

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
FRL	Final Remediation Level
GMA	Great Miami Aquifer
Ohio EPA	Ohio Environmental Protection Agency
PRRS	Paddys Run Road Site
WSA	Waste Storage Area

Measurement Abbreviations

95% UCL	95% upper confidence limit
amsl	above mean sea level
ft	feet
gpm	gallons per minute
K _d	distribution coefficient
lb	pounds
Mgal	million gallons
µg/L	micrograms per liter

A.1.0 Operational Assessment

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

- Operational data for the 20 extraction wells pumping in 2021.
- Uranium concentrations trends for each extraction well compared to model-predicted concentration trends.
- Uranium concentrations at selected monitoring wells compared to model-predicted concentrations.
- Pounds of uranium removed from the aquifer.
- Estimates of the pounds of uranium remaining to be removed from the aquifer to complete the pumping stage of the aquifer remedy.

From July 1, 2014, through June 2018, extraction wells were operated to achieve a design pumping rate of 5,075 gallons per minute (gpm). The design pumping rate is the pumping rate used in the groundwater model to estimate cleanup times for the aquifer remedy. Beginning in July 2018, the design pumping rate was reduced to 4,975 gpm because of a decreased pumping rate from 200 to 100 gpm in extraction well RW-4 (Section A.1.9). Groundwater modeling predicted that the design pumping rate reduction would have no effect on the estimated cleanup times for the aquifer remedy. Figure A.1-1 depicts the locations of the extraction and former reinjection wells and identifies surrounding monitoring wells. Table A.1-1 provides summaries of gallons of water pumped, total uranium removed, and uranium removal indexes for 2021 and for the duration of the remedy to date (August 1993 through December 2021).

Information in this attachment is organized into the following subsections:

- Operational System Overview (Section A.1.1)
- Well field Shutdowns in 2021 (Section A.1.2)
- South Field Module (Section A.1.3)
- South Plume Module (Section A.1.4)
- WSA Module (Section A.1.5)
- Total Uranium Data (Section A.1.6)
- Total Uranium Data Discussion (Section A.1.7)
- DOE National Laboratory Collaboration (Section A.1.8)
- Pumping Rates (Section A.1.9)
- Converted Advanced Wastewater Treatment (CAWWT) Capacity Reduction (Section A.1.10)

A.1.1 Operational System Overview

The current Operational Design for the groundwater remedy has been in effect since design changes were implemented on July 1, 2014. Under the 2014 Operational Design, modeling

predictions indicate that the pumping stage of the aquifer remedy will be achieved by the following dates:

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

Progress was made in decreasing the South Plume between 2014 and the end of 2021. In 2014, the maximum uranium South Plume was determined to be 29.8 acres in area. At the end of 2021, the maximum uranium South Plume was determined to be 14.9 acres in area, a reduction of 50%. In 2014, the maximum uranium South Field plume was determined to be 62.0 acres in size. At the end of 2021, the maximum uranium South Field plume was determined to be 47.6 acres, a reduction of 23.2%.

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

As was done for past model runs, modeled predicted cleanup date uncertainty, due to changes in the elevation of the water table in the aquifer over time, was bracketed by modeling three different sets of 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 results 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 date for each boundary condition was selected as the new targeted cleanup date, resulting in the following new predicted cleanup years.

- South Plume – 2025
- South Field – 2038
- 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). 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 in that for the first 9 years, the target system design pumping rate is 300 gpm higher. The 2014 design was more efficient than previous designs because pumping was more concentrated

where the pumping is needed and when it is needed. The strategy is to decrease design pumping rates as the remedy progresses.

The more-aggressive pumping rates required more maintenance due to iron fouling of the pumps and well screens than earlier pumping designs 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 when operational parameters indicate that cleaning is warranted. As shown in the following table, considering the number of extraction wells decreased from 23 to 20, the number of chemical treatments increased as a result of pumping at higher rates and dealing with an aging well pumping system. The number of treatments was down in 2016, but 2016 was not a normal operating year due to an unplanned well field 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 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. As discussed further below, in 2021 the number of treatments was reduced due to the realization that the long-term use of liquid acid descaler over time is harmful to metal components of an aging wellfield system.

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

^a Number of chemical treatments was affected by replacement of the CAWWT backwash basin.

^b Number of chemical treatments was affected by the CAWWT construction project.

^c Number of chemical treatments was affected by an extended unplanned shutdown (DOE 2017).

^d The number of operating extraction wells was reduced in July 2014.

Although the well treatment program has been successful to date, it has become apparent that the repeated chemical treatments are slowly corroding any metal that the chemicals come in contact with (e.g., cast iron pumps, bolts, cable connectors, and pipes). In 2021, the situation became even more apparent when the seals of the pitless adaptor on South Plume Recovery Well 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. More maintenance and pump replacements will be required in the future.

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 well field maintenance experts to determine if 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 collaboration that was held in 2021. More information is provided in Section A.1.8.

A.1.2 Well Field Shutdowns in 2021

The planned annual well field shutdown in 2021 lasted 36 days (June 1 to July 6, 2021). During the planned annual well field shutdown, extraction wells 1, 2, 3, and 4 continued to pump to maintain capture at the leading south edge of the uranium plume.

In addition to the annual planned well field shutdown, the well field is shut down whenever the Great Miami River reaches a river stage of 14 feet at the U.S. Geological Survey measurement gauge at Miamitown, Ohio. When flow in the river reaches this level, gravity flow from the site discharge pipe is affected. The well field remains off until the river stage falls below 14 feet. This approach was discussed with the U.S. Environmental Protection Agency (EPA) and the Ohio Environmental Protection Agency (Ohio EPA) during the March 14, 2018, regulatory meeting. These temporary well field shutdowns have not had a negative impact on remediation progress and could actually be beneficial from a rebound perspective. In 2019, the entire well field was off for a combined 7 days due to high river levels. In 2020, the entire well field was off for a combined 4 days due to high river levels. In 2021, the Great Miami River did not reach flood stage, so well field shutdowns were not necessary.

The wellfield was shut down for 5 days in 2021 (July 26 to July 30) to replace the main site circuit breakers.

A.1.3 South Field Module

Eleven extraction wells were operational in the South Field Module in 2021. 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 2021 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 2021. 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 2021, 1,275.60 million gallons (Mgal) of groundwater were pumped from the active extraction wells in the South Field Module, resulting in the removal of 228.59 pounds (lb) of uranium from the Great Miami Aquifer (GMA). Since startup in July 1998, the South Field Module has removed 27.804 billion gallons of water and 9,422.56 lb of uranium from the GMA.

A.1.4 South Plume Module

Six extraction wells were operational in the South Plume Module in 2021. The six active recovery wells are 3924 (RW-1), 3925 (RW-2), 3926 (RW-3), 3927 (RW-4), 32308 (RW-6), and 32309 (RW-7). These wells are located south of Willey Road and north of New Haven Road. The target combined pumping rate for the South Plume Module wells in 2021 was 1,300 gpm. As discussed in Section A.1-9, in July 2018 the pumping rate at RW-4 was reduced from 200 gpm to 100 gpm.

Table A.1-1 presents the combined performance data for the South Plume Module. Tables A.1-13 through A.1-18 provide individual extraction well performance data for the South Plume Module wells in 2021. 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 2021, 529.00 Mgal of groundwater were pumped from the active extraction wells in the South Plume Module, resulting in the removal of 69.22 lb of uranium from the GMA. Since its startup in August 1993, the South Plume Module has removed 18.809 billion gallons of groundwater and 3,570.60 lb of uranium from the GMA.

During 2021, the South Plume Module continued to meet the primary objectives of:

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

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

The year 2021 was a challenging one for the operation of RW-7. RW-7 was down from January 29 to October 18, Table A.1-18. The well experienced motor issues, as well as needing to be chemically treated. The well was chemically treated between May 28 and June 11, but when the pump and motor were restarted, sand was being produced through the screen into the pump. This can damage the pump and could indicate a hole in the well screen. Using a downhole camera, no visible issues were detected in the screen. Believed to be a problem with the casing at the bottom of the screen, a cement plug was installed in the base of the screen, which appears to have corrected the problem.

In 2021, 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 (refer to Figure A.1-1).

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

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

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

Groundwater flow directions are reported in Attachment A.3 in the form of water table maps (see Figures A.3-1 thru A.3-4). The water table maps for 2021 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 water table maps also indicate that flow from monitoring well 3636 was away from the South Plume, not toward 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 origin (ERM Midwest Inc. 1994). No volatile organic compounds were detected in 2021.

Monitoring water levels appears to be more effective than monitoring water quality for determining if 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 2021. 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 2021 was 800 gpm. The combined performance data for the WSA Module are presented in Table A.1-1. Tables A.1-20 through A.1-22 provide individual extraction well performance data for the WSA Module wells for 2021. 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 2021, 370.4 Mgal of groundwater were pumped from extraction wells in the WSA Module, resulting in the removal of 64.93 lb of uranium from the GMA. Since startup in May 2002, the WSA Module has removed 8.439 billion gallons of water and 2,479.97 lb of uranium from the GMA.

A.1.6 Total Uranium Data

In 2021, 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 if 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 [$\mu\text{g/L}$] 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 prior to treatment.

In 2021, 2.175 billion gallons of groundwater were pumped from the GMA, and 4.57 Mgal (0.22%) of groundwater was treated. The table below 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 ($\mu\text{g/L}$)	Maximum Total Uranium ($\mu\text{g/L}$)	Average Total Uranium ($\mu\text{g/L}$)
January	568,295	2.5	26.1	16.5
February	675,005	2.9	33.8	21.4
March	396,040	3.1	31.5	19.6
April	377,590	3.3	31.8	20.1
May	357,225	3.5	32.4	20.4
June	224,885	2.8	32.4	20.3
July	212,960	3.1	31.7	18.9
August	339,245	3.1	30.8	19.6
September	422,635	2.7	30.7	18.2
October	350,125	2.7	29.5	18.0
November	327,775	2.9	32.2	20.6
December	321,925	2.8	31.6	20.2
Total	4,573,705			

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. Figures A.1-13 through A.1-32 are uranium concentration versus time plots for each extraction well. Each graph displays three different datasets (operational data, the 95% upper confidence limit [95% UCL] of the operational data, and model predictions). Concentration trend lines for the operational dataset and the 95% UCL of the operational dataset were produced using the regression analysis function in Microsoft Excel.

As pumping continues, the uranium concentration of the pumped groundwater will decrease. The slope of a fitted regression curve through the uranium concentration dataset collected at each extraction well provides a prediction of how pumping concentrations will continue to decrease. However, the slope of a fitted regression curve through the pumped uranium concentration dataset is an insufficient statistical measure by itself because future measured concentrations

could vary about the trend curve. EPA guidelines in *General Methods for Remedial Operation Performance Evaluations* (EPA 1992) suggest that a 95% UCL of the measured uranium concentration dataset also be used to help evaluate the uncertainty of the predicted trend.

The graphs in Figures A.1-13 through A.1-32 predict for each extraction well when the actual measured concentrations and the 95% UCL calculated concentrations will reach the 30 µg/L final remediation level (FRL) for total uranium. Figures A.1-13 through A.1-32 also provide a comparison of the modeled uranium concentration predictions to the measured and 95% UCL data trends. 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 DOE 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 current Operational Design 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 FRL goals. This prediction (broken down by year) is used to judge how closely the measured 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. Regression 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. Regression equations based on uranium concentration data collected at extraction wells through December 31, 2021, are summarized in Table A.1-23. Changing water levels in the aquifer result in cleanup prediction variations and 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 this year, this tracking exercise used model predictions for high water-level conditions, as 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 as this is the most conservative boundary condition for cleanup of the off-property South Plume.

Every year, the average uranium concentration data used to create the regression curves for each extraction well are updated with the data for the current reporting year. The new regression equations are computed using Microsoft Excel software and the updated dataset to determine future mass removal predictions. This results in the regression equations for each well changing slightly from year to year in response to the incorporation of the new data. At the end of December 2021, data indicated that 15,397 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 will not be achieved.

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

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

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

As 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.

The 2022 model run predicts that through 2045 an additional 2,890 lb of uranium will be removed from the GMA to achieve concentration-based FRL goals under nominal boundary conditions. It should be noted that, by loading the 2021 plume concentrations into the groundwater model, the predicted pound of uranium needing to be removed to achieve remediation goals increased by 1,812 lb (2,890 lb – 1,078 lb).

The concentration dataset indicates that an additional 2,914 lb of uranium will be removed from the GMA based on regression analyses of the individual well data. The 95% UCL measured concentration dataset indicates that an additional 11,192 lb of uranium will be removed from the GMA based on regression analyses of the individual well data. A summary of the three predictions is provided below.

Net pounds of uranium extracted through December 2021	15,397		
	Data	Model	95% UCL
Predicted pounds of uranium to be extracted between 2022 and the end of the pump-and-treat stage of the aquifer remedy (in accordance with the current Operational Design)	2,914	2,890	11,192
Total predicted pounds of uranium to be removed to achieve concentration-based FRL goals	18,311	18,287	26,589
Estimated percent complete (based on pounds of uranium to be removed)	84.1%	84.2%	57.9%

Table A.1-24 provides a yearly breakdown of the pounds of uranium to be removed from 2022 to 2040 based on the three predictions (i.e., data, model, 95% UCL) to achieve concentration-based FRL goals. Figure A.1-33 illustrates the relationship between the three estimates. Tracking pounds of uranium removed against groundwater modeling predictions provides an indirect status on progress being made to attain cleanup goals. Other methods (mapping and the Ricker Method) of tracking reduction in the plume size are presented in Attachment A.2.

Results shown above indicate that as of December 31, 2021, the estimated percent complete (based on pounds of uranium to be removed to achieve concentration-based FRL goals) are 84.1%, 84.2%, and 57.9% 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 57.9% and 84.1%. The groundwater model prediction indicates 84.2% complete.

A.1.7 Total Uranium Data Discussion

In early 2022 the groundwater model was re-run with updated uranium plume concentrations consistent with monitoring results for the first half of 2021. The groundwater model run previously was based on an initial mass loading of 16,000 pounds of uranium. As can be seen from Table A.1-24, both monitoring data and modeling now predict that over 18,000 pounds of dissolved uranium will need to be pumped from the aquifer in order to achieve cleanup objectives.

A comparison of groundwater model-predicted uranium concentrations and the actual uranium concentrations measured at each extraction well is provided in Table A.1-25. This is the seventh year this comparison has been completed for the current Operational Design. The comparison shows that the average model-predicted total uranium concentration for 2021 (13.2 µg/L) is lower than the actual average concentration measured in December 2021 (20.2 µg/L). The residual average uranium concentration (actual uranium concentration minus model-predicted uranium concentration) was 7.07 µg/L. The standard deviation for the residual dataset was 8.0. The same annual summary statistics for 2015 through 2020 are also provided at the bottom of Table A.1-25. Average model-predicted concentrations decreased from 23.1 µg/L in 2015 to 13.2 µg/L in 2021. During that same period, the actual average concentrations measured were 22.6 µg/L in 2015 and 20.2 µg/L in 2021. Uranium data collected at the extraction wells indicate that model-predicted uranium concentrations are decreasing at a faster rate than the actual uranium concentration data collected at the extraction wells, indicating that the pumping operation is becoming less efficient over time.

A comparison of groundwater model-predicted concentrations and actual observed concentrations measured at selected monitoring wells in 2021 is provided in Table A.1-26. It should be noted that the 2021 model predictions shown in Figure A.1-26 were made in 2012 when the groundwater model was run to implement the 2014 operational changes. Actual uranium concentrations measured in the first half of 2021 are compared against model-predicted uranium concentrations for April 2021. Changing water levels in the aquifer result in model-predicted cleanup variations and uncertainty. Modeling is, therefore, conducted under low water-level conditions, high water-level conditions, and nominal water-level conditions. The comparison shown in Table A.1-26 represents high water-level conditions. Groundwater modeling conducted under high water-level conditions resulted in the longest cleanup time

predictions; therefore, they are the most conservative. Comparing observed uranium concentrations against the model-predicted concentrations began in 2016. It should be noted that starting in 2017 the comparison is based on 13 fewer data points as a result of the monitoring reductions implemented in 2017.

As shown in Table A.1-26, the average residual uranium concentration in 2021 was 35.3 µg/L. As was presented in previous years, Table A.1-27 shows the average residual for 2021 with the five monitoring wells that were the main contributors to the difference (2386, 2387, 23273, 23281, and 83294_C2) removed. Those five wells are in the South Field. The average residual decreases from 35.3 µg/L (all the measured wells) to 11.90 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.

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

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

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

It should be recognized that pumping may only progress the remediation to a certain point and there may be recalcitrant area challenges 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 could also be playing a role in lowering dissolved uranium concentrations in the groundwater. Under reducing conditions, uranium sorbs to sediments, which would also contribute to lower dissolved concentrations. Reducing conditions could also play a role in why some areas of the aquifer might not respond as well to pump-and-treat 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, as there is more surface area available for the uranium to sorb to. 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 are. Uranium in effect slowly de-sorbs from the areas of finer grained sediments as the water moves past, and around them. This slow desorption process lengthens aquifer cleanup times.

As the groundwater remedy progresses, additional work to define the uranium partitioning coefficient (K_d) may also be deemed beneficial to help refine cleanup efforts in recalcitrant areas of the uranium plume. Selecting a K_d for uranium in the groundwater model that reflects actual site conditions everywhere in the uranium plume over the life of the groundwater remediation effort might not be appropriate. Groundwater model predictions for the Fernald Preserve are based on the assumption 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 Collaboration on the Fernald Aquifer Remediation

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

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

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

Results of Focus Group 1, Aging Well Field System

Focus Group 1 did not identify anything that is currently being done to maintain the aging well field system at the Fernald Preserve that should stop being done. Focus Group 1 acknowledged that operating an aging wellfield system efficiently is somewhat of a black 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 Collaboration personnel contacted area experts for information, those familiar with the Fernald Preserve well field maintenance program emphasized that they often refer to the Fernald Preserve site when they need an example of how to approach the challenge. Focus Group 1 presented the following three consensus recommendation::

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 is planning to begin implementation of these recommendations in 2022, pending funding availability. It is anticipated that full implementation will take from 1 to 5 years.

Implementation of the automatic biofilm and scale control recommendation will consist 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 will require infrastructure modifications to the wellheads of the extraction wells. Prior to making these wellhead modifications, DOE is conducting a manual test on select wells. With concurrence from EPA and Ohio EPA the manual test began in November 2021. Following the manual test, a decision will be made about whether to proceed with the automatic approach, or to move on to test the liquid carbon dioxide recommendation.

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

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

What Fernald 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 Fernald is doing that should continue, but 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 is planning to begin implementation of these Focus Group 2 recommendations in 2022, and it is anticipated that full implementation will take from 1 to 5 years. Implementation of any National Laboratory Network recommendation is subject to availability of resources, stakeholder coordination (as appropriate) and regulatory approval.

A.1.9 Pumping Rates

Target extraction well pumping rates for 2021 are provided in Table A.1-28. From July 1, 2014, through June 2018, extraction wells were operated to achieve a design pumping rate of 5,075 gpm (DOE 2014). The design pumping rate is the pumping rate used in the groundwater model to estimate cleanup times for the aquifer remedy. Beginning in July 2018, the design pumping rate was reduced to 4,975 gpm because of a decreased pumping rate from 200 to 100 gpm in extraction well RW-4. As additional operational experience is gained, pumping rates may change as efforts are made to maximize the effectiveness of each module.

In September of 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, all four of these 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.

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

The modeling indicated that extraction well 3927 (RW-4) could be turned off in 2018 without impacting the model-predicted cleanup times and that capture of the remaining uranium plume would be maintained. Particle track maps showed that water supplying extraction well 3927 (RW-4) was coming mostly from outside the remaining uranium plume footprint. Based on the modeling results, DOE took a conservative approach and continues to pump extraction well 3927

(RW-4) at 100 gpm, rather than 200 gpm, and plans to continue to operate the well until it fails. The continued pumping at the lower rate should help to further flush the aquifer in this area. This approach was discussed with EPA and Ohio EPA at an update meeting held 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 2021, RW-4 remained in operation.

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 treatment system with a 50 gpm system inside the CAWWT building. DOE received concurrence on a path forward in July 2015 from EPA and Ohio EPA and in August 2015 from the Fernald Community Alliance. 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. The two remaining existing 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, well field maintenance activities were put on hold until the new backwash basin was available to temporarily store spent well maintenance fluids prior to being treated in the CAWWT system.

In 2020, post-construction walk down inspections of the backwash basin were required until grass was established. Establishment of grass around the backwash basin construction area was confirmed the week of April 6, 2020. In addition to the post-construction walk down inspections, the construction area was also visually inspected after rain events to check for soil runoff. It should be noted that one post-rain inspection (March 25, 2020) was missed due to the response to the COVID-19 pandemic.

A.1.11 References

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

	Reporting Period					
	January 2021 Through December 2021			August 1993 Through December 2021		
	Gallons Pumped/ Reinjected (Mgal)	Total Uranium Removed/ Reinjected (lb)	Uranium Removal Index (lb/Mgal) ^a	Gallons Pumped/ Reinjected (Mgal)	Total Uranium Removed/ Reinjected (lb)	Uranium Removal Index (lb/Mgal) ^a
South Field Module	1275.60	228.59	0.18	27,804.28	9,422.56	0.34
Waste Storage Area Module	370.40	64.93	0.18	8,438.57	2,479.97	0.29
South Plume Module	529.00	69.22	0.13	18,808.66	3,570.60	0.19
Reinjection Module ^b	0	0	NA	1,936.48	76.27	NA
Aquifer Restoration Systems Totals						
Extraction Wells	2,175.00	362.74	0.17	55,051.50	15,473.13	0.28
(Reinjection Wells ^b)	0	0	NA	(1,936.48)	(76.27)	NA
Net	2,175.00	362.74	0.17	53,115.02	15,396.86	NA

^a NA = not applicable.

^b Reinjection Module was shut down in September 2004.

Table A.1-2. Extraction Well 31550 (EW-18) Operational Summary for 2021

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 pumped: 7,680.5 Target pumping rate: 100 gpm
 Hours not pumped: 1,079.5 Operational percent: 87.68

Adjusted operational percent^a: 96.98

Monthly Measurements at Well Field				
Month	Monthly Average Pumping Rate ^b (gpm)	Volume Pumped (Mgal)	Monthly Total Uranium Concentration ^c (µg/L)	Uranium Removal Index (lb of total uranium removed/Mgal pumped)
Jan	110.6	4.936	26.1	0.22
Feb	110.1	4.441	33.8	0.28
Mar	110.1	4.917	31.5	0.26
Apr	110.6	4.779	31.8	0.27
May	117.9	5.264	30.4	0.25
Jun	0.0	0.000	0.0	0.00
Jul	81.8	3.651	26.3	0.22
Aug	100.2	4.473	30.0	0.25
Sep	110.3	4.765	28.1	0.23
Oct	120.9	5.397	26.0	0.22
Nov	110.3	4.766	32.2	0.27
Dec	110.7	4.940	31.6	0.26
Average	99.5	Total 52.328	Average 27.3	Average 0.25

^a Adjusted for planned annual well field shutdowns.

^b Well EW-18 was down from June 1 to July 7 for planned annual well field shutdown.

Well EW-18 was down from July 26 to August 4 due to sitewide power outage for substation breaker replacement.

^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 2021

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 pumped: 7,680.5 Target pumping rate: 100 gpm
 Hours not pumped: 1079.5 Operational percent: 87.68

Adjusted operational percent^a: 96.98

Monthly Measurements at Well Field						
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	110.8	4.946	14.1	0.12		
Feb	110.2	4.443	17.6	0.15		
Mar	109.8	4.901	16.2	0.14		
Apr	110.4	4.771	17.3	0.14		
May	110.4	4.928	17.4	0.15		
Jun	0.0	0.000	0.0	0.00		
Jul	82.0	3.660	16.5	0.14		
Aug	101.6	4.534	18.9	0.16		
Sep	110.4	4.771	17.1	0.14		
Oct	110.5	4.931	16.7	0.14		
Nov	111.0	4.796	18.4	0.15		
Dec	116.4	5.196	18.1	0.15		
Average	98.6	Total 51.878	Average 15.7	Average	0.13	

^a Adjusted for planned annual well field shutdowns.

^b Well EW-19 was down from June 1 to July 7 for planned annual well field shutdown.

Well EW-19 was down from July 26 to August 3 due to sitewide power outage for substation breaker replacement.

^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 2021

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: 1,623.5

Hours pumped: 7,136.5
 Operational percent: 81.47

Target pumping rate: 200 gpm

Adjusted operational percent^a: 90.11

Monthly Measurements at Well Field				
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	221.0	9.866	23.8	0.20
Feb	218.0	8.790	32.4	0.27
Mar	197.0	8.794	29.8	0.25
Apr	218.4	9.434	30.0	0.25
May	219.0	9.775	32.4	0.27
Jun	0.0	0.000	0.0	0.00
Jul	121.9	5.443	29.0	0.24
Aug	66.8	2.982	19.7	0.16
Sep	219.3	9.475	24.2	0.20
Oct	221.4	9.885	21.1	0.18
Nov	273.3	11.806	30.4	0.25
Dec	271.4	12.117	30.8	0.26
Average	187.3	Total 98.368	Average 25.3	Average 0.21

^a Adjusted for planned annual well field shutdowns.

^b Well EW-20 was down from March 23 to March 25 for liquid acid descaler chemical treatment.

Well EW-20 was down from June 1 to July 9 for planned annual well field shutdown.

Well EW-20 was down from July 26 to August 3 due to sitewide power outage for substation breaker replacement.

Well EW-20 was down from August 3 to August 23 for rehabilitation.

^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 2021

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: 2,748.5

Hours pumped: 6011.5
 Operational percent: 68.62

Target pumping rate: 175 gpm

Adjusted operational percent^a: 75.90

Monthly Measurements at Well Field				
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	195.4	8.724	7.8	0.07
Feb	194.2	7.832	10.9	0.09
Mar	180.4	8.052	10.0	0.08
Apr	194.4	8.400	10.3	0.09
May	181.1	8.083	10.2	0.09
Jun	0.0	0.000	0.0	0.00
Jul	112.4	5.018	11.5	0.10
Aug	175.8	7.850	10.9	0.09
Sep	92.4	3.993	9.4	0.08
Oct	0.5	0.021	17.1	0.14
Nov	85.5	3.694	14.3	0.12
Dec	189.3	8.449	9.1	0.08
Average	133.5	Total 70.116	Average 10.1	Average 0.08

^a Adjusted for planned annual well field shutdowns.

^b Well EW-17A was down from March 23 to March 25 for liquid acid descaler chemical treatment.

Well EW-17A was down from May 26 to May 28 for liquid acid descaler chemical treatment.

Well EW-17A was down from June 1 to July 8 for planned annual wellfield shutdown.

Well EW-17A was down from July 26 to August 4 due to sitewide power outage for substation breaker replacement.

Well EW-17A was down from September 15 to September 27 well rehabilitation.

Well EW-17A was down from September 27 to November 17 in preparation for a manual treatment test.

^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 2021

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 pumped: 6,501.5 Target pumping rate: 300 gpm
 Hours not pumped: 2,258.5 Operational percent: 74.22

Adjusted operational percent^a: 82.09

Monthly Measurements at Well Field				
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	330.1	14.735	15.2	0.13
Feb	329.3	13.278	20.9	0.00
Mar	328.4	14.662	18.8	0.16
Apr	329.5	14.234	20.0	0.17
May	329.5	14.710	20.2	0.17
Jun	0.0	0.000	0.0	0.00
Jul	190.2	8.493	18.8	0.16
Aug	281.7	12.575	21.1	0.18
Sep	329.6	14.237	17.1	0.14
Oct	329.3	14.699	17.5	0.15
Nov	159.4	6.885	18.7	0.16
Dec	0.0	0.000	0.0	0.00
Average	244.7	Total 128.506	Average 15.7	Average 0.12

^a Adjusted for planned annual well field shutdowns.

^b Well EW-22 was down from June 1 to July 8 for planned annual well field shutdown.

Well EW-22 was down from July 26 to August 4 due to sitewide power outage for substation breaker replacement.

Well EW-22 was down from August 7 to August 8 due to electrical issues.

Well EW-22 was down from November 10 to November 14 due to electrical issues.

Well EW-22 was down on November 18 due to electrical issues.

Well EW-22 was down from November 22 to December 31 due to motor issues.

^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 2021

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: 1,344.0

Hours pumped: 7416.0
 Operational percent: 84.66

Target pumping rate: 400 gpm

Adjusted operational percent^a: 93.64

Monthly Measurements at Well Field				
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	425.0	18.971	21.4	0.18
Feb	386.0	15.562	29.4	0.25
Mar	428.4	19.122	26.0	0.22
Apr	413.5	17.865	26.3	0.22
May	346.3	15.457	26.3	0.22
Jun	0.0	0.000	0.0	0.00
Jul	281.7	12.575	21.1	0.18
Aug	408.9	18.255	22.9	0.19
Sep	377.9	16.324	21.7	0.18
Oct	363.7	16.236	22.4	0.19
Nov	361.4	15.614	26.0	0.22
Dec	363.8	16.241	26.2	0.22
Average	346.4	Total 182.221	Average 22.5	Average 0.19

^a Adjusted for planned annual well field shutdowns.

^b Well EW-24 was down from February 23 to February 25 for liquid acid descaler chemical treatment.

Well EW-24 was down from May 4 to May 6 for liquid acid descaler chemical treatment.

Well EW-24 was down from May 30 to June 1 due to variable frequency drive issues.

Well EW-24 was down from June 1 to July 6 for planned annual wellfield shutdown.

Well EW-24 was down from July 26 to August 3 due to sitewide power outage for substation breaker replacement.

Well EW-24 was down from September 13 to September 15 for liquid acid descaler chemical treatment.

Well EW-24 was down from October 26 to October 28 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 2021

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 pumped: 7,625.5 Target pumping rate: 500 gpm
 Hours not pumped: 1,134.5 Operational percent: 87.05

Adjusted operational percent^a: 96.28

Monthly Measurements at Well Field				
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	549.8	24.542	24.5	0.20
Feb	548.4	22.112	33.8	0.28
Mar	535.5	23.906	28.8	0.24
Apr	488.6	21.108	28.9	0.24
May	504.0	22.498	31.1	0.26
Jun	0.0	0.000	0.0	0.00
Jul	353.5	15.780	21.0	0.18
Aug	429.7	19.180	30.8	0.26
Sep	454.6	19.640	28.4	0.24
Oct	542.3	24.208	26.2	0.22
Nov	525.6	22.705	30.3	0.25
Dec	488.8	21.818	30.7	0.26
Average	451.7	Total 237.497	Average 26.2	Average 0.22

^a Adjusted for planned annual well field shutdowns.

^b Well EW-23 was down from May 4 to May 6 for liquid acid descaler chemical treatment.

Well EW-23 was down from June 1 to July 6 for planned annual well field shutdown.

Well EW-23 was down from July 26 to August 3 due to sitewide power outage for substation breaker replacement.

Well EW-23 was down from September 13 to September 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 2021

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: 1,370.0

Hours pumped: 7,390.0
 Operational percent: 84.36

Target pumping rate: 100 gpm

Adjusted operational percent^a: 93.31

Monthly Measurements at Well Field					
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	111.2	4.966	18.2	0.15	
Feb	113.3	4.567	24.2	0.20	
Mar	100.9	4.505	20.7	0.17	
Apr	113.9	4.921	19.7	0.16	
May	89.8	4.008	20.1	0.17	
Jun	0.0	0.000	0.0	0.00	
Jul	80.4	3.587	18.2	0.15	
Aug	102.7	4.584	20.2	0.17	
Sep	110.7	4.783	17.3	0.14	
Oct	111.5	4.976	16.1	0.13	
Nov	101.1	4.369	20.1	0.17	
Dec	107.7	4.806	21.0	0.18	
Average	95.3	Total 50.071	Average 18.0	Average	0.15

^a Adjusted for planned annual well field shutdowns.

^b Well EW-25 was down from March 8 to March 10 for liquid acid descaler chemical treatment.

Well EW-25 was down from May 24 to May 26 for liquid acid descaler chemical treatment.

Well EW-25 was down from May 28 to June 1 due to programmatic logic control issues.

Well EW-25 was down from June 1 to July 8 for planned annual well field shutdown.

Well EW-25 was down from July 26 to August 4 due to sitewide power outage for substation breaker replacement.

Well EW-25 was down from November 10 to November 12 due to electrical issues.

^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 2021

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 pumped: 7,654.0 Target pumping rate: 300 gpm
 Hours not pumped: 1,106.0 Operational percent: 87.37

Adjusted operational percent^a: 96.64

Monthly Measurements at Well Field				
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	330.3	14.746	16.1	0.13
Feb	328.9	13.262	19.6	0.16
Mar	328.3	14.656	19.6	0.16
Apr	329.4	14.230	23.9	0.20
May	329.4	14.706	22.4	0.19
Jun	0.0	0.000	0.0	0.00
Jul	190.0	8.481	25.9	0.22
Aug	297.4	13.278	25.1	0.21
Sep	329.3	14.227	20.4	0.17
Oct	329.3	14.699	19.3	0.16
Nov	330.0	14.256	20.1	0.17
Dec	328.4	14.659	18.7	0.16
Average	287.6	Total 151.200	Average 19.3	Average 0.16

^a Adjusted for planned annual well field shutdowns.

^b Well EW-15A was down from June 1 to July 8 for planned annual well field shutdown.

Well EW-15A was down from July 26 to August 4 due to sitewide power outage for substation breaker replacement.

^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 2021

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

Hours in reporting period: 8,760
 Hours not pumped: 1,873.5

Hours pumped: 6,886.5
 Operational percent: 78.61

Target pumping rate: 400 gpm

Adjusted operational percent^a: 86.95

Monthly Measurements at Well Field				
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	411.6	18.374	8.3	0.07
Feb	355.1	14.319	10.9	0.09
Mar	437.9	19.548	9.9	0.08
Apr	439.2	18.974	10.7	0.09
May	403.8	18.028	9.7	0.08
Jun	0.0	0.000	0.0	0.00
Jul	0.0	0.000	0.0	0.00
Aug	394.8	17.623	9.0	0.08
Sep	420.5	18.164	9.0	0.08
Oct	319.2	14.249	8.8	0.07
Nov	316.0	13.653	10.2	0.09
Dec	437.8	19.544	10.9	0.09
Average	328.0	Total 172.476	Average 8.1	Average 0.07

^a Adjusted for planned annual well field shutdowns.

^b Well EW-30 was down from February 22 to February 24 for liquid acid descaler chemical treatment.

Well EW-30 was down from May 28 to May 30 for liquid acid descaler chemical treatment.

Well EW-30 was down from June 1 to July 9 for planned annual well field shutdown.

Well EW-30 was down from July 9 to July 29 for well rehabilitation.

Well EW-30 was down from July 29 to August 4 due to sitewide power outage for substation breaker replacement.

Well EW-30 was down from October 4 to October 6 for liquid acid descaler chemical treatment.

Well EW-30 was down from October 26 to October 28 for liquid acid descaler chemical treatment.

Well EW-30 was down from November 8 to November 11 to replace pump.

^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 2021

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: 3,442.0

Hours pumped: 5318.0
 Operational percent: 60.71

Target pumping rate: 300 gpm

Adjusted operational percent^a: 67.15

Monthly Measurements at Well Field					
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	220.5	9.841	18.0	0.15	
Feb	223.1	8.995	21.9	0.18	
Mar	249.4	11.133	20.3	0.17	
Apr	249.6	10.783	22.9	0.19	
May	232.6	10.383	24.9	0.21	
Jun	0.0	0.000	0.0	0.00	
Jul	152.7	6.818	31.7	0.26	
Aug	71.7	3.203	30.7	0.26	
Sep	0.0	0.000	0.0	0.00	
Oct	0.9	0.038	29.5	0.25	
Nov	144.2	6.231	29.1	0.24	
Dec	319.8	14.274	26.1	0.22	
Average	155.4	Total 81.698	Average 21.3	Average 0.18	

^a Adjusted for planned annual well field shutdowns.

^b Well EW-21A was down from May 24 to May 26 for liquid acid descaler chemical treatment.

Well EW-21A was down from June 1 to July 7 for planned annual well field shutdown.

Well EW-21A was down from July 26 to August 3 due to sitewide power outage for substation breaker replacement.

Well EW-21A was down from August 12 to September 1 for rehabilitation.

Well EW-21A was down from September 1 to November 17 in preparation for a manual treatment test.

^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 2021

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 not pumped: 962.5

Hours pumped: 7,797.5
 Operational percent: 89.01

Target pumping rate: 200 gpm

Monthly Measurements at Well Field				
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	220.2	9.828	10.3	0.09
Feb	218.3	8.803	14.5	0.12
Mar	204.1	9.113	13.5	0.11
Apr	218.7	9.447	13.2	0.11
May	218.7	9.763	12.3	0.10
Jun	223.2	9.644	11.0	0.00
Jul	176.1	7.861	9.3	0.08
Aug	210.8	9.411	10.3	0.09
Sep	219.2	9.471	9.5	0.08
Oct	216.4	9.660	9.7	0.08
Nov	214.3	9.256	11.5	0.10
Dec	214.4	9.572	11.4	0.10
Average	212.9	Total 111.829	Average 11.4	Average 0.09

^a Well RW-1 was down from March 29 to March 31 for liquid acid descaler chemical treatment.

Well RW-1 was down from July 26 to August 1 due to sitewide power outage for substation breaker replacement.

^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 2021

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

Hours in reporting period: 8,760
 Hours not pumped: 1,134.5

Hours pumped: 7,625.5
 Operational percent: 87.05

Target pumping rate: 200 gpm

Monthly Measurements at Well Field				
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	220.2	9.828	10.6	0.09
Feb	218.5	8.810	13.4	0.11
Mar	201.3	8.984	12.5	0.10
Apr	218.8	9.451	12.6	0.11
May	219.0	9.775	13.5	0.11
Jun	109.2	4.717	13.3	0.11
Jul	41.0	1.829	14.0	0.12
Aug	210.8	9.411	13.1	0.11
Sep	218.7	9.449	11.1	0.09
Oct	218.5	9.754	11.4	0.10
Nov	219.5	9.483	12.6	0.11
Dec	214.5	9.574	12.9	0.11
Average	192.5	Total 101.065	Average 12.6	Average 0.11

^a Well RW-2 was down from March 29 to March 31 for liquid acid descaler chemical treatment.

Well RW-2 was down from June 16 to July 20 for rehabilitation.

Well RW-2 was down from July 26 to August 1 due to sitewide power outage for substation breaker replacement.

^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 2021

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 not pumped: 1,256.0

Hours pumped: 7,504.0
 Operational percent: 85.66

Target pumping rate: 200 gpm

Monthly Measurements at Well Field				
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	213.1	9.514	15.6	0.13
Feb	173.2	6.983	20.8	0.17
Mar	217.5	9.708	19.4	0.16
Apr	180.2	7.785	19.1	0.16
May	194.7	8.690	19.8	0.17
Jun	226.3	9.774	18.2	0.15
Jul	143.0	6.384	16.3	0.14
Aug	76.7	3.422	17.1	0.14
Sep	223.8	9.669	15.6	0.13
Oct	222.4	9.928	15.6	0.13
Nov	205.6	8.884	18.7	0.16
Dec	215.1	9.601	19.6	0.16
Average	191.0	Total 100.341	Average 18.0	Average 0.15

^a Well RW-3 was down from February 23 to February 25 for liquid acid descaler chemical treatment.

Well RW-3 was down on April 11 for unknown reasons.

Well RW-3 was down from May 3 to May 5 for liquid acid descaler chemical treatment.

Well RW-3 was down from July 26 to August 1 due to sitewide power outage for substation breaker replacement.

Well RW-3 was down from August 5 to August 25 due to motor cable and pump issues.

Well RW-3 was down from November 9 to November 10 to replace the pump and inspect pitless adaptor.

^b Average is used if more than one concentration measurement is available for a particular month.

Table A.1-16. Extraction Well 3927 (RW-4) Operational Summary for 2021

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

Hours in reporting period: 8,760 Hours pumped: 7,090.0 Target pumping rate: 200/100^a gpm
 Hours not pumped: 1,670.0 Operational percent: 80.94

Monthly Measurements at Well Field				
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	89.3	3.987	2.5	0.02
Feb	144.3	5.819	2.9	0.02
Mar	139.4	6.224	3.1	0.03
Apr	128.1	5.536	3.3	0.03
May	128.3	5.729	3.5	0.03
Jun	185.5	8.014	2.8	0.02
Jul	136.3	6.084	3.1	0.03
Aug	150.0	6.696	3.1	0.03
Sep	129.5	5.594	2.7	0.02
Oct	104.8	4.677	2.7	0.00
Nov	106.8	4.616	2.9	0.00
Dec	107.6	4.804	2.8	0.00
Average	129.2	Total 67.779	Average 2.9	Average 0.02

^a The target pumping rate changed from 200 to 100 gpm in July 2018.

^b Well RW-4 was down from January 25 to Jan 26 for liquid acid descaler chemical treatment.

Well RW-4 was down from May 10 to May 12 for liquid acid descaler chemical treatment.

Well RW-4 was down from July 26 to August 1 due to sitewide power outage for substation breaker replacement.

Well RW-4 was down from October 12 to October 14 for liquid acid descaler chemical treatment.

^c Average is used if more than one concentration measurement is available for a particular month.

Table A.1-17. Extraction Well 32308 (RW-6) Operational Summary for 2021

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

Hours in reporting period: 8,760
 Hours not pumped: 1,464.5

Hours pumped: 7,295.5
 Operational percent: 83.28

Target pumping rate: 300 gpm

Adjusted operational percent^a: 92.11

Monthly Measurements at Well Field							
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	249.8	11.150	25.2	0.21			
Feb	247.0	9.958	32.1	0.27			
Mar	247.1	11.030	29.9	0.25			
Apr	248.2	10.722	28.6	0.24			
May	231.0	10.313	28.6	0.24			
Jun	0.0	0.000	0.0	0.00			
Jul	40.4	1.803	14.0	0.12			
Aug	315.2	14.072	25.0	0.21			
Sep	327.7	14.157	23.3	0.19			
Oct	278.8	12.444	23.7	0.20			
Nov	219.2	9.469	29.0	0.24			
Dec	214.2	9.562	29.7	0.25			
Average	218.2	Total 114.679	Average 24.1	Average	0.20		

^a Adjusted for planned annual well field shutdown.

^b Well RW-6 was down from May 10 to May 12 for liquid acid descaler chemical treatment.

Well RW-6 was down from June 1 to July 22 for rehabilitation.

Well RW-6 was down from July 26 to August 1 due to sitewide power outage for substation breaker replacement.

^c Average is used if more than one concentration measurement is available for a particular month.

Table A.1-18. Extraction Well 32309 (RW-7) Operational Summary for 2021

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 pumped: 2,445.5 Target pumping rate: 300 gpm
 Hours not pumped: 6,314.5 Operational percent: 27.92

Adjusted operational percent^a: 30.88

Monthly Measurements at Well Field				
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	228.5	10.201	17.0	0.14
Feb	0.0	0.000	0.0	0.00
Mar	0.0	0.000	0.0	0.00
Apr	0.0	0.000	0.0	0.00
May	0.0	0.000	0.0	0.00
Jun	0.0	0.000	0.0	0.00
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	97.3	4.344	19.7	0.16
Nov	213.1	9.205	21.9	0.18
Dec	214.1	9.559	22.2	0.14
Average	62.8	Total 33.309	Average 6.7	Average 0.06

^a Adjusted for planned annual well field shutdown.

^b Well RW-7 was down from January 29 to October 18. The well experienced motor issues, as well as needing to be rehabilitated. It was rehabilitated between May 28 and June 11, but when restarted, sand was being pulled into the pump. No visible hole was detected in the screen. Believed to be a problem with the casing at the bottom of the screen, a cement plug was installed in the base of the screen. This seemed to have corrected the problem.

^c Average is used if more than one concentration measurement is available for a particular month.

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

Analyte	Monitoring Well	Number of Samples ^{a,b,c}	Minimum ^{a,b,c,d} (mg/L)	Maximum ^{a,b,c,d} (mg/L)	Average ^{a,b,c,d} (mg/L)	SD ^{a,b,c,d,e}	Trend ^{a,b,c,d,f}
Arsenic	2128	253	0.000195	0.188	0.0108	0.0201	Down
	2636	191	0.0100	0.0939	0.0434	0.0185	Down
	2898	70	0.000147	0.0820	0.00410	0.0104	No Trend ^g
	2899	63	0.00032	0.0283	0.00254	0.00388	No Trend ^g
	2900	252	0.00032	0.0609	0.00486	0.00530	Down
	3128	73	0.00040	0.234	0.00683	0.0274	No Trend
	3636	70	0.00050	0.0233	0.00292	0.00372	No Trend ^g
	3898	70	0.00050	0.0434	0.00425	0.00619	No Trend ^g
	3899	71	0.000147	0.0307	0.00282	0.00447	No Trend ^g
	3900	71	0.000375	0.0208	0.00302	0.00355	No Trend
Phosphorus	2128	79	0.0250	16.2	1.26	2.24	Down
	2636	43	9.60	170	77.9	42.6	Down
	2898	71	0.0050	9.95	0.221	1.19	Down
	2899	62	0.0050	0.831	0.0544	0.109	No Trend
	2900	69	0.0431	4.74	0.432	0.619	Down
	3128	80	0.0050	13.0	0.218	1.45	No Trend
	3636	69	0.0091	1.10	0.0666	0.134	No Trend
	3898	69	0.0075	1.24	0.0913	0.161	Down
	3899	70	0.0050	1.86	0.105	0.253	Down
	3900	71	0.0050	1.38	0.0812	0.219	Down
Potassium	2128	71	0.830	18.0	3.16	3.09	Down
	2636	43	4.60	218	57.7	49.6	Down
	2898	71	1.11	9.64	4.41	1.14	Up
	2899	63	1.36	8.85	4.11	0.91	Up
	2900	70	0.0095	6.00	1.95	1.04	No Trend
	3128	73	1.09	3.70	1.88	0.61	Down
	3636	69	1.09	4.24	2.08	0.57	Down
	3898	70	0.610	4.23	2.72	0.74	Up
	3899	71	0.875	4.55	2.86	0.80	Up
	3900	71	0.975	3.19	1.69	0.37	Down
Sodium	2128	71	12.3	75.2	33.3	11.2	Down
	2636	43	14.4	148	48.2	26.8	Down
	2898	71	4.95	31.0	19.8	4.7	Up
	2899	63	11.2	25.1	18.0	3.4	Up
	2900	70	0.0136	43.3	25.3	7.8	Down
	3128	73	3.52	13.4	5.46	2.45	Down
	3636	69	3.14	13.0	5.61	2.63	Down
	3898	70	7.29	28.8	13.0	5.8	Up
	3899	71	6.24	43.6	14.1	10.2	Up
	3900	71	3.13	10.8	4.72	1.69	Down

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

- ^a The data are based on unfiltered samples from the Operable Unit 5 Remedial Investigation/Feasibility Study dataset (1988–1993) and 1994 through 2021 groundwater data (unfiltered and filtered for 2001–2021).
- ^b If more than one sample is collected per well per day (e.g., duplicate), then only one sample is counted for the total number of samples, and the sample with the maximum concentration is used to determine the summary statistics (minimum, maximum, average, standard deviation, and Mann-Kendall test for trend).
- ^c Rejected data qualified with an R were not included in this count or the summary statistics.
- ^d Where concentrations are below the detection limit, each result used in the summary statistics is set at half the detection limit.
- ^e SD = standard deviation.
- ^f Trend starts on August 27, 1993, and is based on the startup of the South Plume extraction wells (DOE 1993). This Mann-Kendall test for trend is performed with a 95% confidence interval.
- ^g The original statistics indicated an upward trend; however, the upward trend was due to a slight increase in the method detection limit for nondetected concentrations. As a result, “No Trend” is indicated.

Table A.1-20. Extraction Well 32761 (EW-26) Operational Summary for 2021

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 pumped: 7,584.0 Target pumping rate: 300 gpm
 Hours not pumped: 1,176.0 Operational percent: 86.58

Adjusted operational percent^a: 95.76

Monthly Measurements at Well Field							
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	329.2	14.694	17.6	0.15			
Feb	328.8	13.256	23.2	0.19			
Mar	328.5	14.662	20.4	0.17			
Apr	327.3	14.139	21.3	0.18			
May	329.3	14.701	22.3	0.19			
Jun	0.0	0.000	0.0	0.00			
Jul	175.2	7.820	23.8	0.20			
Aug	264.3	11.798	21.8	0.18			
Sep	327.7	14.155	17.9	0.15			
Oct	329.0	14.689	17.4	0.15			
Nov	320.1	13.827	19.9	0.17			
Dec	325.2	14.517	19.9	0.17			
Average	282.0	Total 148.259	Average 18.8	Average 0.16			

^a Adjusted for planned annual well field shutdowns.

^b Well EW-26 was down from June 1 to July 9 for planned annual well field shutdown.

Well EW-26 was down from July 26 to August 5 due to sitewide power outage for substation breaker replacement.

^c Average is used if more than one concentration measurement is available for a particular month.

