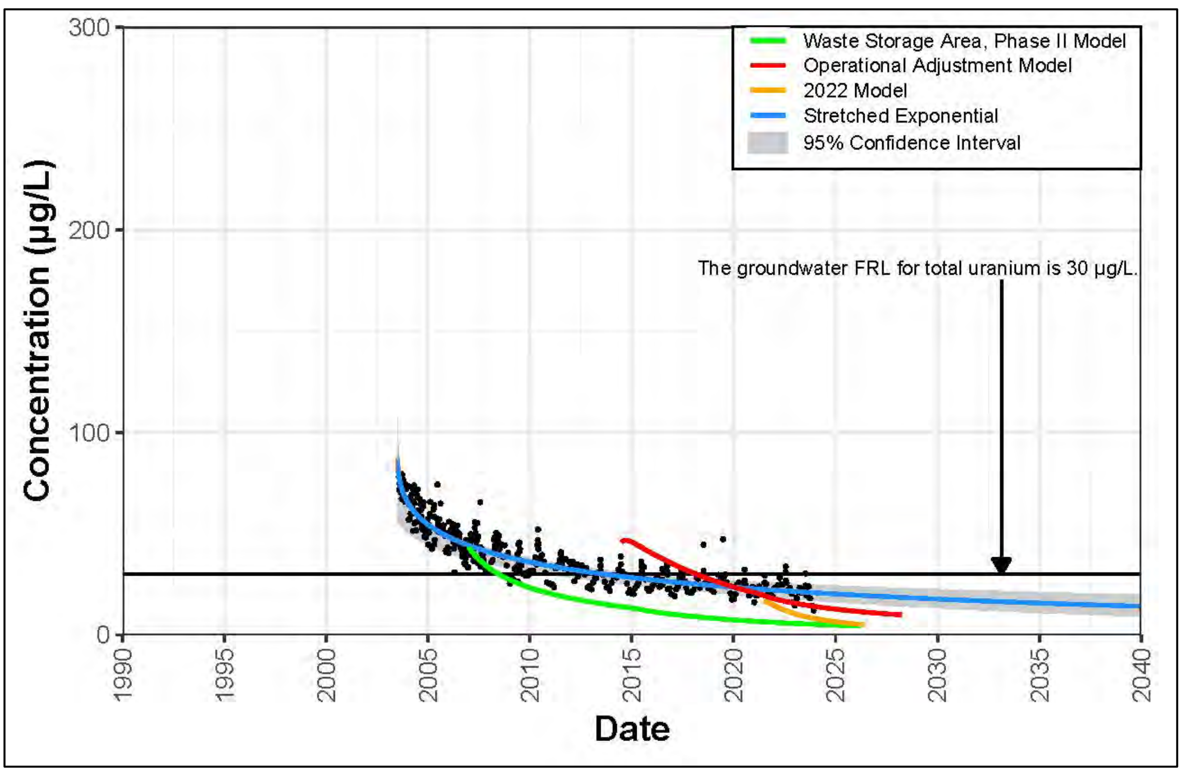

Figure A.1-26. Total Uranium Concentration Versus Time Plot for Extraction Well 33262 (EW-15a) with Regression Analysis

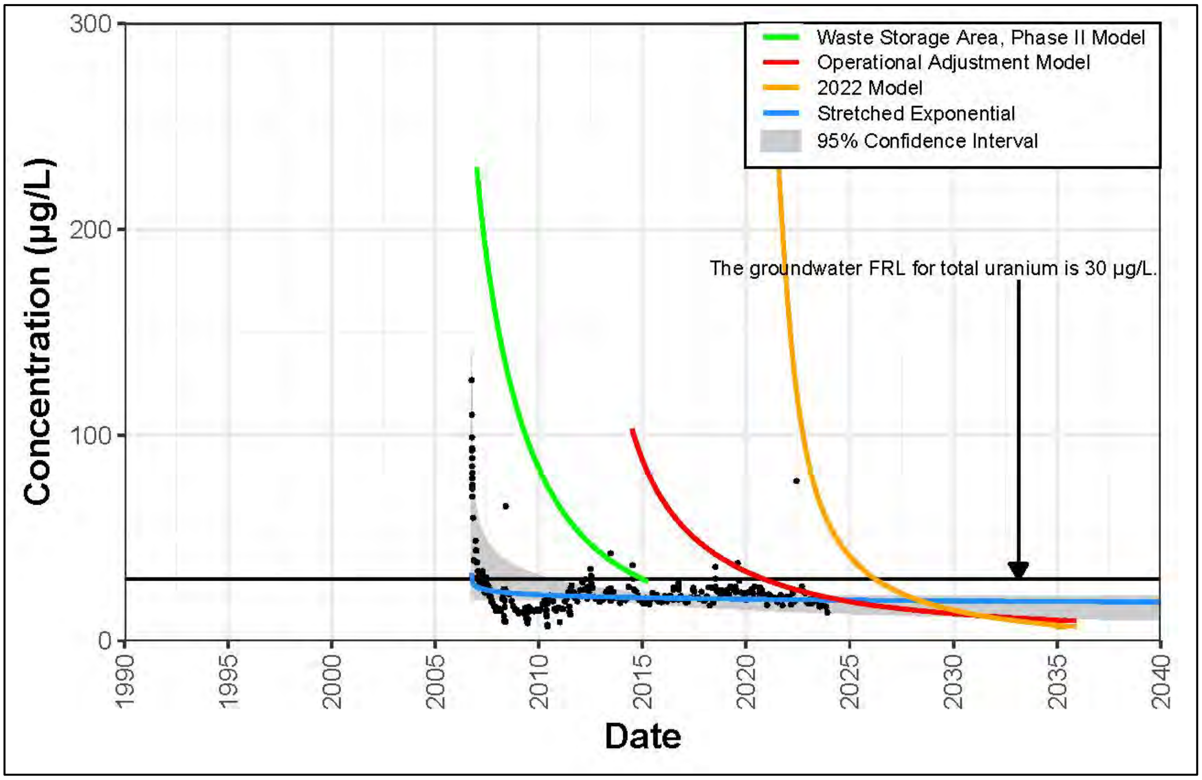

Figure A.1-27. Total Uranium Concentration Versus Time Plot for Extraction Well 33347 (EW-33a) with Regression Analysis

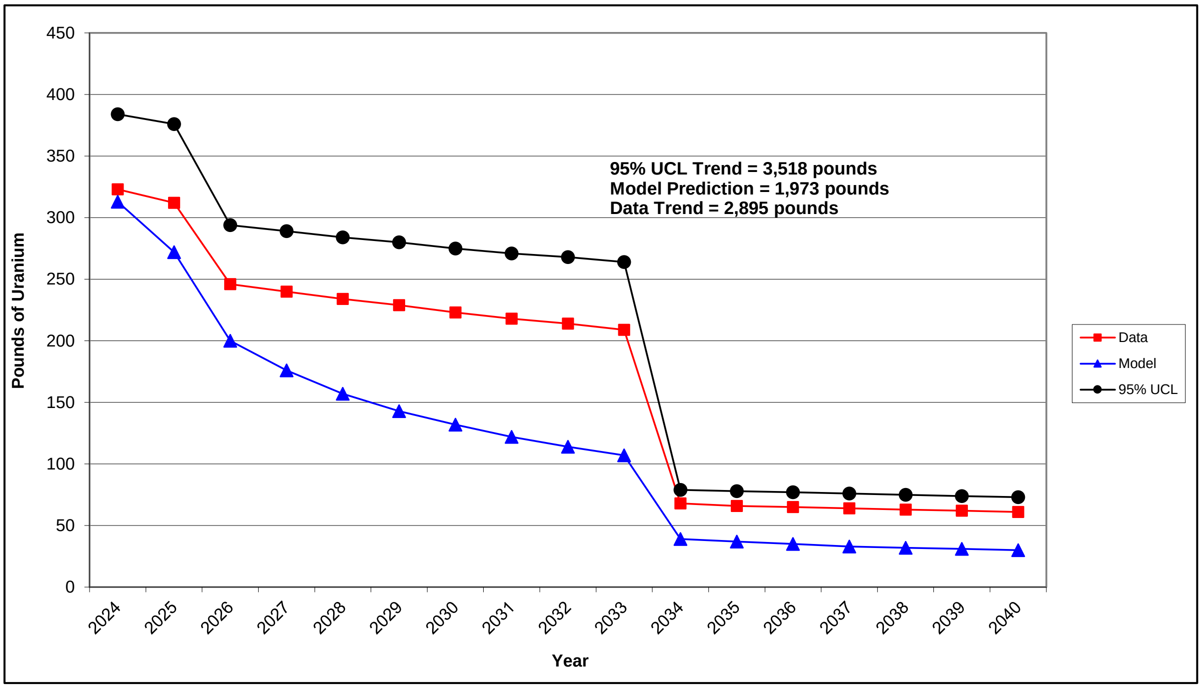

Figure A.1-28. Estimate of Yearly Pounds of Uranium to Be Pumped from Aquifer to Achieve Concentration-Based FRL Goals (Model Predictions Versus Measured Concentration Trends) Data Collected Through 2023

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Attachment A.2

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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 2023, 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 2023b). 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, 29 locations were sampled using a direct-push sampling tool (Geoprobe) in 2023. One location was sampled twice, resulting in 30 sampling events. 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 29 locations (30 sampling events) (12411F, 13508A, 13509C, 13523A, 13533B, 13534A, 13603A, 13630, 13631, 13632, 13633, 13634, 13229J, 13536A, 13542B, 13508A, 13618, 13919, 13919A, 13620, 13621, 13622, 13623, 13624, 13625, 13626, 13627, 13628, 13629, and 13635) are presented in Tables A.2-1 through A.2-30.

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 2023. 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. 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.2-31 lists the monitoring wells where total uranium concentrations exceeded the 30 µg/L FRL during 2023. Included in the table are total uranium statistical summaries for each well, which include Mann-Kendall trend analyses. Table A.2-32 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.2-31, 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 2022 compared to the footprint of the 30 µg/L total uranium plume from 2023. The 2022 plume is highlighted yellow, indicating areas where the plume was reduced for mapping purposes in 2023. 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 2022 and 2023 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
2022 (acres)	74.0	49.4	27.8
2023 (acres)	72.1	49.3	27.8
Change (acres)	−1.9	−0.1	0
Change (percent)	−2.6	-0.2	0

Since 1997, the footprint of the total uranium plume being targeted for cleanup has decreased 165.5 acres. Table A.2-33 provides a tabulation of plume area from 1997 through 2023.

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 2022 and 2023 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 2023 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 2023 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 2023 was below the uranium FRL. Channel 1 was dry during the second half of 2023.

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 has been at or above 30 µg/L since 2018.

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. The uranium concentration measured in the first half of 2023 was below 30 µg/L. Channel 1 was dry during the second half of 2023.

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. In 2023, the total uranium concentration for channel 1 was 29.8 µg/L.

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 in 2023. Monitoring well 83340 is discussed in the previous section. Monitoring well 2649 is discussed below. Table A.2-31 provides summary statistics for monitoring well 2649. 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, 2022, and 2023. In the first half 2023 sample the uranium concentration was 1,260 µg/L. In the second half of 2023 the uranium concentration was 192 µg/L. Monitoring well 2649 is located in 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 2023, the concentration in monitoring well 83337_C1 was 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) during the certification stage of the remedy for this area. A different technology other than pumping will most likely be needed in this area to achieve FRLs in the aquifer.

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 2022 and 2023 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 2023 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 2023 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 were 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.2-31 and Figure A.2-4, one monitoring well (83124_C4) had an increasing total uranium concentration trend in 2023 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 4 is attributed to pumping in the nearby extraction well.

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 2023 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 of the Former Production Area where Plant 6 was once located (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.2-31).

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 above mean sea level (amsl) or higher. Since 2011, water levels have been at or near 515 ft amsl, and the uranium FRL exceedances have been consistent. In 2023, total uranium concentrations were above 30 µg/L. As shown in Figure A.2-14, the water level during both 2023 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 2022 and 2023. The size of the footprint was 61.53 acres in 2022 and 59.63 acres in 2023, a decrease of 1.9 acres (3.1%) (Figure A.2-5).

The mapped footprint of the 50 µg/L area of the plume decreased in size between 2022 and 2023. The size of the area was 39.499 acres in 2022 and 39.393 acres in 2023, a decrease of 0.11 acre (0.28%).

The mapped footprint 100 µg/L area of the plume remined the same between 2022 and 2023 at 20 acres.

A.2.3.1 South Field

In 2023, direct-push sampling was conducted at twelve locations in the South Field (locations 12411F, 13508A, 13509C, 13523A, 13533B, 13534A, 13603A, 13630, 13631, 13632, 13633, and 13634). Figure A.2-2 shows the locations and the 2023 total uranium results. All 12 locations are in the southwest area of the South Field Plume.

Location 12411F

Location 12411F is situated on the west side of the South Field. Direct-push sampling results for location 12411F are provided in Table A.2-1. The location is identified in Figure A.2-2.

This location has been sampled seven times: 1999, 2003, 2012, 2015, 2017, 2020, and 2023. The samples collected in 1999 were identified as location 12411. The samples collected in 2023 were identified as location 12411F. Total uranium concentrations for all seven sampling events are provided below.

Location 12411 (1999)		Location 12411A (2003)		Location 12411B (2012)		Location 12411C (2015)	
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	51.0	515	33.4	515	35.6	512	39.1
509	40.0	506	39.7	505	22.2	502	16.0
499	44.0	496	48.2	495	13.5	492	11.6
489	62.0	486	24.1	485	7.1	482	5.2
479	26.0	476	18.7	475	5.2	472	6.6
469	20.0	466	31.7	465	4.1		
459	25.0	456	19.1	455	5.9		
449	25.0	446	4.0	445	1.4		
439	1.9	436	4.9				
429	2.6						
419	<1.0						

Location 12411D (2017)		Location 12411E (2020)		Location 12411F (2023)	
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	51.1	514	52.0	511	46.4
502	20.6	504	22.9	501	10.1
492	11.9	494	6.1	491	5.0
482	7.1	484	6.7	481	3.5
				471	5.7

The maximum total uranium concentration measured at this location was greater than 50 µg/L in 2020. In 2023, the concentration was 46.4 µg/L (elevation 511 ft amsl). This elevation is 3 ft lower than the 2020 elevation. The maximum total uranium plume map for 2023 was not adjusted to honor the 2023 concentration. This location will be sampled again at a later date.

<u>Location 13508A</u>

Location 13508A is situated in the southeastern portion of the South Field, south of extraction well 32276. Direct-push sampling results for location 13508A are provided in Table A.2-2. The location is identified in Figure A.2-2, Inset 2.

This location has been sampled two times: 2018 and 2023. The sample collected in 2018 was identified as location 13508. The sample collected in 2023 was identified as location 13508A. Total uranium concentrations for both samples are provided below.

Location 13508 (2018)		Location 13508A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
511	12.2	510	21.9
501	14.7	500	13.7
491	11.6	490	12.1
481	8.7	480	3.7
471	2.1	470	3.4

The maximum uranium concentration measured at this location in 2023 was below 30 µg/L. The 30 µg/L contour on the 2023 maximum uranium plume map did not require adjustment to honor the 2023 concentration.

<u>Location 13509C</u>

Location 13509C is located just north of the site property boundary in the southern portion of the South Field plume. Direct-push sampling results are provided in Table A.2-3. The location is identified in Figure A.2-2, Inset 2.

This location has been sampled four times: 2018, 2020, 2021, and 2023. The samples collected in 2018 were identified as location 13509. The samples collected in 2023 were identified as location 13509C. Results for all sampling events are provided below.

Location 13509 (2018)		Location 13509A (2020)		Location 13509B (2021)		Location 13509C (2023)	
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	43.3	514	33.0	512	36.8	512	34.6
505	13.4	504	22.9	502	14.2	502	5.2
495	3.9	494	9.3	492	5.7	492	4.5
485	7.3	484	7.2	482	5.9	482	8.0
475	8.8	474	4.1	472	< 1.0	472	1.9

As shown in the table above, the maximum total uranium concentration was 34.6 µg/L in 2023 (elevation 512 ft amsl). No change was needed to the maximum total uranium plume map based on the 2023 result at this location. As reported below, the plume map was adjusted in this area to honor the 2023 result from location 13533B.

Location 13523A

Location 13523A is located on the west side of the South Field uranium plume in approximately the center of the north to south direction. Direct-push sampling results for location 13523A are provided in Table A.2-4, and the location is identified in Figure A.2-2.

This location has been sampled two times: 2020 and 2023. The sample collected in 2020 was identified as location 13523. The sample collected in 2023 was identified as location 13523A. Total uranium concentrations for both samples are provided below.

Location 13523 (2020)		Location 13523A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
514	<1.0	512	16.0
504	16.2	502	7.4
494	4.9	492	4.5
484	10.9	482	2.5
474	4.9	472	3.0

The maximum total uranium concentration measured at location 13523 was below 30 µg/L in 2020 and 2023; however, based on monitoring results in nearby monitoring well 2049, the 30 µg/L contour on the maximum uranium plume map for 2023 was not adjusted.

Figure A.2-15 is a time versus uranium concentration plot for monitoring well 2049. As shown in Figure A.2-15 a slug of uranium contamination appears to be moving through this location since 2021. No adjustment will be made to the total uranium plume map in this area until the uranium concentration in monitoring well 2049 is consistently (at least 2 years) below 30 µg/L.

Location 13533B

Location 13533B is located on the west side of the South Field uranium plume, in the southern half of the South Plume. Direct-push sampling results for location 13533B are provided in Table A.2-5. The location is identified in Figure A.2-2, Inset 2.

This location has been sampled three times in 2021, 2022, and 2023. The location sampled in 2021 was identified as location 13533. The location sampled in 2023 was identified as location 13533B. The following table provides total uranium concentrations from the two sampling events.

Location 13533 (2021)		Location 13533A (2022)		Location 13533B (2023)	
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)
510	31.8	511	45.4	511	21.6
500	3.6	501	8.5	501	4.5
490	6.7	491	6.1	491	3.8
480	3.3	481	<1.0	481	3.2
470	5.4	471	3.4	471	6.4

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 maximum total uranium concentration measured in 2023 was 21.6 µg/L (elevation of 511 ft amsl). The 30 µg/L contour on the 2023 maximum uranium plume map was adjusted to honor the 2023 concentration. The location will be sampled again in 2024 to verify that the location remains below 30 µg/L.

Location 13534A

Location 13534A is in the South Field uranium plume, just north of Willey Road. Direct-push sampling results for location 13534A are provided in Table A.2-6. The location is identified in Figure A.2-2.

This location has been sampled two times: 2021 and 2023. The sample collected in 2021 was identified as location 13534. The sample collected in 2023 was identified as location 13534A. Total uranium concentrations for both samples are provided below.

Location 13534 (2021)		Location 13534A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
514	53.5	512	13.2
504	7.9	502	15.4
494	6.1	492	1.2
484	3.2	482	5.0
474	5.7	472	2.6

The maximum uranium concentration at this location decreased from 53.5 µg/L (elevation 514 ft amsl) in 2021 to 13.2 µg/L (elevation 512 ft amsl) in 2023. The 2023 total uranium plume map was adjusted so that this location is no longer in an area above 50 µg/L; however, this location is in an area of the total uranium plume map that is identified as being above 30 µg/L. Additional sampling will be conducted in the area before the 30 µg/L contour is adjusted (see discussion on location 13630 below).

Location 13603A

Location 13603A is in the southwest area of the South Field. Direct-push sampling results for location 13603A are provided on Table A.2-7, and the location is identified on Figure A.2-2.

This location has been sampled two times: 2022 and 2023. The sample collected in 2022 was identified as location 13603. The sample collected in 2023 was identified as location 13603A. Total uranium concentrations for both samples are provided below.

Location 13603 (2022)		Location 13603A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
516	105.5	511	18.8
506	12.9	501	12.6
496	16.8	491	12.4
486	16.9	481	6.0
476	9.1	471	9.9

The maximum uranium concentration at this location in 2023 was 18.8 µg/L (elevation 511 ft amsl). This sample was 5 ft lower than the sample collected in 2022, therefore it was too low to be used to adjust the uranium plume map. No adjustment was made to the 2023 uranium plume map based on the 2023 sample results.

Location 13630

Location 13630 is located just north of Willey Road in the South Field. Direct-push sampling results for location 13630 are provided on Table A.2-8, and the location is identified on Figure A.2-2.

As shown in Table A.2-8, the maximum total uranium concentration measured in 2023 was 30.0 µg/L (elevation 511 ft amsl). The maximum uranium plume map was adjusted to honor the 2023 measurement. This adjustment was based in part on results from location 13534A that recorded less than 30 µg/L up to an elevation of 514 ft amsl. Location 13630 will be sampled again in 2024 to verify that the location remains at or below 30 µg/L.

Location 13631

Location 13631 is located in the southeast portion of the South Field. Direct-push sampling results for location 13631 are provided on Table A.2-9, and the location is identified on Figure A.2-2.

As shown in Table A.2-9, the maximum total uranium concentration measured in 2023 was 29.2 µg/L (elevation 514 ft amsl). The maximum uranium plume map was adjusted to honor the 2023 measurement.

Location 13632

Location 13632 is located on the west edge of the South Field. Direct-push sampling results for location 13632 are provided on Table A.2-10, and the location is identified on Figure A.2-2.

As shown in Table A.2-10, the maximum total uranium concentration measured in 2023 was 16.9 µg/L (elevation 512 ft amsl). The maximum uranium plume map did not need to be adjusted to honor the 2023 measurement.

Location 13633

Location 13633 is located on the west edge of the South Field. Direct-push sampling results for location 13633 are provided on Table A.2-11, and the location is identified on Figure A.2-2.

As shown in Table A.2-11, the maximum total uranium concentration measured in 2023 was 32.4 µg/L (elevation 513 ft amsl). The maximum uranium plume map was adjusted to honor the 2023 measurement.

Location 13634

Location 13634 is located on the southeast edge of the South Field. Direct-push sampling results for location 13634 are provided on Table A.2-12, and the location is identified on Figure A.2-2.

As shown in Table A.2-12, the maximum total uranium concentration measured in 2023 was 78.2 µg/L (elevation 481 ft amsl). The maximum uranium plume map was adjusted to honor the 2023 measurement.

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

One monitoring well (82372) is identified on the maximum total uranium plume map for 2023 in the South Field (Figure A.2-3) as being a monitoring location with intermittent total uranium FRL exceedances. This designation is being made for the first time based on 2023 sampling results. Figure A.2-16 provides a time versus total uranium concentration plot for monitoring well 82372. The figure shows that total uranium concentrations measured from 2018 through 2023 at 82372 were below the 30 µg/L uranium concentration with an exception in 2020 and 2023 where the concentration was just slightly above 30 µg/L. In 2023, two samples were collected from the well (June and November). The uranium concentrations were 11.6 µg/L and 32.6 µg/L, respectively. 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.2.3.1.2 Monitoring Wells with Increasing Total Uranium Concentration Trends in the South Field

As Table A.2-31 shows, three monitoring wells in the South Field—21033, 2386, and 83294_C1—had upward trends for total uranium concentrations in 2023. The locations are shown in Figure A.2-4. Figures A.2-17 through A.2-19 provide time versus total uranium concentration plots for these three 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.2-15, 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.2-31 the uranium dataset 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. As shown in Figure A.2-15, the uranium concentration measured at well 2049 continued to decrease in 2023. Samples were collected in March and September of 2023. The uranium concentration was 143 µg/L and 40.0 µg/L, respectively.

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 2023, direct-push sampling was conducted at 17 locations in the South Plume resulting in 18 samples (13229J, 13536A, 13542B, 13608A 13618, 13619, 13619A, 13620, 13621, 13622, 13623, 13624, 13625, 13626, 13627, 13628, 13629, and 13635). Location 13619 was sampled twice. Sampling locations are shown in Figure A.2-2. Sampling results are discussed below.

<u>Location 13229J</u>
Location 13229J is located on the west edge of the South Plume. Direct-push sampling results for location 13229J are provided in Table A.2-13. The location is identified in Figure A.2-2.

This location has been sampled 11 times: 2002, 2003, 2008, 2013, 2015, 2017, 2018, 2019, 2020, 2022, and 2023. The samples collected in 2002 were identified as location 13229. The samples collected in 2023 were identified as location 13229J. Total uranium concentration data from all eleven 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)		Location 13229J (2023)	
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	46.7	512	52.8	512	39.3
505	20.8	502	33.1	502	15.5
495	18.1	492	19.9	492	19.4
485	12.5	482	20.0	482	12.4
		472	13.0	472	12.3

Between 2015 and 2023, the samples collected from this location show that the maximum uranium concentration has ranged between 58.8 µg/L in 2019 (elevation 516 ft amsl) and 39.3 µg/L in 2023 (elevation 512 ft amsl). In 2023, the concentration was below 50.0 µg/L (elevation 512 ft amsl). Since the 2023 maximum uranium concentration was at a lower elevation than some of the previous maximum concentrations, the 2023 total uranium plume map was not adjusted to honor the 2023 concentration. The location is selected to be resampled in 2024.

Location 13536A

Location 13536A is in the middle of the South Plume. Direct-push results are provided in Table A.2-14. The location is identified in Figure A.2-2.

This location has been sampled twice: 2021 and 2023. The samples collected in 2021 were identified as location 13536. The samples collected in 2023 were identified as location 13536A. Total uranium concentration data from both sampling events are provided below.

Location 13536 (2021)		Location 13536A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
510	43.5	510	48.9
500	23.3	500	22.0
490	11.2	490	14.2
480	15.2	480	7.0
470	3.8	470	4.2

The maximum total uranium concentration measured in 2023 was 48.9 µg/L (510 ft amsl), a slight increase from the maximum measured in 2021 that was 43.5 µg/L (elevation 510 ft amsl). The 50 µg/L contour on the 2023 maximum total uranium plume map was moved closer to this location based on the 2023 concentration.

Location 13542B

Location 13542B is on the southwest corner of the South Plume. Direct-push results are provided in Table A.2-15. This location is identified on Figure A.2-2.

Location 13542 has been sampled five times, three times in 2021, then in 2022, and 2023. The first three samples collected in 2021 were identified as location 13542. The samples collected in 2022 were identified as 13542A. The samples collected in 2023 were identified as 13542B. Total uranium concentrations from all five sampling events are provided in the table below.

Location 13542 (7/20/2021)		Location 13542 (7/28/2021)		Location 13542 (8/6/2021)	
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
499	5.4	499	4.8	499	2.7
489	8.9	489	6.1	489	6.8
479	22.7	479	17.2	479	9.7
469	40.9	469	20.2	469	19.8
		459	10.2	459	15.4
		449	3.9	449	8.0
		439	1.4	439	1.0

Location 13542A (2022)		Location 13542B (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
512	40.4	512	12.8
502	5.9	502	4.9
492	5.4	492	4.2
482	11.4	482	12.5
472	23.6	472	32.1
462	20.5	462	19.5
452	18.5	452	21.6
442	1.6	442	4.8

The first sample was collected 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). The uranium concentration measured at nearby monitoring wells 2095 and 3095 in 2022 were 37.9 and 33.9 µg/L, respectively.

Location 13542 was sampled again in 2023. The maximum uranium concentration measured in 2023 was 32.1 µg/L (elevation 472 ft amsl). The uranium concentration measured at nearby monitoring wells 2095 and 3095 in 2023 were 13.7 µg/L and 27.9 µg/L, respectively. Figure A.2-20 and Figure A.2-21 are time versus total uranium concentration plots for monitoring wells 2095 and 3095, respectively. As shown in Figures A.2-20 and A.2-21, total uranium concentrations at both monitoring wells were below 30 µg/L in 2023. The 2023 total uranium plume map did not need to be revised to honor the 2023 result from location 13542B. The location is selected to be resampled in 2024.

Location 13608A

Location 13608A is located on the east side of the South Plume. Direct-push results are provided in Table A.2-16. This location has been sampled two times: 2022 and 2023. The 2022 sample was identified at 13608. The sample collected in 2023 was identified as 13608A. This location is identified on Figure A.2-2. Results from both sampling events are provided below.

Location 13608 (2022)		Location 13608A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
511	4.3	512	<1.0
501	37.8	502	11.1
491	14.2	492	10.0
481	22.3	482	3.7
471	1.9	472	1.4

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 is in 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.

Location 13608 was sampled again in 2023. The maximum total uranium concentration measured in 2023 was 11.1 µg/L (502 ft amsl). To be conservative, the plume map was not adjusted to honor the 2023 result. As discussed below, location 13619 is being resampled in 2024 due to conflicting 2023 sampling results. Map revisions in this area are pending the 2024 sampling results at location 13619.

Location 13618

Location 13618 is located on the east side of the South Plume, southeast of location 13608. Direct-push results are provided in Table A.2-17. The 2023 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 2023 was 15.4 µg/L (elevation 503 ft msl). The 2023 maximum total uranium plume map did not need to be revised to honor the 2023 concentration.

This location was selected for sampling in 2023 to determine if the uranium plume might extend south of location 13608. In 2022 the maximum uranium result at location 13608 was 37.8 µg/L (elevation 501 ft amsl). In 2023 the maximum uranium result at location 136018A was 11.1 µg/L (elevation 502 ft amsl) showing the fact that the uranium plume is not present in this area.

Location 13619 and 13619A

Locations 13619 and 13619A are located on the east side of the South Plume, southwest of location 13618. Direct-push results are provided in Table A.2-18 and Table A.2-19 for 13619 and 13619A respectively. The 2023 sampling events were the first time this location was sampled. This location is identified on Figure A.2-2.

Two samples were collected in 2023. The first sample was identified as 13619 and the second sample was identified as 13619A. Total uranium concentrations from both samples are provided below.

Location 13619 (2023)		Location 13619A (2023)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
512	17.0	512	12.2
502	36.4	502	19.9
492	4.7	492	4.0
482	6.6	482	2.4
472	2.7	472	<1.0

Location 13619 was selected for sampling in 2023 to determine if the uranium plume might extend south of location 13608. In 2022 the maximum uranium concentration at a location north of location 13608 was 37.8 µg/L (elevation 501 ft amsl). In 2023 the maximum uranium concentration at location 13608 was 11.1 µg/L (elevation 502 ft amsl).

In 2023 the first sample collected at location 13619 had a total uranium concentration of 36.4 µg/L (502 ft. amsl). A confirmatory sample (13619A) was collected in 2023. The maximum total uranium result from the confirmatory sample at location 13619 in 2023 was 19.9 µg/L (502 ft amsl).

Sampling results from the two samples collected at location 13619 in 2023 contradict each other on the presence of the 30 µg/L total uranium plume at this location. Location 13619 will be sampled again in 2024.

<u>Location 13620</u>
Location 13620 is located on the east side of the South Plume. Direct-push results are provided in Table A.2-20. The 2023 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 2023 was 17.7 µg/L (elevation 494 ft amsl). Sampling results indicate that uranium concentrations are below 30 µg/L from 514 ft amsl to 474 ft amsl. The 2023 maximum total uranium plume map was revised to honor the 2023 concentration.

<u>Location 13621</u>
Location 13621 is located in the center of the South Plume. Direct-push results are provided in Table A.2-21. The 2023 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 2023 was 29.2 µg/L (elevation 511 ft amsl). Historical results at nearby location 13230 show that the plume in this area has been measured at an elevation of 516 ft amsl. The 2023 total uranium plume map was not revised to honor the 2023 concentration. A sample closer to an elevation of 516 ft amsl is needed before the map in this area can be adjusted.

Location 13622

Location 13622 is located on the northwest side of the South Plume. Direct-push results are provided in Table A.2-22. The 2023 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 2023 was 21.5 µg/L (elevation 502 ft amsl). The 2023 maximum total uranium plume map was revised to honor the 2023 concentration.

Location 13623

Location 13623 is located in the north center of the South Plume. Direct-push results are provided in Table A.2-23. The 2023 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 2023 was 22.7 µg/L (elevation 511 ft amsl). Historical results at nearby location 13230 show that the plume in this area has been measured at an elevation of 516 ft amsl. The 2023 total uranium plume map was not revised to honor the 2023 concentration. A sample closer to an elevation of 516 ft amsl is needed before the map in this area can be adjusted.

Location 13624

Location 13624 is located on the east of the South Plume. Direct-push results are provided in Table A.2-24. The 2023 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 2023 was 22.4 µg/L (elevation 492 ft amsl). Sampling results indicate that uranium concentrations are below 30 µg/L from 512 ft amsl to 472 ft amsl. The 2023 maximum total uranium plume map was revised to honor the 2023 concentration.

Location 13625

Location 13625 is located on the west side of the South Plume. Direct-push results are provided in Table A.2-25. The 2023 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 2023 was 34.1 µg/L (elevation 493 ft amsl). The 2023 maximum total uranium plume map did not need to be revised to honor the 2023 concentration.

Location 13626

Location 13626 is located on the west side of the South Plume. Direct-push results are provided in Table A.2-26. The 2023 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 2023 was 35.0 µg/L (elevation 514 ft amsl). The 2023 maximum total uranium plume map did not need to be revised to honor the 2023 concentration.

Location 13627

Location 13627 is located on the west side of the South Plume. Direct-push results are provided in Table A.2-27. The 2023 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 2023 was 17.7 µg/L (elevation 517 ft amsl). The 2023 maximum total uranium plume map did not need to be revised to honor the 2023 concentration.

Location 13628

Location 13628 is located on the southeast side of the South Plume. Direct-push results are provided in Table A.2-28. The 2023 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 2023 was 26.0 µg/L (elevation 513 ft amsl). The 2023 maximum total uranium plume map was revised to honor the 2023 concentration.

Location 13629

Location 13629 is located on the east side of the South Plume. Direct-push results are provided in Table A.2-29. The 2023 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 2023 was 30.5 µg/L (elevation 492 ft amsl). The 2023 maximum total uranium plume map did not need to be revised to honor the 2023 concentration.

Location 13635

Location 13635 is located in the middle of the South Plume. Direct-push results are provided in Table A.2-30. The 2023 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 2023 was 38.3 µg/L (elevation 513 ft amsl). The 2023 maximum total uranium plume map did not need to be revised to honor the 2023 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 2023 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.2-22. 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.2-23. The figure indicates that no total uranium FRL exceedances occurred in 2023. Only two total uranium FRL exceedances have been measured at this well since 1993. The last FRL exceedance 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.2-31, two monitoring wells (2880 and 82369_C3) had upward trends for total uranium concentration in the South Plume in 2023. Time versus concentration graphs for these wells are provided in Figures A.2-24 and A.2-25. 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 2023 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 included vegetation or branches removed from around them to improve access and 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 are conducted every 5 years. The last camera survey was conducted in 2017 and 2018. The most recent camera survey began in 2022 and was completed in 2023. Leaking well riser joins were identified in seven monitoring wells. DOE will determine the path forward for those seven wells. The wells will most likely be properly plugged and abandoned unless it can be determined that the issue can be corrected.

Identified Issues Based on Camera Survey Results

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
2936	1993	None	Protective casing leaning, preventing access to well
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 the 2022 Site Environmental Report (DOE 2023c), 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 2023 and a consistent set of monitoring well data that span all 11 selected years. The most recent maximum total uranium results available at Geoprobe locations were also included. Surfer software (version 26.2.243) 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.2-26 provides a uranium plume map that identifies the calculated center of mass for each year (2006, 2010, 2014, and 2016 through 2023). As shown in Figure A.2-26, 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.2-27 provides 2023 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.2-27, for 2023, the Ricker method calculations indicate that the total uranium plume area was 75.6 acres, the average uranium plume concentration was 87.25 µg/L, and the total uranium plume dissolved mass was 150 pounds (lb).

A.2.5.2 Earth Volumetric Studio Software Mapping Assessment

To address a National Laboratory Network recommendation for obtaining better understanding of remediation progress, an EVS data assessment exercise began in the 2022 Site Environmental Report.

The first EVS assessment showed that the footprint of the 2021 total uranium plume generated through EVS was very similar to the 2021 total uranium plume footprint provided in the 2021 Site Environmental Report. This showed that the interpretation obtained from the EVS mapping was consistent with previous plume interpretations. For this report, a footprint of the 2023 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 2023 plume interpretation are presented in Figures A.2-28 and A.2-29, respectively.

The bulk plume metrics provided in Figure A.2-29 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 64% between 2007 and 2023, decreasing from 160 lb in 2006 to 57 lb in 2023 (Figure A.2-29). 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, October 1, 2022, and October 1, 2023, for the entire uranium plume are as follows.

Metric	October 1, 2006	October 1, 2021	October 1, 2022	October 1, 2023
Dissolved Mass (lb)	159.64	67.21	56.59	56.93
Average Concentration (µg/L)	68.44	67.47	61.10	64.12
Area (acres)	136.50	88.87	84.93	83.13
Volume (cubic feet)	279.55	119.39	111.00	102.67
Average Thickness (feet)	22.45	14.73	14.33	13.54

It should be noted that an error was made in the 2022 Site Environmental Report for reporting EVS metrics for October 1, 2022. EVS results for December 1, 2022, were reported by mistake. The table above was corrected and correctly reports results for October 1, 2022. The table below show results for both October 1, 2022, and December 1, 2022, for comparison.

Metric	October 1, 2022	December 1, 2022
Dissolved Mass (lb)	56.59	54.45
Average Concentration (µg/L)	61.10	59.21
Area (acres)	84.93	85.25
Volume (cubic feet)	111.00	110.21
Average Thickness (feet)	14.33	14.17

A.2.5.3 Total Uranium Plume Area

Table A.2-34 presents a comparison of the 2023 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 2023, the percent difference for Ricker method has ranged between 2.6% and 9.1%. The percent difference in 2023 was 4.8%. For 2021, 2022, and 2023 the percent difference for the EVS method was 18.5%, 15.3%, and 15.5% 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.

Ricker Method

The value of 150 lb for the total mass of uranium remaining in the aquifer based on the Ricker method presented in Figure A.2-27 represents the dissolved mass of total uranium remaining in the aquifer based on 2023 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 g/cm^3)(1,000 cm^3/L) = 6,610 g/L

(6,610 g/L)(1,000 mg/g) = 6,610,000 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 mg/kg)(1 kg/1,000,000 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 150 lb (Figure A.2-27); therefore, the estimated total mass in the aquifer (based on 2023 data) was 3,124.5 lb.

$$3{,}124.5\ \text{lb total} = 150\ \text{lb}_{aq} + (150\ \text{lb}_{aq})(19.83)$$

$$3{,}124.5\ \text{lb total} = 150\ \text{lb} + 2{,}974.5\ \text{lb}$$

The result of 3,124.5 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.1-22 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:

- 1,973 lb dissolved mass (based on new 2022 model predictions)
- 2,895 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 1,151.5 and 229.5 lb of uranium will remain sorbed to aquifer sediments when the concentration-based cleanup of 30 µg/L is achieved:

- 3,124.5 lb – 1,973 lb = 1,151.5 lb sorbed uranium mass remains
- 3,124.5 lb – 2,895 lb = 229.5 lb sorbed uranium mass remains

EVS Interpretation

As presented earlier, through EVS analysis, the dissolved uranium mass present in the aquifer in October 2023 was determined to be 56.93 lb (considerably lower than the 150 lb determined through the Ricker method). Using 56.93 lb and a multiplier of 19.83 (as shown below), results in an estimated mass remaining of 1,185.85 lb. This is considerably lower than the 3,395.29 lb determined previously.

$$1{,}185.85 \text{ lb total} = 56.93 \text{ lb}_{aq} + (56.93 \text{ lb}_{aq})(19.83)$$

$$1{,}185.85 \text{ lb total} = 56.93 \text{ lb} + 1{,}128.92 \text{ lb}$$

In Table A.1-22 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:

1,973 lb dissolved mass (based on new 2022 model predictions)

2,895 lb dissolved mass (based on regression of concentration data)

As shown below, subtracting the predicted dissolved mass removal estimates presented in Table A.1-22 from the EVS interpreted result of 1,185.85 lb remaining in the aquifer results in negative numbers.

1,185.85 lb – 1,973 lb = −787.15 lb sorbed uranium mass remains

1,185.85 lb – 2,895 lb = −1,709.15 lb sorbed uranium mass remains

Summary

The estimated range for dissolved mass of uranium remaining in the aquifer is 56.93 lb (EVS) to 150 lb (Ricker). These dissolved mass estimates were put into the context of the aquifer remediation by using the contaminant distribution coefficient (K_d) 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 1,185.85 lb (EVS) to 3,124.5 lb (Ricker).

Of the two estimates, the Ricker method estimate (3,124.5 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 µg/L reported in Attachment A.1, Table A.1-22 (i.e., 1,973 lb based on 2022 model predictions, and 2,895 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.2-30, A.2-31, and A.2-32. These three figures also display the maximum total uranium plume interpretation 2023. The cross sections (A–A′, B–B′, C–C′, D–D′, and E–E′) are provided in Figures A.2-33 through A.2-37, respectively. All five cross sections were constructed using EVS software. A vertical exaggeration of 10 to 1 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 April 2023 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 small triangle 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. 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

The sampling program at private homeowner wells is the longest running groundwater monitoring effort at the site. The private homeowner well sampling 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.

Since 1987, DOE has participated in a split sampling program with Ohio EPA at the homeowner wells. 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.

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 (DOE 1997). 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). These three private wells were sampled monthly or quarterly depending upon location, and sampling results were reported annually in the Site Environmental Report. Data from these three remaining private wells were used to produce the total uranium plume maps presented in the SER reports. These three private wells were sampled through 2022. Beginning in 2023, the scope of this program was reduced from three wells to one well.

In the 2022 Site Environmental Report, results for locations 13 and 14 were presented showing that the historical sampling results for total uranium at wells 13 and 14 are well below the 30 µg/L FRL. Well 13 had been below the FRL since 2002 and well 14 had been below the FRL since this well was first sampled in 1988. With concurrence from EPA and Ohio EPA, DOE stopped monitoring in these two private wells which occur outside the current plume (wells 13 and 14) in 2023 and continued monitoring uranium in well 2060. The time versus concentration graph for well 2060 is provided in Figure A.2-38. This well will continue to be monitored as part of the IEMP program and results will be used to help prepare the total uranium plume map.

A.2.8 Uranium Concentration Trends at Select Monitoring Wells

New to the 2022 Site Environmental Report was an additional prediction of when cleanup goals would be achieved at individual monitoring wells, which was independent of the groundwater model. The 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 showed 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 2023a).

The results of the exercise are provided in Table A.2-35. 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 (which will be operational in 2024) in this area should help accelerate the decreasing trend observed at this well. Table A.2-35 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.2-35 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. DOE plans to update this assessment, after the two new replacement wells in the South Plume have been operating for about a year. Once the two new replacement extraction wells (33616 [RW-6A] and 33617 [RW-7A]) are operational in the South Plume Module, DOE will focus efforts on optimizing the southern South Field Plume area next. A few of the aging extraction wells in the South Field are no longer responding to rehabilitation efforts. Modeling will be conducted to determine how best to replace the older, non-responsive wells, and how to improve cleanup efficiency in the southern South Field area.

A.2.9 References

Deutsch, W.J., 1997. *Groundwater Geochemistry, Fundamentals and Applications to Contamination*, CRC Press, Boca Raton, Florida.

DOE (U.S. Department of Energy), 1995. *Remedial Investigation Report for Operable Unit 5*, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio, March.

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), 1997. *1996 Site Environmental Report*, Fernald Environmental Management Project, Fernald Field Office, June.

DOE (U.S. Department of Energy), 1998. *1997 Integrated Site Environmental Monitoring Report*, Fluor Daniel Fernald, June.

DOE (U.S. Department of Energy), 2001. *Design for Remediation of the Great Miami Aquifer in the Waste Storage and Plant 6 Areas*, 52462-RP-0003, Revision A, Draft Final, Fluor Fernald, Fernald Area Office, Cincinnati, Ohio, April.

DOE (U.S. Department of Energy), 2003. *Comprehensive Groundwater Strategy Report*, Revision 0, prepared by Fluor Fernald, June.

DOE (U.S. Department of Energy), 2006. *Fernald Groundwater Certification Plan*, Revision 2, 51900-PL-0002, prepared by Fluor Fernald, August.

DOE (U.S. Department of Energy), 2016. *Fernald Preserve 2015 Site Environmental Report*, LMS/FER/S13591, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2017a. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2017b. S. Smiley, Fernald Preserve DOE Site Lead, letter, (transmittal of Responses to Ohio Environmental Protection Agency Comments on the 2016 Fernald Preserve Site Environmental Report) to D. Seely, EPA and T. Schneider, Ohio EPA, November 8.

DOE (U.S. Department of Energy), 2018. *Fernald Preserve 2017 Site Environmental Report*, LMS/FER/S17983, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2022. *Fernald Preserve 2021 Site Environmental Report*, LMS/FER/S37811, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2023a. *Alternative Mathematical Expressions for Projecting Remedial Time Frame Report, Fernald Preserve, Ohio Site*, LMS/FER/43208, Office of Legacy Management, June.

DOE (U.S. Department of Energy), 2023b. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 13, Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2023c. *Fernald Preserve 2022 Site Environmental Report*, LMS/FER/S43783, Office of Legacy Management, May.

Ricker, J.A., 2008. "A Practical Method to Evaluate Ground Water Contaminant Plume Stability," *Groundwater Monitoring and Remediation* 28(4):85–94.

Table A.2-1. Geoprobe Location 12411F

Easting '83:	1348469	feet
Northing '83:	476846	feet
Ground Elevation:	570	feet above mean sea level (AMSL)
Depth to Water Table:	54.00	feet below ground surface (BGS)
Water Table Elevation:	516.15	feet AMSL
Work Completed:	5/23/2023	

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	59	0 - 10	46.4	15.5	7.14	0.820	>999	17.1	5.98
2	501	69	10 - 20	10.1	15.2	7.82	0.569	>999	17.2	6.45
3	501	69	10 - 20	10.0	15.2	7.82	0.569	>999	17.2	6.45
4	491	79	20 - 30	5.0	16.0	7.72	0.690	>999	4.1	4.85
5	481	89	30 - 40	3.5	18.0	7.69	0.640	>999	27.0	6.39
6	471	99	40 - 50	5.7	15.7	7.66	0.660	>999	16.2	3.99

[a]Samples are filtered through a 5 micron filter.

Table A.2-2. Geoprobe Location 13508A

Easting '83:	1348763	feet
Northing '83:	476357	feet
Ground Elevation:	571	feet above mean sea level (AMSL)
Depth to Water Table:	56.00	feet below ground surface (BGS)
Water Table Elevation:	515.45	feet AMSL
Work Completed:	5/25/2023	

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	510	61	0 - 10	21.9	15.6	7.39	0.780	>999	>999	6.59
2	500	71	10 - 20	13.7	14.0	7.52	0.640	>999	25.3	4.81
3	500	71	10 - 20	13.2	14.0	7.52	0.640	>999	25.3	4.81
4	490	81	20 - 30	12.1	13.8	7.52	0.615	>999	>999	5.52
5	480	91	30 - 40	3.7	13.9	7.42	0.820	>999	48.2	3.17
6	470	101	40 - 50	3.4	13.9	7.35	0.800	>999	>999	4.02

[a]Samples are filtered through a 5 micron filter.

Table A.2-3. Geoprobe Location 13509C

Easting '83:	1348727	feet
Northing '83:	476134	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	516.66	feet AMSL
Work Completed:	5/2/2023	

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	34.6	14.8	7.11	0.860	>999	40.7	6.93
2	502	77	10 - 20	5.2	13.9	7.58	0.870	>999	30.7	5.55
3	502	77	10 - 20	3.2	13.9	7.58	0.870	>999	30.7	5.55
4	492	87	20 - 30	4.5	13.6	7.70	0.632	>999	48.3	5.04
5	482	97	30 - 40	8.0	13.5	7.76	0.690	>999	87.8	5.64
6	472	107	40 - 50	1.9	13.4	7.55	0.820	>999	191	5.45

[a]Samples are filtered through a 5 micron filter.

Table A.2-4. Geoprobe Location 13523A

Easting '83:	1348582	feet
Northing '83:	477052	feet
Ground Elevation:	541	feet above mean sea level (AMSL)
Depth to Water Table:	24.00	feet below ground surface (BGS)
Water Table Elevation:	517.16	feet AMSL
Work Completed:	5/11/2023	

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	29	0 - 10	16.0	14.2	7.57	0.389	>999	47.0	8.50
2	502	39	10 - 20	7.4	13.9	7.64	0.700	>999	698	6.11
3	502	39	10 - 20	7.3	13.9	7.64	0.700	>999	698	6.11
4	492	49	20 - 30	4.5	13.8	7.71	0.617	>999	409	6.80
5	482	59	30 - 40	2.5	13.3	7.76	0.613	>999	9.77	5.47
6	472	69	40 - 50	3.0	12.8	7.73	0.604	>999	52.7	5.26

[a]Samples are filtered through a 5 micron filter.

Table A.2-5. Geoprobe Location 13533B

Easting '83:	1348682	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:	515.78	feet AMSL
Work Completed:	5/8/2023	

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	21.6	16.7	7.25	0.790	>999	109	6.10
2	501	75	10 - 20	4.5	15.9	7.76	0.630	>999	24.4	5.05
3	501	75	10 - 20	3.8	15.9	7.76	0.630	>999	24.4	5.05
4	491	85	20 - 30	3.8	15.5	7.67	0.700	>999	114	5.03
5	481	95	30 - 40	3.2	16.5	7.77	0.900	>999	13.4	5.45
6	471	105	40 - 50	6.4	15.1	7.35	1.01	>999	34.7	4.65

[a]Samples are filtered through a 5 micron filter.

Table A.2-6. Geoprobe Location 13534A

Easting '83:	1348847	feet
Northing '83:	476184	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	59.00	feet below ground surface (BGS)
Water Table Elevation:	517.50	feet AMSL
Work Completed:	5/17/2023	

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	64	0 - 10	13.2	16.1	7.31	0.880	>999	144	5.37
2	502	74	10 - 20	15.4	15.5	7.35	0.820	>999	12.3	6.01
3	502	74	10 - 20	14.6	15.5	7.35	0.820	>999	12.3	6.01
4	492	84	20 - 30	1.2	15.0	7.74	0.740	>999	15.0	4.15
5	482	94	30 - 40	5.0	14.3	7.64	0.690	>999	12.3	4.64
6	472	104	40 - 50	2.6	15.0	7.58	0.800	>999	8.71	4.99

[a]Samples are filtered through a 5 micron filter.

Table A.2-7. Geoprobe Location 13603A

Easting '83:	1348653	feet
Northing '83:	476573	feet
Ground Elevation:	572	feet above mean sea level (AMSL)
Depth to Water Table:	56.00	feet below ground surface (BGS)
Water Table Elevation:	515.66	feet AMSL
Work Completed:	5/24/2023	

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	61	0 - 10	18.8	16.6	7.14	0.710	>999	71.5	6.51
2	501	71	10 - 20	12.6	17.0	7.55	0.690	>999	17.0	4.94
3	501	71	10 - 20	12.2	17.0	7.55	0.690	>999	17.0	4.94
4	491	81	20 - 30	12.4	16.3	7.59	0.770	>999	29.0	4.31
5	481	91	30 - 40	6.0	16.6	7.66	0.770	>999	46.3	4.00
6	471	101	40 - 50	9.9	15.8	7.39	0.790	>999	241	4.59

[a]Samples are filtered through a 5 micron filter.

Table A.2-8. Geoprobe Location 13630

Easting '83:	1348844	feet
Northing '83:	476239	feet
Ground Elevation:	574	feet above mean sea level (AMSL)
Depth to Water Table:	58.00	feet below ground surface (BGS)
Water Table Elevation:	516.09	feet AMSL
Work Completed:	5/18/2023	

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	63	0 - 10	30.0	16.1	7.22	0.810	>999	20.3	6.40
2	501	73	10 - 20	6.9	16.1	7.63	0.680	>999	6.56	5.10
3	501	73	10 - 20	6.5	16.1	7.63	0.680	>999	6.56	5.10
4	491	83	20 - 30	1.7	15.2	7.76	0.720	>999	31.7	4.11
5	481	93	30 - 40	2.0	14.8	7.62	0.810	>999	431	4.46
6	471	103	40 - 50	1.4	15.0	7.51	0.880	>999	680	4.26

[a]Samples are filtered through a 5 micron filter.

Table A.2-9. Geoprobe Location 13631

Easting '83:	1349432	feet
Northing '83:	476745	feet
Ground Elevation:	582	feet above mean sea level (AMSL)
Depth to Water Table:	63.00	feet below ground surface (BGS)
Water Table Elevation:	519.38	feet AMSL
Work Completed:	6/6/2023	

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	29.2	16.7	7.07	1.01	>999	14.6	7.41
2	504	78	10 - 20	12.4	16.4	7.22	0.980	>999	75.6	5.14
3	504	78	10 - 20	12.4	16.4	7.22	0.98	>999	75.6	5.14
4	494	88	20 - 30	2.8	16.2	7.23	0.960	>999	78.2	4.74
5	484	98	30 - 40	< 1.0	16.5	7.38	0.980	>999	41.6	3.77
6	474	108	40 - 50	< 1.0	16.5	7.30	0.95	>999	22.8	3.65

[a]Samples are filtered through a 5 micron filter.

Table A.2-10. Geoprobe Location 13632

Easting '83:	1348433	feet
Northing '83:	476750	feet
Ground Elevation:	569	feet above mean sea level (AMSL)
Depth to Water Table:	52.00	feet below ground surface (BGS)
Water Table Elevation:	516.56	feet AMSL
Work Completed:	5/22/2023	

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	57	0 - 10	16.9	17.7	7.67	0.492	>999	135	7.58
2	502	67	10 - 20	6.6	17.3	7.98	0.566	>999	17.3	5.65
3	502	67	10 - 20	6.4	17.3	7.98	0.566	>999	17.3	5.65
4	492	77	20 - 30	2.5	16.7	7.98	0.610	>999	33.3	6.32
5	482	87	30 - 40	1.7	14.2	7.98	0.565	>999	20.3	4.26
6	472	97	40 - 50	2.6	13.9	7.75	0.552	>999	18.1	6.10

[a]Samples are filtered through a 5 micron filter.

Table A.2-11. Geoprobe Location 13633

Easting '83:	1348219	feet
Northing '83:	477133	feet
Ground Elevation:	545	feet above mean sea level (AMSL)
Depth to Water Table:	27.00	feet below ground surface (BGS)
Water Table Elevation:	518.04	feet AMSL
Work Completed:	5/9/2023	

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	32	0 - 10	32.4	17.1	7.35	0.640	>999	441	7.81
2	503	42	10 - 20	4.5	16.1	7.81	0.660	>999	62.4	6.31
3	503	42	10 - 20	4.2	16.1	7.81	0.660	>999	62.4	6.31
4	493	52	20 - 30	1.9	16.2	7.86	0.680	>999	10.5	6.22
5	483	62	30 - 40	3.3	14.9	7.85	0.630	>999	16.4	5.78
6	473	72	40 - 50	4.8	13.6	7.90	0.606	>999	13.3	5.25

[a]Samples are filtered through a 5 micron filter.

Table A.2-12. Geoprobe Location 13634

Easting '83:	1349208	feet
Northing '83:	476608	feet
Ground Elevation:	575	feet above mean sea level (AMSL)
Depth to Water Table:	59.00	feet below ground surface (BGS)
Water Table Elevation:	515.78	feet AMSL
Work Completed:	6/5/2023	

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	64	0 - 10	2.9	15.5	7.43	0.680	>999	8.01	6.97
2	501	74	10 - 20	1.1	14.0	7.62	0.690	>999	134	8.28
3	501	74	10 - 20	1.0	14.0	7.62	0.690	>999	134	8.28
4	491	84	20 - 30	1.9	14.7	7.70	0.690	>999	37.7	8.15
5	481	94	30 - 40	78.2	13.7	7.62	0.616	>999	46.0	4.90
6	471	104	40 - 50	13.4	14.1	7.71	0.660	>999	82.8	4.20

[a]Samples are filtered through a 5 micron filter.

Table A.2-13. Geoprobe Location 13229J

Easting '83:	1348244	feet
Northing '83:	475528	feet
Ground Elevation:	571	feet above mean sea level (AMSL)
Depth to Water Table:	54.00	feet below ground surface (BGS)
Water Table Elevation:	517.47	feet AMSL
Work Completed:	4/25/2023	

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	59	0 - 10	39.3	12.4	7.36	0.790	>999	331	8.92
2	502	69	10 - 20	15.5	12.7	7.74	0.690	>999	43.4	5.39
3	502	69	10 - 20	13.6	12.7	7.74	0.690	>999	43.4	5.39
4	492	79	20 - 30	19.4	12.9	7.67	0.624	>999	19.3	5.26
5	482	89	30 - 40	12.4	13.1	7.78	0.605	>999	439.0	7.74
6	472	99	40 - 50	12.3	12.6	7.61	0.660	>999	61.4	5.22

[a]Samples are filtered through a 5 micron filter.

Table A.2-14. Geoprobe Location 13536A

Easting '83:	1348846	feet
Northing '83:	475691	feet
Ground Elevation:	575	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	515.42	feet AMSL
Work Completed:	3/27/2023	

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	510	65	0 - 10	48.9	12.4	6.95	0.750	>999	>999	10.95
2	500	75	10 - 20	22.0	14.0	7.94	0.680	>999	>999	10.11
3	500	75	10 - 20	19.5	14.0	7.94	0.680	>999	>999	10.11
4	490	85	20 - 30	14.2	13.3	7.81	0.616	>999	123	8.78
5	480	95	30 - 40	7.0	13.9	6.85	0.680	>999	24.4	8.37
6	470	105	40 - 50	4.2	13.2	7.47	0.820	>999	>999	8.08

[a]Samples are filtered through a 5 micron filter.

Table A.2-15. Geoprobe Location 13542B

Easting '83:	1348155	feet
Northing '83:	474984	feet
Ground Elevation:	540	feet above mean sea level (AMSL)
Depth to Water Table:	23.00	feet below ground surface (BGS)
Water Table Elevation:	516.54	feet AMSL
Work Completed:	4/24/2023	

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	12.8	11.3	7.56	0.790	>999	424	8.40
2	502	38	10 - 20	4.9	10.6	7.74	0.690	>999	6.09	4.81
3	502	38	10 - 20	3.6	10.6	7.74	0.690	>999	6.1	4.81
4	492	48	20 - 30	4.2	10.4	7.65	0.730	>999	29.4	6.58
5	482	58	30 - 40	12.5	9.7	7.57	0.820	>999	21.4	4.50
6	472	68	40 - 50	32.1	9.7	7.45	0.860	>999	29.5	4.20
7	462	78	50 - 60	19.5	9.4	7.57	0.920	>999	664	3.96
8	452	88	60 - 70	21.6	9.8	7.53	0.870	>999	>999	5.24
9	442	98	70 - 80	4.8	9.9	7.51	0.790	>999	>999	5.26

[a]Samples are filtered through a 5 micron filter.

Table A.2-16. Geoprobe Location 13608A

Easting '83:	1349115	feet
Northing '83:	475611	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.20	feet AMSL
Work Completed:	4/13/2023	

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	< 1.0	15.7	7.37	1.010	>999	25.0	7.59
2	502	77	10 - 20	11.1	15.8	7.84	0.820	>999	14.7	6.18
3	502	77	10 - 20	9.8	15.8	7.84	0.820	>999	14.7	6.18
4	492	87	20 - 30	10.0	16.3	7.70	0.660	>999	21.2	3.75
5	482	97	30 - 40	3.7	14.8	7.61	0.730	>999	14.5	2.82
6	472	107	40 - 50	1.4	15.6	7.56	0.750	>999	22.2	3.39

[a]Samples are filtered through a 5 micron filter.

Table A.2-17. Geoprobe Location 13618

Easting '83:	1349182	feet
Northing '83:	475548	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	518.18	feet AMSL
Work Completed:	4/17/2023	

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	66	0 - 10	< 1.0	11.8	7.36	0.990	>999	51.8	7.66
2	503	76	10 - 20	15.4	12.1	7.85	0.800	>999	21.8	5.91
3	503	76	10 - 20	15.0	12.1	7.85	0.800	>999	21.8	5.91
4	493	86	20 - 30	2.2	12.0	7.81	0.690	>999	9.65	4.21
5	483	96	30 - 40	1.2	12.0	7.68	0.730	>999	24.3	4.31
6	473	106	40 - 50	< 1.0	11.4	7.59	0.820	>999	24.3	4.71

[a]Samples are filtered through a 5 micron filter.

Table A.2-18. Geoprobe Location 13619

Easting '83:	1349108	feet
Northing '83:	475515	feet
Ground Elevation:	577	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	517.18	feet AMSL
Work Completed:	4/18/2023	

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	65	0 - 10	17.0	13.7	7.51	0.890	>999	568	5.98
2	502	75	10 - 20	36.4	13.7	7.71	0.750	>999	76.2	6.40
3	502	75	10 - 20	35.1	13.7	7.71	0.750	>999	76.2	6.40
4	492	85	20 - 30	4.7	13.5	7.79	0.690	>999	8.54	4.50
5	482	95	30 - 40	6.6	13.6	7.68	0.680	>999	599	5.45
6	472	105	40 - 50	2.7	13.5	7.61	0.830	>999	>999	5.50

[a]Samples are filtered through a 5 micron filter.

Table A.2-19. Geoprobe Location 13619A

Easting '83:	1349108	feet
Northing '83:	475515	feet
Ground Elevation:	577	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	517.18	feet AMSL
Work Completed:	4/27/2023	

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	65	0 - 10	12.2	15.1	7.38	0.920	>999	168	6.19
2	502	75	10 - 20	19.9	14.3	7.75	0.700	>999	13.4	5.29
3	502	75	10 - 20	18.8	14.3	7.75	0.700	>999	13.4	5.29
4	492	85	20 - 30	4.0	14.0	7.80	0.700	>999	27.6	5.00
5	482	95	30 - 40	2.4	13.7	7.63	0.740	>999	23.0	4.33
6	472	105	40 - 50	< 1.0	13.8	7.57	0.820	>999	741	4.00

[a]Samples are filtered through a 5 micron filter.

Table A.2-20. Geoprobe Location 13620

Easting '83:	1348809	feet
Northing '83:	475329	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	518.93	feet AMSL
Work Completed:	4/11/2023	

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	66	0 - 10	6.3	14.2	7.36	0.790	>999	2.62	6.02
2	504	76	10 - 20	15.1	14.4	7.74	0.720	>999	2.62	3.66
3	504	76	10 - 20	14.5	14.4	7.74	0.720	>999	2.62	3.66
4	494	86	20 - 30	17.7	14.1	7.70	0.660	>999	0.52	3.42
5	484	96	30 - 40	12.4	14.5	7.67	0.710	>999	1.70	3.25
6	474	106	40 - 50	5.9	14.5	7.59	0.780	>999	1.98	3.30

[a]Samples are filtered through a 5 micron filter.

Table A.2-21. Geoprobe Location 13621

Easting '83:	1348713	feet
Northing '83:	475640	feet
Ground Elevation:	577	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	516.15	feet AMSL
Work Completed:	4/4/2023	

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	29.2	14.3	7.46	0.750	>999	6.24	10.63
2	501	76	10 - 20	17.3	14.5	7.73	0.617	>999	94.5	8.06
3	501	76	10 - 20	17.1	14.5	7.73	0.617	>999	94.5	8.06
4	491	86	20 - 30	4.3	14.9	7.95	0.690	>999	14.0	6.33
5	481	96	30 - 40	8.3	14.0	7.68	0.710	>999	95.1	6.19
6	471	106	40 - 50	2.6	14.2	7.52	0.830	>999	11.7	6.00

[a]Samples are filtered through a 5 micron filter.

Table A.2-22. Geoprobe Location 13622

Easting '83:	1348355	feet
Northing '83:	475628	feet
Ground Elevation:	574	feet above mean sea level (AMSL)
Depth to Water Table:	57.00	feet below ground surface (BGS)
Water Table Elevation:	517.14	feet AMSL
Work Completed:	5/3/2023	

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	62	0 - 10	21.1	13.2	7.44	0.720	>999	>999	6.96
2	502	72	10 - 20	21.5	13.4	7.66	0.690	>999	30.8	5.28
3	502	72	10 - 20	20.1	13.4	7.66	0.690	>999	30.8	5.28
4	492	82	20 - 30	4.1	13.6	7.78	0.630	>999	49.2	5.26
5	482	92	30 - 40	7.6	13.6	7.65	0.650	>999	17.6	4.18
5	472	102	40 - 50	2.3	13.4	7.53	0.760	>999	15.7	4.76

[a]Samples are filtered through a 5 micron filter.

Table A.2-23. Geoprobe Location 13623

Easting '83:	1348723	feet
Northing '83:	475715	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	60.60	feet below ground surface (BGS)
Water Table Elevation:	515.60	feet AMSL
Work Completed:	3/28/2023	

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	22.7	14.0	7.46	0.790	>999	>999	12.73
2	501	76	10 - 20	19.7	13.5	7.68	0.627	>999	37.8	9.13
3	501	76	10 - 20	19.7	13.5	7.68	0.627	>999	37.8	9.13
4	491	86	20 - 30	11.9	13.5	7.84	0.650	>999	17.2	7.60
5	481	96	30 - 40	8.7	12.9	7.75	0.680	>999	38.6	6.06
6	471	106	40 - 50	5.7	13.2	6.88	0.840	>999	>999	7.11

[a]Samples are filtered through a 5 micron filter.

Table A.2-24. Geoprobe Location 13624

Easting '83:	1348801	feet
Northing '83:	475489	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.36	feet AMSL
Work Completed:	4/12/2023	

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	7.0	15.5	7.38	0.800	>999	221	6.17
2	502	77	10 - 20	19.1	15.4	7.72	0.670	>999	18.6	4.78
3	502	77	10 - 20	18.8	15.4	7.72	0.670	>999	18.6	4.78
4	492	87	20 - 30	22.4	15.1	7.73	0.650	>999	96.2	5.61
5	482	97	30 - 40	8.6	15.3	7.71	0.730	>999	24.5	3.78
6	472	107	40 - 50	3.5	15.8	7.51	0.770	>999	334	4.81

[a]Samples are filtered through a 5 micron filter.

Table A.2-25. Geoprobe Location 13625

Easting '83:	1348347	feet
Northing '83:	475470	feet
Ground Elevation:	574.98	feet above mean sea level (AMSL)
Depth to Water Table:	57.00	feet below ground surface (BGS)
Water Table Elevation:	517.98	feet AMSL
Work Completed:	4/26/2023	

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	62	0 - 10	28.0	13.1	7.39	0.810	>999	22.9	7.07
2	503	72	10 - 20	23.6	13.1	7.65	0.760	>999	61.7	5.49
3	503	72	10 - 20	23.0	13.1	7.65	0.760	>999	61.7	5.49
4	493	82	20 - 30	34.1	12.6	7.58	0.710	>999	104	4.01
5	483	92	30 - 40	7.7	12.7	7.81	0.635	>999	19.9	4.16
6	473	102	40 - 50	5.9	12.5	7.77	0.700	>999	749	5.91

[a]Samples are filtered through a 5 micron filter.

Table A.2-26. Geoprobe Location 13626

Easting '83:	1348439	feet
Northing '83:	475268	feet
Ground Elevation:	579	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	519.17	feet AMSL
Work Completed:	4/3/2023	

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	65	0 - 10	35.0	10.8	4.89	0.760	>999	>999	13.83
2	504	75	10 - 20	22.7	11.5	7.63	0.740	>999	>999	9.10
3	504	75	10 - 20	19.7	11.5	7.63	0.740	>999	>999	9.10
4	494	85	20 - 30	8.8	11.0	7.91	0.678	>999	31.7	9.71
5	484	95	30 - 40	5.1	10.9	7.8	0.680	>999	133	6.54
6	474	105	40 - 50	1.6	11.0	7.82	0.648	>999	14.3	6.50

[a]Samples are filtered through a 5 micron filter.

Table A.2-27. Geoprobe Location 13627

Easting '83:	1348437	feet
Northing '83:	475123	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	59.00	feet below ground surface (BGS)
Water Table Elevation:	521.77	feet AMSL
Work Completed:	3/29/2023	

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	517	64	0 - 10	17.7	12.7	5.70	0.770	>999	174	12.76
2	507	74	10 - 20	11.8	12.8	7.30	0.670	>999	50.5	11.33
3	507	74	10 - 20	11.0	12.8	7.30	0.670	>999	50.5	11.33
4	497	84	20 - 30	14.3	12.6	6.98	0.660	>999	347	9.07
5	487	94	30 - 40	8.9	12.3	7.07	0.639	>999	>999	7.30
6	477	104	40 - 50	2.0	12.2	7.19	0.740	>999	>999	7.04

[a]Samples are filtered through a 5 micron filter.

Table A.2-28. Geoprobe Location 13628

Easting '83:	1348934	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:	517.71	feet AMSL
Work Completed:	4/10/2023	

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	26.0	14.9	7.41	0.690	>999	10.4	6.26
2	503	77	10 - 20	18.1	14.2	7.72	0.680	>999	3.61	5.73
3	503	77	10 - 20	17.5	14.2	7.72	0.680	>999	3.61	5.73
4	493	87	20 - 30	14.9	14.6	7.75	0.730	>999	2.29	3.31
5	483	97	30 - 40	9.5	14.3	7.74	0.770	>999	2.48	3.79
6	473	107	40 - 50	< 1.0	14.7	7.65	0.850	>999	2.22	4.61

[a]Samples are filtered through a 5 micron filter.

Table A.2-29. Geoprobe Location 13629

Easting '83:	1348952	feet
Northing '83:	475608	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	59.00	feet below ground surface (BGS)
Water Table Elevation:	517.04	feet AMSL
Work Completed:	4/19/2023	

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	64	0 - 10	< 1.0	15.0	7.32	0.970	>999	233	6.74
2	502	74	10 - 20	15.2	14.9	7.91	0.700	>999	15.1	6.12
3	502	74	10 - 20	15.1	14.9	7.91	0.700	>999	15.1	6.12
4	492	84	20 - 30	30.5	14.8	7.80	0.680	>999	>999	6.32
5	482	94	30 - 40	7.6	14.7	7.70	0.710	>999	>999	6.35
6	472	104	40 - 50	20.3	14.8	7.67	0.770	>999	24.4	7.05

[a]Samples are filtered through a 5 micron filter.

Table A.2-30. Geoprobe Location 13635

Easting '83:	1348595	feet
Northing '83:	475321	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	61.60	feet below ground surface (BGS)
Water Table Elevation:	518.24	feet AMSL
Work Completed:	3/30/2023	

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	38.3	12.7	4.05	0.740	>999	177	10.94
2	503	77	10 - 20	34.8	12.2	3.59	0.680	>999	227	8.76
3	503	77	10 - 20	34.7	12.2	3.59	0.680	>999	227	8.76
4	493	87	20 - 30	22.0	12.1	3.67	0.670	>999	220	6.40
5	483	97	30 - 40	10.3	12.3	6.53	0.680	>999	60.1	6.04
6	473	107	40 - 50	< 1.0	12.3	6.72	0.720	>999	440	3.56

[a]Samples are filtered through a 5 micron filter.

Table A.2-31. Summary Statistics and Trend Analysis of Monitoring Wells for Total Uranium with 2023 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	98	12.0	462	107	92	No Trend
2049	73	3.00	278	70.0	53.0	Down
21033	64	7.34	43.2	22.4	8.2	Up
23271	44	31.1	144	66.4	30.2	Down
23273	44	79.2	421	205	81.1	Down
23274	66	58.8	384	150	64	Down
23275	43	69.1	349	151	57	Down
23276	44	3.56	115	77.7	18.8	Down
23280	44	17.5	700	118	126	Down
23281	44	16.1	367	117	73	Down
2386	67	6.67	180	41.2	41.1	Up
2387	67	18.1	492	151	74	No Trend
2389	56	0.899	120	33.2	20.8	Up
2397	52	135	737	338	128	Down
2649	63	6.01	1,260	301	355	Up
2880	67	0.400	71.8	30.3	26.5	Up
63285	44	46.7	277	154	69	Down
6880	54	35.7	145	73.7	25.8	Down
82369_C1	22	12.1	210	121	47	No Trend
82369_C2	14	25.1	50.6	34.9	6.81	No Trend
82369_C3	12	24.0	41.3	32.3	4.8	Up
82372_C1	25	19.8	62.4	35.8	9.5	Down
83117_C1	44	1.28	1,620	674	317	Down
83117_C4	25	33.2	111	68.6	21.8	Down
83124_C1	69	44.3102	1,070	463	213	No Trend
83124_C4	23	25.4	62.2	42.7	8.7	Up
83124_C5	23	24.4	61.4	45.4	9.0	Down
83294_C1	38	98.5	340	217	59.1	Up
83294_C2	60	1.24	575	279	128	Down
83295_C2	39	53.1	178	107	39	Down
83295_C3	28	39.1	175	99.9	46.9	Down
83296_C1	22	49.3	135	75.4	20.5	Down
83337_C1	41	255	2,660	1,330	570	Down
83338_C1	29	282	1,100	503	149	Down
83338_C2	36	14.0	648	82.3	132	Down
83340_C1	31	13.2	72.7	31.7	10.4	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 2023 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 2023.

Table A.2-32. 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, 2023)						
3924	756	1.2	180	26.4	15.1	Down
3925	759	0.5	84.0	22.0	8.2	Down
3926	737	1.5	42.4	24.2	7.7	Down
South Plume Optimization Module (August 9, 1998, through December 31, 2023)						
32309	675	14.9	123	47.7	21.5	Down
South Field Module (July 13, 1998, through December 31, 2023)						
31550	707	16.2	128	46.8	18.2	Down
31560	734	11.2	183	50.0	37.3	Down
31561	706	17.7	114[e]	38.2	10.0	Down
32276	747	12.3	290	83.8	63.9	Down
32446	600	17.4	168	51.8	22.0	Down
32447	620	9.4	302	88.8	55.7	Down
33061	504	13.6	98.5	39.4	15.8	Down
33262	463	12.1	110	39.5	15.2	Down
33264	447	3.6	364	60.3	45.0	Down
33298	411	10.1	76.2	44.0	13.4	Down
33326	357	6.6	62.2	20.2	8.5	Down
Waste Storage Area Module (May 8, 2002, through December 31, 2023)						
32761	485	15.9	161	49.5	31.9	Down
33062	509	10.2	236	55.0	42.2	Down
33347	313	7.0	126	24.9	15.2	Down

[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.2-33. Plume Size 1997 Through 2023

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
2023	72.11

[a] Plume size based on 20 µg/L total uranium.

Table A.2-34. 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%
2023	72.1	75.6	4.8%	83.1	15.5%

[a] Relative percent difference = [(maximum-Ricker)/maximum] X 100.

[b] Relative percent difference = [(maximum-EVS)/maximum] X 100.

Table A.2-35. 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).

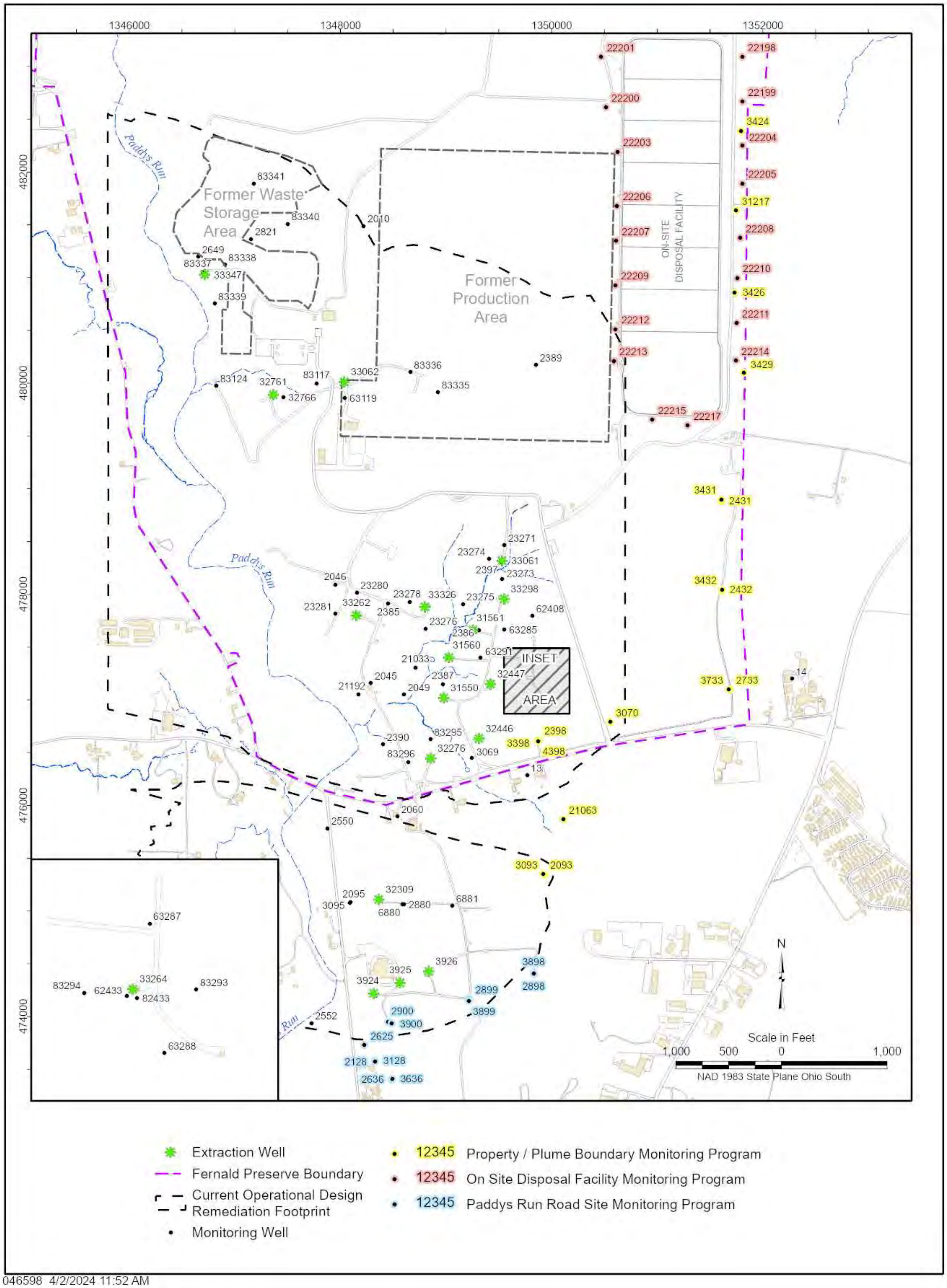

Figure A.2-1. IEMP Water Quality Monitoring Wells and Extraction Wells

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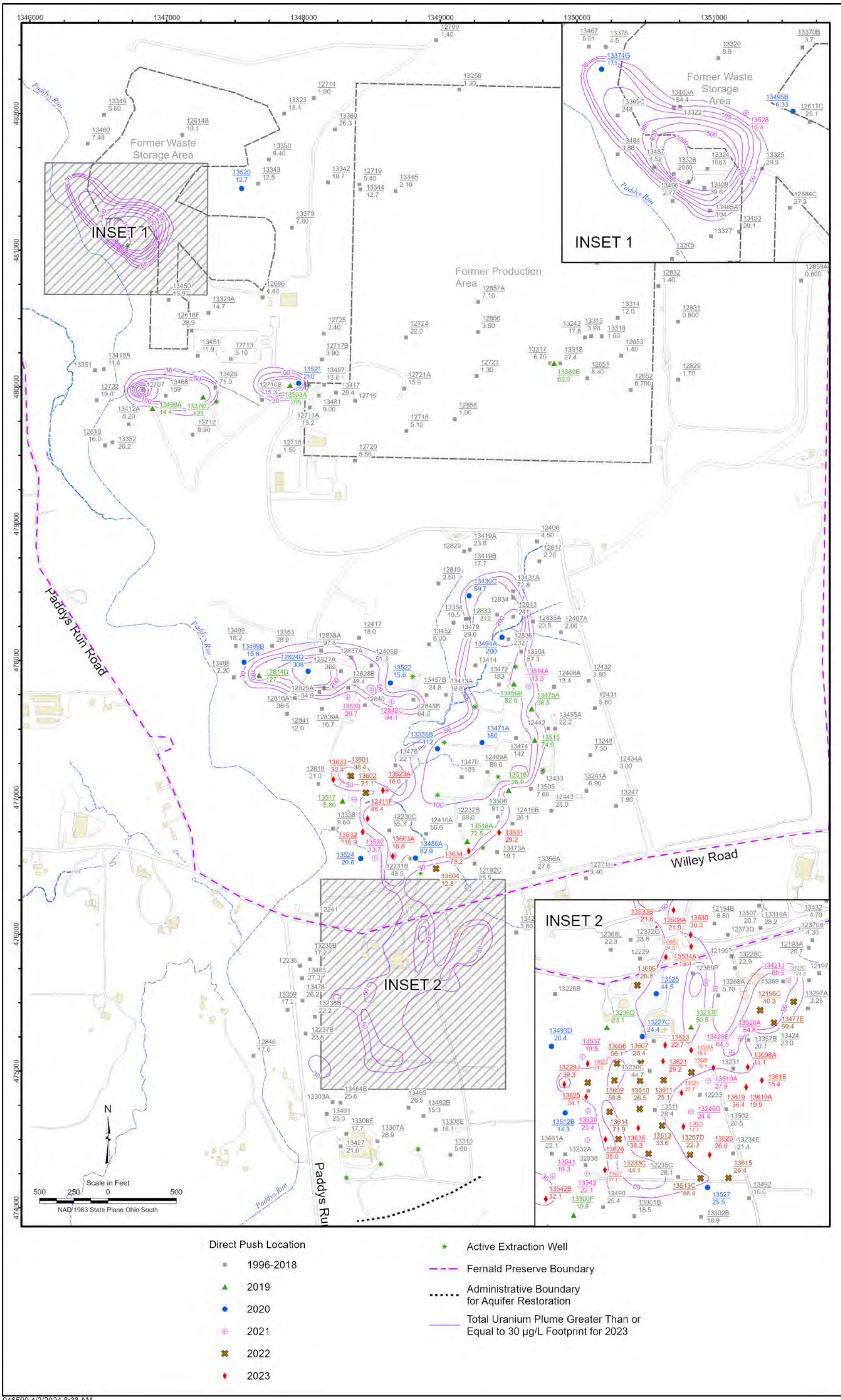

Figure A.2-2. Direct-Push Data and Maximum Total Uranium Plume for 2023

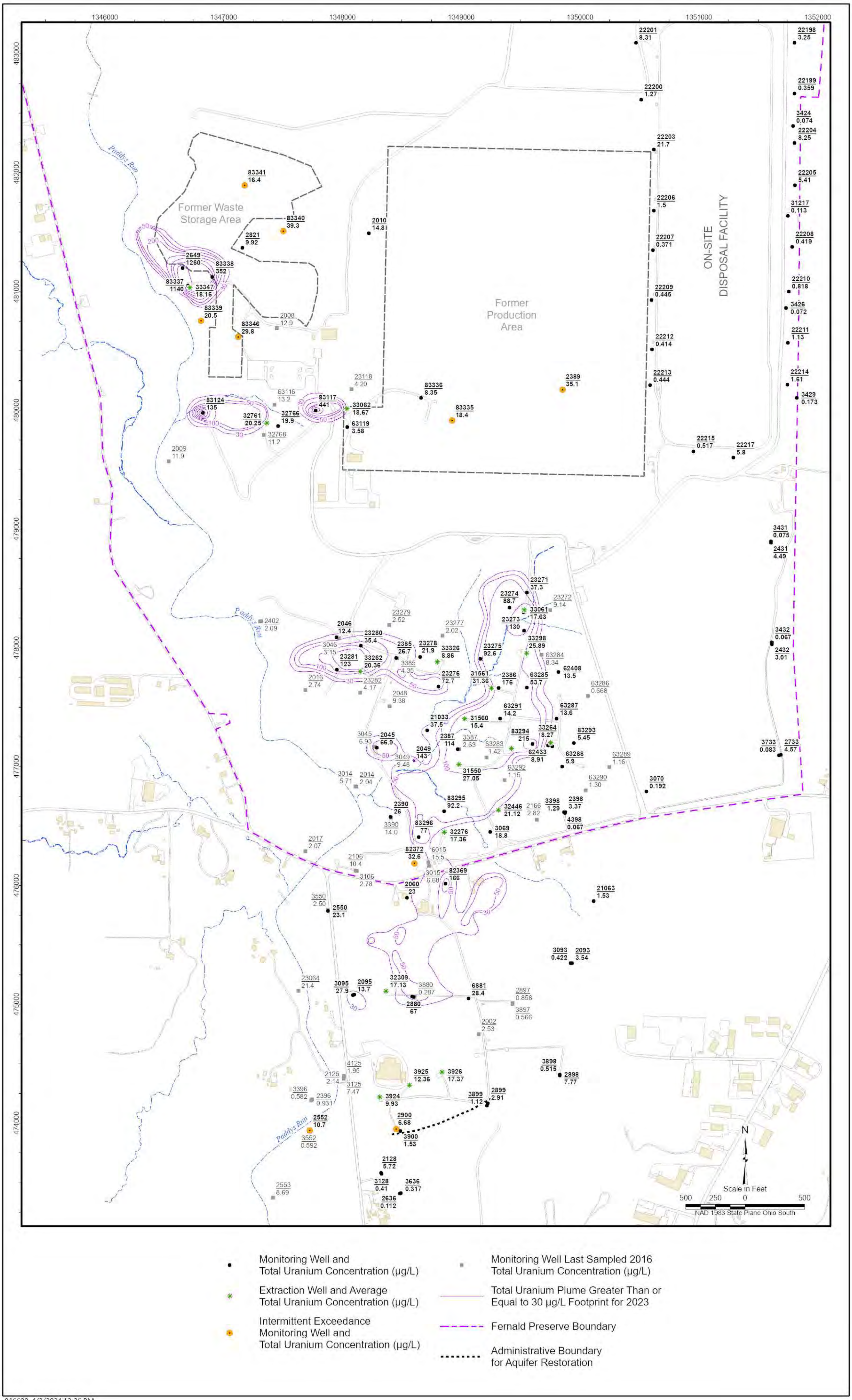

Figure A.2-3. Monitoring Well Data and Maximum Total Uranium Plume for 2023

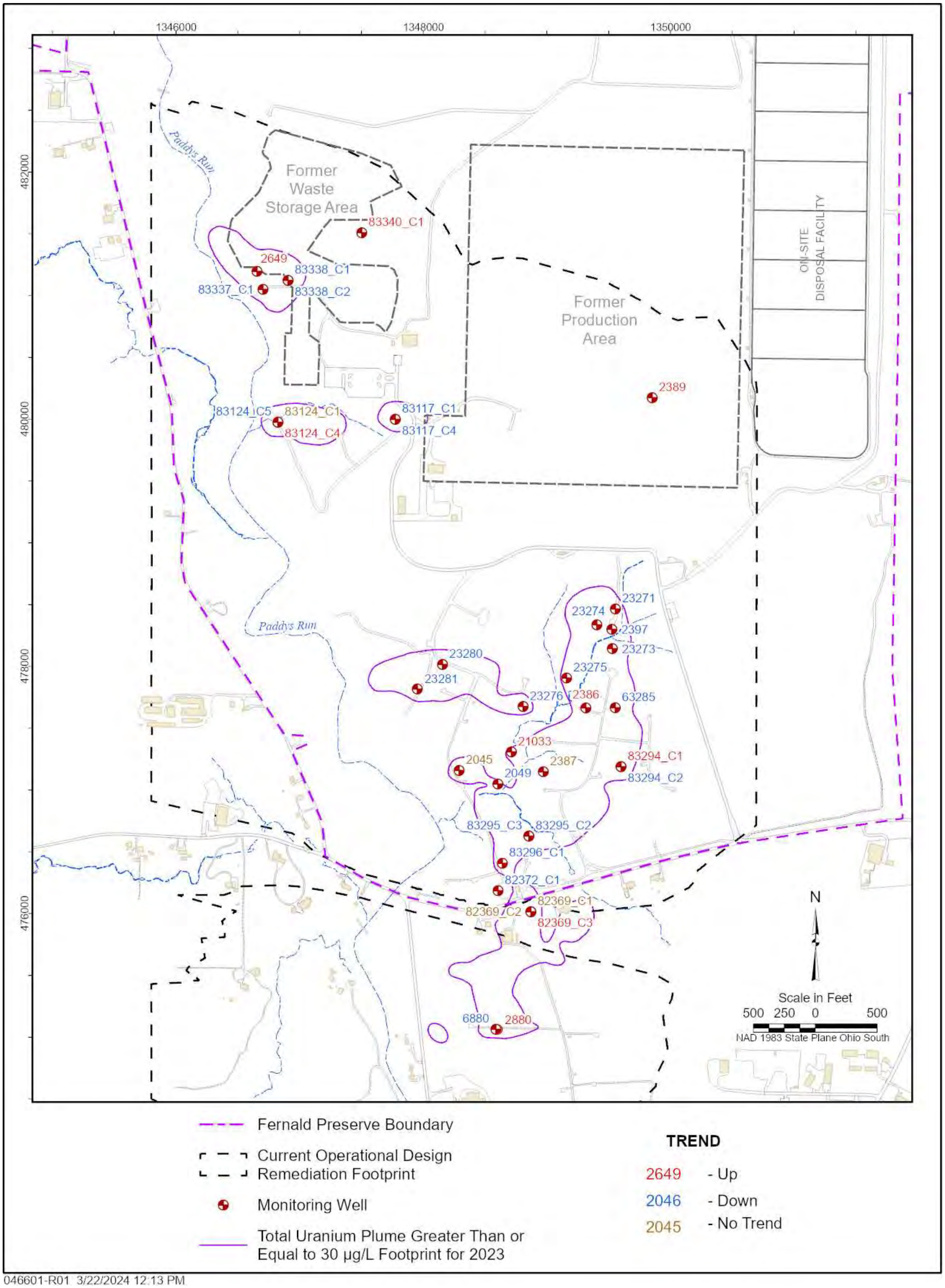

Figure A.2-4. Monitoring Wells with 2023 Exceedances for Total Uranium with Up, Down, or No Significant Trends

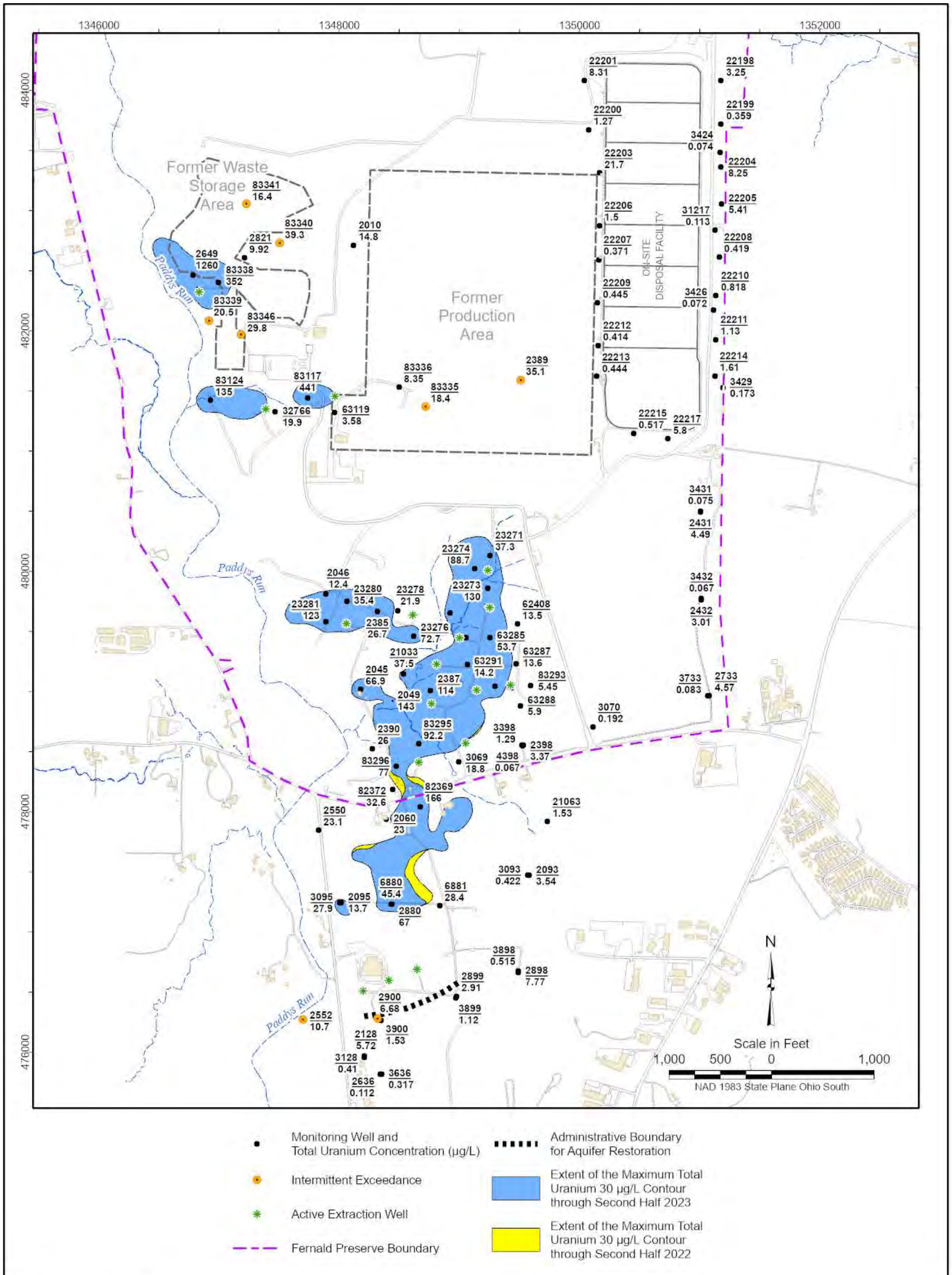

Figure A.2-5. Monitoring Well Data from 2023 Comparison to Maximum Total Uranium Footprint at end of 2022

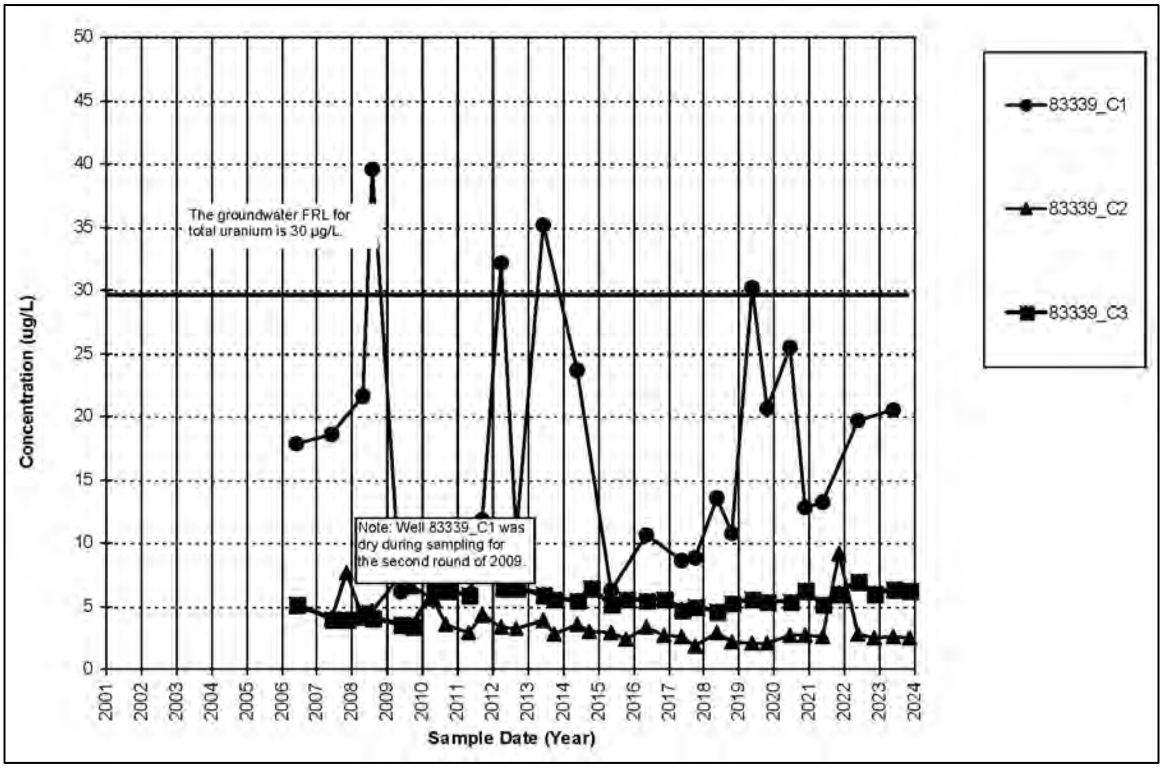

Figure A.2-6. Total Uranium Concentration Versus Time Plot for Monitoring Well 83339

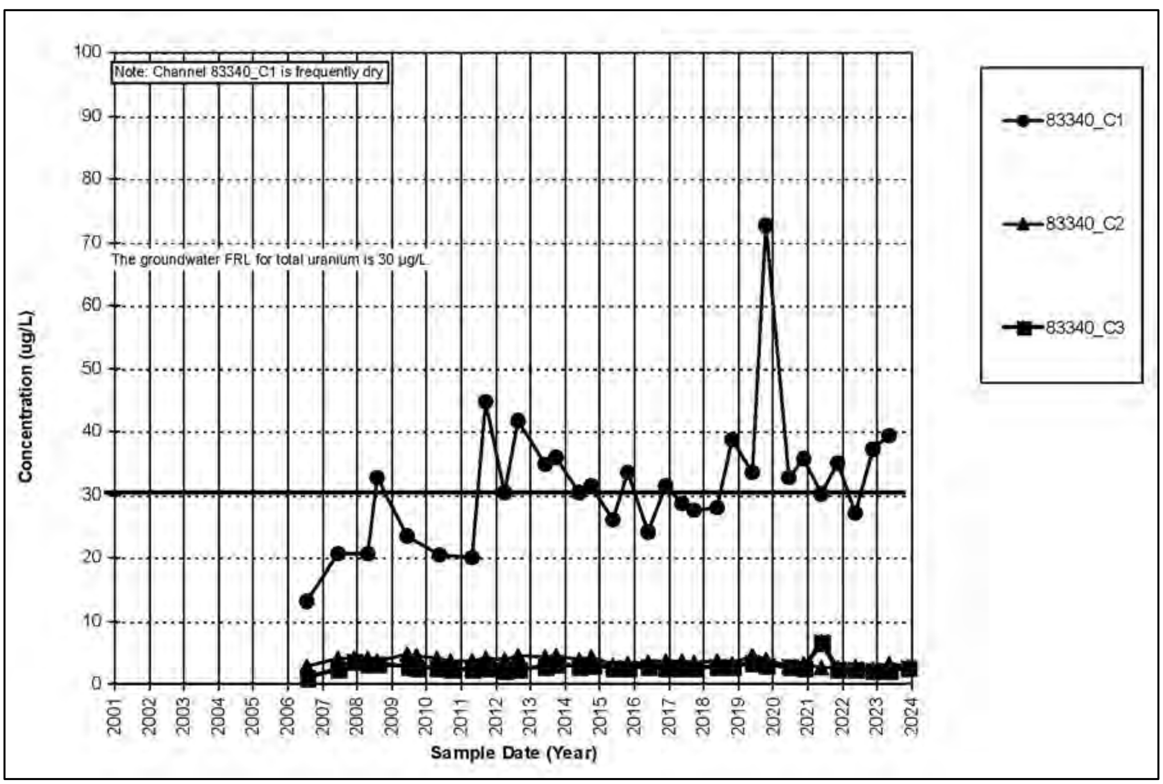

Figure A.2-7. Total Uranium Concentration Versus Time Plot for Monitoring Well 83340

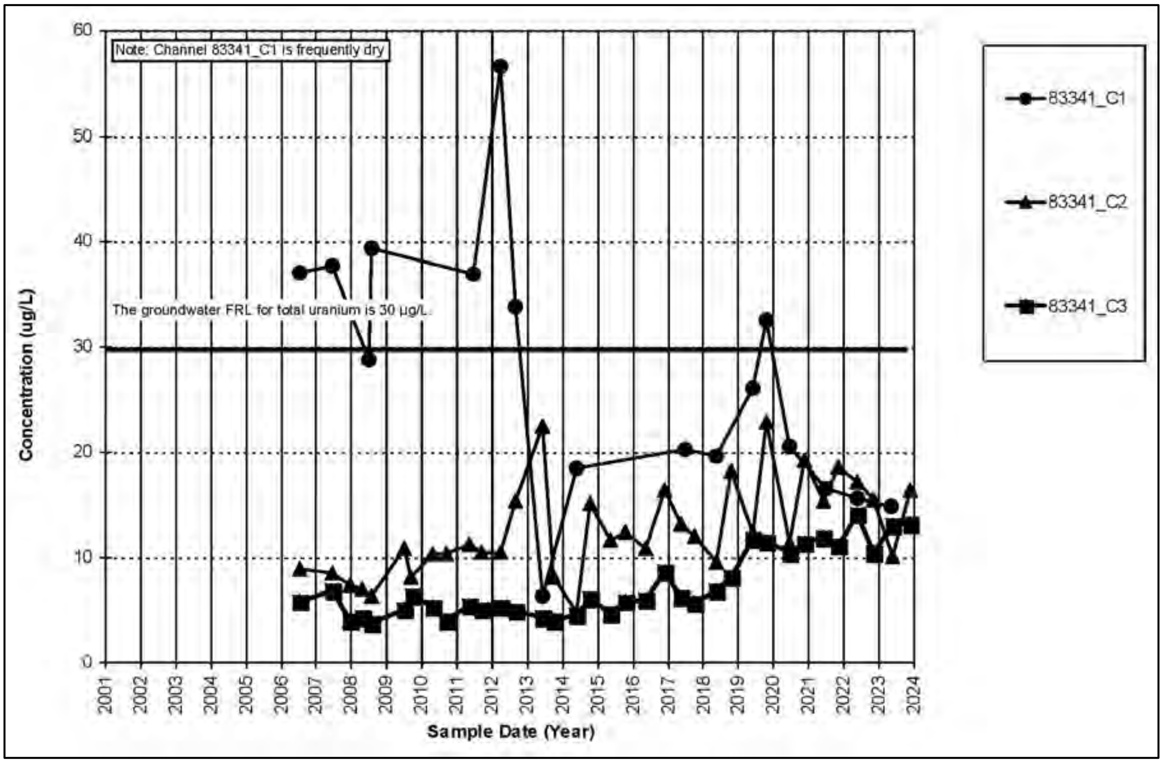

Figure A.2-8. Total Uranium Concentration Versus Time Plot for Monitoring Well 83341

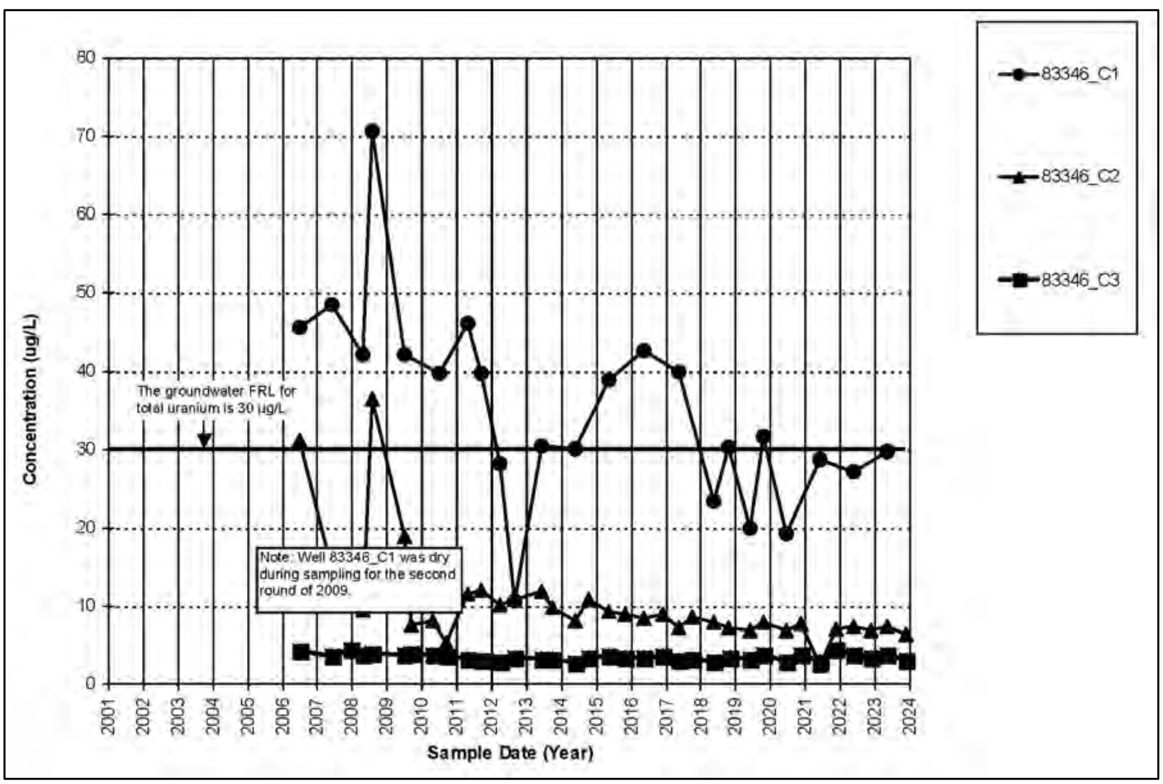

Figure A.2-9. Total Uranium Concentration Versus Time Plot for Monitoring Well 83346

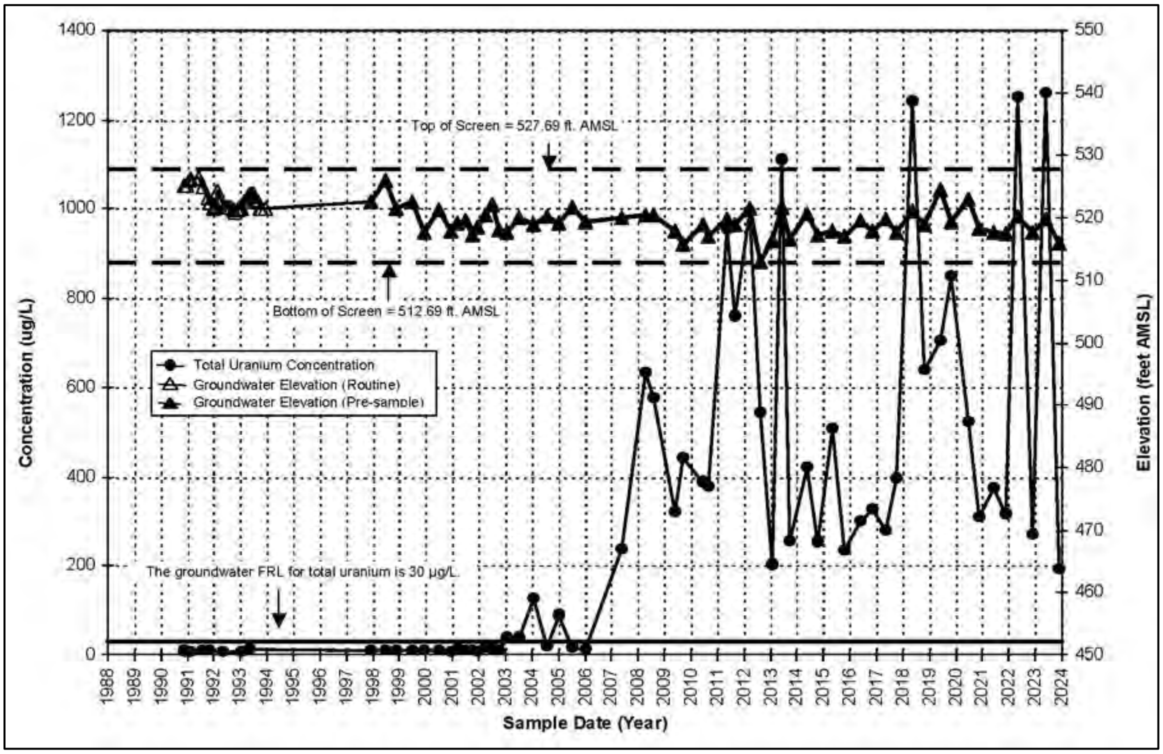

Figure A.2-10. Total Uranium Concentration Versus Time Plot for Monitoring Well 2649

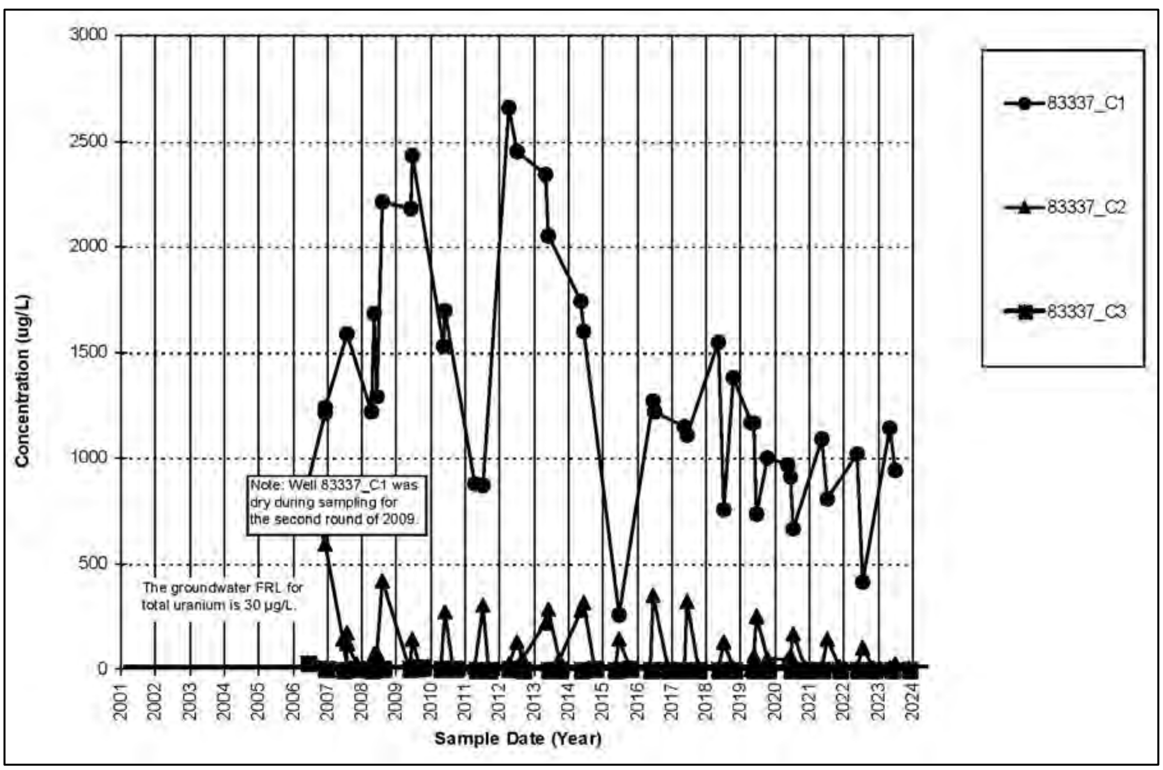

Figure A.2-11. Total Uranium Concentration Versus Time Plot for Monitoring Well 83337

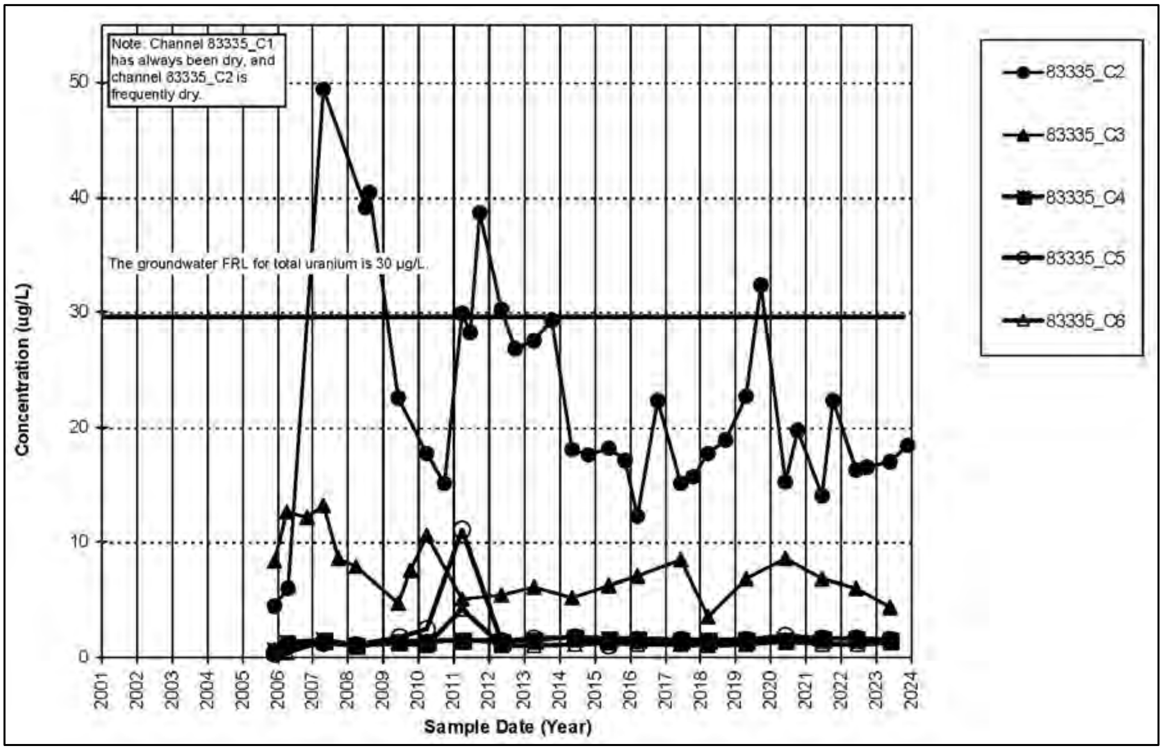

Figure A.2-12. Total Uranium Concentration Versus Time Plot for Monitoring Well 83335

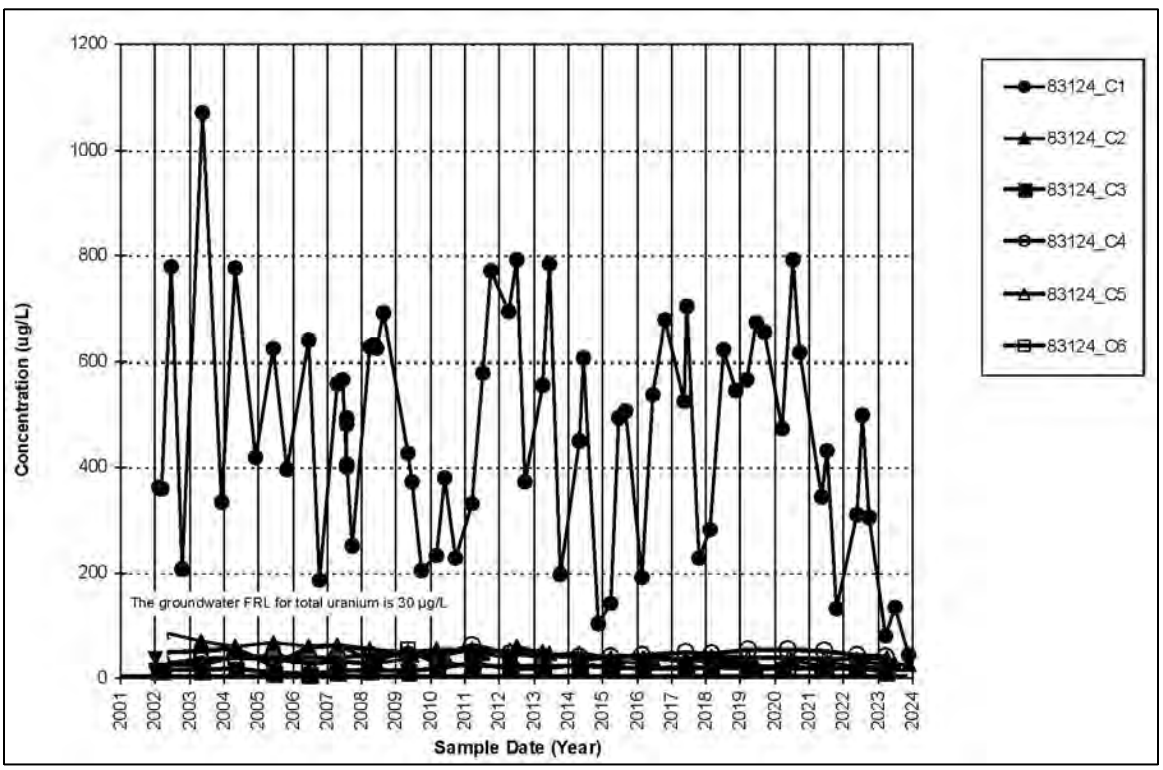

Figure A.2-13. Total Uranium Concentration Versus Time Plot for Monitoring Well 83124

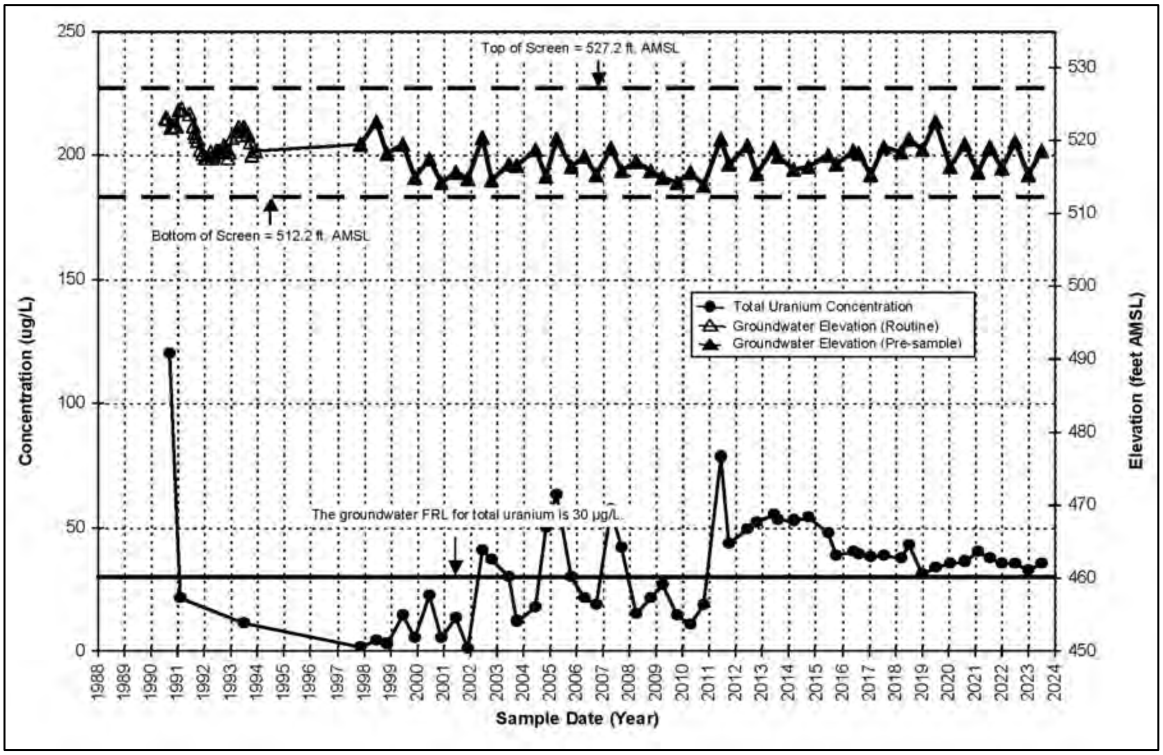

Figure A.2-14. Total Uranium Concentration Versus Time Plot for Monitoring Well 2389