Table A.1-21. Extraction Well 33062 (EW-27) Operational Summary for 2021

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 pumped: 7,325.5 Target pumping rate: 200 gpm
 Hours not pumped: 1,434.5 Operational percent: 83.62

Adjusted operational percent^a: 92.49

Monthly Measurements at Well Field							
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	221.0	9.864	19.3	0.16			
Feb	219.5	8.848	25.6	0.21			
Mar	204.6	9.132	22.9	0.19			
Apr	219.7	9.492	23.9	0.20			
May	204.7	9.138	25.1	0.21			
Jun	23.6	1.018	27.5	0.23			
Jul	124.5	5.559	22.3	0.19			
Aug	191.7	8.556	23.0	0.19			
Sep	220.0	9.505	21.5	0.18			
Oct	199.8	8.920	21.1	0.18			
Nov	199.7	8.628	24.6	0.21			
Dec	154.6	6.901	23.0	0.00			
Average	181.9	Total 95.563	Average 23.32	Average 0.18			

^a Adjusted for planned annual well field shutdowns.

^b Well EW-27 was down from March 8 to March 10 for liquid acid descaler chemical treatment.

Well EW-27 was down from May 25 to May 27 for liquid acid descaler chemical treatment.

Well EW-27 was down from June 1 to July 8 for planned annual wellfield shutdown.

Well EW-27 was down from July 26 to August 5 due to sitewide power outage for substation breaker replacement.

Well EW-27 was down from November 8 to November 10 for liquid acid descaler chemical treatment.

Well EW-27 was down on December 23 due to programming problems.

^c Average is used if more than one concentration measurement is available for a particular month.

Table A.1-22. Extraction Well 33347 (EW-33a) Operational Summary for 2021

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: 1,980.0

Hours pumped: 6,780.0
 Operational percent: 77.40

Target pumping rate: 300 gpm

Adjusted operational percent^a: 85.61

Monthly Measurements at Well Field							
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	326.1	14.556	17.4	0.15			
Feb	313.4	12.636	22.5	0.19			
Mar	305.2	13.626	22.1	0.18			
Apr	283.3	12.239	21.2	0.18			
May	248.6	11.096	20.9	0.17			
Jun	0.0	0.000	0.0	0.00			
Jul	146.3	6.530	19.1	0.16			
Aug	98.1	4.380	21.2	0.18			
Sep	265.0	11.446	22.2	0.19			
Oct	315.9	14.101	17.2	0.14			
Nov	296.2	12.796	20.2	0.17			
Dec	295.0	13.168	21.0	0.18			
Average	241.1	Total 126.576	Average 18.75	Average 0.16			

^a Adjusted for planned annual well field shutdowns.

^b Well EW-33A was down from March 30 to April 1 for liquid acid descaler chemical treatment.

Well EW-33A was down from May 25 to May 27 for liquid acid descaler chemical treatment.

Well EW-33A was down from June 1 to July 9 for planned annual wellfield shutdown.

Well EW-33A was down from July 26 to August 5 due to sitewide power outage for substation breaker replacement.

Well EW-33A was down from August 16 to August 19 for liquid acid descaler chemical treatment.

^c Average is used if more than one concentration measurement is available for a particular month.

Table A.1-23. Regression Equations for Uranium Concentration Data Collected at Extraction Wells—Data Collected Through December 31, 2021

Extraction Well Number	Database Identification	Data Trend	R ² ^a	95% Upper Confidence Limit	R ² ^a	Function Type
RW-1	3924	$1E+32x^{-6.69}$	0.86	$5E+15x^{-3.041}$	0.77	Power
RW-2	3925	$y = -1E-10x^3 + 1E-05x^2 - 0.4981x + 6963.2$	0.79	$y = -1E-10x^3 + 1E-05x^2 - 0.4981x + 6979.1$	0.79	Polynomial
RW-3	3926	$y = 2E-10x^3 - 2E-05x^2 + 0.8852x - 11947$	0.74	$y = 2E-10x^3 - 2E-05x^2 + 0.8852x - 11930$	0.74	Polynomial
RW-4	3927	$y = 2E-15x^{3.293}$	0.29	$y = 2E-06x^{1.4129}$	0.20	Power
RW-6	32308	$y = 2E+26x^{-5.336}$	0.87	$y = 2E+16x^{-3.154}$	0.85	Power
RW-7	32309	$y = 4E+34x^{-7.184}$	0.93	$y = 7E+18x^{-3.682}$	0.89	Power
EW-15a	33262	$y = 1E+34x^{-7.063}$	0.81	$y = 2E+19x^{-3.807}$	0.79	Power
EW-17a	33326	$y = 14337E4^{-2E-04x}$	0.84	$y = 11809E^{-8.E-05x}$	0.80	Exponential
EW-18	31550	$y = 8E+19x^{-3.974}$	0.54	$y = 3E+12x^{-2.312}$	0.49	Power
EW-19	31560	$y = 1E+49x^{-10.35}$	0.84	$y = 2E+19x^{-3.745}$	0.71	Power
EW-20	31561	$y = 4E+14x^{-2.836}$	0.50	$y = 2E+10x^{-1.868}$	0.49	Power
EW-21a	33298	$y = 8E+36x^{-7.651}$	0.84	$y = 1E+18x^{-3.487}$	0.78	Power
EW-22	32276	$y = 8E+57x^{-12.22}$	0.91	$y = 3E+21x^{-4.184}$	0.79	Power
EW-23	32447	$y = 2E+47x^{-9.898}$	0.89	$y = 1E+21x^{-4.07}$	0.80	Power
EW-24	32446	$y = 9E+30x^{-6.364}$	0.88	$y = 1E+17x^{-3.302}$	0.81	Power
EW-25	33061	$y = 7E+26x^{-5.489}$	0.62	$y = 5.E+15x^{-3.012}$	0.60	Power
EW-30	33264	$y = 1E+76x^{-16.16}$	0.97	$y = 6E+26x^{-5.347}$	0.91	Power
EW-26	32761	$y = 1E+48x^{-10.1}$	0.83	$y = 8E+20x^{-4.091}$	0.73	Power
EW-27	33062	$y = 5E+49x^{-10.43}$	0.79	$y = 1E+20x^{-3.898}$	0.65	Power
EW-33a	33347	$y = 9E+12x^{-2.506}$	0.10	$y = 5E+8x^{-1.485}$	0.10	Power

^a R² = Coefficient of Determination

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

Year	Estimate of Annual Pounds of Uranium to Be Extracted to Achieve Concentration-Based FRL Goals Based on Regression of Concentration Data	Estimate of Annual Pounds of Uranium to Be Extracted to Achieve Concentration-Based FRL Goals Based on Model Predictions	Estimate of Annual Pounds of Uranium to Be Extracted to Achieve Concentration-Based FRL Goals Based on Regression of 95% UCL
2022	412	535	1589
2023	391	382	1545
2024	372	313	1503
2025	354	272	1463
2026	153	200	587
2027	147	176	573
2028	140	157	559
2029	134	143	546
2030	129	132	533
2031	123	122	521
2032	118	114	509
2033	114	107	498
2034	51	39	260
2035	49	37	255
2036	48	35	250
2037	46	33	245
2038	45	32	241
2039	44	31	236
2040	42	30	232
Estimate of total to be extracted	2,914	2,890	11,192
<i>Actual net pounds extracted through December 31, 2021</i>	15,397	15,397	15,397
Estimate of total pounds to be extracted to achieve concentration-based FRL goals.	18,311	18,287	26,589
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
2021	84.1%	84.2%	57.9%

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

Extraction Well	Model-Predicted Total Uranium Concentration December 2021 ^a (µg/L)	Total Uranium Concentration December 2021 (µg/L)	Residual Total Uranium Concentration ^b (µg/L)
3924 (RW-1)	4.22	11.4	7.2
3925 (RW-2)	6.65	12.9	6.3
3926 (RW-3)	8.19	19.6	11.4
3927 (RW-4)	3.23	2.80	-0.40
32308 (RW-6)	16.66	29.7	13.0
32309 (RW-7)	14.09	22.2	8.1
33262 (EW-15a)	18.02	18.7	0.7
33326 (EW-17a)	22.42	9.10	-13.3
31550 (EW-18)	16.48	31.6	15.1
31560 (EW-19)	13.63	18.1	4.5
31561 (EW-20)	14.84	30.8	16.0
33298 (EW-21a)	11.97	26.1	14.1
32276 (EW-22)	13.32	18.7	5.4
32447 (EW-23)	12.29	30.7	18.4
32446 (EW-24)	12.28	26.4	14.1
33061 (EW-25)	13.11	21.0	7.9
32761 (EW-26)	19.9	19.9	0.0
33062 (EW-27)	8.68	23.0	14.3
33264 (EW-30)	6.70	10.9	4.2
33347 (EW-33a)	26.28	21.0	-5.3
2021 Average	13.2	20.2	7.07
2021 Standard Deviation	5.91	7.90	8.0
2021 Maximum	26.28	31.6	18.4
2021 Minimum	3.23	2.80	-13.3
2021 Range	23.05	28.8	31.7
2020 Average	14.1	20.7	6.66
2020 Standard Deviation	6.8	7.90	8.0
2020 Maximum	29.8	32.3	18.6
2020 Minimum	3.23	2.90	-13.0
2020 Range	26.6	29.4	31.6
2019 Average	15.3	19.9	4.70
2019 Standard Deviation	7.8	8.20	9.10
2019 Maximum	34.0	34.8	20.5
2019 Minimum	3.23	2.80	-14.6
2019 Range	30.8	32.0	35.1
2018 Average	16.8	21.1	4.3
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

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

Extraction Well	Model-Predicted Total Uranium Concentration December 2021 ^a (µg/L)	Total Uranium Concentration December 2021 (µg/L)	Residual Total Uranium Concentration ^b (µg/L)
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 Model predicted total uranium concentrations are from April 1, 2021.

^b Residual total uranium concentration = actual total uranium concentration – model-predicted total uranium concentration.

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

Well Number	Observed Total Uranium Concentrations 1st Half 2021 (µg/L)	Predicted Total Uranium Concentrations^a April 1, 2021 (µg/L)	Total Uranium Concentration Residuals (µg/L)
2045	59.8	13.01	46.79
2046	14.3	18.82	-4.52
2049	12.7	17.00	14.30
2093	3.66	2.11	1.55
2385	30.3	60.02	-29.72
2386	143	21.24	121.76
2387	126	22.60	103.4
2821	10.4	17.58	-7.18
23271	47.1	21.38	25.72
23273	161	24.76	136.24
23274	74.4	32.06	42.34
23275	82.9	28.46	54.44
23276	91.6	41.57	50.03
23278	21.1	36.99	-15.9
23280	23.1	27.63	-4.35
23281	148	18.2	129
82433_C2	3.19	7.46	-4.27
83117_C2	24.6	22.43	2.17
83124_C2	23.1	24.55	-1.45
83293_C2	2.49	4.63	-2.14
83294_C2	124	16.64	107
83295_C2	73.9	19.57	54.33
83296_C2	24.7	13.96	10.74
2021 Average	57.6	22.3	35.3
2021 Standard Deviation	51.9	12.4	51.4
2021 Maximum	161	60.0	136
2021 Minimum	2.49	2.11	-29.7
2021 Range	159	57.9	166
2020 Average	56.9	24.4	32.4
2020 Standard Deviation	51.1	13.8	51.1
2020 Maximum	184	66.0	156
2020 Minimum	2.54	2.14	-49.6
2020 Range	181	63.9	205
2019 Average	62.9	27.3	35.7
2019 Standard Deviation	52.2	15.6	52.5
2019 Maximum	174	72.5	156
2019 Minimum	2.20	2.19	-60.0
2019 Range	172	70.3	216
2018 Average	60.6	30.1	30.4
2018 Standard Deviation	57.6	17.6	57.5
2018 Maximum	203	81.4	182
2018 Minimum	2.80	2.20	-60.5
2018 Range	200	79.24	242

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

Well Number	Observed Total Uranium Concentrations 1st Half 2021 (µg/L)	Predicted Total Uranium Concentrations^a April 1, 2021 (µg/L)	Total Uranium Concentration Residuals (µg/L)
2017 Average	68.6	33.6	35.0
2017 Standard Deviation	68.7	20.0	68.2
2017 Maximum	250	91.77	225
2017 Minimum	3.36	2.21	-62.6
2017 Range	247	89.56	288

^a Model predictions based on high water levels.

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

Well Number	Observed Total Uranium Concentrations 1st Half 2021 (µg/L)	Predicted Total Uranium Concentrations April 1, 2021^b (µg/L)	Total Uranium Concentration Residuals (µg/L)
2045	59.8	13.0	46.8
2046	14.3	18.8	-4.52
2049	12.7	17.0	-4.30
2093	3.66	2.11	1.55
2385	30.3	60.0	-29.7
2821	10.4	17.58	-7.18
23271	47.1	21.38	25.72
23274	74.4	32.06	42.34
23275	82.9	28.46	54.4
23276	91.6	41.57	50.0
23278	21.1	36.99	-15.9
23280	23.1	27.63	4.53
82433_C2	3.19	7.46	-4.27
83117_C2	24.6	22.43	2.17
83124_C2	23.1	24.55	-1.45
83293_C2	2.49	4.63	-2.14
83295_C2	73.9	19.57	54.33
83296_C2	24.7	13.96	10.74
2021 Average	34.6	22.7	11.9
2021 Standard Deviation	29.3	14.0	26.5
2021 Maximum	91.6	60.0	54.4
2021 Minimum	2.49	2.11	-29.7
2021 Range	89.1	57.9	84.2
2020 Average	34.8	24.9	9.97
2020 Standard Deviation	28.5	15.6	27.3
2020 Maximum	88.3	66.0	62.9
2020 Minimum	2.54	2.14	-49.6
2020 Range	85.8	63.9	112
2019 Average	40.8	27.4	13.5
2019 Standard Deviation	31.2	17.6	30.0
2019 Maximum	106	72.5	55.2
2019 Minimum	2.20	2.19	-60.0
2019 Range	104	70.3	115.2
2018 Average	38.45	30.20	8.24
2018 Standard Deviation	30.90	19.22	29.54
2018 Maximum	110	81.44	58.56
2018 Minimum	2.80	2.20	-60.54
2018 Range	107.20	79.24	119.10

Table A.1-27. Comparison of Model-Predicted Versus Actual Total Uranium Concentrations with Select Wells Removed^a (continued)

Well Number	Observed Total Uranium Concentrations 1st Half 2021 (µg/L)	Predicted Total Uranium Concentrations April 1, 2021^b (µg/L)	Total Uranium Concentration Residuals (µg/L)
2017 Average	42.0	33.85	8.15
2017 Standard Deviation	32.9	21.89	30.48
2017 Maximum	120	91.77	61.7
2017 Minimum	3.36	2.21	-62.6
2017 Range	117	89.56	124

^a Data from monitoring wells 2386, 2387, 23273, 23275, 23281, and 83294_C2 are not presented.

^b Model predictions based on high water levels.

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

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

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

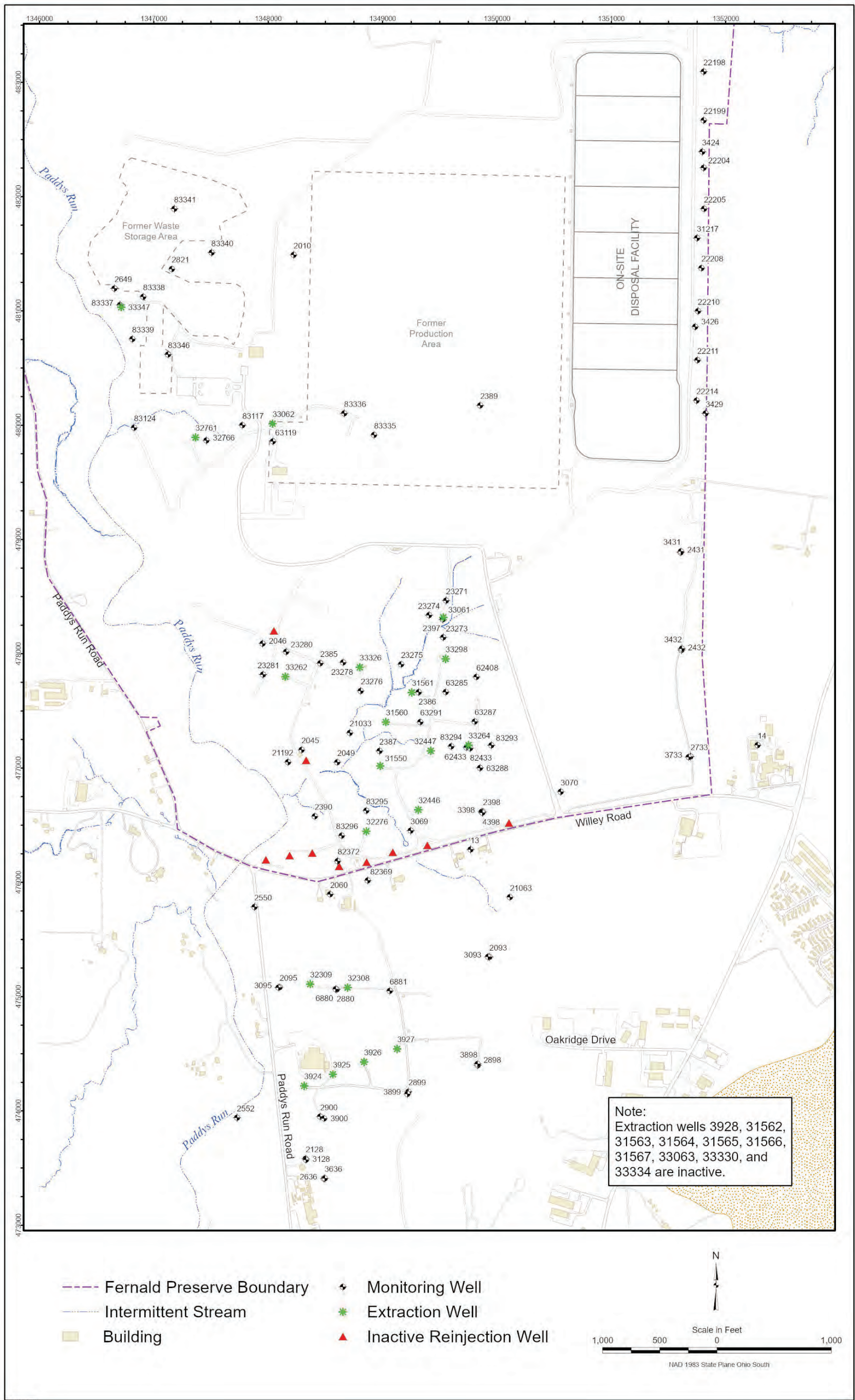


Figure A.1-1. Well Locations for South Plume, South Field, Waste Storage Area, and PRRS Monitoring Activities

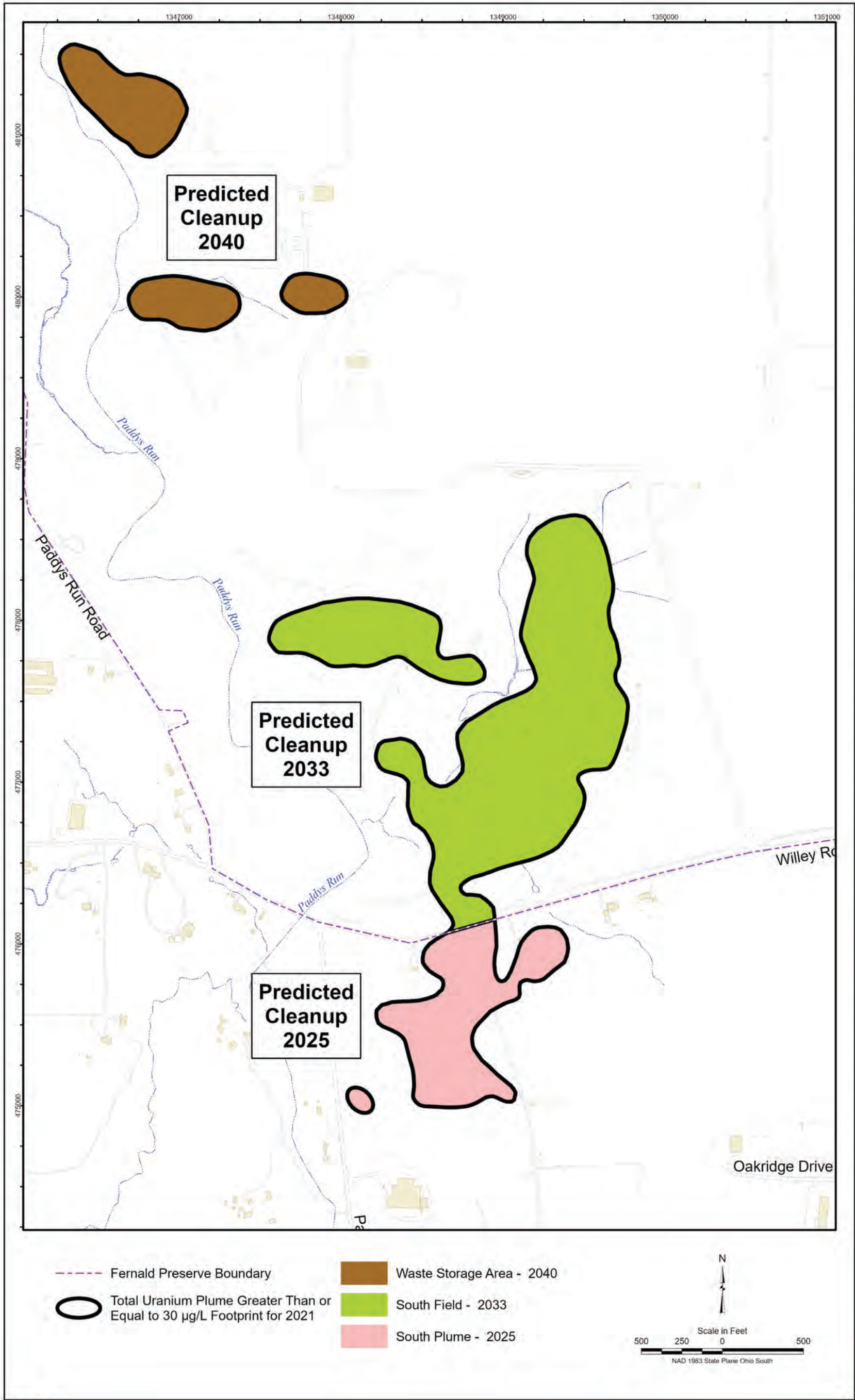


Figure A.1-2. Operational Design

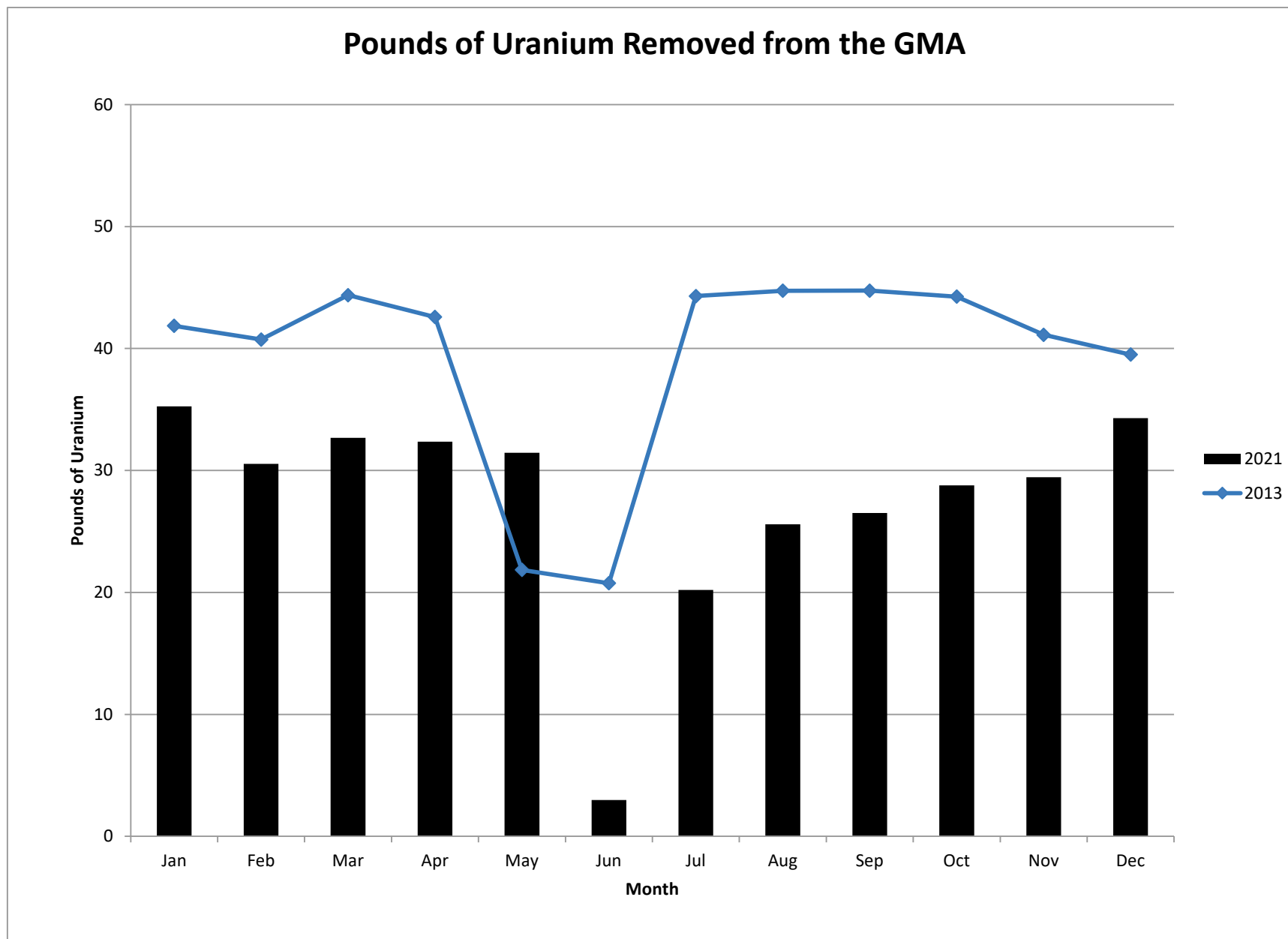


Figure A.1-3. Pounds of Uranium Removed from the Great Miami Aquifer



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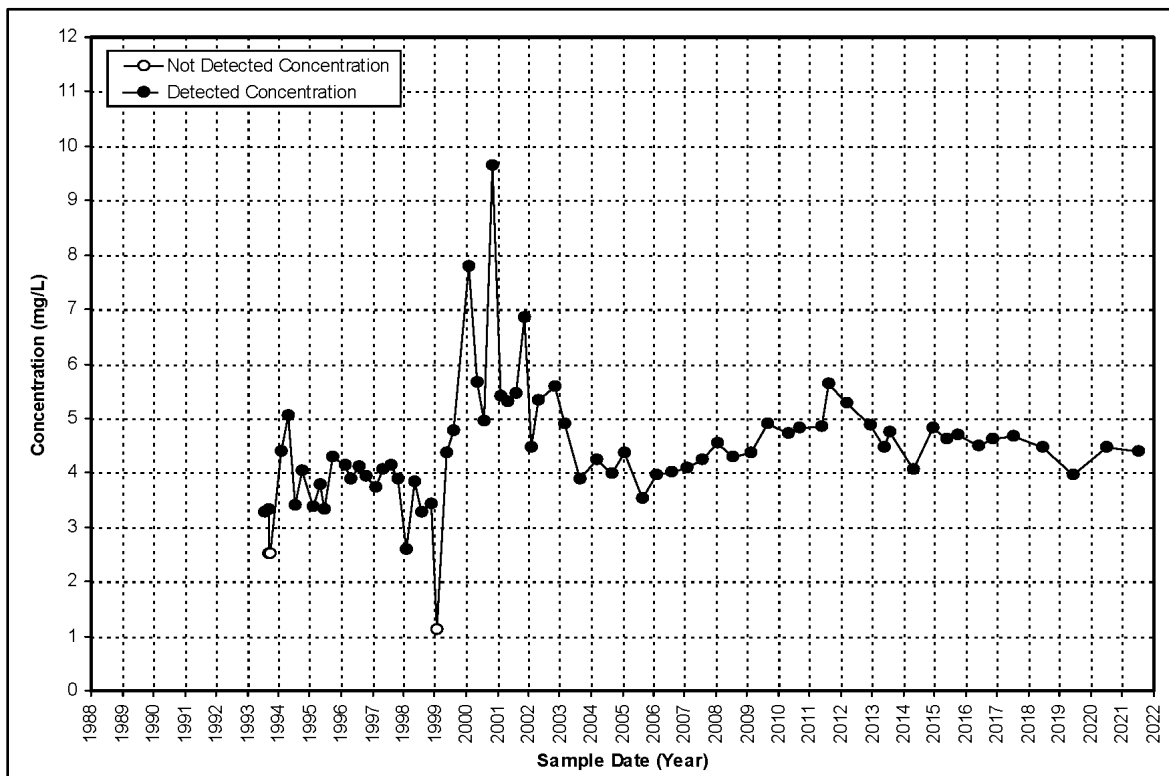


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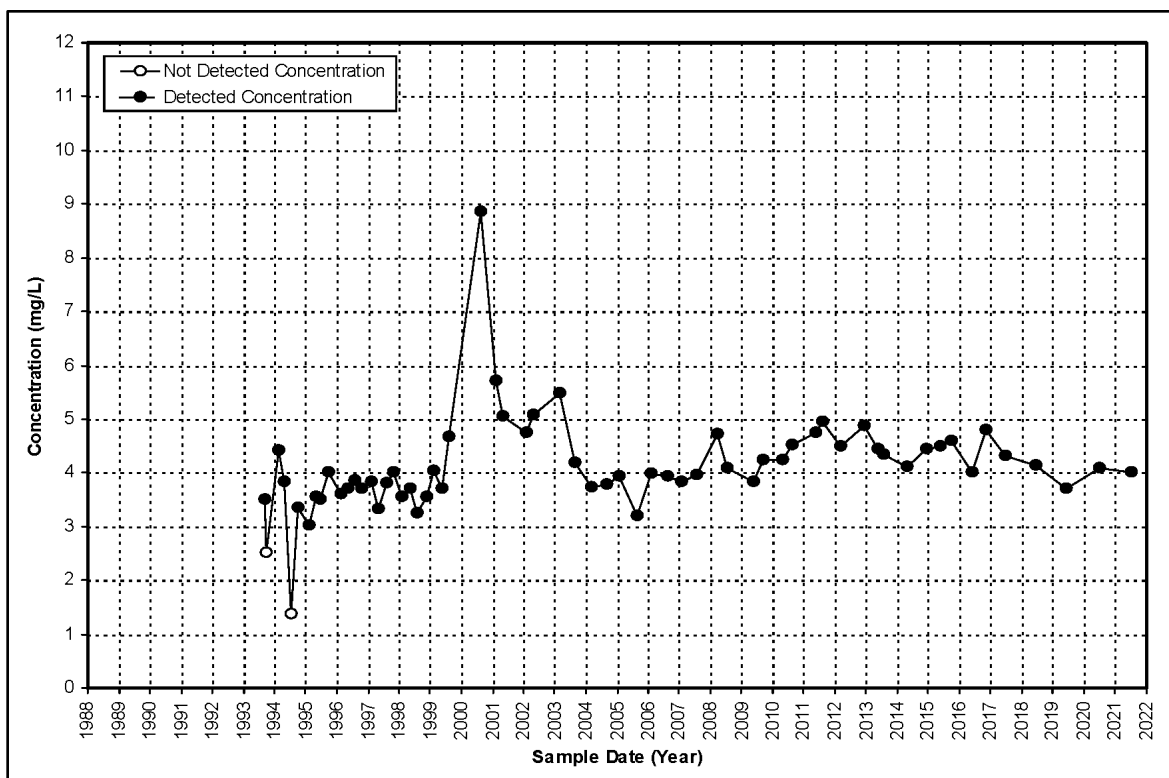


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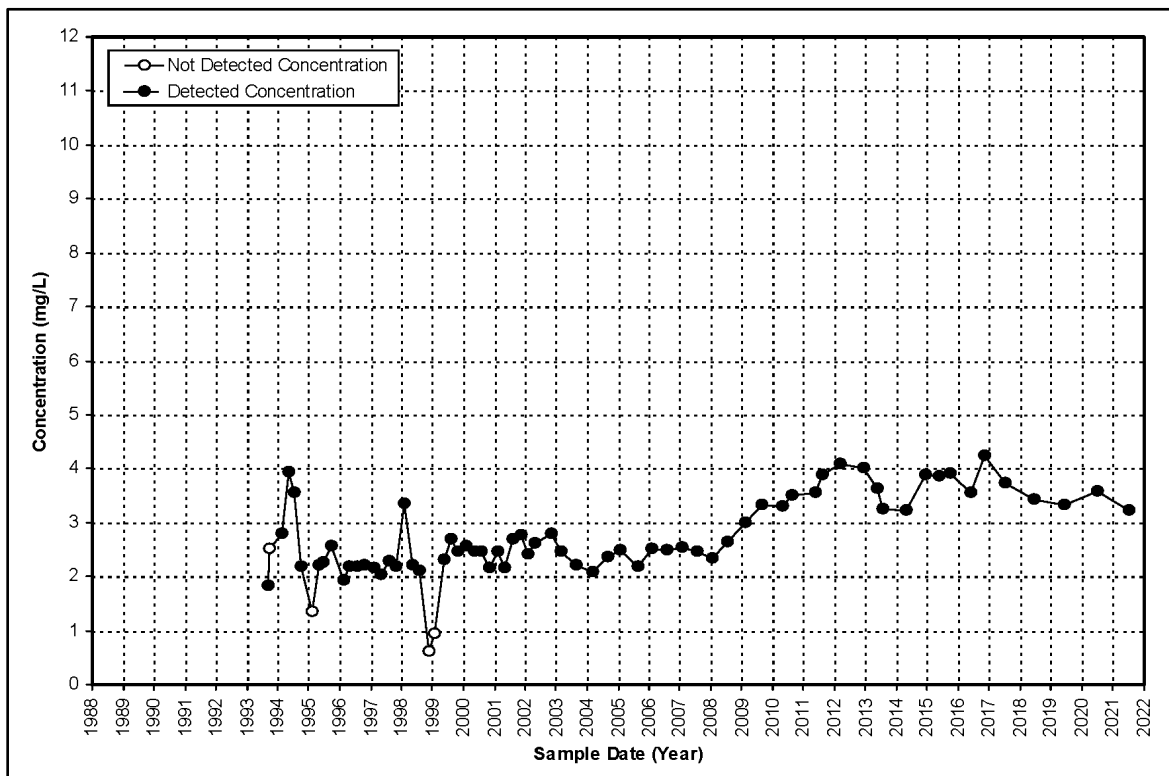


Figure A.1-7. Potassium Concentration Versus Time Plot for Monitoring Well 3898

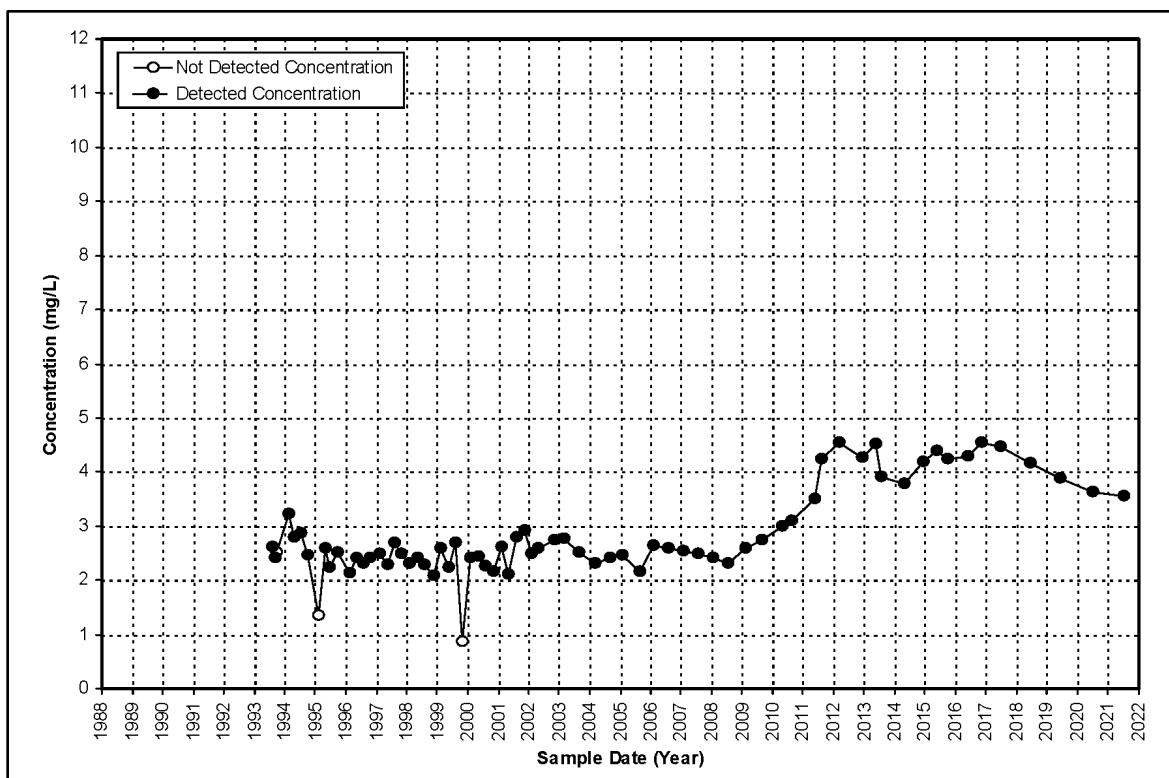


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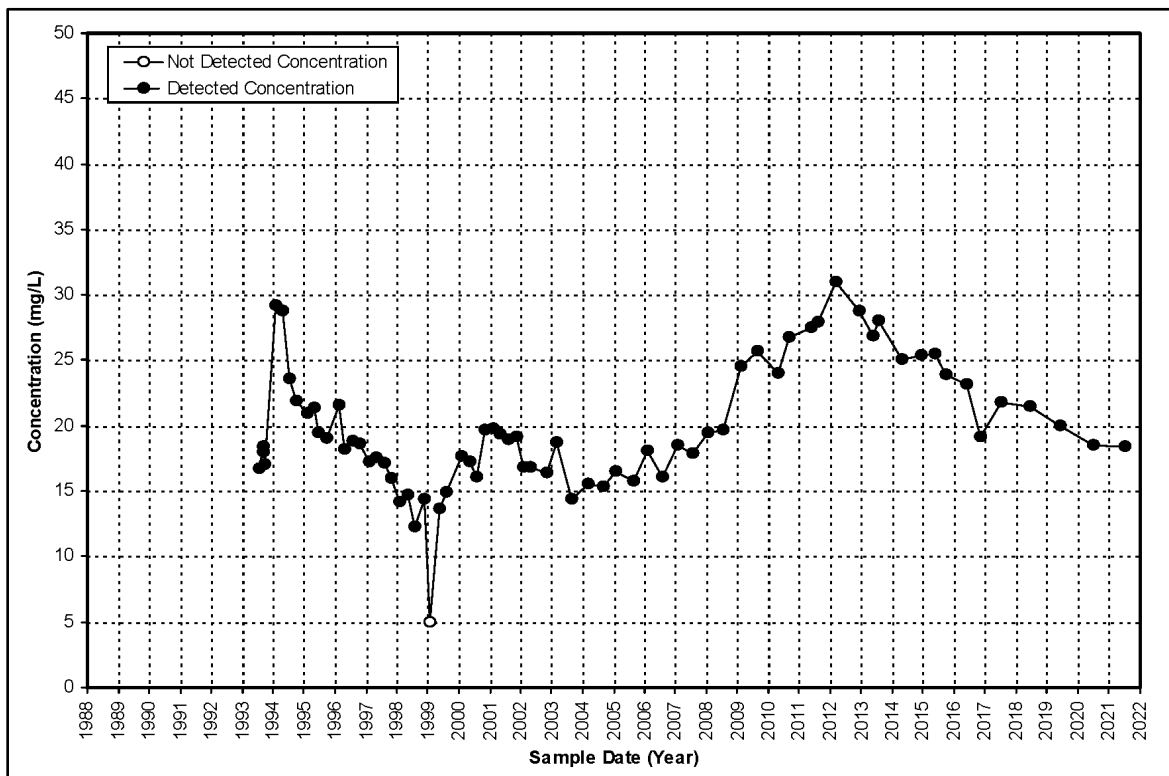


Figure A.1-9. Sodium Concentration Versus Time Plot for Monitoring Well 2898

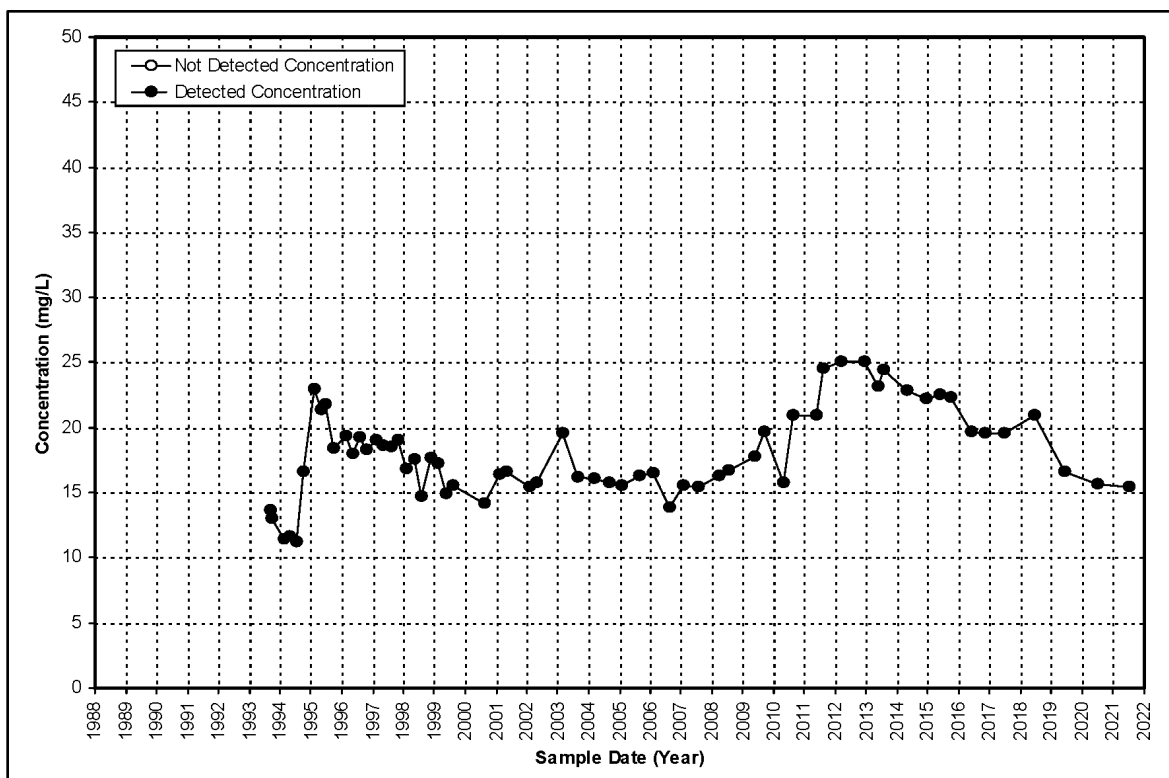


Figure A.1-10. Sodium Concentration Versus Time Plot for Monitoring Well 2899

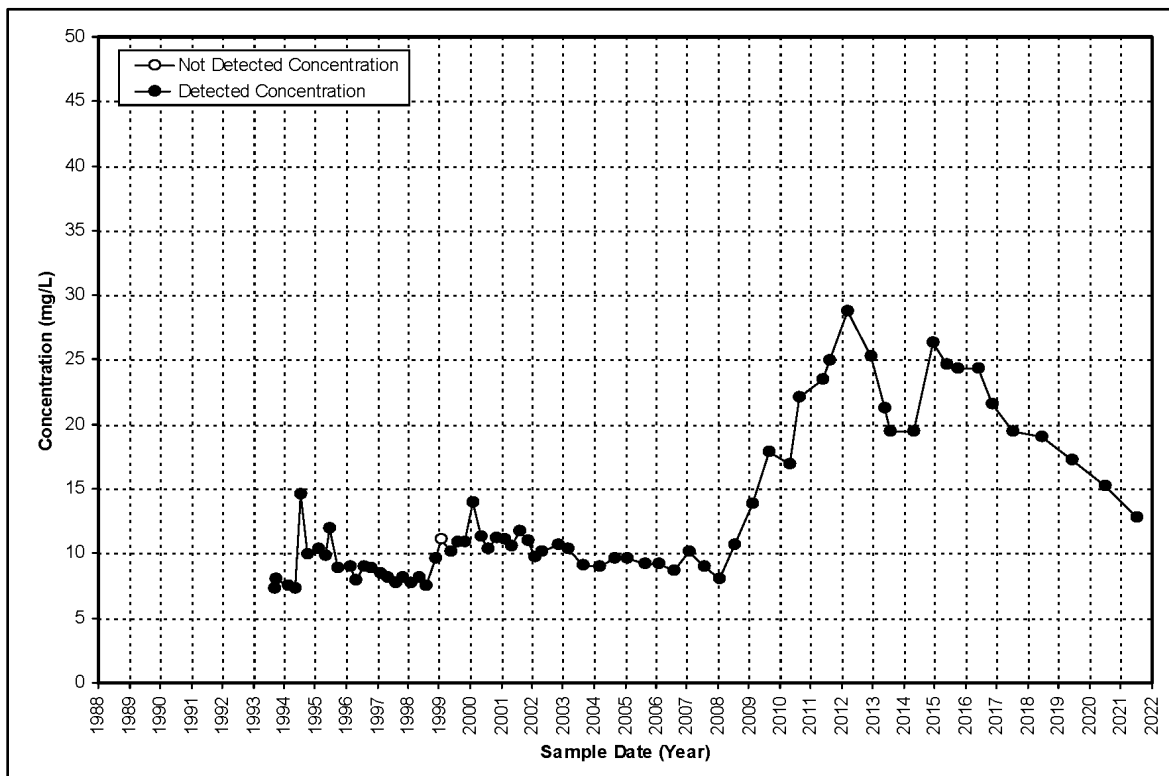


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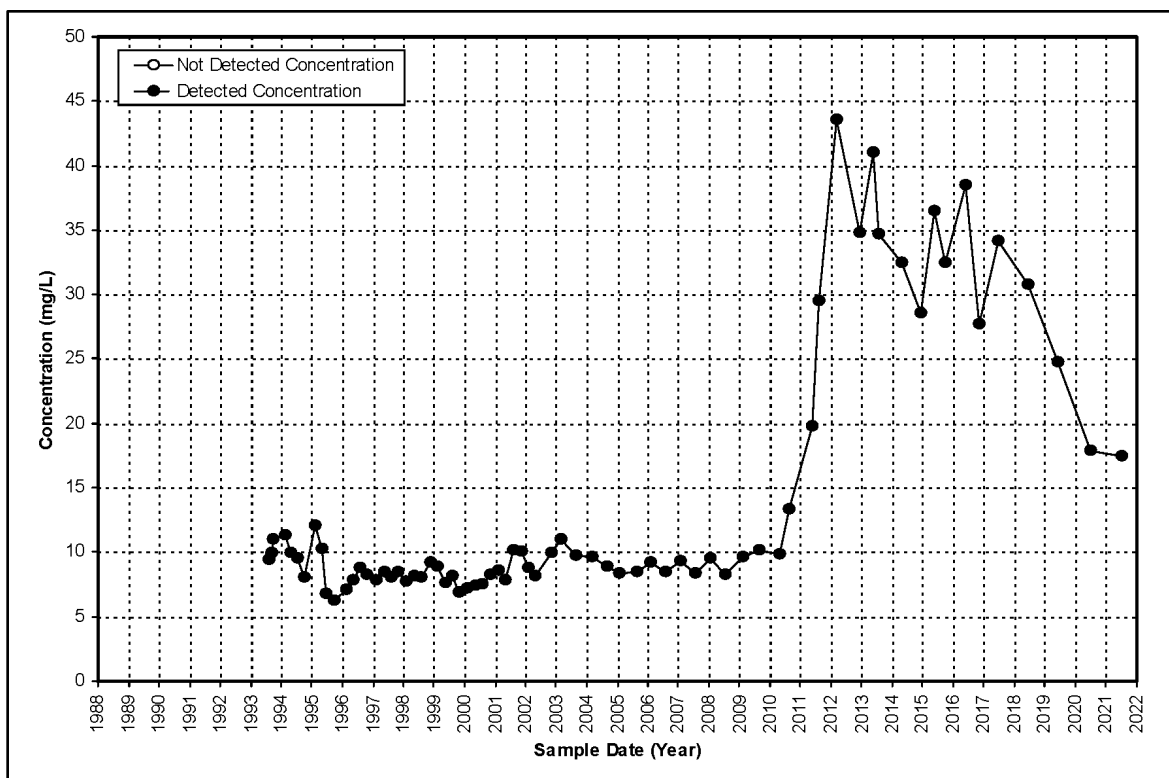


Figure A.1-12. Sodium Concentration Versus Time Plot for Monitoring Well 3899

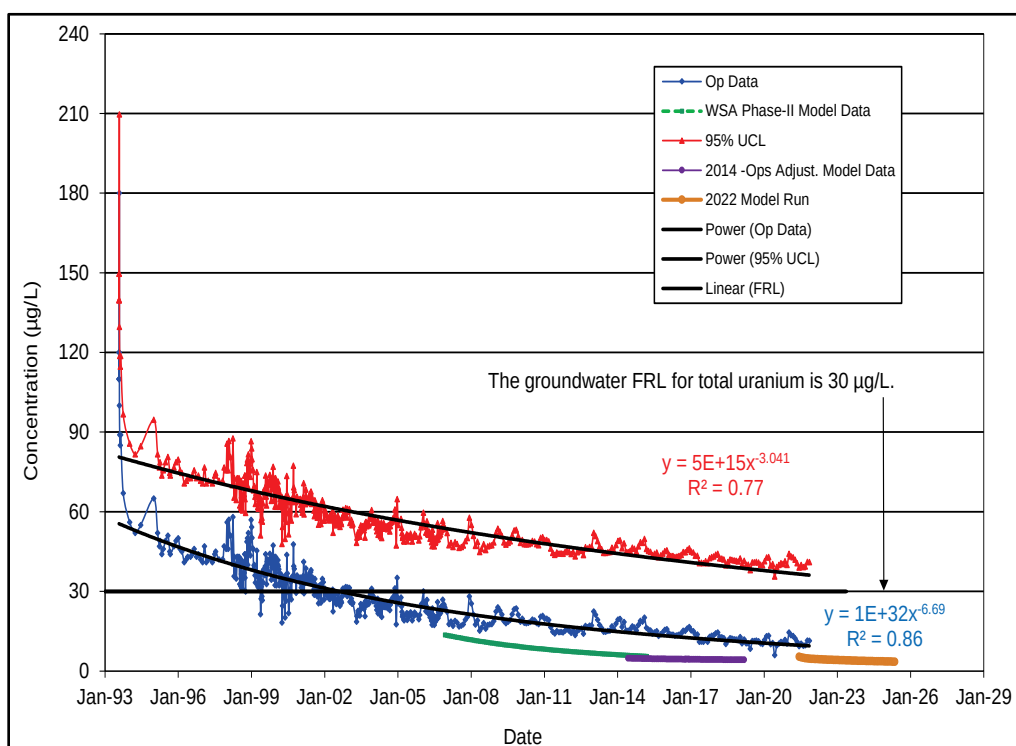


Figure A.1-13. Total Uranium Concentration Versus Time Plot for Extraction Well 3924 (RW-1) with Regression Analysis

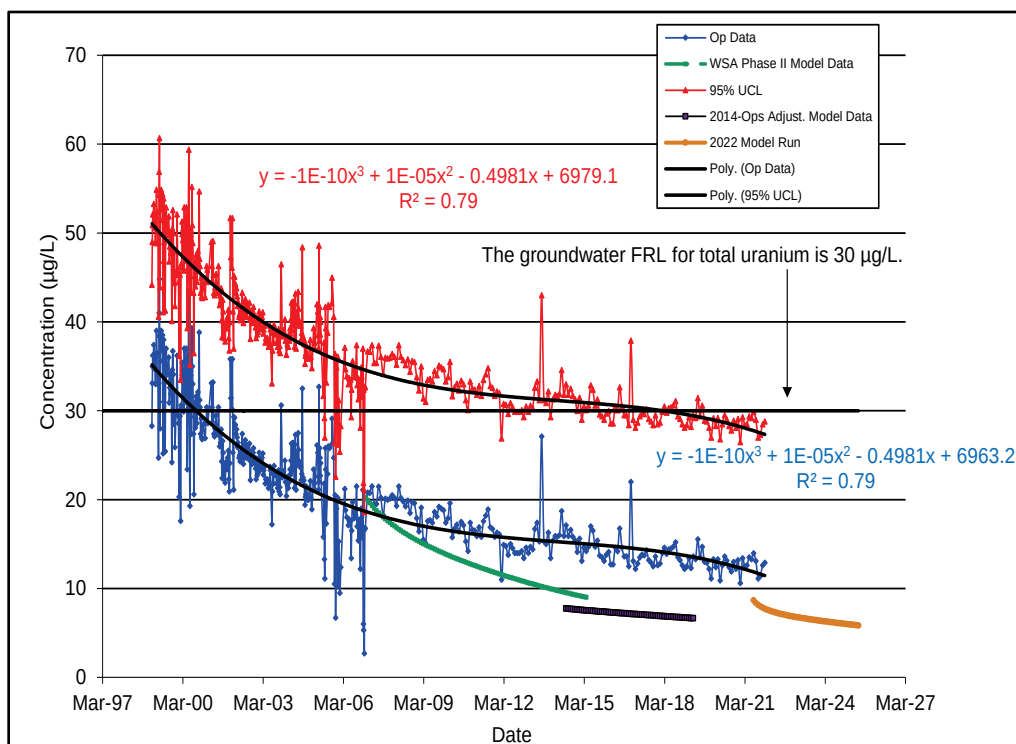


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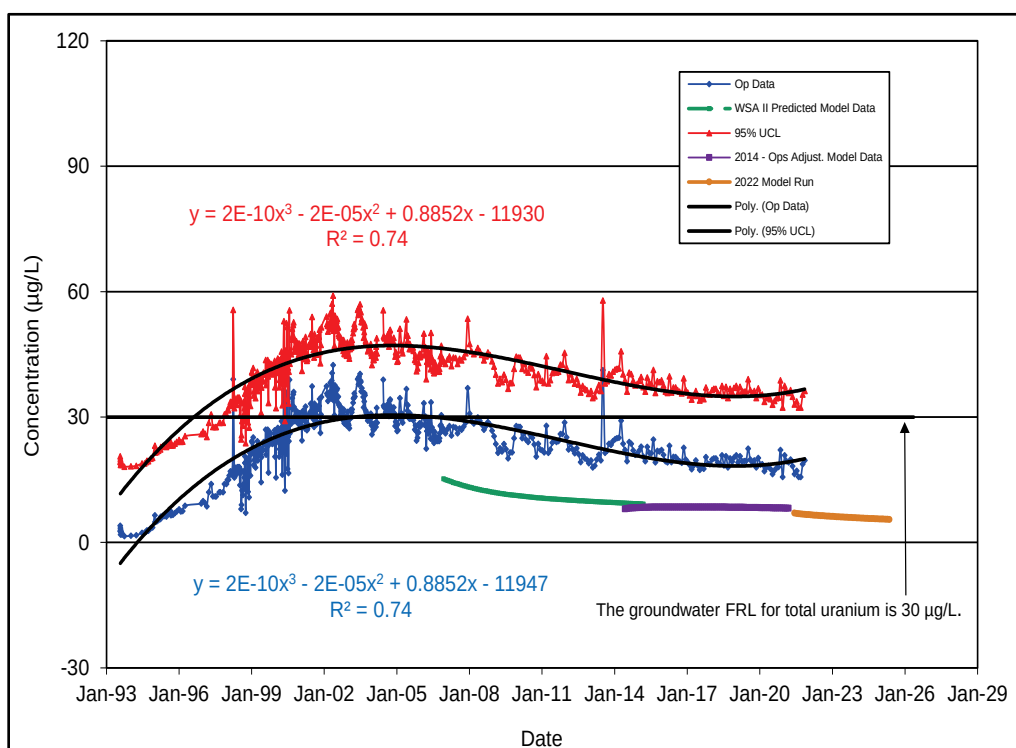


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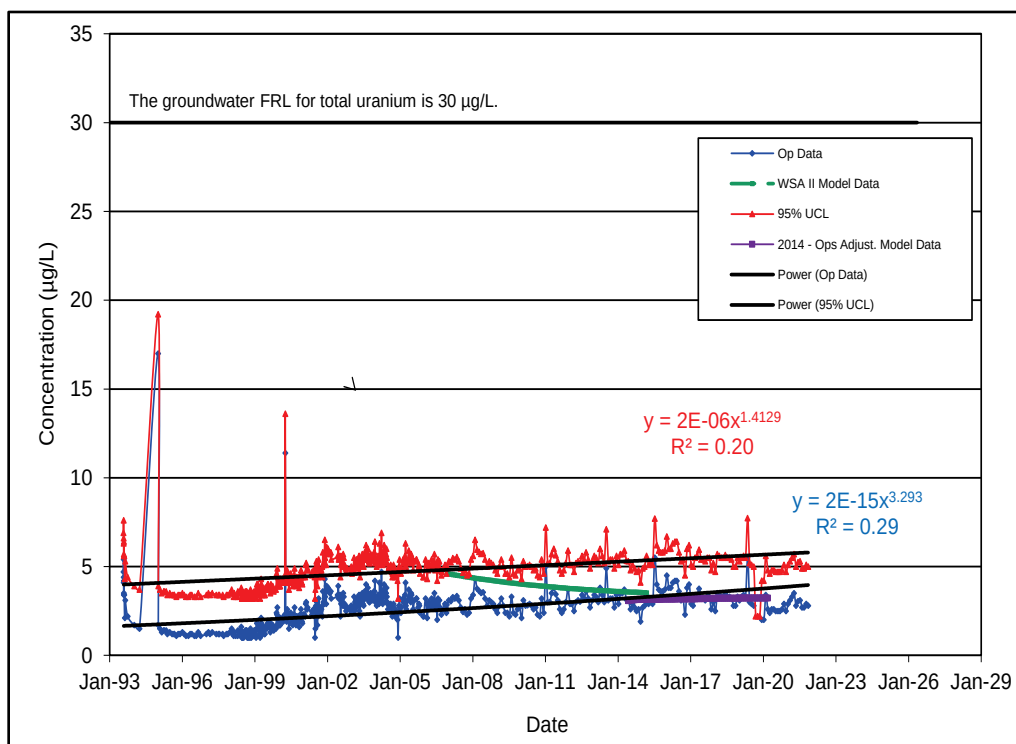


Figure A.1-16. Total Uranium Concentration Versus Time Plot for Extraction Well 3927 (RW-4) with Regression Analysis

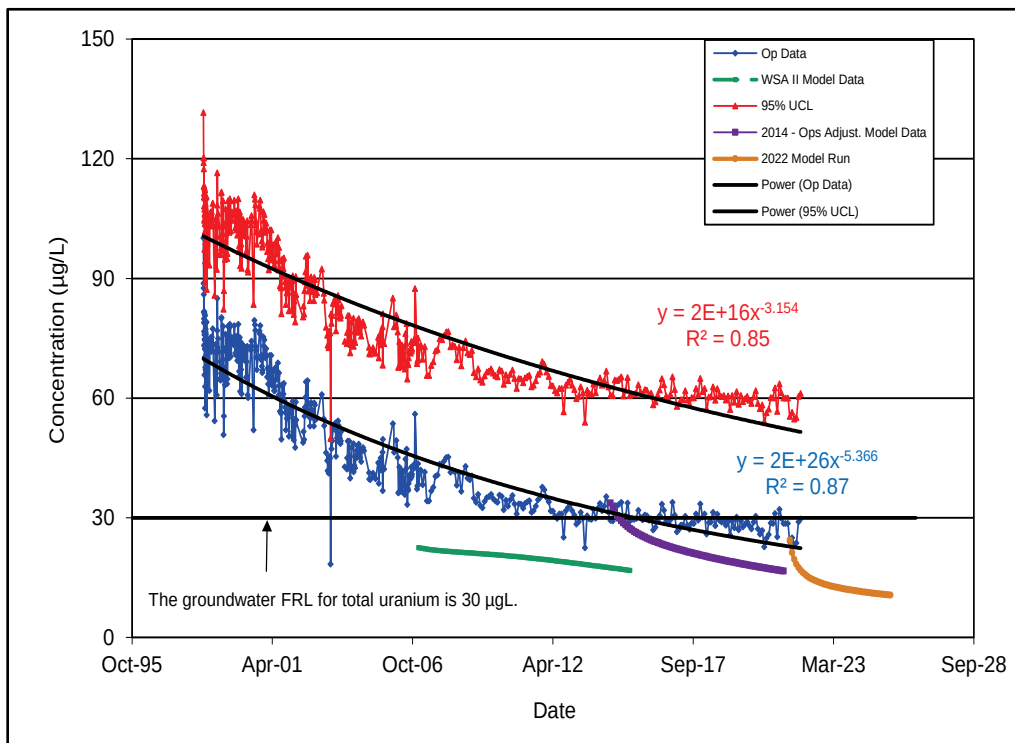


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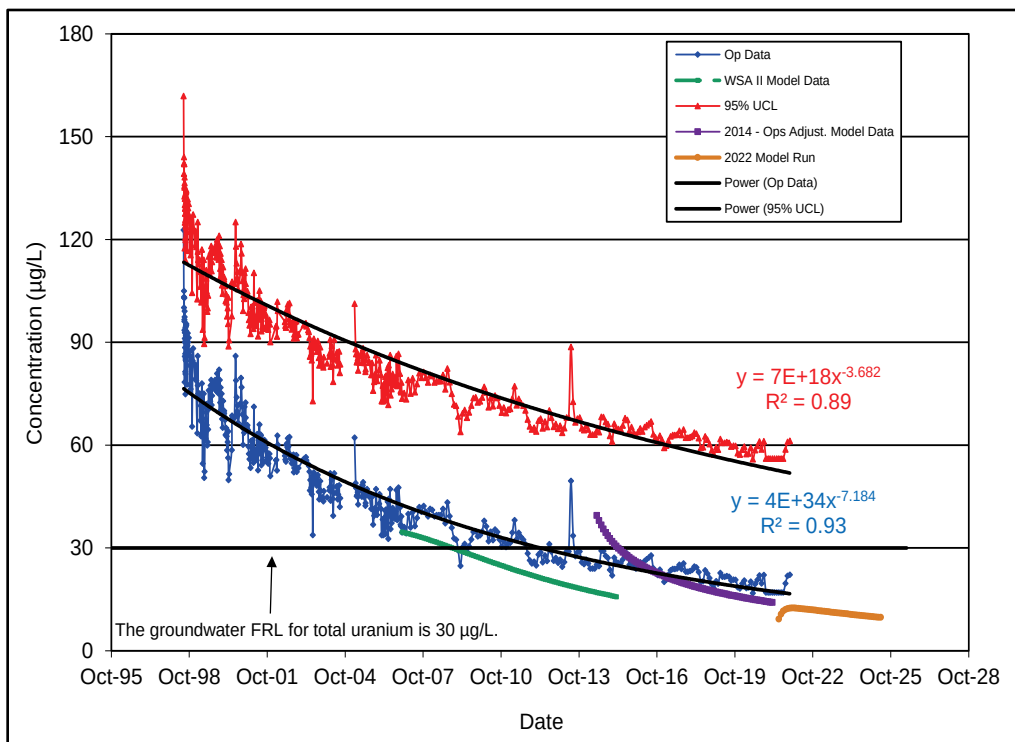


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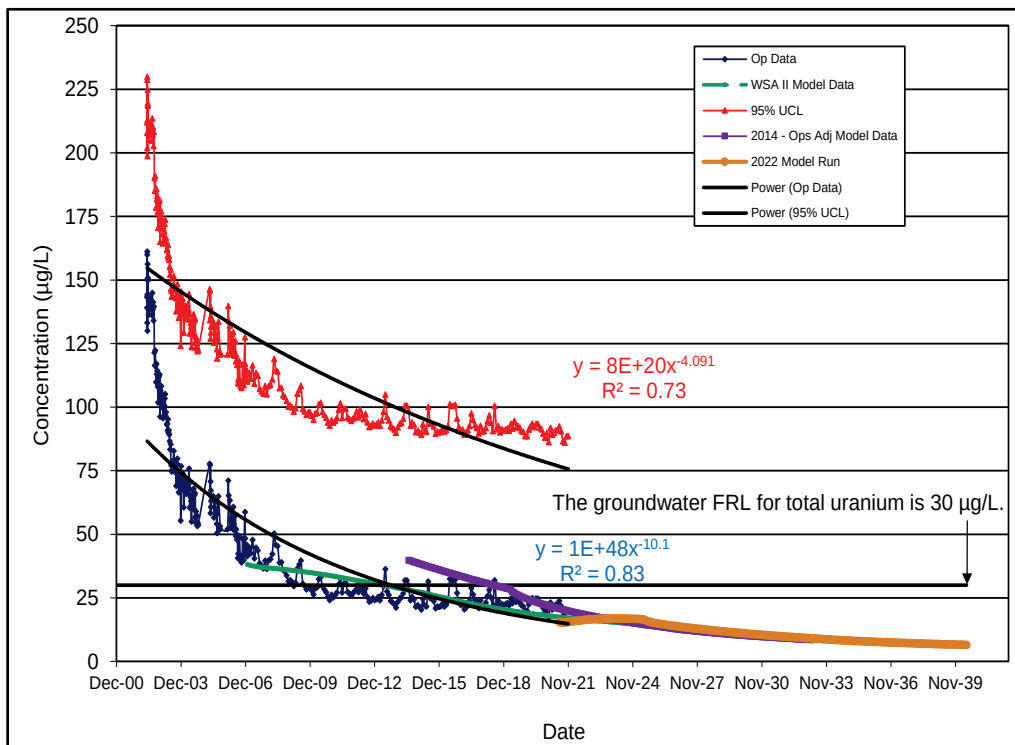


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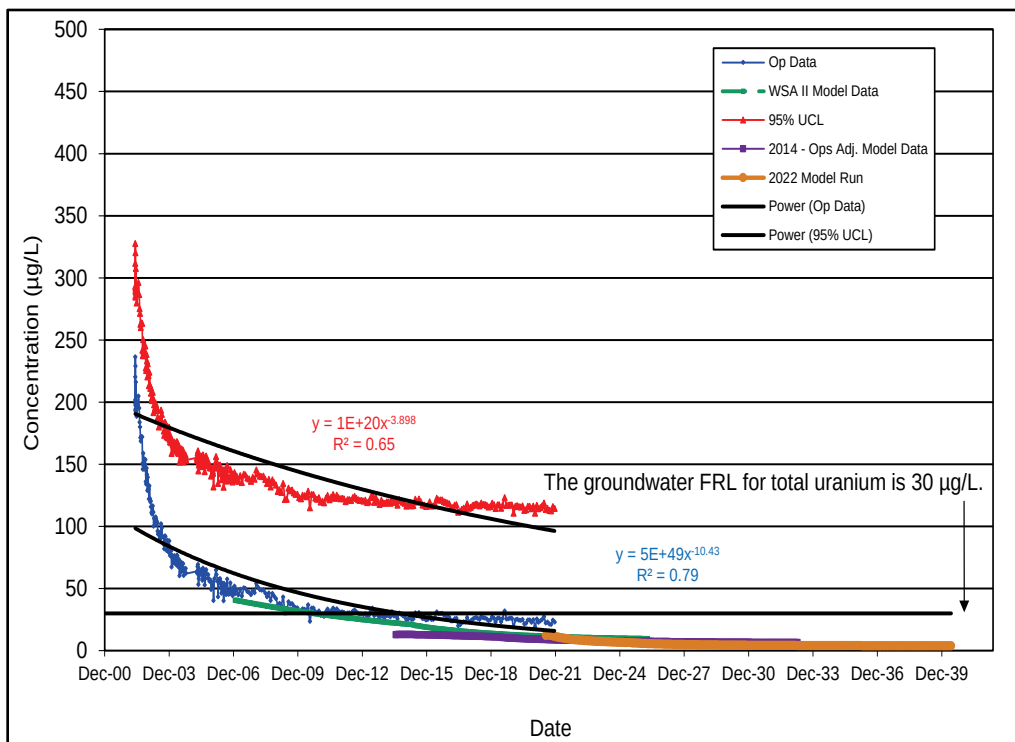


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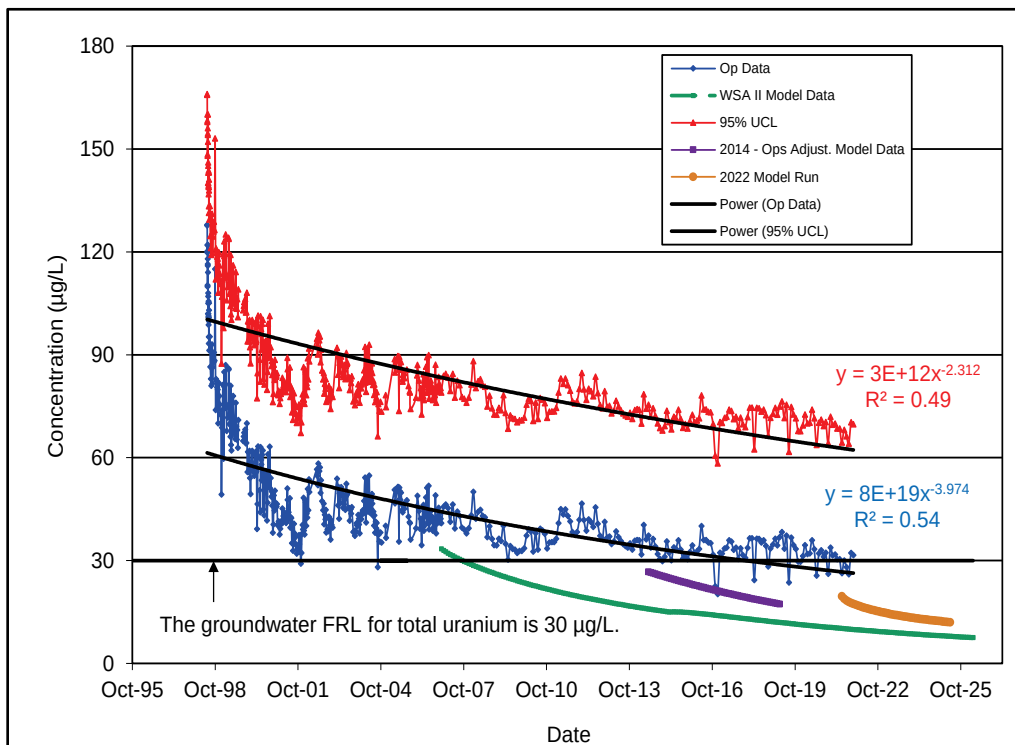


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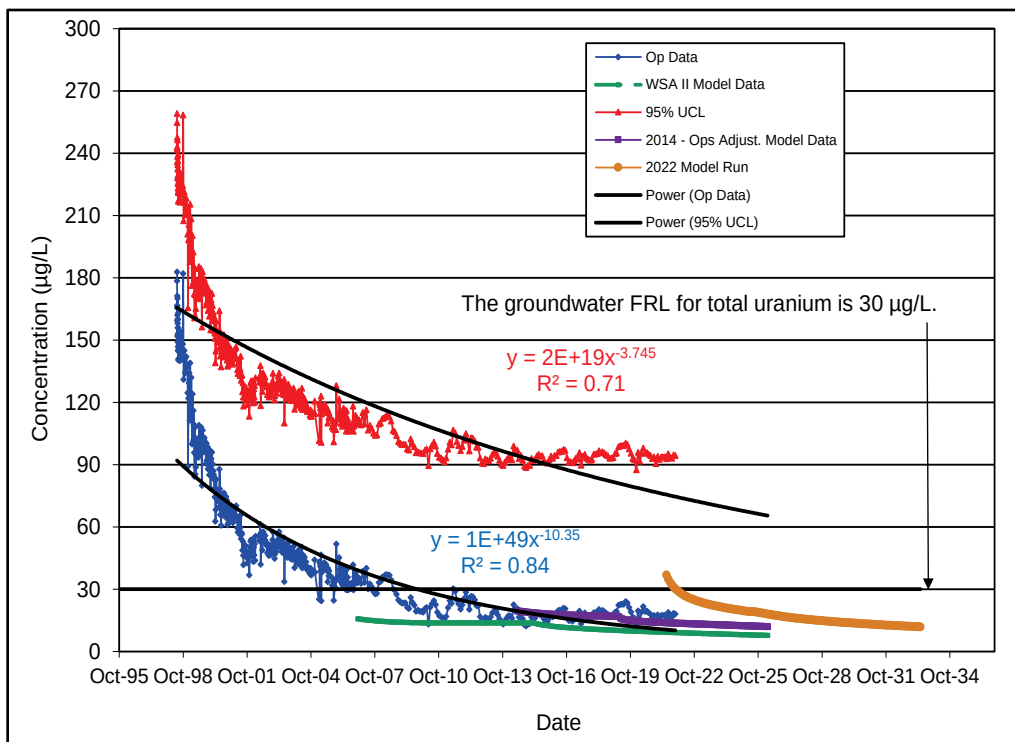


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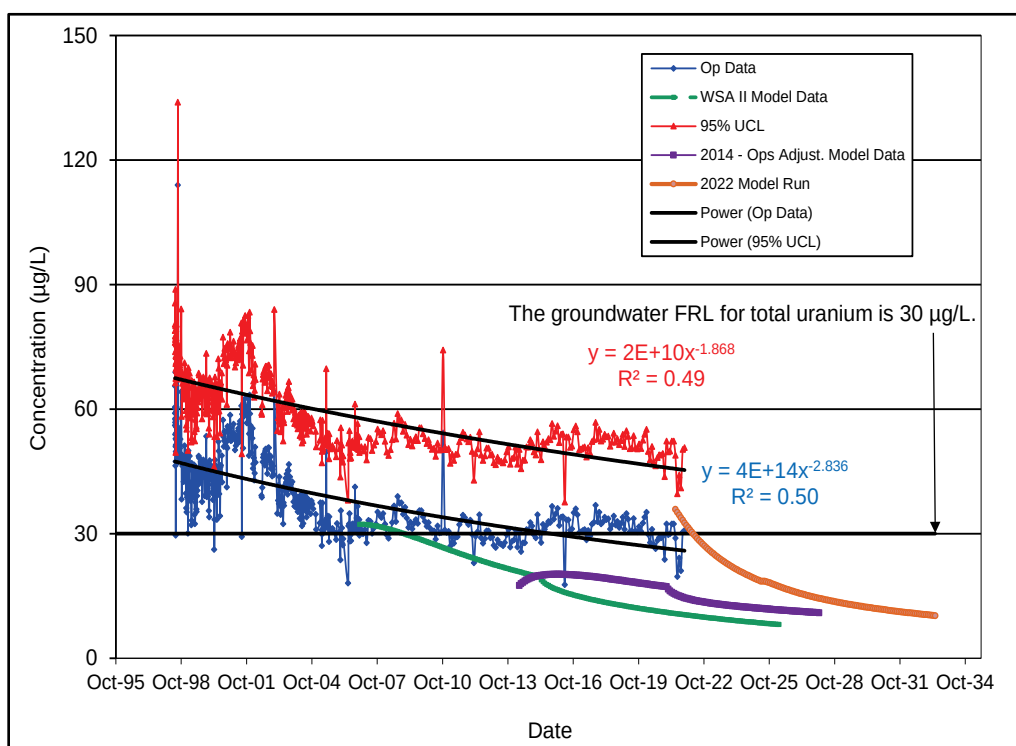


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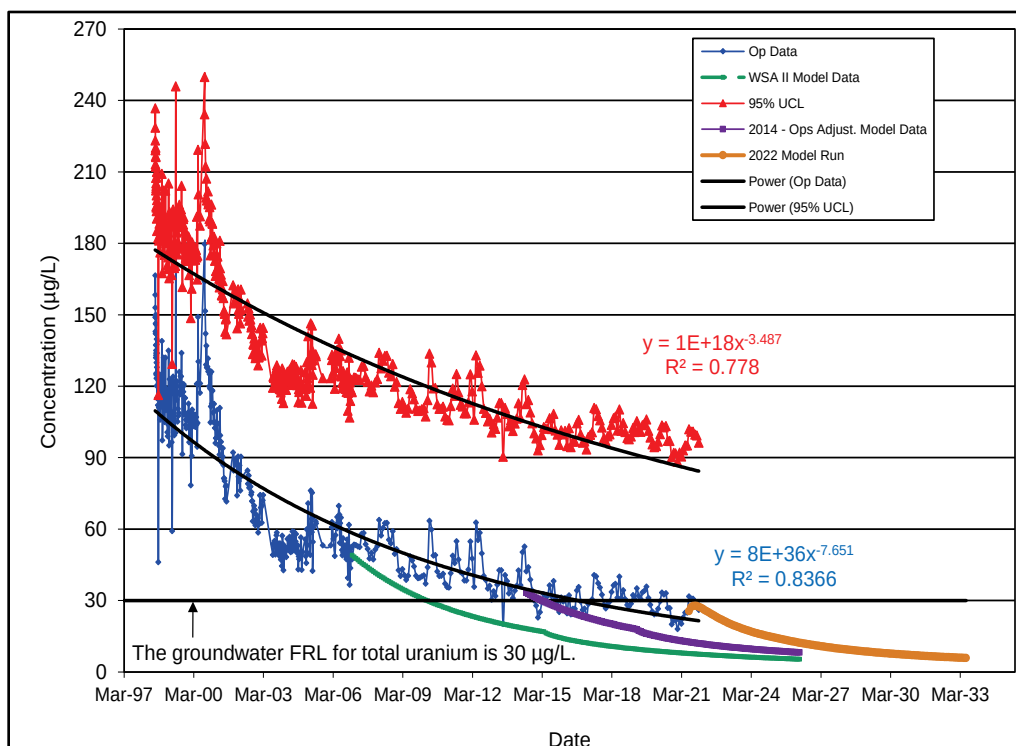


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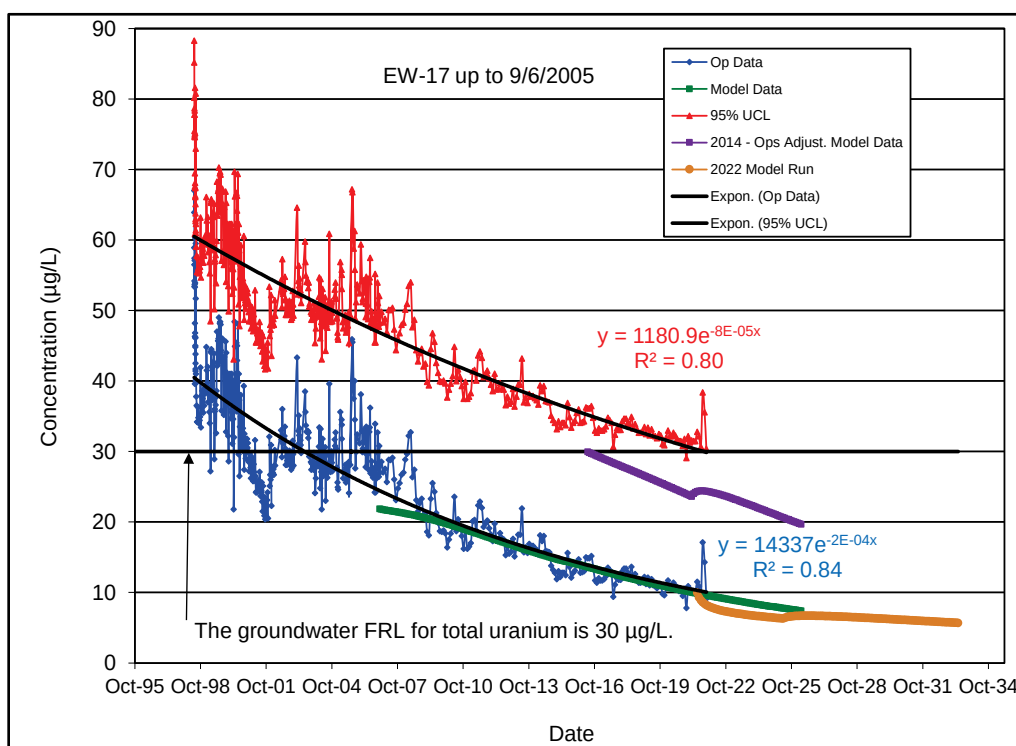


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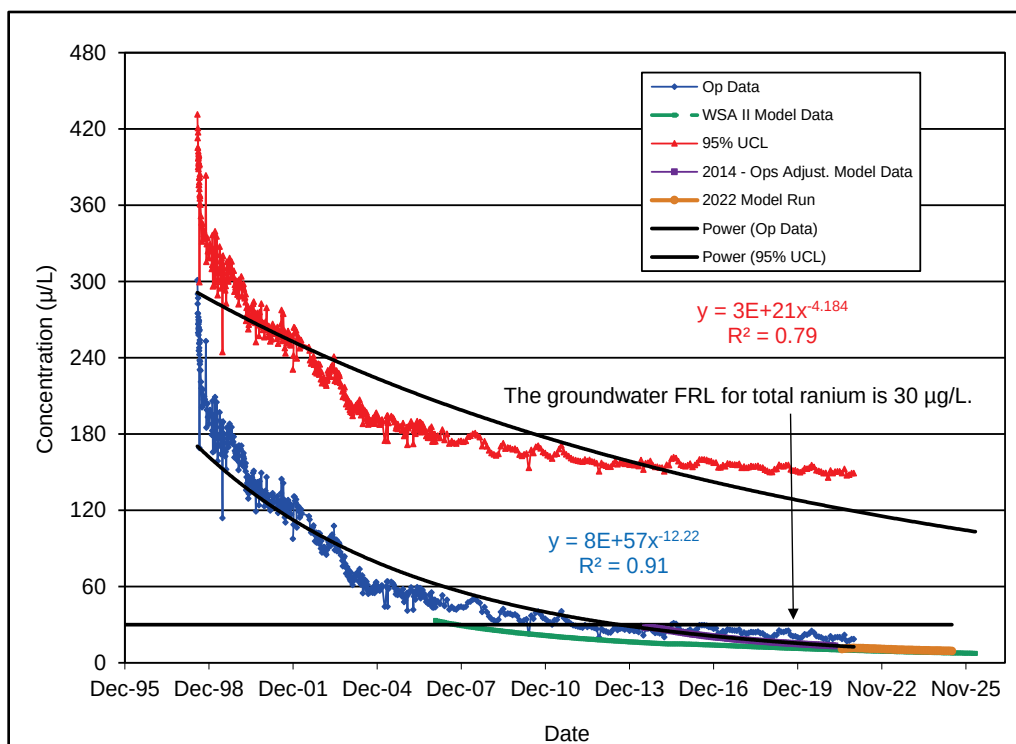


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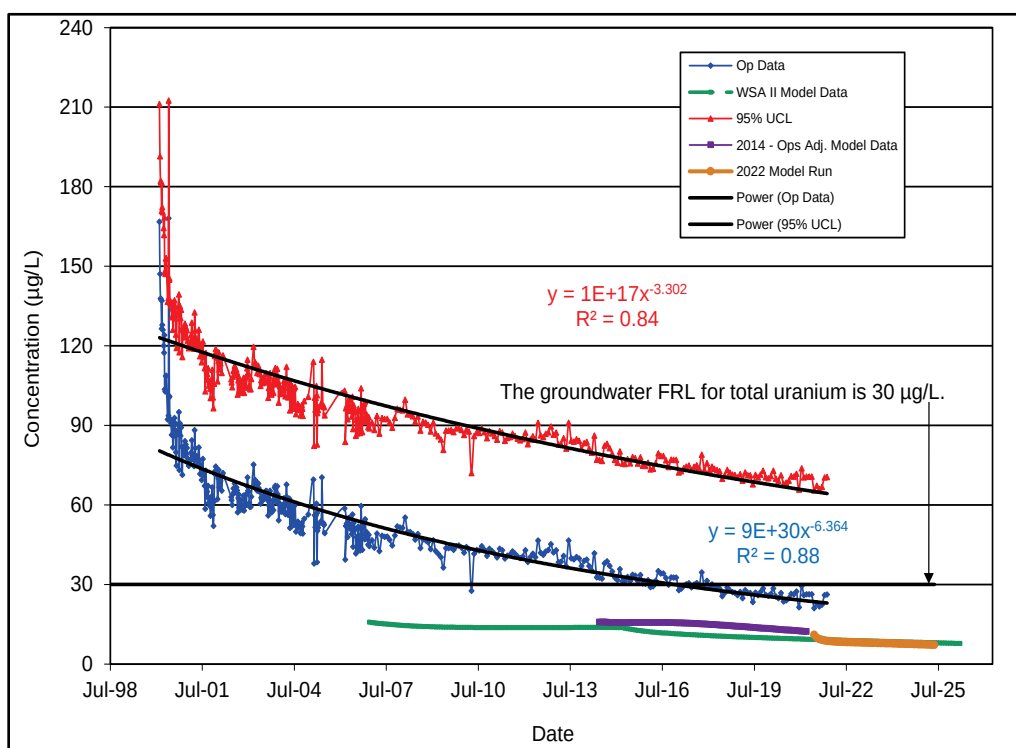


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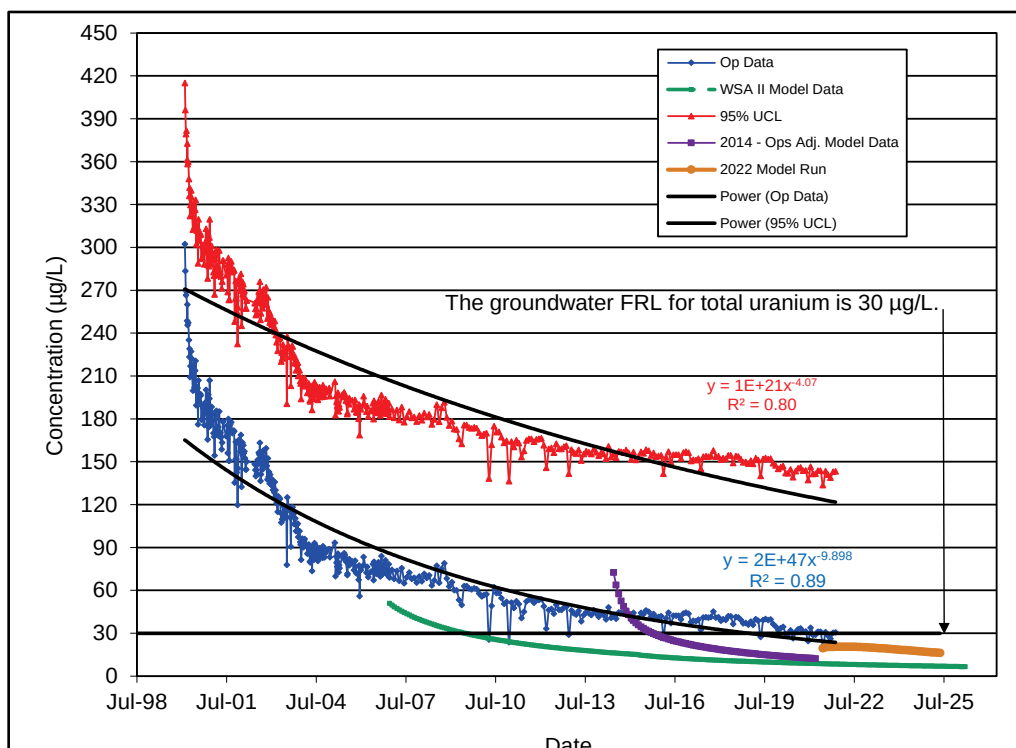


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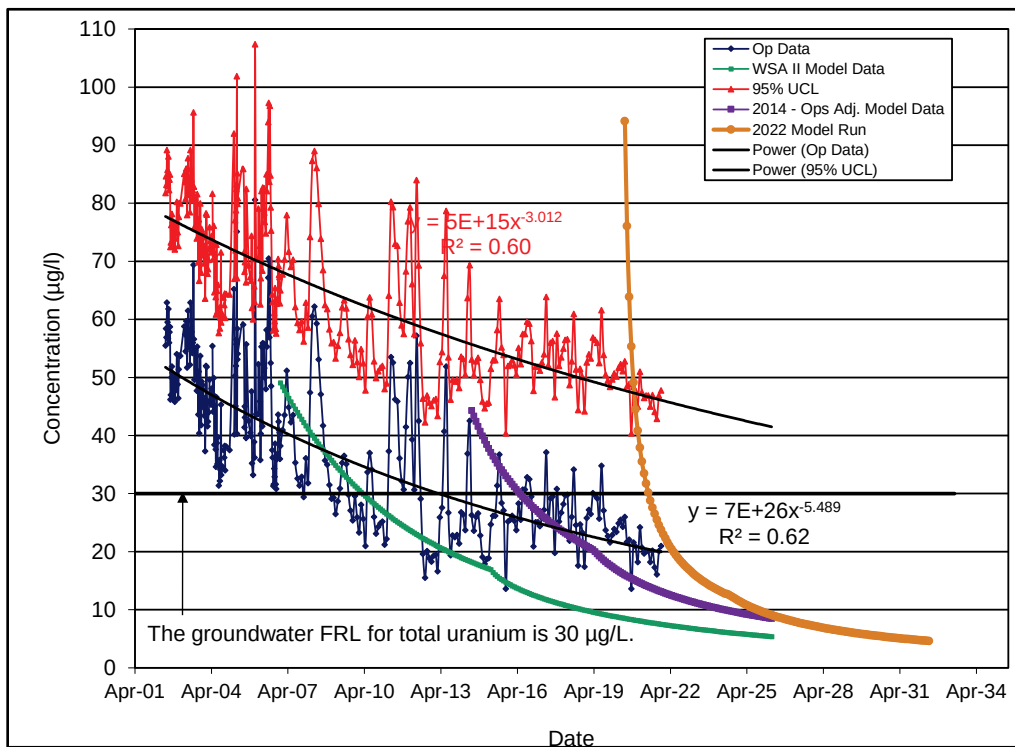


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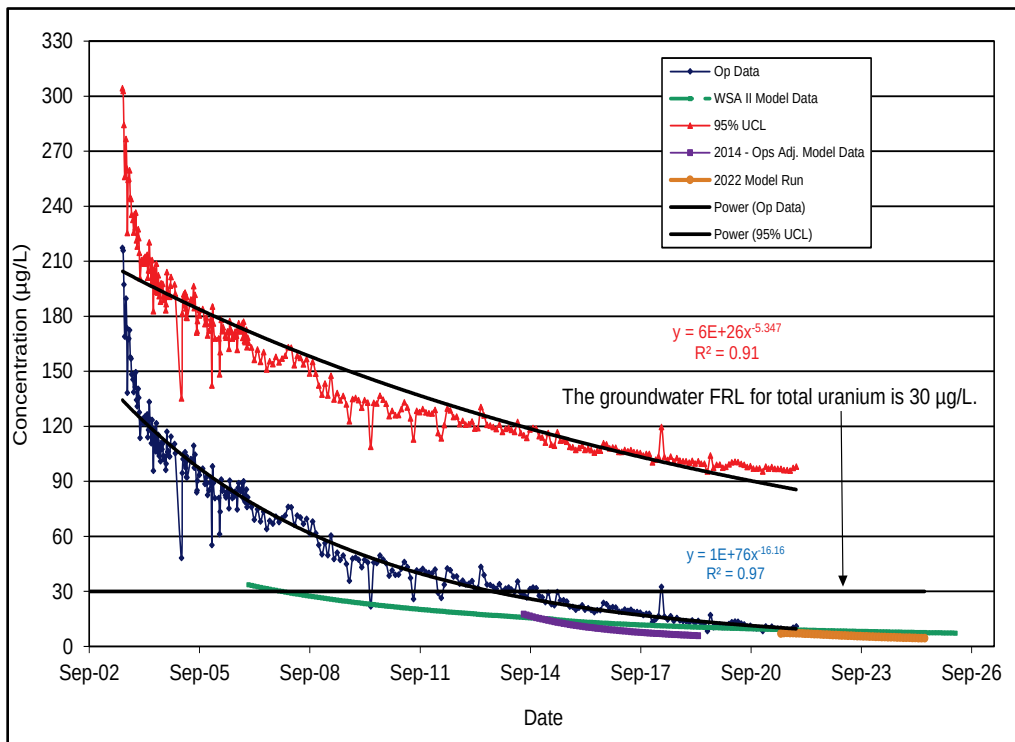


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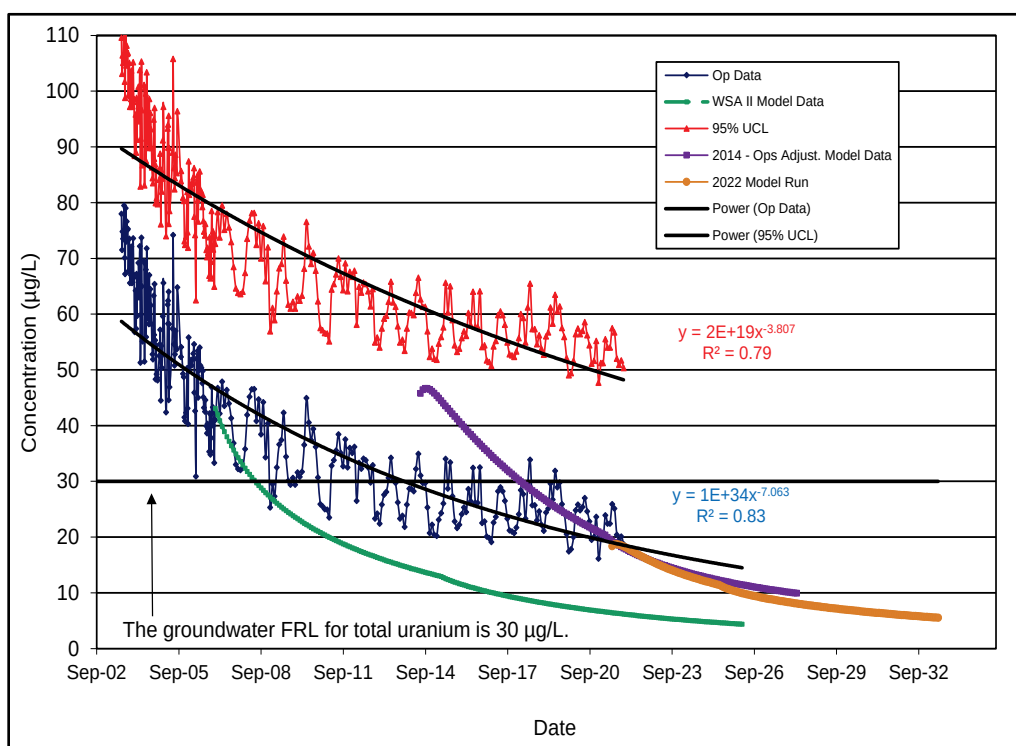


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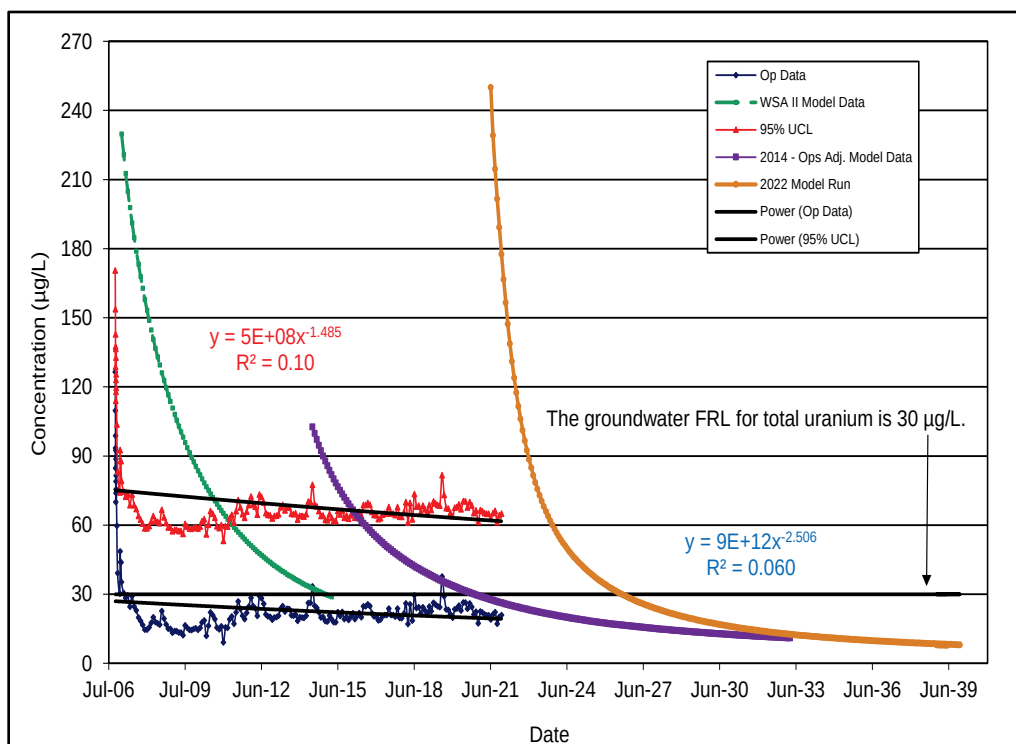


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**Estimate of Yearly Pounds of Uranium to be Pumped from Aquifer
(Model Predictions versus Measured Concentration Trends
Data Collected Through 2021)**

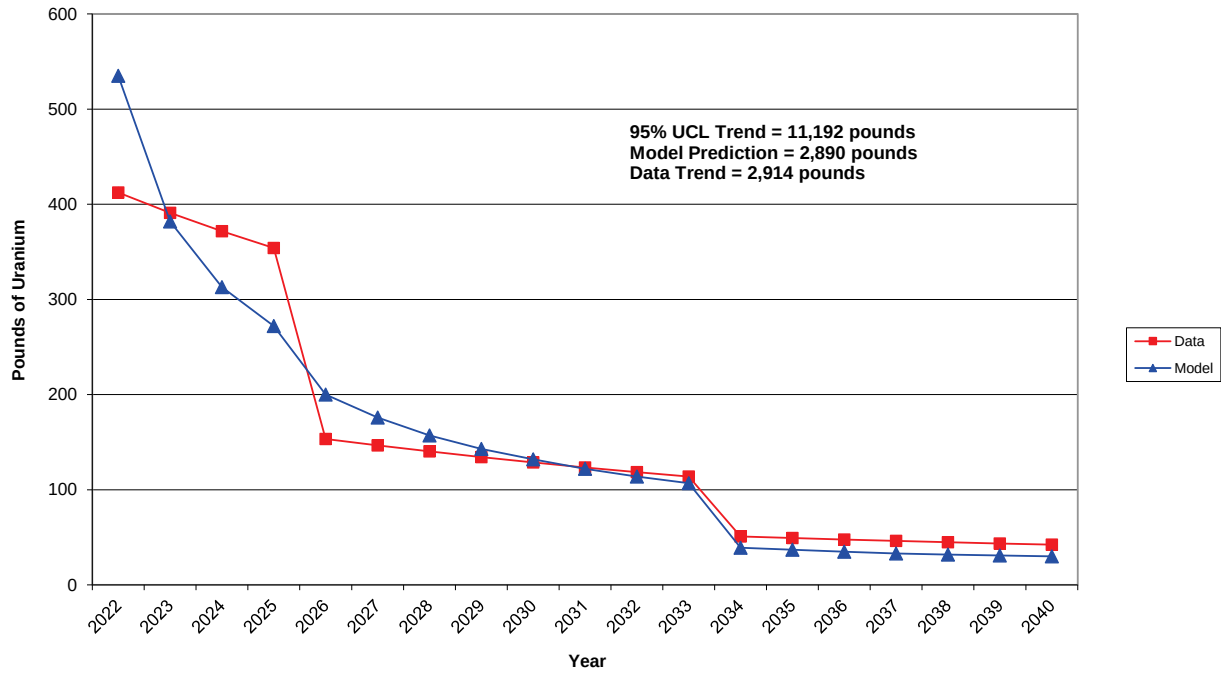


*Figure A.1-33. Estimate of Yearly Pounds of Uranium to Be Pumped from Aquifer to Achieve
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Abbreviations

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
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
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 2021, 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 will be restored through extraction methods.” Uranium is the primary constituent of concern for groundwater. The groundwater final remediation level (FRL) for total uranium is 30 micrograms per liter (µg/L). The background total uranium concentration for unfiltered groundwater samples from the Great Miami Aquifer near the Fernald Preserve is 1.2 µg/L. This background value is based on the 95th percentile of unfiltered samples (*Remedial Investigation Report for Operable Unit 5* [DOE 1995], Section 4, Table 4-8). Both the area of the aquifer targeted for remediation and the statistical procedures that will be used to verify that aquifer cleanup objectives have been achieved are described in the *Fernald Groundwater Certification Plan* (DOE 2006).