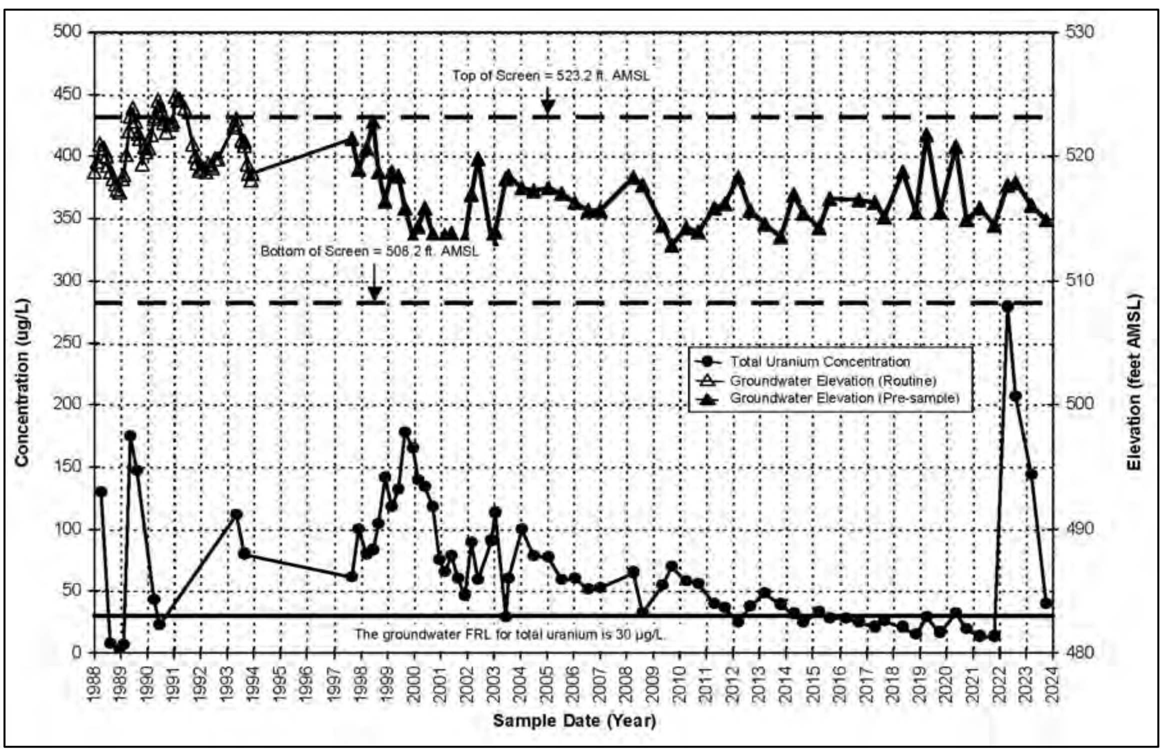

Figure A.2-15. Total Uranium Concentration Versus Time Plot for Monitoring Well 2049

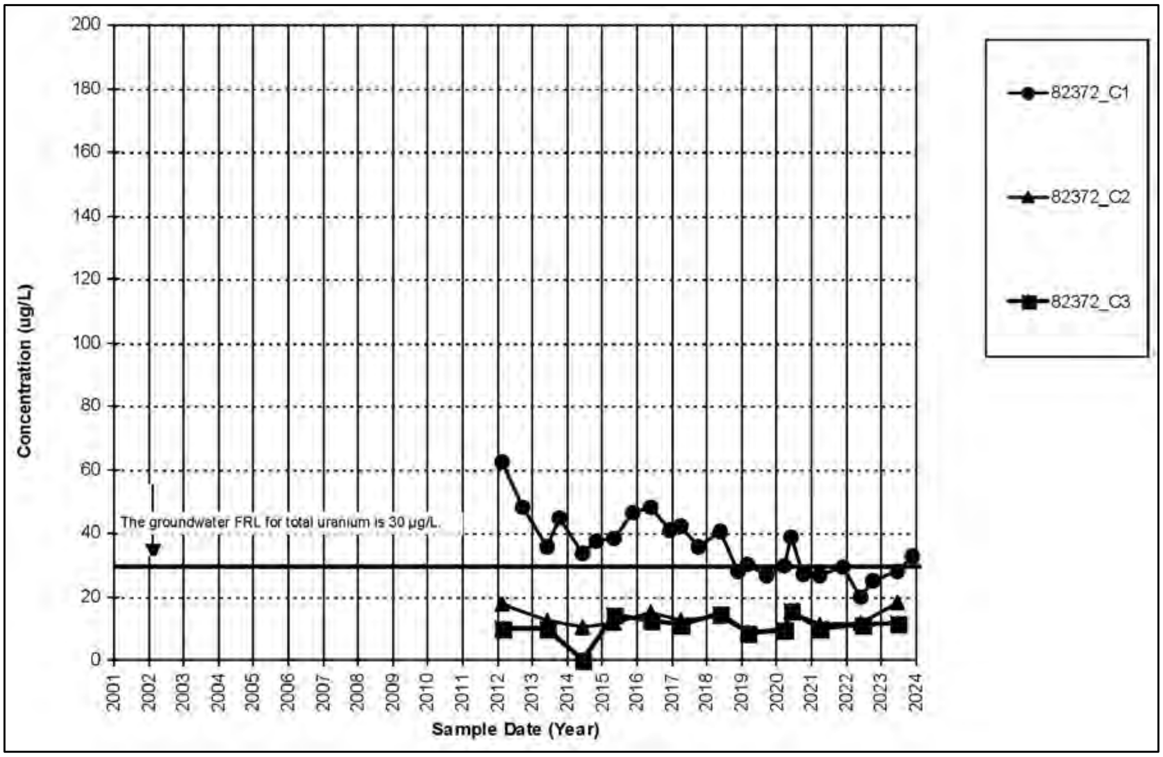

Figure A.2-16. Total Uranium Concentration Versus Time Plot for Monitoring Well 82372

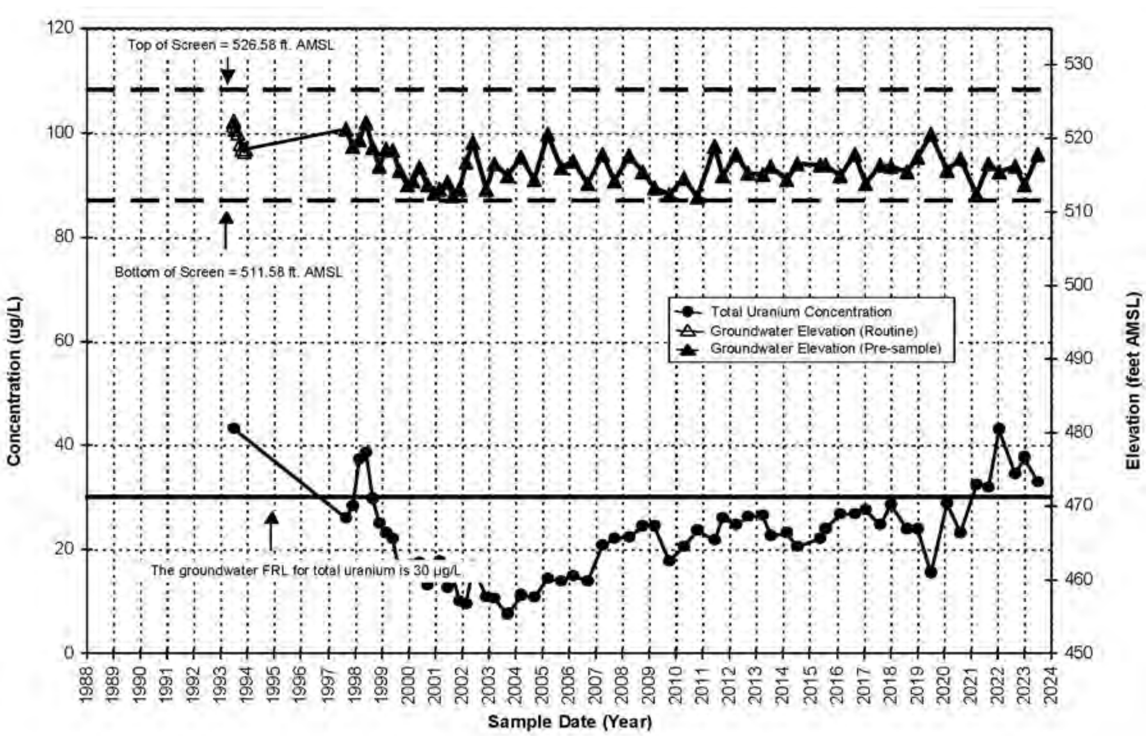

Figure A.2-17. Total Uranium Concentration Versus Time Plot for Monitoring Well 21033

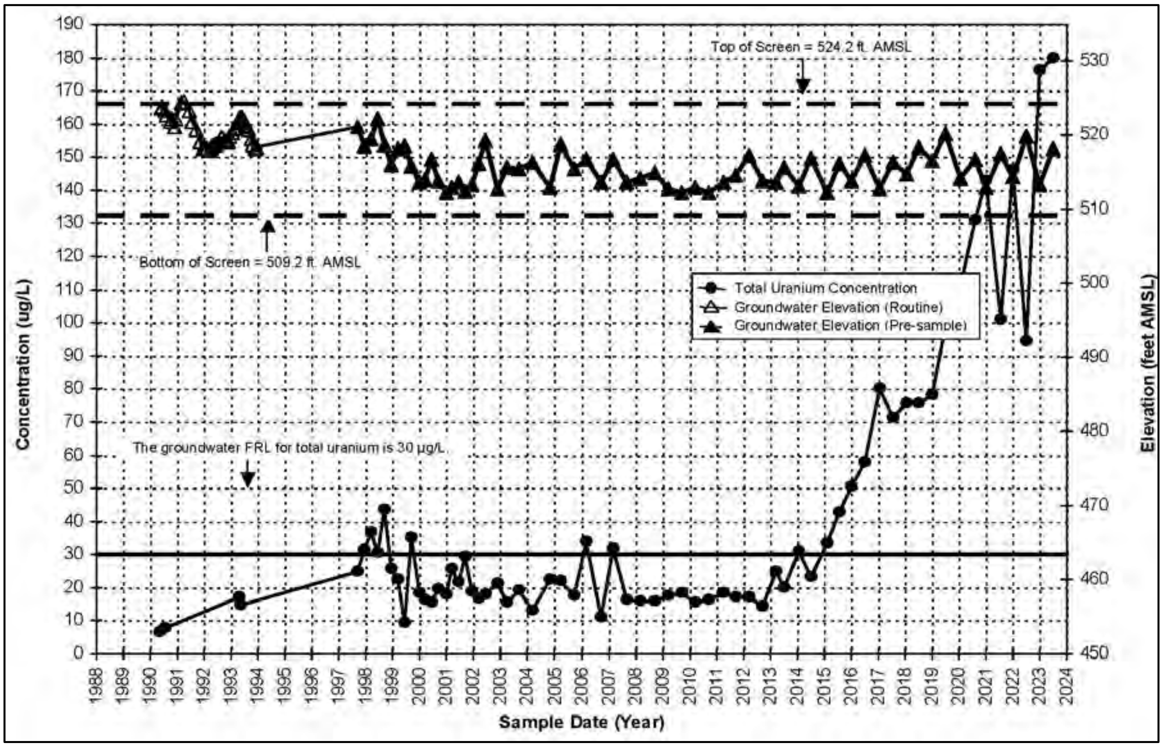

Figure A.2-18. Total Uranium Concentration Versus Time Plot for Monitoring Well 2386

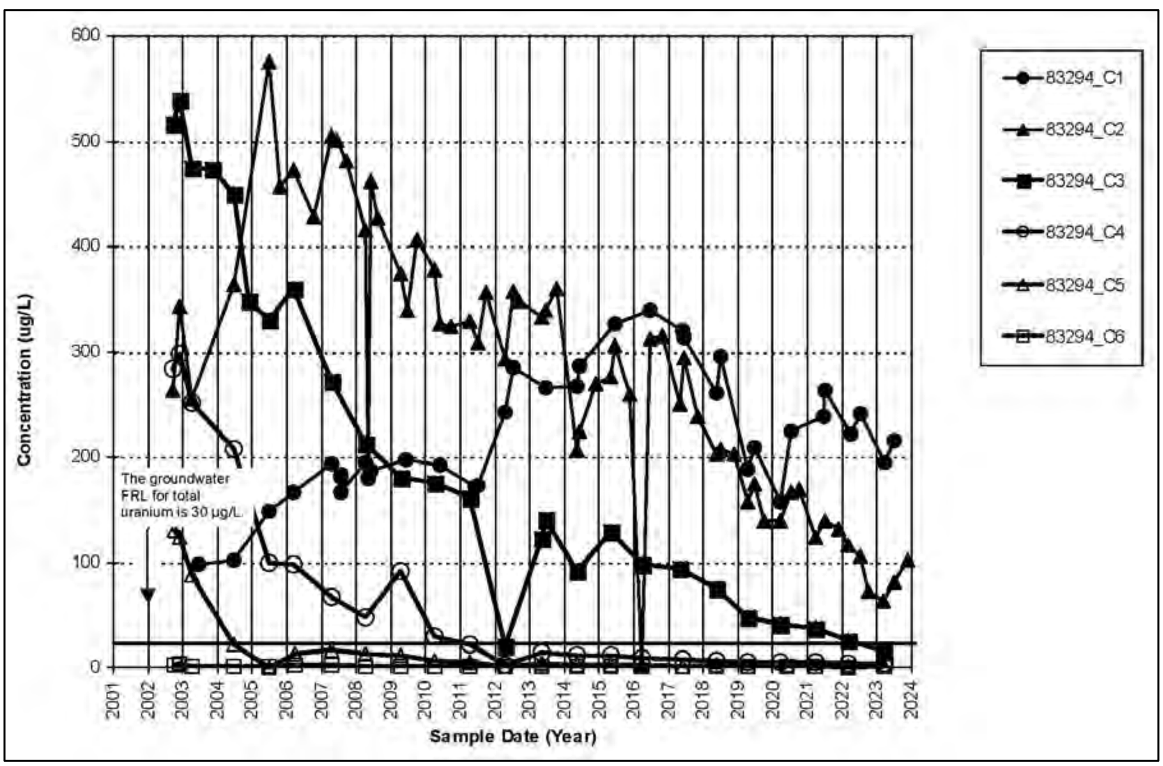

Figure A.2-19. Total Uranium Concentration Versus Time Plot for Monitoring Well 83294

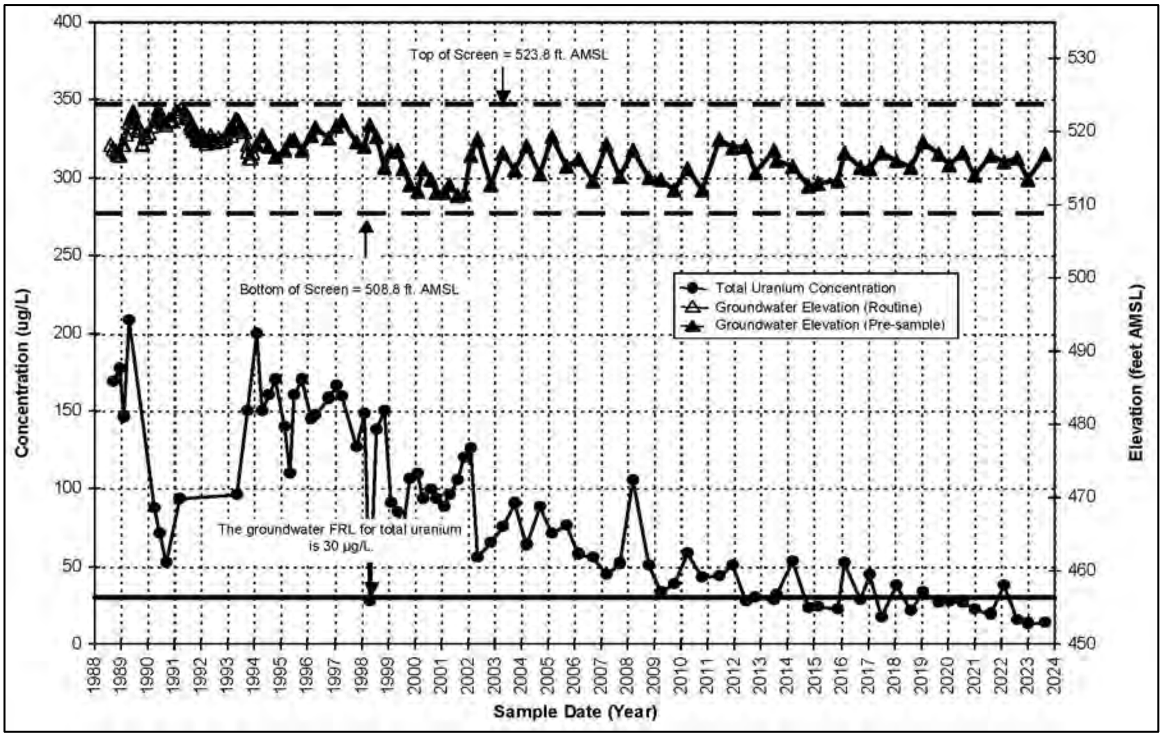

Figure A.2-20. Total Uranium Concentration Versus Time Plot for Monitoring Well 2095

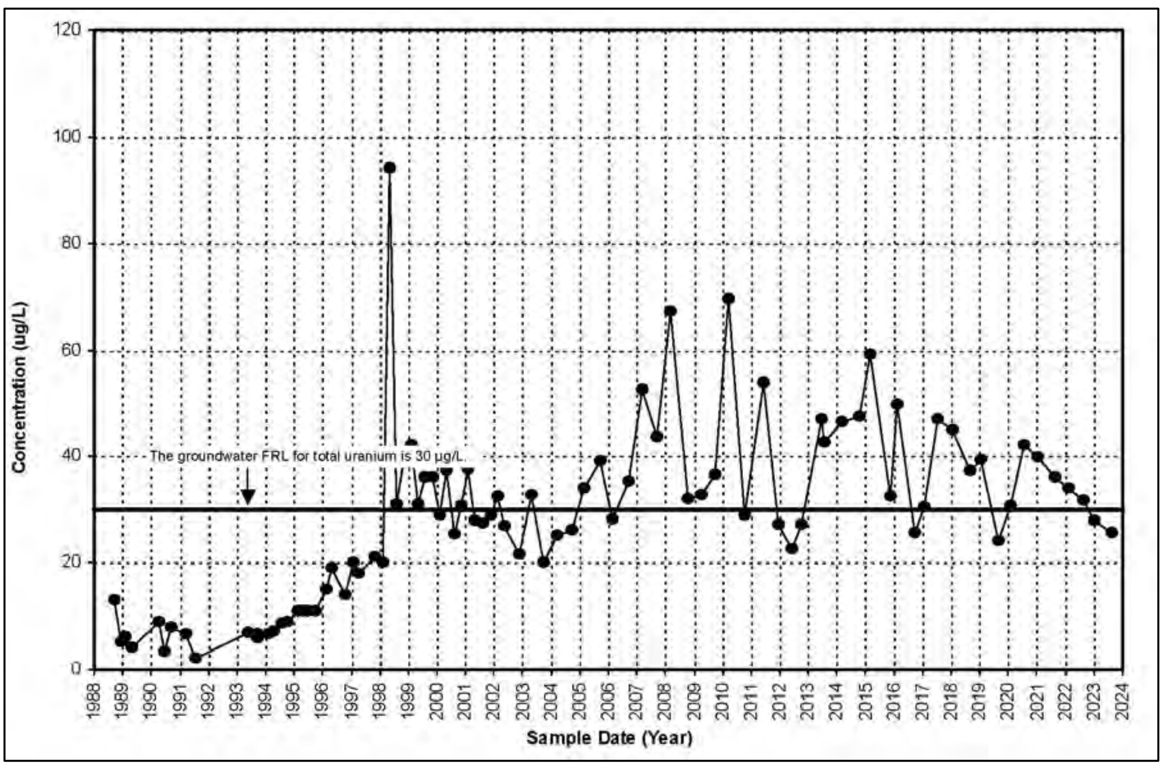

Figure A.2-21. Total Uranium Concentration Versus Time Plot for Monitoring Well 3095

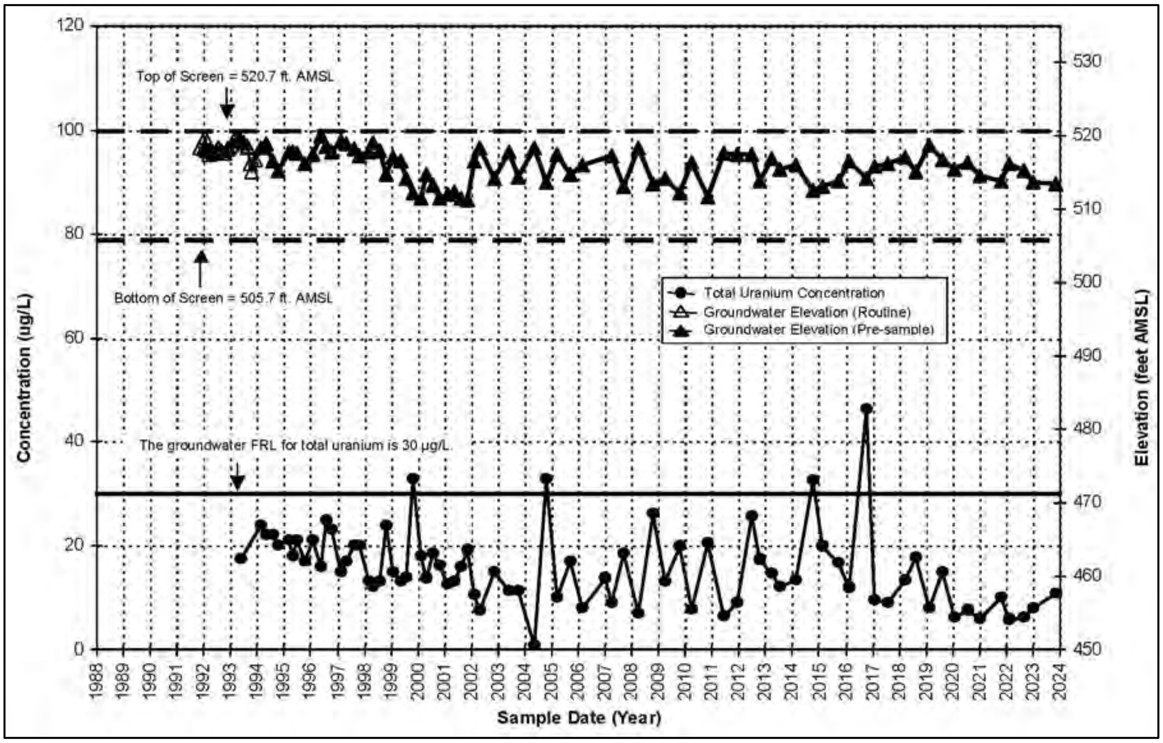

Figure A.2-22. Total Uranium Concentration Versus Time Plot for Monitoring Well 2552

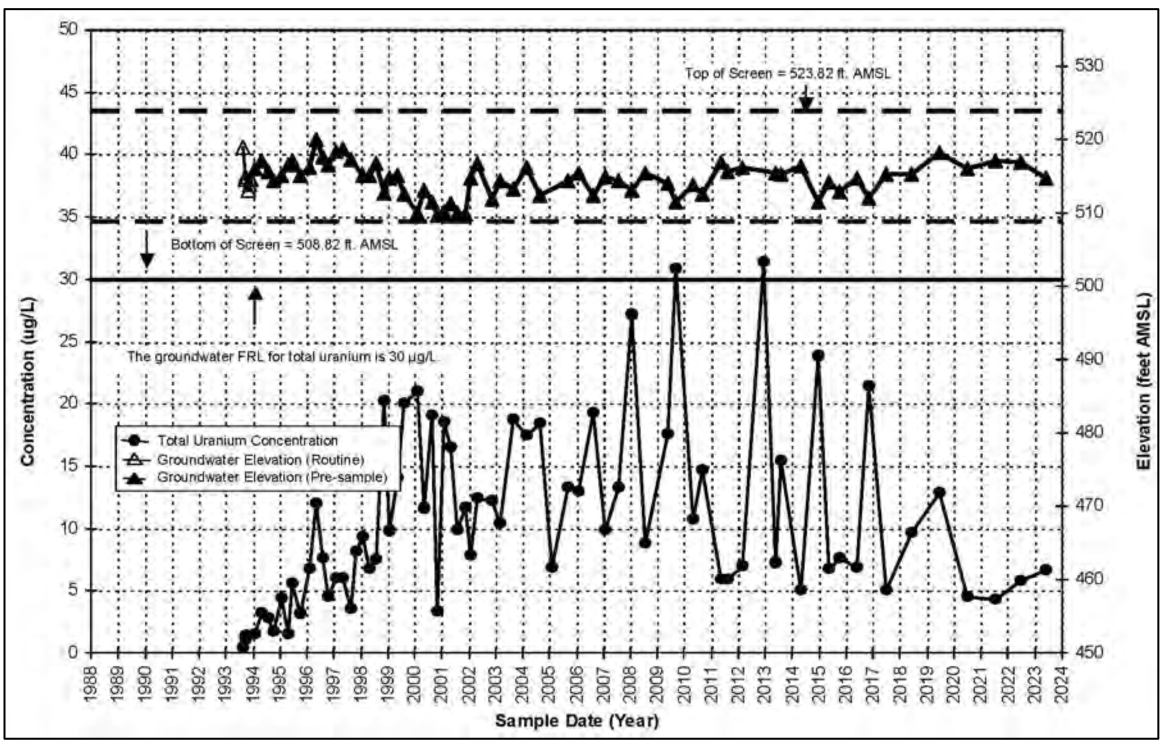

Figure A.2-23. Total Uranium Concentration Versus Time Plot for Monitoring Well 2900

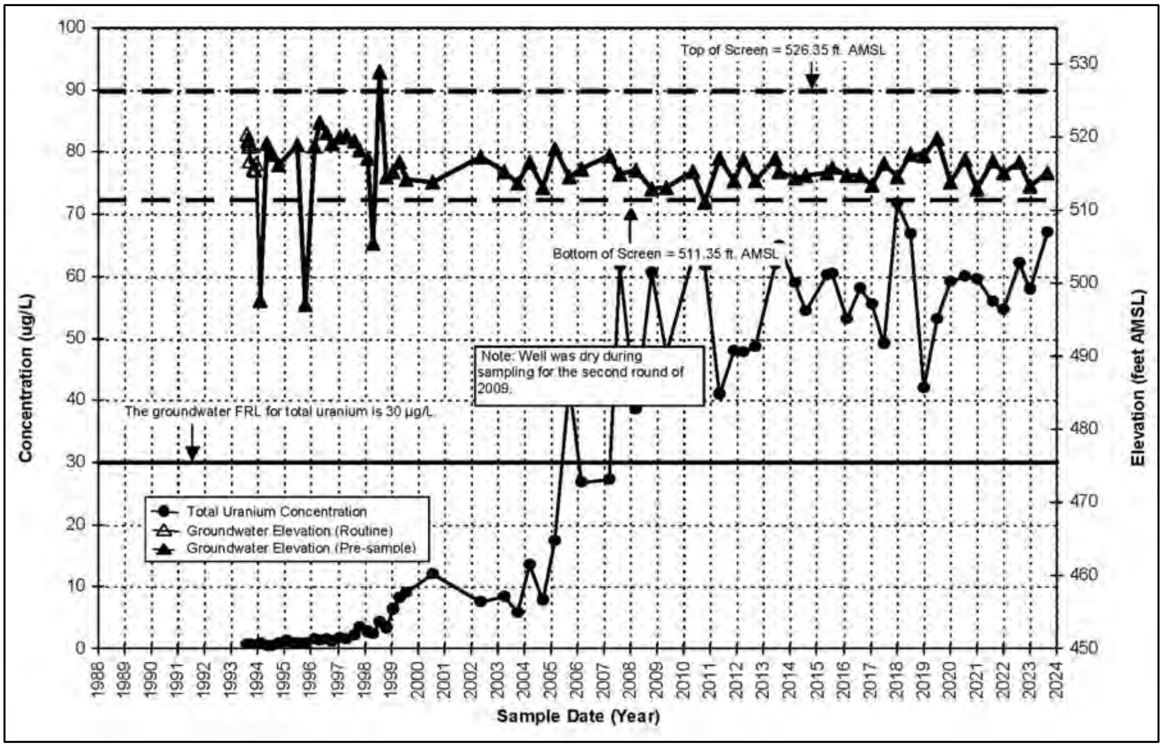

Figure A.2-24. Total Uranium Concentration Versus Time Plot for Monitoring Well 2880

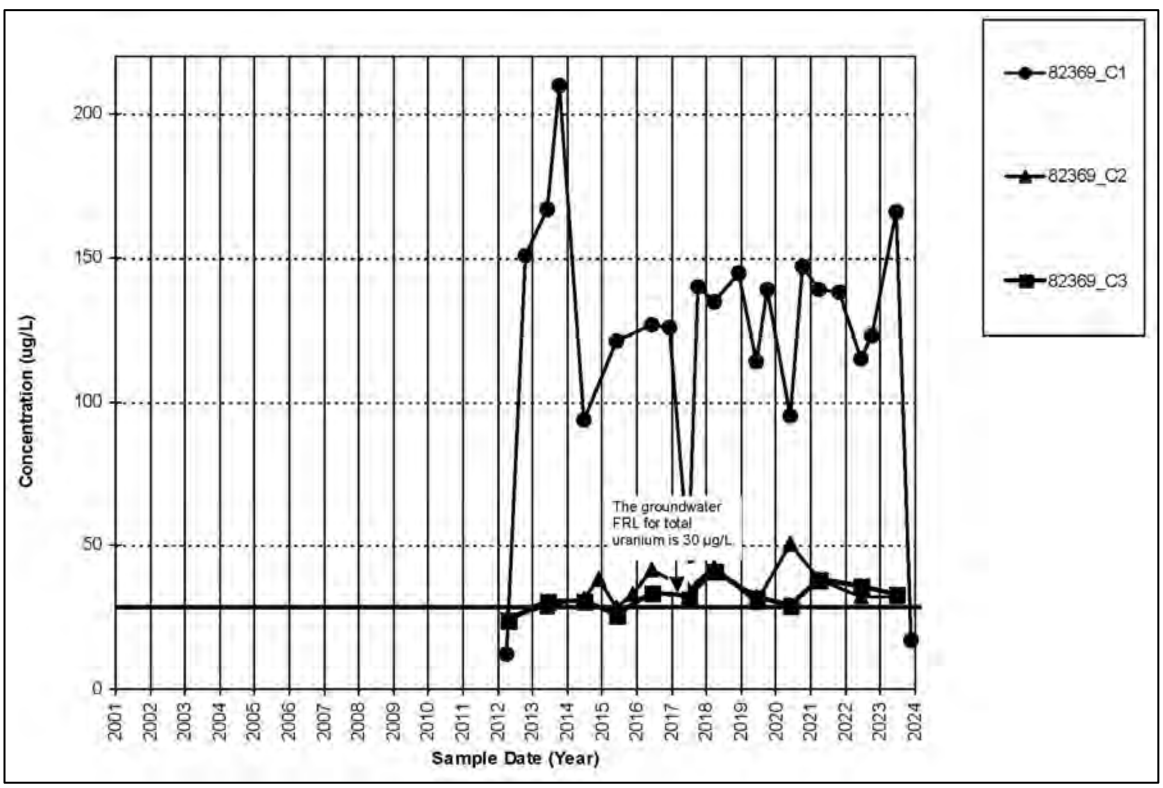

Figure A.2-25. Total Uranium Concentration Versus Time Plot for Monitoring Well 82369

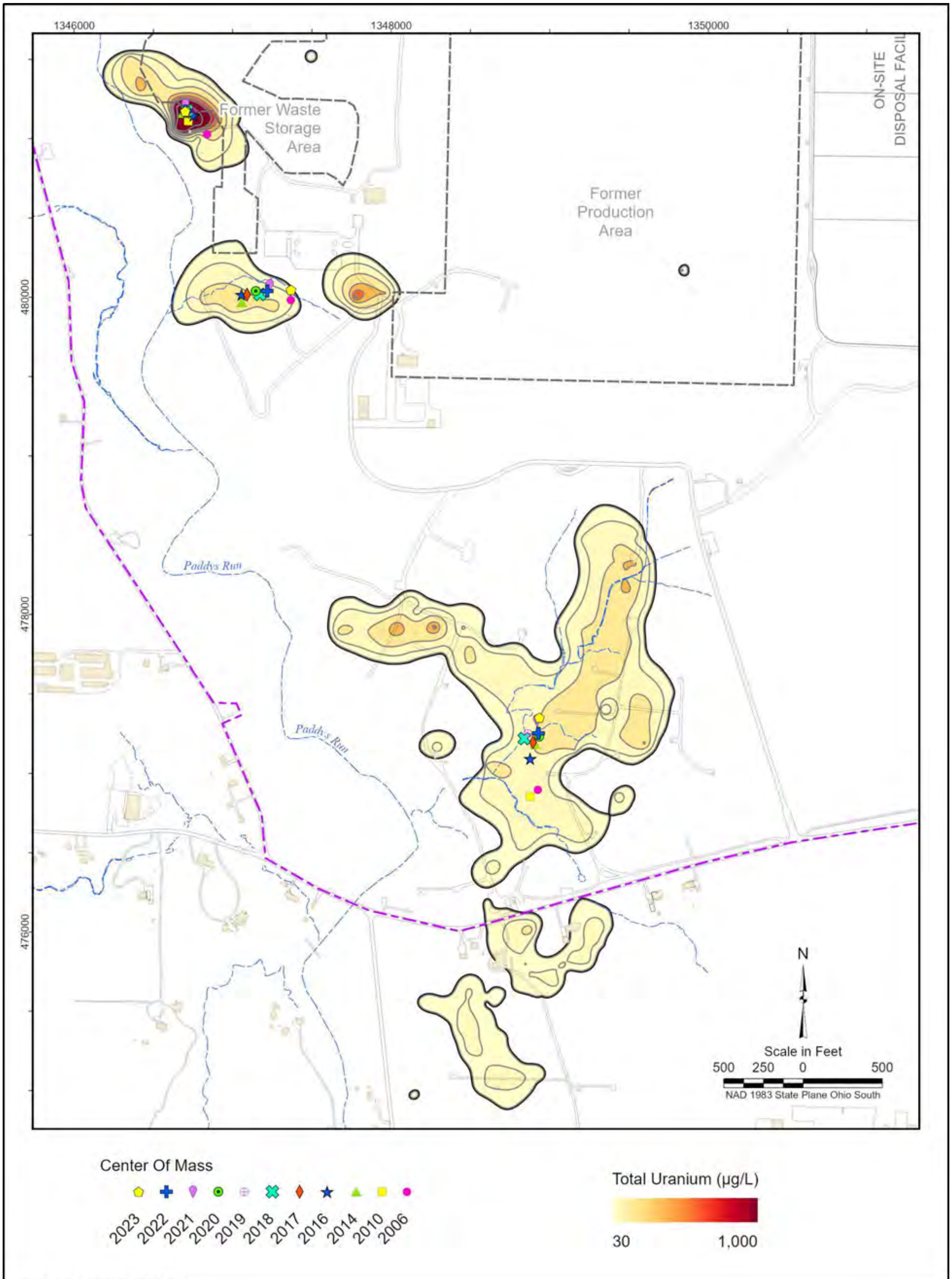

Figure A.2-26. Ricker Method Center of Mass

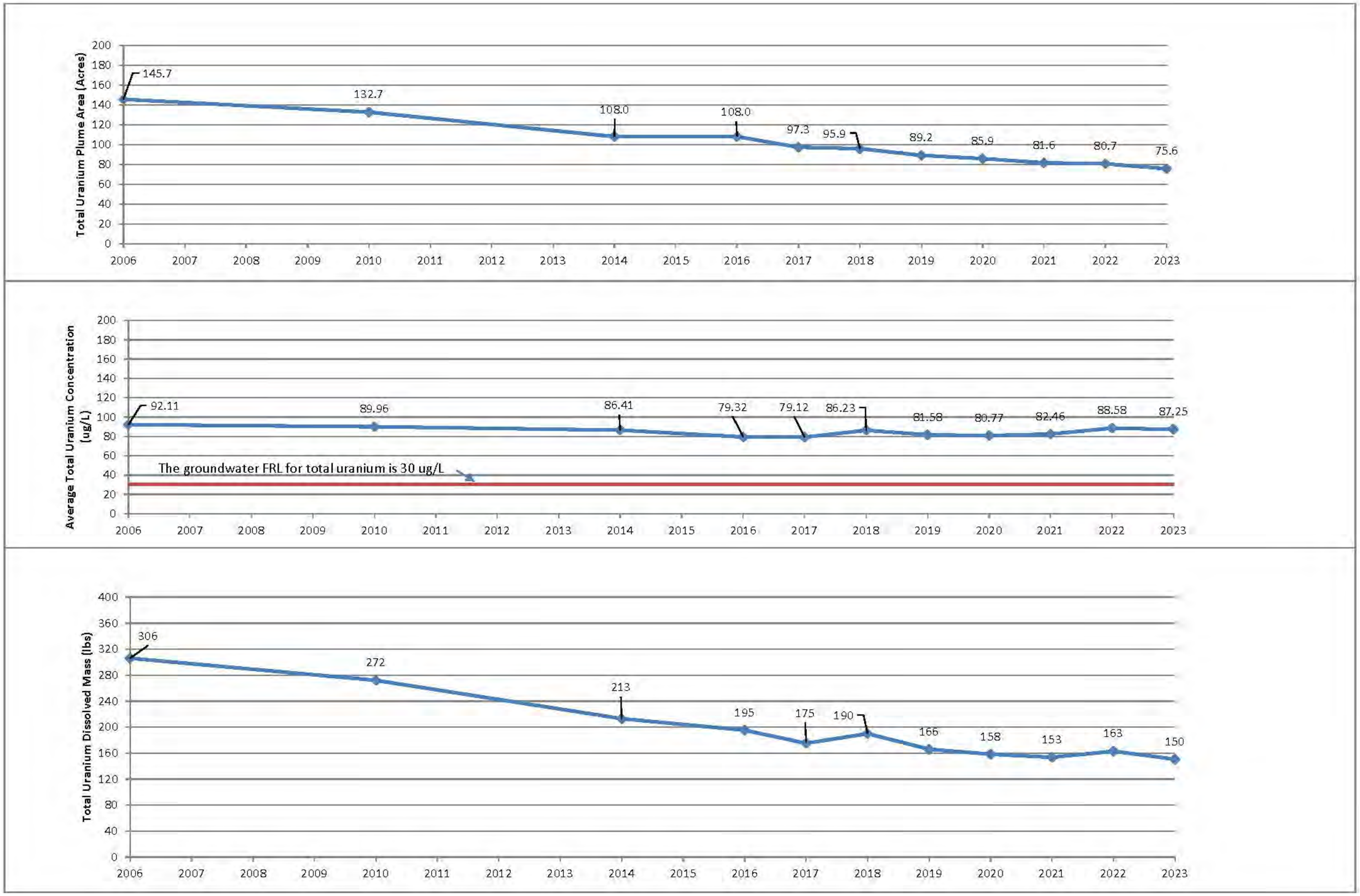

Figure A.2-27. Ricker Method Total Uranium Plume Calculations

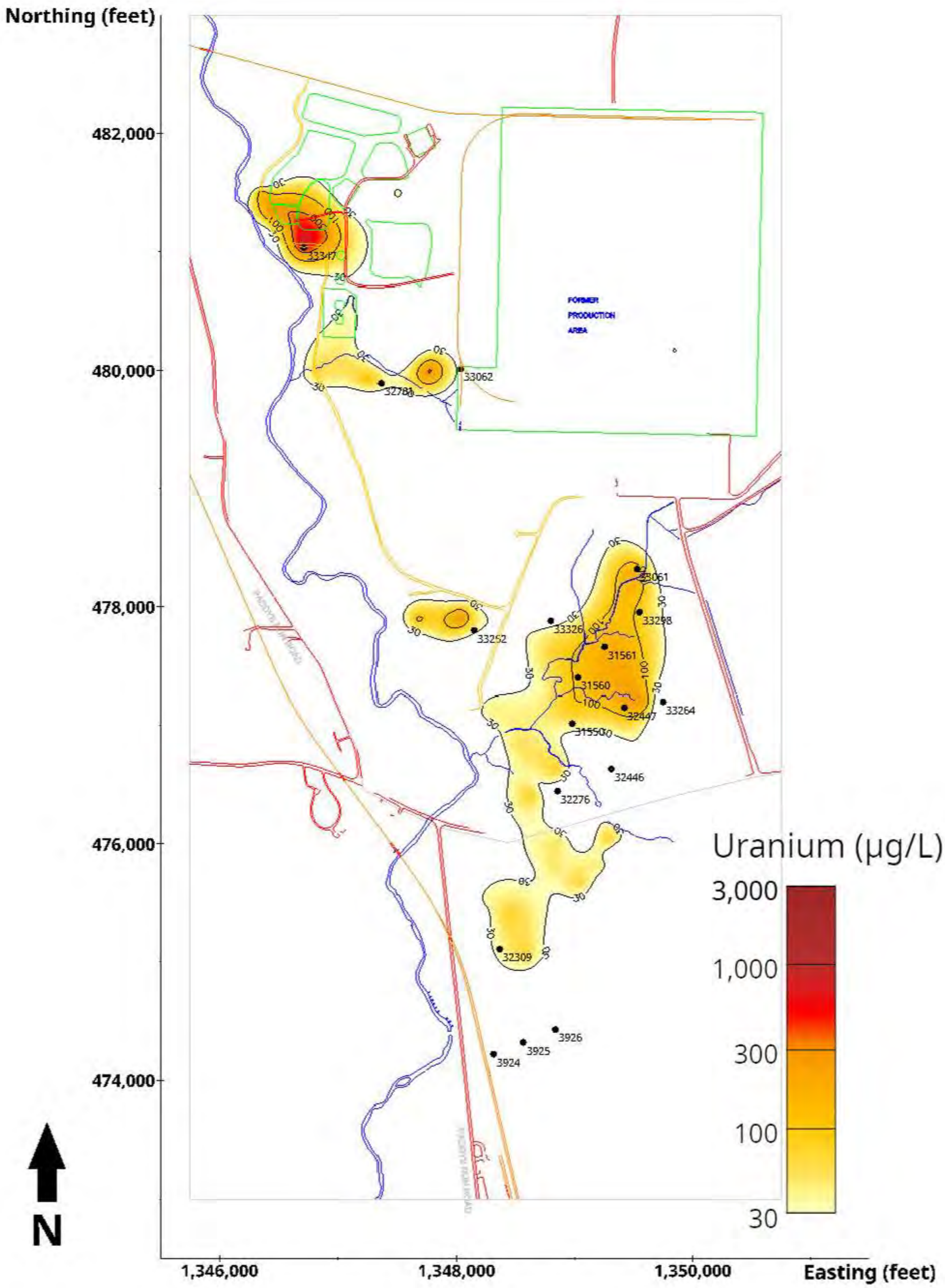

Figure A.2-28. EVS 2023 Plume Interpretation

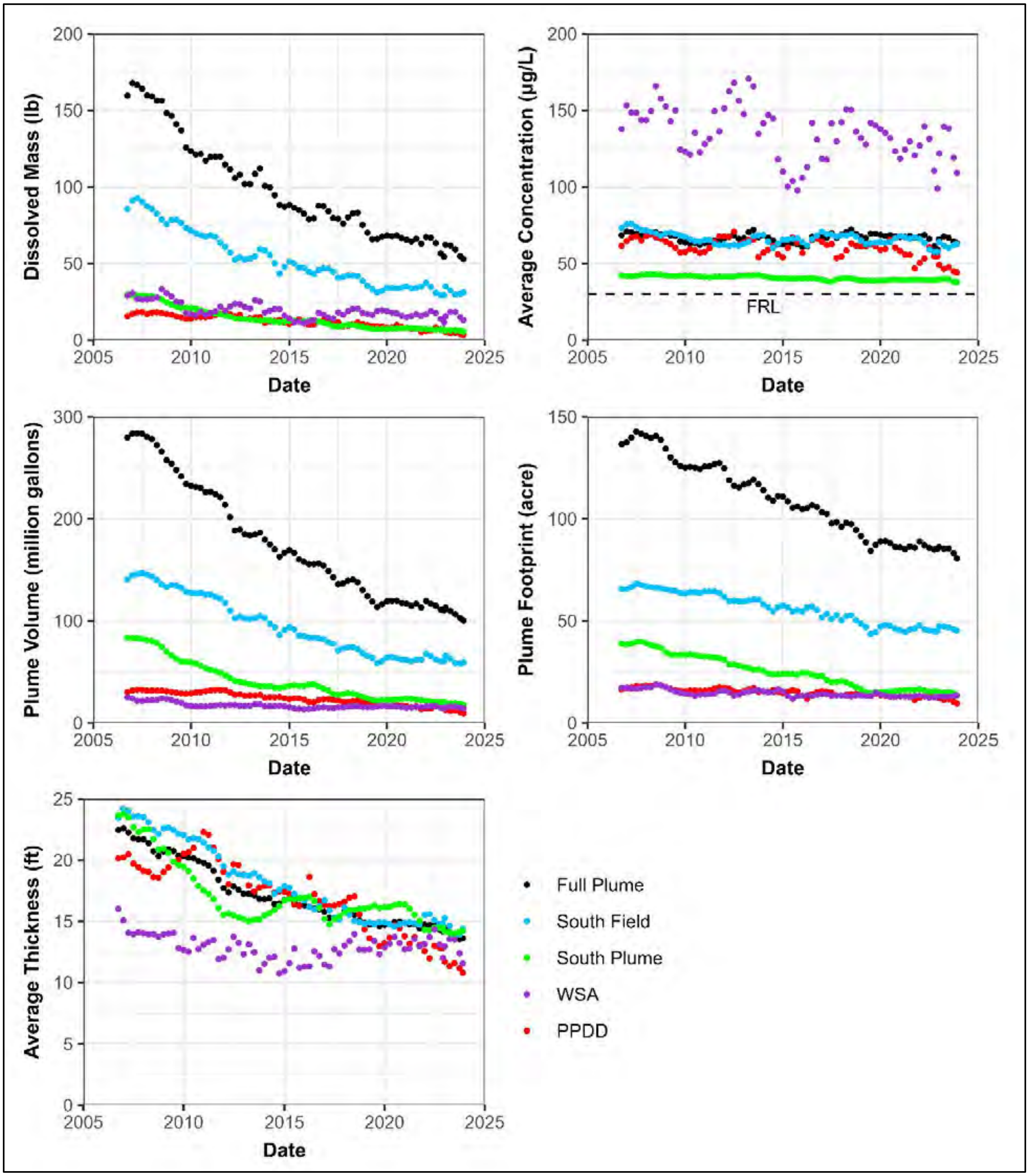

Figure A.2-29. EVS 2023 Plume Metrics

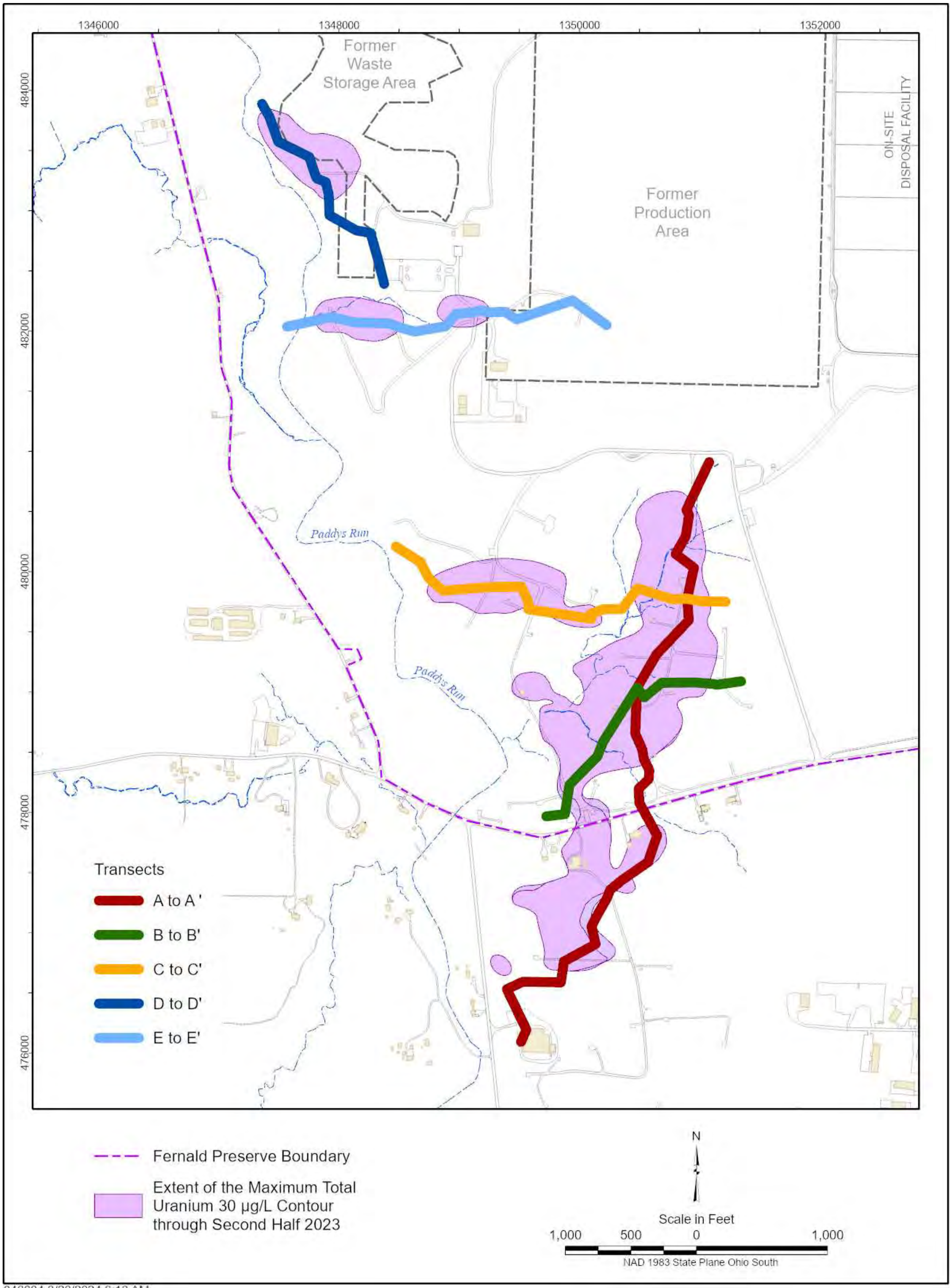

Figure A.2-30. Uranium Plume Cross Section Overview Map

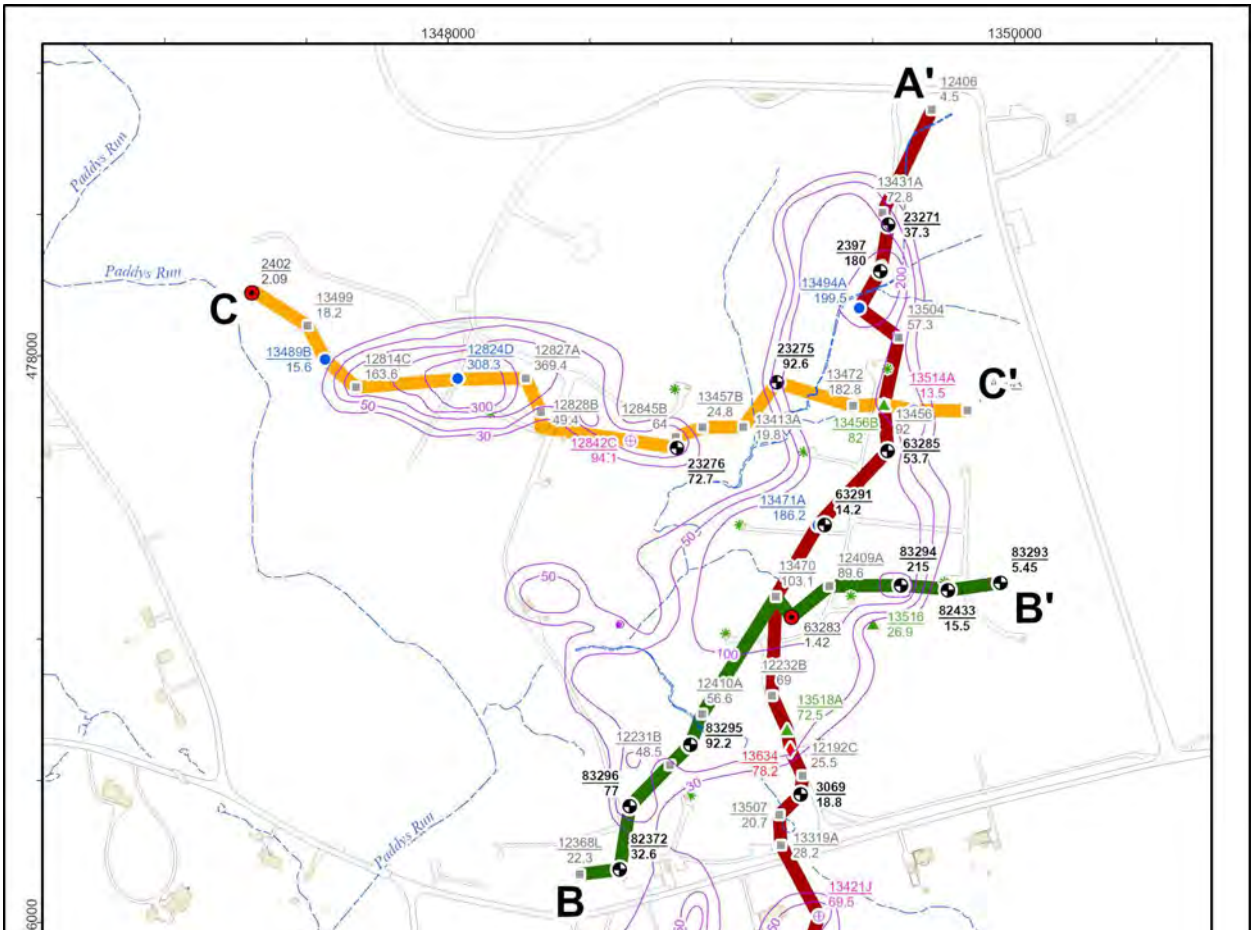

Figure A.2-31. Uranium Plume South Cross Section Location Map

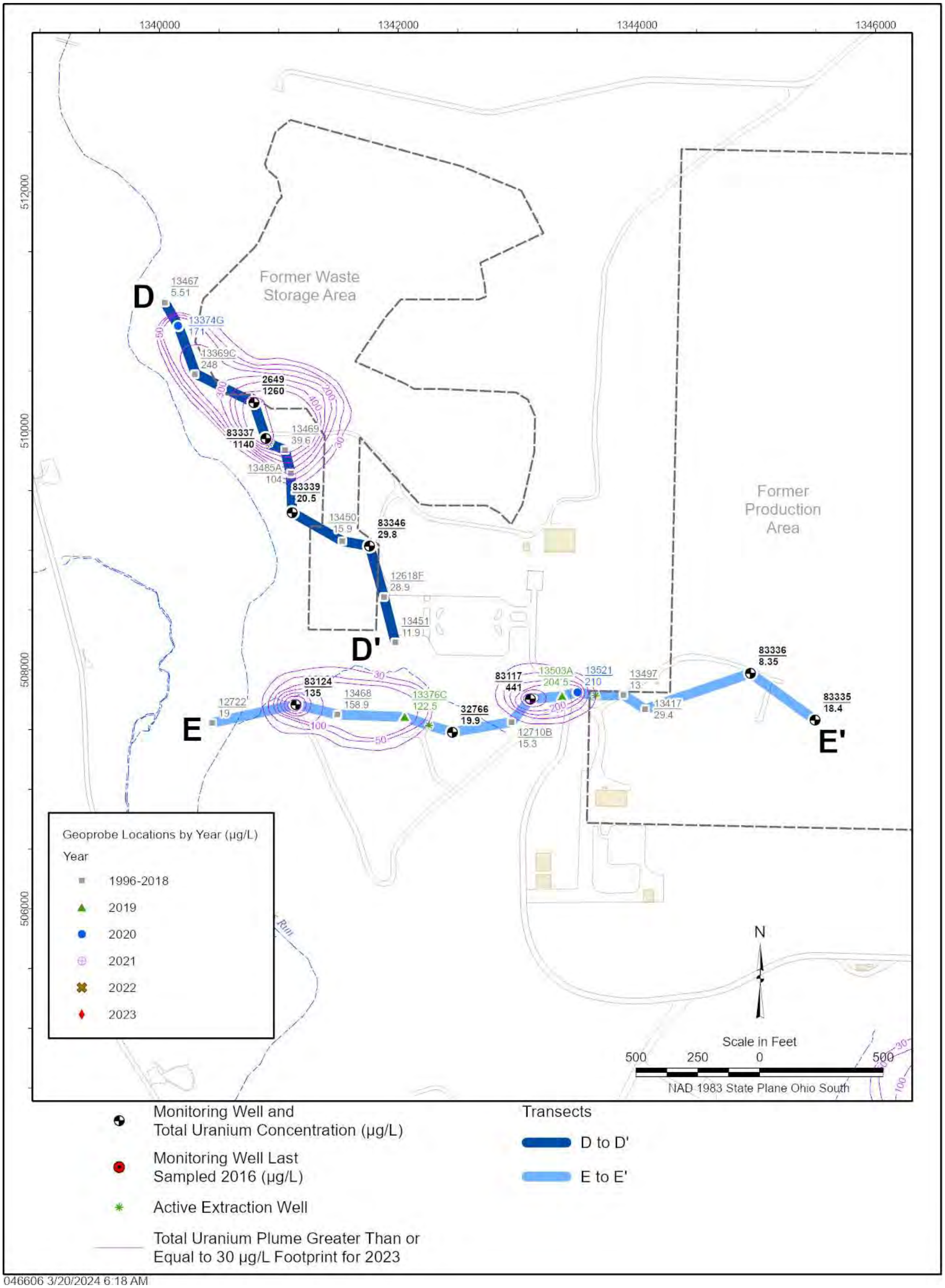

Figure A.2-32. Uranium Plume North Cross Section Location Map

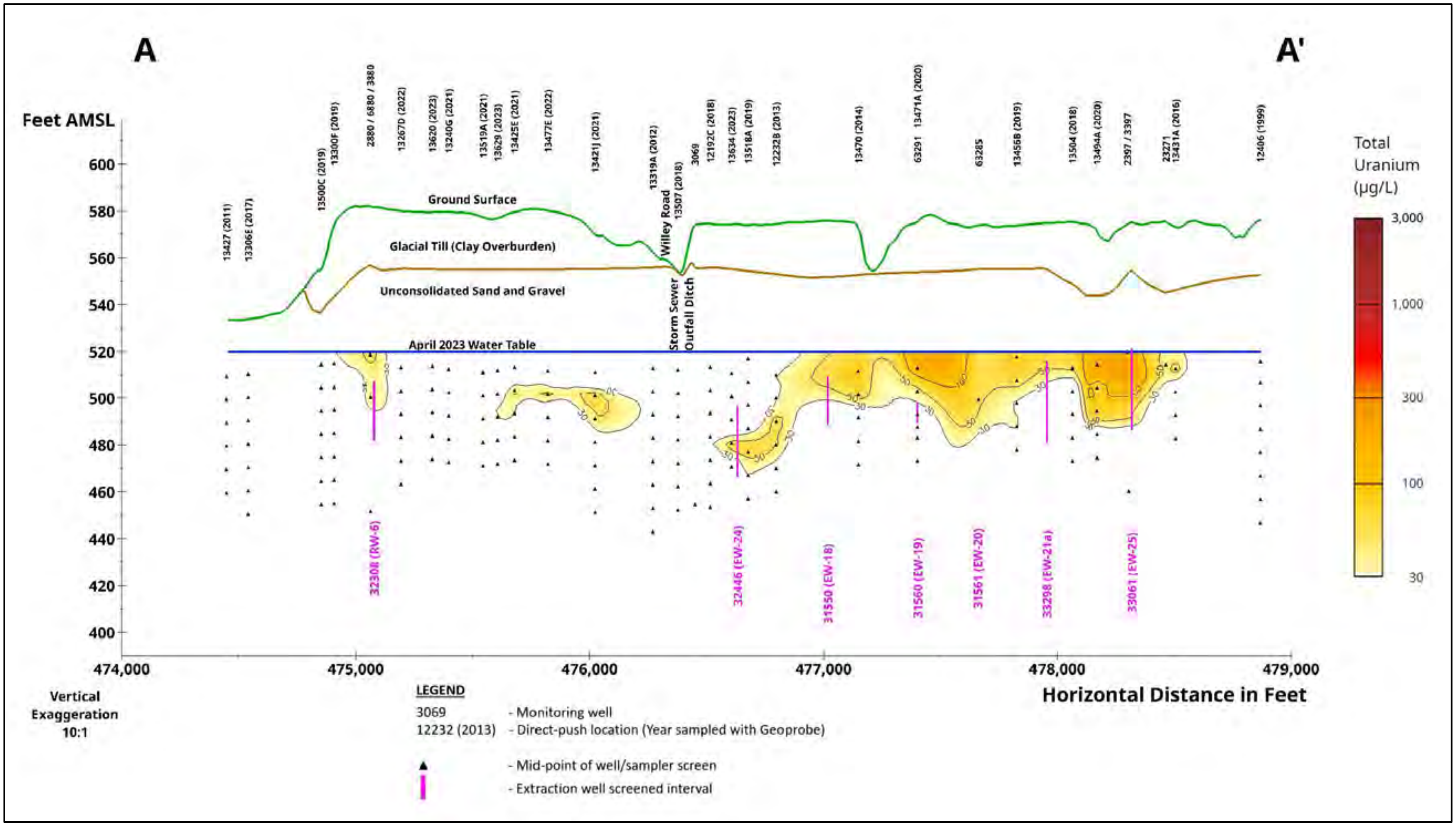

Figure A.2-33. EVS Total Uranium Plume Cross Section A–A'

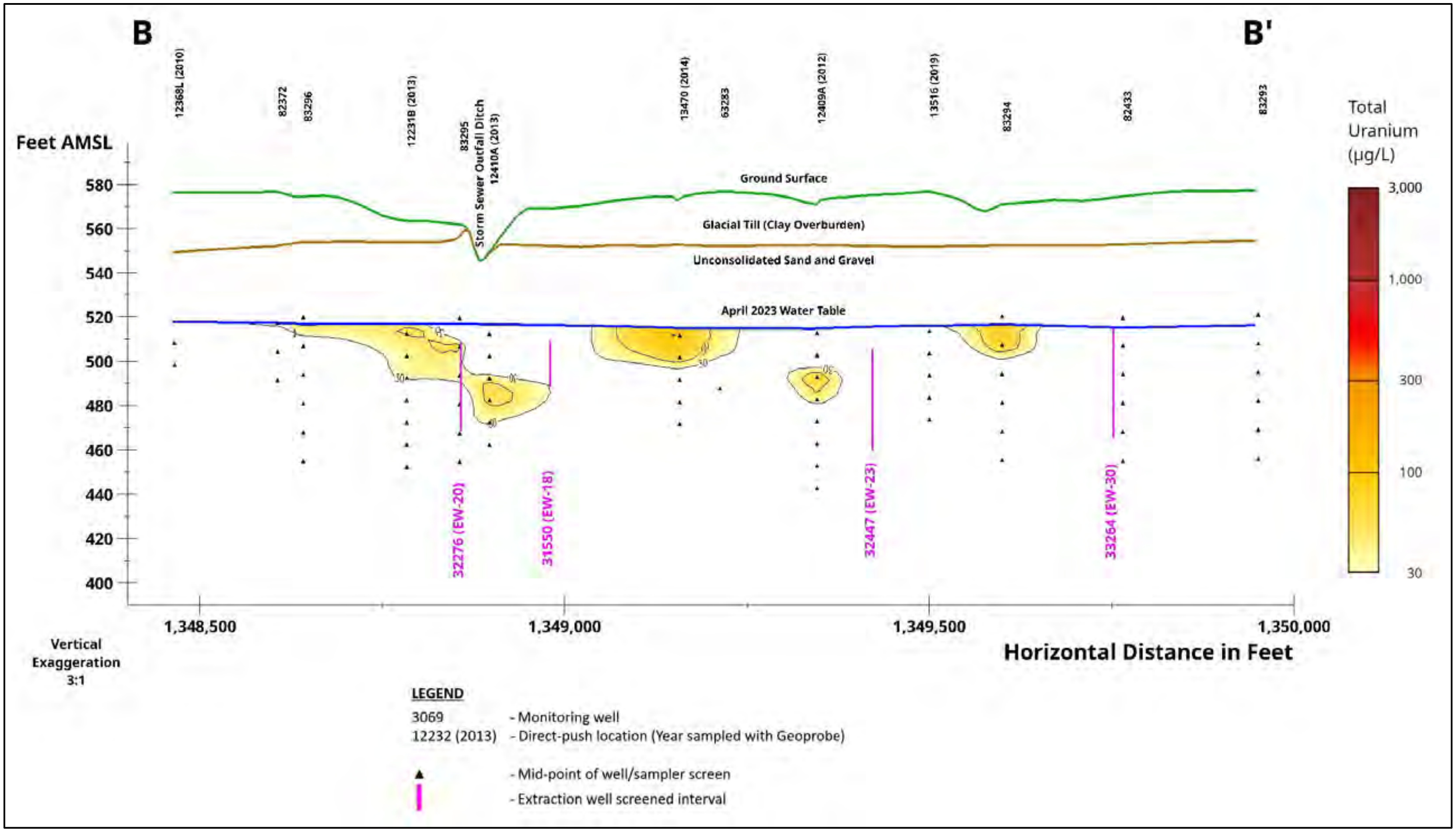

Figure A.2-34. EVS Total Uranium Plume Cross Section B–B'

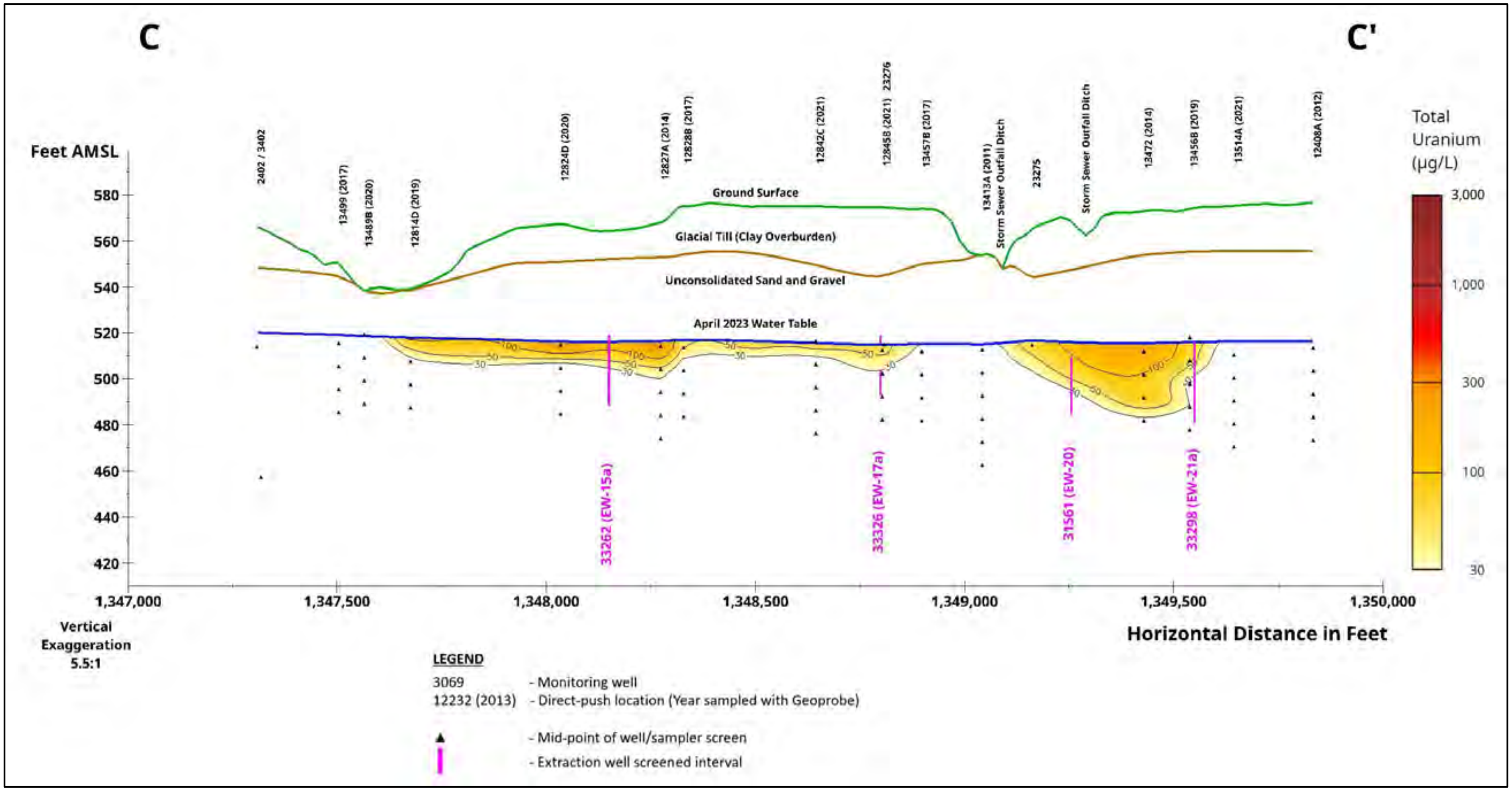

Figure A.2-35. EVS Total Uranium Plume Cross Section C–C′

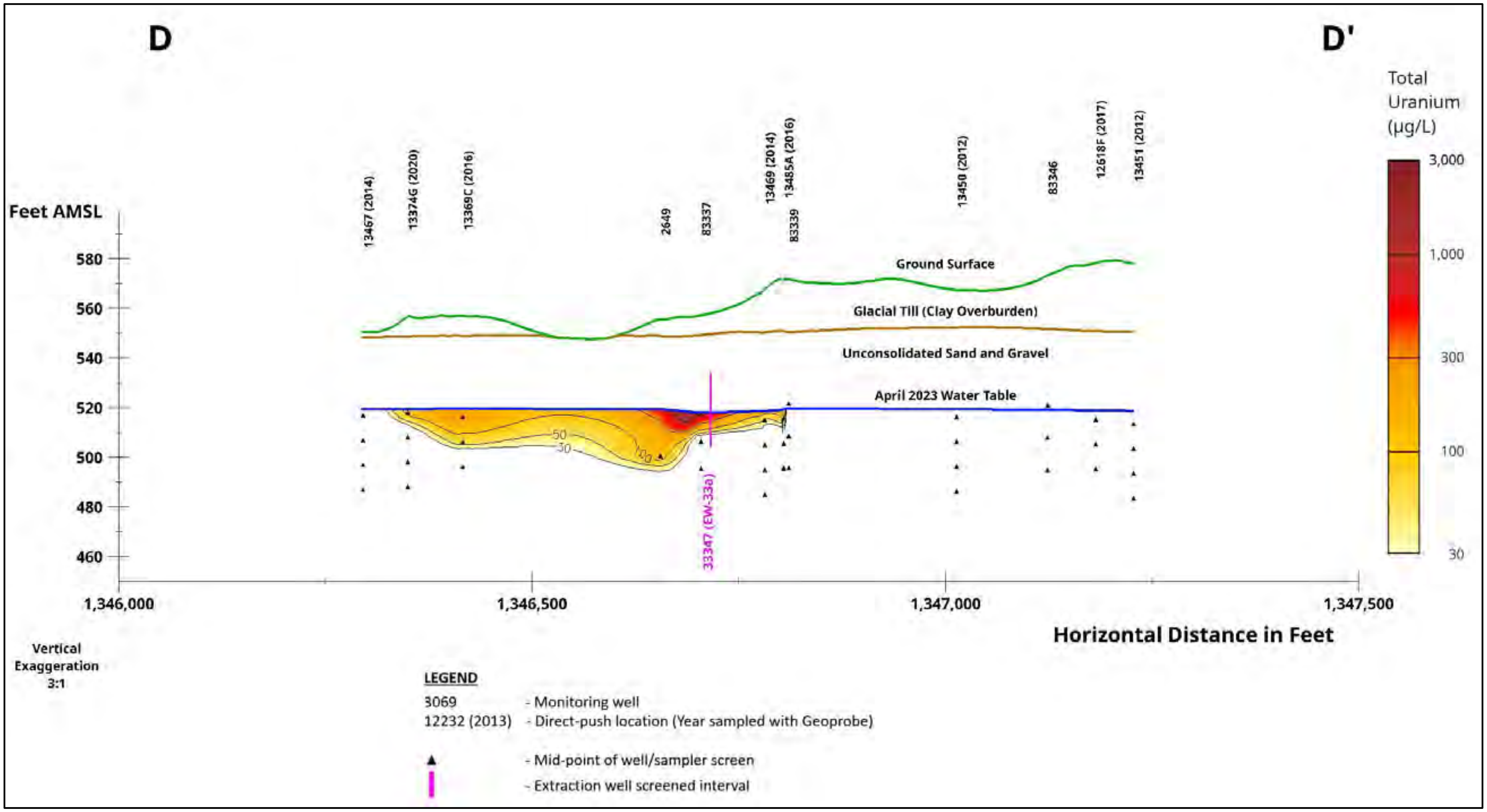

Figure A.2-36. EVS Total Uranium Plume Cross Section D–D'

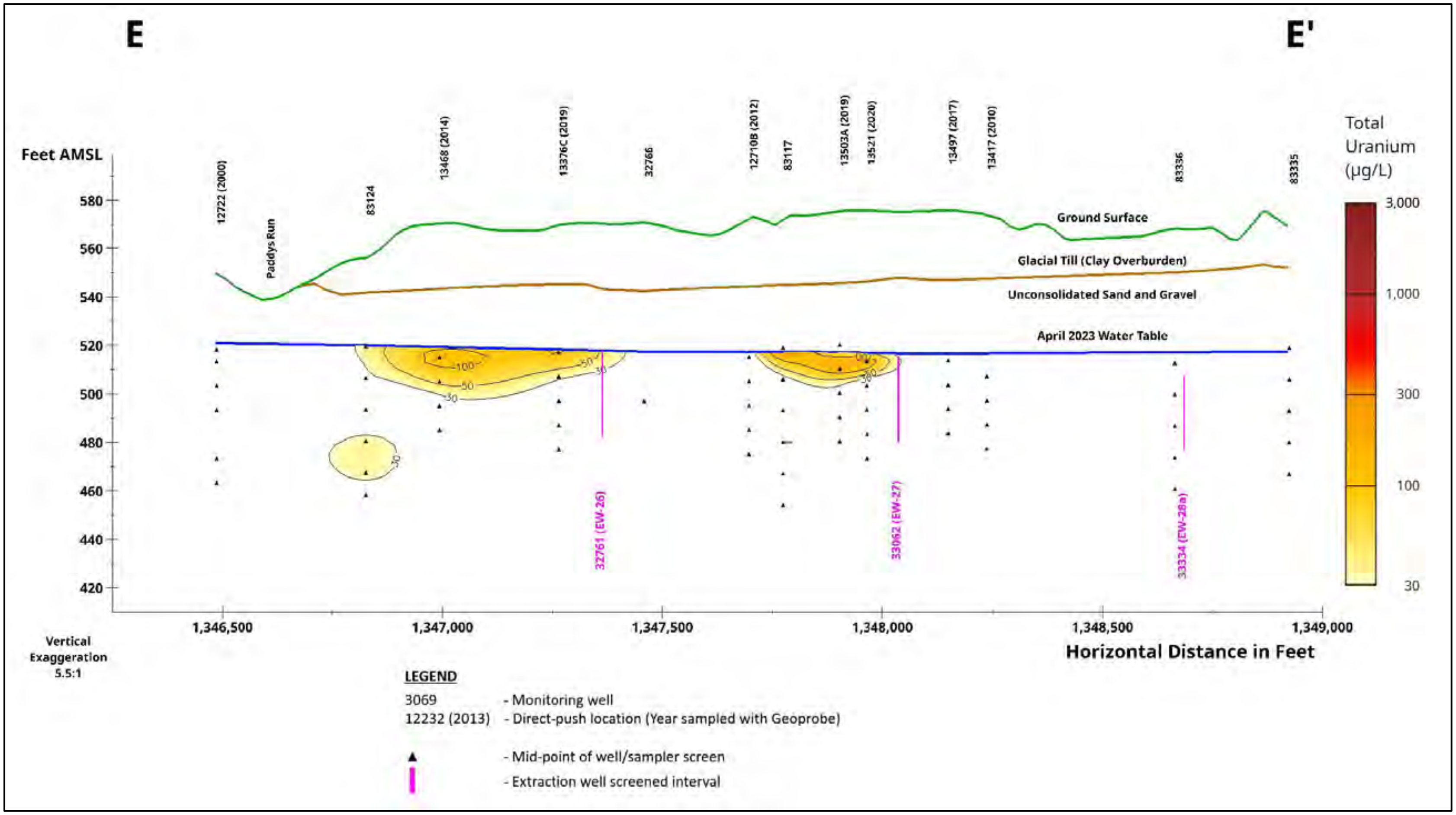

Figure A.2-37. EVS Total Uranium Plume Cross Section E–E'

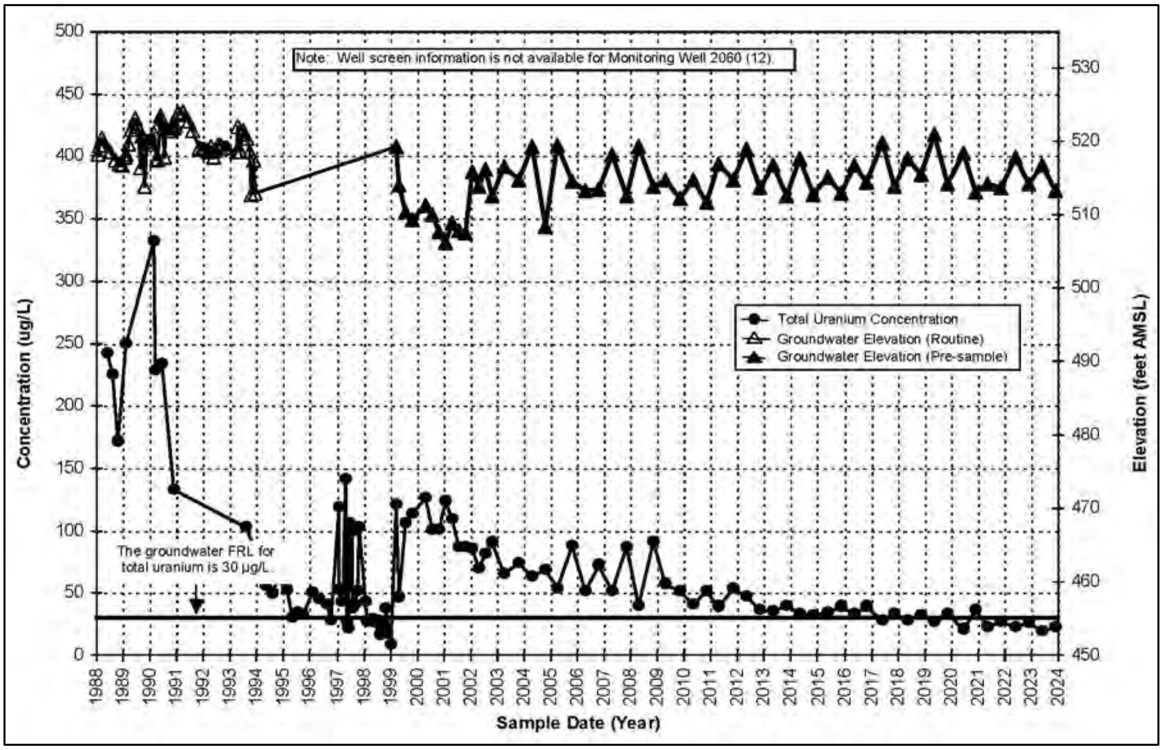

Figure A.2-38. Total Uranium Concentration Versus Time Plot for Monitoring Well 2060

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Attachment A.3

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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 2023 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 2023 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 2023). A total of 172 monitoring wells were available for measurement. As required by the IEMP, during the second quarter of 2023, 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 (2023)	Number of Days	Average Water Level (ft amsl)[a]
1	February 13 to February 15	3	515.54
2	April 3 to April 6	4	517.33
3	July 17 to July 19	3	517.25
4	October 2 to October 5	4	515.44

[a] ft amsl = feet above mean sea level.

Four monitoring wells and the uppermost channel in nine multichannel wells were dry at various times of the year. One well was inaccessible due to an issue with the locking well cap in the second quarter elevation round. A summary is provided below.

Well	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
2014	DRY		DRY	DRY
2384	DRY	DRY		DRY
2546		INACCESSIBLE[a]		
2636	DRY	DRY	DRY	DRY
22192	DRY	DRY	DRY	DRY
82433_C1		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			
83346_C1	DRY			

[a] Well was inaccessible due a lock issue.

Quarterly groundwater elevation maps for 2023 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 2023 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 2023, flow in the vicinity of the On-Site Disposal Facility (OSDF) was generally from the northwest and northeast. 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 2023, as recorded at the Butler County Regional Airport. Cumulative precipitation in 2023 was 34.82 inches. Between 2004 and 2023, 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 2023 are as follows.

Year	Average Fluctuation (feet)	Fluctuation Range (feet)
2023	3.62	1.5 to 5.74
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 2023 coupled with the particle track interpretations and contoured water-table gradients indicate that the 30 µg/L total uranium plume was being captured in 2023.

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 wells 3924 [RW-1], 3925 [RW-2], and 3926 [RW-3]) was shut down from May 1 to July 9, 2023, as planned to allow water levels to recover to nonpumping elevations. It should be noted that 3927 (RW-3) was permanently shut down on June 12, 2023, during the planned shutdown. Quarterly measurement of water levels in 2023 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 2023, is presented below.

Planned Shutdown: May 30 to July 1, 2023

Location	Elevation at Midnight Prior to Shutdown May 30, 2023 (ft amsl)	Elevation at Midnight Prior to Restart July 10, 2023 (ft amsl)	Water Level Rise (ft)
2045	516.66	517.93	1.27
2046	517.70	518.48	0.78
2649	520.52	520.08	−0.44
23274	516.92	518.37	1.45
63119	518.05	518.50	0.45
22302	515.71	517.47	1.76
3881	515.90	516.79	0.89
22301	516.18	517.61	1.43
2095	515.94	516.78	0.84
32763	519.05	519.22	0.17
62433	514.85	517.78	2.93

The water level rise measurements indicate that during the shutdown, the water level “rise” ranged from −0.44 feet (ft) (well 2649) to 2.93 ft (well 62433).

Figure A.3-8 shows water levels versus precipitation from May 25, 2007, through January 4, 2024. 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 2023 resulted in the following water level rises:

- 4.34 ft in the former WSA (monitoring well 2649)
- 4.47 ft in the west side of the South Field (monitoring well 2046)
- 5.69 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 2023 shutdown. The results of the 2023 IEMP first-half uranium sampling are used to represent uranium concentrations in the well before the shutdown. Groundwater samples collected in June 2023 represent concentrations during the shutdown. The results of the 2023 IEMP second-half uranium sampling are used to represent uranium concentrations in the well after the shutdown exercise was completed. 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 2023 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, 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 2023, wells 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 wells RW-1 and RW-2 continued to run during the full length of the shutdown. RW-3 was shut down permanently on June 12, 2023.

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 extraction well EW-21A (12.4 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 4, 2024. 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

DOE (U.S. Department of Energy), 2014. *Operational Design Adjustments-1, WSA Phase-II Groundwater Remediation Design, Fernald Preserve*, LMS/FER/S10798, Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2023. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 13, Office of Legacy Management, January.

Tonkin, M.J., and S.P. Larson, 2002. "Kriging Water Levels with a Regional-Linear and Point-Logarithmic Drift," *Groundwater* 40(2):185–193.

Table A.3-1. Uranium Concentrations at Monitoring Wells Before, During, and After the 2023 Well Field Shutdown

Uranium Concentrations at Monitoring Wells Before, During, and After the 2023 Wellfield Shut Down								
Well	**Easting**	**Northing**	**First Half 2023 Pre-Shutdown Concentrations**		**Pre-Start-Up Concentrations June 2023**		**Second Half 2023 Post-Shutdown Concentrations**	
			Date	**Uranium (μg/L)**	**Date**	**Uranium (μg/L)**	**Date**	**Uranium (μg/L)**
2045	1348291	477159	3/9/2023	57.4	6/26/2023	66.9	9/27/2023	40.6
2046	1347950	478088	1/4/2023	12.3	6/26/2023	11.3	10/26/2023	12.4
23274	1349406	478337	1/17/2023	88.7	6/26/2023	70.3	8/9/2023	70.2
83124_C1	1346826	479977	3/22/2023	79.9	6/28/2023	135	11/15/2023	44.3
83124_C2	1346826	479977	3/22/2023	25.0	6/28/2023	26.9	11/15/2023	26.6
83294_C1	1349599	477190	3/27/2023	195	6/27/2023	215	Not Sampled	Not Sampled
83294_C2	1349599	477190	3/2/2023	63.1	6/28/2023	81.3	11/16/2023	102.0
83337_C1	1346704	481052	5/8/2023	1,140	6/27/2023	939	Not Sampled	Not Sampled
83337_C2	1346704	481052	5/8/2023	7.26	6/27/2023	28.0	11/14/2023	5.4

Table A.3-2. Total Uranium Concentration at Extraction Wells During 2023 Well Field Shutdown

Extraction Well	May 30, 2023 Total Uranium Concentration (ug/L)	Date of Well Restart	Total Uranium Concentration (ug/L) After Well Field Re-Start							Maximum Post Re-Start Minus May 30, 2023 Concentration
			1st Restart Sample	2nd Restart Sample	3rd Restart Sample	4th Restart Sample	Minimum	Maximum	Range	
RW-1[b]	10.4	NA	9.6	9.6	9.8	9.6	9.6	9.8	0.2	-0.6
RW-2[b]	11.6	NA	12.4	11.9	12.5	12.2	11.9	12.5	0.6	0.9
RW-3[b]	19.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
RW-7	17.2	7/10/2023	15.3	14.9	15.9	16.0	14.9	16.0	1.1	-1.2
EW-15A	20.7	7/12/2023	30.3	24.3	23.1	21.7	21.7	30.3	8.6	9.6
EW-17A	9.4	8/23/2023	9.4	10.0	9.0	7.3	7.3	10.0	2.7	0.6
EW-18	29.7	7/12/2023	25.3	26.3	27.9	26.8	25.3	27.9	2.6	-1.8
EW-19	15.5	7/12/2023	14.6	15.3	15.2	15.1	14.6	15.3	0.7	-0.2
EW-20	31.6	7/12/2023	32.1	33.2	32.3	28.4	28.4	33.2	4.8	1.6
EW-21A	25.3	7/11/2023	37.7	33.9	32.3	28.4	28.4	37.7	9.3	12.4
EW-22	17.8	7/10/2023	18.6	17.7	18.0	17.4	17.4	18.6	1.2	0.8
EW-23	24.7	8/29/2023	41.7	23.5	24.1	22.0	22.0	41.7	19.7	17
EW-24	22.0	7/11/2023	17.6	19.0	20.0	19.7	17.6	20.0	2.4	-2.0
EW-25	17.9	7/13/2023	14.9	16.1	17.5	17.2	14.9	17.5	2.6	-0.4
EW-26	18.9	8/1/2023	25.7	22.6	19.5	17.0	17.0	25.7	8.7	6.8
EW-27[c]	20.1	NA	19.9	18.1	14.1	18.0	14.1	19.9	5.8	-0.2
EW-30	7.4	9/11/2022	10.4	9.3	8.4	8.4	8.4	10.4	2.0	3.0
EW-33A	19.4	7/13/2023	21.2	16.9	17.1	17.9	16.9	21.2	4.3	1.8

Shading indicates uranium concentration after well field re-start was greater than May 30, 2023, uranium concentration.

NA = Not Applicable.

[a] Shutdown began on May 30, 2023 at 7:00 a.m. and ended on July 10, 2023, for a duration of 41 days.

[b] Leading edge well continued operating during the shutdown, RW-3 was permanently turned off during the shutdown.

[c] Well operated as needed for the CAWWT treatment system.

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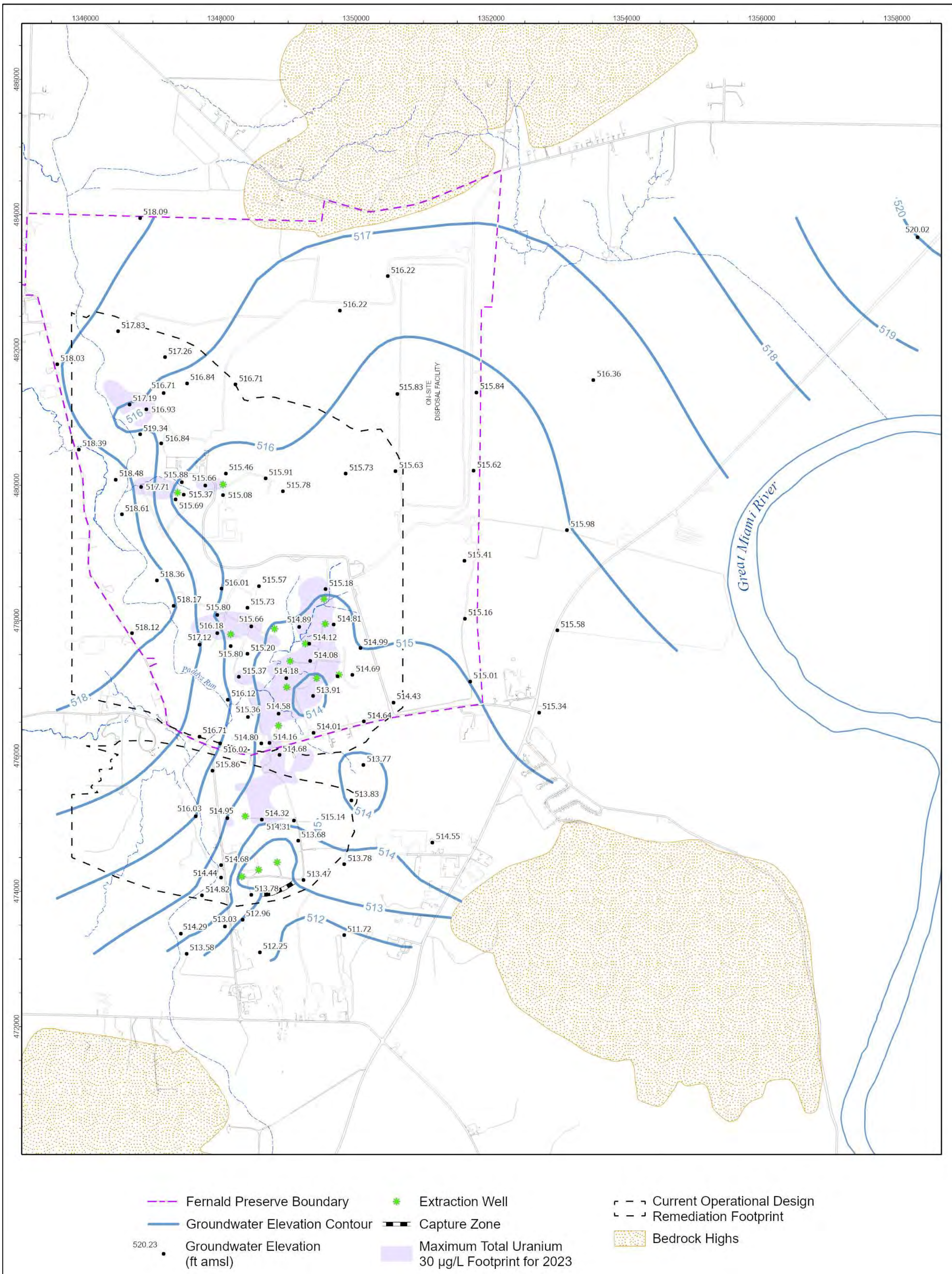

February 13 to February 15, 2023, Operational Status
Average Pumping Rates

South Plume (4 wells)[a] : 926 gpm
South Field Extraction (11 wells): 2,660 gpm
Waste Storage Area (2 wells)[b] : 528 gpm

[a] RW-4 and RW-6 permanently shut off.
[b]EW-30 turned off February 13 to 15, 2023.

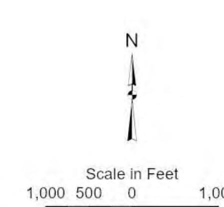

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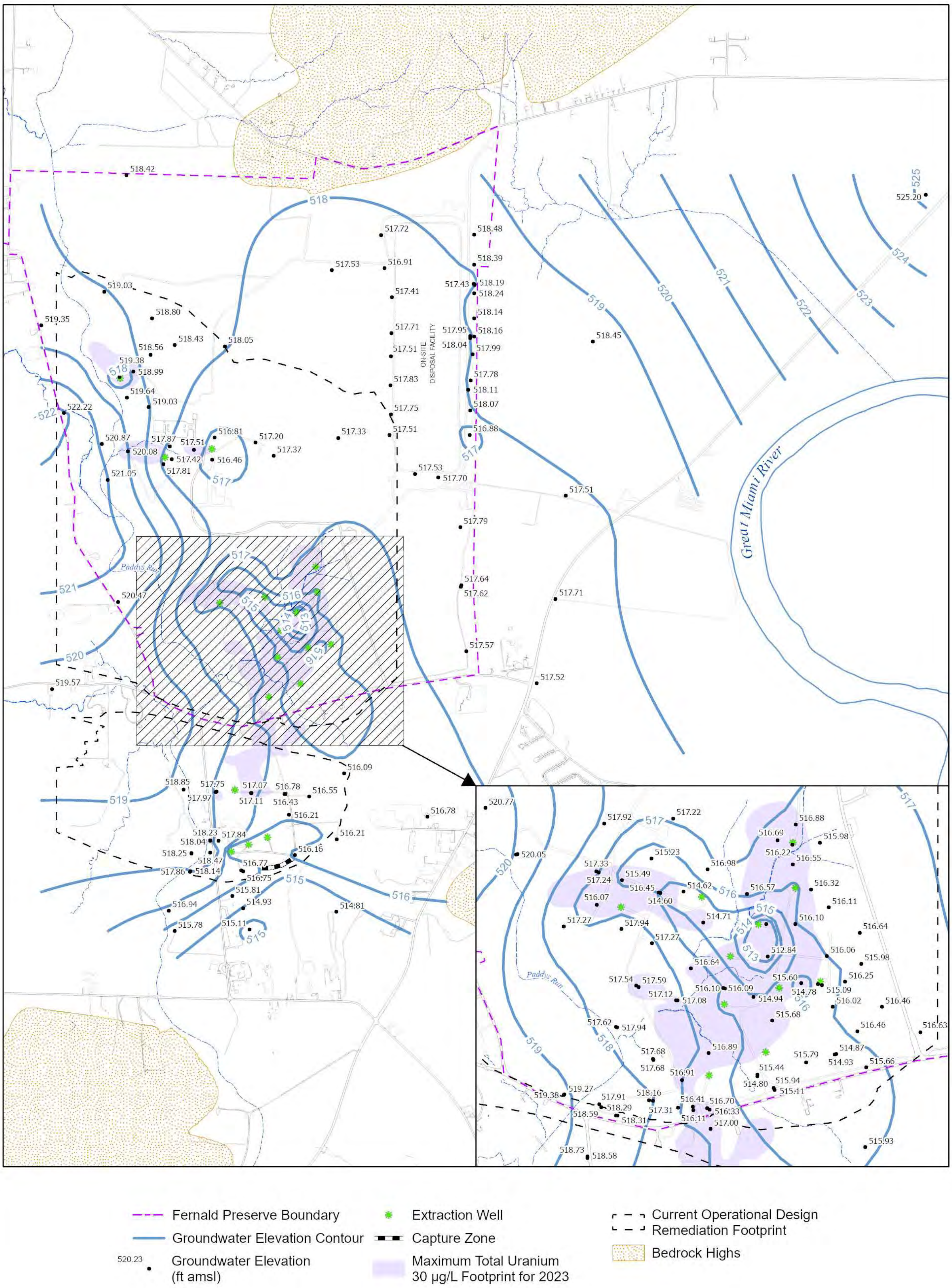
Figure A.3-1. Routine Groundwater Elevation Map, First Quarter 2023 (February 13 Through February 15, 2023)



April 3 to April 6, 2023, Operational Status
Average Pumping Rates

South Plume (4 wells)[a] : 786 gpm
South Field Extraction (11 wells): 2,817 gpm
Waste Storage Area (3 wells) : 715 gpm

[a]RW-4 and RW-6 permanently shut off.

N

Scale in Feet
1,000 500 0 1,000
NAD 1983 State Plane Ohio South

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Figure A.3-2. Routine Groundwater Elevation Map, Second Quarter 2023 (April 3 Through April 6, 2023)

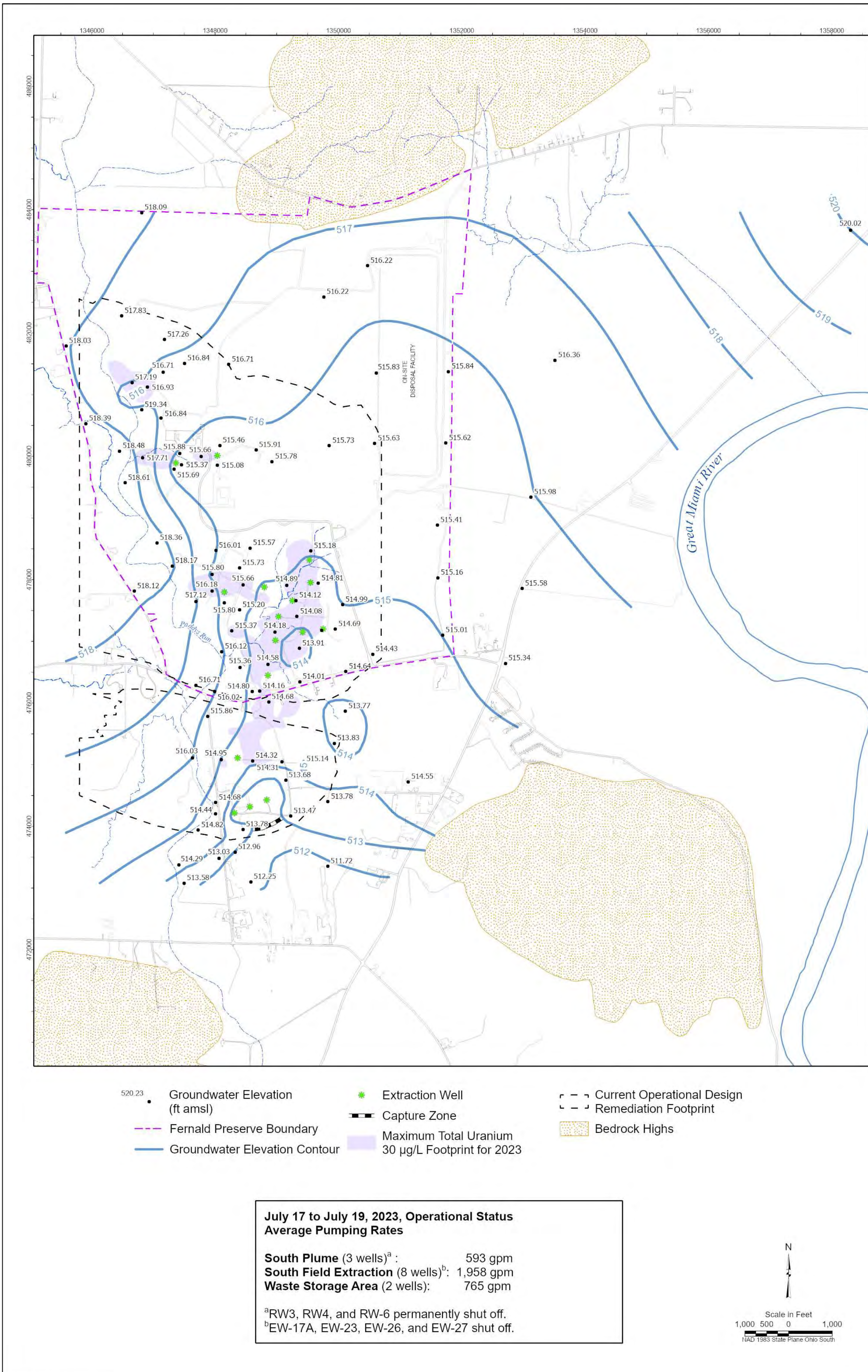

Figure A.3-3. Routine Groundwater Elevation Map, Third Quarter 2023 (July 17 Through July 19, 2023)

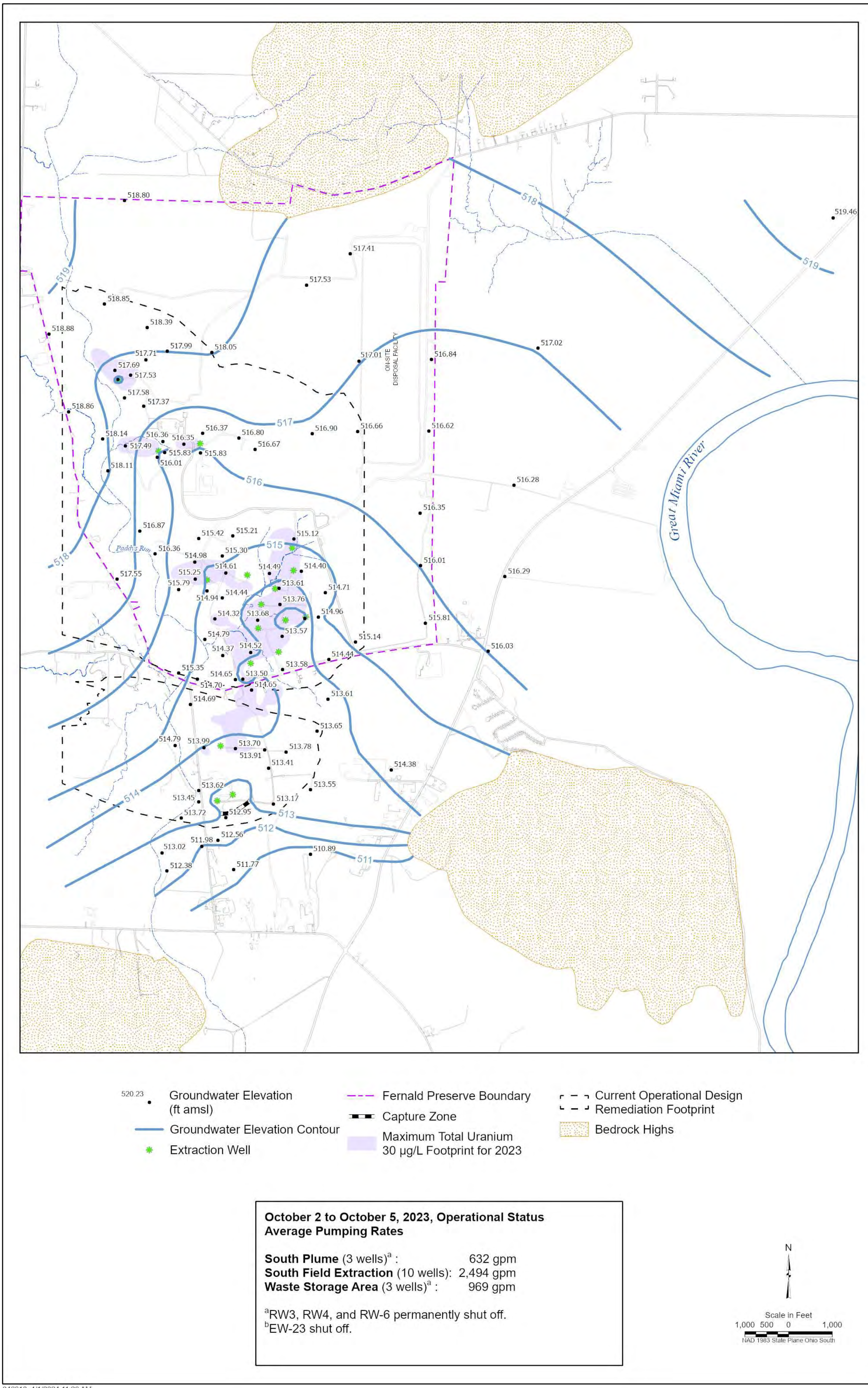

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Figure A.3-4. Routine Groundwater Elevation Map, Fourth Quarter 2023 (October 2 Through October 5, 2023)

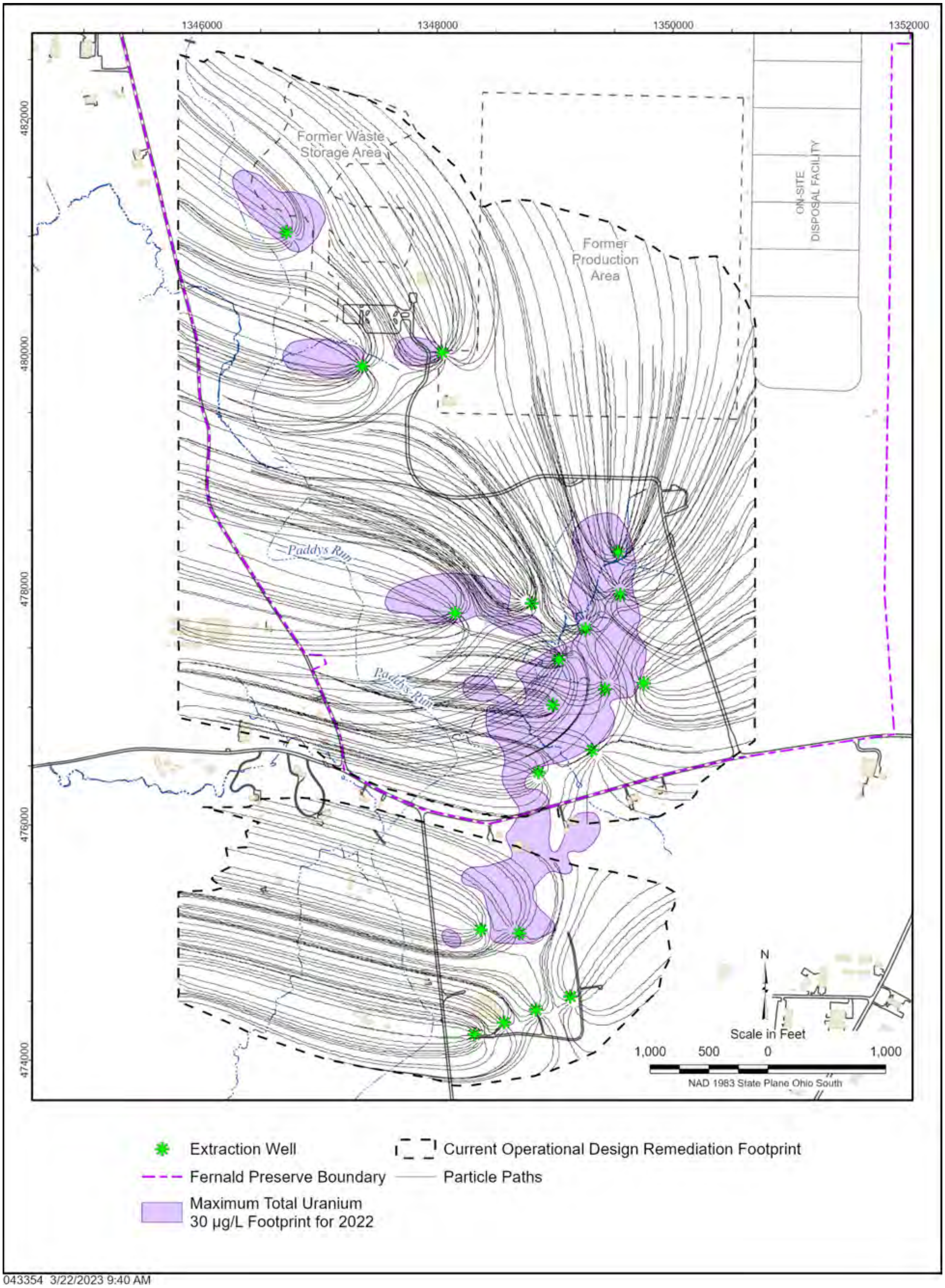

Figure A.3-5. Current Operational Design Remediation Footprint

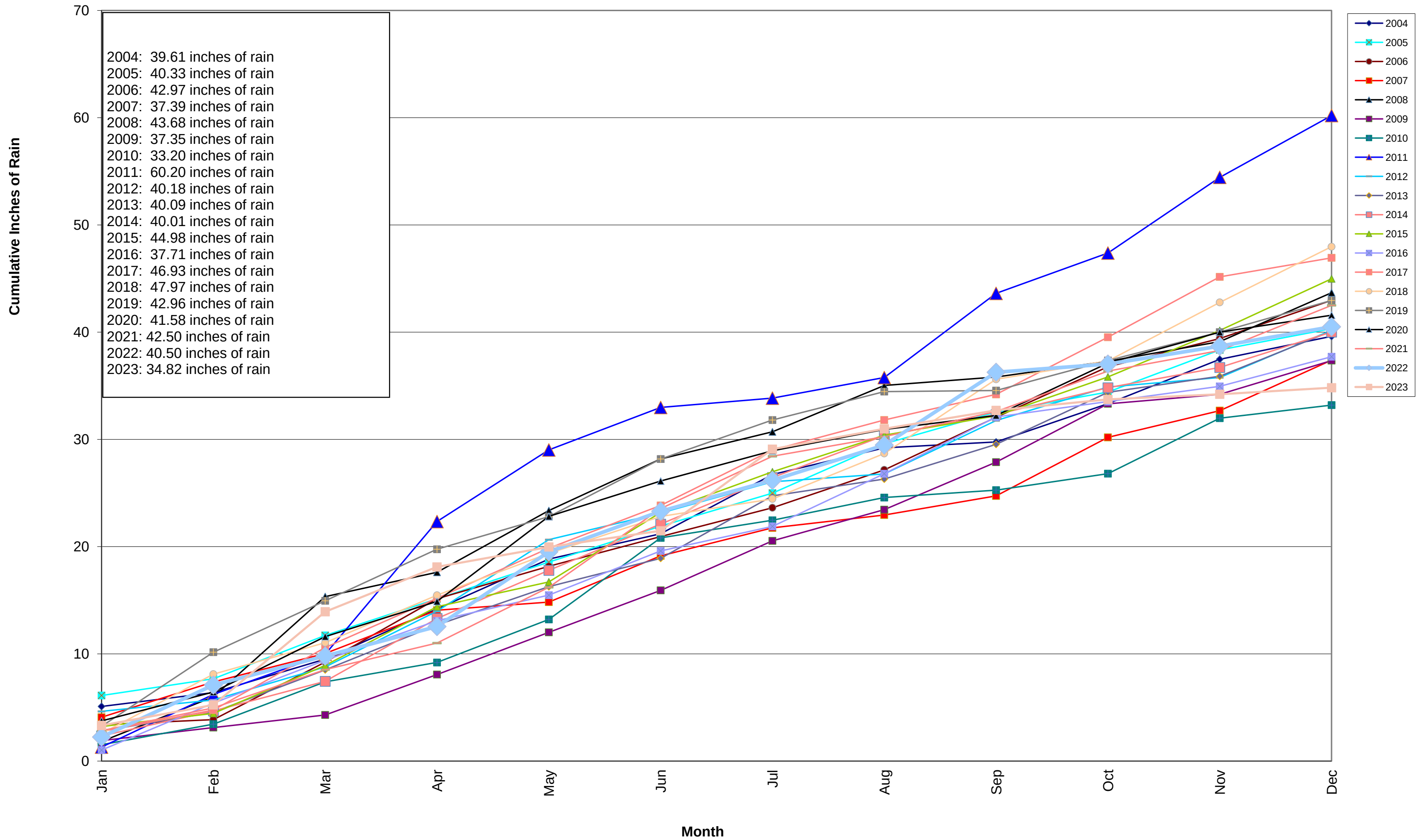

Figure A.3-6. Cumulative Annual Precipitation: 2004 Through 2023 as Recorded at the Butler County Regional Airport

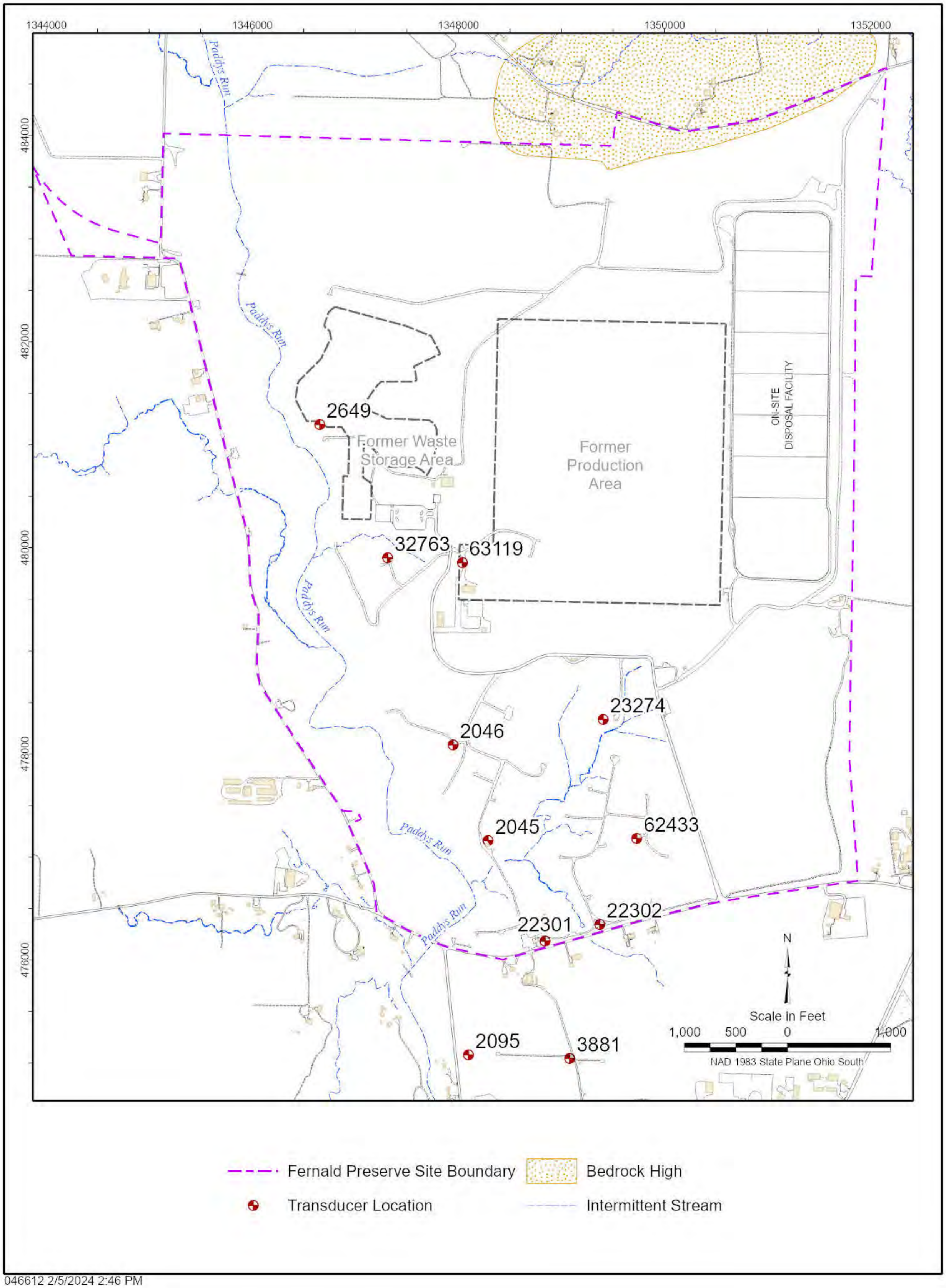

Figure A.3-7. Transducer Locations for the 2023 Operational Shutdown

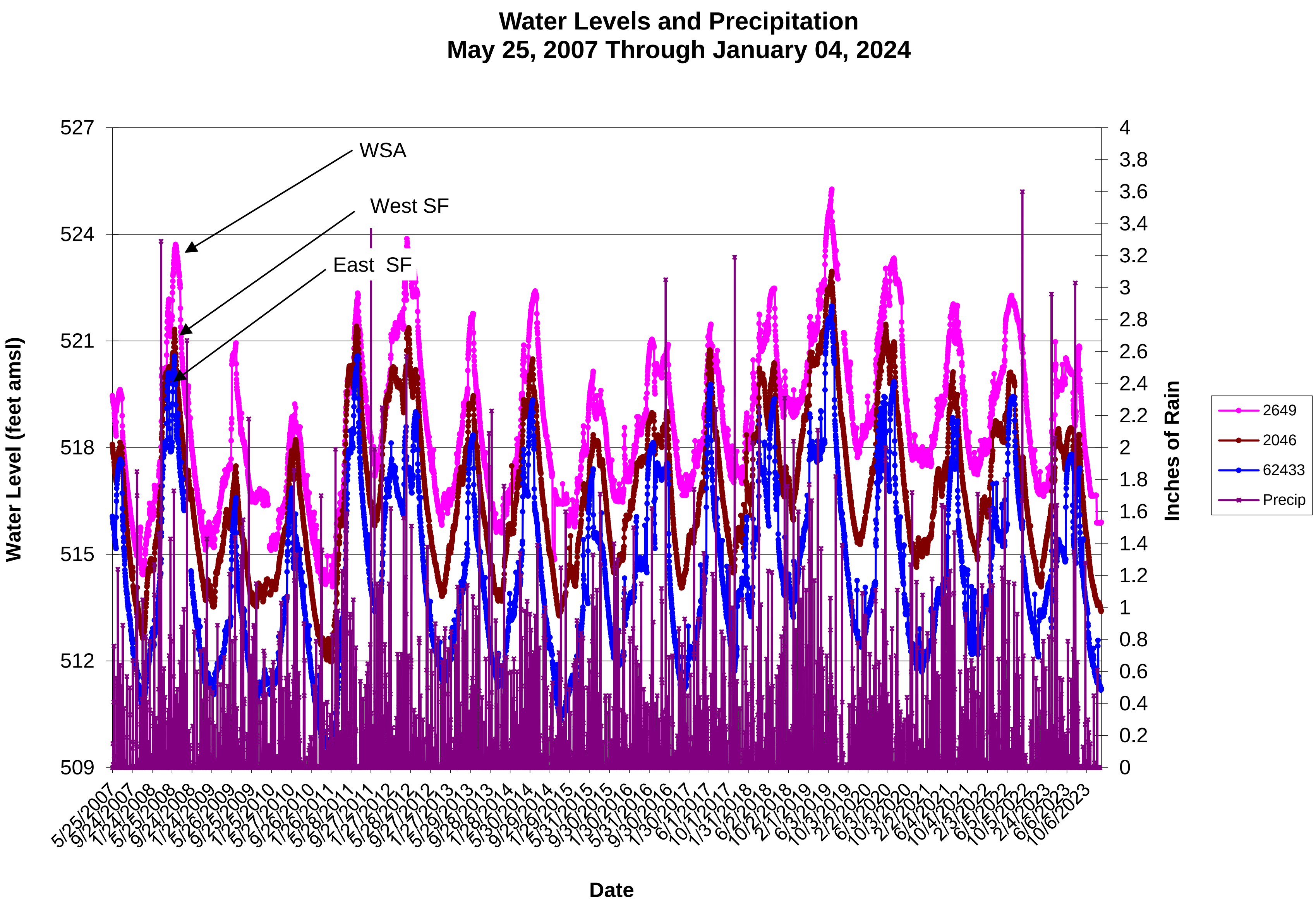

Figure A.3-8. Water Levels Versus Precipitation May 25, 2007, Through December 31, 2023

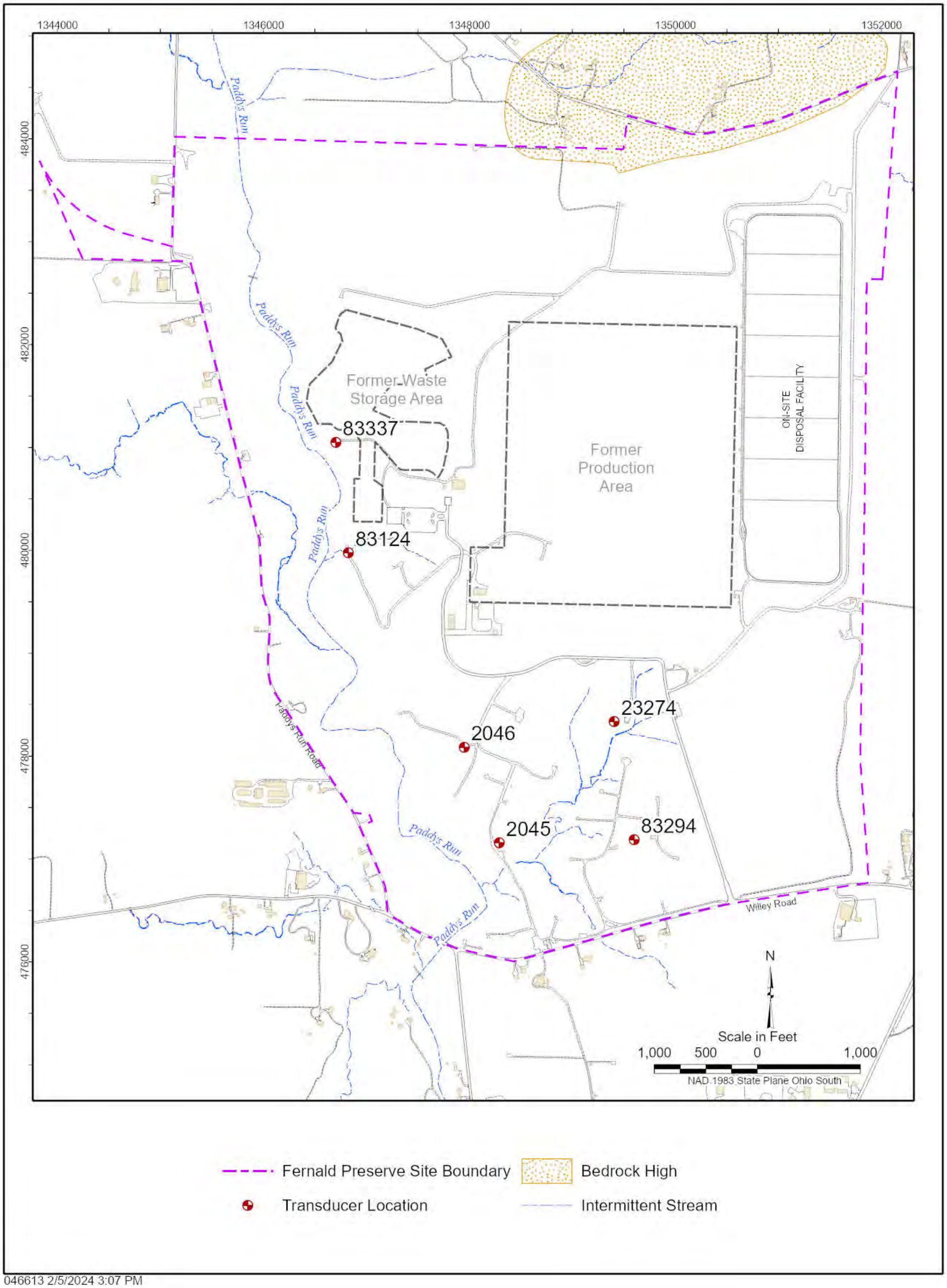

Figure A.3-9. Monitoring Well Locations for the 2023 Operational Shutdowns

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Attachment A.4

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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 2023 collected under the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP) (DOE 2023). The purpose of the evaluation is to:

- Identify 2023 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 2023 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 2023). 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 2023

Table A.4-1 shows the summary statistics and trend analysis for the 2023 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 2023. Figure A.4-1 identifies the locations of these exceedances.