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

In addition to the routine well monitoring specified in the IEMP, 27 locations were sampled using a direct-push sampling tool (Geoprobe) in 2021. Direct-push sampling results for the 27 locations (13513B, 13267C, 13240G, 13519A, 13536, 13541, 13425E, 13526A, 13477D, 13535, 13421J, 13537, 13538, 13539, 13540, 13543, 13542, 13532, 13534, 13509B, 13533, 13531, 13514A, 13530, 13529, 12842C, and 13528) are presented in Tables A.2-1 through A.2-27.

Direct-push sampling locations are often sampled several times over the course of the remediation. When a direct-push location is resampled, the convention is to identify the new sample with the same location number but with an alphabetic 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 2021. Figure A.2-2 shows direct-push data. Figure A.2-3 shows monitoring well and extraction well data. Data collected from the aquifer are used to progressively update the maximum total uranium plume maps in the following conservative manner:

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

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

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

Table A.2-28 lists the monitoring wells where total uranium concentrations exceeded the 30 µg/L FRL during 2021. Included in the table are total uranium statistical summaries for each well, which include Mann-Kendall trend analyses. Table A.2-29 provides total uranium statistical summaries for the extraction wells, including Mann-Kendall trend analyses. Extraction well trends are discussed in Attachment A.1. Figure A.2-4 illustrates the statistics presented in Table A.2-28, showing where total uranium concentrations have an upward trend, downward trend, or no trend. Monitoring wells with an upward trend based on the Mann-Kendall analysis are discussed further.

Tracking the acreage of the maximum total uranium plume footprint provides a means for assessing progress in achieving remediation goals. Figure A.2-5 shows the footprint of the 30 µg/L total uranium plume from the second half of 2020 compared to the footprint of the 30 µg/L total uranium plume from 2021. The 2020 plume is highlighted in yellow; the yellow indicates areas where the plume was reduced for mapping purposes in 2021. 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 2020 and 2021 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
2020 (acres)	81.5	50.4	28.2
2021 (acres)	75.0	48.7	28.3
Change (acres)	-6.5	-1.7	0.1
Change (percent)	-8.0	-3.4	0.4

Between 2020 and 2021 the acreage mapped for the area of the maximum uranium plume above 100 µg/L increased by 0.1 acre. Periodic concentration fluctuations within the plume are expected and are attributed to dissolved uranium movement in response to active pumping.

Since 1997, the footprint of the total uranium plume being targeted for cleanup has decreased 162.6 acres. Table A.2-30 provides a tabulation of plume size from 1997 through 2021.

Monitoring results are presented in three sections as outlined below:

- 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) decreased in size between 2020 and 2021. At the end of 2020, the mapped footprint (excluding the PPDD area described below) was estimated to be 7.3 acres. At the end of 2021, the mapped footprint (excluding the PPDD area described below) was estimated to be 6.7 acres, a decrease of 0.6 acres (8.2%).

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

Direct-push sampling was conducted in 2021 at one location in the former WSA (location 13528).

Location 13528

Location 13528 is northeast of the former WSA plume. Direct-push sampling results for location 13528 are provided in Table A.2-1, and the location is identified in Figure A.2-2.

As shown in Table A.2-1, the maximum total uranium concentration measured in 2021 was 15.4 µg/L (elevation 501 ft above mean sea level [amsl]). The 30 µg/L contour was adjusted to honor this concentration.

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 2021 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 2021 was below the uranium FRL. Channel 1 was dry during the second half of 2021.

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 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 in channel 1 was below 30 µg/L. Channel 1 was dry during the second half of 2021.

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 was below 30 µg/L in 2020 and 2021.

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 if a

plume can be defined. These four wells will continue to be identified on maximum total uranium plume maps as locations where intermittent total uranium FRL exceedances have been measured so that their presence will be carried forward into the certification stage of the aquifer remediation.

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

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

Figure A.2-10 is a total uranium concentration versus time plot for monitoring well 2649. The figure shows an increase in uranium concentration in 2007. The increase is attributed to pumping in nearby extraction well 33347, which began in late 2006. As is shown in Figure A.2-10, the concentration of uranium in monitoring well 2649 has exceeded 1,000 µg/L in 2013 and 2018. This is an area of the plume where uranium contamination is known to be sorbed to aquifer sediments in the vadose zone. When this sediment is saturated or flushed due to high water levels in the aquifer, the uranium can desorb into the water, resulting in the high concentration measurements. Multichannel well 83337 is near monitoring well 2649. The shallowest channel in well 83337 is channel 1. As shown in Figure A.2-11, the uranium concentration of channel 1 in monitoring well 83337 has also been above 1,000 µg/L, while the other two deeper channels in that well have not. In 2021, concentration was again above 1,000 µg/L.

A.2.1.1.4 Former WSA Summary

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

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

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

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

High surface water uranium concentrations occur in a swale located between the former waste pits and Paddys Run: Intermittent puddles of surface water occur in a swale bounded by Paddys Run to the west and the former waste pits to the east. As presented in Appendix B, the total uranium concentrations of many of the surface water samples collected from this area exceed the groundwater FRL.

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

During normal flow conditions, surface water from the swale area infiltrates into the ground. This is also the case in the former Waste Pit 3 area, where water infiltrates into the ground and serves as a source of recharge to the aquifer. The uranium concentration in the aquifer beneath this infiltration area is above the uranium groundwater FRL (30 µg/L). Surface water from much of the former WSA drains into the former Waste Pit 3. The area of infiltration in the swale and former WSA is within capture of the groundwater remediation system. Because the area is within capture, there is currently no risk to the public from the infiltrating surface water. Continued monitoring will document if 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 beyond 2035, 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 2020 and 2021 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 2021 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 2021 in the former PPDD area (Figure A.2-3) as being a monitoring location with intermittent total uranium FRL exceedances.

Figure A.2-12 provides a time versus total uranium concentration plot for monitoring well 83335. The figure shows that total uranium concentrations measured from 2013 through the first half of 2019 have been below the total uranium groundwater FRL for all monitoring channels. In the second half of 2019, channel 2 had a concentration of 32.4 µg/L. Since 2019, the uranium concentration of both collected samples were below the total uranium groundwater FRL. Channel 1 has always been dry. This well will continue to be identified on maximum total uranium plume maps as being a location where intermittent total uranium FRL exceedances have been measured so that its presence will be carried forward into the certification stage of the aquifer remediation.

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

As shown in Table A.2-28 and Figure A.2-4, one monitoring well (83124_C4) had an increasing total uranium concentration trend in 2021 in the PPDD Area. Figure A.2-13 is a total uranium concentration versus time plot for monitoring well 83124. This monitoring well is located upgradient of extraction well 33062. The increase in uranium concentration in channel 1 is attributed to uranium contamination sorbed to aquifer sediments in the vadose zone.

A.2.2 Former Plant 6 Area

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

No direct-push sampling was conducted in 2021 in the Plant 6 Area.

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

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

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

Figure A.2-14 is a total uranium concentration versus time plot for monitoring well 2389 and shows that sporadic total uranium FRL exceedances were detected at this well between 2002 and 2010, but exceedances have been constant since 2011. As discussed below, FRL exceedances are detected in this area when the sample is approximately 515 ft amsl or higher. Since 2011, water levels have been at or near 515 ft amsl, and the uranium FRL exceedances have been consistent. In 2021, total uranium concentrations were above 30 µg/L. As shown in Figure A.2-14, the water level during both 2021 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 2020 and 2021. The size of the footprint was 68.41 acres in 2020 and 62.52 acres in 2021, a decrease of 5.89 acres (8.6%) (Figure A.2-5).

The mapped footprint of the 50 µg/L area of the plume decreased in size between 2020 and 2021. The size of the area was 40.25 acres in 2020 and 38.86 acres in 2021, a decrease of 1.39 acres (3.5%).

The mapped footprint 100 µg/L area of the plume increased between 2020 and 2021. The size of the area was 20.32 acres in 2020 and 20.41 acres in 2021, an increase of 0.09 acres (0.4%).

A.2.3.1 South Field

In 2021, direct-push sampling was conducted at nine locations in the South Field (locations 13532, 13534, 13509B, 13533, 13531, 13514A, 13530, 13529, and 12842C).

Figure A.2-2 shows the locations and the 2021 total uranium results. Three of the locations are in

the area of the former Flyash Pile (13529, 13530, and 12842C). The remaining locations were in the east side of the plume.

Location 13529

Location 13529 is in the former Flyash Pile Area of the South Field. Direct-push sampling results for location 13529 are provided on Table A.2-2, and the location is identified on Figure A.2-2.

As shown in Table A.2-2, the maximum total uranium concentration measured in 2021 was 122 µg/L (elevation 517 ft amsl). The maximum uranium plume map was adjusted to honor the 2021 measurement.

Location 13530

Location 13530 is in the former Flyash Pile Area of the South Field. Direct-push sampling results for location 13530 are provided on Table A.2-3, and the location is identified on Figure A.2-2.

As shown in Table A.2-3, the maximum total uranium concentration measured in 2021 was 20.7 µg/L (elevation 518 ft amsl). The maximum uranium plume map was adjusted to honor the 2021 measurement.

Location 12842C

Location 12842C is in the former Flyash Pile Area of the South Field. Direct-push sampling results for location 12842C are provided on Table A.2-4, and the location is identified on Figure A.2-2.

This location has been sampled four times: 2001, 2013, 2018, and 2021. The samples collected in 2001 was identified as location 12842. The samples collected in 2021 were identified as location 12842C. The following table provides total uranium concentrations from the four sampling events.

Location 12842 (2001)		Location 12842A (2013)		Location 12842B (2018)		Location 12842C (2021)	
Midpoint Screen Elevation (ft amsl)	Uranium Concentration (µg/L)	Midpoint Screen Elevation (ft amsl)	Uranium Concentration (µg/L)	Midpoint Screen Elevation (ft amsl)	Uranium Concentration (µg/L)	Midpoint Screen Elevation (ft amsl)	Uranium Concentration (µg/L)
511	139	513	65.4	513	45.3	516	94.1
504	58	503	22.2	503	18.1	506	17.3
493	4.6	493	5.20	493	8.4	496	15.8
483	1.1			483	<1.0	486	2.7
473	1.8					476	2.2
463	1.2						
453	1.9						

The maximum total uranium concentration at this location decreased from 139 µg/L in 2001 (elevation 511 ft amsl) to 45.3 µg/L in 2018 (elevation 513 ft amsl). The maximum uranium concentration measured in 2021 was 94.1 ug/L (elevation of 516 ft amsl). The decreasing trend between 2001 and 2018 did not continue. The total uranium plume map for 2021 was adjusted to honor the 2021 concentration.

Location 13509B

Location 13509B is 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.2-5. The location is identified in Figure A.2-2.

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

Location 13509 (2018)		Location 13509A (2020)		Location 13509B (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)
515	43.3	514	33.0	512	36.8
505	13.4	504	22.9	502	14.2
495	3.9	494	9.3	492	5.7
485	7.3	484	7.2	482	5.9
475	8.8	474	4.1	472	1.0

As shown in the table above, the maximum total uranium concentration was 43.3 µg/L in 2018 (elevation 515 ft amsl) and 36.8 µg/L in 2021 (elevation 512 ft amsl). No change was made to the maximum total uranium plume map based on the 2021 result.

Location 13514A

Location 13514A is on the leading eastern edge of the South Field plume. Direct-push sampling results are provided in Table A.2-6. The location is identified in Figure A.2-2.

This location has been sampled twice: 2019 and 2021. The samples collected in 2019 were identified as location 13514. The samples collected in 2021 were identified as location 13514A. Results for both sampling events are provided below.

Location 13514 (2019)		Location 13514A (2021)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
517	83.0		
507	11.7	510	13.5
497	18.4	500	10.3
487	11.0	490	4.3
477	2.4	480	1.7
		470	4.0

As shown in the table above, the maximum total uranium concentration measured in 2021 was not at a high enough elevation to determine if cleanup has progressed at this location. No change was made to the maximum total uranium plume map for the 2021 result.

Location 13531

Location 13531 is on the west side of the South Field uranium plume. Direct-push sampling results for location 13522 are provided on Table A.2-7, and the location is identified on Figure A.2-2.

As shown in Table A.2-7, the maximum total uranium concentration measured in 2021 was 7.7 µg/L (elevation 511 ft amsl). The 30 µg/L contour on the maximum uranium plume map was adjusted to honor the 2021 measurement.

Location 13532

Location 13532 is on the west side of the South Field uranium plume, south of location 13531. Direct-push sampling results for location 13532 are provided in Table A.2-8, and the location is identified in Figure A.2-2.

As shown in Table A.2-8, the maximum total uranium concentration measured in 2021 was 13.7 µg/L (elevation 512 ft amsl). The 30 µg/L contour on the maximum uranium plume map was adjusted to honor the 2021 measurement.

Location 13533

Location 13533 is west of the South Field uranium plume, in the southern half of the South Plume. Direct-push sampling results for location 13533 are provided in Table A.2-9. The location is identified in Figure A.2-2.

As shown in Table A.2-9, the maximum total uranium concentration measured in 2021 was 31.8 µg/L (elevation of 510 ft amsl). The 30 µg/L contour on the 2021 maximum uranium plume map did not need to be adjusted to honor the 2021 concentration.

Location 13534

Location 13534 is in the South Field uranium plume, just north of Willy Road. Direct-push sampling results for location 13534 are provided in Table A.2-10. The location is identified in Figure A.2-2.

As shown in Table A.2-10, the maximum total uranium concentration measured in 2021 was 53.5 µg/L (elevation of 514 ft amsl). The maximum total uranium plume map for 2021 was adjusted to honor the 2021 measurement.

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

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

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

As Table A.2-28 shows, four monitoring wells in the South Field—21033, 2386, 2387, and 83294_C1—had upward trends for total uranium concentrations in 2021. The locations are shown in Figure A.2-4. Figures A.2-15 through A.2-18 provide time versus total uranium concentration plots for these four wells. The total uranium concentration increases are attributed

to changes in the plume caused by the active groundwater remediation. Uranium contamination is being pulled toward the extraction wells.

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 2021, direct-push sampling was conducted at 17 locations in the South Plume (13240G, 13267C, 13421J, 13425E, 13477D, 13513B, 13519A, 13526A, 13535, 13536, 13537, 13538, 13539, 13540, 13541, 13542, and 13543). Sampling locations are shown in Figure A.2-2. Sampling results are discussed below.

Location 13240G

Location 13240G is situated on the east edge of the South Plume. Direct-push sampling results for location 13240G are provided in Table A.2-11. The location is identified in Figure A.2-2.

This location has been sampled eight times: 2002, 2003, 2005, 2013, 2015, 2016, 2017, and 2021. The samples collected in 2002 were identified as location 13240. The samples collected in 2021 were identified as location 13240G. Total uranium concentration data from all eight sampling events are provided below.

Location 13240 (2002)		Location 13240A (2003)		Location 13240B (2005)		Location 13240C (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)
515	4.7	516	11.0				
508	23.0	507	123	509	28.6	511	18.7
498	114	497	62.3	499	62.4	501	26.0
488	92.0	487	53.9	489	63.0	491	29.7
478	36.0	477	15.2	479	15.5	481	23.1
468	3.4	467	4.4	469	5.9	471	1.4
458	1.6	457	1.3	459	4.4	461	3.3
448	1.7						

Location 13240D (2015)		Location 13240E (2016)		Location 13240F (2017)		Location 13240G (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)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
510	26.5	510	28.7	510	11.6	513	24.4
500	36.8	500	23.0	500	40.1	503	13.0
490	23.9	490	29.6	490	52.2	493	16.6
480	21.5	480	9.0	480	36.8	483	18.0
470	6.9	470	7.3	470	12.5	473	2.8
460	1.4	460	4.8	460	3.0		

The maximum total uranium concentration at this location has decreased from a high of 123 µg/L in 2003 (elevation 507 ft amsl) to 24.4 µg/L in 2021 (elevation 513 ft amsl). The 30 µg/L uranium contour was adjusted on the 2021 maximum total uranium plume map to honor the 2021 concentration.

Location 13267C

Location 13267C is in the southeast corner of the South Plume. Direct-push sampling results for location 13267C are provided in Table A.2-12. The location is identified in Figure A.2-2.

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

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

The maximum total uranium concentration at this location has fluctuated between a high of 64.0 µg/L in 2002 (elevation 508 ft amsl) and 18.8 µg/L in 2013 (elevation 501 ft amsl). In 2020 the concentration was once again above 50 µg/L (52.2 µg/L at an elevation of 504 ft amsl). A 50 µg/L contour was added around this location on the 2020 total uranium plume map to honor the 2020 result. The result in 2021 was 57.4 ug/L (513 amsl). No change was made to the 2021 total uranium plume map based on the 2021 result.

Location 13421J

Location 13421J is in the northeast corner of the South Plume. Direct-push sampling results for location 13421J are provided in Table A.2-13. The location is identified in the Inset 2 area in Figure A.2-2.

This area of the plume has been sampled 13 times. It was first sampled in 1996. From 1996 to 2007, the location was identified as 12196. In 2011, the location was moved 50 ft to accommodate a landowner request and renamed 13421. Location 12196 was sampled three times: 1996, 2005, and 2007. The samples collected in 1996 were identified as location 12196. The samples collected in 2007 were identified as 12196B. Results for the three sampling events at location 12196 are provided below.

Location 12196 (1996)		Location 12196A (2005)		Location 12196B (2007)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
518	0.40	515	4.30		
509	0.30	505	87.5	512	6.7
499	0.70	495	101	502	59.6
489	0.50	485	14.4	492	104
479	0.30	475	37.4	482	3.2
469	0.50	465	18.7	472	9.0
459	0.70			462	3.0
449	0.40				
439	1.60				

As the data above indicate, it appears that the total uranium plume migrated into this area between 1996 and 2005. From 2005 to 2007, the plume was located above an elevation of 492 to 495 ft amsl and had concentrations near 100 µg/L.

Location 13421 has been sampled ten times. It was sampled twice in 2011 and again in 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021. The samples collected in 2011 were identified as 13421 and 13421A. Although not shown on the table, this location was actually sampled twice in 2015. The results of the first sample (13421C) were rejected because it was later determined that a field error concerning the elevation of the results could not be rectified with certainty; therefore, the location was resampled as 13421D. Total uranium concentration data from all ten acceptable sampling events are provided below.

Location 13421 (2011)		Location 13421A (2011)		Location 13421B (2014)		Location 13421D (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)
		514	3.7	513	6.4	510	2.1
506	42.3	504	116	503	111	500	78.2
596	167	494	216	493	253	490	101
486	85.9	484	82.3	483	93.6	480	71.1
476	5.3	474	5.1	473	4.9	470	1.3
466	2.4	464	3.5	463	15.6	460	55.3
456	60.9	454	7.2	453	9.8	450	4.3
		444	6.4				

Location 13421E (2016)		Location 13421F (2017)		Location 13421G (2018)		Location 13421H (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	5.7	512	2.7	512	13.0	514	1.8
501	84.6	502	68.1	502	83.6	504	2.2
491	174.6	492	126.6	492	85.9	494	49.1
481	50.0	482	28.8	482	30.7	484	8.0
471	1.0	472	4.7	472	1.5	474	5.6
461	8.1	462	27.2	462	37.0	464	13.9
451	17.1	452	2.9	452	4.4	454	11.2
441	1.0	442	1.0				

Location 13421I (2020)		Location 13421J (2021)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
514	1.8	511	2.7
504	46.5	501	69.5
494	83.8	491	47.9
484	58.9	481	17.4
474	10.4	471	1.1
464	8.8	461	4.4
454	13.4	451	3.6

The initial sampling event at location 13421 in 2011 resulted in a total uranium concentration of 167 µg/L at an elevation of 596 ft amsl and 60.9 µg/L at an elevation of 456 ft amsl. The high concentration at the 456 ft amsl elevation had not been measured before in this area (see data from 12196 above). Therefore, it was considered suspect and resampled in the same year (13421A). As shown above, the total uranium concentrations measured in 13421A indicated that

the total uranium plume was at an elevation of approximately 494 ft amsl and was not present at deeper elevations. A deeper FRL exceedance was measured again in 2015 (55.3 µg/L at an elevation of 460 ft amsl), while sampling in 2016 did not show an exceedance at the 461 ft amsl elevation.

The samples collected between 2015 and 2017 indicate that the maximum uranium concentration at this location fluctuated within the 100–200 µg/L range. The maximum uranium concentration measured in 2018 was 85.9 µg/L (elevation 492 ft amsl) and the maximum measured in 2019 was 49.1 µg/L (elevation 494 ft amsl). The maximum uranium plume map for 2019 was adjusted to honor the 2019 concentration. In 2020, the maximum uranium concentration was 83.8 µg/L (elevation 494 ft amsl). In 2021, the maximum uranium concentration was 69.5 µg/L (elevation 501 ft amsl). The 2021 total uranium plume map was revised in this area mostly due to the result measured at location 13535 (which is discussed further below).

Location 13425E

Location 13425E is on the east side of the South Plume. Direct-push sampling results for location 13425E are provided in Table A.2-14. The location is identified in Figure A.2-2.

This location has been sampled six times: 2011, 2014, 2016, 2018, 2019, and 2021. The samples collected in 2011 were identified as location 13425. The samples collected in 2021 were identified as location 13425E. Total uranium concentration data from all six sampling events are provided below.

Location 13425 (2011)		Location 13425A (2014)		Location 13425B (2016)		Location 13425C (2018)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
513	2.6	516	8.0	511	7.0	515	<1.0
503	20.7	506	20.8	501	35.6	505	42.5
493	49.0	496	36.9	491	23.2	495	18.6
483	17.3	486	3.9	481	11.1	485	12.7
473	1.1	476	1.0	471	5.0	475	3.9
463	1.0						
453	1.3						
443	1.6						

Location 13425D (2019)		Location 13425E (2021)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
514	<1.0	514	16.8
504	34.4	504	64.5
494	37.4	494	37.8
484	21.1	484	28.8
		474	13.4

The maximum total uranium concentration at this location had been below 50 ug/L prior to 2021. In 2021, the maximum uranium concentration was 64.5 µg/L (elevation 504 ft amsl). The 50 µg/L contour on the 2021 maximum total uranium plume map was adjusted to honor the 2021 concentration

Location 13477D

Location 13477D is in the northeast corner of the South Plume. Direct-push sampling results for location 13477D are provided in Table A.2-15. The location is identified in Figure A.2-2.

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

Location 13477 (2014)		Location 13477A (2015)		Location 13477B (2018)		Location 13477C (2019)		Location 13477D (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)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
512	1.4	511	<1.0	515	< 1.0	518	<1.0	513	<1.0
502	31.8	501	18.4	505	< 1.0	508	<1.0	503	32.0
492	58.6	491	52.0	495	65.0	498	56.5	493	59.3
482	2.6	481	3.6	485	13.5	488	13.0	483	13.7
472	2.7	471	5.7	475	16.7	478	8.2	473	8.8

The maximum uranium concentration at this location in 2021 remained above 50 µg/L. The 2021 total uranium plume map did not need to be adjusted to honor the 2021 concentration.

Location 13513B

Location 13513B is in the southeast corner of the South Plume. Direct-push sampling results for location 13513B are provided in Table A.2-16. The location is identified on Figure A.2-2.

This location has been sampled three times: 2018, 2020, and 2021. The samples collected in 2018 were identified as location 13513. The samples collected in 2021 were identified as location 13513B. Total uranium concentrations from all three sampling events are provided below.

Location 13513 (2018)		Location 13513A (2020)		Location 13513B (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)
513	10.1	515	10.3	514	38.0
503	26.4	505	19.3	504	25.7
493	43.5	495	45.3	494	28.6
483	33.0	485	10.8	484	22.7
473	<1.0	475	1.4	474	2.2

The maximum total uranium concentration at this location remains above 30 ug/L. No change was made to the maximum total uranium plume map based on the 2021 result.

Location 13519A

Location 13519A is on the east edge of the South Plume. Direct-push sampling results for location 13519A are provided in Table A.2-17. The location is identified on Figure A.2-2.

This location has been sampled two times: 2019 and 2021. The samples collected in 2019 were identified as location 13519. The samples collected in 2021 were identified as location 13519A. Total uranium concentrations from both sampling events are provided below.

Location 13519 (2019)		Location 13519A (2021)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
514	1.5	511	21.0
504	42.3	501	27.9
494	22.1	491	19.5
484	39.7	481	13.8
474	19.4	471	8.5

The maximum total uranium concentration at this location has decreased below 30 ug/L. The maximum total uranium plume map for 2021 was adjusted to honor the 2021 result.

Location 13526A

Location 13526A is in the northeast portion of the South Plume. Direct-push sampling results for location 13526A are provided in Table A.2-18. This location is identified in Inset 2 on Figure A.2-2.

This location has been sampled two times: 2020 and 2021. The samples collected in 2020 were identified as location 13526. The samples collected in 2021 were identified as location 13526A. Total uranium concentrations from both sampling events are provided below.

Location 13526 (2020)		Location 13526A (2021)	
Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)	Midpoint Screen Elevation (ft amsl)	Total Uranium (µg/L)
512	15.9	513	4.7
502	63.4	503	54.8
492	34.2	493	7.7
482	14.4	483	2.2
472	1.6	473	2.5

The maximum total uranium concentration measured in 2021 remains above 50 µg/L. No change to the 2021 maximum total uranium plume map was made based on the 2021 result.

Location 13535

Location 13535 is in the northeastern corner of the South Plume. Direct-push results are provided in Table A.2-19. The 2021 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 2021 was 76.1 µg/L (elevation 501 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 concentration.

Location 13536

Location 13536 is in the middle of the South Plume. Direct-push results are provided in Table A.2-20. The 2021 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 2021 was 43.5 µg/L (elevation 510 ft amsl). The 2021 maximum total uranium plume map did not need to be revised to honor the 2021 concentration.

Location 13537

Location 13537 is in the northwest portion of the South Plume. Direct-push results are provided in Table A.2-21. The 2021 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 2021 was 19.5 µg/L (elevation 511 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 concentration.

Location 13538

Location 13538 is in the northwest portion of the South Plume. Direct-push results are provided in Table A.2-22. The 2021 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 2021 was 35.5 µg/L (elevation 511 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 concentration.

Location 13539

Location 13539 is on the west edge of the South Plume. Direct-push results are provided in Table A.2-23. The 2021 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 2021 was 20.4 µg/L (elevation 502 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 concentration.

Location 13540

Location 13540 is on the west edge of the South Plume. Direct-push results are provided in Table A.2-24. The 2021 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 2021 was 11.6 µg/L (elevation 491 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 concentration.

Location 13541

Location 13541 is on the west edge of the South Plume. Direct-push results are provided in Table A.2-25. The 2021 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 2021 was 19.3 µg/L (elevation 509 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 concentration.

Location 13542

Location 13542 is on the southwest corner of the South Plume. Direct-push results are provided in Table A.2-26A through A.2-26C. The 2021 sampling event was the first time this location was sampled. This location is identified on Figure A.2-2.

Location 13542 was sampled three times in 2021. Results 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	21.8	479	17.2	479	9.7
469	40.4	469	20.2	469	19.8
		459	10.2	459	15.4
		449	3.9	449	8.0
		439	1.4	439	1.0

The first sampling was conducted on July 20, 2021, and resulted in a maximum uranium concentration of 40.4 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. Results from July 28, 2021 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 shows 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 has been selected to be resampled in 2022.

Location 13543

Location 13543 is on the western edge of the South Plume. Direct-push results are provided in Table A.2-27. The 2021 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 2021 was 22.1 µg/L (elevation 511 ft amsl). The 2021 maximum total uranium plume map was revised to honor the 2021 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 2021 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.2-19. 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.2-20. The figure indicates that no total uranium FRL exceedances occurred in 2021. Only two total uranium FRL exceedances have been measured at this well since 1993. The last one occurred in 2012.

These wells will continue to be identified on maximum total uranium plume maps as locations where intermittent total uranium FRL exceedances have been measured so that their presence will be carried forward into the certification stage of the aquifer remediation.

A.2.3.2.3 Monitoring Wells with Increasing Total Uranium Concentration Trends in the South Plume

As shown in Figure A.2-4 and Table A.2-28, two monitoring wells (2880 and 82369_C2) had upward trends for total uranium concentration in the South Plume in 2021. Time versus concentration graphs for these wells are provided in Figures A.2-21 and A.2-22. 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 2021 with particular emphasis on those wells that are not routinely used for sampling or water level measurements. The main concern noted for wells not routinely sampled was that protective casings on some of them need to be painted and have identification markings reapplied. Additional minor findings include:

- Some protective casing lids were hard to open.
- Some wells need to have vegetation or branches removed from around them to improve access.
- Uneven surfaces were noted around some wells.

Many of the inspection findings noted above were corrected immediately (e.g., vegetation removal). Deficiencies that could not be corrected immediately (e.g., removal of overhanging trees) will be corrected as time permits.

Annual visual inspections of all monitoring wells will continue in future years with any deficiencies documented and corrected. Additionally, camera surveys of monitoring wells that are not routinely sampled will be conducted every 5 years. The last camera survey of these wells was begun in 2017 and completed in 2018; therefore, the next camera surveys of these wells will occur in 2022.

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. The 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.

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 taken into account 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 uranium mass remaining (DOE 2017b).

The analysis presented in this year's report uses the annual maximum concentration in 2006, 2010, 2014, 2016 through 2021 and a consistent set of monitoring well data that span all nine selected years. The most recent maximum total uranium results available at Geoprobe locations were also included. Surfer software (Version 15.5.382) was used for kriging the data and mapping the results. Until 2017, the analysis was conducted for three separate plume areas: the PPDD, the South Field and South Plume, and the former WSA. With the addition of Geoprobe data, the analysis in 2017 changed to being applied to the entire plume. A homogenous effective porosity equal to that modeled for the aquifer (28%) was assumed, and a plume thickness of 30 ft was used.

Figure A.2-23 provides a uranium plume map that identifies the calculated center of mass for each year (2006, 2010, 2014, and 2016 through 2021). As shown in Figure A.2-23, 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.2-24 provides 2021 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.2-24, for 2021, the Ricker method calculations indicate that the total uranium plume area was 81.6 acres, the average uranium plume concentration was 80.85 µg/L, and the total uranium plume dissolved mass was 150 pounds.

A.2.5.1 Total Uranium Plume Area

Table A.2-31 presents a comparison of the 2021 plume size interpretation (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 2021, the percent difference has ranged between 2.6% and 8.8%. The percent difference in 2021 was 8.8%.

A.2.5.2 Total Mass of Uranium Remaining in the Aquifer

The value of 150 pounds for the total mass of uranium remaining in the aquifer based on the Ricker method presented in Figure A.2-24 represents the dissolved mass of total uranium remaining in the aquifer based on 2021 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 3 times the concentration of uranium in the groundwater. However, as discussed below, the sorbed mass of

uranium is actually greater than 3 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, $\rho_b/\eta = 6.61 \text{ g/cm}^3$.

The total uranium mass in the aquifer can be estimated by adding both the aqueous mass and solid mass using the following formula (Deutsch 1997):

$$\text{Total mass} = [(C_{aq})(1 \text{ L})] + [(\rho_b/\eta)(C_s)(1 \text{ L})]$$

where:

C_{aq} = concentration of total uranium dissolved in groundwater, mg/L

ρ_b = bulk density of aquifer sediments, g/cm^3

η = porosity of aquifer, percent

C_s = concentration of total uranium sorbed to aquifer sediments, mg/kg

This equation is solved below for a 1 L aquifer volume with an assumed C_{aq} of 1 mg/L. Site-specific values defined in the groundwater model for bulk density (1.85 g/cm^3) and aquifer porosity (28%) are used. A K_d of 3 L/kg is used to define a C_s of 3 mg/kg.

$$\text{Total Mass} = [(C_{aq})(1 \text{ L})] + [(\rho_b/\eta)(C_s)(1 \text{ L})]$$

$$\text{Total Mass} = [(1 \text{ mg}_{aq}/\text{L})(1 \text{ L})] + \{[(1.85 \text{ g/cm}^3)/0.28][(3 \text{ mg/kg})(1 \text{ L})]\}$$

$$\text{Total Mass} = (1 \text{ mg}_{aq}) + \{(6.61 \text{ g/cm}^3)[(3 \text{ mg/kg})(1 \text{ L})]\}$$

Unit Conversions

$$(6.61 \text{ g/cm}^3)(1,000 \text{ cm}^3/\text{L}) = 6610 \text{ g/L}$$

$$(6610 \text{ g/L})(1,000 \text{ mg/g}) = 6,610,000 \text{ mg/L}$$

$$\text{Total Mass} = (1 \text{ mg}_{aq}) + [(6,610,000 \text{ mg/L})(3 \text{ mg/kg})(1 \text{ L})]$$

Unit Conversion

$$(3 \text{ mg/kg})(1 \text{ kg}/1,000,000 \text{ mg}) = 0.000003$$

$$\text{Total Mass} = 1 \text{ mg}_{aq} + (6,610,000 \text{ mg/L})[(0.000003)(1 \text{ L})]$$

$$\text{Total Mass} = 1 \text{ mg}_{aq} + 19.83 \text{ mg}_s$$

This total mass calculation shows that the uranium mass sorbed in a 1 L volume of aquifer is 19.83 times greater than the uranium mass dissolved. This relationship can be combined with the result of the Ricker dissolved mass estimate to determine a total uranium mass for the aquifer. The Ricker method estimated a dissolved uranium mass of 150 pounds (Figure A.2-24); therefore, the estimated total mass in the aquifer (based on 2021 data) was 3,124.50 pounds.

$$3,124.50 \text{ pounds total} = 150 \text{ pounds}_{aq} + (150 \text{ pounds}_{aq})(19.83)$$

$$3,124.50 \text{ pounds total} = 150 \text{ pounds} + 2,974.50 \text{ pounds}$$

The result of 3,124.50 pounds of uranium mass total from the Ricker method can be compared to the predicted dissolved mass removal estimates presented in Attachment A.1 to achieve an estimate of the dissolved mass required to be removed from the aquifer to achieve a concentration-based cleanup of 30 µg/L. The estimate will also show how much sorbed uranium mass will remain in the aquifer when the concentration-based cleanup is achieved.

As shown in Table A.1-24 in Attachment A.1, two estimates are provided for the estimated total pounds of dissolved uranium mass to be removed from the aquifer to achieve the concentration-based cleanup FRL of 30 µg/L:

- 2,890 pounds dissolved mass (based on new 2022 model predictions)
- 2,914 pounds 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 210.5 and 234.5 pounds of uranium will remain sorbed to aquifer sediments when the concentration-based cleanup of 30 µg/L is achieved:

- 3,124.50 pounds – 2,890 pounds = 234.5 pounds sorbed uranium mass remains
- 3,124.50 pounds – 2,914 pounds = 210.5 pounds sorbed uranium mass remains

From a percentage perspective, this equates to 6.7% to 7.5% of the remaining mass (as of 2021).

- $(234.5 \text{ pounds} / 3,124.50 \text{ pounds})(100) = 7.5 \%$
- $(210.5 \text{ pounds} / 3,124.50 \text{ pounds})(100) = 6.7 \%$

A.3.0 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.2-25A, A.2-25B, and A.2-25C. These three figures also display the maximum total uranium plume interpretation for the second half of 2021. The cross sections (A–A', B–B', C–C', D–D', and E–E') are provided in Figures A.2-26 through A.2-30, respectively.

Surfer software (Version 15.5.382) was used to krig the total uranium concentration datasets and produce the plume cross sections. Point kriging of the data for all total uranium cross sections was performed using the Surfer default settings with the exception of the anisotropy ratio. For anisotropy, a ratio of 10 to 1 (vertical to horizontal) was used.

The plume interpretations shown in the cross sections provide a less conservative plume interpretation of area than the maximum total uranium plume maps presented in Figures A.2-2, and A.2-3. The cross sections, therefore, do not correlate directly with the maximum total uranium plume interpretations presented in those figures. The cross sections provide an additional interpretation of the total uranium concentration data that were used to develop the maximum total uranium plume maps.

Each cross section depicts the ground surface, the base of the glacial till (clay overburden), the top of the unconsolidated sand and gravel Great Miami Aquifer, and the average water-table elevation. Monitoring well data are the maximum total uranium concentrations measured in elevation is the elevation recorded at the time that the sample was collected. The midpoint of the monitoring well screen or Geoprobe screen is shown for each location with a “+” symbol. Vertical depth total uranium profiles are provided for each Geoprobe location. Extraction well screen locations and depths are also shown in the cross sections, if applicable.

As illustrated in the cross sections, the top of the 30 µg/L total uranium plume is normally situated at the water table, but in a few areas in the aquifer the top of the 30 µg/L total uranium plume is located beneath the water table. Some of the plume areas depicted in the maximum total uranium plume maps appear as smaller, separated plume areas in the cross sections. The separate areas help to point out where most of the total uranium concentrations are located based on the kriging results. Tracking the location and size of the plume areas beneath the water table should prove helpful in making operational decisions as the remedy progresses.

A.3.1 Split Sampling Program

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

The three wells sampled in the split sampling program are private homeowner wells and is the longest running groundwater monitoring effort at the site. The program was initiated in 1982 in response to monitoring results indicating above background concentrations of uranium in private wells near the site. By 1984, the site had officially established the program with the monthly sampling of 19 privately-owned wells. In 1996, the private well program had grown to 32 private wells. At a property owner’s request, any drinking water well near the site was sampled for uranium, and the one-time results were reported to the well owner. If any special request sample showed a questionable or significant total uranium concentration, or if the private well was determined to provide critical groundwater information in an area, the property owner had the option to participate in the routine sampling program. These private wells were sampled monthly or quarterly depending upon location, and sampling results were reported annually in the Site Environmental Report. Three private wells (13, 14 and 2060) were included in the monitoring effort (DOE 1997). These three private wells continued to be sampled through 2021.

In 1997, with implementation of the IEMP, the private well program was modified to include only these three private wells and included the private well where off-property contamination was initially reported in 1981. Other private wells that had been previously monitored were not carried forward into the IEMP program because a public water supply was made available to the surrounding properties who had been affected by the off-property groundwater contamination

(DOE 1998). Data from these three remaining private wells have been used to produce the total uranium plume presented in Attachment A.2.

As shown in Figures A.2-31 and A.2-32, the historical sampling results for total uranium at wells 13 and 14 are well below the 30 µg/L FRL. Well 13 has been below the FRL since 2002 and well 14 has been below the FRL since this well was first sampled in 1988. These wells are located off-site and are outside of the uranium plume boundary identified in Section 3 and have been below the FRL for over 20 years. For this reasons, DOE is proposing to eliminate monitoring in two of the private wells which occur outside the current plume, (13 and 14) and to continue monitoring uranium in well 2060. The time versus concentration graph for well 2060 is provided in Figures A.2-33. This well will continue to be monitored as part of the IEMP program. These changes will be proposed in the upcoming revision to the LMICP.

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Table A.2-1. Geoprobe Location 13528

Easting '83:	1346957	feet
Northing '83:	481323	feet
Ground Elevation:	572	feet above mean sea level (AMSL)
Depth to Water Table:	56.00	feet below ground surface (BGS)
Water Table Elevation:	516.33	feet AMSL
Work Completed:	6/24/2021	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium ^{a,b} (ug/L) (FRL=30)	Uranium (ug/L) ^c (FRL = 30)	Technetium-99 ^c (pCi/L) (FRL=94)	Nitrate/Nitrite (mg/L) (FRL=11)	Manganese ^c (mg/L) (FRL=0.90)	Molybdenum ^c (mg/L) (FRL=0.1)	Nickel ^c (mg/L) (FRL=0.1)	Temperature ^a (°C)	pH ^a (SU)	Specific Conductance ^a (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered ^a (NTU)	Turbidity Filtered ^c (NTU)	Dissolved Oxygen ^a (mg/L)
1	511	61	0 - 10	15.3	11.2	3.41	4.08	0.578	0.0762	0.00982	19.7	7.47	0.800	>999	>999	21.5	6.39
2	501	71	10 - 20	15.4	11.4	-1.31	1.26	0.417	0.0304	0.00479	17.3	7.60	0.720	>999	>999	8.72	5.97
3	501	71	10 - 20	15.0	12.5	-0.519	1.29	0.371	0.0287	0.00471	17.3	7.60	0.720	>999	>999	8.72	5.97
4	491	81	20 - 30	8.15	6.45	13.2	1.60	0.221	0.0108	0.00271	16.6	7.30	0.670	>999	>999	8.14	6.01
5	481	91	30 - 40	1.70	1.35	6.25	4.90	0.199	0.00930	0.00477	16.9	7.56	0.710	>999	>999	11.8	6.49
6	471	101	40 - 50	3.80	1.44	4.58	0.0908	0.263	0.00775	0.00263	16.8	7.67	0.680	>999	204	4.51	4.20

^aSamples are filtered through a 5 micron filter.

^bMaximum uranium result reported regardless of laboratory (i.e., onsite versus offsite) analyzing samples.

^cSamples are filtered through a 0.45 micron filter.

Table A.2-2. Geoprobe Location 13529

Easting '83:	1348497	feet
Northing '83:	477784	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	54.00	feet below ground surface (BGS)
Water Table Elevation:	522.05	feet AMSL
Work Completed:	6/15/2021	

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	59	0 - 10	122	15.9	7.90	0.680	888	170	7.44
2	507	69	10 - 20	24.3	16.1	7.61	0.670	>999	>999	6.25
3	507	69	10 - 20	23.4	16.1	7.61	0.670	>999	>999	6.25
4	497	79	20 - 30	10.1	15.5	7.62	0.710	>999	42.3	5.33
5	487	89	30 - 40	4.1	17.0	7.82	0.710	>999	>999	6.38
6	477	99	40 - 50	1.0	14.9	7.63	0.680	>999	233	4.52

^aSamples are filtered through a 5 micron filter.

Table A.2-3. Geoprobe Location 13530

Easting '83:	1348322	feet
Northing '83:	477731	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	53.00	feet below ground surface (BGS)
Water Table Elevation:	522.81	feet AMSL
Work Completed:	6/10/2021	

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	518	58	0 - 10	20.7	16.2	7.31	0.660	>999	315	7.50
2	508	68	10 - 20	8.7	16.2	7.07	0.670	>999	148	5.81
3	508	68	10 - 20	8.0	16.2	7.07	0.670	>999	148	5.81
4	498	78	20 - 30	2.9	17.9	7.80	0.680	>999	>999	6.02
5	488	88	30 - 40	2.9	16.6	7.46	0.680	>999	>999	5.34
6	478	98	40 - 50	3.1	15.9	7.46	0.700	>999	>999	5.43

^aSamples are filtered through a 5 micron filter.

Table A.2-4. Geoprobe Location 12842C

Easting '83:	1348644	feet
Northing '83:	477700	feet
Ground Elevation:	575	feet above mean sea level (AMSL)
Depth to Water Table:	54.00	feet below ground surface (BGS)
Water Table Elevation:	521.41	feet AMSL
Work Completed:	6/16/2021	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered ^a (µg/L)	Temperature Filtered ^a (°C)	pH Filtered ^a (SU)	Specific Conductance Filtered ^a (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered ^a (NTU)	Dissolved Oxygen Filtered ^a (mg/L)
1	516	59	0 - 10	94.1	16.4	7.86	0.740	>999	>999	7.62
2	506	69	10 - 20	17.3	15.2	7.65	0.690	>999	18.0	5.29
3	506	69	10 - 20	16.2	15.2	7.65	0.690	>999	18.0	5.29
4	496	79	20 - 30	15.8	15.0	7.60	0.670	>999	>999	5.85
5	486	89	30 - 40	2.7	16.0	8.04	0.690	>999	>999	5.66
6	476	99	40 - 50	2.2	15.6	7.99	0.670	>999	>999	4.98

^aSamples are filtered through a 5 micron filter.

Table A.2-5. Geoprobe Location 13509B

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:	516.88	feet AMSL
Work Completed:	5/25/2021	

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	36.8	17.3	7.10	0.830	>999	63.5	7.21
2	502	77	10 - 20	14.2	17.4	7.09	0.710	>999	444	7.35
3	502	77	10 - 20	13.1	17.4	7.09	0.710	>999	444	7.35
4	492	87	20 - 30	5.7	17.0	7.15	0.600	>999	>999	5.92
5	482	97	30 - 40	5.9	16.5	7.52	0.650	>999	924	6.63
6	472	107	40 - 50	1.0	16.9	7.05	0.810	>999	>999	6.08

^aSamples are filtered through a 5 micron filter.

Table A.2-6. Geoprobe Location 13514A

Easting '83:	1349645	feet
Northing '83:	477809	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	60.06	feet below ground surface (BGS)
Water Table Elevation:	515.51	feet AMSL
Work Completed:	6/1/2021	

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	13.5	18.8	6.62	1.33	>999	>999	7.10
2	501	75	10 - 20	10.3	18.8	6.54	1.20	>999	>999	6.21
3	501	75	10 - 20	8.1	18.8	6.54	1.20	>999	>999	6.21
4	491	85	20 - 30	4.3	17.2	6.52	1.25	>999	135	5.07
5	481	95	30 - 40	1.7	17.1	6.75	1.31	>999	>999	5.96
6	471	105	40 - 50	4.0	17.6	6.72	1.37	>999	>999	5.09

^aSamples are filtered through a 5 micron filter.

Table A.2-7. Geoprobe Location 13531

Easting '83:	1348371	feet
Northing '83:	476986	feet
Ground Elevation:	546	feet above mean sea level (AMSL)
Depth to Water Table:	30.00	feet below ground surface (BGS)
Water Table Elevation:	515.79	feet AMSL
Work Completed:	6/23/2021	

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	35	0 - 10	7.7	17.3	7.88	0.660	>999	318	7.62
2	501	45	10 - 20	7.6	16.2	7.52	0.680	>999	>999	6.86
3	501	45	10 - 20	6.7	16.2	7.52	0.680	>999	>999	6.86
4	491	55	20 - 30	3.4	16.0	7.57	0.660	>999	109	6.38
5	481	65	30 - 40	2.2	15.8	7.84	0.601	>999	178	7.65
6	471	75	40 - 50	7.7	15.4	7.57	0.620	>999	>999	6.79

^aSamples are filtered through a 5 micron filter.

Table A.2-8. Geoprobe Location 13532

Easting '83:	1348521	feet
Northing '83:	476559	feet
Ground Elevation:	566	feet above mean sea level (AMSL)
Depth to Water Table:	48.50	feet below ground surface (BGS)
Water Table Elevation:	517.30	feet AMSL
Work Completed:	6/8/2021	

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	54	0 - 10	13.7	18.7	7.15	0.750	>999	134	7.39
2	502	64	10 - 20	6.0	17.6	7.18	0.610	>999	>999	8.17
3	502	64	10 - 20	6.0	17.6	7.18	0.610	>999	>999	8.17
4	492	74	20 - 30	10.9	16.7	7.22	0.740	>999	593	6.86
5	482	84	30 - 40	5.3	16.4	7.75	0.700	>999	58.4	6.75
6	472	94	40 - 50	6.6	16.3	7.28	0.870	>999	>999	5.43

^aSamples are filtered through a 5 micron filter.

Table A.2-9. Geoprobe Location 13533

Easting '83:	1348683	feet
Northing '83:	476268	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	515.02	feet AMSL
Work Completed:	5/26/2021	

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	66	0 - 10	31.8	19.5	6.87	0.770	>999	230	7.66
2	500	76	10 - 20	1.0	16.6	6.73	0.940	>999	>999	6.87
3	500	76	10 - 20	3.6	16.5	6.73	0.940	>999	>999	6.87
4	490	86	20 - 30	6.7	15.5	6.74	0.930	>999	201	5.93
5	480	96	30 - 40	3.3	15.0	6.80	0.910	>999	191	5.07
6	470	106	40 - 50	5.4	15.1	6.85	0.820	>999	>999	6.92

^aSamples are filtered through a 5 micron filter.

Table A.2-10. Geoprobe Location 13534

Easting '83:	1348833	feet
Northing '83:	476168	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	59.00	feet below ground surface (BGS)
Water Table Elevation:	519.23	feet AMSL
Work Completed:	5/24/2021	

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	64	0 - 10	53.5	19.2	7.14	0.830	>999	193	7.87
2	504	74	10 - 20	7.9	17.6	7.30	0.700	>999	>999	6.18
3	504	74	10 - 20	1.0	17.6	7.30	0.700	>999	>999	6.18
4	494	84	20 - 30	6.1	16.4	7.13	0.610	>999	106	6.33
5	484	94	30 - 40	3.2	16.5	7.14	0.660	>999	334	6.23
6	474	104	40 - 50	5.7	16.4	7.05	0.840	>999	172	6.17

^aSamples are filtered through a 5 micron filter.

Table A.2-11. Geoprobe Location 13240G

Easting '83:	1348845	feet
Northing '83:	475399	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.56	feet AMSL
Work Completed:	4/26/2021	

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	24.4	16.9	7.89	0.860	>999	>999	7.12
2	503	77	10 - 20	13.0	16.6	7.83	0.690	>999	>999	6.70
3	503	77	10 - 20	8.9	16.6	7.83	0.690	>999	>999	6.70
4	493	87	20 - 30	16.6	15.9	7.80	0.650	>999	>999	5.92
5	483	97	30 - 40	18.0	15.7	7.73	0.680	>999	>999	6.10
6	473	107	40 - 50	2.8	15.8	7.90	0.710	>999	>999	6.31

^aSamples are filtered through a 5 micron filter.

Table A.2-12. Geoprobe Location 13267C

Easting '83:	1348841	feet
Northing '83:	475194	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	518.18	feet AMSL
Work Completed:	5/12/2021	

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	57.4	15.5	7.50	0.770	>999	653	6.05
2	503	77	10 - 20	32.1	14.9	7.09	0.720	>999	441	5.50
3	503	77	10 - 20	29.6	14.9	7.09	0.720	>999	441	5.50
4	493	87	20 - 30	30.9	14.5	7.17	0.621	>999	>999	5.77
5	483	97	30 - 40	14.6	14.2	7.60	0.700	>999	70.6	5.54
6	473	107	40 - 50	3.4	14.8	7.27	0.740	>999	>999	4.99

^aSamples are filtered through a 5 micron filter.

Table A.2-13. Geoprobe Location 13421J

Easting '83:	1349309	feet
Northing '83:	476023	feet
Ground Elevation:	571	feet above mean sea level (AMSL)
Depth to Water Table:	55.00	feet below ground surface (BGS)
Water Table Elevation:	516.29	feet AMSL
Work Completed:	5/20/2021	

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	60	0 - 10	2.7	17.6	7.45	0.860	>999	>999	7.49
2	501	70	10 - 20	69.5	17.7	7.24	0.740	>999	>999	3.80
3	501	70	10 - 20	61.2	17.7	7.24	0.740	>999	>999	3.80
4	491	80	20 - 30	47.9	17.1	7.25	0.700	>999	140	3.60
5	481	90	30 - 40	17.4	16.5	7.19	0.730	>999	886	5.71
6	471	100	40 - 50	1.1	17.3	7.60	0.730	>999	>999	5.01
7	461	110	50 - 60	4.4	17.4	7.16	0.840	>999	>999	6.51
8	451	120	60 - 70	3.6	16.8	7.13	0.820	>999	>999	6.29

^aSamples are filtered through a 5 micron filter.

Table A.2-14. Geoprobe Location 13425E

Easting '83:	1349039	feet
Northing '83:	475681	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	518.54	feet AMSL
Work Completed:	7/9/2021	

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	16.8	16.7	7.68	1.00	>999	>999	7.74
2	504	76	10 - 20	62.0	15.9	7.55	0.950	>999	322	6.73
3	504	76	10 - 20	64.5	15.9	7.55	0.950	>999	322	6.73
4	494	86	20 - 30	37.8	15.7	7.67	0.820	>999	915	5.56
5	484	96	30 - 40	28.8	15.80	7.57	0.750	>999	>999	6.02
6	474	106	40 - 50	13.4	15.6	7.81	0.820	>999	>999	4.13

^aSamples are filtered through a 5 micron filter.

Table A.2-15. Geoprobe Location 13477D

Easting '83:	1349240	feet
Northing '83:	475822	feet
Ground Elevation:	580	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	517.96	feet AMSL
Work Completed:	7/8/2021	

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	1.0	17.0	7.80	0.960	>999	31.9	5.60
2	503	77	10 - 20	32.0	17.0	7.70	0.860	>999	89.6	5.97
3	503	77	10 - 20	31.9	17.0	7.70	0.860	>999	89.6	5.97
4	493	87	20 - 30	59.3	16.5	7.85	0.760	>999	>999	6.21
5	483	97	30 - 40	13.7	16.2	7.75	0.790	>999	>999	5.94
6	473	107	40 - 50	8.8	16.4	7.67	0.880	>999	>999	5.20

^aSamples are filtered through a 5 micron filter.

Table A.2-16. Geoprobe Location 13513B

Easting '83:	1348891	feet
Northing '83:	475083	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	62.00	feet below ground surface (BGS)
Water Table Elevation:	519.17	feet AMSL
Work Completed:	4/28/2021	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered ^a (µg/L)	Temperature Filtered ^a (°C)	pH Filtered ^a (SU)	Specific Conductance Filtered ^a (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered ^a (NTU)	Dissolved Oxygen Filtered ^a (mg/L)
1	514	67	0 - 10	38.0	17.0	7.36	0.980	>999	>999	5.64
2	504	77	10 - 20	25.7	15.7	7.64	0.830	>999	>999	3.82
3	504	77	10 - 20	25.2	15.7	7.64	0.830	>999	>999	3.82
4	494	87	20 - 30	28.6	15.5	7.61	0.780	>999	>999	4.60
5	484	97	30 - 40	22.7	15.0	7.69	0.770	>999	>999	5.56
6	474	107	40 - 50	2.2	15.4	7.63	0.890	>999	>999	5.73

^aSamples are filtered through a 5 micron filter.

Table A.2-17. Geoprobe Location 13519A

Easting '83:	1348927	feet
Northing '83:	475545	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	61.50	feet below ground surface (BGS)
Water Table Elevation:	516.17	feet AMSL
Work Completed:	4/27/2021	

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	67	0 - 10	21.0	16.9	7.33	1.00	>999	>999	5.69
2	501	77	10 - 20	27.9	16.8	7.50	0.840	>999	>999	5.39
3	501	77	10 - 20	19.5	16.8	7.50	0.840	>999	>999	5.39
4	491	87	20 - 30	19.5	16.5	7.62	0.730	>999	>999	5.53
5	481	97	30 - 40	13.8	16.8	7.72	0.750	>999	>999	5.52
6	471	107	40 - 50	8.5	16.6	7.70	0.780	>999	>999	5.64

^aSamples are filtered through a 5 micron filter.

Table A.2-18. Geoprobe Location 13526A

Easting '83:	1349081	feet
Northing '83:	475747	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	63.00	feet below ground surface (BGS)
Water Table Elevation:	518.32	feet AMSL
Work Completed:	7/7/2021	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered ^a (µg/L)	Temperature Filtered ^a (°C)	pH Filtered ^a (SU)	Specific Conductance Filtered ^a (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered ^a (NTU)	Dissolved Oxygen Filtered ^a (mg/L)
1	513	68	0 - 10	4.7	17.7	7.58	1.05	>999	>999	7.71
2	503	78	10 - 20	54.8	17.2	7.63	0.860	>999	>999	6.69
3	503	78	10 - 20	53.0	17.2	7.63	0.860	>999	>999	6.69
4	493	88	20 - 30	7.7	17.9	7.82	0.800	>999	79.4	4.72
5	483	98	30 - 40	2.2	17.8	7.86	0.790	>999	103	5.27
6	473	108	40 - 50	2.5	17.9	7.86	0.870	>999	>999	5.31

^aSamples are filtered through a 5 micron filter.

Table A.2-19. Geoprobe Location 13535

Easting '83:	1349334	feet
Northing '83:	475922	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	60.00	feet below ground surface (BGS)
Water Table Elevation:	516.12	feet AMSL
Work Completed:	5/19/2021	

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	1.0	17.4	7.28	0.890	>999	135	7.12
2	501	75	10 - 20	76.1	17.1	7.05	0.740	>999	85.3	6.37
3	501	75	10 - 20	75.1	17.1	7.05	0.740	>999	85.3	6.37
4	491	85	20 - 30	6.1	17.5	7.25	0.740	>999	>999	5.70
5	481	95	30 - 40	2.4	17.7	7.08	0.790	>999	809	5.43
6	471	105	40 - 50	2.4	17.2	7.13	0.780	>999	>999	5.59

^aSamples are filtered through a 5 micron filter.

Table A.2-20. Geoprobe Location 13536

Easting '83:	1348847	feet
Northing '83:	475691	feet
Ground Elevation:	576	feet above mean sea level (AMSL)
Depth to Water Table:	60.50	feet below ground surface (BGS)
Water Table Elevation:	515.03	feet AMSL
Work Completed:	4/21/2021	

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	66	0 - 10	43.5	13.6	7.16	0.980	>999	277	6.30
2	500	76	10 - 20	23.3	12.9	7.38	0.760	>999	>999	6.45
3	500	76	10 - 20	22.5	12.9	7.38	0.760	>999	>999	6.45
4	490	86	20 - 30	11.2	13.3	7.56	0.700	>999	>999	7.55
5	480	96	30 - 40	15.2	13.3	7.78	0.740	>999	>999	6.37
6	470	106	40 - 50	3.8	13.7	7.74	0.760	>999	55.3	4.40

^aSamples are filtered through a 5 micron filter.

Table A.2-21. Geoprobe Location 13537

Easting '83:	1348330	feet
Northing '83:	475659	feet
Ground Elevation:	573	feet above mean sea level (AMSL)
Depth to Water Table:	57.00	feet below ground surface (BGS)
Water Table Elevation:	515.99	feet AMSL
Work Completed:	5/6/2021	

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	62	0 - 10	19.5	14.1	7.79	0.660	>999	>999	6.09
2	501	72	10 - 20	15.9	15.4	7.82	0.670	>999	>999	6.23
3	501	72	10 - 20	13.4	15.4	7.82	0.670	>999	>999	6.23
4	491	82	20 - 30	7.9	15.0	7.95	0.640	>999	>999	7.01
5	481	92	30 - 40	7.4	15.1	7.88	0.720	>999	>999	5.30
6	471	102	40 - 50	3.5	14.9	7.77	0.840	>999	>999	5.90

^aSamples are filtered through a 5 micron filter.

Table A.2-22. Geoprobe Location 13538

Easting '83:	1348356	feet
Northing '83:	475537	feet
Ground Elevation:	575	feet above mean sea level (AMSL)
Depth to Water Table:	59.00	feet below ground surface (BGS)
Water Table Elevation:	515.92	feet AMSL
Work Completed:	5/5/2021	

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	35.5	13.5	7.69	0.760	>999	>999	6.79
2	501	74	10 - 20	24.4	13.9	7.85	0.730	>999	>999	6.63
3	501	74	10 - 20	31.7	13.9	7.85	0.730	>999	>999	6.63
4	491	84	20 - 30	10.3	13.5	7.93	0.680	>999	>999	5.98
5	481	94	30 - 40	6.1	13.6	8.02	0.650	>999	>999	6.19
6	471	104	40 - 50	2.6	13.6	7.91	0.690	>999	>999	6.82

^aSamples are filtered through a 5 micron filter.

Table A.2-23. Geoprobe Location 13539

Easting '83:	1348355	feet
Northing '83:	475402	feet
Ground Elevation:	578	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	516.81	feet AMSL
Work Completed:	5/10/2021	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered ^a (µg/L)	Temperature Filtered ^a (°C)	pH Filtered ^a (SU)	Specific Conductance Filtered ^a (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered ^a (NTU)	Dissolved Oxygen Filtered ^a (mg/L)
1	512	66	0 - 10	15.8	14.1	7.56	0.810	>999	>999	8.02
2	502	76	10 - 20	4.9	13.8	7.61	0.740	>999	>999	6.09
3	502	76	10 - 20	20.4	13.8	7.61	0.740	>999	>999	6.09
4	492	86	20 - 30	14.1	14.0	7.83	0.640	>999	>999	6.47
5	482	96	30 - 40	1.3	14.0	7.72	0.614	>999	>999	5.78
6	472	106	40 - 50	9.1	13.6	7.54	0.650	>999	>999	6.48

^aSamples are filtered through a 5 micron filter.

Table A.2-24. Geoprobe Location 13540

Easting '83:	1348353	feet
Northing '83:	475265	feet
Ground Elevation:	577	feet above mean sea level (AMSL)
Depth to Water Table:	61.00	feet below ground surface (BGS)
Water Table Elevation:	516.04	feet AMSL
Work Completed:	5/13/2021	

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	7.8	13.3	7.27	0.720	>999	>999	9.97
2	501	76	10 - 20	3.9	14.4	7.00	0.690	>999	53.8	6.15
3	501	76	10 - 20	4.0	14.4	7.00	0.690	>999	53.8	6.15
4	491	86	20 - 30	11.6	13.6	7.15	0.549	>999	>999	5.33
5	481	96	30 - 40	7.4	14.8	7.30	0.578	>999	>999	7.09
6	471	106	40 - 50	2.6	13.7	7.38	0.579	>999	61.2	2.65

^aSamples are filtered through a 5 micron filter.

Table A.2-25. Geoprobe Location 13541

Easting '83:	1348189	feet
Northing '83:	475092	feet
Ground Elevation:	536	feet above mean sea level (AMSL)
Depth to Water Table:	22.00	feet below ground surface (BGS)
Water Table Elevation:	513.70	feet AMSL
Work Completed:	4/22/2021	

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	509	27	0 - 10	19.3	10.9	7.48	0.679	>999	203	8.61
2	499	37	10 - 20	5.9	10.5	7.91	0.591	>999	274	7.60
3	499	37	10 - 20	6.1	10.5	7.91	0.591	>999	274	7.60
4	489	47	20 - 30	3.3	10.3	7.82	0.616	>999	>999	9.51
5	479	57	30 - 40	7.3	10.7	7.79	0.626	>999	>999	6.59
6	469	67	40 - 50	7.5	10.7	7.84	0.740	>999	>999	7.19

^aSamples are filtered through a 5 micron filter.

Table A.2-26A. Geoprobe Location 13542, July 20, 2021

Easting '83:	1348154	feet
Northing '83:	474985	feet
Ground Elevation:	540	feet above mean sea level (AMSL)
Depth to Water Table:	26.00	feet below ground surface (BGS)
Water Table Elevation:	513.80	feet AMSL
Work Completed:	7/20/2021	

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	509	31	0 - 10	32.2	18.3	7.35	1.04	>999	49.8	8.09
2	499	41	10 - 20	5.4	18.5	7.41	0.780	>999	40.7	6.75
3	499	41	10 - 20	4.3	18.5	7.41	0.780	>999	40.7	6.75
4	489	51	20 - 30	8.9	15.9	7.64	0.820	>999	323	5.47
5	479	61	30 - 40	21.8	15.5	7.70	0.900	>999	>999	6.65
6	469	71	40 - 50	40.4	15.1	7.55	0.970	>999	>999	5.28

^aSamples are filtered through a 5 micron filter.

Table A.2-26B. Geoprobe Location 13542, July 28, 2021

Easting '83:	1348154	feet
Northing '83:	474985	feet
Ground Elevation:	540	feet above mean sea level (AMSL)
Depth to Water Table:	26.00	feet below ground surface (BGS)
Water Table Elevation:	513.80	feet AMSL
Work Completed:	7/28/2021	

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	509	31	0 - 10	21.1	19.3	7.59	1.03	>999	72.9	7.43
2	499	41	10 - 20	4.8	16.7	7.63	0.730	>999	311	5.81
3	499	41	10 - 20	4.6	16.7	7.63	0.730	>999	311	5.81
4	489	51	20 - 30	6.1	16.5	7.48	0.820	>999	8.90	5.41
5	479	61	30 - 40	17.2	16.0	7.51	0.910	>999	412	4.80
6	469	71	40 - 50	20.2	16.6	7.61	0.920	>999	930	4.88
7	459	81	50 - 60	10.2	16.5	7.64	0.820	>999	121	4.44
8	449	91	60 - 70	3.9	15.2	7.64	0.780	>999	>999	4.86
9	439	101	70 - 80	1.4	15.9	7.71	0.730	>999	174	3.35

^aSamples are filtered through a 5 micron filter.

Table A.2-26C. Geoprobe Location 13542, August 6, 2021

Easting '83:	1348154	feet
Northing '83:	474985	feet
Ground Elevation:	540	feet above mean sea level (AMSL)
Depth to Water Table:	26.00	feet below ground surface (BGS)
Water Table Elevation:	513.80	feet AMSL
Work Completed:	8/6/2021	

Sample Point	Elevation (ft AMSL)	Depth (ft BGS)	Sample Interval (ft)	Uranium Filtered ^a (µg/L)	Uranium Filtered ^b (µg/L)	Temperature Filtered ^a (°C)	pH Filtered ^a (SU)	Specific Conductance Filtered ^a (mS/cm)	Turbidity Unfiltered (NTU)	Turbidity Filtered ^a (NTU)	Turbidity Filtered ^b (NTU)	Dissolved Oxygen Filtered ^a (mg/L)
1	509	31	0 - 10	20.4	21.9	16.0	7.40	0.990	>999	5.50	2.60	6.67
2	499	41	10 - 20	2.7	2.4	16.9	7.51	0.770	>999	36.4	1.40	6.71
3	499	41	10 - 20	2.7	2.3	16.9	7.51	0.770	>999	36.4	1.40	6.71
4	489	51	20 - 30	6.8	5.6	15.6	7.43	0.750	>999	166	1.14	4.71
5	479	61	30 - 40	9.7	8.5	15.0	7.45	0.870	>999	12.0	1.65	3.91
6	469	71	40 - 50	17.9	19.8	14.9	7.54	0.960	>999	>999	11.8	5.23
7	459	81	50 - 60	15.4	12.5	14.5	7.60	0.810	>999	>999	11.7	5.64
8	449	91	60 - 70	8.0	5.9	14.5	7.65	0.780	>999	>999	9.08	4.71
9	439	101	70 - 80	1.0	1.0	14.8	7.69	0.760	>999	11.8	2.47	3.39

^aSamples are filtered through a 5 micron filter.

^bSamples are filtered through a .45 micron filter.

Table A.2-27. Geoprobe Location 13543

Easting '83:	1348350.898	feet
Northing '83:	475104.656	feet
Ground Elevation:	581	feet above mean sea level (AMSL)
Depth to Water Table:	65.00	feet below ground surface (BGS)
Water Table Elevation:	516.01	feet AMSL
Work Completed:	5/11/2021	

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	70	0 - 10	22.1	13.5	7.04	0.720	>999	84.8	8.29
2	501	80	10 - 20	3.8	13.4	6.70	0.629	>999	373	6.30
3	501	80	10 - 20	1.0	13.4	6.70	0.629	>999	373	6.30
4	491	90	20 - 30	7.6	12.4	7.50	0.535	>999	>999	5.51
5	481	100	30 - 40	4.7	12.4	7.45	0.559	>999	221	6.82
6	471	110	40 - 50	1.0	12.5	7.31	0.554	>999	>999	5.59

^aSamples are filtered through a 5 micron filter.

Table A.2-28. Summary Statistics and Trend Analysis of Monitoring Wells for Total Uranium with 2021 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	92	12.0	462	110	94	No Trend
2046	91	14.3	907	122	185	Down
21033	60	7.34	43.2	21.4	7.4	Up
23271	40	34.6	144	69.0	30	Down
23273	40	114	421	216	76	Down
23274	61	74.4	384	156	62	Down
23275	39	82.9	349	158	54	Down
23276	40	3.56	115	78.3	19.3	Down
23280	40	19.1	700	127	128	Down
23281	40	16.1	367	118	76	Down
2385	63	12.5	592	183	128	Down
2386	63	6.67	143	34.3	30.4	Up
2387	63	18.1	492	154	75	Up
2389	52	0.899	120	33.1	21.6	Up
2397	49	135	737	347	126	Down
2649	59	6.01	1240	271	320	Up
2880	63	0.400	71.8	28.4	26.2	Up
3095	83	2.00	94.0	28.5	17.0	No Trend
63285	40	69.8	277	163	64	Down
6880	50	37.8	145	76.4	24.9	Down
82369_C1	18	12.1	210	125	44	No Trend
82369_C2	12	25.1	50.6	35.3	7.3	Up
82369_C3	10	24.0	41.3	31.9	5.2	No Trend
82372_C1	19	26.8	62.4	38.7	9.0	Down
83117_C1	41	1.28	1620	692	321	Down
83117_C4	22	42.9	111	73.1	19.1	Down
83124_C1	63	102	1070	485	204	No Trend
83124_C2	37	22.8	103	43.4	18.0	Down
83124_C4	21	25.4	62.2	42.8	9.1	Up
83124_C5	21	24.4	61.4	46.2	9.1	Down
83294_C1	34	98.5	340	217	62	Up
83294_C2	54	1.24	575	300	117	Down
83294_C3	24	20.5	539	225	169	Down
83295_C2	35	53.1	178	111	40	Down
83295_C3	26	40.9	175	105	45	Down
83295_C5	21	29.9	155	63.1	32.9	Down
83296_C1	20	49.3	135	76.2	21.1	Down
83337_C1	37	255	2660	1380	570	Down
83337_C2	53	2.40	835	123	165	No Trend
83338_C1	26	282	1100	519	149	Down
83338_C2	32	14	648	88.6	139	Down
83340_C1	28	13.2	72.7	31.4	10.8	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 2021 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.

Table A.2-28. Summary Statistics and Trend Analysis of Monitoring Wells for Total Uranium with 2021 Results Above FRLs (continued)

^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 2021.

Table A.2-29. Summary Statistics and Trend Analysis of Extraction Wells for Total Uranium

Well	Number of Samples ^{a,b}	Minimum (µg/L) ^{a,b,c}	Maximum (µg/L) ^{a,b,c}	Average (µg/L) ^{a,b,c}	Standard Deviation (µg/L) ^{a,b,c}	Trend ^{a,b,c,d}
South Plume Module (August 27, 1993, through December 31, 2021)						
3924	727	1.2	180	27.0	15.1	Down
3925	731	0.5	84.0	22.4	8.1	Down
3926	717	1.5	42.4	24.3	7.8	Down
3927	716	1.0	17.0	2.7	1.1	Up
South Plume Optimization Module (August 9, 1998, through December 31, 2021)						
32308	646	18.4	100	48.9	17.0	Down
32309	648	15.6	123	48.9	21.1	Down
South Field Module (July 13, 1998, through December 31, 2021)						
31550	678	16.2	128	47.6	18.1	Down
31560	705	11.2	183	51.3	37.4	Down
31561	678	17.7	114 ^e	38.5	10.1	Down
32276	719	12.3	290	86.4	63.8	Down
32446	573	17.4	168	52.3	21.6	Down
32447	596	9.4	302	91.3	55.3	Down
33061	475	13.6	98.5	40.6	15.4	Down
33262	434	16.1	110	40.6	14.9	Down
33264	422	3.6	364	63.3	44.5	Down
33298	38269	10.1	76.2	45.2	13.0	Down
33326	333	7.8	62.2	20.9	8.3	Down
Waste Storage Area Module (May 8, 2002, through December 31, 2021)						
32761	465	17.4	161	50.8	32.0	Down
33062	480	10.2	236	57.0	42.5	Down
33347	289	7.0	126	25.1	15.4	No Trend

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

^b Rejected data qualified with an R were not included in this count, the summary statistics, or Mann-Kendall test for trend.

^c For results where the concentrations are below the detection limit, the results used in the summary statistics and Mann-Kendall test for trend are each set at half the detection limit.

^d Mann-Kendall test for trend is performed with a 95% confidence interval.

^e This result (sampled August 31, 1998) appears to be an outlier. It is suspected that the sample for this well was switched with the sample from extraction well 31562, which is no longer active as an extraction well.

Table A.2-30. Plume Size 1997 Through 2021

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

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

Table A.2-31. Comparison of Plume Size Interpretation and Ricker Method Plume Size Calculation

Year	Maximum Uranium Plume Size Interpretation (acres)	Ricker Method Plume Size Calculation (acres)	Relative Percent Difference ^a
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%

^a Relative percent difference = [(maximum-Ricker)/maximum]* 100

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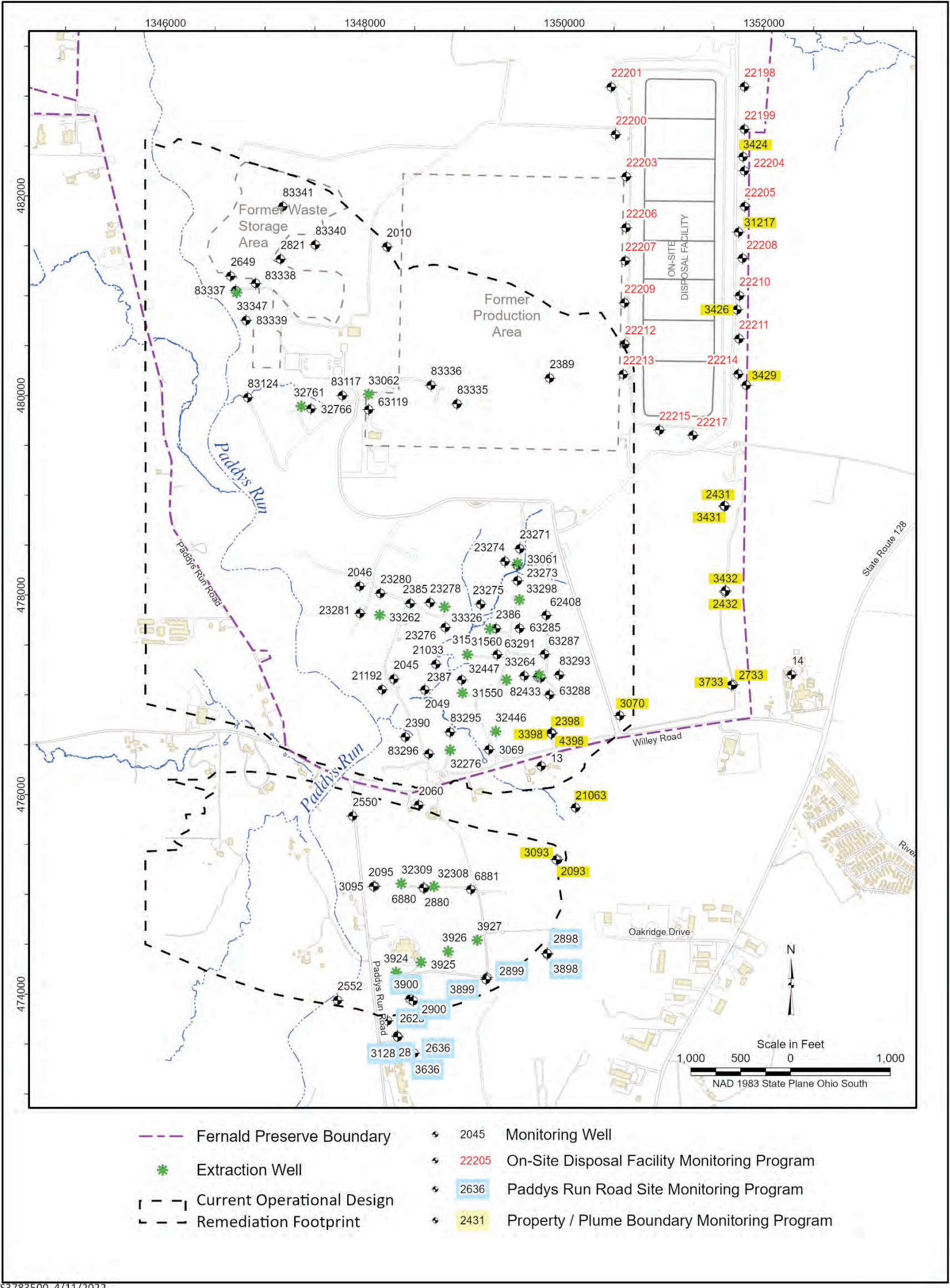


Figure A.2-1. IEMP Water Quality Monitoring Wells and Extraction Wells

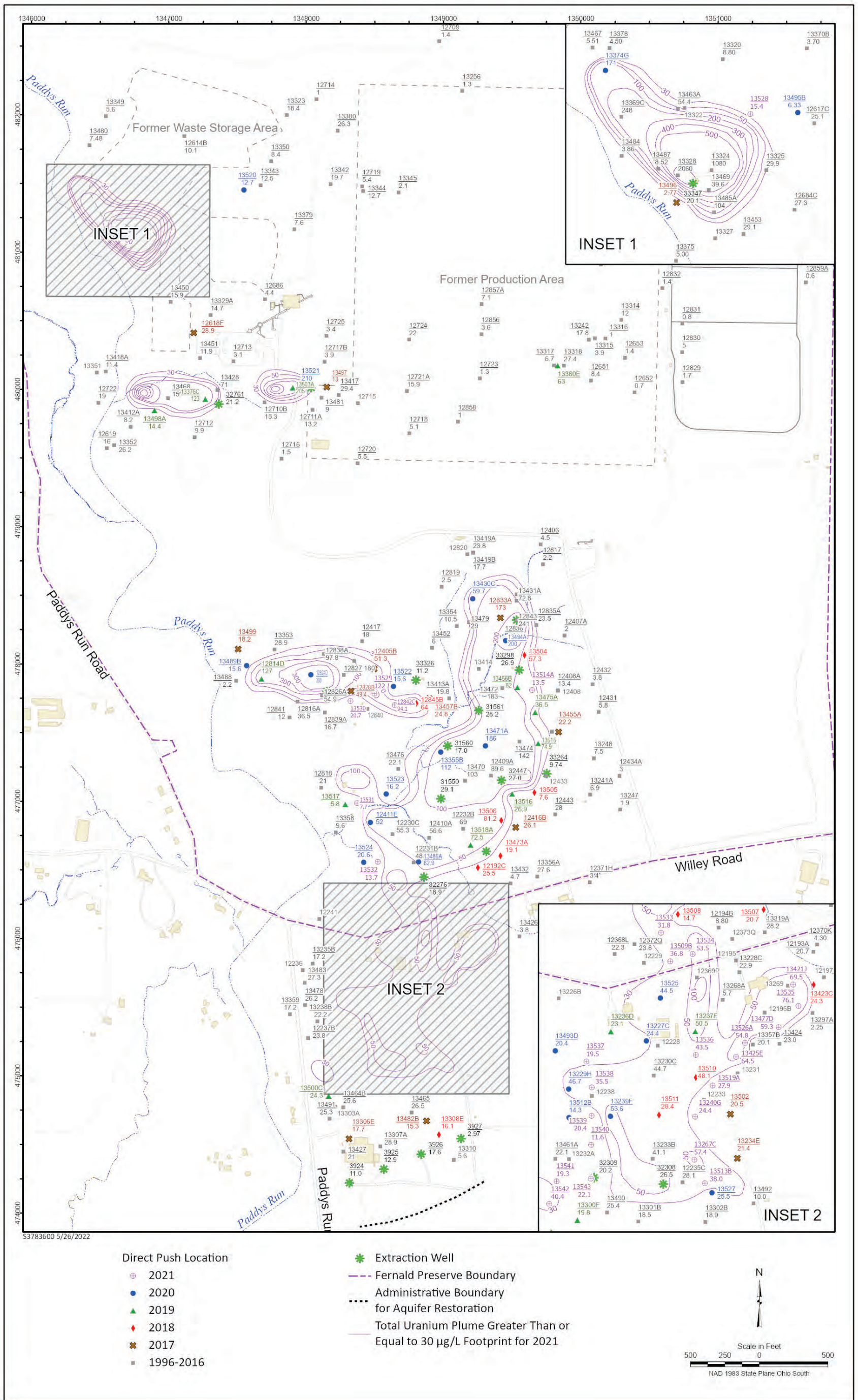


Figure A.2-2. Direct-Push Data and Maximum Total Uranium Plume for 2021

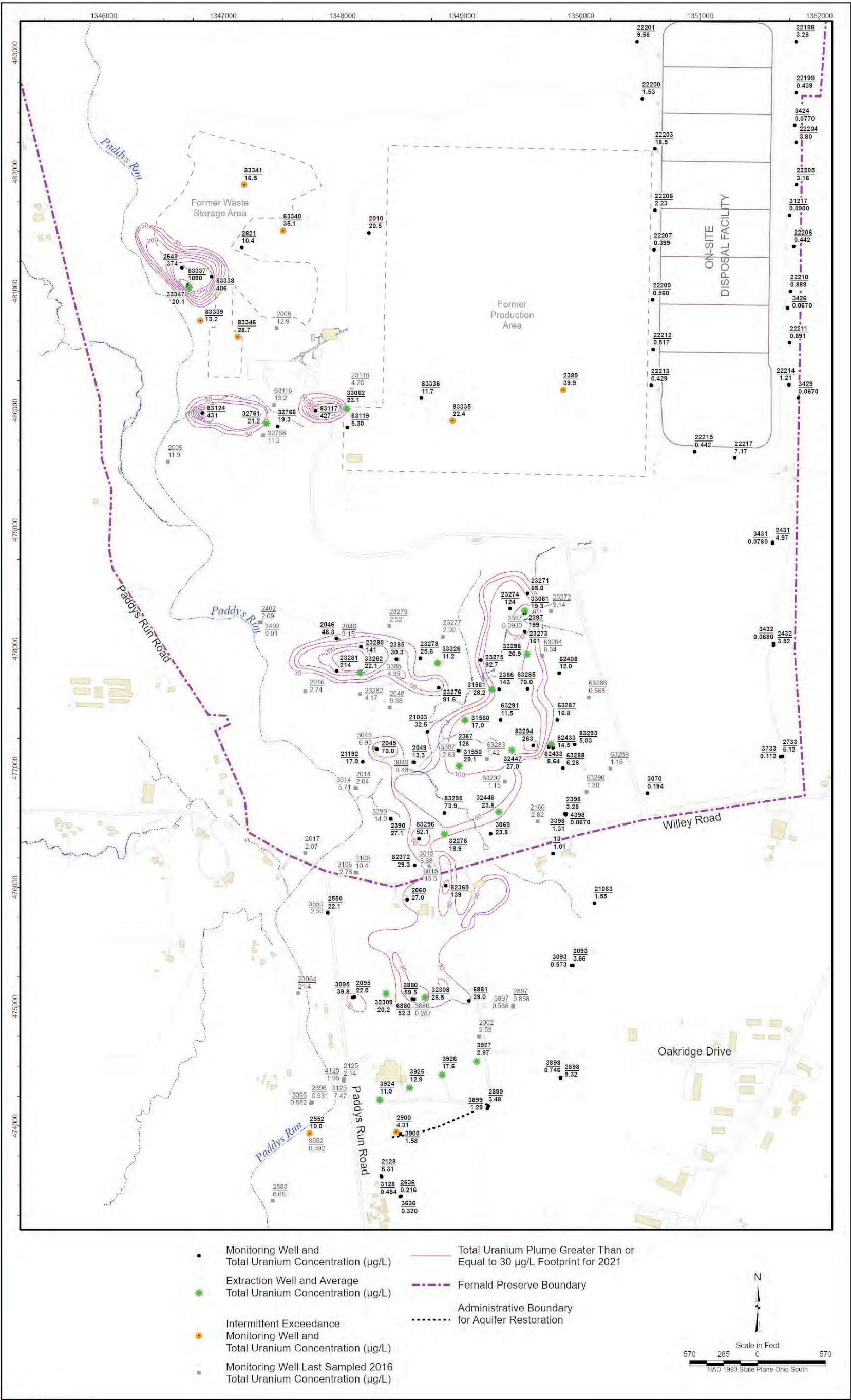
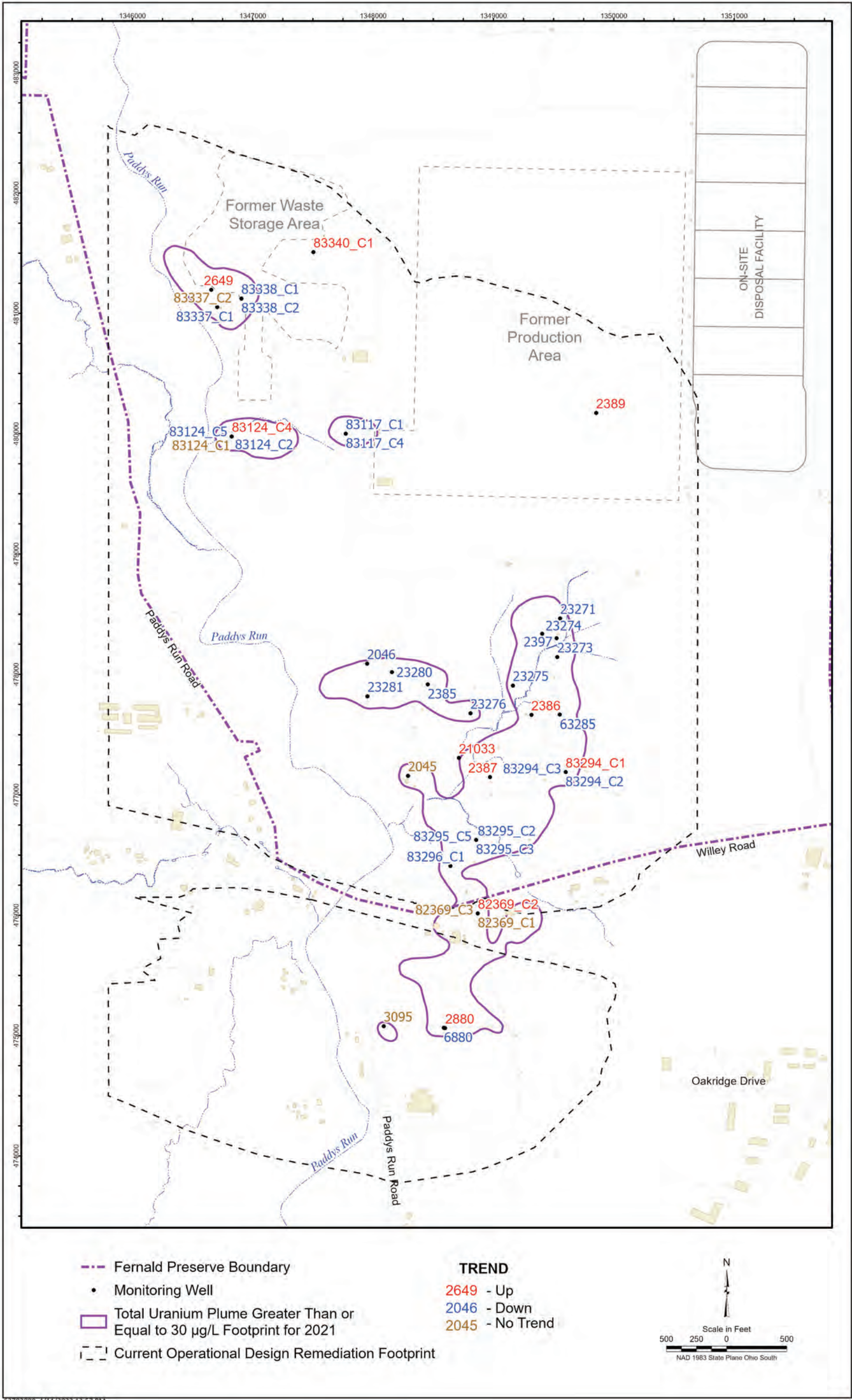


Figure A.2-3. Monitoring Well Data and Maximum Total Uranium Plume for 2021



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Figure A.2-4. Monitoring Wells with 2021 Exceedances for Total Uranium with Up, Down, or No Significant Trends

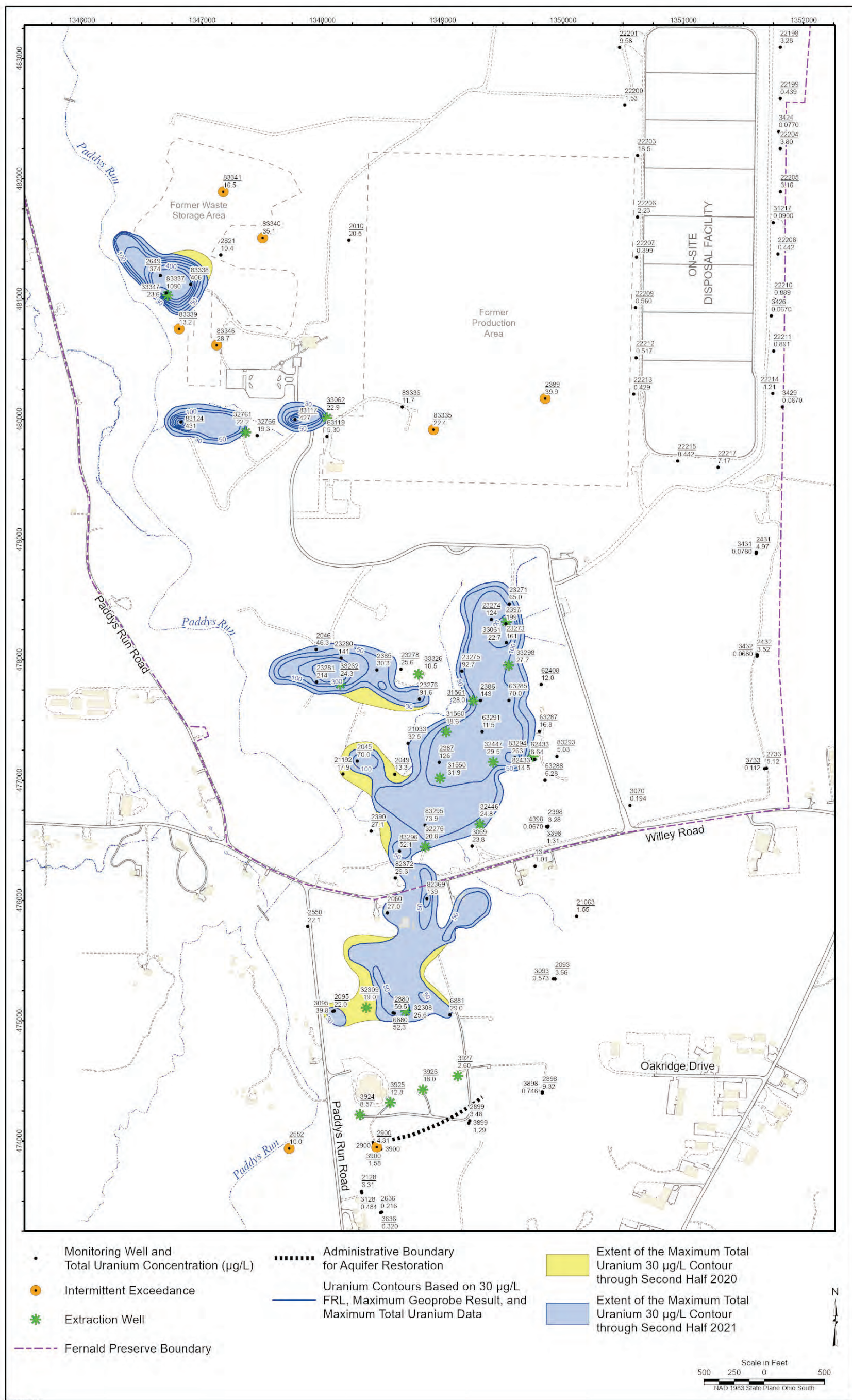


Figure A.2-5. Monitoring Well Data from 2021 Comparison to Maximum Total Uranium Footprint at end of 2020.