Figure A.4-1 shows that the non-uranium FRL exceedances in 2023 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 2023. The first column in Table A.4-2 lists the groundwater FRL constituents monitored in 2023. 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 2023), there were 13 non-uranium constituents monitored in 2023; as stated above, five constituents had exceedances during 2023. The following table summarizes the 2023 non-uranium monitoring information.

Constituent (units[a])	Groundwater Final Remediation Level	2023 Monitoring Summary	2023 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	Exceedance in the Property Plume Boundary Wells	0.939
Molybdenum (mg/L)	0.10	Exceedances in former WSA wells	0.523
Nickel (mg/L)	0.10	No exceedances	Not applicable
Nitrate + nitrite, as nitrogen (mg/L)	11	Exceedances in former WSA wells	44.4
Technetium-99 (pCi/L)	94	Exceedances in former WSA wells	303
Trichloroethene (µg/L)	5	Exceedances in former WSA wells	9.4
Zinc (mg/L)	0.021	No exceedances	Not applicable

[a] mg/L = milligrams per liter, µg/L = milligrams per liter, pCi/L = picocuries per liter.

A.4.1.1 Non-Uranium Direct-Push Sampling Results for 2023

In 2023, no direct-push sampling was conducted in the former WSA.

A.4.2 Evaluation of 2023 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 2023 non-uranium FRL exceedances outside the current Operational Design Remediation Footprint. In 2023, there was one FRL exceedance outside the current Operational Design Remediation Footprint: manganese in monitoring well 3429.

Table A.4-3 addresses possible persistent FRL exceedances that occurred outside the current Operational Design Remediation Footprint in 2023. 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 22205, identified as being potentially persistent in 2022, was shown to be not persistent in 2023.
- The manganese FRL exceedance at monitoring well 3429 requires that additional routine 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 2023 marks 27 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 2023, 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 2023, a zinc FRL exceedance in monitoring well 22205 (detected in 2022) was determined to be non-persistent.
- In 2023, a manganese FRL exceedance in monitoring well 3429 requires that additional routine data be collected to determine whether it is 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.

DOE (U.S. Department of Energy), 1998. *Restoration Area Verification Sampling Program Summary Report*, Final, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio.

DOE (U.S. Department of Energy), 2001. *2000 Integrated Site Environmental Report*, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio.

DOE (U.S. Department of Energy), 2004. *2003 Site Environmental Report*, 51350-RP-0024, Fluor Fernald, Fernald Area Office, Cincinnati, Ohio, June.

DOE (U.S. Department of Energy), 2014. *Operational Design Adjustments-1, WSA-Phase-II Groundwater Remediation Design, Fernald Preserve*, LMS/FER/S10798, Office of Legacy Management, September.

DOE (U.S. Department of Energy), 2016. *Fernald Preserve 2015 Site Environmental Report*, LMS/FER/S13591, Office of Legacy Management, May.

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), 2023. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 13, Office of Legacy Management, January.

Table A.4-1. Summary Statistics and Trend Analysis for Non-Uranium Constituents with 2023 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 2023[b,c,d]	Maximum Exceedance for 2023[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)	
Manganese (0.9 mg/L)	3429	55	1	1	0.939	0.113	0.939	0.229	0.112	No Trend
Molybdenum (0.10 mg/L)	2649	47	47	2	0.523	0.149	1.26	0.467	0.236	No Trend
Nitrate + nitrite as nitrogen (11 mg/L)[h]										
	83338_C1	28	23	1	44.4	0.404	73.8	40.0	20.2	No Trend
	83340_C2	34	33	2	33.2	2.93	86.7	38.6	23.8	Down
	83340_C3	34	28	1	12.9	1.13	133	37.0	32.2	Down
	83341_C1	16	12	1	31.8	0.265	56.3	22.6	18.5	Up
					(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	
Technetium-99 (94 pCi/L)	2649	55	50	1	303	55.0	1660	468	425	Down
	83338_C1	28	23	1	285	10.1	515	238	129	Up
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	
Trichloroethene (5 µg/L)	2649	47	29	1	9.40	0.125	120	24.4	29.8	Down

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 2023.
[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 2023.
[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 2023

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]		2022[e]		2023[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	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	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																													
	3429	0	P/PB																																										1										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	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	1	
	83338_C2	1	WSA																					1				1	1	1	1		1	1	1	1	1		1	1				1			1									
	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	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			1
	83341_C1	1	WSA																				1										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	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	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		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

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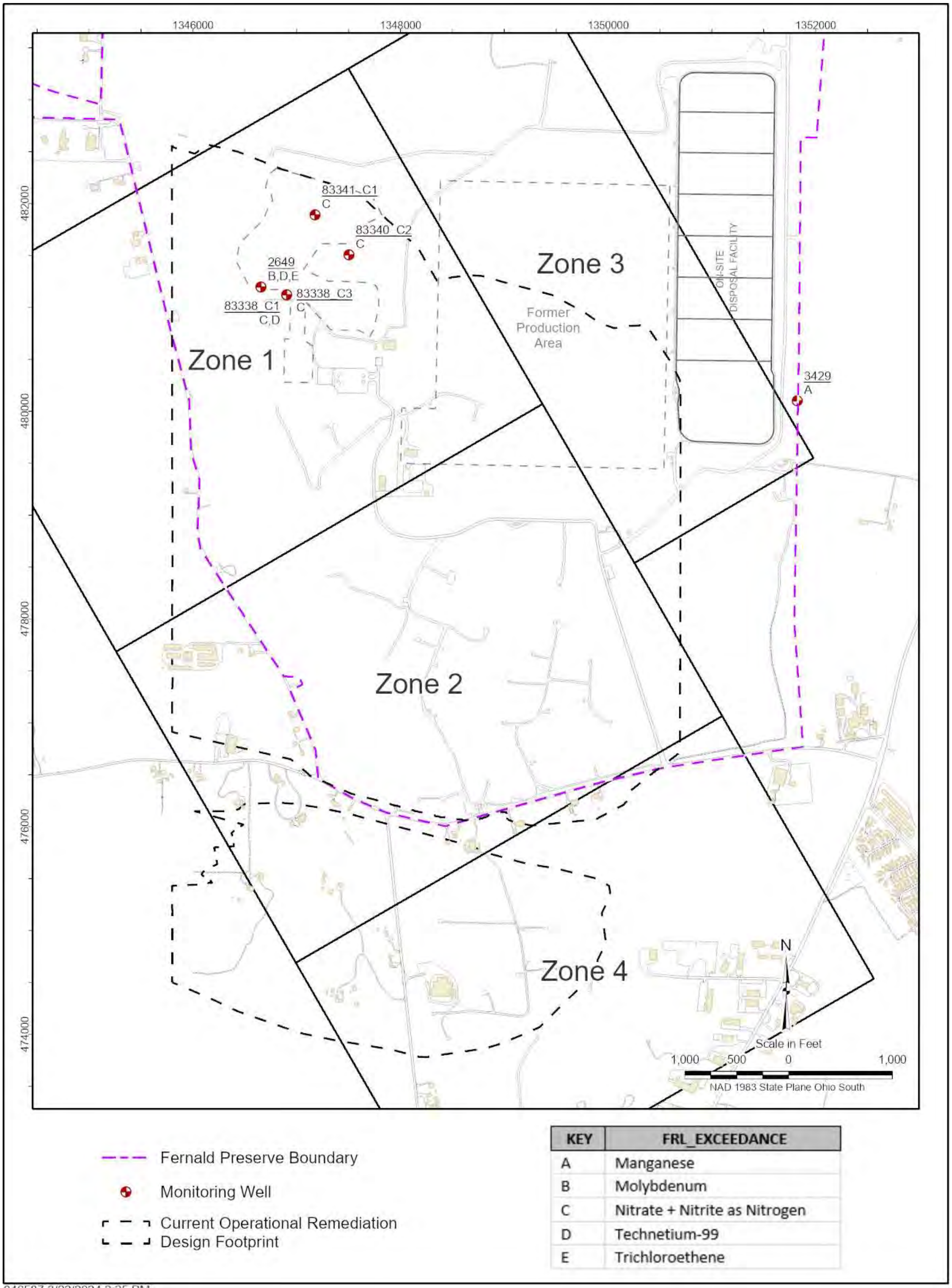
Table A.4-3. Summary of Persistence Evaluation of Non-Uranium FRL Exceedances Outside the Current Operational Design Remediation Footprint

Constituent	Monitoring Well	Monitoring Program	Pertinent 2022 Results	2023 FRL Exceedance	Evaluation Results for 2023	Figure Number
Zinc	22205	Property/Plume Boundary	Additional routine data required	No	Not persistent	A.4-2
Manganese	3429	Property/Plume Boundary	Not applicable	Yes	Additional routine data required	A.4-3



KEY	FRL_EXCEEDANCE
A	Manganese
B	Molybdenum
C	Nitrate + Nitrite as Nitrogen
D	Technetium-99
E	Trichloroethene

046587 3/22/2024 2:25 PM

Figure A.4-1. Non-Uranium Constituent Locations with 2023 Results Above FRLs

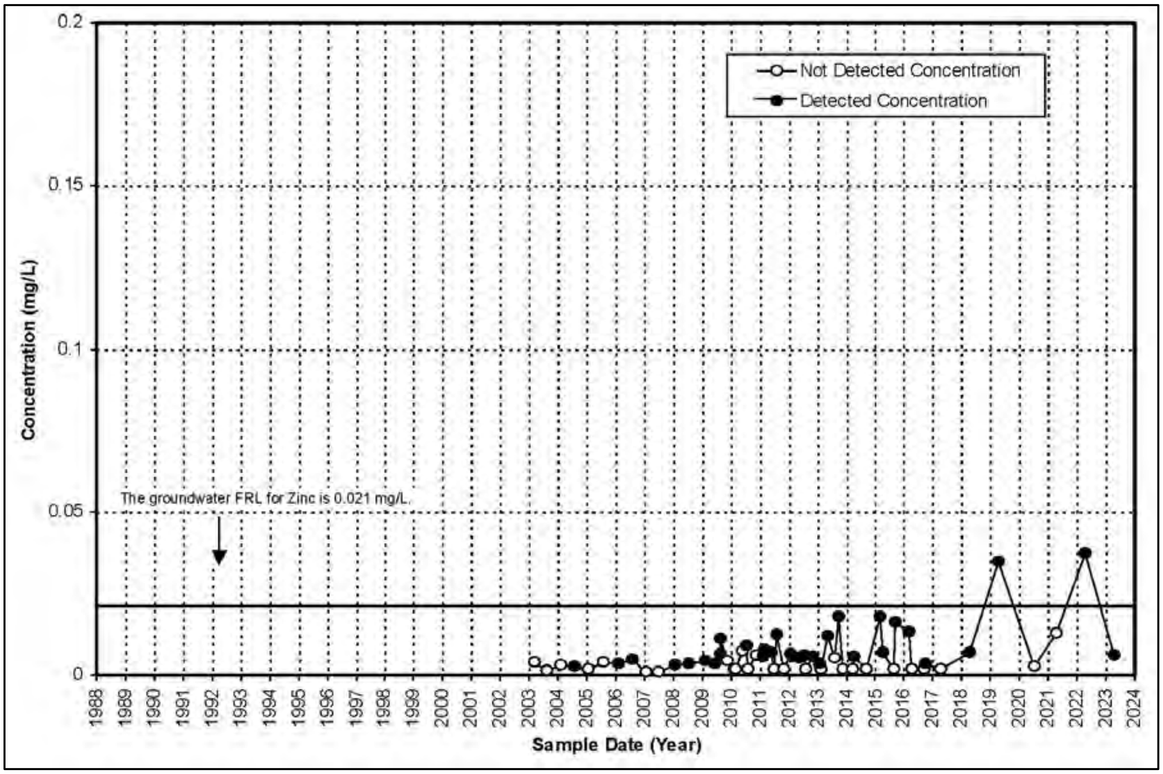


Figure A.4-2. Zinc Concentration Versus Time Plot for Monitoring Well 22205

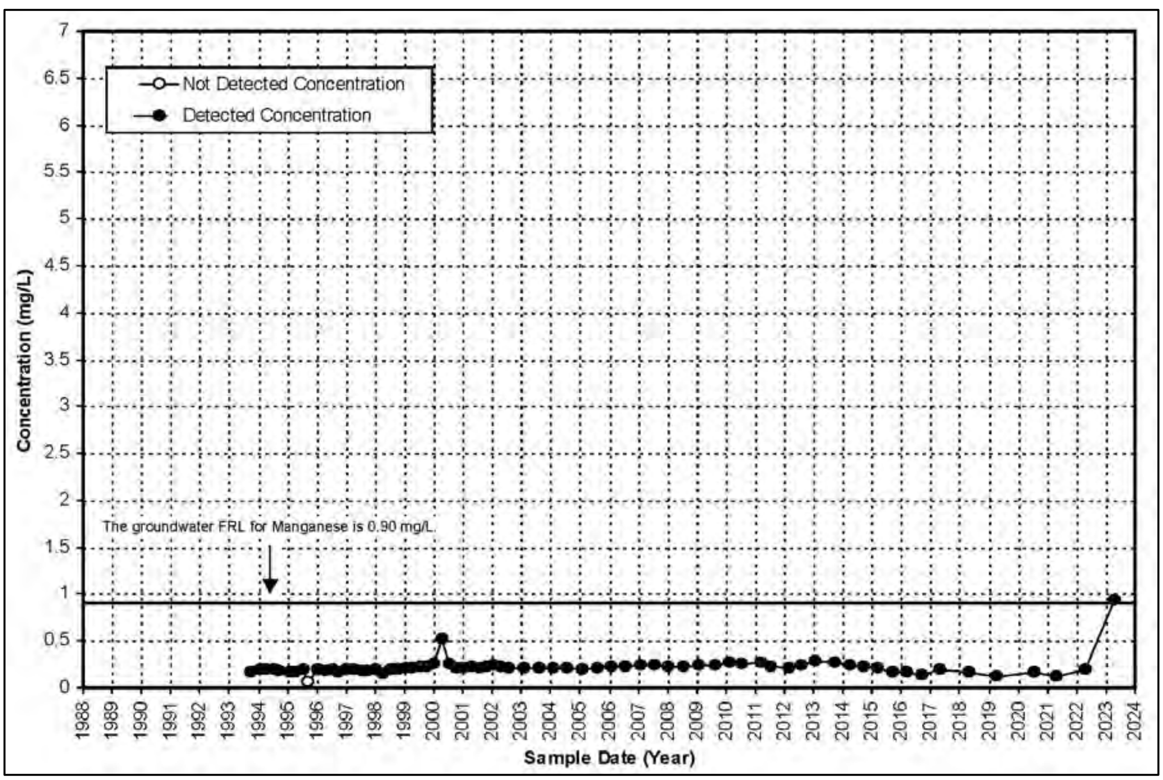


Figure A.4-3. Manganese Concentration Versus Time Plot for Monitoring Well 3429

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Attachment A.5

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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 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. As discussed in this attachment, flow from the facility is monitored to document that the needed hydraulic head to drive leachate through a breach in the liner and into the underlying horizon is not achieved.

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 2023 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 LCS flows from October 2006 through December 2023. Figure A.5-4 is a graph that shows the annual LCS flows from 2007 through 2023.

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.

As in 2022, leachate volumes for 2023 reflect the entire calendar year with the valves open, during which time a total of 91,855 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 2023 was approximately 51.5 million gallons (34.82 inches over 54.1 acres). The facility cap was designed to inhibit water from infiltrating the OSDF. Leachate collected in 2023 (91,855 gallons) represents approximately 0.18% of the 51.5 million gallons. This value indicates that in 2023 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 could 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 would register via the probes, there was often not enough water present to physically obtain a sample. Pump out of the tank would occur automatically if an LDS tank water level reached 80% of its capacity (1.86 ft of water). Pump out also occurred after semiannual sampling was completed to remove any water that remained after sampling, to ensure newer water was sampled for the next semiannual sampling event. From 2017 through 2022, LDS flow rates were estimated by tracking the volume of water removed from the LDS tanks. In 2022, piping modifications in the LDS line were made that provided a smaller 5-gallon container in place of the larger LDS tank to collect a sample from. The 5-gallon containers were sized to collect all LDS flow. Water collected in the 5-gallon container will be sampled twice per year. Water collected in the 5-gallon container is monitored to determine whether the low flow response leakage rate of 2 gpad is reached.

In 2023, LDS tanks for all cells (with the exception of Cell 6) were too dry to collect semiannual samples, resulting in an accumulation rate of 0.0 gpad. The LDS Cell 6 container accumulated enough water to collect a routine semiannual sample in the second half of 2023. The amount of water accumulated in the LDS Cell 6 container in 2023 was very low, so the accumulation rate was calculated by noting the volume of water collected in the LDS Cell 6 container and the amount of time since it was previously drained (or since LDS Cell 6 was previously sampled). The calculation for estimated maximum accumulation rates based on LDS container accumulation is summarized in the following table.

Cell	Estimated Volume Collected from LDS (gallons)	Estimated Maximum Accumulation Rate (gpad)
1, 2, 3, 4, 5, 7, and 8	0	0.00
6	7.3	0.00465

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 2023 (0.00465 gpad in Cell 6) is only 0.23% of the low-flow response leakage rate of 2 gpad.

The 2023 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	2023 Maximum LDS Accumulation Rate Calculated from Collected Water (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	0.00	0.0	0.0
5	0.00	0.0	0.0
6	0.00465	0.023	0.23
7	0.00	0.0	0.0
8	0.00	0.0	0.0

These 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 maximum accumulation rate measured for the only cell that had flow in the LDS in 2023 (Cell 6) was only 0.00465 gpad. The former LDS tanks held 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. DOE completed these modifications in early 2023. Both semiannual sampling events (and associated LDS water collection observations) were performed after these modifications, ensuring that all data in 2023 reflects data collected after the modifications.

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 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 houses 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 were completed 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 micrograms per liter [µg/L]) matched the very low historical total uranium concentrations in the perched groundwater in the area (2.0–8.61 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. 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:

$$\text{Hydraulic efficiency} = [1 - (\text{Volume}_{LDS}/\text{Volume}_{LCS})] \times 100$$

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 all cells but Cell 6 were dry in 2023, and no water accumulation occurred in those LDS 5-gallon containers 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 (Cell 6 for 2023). In the following table, Cell 6 is reported at 99.96% in the third quarter of 2023 because, as a sample was collected, the water collected in the 5-gallon container was noted to be sufficient (1 gallon) to calculate a liner efficiency of less than 100%.

Apparent Liner Efficiency (Percent), Quarterly for 2023

Quarter	Cell 6
First	100.00
Second	100.00
Third	99.96
Fourth	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 2023, 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 2023

Location ID	Cell	First Half Purge March 7, 2023 (gallons)	Second Half Purge September 11, 2023 (gallons)	Annual Total (gallons)	Annual Average (gallons)
12338	Cell 1	300	600	900	450
12339	Cell 2	800	700	1,500	750
12340	Cell 3	500	950	1,450	725
12341	Cell 4	600	450	1,050	525
12342	Cell 5	1,050	1,050	2,100	1,050
12343	Cell 6	250	400	650	325
12344	Cell 7	900	425	1,325	663
12345	Cell 8	Dry	Dry	Dry	Dry
	Totals	4,400	4,575	8,975	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 (OAC 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 (OAC 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 improved 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 2023, only Cell 6 had enough water present to collect a sample.

A.5.2.2 Concentration Plots

Concentration plots for the parameters monitored semiannually in 2023 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 no sampling locations had new high total uranium concentrations in 2023.

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.

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).

Twenty-three Shewhart-CUSUM control charts were prepared in 2023 and are presented in Subattachments A.5.1 through A.5.8 for parameters monitored semiannually in the HTW and GMA wells in 2023 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 23 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.

The bivariate plots for 2023 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 2023 (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 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 2023, inspections were conducted in March, June, September, and December. Following a prescribed burn of the OSDF cap in February, a post-burn walkdown of the entire OSDF cap was conducted as part of the March quarterly inspection. The regularly scheduled annual OSDF cap walkdown was conducted in December. 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. Appendix C provides additional information regarding the OSDF cap inspections.

The issues are addressed as follows:

- Rocks greater than 4 inches in diameter are removed.
- 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 2023, there were no visual signs that the integrity of the cap had been compromised. A light detection and ranging (lidar) flyover of the OSDF was conducted following the prescribed burn. The results of this flyover will be used as a baseline for comparison of future flyovers. The next flyover schedule to occur in spring 2025.

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 2023 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 2023 was 12.68% less than in 2022 (approximately 91,855 gallons in 2023 compared with 105,198 gallons in 2022).
- In 2023, there was not enough water in the LDS of any cell, with the exception of Cell 6, to collect a water sample.
- LDS accumulation rate for 2023 in Cell 6 indicates that the liner system is performing as designed. The estimated LDS maximum accumulation rate calculated in 2023 was 0.00465 gpad in Cell 6, approximately 0.023% of the initial response leakage rate of 20 gpad, and 0.23% of the low-flow response leakage rate of 2 gpad.
- Quarterly apparent liner efficiencies were 100% for all cells in 2023 with the exception of Cell 6 in the third quarter. The apparent liner efficiency of Cell 6 in the third quarter was 99.96%.
- No sampling locations had new high total uranium concentrations in 2023.
- 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.
- In 2023, 23 datasets met the criteria for Shewhart-CUSUM control charts. All control charts exhibited "in control" conditions.
- In 2023, quarterly physical inspections of the OSDF revealed no visual signs that the integrity of the OSDF cap had been compromised.

A.5.5 References

DOE (U.S. Department of Energy), 1995. *Remedial Investigation Report for Operable Unit 5*, Final, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio, May.

DOE (U.S. Department of Energy), 1997. *On-Site Disposal Facility Final Design Calculation Package*, Volume 2 of 4, Fernald Environmental Management Project, Fernald Area Office, Cincinnati, Ohio.

DOE (U.S. Department of Energy), 2008. *Evaluation of Aqueous Ions in the Monitoring Systems of the On-Site Disposal Facility*, DOE-LM/1591-2008, Office of Legacy Management, March.

DOE (U.S. Department of Energy), 2010. *Fernald Preserve 2009 Site Environmental Report*, LMS/FER/S06109, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2016. *Fernald Preserve 2015 Site Environmental Report*, LMS/FER/S13591, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2017. *Fernald Preserve 2016 Site Environmental Report*, LMS/FER/S15232, Office of Legacy Management, May.

DOE (U.S. Department of Energy), 2019a. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 12, Office of Legacy Management, January.

DOE (U.S. Department of Energy), 2019b. *Fernald Preserve 2018 Site Environmental Report*, LMS/FER/S23329, Office of Legacy Management, May.

EPA (U.S. Environmental Protection Agency), 1996. *Report on the 1995 Workshop on Geosynthetic Clay Liners*, EPA/600/R-96/149, Washington, D.C., June.

EPA (U.S. Environmental Protection Agency), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance*, EPA 530/R-09-007, March.

Geochemical Consultants, 2016. *Evaluation of Select Ion Concentrations and Fluid Levels in the On-Site Disposal Facility Leachate and Monitoring Systems*, Draft, March.

OAC 3745-27-10. "Ground Water Monitoring Program for a Sanitary Landfill Facility," *Ohio Administrative Code.*

OAC 3745-27-19. "Operational Criteria for a Sanitary Landfill Facility," *Ohio Administrative Code.*

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 2023[a,c] (µg/L)	Second Half 2023[a,c] (µg/L)	Historical Trend[d] (Year Last Sampled)
Cell 1 (Dec 1997)	12338C	LCS	Feb 17, 1998	78	ND–206	26.0	12.0	None (2023)
	12338D	LDS	Feb 18, 1998	37	1.50–37.0	DRY	DRY	Up (2011)
	12338	Glacial Till	Oct 30, 1997	87	ND–19	7.13	7.97	Up (2023)
	22201	Great Miami Aquifer	Mar 31, 1997	94	ND–12.4	8.31	6.82	Up (2023)
	22198	Great Miami Aquifer	Mar 31, 1997	143	0.540–15.2	3.25	2.77	Down (2023)
Cell 2 (Nov 1998)	12339C	LCS	Nov 23, 1998	74	4.51–686	67.1	49.6	Up (2023)
	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	18.0	16.0	Up (2023)
	22200	Great Miami Aquifer	Jun 30, 1997	89	ND–4.69	0.365	1.27	Up (2023)
	22199	Great Miami Aquifer	Jun 25, 1997	120	ND–12.1	0.359	0.5 54	Down (2023)
Cell 3 (Oct 1999)	12340C	LCS	Oct 13, 1999	72	9.27–206	151	162	Up (2023)
	12340D	LDS	Aug 26, 2002	20	8.90–27.7[e]	DRY	DRY	Down (2007)
	12340	Glacial Till	Jul 28, 1998	31	ND–58.5	15.9	18.0	None (2023)
	22203	Great Miami Aquifer	Aug 24, 1998	84	ND–23.5	21.723.5	6.92	Up (2023)
	22204	Great Miami Aquifer	Aug 24, 1998	115	ND–22.9	2.79	8.25	Up (2023)
Cell 4 (Nov 2002)	12341C	LCS	Nov 04, 2002	58	4.41–234	86.2	99.8	None (2023)
	12341D	LDS	Nov 04, 2002	41	5.74–79.8	DRY	DRY	Up (2022)[f]
	12341	Glacial Till	Feb 26, 2002	71	**3.38**–7.91	3.39	**3.38**	Down (2023)
	22206	Great Miami Aquifer	Nov 06, 2001	75	ND–5.78	0.742	1.50	Up (2023)
	22205	Great Miami Aquifer	Nov 05, 2001	102	0.446–19.7	1.28	5.41	None (2023)
Cell 5 (Nov 2002)	12342C	LCS	Nov 04, 2002	60	3.39–285	114	123	None (2023)
	12342D	LDS	Nov 04, 2002	40	2.93–27.1	DRY	DRY	Down (2013)
	12342	Glacial Till	Feb 26, 2002	72	**7.29**–21.1	**7.29**	7.61	Down (2023)
	22207	Great Miami Aquifer	Nov 06, 2001	75	ND–4.48	0.371	0.298	Down (2023)
	22208	Great Miami Aquifer	Nov 05, 2001	101	ND–2.1	0.419	0.298	None (2023)

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 2023[a,c] (µg/L)	Second Half 2023[a,c] (µg/L)	Historical Trend[d] (Year Last Sampled)
Cell 6 (Nov 2003)	12343C	LCS	Oct 27, 2003	57	8.03–276	99.1	110	Down (2023)
	12343D	LDS	Oct 27, 2003	55	3.1–160	DRY	72	Up (2023)
	12343	Glacial Till	Mar 14, 2003	64	ND–24.2	7.67	8.16	None (2023)
	22209	Great Miami Aquifer	Dec 16, 2002	70	ND–2.43	0.445	0.408	Down (2023)
	22210	Great Miami Aquifer	Dec 16, 2002	96	ND–1.02	0.678	0.818	None (2023)
Cell 7 (Sep 2004)	12344C	LCS	Sep 02, 2004	53	4.72–355	99.7	126	Down (2023)
	12344D	LDS	Sep 02, 2004	29	12.2–169[e]	DRY	DRY	Up (2015)
	12344	Glacial Till	Feb 24, 2004	61	0.674–12.1	3.82	4.25	Up (2023)
	22212	Great Miami Aquifer	Jan 21, 2004	63	ND–5.53	0.397	0.414	Down (2023)
	22211	Great Miami Aquifer	Jan 21, 2004	86	ND–4.31	0.429	1.13	None (2023)
Cell 8 (Dec 2004)	12345C	LCS	Oct 18, 2004	50	1.51–335	139	152	None (2023)
	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	0.388	0.444	Up (2023)
	22214	Great Miami Aquifer	Mar 31, 2004	86	ND–2.95	0.260	1.61	Down (2023)
	22215	Great Miami Aquifer	Aug 22, 2005	53	ND–16.4	0.517	0.414	None (2023)
	22217[g]	Great Miami Aquifer	Aug 22, 2005	52	ND–18.3	2.16	5.80	Down (2023)

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 2023**.
[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.

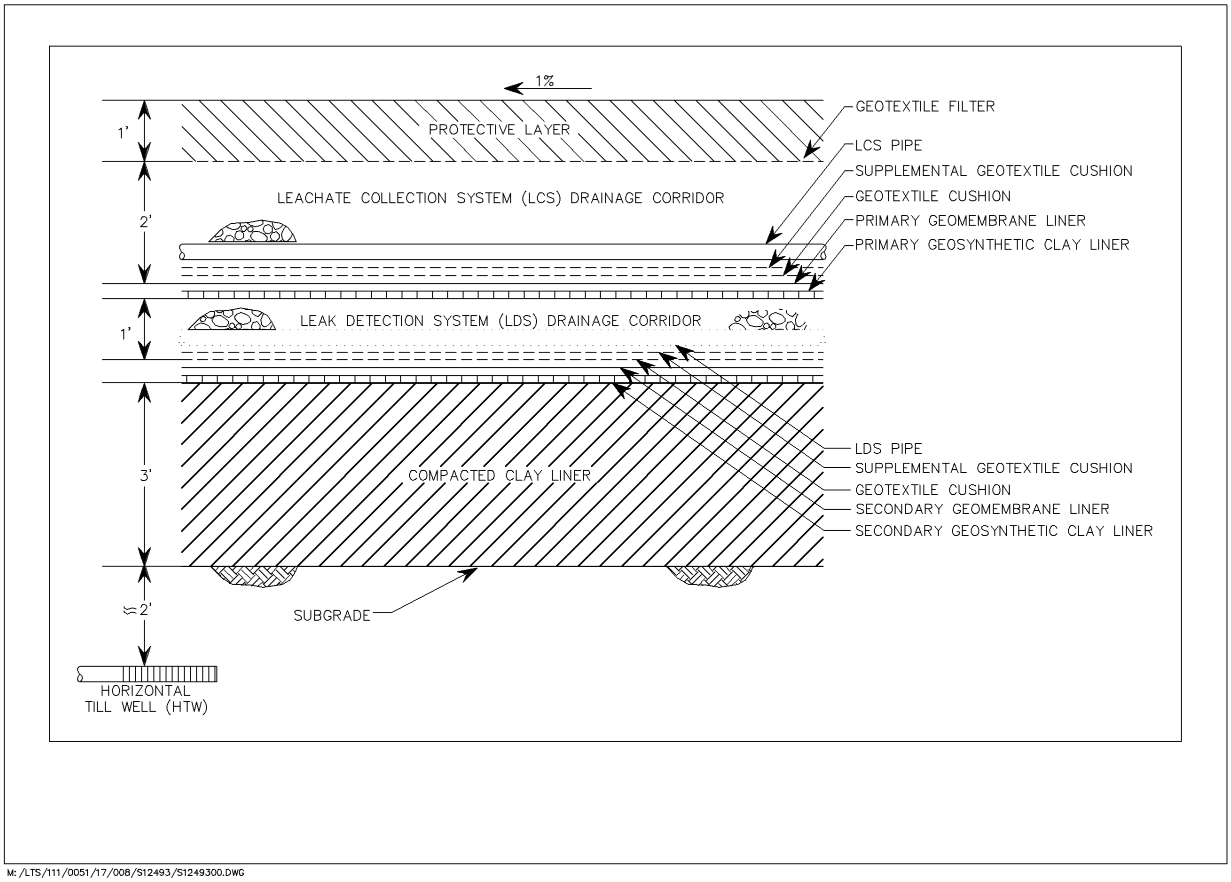

Figure A.5-1. Cross Section of OSDF Liner System with HTW at the Drainage Corridor

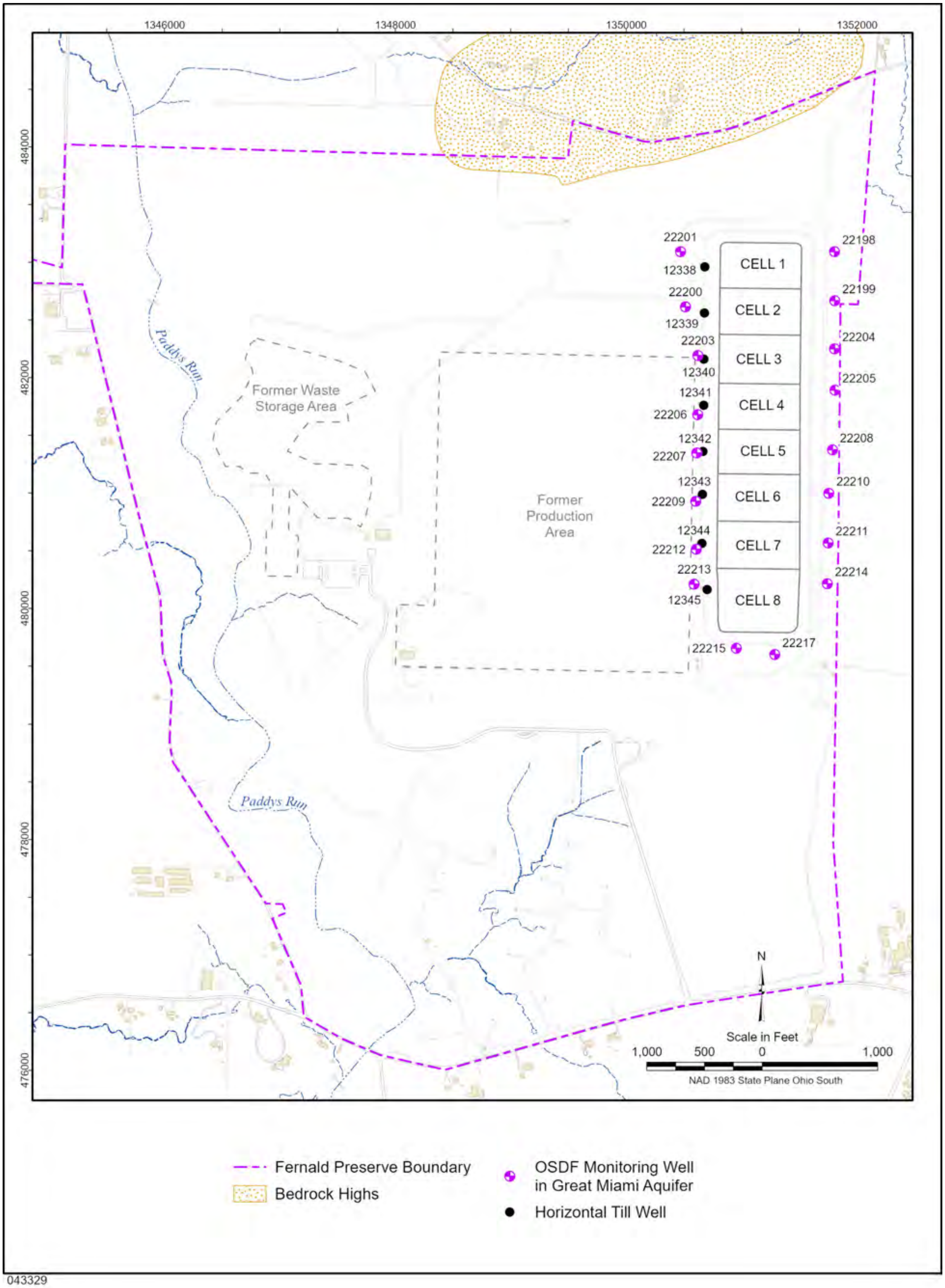

Figure A.5-2. OSDF Footprint and Monitoring Well Locations

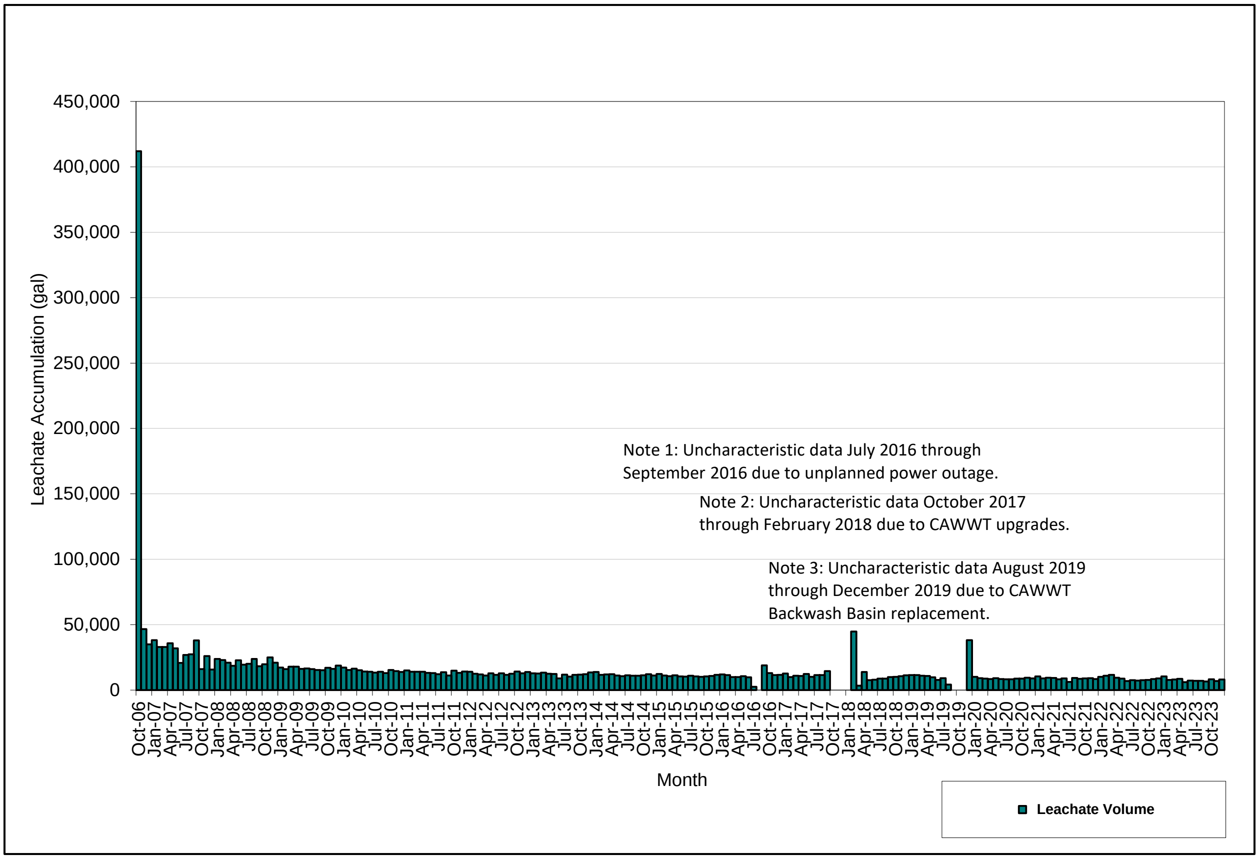

Figure A.5-3. OSDF Monthly LCS Flow (October 2006 Through December 2023)

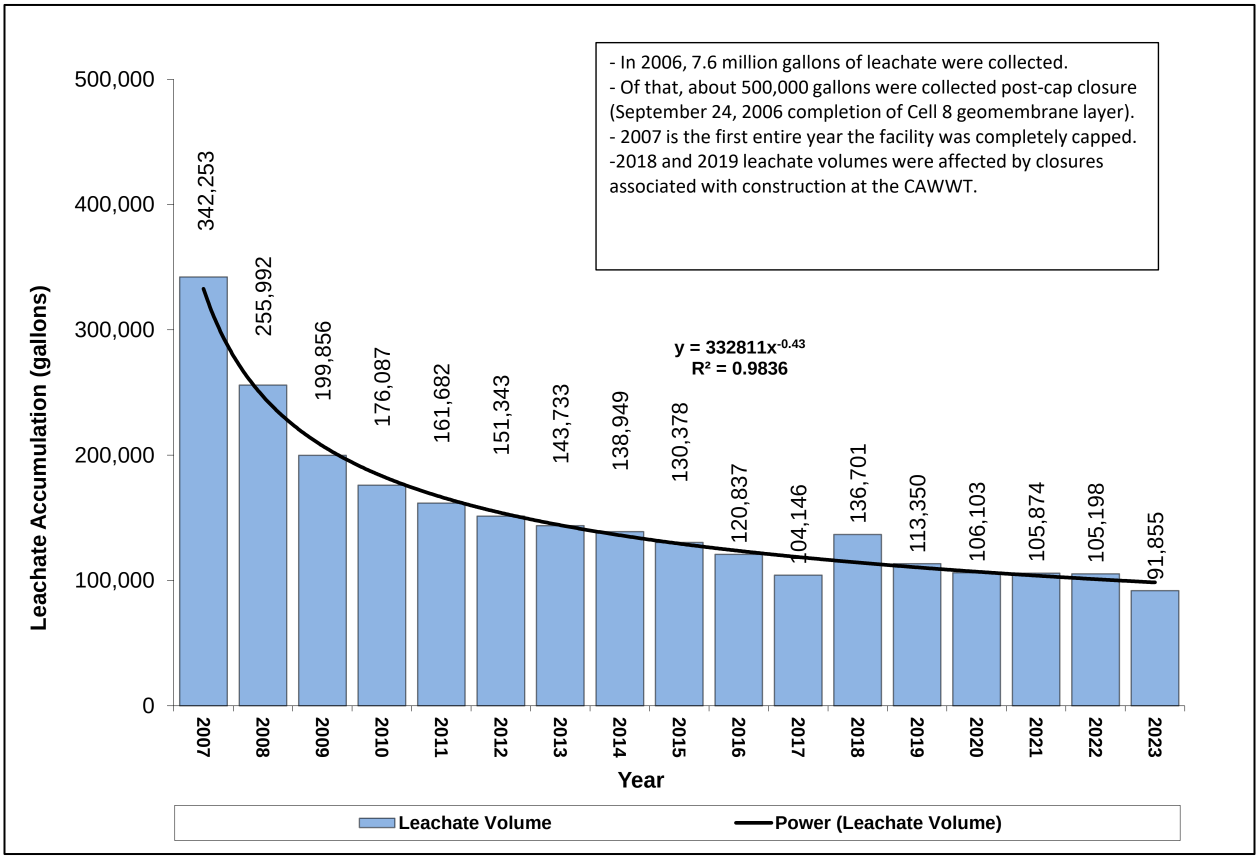

Figure A.5-4. OSDF Annual LCS Flow (2007 Through 2023)

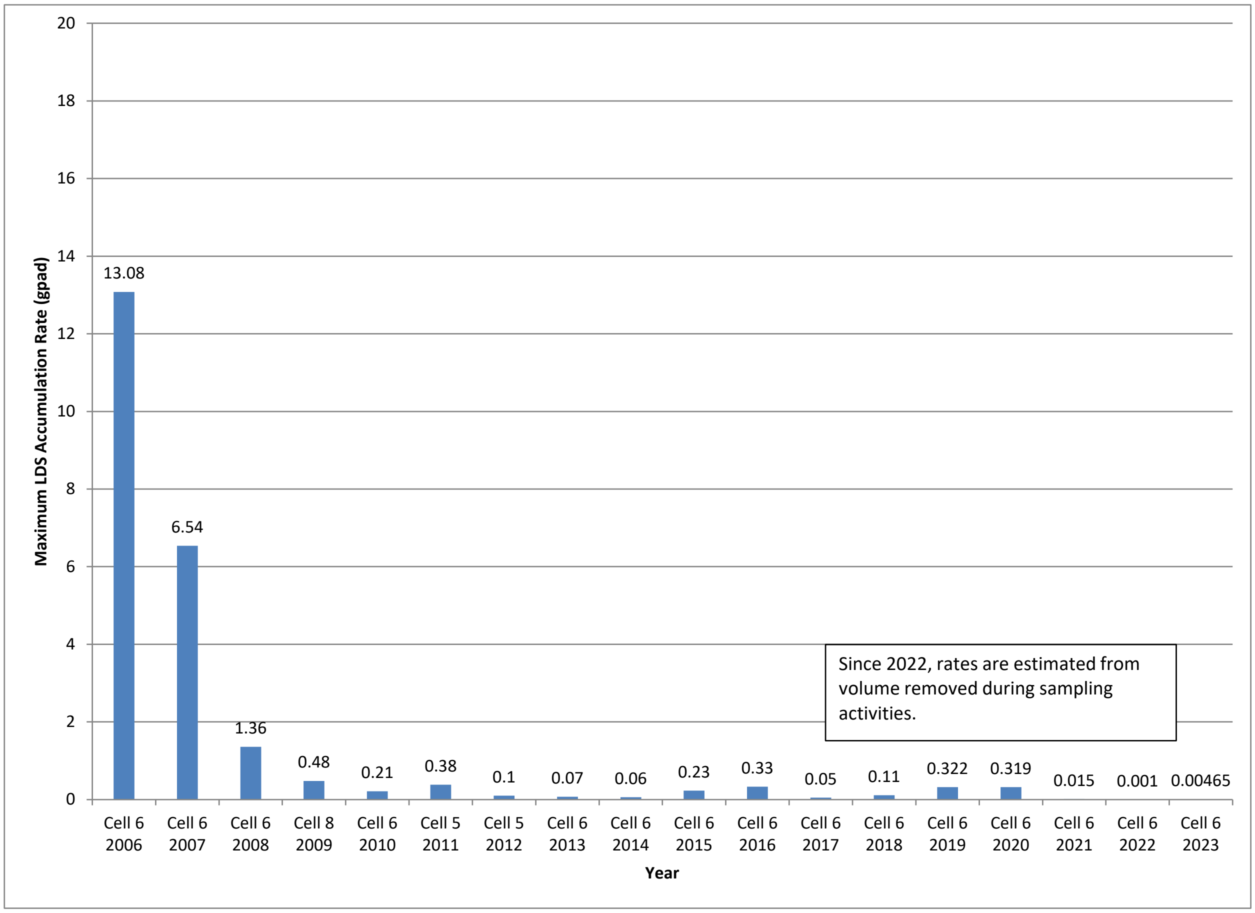

Figure A.5-5. Maximum LDS Accumulation Rate Between 2006 and 2023

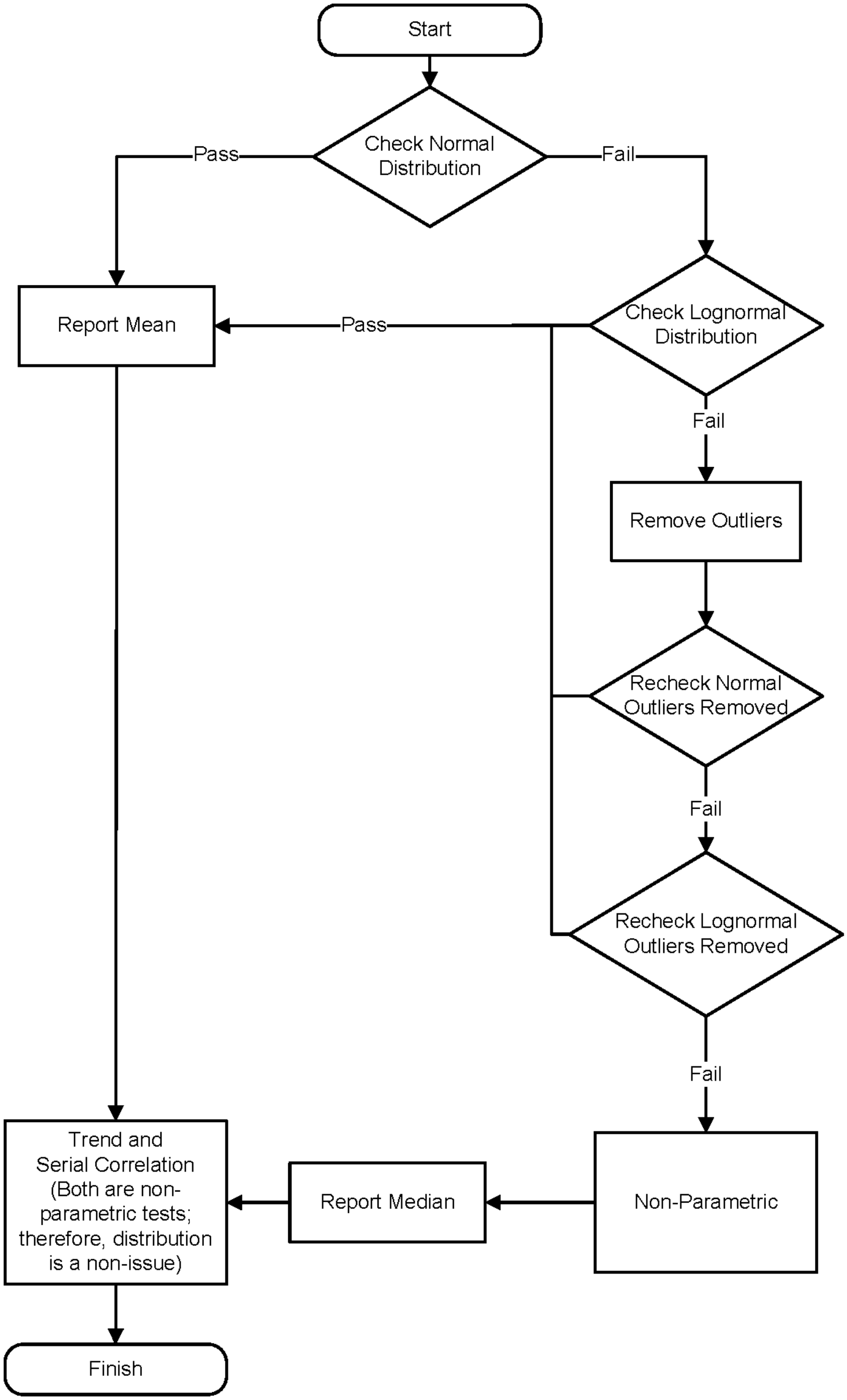

Figure A.5-6. OSDF Statistical Evaluation Process

Subattachment A.5.1

Cell 1

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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 2023 (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 2023. The volume of water in the LDS tank of Cell 1 has been insufficient to collect a sample since 2011.

It should be noted that this year the 206 micrograms per liter (µg/L) result on Table A.5.1 from the year 2010 was no longer an outlier. In 2023, it was determined that a normal distribution could be obtained by not treating the 206 µg/L result as an outlier. This presents the appearance of a new high for uranium in 2023 on Table A.5.1-1 compared to the table from 2022, but this is not the case, because the 206 µg/L result was measured in 2010.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 1

Parameter	LCS 12338C 2023 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

[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 2023 shows that the uranium concentrations measured in the LCS were 26 µg/L and 12 µg/L. These uranium concentrations in the LCS are similar to uranium concentrations measured in the HTW in 2023. In 2023, the uranium concentrations measured in the HTW were 7.13 µg/L and 7.97 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 2023. 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 2023 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 2023. 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

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	12338C	81	82	98.8	ND	206	76.4	40.8	Normal	None (2023)	Detected	
	LDS	12338D	37	37	100	1.5	37.0	10.8	6.8	Undefined	Up (2011)	Detected	
	HTW	12338	78	80	97.5	ND	12.7	7.92	3.40	Undefined	Up (2023)	Detected	
	GMA-U	22201	83	87	95.4	ND	12.4	5.15	3.30	Undefined	Up (2023)	Detected	
	GMA-D	22198	96	96	100	0.574	15.2	4.68	2.49	Undefined	Down (2023)	Detected	
Boron (mg/L)	LCS	12338C	82	83	98.8	ND	1.72	0.977	0.309	Undefined	Down (2023)	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	60	63	95.2	ND	0.271	0.138	0.061	Normal	None (2023)	Detected	
	GMA-U	22201	85	87	97.7	ND	0.158	0.122	0.027	Undefined	Up (2023)	Detected	
	GMA-D	22198	82	86	95.4	ND	0.131	0.0545	0.0156	LN Normal	Down (2023)	Detected	
Sodium (mg/L)	LCS	12338C	56	56	100	11.7	22.0	19.2	2.5	Undefined	Up (2023)	Detected	29.3(Q3-05), 34.8 (Q2-23)
	LDS	12338D	9	9	100	335	896	571	216	Normal	Up (2011)	Not Detected	
	HTW	12338	48	48	100	8.72	23.8	12.8	3.8	Undefined	Down (2023)	Detected	
	GMA-U	22201	39	39	100	11.1	65.5	39.5	14.3	Undefined	Down (2023)	Detected	
	GMA-D	22198	41	41	100	9.93	18.6	13.2	2.1	Normal	Down (2023)	Detected	
Sulfate (mg/L)	LCS	12338C	68	68	100	707	3360	1820	670	Undefined	Up (2023)	Detected	
	LDS	12338D	19	19	100	675	3500	1590	780	LN Normal	Up (2011)	Detected	
	HTW	12338	58	58	100	365	907	612	135	LN Normal	Down (2023)	Detected	
	GMA-U	22201	63	63	100	91.8	735	253	143	LN Normal	None (2023)	Detected	1,980(Q4-04)
	GMA-D	22198	63	63	100	101	506	158	89	Undefined	Down (2023)	Detected	
Calcium (mg/L)	GMA-U	22201	32	32	100	140	334	192	41	LN Normal	Down (2023)	Not Detected	
	GMA-D	22198	32	32	100	133	192	153	14	Normal	Down (2023)	Not Detected	
Lithium (mg/L)	GMA-U	22201	39	39	100	0.00665	0.0153	0.0108	0.0024	Normal	None (2023)	Not Detected	
	GMA-D	22198	39	39	100	0.00624	0.0107	0.00918	0.00081	Undefined	None (2023)	Not Detected	
Magnesium (mg/L)	GMA-U	22201	32	32	100	36.1	82.2	49.9	9.2	LN Normal	Up (2023)	Not Detected	
	GMA-D	22198	32	32	100	36.2	47.8	40.4	3.0	Normal	Down (2023)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22201	26	32	81.2	ND	1.44	0.322	0.485	Undefined	Up (2023)	Not Detected	
	GMA-D	22198	9	52	17.3	ND	0.55	0.0100	0.172	Undefined	Down (2023)	Detected	
Potassium (mg/L)	GMA-U	22201	32	32	100	1.33	3.97	2.82	0.53	Normal	Down (2023)	Detected	
	GMA-D	22198	34	34	100	1.15	3.3	1.58	0.38	Undefined	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22201	3	39	7.7	ND	0.0289	0.004951	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22198	6	59	10.2	ND	0.0153	0.00300	0.00299	Undefined	Up (2023)	Detected	
Technetium-99 (pCi/L)	GMA-U	22201	1	36	2.8	ND	3.86	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22198	2	37	5.4	ND	8.30	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22201	39	39	100	594	1600	913	193	LN Normal	Down (2023)	Not Detected	
	GMA-D	22198	39	39	100	552	805	617	64	Undefined	Down (2023)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22201	39	87	44.8	ND	0.0319	0.00645	0.00688	Undefined	Down (2023)	Not Detected	0.078(Q1-97), 0.308(Q2-2000)
	GMA-D	22198	20	86	23.3	ND	0.0235	0.00182	0.00521	Undefined	None (2023)	Detected	0.0473(Q2-98), 0.092(Q2-00), 0.100(Q2-2010)

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 has 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: Ln Normal 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
2023	900	2	450

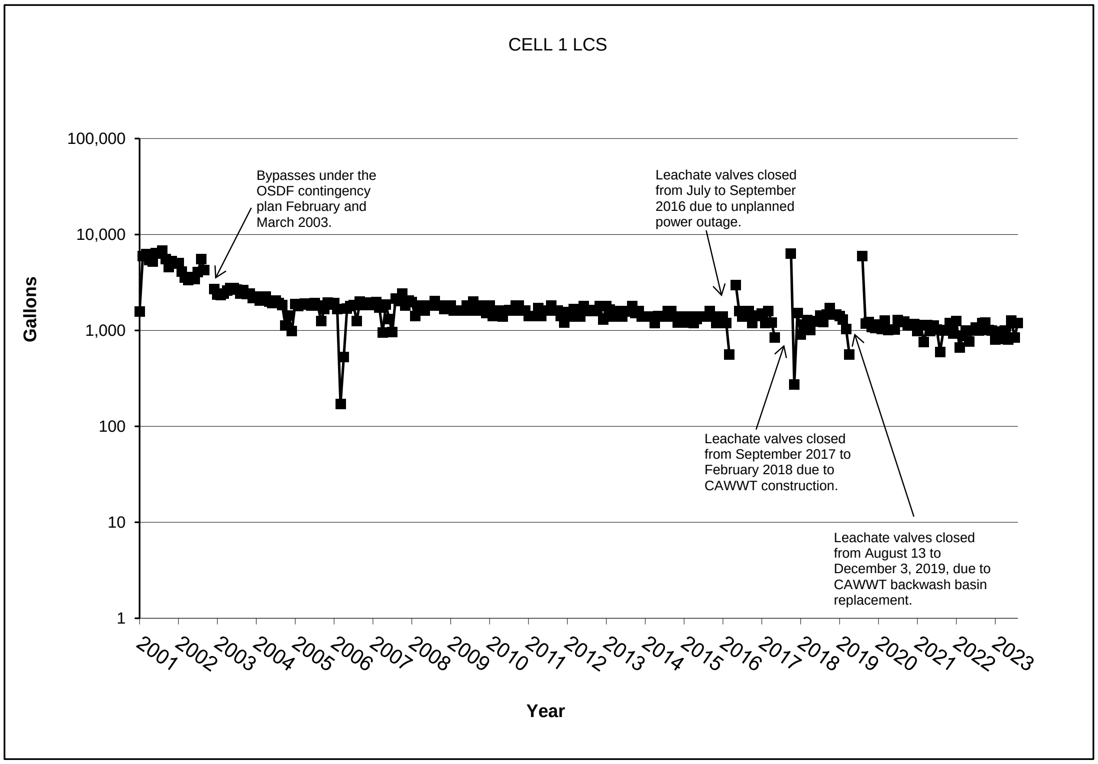

Figure A.5.1-1. Monthly Accumulation Volumes for Cell 1 LCS

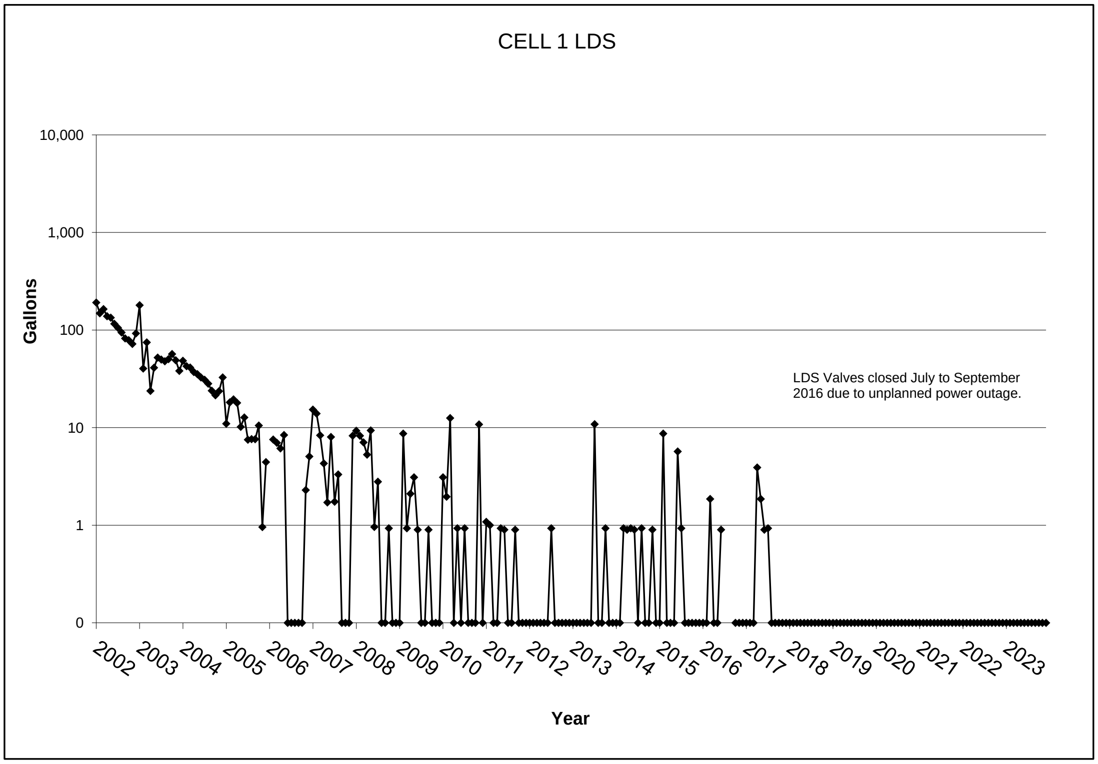

Figure A.5.1-2. Monthly Accumulation Volumes for Cell 1 LDS

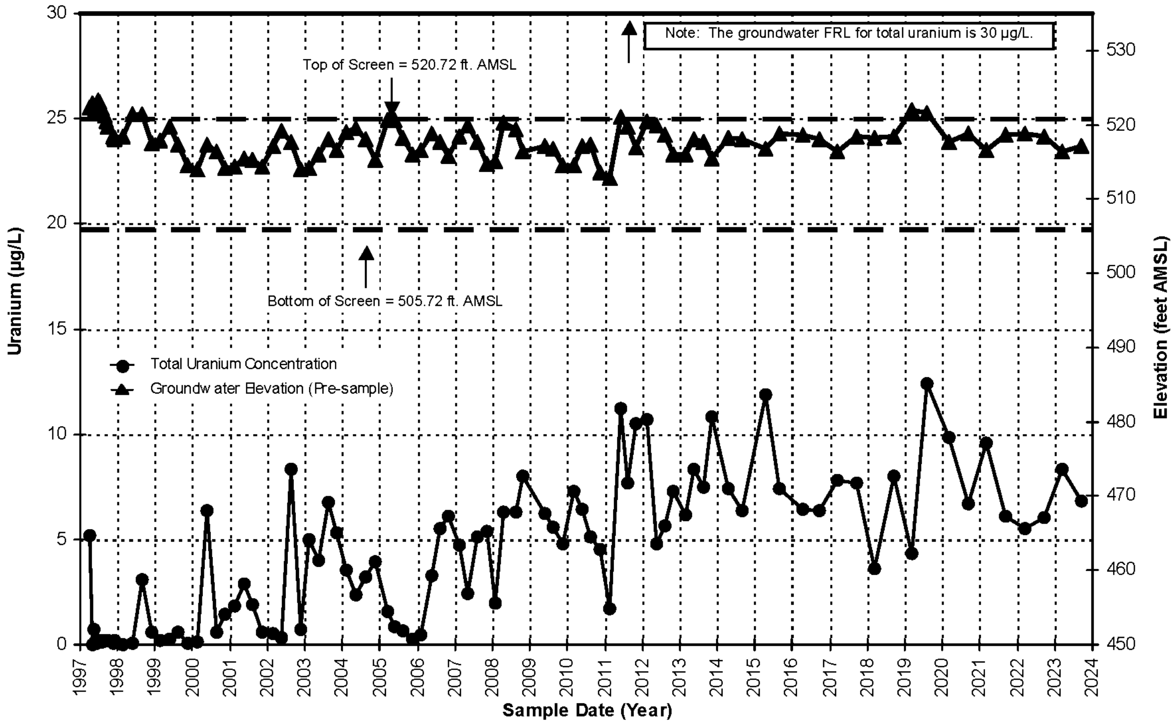

Figure A.5.1-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 1 Upgradient Monitoring Well 22201

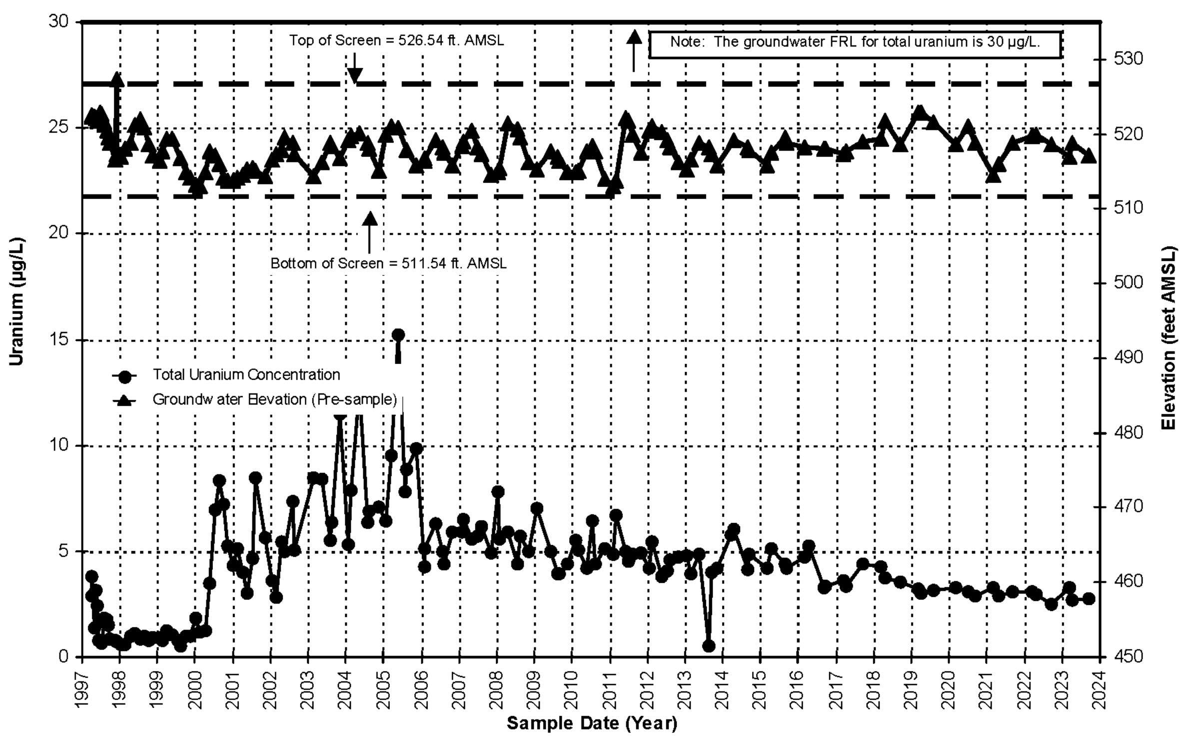

Figure A.5.1-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 1 Downgradient Monitoring Well 22198

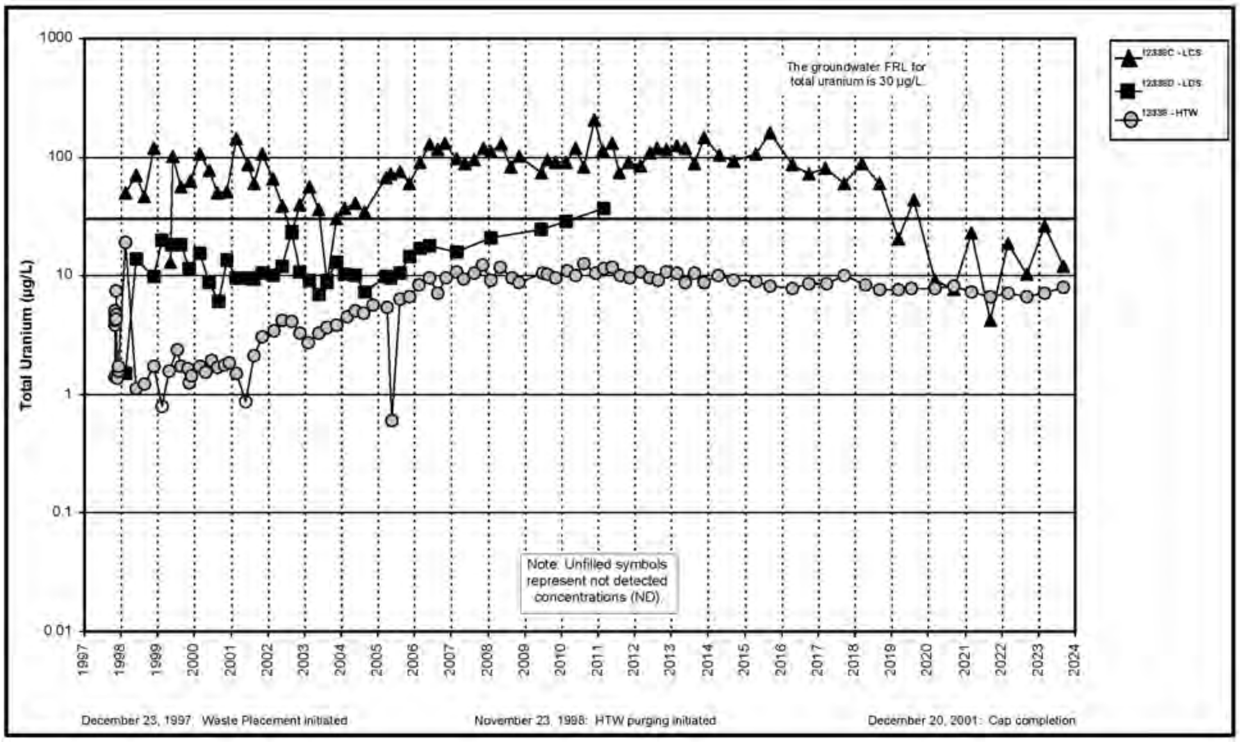

Figure A.5.1-5A. Cell 1 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

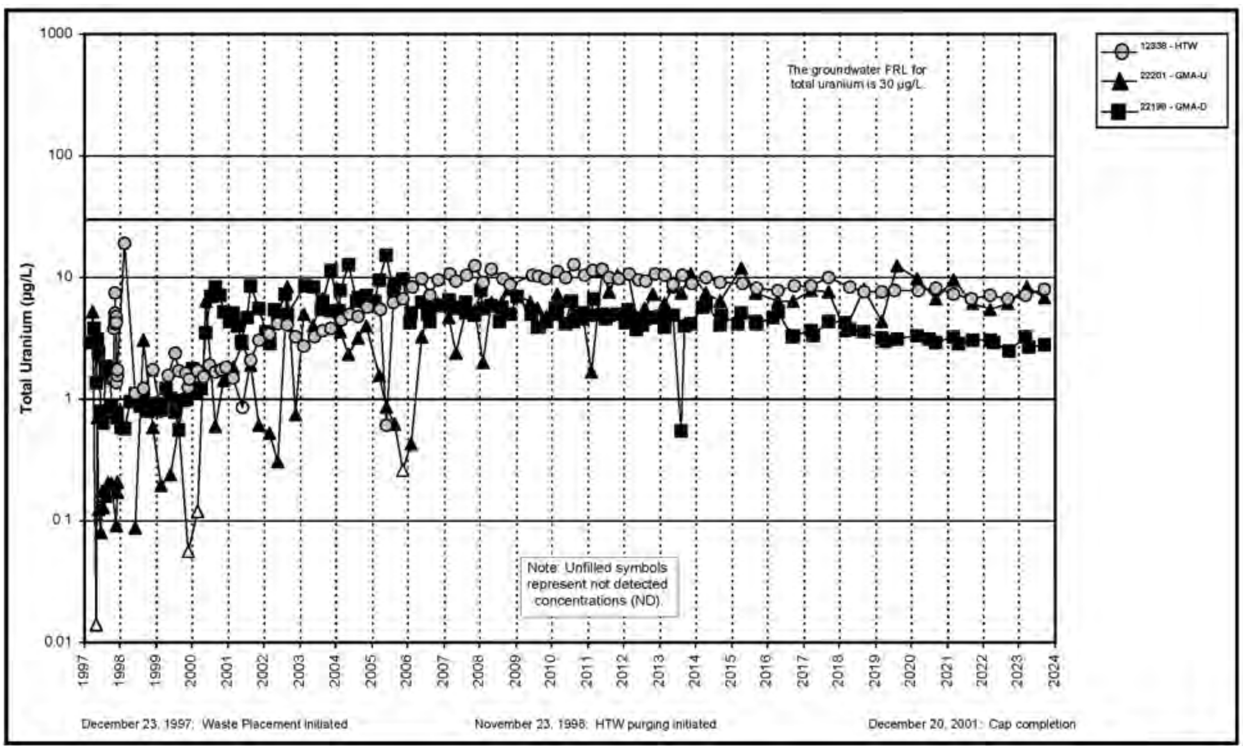

Figure A.5.1-5B. Cell 1 Total Uranium Concentration Versus Time Plot for HTW, Upgradient GMA Well, and Downgradient GMA Well

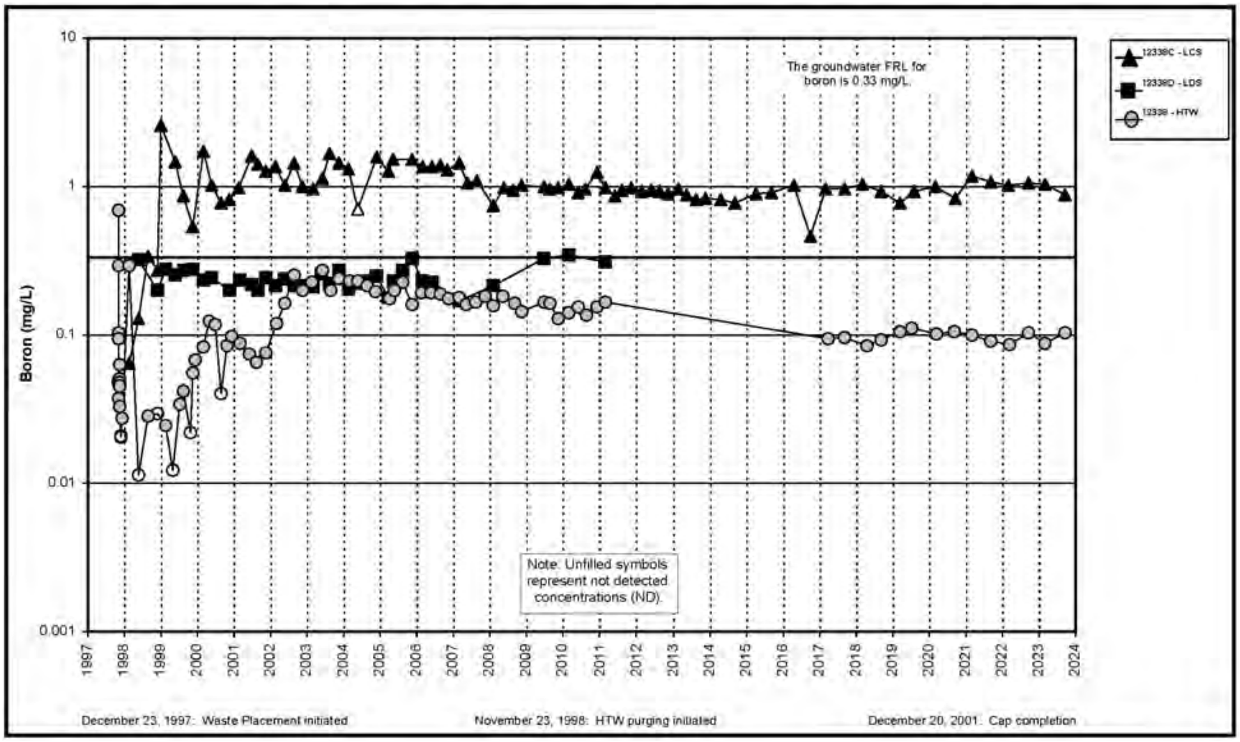

Figure A.5.1-6A. Cell 1 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

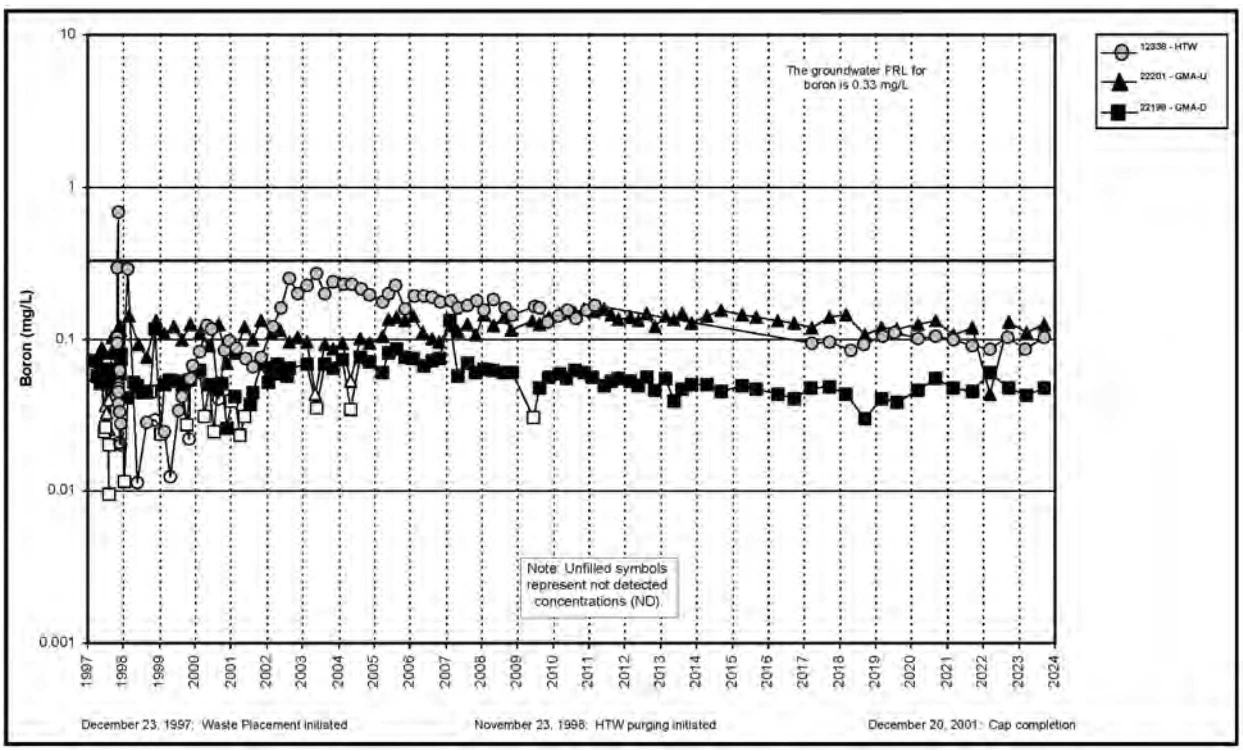

Figure A.5.1-6B. Cell 1 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

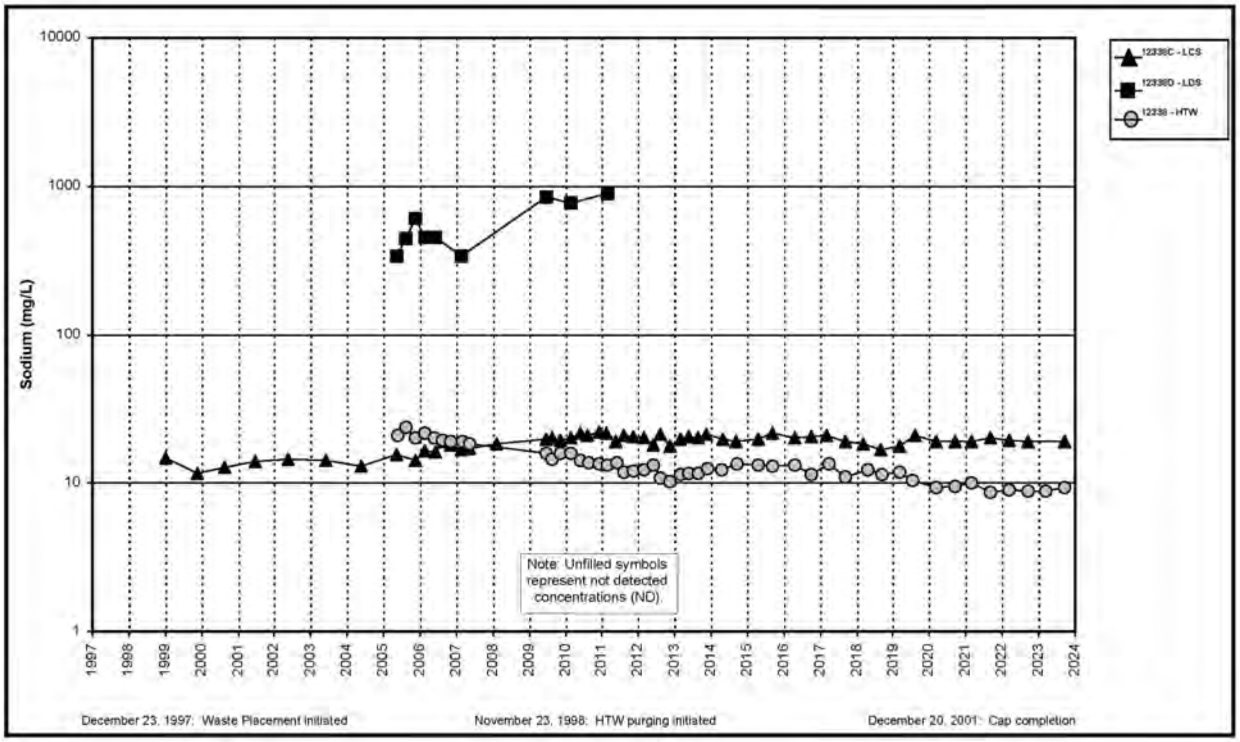

Figure A.5.1-7A. Cell 1 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

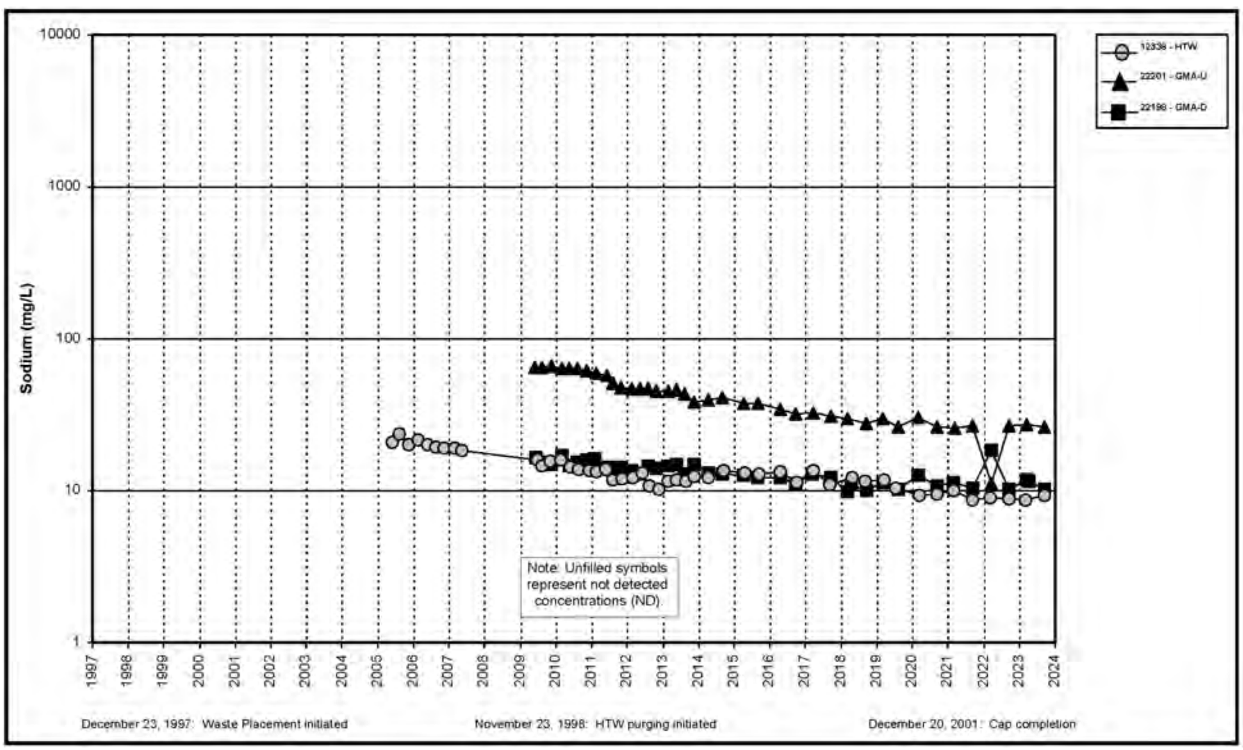

Figure A.5.1-7B. Cell 1 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

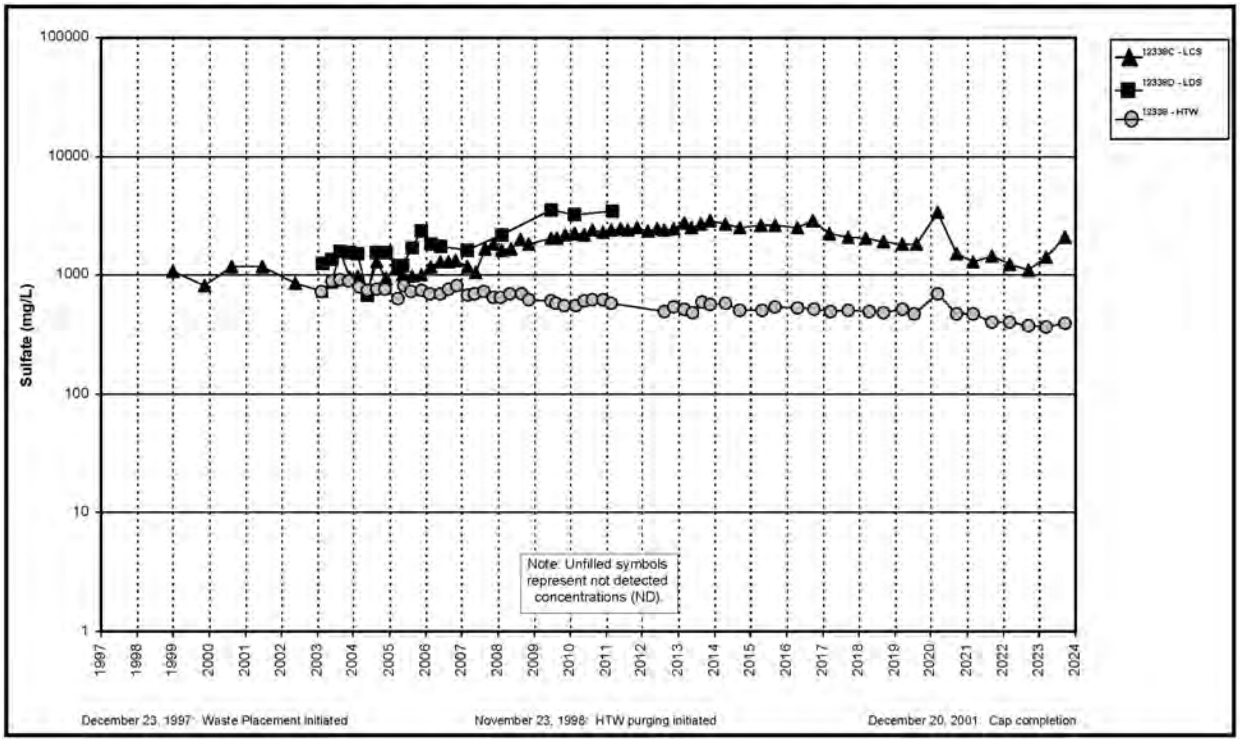

Figure A.5.1-8A. Cell 1 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

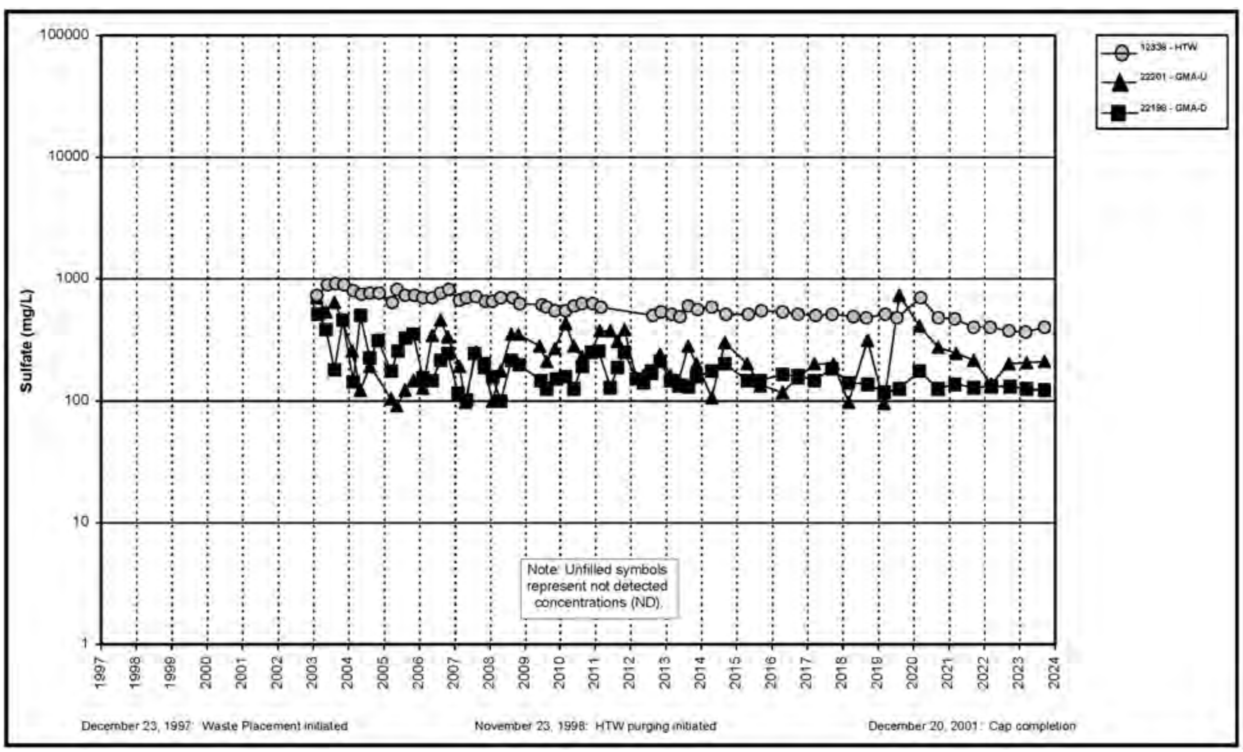

Figure A.5.1-8B. Cell 1 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

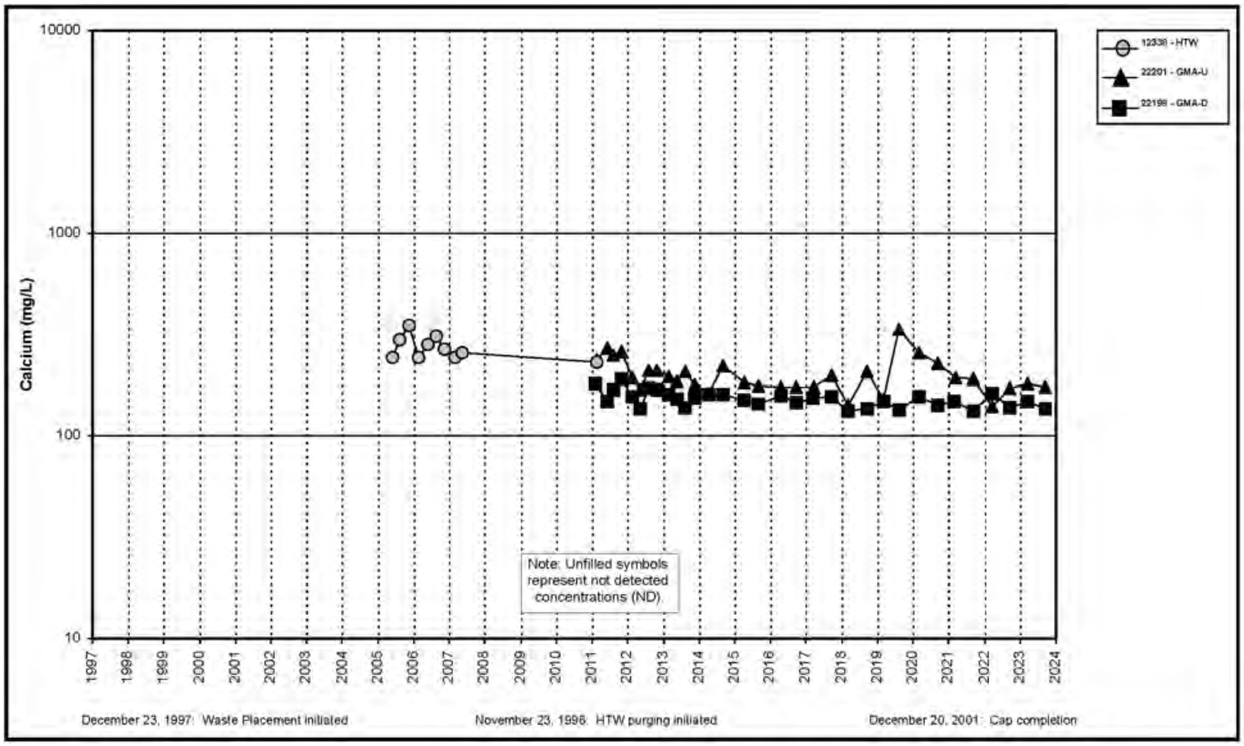

Figure A.5.1-9. Cell 1 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

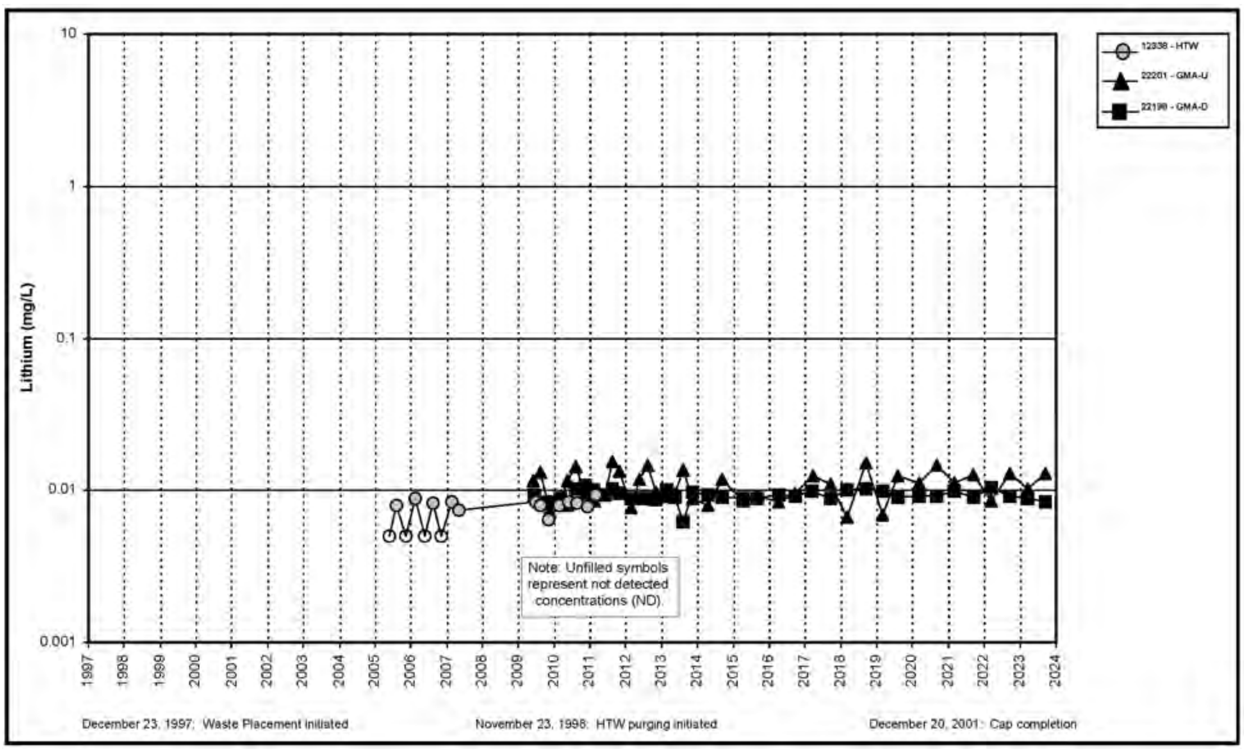

Figure A.5.1-10. Cell 1 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

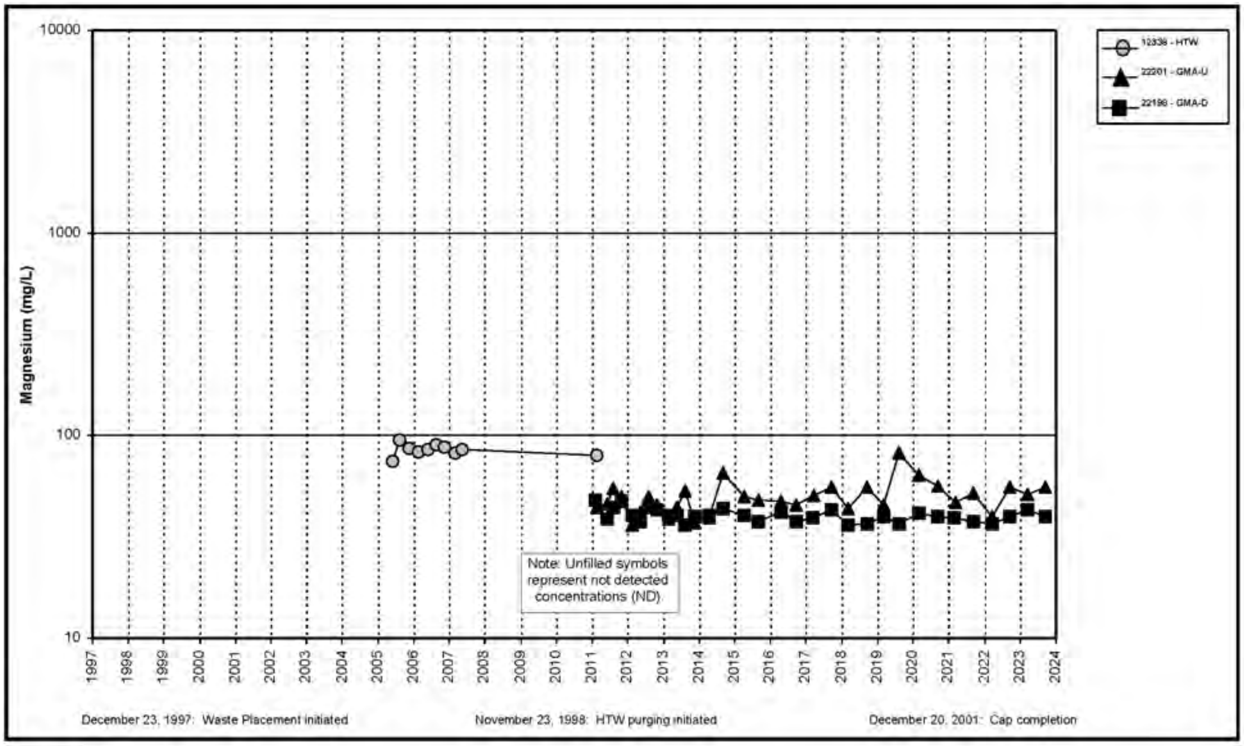

Figure A.5.1-11. Cell 1 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

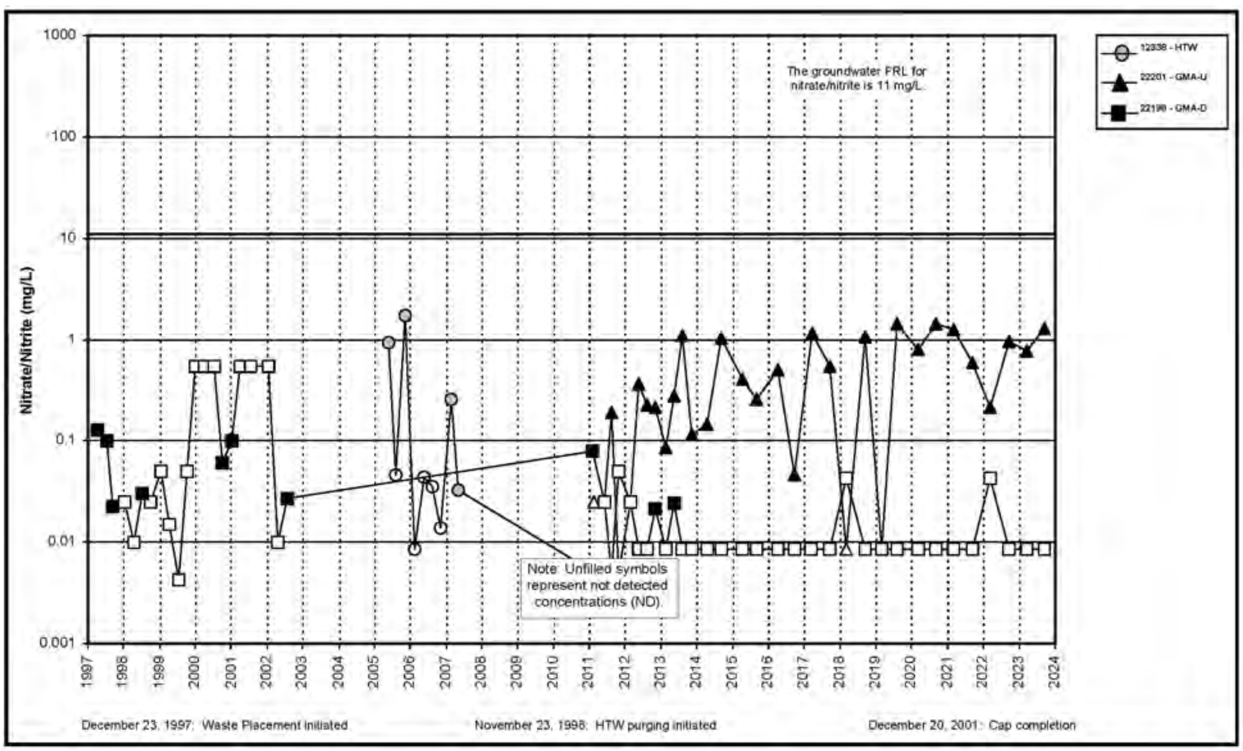

Figure A.5.1-12. Cell 1 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

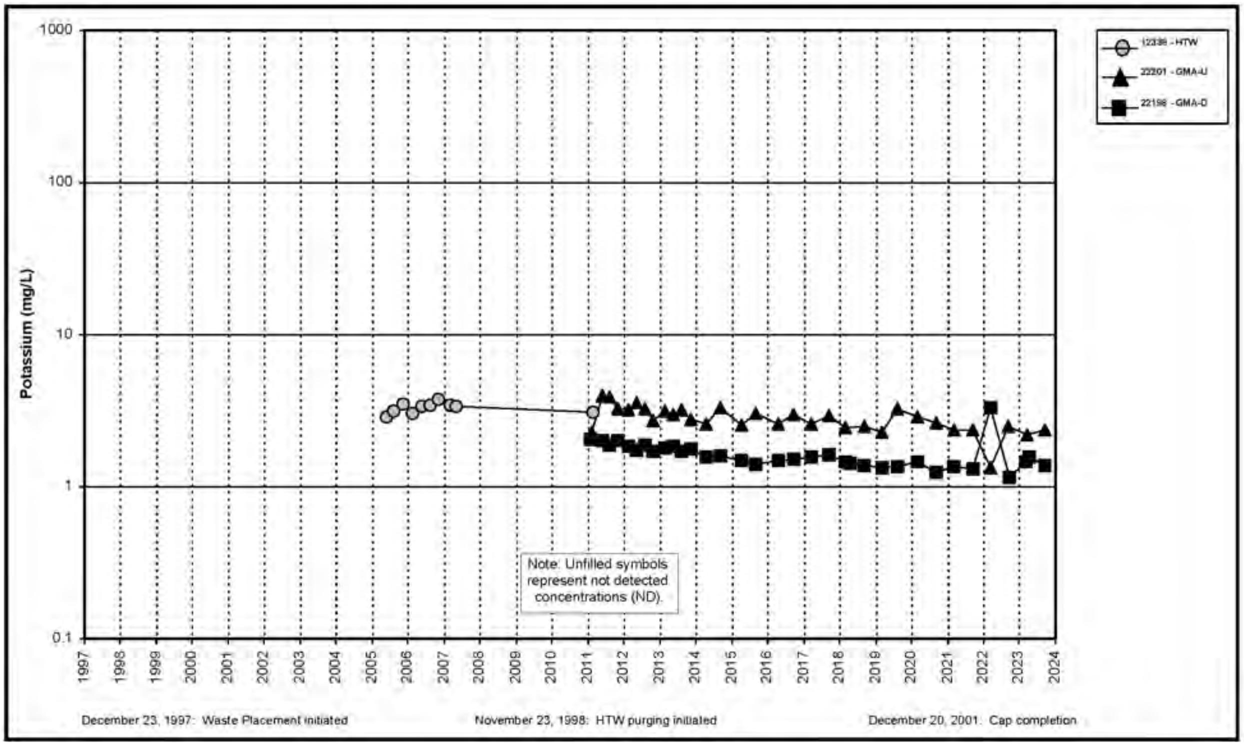

Figure A.5.1-13. Cell 1 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

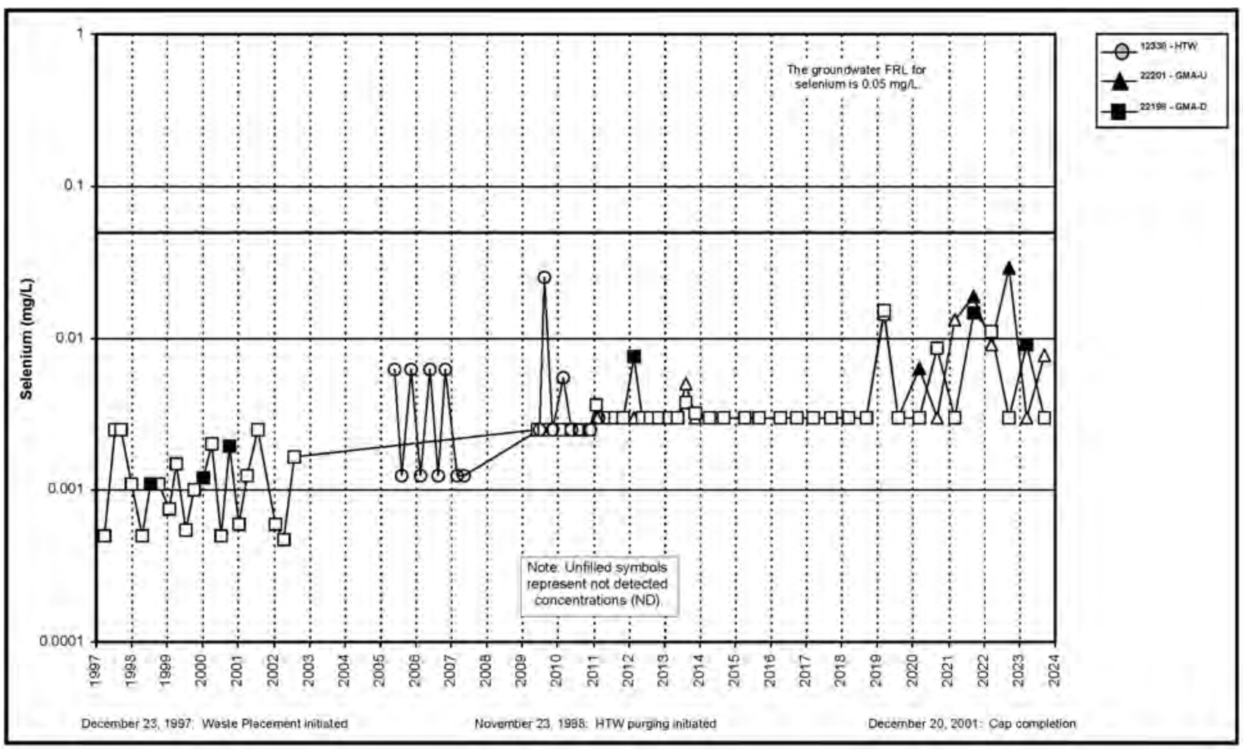

Figure A.5.1-14. Cell 1 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

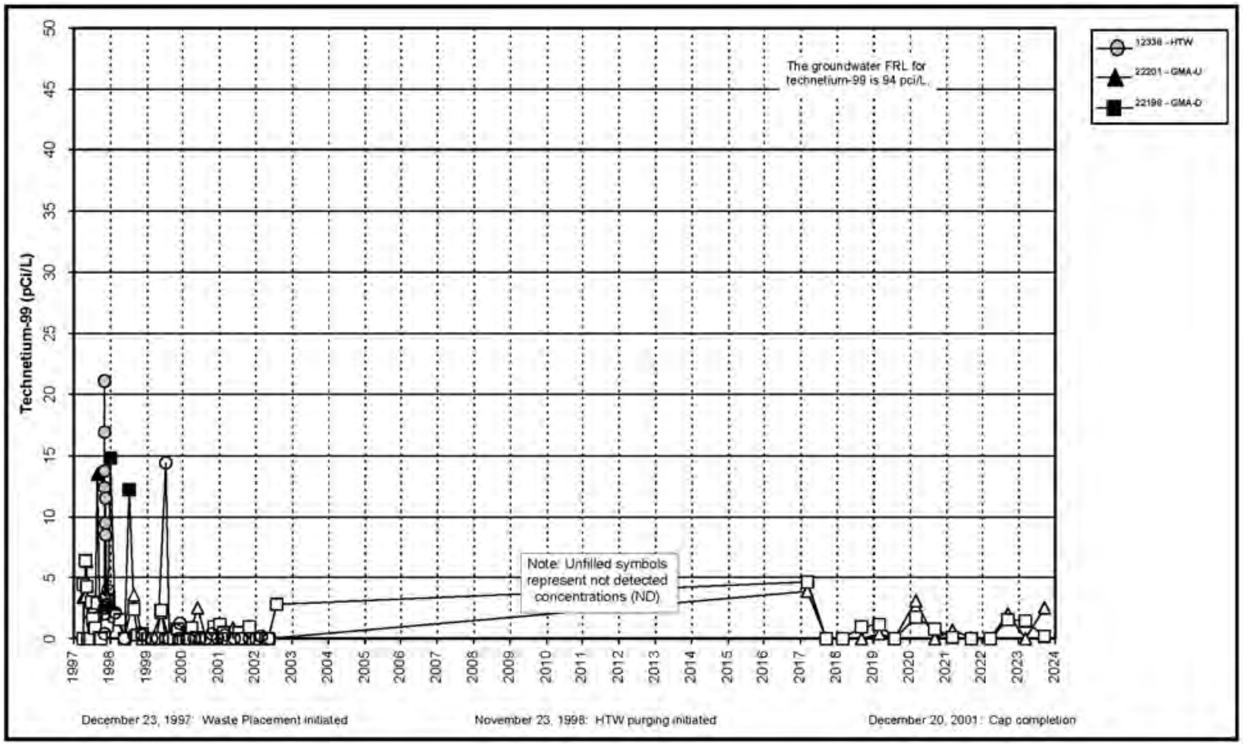

Figure A.5.1-15. Cell 1 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

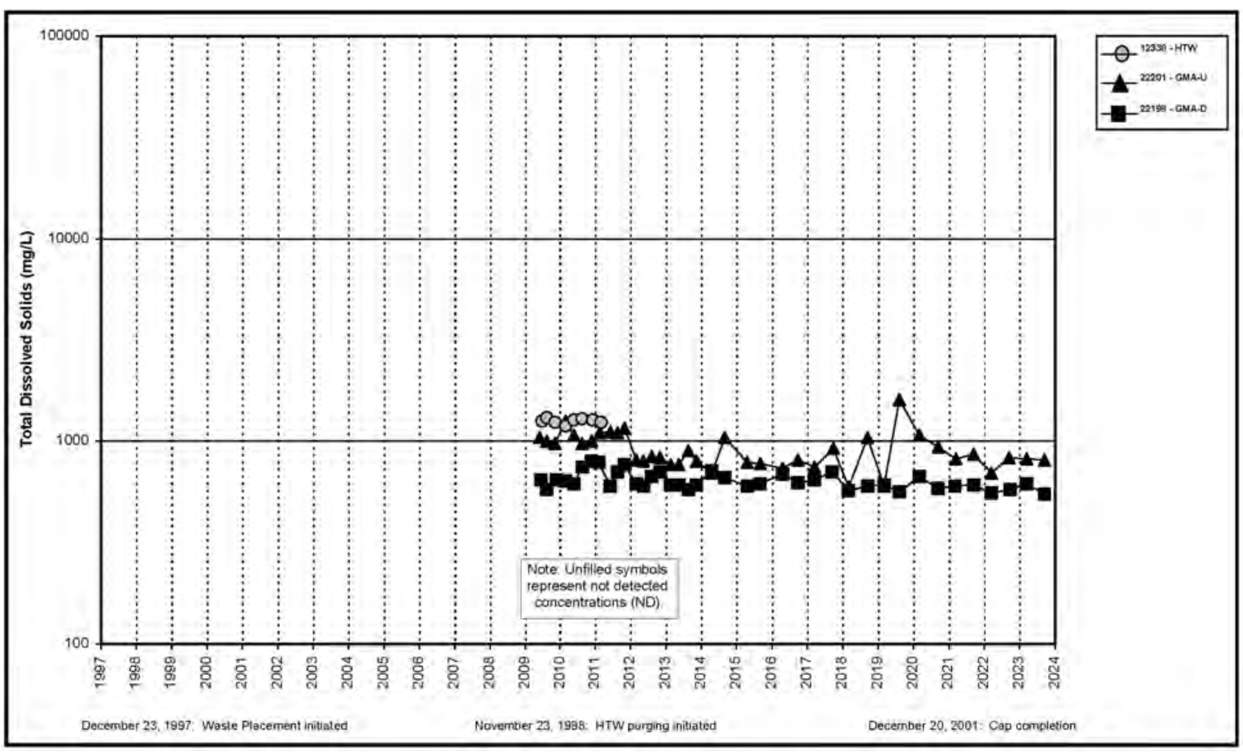

Figure A.5.1-16. Cell 1 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

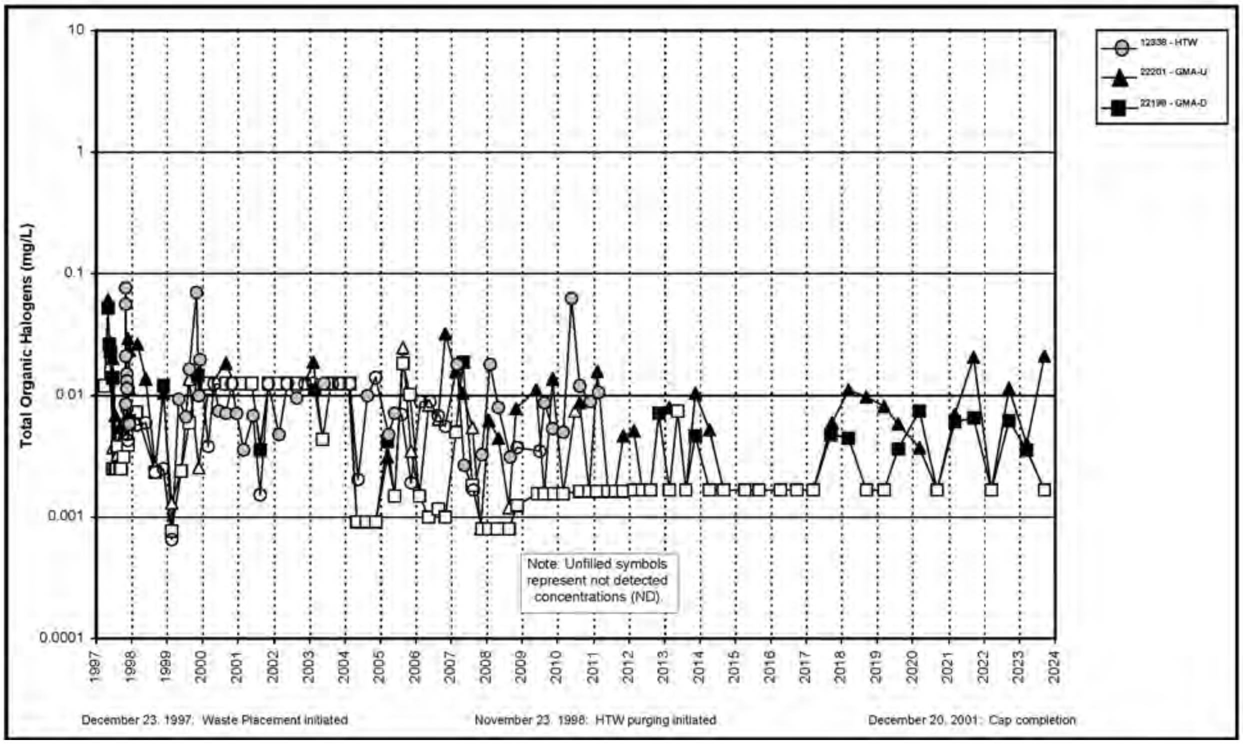

Figure A.5.1-17. Cell 1 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

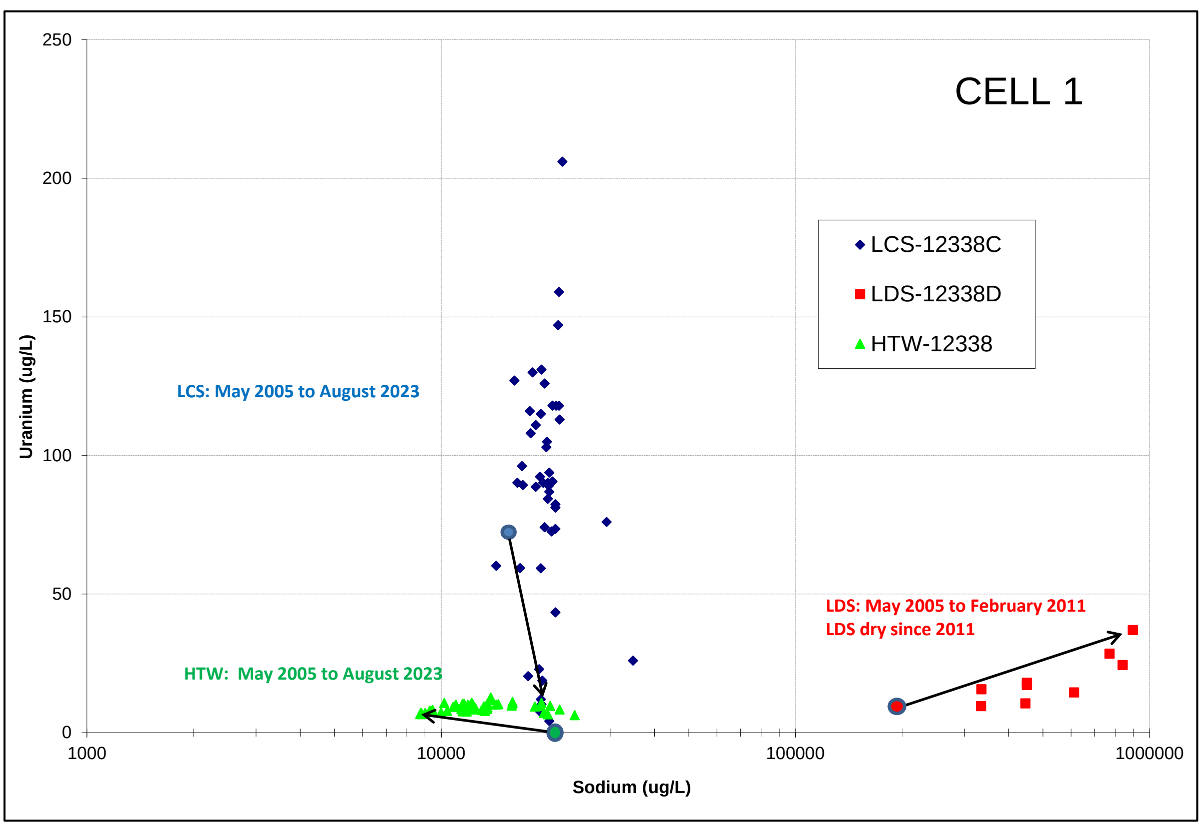

Figure A.5.1-18. Cell 1 Bivariate Plot for Uranium and Sodium

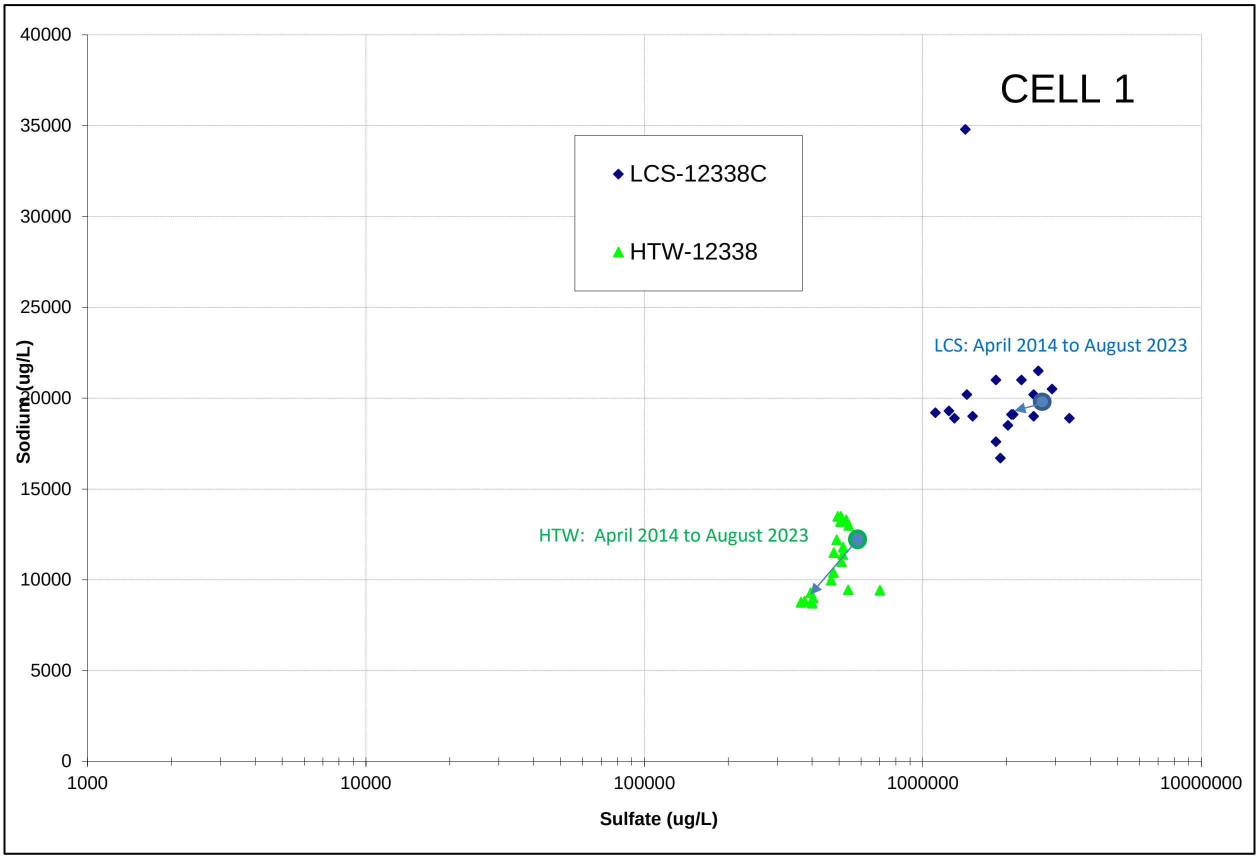

Figure A.5.1-19. Cell 1 Bivariate Plot for Sodium and Sulfate

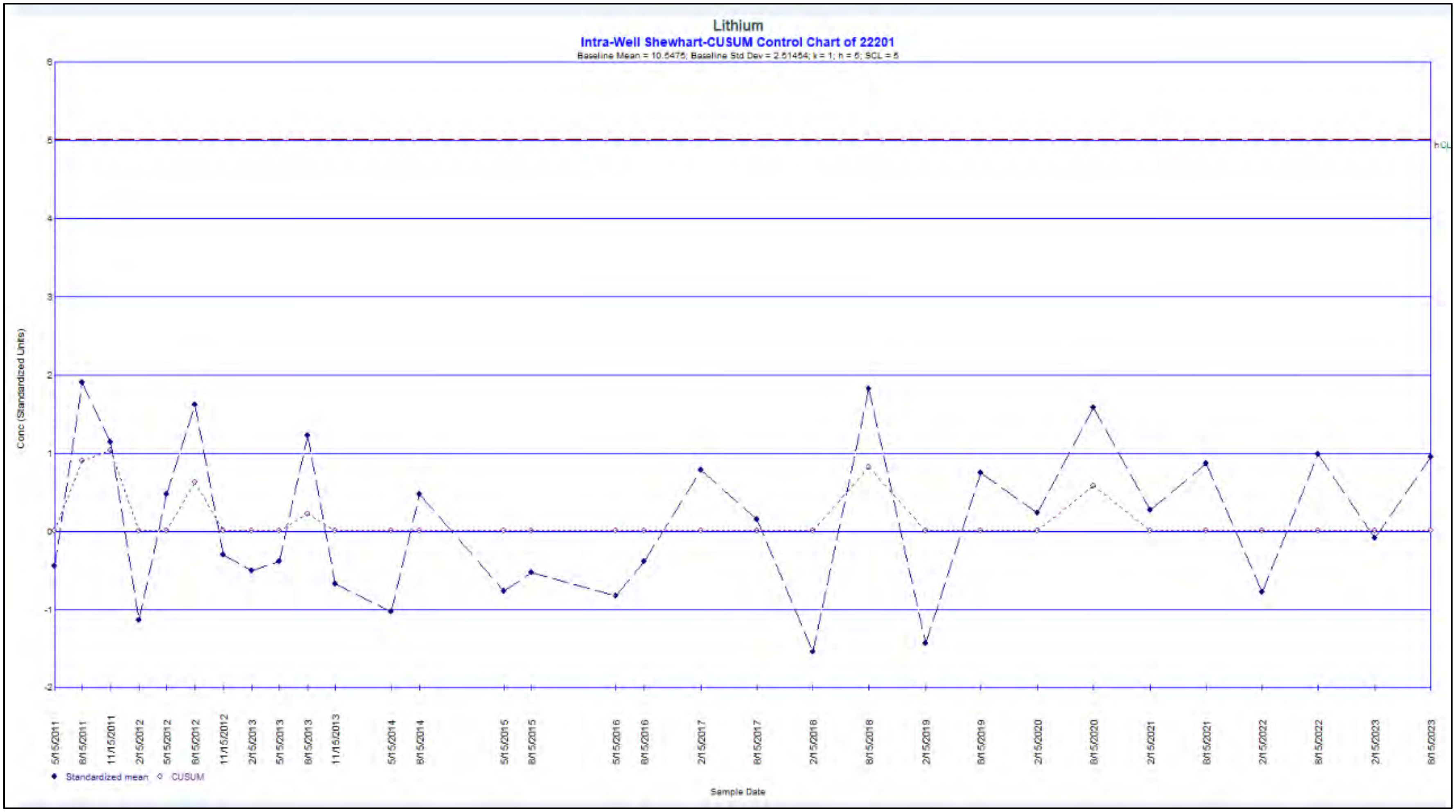

Figure A.5.1-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22201

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Subattachment A.5.2

Cell 2

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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 through A.5.2-21)

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 2023 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 2023. 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 2023 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, six parameters in 2023 (total uranium, boron, lithium, potassium, selenium, and sodium) 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	
Sodium	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, three parameters 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 three control charts (Figure A.5.2-19 through A.5.2-21). Control charts for Cell 2 indicate "in control" conditions.