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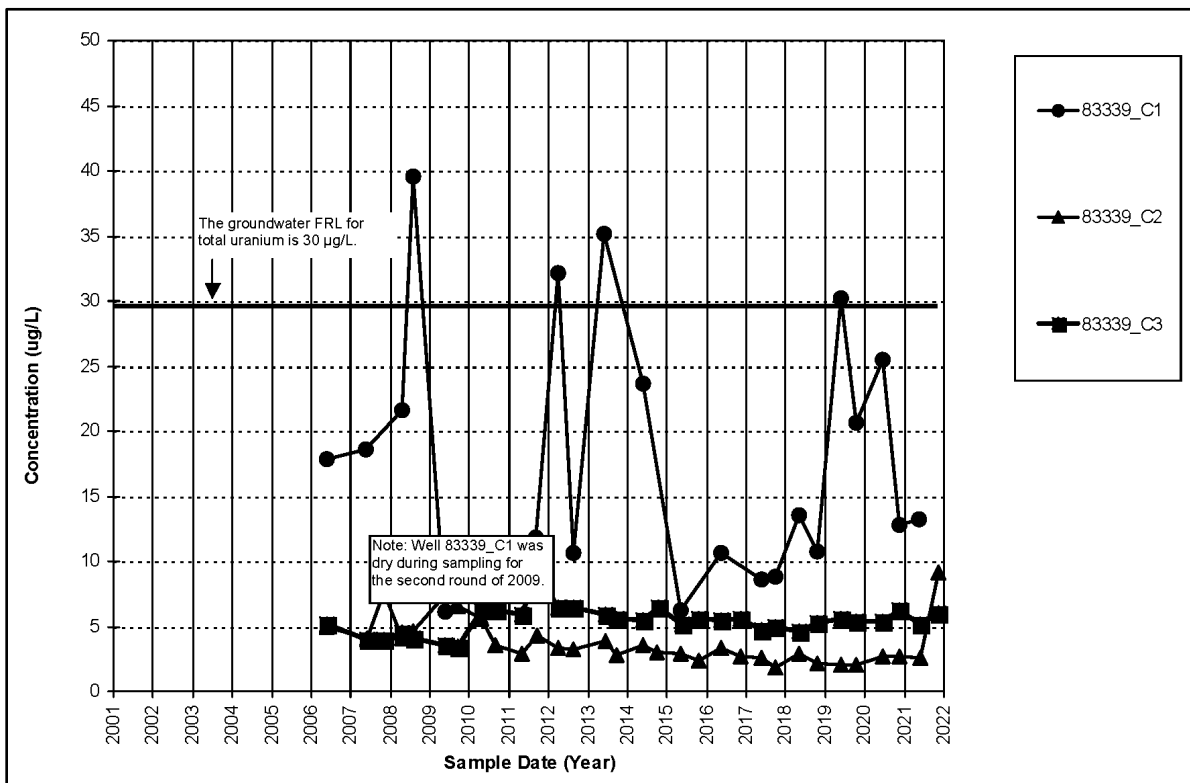


Figure A.2-6. Total Uranium Concentration Versus Time Plot for Monitoring Well 83339

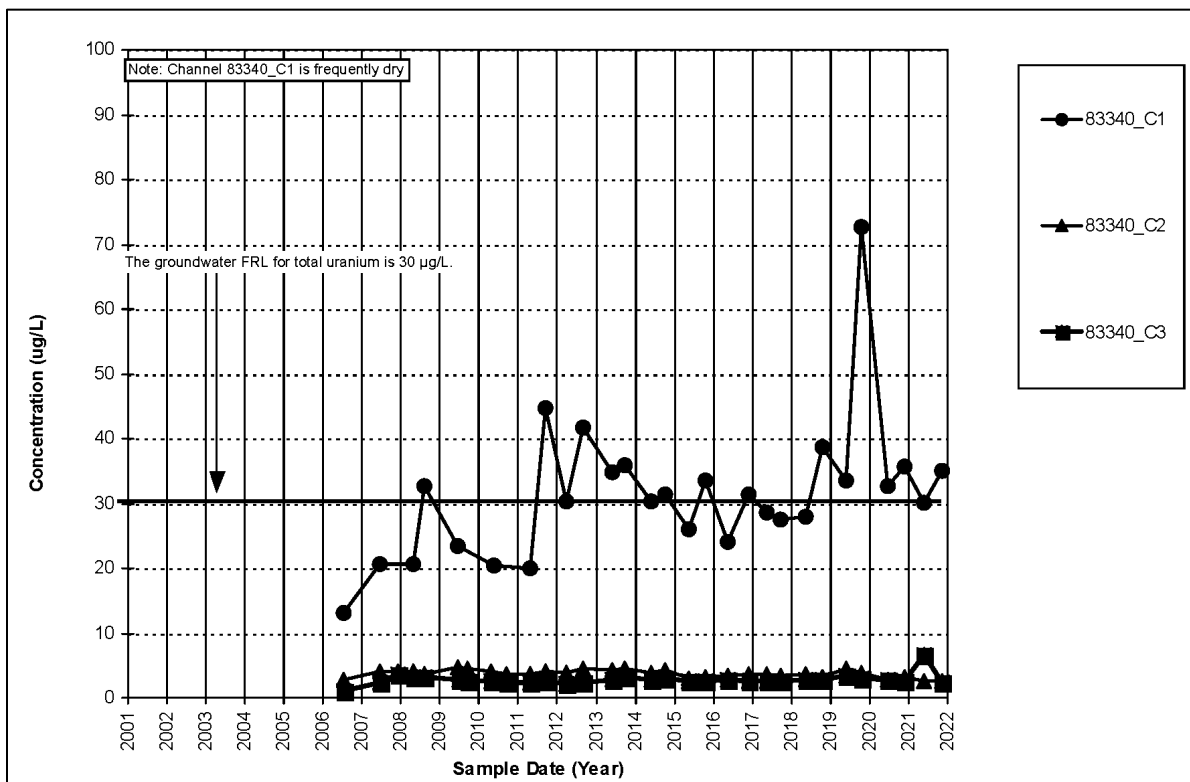


Figure A.2-7. Total Uranium Concentration Versus Time Plot for Monitoring Well 83340

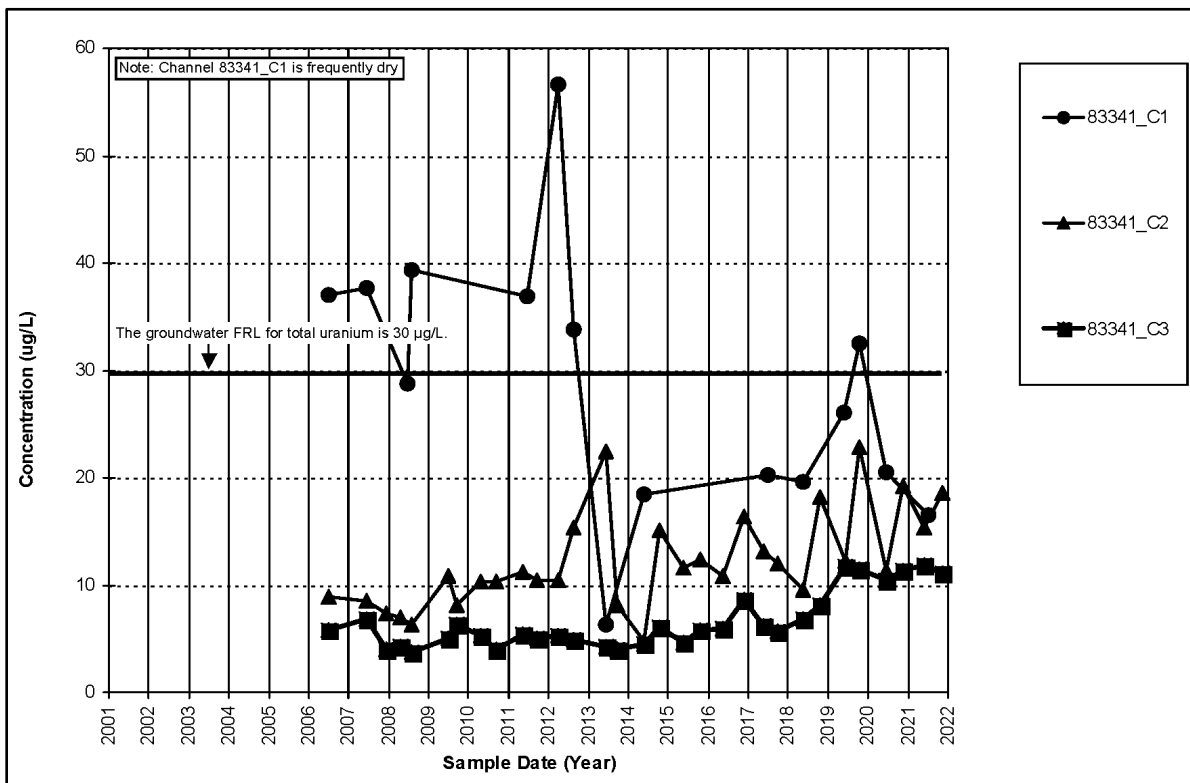


Figure A.2-8. Total Uranium Concentration Versus Time Plot for Monitoring Well 83341

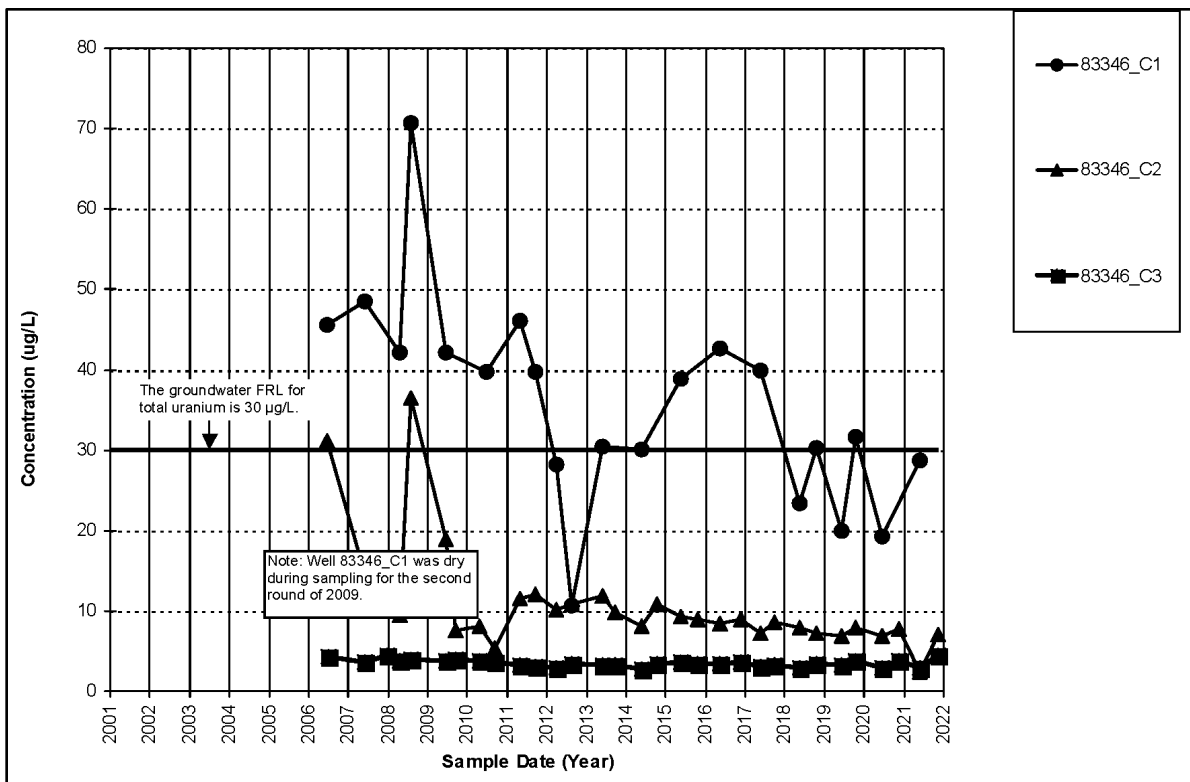


Figure A.2-9. Total Uranium Concentration Versus Time Plot for Monitoring Well 83346

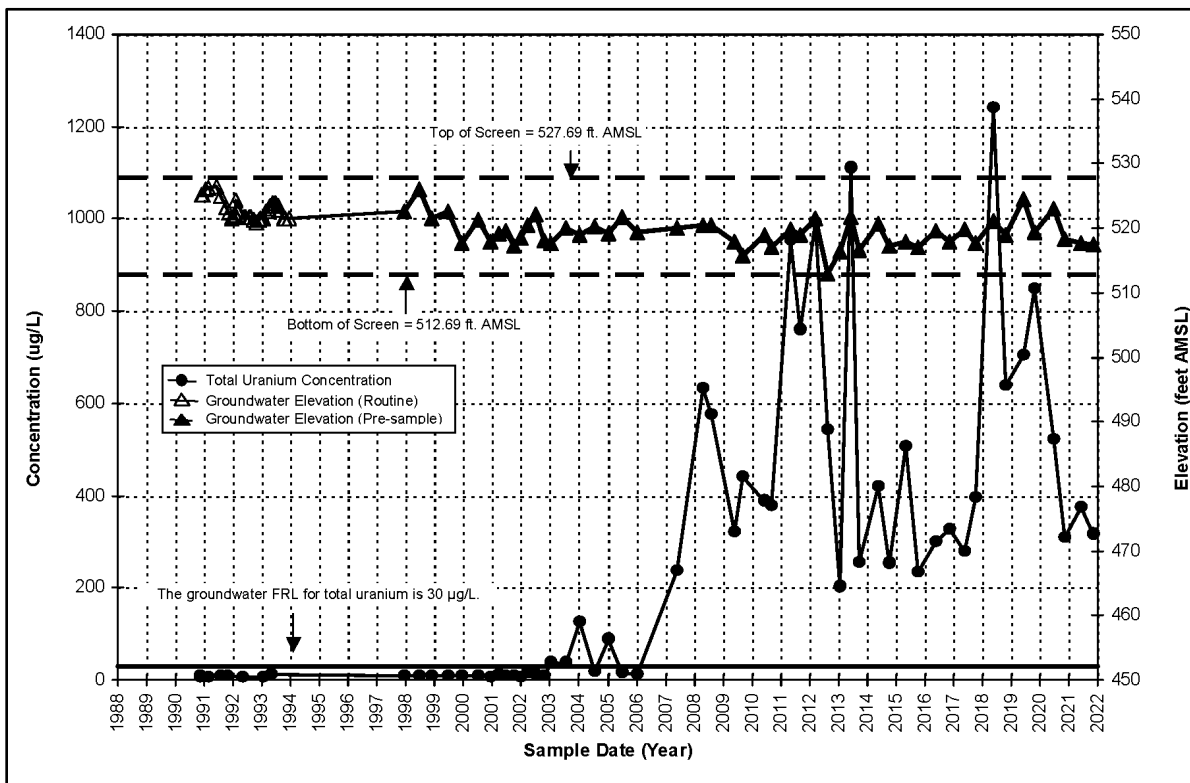


Figure A.2-10. Total Uranium Concentration Versus Time Plot for Monitoring Well 2649

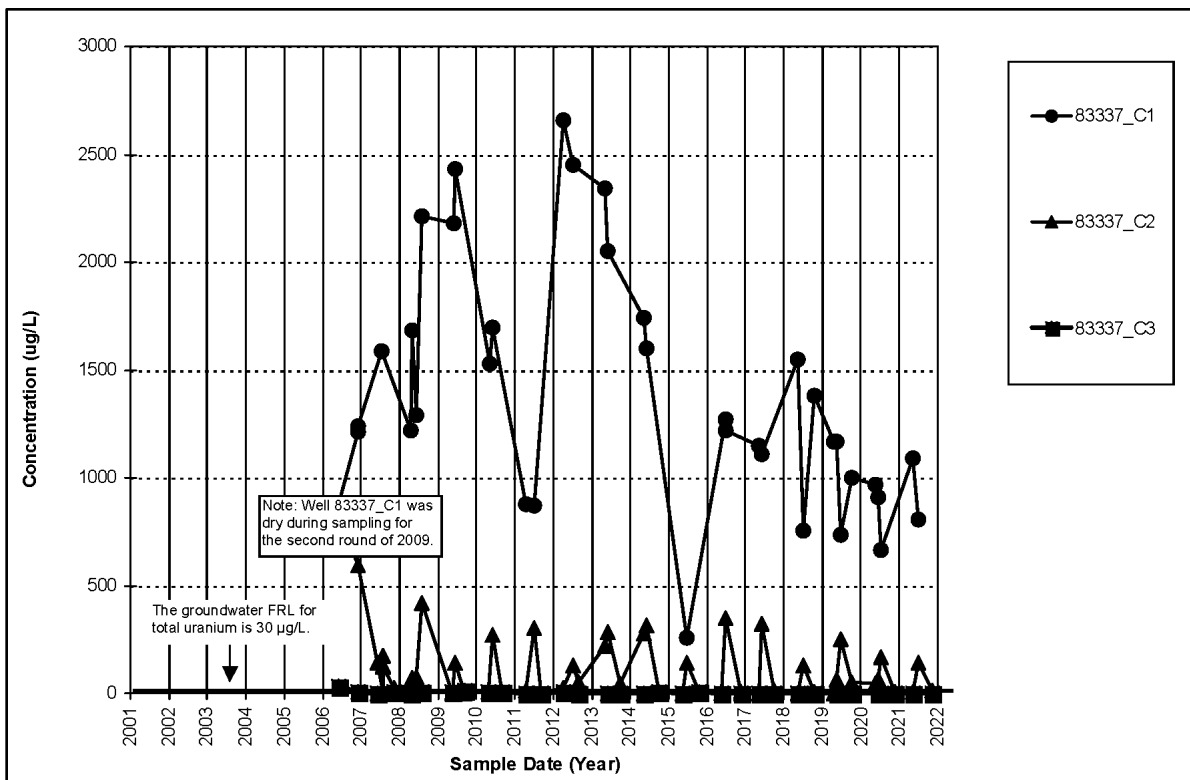


Figure A.2-11. Total Uranium Concentration Versus Time Plot for Monitoring Well 83337

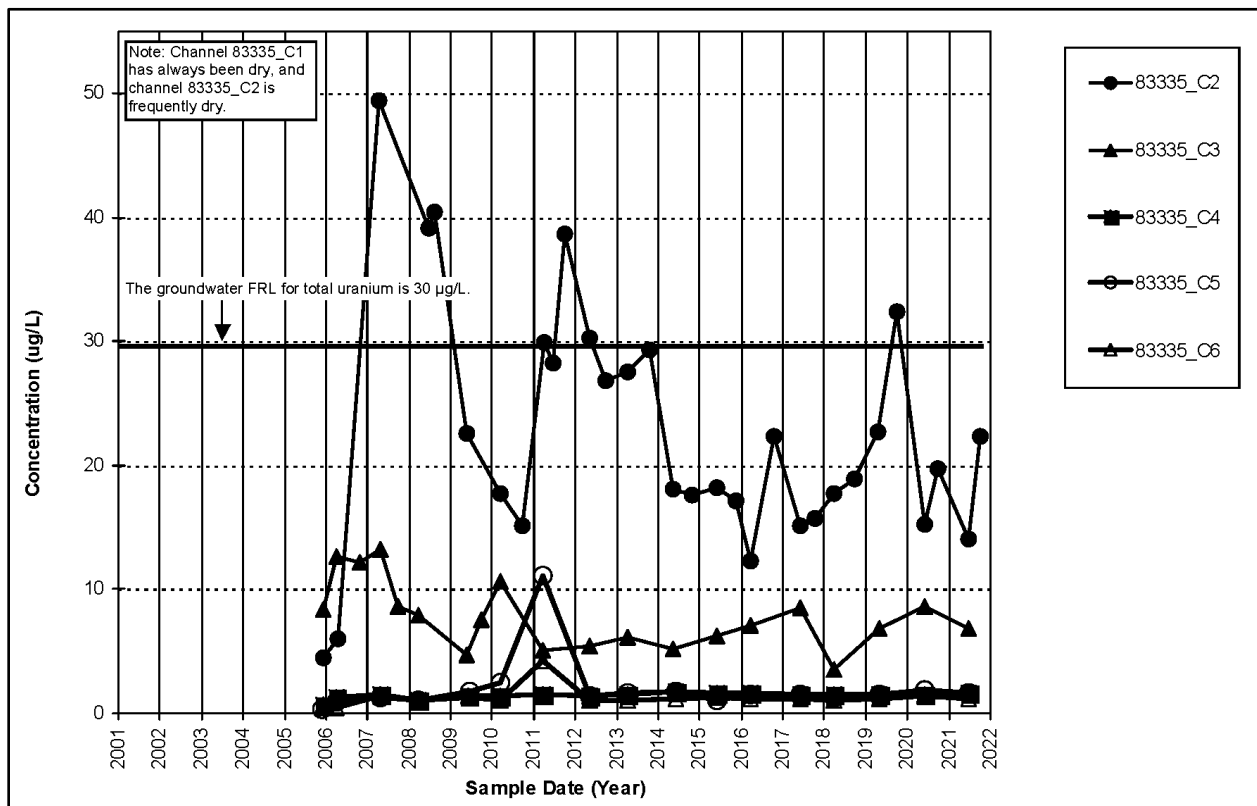


Figure A.2-12. Total Uranium Concentration Versus Time Plot for Monitoring Well 83335

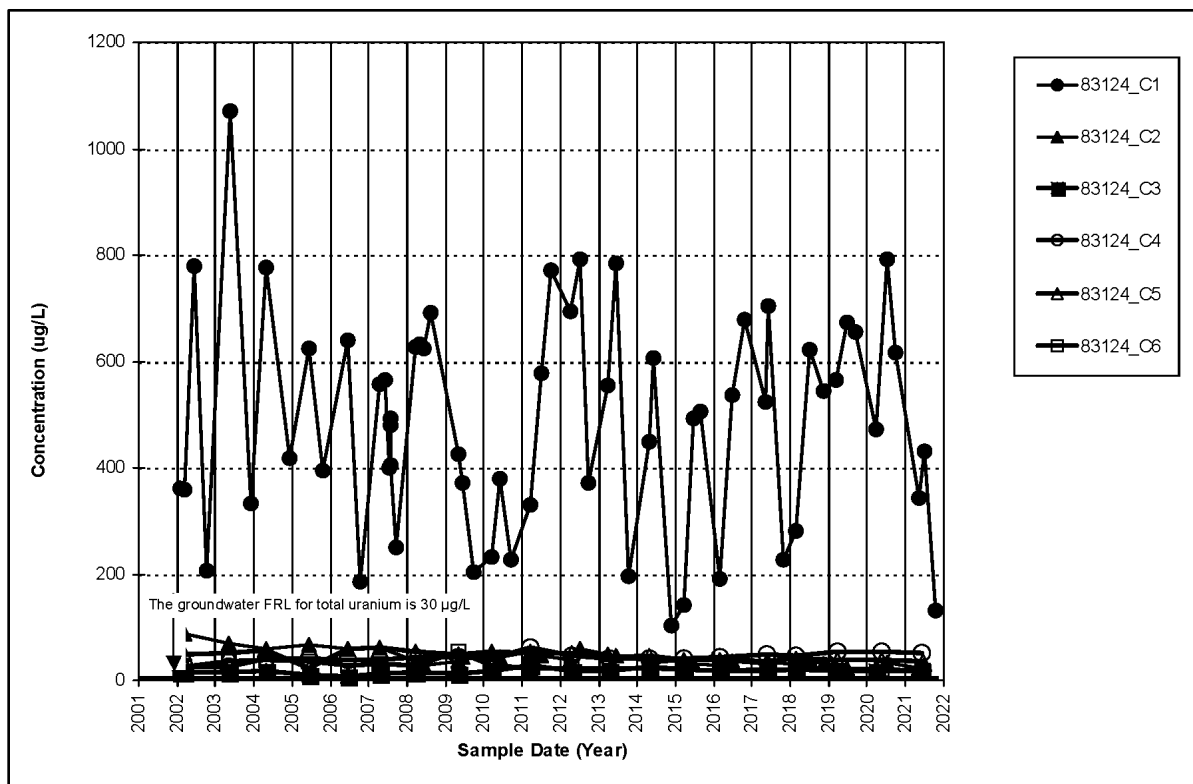


Figure A.2-13. Total Uranium Concentration Versus Time Plot for Monitoring Well 83124

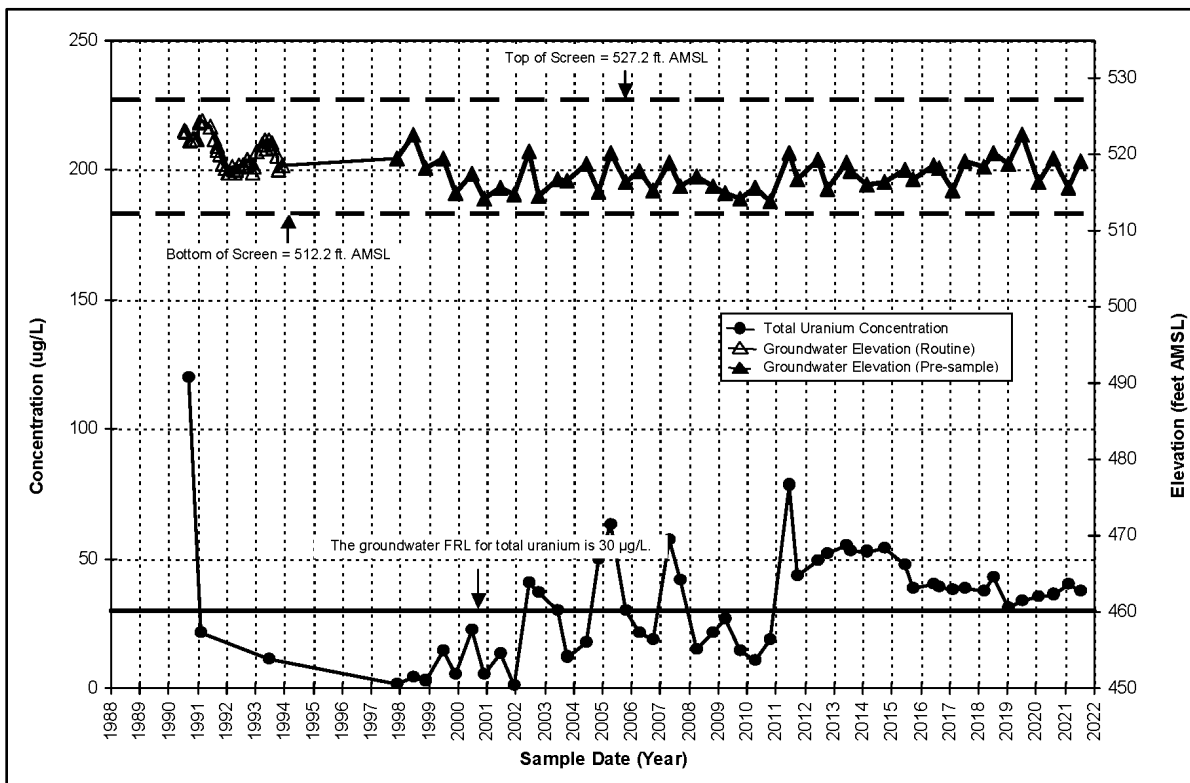


Figure A.2-14. Total Uranium Concentration Versus Time Plot for Monitoring Well 2389

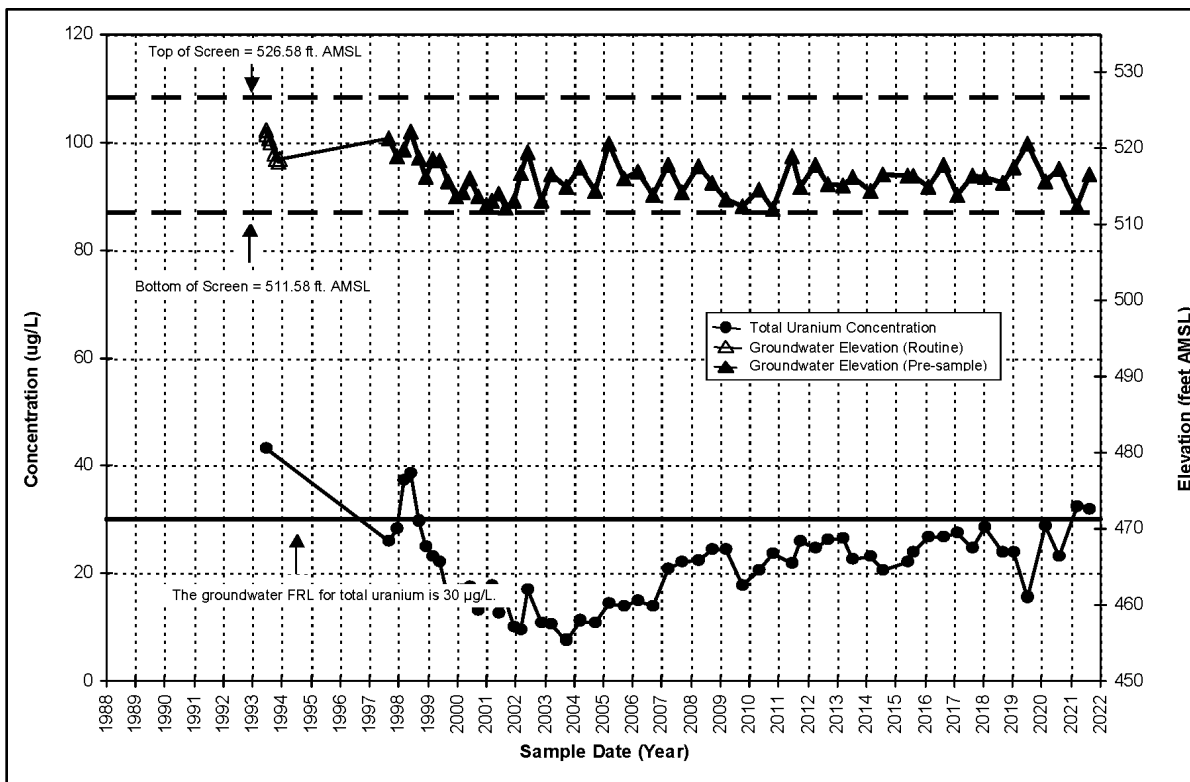


Figure A.2-15. Total Uranium Concentration Versus Time Plot for Monitoring Well 21033

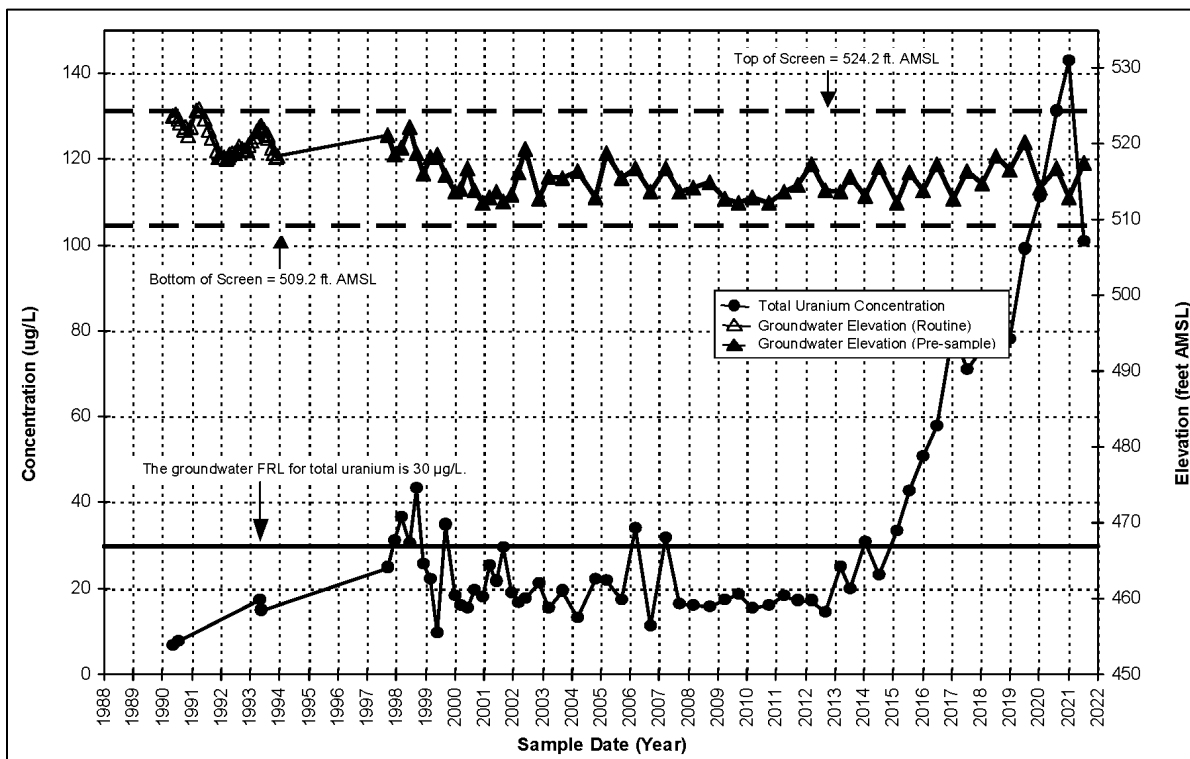


Figure A.2-16. Total Uranium Concentration Versus Time Plot for Monitoring Well 2386

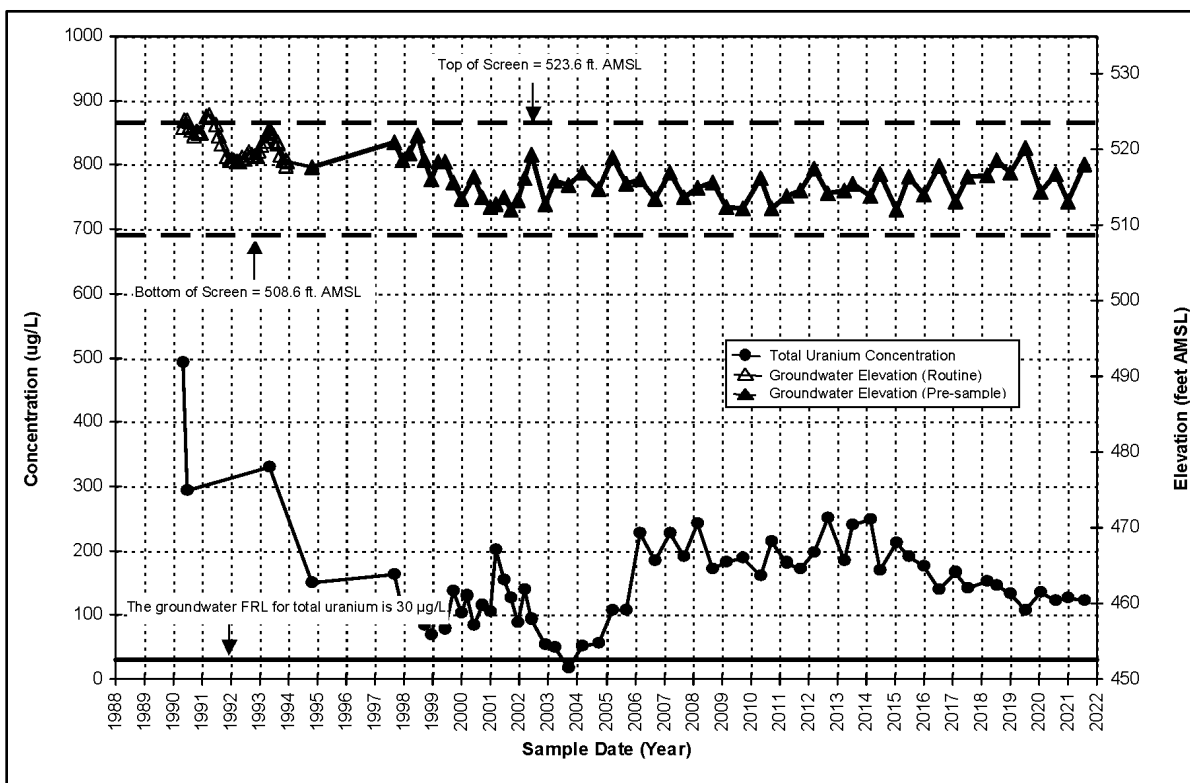


Figure A.2-17. Total Uranium Concentration Versus Time Plot for Monitoring Well 2387

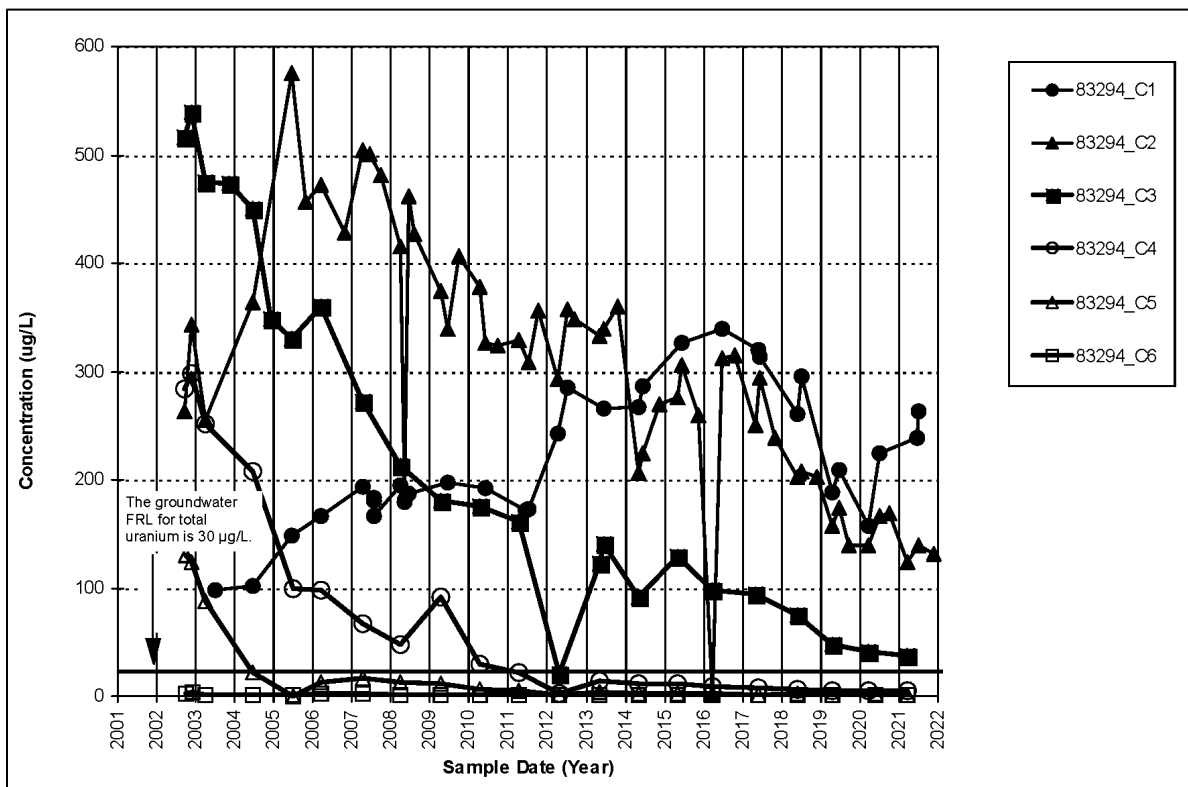


Figure A.2-18. Total Uranium Concentration Versus Time Plot for Monitoring Well 83294

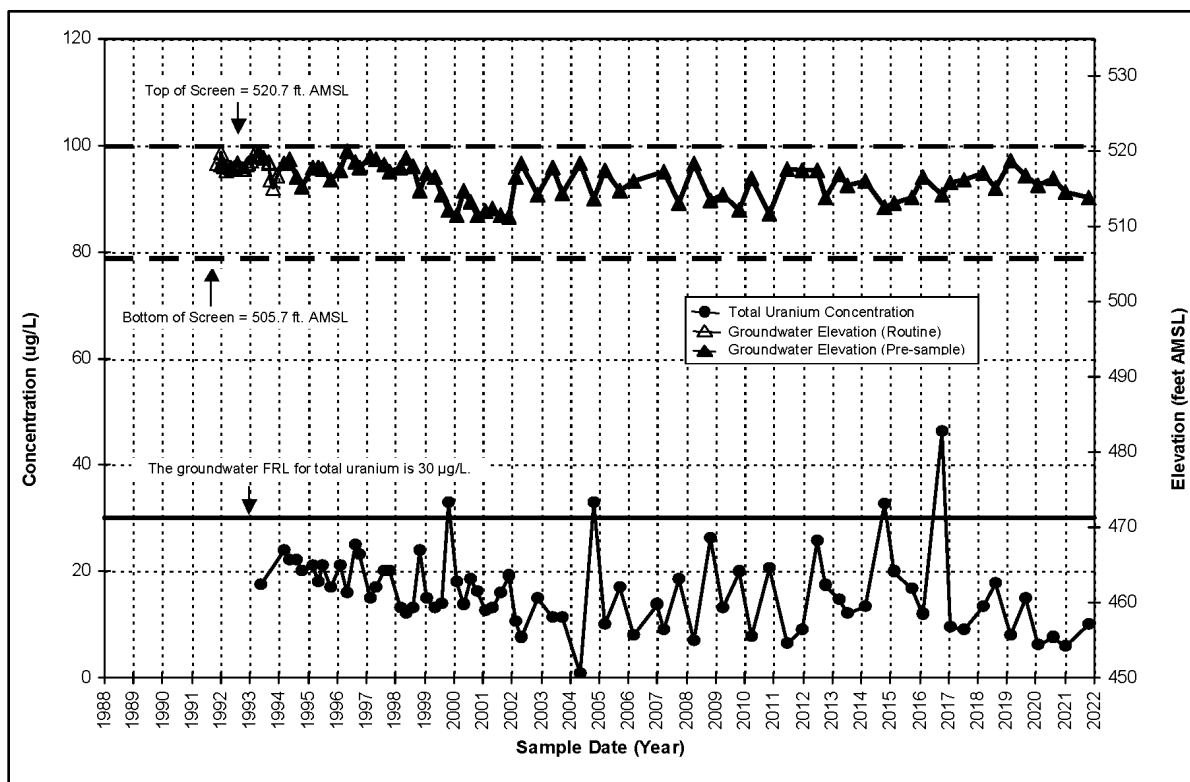


Figure A.2-19. Total Uranium Concentration Versus Time Plot for Monitoring Well 2552

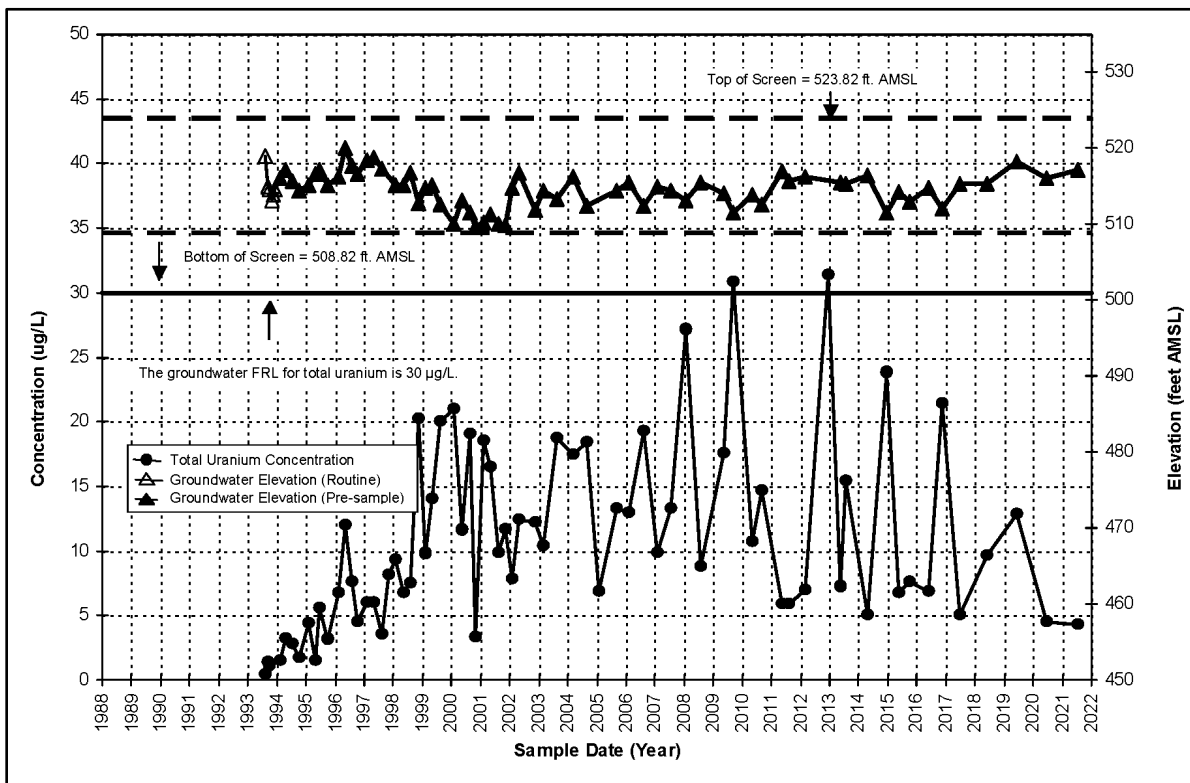


Figure A.2-20. Total Uranium Concentration Versus Time Plot for Monitoring Well 2900

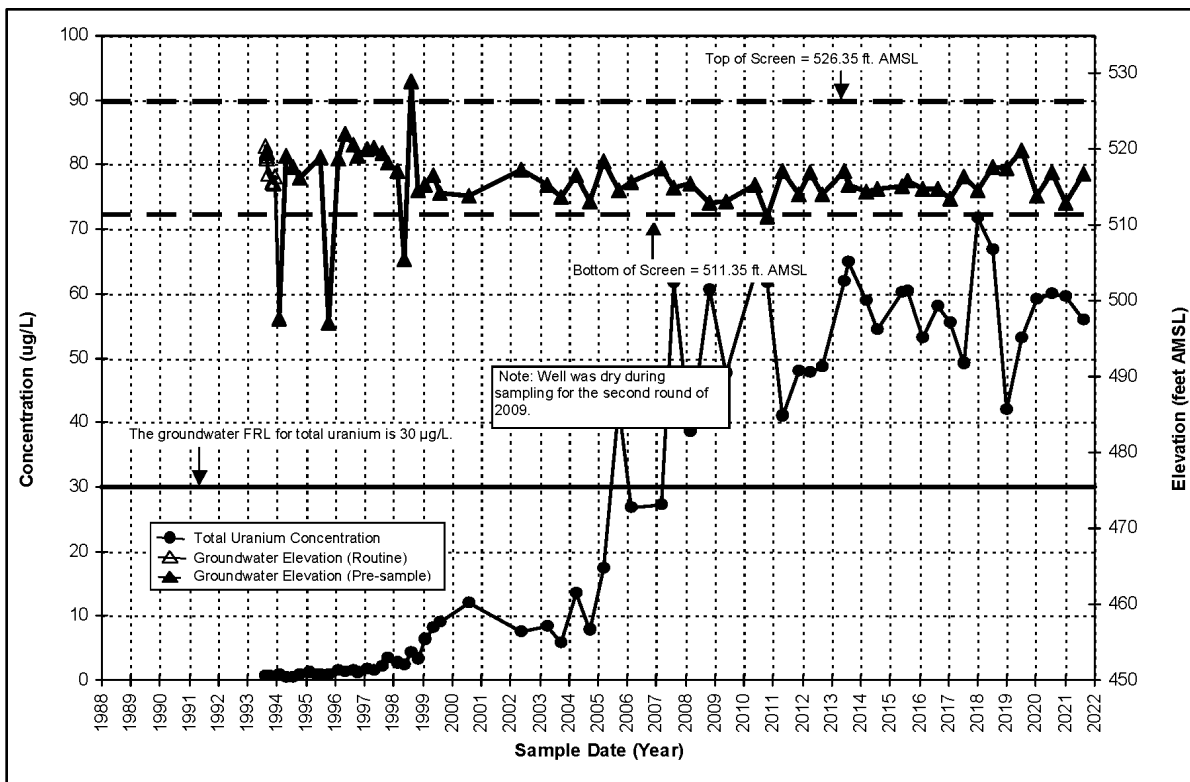


Figure A.2-21. Total Uranium Concentration Versus Time Plot for Monitoring Well 2880

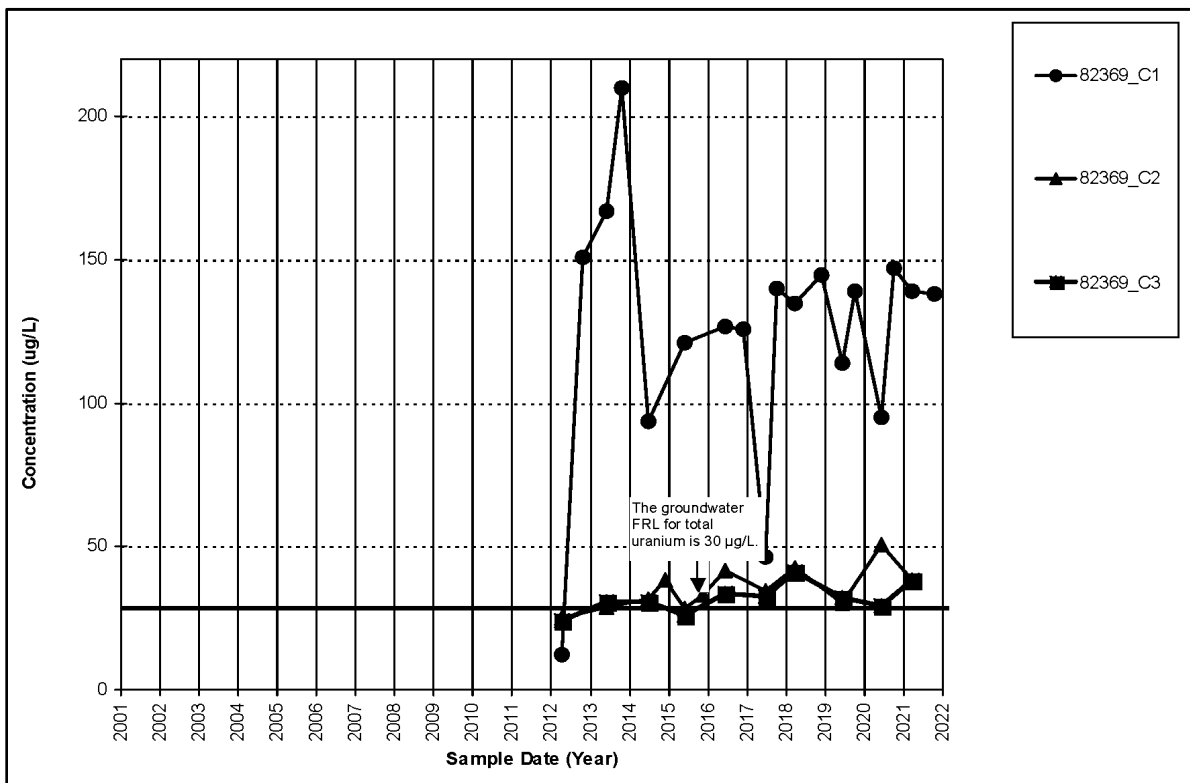


Figure A.2-22. Total Uranium Concentration Versus Time Plot for Monitoring Well 82369