Parameter	Monitoring Point[a]	Well Number	Assessment	Figure Number
Lithium	GMA-U	22200	In Control	A.5.2-19
Magnesium	GMA-U	22200	In Control	A.5.2-20
Total Dissolved Solids	GMA-D	22199	In Control	A.5.2-21

[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 2023: total uranium, boron, sodium, and sulfate. No new high concentrations were measured in the LCS of Cell 2 in 2023.
- The volume of water in the LDS tank of Cell 2 has been insufficient to collect a sample since 2013.

- Six parameters monitored semiannually in 2023 have an upward concentration trend in the HTW or GMA wells of Cell 2: total uranium, boron, lithium, potassium, selenium, and sodium. 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.
- Three control charts were constructed for Cell 2 parameters. The control charts exhibit "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	78	78	100	4.51	686	126	113	Ln Normal	Up (2023)	Dectected	
	LDS	12339D	35	35	100	4.08	71.0	14.5	13.2	Undefined	None (2013)	Dectected	
	HTW	12339	79	80	98.8	ND	36.9	11.6	6.6	Undefined	Up (2023)	Dectected	
	GMA-U	22200	66	86	76.7	ND	4.69	0.312	0.586	Undefined	Up (2023)	Not Detected	
	GMA-D	22199	91	96	94.8	ND	12.1	0.586	2.13	Undefined	Down (2023)	Not Detected	
Boron (mg/L)	LCS	12339C	79	79	100	0.207	4.78	2.71	1.08	Undefined	Up (2023)	Dectected	
	LDS	12339D	35	35	100	0.289	2.22	0.422	0.371	Undefined	Up (2013)	Dectected	
	HTW	12339	60	63	95.2	ND	0.213	0.102	0.051	Undefined	Up (2023)	Dectected	
	GMA-U	22200	74	86	86.0	ND	0.105	0.0594	0.0238	Undefined	Up (2023)	Dectected	
	GMA-D	22199	77	86	89.5	ND	0.0899	0.0497	0.0146	Normal	Up (2023)	Dectected	
Sodium (mg/L)	LCS	12339C	55	55	100	3.32	42.8	20.1	6.4	Undefined	Up (2023)	Dectected	
	LDS	12339D	10	10	100	664	2,450	1,230	540	Normal	Up (2013)	Dectected	
	HTW	12339	48	48	100	29.5	119	43.0	23.4	Undefined	Up (2023)	Dectected	
	GMA-U	22200	39	39	100	20.4	32.9	26.3	3.4	Normal	Down (2023)	Dectected	
	GMA-D	22199	41	41	100	7.94	19.5	13.1	3.5	Undefined	Down (2023)	Dectected	
Sulfate (mg/L)	LCS	12339C	67	67	100	155	1,960	1,580	310	Undefined	Up (2023)	Dectected	
	LDS	12339D	18	18	100	2,290	13,000	4,820	2,680	Ln Normal	Up (2013)	Dectected	
	HTW	12339	58	58	100	292	850	541	134	Normal	Down (2023)	Dectected	
	GMA-U	22200	63	63	100	61.1	434	129	92	Undefined	Down (2023)	Not Detected	
	GMA-D	22199	63	63	100	101	540	163	84	Undefined	None (2023)	Not Detected	
Calcium (mg/L)	GMA-U	22200	32	32	100	115	205	136	23	Undefined	Down (2023)	Not Detected	
	GMA-D	22199	32	32	100	125	193	142	18	Undefined	None (2023)	Not Detected	
Lithium (mg/L)	GMA-U	22200	39	39	100	0.00345	0.00587	0.00424	0.00054	Ln Normal	None (2023)	Not Detected	
	GMA-D	22199	39	39	100	0.0065	0.0101	0.00771	0.00074	Normal	Up (2023)	Dectected	
Magnesium (mg/L)	GMA-U	22200	32	32	100	33.1	54.9	40.9	4.7	Normal	None (2023)	Not Detected	
	GMA-D	22199	32	32	100	35.6	54.8	40.4	4.5	Undefined	None (2023)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22200	4	32	12.5	ND	0.2	0.0085	0.0396	Undefined	None (2023)	Not Detected	
	GMA-D	22199	2	32	6.2	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22200	32	32	100	1.50	2.33	1.90	0.21	Normal	Up (2023)	Dectected	
	GMA-D	22199	34	34	100	1.23	1.75	1.44	0.11	Normal	Down (2023)	Not Detected	
Selenium (mg/L)	GMA-U	22200	6	39	15.4	ND	0.0134	0.0030	0.0030	Undefined	Up (2023)	Dectected	
	GMA-D	22199	2	39	5.1	ND	0.0186	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22200	0	35	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22199	0	35	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22200	39	39	100	497	857	613	93	Undefined	None (2023)	Not Detected	
	GMA-D	22199	39	39	100	520	820	644	72	Normal	None (2023)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22200	33	86	38.4	ND	0.177	0.00453	0.0238	Undefined	Down (2023)	Dectected	
	GMA-D	22199	21	86	24.4	ND	0.0775	0.00253	0.0115	Undefined	Down (2023)	Dectected	

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 has 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: Ln Normal 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
2023	1,500	2	750

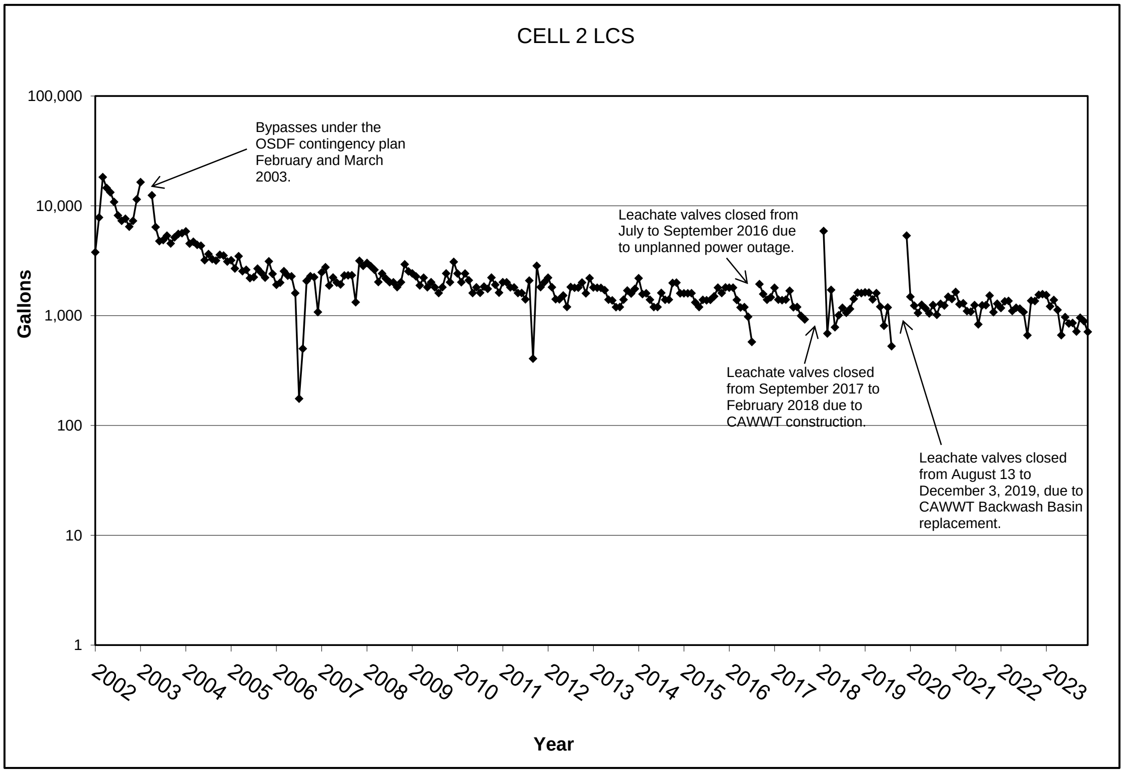

Figure A.5.2-1. Monthly Accumulation Volumes for Cell 2 LCS

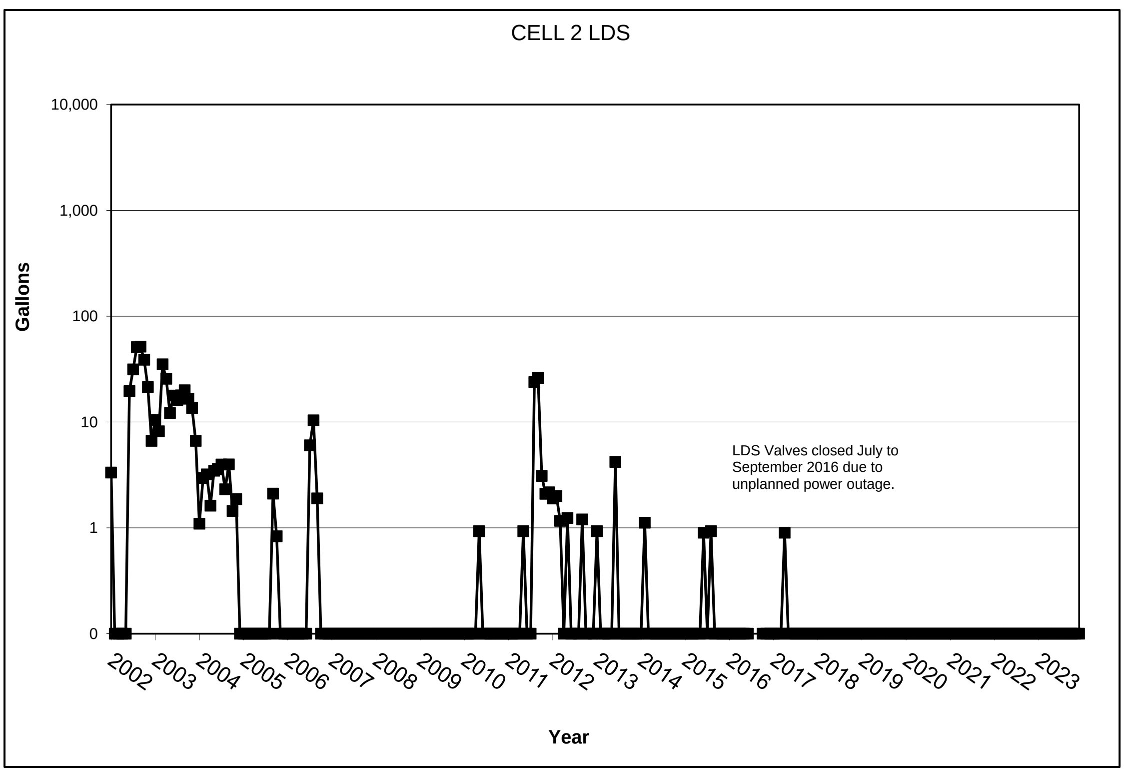

Figure A.5.2-2. Monthly Accumulation Volumes for Cell 2 LDS

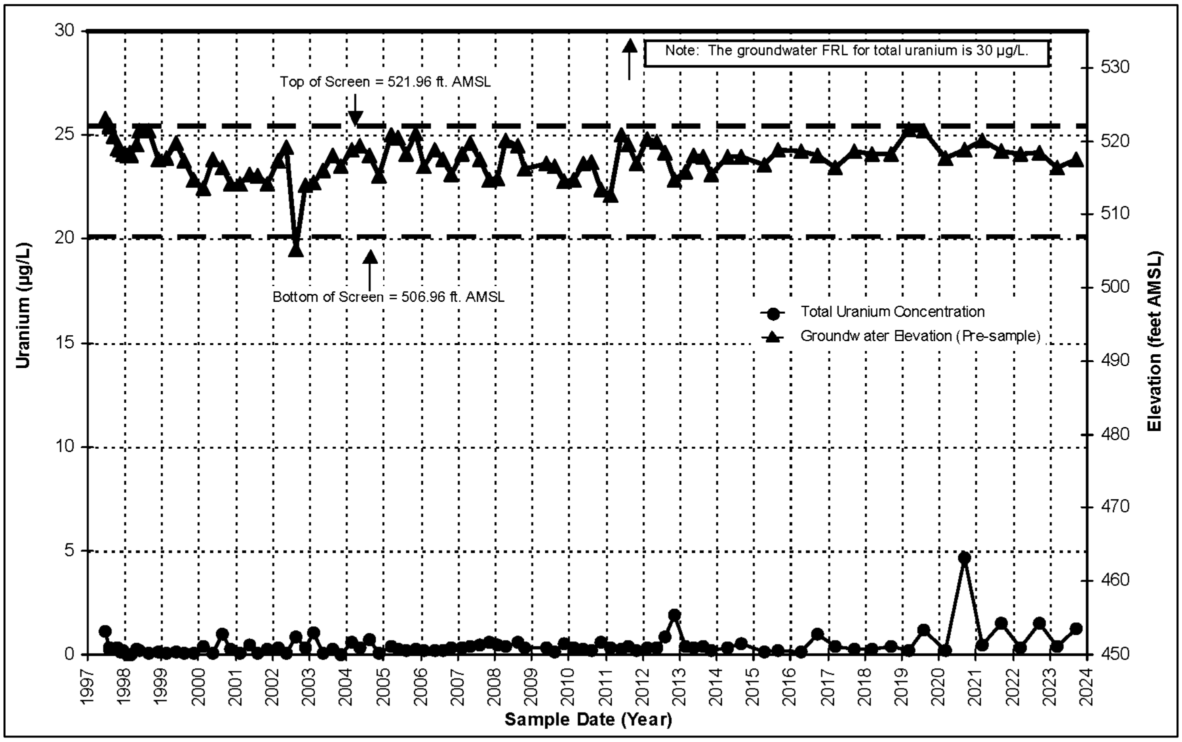

Figure A.5.2-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 2 Upgradient Monitoring Well 22200

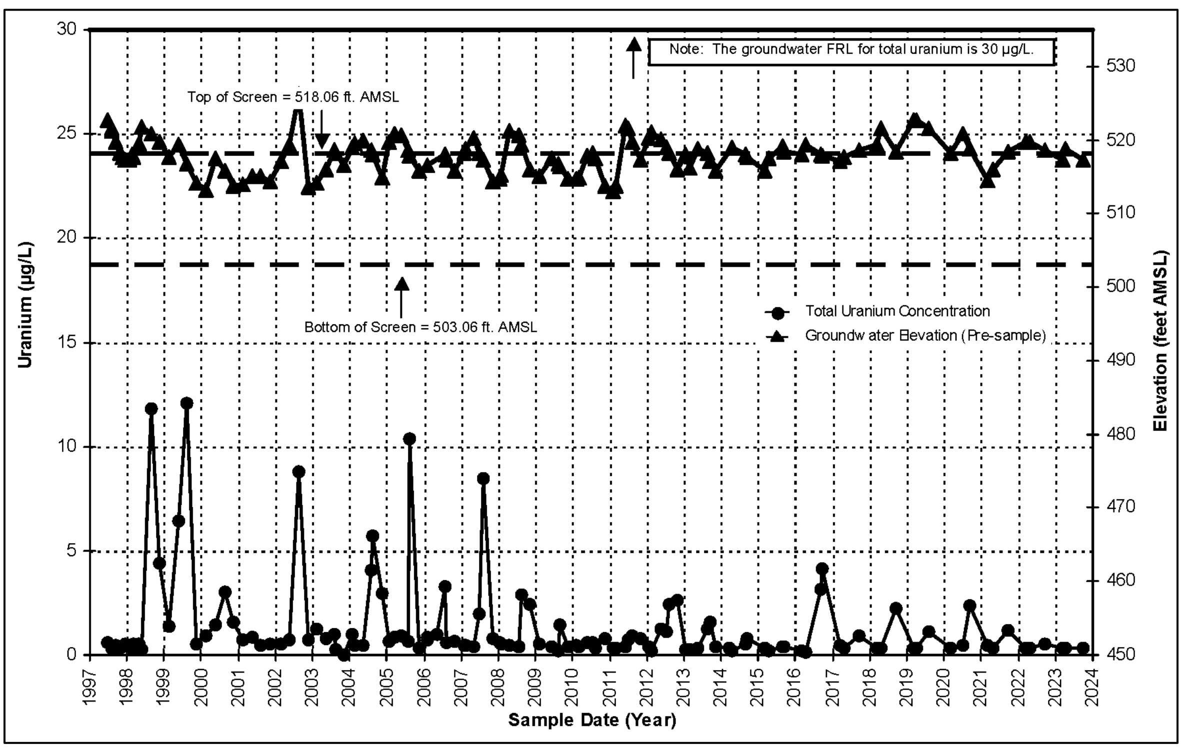

Figure A.5.2-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 2 Downgradient Monitoring Well 22199

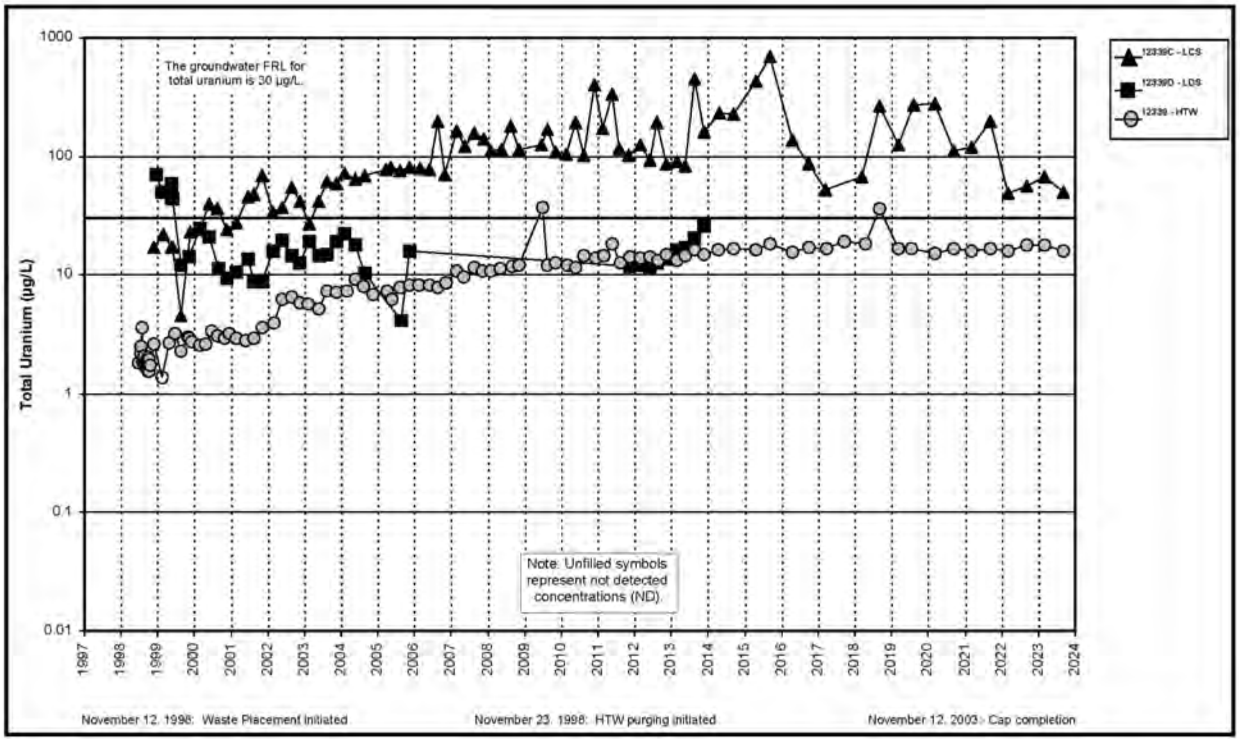

Figure A.5.2-5A. Cell 2 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

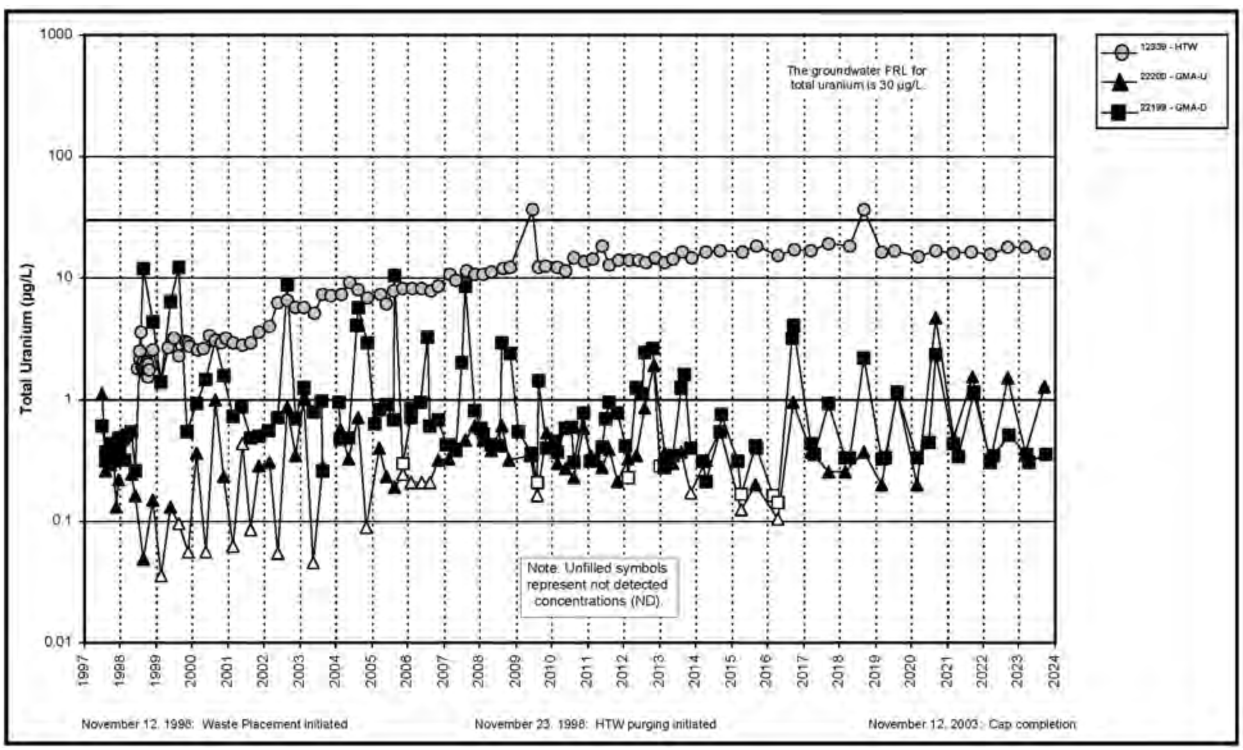

Figure A.5.2-5B. Cell 2 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

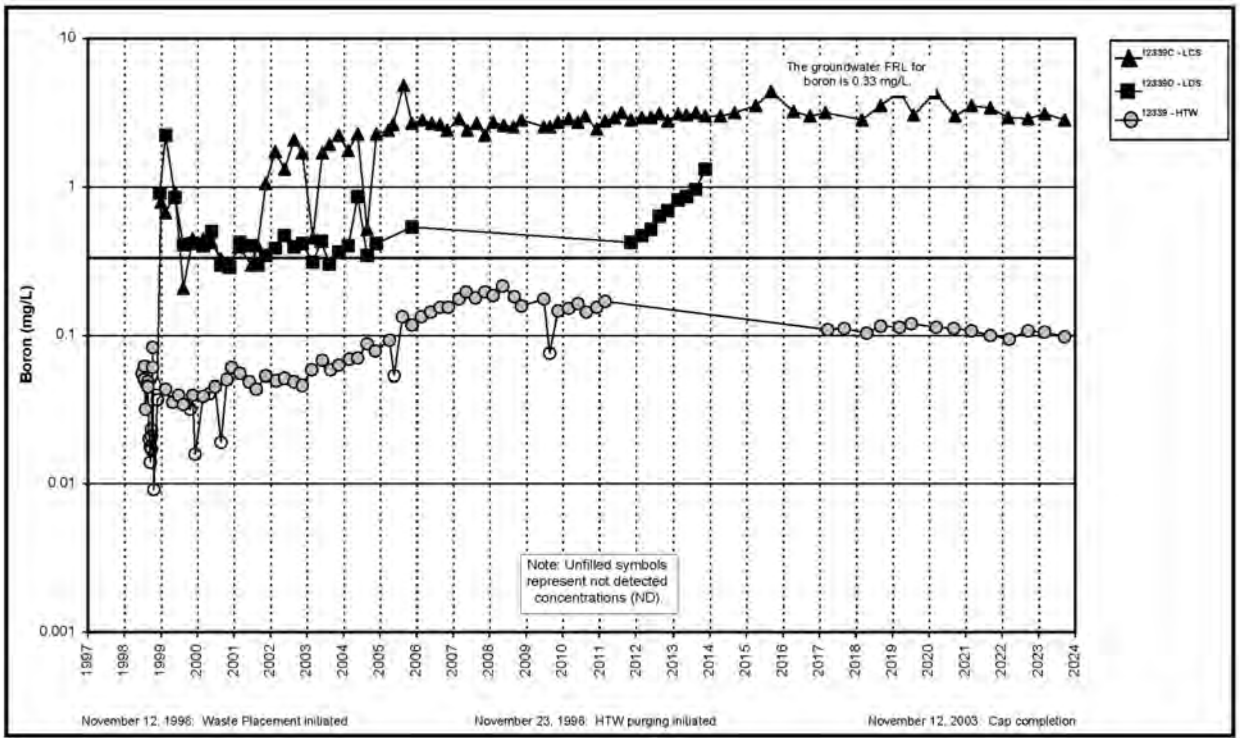

Figure A.5.2-6A. Cell 2 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

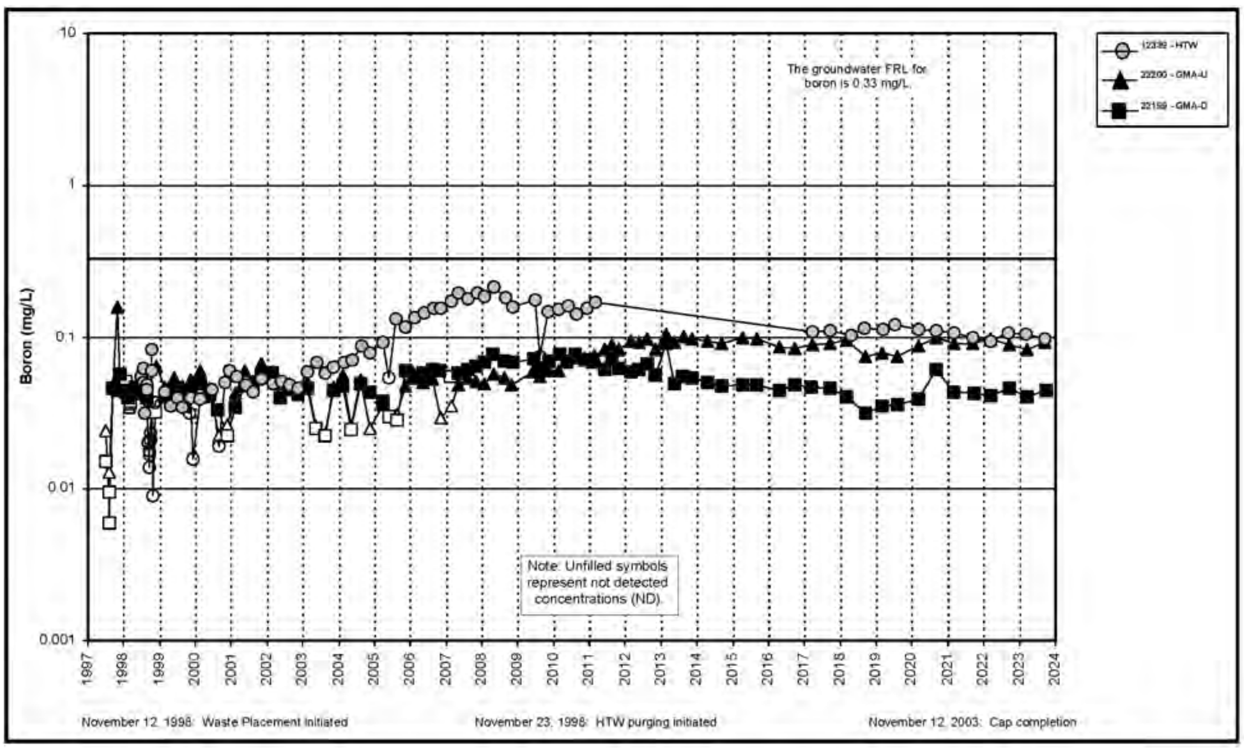

Figure A.5.2-6B. Cell 2 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

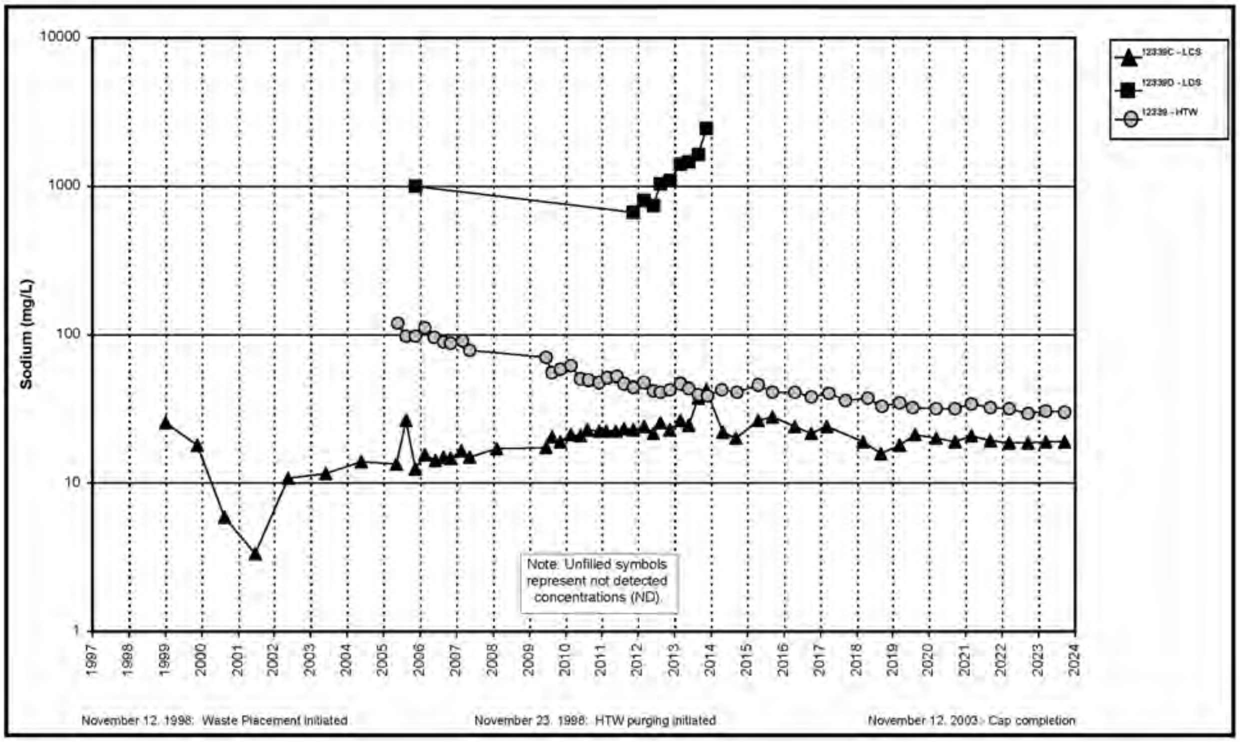

Figure A.5.2-7A. Cell 2 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

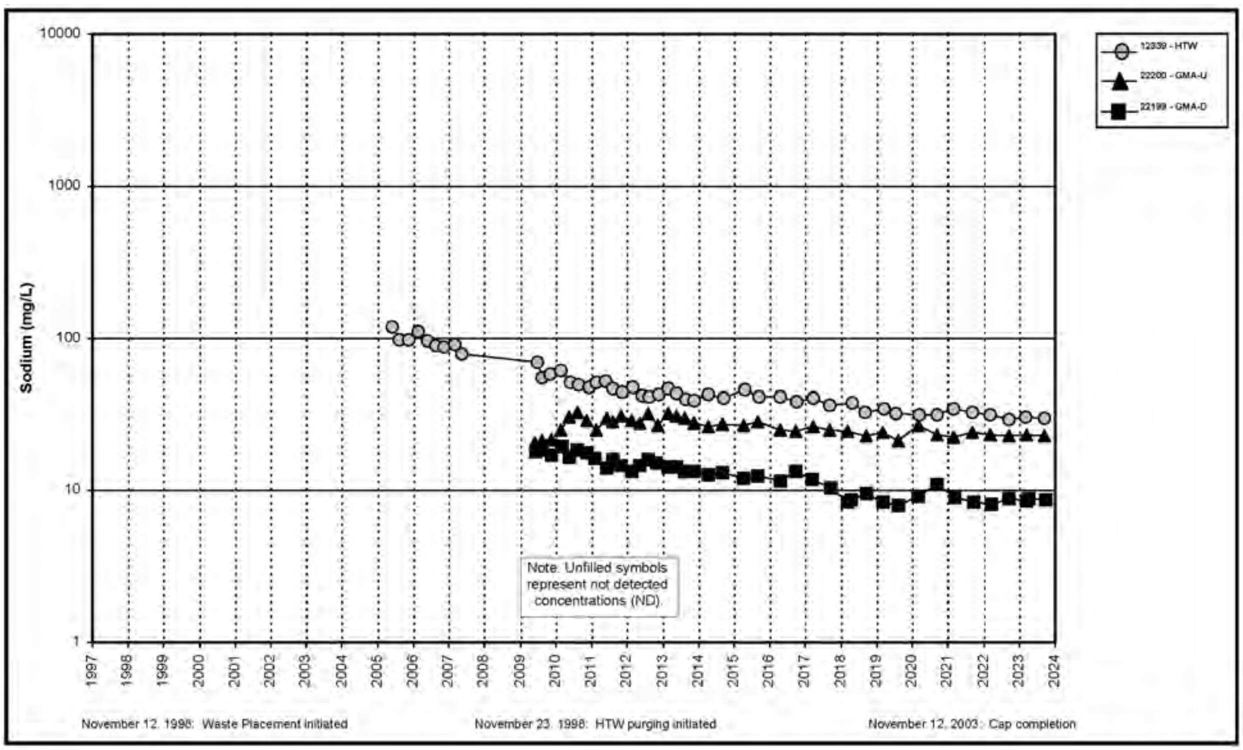

Figure A.5.2-7B. Cell 2 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

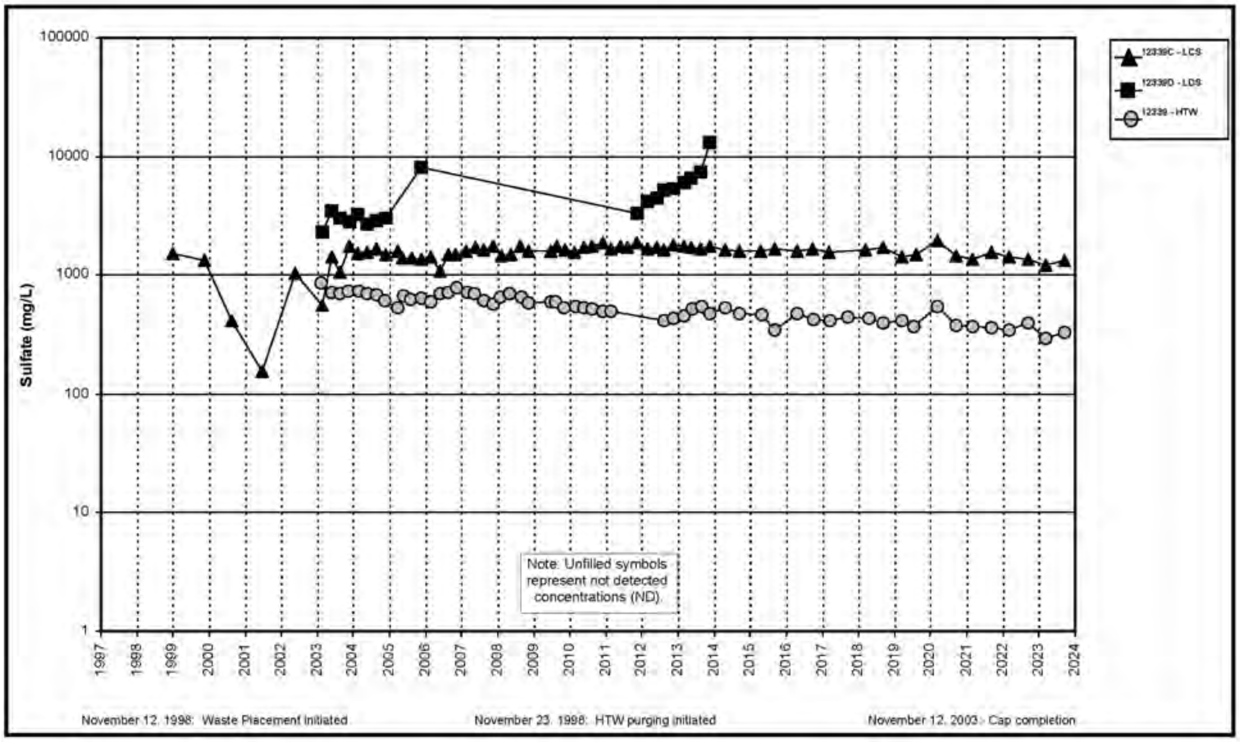

Figure A.5.2-8A. Cell 2 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

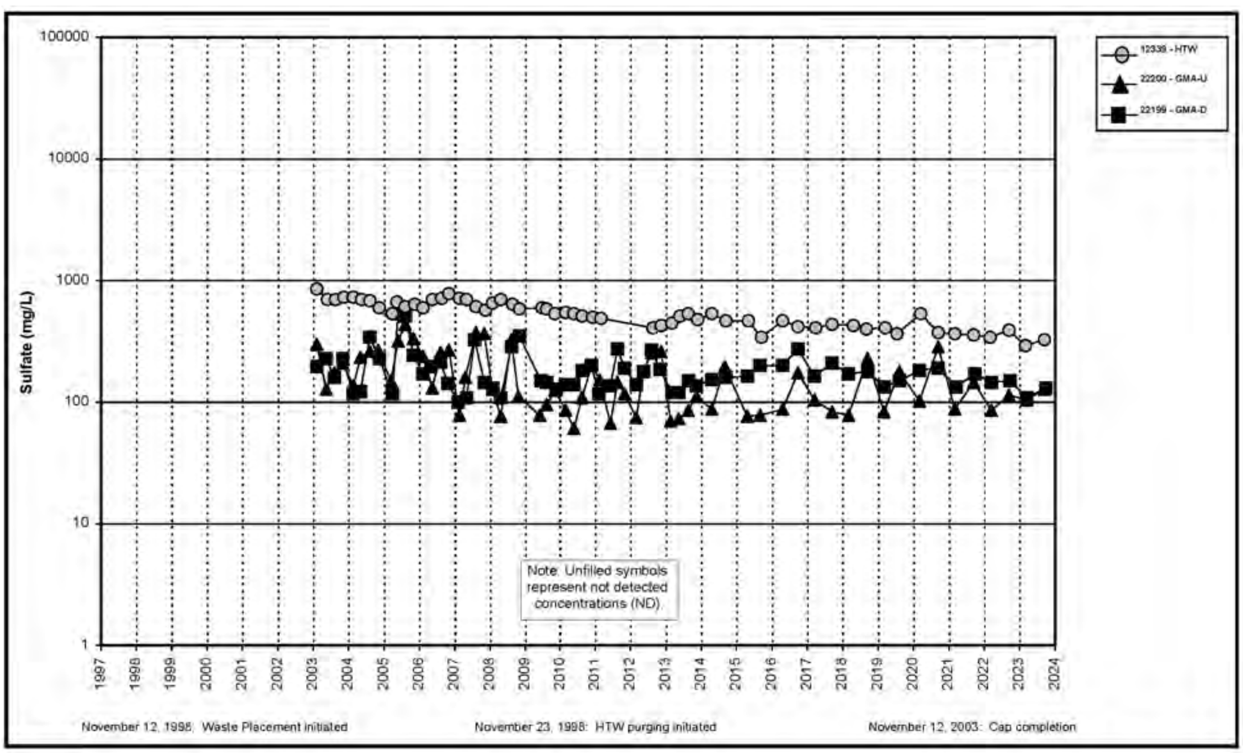

Figure A.5.2-8B. Cell 2 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

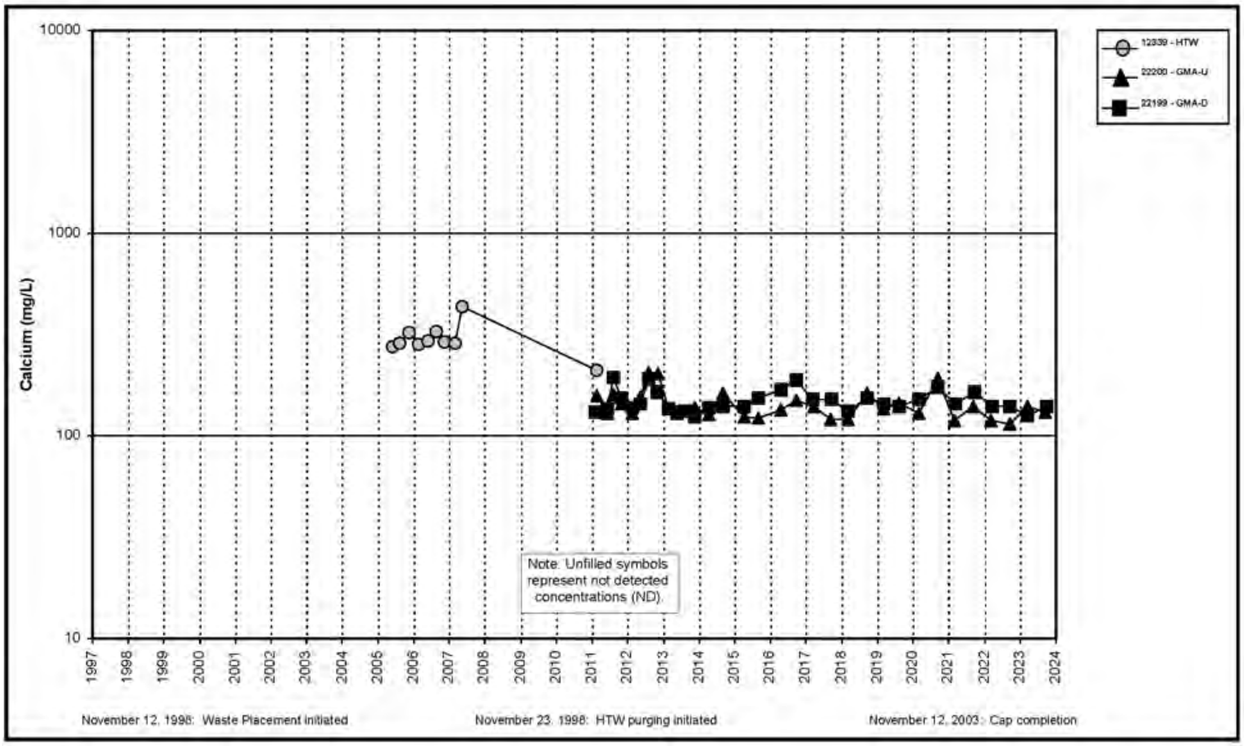

Figure A.5.2-9. Cell 2 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

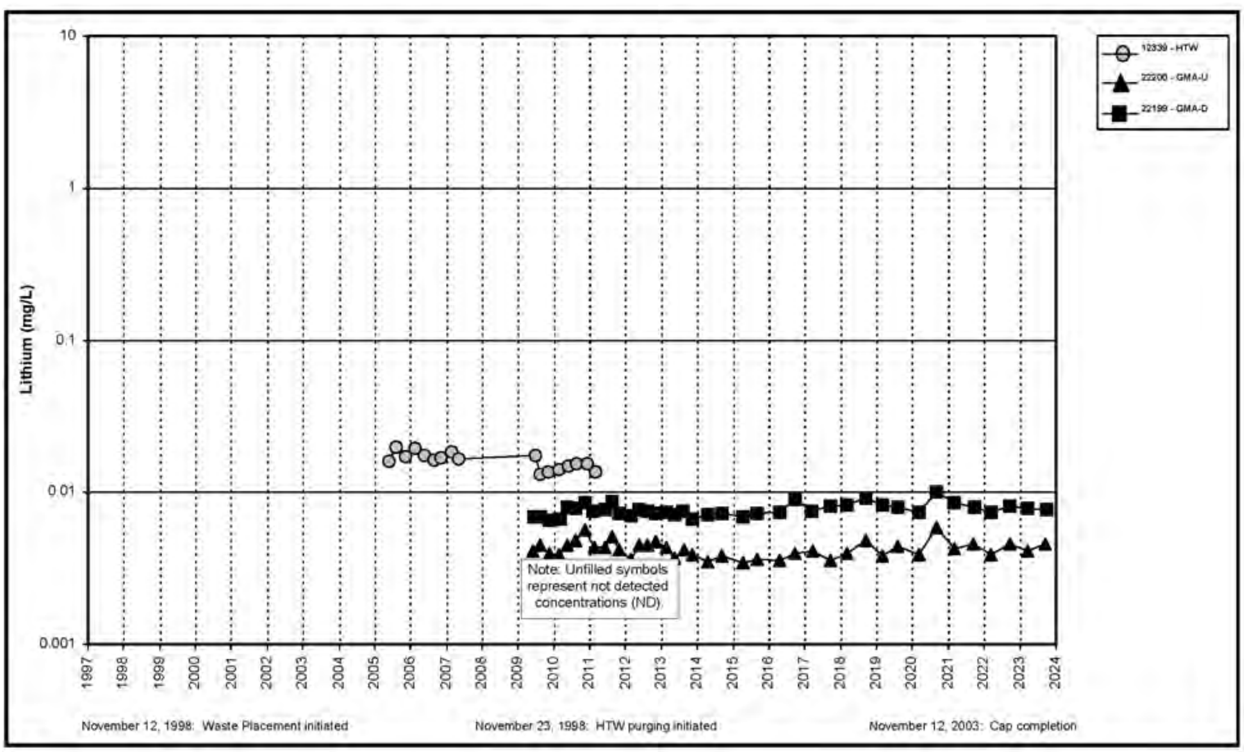

Figure A.5.2-10. Cell 2 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

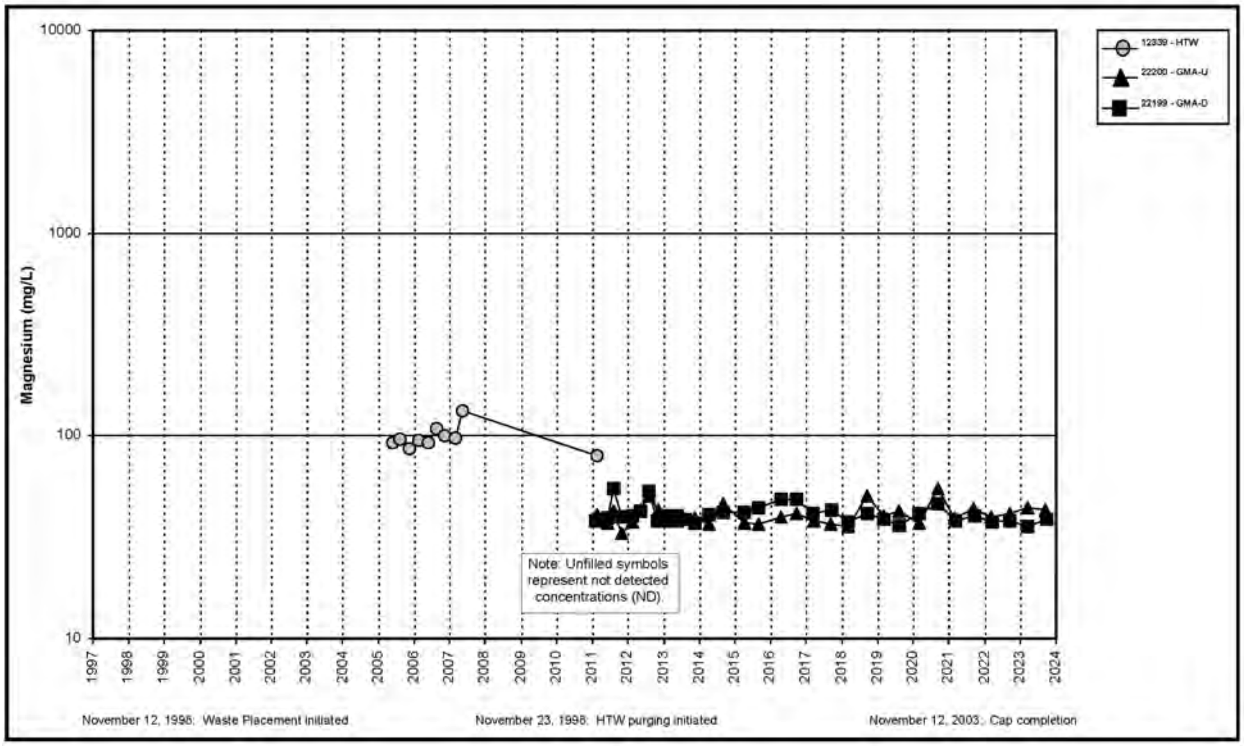

Figure A.5.2-11. Cell 2 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

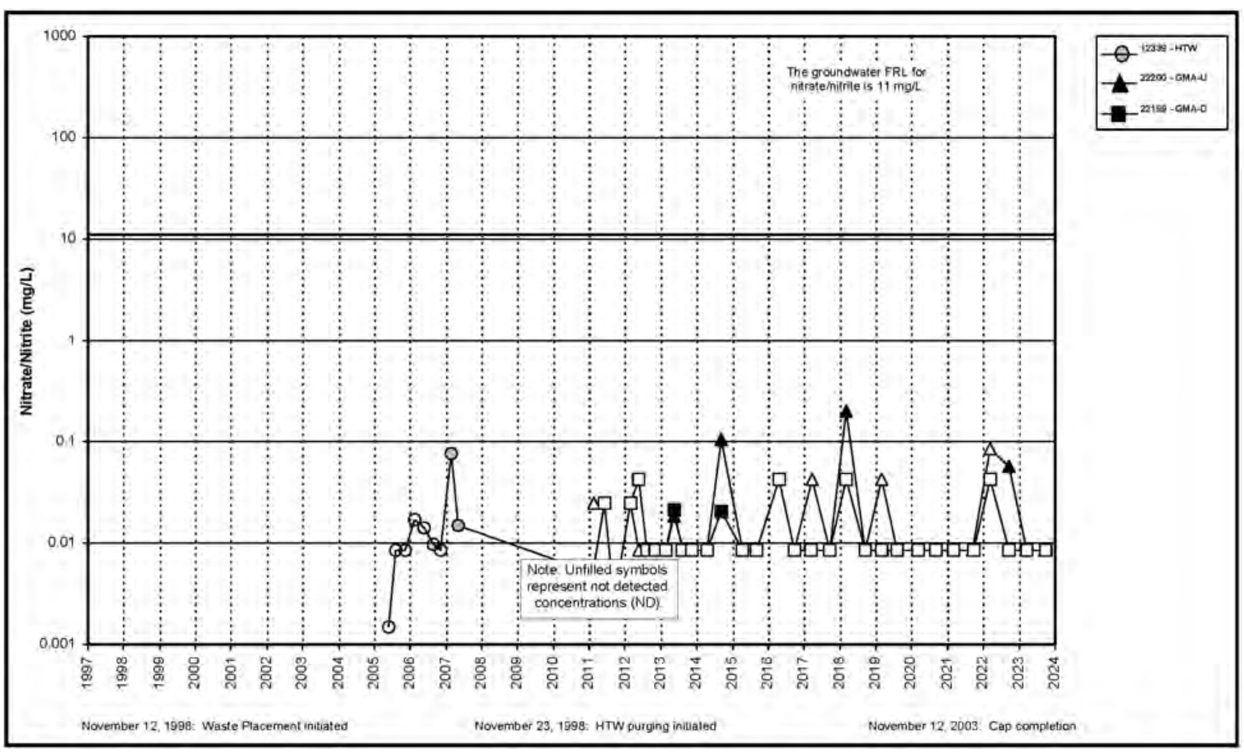

Figure A.5.2-12. Cell 2 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

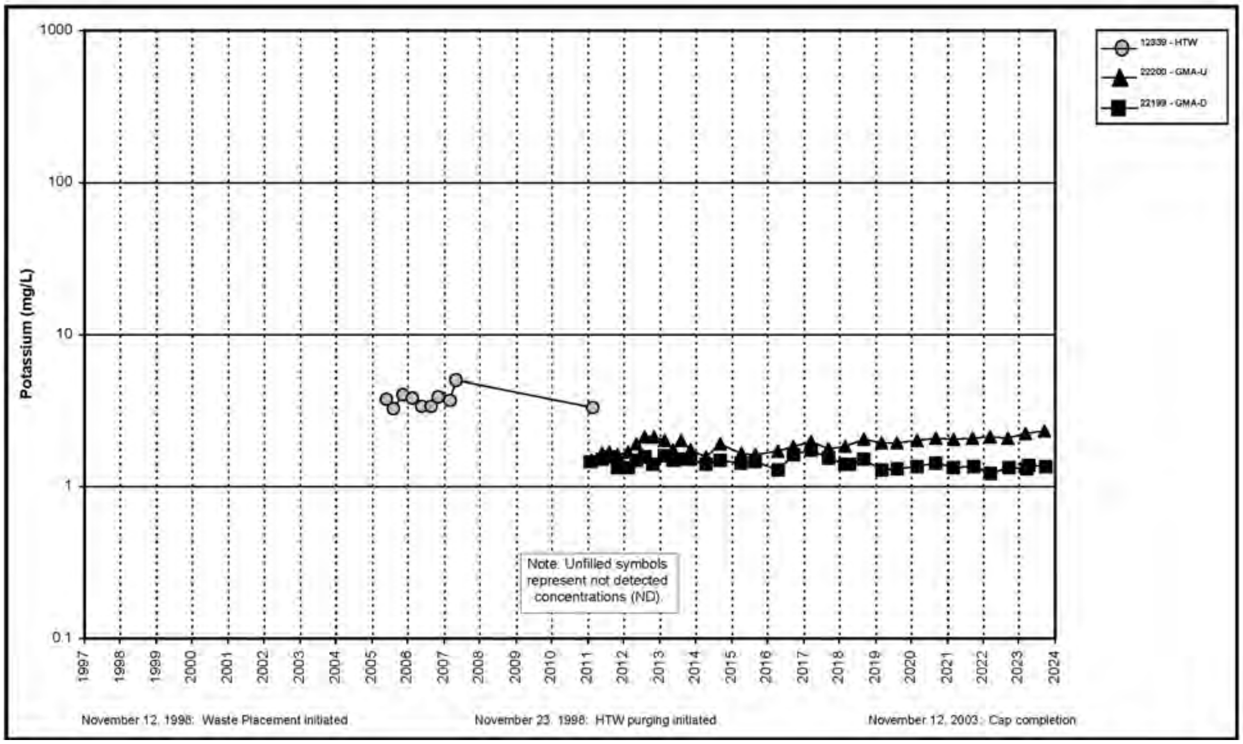

Figure A.5.2-13. Cell 2 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

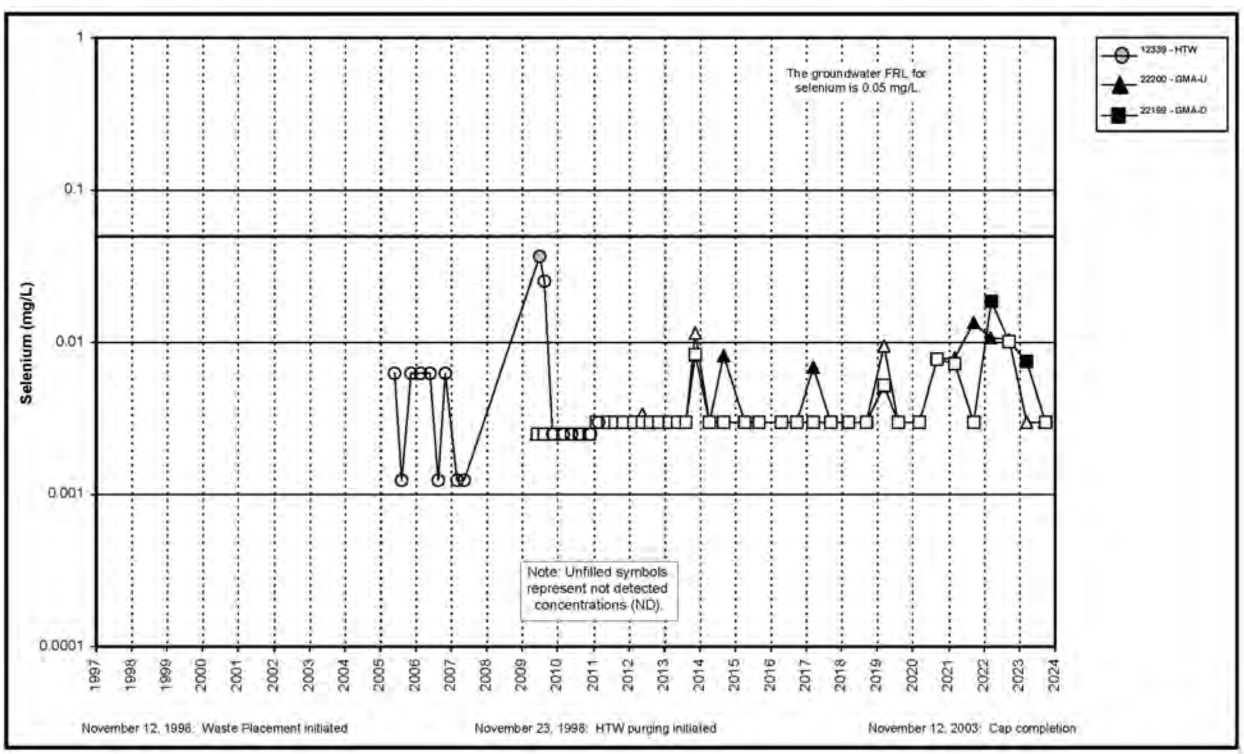

Figure A.5.2-14. Cell 2 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

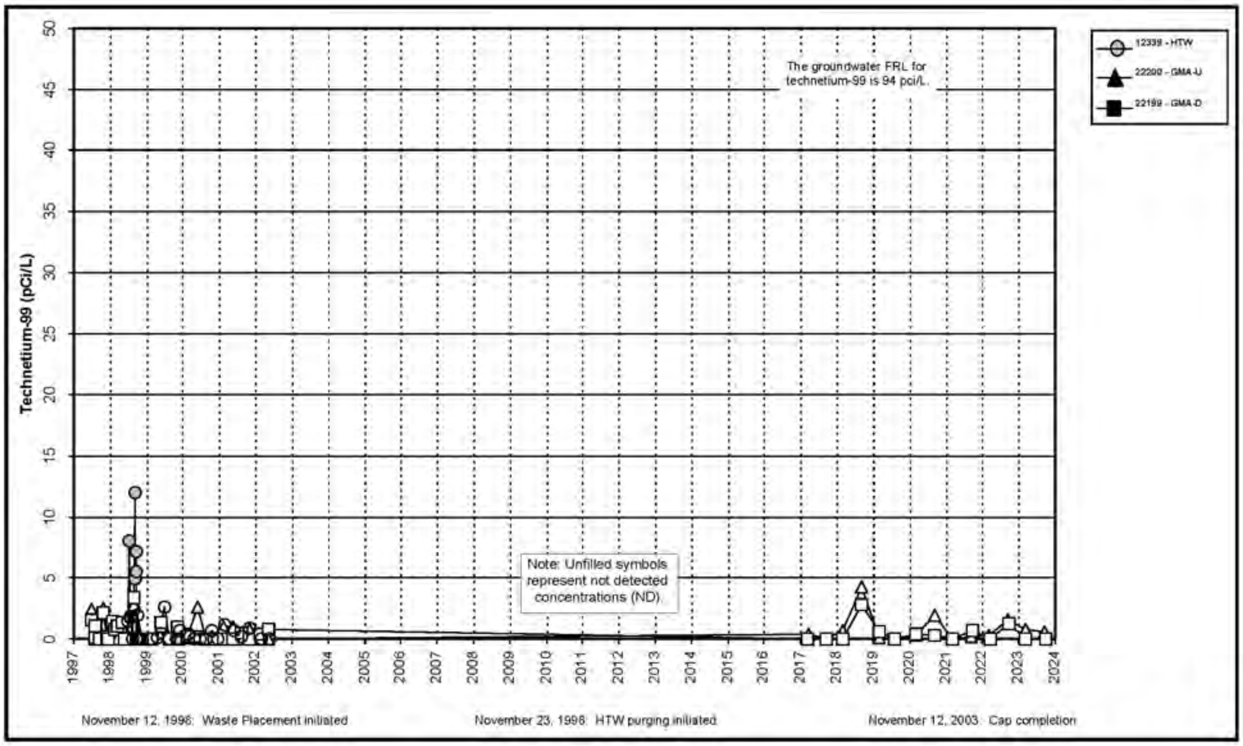

Figure A.5.2-15. Cell 2 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

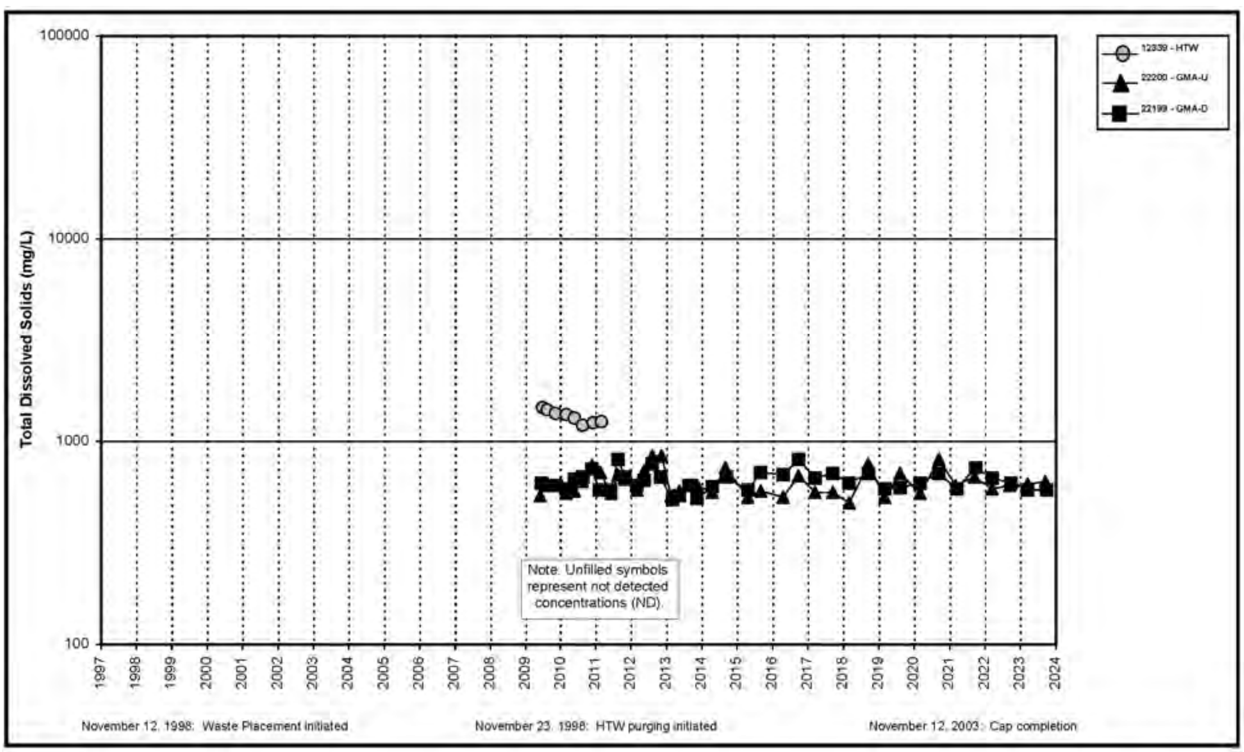

Figure A.5.2-16. Cell 2 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

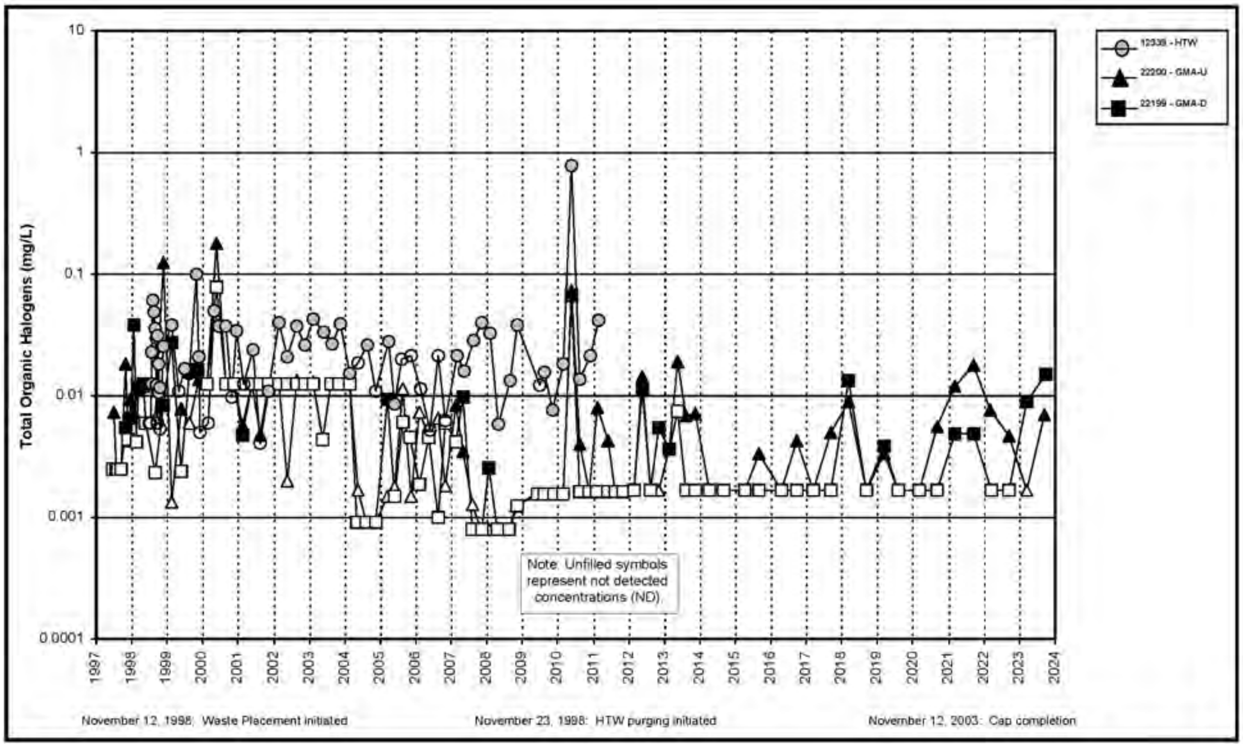

Figure A.5.2-17. Cell 2 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

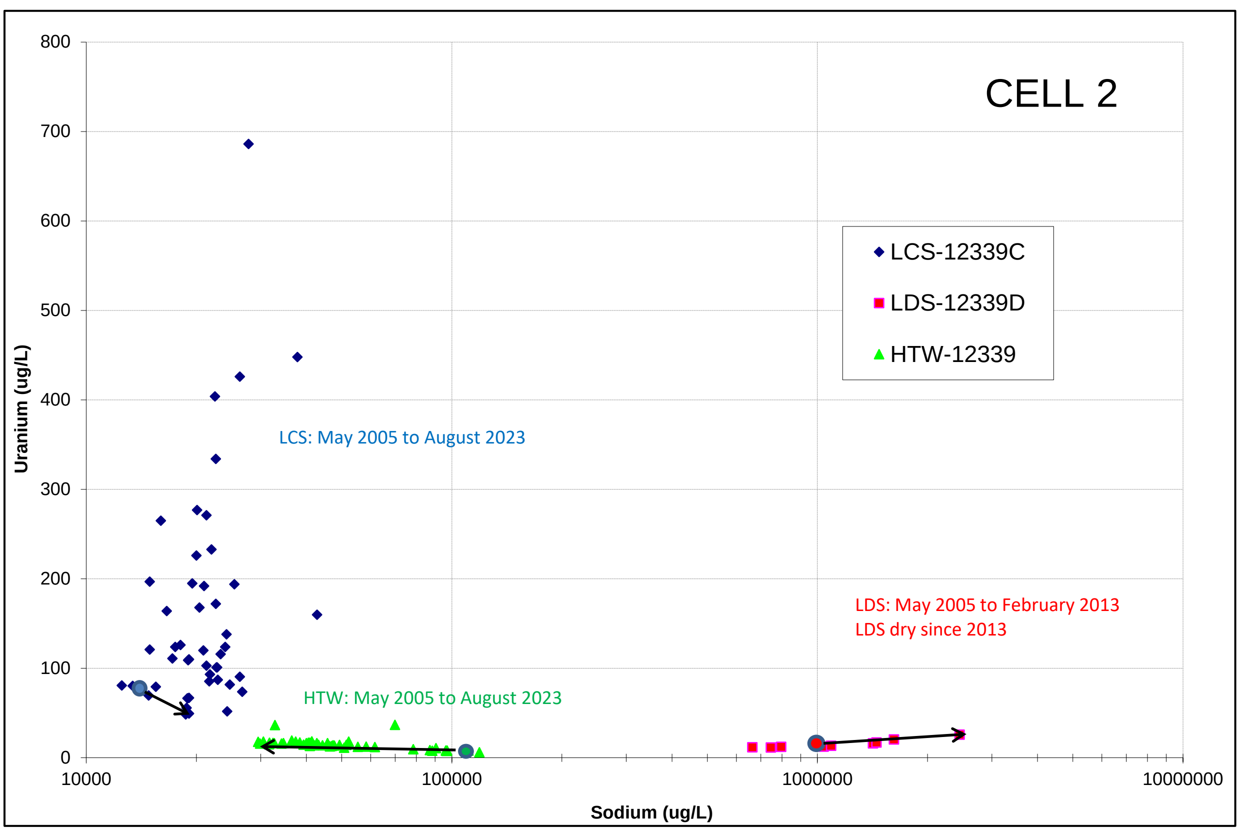

Figure A.5.2-18. Cell 2 Bivariate Plot for Uranium and Sodium

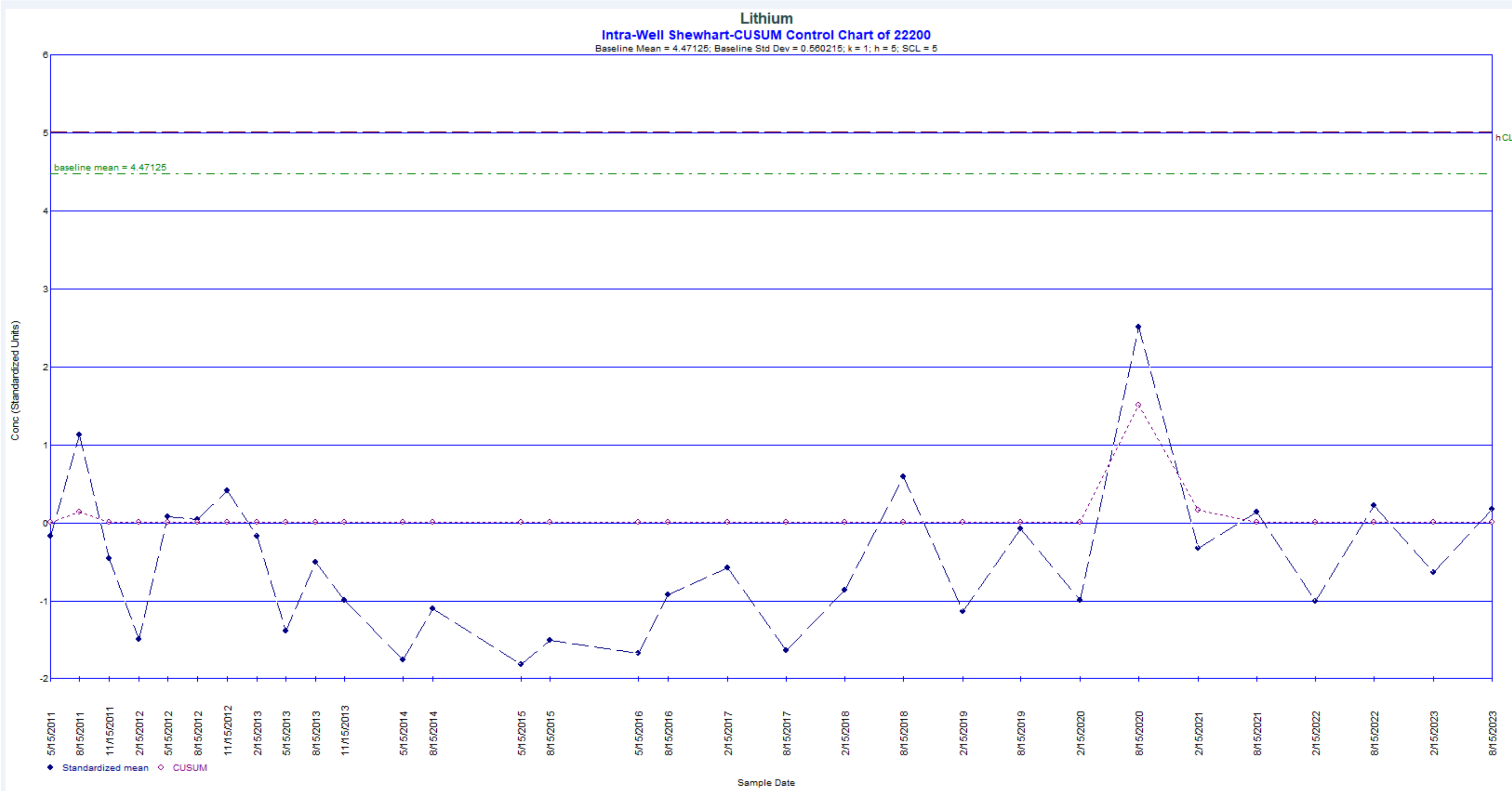

Figure A.5.2-19. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22200

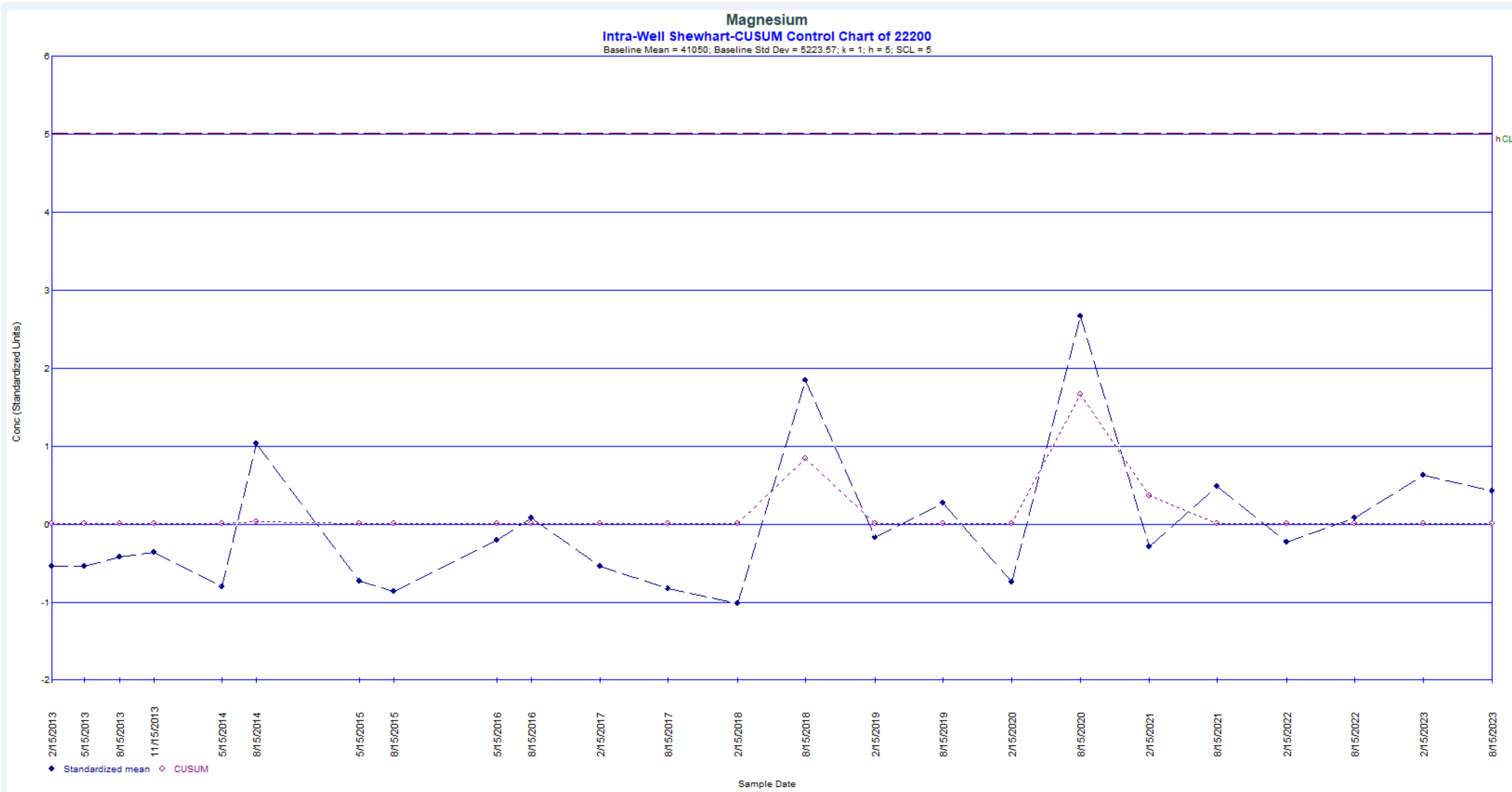

Figure A.5.2-20. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22200

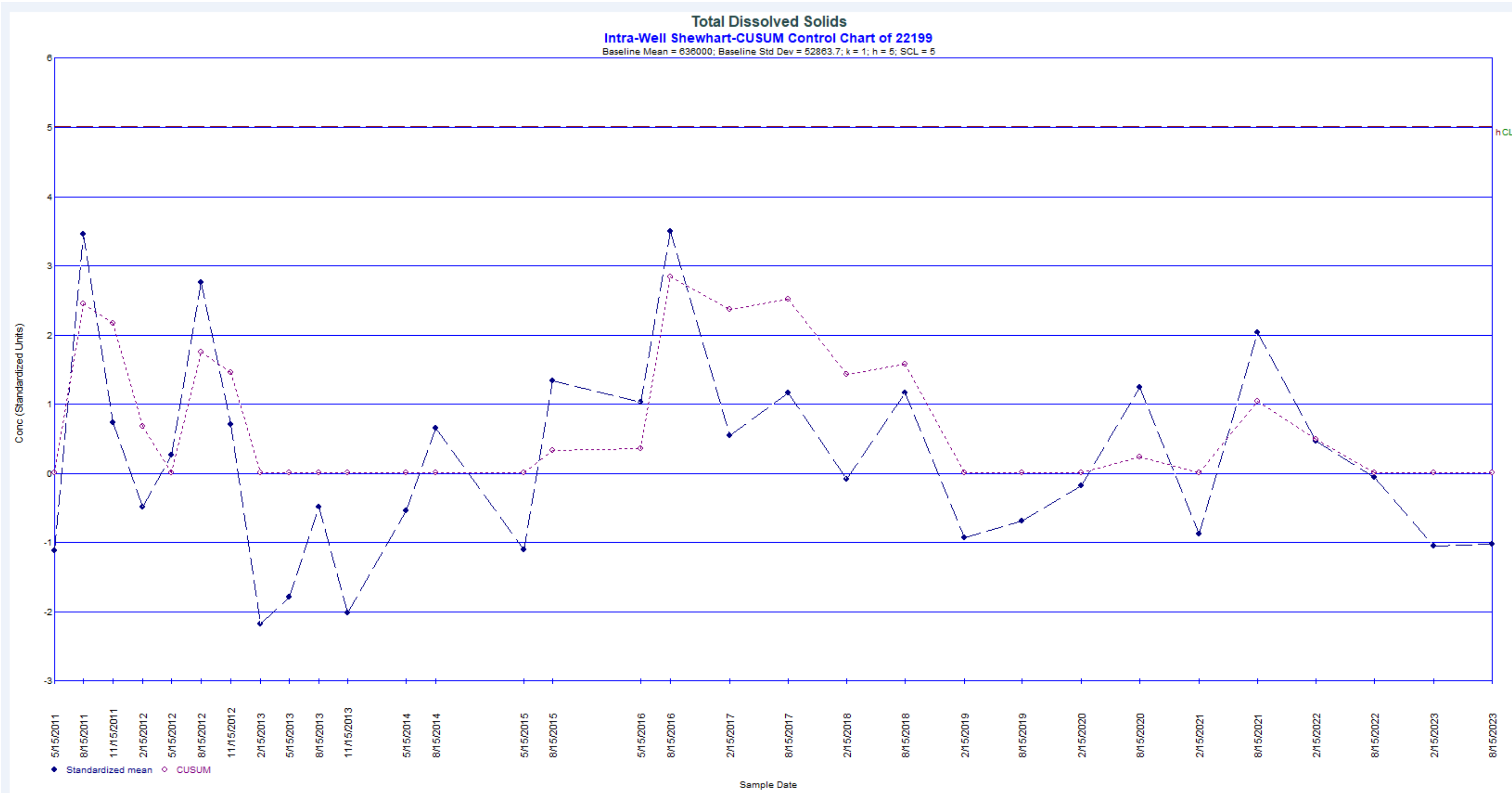

Figure A.5.2-21. Intrawell Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22199

Subattachment A.5.3

Cell 3

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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 and A.5.3-20)

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 2023 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 2023. 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 2023 Trend	LDS 12340D Trend (Year Last Sampled)[a]
Total Uranium	Up	Down (2007)
Boron	Up	Down (2007)
Sodium	Up	
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 parameters 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 2023 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 2023.
- 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	76	76	100	9.35	206	86.9	41.4	Normal	Up (2023)	Detected	
	LDS	12340D	21	21	100	8.90	27.7	17.0	13	Normal	Down (2007)	Not Detected	72.4 (Q4-04)
	HTW	12340	79	79	100	3.89	29.3	18.8	5.8	Undefined	None (2023)	Detected	58.5 (Q3-09), 42.1 (Q3-16)
	GMA-U	22203	78	81	96.3	0.118	23.5	4.60	4.99	Ln Normal	Up (2023)	Detected	
	GMA-D	22204	90	91	98.9	ND	22.9	3.78	4.53	Undefined	Up (2023)	Detected	
Boron (mg/L)	LCS	12340C	76	77	98.7	ND	9.19	4.44	1.79	Undefined	Up (2023)	Detected	
	LDS	12340D	20	21	95.2	ND	0.557	0.128	0.149	Undefined	Down (2007)	Detected	
	HTW	12340	62	62	100	0.0481	0.259	0.141	0.050	Normal	Up (2023)	Detected	0.960 (Q3-06)
	GMA-U	22203	70	81	86.4	ND	0.0870	0.0502	0.0169	Normal	Up (2023)	Detected	
	GMA-D	22204	73	81	90.1	ND	0.0887	0.0456	0.0149	Normal	Up (2023)	Detected	
Sodium (mg/L)	LCS	12340C	56	56	100	4.35	49.9	27.5	7.5	Undefined	Up (2023)	Detected	
	LDS	12340D	9	9	100	263	344	315	27	Normal	None (2007)	Not Detected	
	HTW	12340	48	48	100	10.2	74.1	33.8	17.6	Ln Normal	Down (2023)	Detected	
	GMA-U	22203	39	39	100	15.9	30.7	20.8	3.9	Ln Normal	Down (2023)	Detected	
	GMA-D	22204	41	41	100	7.88	20.5	12.0	3.8	Undefined	Down (2023)	Detected	
Sulfate (mg/L)	LCS	12340C	68	68	100	26.1	2650	1,865	520	Undefined	Up (2023)	Detected	
	LDS	12340D	19	19	100	112	2,510	1,250	700	Undefined	Down (2007)	Not Detected	
	HTW	12340	58	58	100	352	958	621	158	Normal	Down (2023)	Detected	
	GMA-U	22203	63	63	100	64.2	738	254	145	Ln Normal	None (2023)	Detected	4,020 (Q3-12)
	GMA-D	22204	63	63	100	186	779	423	159	Normal	Down (2023)	Detected	
Calcium (mg/L)	GMA-U	22203	32	32	100	135	290	180	36	Normal	None (2023)	Not Detected	
	GMA-D	22204	32	32	100	134	365	221	57	Ln Normal	Down (2023)	Detected	
Lithium (mg/L)	GMA-U	22203	39	39	100	0.00577	0.0229	0.0102	0.0054	Undefined	Up (2023)	Not Detected	
	GMA-D	22204	39	39	100	0.00694	0.0102	0.00865	0.00088	Ln Normal	None (2023)	Not Detected	
Magnesium (mg/L)	GMA-U	22203	32	32	100	32.5	65.6	48.2	9.2	Normal	Up (2023)	Not Detected	
	GMA-D	22204	32	32	100	37.2	66.6	49.1	8.2	Normal	Down (2023)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22203	19	32	59.4	ND	0.273	0.0526	0.0924	Undefined	Up (2023)	Not Detected	
	GMA-D	22204	1	32	3.1	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22203	32	32	100	2.07	3.50	2.55	0.35	Ln Normal	Down (2023)	Not Detected	
	GMA-D	22204	34	34	100	1.17	3.07	1.97	0.53	Normal	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22203	5	39	12.8	ND	0.0130	0.00300	0.00294	Undefined	Up (2023)	Detected	
	GMA-D	22204	5	39	12.8	ND	0.0178	0.00300	0.00328	Undefined	Up (2023)	Detected	
Technitium-99 (pCi/L)	GMA-U	22203	1	30	3.3	ND	8.44	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22204	0	30	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22203	39	39	100	524	1,410	720	191	Undefined	Up (2023)	Detected	
	GMA-D	22204	39	39	100	487	1,530	942	230	Normal	Down (2023)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22203	43	81	53.1	ND	0.213	0.00520	0.0247	Undefined	None (2023)	Detected	
	GMA-D	22204	18	81	22.2	ND	0.0270	0.00753	0.0185	Undefined	Down (2023)	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 has 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: Ln Normal 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
2023	1,450	2	725

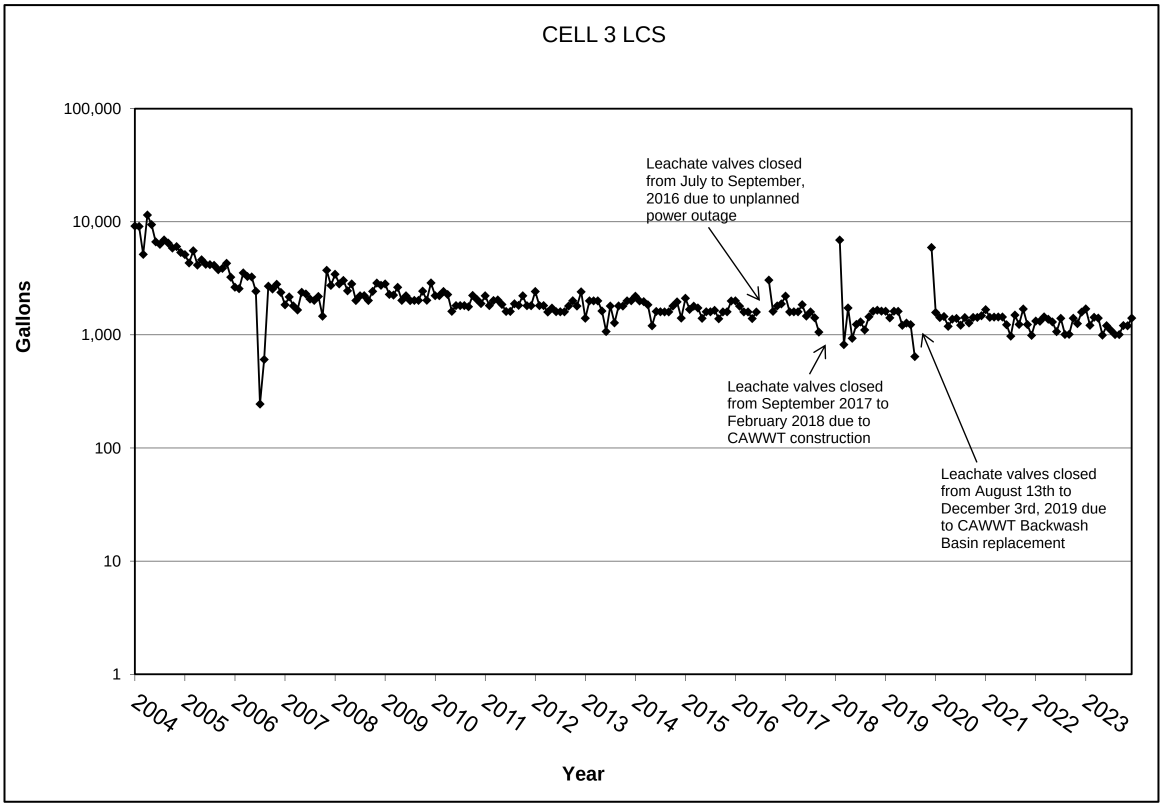


Figure A.5.3-1. Monthly Accumulation Volumes for Cell 3 LCS

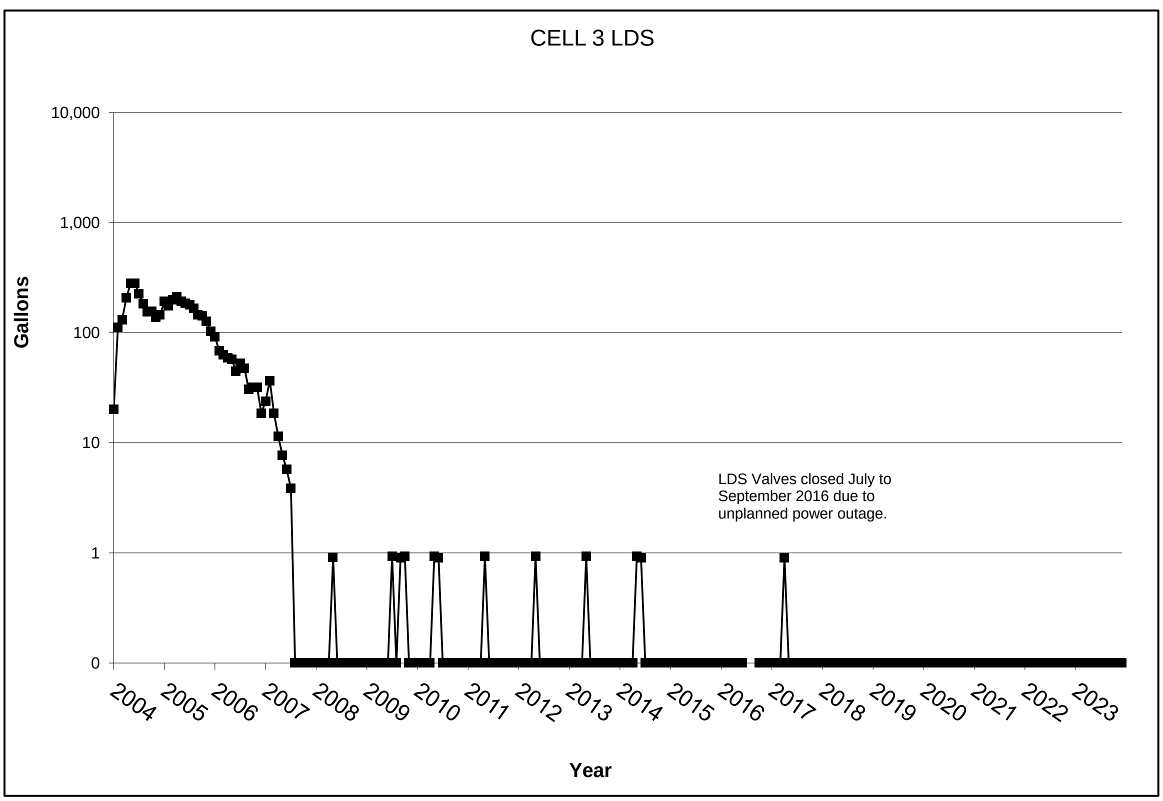


Figure A.5.3-2. Monthly Accumulation Volumes for Cell 3 LDS

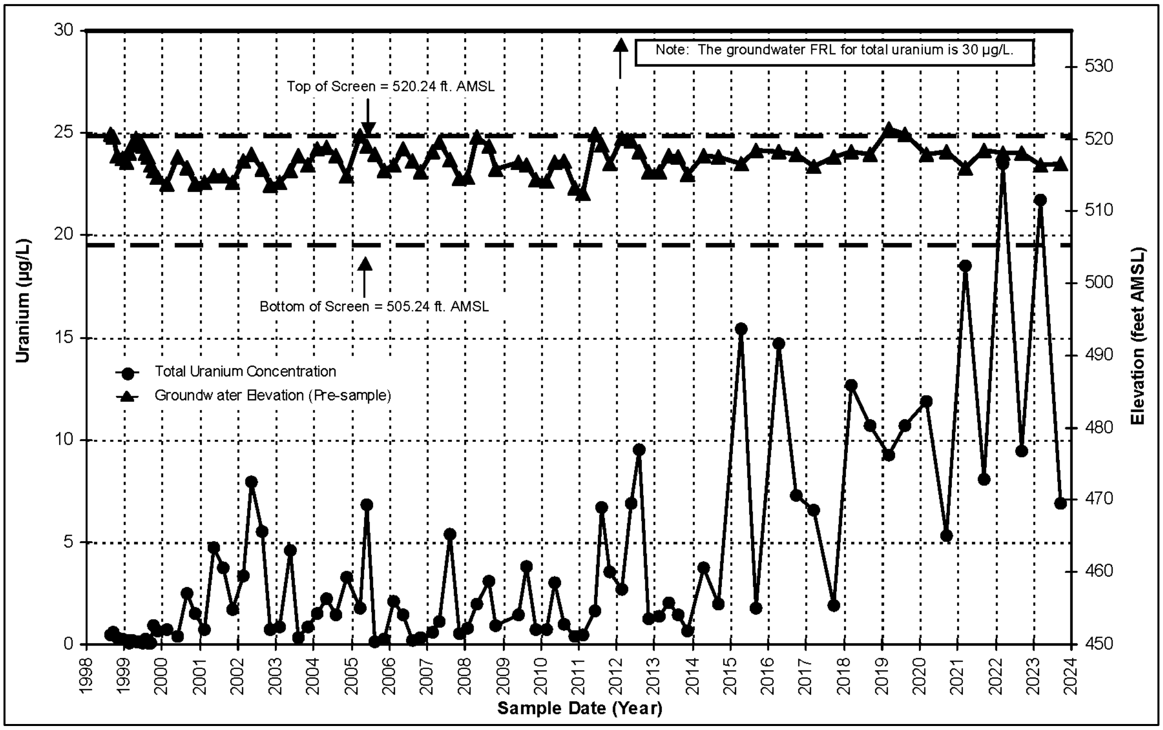


Figure A.5.3-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 3 Upgradient Monitoring Well 22203

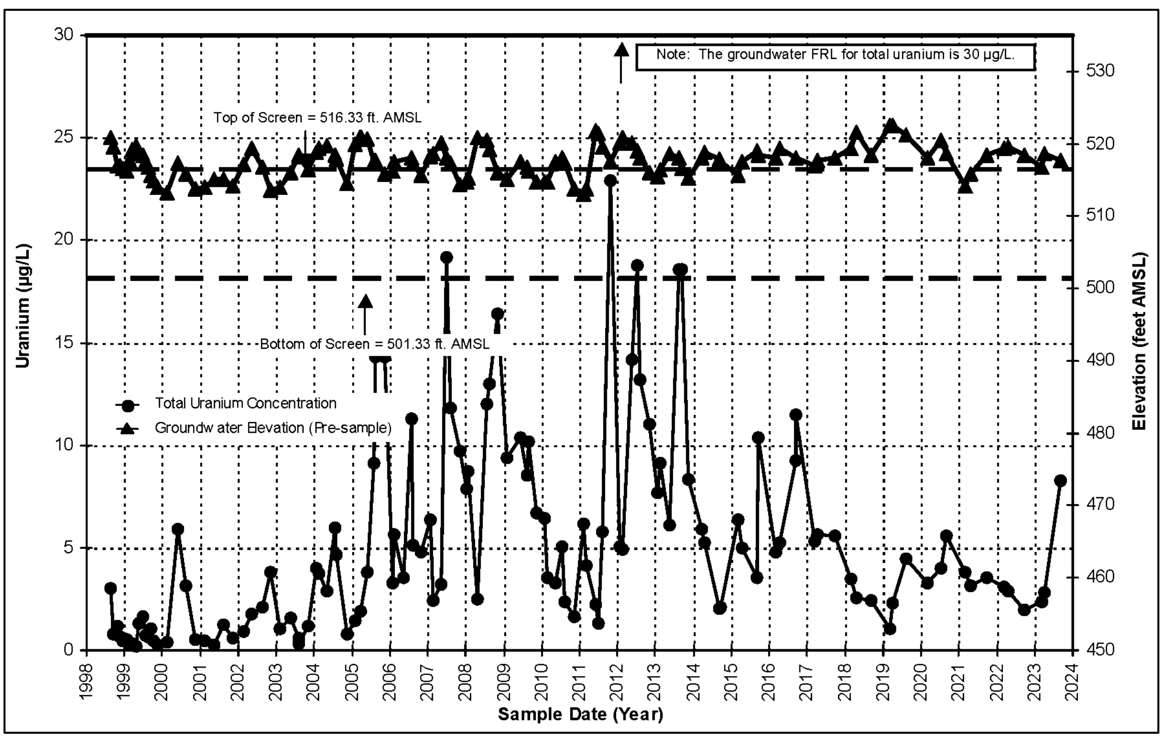


Figure A.5.3-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 3 Downgradient Monitoring Well 22204

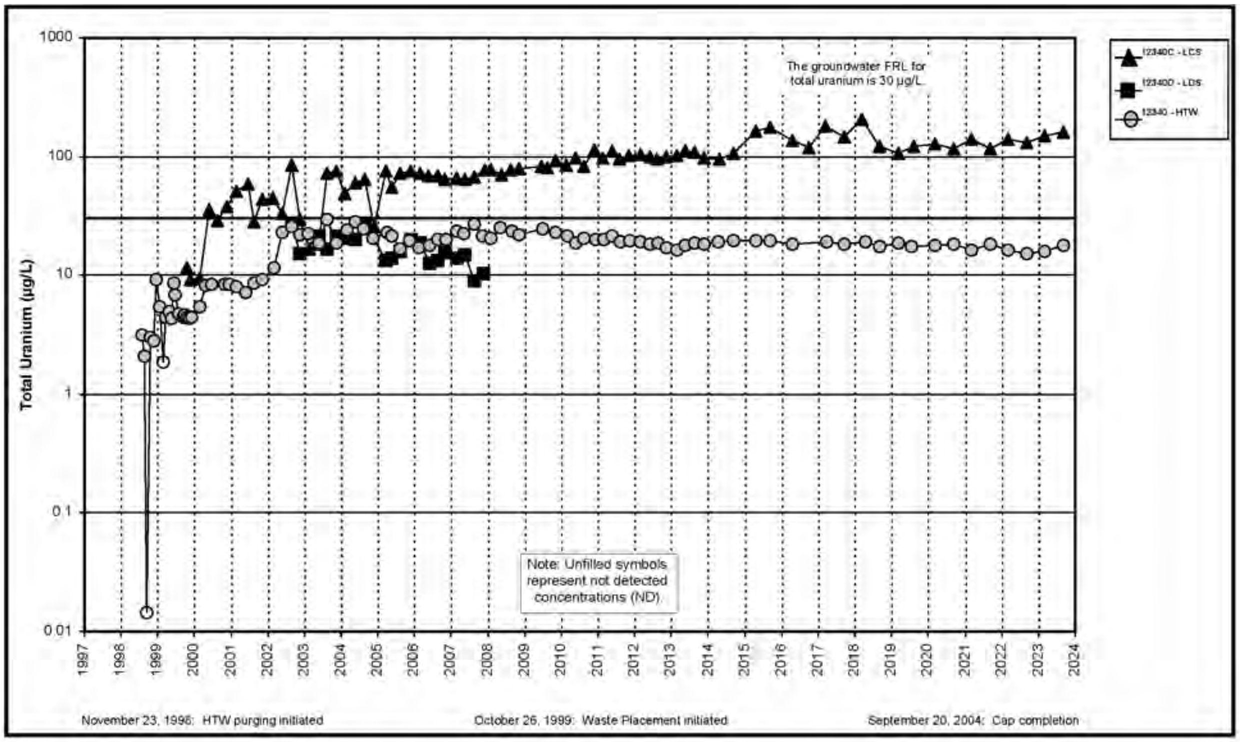


Figure A.5.3-5A. Cell 3 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

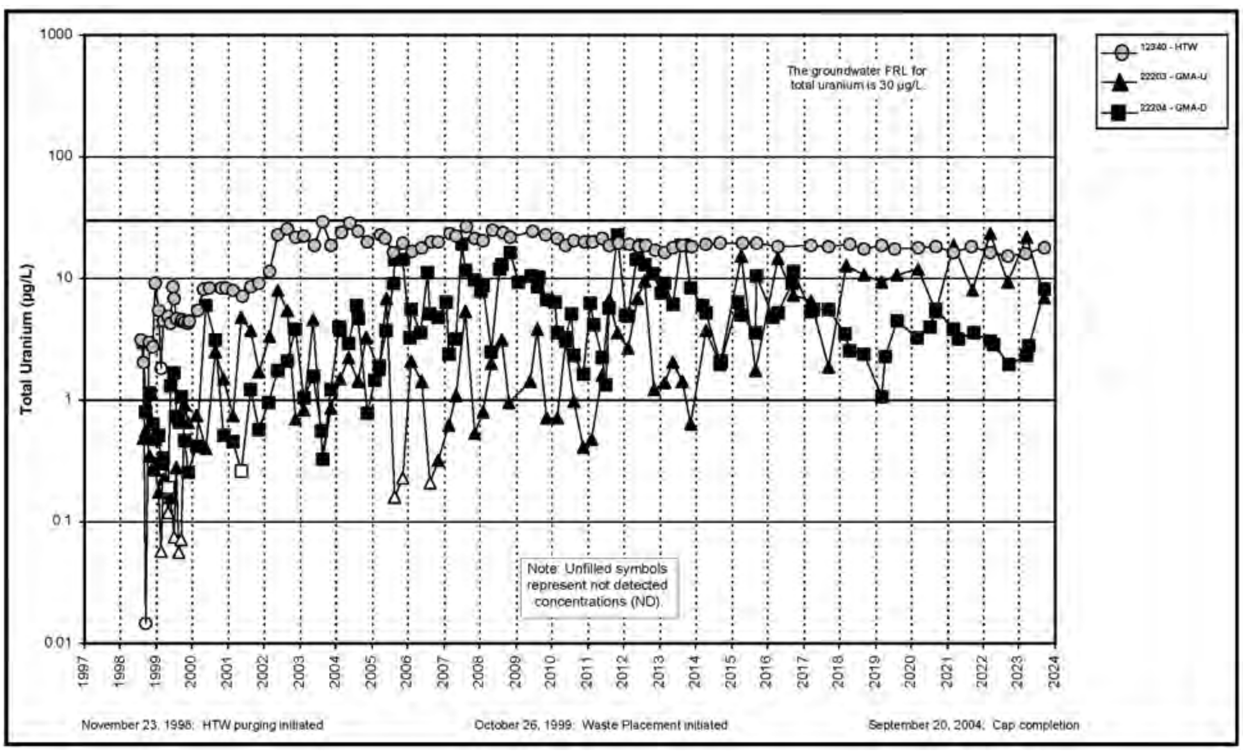


Figure A.5.3-5B. Cell 3 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

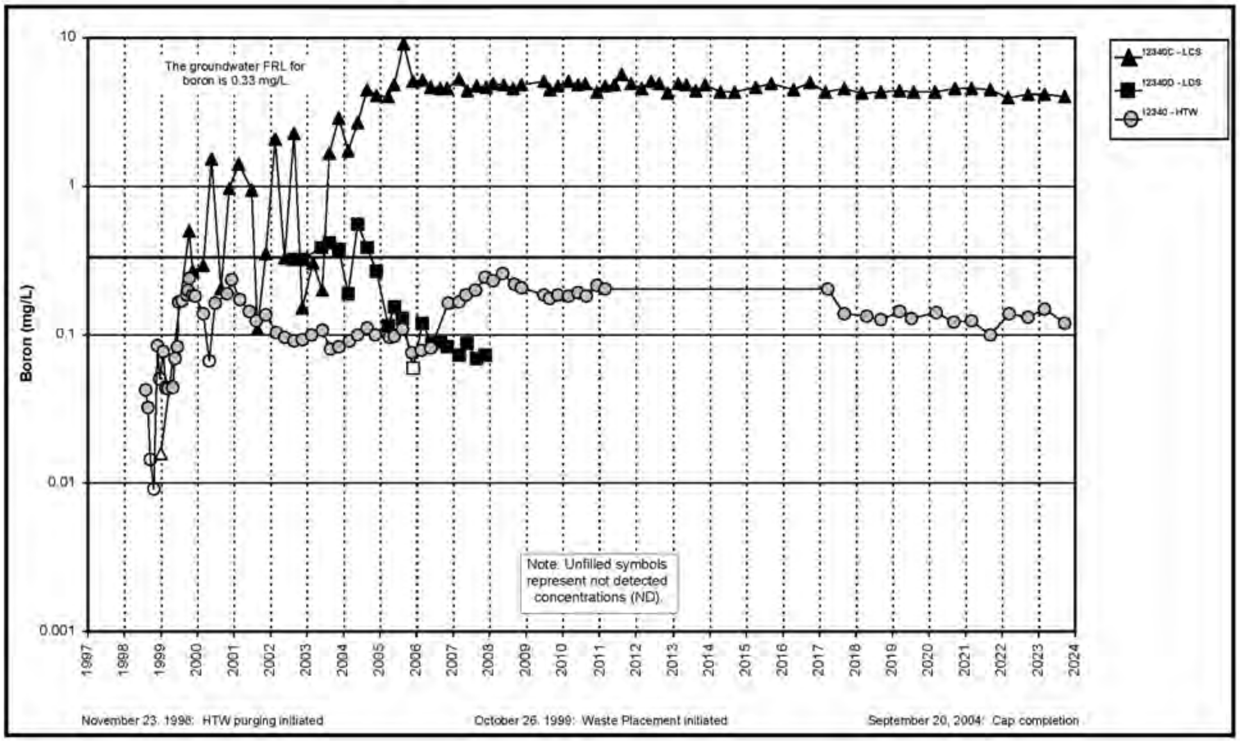


Figure A.5.3-6A. Cell 3 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

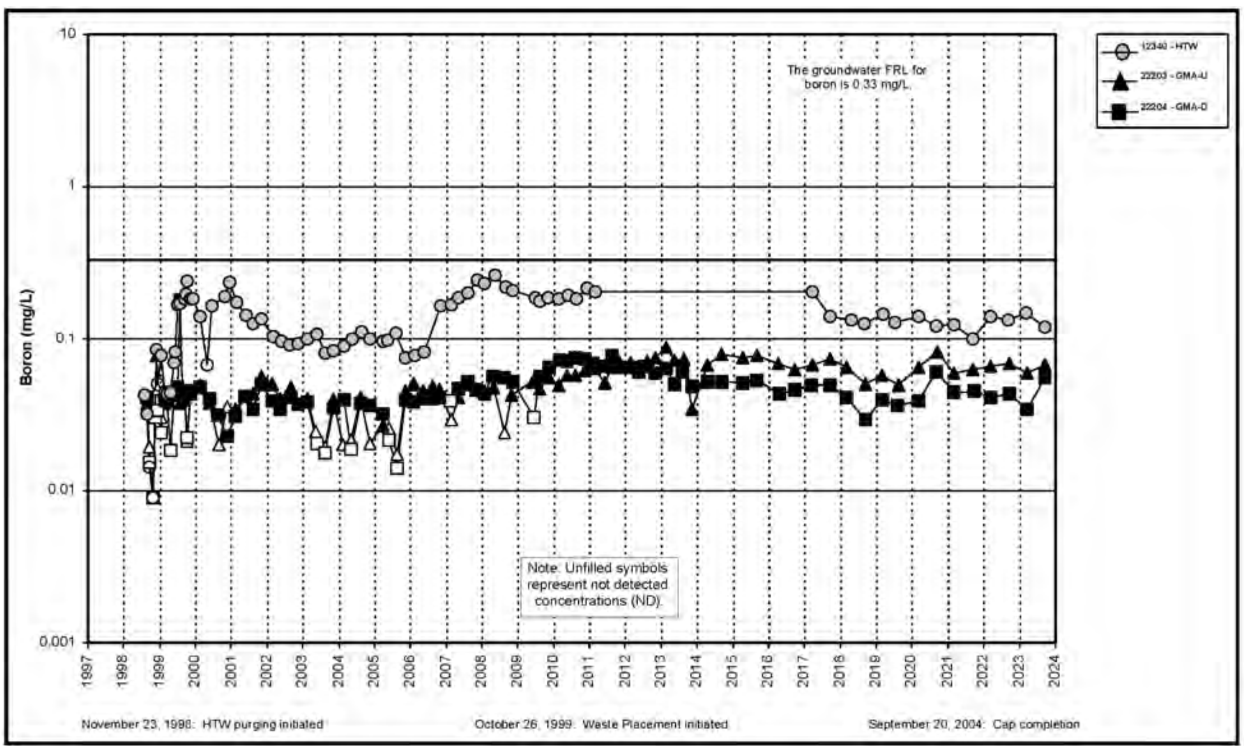


Figure A.5.3-6B. Cell 3 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

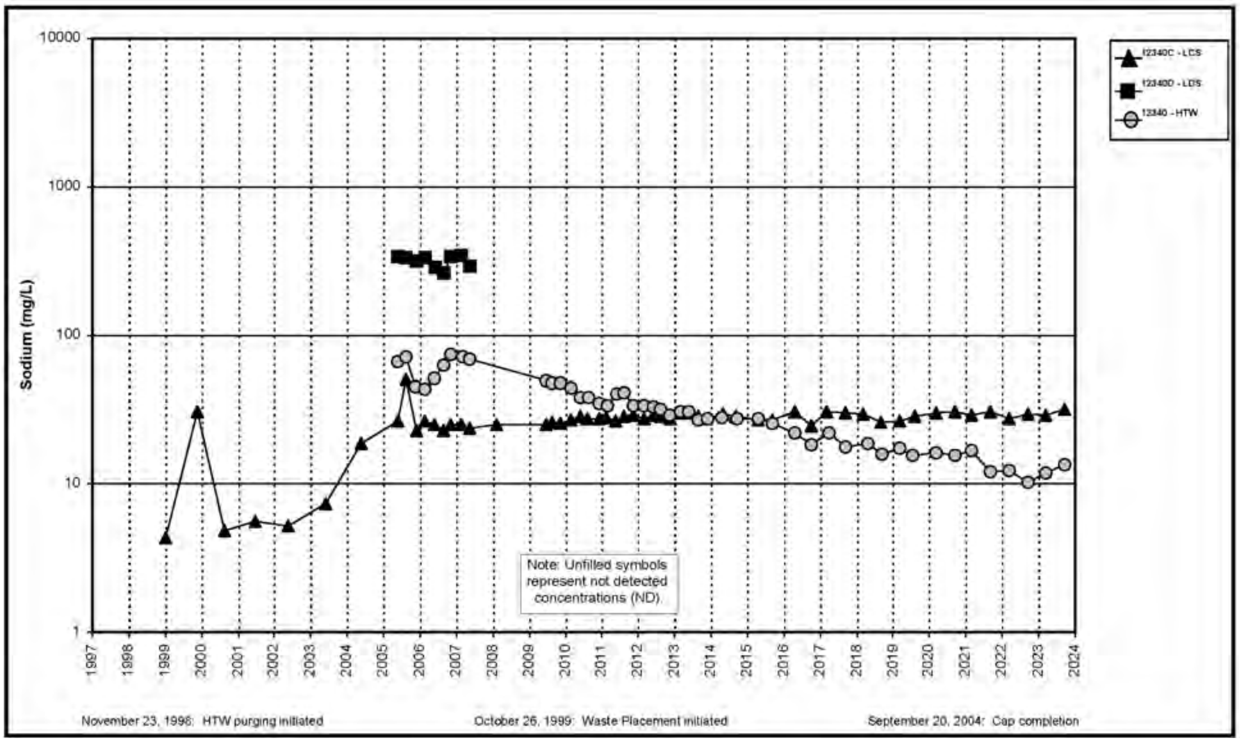


Figure A.5.3-7A. Cell 3 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

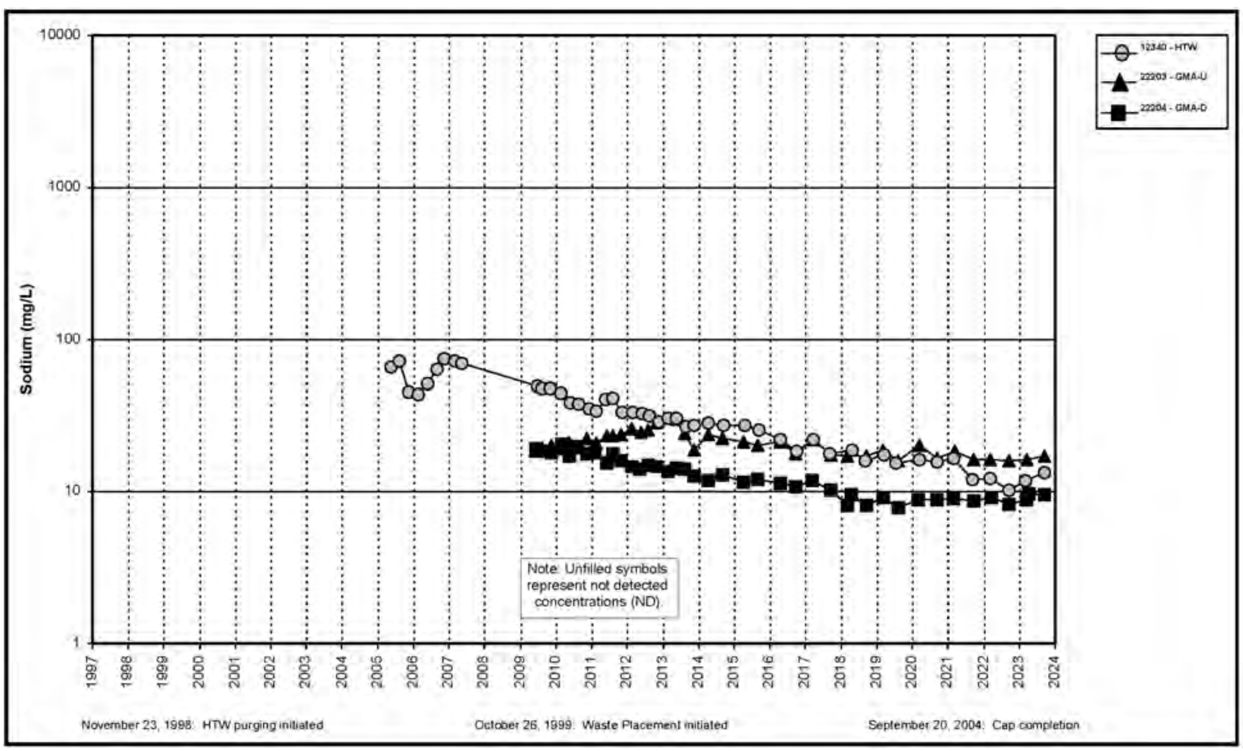


Figure A.5.3-7B. Cell 3 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

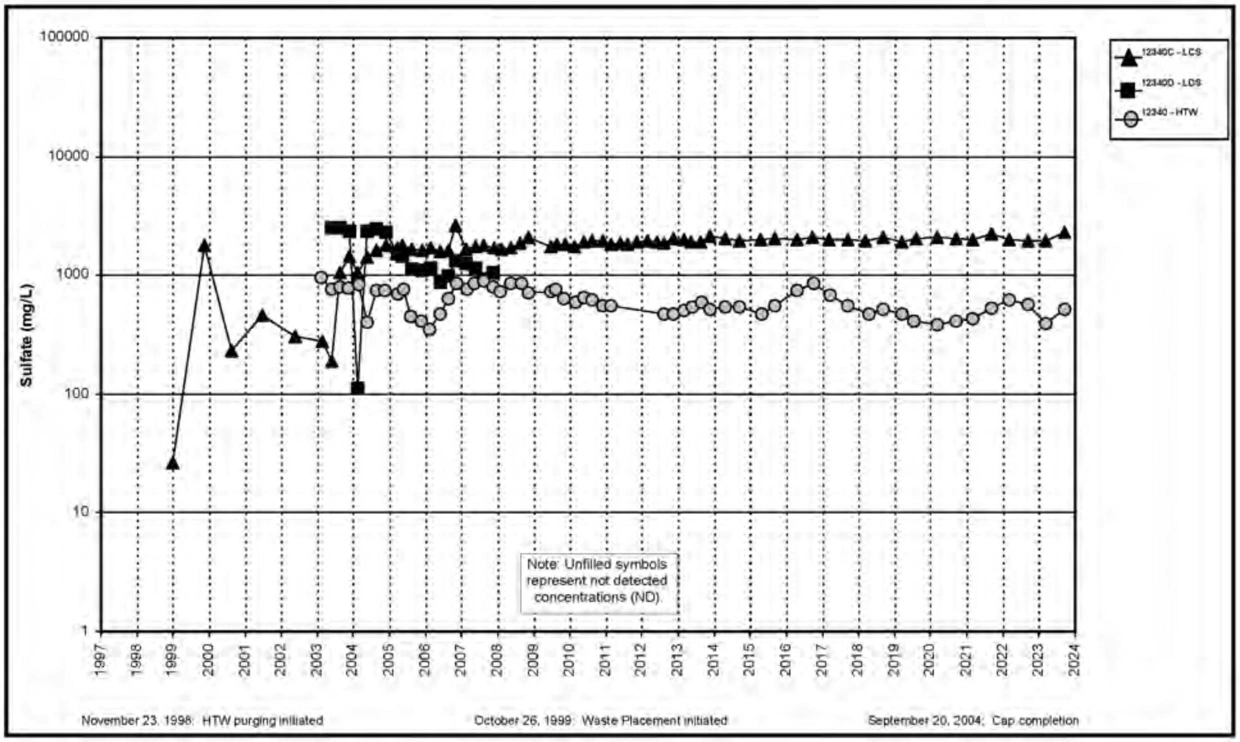


Figure A.5.3-8A. Cell 3 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

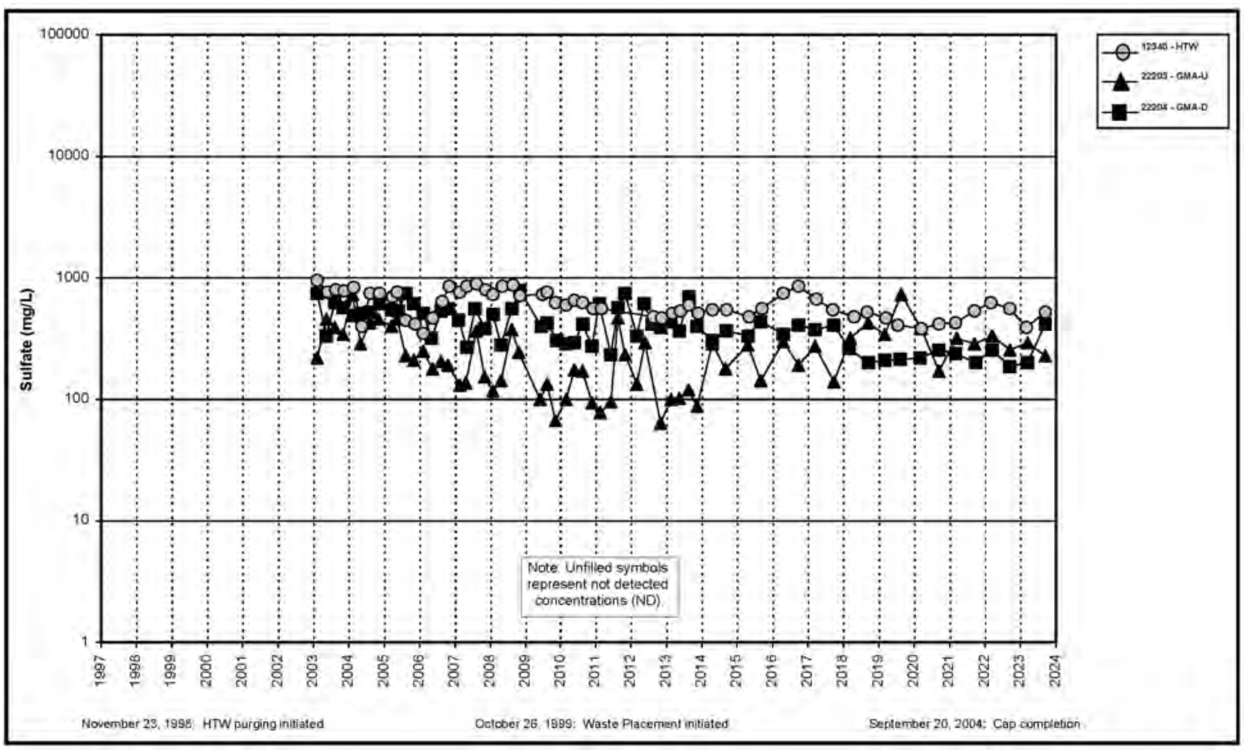


Figure A.5.3-8B. Cell 3 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

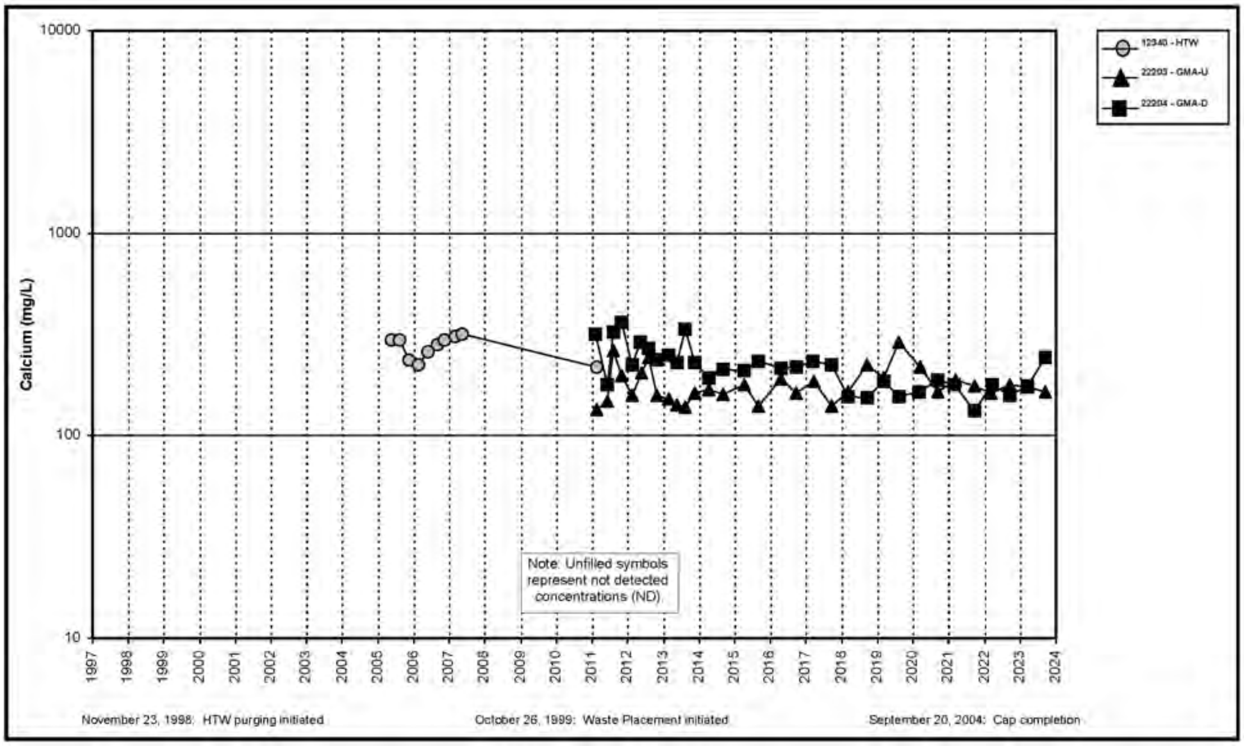


Figure A.5.3-9. Cell 3 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-Dr Well

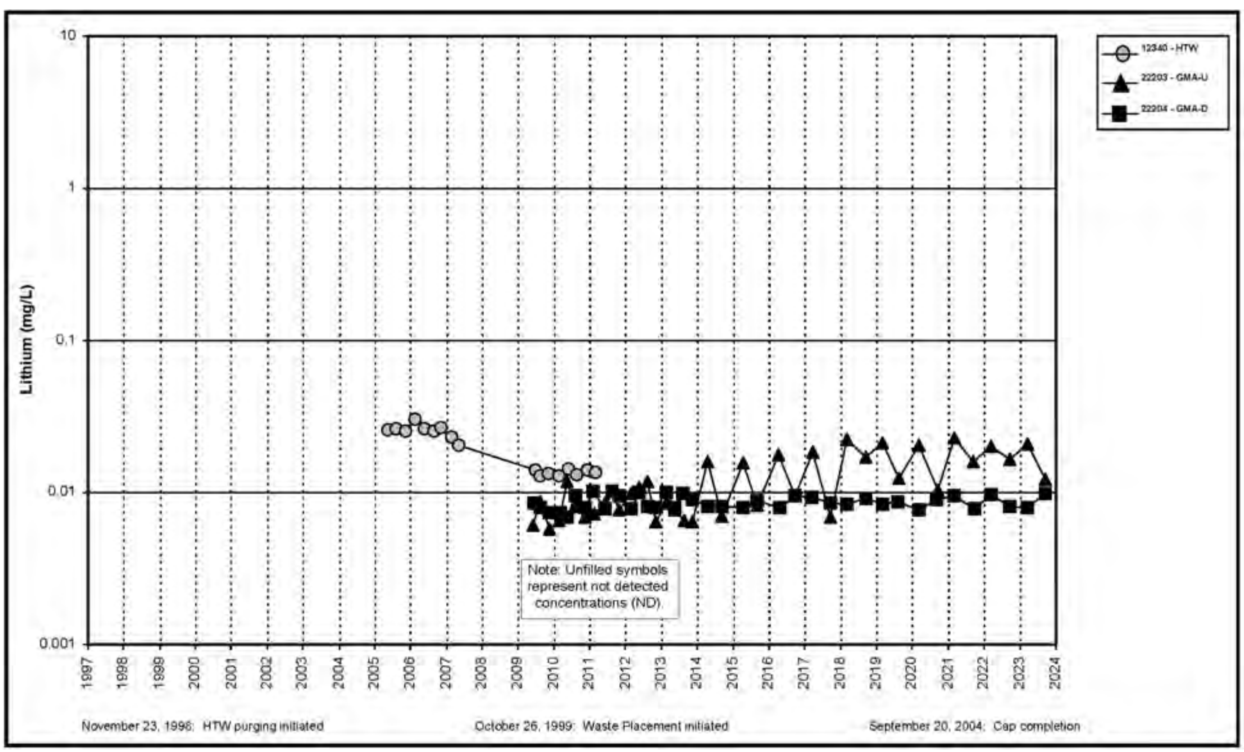


Figure A.5.3-10. Cell 3 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

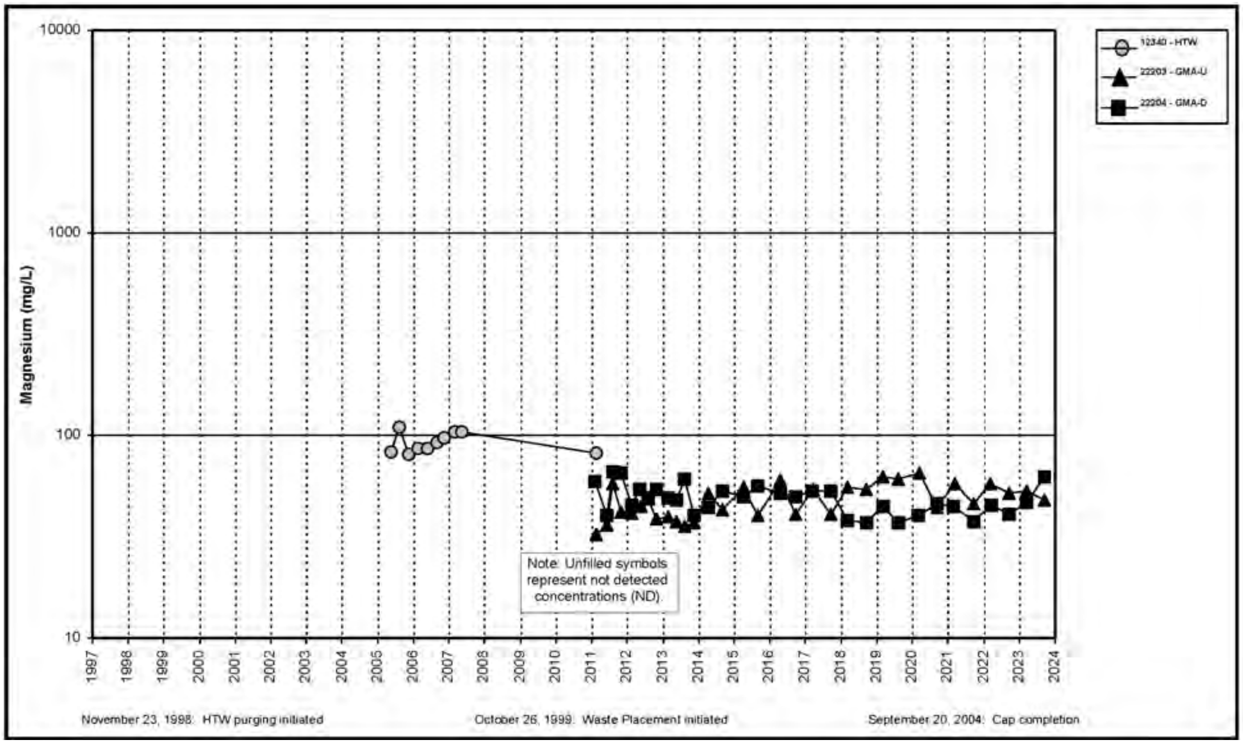
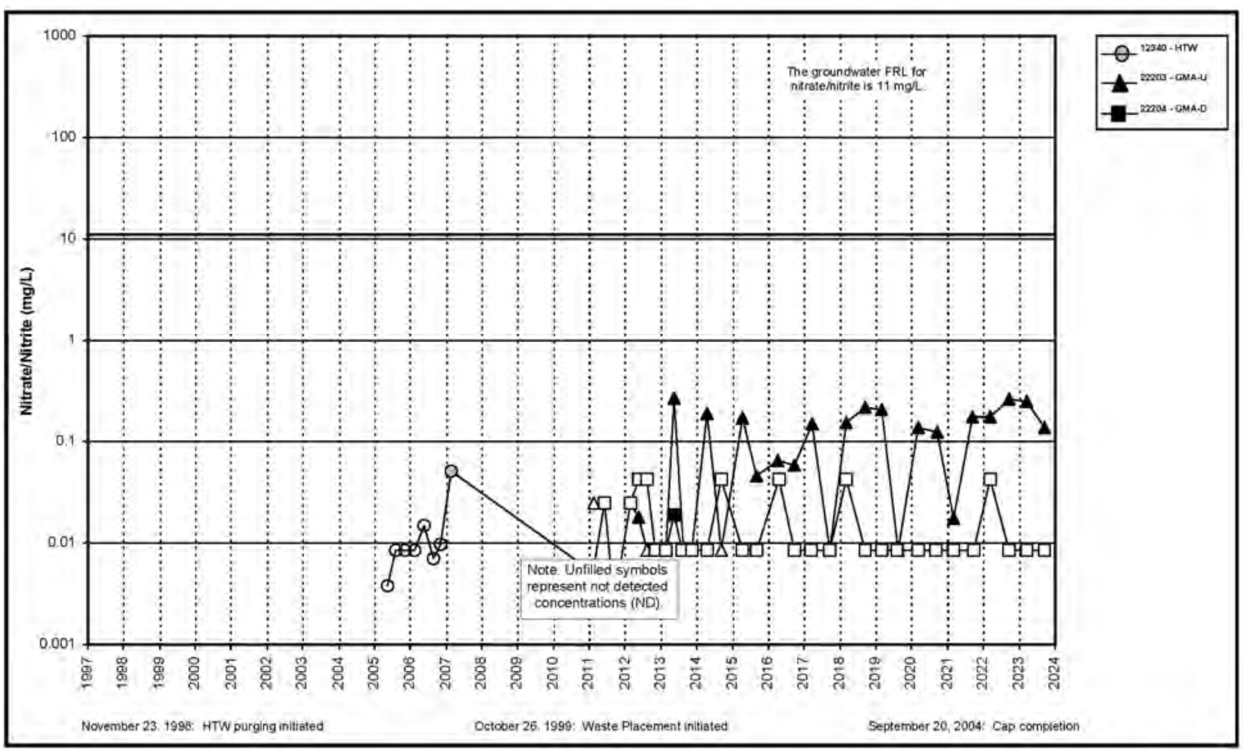


Figure A.5.3-11. Cell 3 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well



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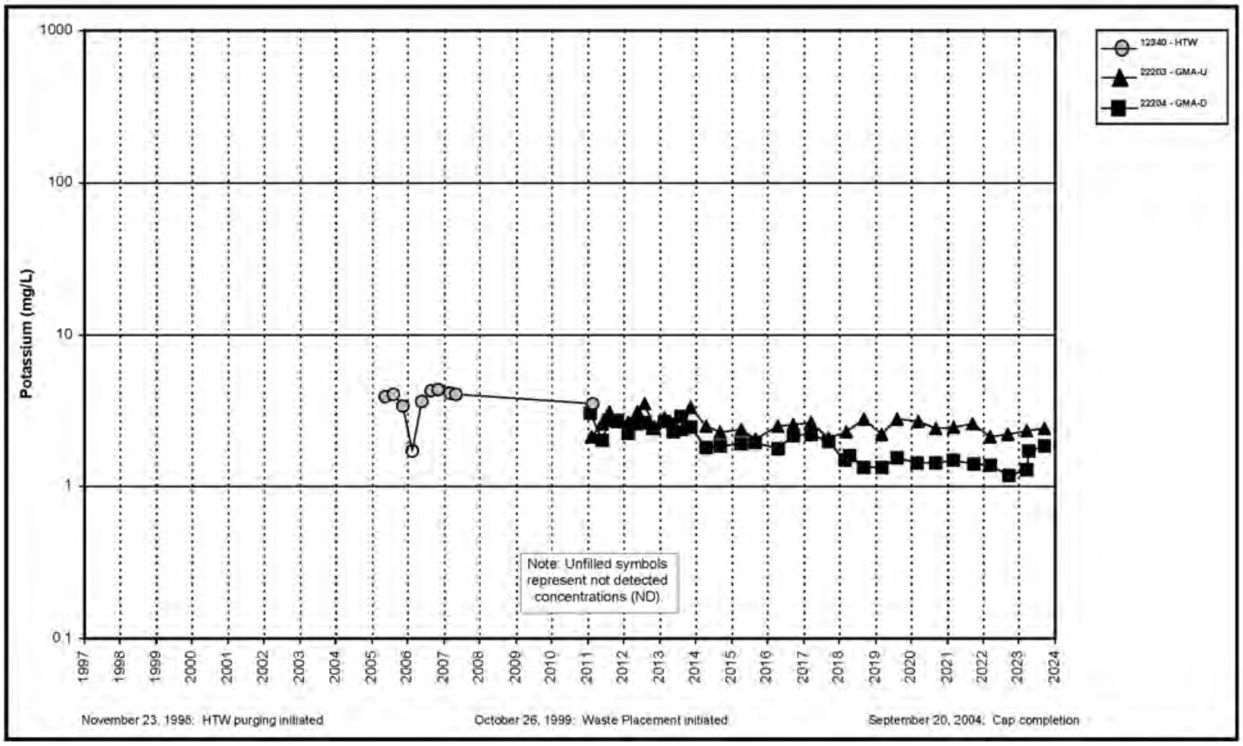

Figure A.5.3-13. Cell 3 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

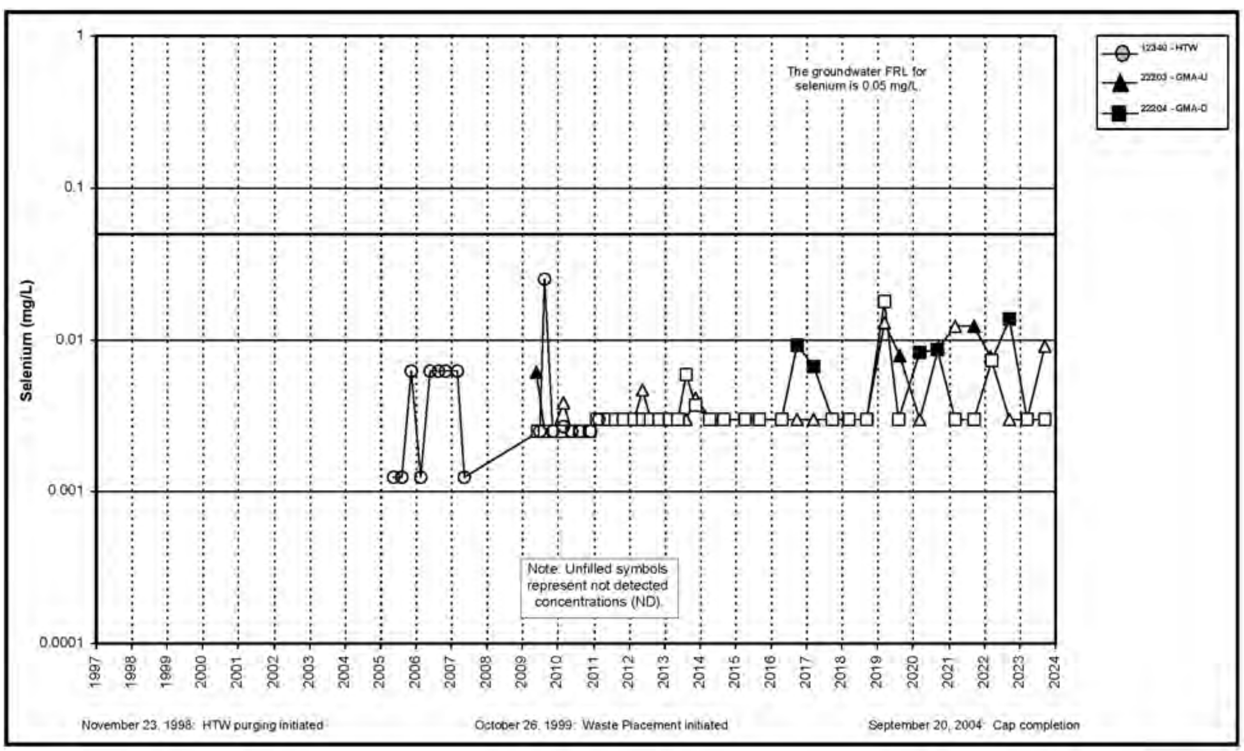

Figure A.5.3-14. Cell 3 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

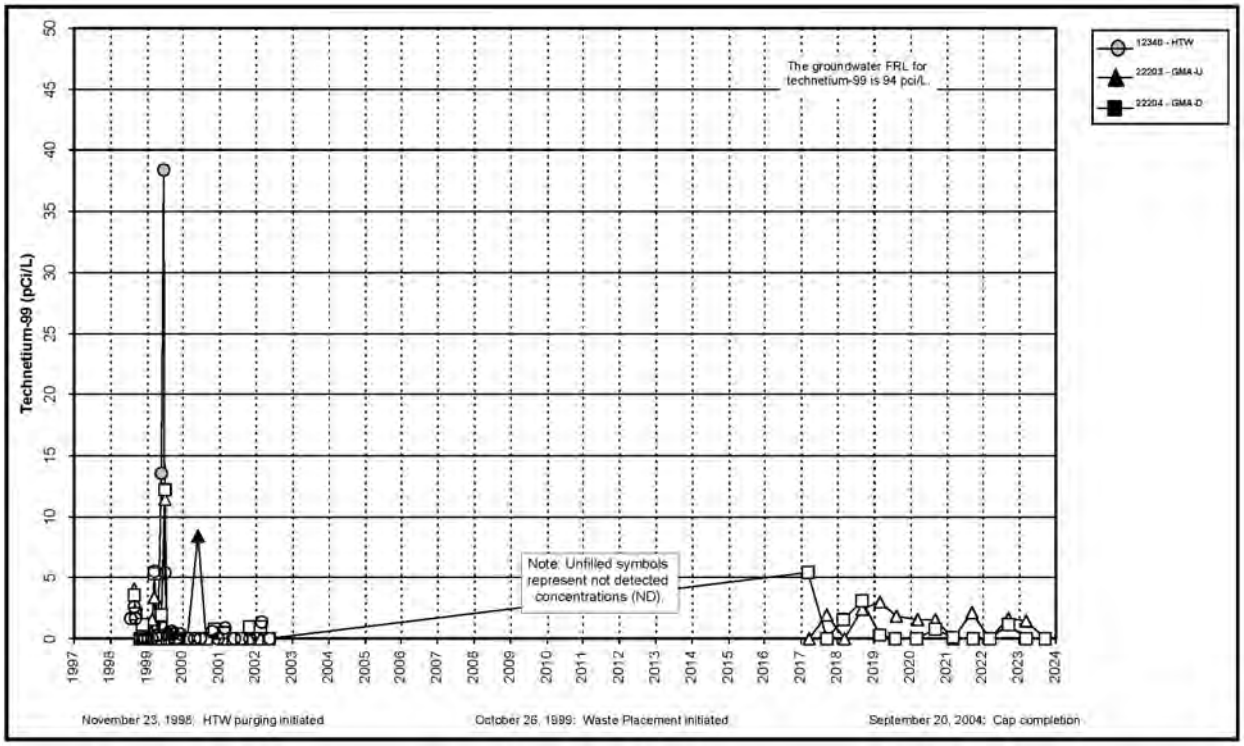

Figure A.5.3-15. Cell 3 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

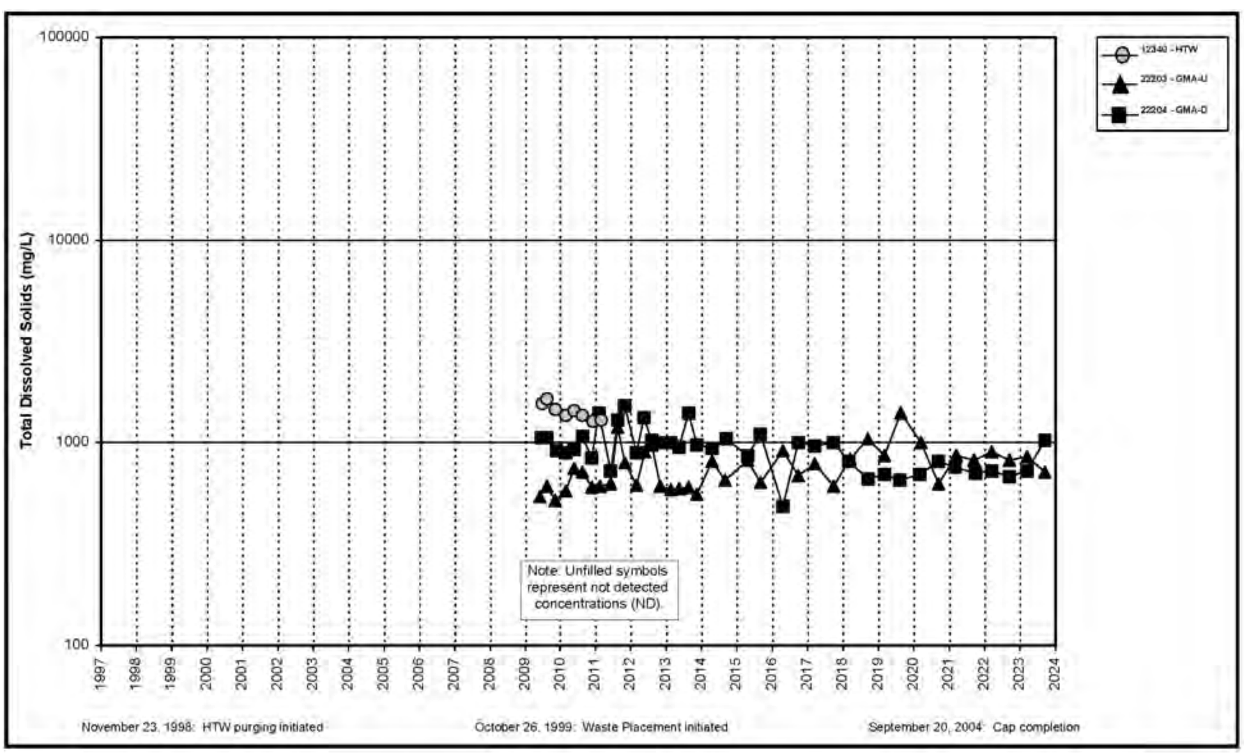

Figure A.5.3-16. Cell 3 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

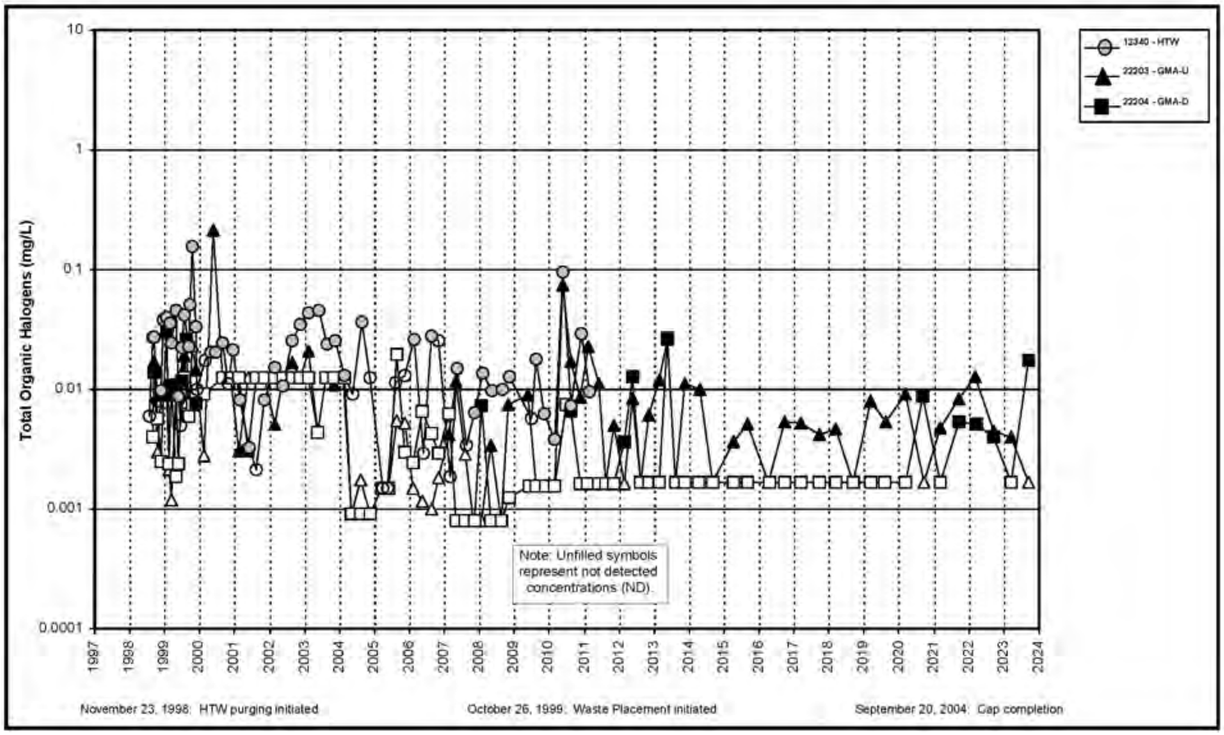

Figure A.5.3-17. Cell 3 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

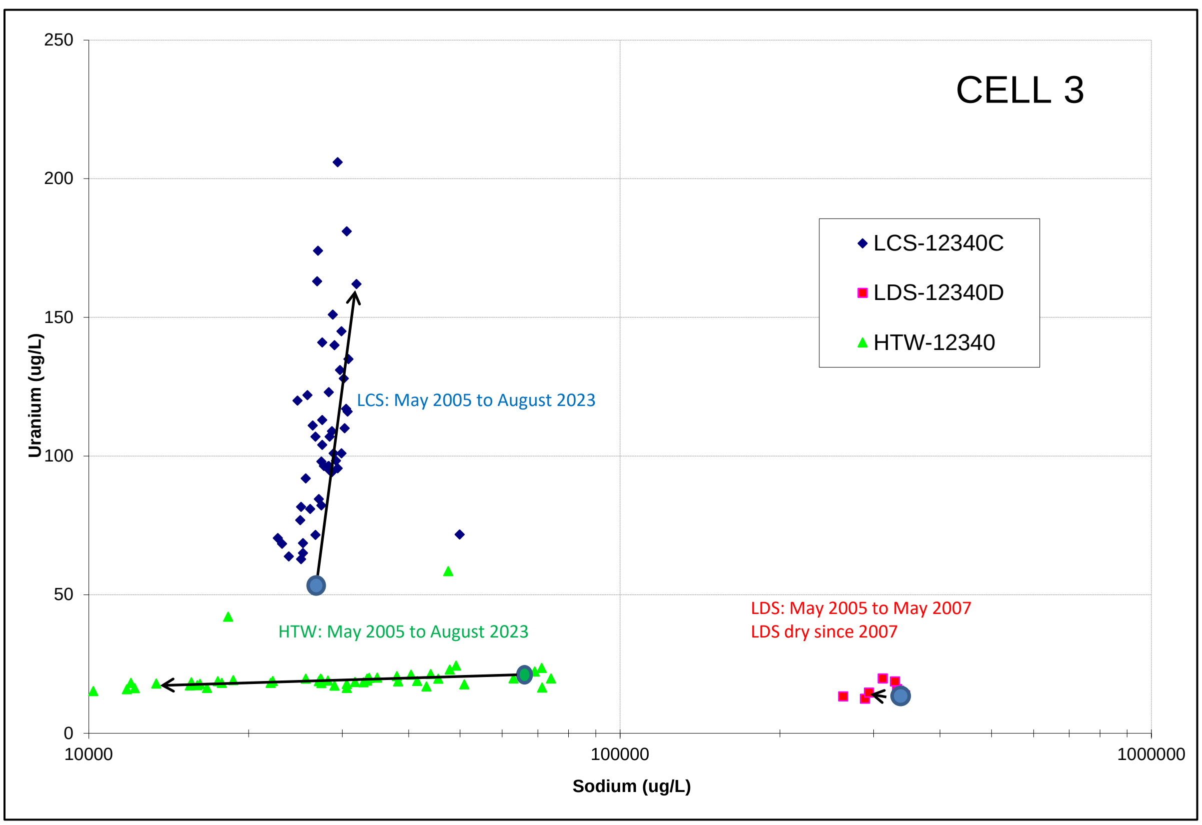

Figure A.5.3-18. Cell 3 Bivariate Plot for Uranium and Sodium

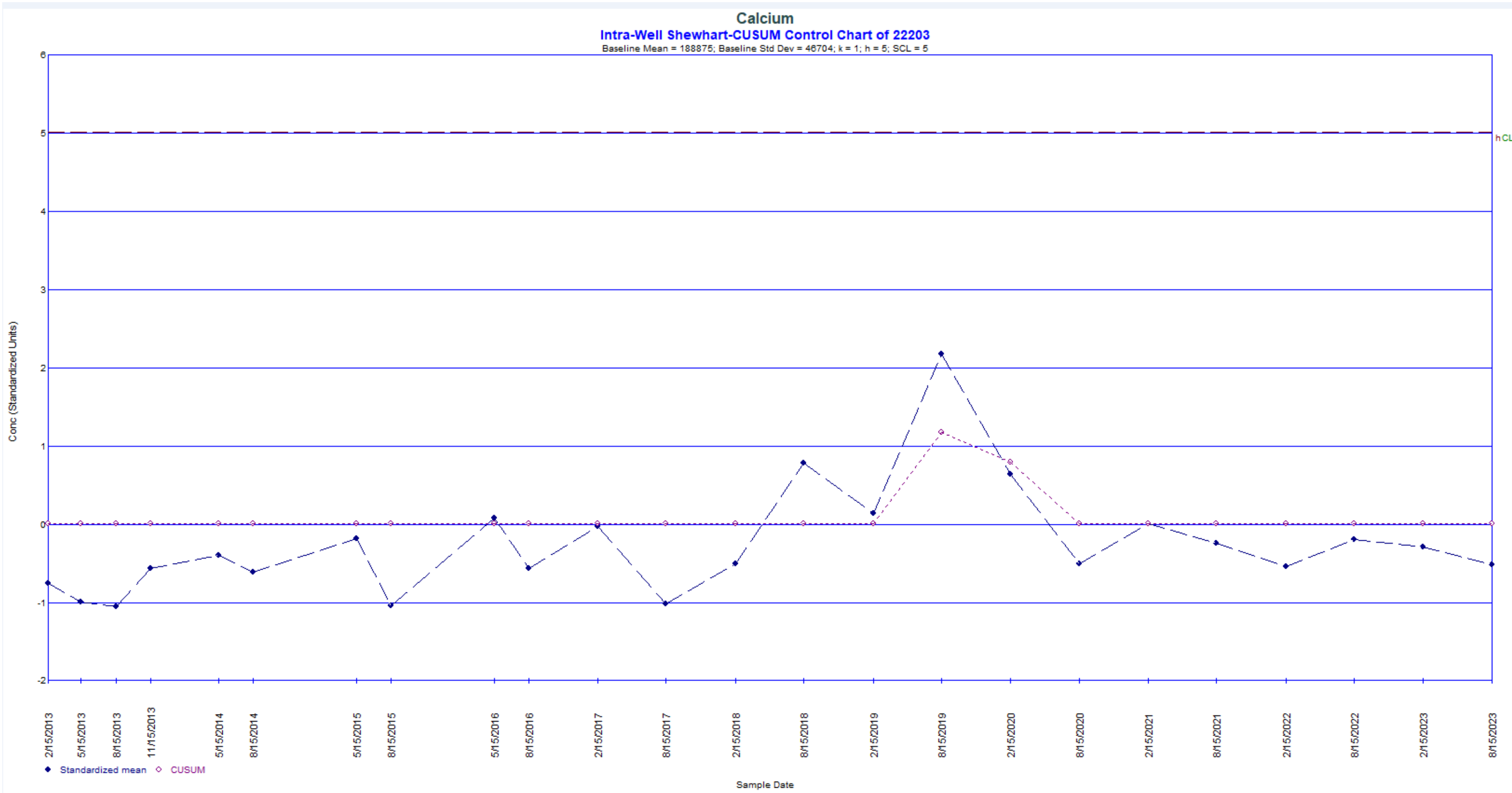

Figure A.5.3-19. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22203

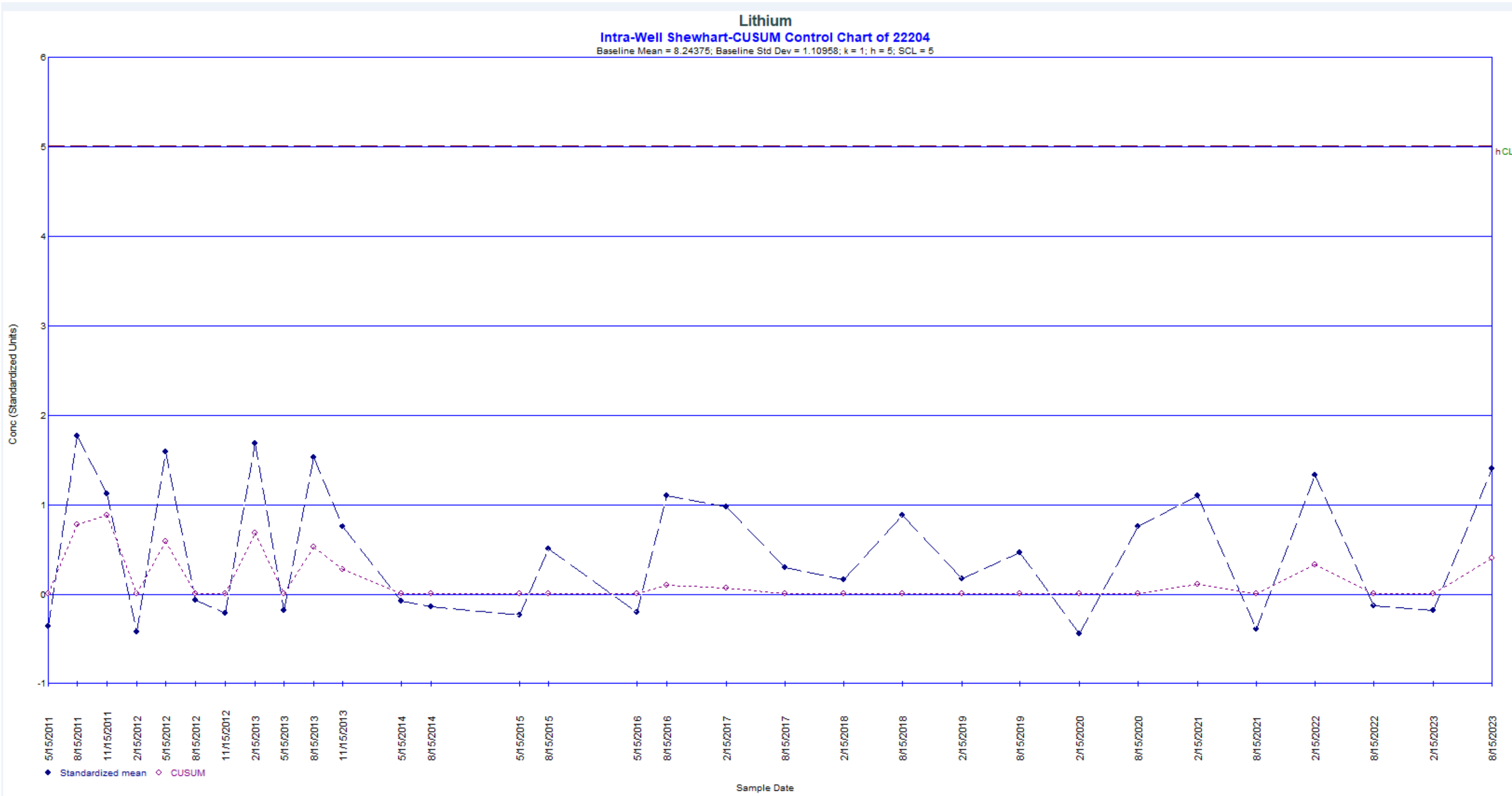

Figure A.5.3-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22204

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Subattachment A.5.4

Cell 4

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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, two parameters (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. No new high concentrations were measured in the LCS of Cell 4 in 2023. The volume of water in the LDS tank of Cell 4 was insufficient to collect a sample in 2023.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 4

Parameter	LCS 12341C 2023 Trend[a]	LDS 12341D Trend (Year Last Sampled)
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		
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

- Two parameters in 2023 (sodium and sulfate) 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 4 in 2023. 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	62	62	100	4.41	234	88.2	34.4	Undefined	None (2023)	Detected	
	LDS	12341D	42	42	100	5.74	79.8	15.1	14.8	Undefined	Up (2022)	Detected	
	HTW	12341	67	67	100	3.19	7.89	5.28	1.12	Normal	Down (2023)	Detected	
	GMA-U	22206	64	68	94.1	ND	4.67	1.34	0.94	Ln Normal	Up (2023)	Not Detected	
	GMA-D	22205	78	78	100	0.525	12.1	2.49	2.26	Ln Normal	None (2023)	Not Detected	
Boron (mg/L)	LCS	12341C	62	62	100	0.0626	1.93	0.842	0.261	Undefined	Down (2023)	Detected	
	LDS	12341D	42	42	100	0.415	3.74	0.708	0.777	Undefined	Up (2022)	Detected	
	HTW	12341	47	50	94.0	0.0284	1.24	0.0898	0.204	Undefined	Up (2023)	Detected	
	GMA-U	22206	63	68	92.6	ND	0.0817	0.0477	0.0139	Normal	Up (2023)	Detected	
	GMA-D	22205	61	68	89.7	ND	0.0807	0.0462	0.0140	Normal	Up (2023)	Detected	
Sodium (mg/L)	LCS	12341C	52	52	100	22	117	54.7	12.6	Undefined	Up (2023)	Detected	
	LDS	12341D	28	28	100	307	4,440	504	799	Undefined	Up (2022)	Detected	
	HTW	12341	48	48	100	13.7	18.1	14.9	1.0	Undefined	Down (2023)	Detected	
	GMA-U	22206	39	39	100	12.3	22.3	17.0	2.9	Normal	Up (2023)	Detected	
	GMA-D	22205	41	41	100	8.53	22.2	14.9	4.4	Undefined	Down (2023)	Detected	
Sulfate (mg/L)	LCS	12341C	62	62	100	140	3,940	2,800	760	Undefined	Up (2023)	Detected	
	LDS	12341D	42	42	100	1,470	25,500	2,660	4,100	Undefined	Up (2022)	Detected	
	HTW	12341	58	58	100	153	531	299	118	Undefined	Up (2023)	Detected	
	GMA-U	22206	63	63	100	90.4	559	208	105	Ln Normal	Down (2023)	Detected	3,720 (Q3-12)
	GMA-D	22205	63	63	100	199	535	333	75	Normal	None (2023)	Not Detected	
Calcium (mg/L)	GMA-U	22206	32	32	100	131	217	148	22	Undefined	Down (2023)	Not Detected	
	GMA-D	22205	32	32	100	163	268	215	23	Normal	Down (2023)	Detected	
Lithium (mg/L)	GMA-U	22206	39	39	100	0.00729	0.0175	0.0117	0.0025	Normal	Down (2023)	Detected	
	GMA-D	22205	39	39	100	0.00665	0.0167	0.00843	0.00213	Undefined	Up (2023)	Detected	
Magnesium (mg/L)	GMA-U	22206	32	32	100	30.2	43.8	35.9	3.4	Normal	None (2023)	Not Detected	
	GMA-D	22205	32	32	100	40.1	63.2	51.7	5.5	Normal	None (2023)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22206	3	32	9.4	ND	0.085	0.0187	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	4	32	12.5	ND	0.0818	0.00850	0.0170	Undefined	None (2023)	Not Detected	
Potassium (mg/L)	GMA-U	22206	32	32	100	2.69	4.39	3.59	0.41	Normal	Down (2023)	Detected	
	GMA-D	22205	34	34	100	1.60	3.22	2.23	0.44	Normal	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22206	4	39	10.3	ND	0.0294	0.00300	0.00545	Undefined	Up (2023)	Detected	
	GMA-D	22205	6	39	15.4	ND	0.0180	0.00300	0.00385	Undefined	Up (2023)	Detected	
Technitium-99 (pCi/L)	GMA-U	22206	1	29	3.4	ND	8.54	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	0	29	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22206	39	39	100	551	877	616	79	Undefined	None (2023)	Not Detected	
	GMA-D	22205	39	39	100	726	1,180	923	106	Normal	None (2023)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22206	25	68	36.8	ND	0.0640	0.00660	0.00936	Undefined	Down (2023)	Detected	
	GMA-D	22205	17	68	25.0	ND	0.0142	0.00166	0.00533	Undefined	None (2023)	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 has 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: Ln Normal 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

[j]The Cell 4 LDS was dry, resulting in no data from fourth quarter 2011 through 2016.

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
2023	1,050	2	525

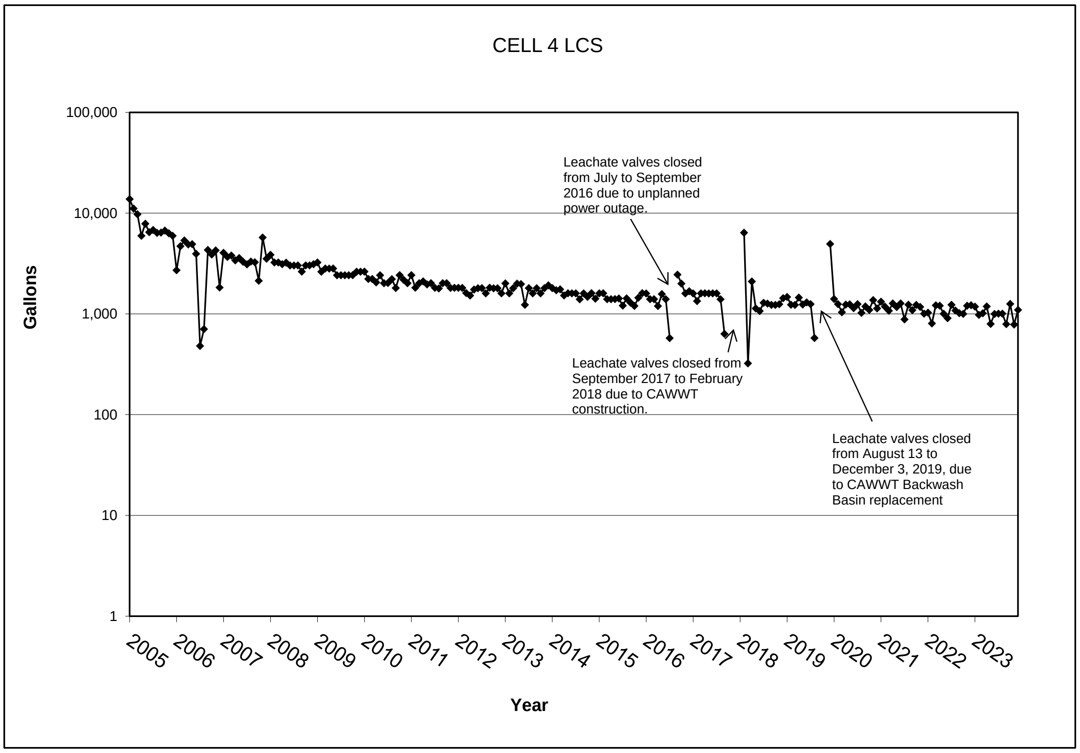


Figure A.5.4-1. Monthly Accumulation Volumes for Cell 4 LCS

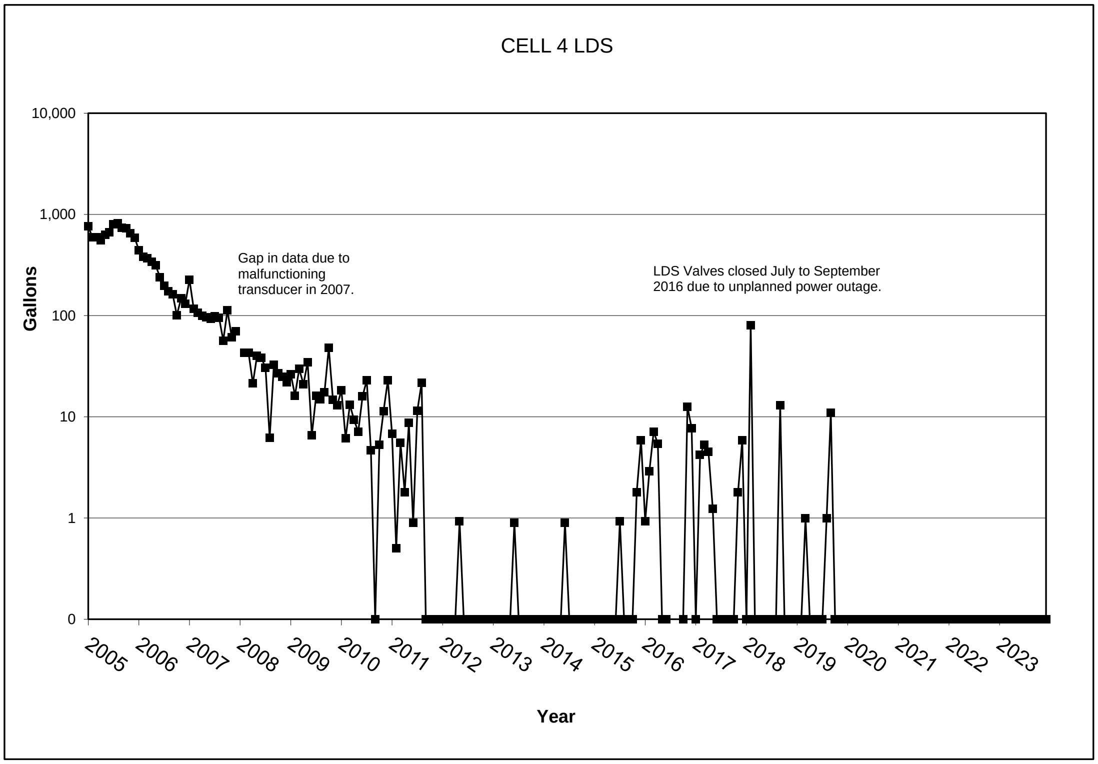


Figure A.5.4-2. Monthly Accumulation Volumes for Cell 4 LDS

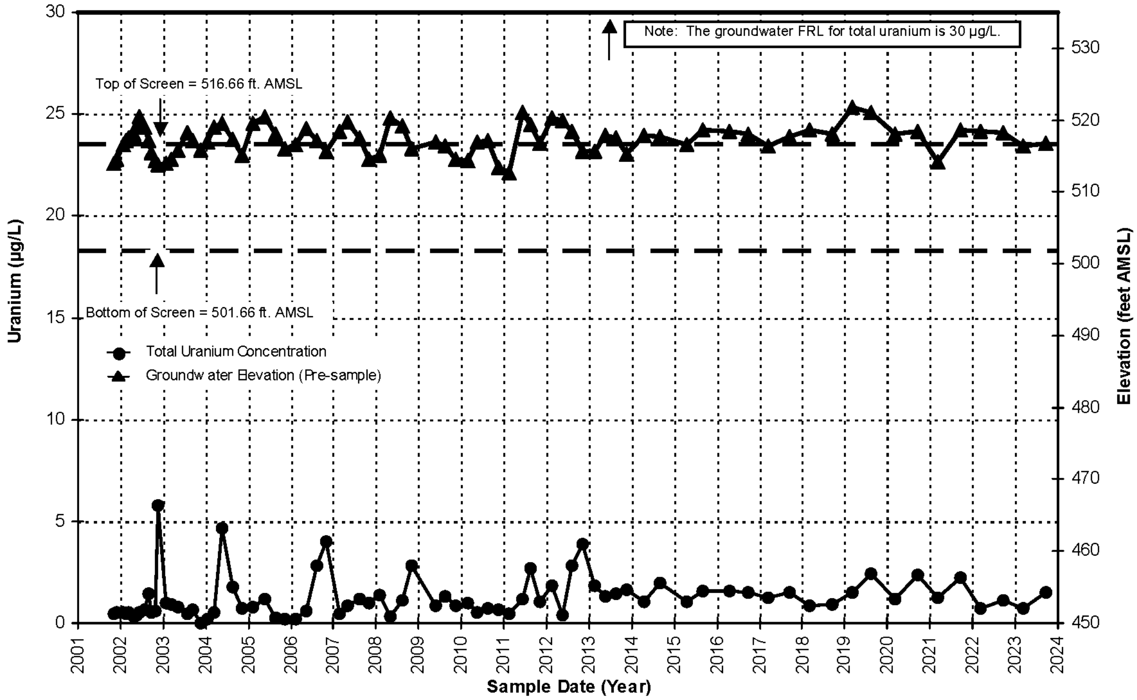
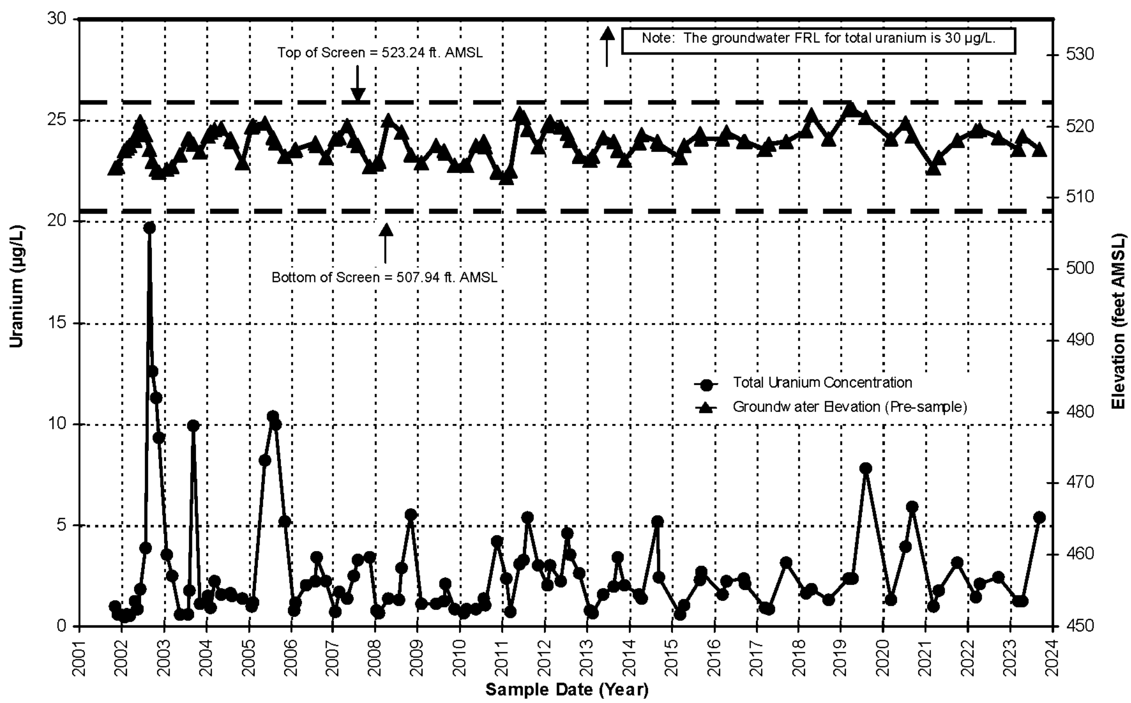


Figure A.5.4-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 4 Upgradient Monitoring Well 22206



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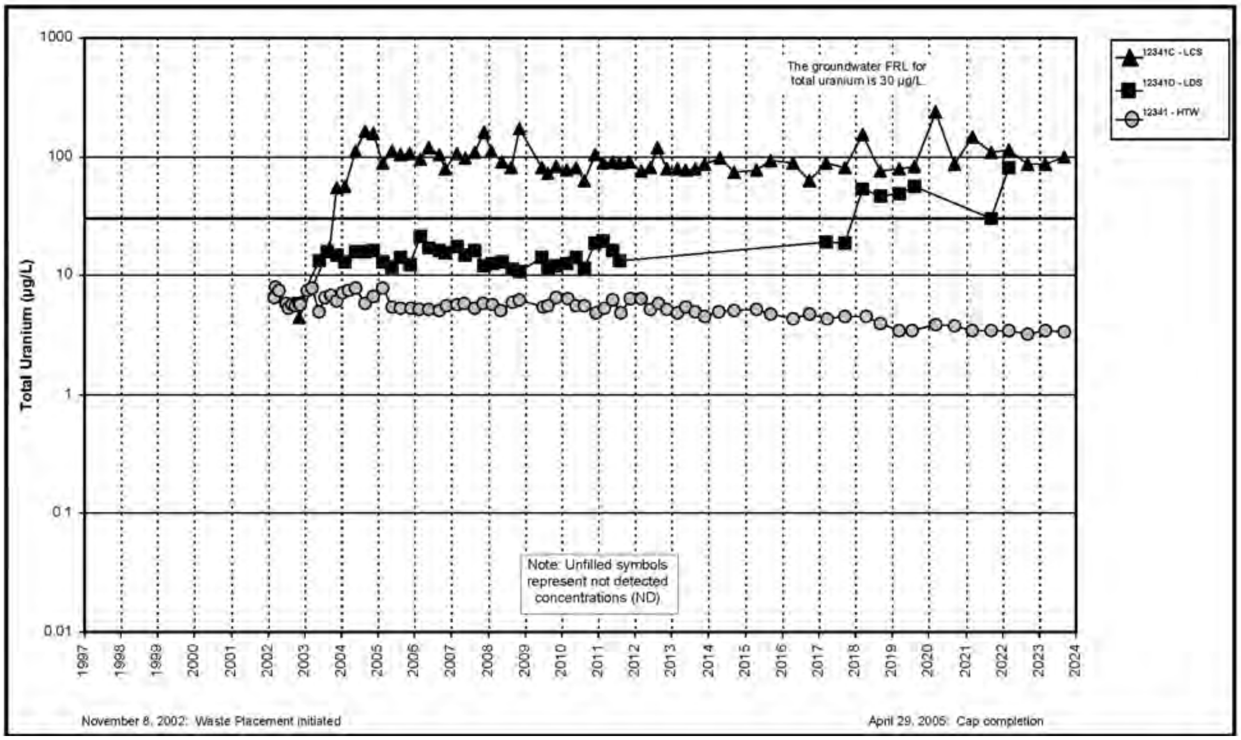


Figure A.5.4-5A. Cell 4 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

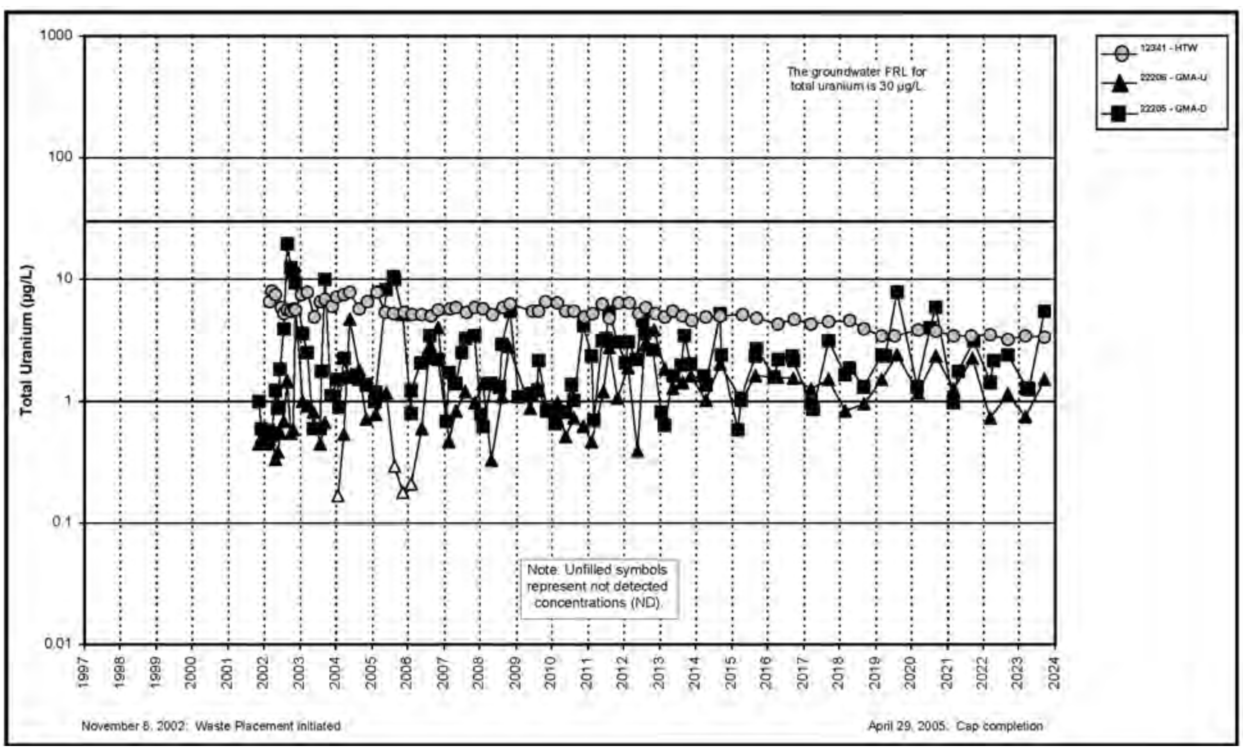


Figure A.5.4-5B. Cell 4 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

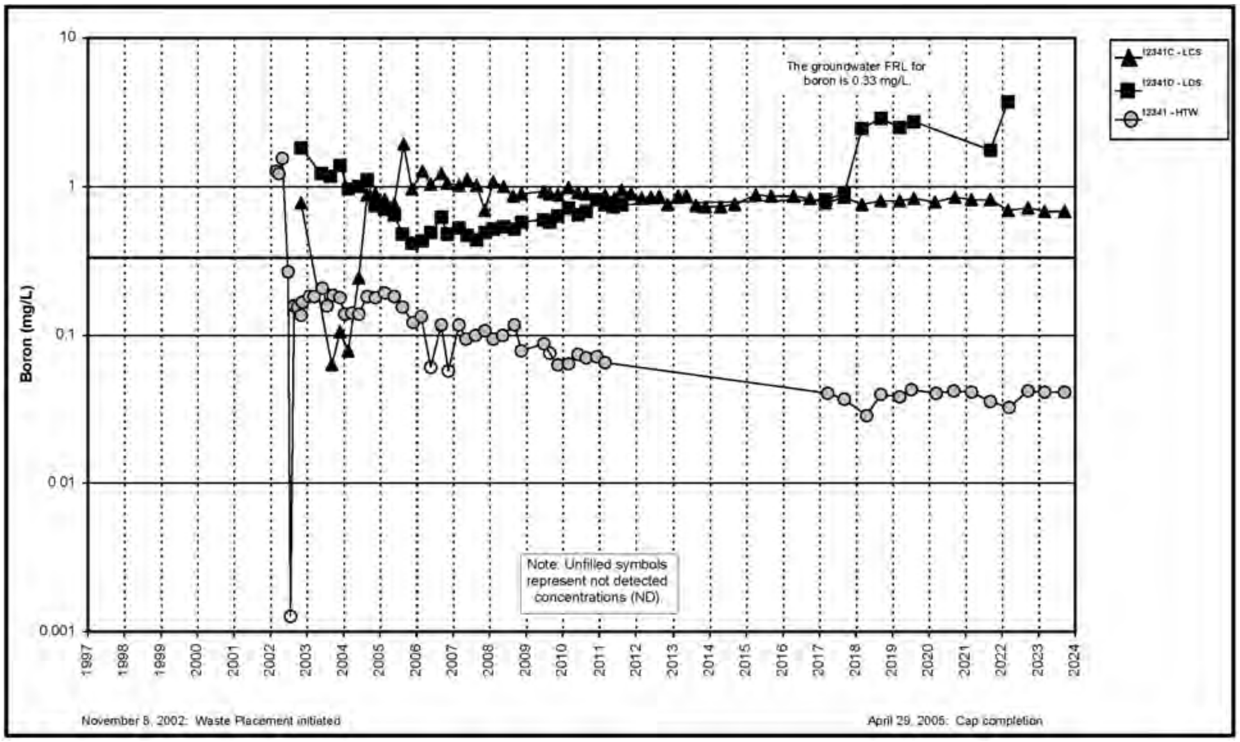


Figure A.5.4-6A. Cell 4 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

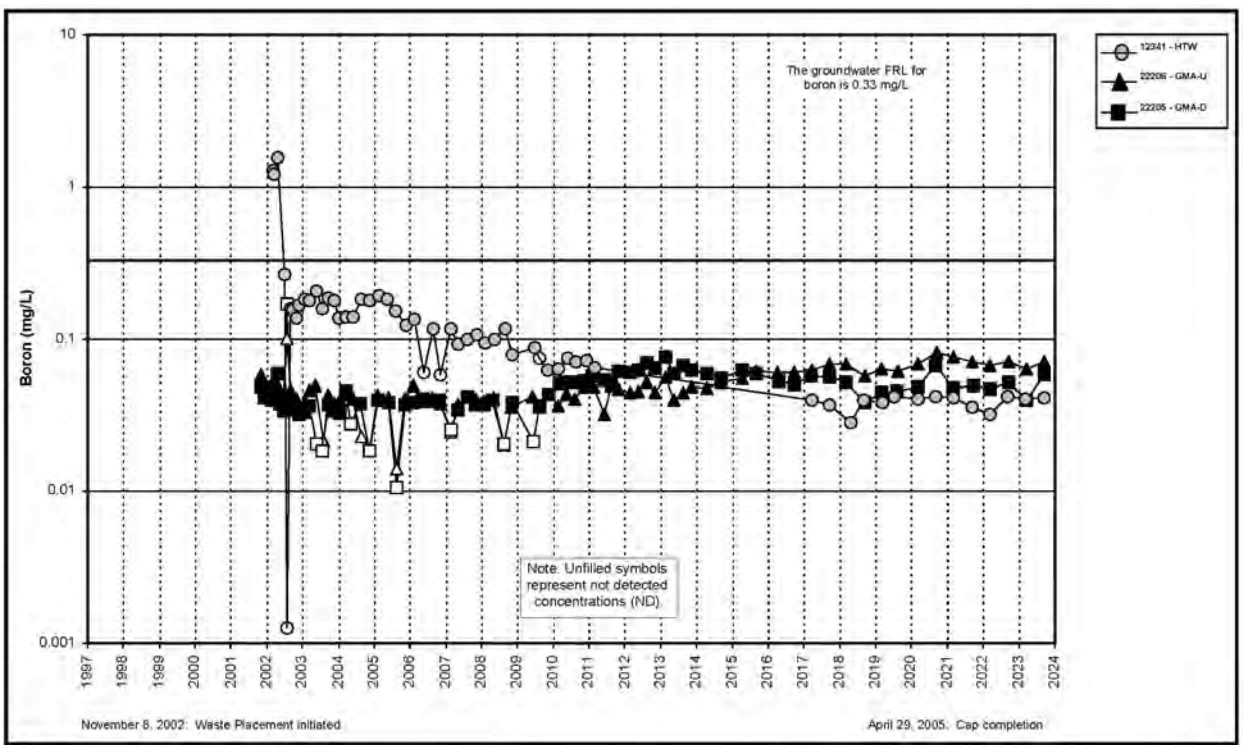


Figure A.5.4-6B. Cell 4 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

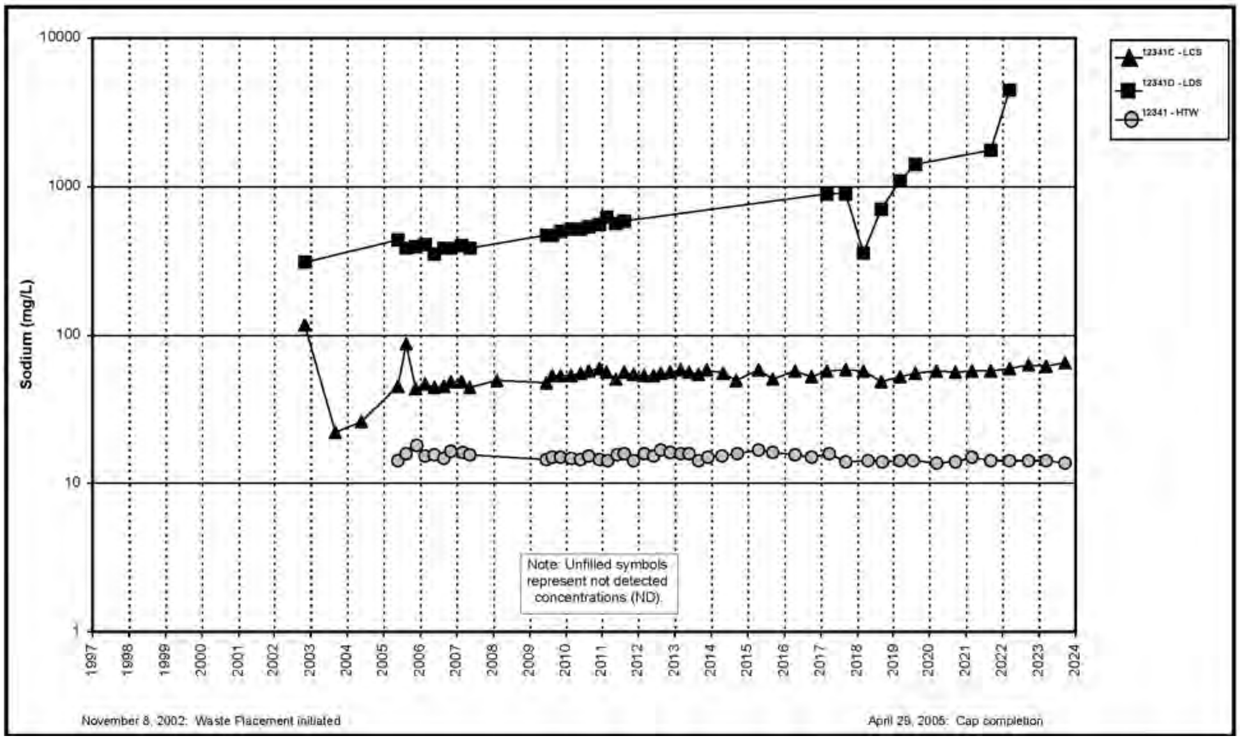


Figure A.5.4-7A. Cell 4 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

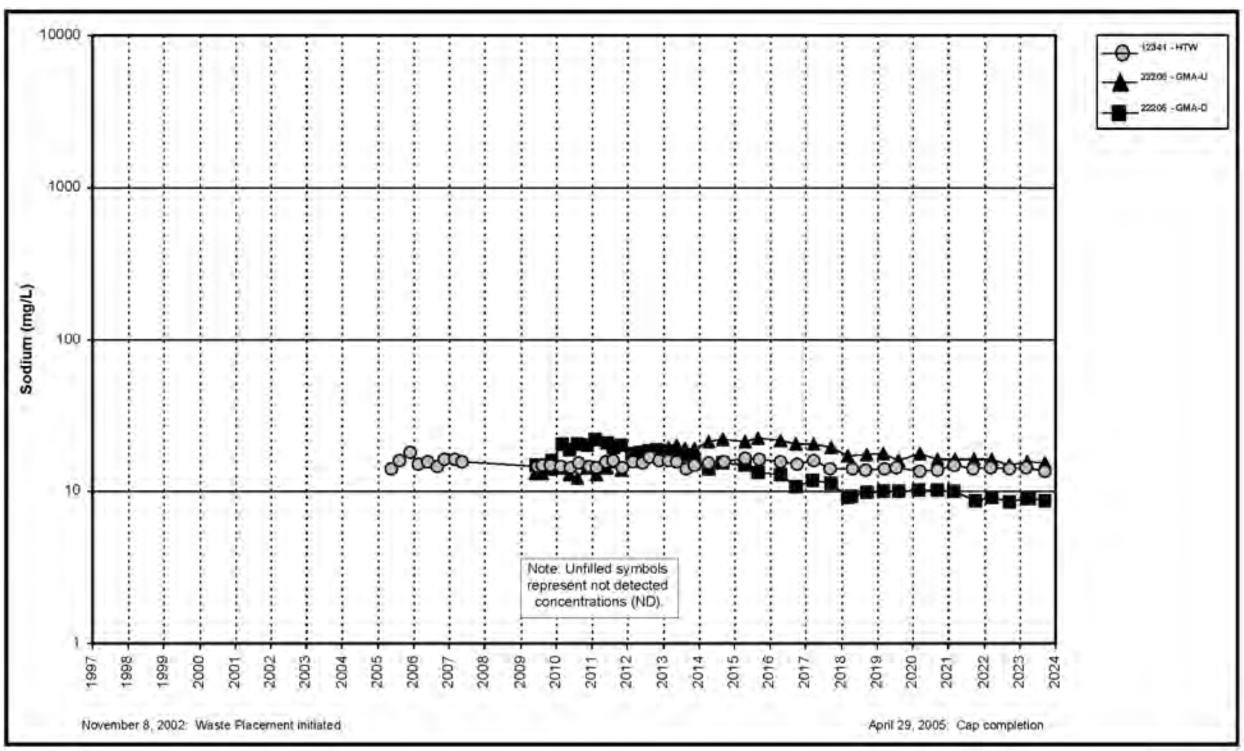


Figure A.5.4-7B. Cell 4 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

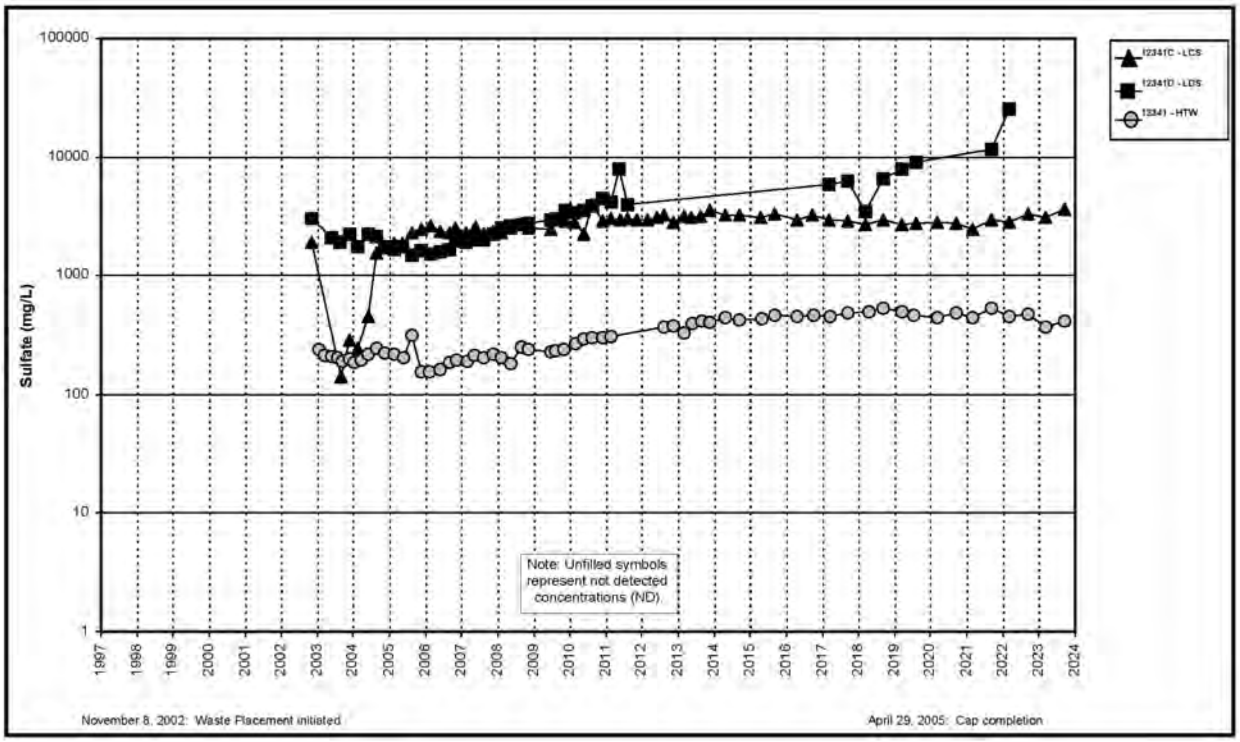


Figure A.5.4-8A. Cell 4 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

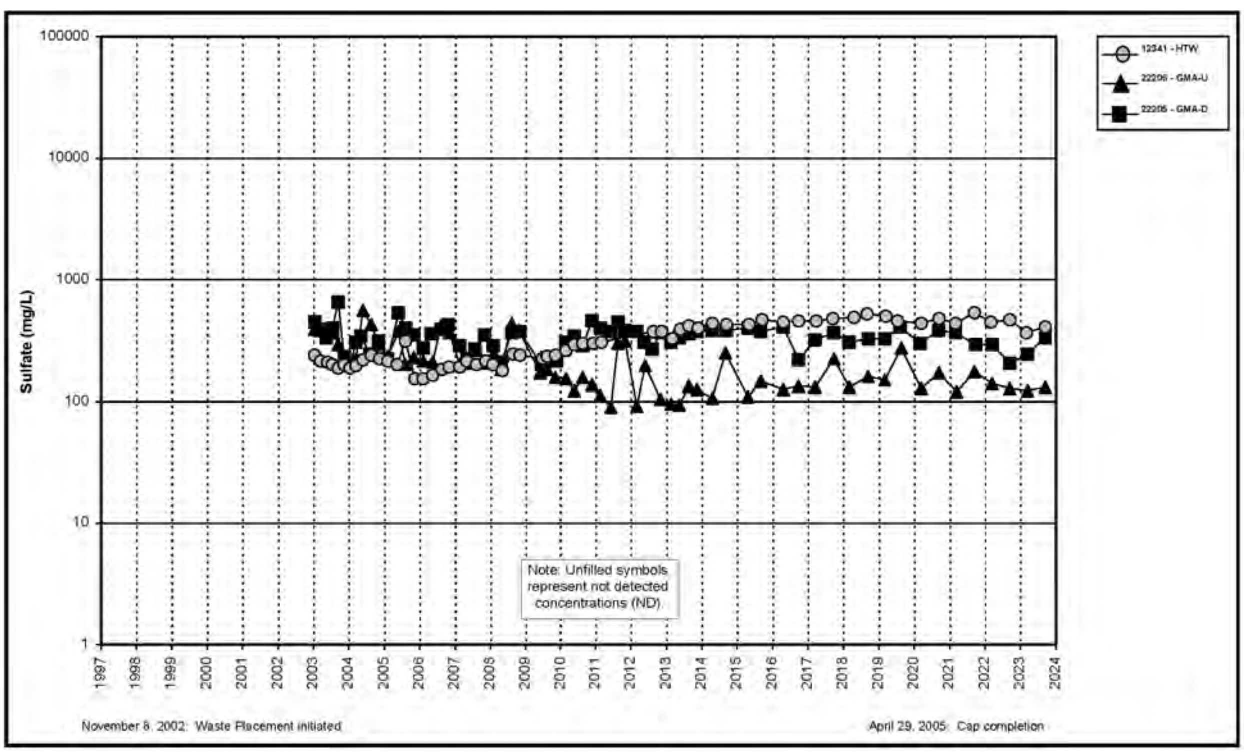
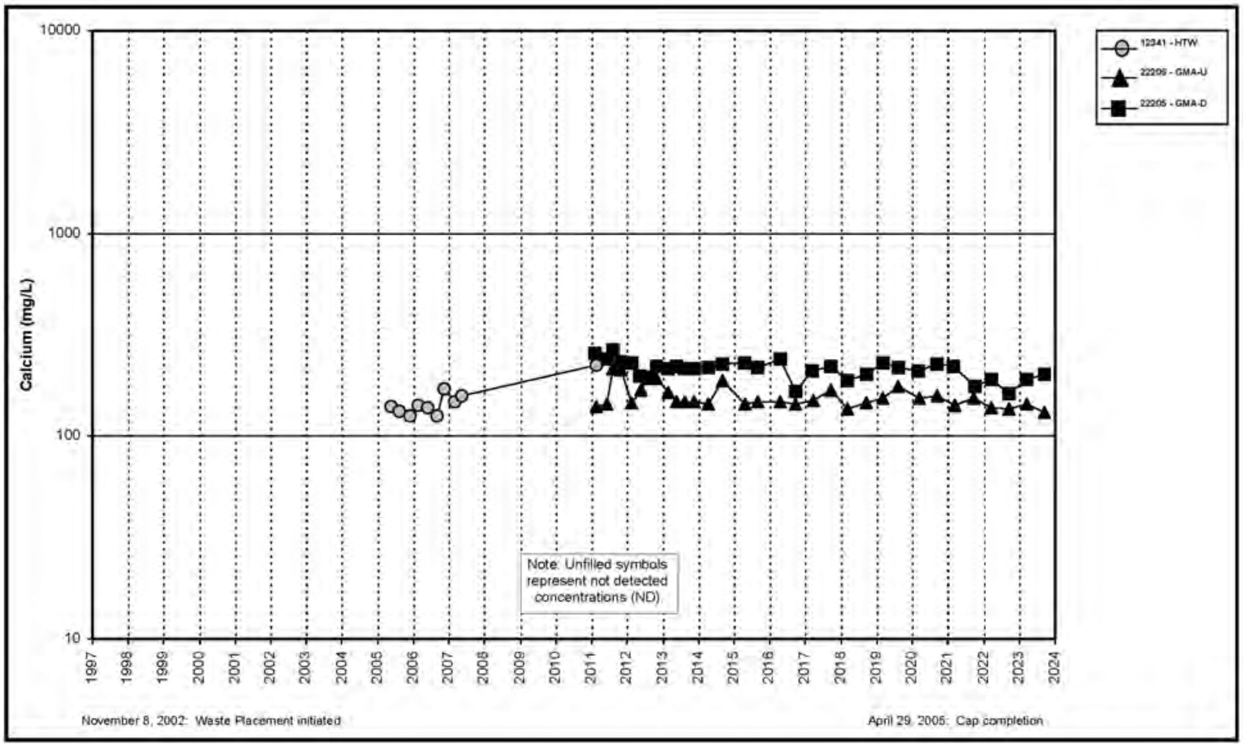


Figure A.5.4-8B. Cell 4 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well



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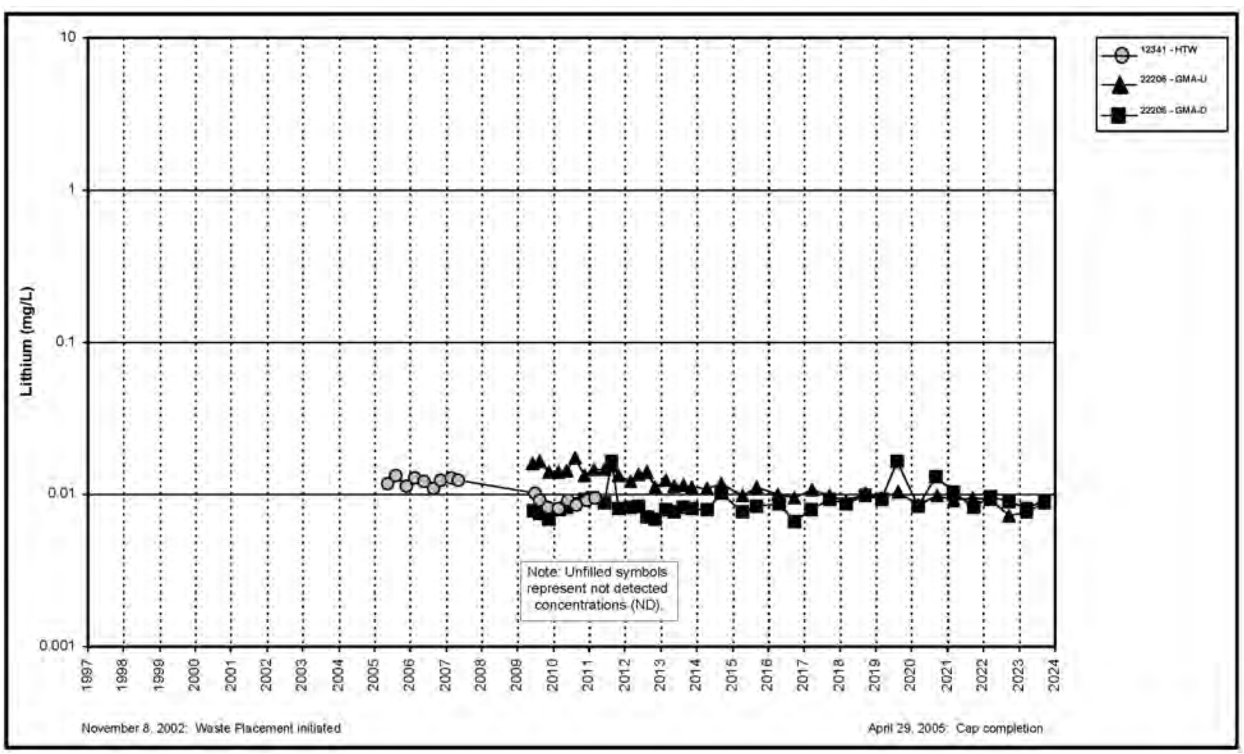

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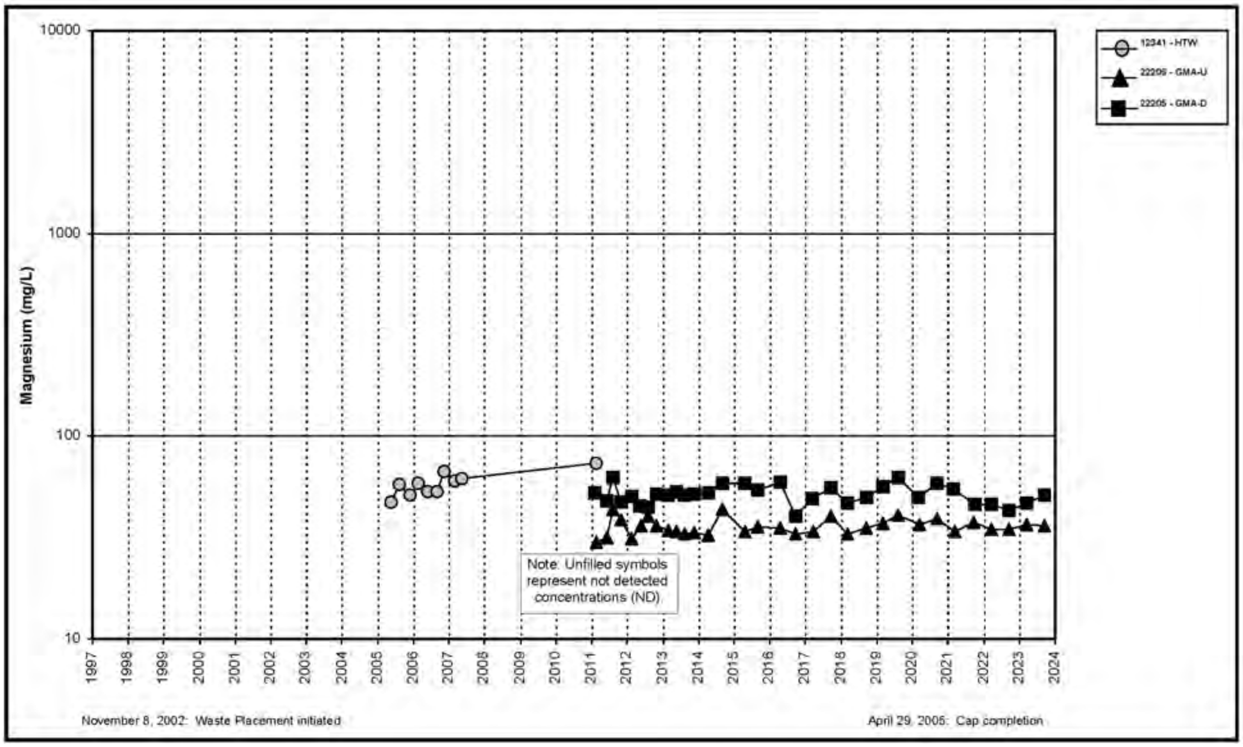

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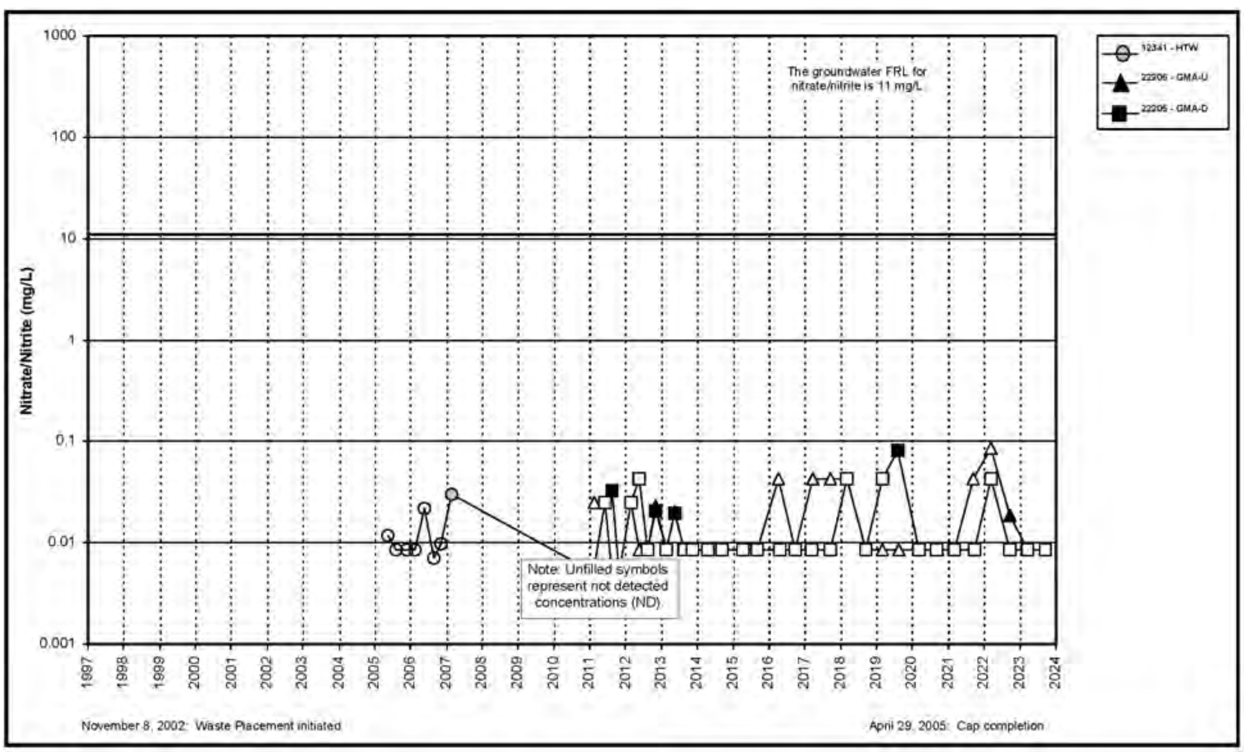

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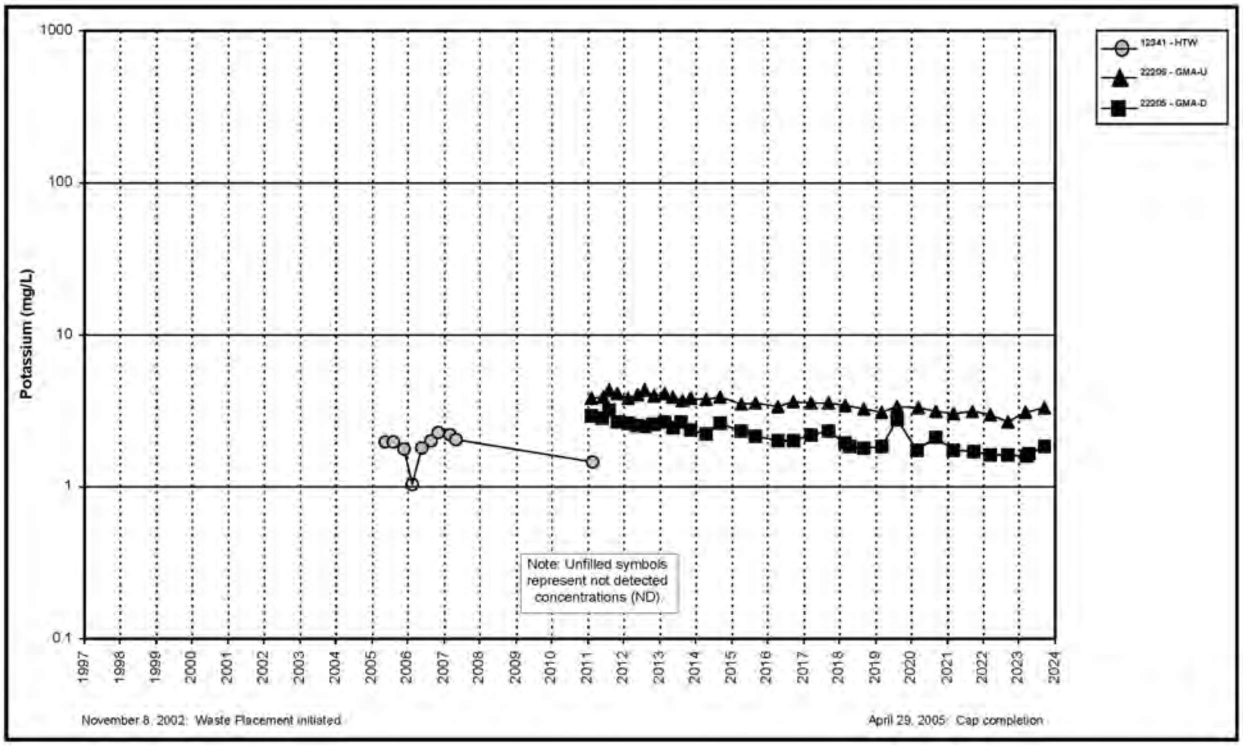

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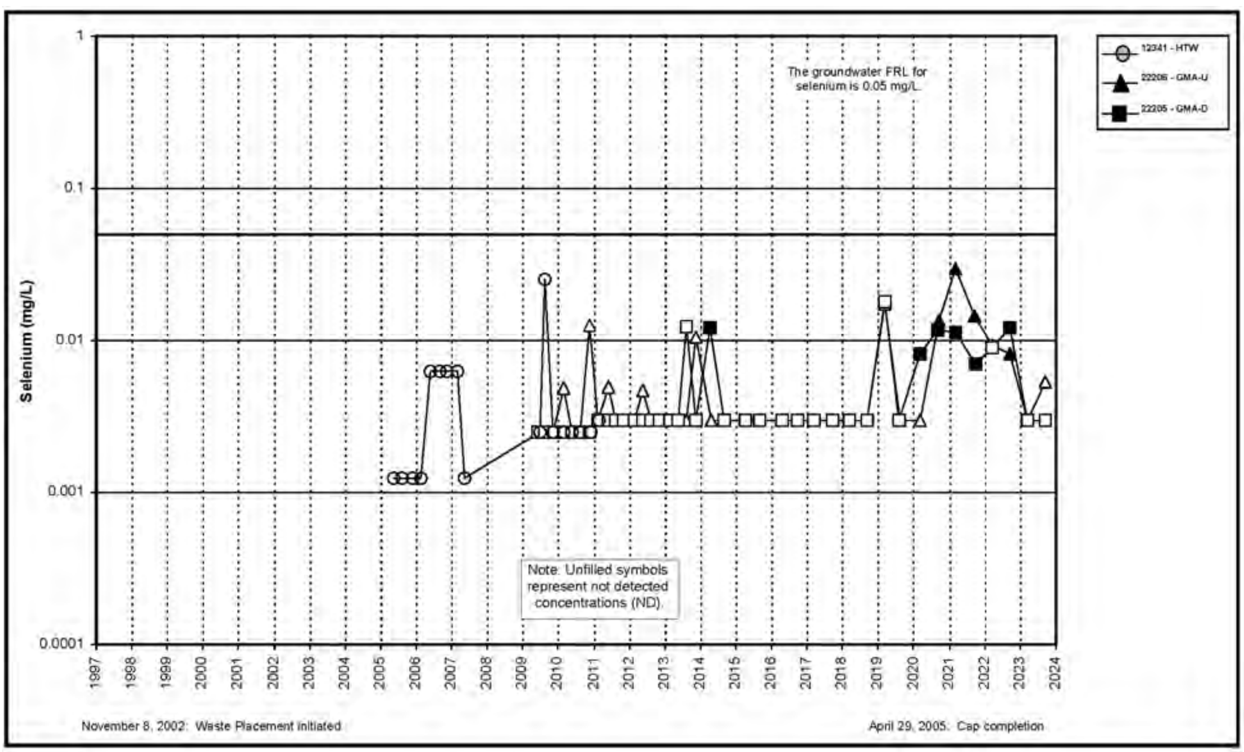

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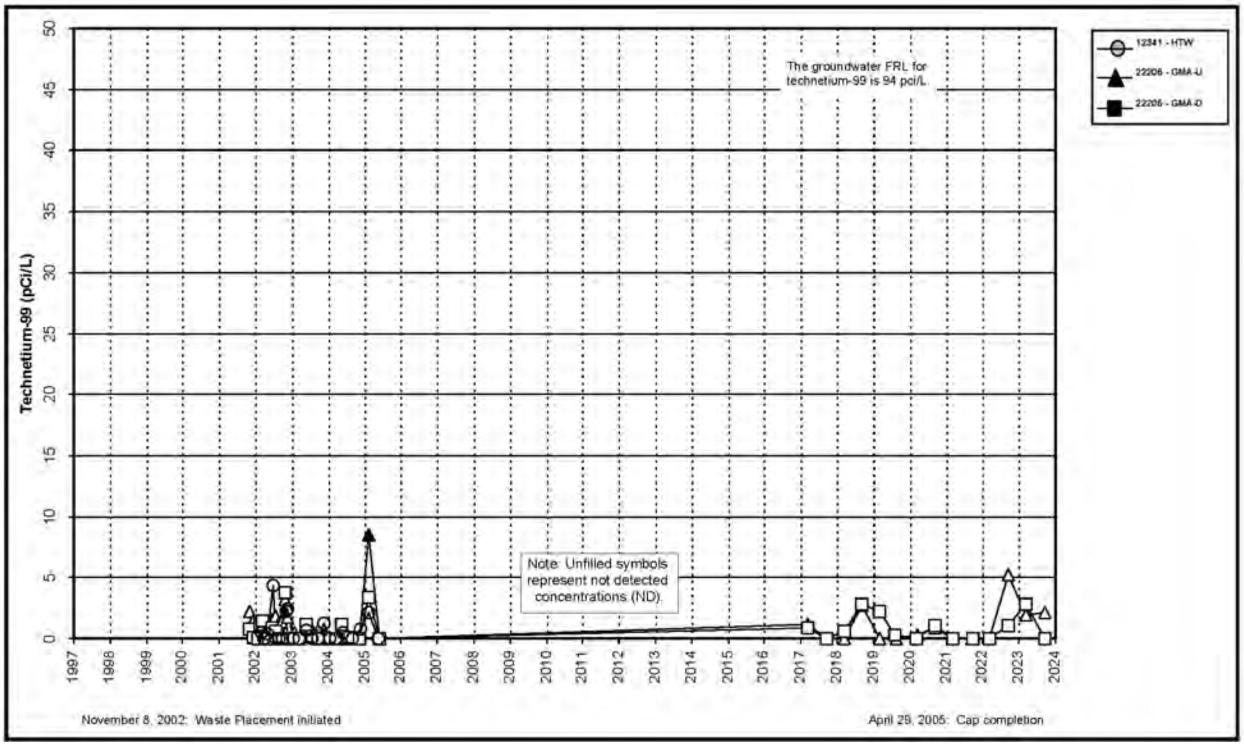

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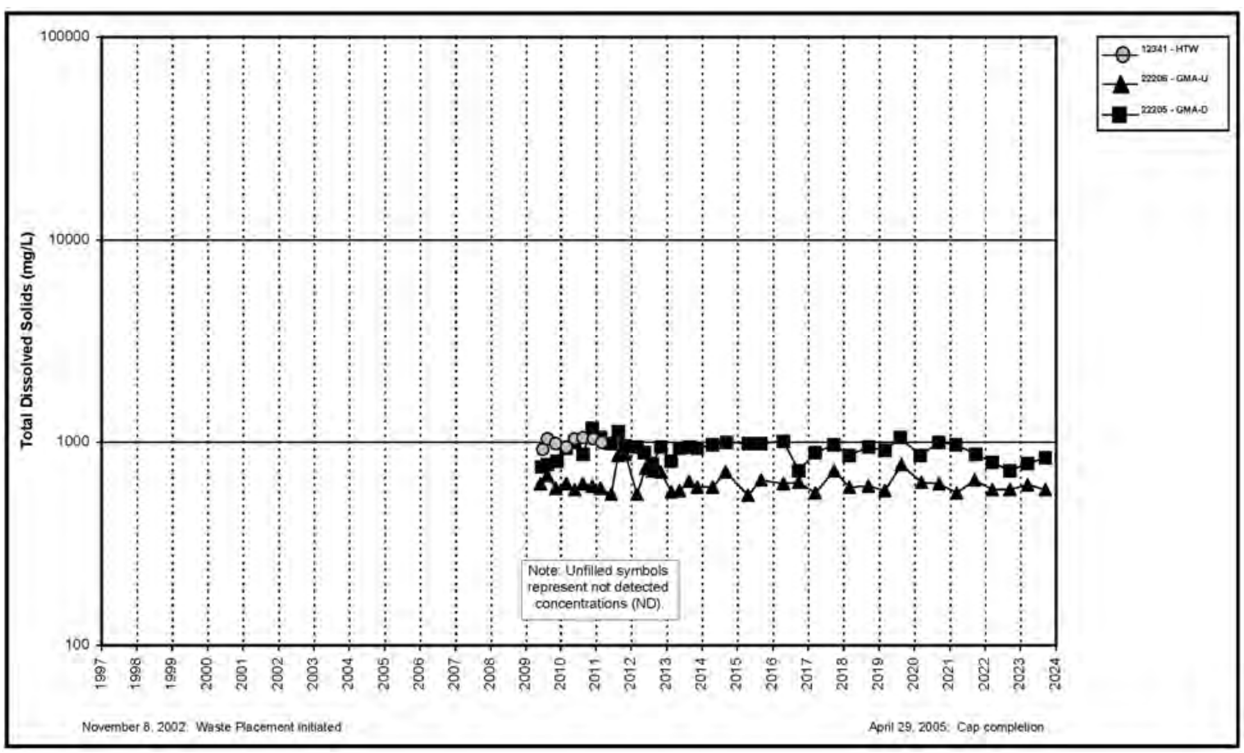

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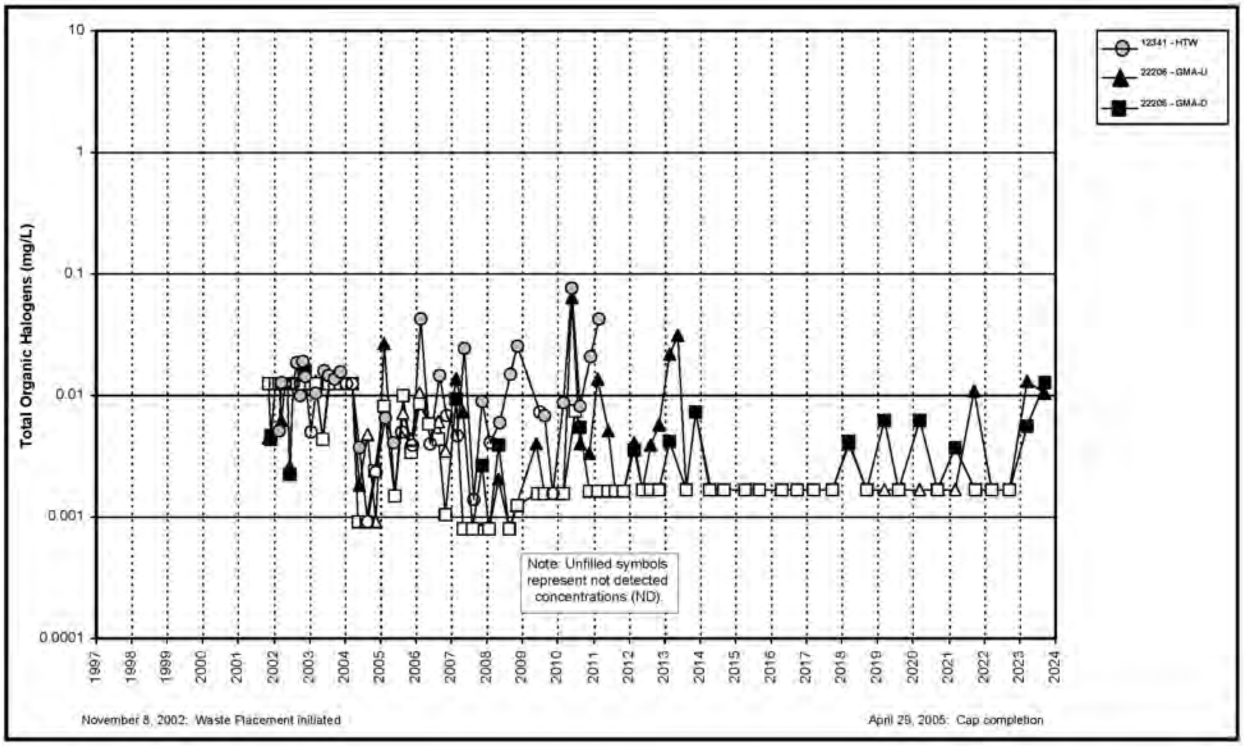