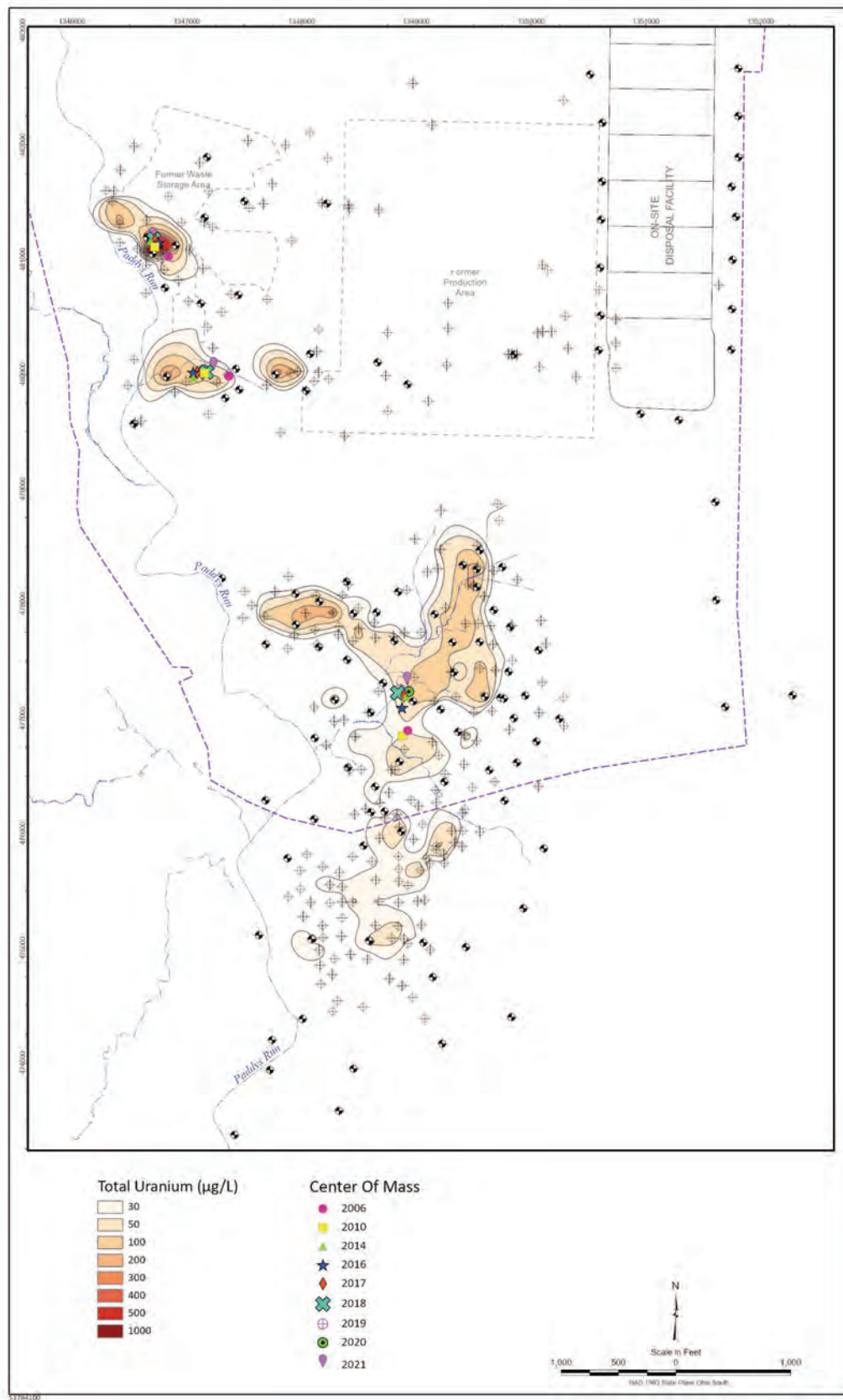


Figure A.2-23. Ricker Method Center of Mass

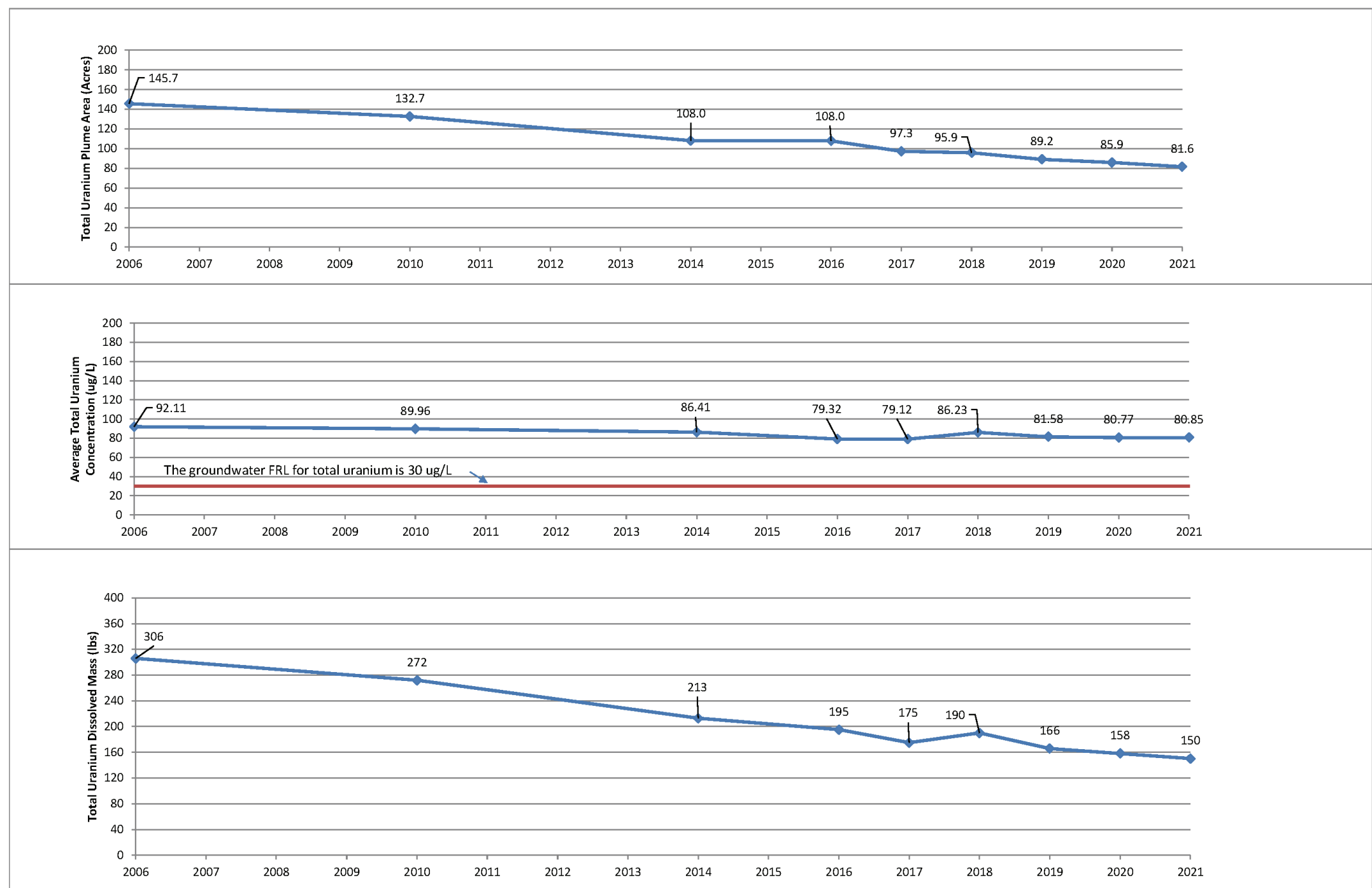


Figure A.2-24. Ricker Method Total Uranium Plume Calculations

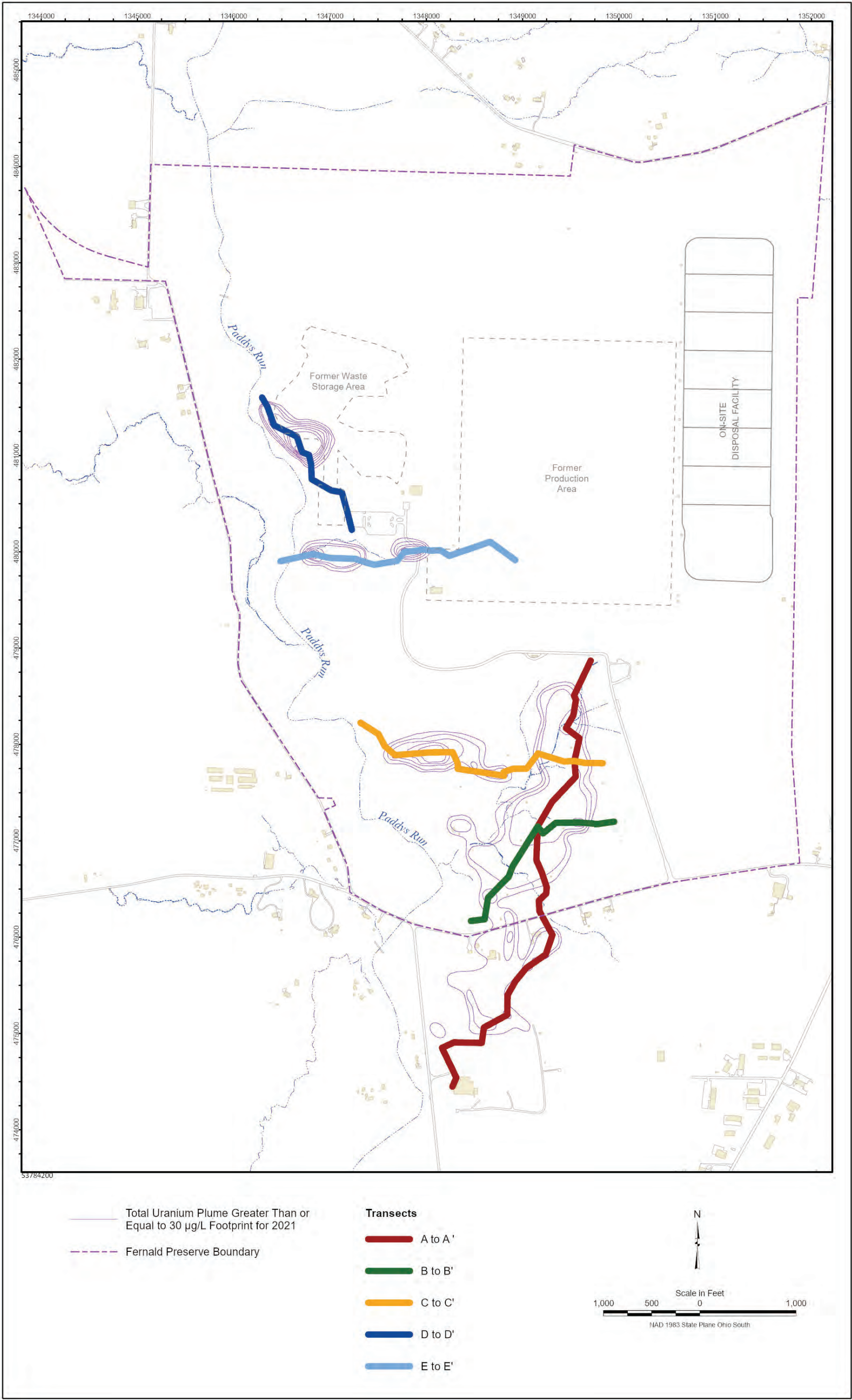


Figure A.2-25A. Uranium Plume Cross Section Overview Map

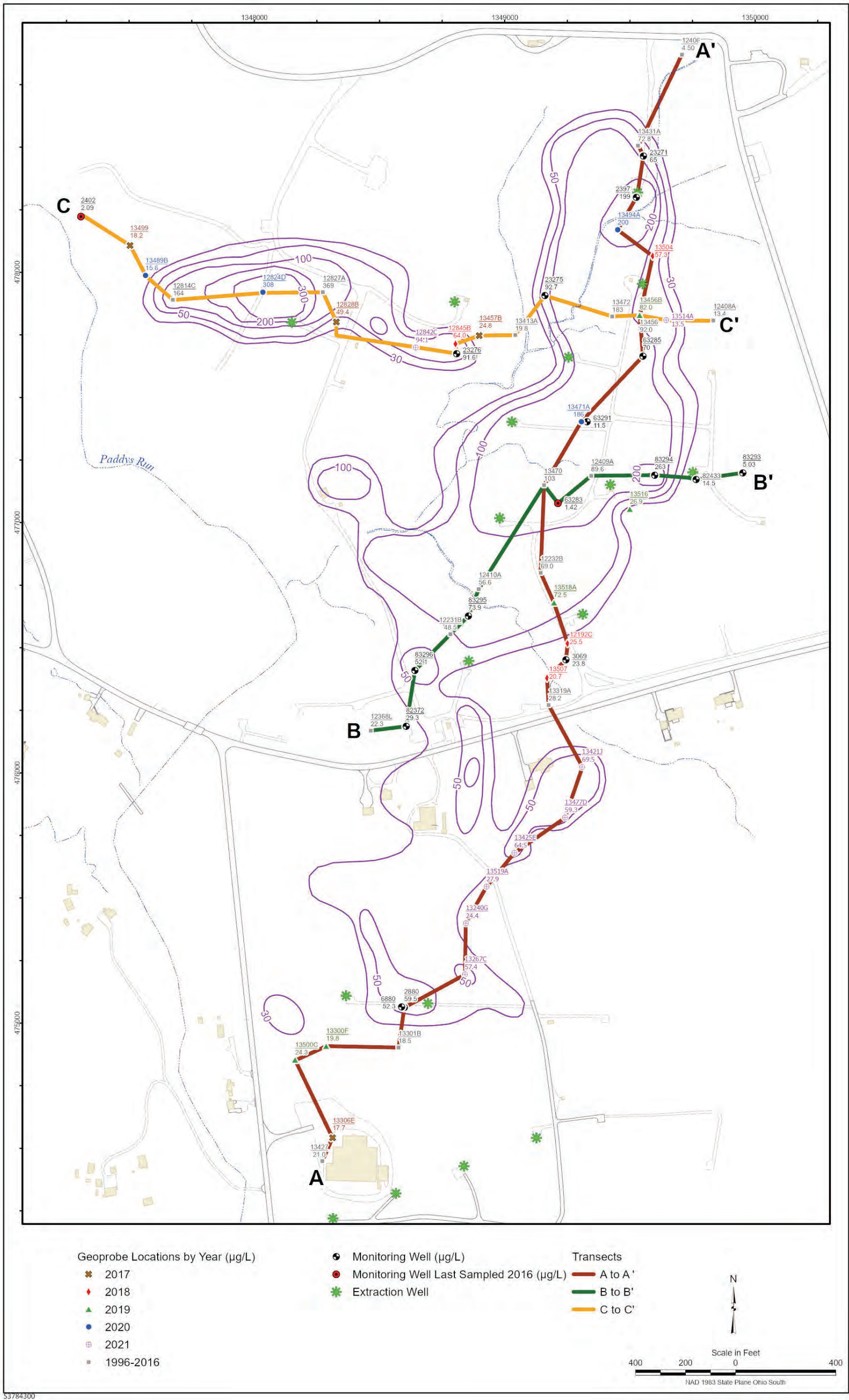


Figure A.2-25B. Uranium Plume South Cross Section Location Map

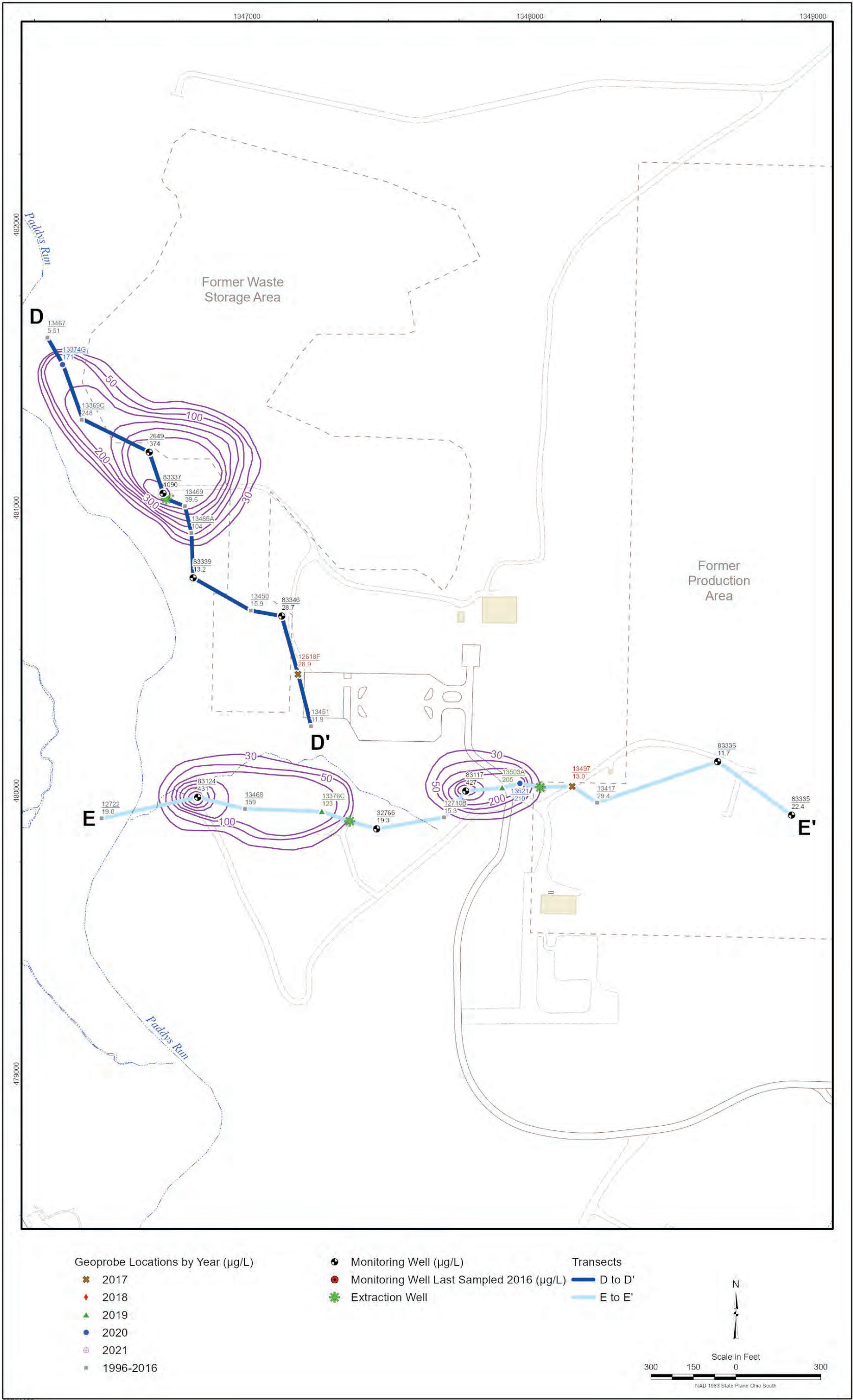


Figure A.2-25C. Uranium Plume North Cross Section Location Map

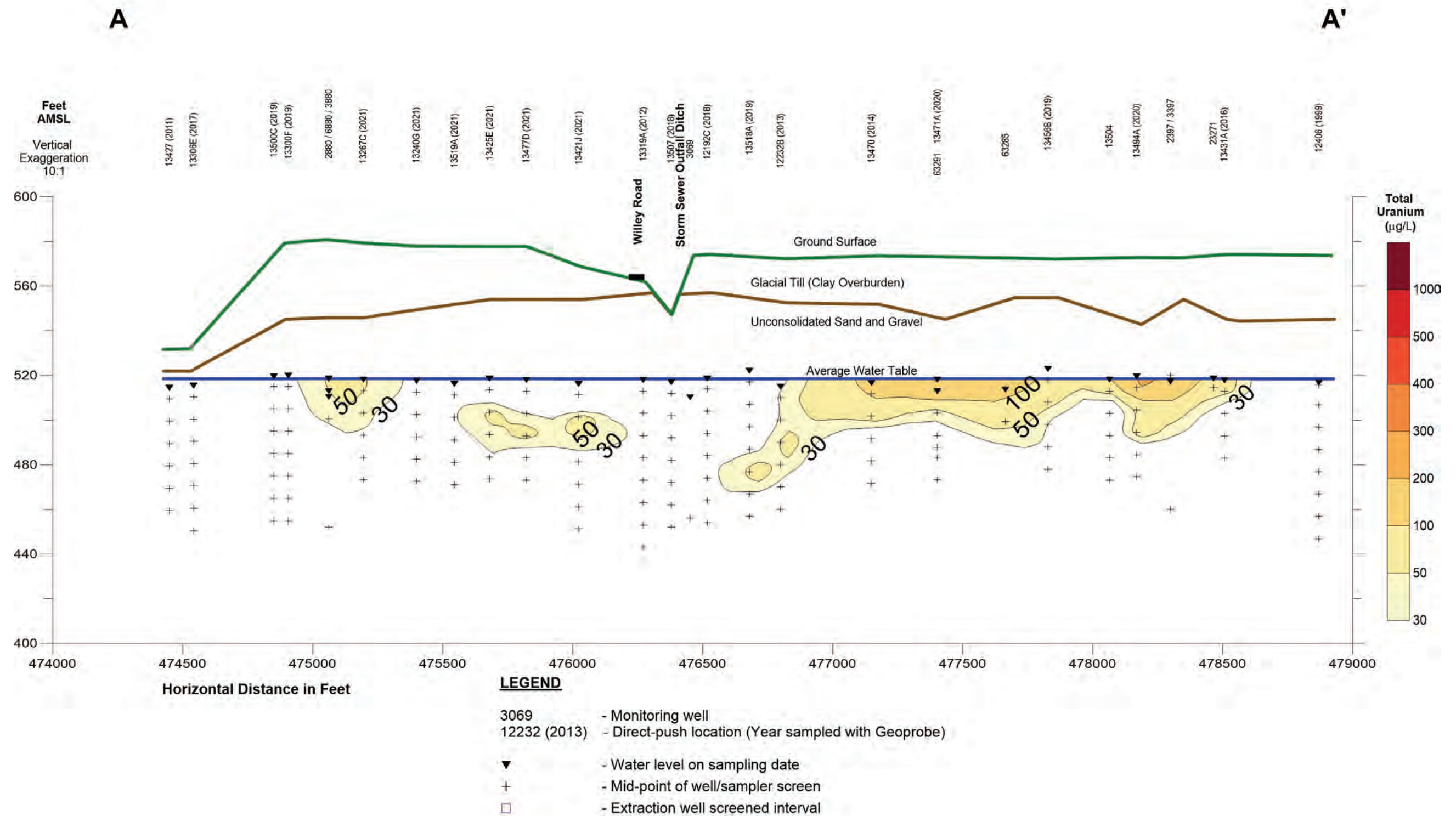


Figure A.2-26. Total Uranium Plume Cross Section A-A'

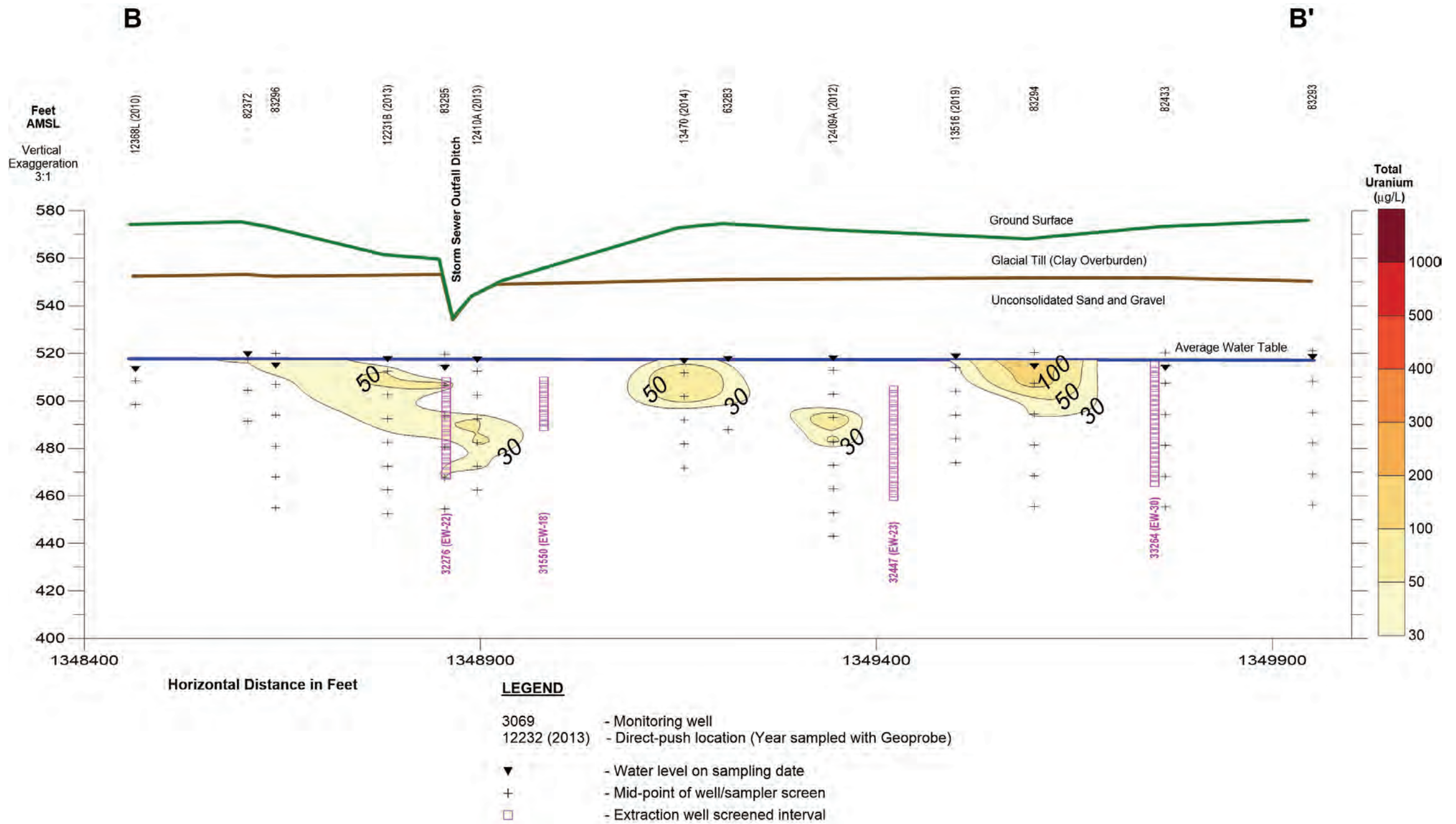


Figure A.2 27. Total Uranium Plume Cross Section B-B'

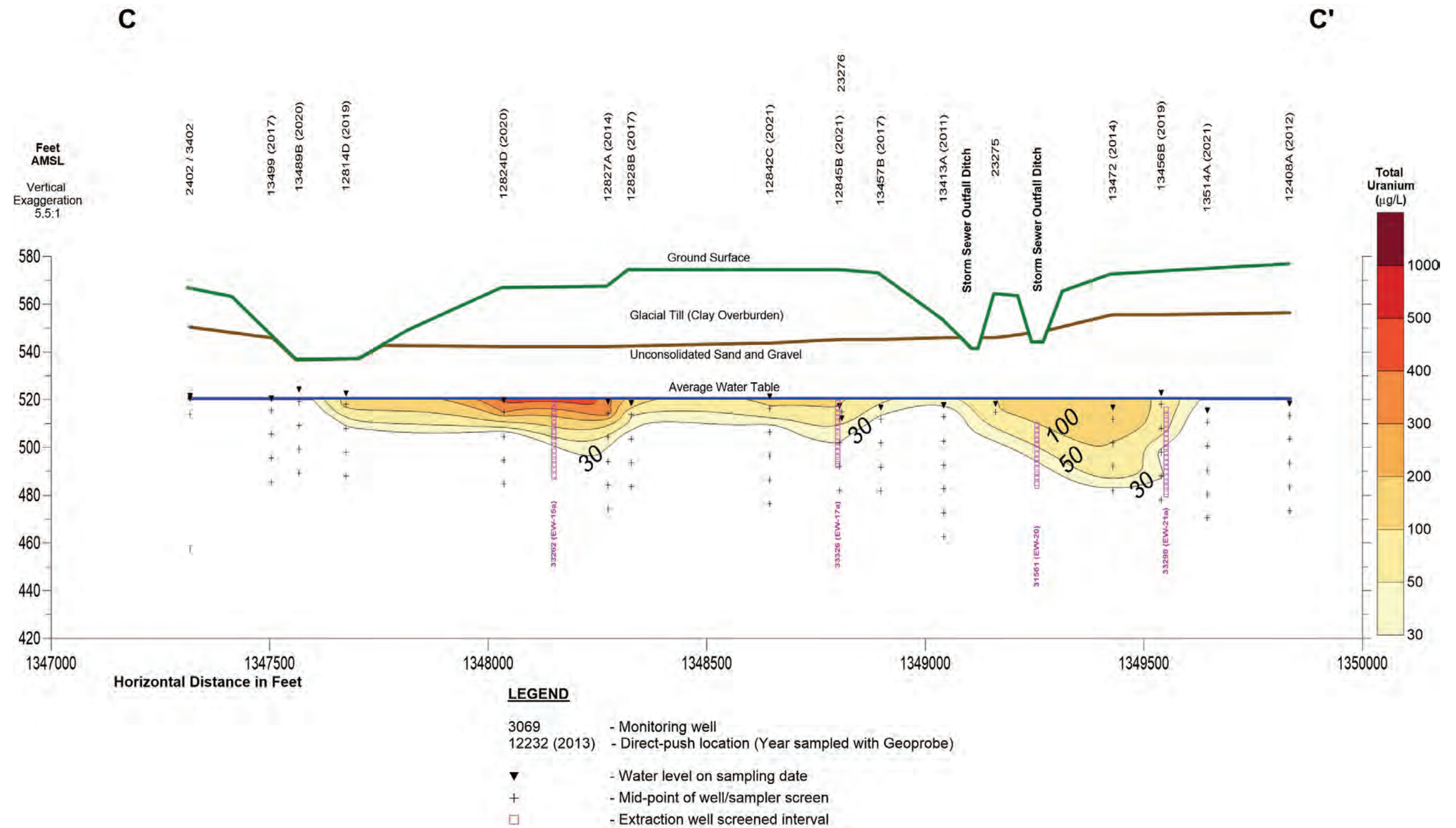


Figure A.2-28. Total Uranium Plume Cross Section C–C'

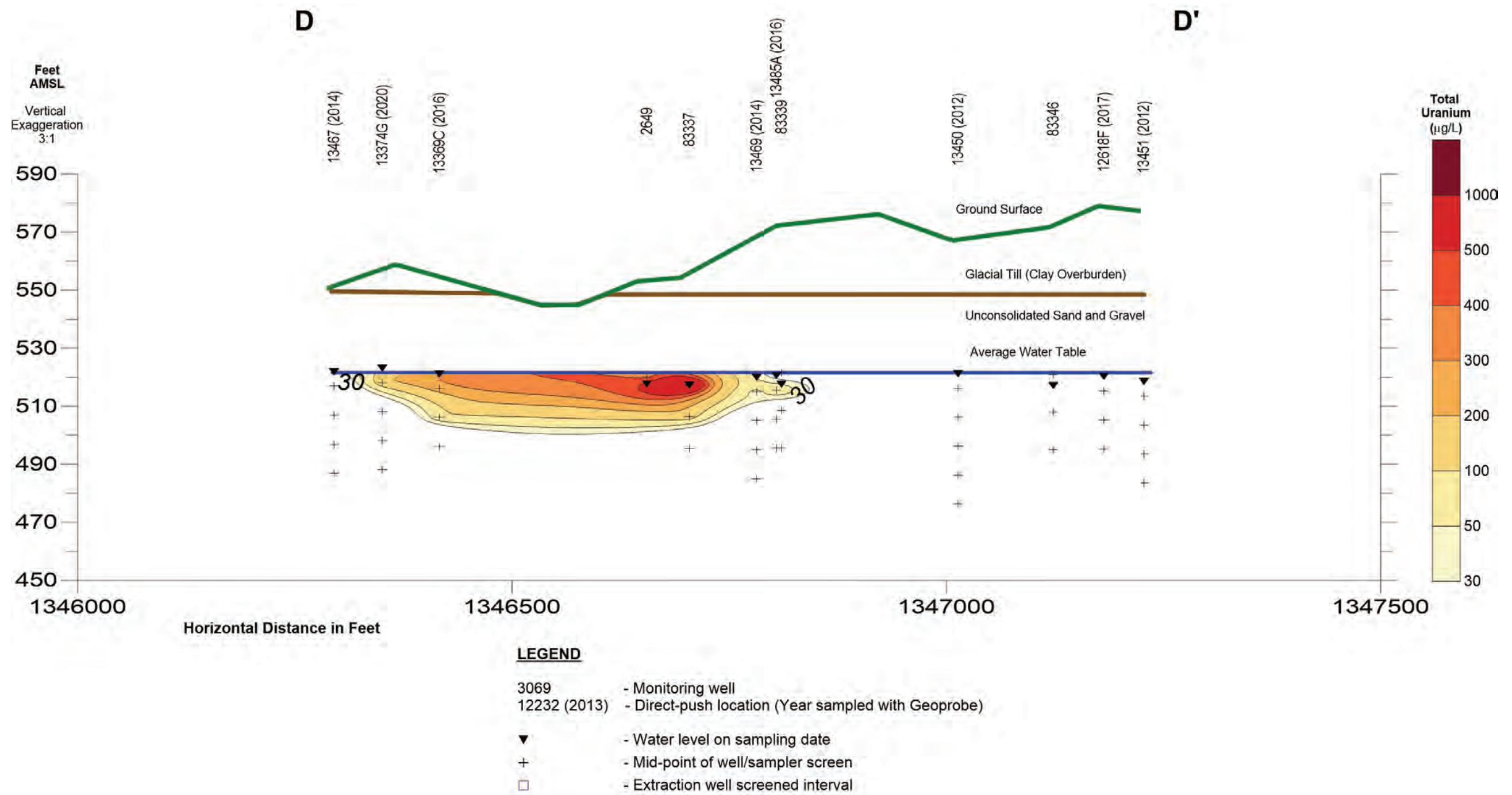


Figure A.2-29. Total Uranium Plume Cross Section D–D'

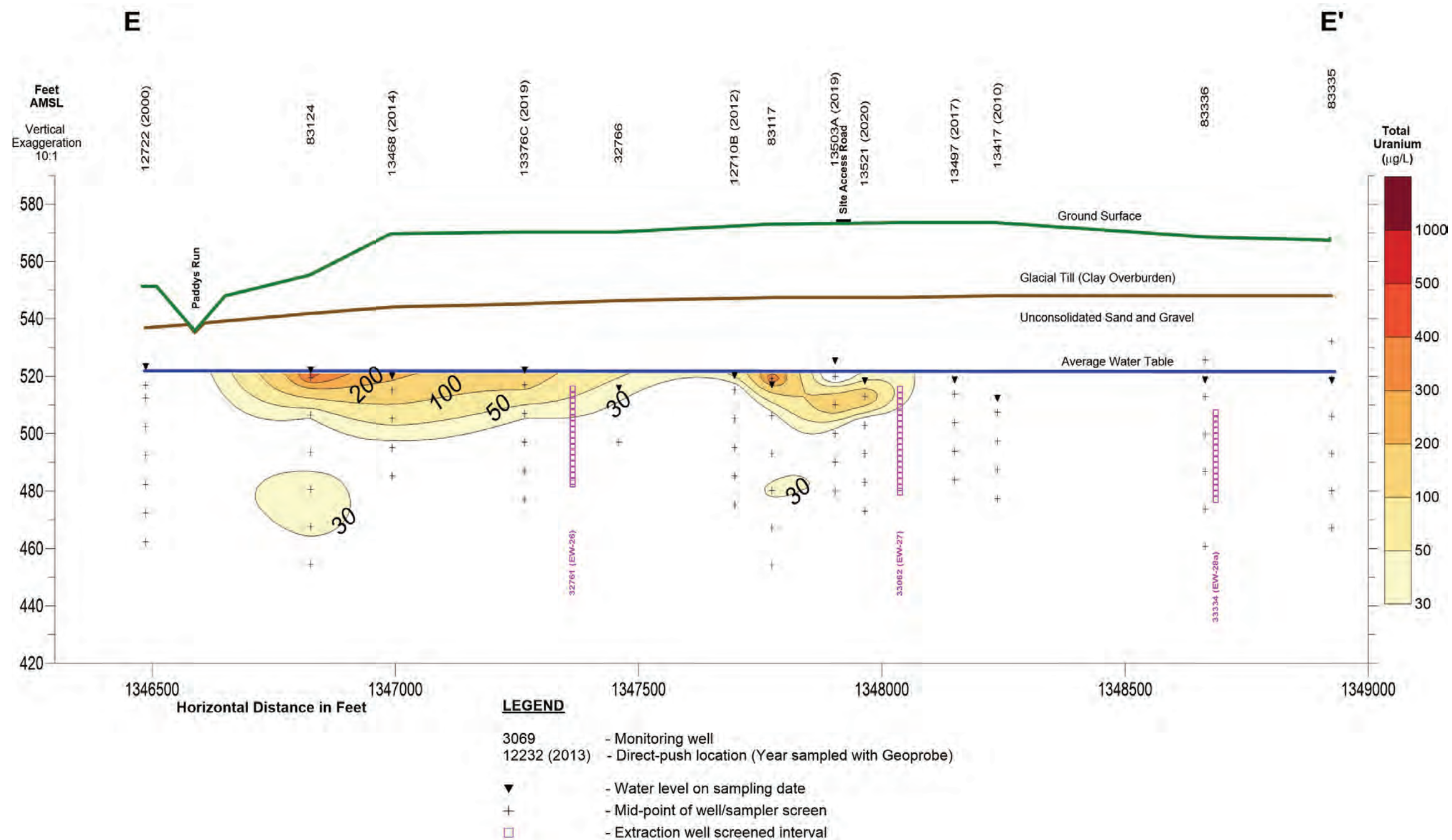


Figure A.2-30. Total Uranium Plume Cross Section E-E'

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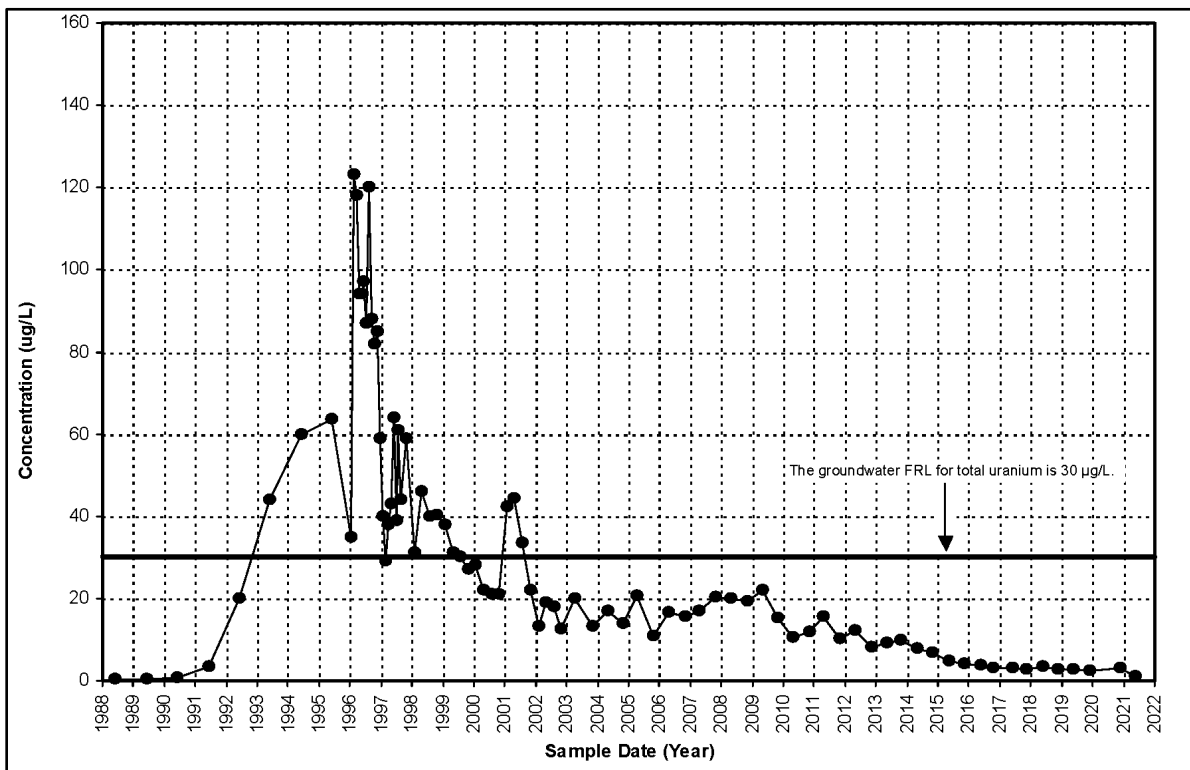


Figure A.2-31. Total Uranium Concentration Versus Time Plot for Monitoring Well 13

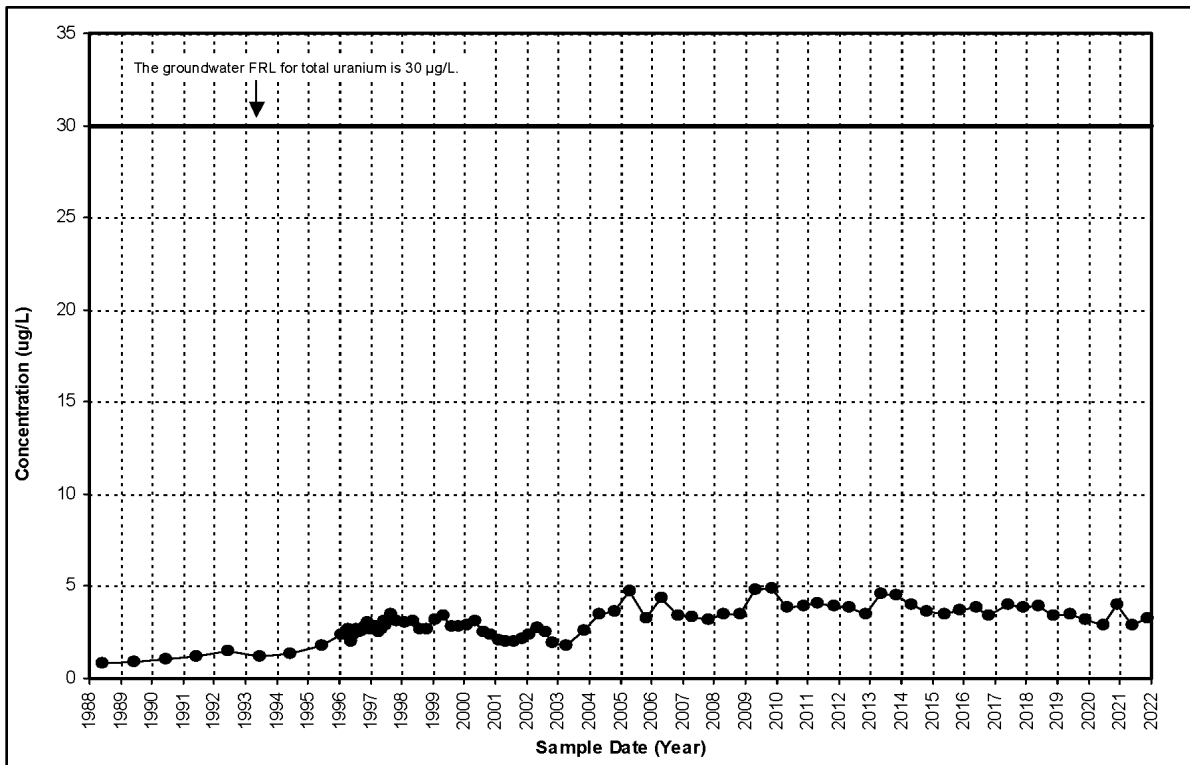


Figure A.2-32. Total Uranium Concentration Versus Time Plot for Monitoring Well 14

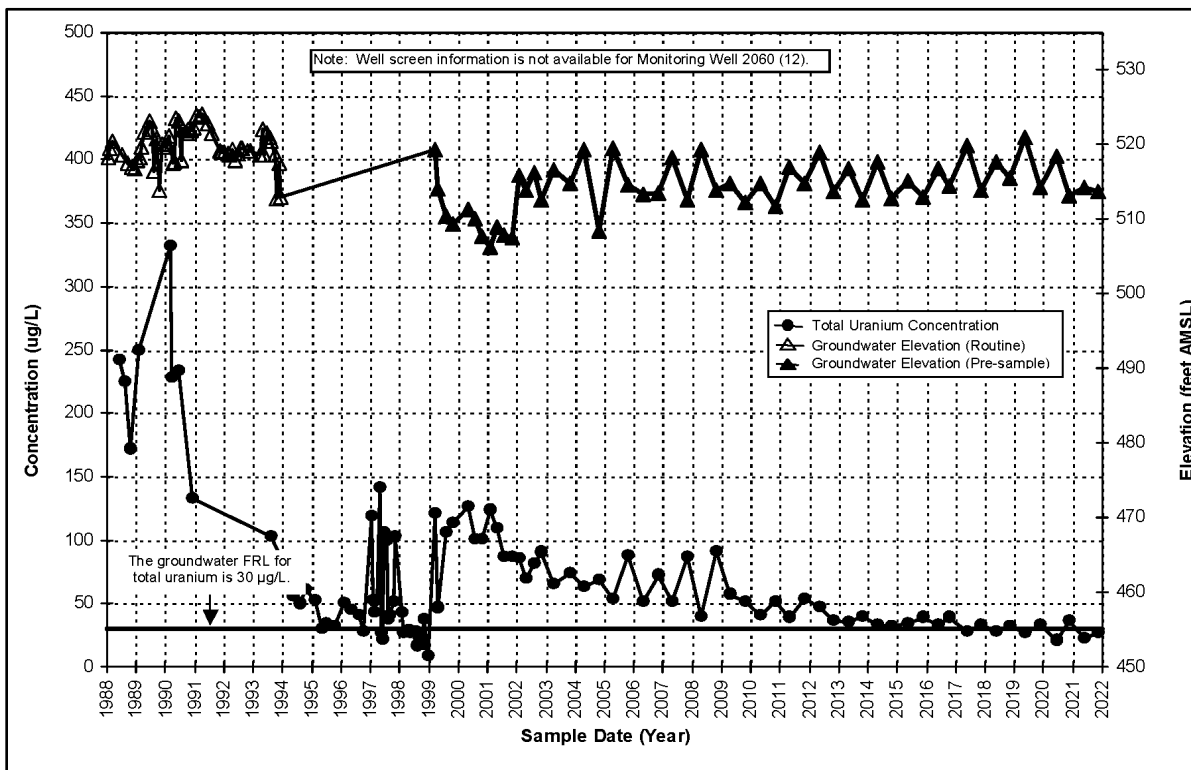


Figure A.2-33. Total Uranium Concentration Versus Time Plot for Monitoring Well 2060

Attachment A.3

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Abbreviations

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 2021 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 2021 were measured as specified in the Integrated Environmental Monitoring Plan (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (DOE 2019). A total of 172 monitoring wells were available for measurement. As required by the IEMP, during the second quarter of 2021, 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 (2021)	Number of Days	Average Water Level (ft amsl) ^a
1	January 4 to January 7	4	515.09
2	April 5 to April 8	4	516.71
3	July 19 to July 22	4	519.09
4	October 18 to October 20	3	515.51

^aft amsl = feet above mean sea level.

Six monitoring wells and the uppermost channel in ten multichannel wells were dry at various times of the year. A summary is provided below.

Well	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
2014	DRY	DRY		DRY
2384	DRY	DRY		DRY
2636	DRY			DRY
2702				DRY
22192	DRY	DRY		DRY
22303	DRY	DRY		
82433_C1		DRY		
83124_C1				DRY
83293_C1	DRY	DRY		DRY
83294_C1		DRY		
83295_C1	DRY			DRY
83335_C1	DRY	DRY	DRY	DRY
83335_C2				DRY
83336_C1	DRY	DRY	DRY	DRY
83337_C1	DRY	DRY		DRY
83338_C1				DRY
83341_C1	DRY	DRY		DRY

Quarterly groundwater elevation maps for 2021 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 2021 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. 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. Three pumping stages were defined:

- Stage 1: 20 wells at a system rate of 5,075 gallons per minute (gpm)
- Stage 2: 10 wells at a system rate of 3,075 gpm
- Stage 3: 3 wells at a system rate of 1,100 gpm

A groundwater flow divide between Paddys Run Outlet and the New Baltimore Outlet is not readily distinguishable. Groundwater flow diverges around the bedrock high that separates the Paddys Run Outlet from the New Baltimore Outlet, but without additional measurement locations in the New Baltimore Outlet, the location where flow is dividing is not apparent. However, additional measurement locations in the New Baltimore Outlet are not needed for capture assessment purposes.

During the first three quarters of 2021, flow in the vicinity of the On-Site Disposal Facility (OSDF) was generally from the northeast. During the last quarter of 2021 flow in the vicinity of the OSDF was more from the north to northwest. Flow direction is influenced by seasonal fluctuations in the aquifer and by the active pumping taking place for the groundwater remediation, which is predicted to last until 2039. Prior to 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 2021, as recorded at the Butler County Regional Airport. Cumulative precipitation in 2021 was 42.50 inches. Between 2004 and 2021, 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 2021 are as follows.

Year	Average Fluctuation (feet)	Fluctuation Range (feet)
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 2021 coupled with the particle track interpretations and contoured water-table gradients indicate that the 30 µg/L total uranium plume was being captured in 2021.

A.3.2 Annual Planned Well Field Shutdown

The entire well field (excluding the South Plume recovery wells RW-1 through RW-4) was shut down from June 1 to July 6 as planned to allow water levels to recover to nonpumping elevations. Quarterly measurement of water levels in 2021 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.

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 2021, is presented below.

Planned Shutdown: June 1 to July 6, 2021

Location	Elevation at Midnight Prior to Shutdown June 1, 2021 (ft amsl)	Elevation at Midnight Prior to Restart July 6, 2021 (ft amsl)	Water Level Rise (ft)
2045	516.55	519.82	3.27
2046	517.12	520.04	2.91
2649	519.56	521.97	2.41
23274 ^a	Not Recorded	Not Recorded	Not Recorded
63119	517.09	519.83	2.74
22302	515.49	518.67	3.18
3881	515.63	518.19	2.56
22301	515.96	519.22	3.26
2095	516.33	518.99	2.66
32763	517.56	521.13	3.57
62433	514.12	518.84	4.72

^a Data not collected due to dead battery in data logger.

The water level rise measurements indicate that during the shutdown, the water level rise ranged from 2.41 feet (ft) (well 2649) to 4.72 ft (well 62433).

Figure A.3-8 shows water levels versus precipitation from May 25, 2007, through January 4, 2022. 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 2021 resulted in the following water level rises:

- 4.57 ft in the former WSA (monitoring well 2649)
- 5.15 ft in the west side of the South Field (monitoring well 2046)
- 7.06 ft in the east side of the South Field (monitoring well 62433)

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 2021 shutdown. The results of the 2021 IEMP first-half uranium sampling are used to represent uranium concentrations in the well before the shutdown. Groundwater samples collected in June represent concentrations during the shutdown. The results of the 2021 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. Uranium concentration measurements at the six monitoring wells before, during, and after the 2021 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 all of the six wells during the shutdown: 2045, 2046, 23274, 83124, 83294, and 83337. 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 2021, 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, RW-2, RW-3, and RW-4 continued to run during the shutdown.

The last column of Table A.3-2 provides the difference between the maximum uranium concentration measured after the wells were restarted and the average uranium concentration measured within a month prior to the shutdown at each extraction well. As the data indicate, approximately half of the wells showed an increase in uranium concentrations. The largest increase in uranium concentration was measured in extraction well EW-21A (8.9 µg/L).

A.3.3 Continued Transducer Monitoring

Although not required by the IEMP, pressure transducers installed in 2007 to support the first annual well field shutdown remain in the wells and continue to operate so that daily changes in water levels can be recorded on a continuous, routine basis at key points in the aquifer. The transducers are programmed to record a water level measurement twice daily, at noon and midnight. Data from three of the six locations (former WSA [2649], west side of the South Field Area [2046], and east side of the South Field Area [62433]) are shown in Figure A.3-7 and are plotted in Figure A.3-8 along with precipitation data collected through January 4, 2022. 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 for planning the timing of future well field shutdowns.