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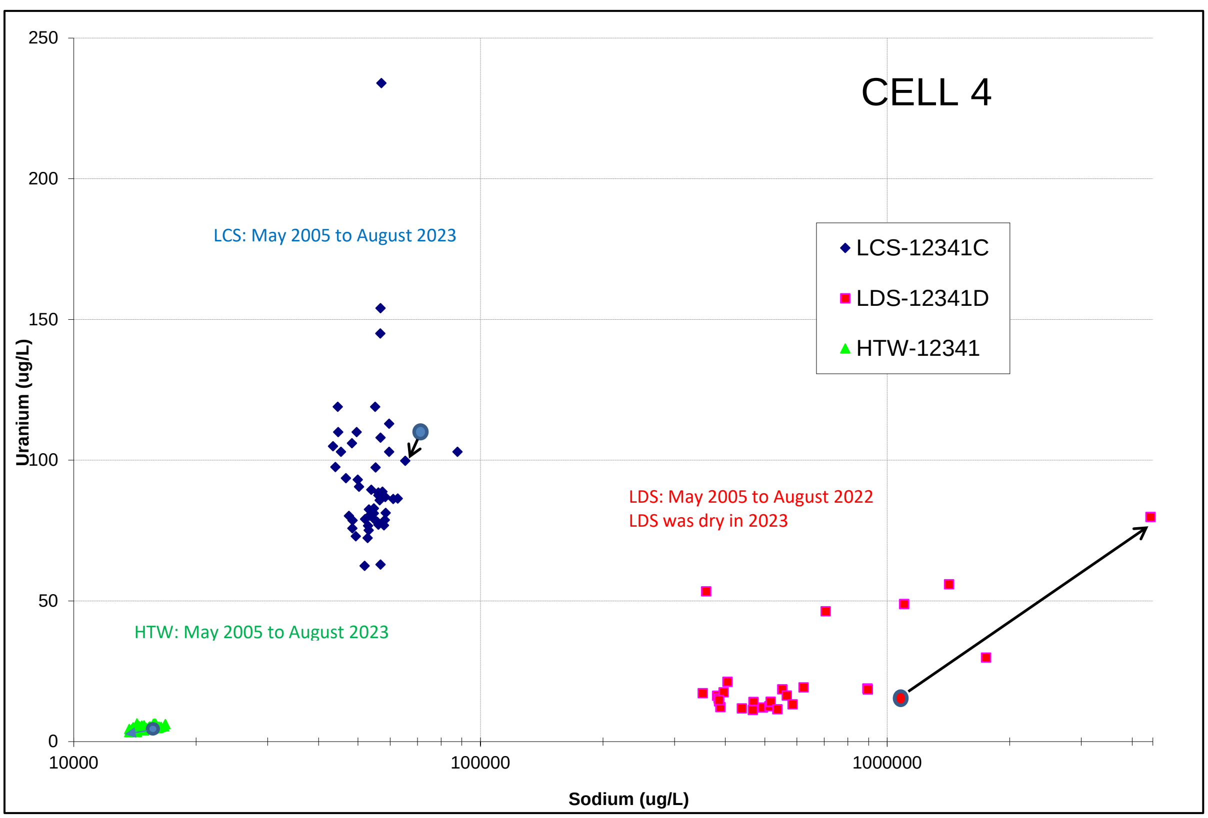

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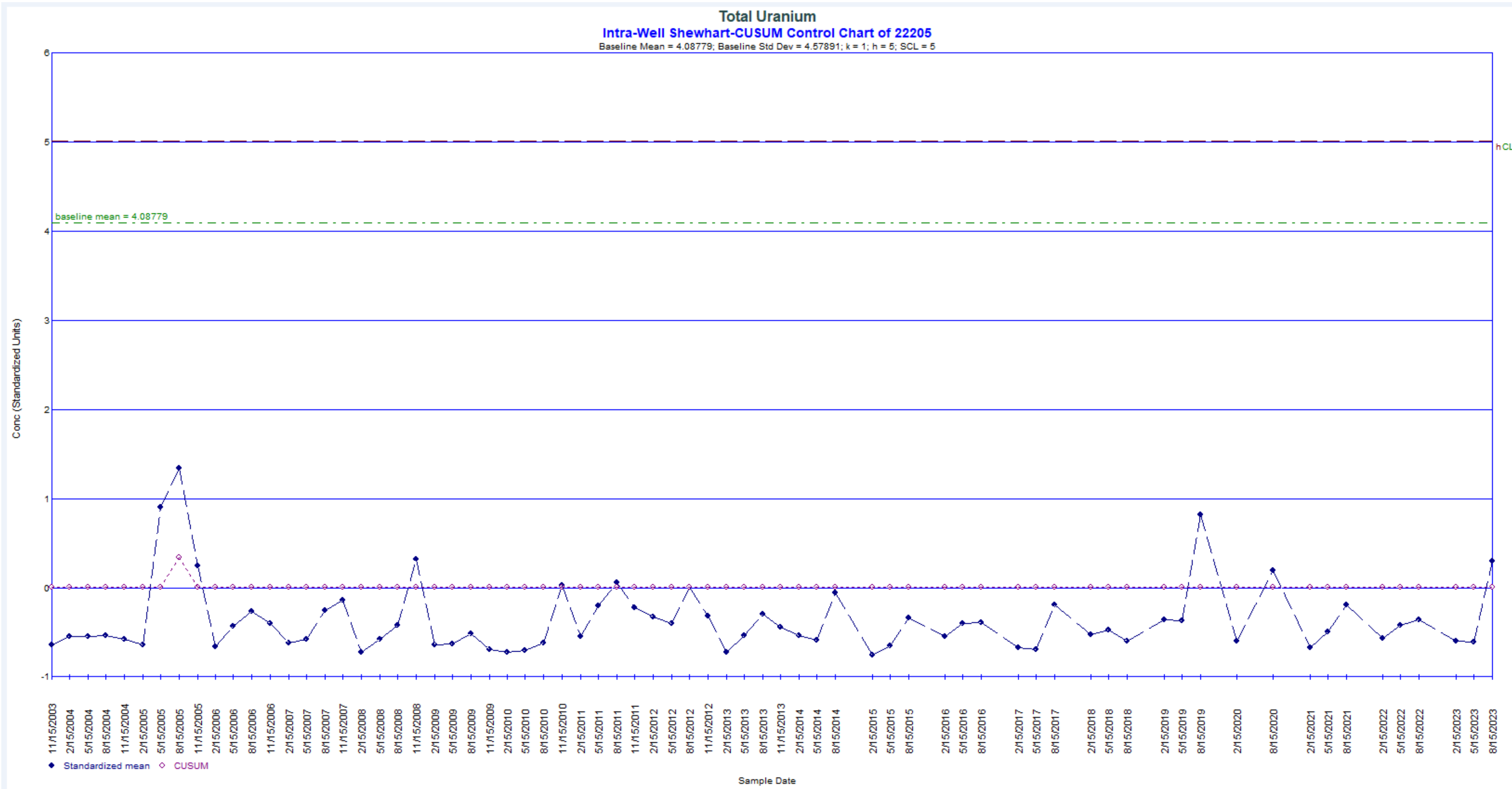

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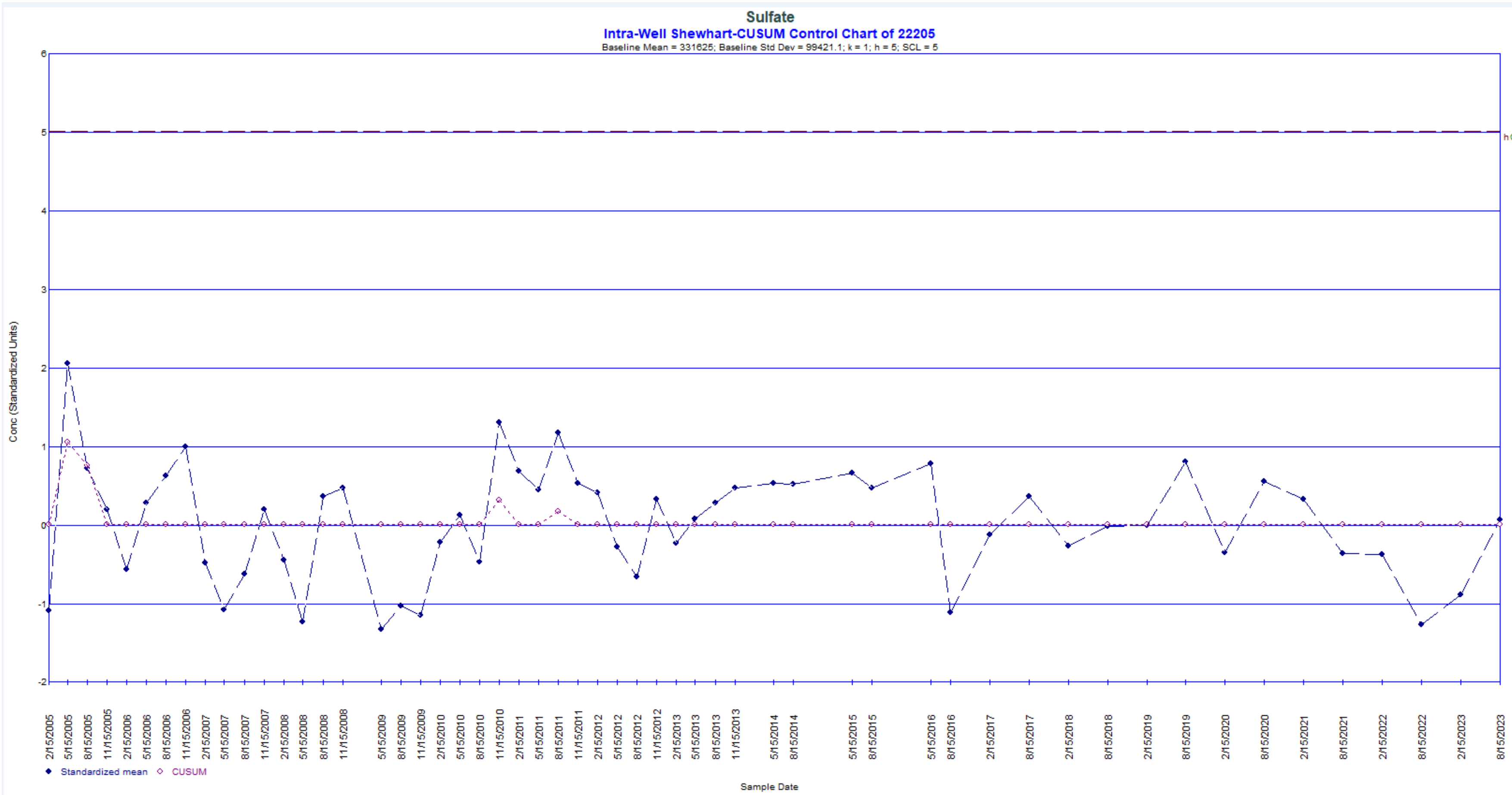

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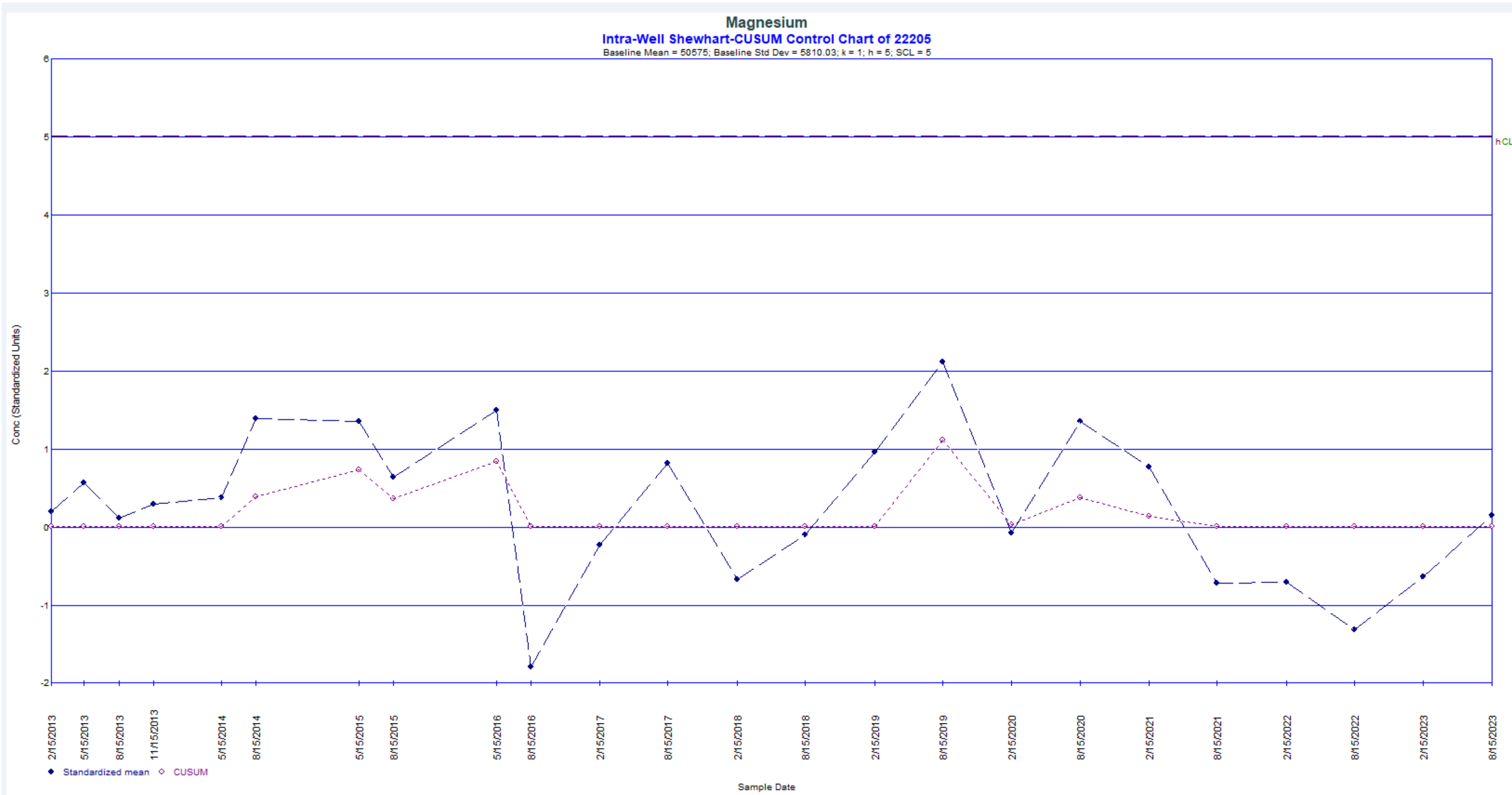

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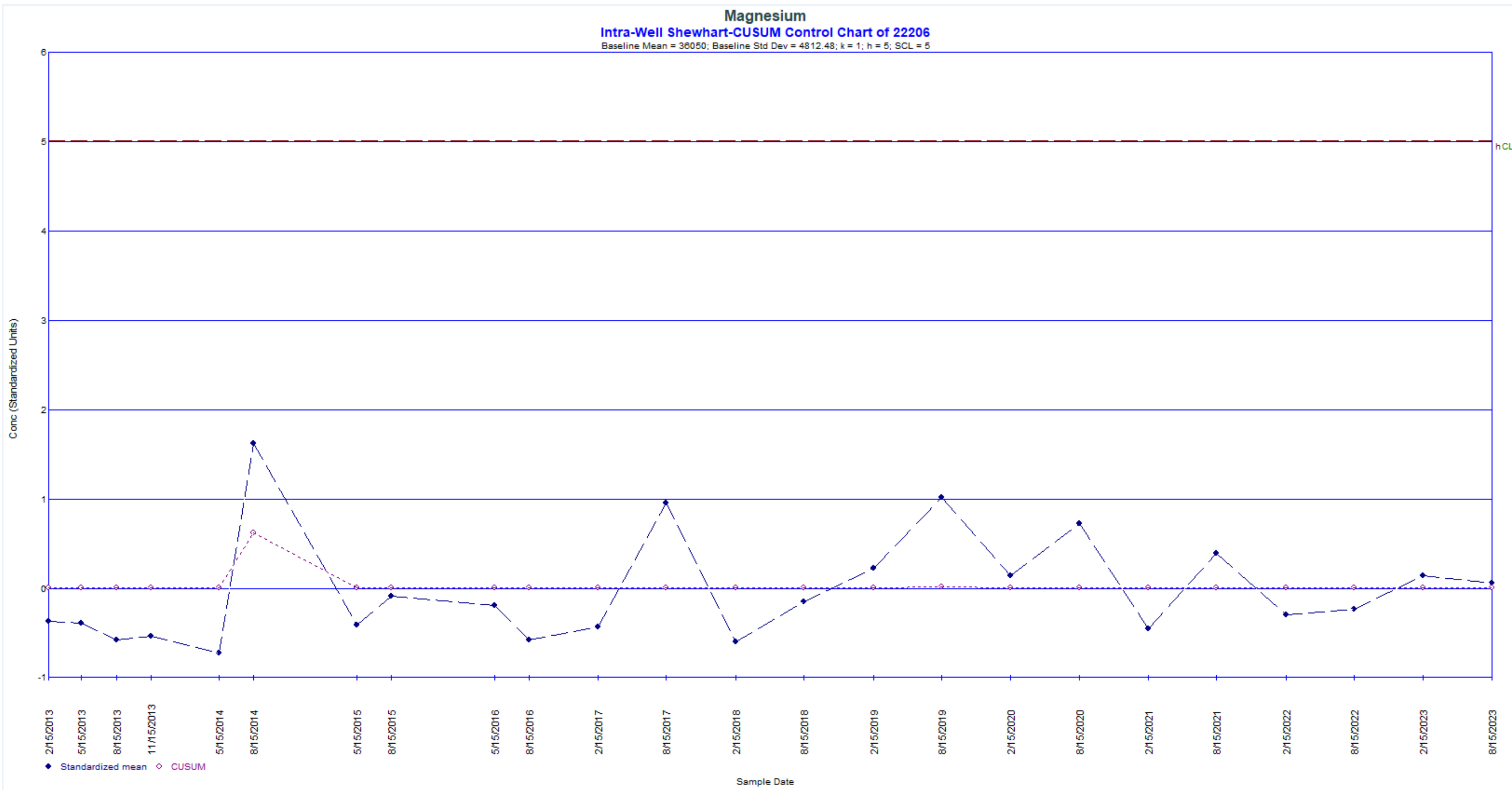

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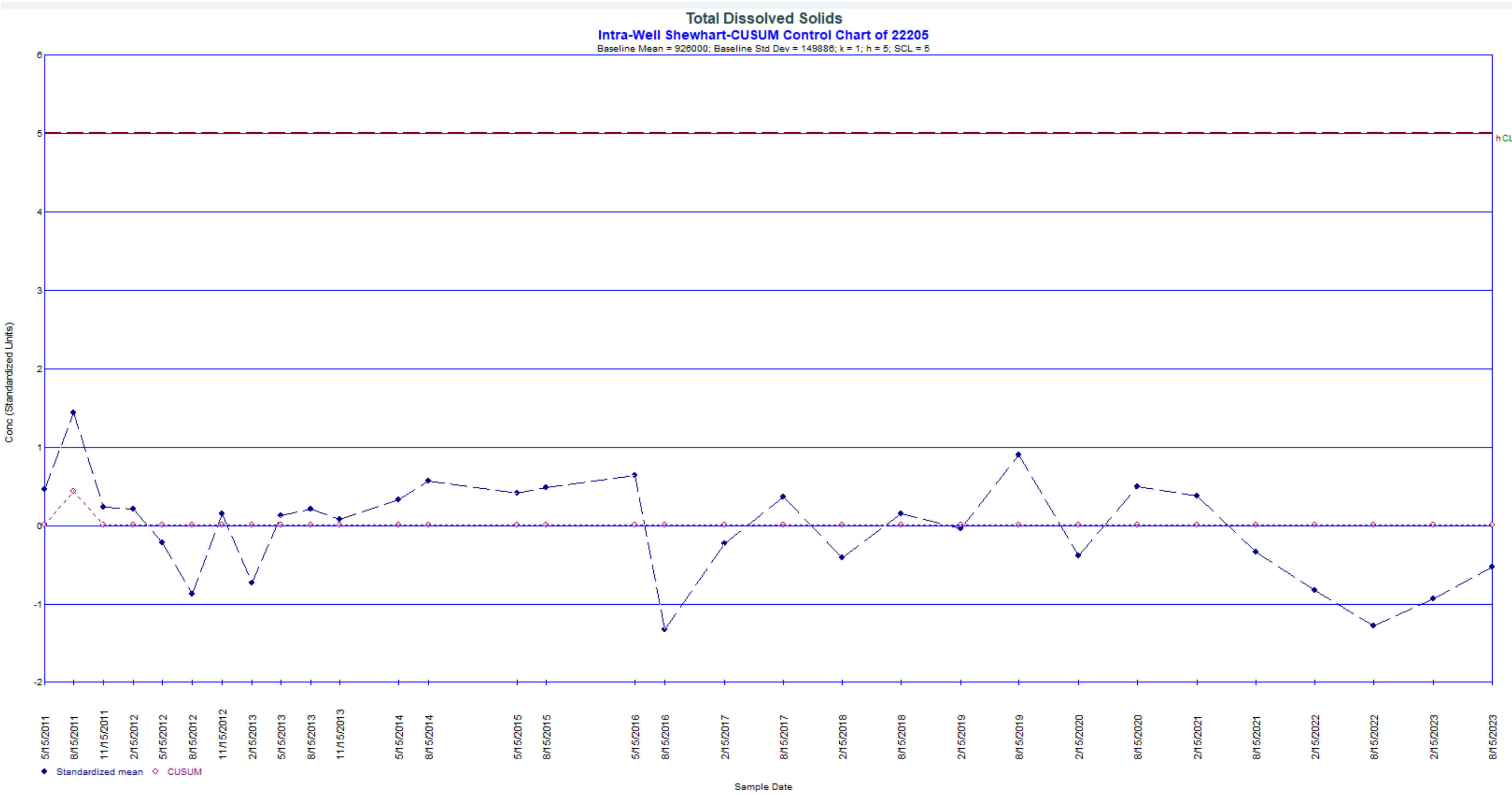

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Subattachment A.5.5

Cell 5

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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.5.5-21)

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 2023. No new high concentrations were measured in the LCS of Cell 5 in 2023. Since 2013, the volume of water in the LDS tank of Cell 5 was insufficient to collect a sample.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 5

Parameter	LCS 12342C 2023 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, seven parameters (boron, sodium, sulfate, lithium, magnesium, 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	
Magnesium		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, three 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 three control charts (Figures A.5.5-19 and A.5-21) which exhibit "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
Lithium	GMA-D	22208	In Control	A.5.5-21

[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 2023 based on the Mann-Kendall test for trend. No new high concentrations were measured in the LCS of Cell 5 in 2023
- The volume of water in the LDS tank of Cell 5 was insufficient to collect a sample in 2023.
- Seven parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 5: boron, sodium, sulfate, lithium, magnesium, 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.
- Three control charts were constructed for Cell 5 parameters. All 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	64	64	100	3.39	285	123	45	Undefined	None (2023)	Detected	
	LDS	12342D	40	40	100	2.93	27.1	15.6	5.2	Normal	Down (2013)	Detected	
	HTW	12342	67	67	100	7.29	19.2	8.99	2.15	Undefined	Down (2023)	Detected	
	GMA-U	22207	57	68	83.8	ND	0.631	0.314	0.123	Ln Normal	Down (2023)	Not Detected	2.39 (Q3-02)
	GMA-D	22208	67	78	85.9	ND	0.523	0.332	0.094	Normal	None (2023)	Not Detected	2.10 (Q2-04); 0.800 (Q1-05); 0.006 (Q2-05); 0.710 (Q2-08)
Boron (mg/L)	LCS	12342C	62	64	96.9	ND	1.59	0.762	0.257	Undefined	None (2023)	Detected	
	LDS	12342D	40	40	100	0.202	1.20	0.398	0.272	Undefined	None (2013)	Detected	
	HTW	12342	48	50	96.0	ND	0.221	0.0862	0.0414	Undefined	None (2023)	Detected	
	GMA-U	22207	63	68	92.6	ND	0.0912	0.0422	0.0145	Undefined	Up (2023)	Detected	
	GMA-D	22208	62	68	91.2	ND	0.0618	0.0372	0.0116	Normal	Up (2023)	Detected	
Sodium (mg/L)	LCS	12342C	51	52	98.1	57.0	79.7	68.2	4.8	Normal	Down (2023)	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	48	48	100	17.0	33.6	25.8	4.8	Undefined	Down (2023)	Detected	
	GMA-U	22207	39	39	100	13.0	23.1	16.7	2.5	Normal	Up (2023)	Detected	
	GMA-D	22208	41	41	100	8.99	17.9	14.9	2.8	Undefined	Down (2023)	Detected	
Sulfate (mg/L)	LCS	12342C	64	64	100	218	5,910	3,600	1,240	Undefined	Up (2023)	Detected	
	LDS	12342D	40	40	100	1,130	6,100	2,160	1,030	Ln Normal	Up (2013)	Detected	
	HTW	12342	58	58	100	101	578	376	128	Undefined	Up (2023)	Detected	
	GMA-U	22207	63	63	100	97.8	470	200	87	Ln Normal	Down (2023)	Detected	770 (Q2-05), 552 (Q3-04)
	GMA-D	22208	63	63	100	98.1	671	353	104	Normal	Down 2023)	Detected	
Calcium (mg/L)	GMA-U	22207	32	32	100	124	187	153	11	Normal	None (2023)	Not Detected	
	GMA-D	22208	32	32	100	107	285	210	36	Normal	Down (2023)	Detected	
Lithium (mg/L)	GMA-U	22207	39	39	100	0.00642	0.0165	0.0137	0.0030	Undefined	Up (2023)	Detected	
	GMA-D	22208	39	39	100	0.00659	0.00985	0.00808	0.00066	Normal	None (2023)	Not Detected	0.00425 (Q1-17)
Magnesium (mg/L)	GMA-U	22207	32	32	100	26.1	38.5	33.9	3.0	Undefined	Up (2023)	Detected	
	GMA-D	22208	32	32	100	43.9	66.4	52.8	6.2	Normal	Down (2023)	Detected	24.3 (Q1-17)
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22207	2	32	6.2	ND	0.425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	3	32	9.4	ND	0.050	0.0176	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22207	32	32	100	2.75	4.82	3.79	0.60	Normal	Up (2023)	Detected	
	GMA-D	22208	34	34	100	2.15	3.53	2.93	0.35	Normal	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22207	3	39	7.7	ND	0.0180	0.0043	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	5	39	12.8	ND	0.0157	0.00300	0.00352	Undefined	Up (2023)	Detected	
Technitium-99 (pCi/L)	GMA-U	22207	0	29	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	1	29	3.4	ND	6.4	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22207	39	39	100	552	770	635	46	Normal	None (2023)	Detected	987 (Q4-09)
	GMA-D	22208	39	39	100	456	1,290	922	157	Normal	Down (2023)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22207	24	68	35.3	ND	0.047	0.00285	0.00719	Undefined	None (2023)	Detected	
	GMA-D	22208	19	68	27.9	ND	0.026	0.00259	0.00514	Undefined	Down (2023)	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 has 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: Ln Normal 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
2023	2,100	2	1,050

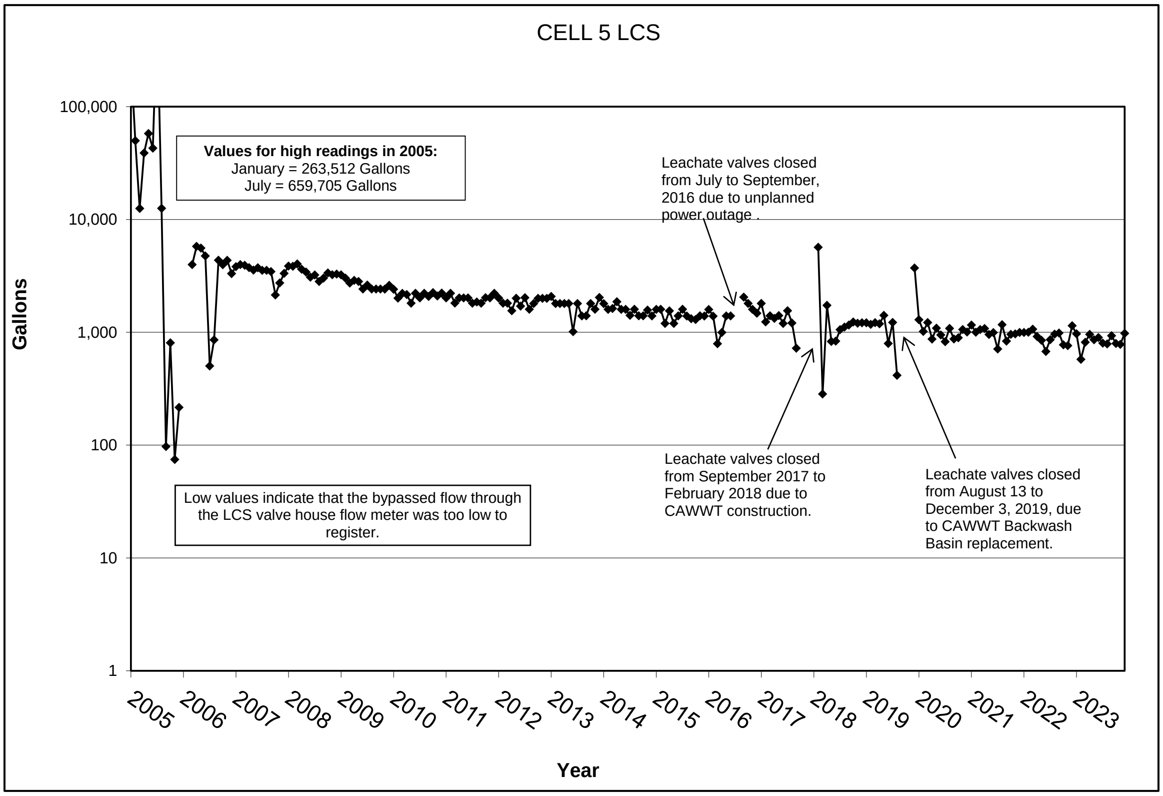

Figure A.5.5-1. Monthly Accumulation Volumes for Cell 5 LCS

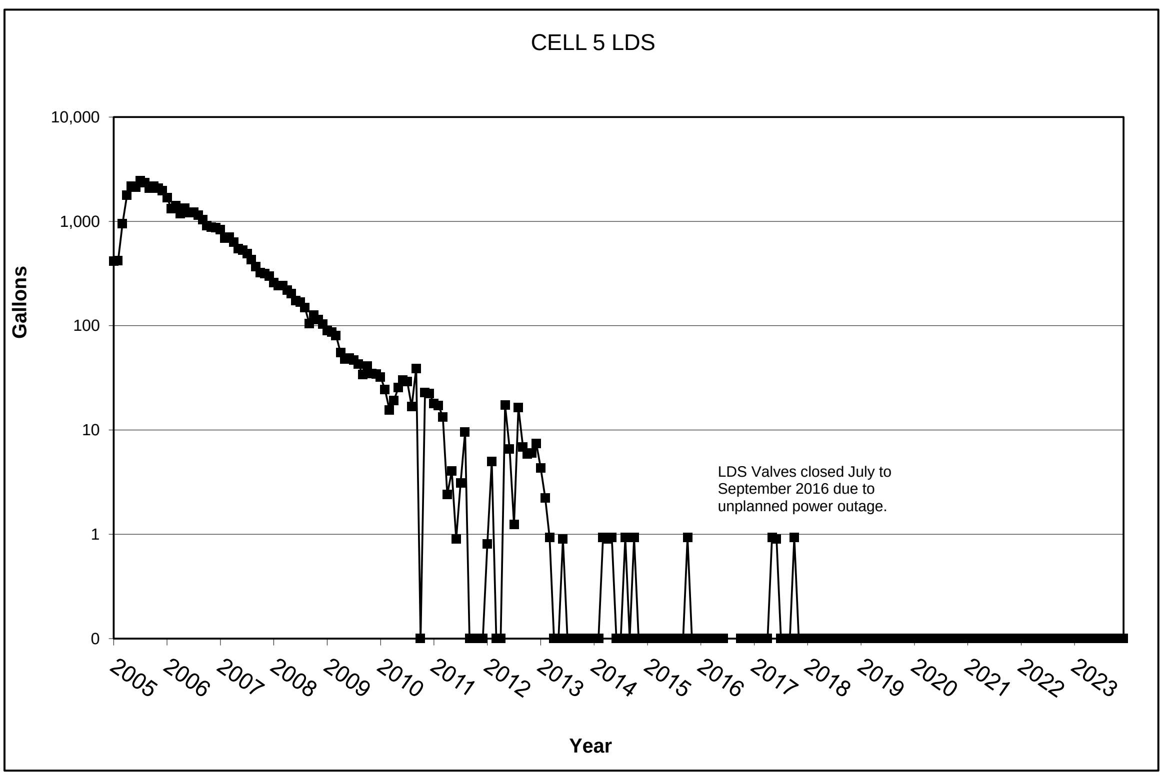

Figure A.5.5-2. Monthly Accumulation Volumes for Cell 5 LDS

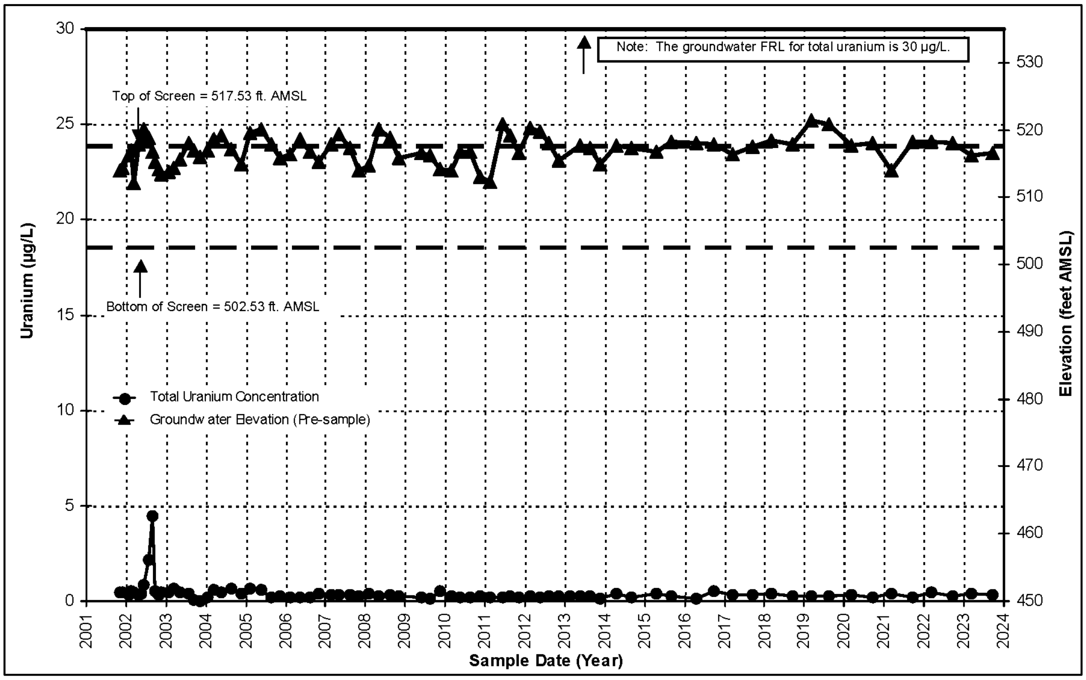

Figure A.5.5-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 5 Upgradient Monitoring Well 22207

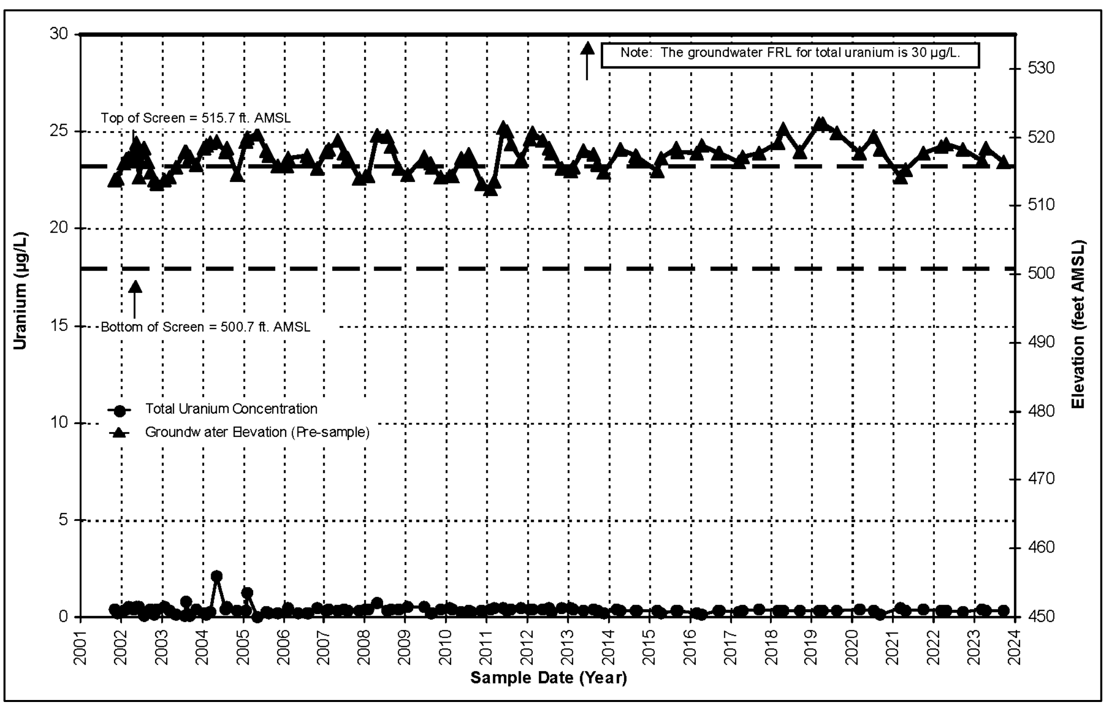

Figure A.5.5-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 5 Downgradient Monitoring Well 22208

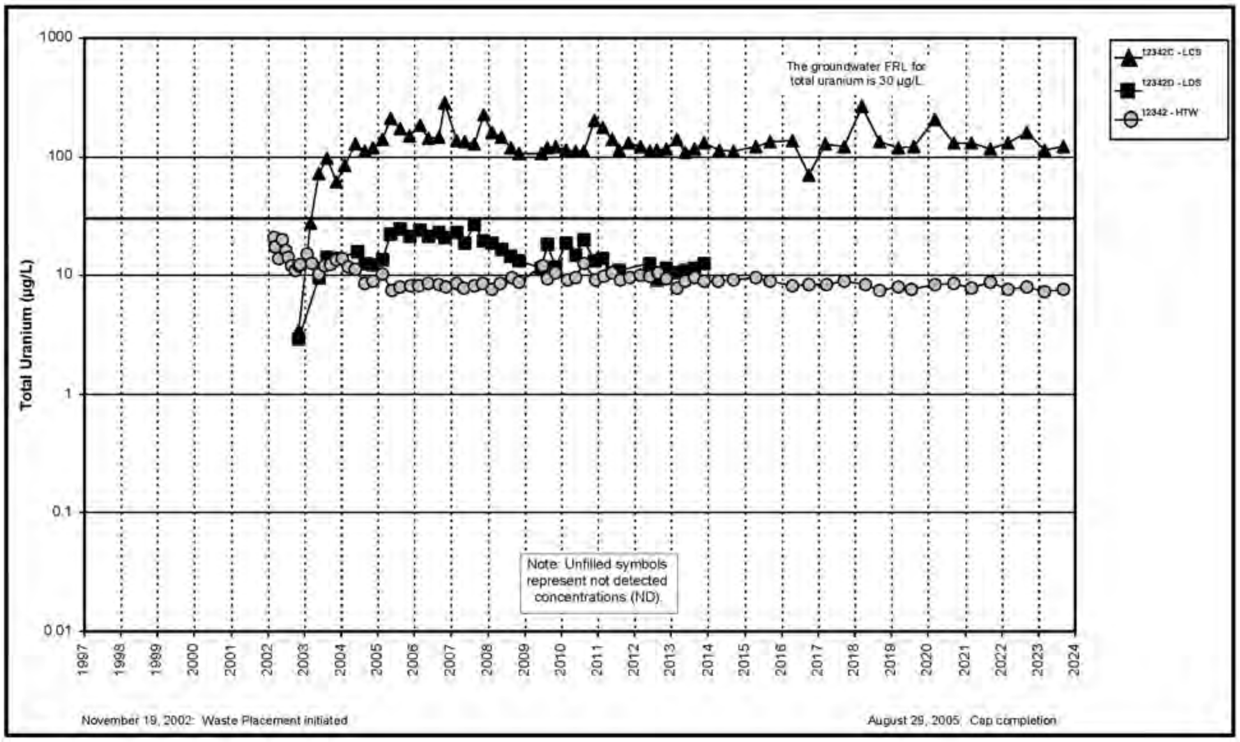

Figure A.5.5-5A. Cell 5 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

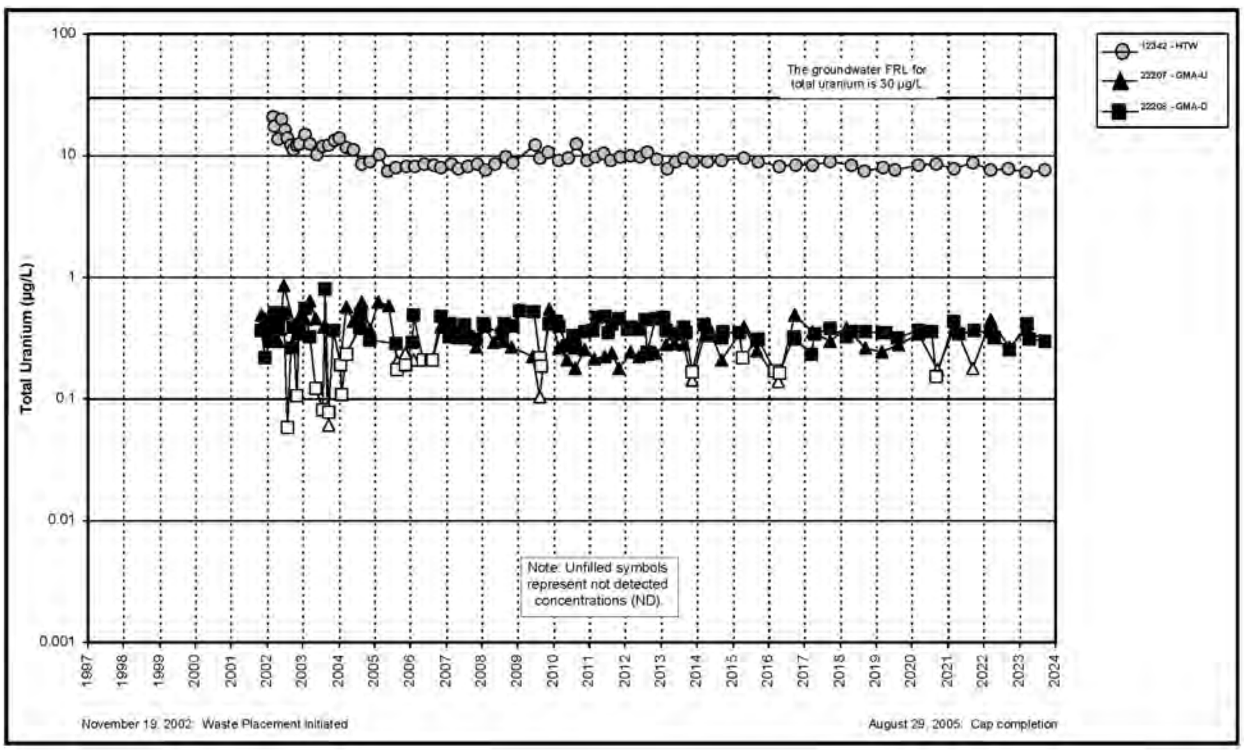

Figure A.5.5-5B. Cell 5 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

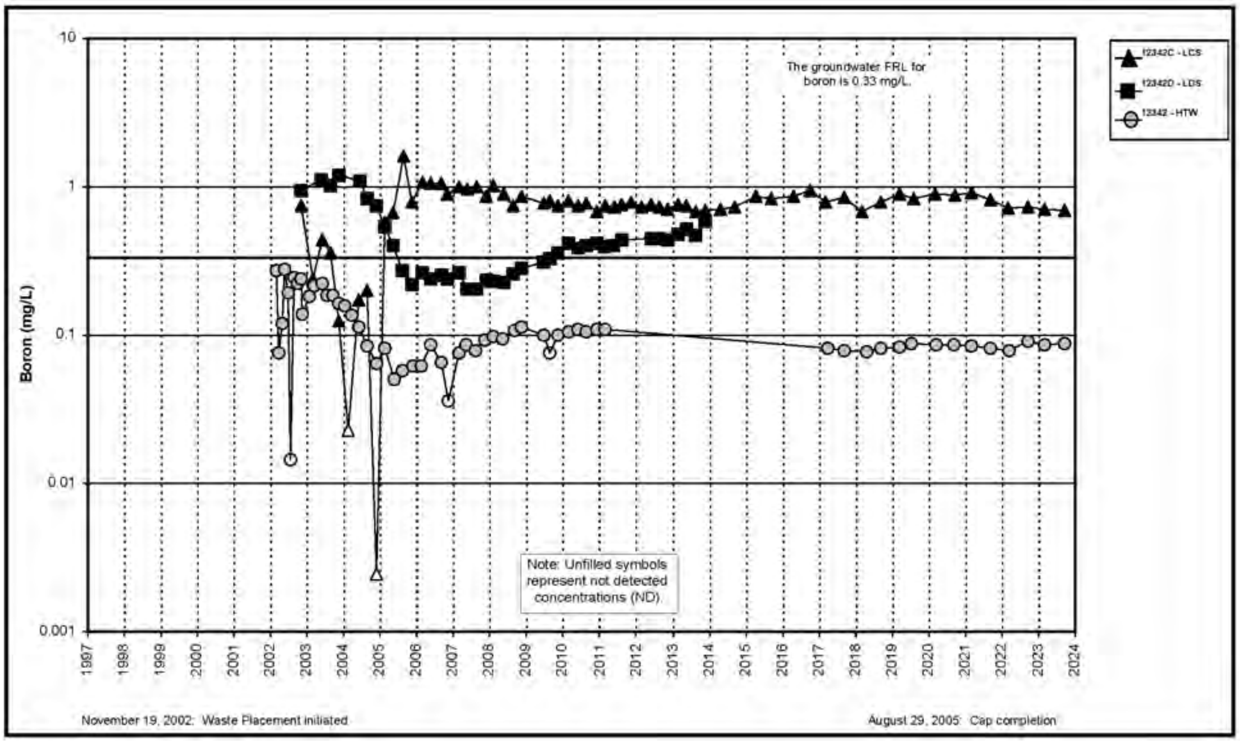

Figure A.5.5-6A. Cell 5 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

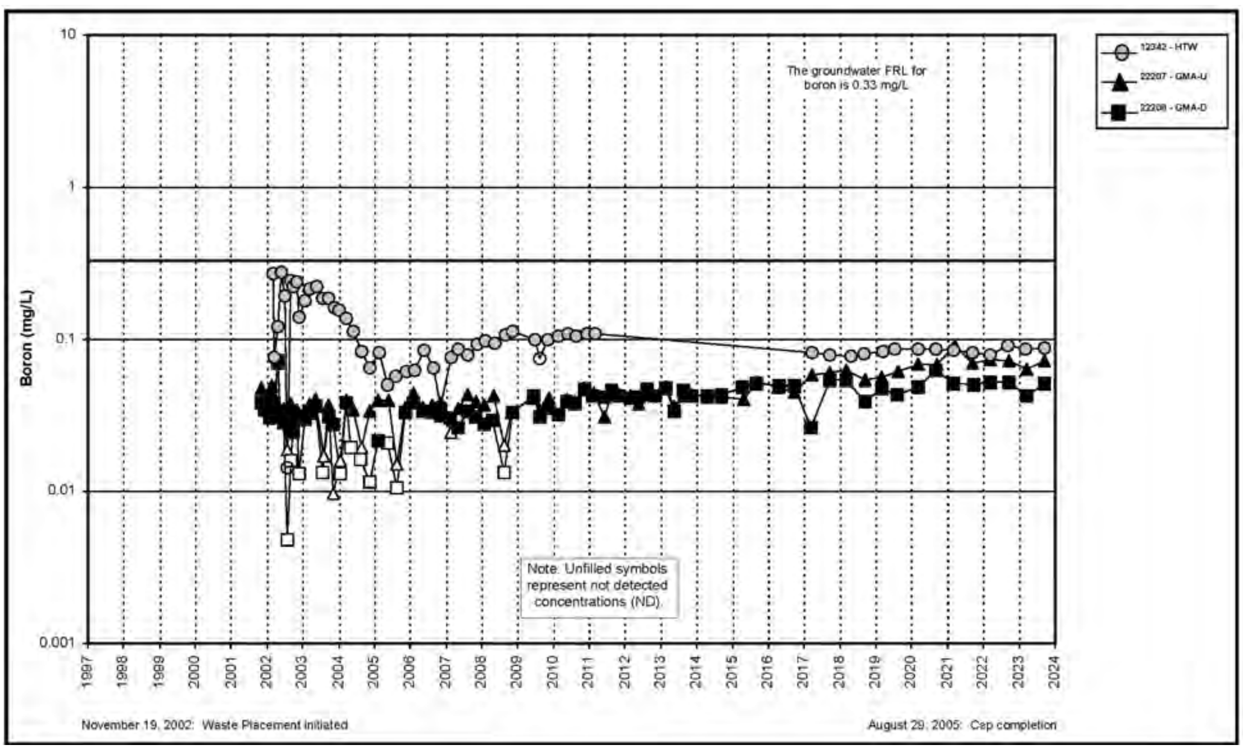

Figure A.5.5-6B. Cell 5 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

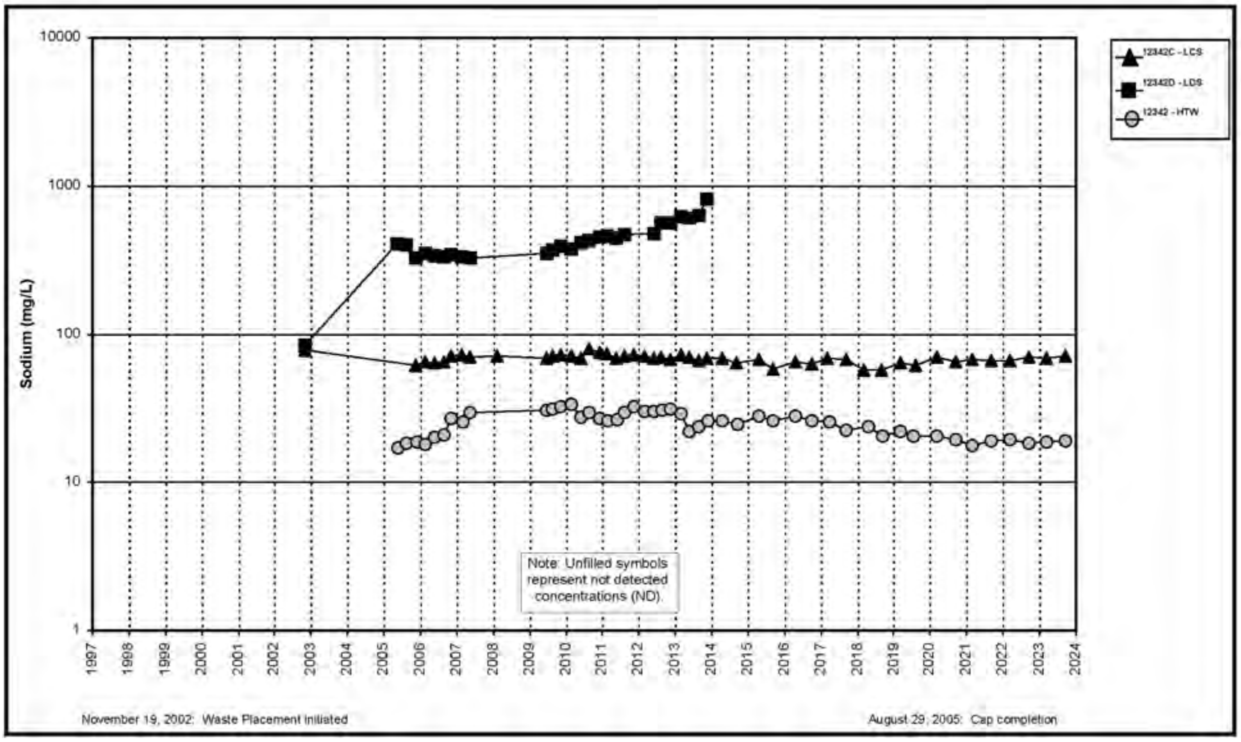

Figure A.5.5-7A. Cell 5 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

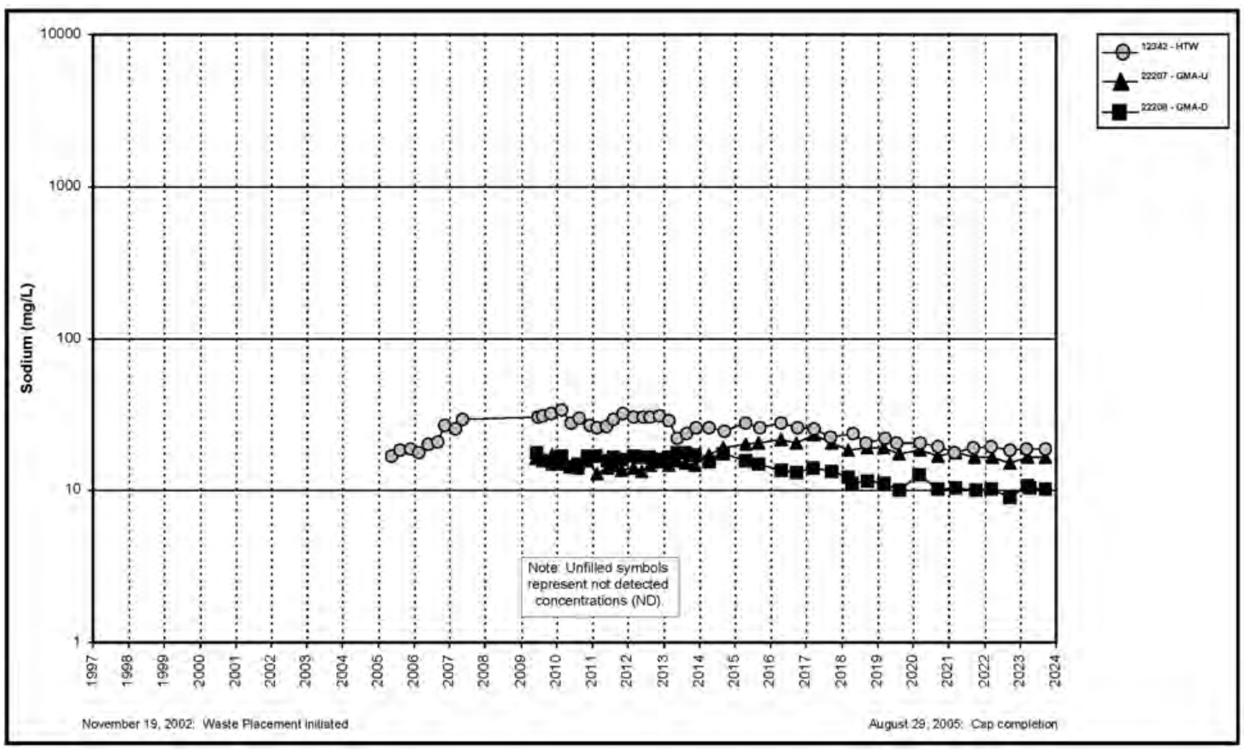

Figure A.5.5-7B. Cell 5 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

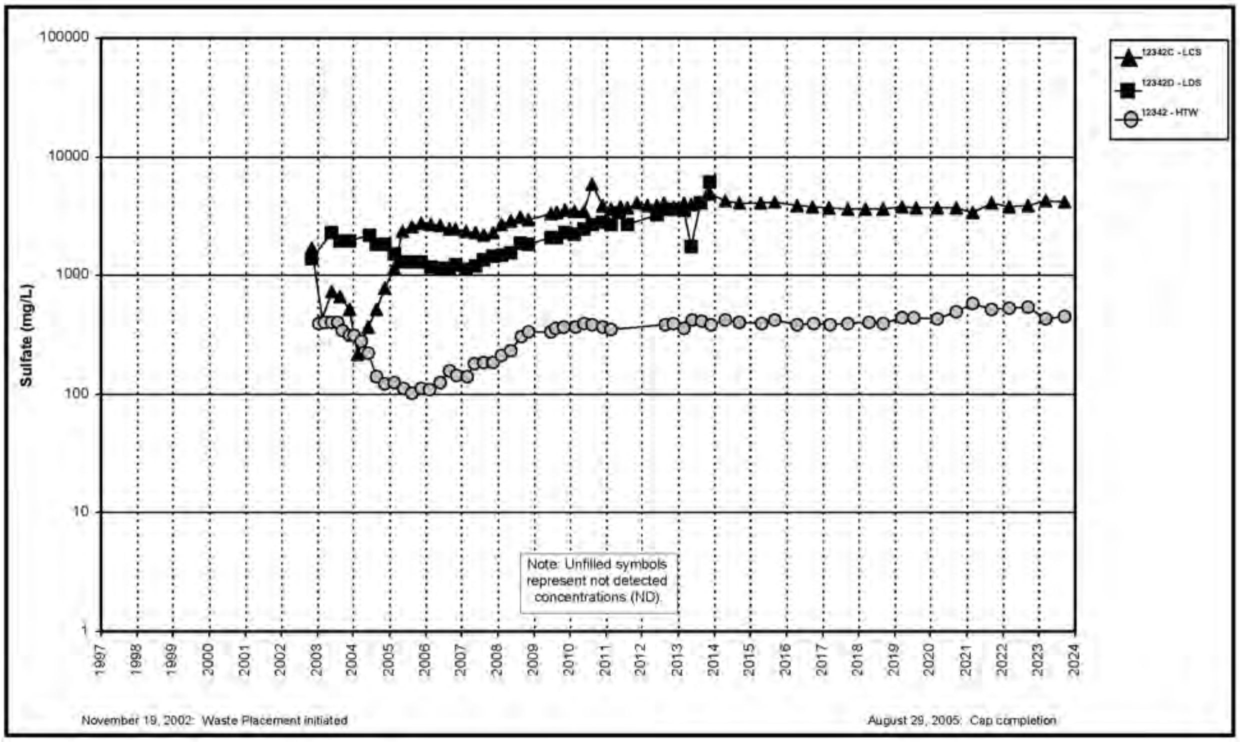

Figure A.5.5-8A. Cell 5 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

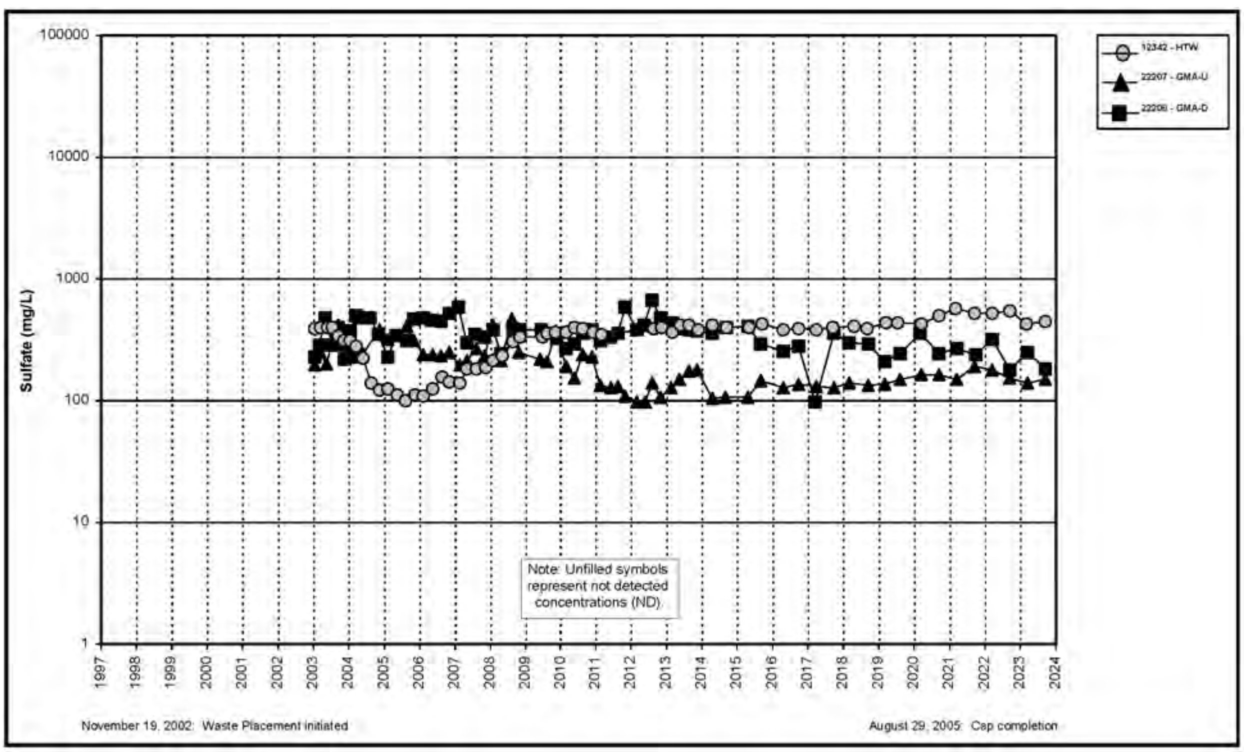

Figure A.5.5-8B. Cell 5 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

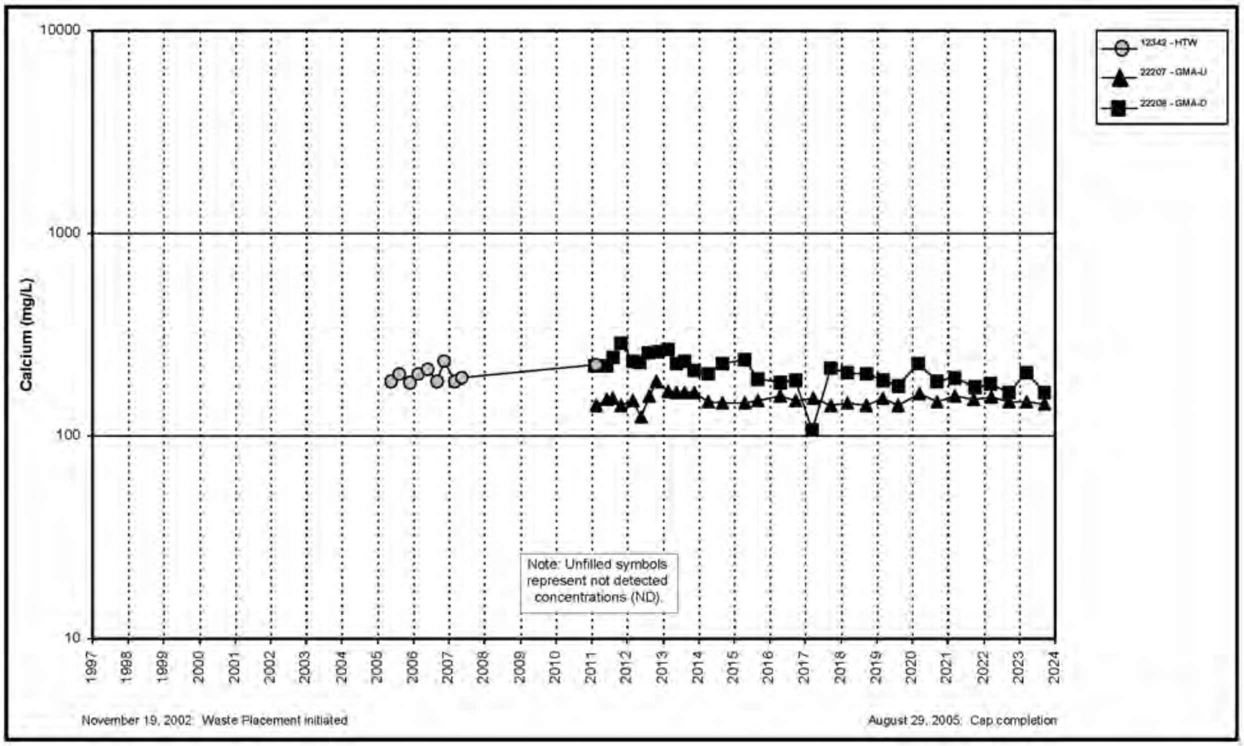

Figure A.5.5-9. Cell 5 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

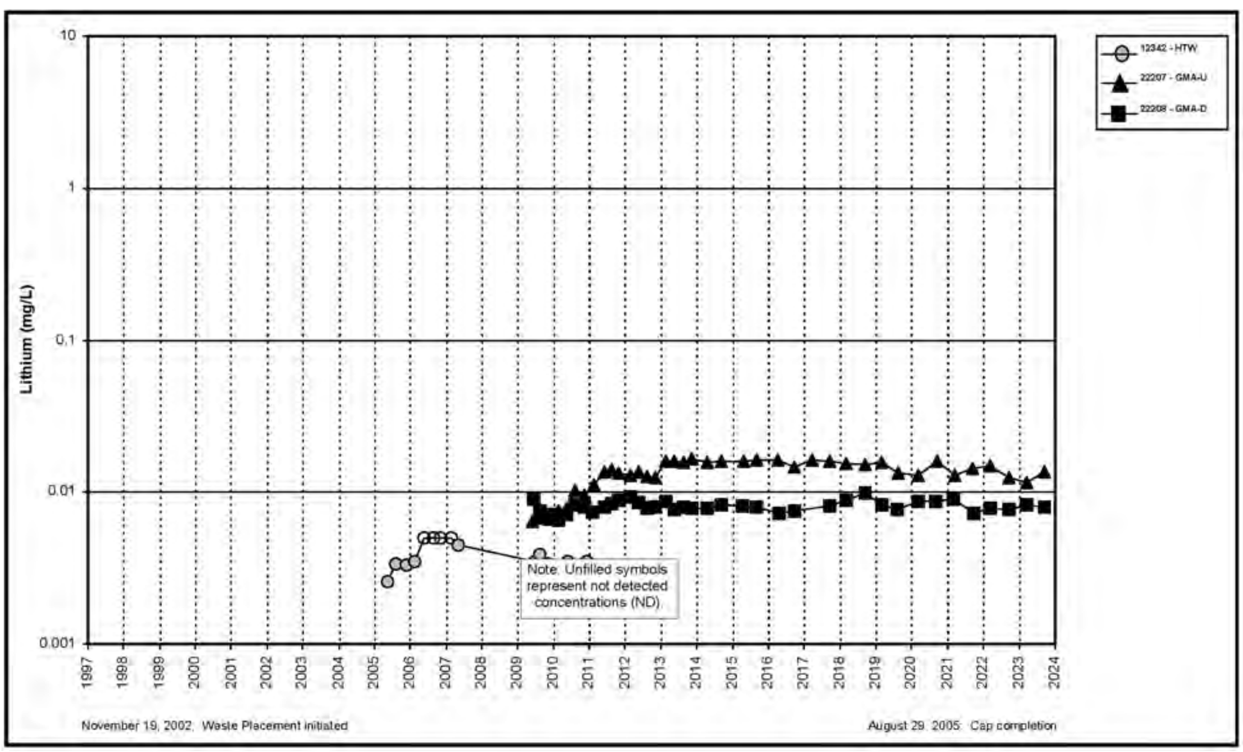

Figure A.5.5-10. Cell 5 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

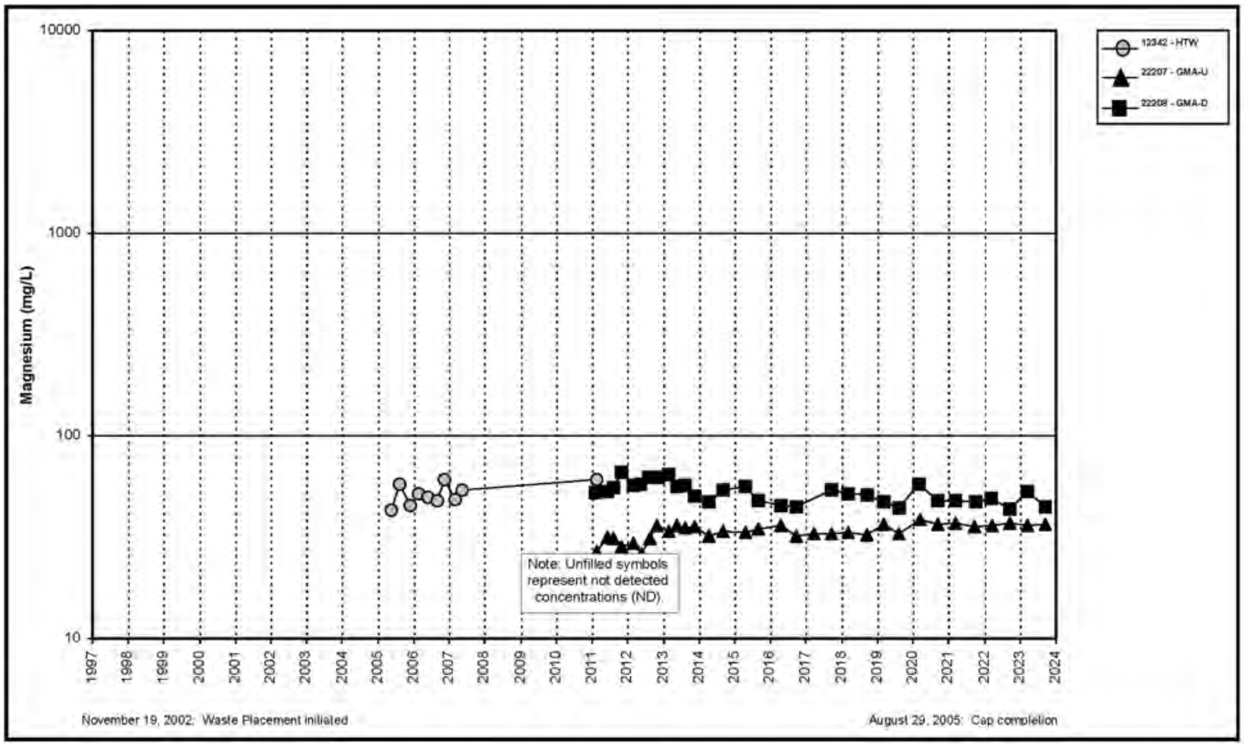

Figure A.5.5-11. Cell 5 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

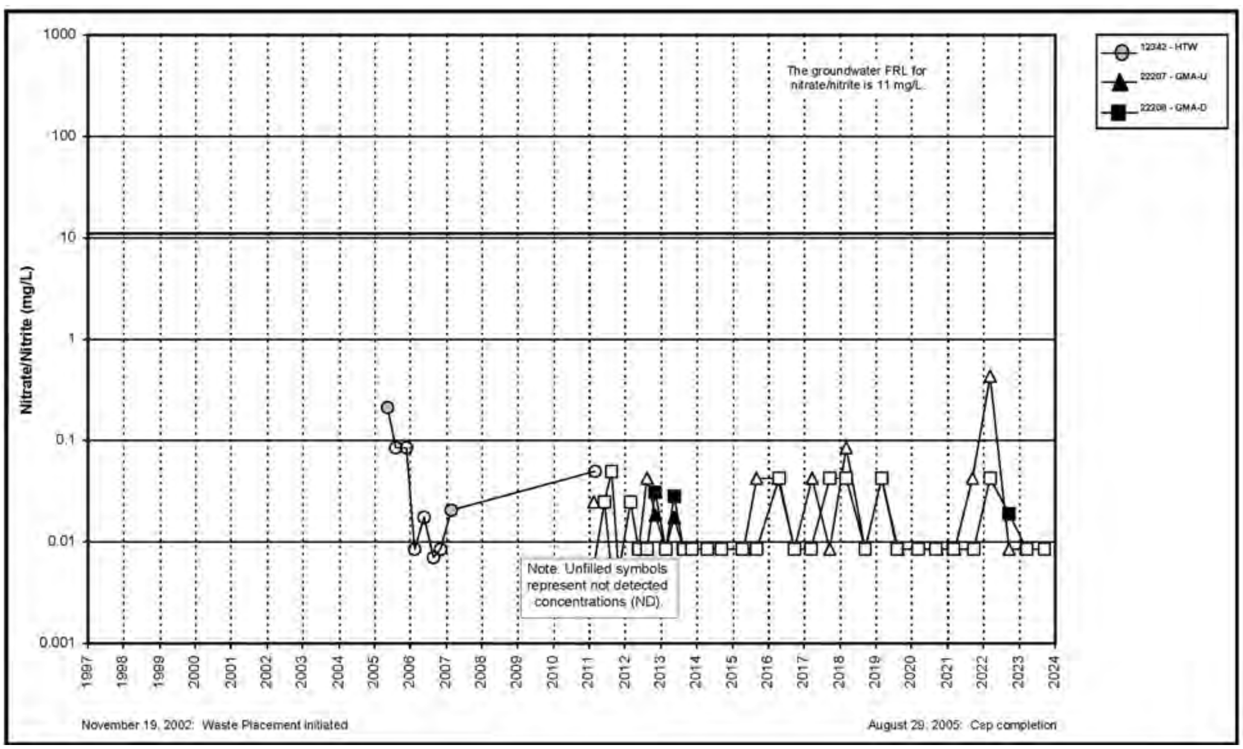

Figure A.5.5-12. Cell 5 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

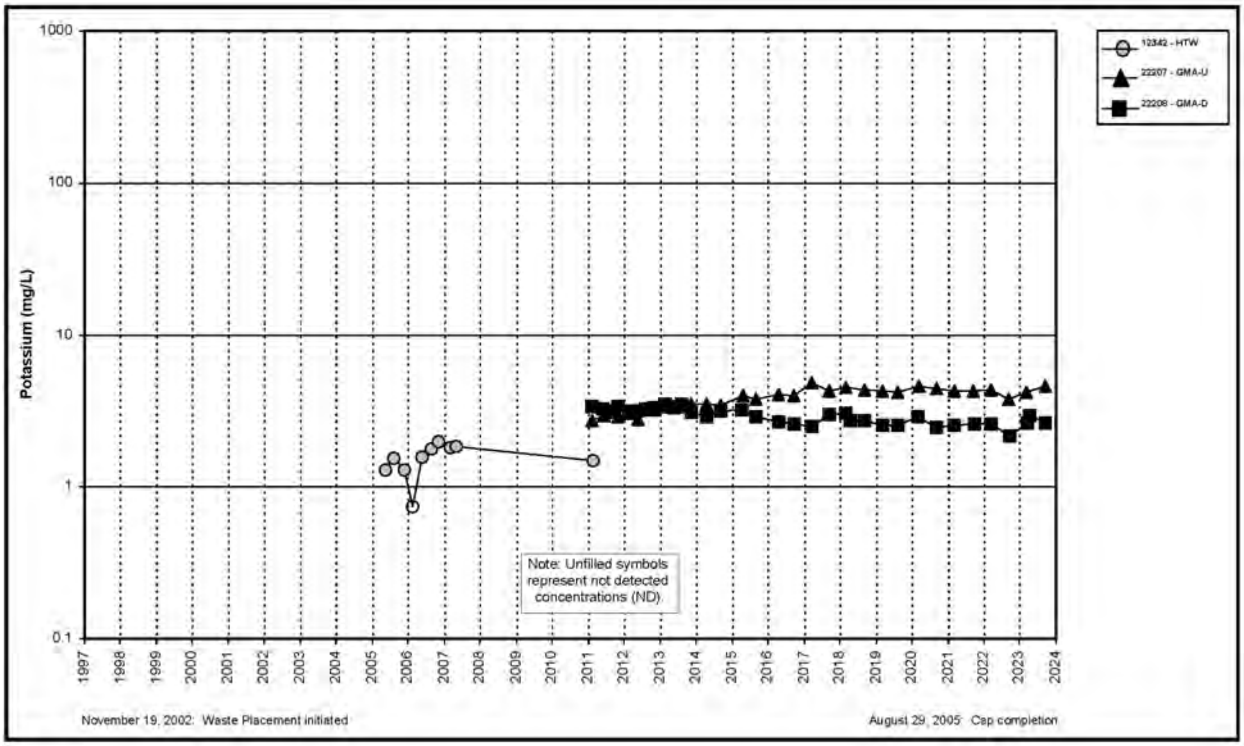

Figure A.5.5-13. Cell 5 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

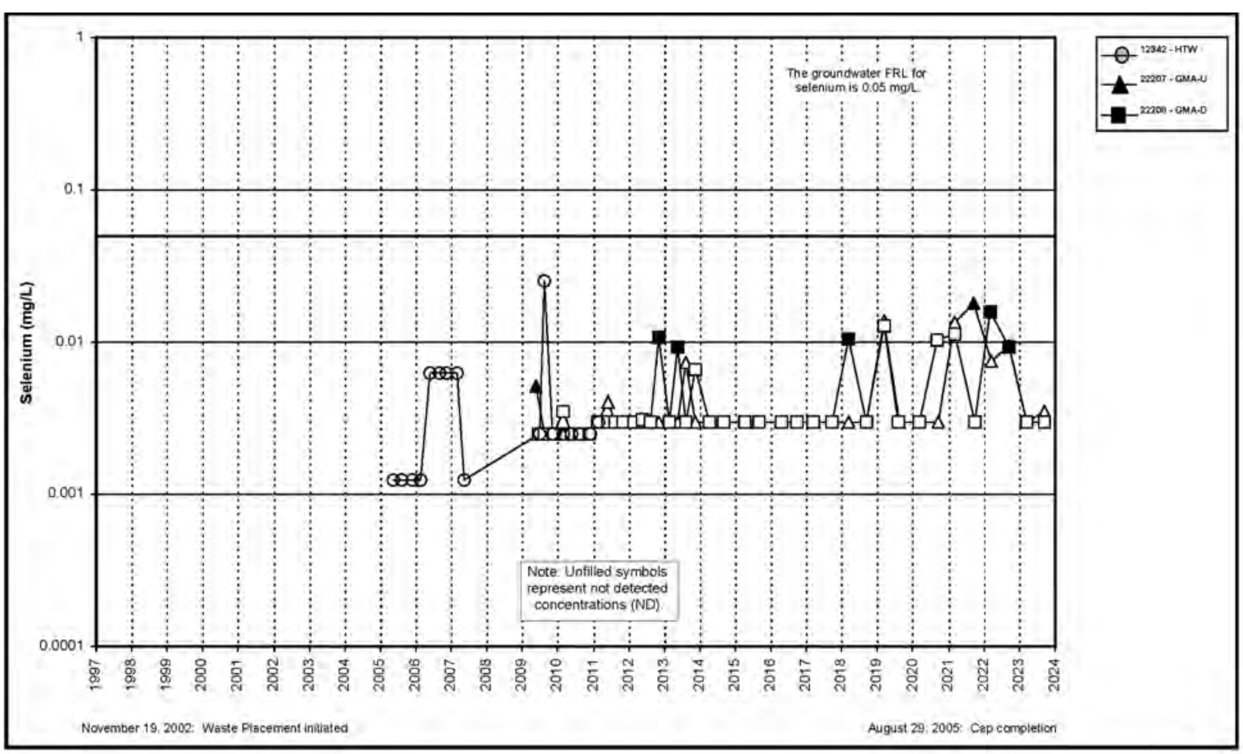

Figure A.5.5-14. Cell 5 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

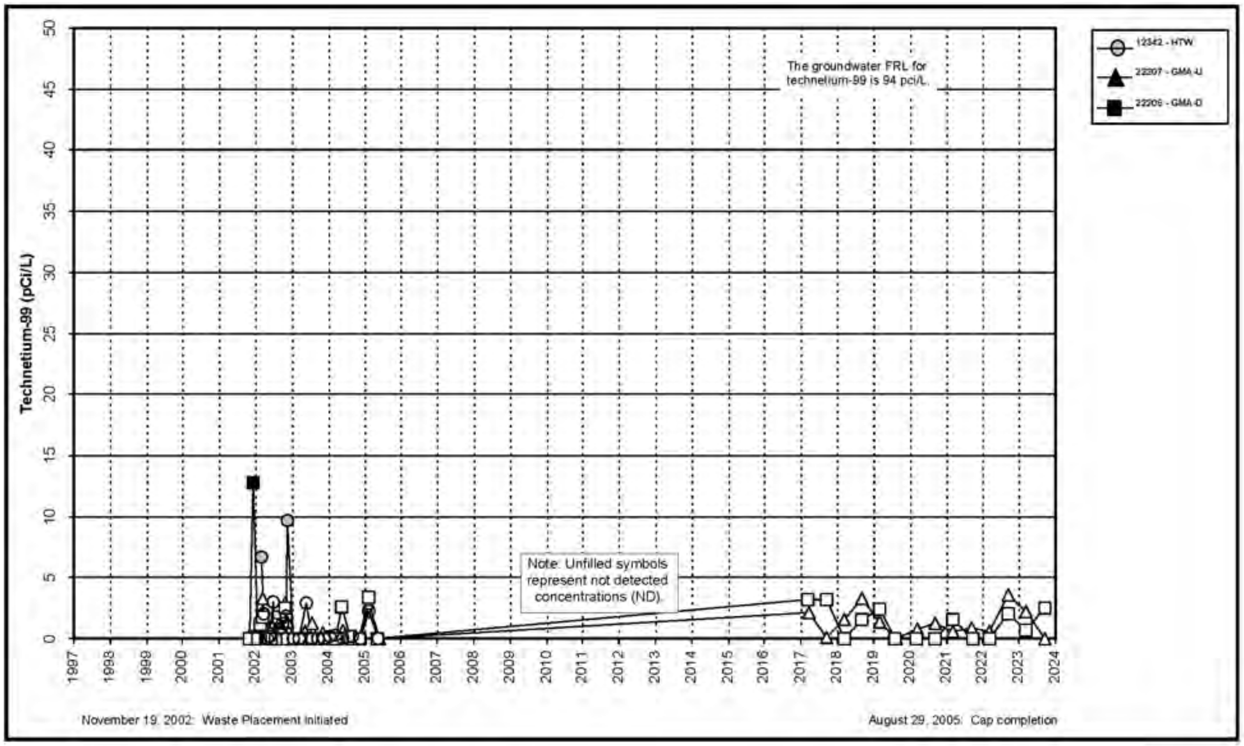

Figure A.5.5-15. Cell 5 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

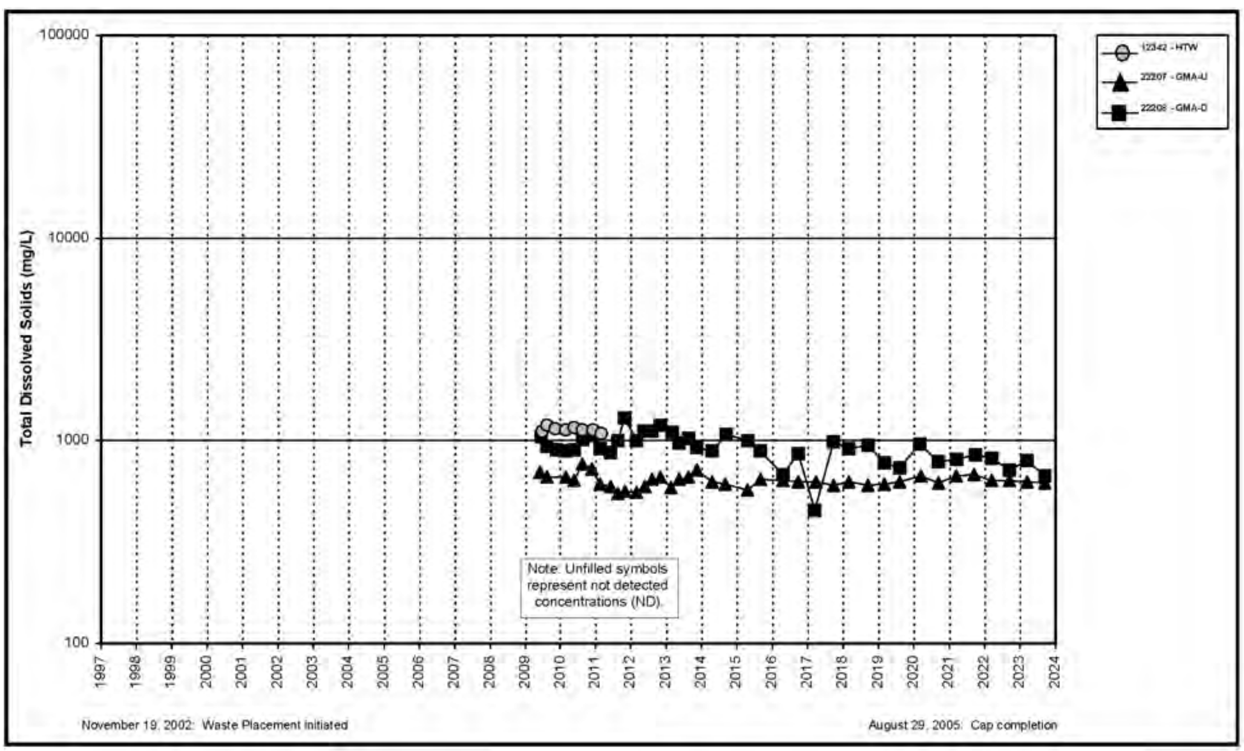

Figure A.5.5-16. Cell 5 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

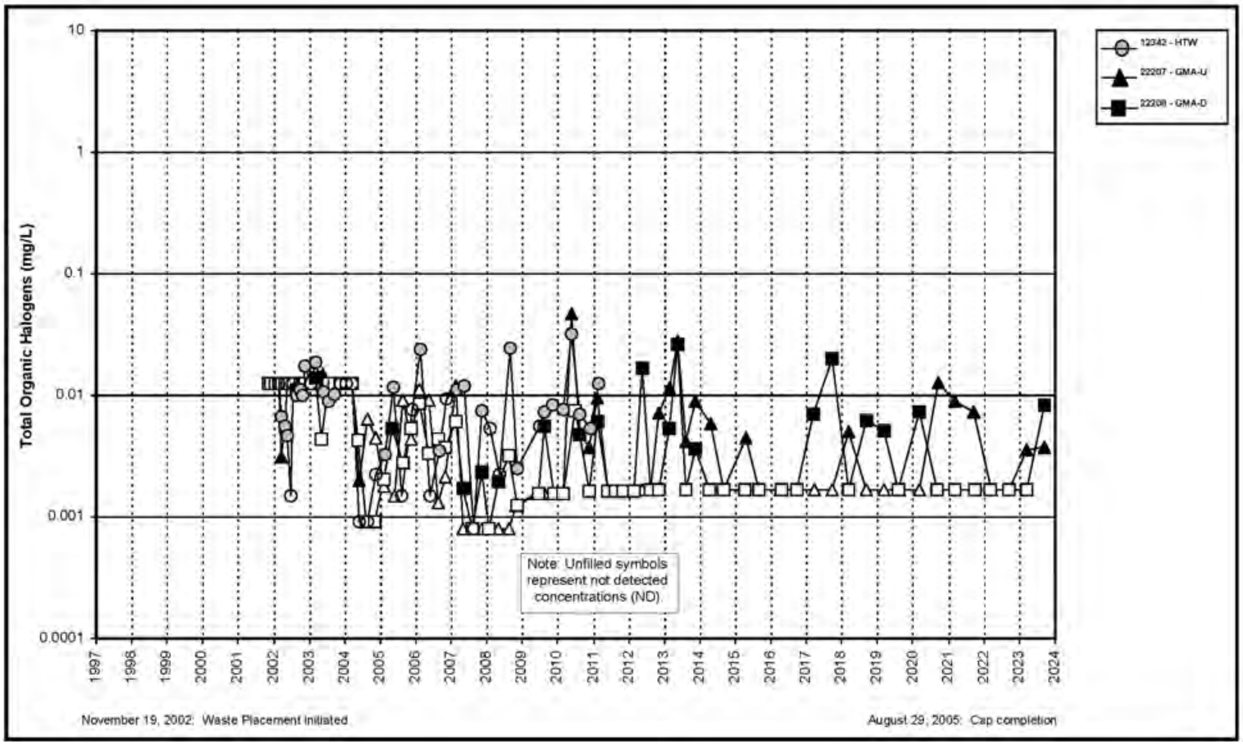

Figure A.5.5-17. Cell 5 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

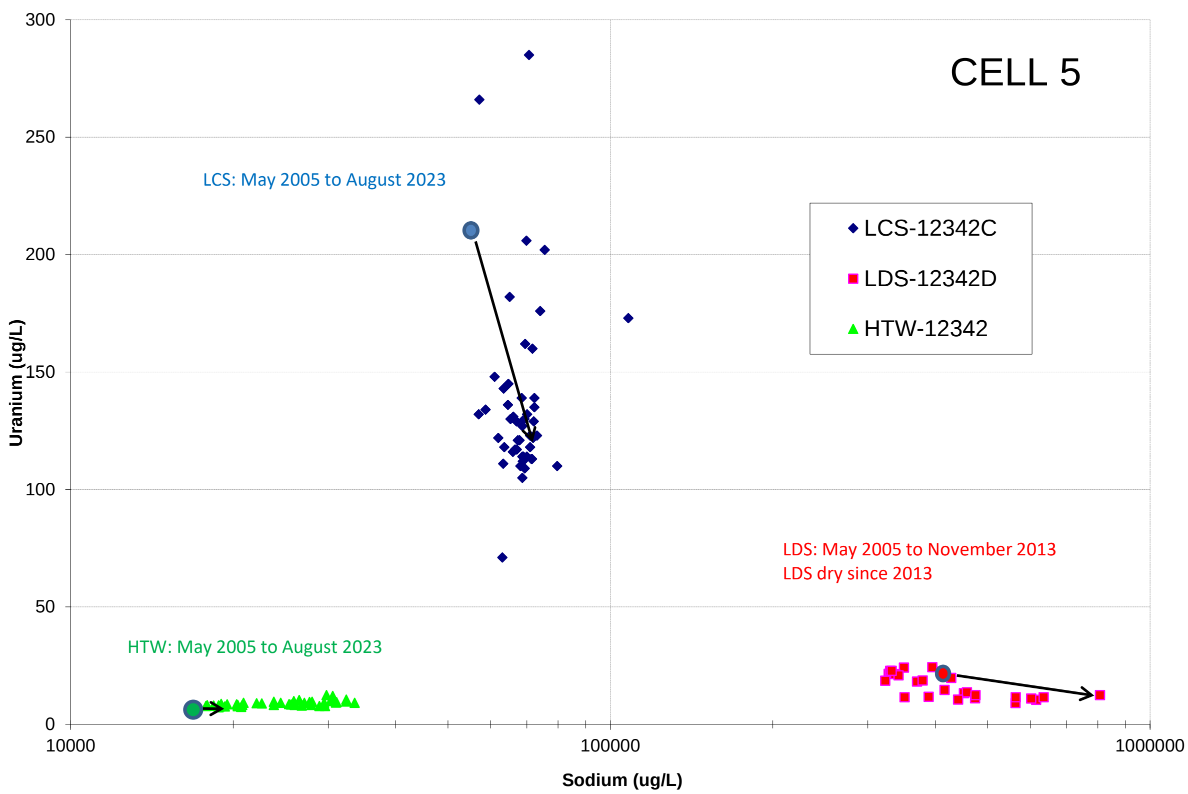

Figure A.5.5-18. Cell 5 Bivariate Plot for Uranium and Sodium

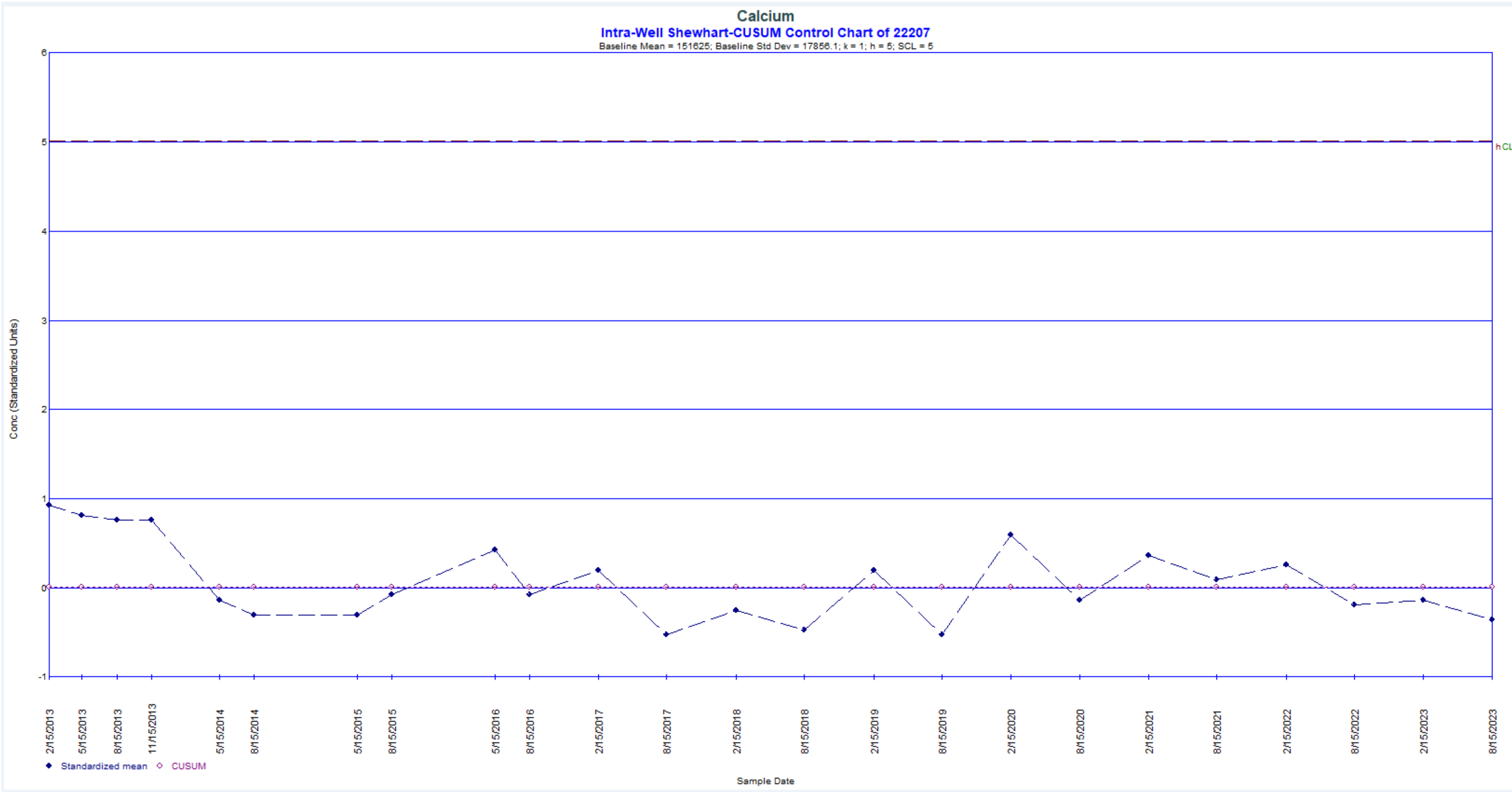

Figure A.5.5-19. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22207

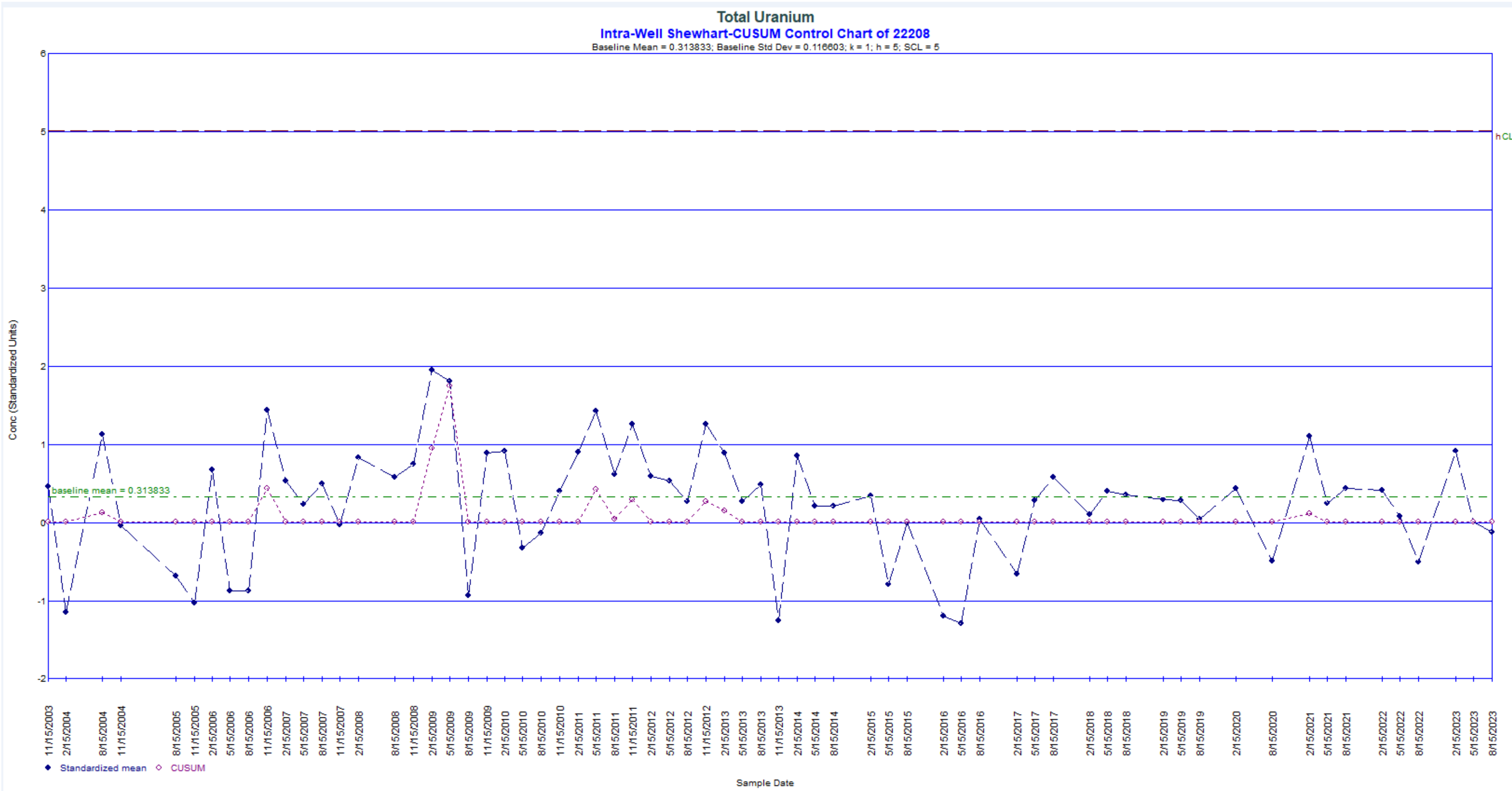

Figure A.5.5-20. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22208

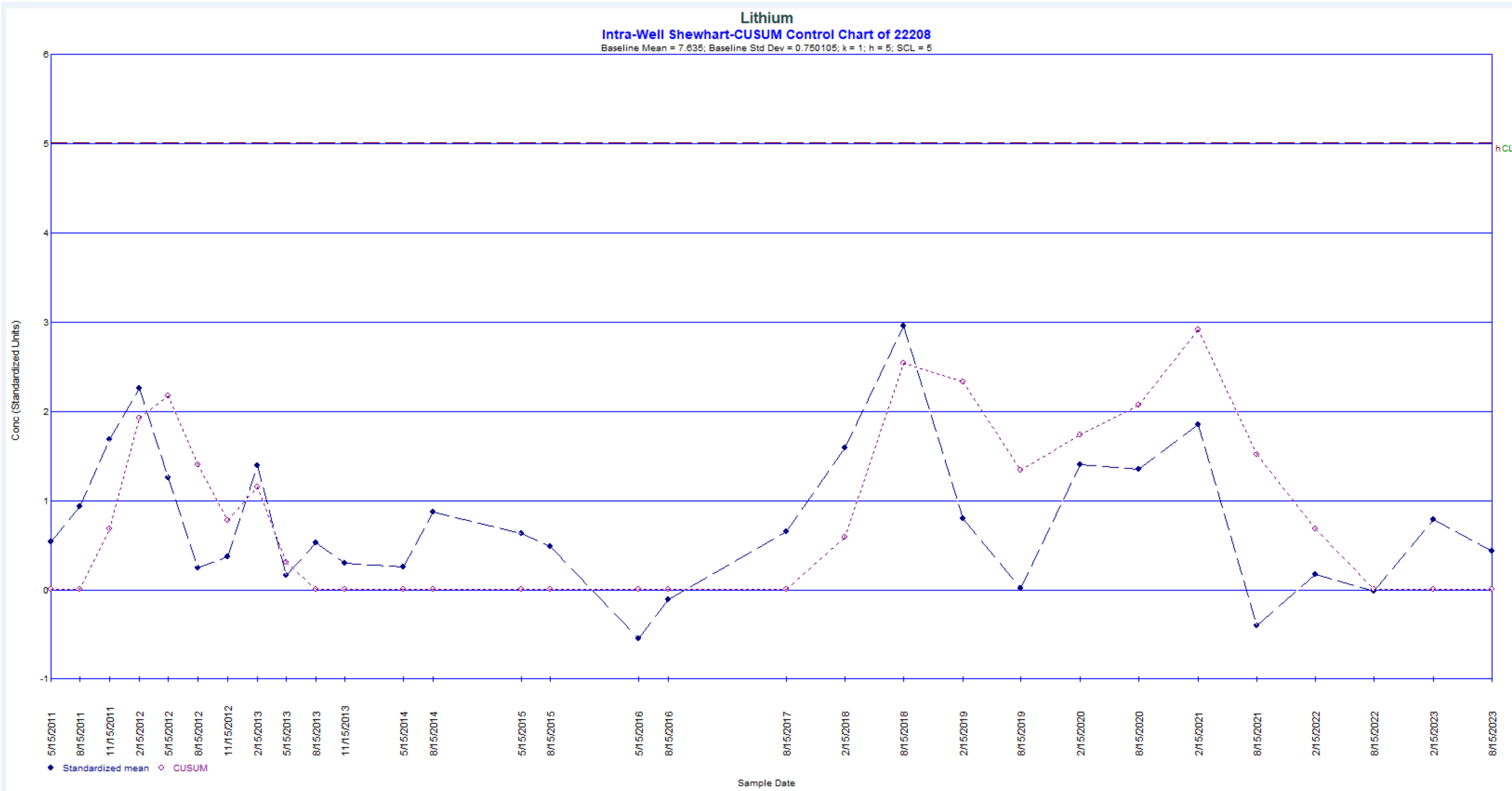

Figure A.5.5-21. *Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22208*

Subattachment A.5.6

Cell 6

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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 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.5.6-22)

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 2023 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 6 in 2023. In 2023, sufficient water was present in the LDS tank of Cell 6 in August to sample the tank once.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 6

Parameter	LCS 12343C 2023 Trend[a]	LDS 12343D 2023 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, six parameters (boron, sulfate, calcium, lithium, magnesium, 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	
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, four parameters in the HTW or GMA wells of Cell 6 (total uranium, lithium, potassium, 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 four control charts (Figures A.5.6-19 through A.5.6-22). 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
Potassium	GMA-U	22209	In Control	A.5.6-21
Total Dissolved Solids	GMA-U	22209	In Control	A.5.6-22

[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. No new high concentrations were measured in the LCS of Cell 6 in 2023.
- Sufficient water was present in the LDS tank of Cell 6 to sample the tank once in 2023. No new high concentrations were measured in the LDS of Cell 6 in 2023.
- Six parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 6: boron, sulfate, calcium, lithium, magnesium, 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.
- Four 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	60	60	100	43.3	276	123	33	Undefined	Down (2023)	Detected	
	LDS	12343D	59	59	100	3.10	160	29.5	40.6	Undefined	Up (2023)	Detected	
	HTW	12343	60	60	100	6.32	21.4	11.3	2.6	Ln Normal	None (2023)	Detected	24.2 (Q1-07)
	GMA-U	22209	58	64	90.6	ND	0.928	0.473	0.158	Undefined	Down (2023)	Not Detected	2.43(Q2-06), 2.1(Q3-08), 1.64(Q3-11)
	GMA-D	22210	72	74	97.3	ND	0.994	0.660	0.134	Ln Normal	None (2023)	Not Detected	
Boron (mg/L)	LCS	12343C	60	60	100	0.0566	1.37	0.732	0.198	Undefined	Down (2023)	Detected	
	LDS	12343D	59	59	100	0.289	1.22	0.418	0.159	Undefined	Up (2023)	Detected	2.38 (Q3-04)
	HTW	12343	39	43	90.7	ND	0.124	0.0899	0.0180	Normal	None (2023)	Detected	0.0409 (Q2-06); 0.0360 (Q4-06)
	GMA-U	22209	59	64	92.2	ND	0.113	0.0388	0.0142	Undefined	Up (2023)	Detected	
	GMA-D	22210	61	64	95.3	ND	0.0616	0.0376	0.0094	Undefined	Up (2023)	Detected	
Sodium (mg/L)	LCS	12343C	51	51	100	44.5	107	72.7	12.6	Undefined	Up (2023)	Detected	23.6 (Q2-04); 23.1 (Q2-05)
	LDS	12343D	48	48	100	109	1,190	500	184	Undefined	Up (2023)	Detected	
	HTW	12343	47	47	100	15.0	66.0	36.5	15.0	Undefined	Down (2023)	Detected	
	GMA-U	22209	39	39	100	14.5	26.8	18.8	2.5	Normal	None (2023)	Detected	
	GMA-D	22210	41	41	100	11.1	20.4	16.6	2.7	Undefined	Down (2023)	Detected	
Sulfate (mg/L)	LCS	12343C	60	60	100	491	5,200	3,530	1,090	Undefined	Up (2023)	Detected	
	LDS	12343D	58	58	100	1,300	10,800	3,690	1,920	Ln Normal	Up (2023)	Detected	
	HTW	12343	54	55	98.2	ND	716	499	84	Normal	Up (2023)	Detected	192 (Q1-03)
	GMA-U	22209	63	63	100	2.07	406	159	65	Undefined	Down (2023)	Detected	
	GMA-D	22210	63	63	100	127	392	270	74	Normal	Up (2023)	Detected	578 (Q1-07)
Calcium (mg/L)	GMA-U	22209	32	32	100	136	184	152	11	Normal	Up (2023)	Not Detected	242 (Q3-11); 231 (Q3-13)
	GMA-D	22210	32	32	100	162	239	203	22	Normal	Down (2023)	Detected	
Lithium (mg/L)	GMA-U	22209	39	39	100	0.00486	0.0107	0.00636	0.00158	Undefined	Up (2023)	Detected	
	GMA-D	22210	39	39	100	0.00631	0.00865	0.00737	0.00056	Normal	None (2023)	Not Detected	
Magnesium (mg/L)	GMA-U	22209	32	32	100	27.0	43.4	33.9	3.3	Normal	Up (2023)	Detected	55.4 (Q3-13)
	GMA-D	22210	32	32	100	41.5	58.3	50.0	4.7	Normal	Down (2023)	Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22209	4	33	12.1	ND	0.500	0.0085	0.0851	Undefined	None (2023)	Not Detected	
	GMA-D	22210	1	32	3.1	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22209	32	32	100	2.92	3.78	3.29	0.18	Normal	None (2023)	Not Detected	2.31 (Q1-22)
	GMA-D	22210	34	34	100	2.54	3.62	3.12	0.27	Normal	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22209	6	39	15.4	ND	0.0236	0.00300	0.00407	Undefined	Up (2023)	Detected	
	GMA-D	22210	5	39	12.8	ND	0.0122	0.00300	0.00252	Undefined	Up (2023)	Detected	
Technitium-99 (pCi/L)	GMA-U	22209	1	25	4.0	ND	8.61	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22210	1	25	4.0	ND	6.61	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22209	39	39	100	550	720	635	41	Normal	None (2023)	Not Detected	876 (Q3-11)
	GMA-D	22210	39	39	100	666	1,020	899	99	Undefined	Down (2023)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22209	20	64	31.2	ND	0.0208	0.00166	0.00476	Undefined	None (2023)	Detected	0.0365 (Q3-06); 0.0377 (Q1-11); 0.0432 (Q1-13)
	GMA-D	22210	20	64	31.2	ND	0.0230	0.00204	0.00444	Undefined	None (2023)	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 has been standardized to quarterly.

aLCS = 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: Ln Normal 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
2023	650	2	325

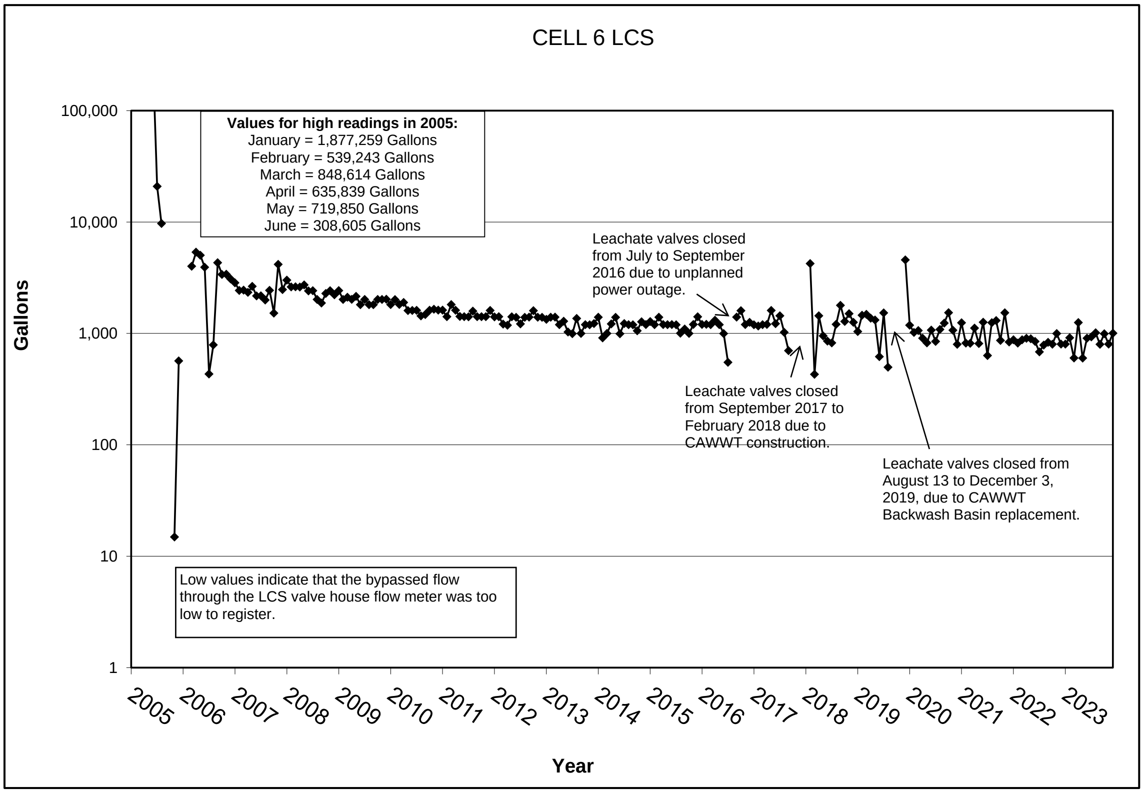

Figure A.5.6-1. Monthly Accumulation Volumes for Cell 6 LCS

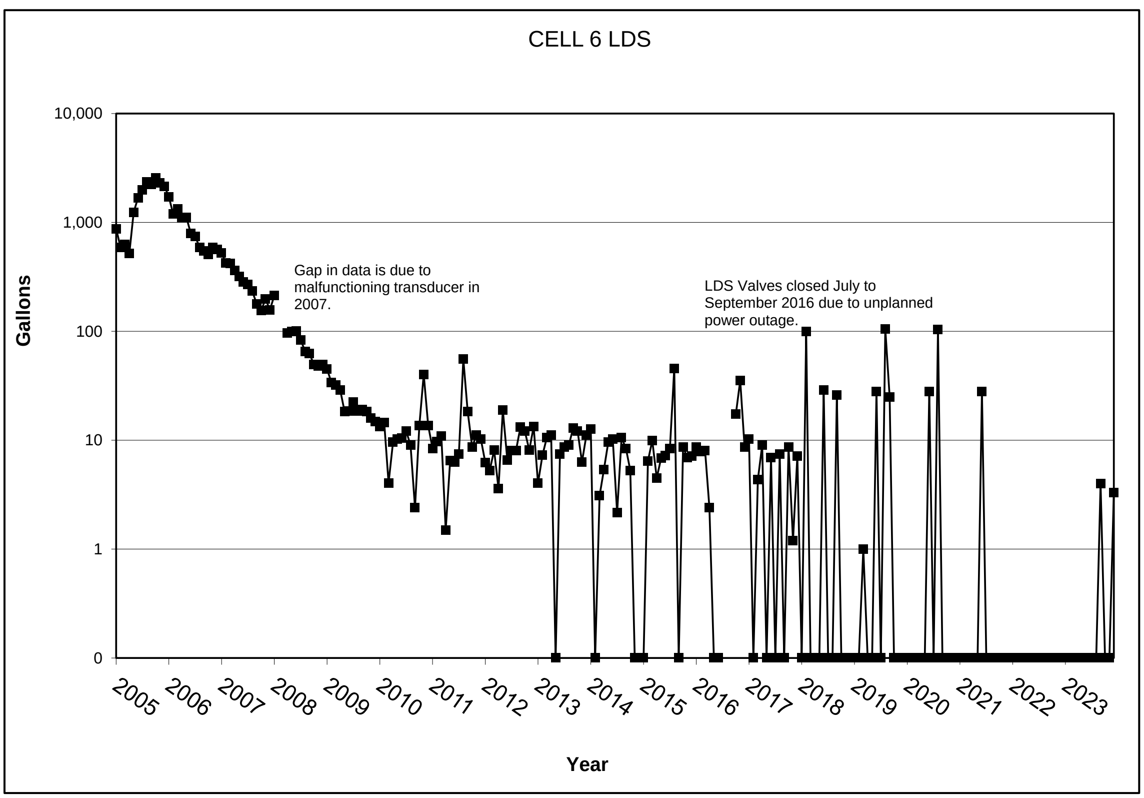

Figure A.5.6-2. Monthly Accumulation Volumes for Cell 6 LDS

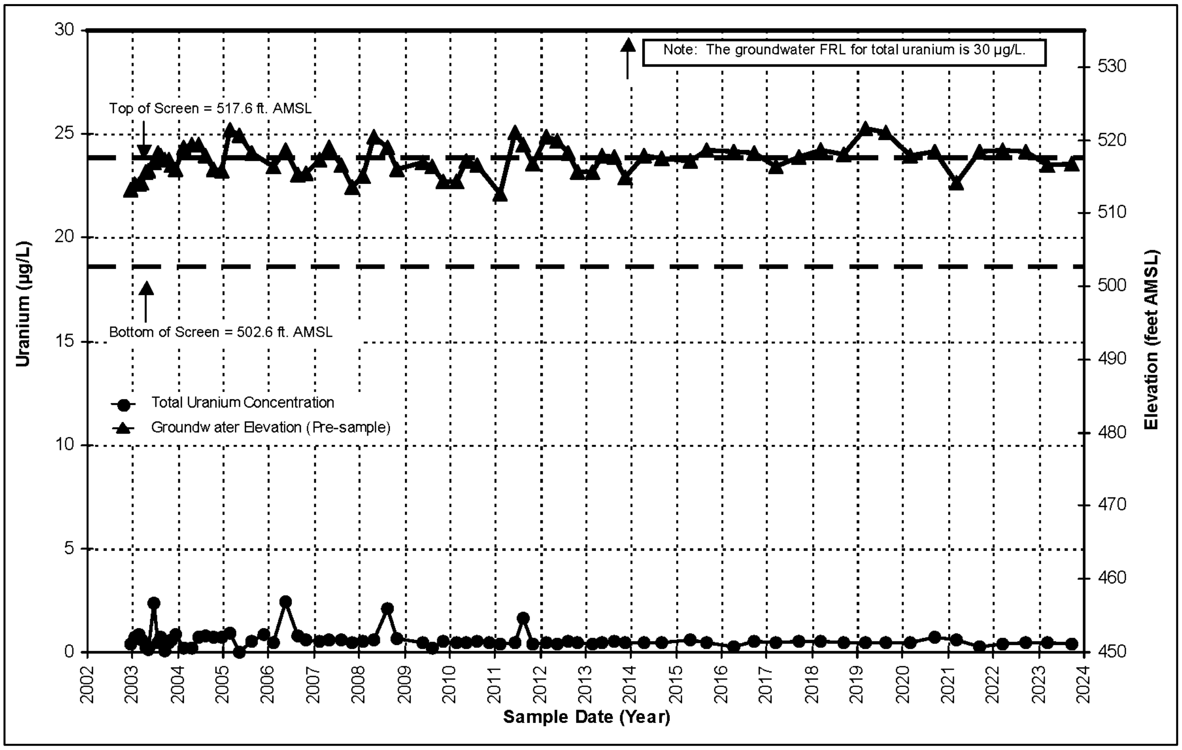

Figure A.5.6-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 6 Upgradient Monitoring Well 22209

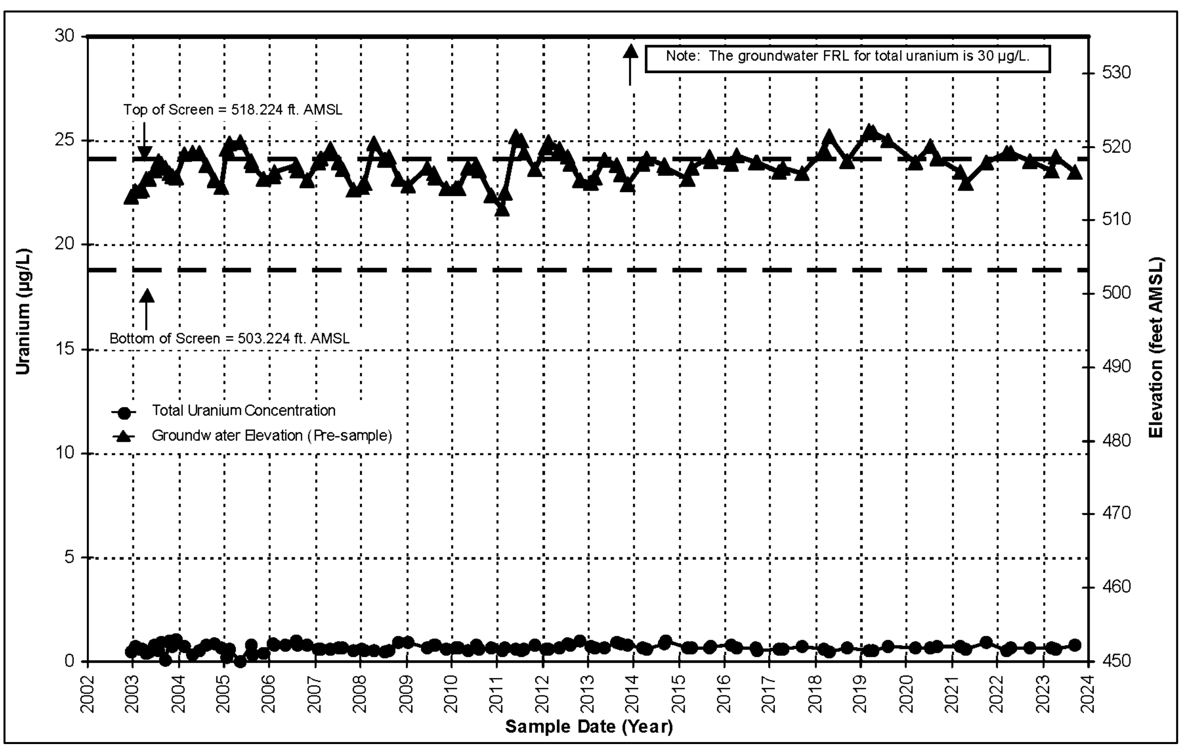

Figure A.5.6-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 6 Downgradient Monitoring Well 22210

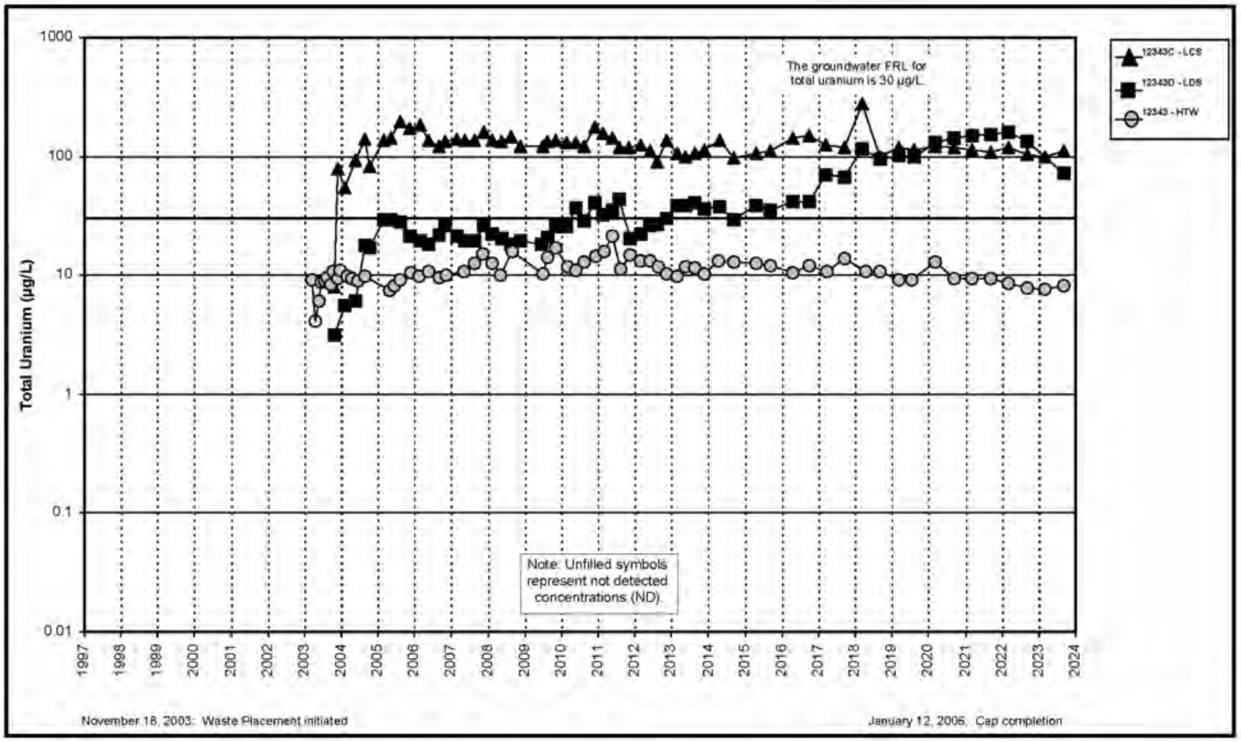

Figure A.5.6-5A. Cell 6 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

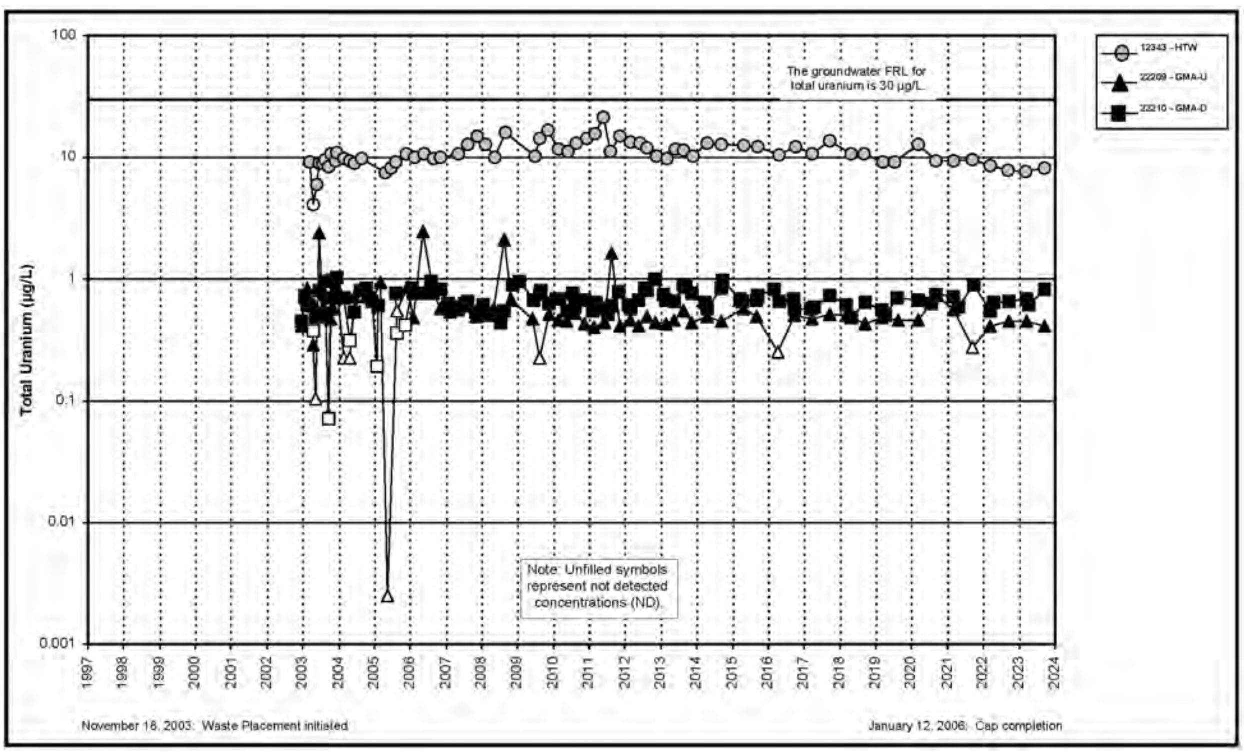

Figure A.5.6-5B. Cell 6 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

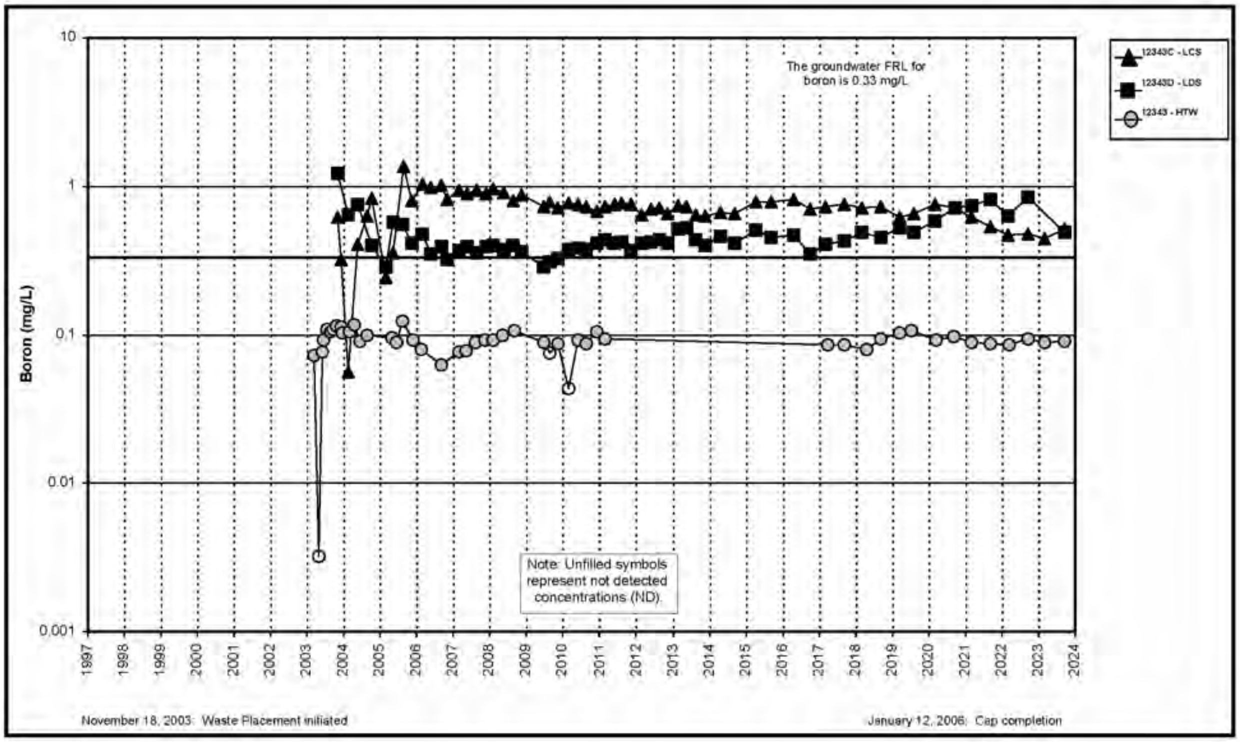

Figure A.5.6-6A. Cell 6 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

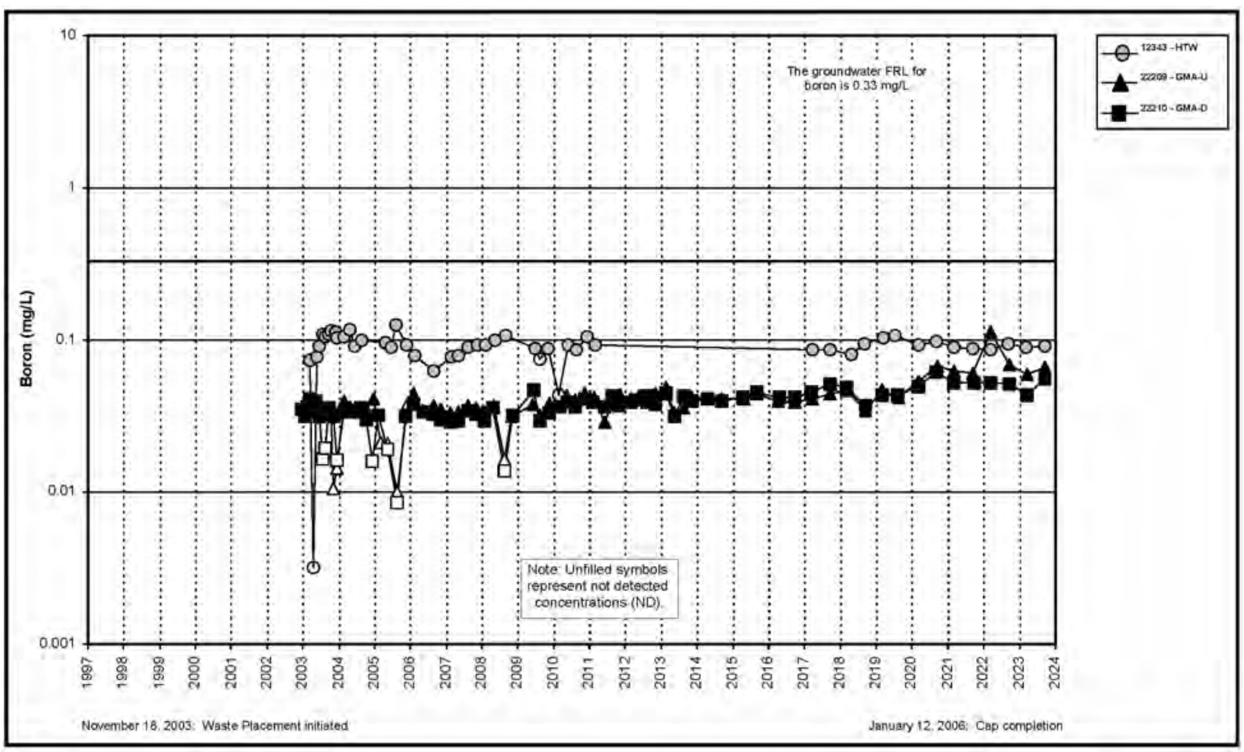

Figure A.5.6-6B. Cell 6 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

Figure A.5.6-7A. Cell 6 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

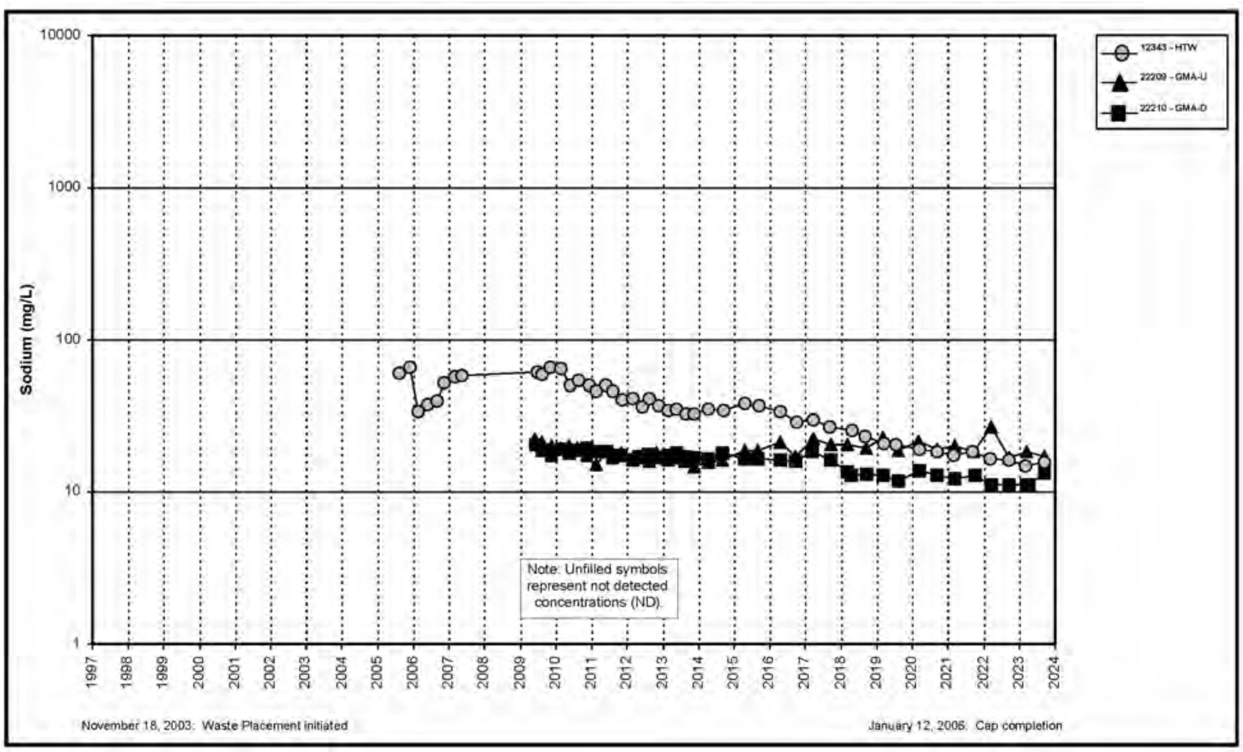

Figure A.5.6-7B. Cell 6 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

Figure A.5.6-8A. Cell 6 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

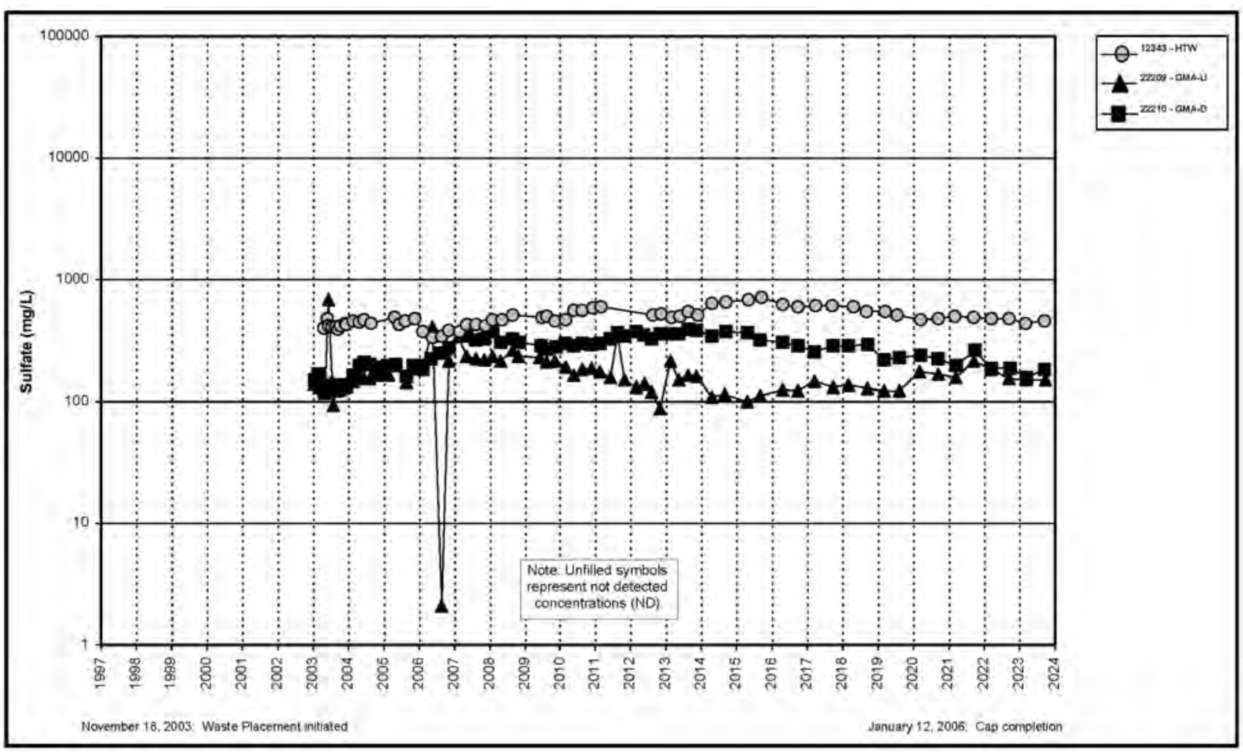

Figure A.5.6-8B. Cell 6 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

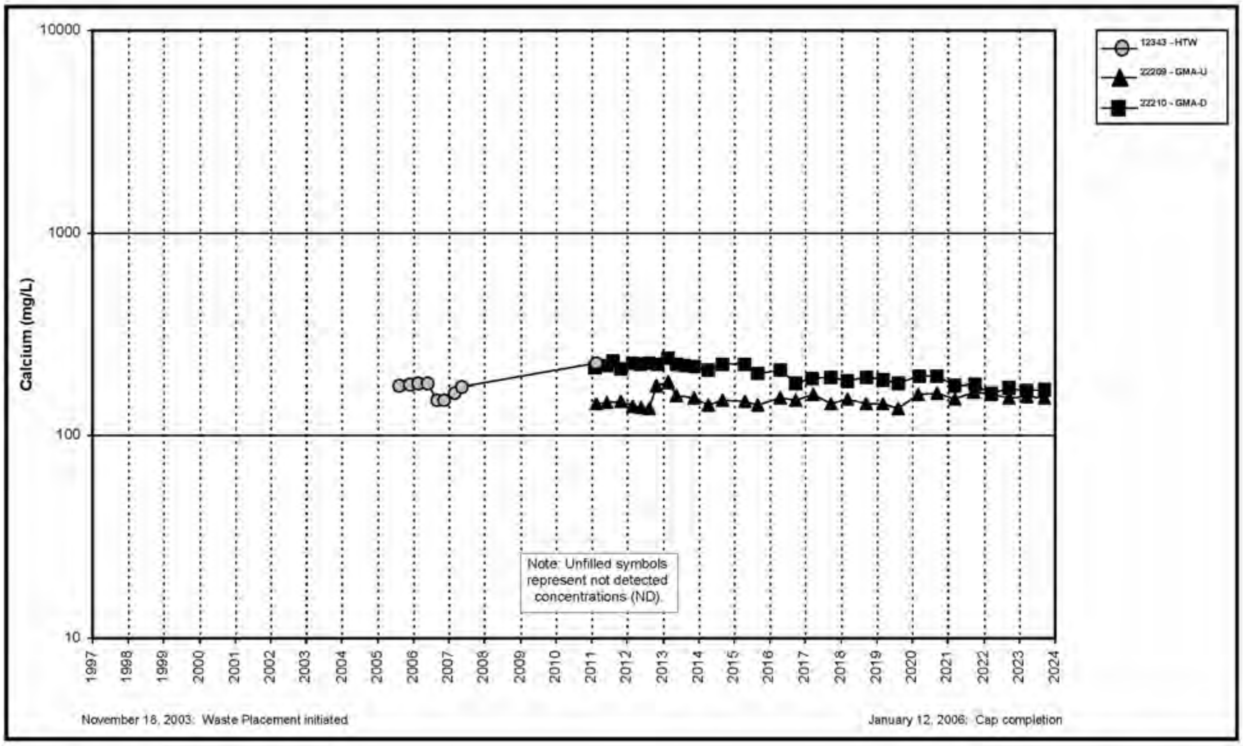

Figure A.5.6-9. Cell 6 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

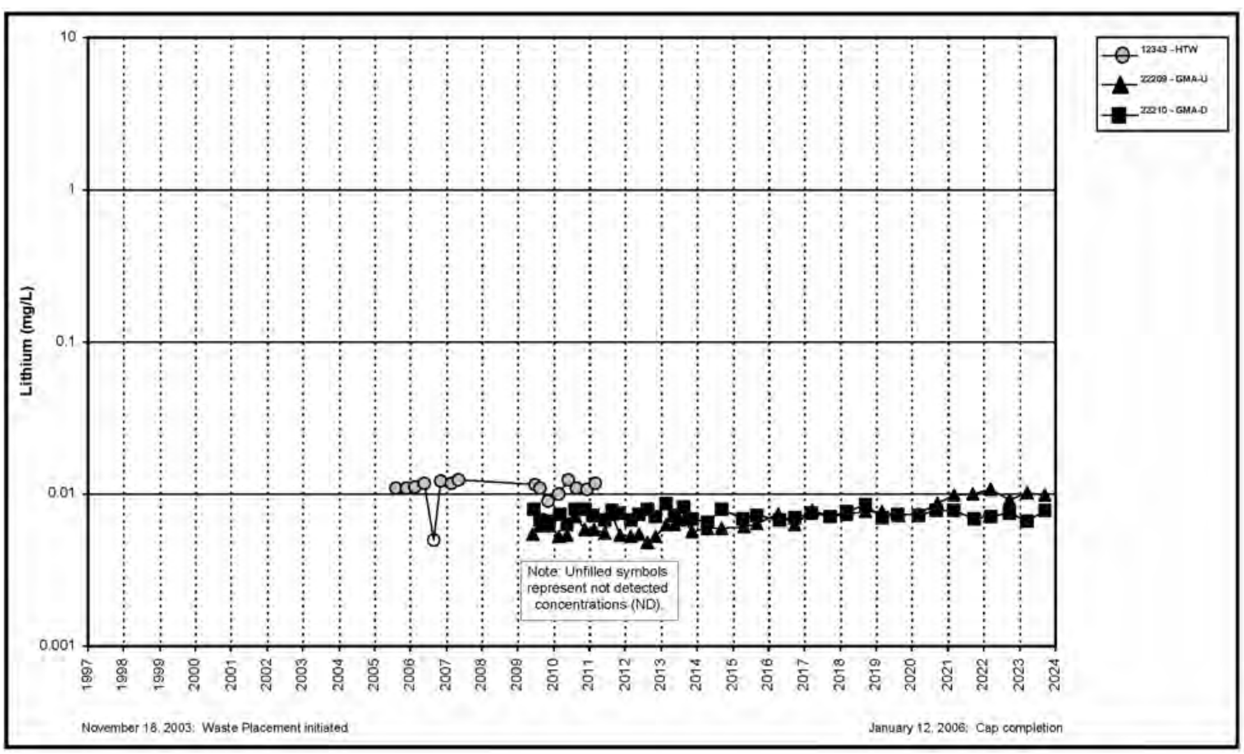

Figure A.5.6-10. Cell 6 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

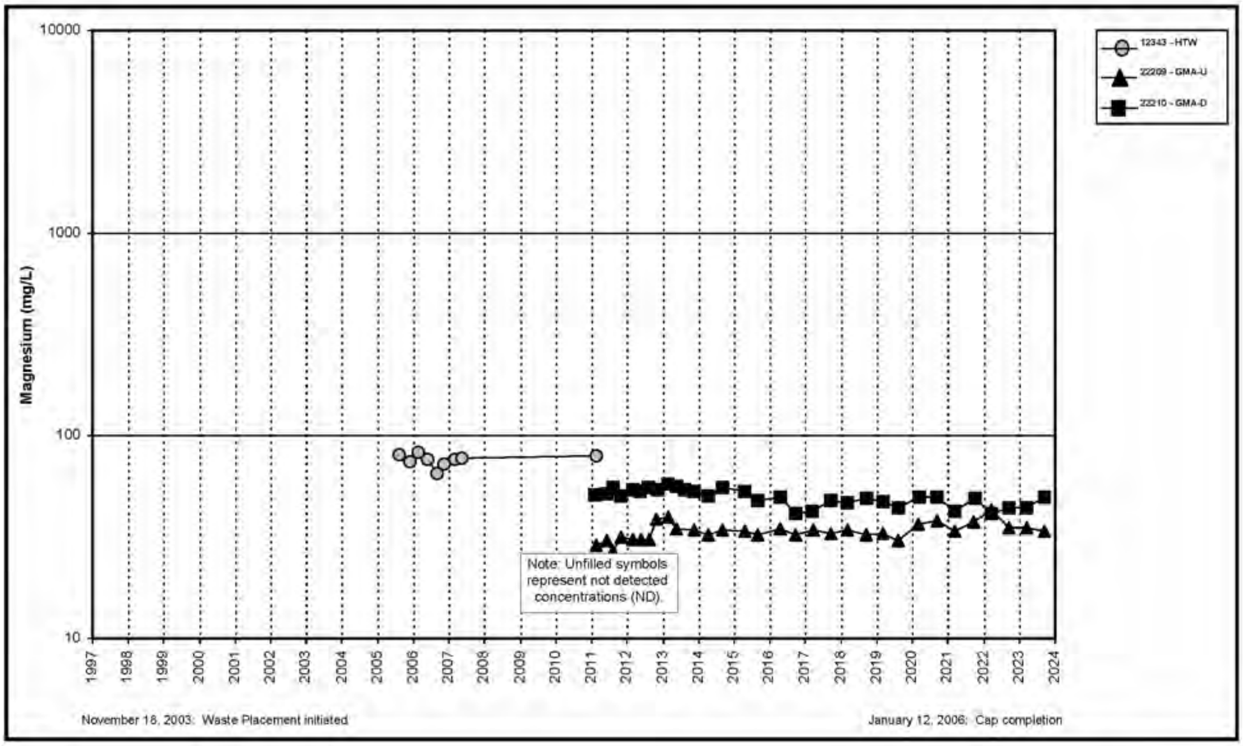

Figure A.5.6-11. Cell 6 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

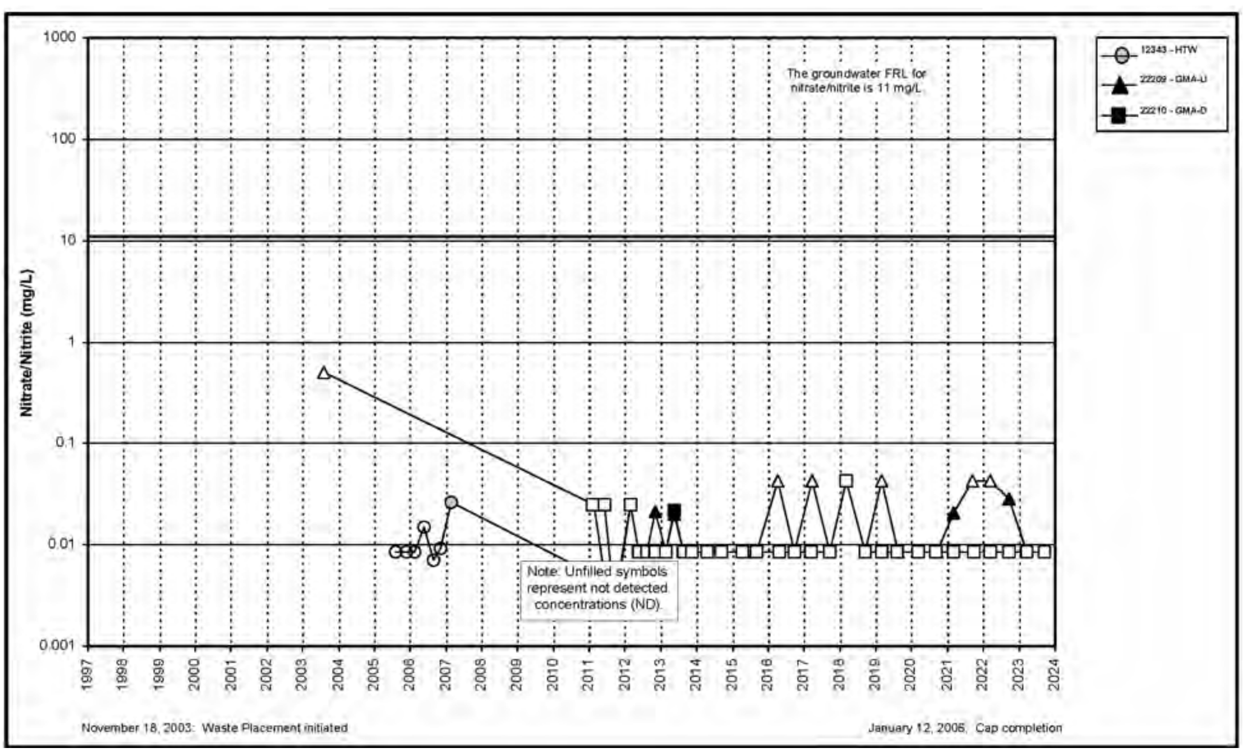

Figure A.5.6-12. Cell 6 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

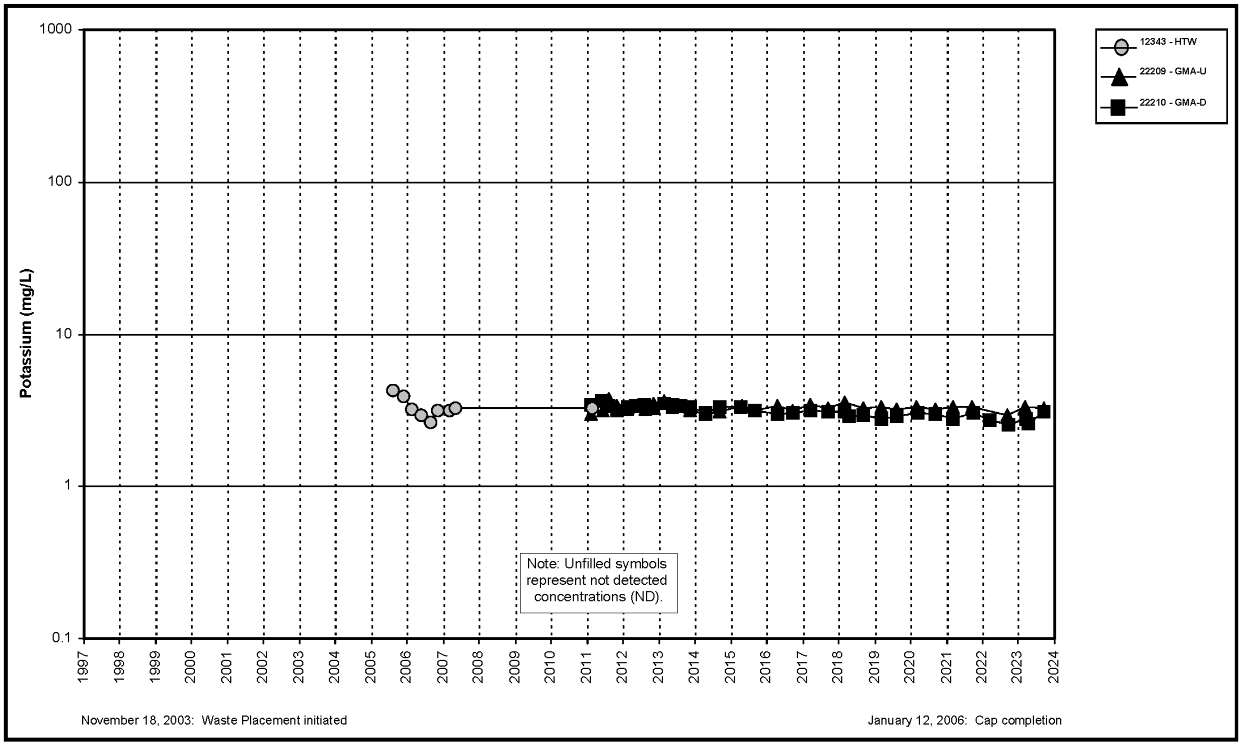

Figure A.5.6-13. Cell 6 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

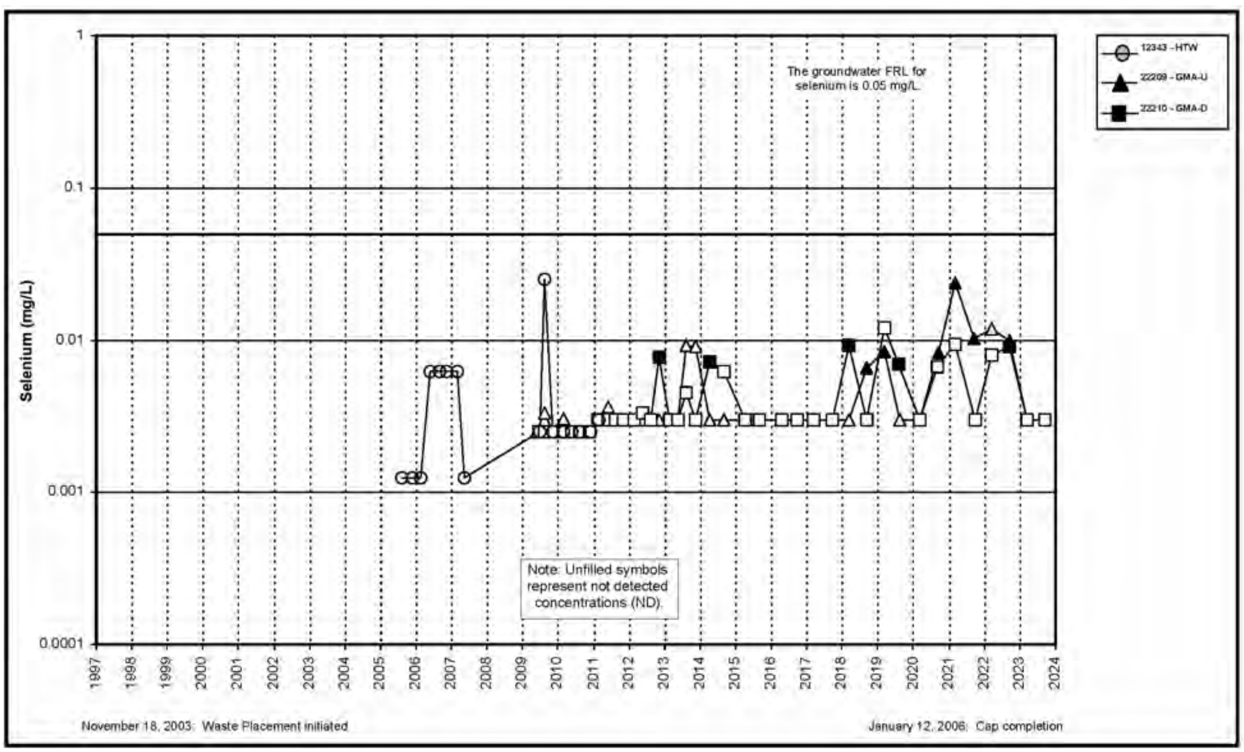

Figure A.5.6-14. Cell 6 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

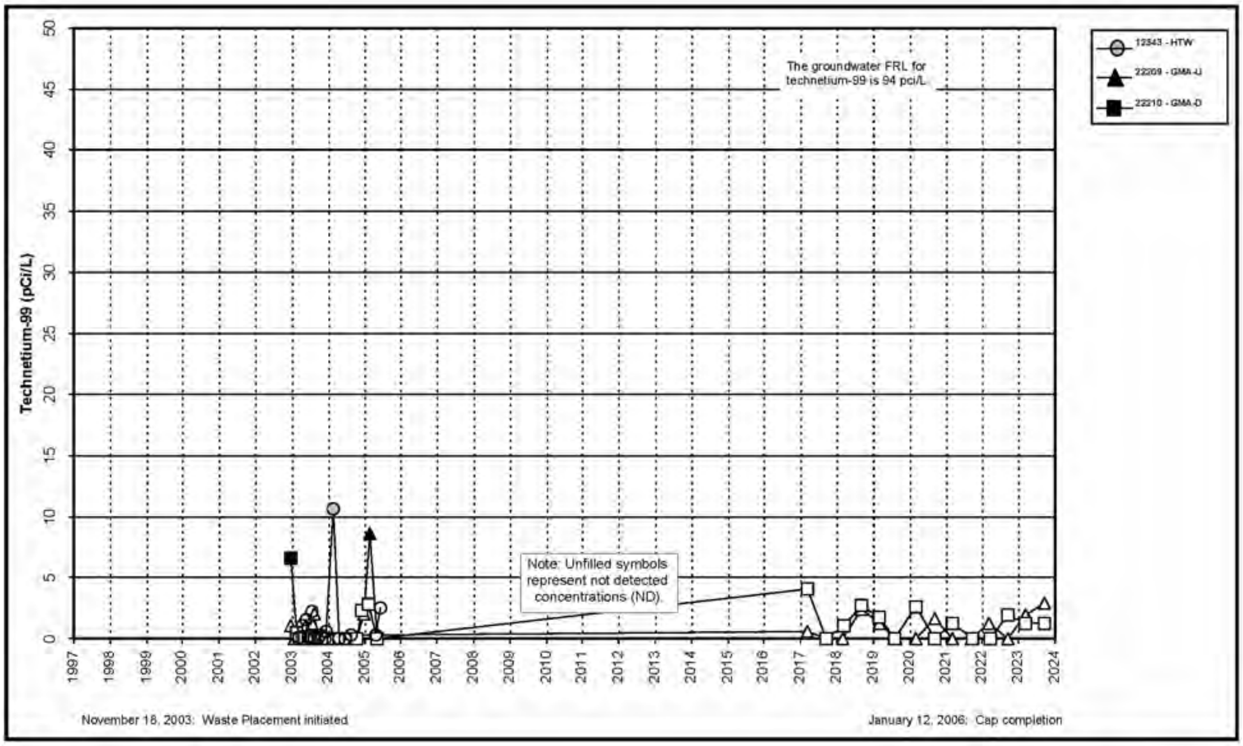

Figure A.5.6-15. Cell 6 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

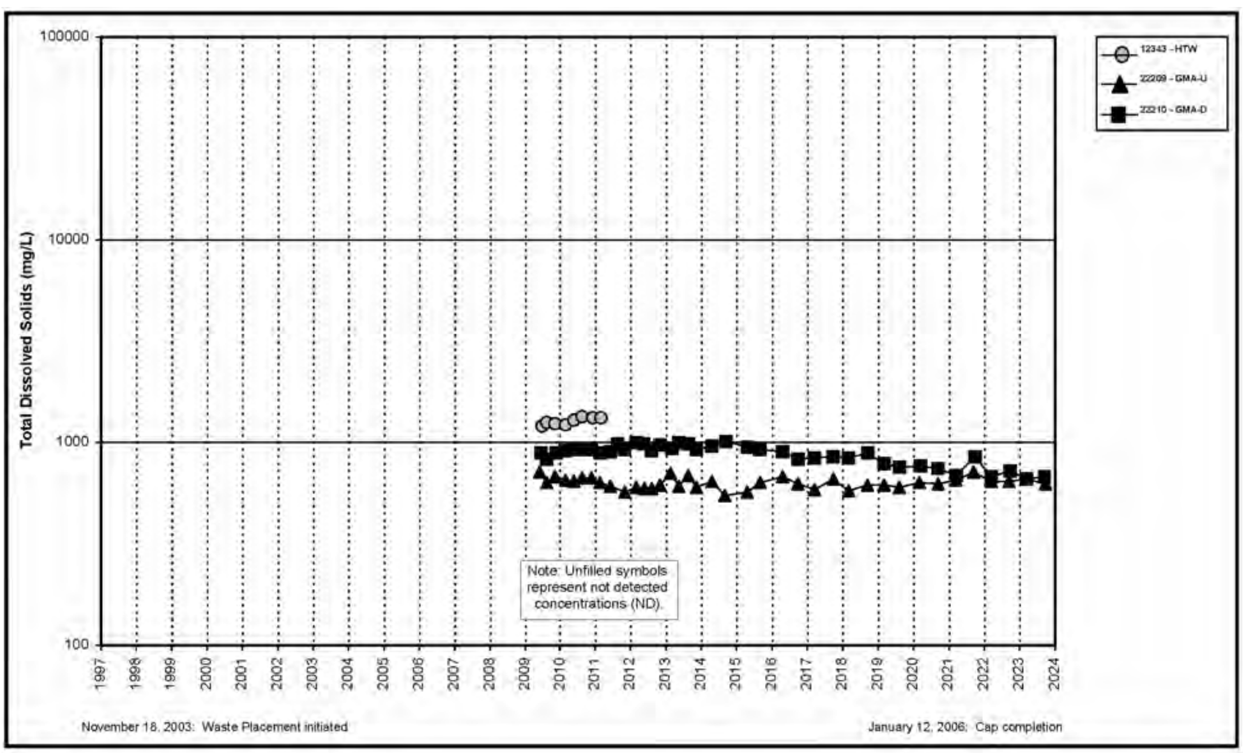

Figure A.5.6-16. Cell 6 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

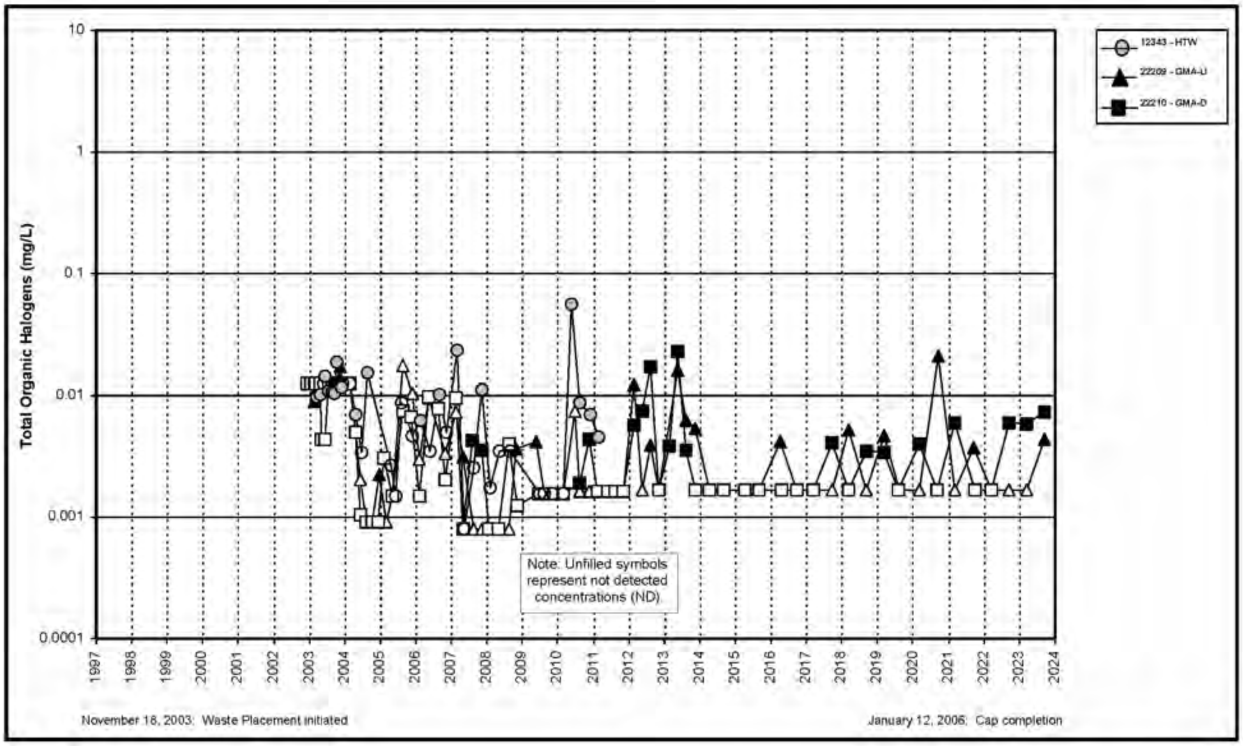

Figure A.5.6-17. Cell 6 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

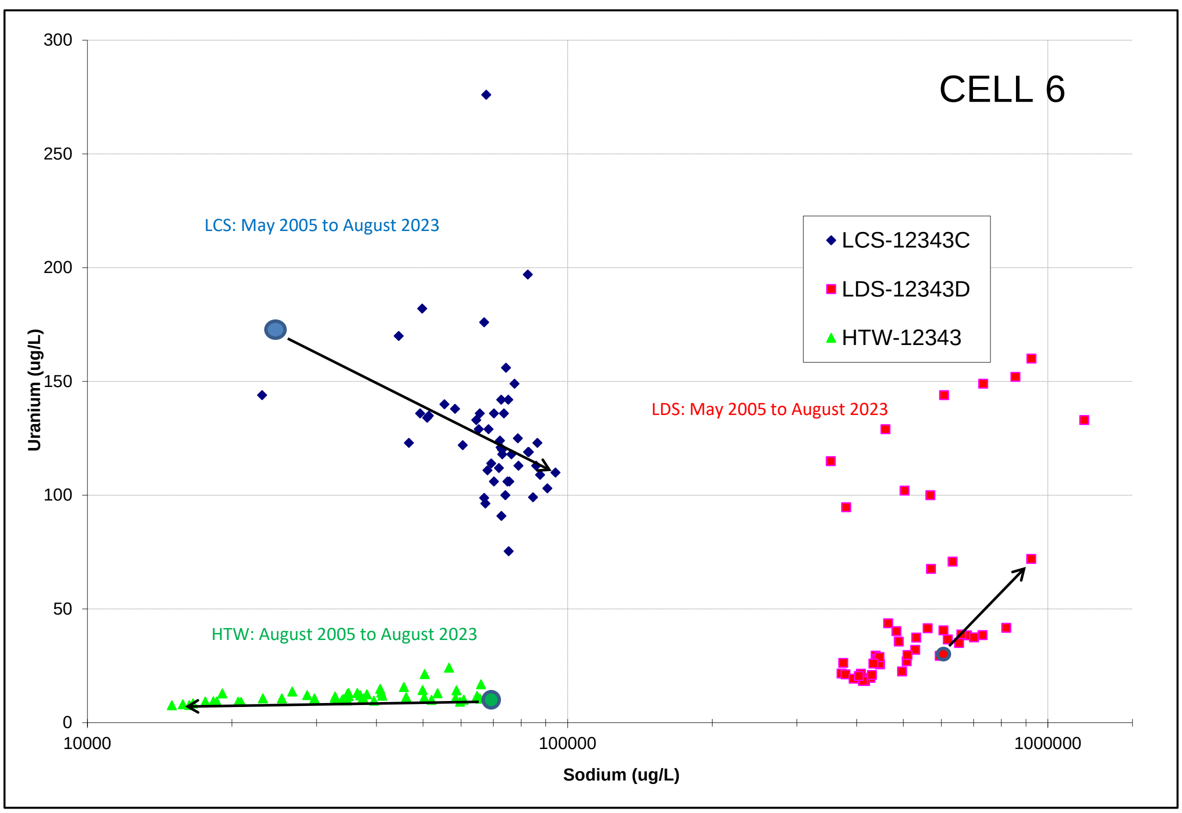

Figure A.5.6-18. Cell 6 Bivariate Plot for Uranium and Sodium

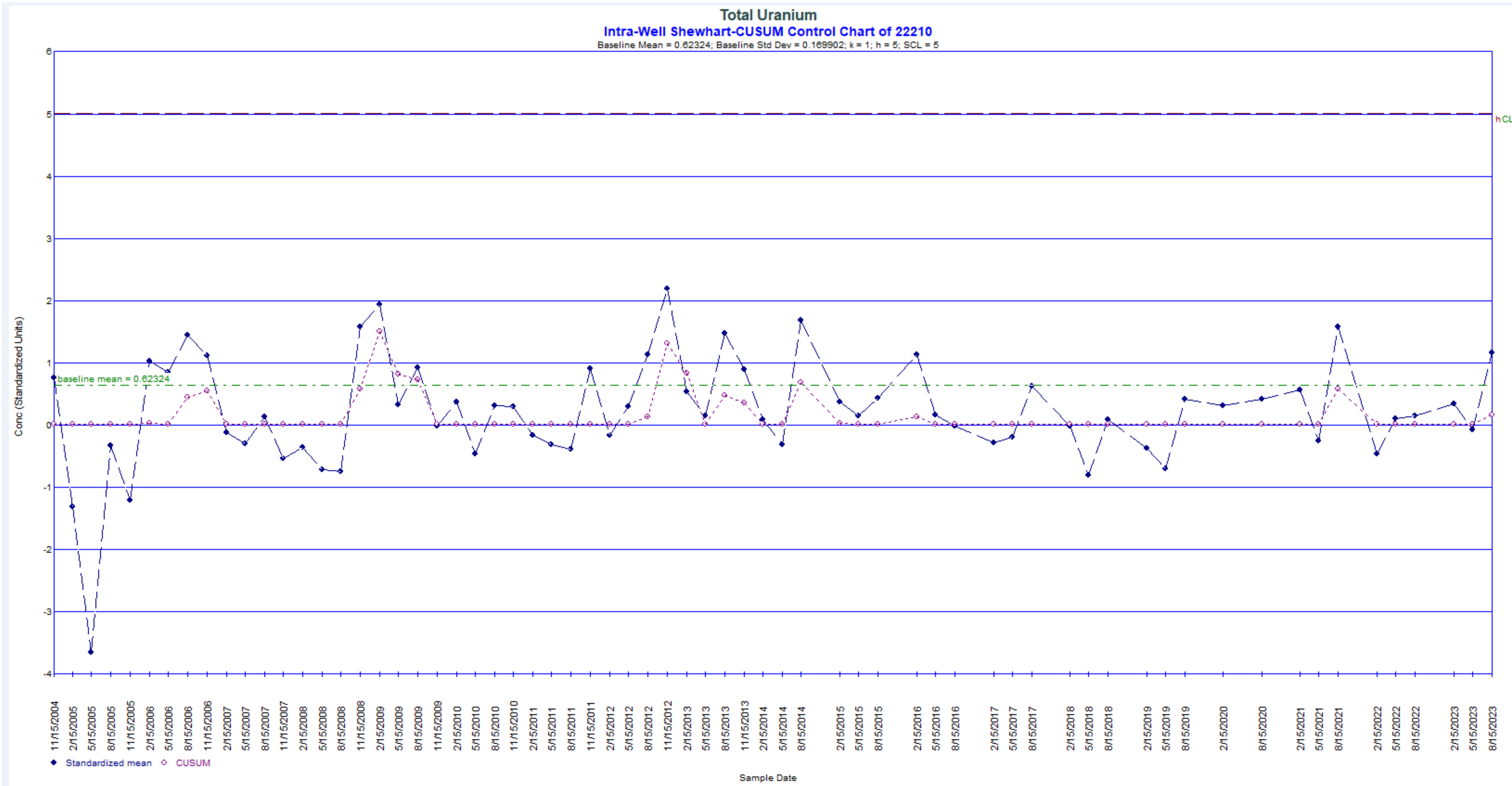

Figure A.5.6-19. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22210

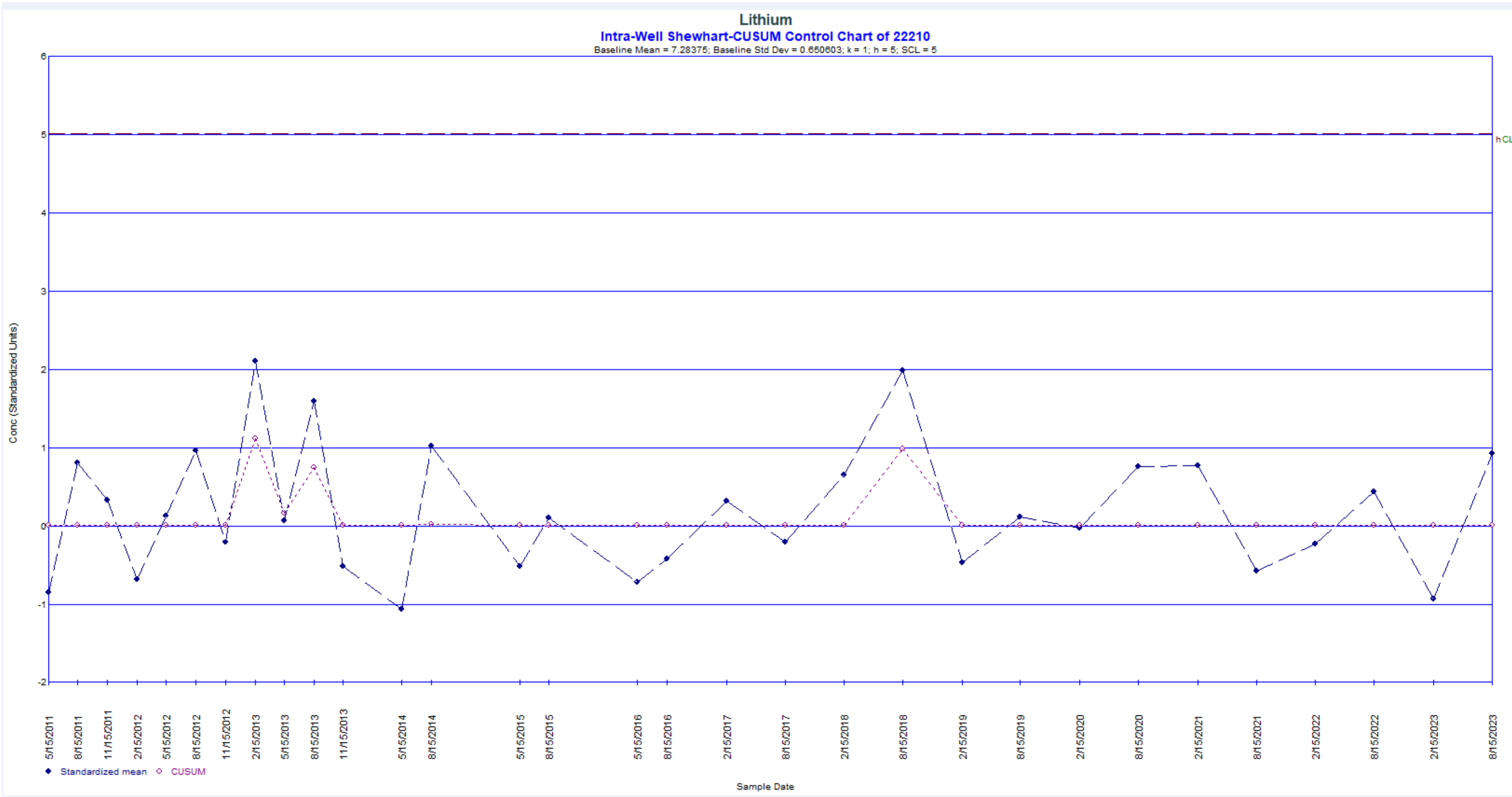

Figure A.5.6-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22210

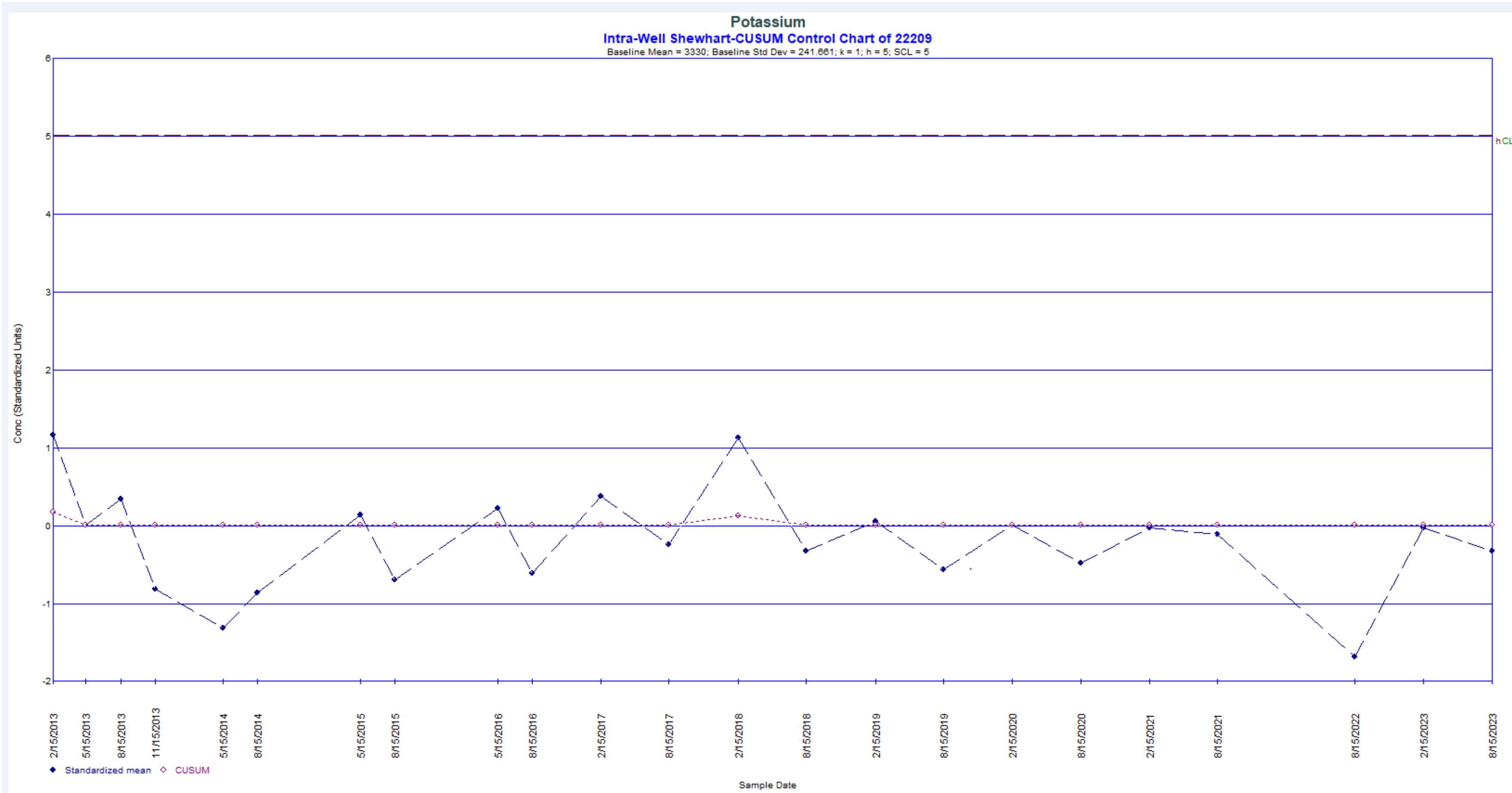

Figure A.5.6-21. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22209

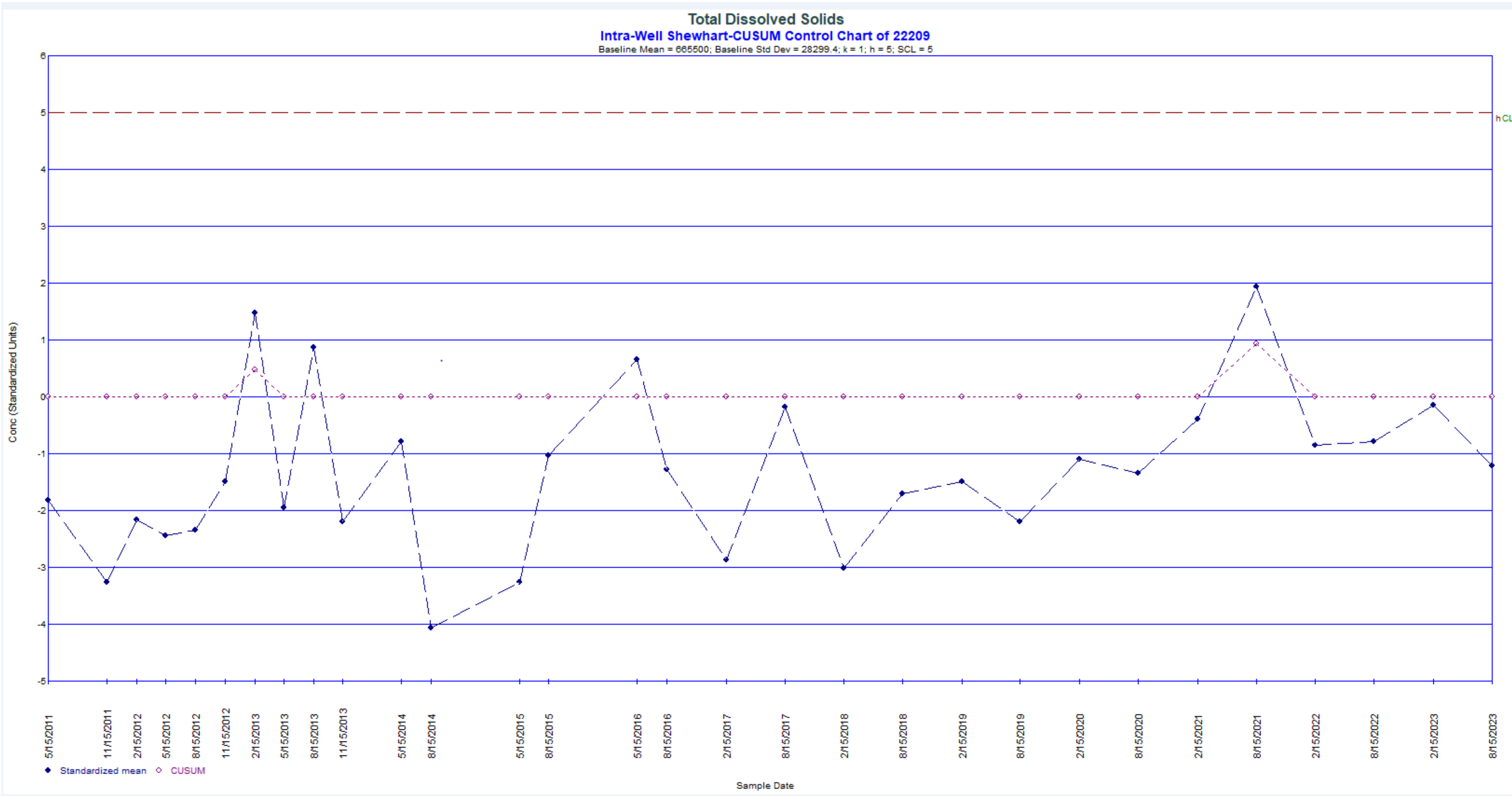

Figure A.5.6-22. Intrawell Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22209

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Subattachment A.5.7

Cell 7

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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 2023 have upward concentration trends in the LCS or LDS based on the Mann-Kendall test for trend. 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.

One new high concentration (sodium) was measured in the LDS of Cell 7 in 2023. The new high for sodium was 138 milligrams per liter (mg/L). The previous high was 131 mg/L.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 7

Parameter	LCS 12344C 2023 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, lithium, 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		
Lithium		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.5.7.1.3 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 2023 have an upward concentration trend in the LCS of Cell 7: sodium and sulfate. One new high concentration (sodium) was measured in the LDS of Cell 7 in 2023. The new high for sodium was 138 mg/L. The previous high was 131 mg/L. The new high sodium concentration measured in the LDS is not attributed to communication with the LCS. It is 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
- Since 2015, the volume of water in the LDS tank of Cell 7 has been insufficient to collect a sample.

- Six parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 7: 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 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	57	57	100	4.72	264	148	53	Normal	Down (2023)	Detected	355 (Q3-07)
	LDS	12344D	31	31	100	12.2	37.6	25.7	6.2	Normal	Up (2015)	Detected	169 (Q2-14)
	HTW	12344	57	57	100	2.00	12.1	3.81	1.80	Undefined	Up (2023)	Detected	
	GMA-U	22212	53	59	89.8	ND	0.634	0.422	0.100	Undefined	Down (2023)	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	65	69	94.2	ND	4.06	0.350	0.640	Undefined	None (2023)	Not Detected	
Boron (mg/L)	LCS	12344C	57	57	100	0.0625	1.35	1.06	0.36	Undefined	Down (2023)	Detected	
	LDS	12344D	31	31	100	0.168	2.10	0.36	0.425	Undefined	Up (2015)	Detected	
	HTW	12344	33	41	80.5	ND	0.0750	0.0623	0.0116	Ln Normal	Up (2023)	Not Detected	
	GMA-U	22212	57	59	96.6	ND	0.0616	0.0395	0.0094	Undefined	Up (2023)	Detected	
	GMA-D	22211	56	59	94.9	ND	0.0622	0.0331	0.0109	Undefined	Up (2023)	Detected	
Sodium (mg/L)	LCS	12344C	50	50	100	18.1	138	98.3	27.8	Undefined	Up (2023)	Detected	
	LDS	12344D	24	24	100	186	1,590	587	374	Undefined	Up (2015)	Detected	
	HTW	12344	45	45	100	19.8	52.0	34.3	6.9	Undefined	Up (2023)	Detected	
	GMA-U	22212	39	39	100	15.5	27.0	20.2	2.8	Normal	Down (2023)	Detected	
	GMA-D	22211	41	41	100	10.1	19.2	13.9	2.6	Ln Normal	Down (2023)	Detected	
Sulfate (mg/L)	LCS	12344C	57	57	100	122	5,470	3,790	1,320	Undefined	Up (2023)	Detected	
	LDS	12344D	31	31	100	1,280	7,370	1,770	1,880	Undefined	Up (2015)	Detected	
	HTW	12344	52	52	100	80.4	765	460	259	Undefined	Up (2023)	Detected	
	GMA-U	22212	59	59	100	96.6	731	168	109	Undefined	Down (2023)	Detected	
	GMA-D	22211	59	59	100	117	572	262	119	Undefined	Down (2023)	Detected	3,640 (Q3-12)
Calcium (mg/L)	GMA-U	22212	32	32	100	140	177	153	10	Undefined	None (2023)	Not Detected	377 (Q3-11)
	GMA-D	22211	32	32	100	136	263	184	36	Ln Normal	Down (2023)	Detected	
Lithium (mg/L)	GMA-U	22212	39	39	100	0.00474	0.00892	0.00575	0.00107	Undefined	Up (2023)	Detected	
	GMA-D	22211	39	39	100	0.00555	0.00930	0.00701	0.00083	Normal	None (2023)	Not Detected	
Magnesium (mg/L)	GMA-U	22212	32	32	100	28.6	41.5	34.7	2.4	Ln Normal	None (2023)	Not Detected	54.6 (Q3-11)
	GMA-D	22211	32	32	100	34.6	64.7	46.5	8.1	Ln Normal	Down (2023)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22212	3	32	9.4	ND	0.0431	0.0162	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22211	4	32	12.5	ND	0.119	0.00850	0.0227	Undefined	None (2023)	Not Detected	
Potassium (mg/L)	GMA-U	22212	32	32	100	3.05	3.81	3.46	0.17	Normal	None (2023)	Not Detected	4.81 (Q3-11)
	GMA-D	22211	34	34	100	2.34	3.65	2.88	0.32	Normal	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22212	8	39	20.5	ND	0.0292	0.00300	0.00544	Undefined	Up (2023)	Detected	
	GMA-D	22211	3	39	7.7	ND	0.0125	0.00396	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22212	1	24	4.2	ND	11.0	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22211	1	24	4.2	ND	9.38	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22212	39	39	100	519	854	652	58	Ln Normal	None (2023)	Detected	1,130 (Q2-10); 1,270 (Q3-10); 1,510 (Q3-11)
	GMA-D	22211	39	39	100	583	1,350	867	210	Ln Normal	Down (2023)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22212	22	59	37.3	ND	0.0125	0.00240	0.00292	Undefined	None (2023)	Not Detected	0.0500 (Q2-10); 0.0190 (Q2-13)
	GMA-D	22211	20	59	33.9	ND	0.0230	0.00166	0.00430	Undefined	None (2023)	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 has 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: Ln Normal 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
2023	1,325	2	663

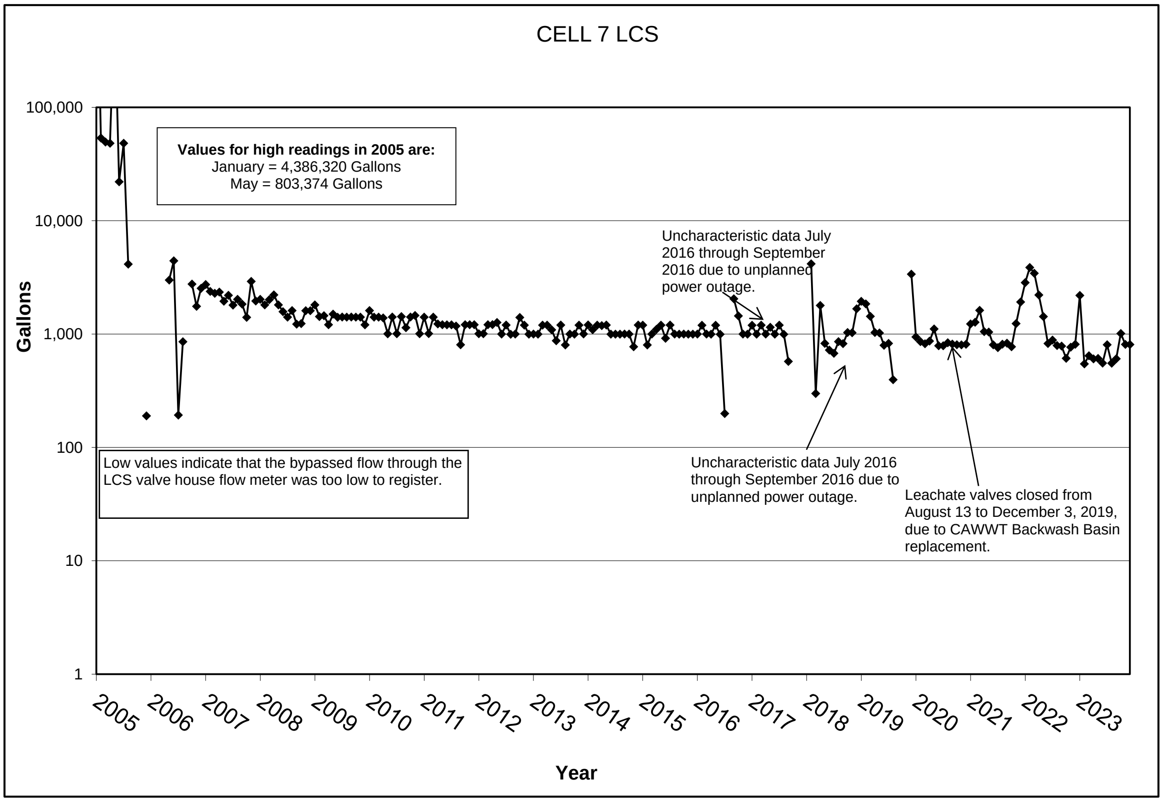

Figure A.5.7-1. Monthly Accumulation Volumes for Cell 7 LCS

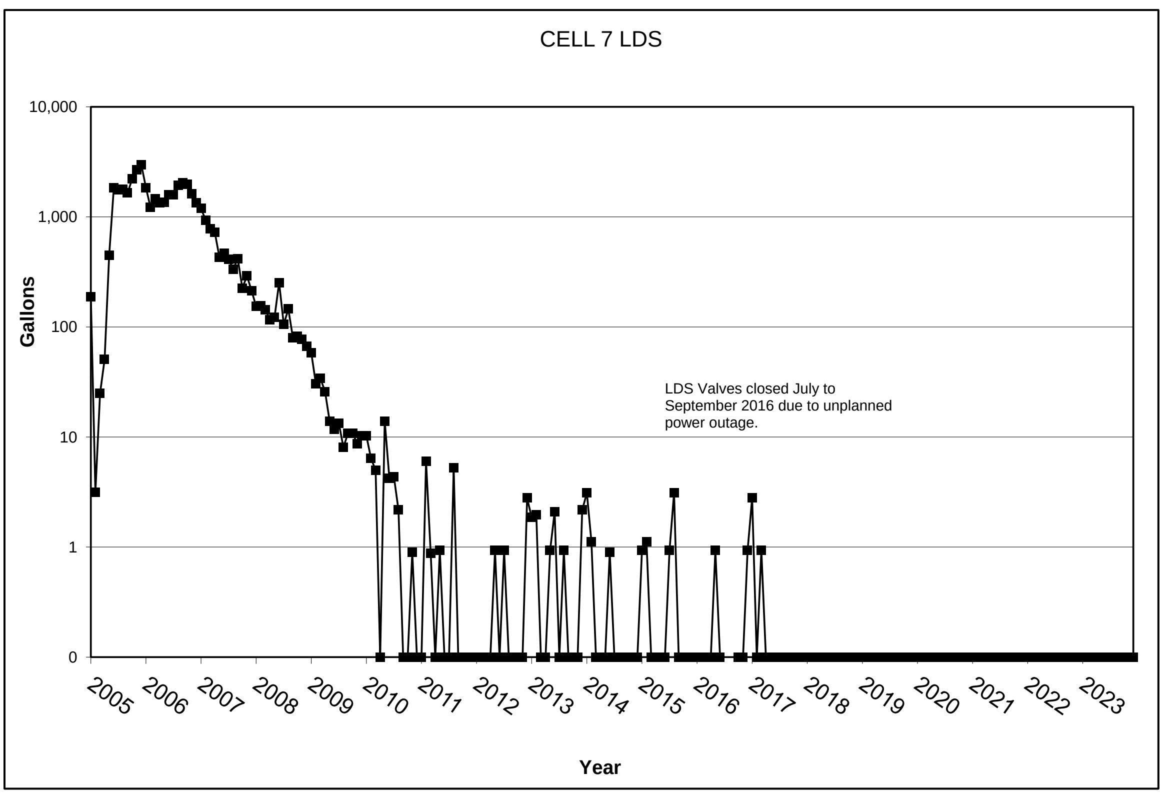

Figure A.5.7-2. Monthly Accumulation Volumes for Cell 7 LDS

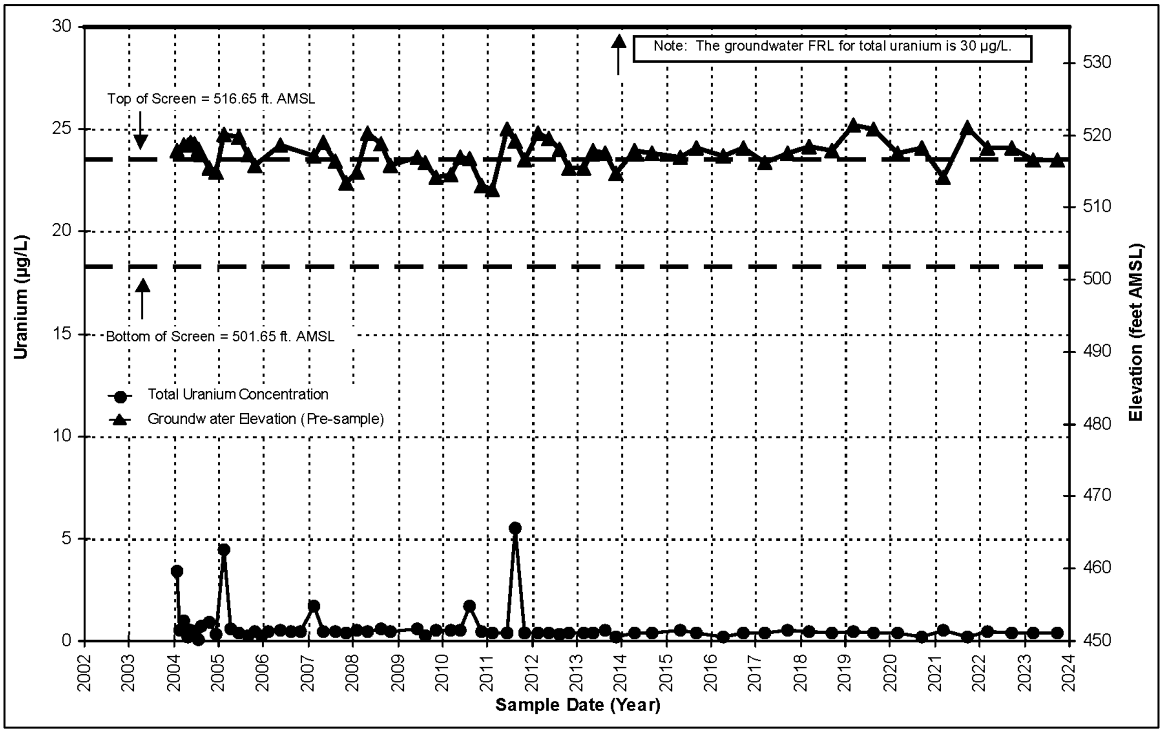

Figure A.5.7-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 7 Upgradient Monitoring Well 22212

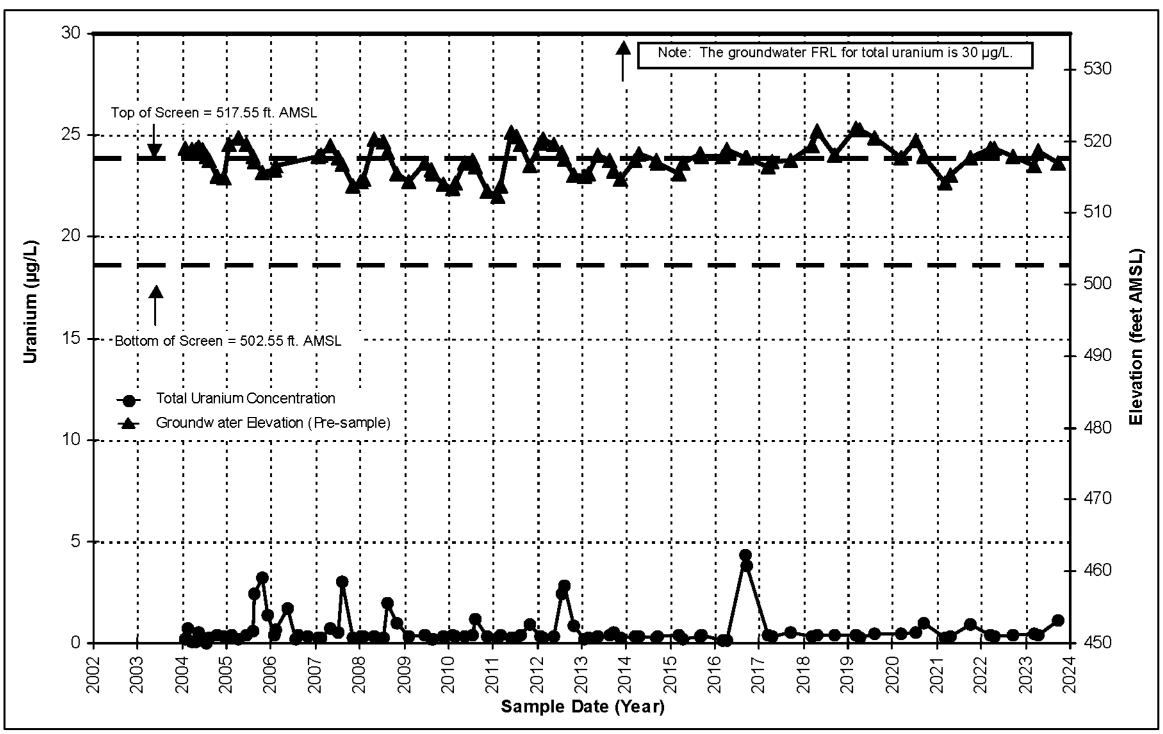

Figure A.5.7-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 7 Downgradient Monitoring Well 22211

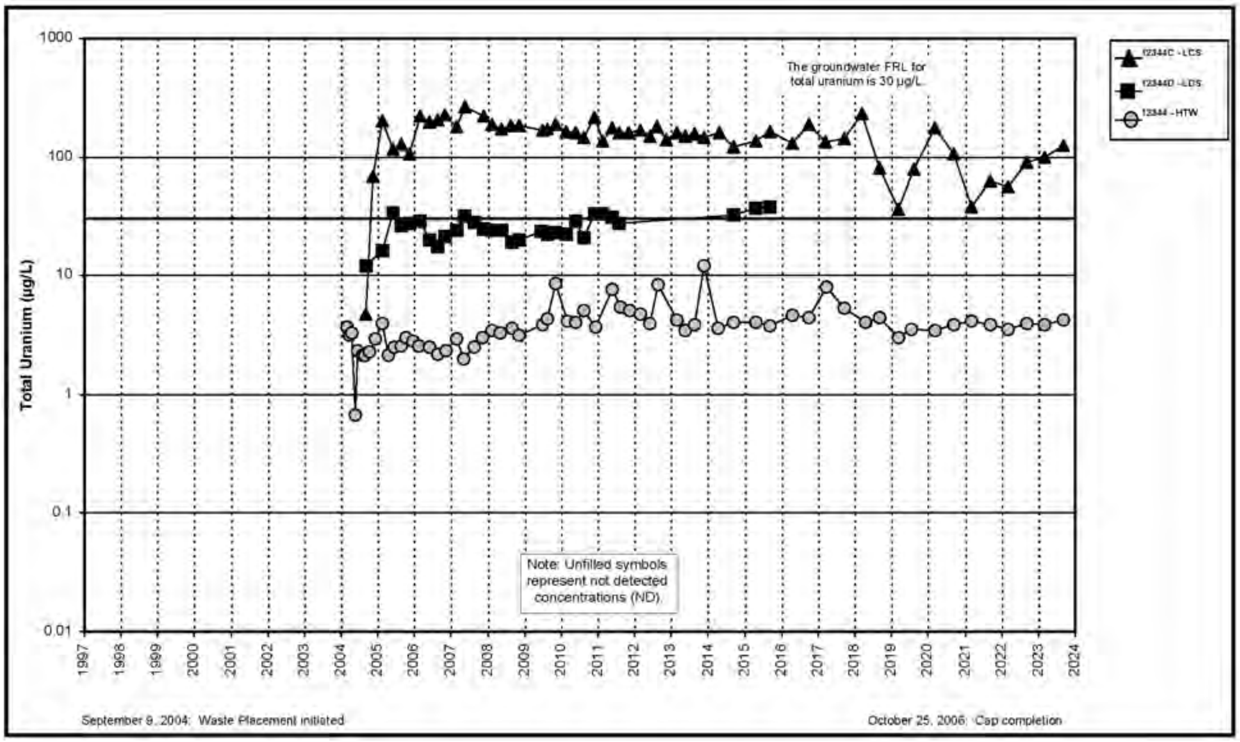

Figure A.5.7-5A. Cell 7 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

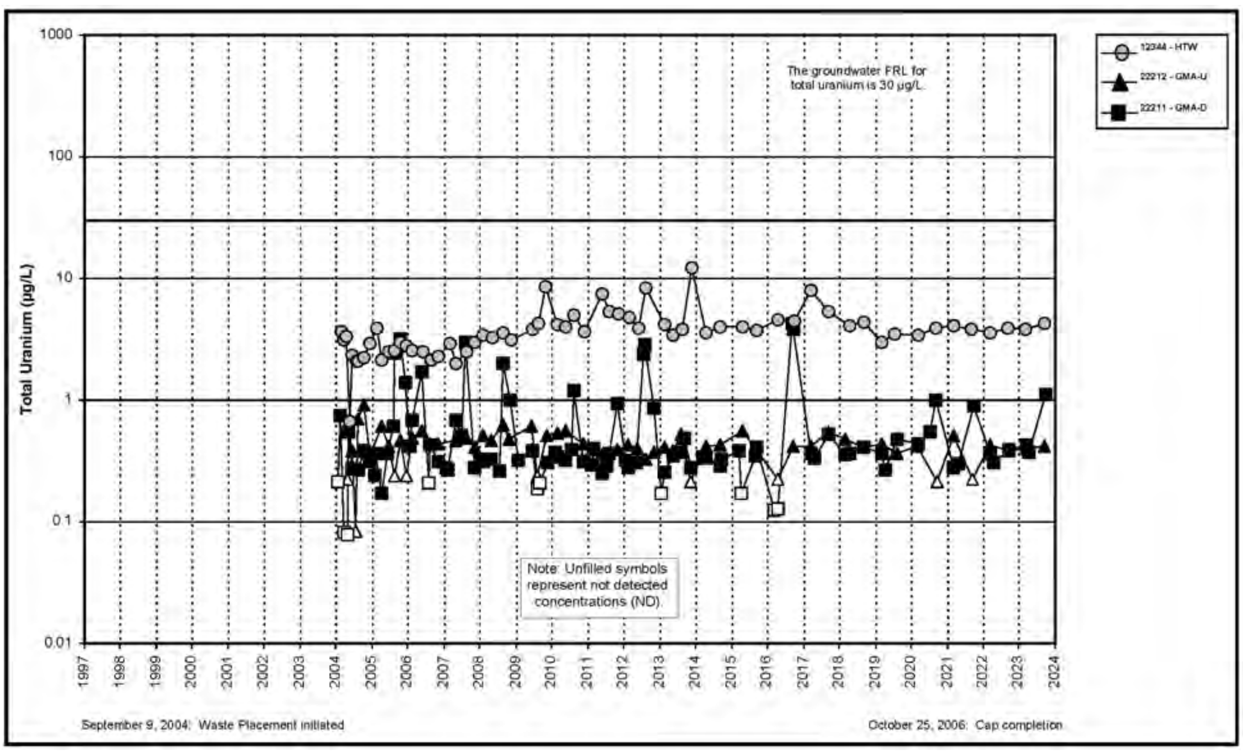

Figure A.5.7-5B. Cell 7 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

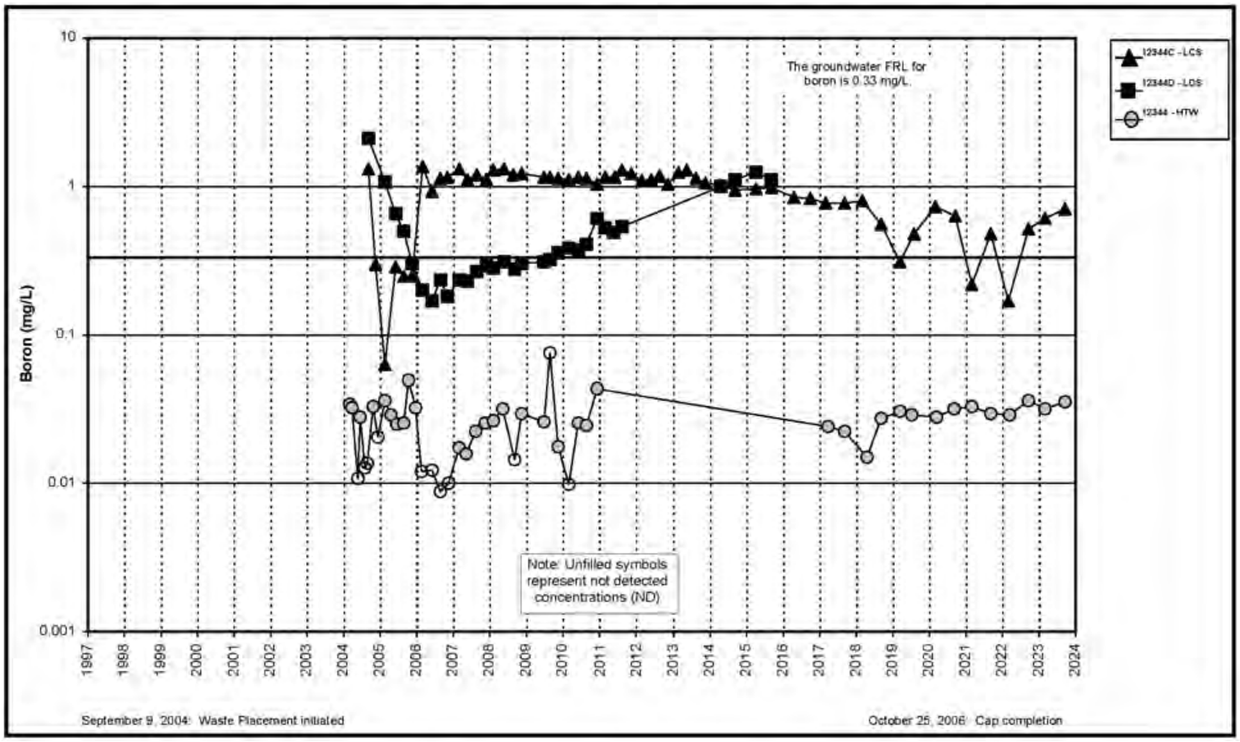

Figure A.5.7-6A. Cell 7 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

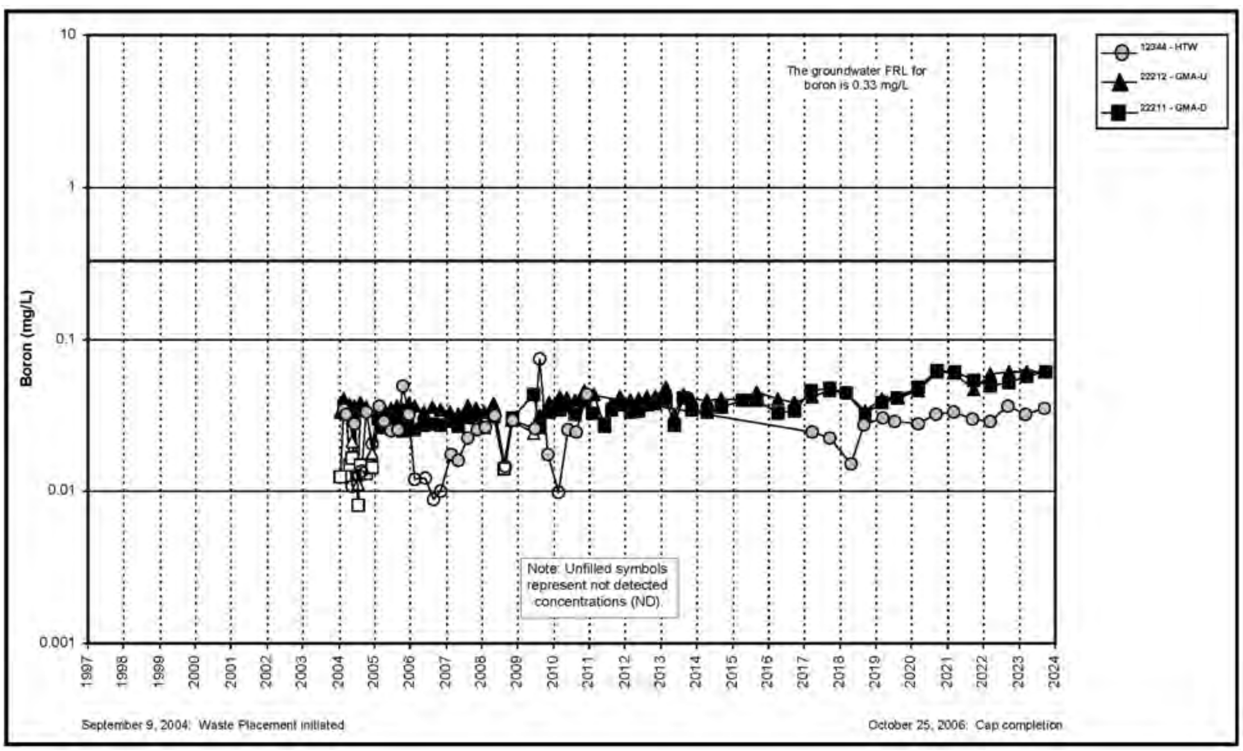

Figure A.5.7-6B. Cell 7 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

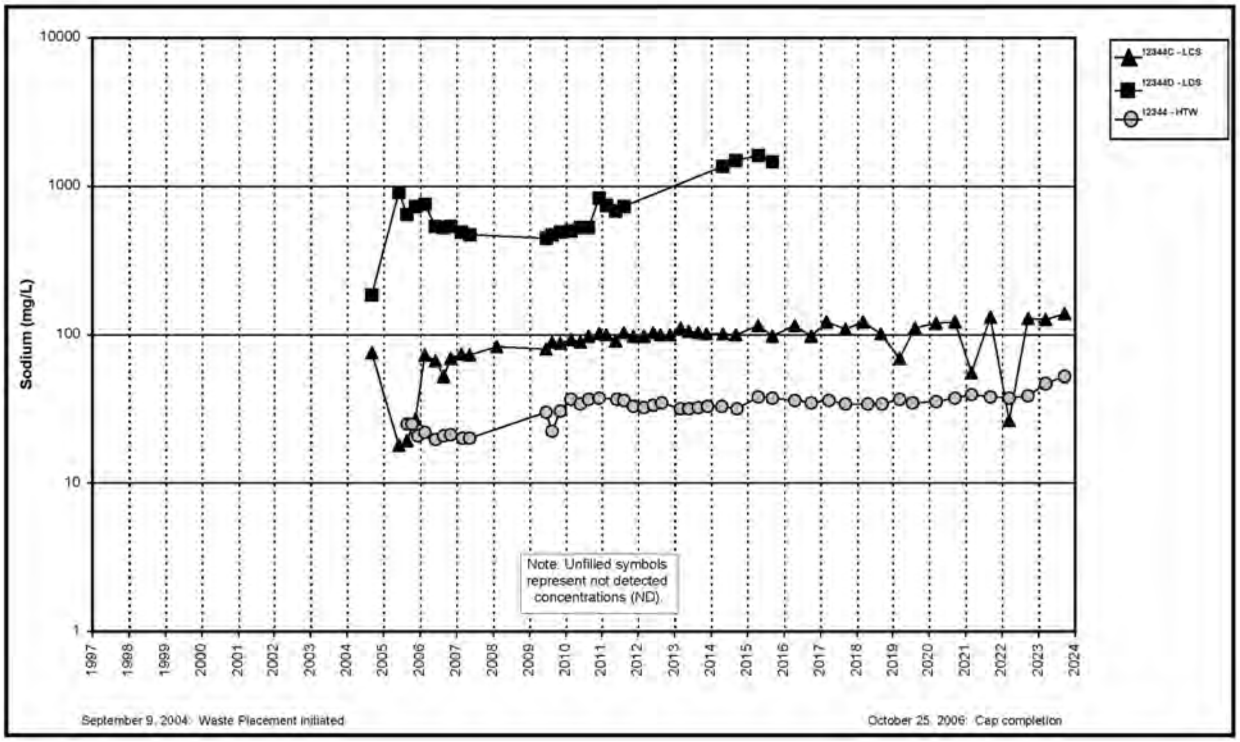

Figure A.5.7-7A. Cell 7 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

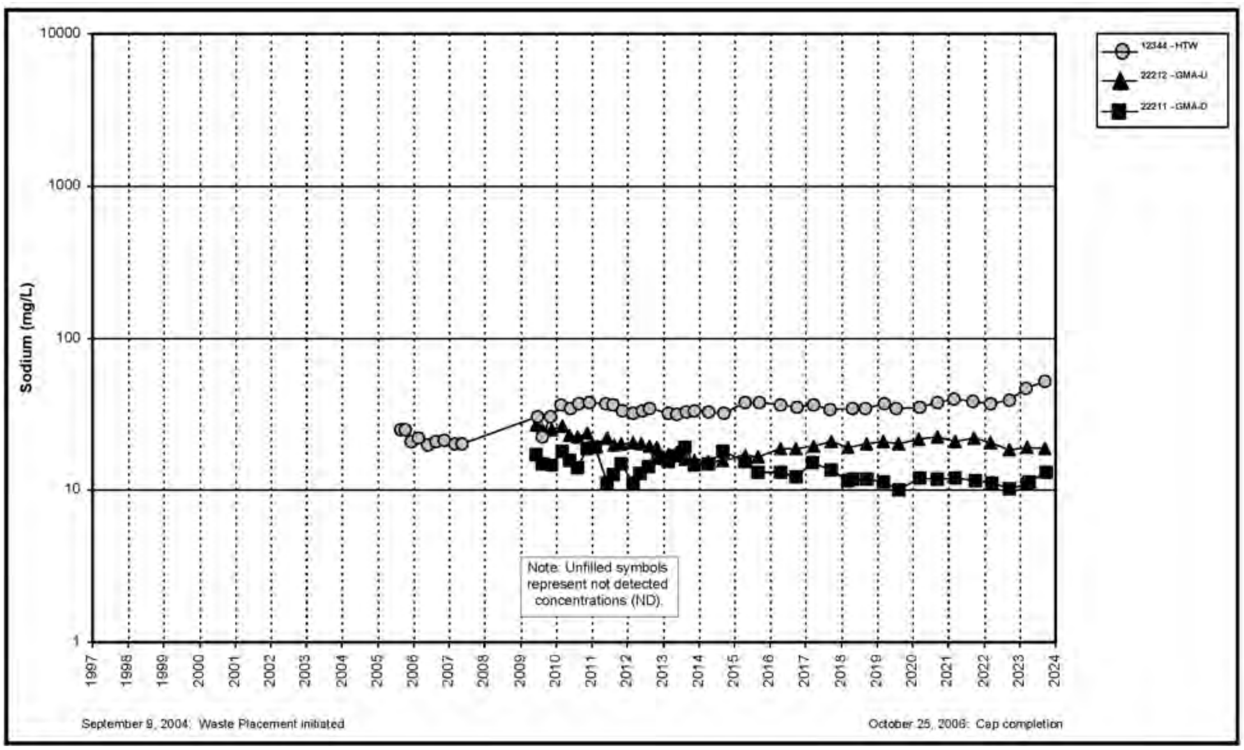

Figure A.5.7-7B. Cell 7 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

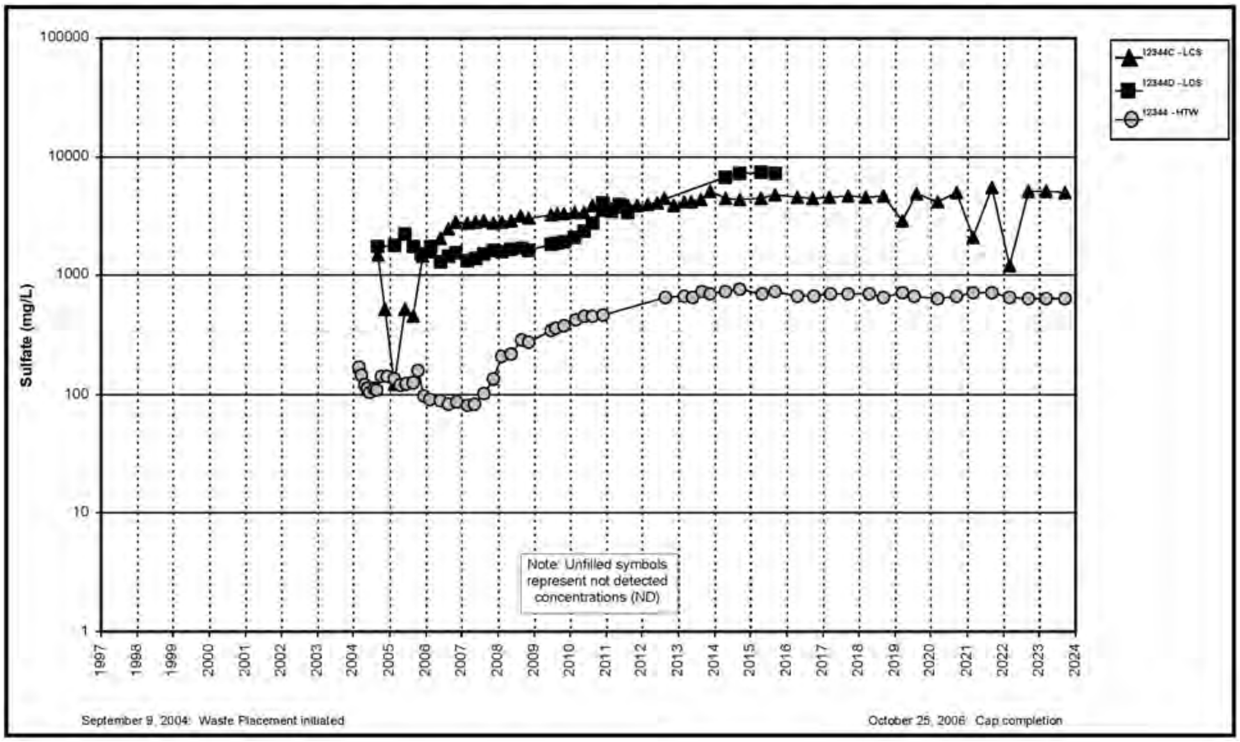

Figure A.5.7-8A. Cell 7 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

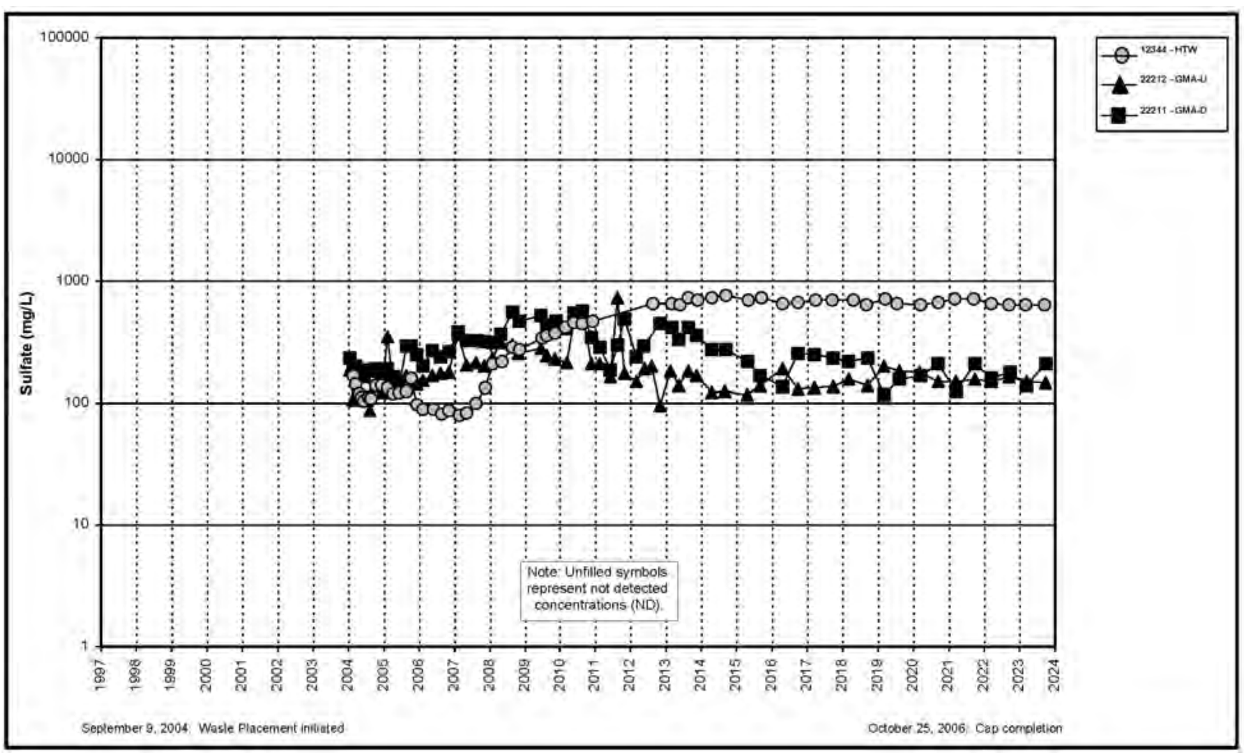

Figure A.5.7-8B. Cell 7 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

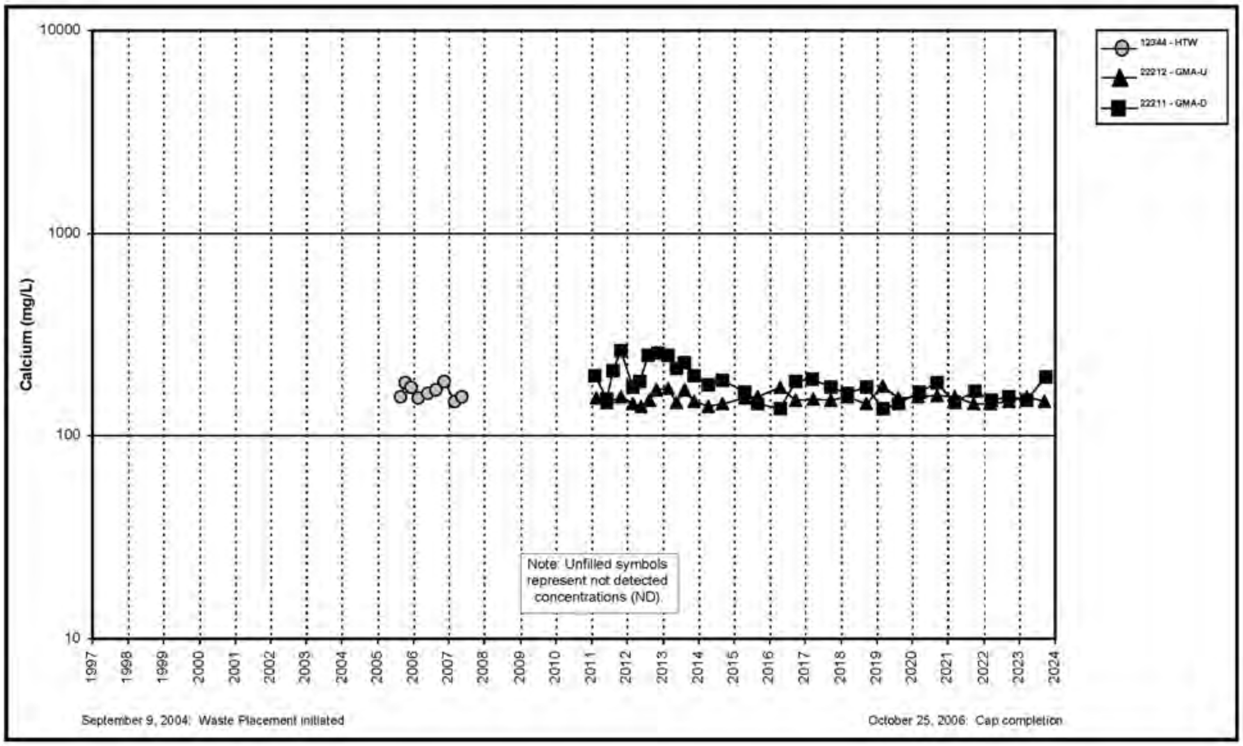

Figure A.5.7-9. Cell 7 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

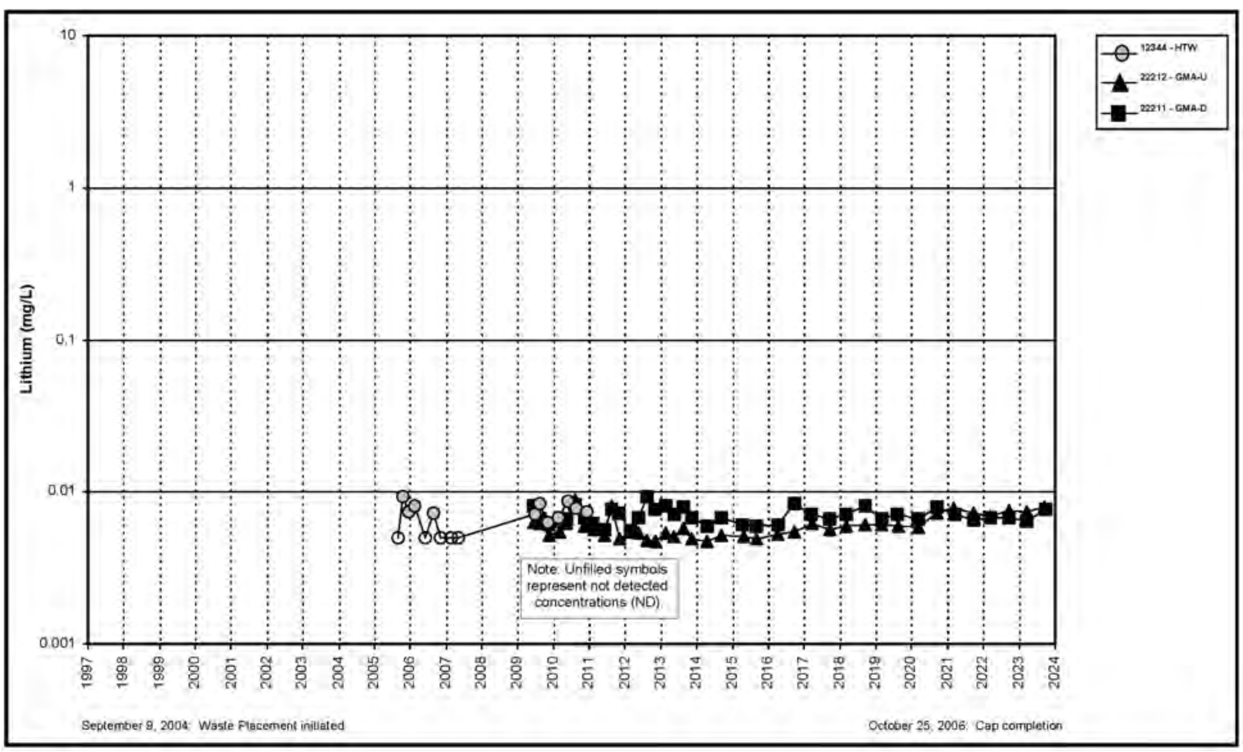

Figure A.5.7-10. Cell 7 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

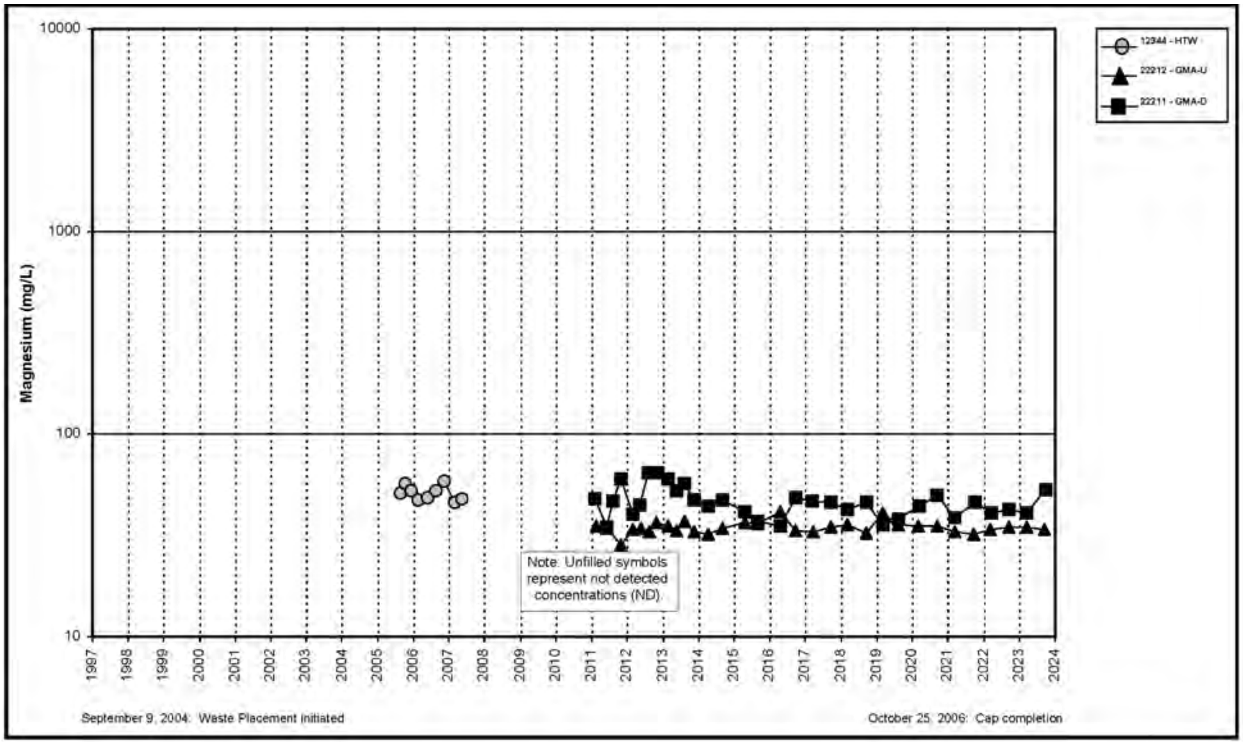

Figure A.5.7-11. Cell 7 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

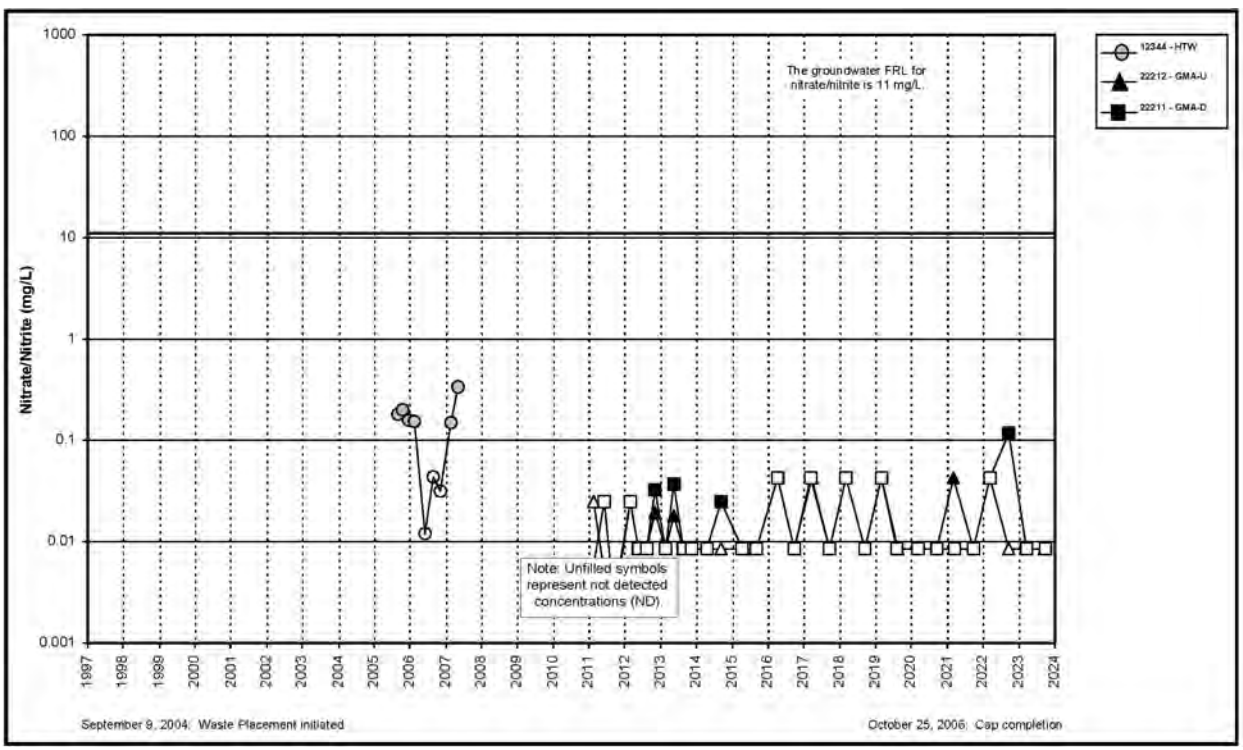

Figure A.5.7-12. Cell 7 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

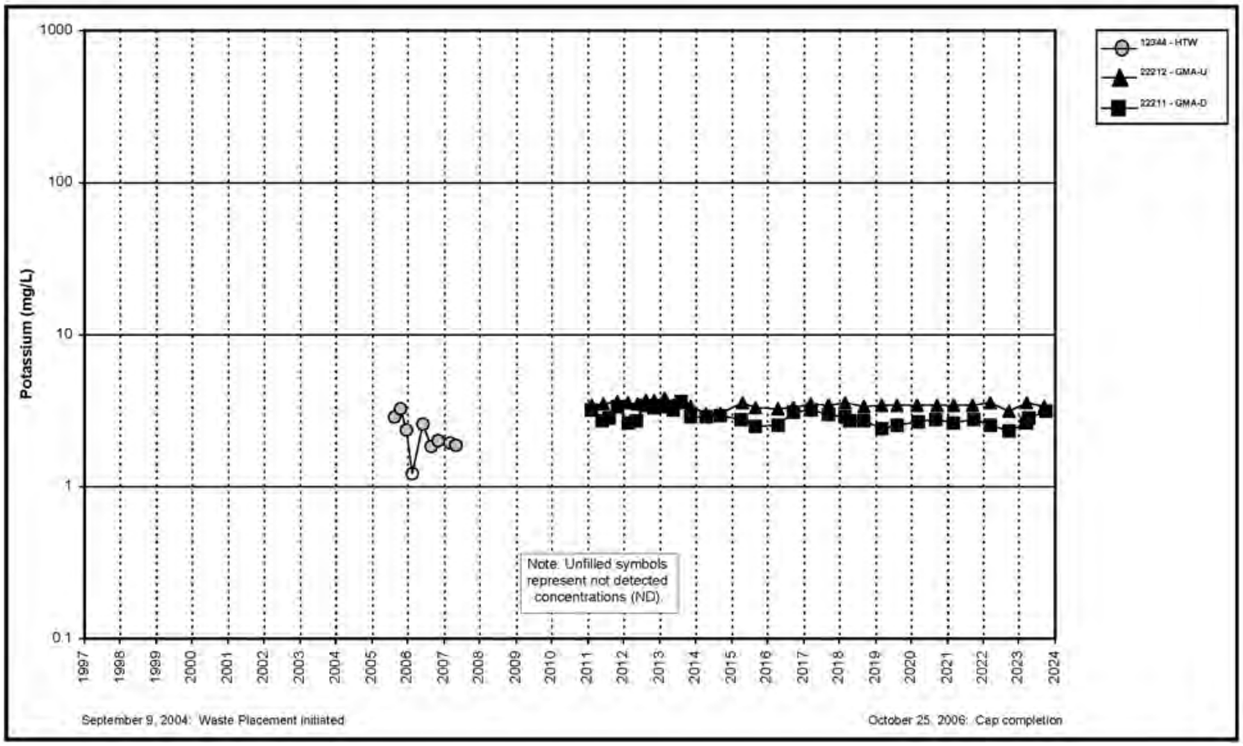

Figure A.5.7-13. Cell 7 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

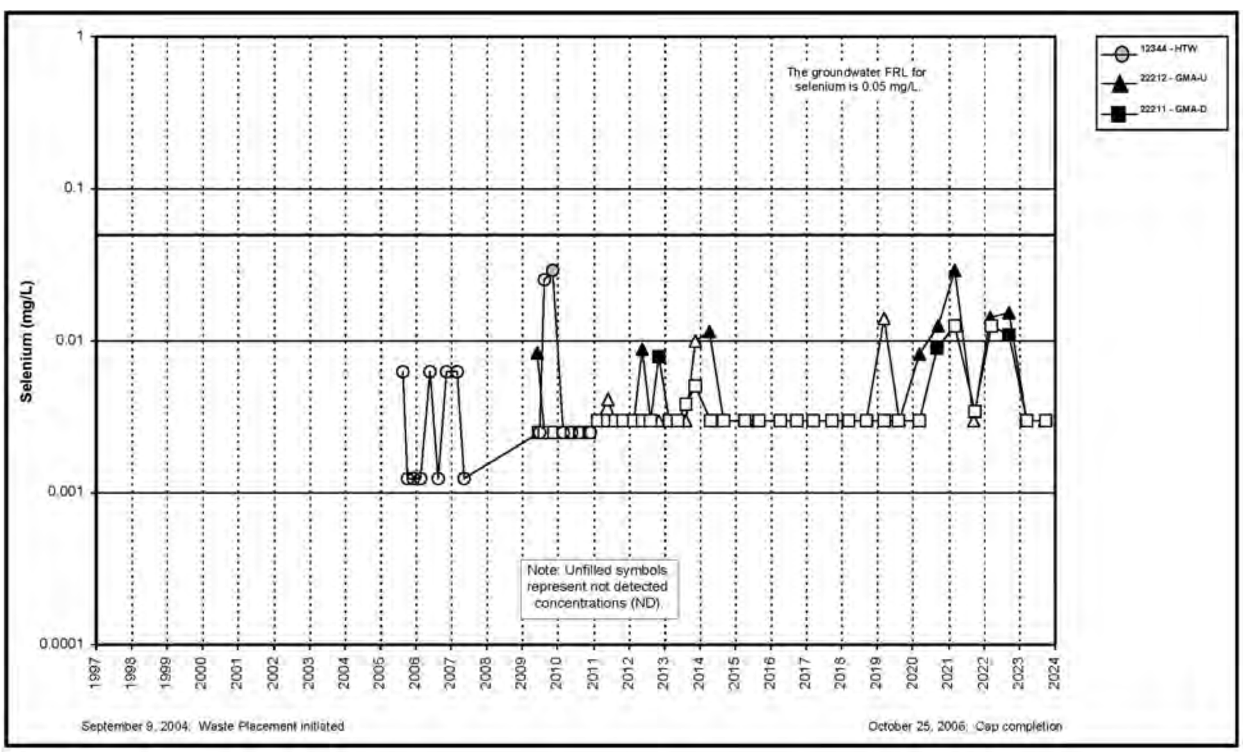

Figure A.5.7-14. Cell 7 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

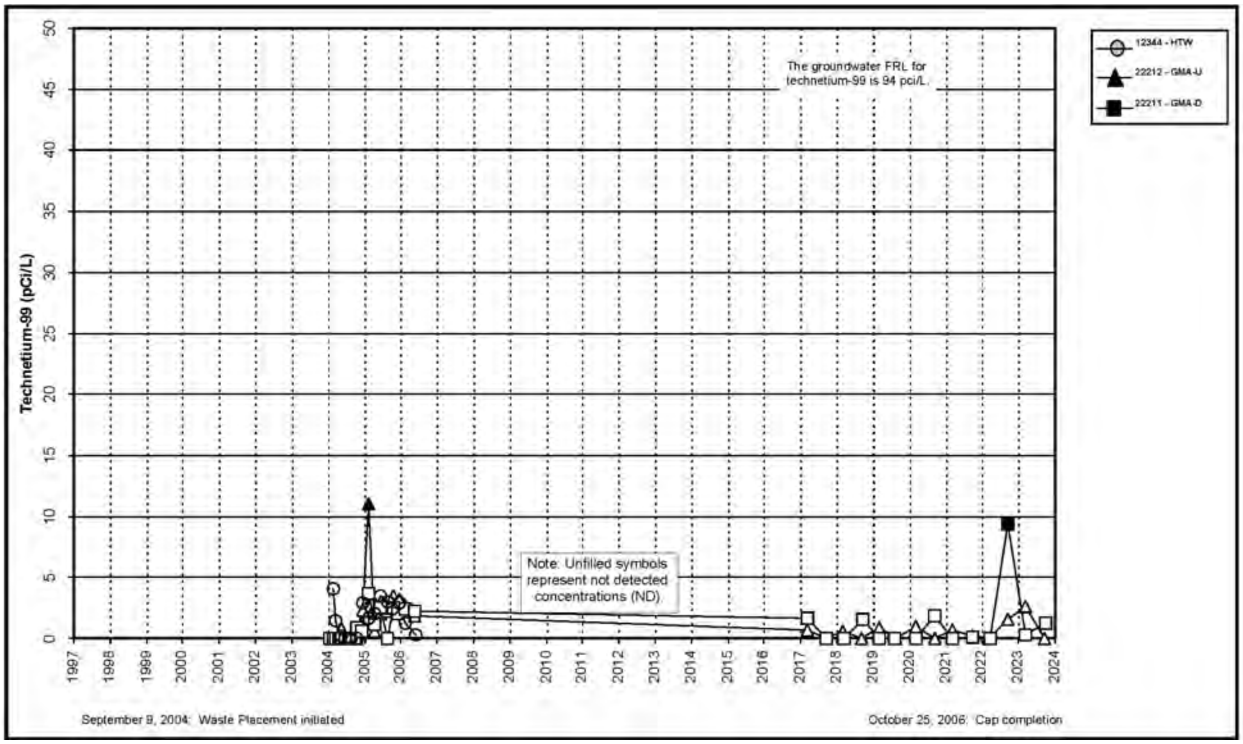

Figure A.5.7-15. Cell 7 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

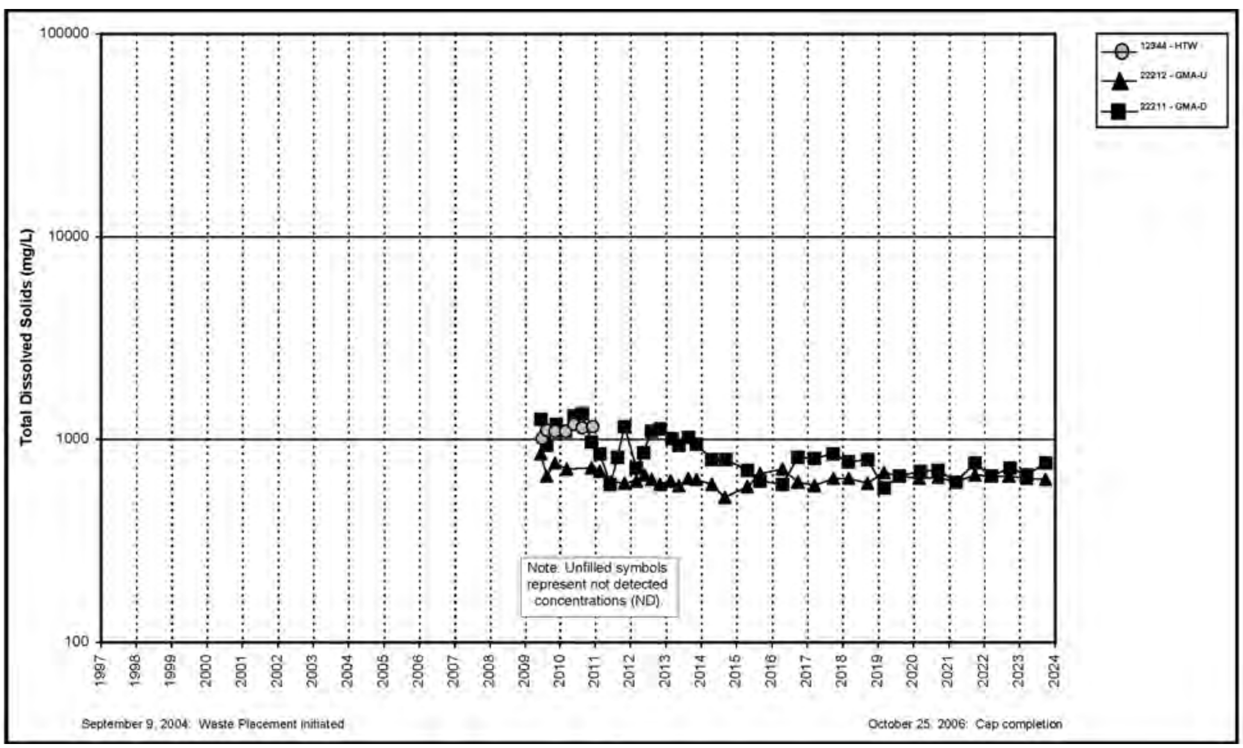

Figure A.5.7-16. Cell 7 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

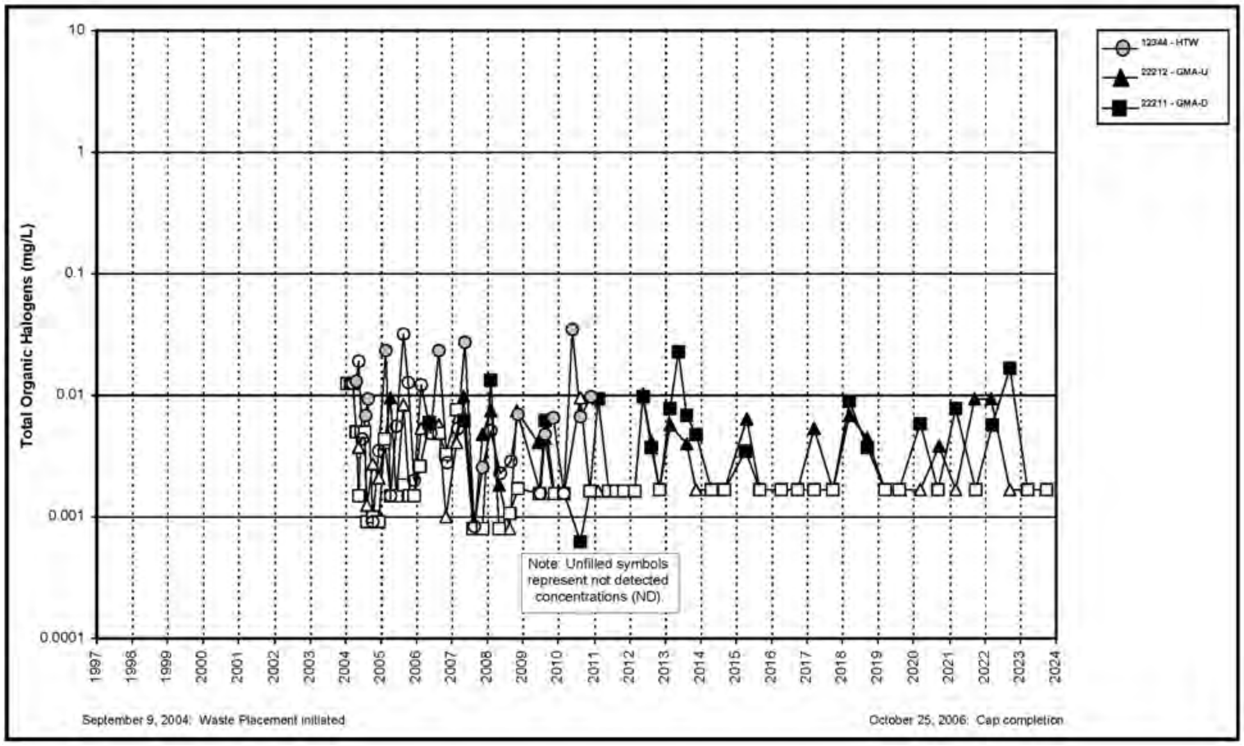

Figure A.5.7-17. Cell 7 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

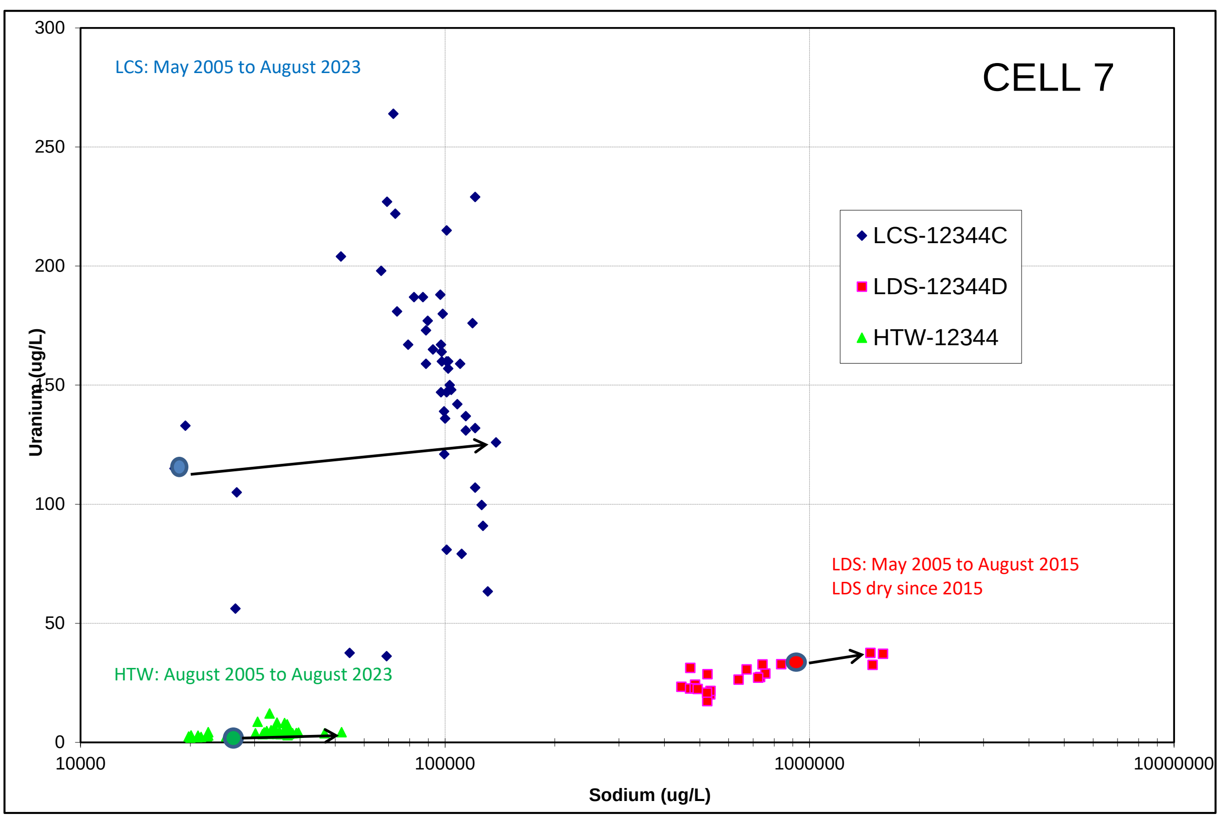

Figure A.5.7-18. Cell 7 Bivariate Plot for Uranium and Sodium

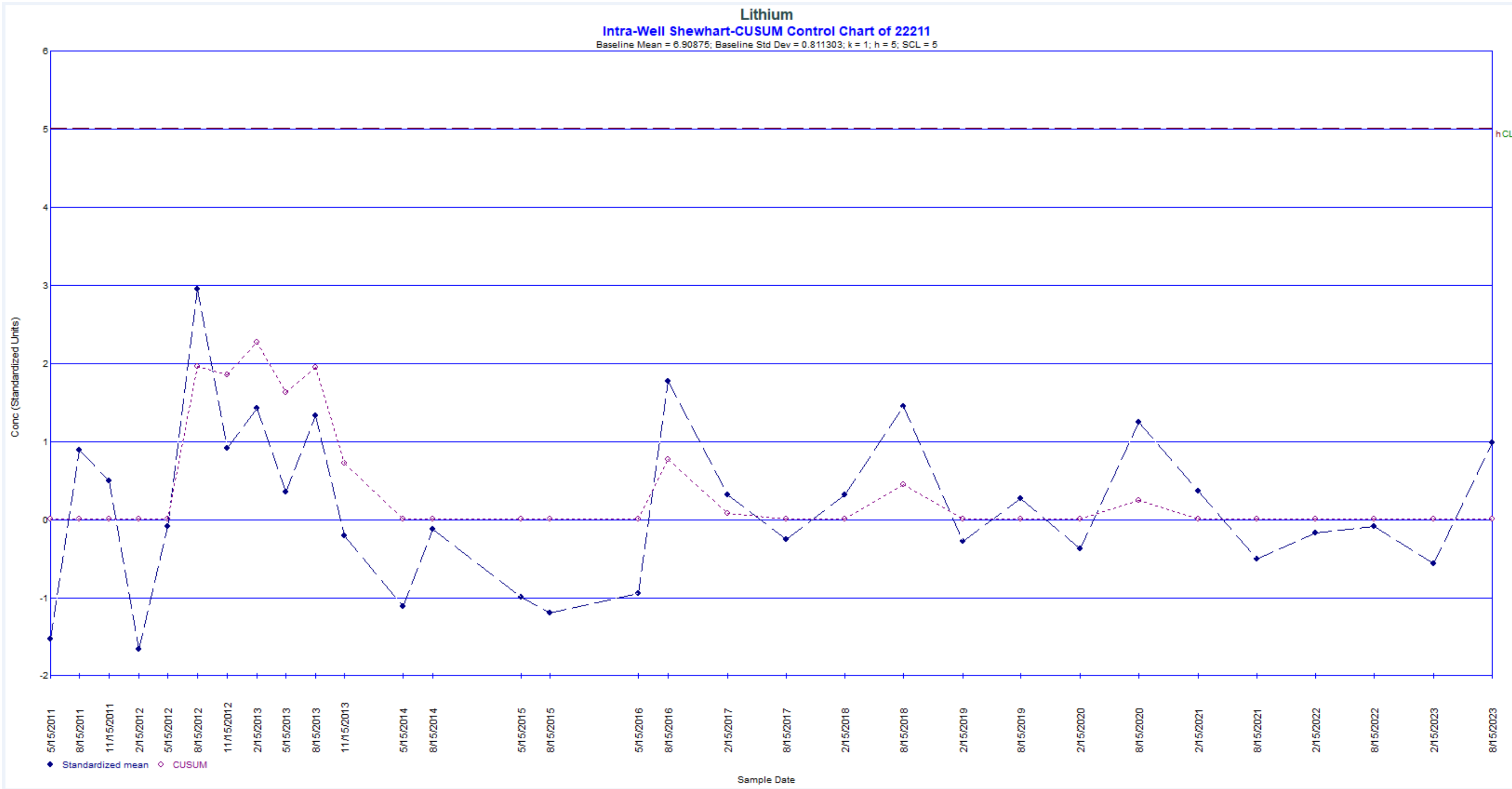

Figure A.5.7-19. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22211

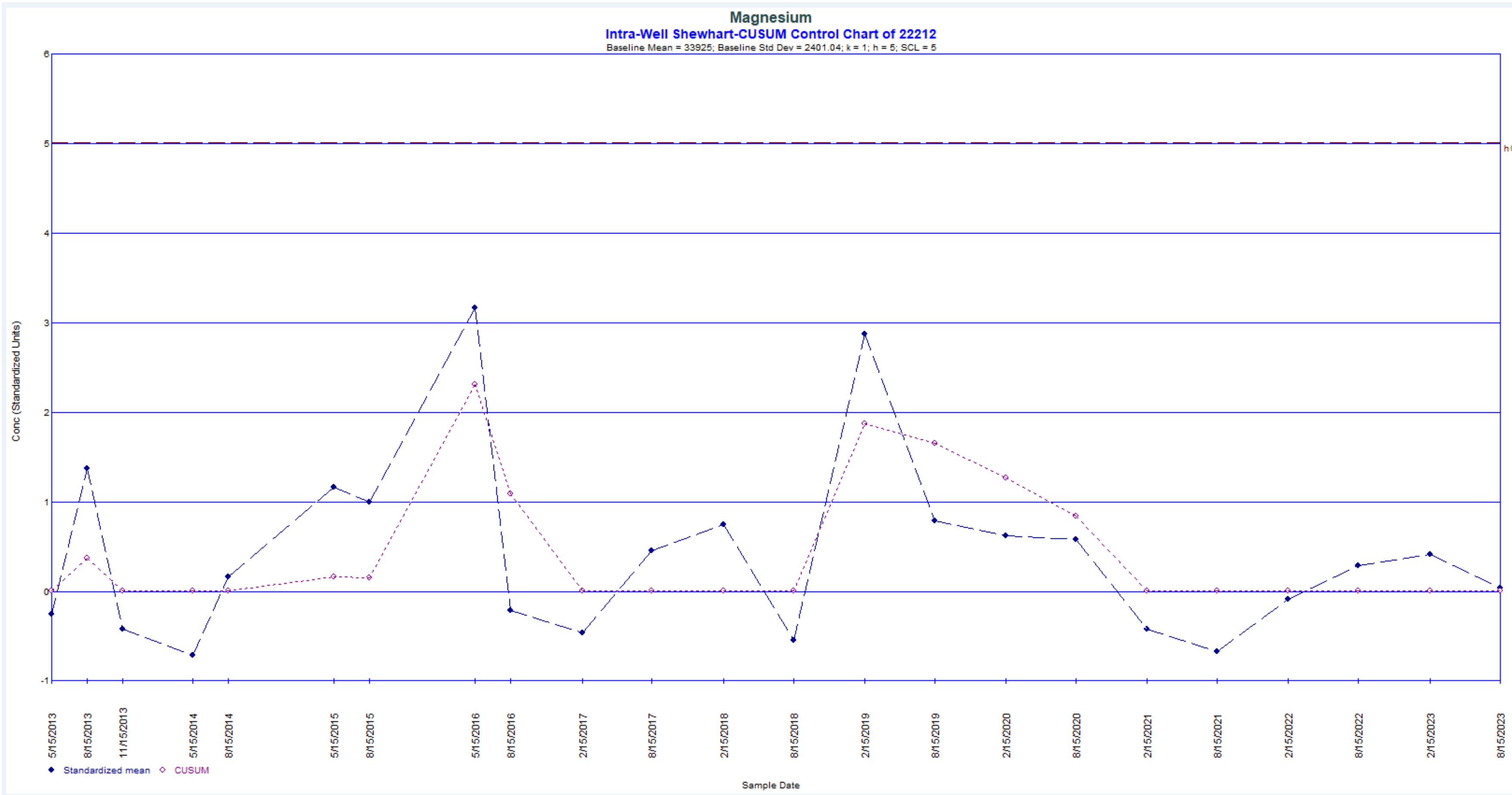

Figure A.5.7-20. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22212

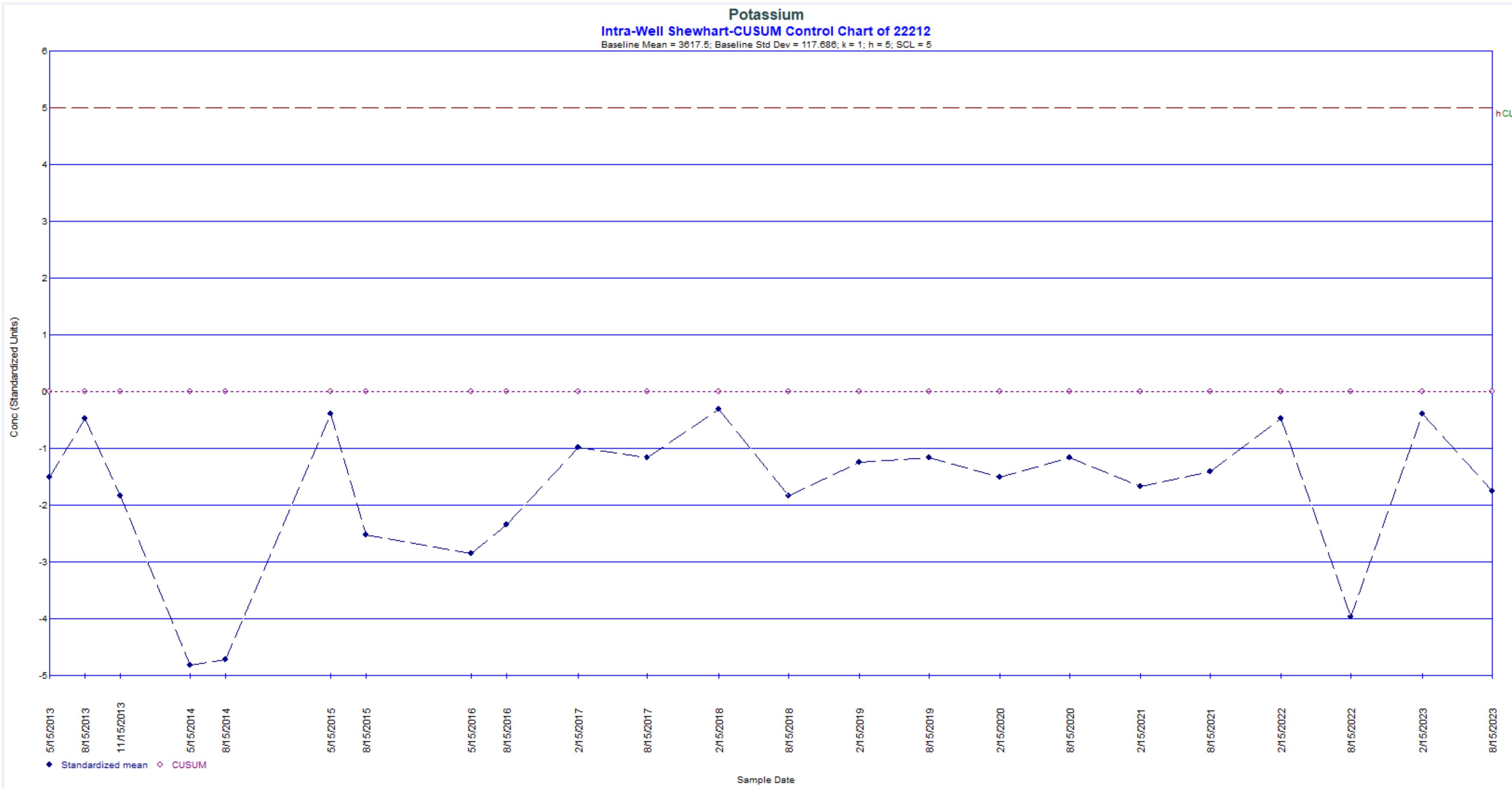

Figure A.5.7-21. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22212

Subattachment A.5.8

Cell 8

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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, two parameters (sodium, and sulfate) in 2023 have upward concentration trends in the LCS or LDS based on the Mann-Kendall test for trend. Since 2021, the volume of water in the LDS tank of Cell 8 has been insufficient to collect a sample.

One new high concentration was measured in the LCS of Cell 8 in 2023 (sodium). The new high sodium concentration measured in the LCS of Cell 8 in 2023 was 155 milligrams per liter (mg/L), which is up from 154 mg/L.

Parameters with Upward Concentration Trends in the LCS and LDS of Cell 8

Parameter	LCS 12345C 2023 Trend	LDS 12345D Trend (Last Year Sampled)
Sodium	Up	Up (2021)
Sulfate	Up	Up (2021)

A.5.8.1.2 HTW and Monitoring Well Results

As shown in Table A.5.8-1 and summarized below, eight parameters sampled in 2023 (total uranium, boron, sodium, sulfate, lithium, 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 has not contained enough water to collect a sample since 2008.

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	
Selenium		Up	Up	Up	Up
Total Dissolved Solids				Up	
Total Organic Halogens		Up	Up		Up

[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
Magnesium	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

- Two parameters monitored semiannually have an upward concentration trend in the LCS or LDS of Cell 8: sodium and sulfate.
- One new high concentration was measured in the LCS of Cell 8 in 2023 (sodium). The new high sodium concentration measured in the LCS of Cell 8 in 2023 was 155 mg/L, which is up from 154 mg/L.
- The Cell 8 HTW did not contain enough water to collect a sample in 2023.
- Eight parameters monitored semiannually are increasing in either the HTW or GMA wells of Cell 8 (total uranium, boron, sodium, sulfate, lithium, 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	56	56	100	1.51	335	163	56	Undefined	None (2023)	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	51	59	86.4	ND	0.717	0.404	0.116	Undefined	Up (2023)	Detected	
	GMA-D	22214	66	69	95.6	ND	2.37	0.414	0.491	Undefined	Down (2023)	Not Detected	
	GMA-SW	22215	48	53	90.6	ND	16.4	0.480	2.44	Undefined	None (2023)	Not Detected	
	GMA-SE	22217	49	49	100	0.898	18.3	6.33	4.14	Undefined	Down (2023)	Detected	
Boron (mg/L)	LCS	12345C	56	56	100	0.0681	0.776	0.613	0.160	Undefined	None (2023)	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	56	59	94.9	ND	0.0583	0.0393	0.0084	Undefined	Up (2023)	Detected	
	GMA-D	22214	57	59	96.6	ND	0.0524	0.0294	0.0081	Undefined	None (2023)	Detected	
	GMA-SW	22215	51	53	96.2	ND	0.0746	0.0354	0.0091	Undefined	Up (2023)	Detected	
	GMA-SE	22217	47	49	95.9	ND	0.0447	0.0288	0.0067	Normal	None (2023)	Detected	
Sodium (mg/L)	LCS	12345C	48	48	100	16.8	155	116	36	Undefined	Up (2023)	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	39	39	100	18.3	30.3	21.5	3.6	Undefined	Down (2023)	Detected	
	GMA-D	22214	41	41	100	9.83	16.8	12.3	1.5	Normal	Up (2023)	Detected	
	GMA-SW	22215	39	39	100	13.5	26.0	18.6	2.5	Normal	Up (2023)	Detected	
	GMA-SE	22217	39	39	100	11.0	17.6	13.5	1.7	Ln Normal	None (2023)	Detected	
Sulfate (mg/L)	LCS	12345C	56	56	100	146	4,190	2,970	1,021	Undefined	Up (2023)	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	59	59	100	90.2	284	179	52	Normal	None (2023)	Detected	
	GMA-D	22214	59	59	100	76.1	457	252	92	Ln Normal	Down (2023)	Detected	
	GMA-SW	22215	52	53	98.1	ND	911	255	163	Undefined	Up (2023)	Detected	
	GMA-SE	22217	49	49	100	113	1,320	346	205	Ln Normal	Down (2023)	Detected	
Calcium (mg/L)	GMA-U	22213	32	32	100	141	186	158	11	Normal	Down (2023)	Detected	
	GMA-D	22214	32	32	100	89.8	230	142	37	Normal	Down (2023)	Detected	
	GMA-SW	22215	32	32	100	127	446	192	67	Undefined	None (2023)	Detected	
	GMA-SE	22217	32	32	100	121	334	190	49	Ln Normal	Down (2023)	Detected	
Lithium (mg/L)	GMA-U	22213	39	39	100	0.00434	0.00728	0.00546	0.00059	Normal	None (2023)	Detected	
	GMA-D	22214	39	39	100	0.00372	0.00858	0.00522	0.00105	Ln Normal	None (2023)	Detected	
	GMA-SW	22215	39	39	100	0.00467	0.00828	0.00597	0.00081	Normal	Up (2023)	Detected	
	GMA-SE	22217	39	39	100	0.00432	0.00799	0.00594	0.00094	Normal	Down (2023)	Detected	
Magnesium (mg/L)	GMA-U	22213	32	32	100	31.7	42.0	36.0	2.5	Normal	Down (2023)	Detected	
	GMA-D	22214	32	32	100	22.0	53.2	34.4	8.2	Normal	None (2023)	Detected	
	GMA-SW	22215	32	32	100	32.5	66.8	43.7	7.2	Ln Normal	None (2023)	Not Detected	74.5 (Q2-11)
	GMA-SE	22217	32	32	100	27.5	63.3	42.3	8.3	Normal	Down (2023)	Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22213	0	32	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22214	1	32	3.1	ND	0.0500	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SW	22215	3	32	9.4	ND	0.0850	0.0216	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SE	22217	7	32	21.9	ND	0.0850	0.0197	0.0177	Undefined	None (2023)	Not Detected	
Potassium (mg/L)	GMA-U	22213	32	32	100	3.3	4.14	3.66	0.18	Normal	Down (2023)	Detected	
	GMA-D	22214	34	34	100	2.14	3.23	2.53	0.27	Normal	None (2023)	Detected	
	GMA-SW	22215	32	32	100	3.09	3.87	3.47	0.19	Normal	Down (2023)	Not Detected	4.73 (Q2-11); 5.01 (Q3-11); 2.30 (Q4-13)
	GMA-SE	22217	32	32	100	2.36	4.09	3.00	0.39	Normal	Down (2023)	Detected	
Selenium (mg/L)	GMA-U	22213	4	39	10.3	ND	0.0260	0.00300	0.00512	Undefined	Up (2023)	Detected	
	GMA-D	22214	6	39	15.4	ND	0.0249	0.00300	0.00497	Undefined	Up (2023)	Detected	
	GMA-SW	22215	9	39	23.1	ND	0.0278	0.00300	0.00503	Undefined	Up (2023)	Detected	
	GMA-SE	22217	4	39	10.3	ND	0.0201	0.00300	0.00439	Undefined	Up (2023)	Detected	
Technitium-99 (pCi/L)	GMA-U	22213	6	50	12.0	ND	24.8	0.450	4.12	Undefined	Down (2023)	Detected	
	GMA-D	22214	4	50	8.0	ND	11.8	0.0150	2.33	Undefined	None (2023)	Not Detected	
	GMA-SW	22215	0	44	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SE	22217	0	40	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22213	39	39	100	429	843	667	80	Undefined	Down (2023)	Detected	
	GMA-D	22214	39	39	100	386	1,020	620	152	Normal	Down (2023)	Detected	
	GMA-SW	22215	39	39	100	457	1,800	821	254	Undefined	Up (2023)	Detected	
	GMA-SE	22217	39	39	100	514	1,550	870	244	Ln Normal	Down (2023)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22213	16	59	27.1	ND	0.0560	0.00166	0.00809	Undefined	Up (2023)	Not Detected	
	GMA-D	22214	14	59	23.7	ND	0.0590	0.00166	0.00867	Undefined	Up (2023)	Not Detected	
	GMA-SW	22215	17	53	32.1	ND	0.0460	0.00166	0.00758	Undefined	None (2023)	Not Detected	
	GMA-SE	22217	18	49	36.7	ND	0.0730	0.00166	0.0109	Undefined	Up (2023)	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 has 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: Ln Normal 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 assumptions 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
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2019	0	2	0
2020	0	2	0
2021	0	2	0
2022	0	2	0
2023	0	2	0

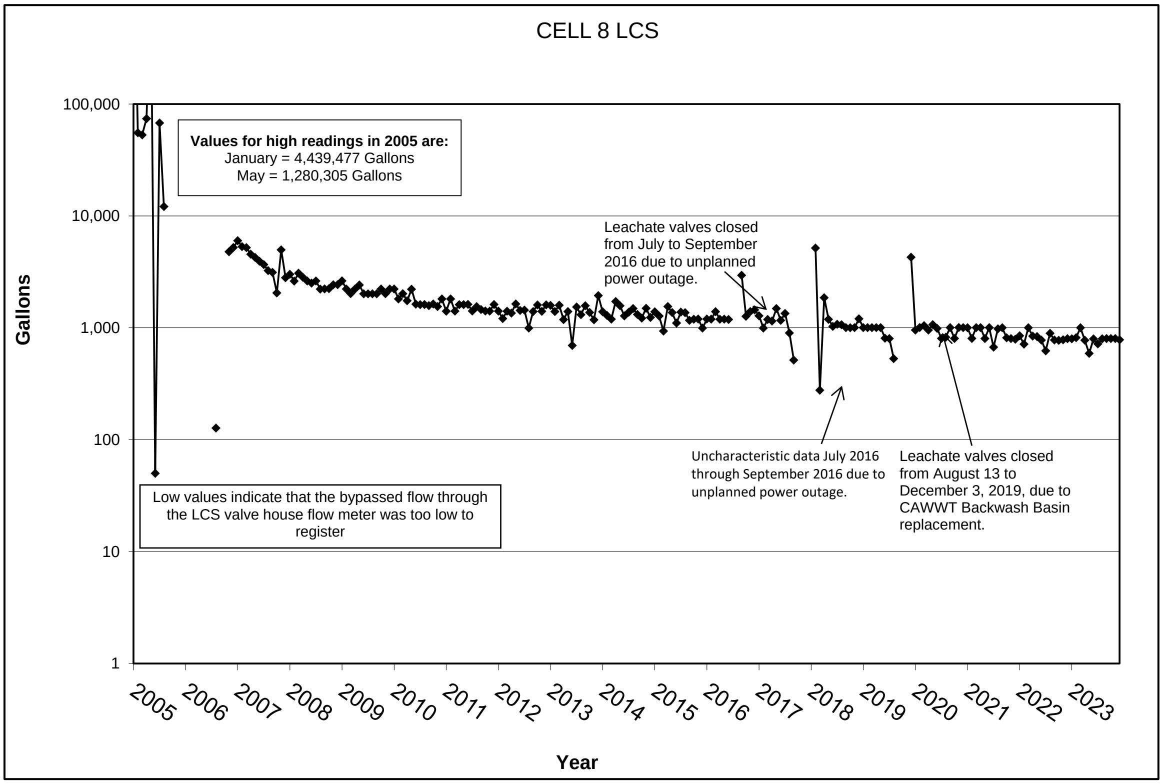

Figure A.5.8-1. Monthly Accumulation Volumes for Cell 8 LCS

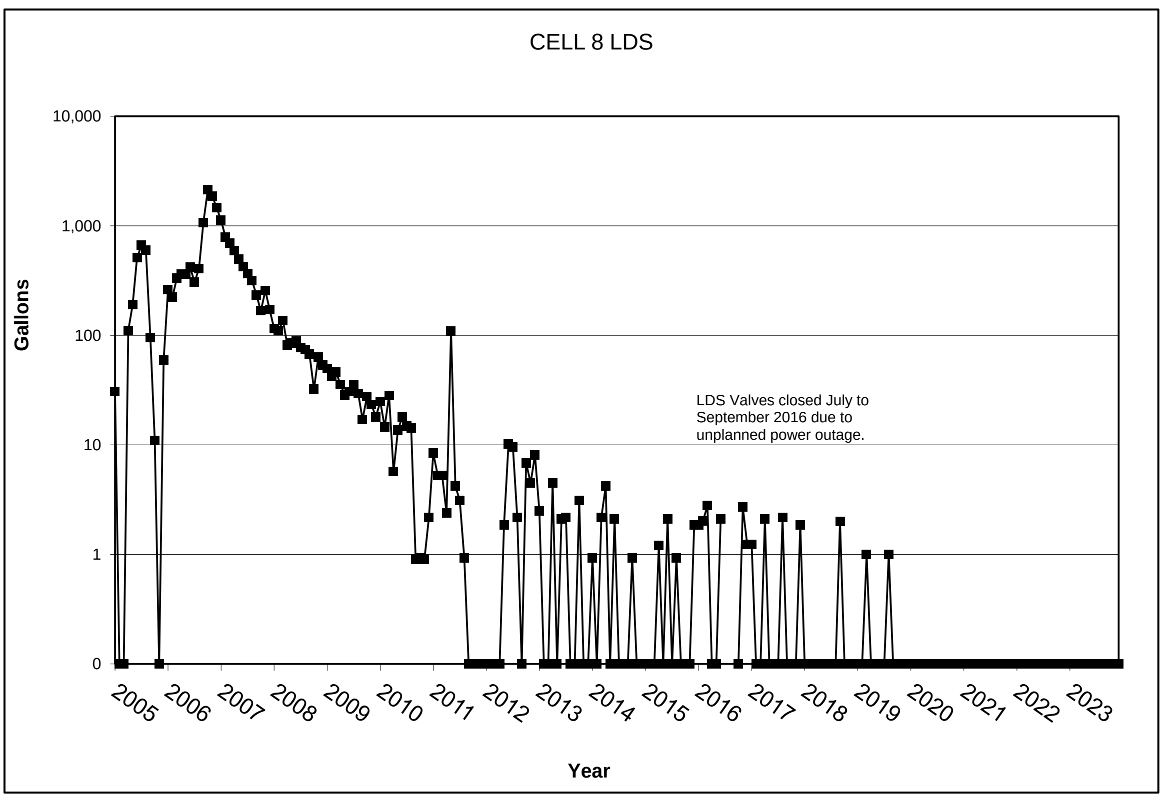

Figure A.5.8-2. Monthly Accumulation Volumes for Cell 8 LDS

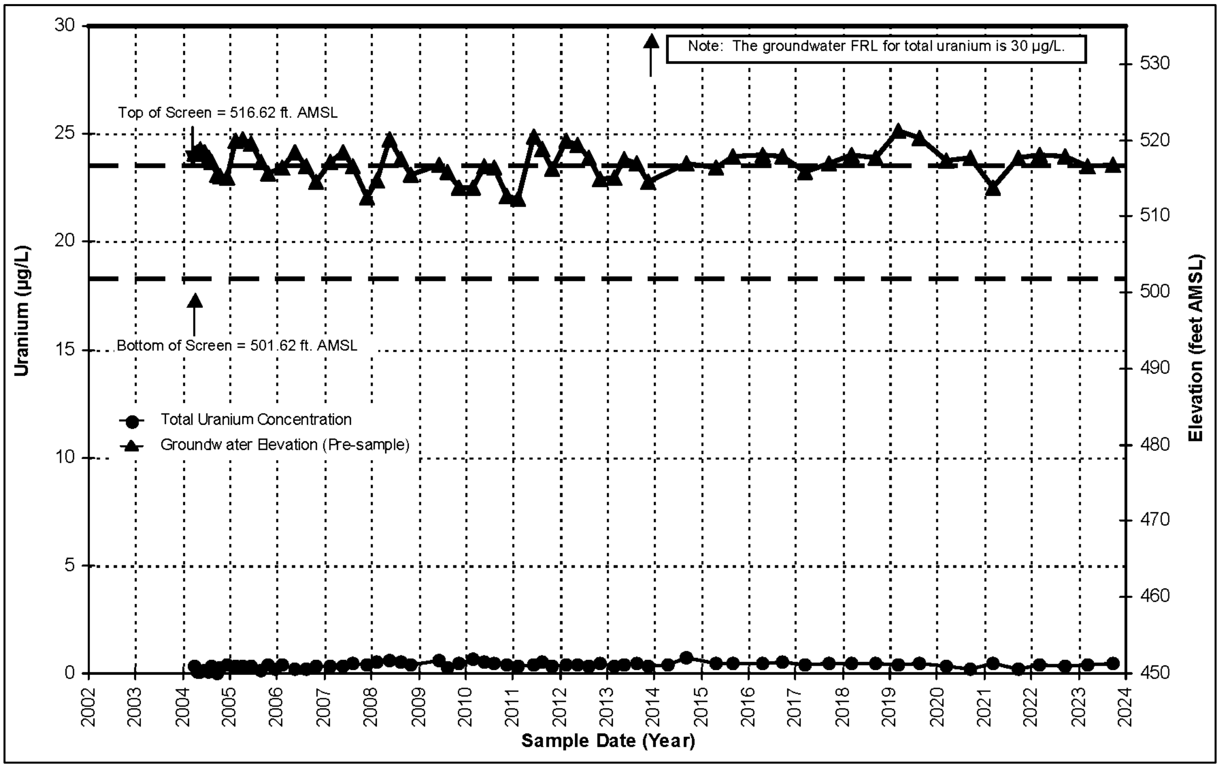

Figure A.5.8-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Upgradient Monitoring Well 22213

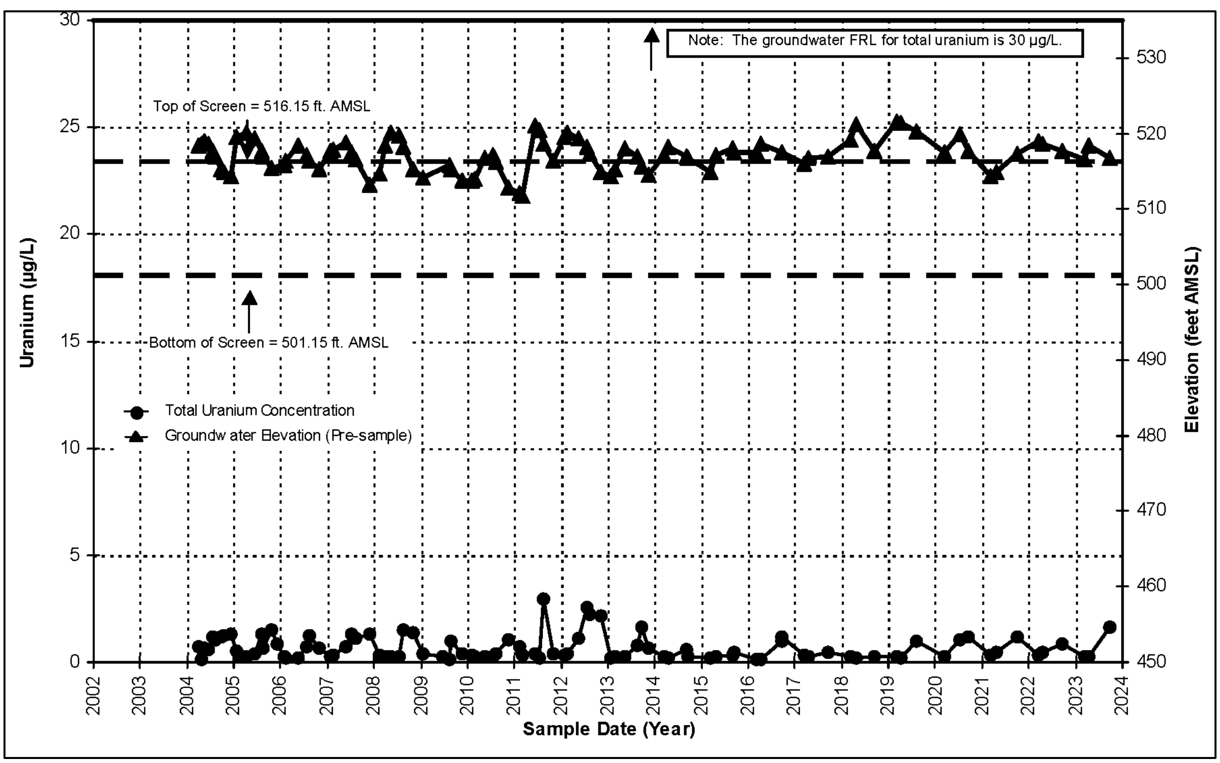

Figure A.5.8-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22214

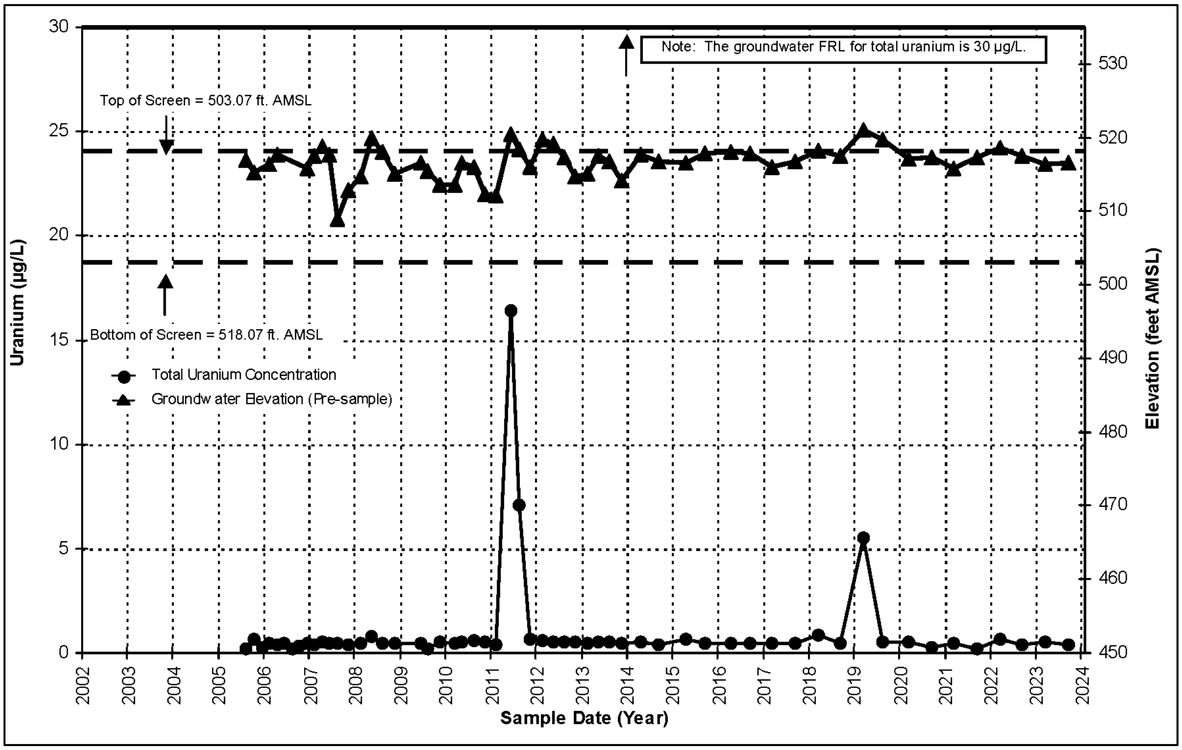

Figure A.5.8-5. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22215

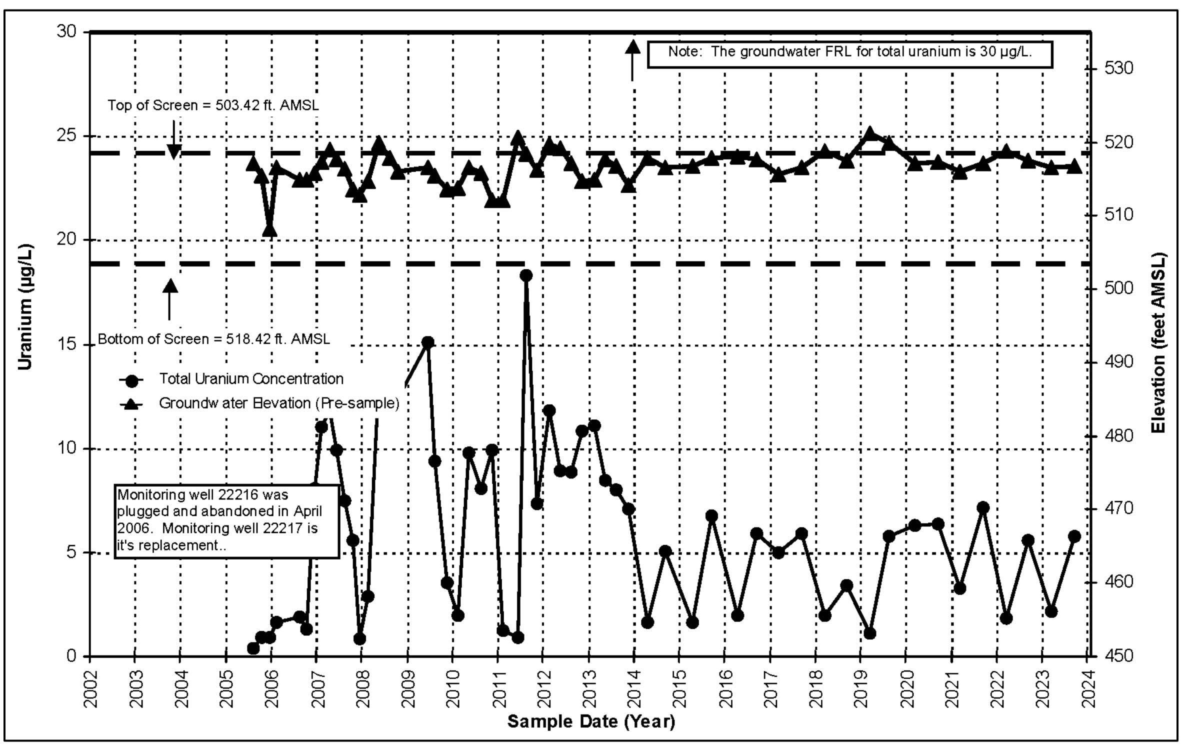

Figure A.5.8-6. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22216/22217

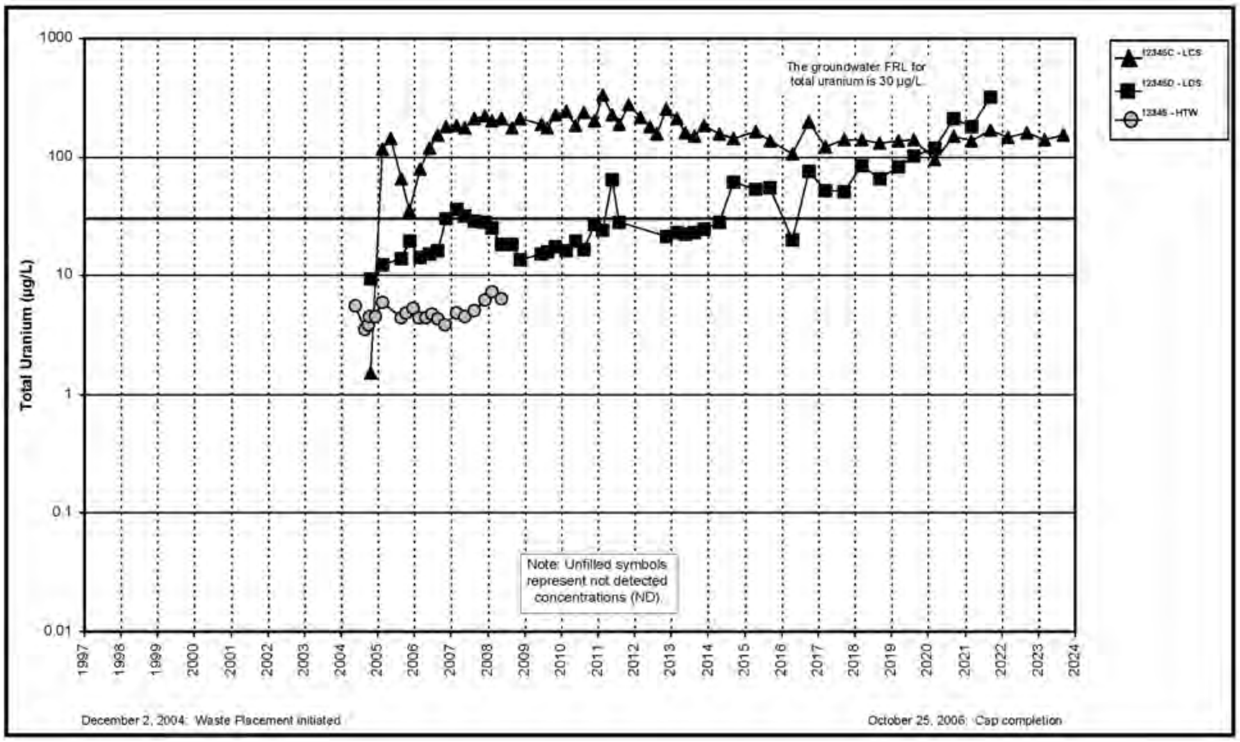

Figure A.5.8-7A. Cell 8 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

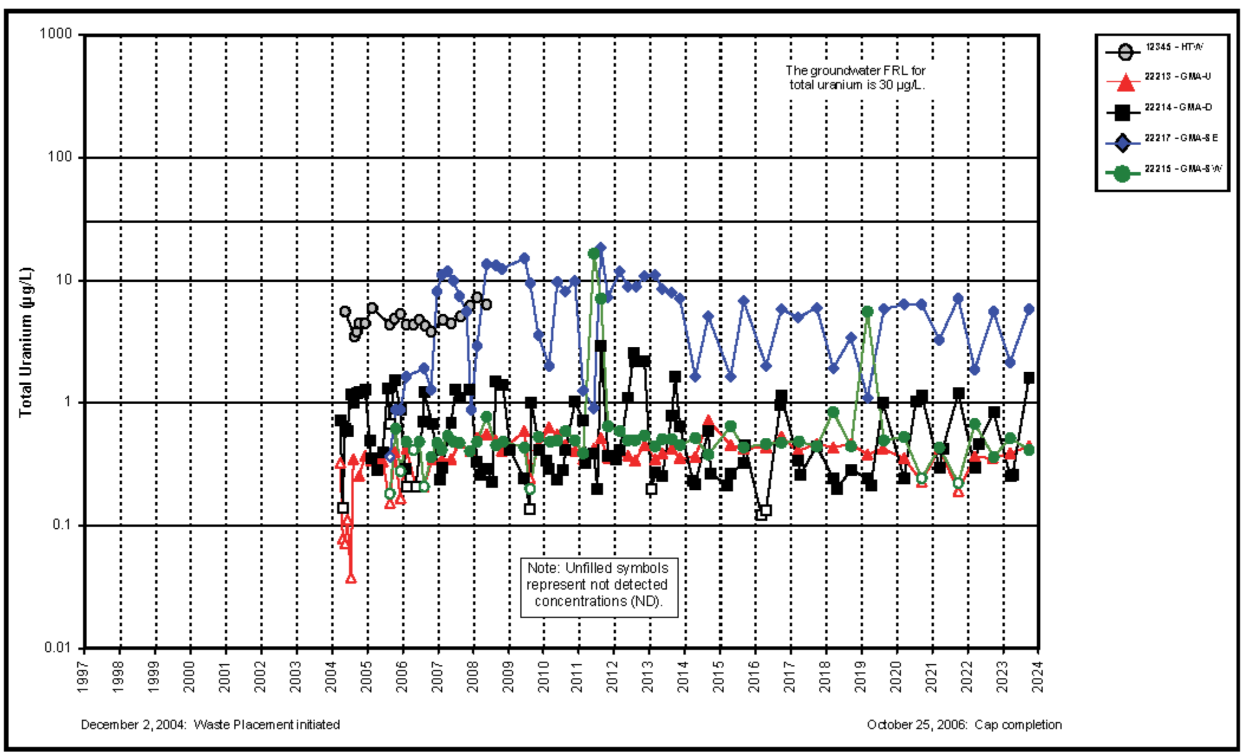

Figure A.5.8-7B. Cell 8 Total Uranium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

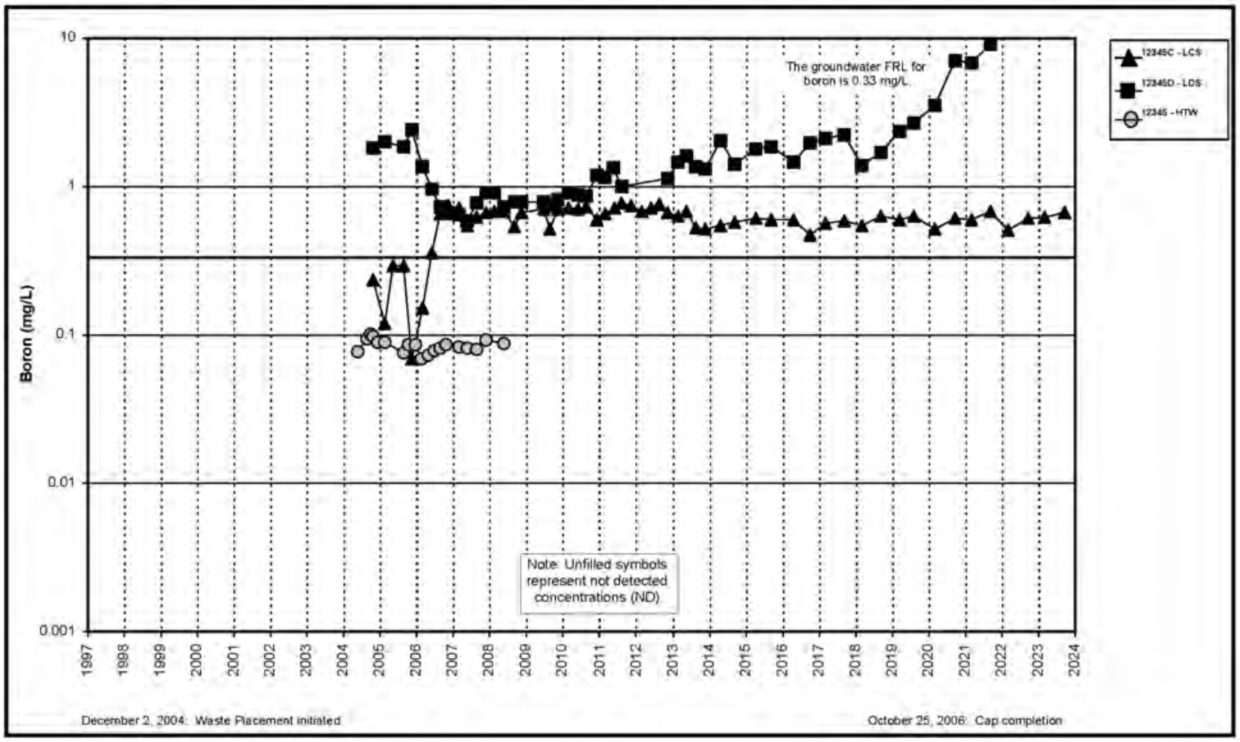

Figure A.5.8-8A. Cell 8 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

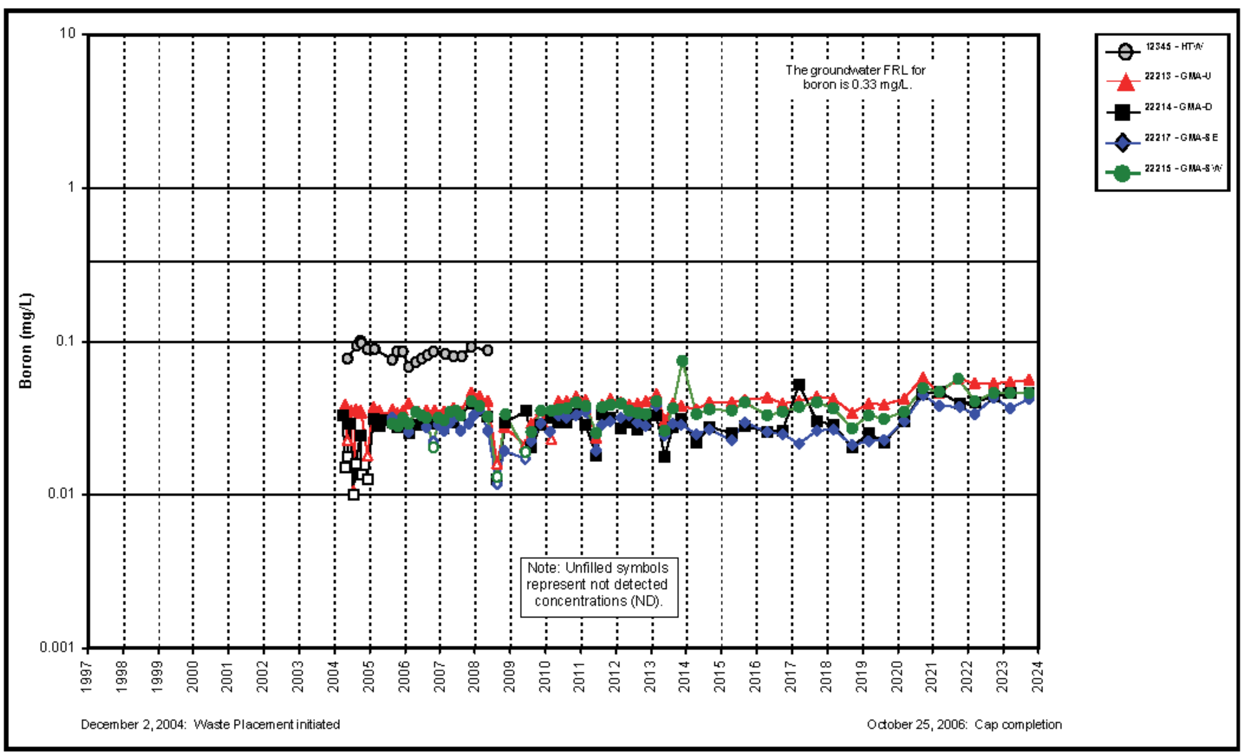

Figure A.5.8-8B. Cell 8 Boron Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

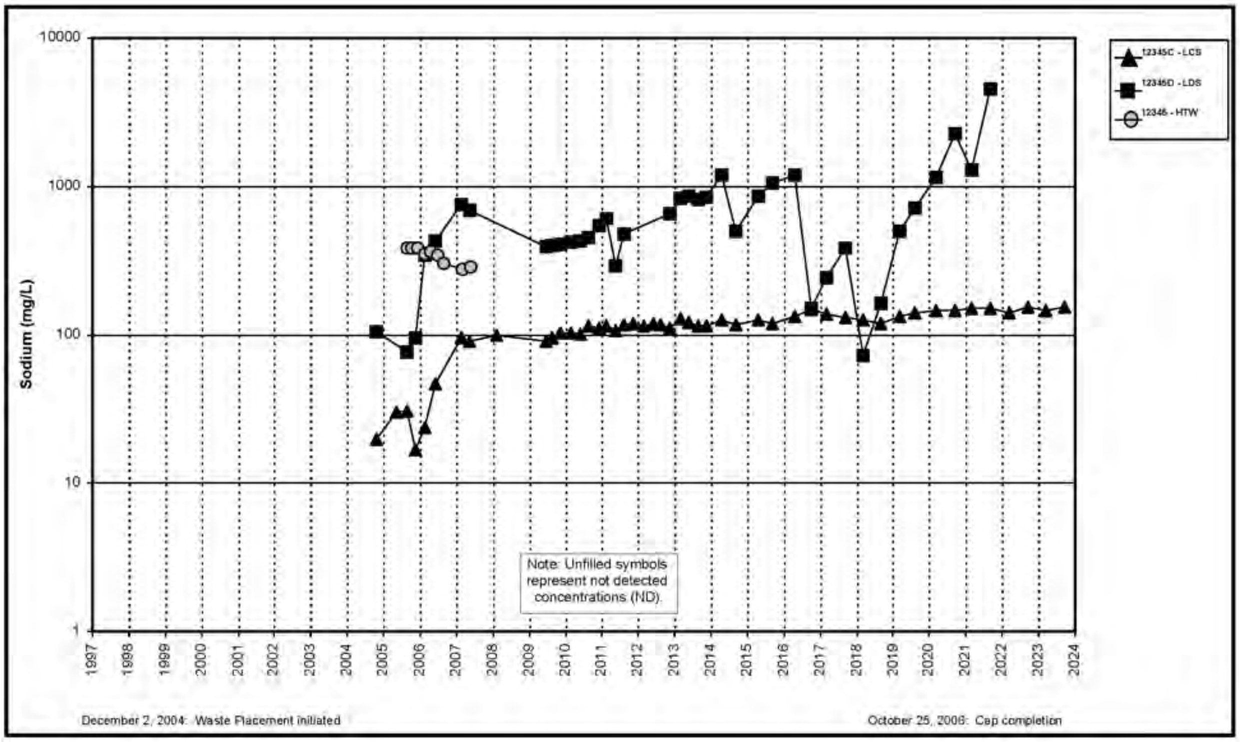

Figure A.5.8-9A. Cell 8 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

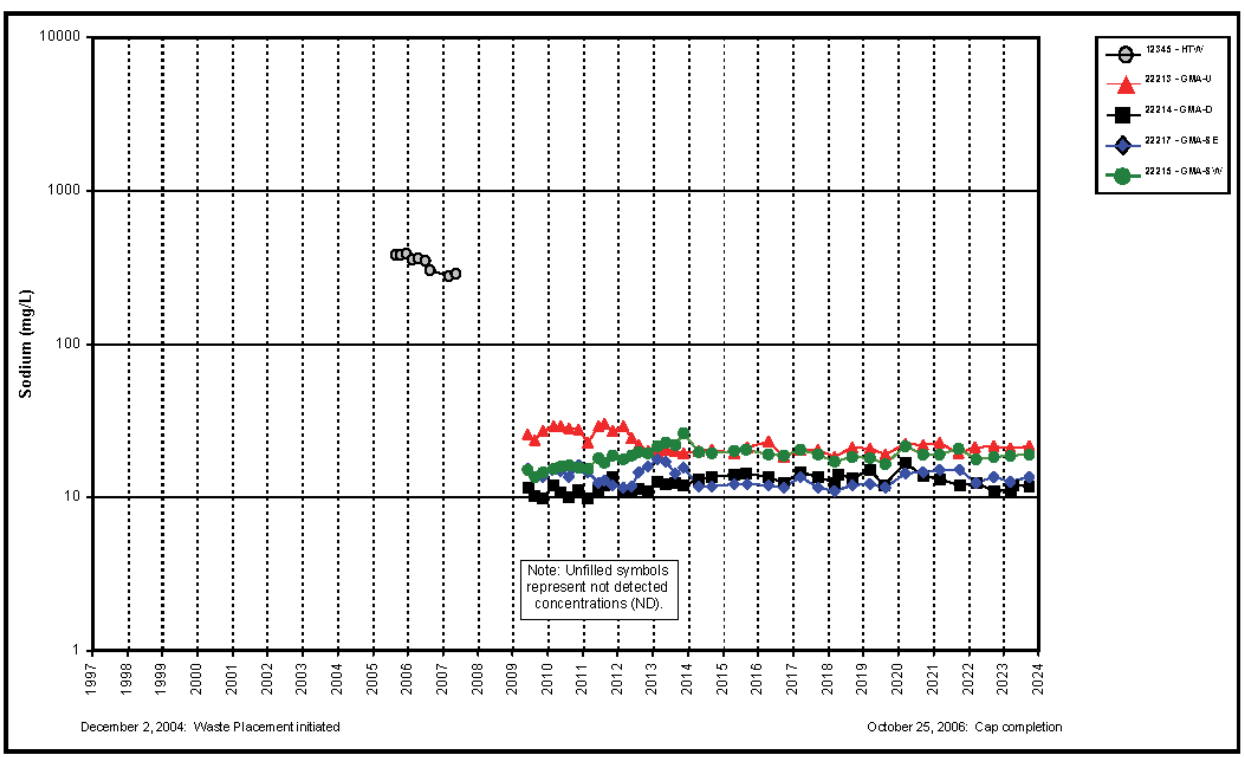

Figure A.5.8-9B. Cell 8 Sodium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

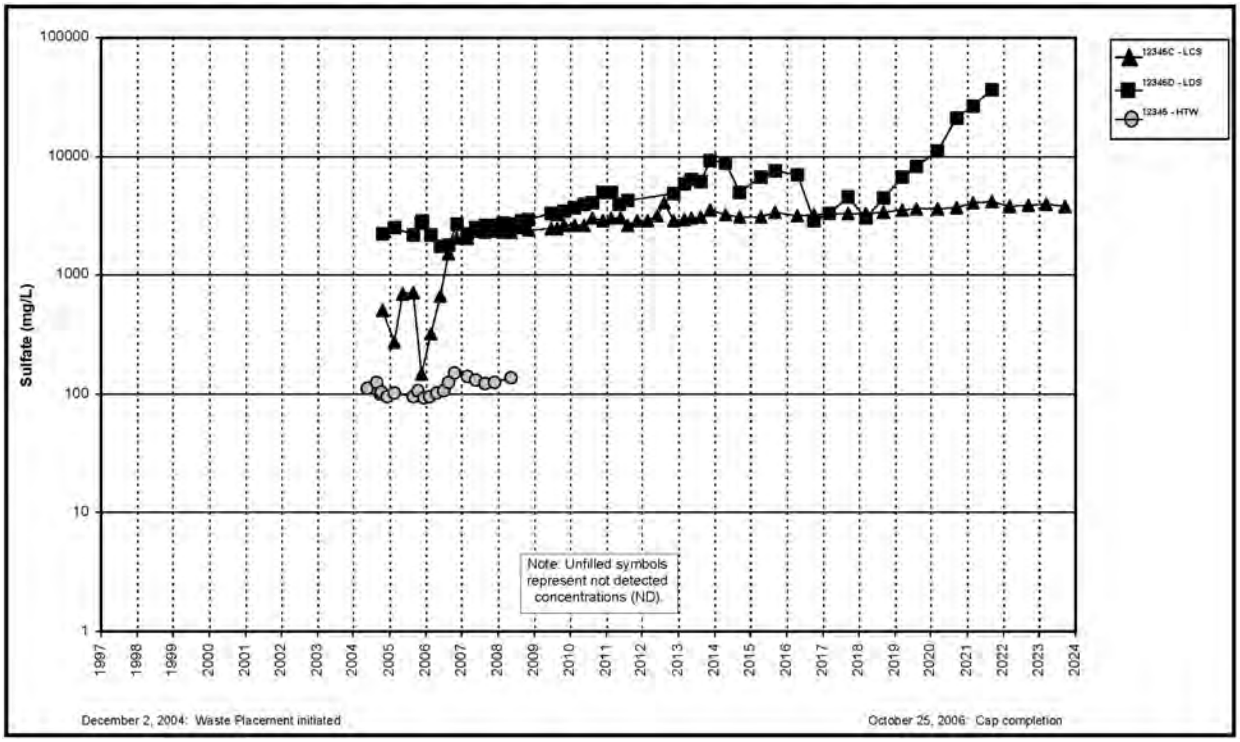

Figure A.5.8-10A. Cell 8 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

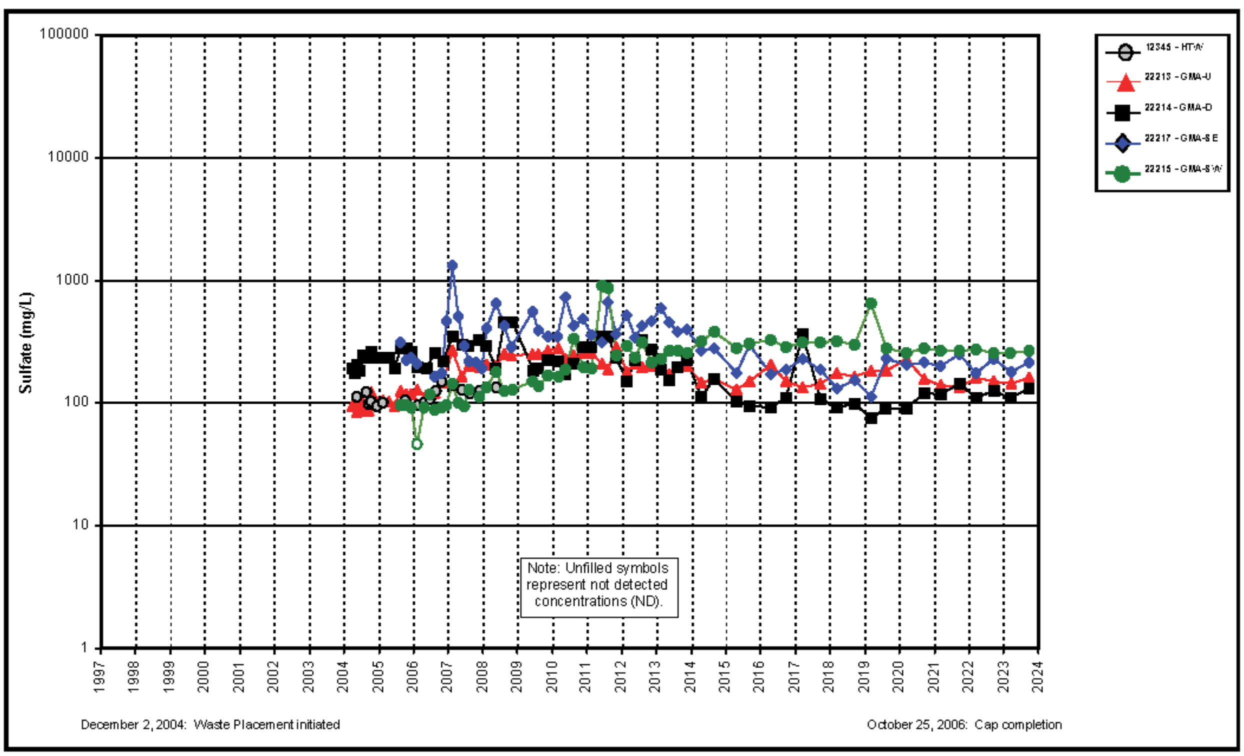

Figure A.5.8-10B. Cell 8 Sulfate Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

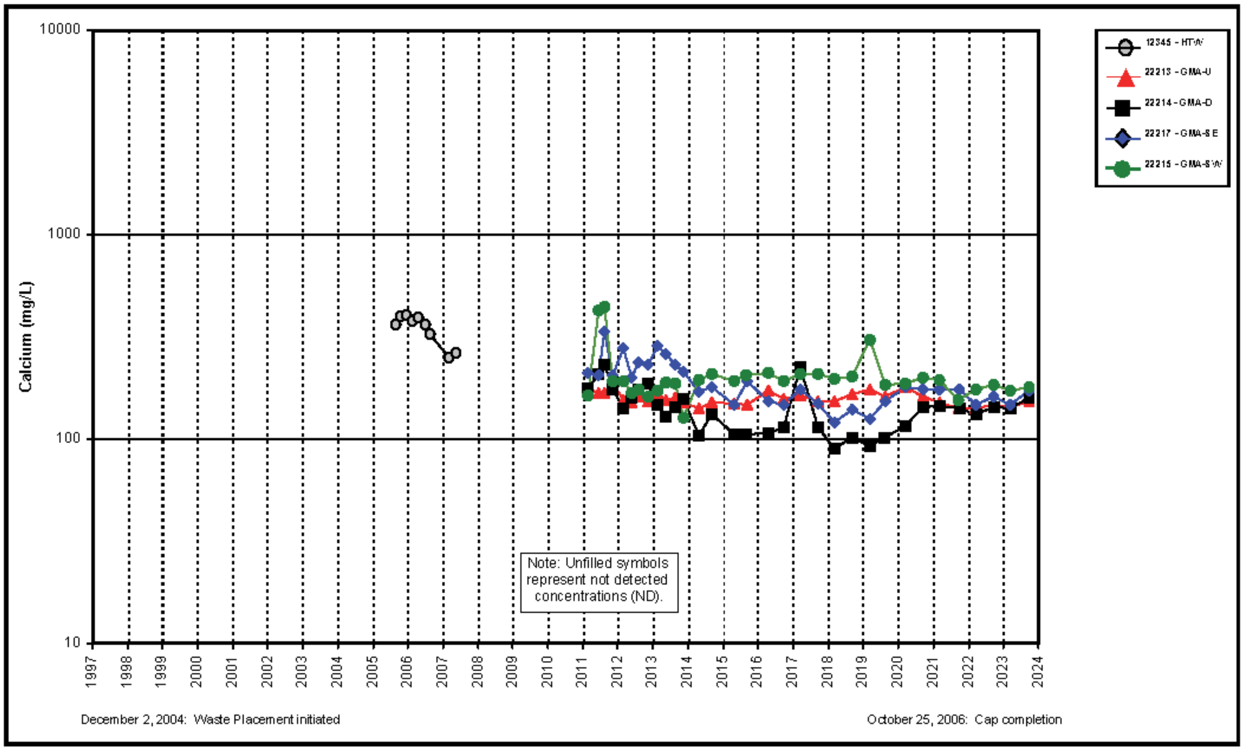

Figure A.5.8-11. Cell 8 Calcium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

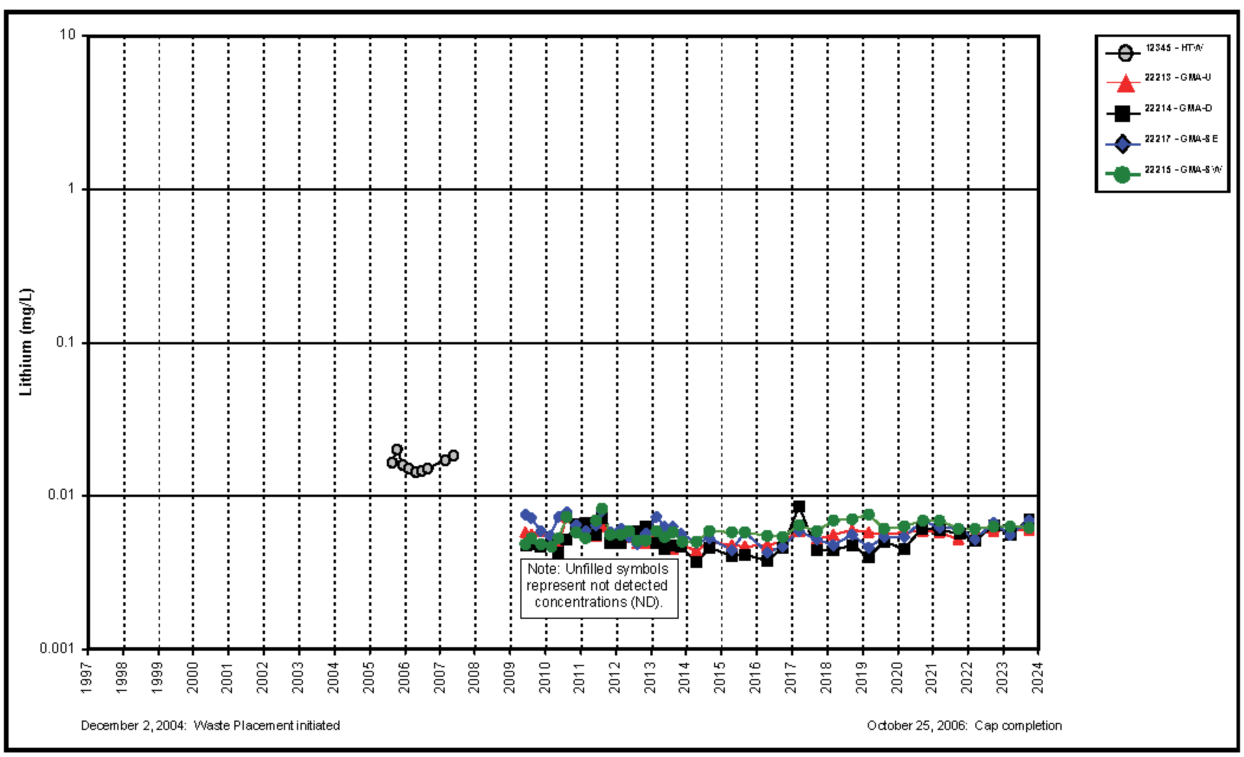

Figure A.5.8-12. Cell 8 Lithium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

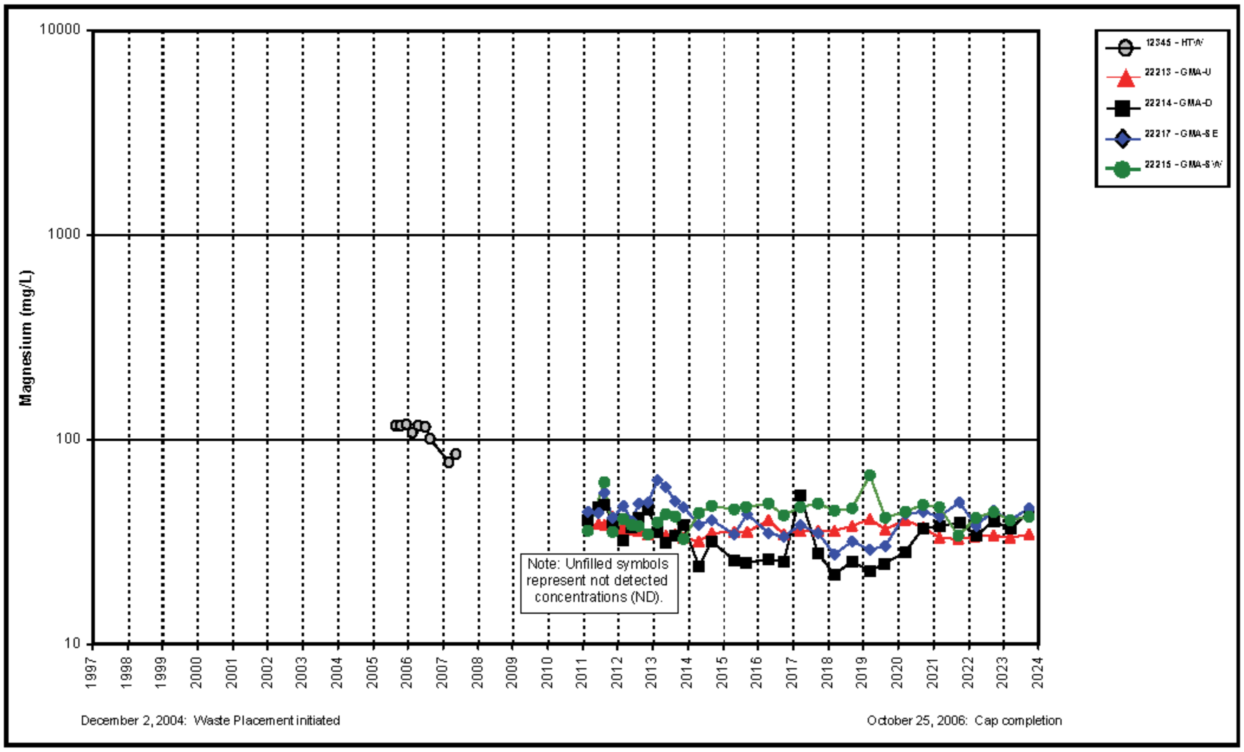

Figure A.5.8-13. Cell 8 Magnesium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

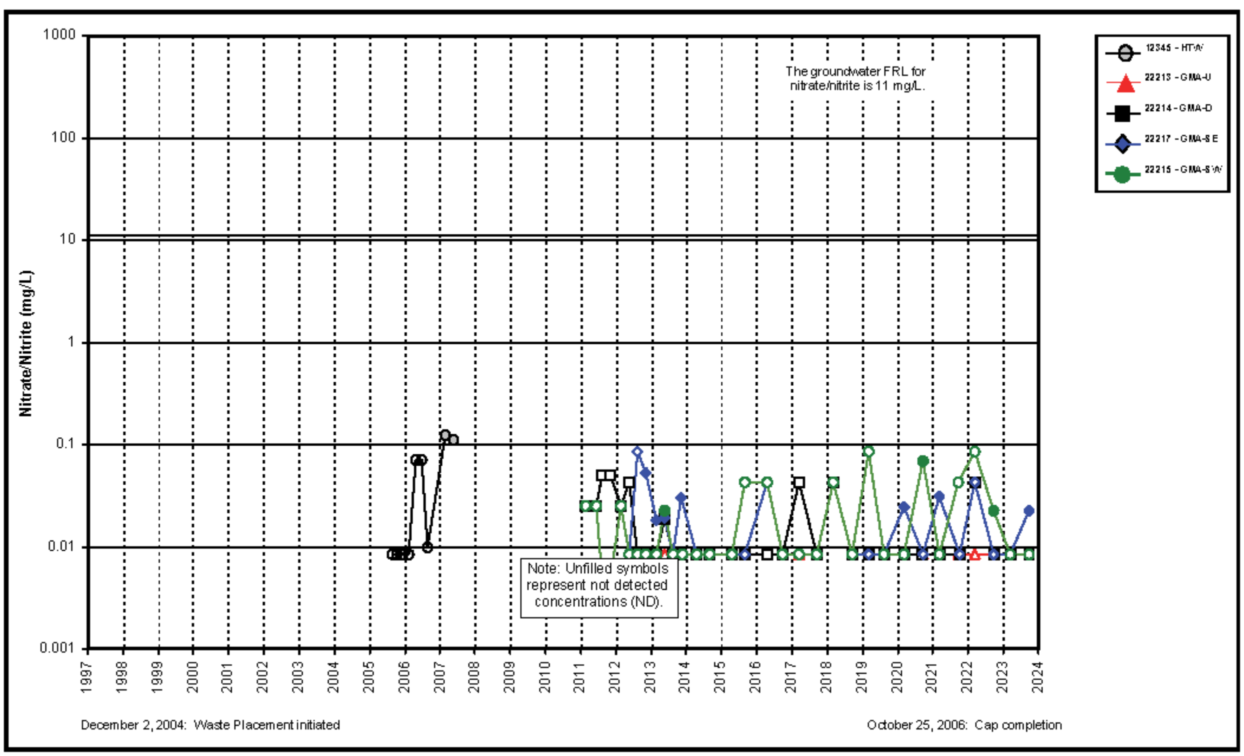

Figure A.5.8-14. Cell 8 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

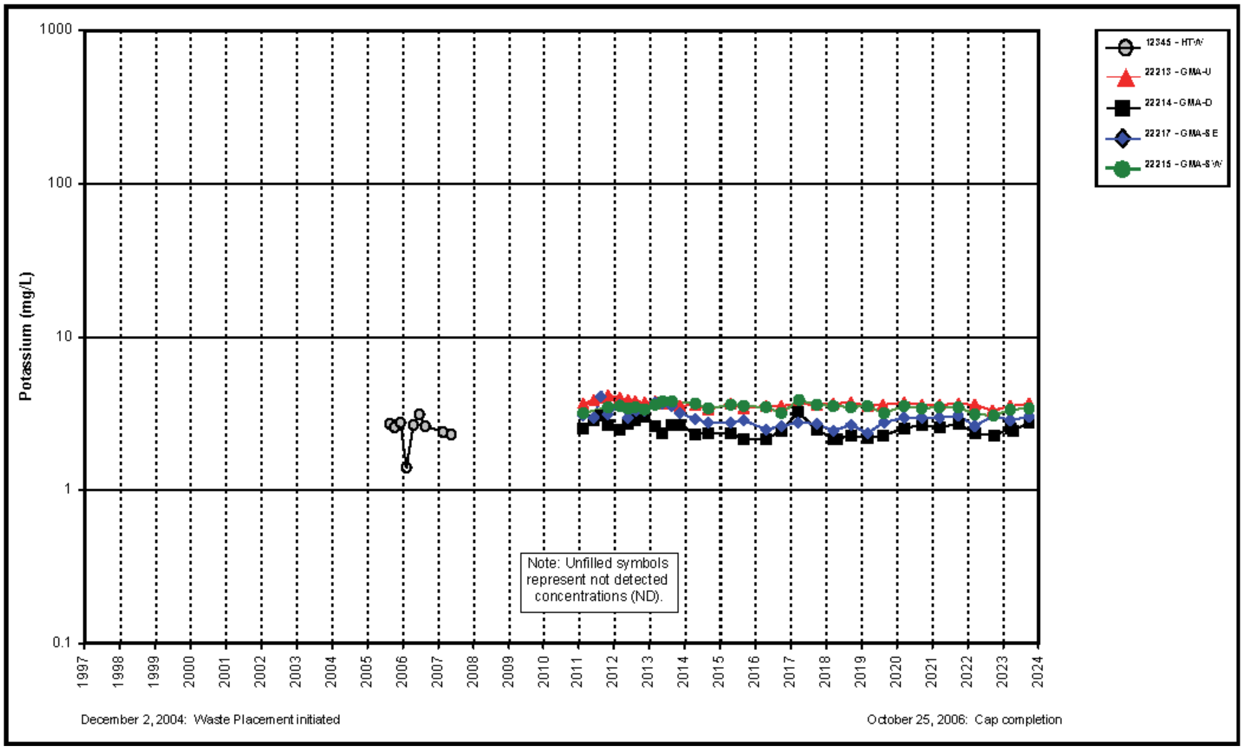

Figure A.5.8-15. Cell 8 Potassium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

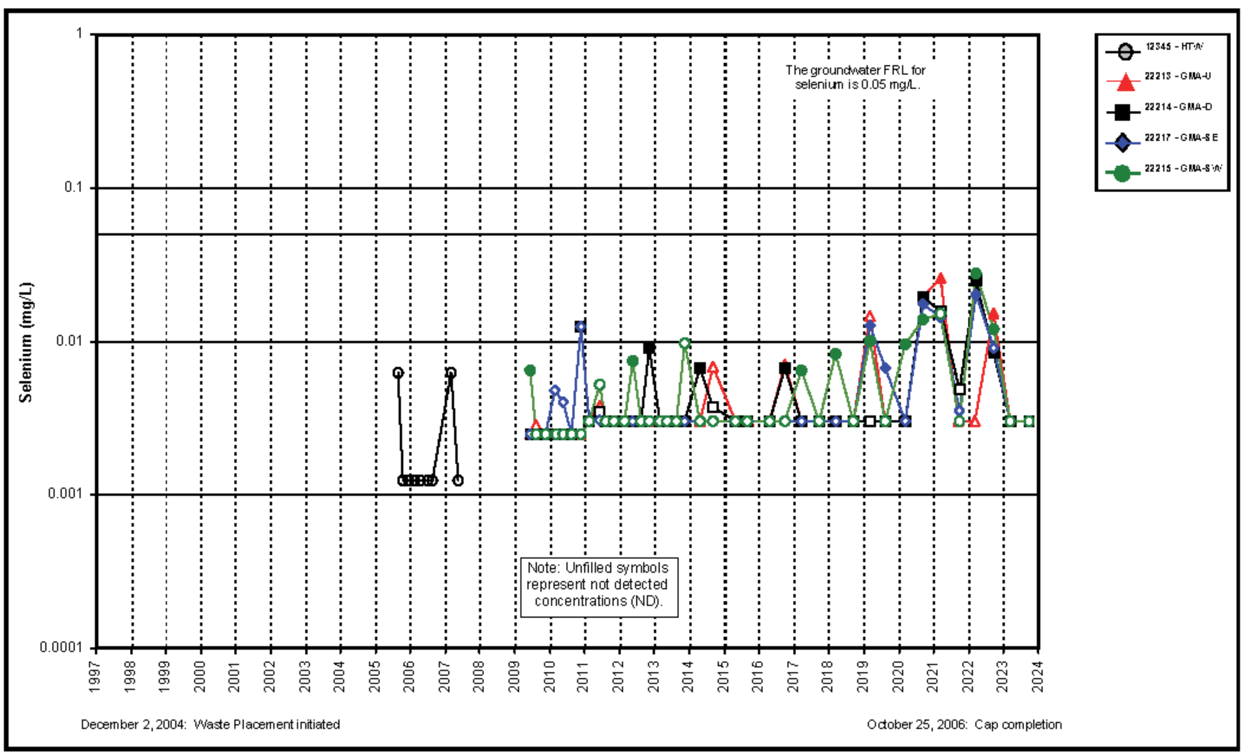

Figure A.5.8-16. Cell 8 Selenium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

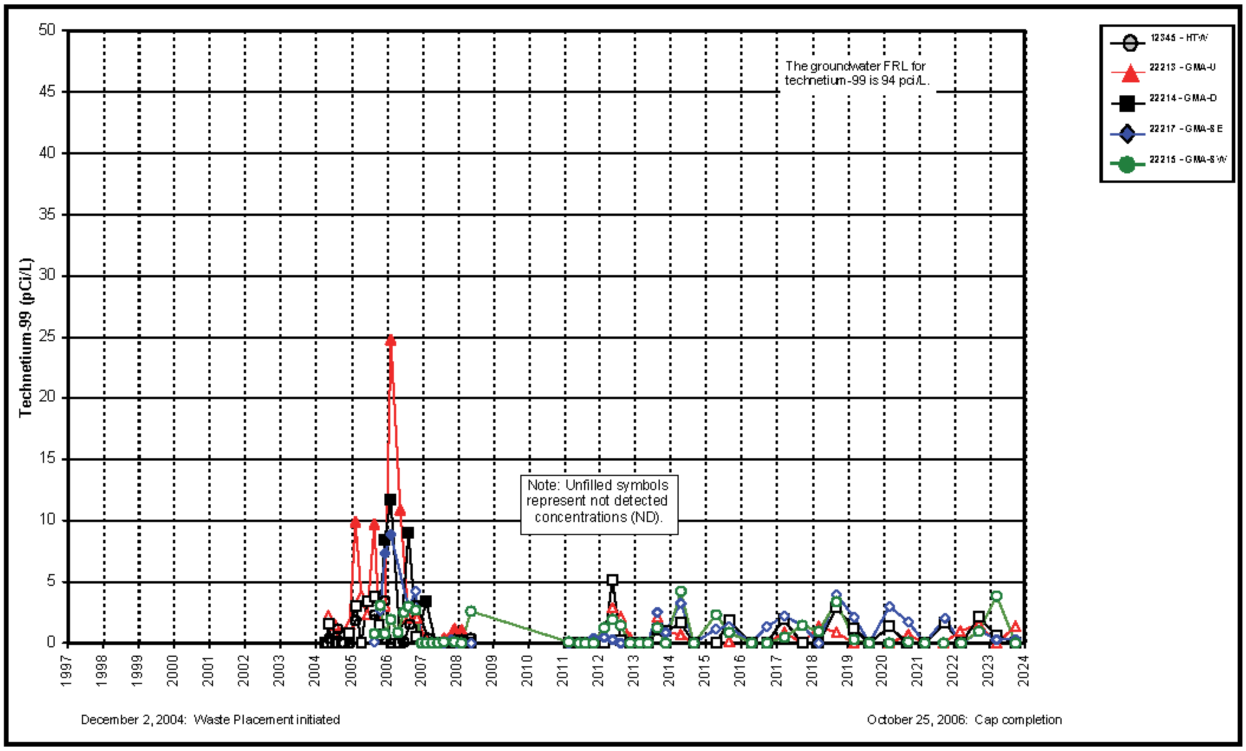

Figure A.5.8-17. Cell 8 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

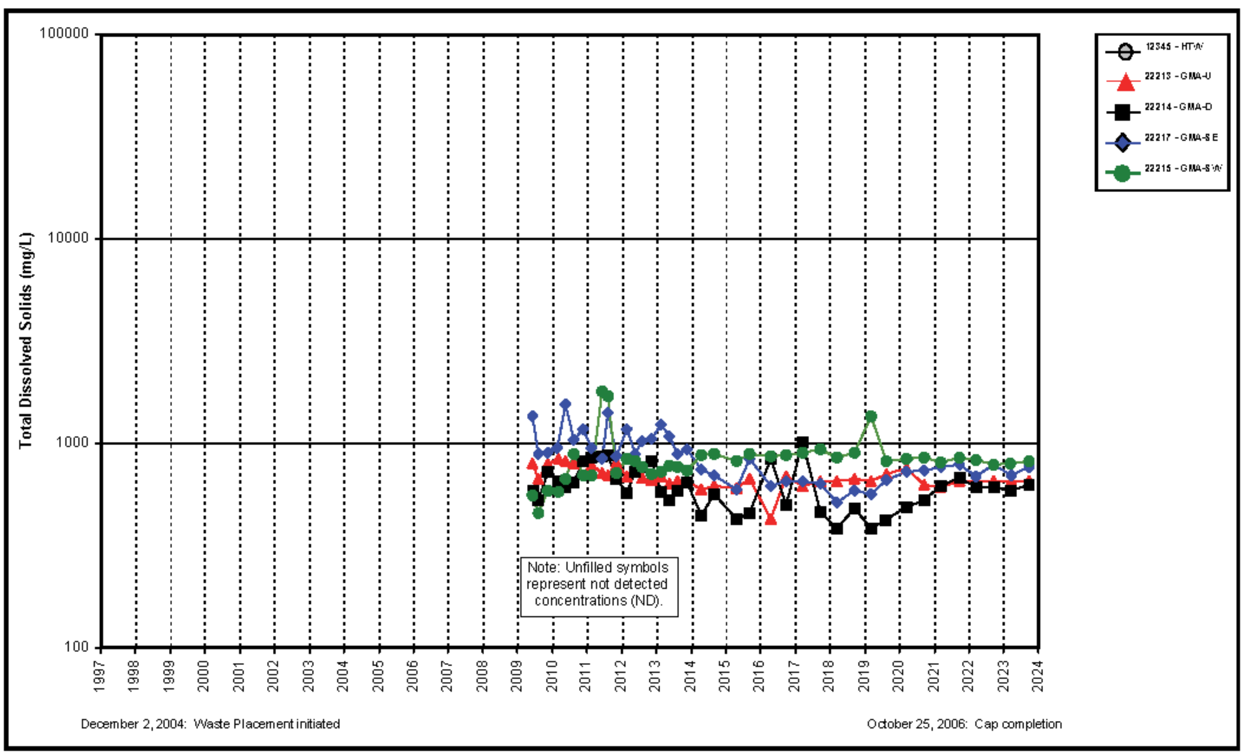

Figure A.5.8-18. Cell 8 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

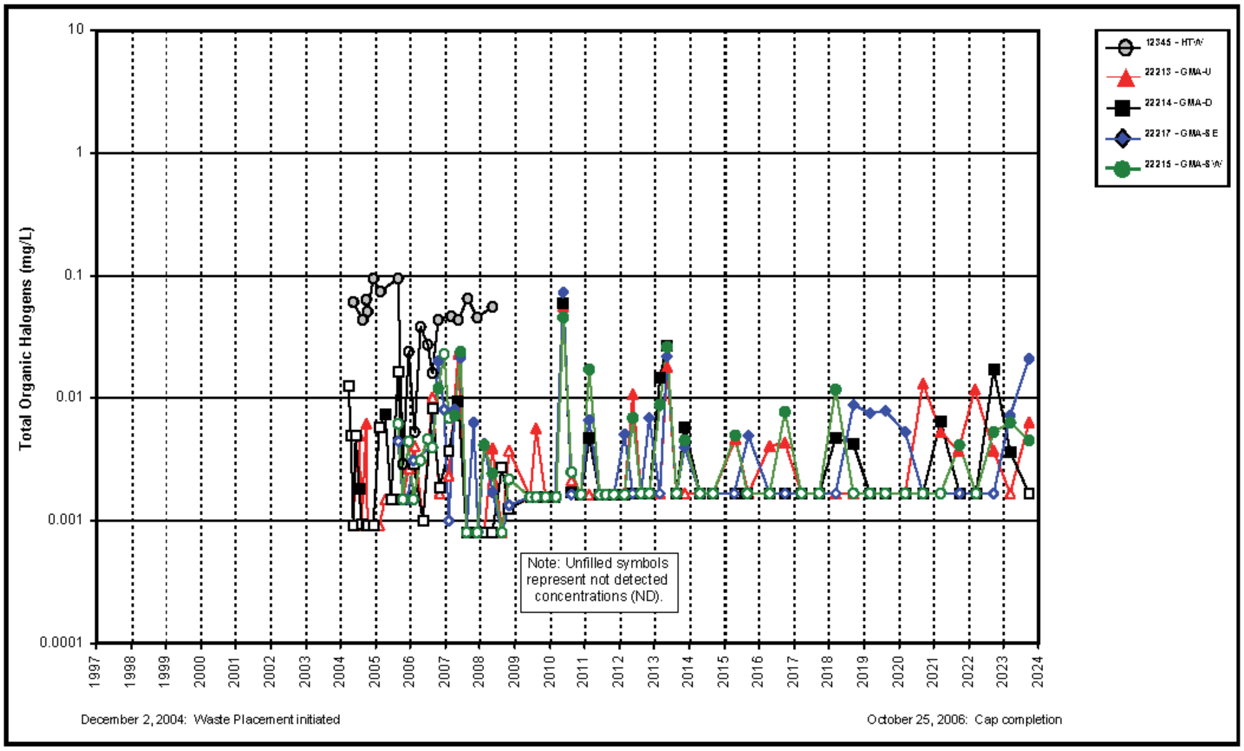

Figure A.5.8-19. Cell 8 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

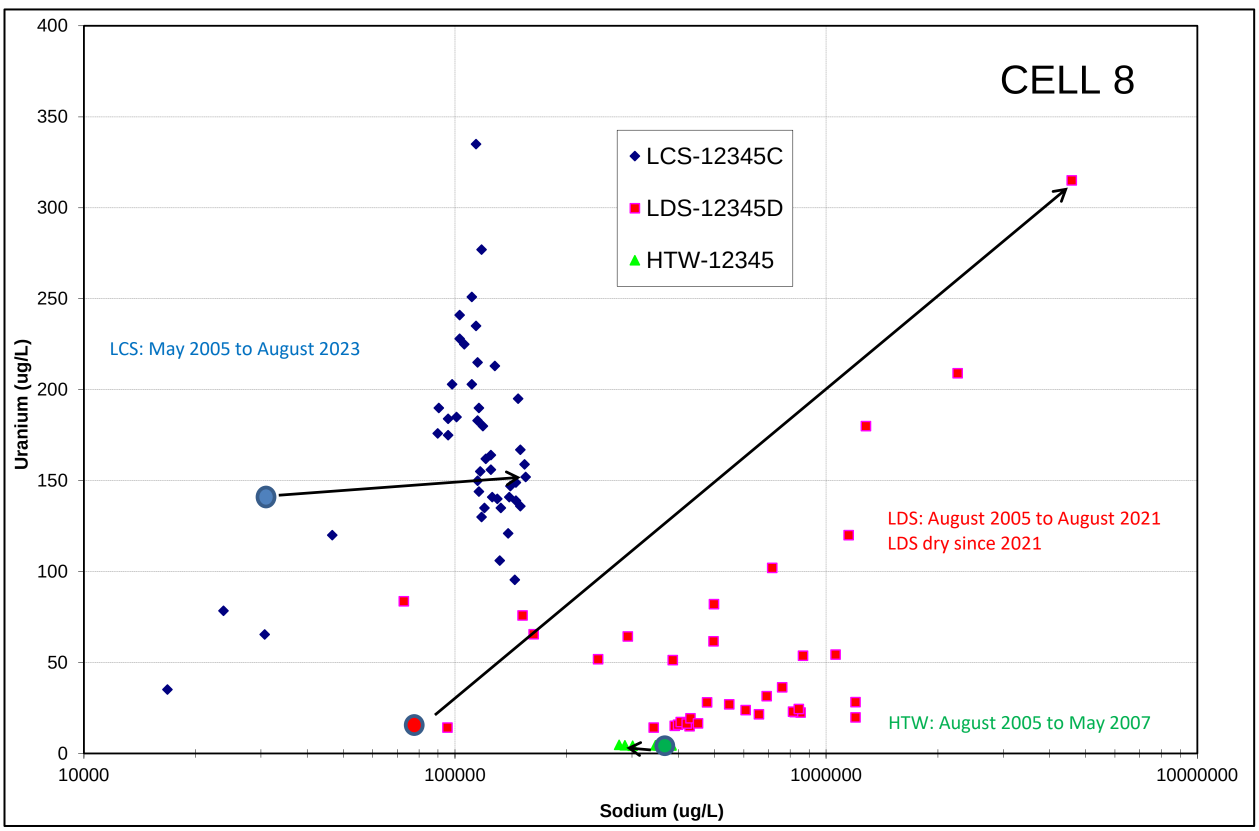

Figure A.5.8-20. Cell 8 Bivariate Plot for Uranium and Sodium

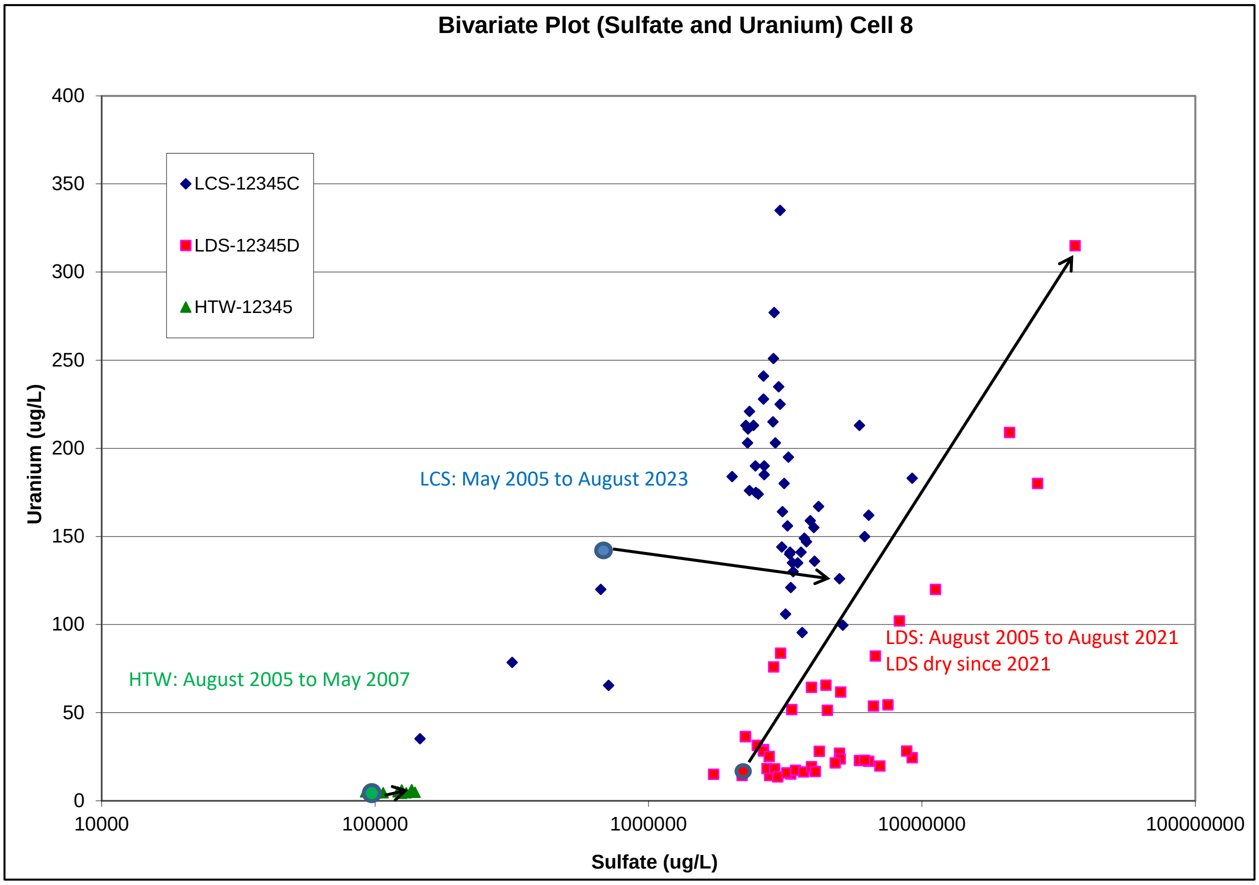

Figure A.5.8-21. Cell 8 Bivariate Plot for Uranium and Sulfate

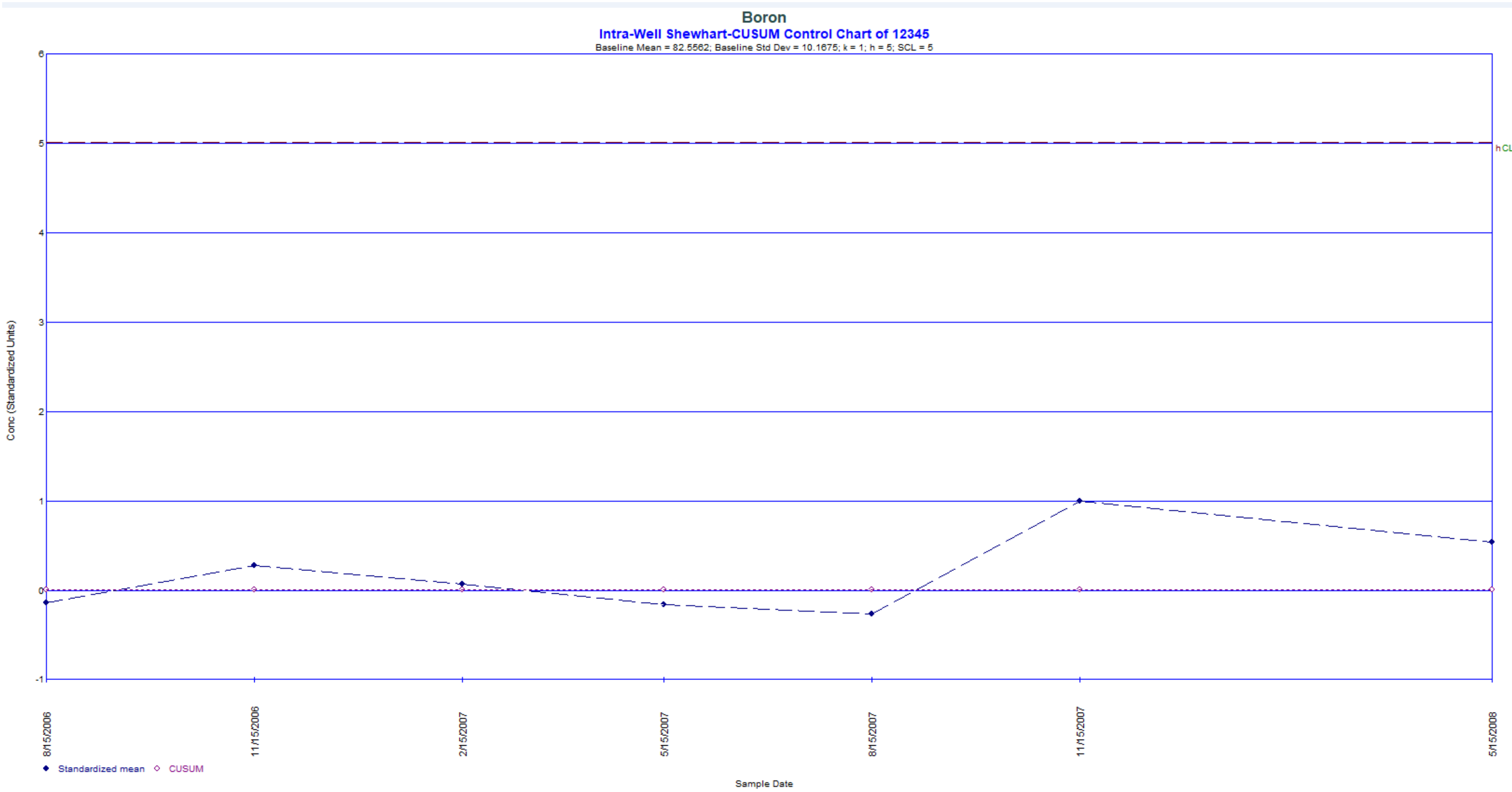

Figure A.5.8-22. Intrawell Shewhart-CUSUM Control Chart for Boron in Monitoring Well 12345

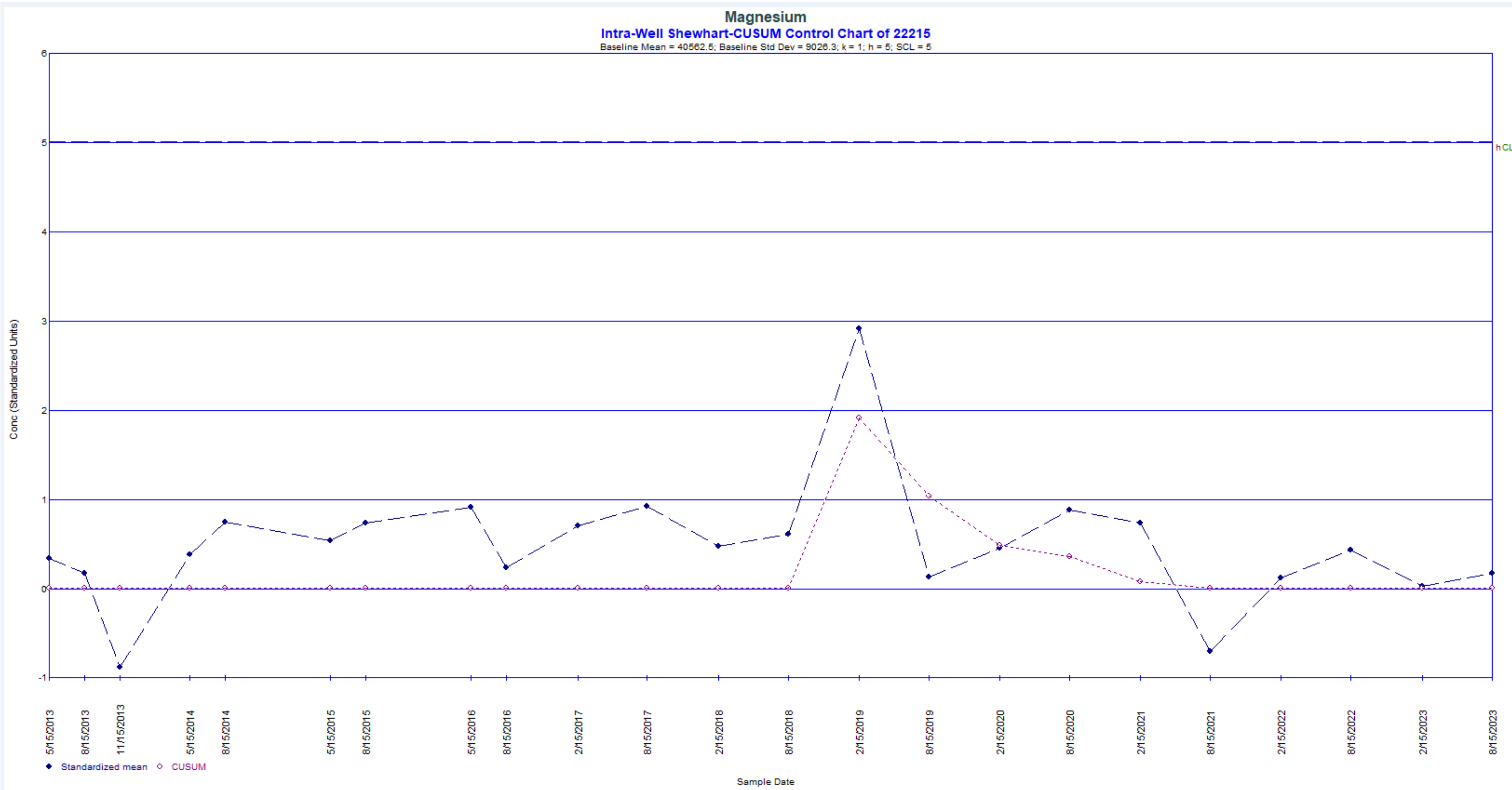

Figure A.5.8-23. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22215

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