A.3.4 References

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

Table A.3-1. Uranium Concentrations at Monitoring Wells Before, During, and After the 2021 Well Field Shutdown

Well	Easting	Northing	First Half 2021 Pre-Shutdown Concentrations		Pre-Start-Up Concentrations June 2021		Second Half 2021 Post-Shutdown Concentrations	
			Date	Uranium (µg/L)	Date	Uranium (µg/L)	Date	Uranium (µg/L)
2045	1348291	477159	4/13/2021	41.8	6/30/2021	69.8	10/18/2021	70.0
2046	1347950	478088	2/22/2021	14.3	6/30/2021	19.0	8/5/2021	46.3
23274	1349406	478337	1/20/2021	74.4	6/30/2021	77.4	8/9/2021	124
83124_C1	1346826	479977	5/11/2021	344	6/29/2021	431	10/13/2021	131
83124_C2	1346826	479977	5/11/2021	23.1	6/29/2021	31.9	Not Sampled	Not Sampled
83294_C1	1349599	477190	6/24/2021	239	6/28/2021	263	Not Sampled	Not Sampled
83294_C2	1349599	477190	3/24/2021	124	6/28/2021	140	11/23/2021	131
83337_C1	1346704	481052	5/12/2021	1090	6/29/2021	805	Not Sampled	Not Sampled
83337_C2	1346704	481052	5/12/2021	8.4	6/29/2021	139	11/5/2021	13.4

Table A.3-2. Total Uranium Concentration at Extraction Wells During 2021 Well Field Shutdown^a

Extraction Well	June 1, 2021 Total Uranium Concentration (ug/L)	Date of Well Restart	Total Uranium Concentration (ug/L) After Well Field Re-Start							Maximum Post Re-Start Minus June 1, 2021 Concentration
			1st Restart Sample	2nd Restart Sample	3rd Restart Sample	4th Restart Sample	Minimum	Maximum	Range	
RW-1^b	12.3	7/6/2021	10.2	8.2	9.7	9.2	8.2	10.2	2.0	-2.1
RW-2^c	13.5	7/16/2021	14.2	14.2	13.8	13.7	13.7	14.2	0.5	0.7
RW-3^b	19.8	7/6/2021	16.2	15.9	16.6	16.6	15.9	16.6	0.7	-3.2
RW-4^b	3.5	7/6/2021	3.1	3.0	3.1	3.0	3.0	3.1	0.1	-0.4
RW-6	28.6	7/22/2021	21.1	24.3	24.8	25.6	21.1	25.6	4.5	-3.0
RW-7^d	17.0	10/18/2021	19.7	21.9	22.2	23.2	19.7	23.2	3.5	6.2
EW-15A	22.4	7/8/2021	29.3	25.7	25.8	22.7	22.7	29.3	6.6	6.9
EW-17A	10.2	7/8/2021	12.2	10.3	10.7	12.9	10.3	12.9	2.6	2.7
EW-18	30.4	7/7/2021	26.7	26.0	25.6	27.0	25.6	27.0	1.4	-3.4
EW-19	17.4	7/7/2021	11.8	17.9	19.1	17.2	11.8	19.1	7.3	1.7
EW-20	32.4	7/9/2021	28.9	29.6	28.6	28.7	28.6	29.6	1.0	-2.8
EW-21A	24.9	7/7/2021	33.8	31.0	30.4	31.7	30.4	33.8	3.4	8.9
EW-22	20.2	7/8/2021	18.6	18.7	19.0	18.8	18.6	19.0	0.4	-1.2
EW-23	31.1	7/6/2021	14.4	21.7	23.5	24.3	14.4	24.3	9.9	-6.8
EW-24	26.3	7/6/2021	21.5	21.0	20.8	21.1	20.8	21.5	0.7	-4.8
EW-25	20.1	7/8/2021	19.6	18.0	19.1	16.2	16.2	19.6	3.4	-0.5
EW-26	22.3	7/9/2021	24.4	24.7	23.3	22.6	22.6	24.7	2.1	2.4
EW-27	25.1	7/9/2021	21.4	23.1	23.3	21.5	21.4	23.3	1.9	-1.8
EW-30^e	9.7	8/4/2021	9.0	9.0	8.8	10.2	8.8	10.2	1.4	0.5
EW-33A	20.9	7/9/2021	18.8	19.5	18.9	19.0	18.8	19.5	0.7	-1.4

Shading indicates uranium concentration after well field re-start was greater than June 1, 2021, uranium concentration.

^a Shutdown began on June 1, 2021 at 7:00 a.m. and ended on July 6, 2021, for a duration of 35 days.^b Leading edge well continued operating during the shutdown.^c Well shutdown June 16 for chemical rehabilitation.^d Well shutdown January 29 to October 18.^e Well shutdown June 1 to August 4 for chemical rehabilitation.

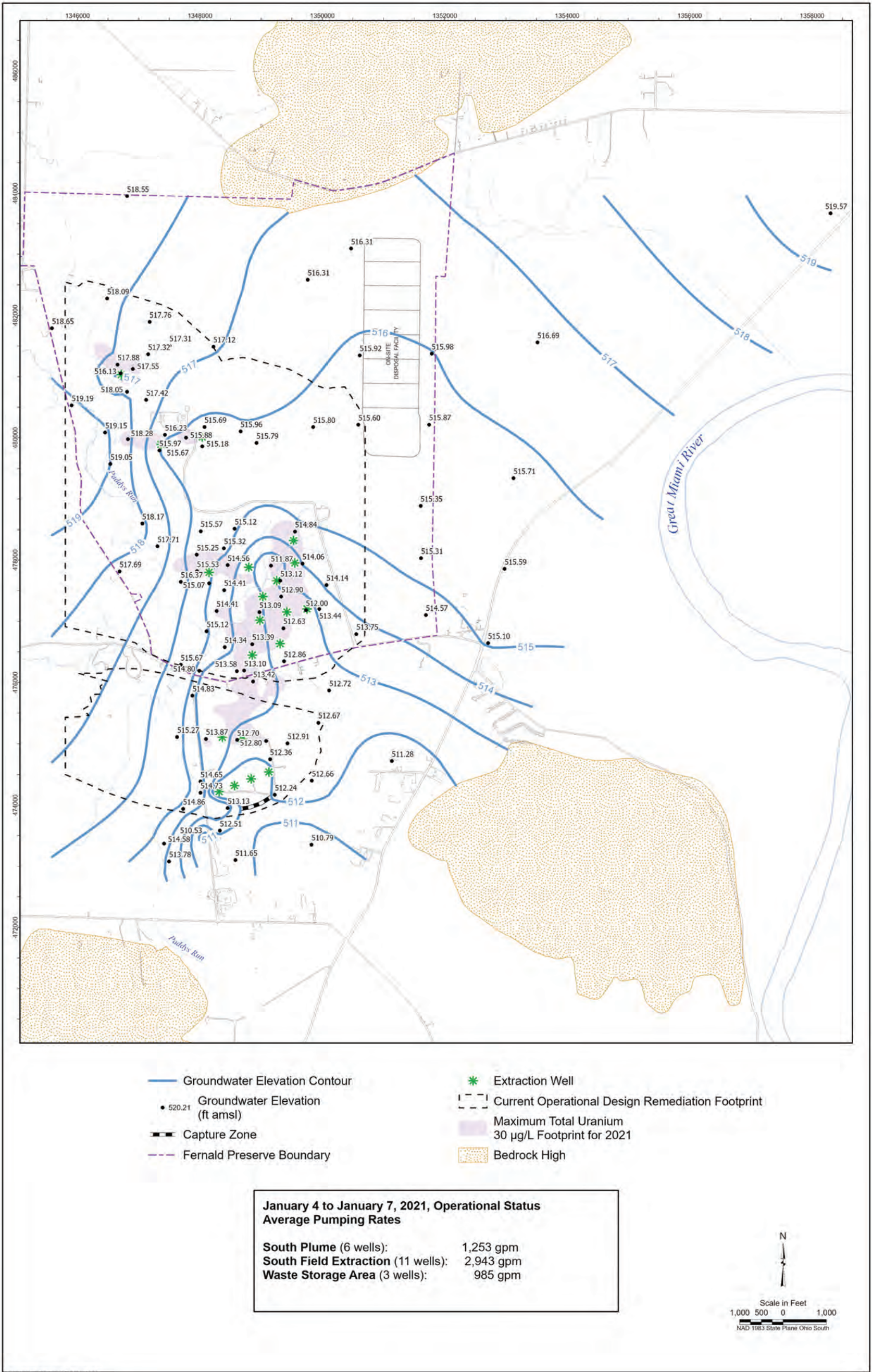


Figure A.3-1. Routine Groundwater Elevation Map, First Quarter 2021 (January 4 Through January 7, 2021)

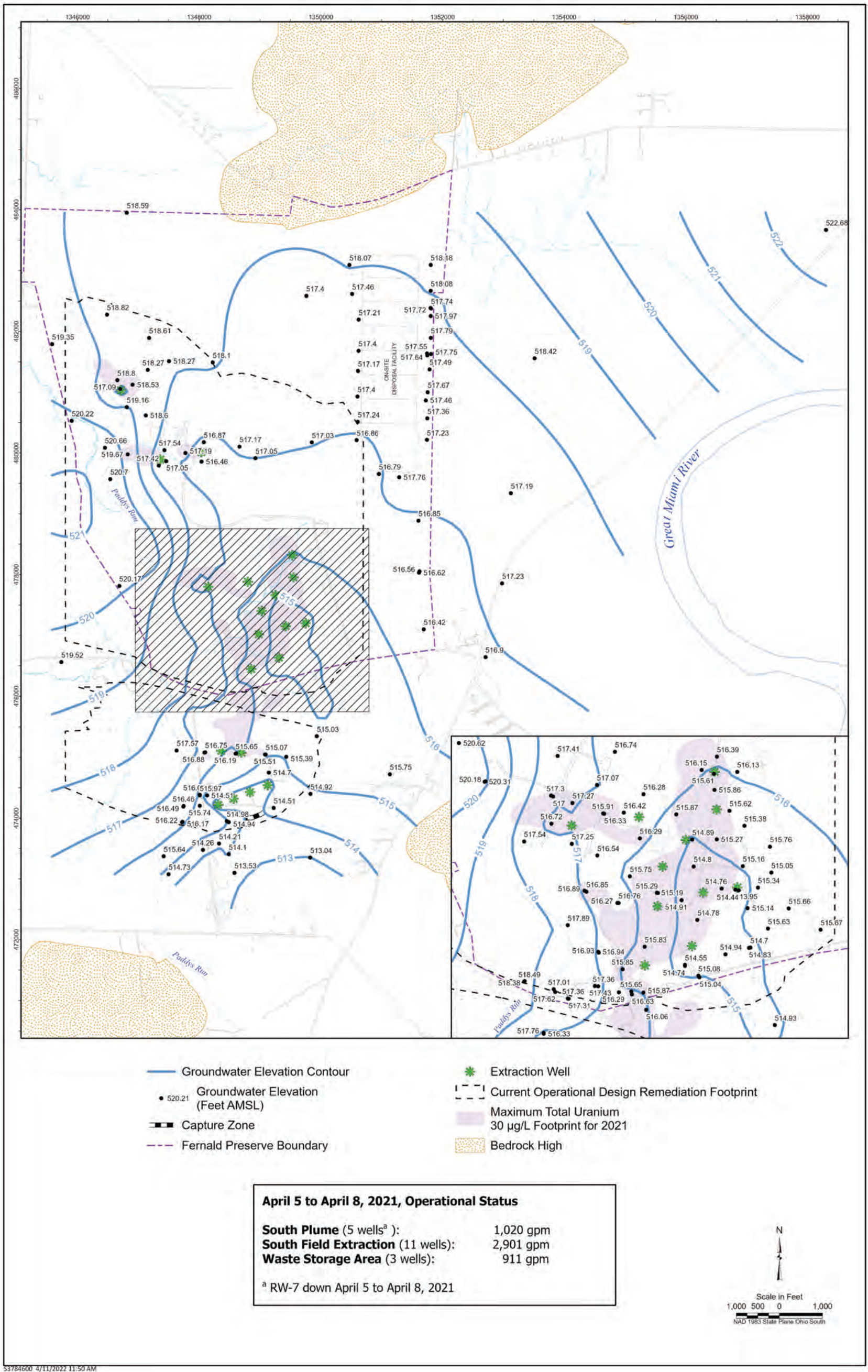


Figure A.3-2. Routine Groundwater Elevation Map, Second Quarter 2021 (April 5 Through April 8, 2021)

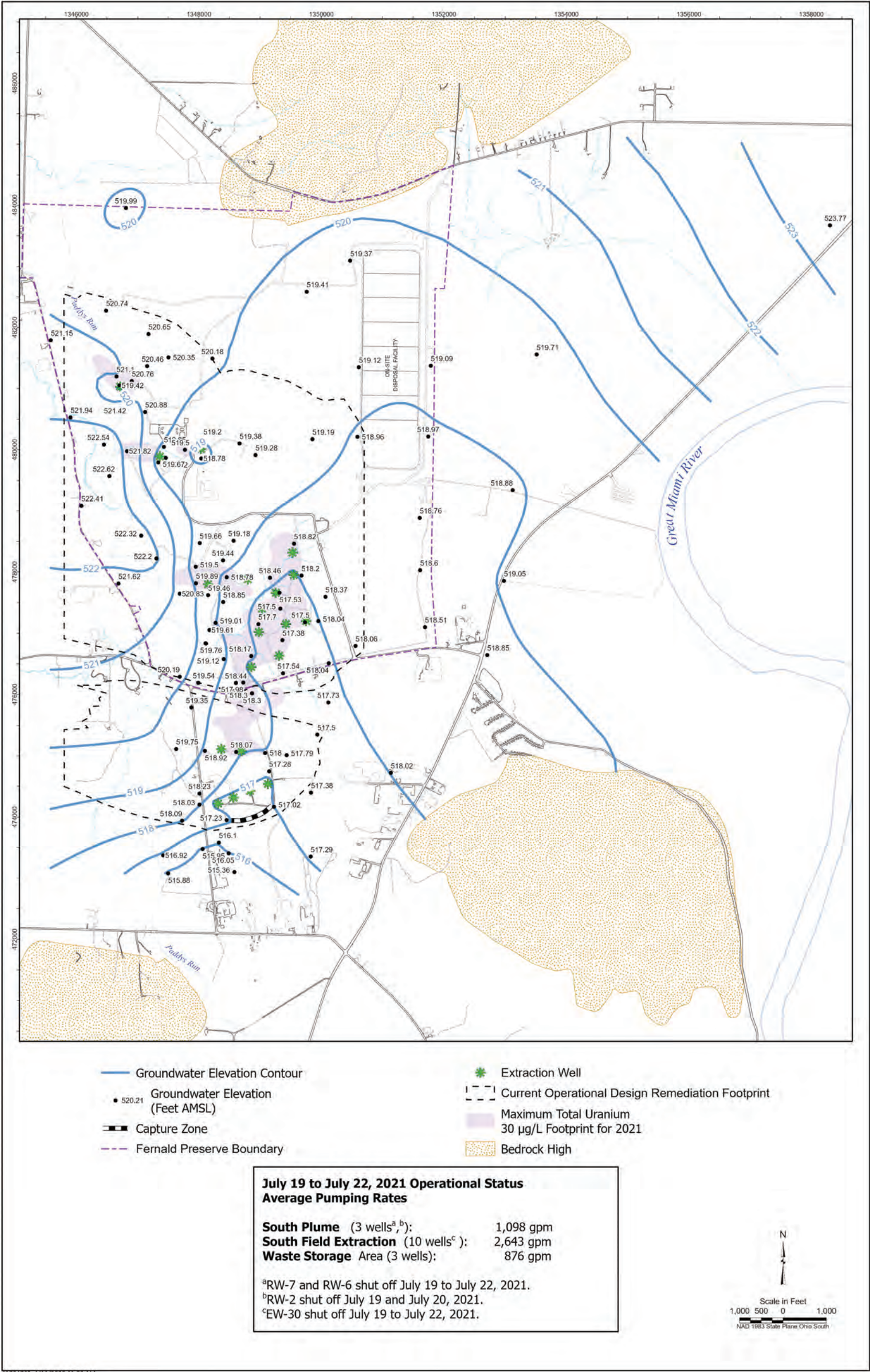


Figure A.3-3. Routine Groundwater Elevation Map, Third Quarter 2021 (July 19 Through July 22, 2021)

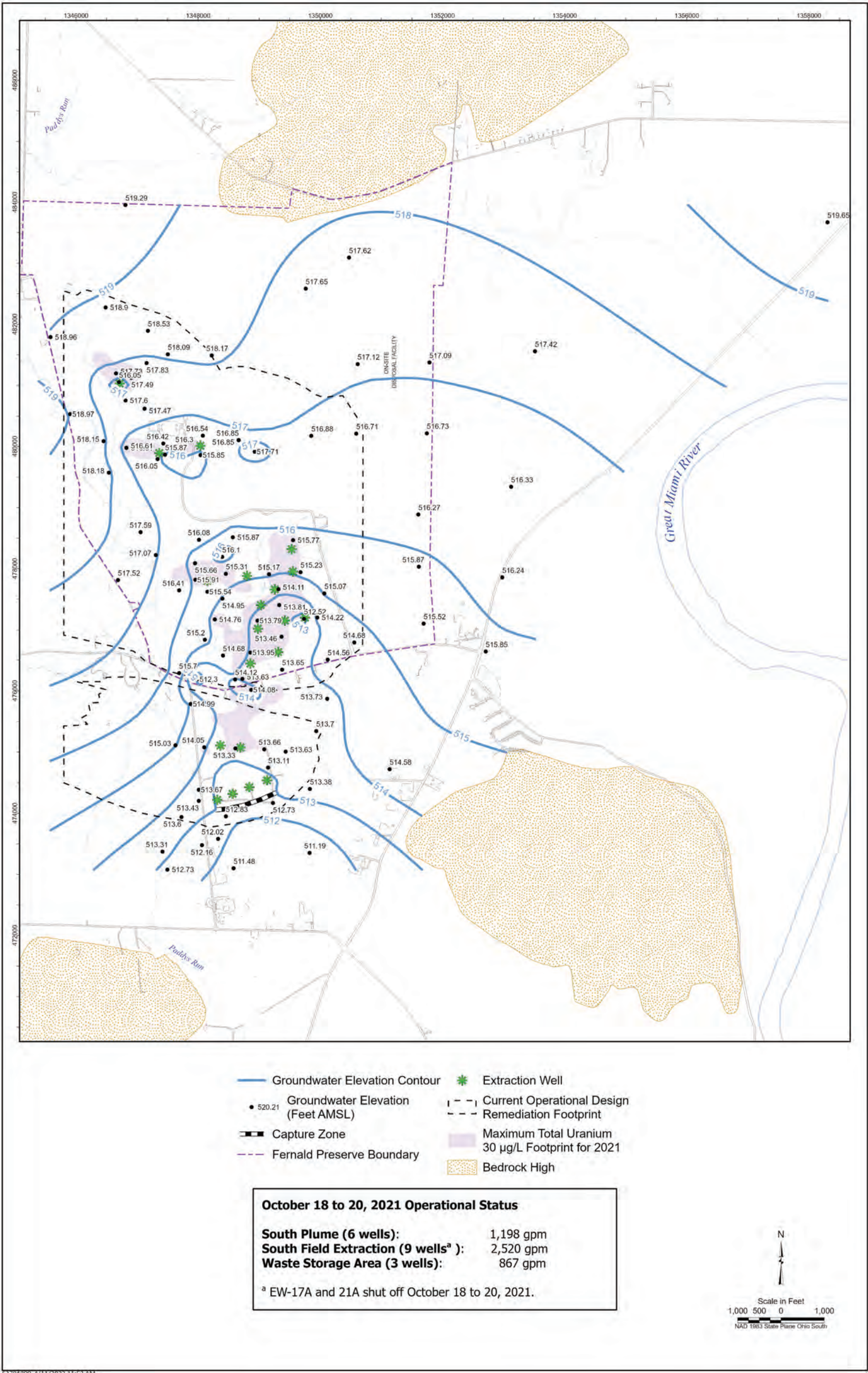


Figure A.3-4. Routine Groundwater Elevation Map, Fourth Quarter 2021 (October 18 Through October 20, 2021)

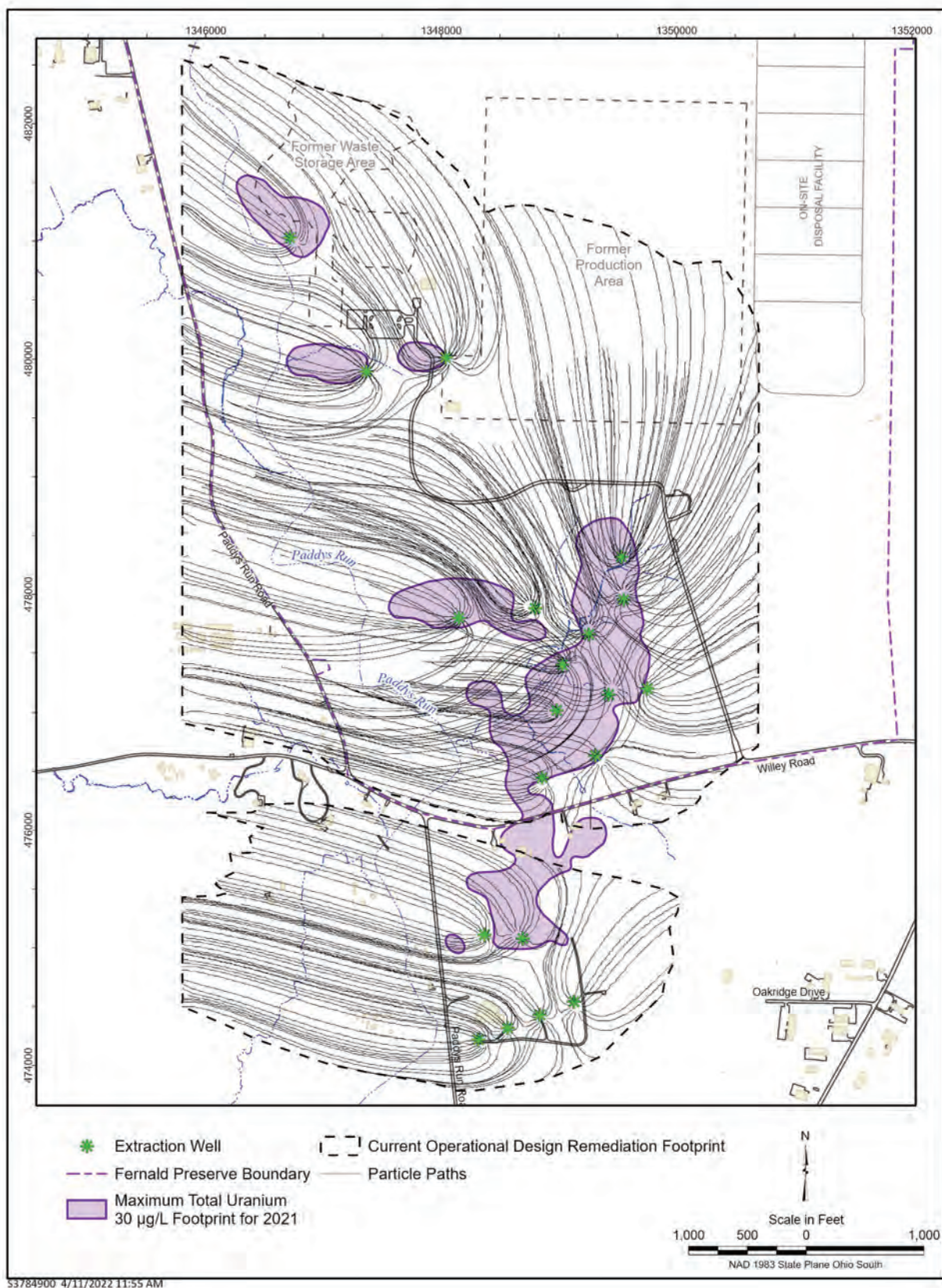


Figure A.3-5. Current Operational Design Remediation Footprint

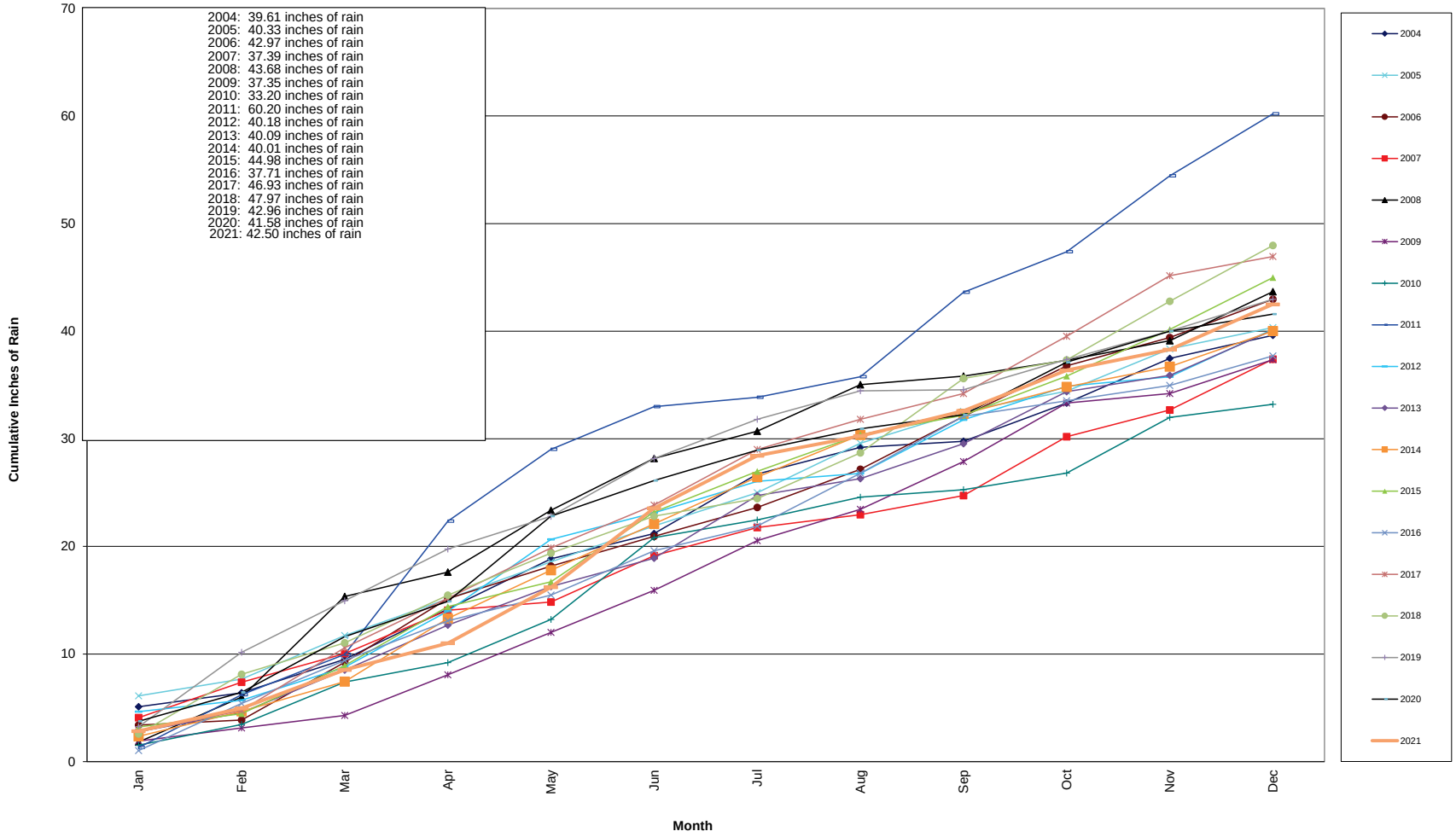


Figure A.3-6. Cumulative Annual Precipitation: 2004 Through 2021 as Recorded at the Butler County Regional Airport

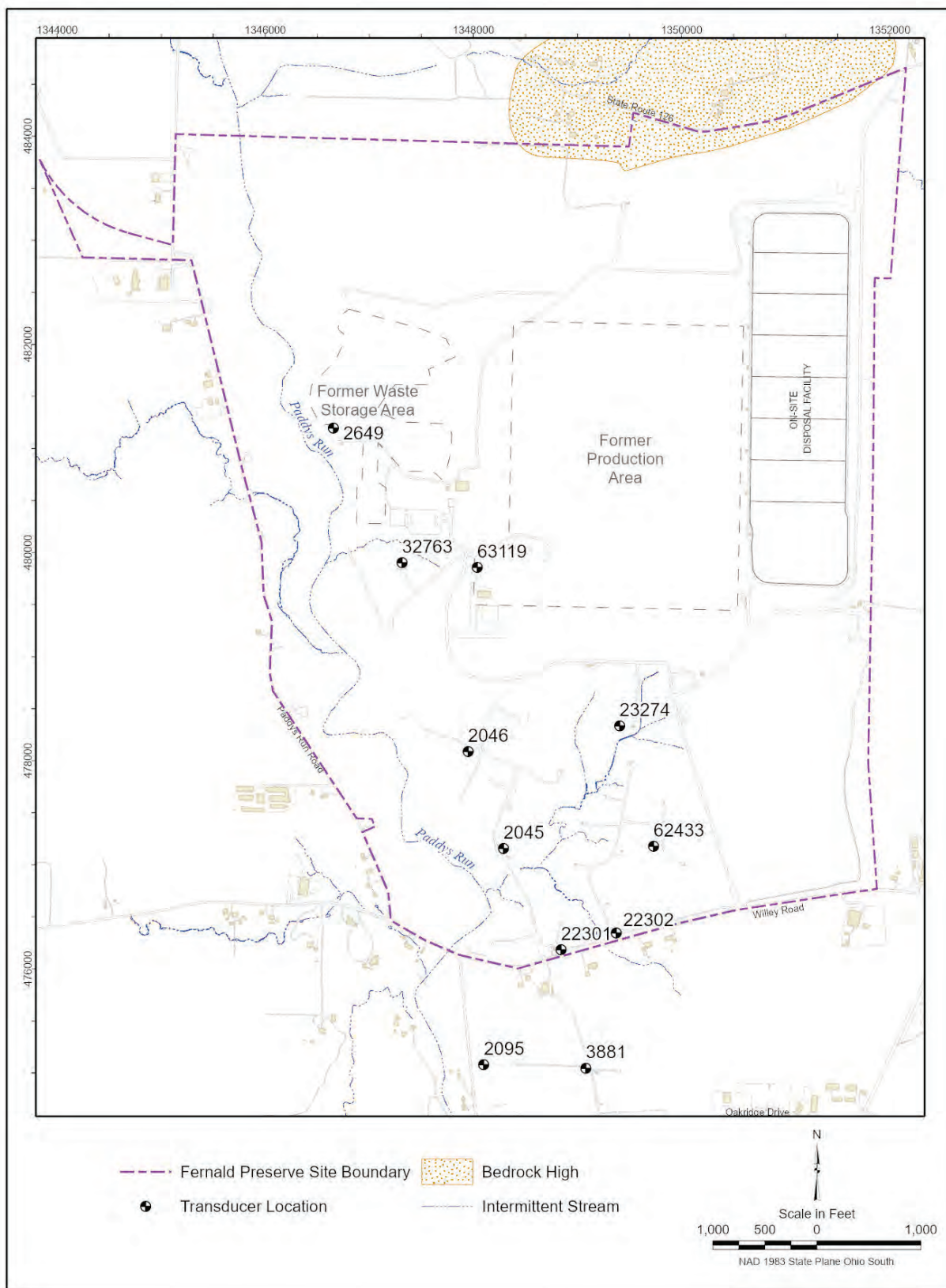


Figure A.3-7. Transducer Locations for the 2021 Operational Shutdown

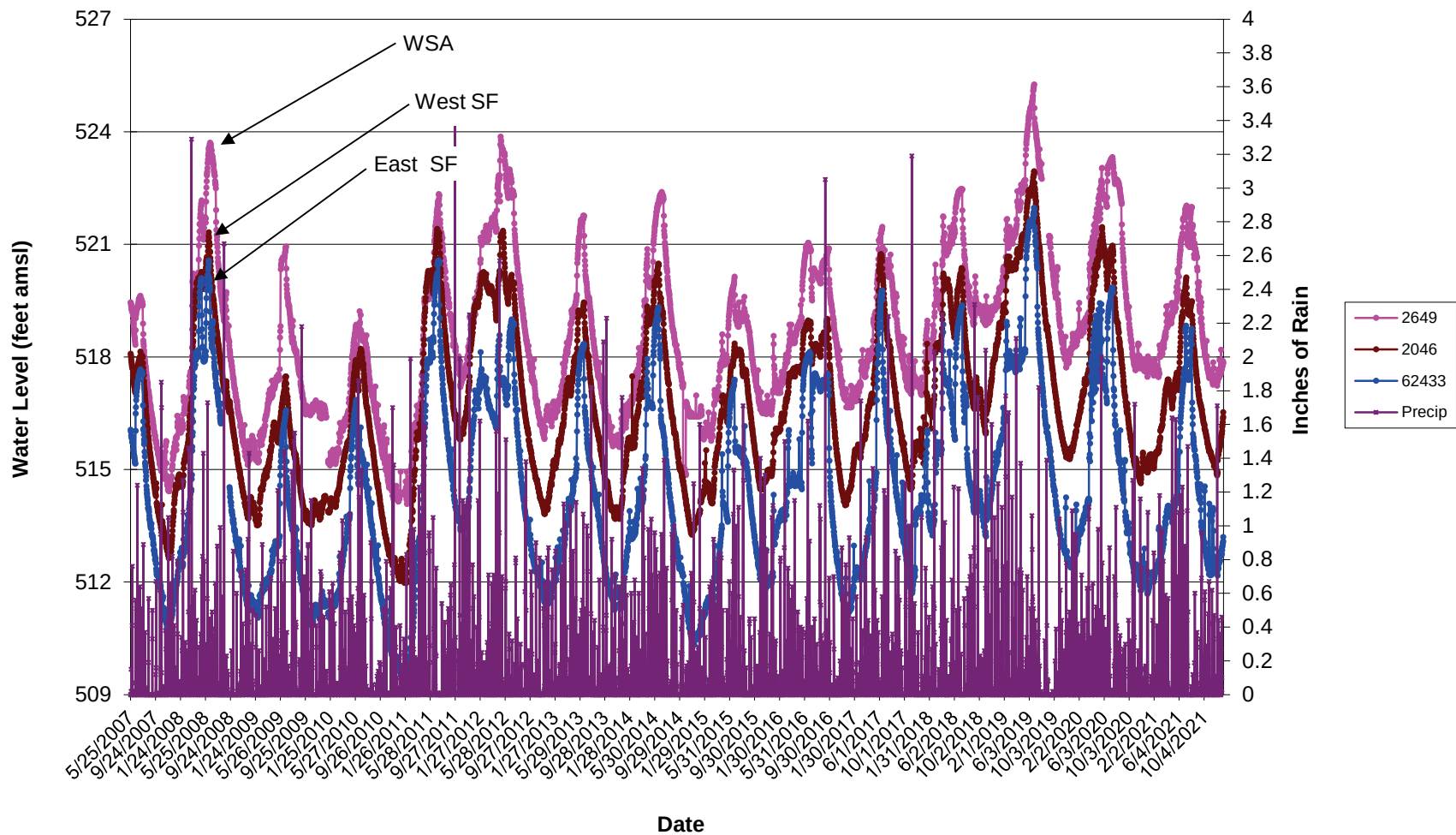


Figure A.3-8. Water Levels Versus Precipitation May 25, 2007, Through December 31, 2021

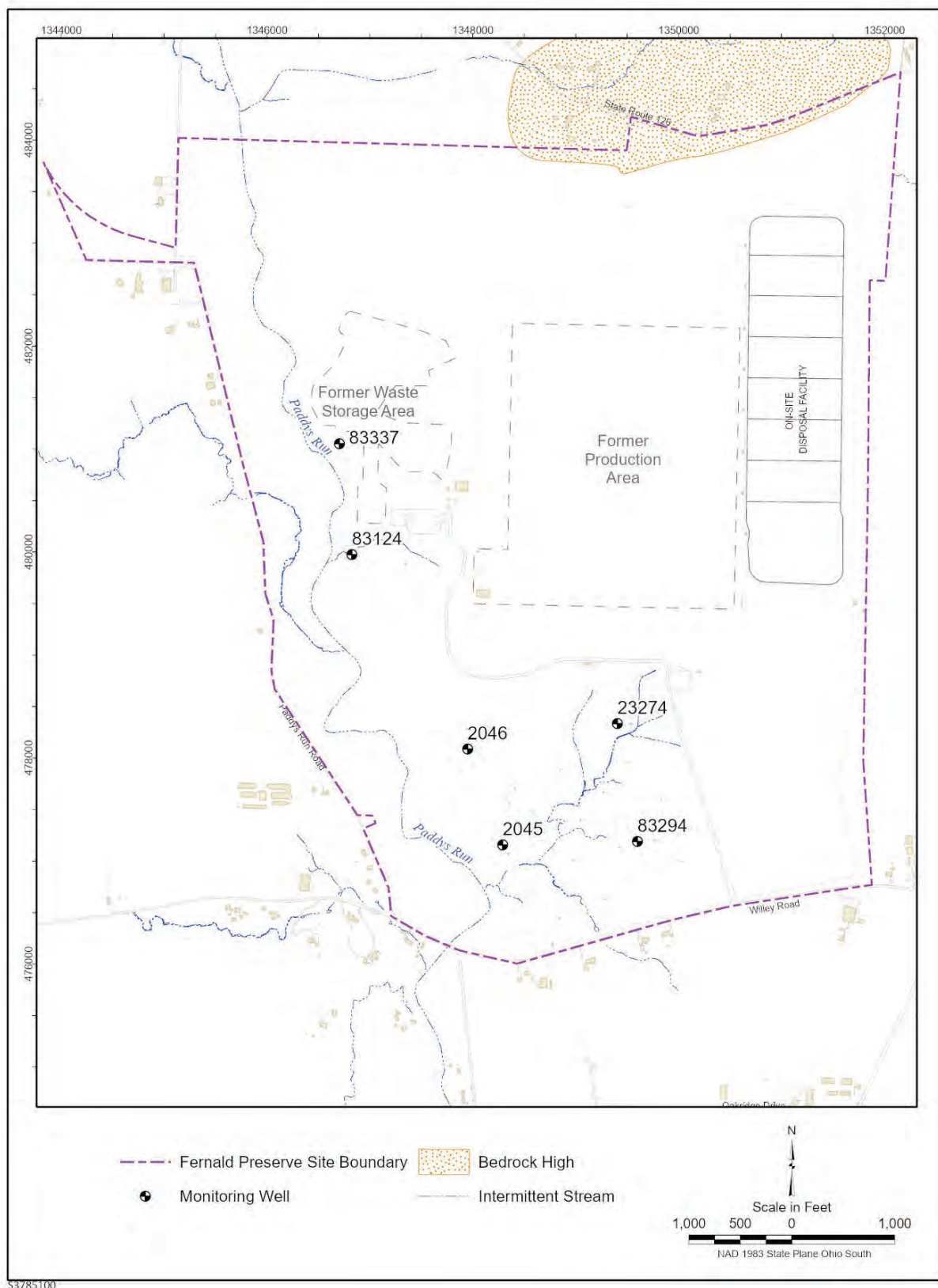


Figure A.3-9. Monitoring Well Locations for the 2021 Operational Shutdowns

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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	<i>Comprehensive Legacy Management and Institutional Controls Plan</i>
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 2021 collected under the “Integrated Environmental Monitoring Plan” (IEMP), which is Attachment D of the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP) (DOE 2019). The purpose of the evaluation is to:

- Identify 2021 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 2021 non-uranium FRL exceedances outside the current Operational Design Remediation Footprint (Section A.4.2).
- Present conclusions (Section A.4.3).

Consistent with past Site Environmental Reports, non-uranium groundwater monitoring results from wells monitored in the Great Miami Aquifer (GMA) for performance of the On-Site Disposal Facility (OSDF) are included in the data evaluation presented in this section of the Site Environmental Report. Beginning in 2017, the number of non-uranium constituents being sampled in the OSDF monitoring program was reduced. Data presented and discussed in the *Fernald Preserve 2015 Site Environmental Report* (DOE 2016) supported making the changes to the OSDF monitoring program. The proposed changes were approved by the U.S. Environmental Protection Agency, the Ohio Environmental Protection Agency, and stakeholders during the routine review and approval process of the 2017 LMICP (DOE 2017a).

As a result of the OSDF monitoring changes, the following nine non-uranium constituents are no longer being routinely sampled for in the GMA as part of the OSDF monitoring program: total organic carbon, iron, sodium, cobalt, total alkalinity, barium, chloride, copper, and chromium. The non-uranium constituents currently being sampled in the GMA as part of the IEMP are provided in Table 6 in Attachment D of the LMICP (DOE 2019). A list of the constituents routinely sampled in the GMA as part of the OSDF monitoring program can be found in Section 3.2.1.3 in Attachment C of the LMICP. Tables and data analyses presented below reflect the current combined sampling effort.

A.4.1 Non-Uranium FRL Exceedances for 2021

Table A.4-1 shows the summary statistics and trend analysis for the 2021 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 2021. Figure A.4-1 identifies the locations of these exceedances.

Figure A.4-1 shows that the non-uranium FRL exceedances in 2021 were in the former Waste Storage Area (WSA), and in the Paddys Run Road Site area. The exceedances in the WSA are within 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 2021. The first column in Table A.4-2 lists the groundwater FRL constituents monitored in 2021. As discussed above, Table A.4-2 reflects the current monitoring effort. The 2016 Site Environmental Report (DOE 2017b) provides a discussion concerning the changes implemented in 2017. The second column in Table A.4-2 identifies the wells monitored that have had an exceedance since 1997, for each constituent. The third column identifies the associated aquifer zone monitored. The fourth column identifies the associated monitoring program for each well or constituent. The remaining columns show monitoring years that reflect a semiannual sampling frequency; a “1” denotes an exceedance for one of the two samples, and a “2” denotes an exceedance for both samples. Beginning in 2017, the sampling frequency of several of the wells that had been sampled quarterly through 2013 was reduced from a semiannual to annual frequency. Data presented and discussed in the 2015 Site Environmental Report (DOE 2016) supported making the sampling frequency change. Table A.4-2 also indicates whether exceedances occurred inside or outside the remediation footprint (shading indicates the well is located outside the footprint).

As specified in Table 4 in the IEMP (DOE 2019), there were 13 non-uranium constituents monitored in 2021; as stated above, 5 had exceedances during 2021. The following table summarizes the 2021 non-uranium monitoring information.

Constituent (units) ^a	Groundwater Final Remediation Level	2021 Monitoring Summary ^b	2021 Maximum Exceedance ^c
Antimony (mg/L)	0.0060	No exceedances	NA
Arsenic (mg/L)	0.050	No exceedances	NA
Boron (mg/L)	0.33	No exceedances	NA
Carbon disulfide (mg/L)	5.5	No exceedances	NA
Fluoride (mg/L)	4	No exceedances	NA
Lead (mg/L)	0.015	No exceedances	NA
Manganese (mg/L)	0.90	Exceedances in former WSA wells	0.918
Molybdenum (mg/L)	0.10	Exceedances in former WSA wells	0.254
Nickel (mg/L)	0.10	No exceedances	NA
Nitrate + nitrite, as nitrogen (mg/L)	11	Exceedances in former WSA wells	47.7
Technetium-99 (pCi/L)	94	Exceedances in former WSA wells	424
Trichloroethene (µg/L)	5	No exceedances	NA
Zinc (mg/L)	0.021	Exceedance in the Property Plume Boundary Wells	0.0274

^a µg/L = micrograms per liter; mg/L = milligrams per liter; pCi/L = picocuries per liter.

^b WSA = Waste Storage Area.

^c NA = not applicable.

A.4.1.1 Non-Uranium Direct-Push Sampling Results for 2021

In 2021, one direct-push sampling location in the former WSA (location 13528) was sampled for non-uranium constituents, as specified in the IEMP for the former WSA. This location is identified in Attachment A.2, Figure A.2-2. Direct-push sampling results for location 13528 are provided in Table A.2-1 in Attachment A.2. Non-uranium results are discussed below. The

former WSA is within capture of the groundwater remediation system. Because the area is within capture, a non-uranium FRL exceedance in the former WSA poses no threat to human health or the environment.

Location 13528

Direct-push sampling results for location 13528 are provided in Attachment A.2, Table A.2-1. The location is identified in Attachment A.2, Figure A.2-2.

This is the first time that this location was sampled. The maximum non-uranium concentrations from all samples are provided below.

Constituent (Units)^a	FRL	13528 (2021)
Technetium-99 (pCi/L)	94	6.25
Nitrate + Nitrite as Nitrogen (mg/L)	11	4.90
Manganese (mg/L)	0.90	0.578
Molybdenum (mg/L)	0.10	0.0762
Nickel (mg/L)	0.10	0.00982

^a mg/L = milligrams per liter; pCi/L = picocuries per liter.

The data indicate that no FRL exceedances were measured in 2021 at this location.

A.4.2 Evaluation of 2021 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 if 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 2021 non-uranium FRL exceedances outside the current Operational Design Remediation Footprint. In 2021, there was one FRL exceedance outside the current Operational Design Remediation Footprint: zinc in monitoring well 3128.

Table A.4-3 addresses possible persistent FRL exceedances that occurred outside the current Operational Design Remediation Footprint in 2020. If the results of two or more sampling events immediately following an FRL exceedance indicate that the concentration decreased below the FRL, then the exceedance is identified as not persistent in Table A.4-3.

The following is a summary of results presented in Table A.4-3:

- The zinc FRL exceedance at monitoring well 3128, identified as being potentially persistent in 2021, requires that additional routine data be collected to determine if it is persistent
- The zinc FRL exceedance at monitoring well 22205, identified as being potentially persistent in 2019, was shown to be not persistent in 2021

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 2021 marks 25 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 2021, 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 2021, a zinc FRL exceedance in monitoring well 22205 (detected in 2019) was determined to be non-persistent
- In 2021, a zinc FRL exceedance in monitoring well 3128 requires that additional routine data be collected to determine if 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.

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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), 2019. *Comprehensive Legacy Management and Institutional Controls Plan*, LMS/FER/S03496, Revision 12, Office of Legacy Management, January.

Table A.4-1. Summary Statistics and Trend Analysis for Non-Uranium Constituents with 2021 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 2021 ^{b,c,d}	Maximum Exceedance for 2021 ^{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}
Manganese (0.90 mg/L)	2010	41	25	1	(mg/L) 0.918	(mg/L) 0.0886	(mg/L) 6.74	(mg/L) 1.76	(mg/L) 1.72	Down
Molybdenum (0.10 mg/L)	2649	43	43	2	0.254	0.178	1.26	0.477	0.236	No Trend
Nitrate + nitrite as nitrogen (11 mg/L) ^h	2821	53	33	1	23.3	1.38	120	25.6	26.9	Up
	83338_C1	25	20	1	47.7	0.404	73.8	39.5	21.4	No Trend
	83340_C1	27	19	1	12.2	0.470	761	46.3	144	Down
	83340_C2	30	29	2	25.4	2.93	86.7	41.1	24.1	No Trend
	83340_C3	30	26	1	44.8	1.13	133	40.5	32.7	Down
	83341_C1	14	10	1	44.0	0.265	56.3	20.9	19.2	Up
Technetium-99 (94 pCi/L)					(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	
	83338_C1	25	20	1	424	10.1	515	230	134	Up
Zinc (0.021 mg/L)	3128	32	2	1	(mg/L) 0.0274	(mg/L) 0.001	(mg/L) 0.0306	(mg/L) 0.00552	(mg/L) 0.00669	(mg/L) No Trend

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 2021.

^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 2021.

^h FRL based upon nitrate from *Record of Decision for Remedial Actions at Operable Unit 5* (DOE 1996), Table 9-4.

ⁱ pCi/L = picocuries per liter

Table A.4-2. Groundwater FRL Exceedances from 1997 Through 2021

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 ^f	2019 ^g	2020 ^g	2021 ^g
				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
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	FRRS									1	1				1		1				1					
	2733	0	P/PB												1		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	FRRS	1	1	2			1		1						1											
	2898	4	FRRS				1																					
	2900	4	FRRS				1																					
Boron																												
	2045	2	SF			1	1	1																				
	2049	2	SF	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	
	22198	0	P/PB						1									1	1	1	1	1						
	22203	0	P/PB																									
	22204	0	P/PB							1		1	1	1	1	1	2	2	1	1	2	2		1				
	22205	0	P/PB								1	1	1	1	1	1	2	1	1	2	2	2						
	22214	0	P/PB										1						1									
	2431	0	P/PB		2																							
	2432	0	P/PB				1		2	1	1																	
	2648	1	WSA	1		1	1	1	1	1		1	1	1														
	2733	0	P/PB																	1								
	3093	4	P/PB														1											
	3821	1	WSA				1	1	1	1	1	1	1	1	1	1	1	1	1	1								
	83337_C1	1	WSA																									
	83337_C2	1	WSA																									
	83337_C3	1	WSA																									
	83338_C2	1	WSA																									
	83339_C1	1	WSA																									
	83339_C2	1	WSA																									
	83339_C3	1	WSA																									
	83341_C1	1	WSA																									
	83341_C2	1	WSA																							1	1	
	83346_C1	1	WSA																								1	
	83346_C2	1	WSA																									
	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
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				1	1	1							
	2649	1	WSA	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	
	2821	1	WSA				1				1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	
	3821	1	WSA					1					1		1		1	1	1	1	1	1	1	1	1	1		
	83338_C1	1	WSA												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		
	83338_C3	1	WSA												1		1	1	1	1	1	1	1	1	1	1		
	83340_C1	1	WSA												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		
	83340_C3	1	WSA												1		1	1	1	1	1	1	1	1	1	1		
	83341_C1	1	WSA												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	1	1		
	Technetium-99																											
2648		1	WSA				1		2		1								1	1	1	1	1	1	1	1	1	
2649		1	WSA	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	
2821		1	WSA				1				1	1	1	1	1	1	1	1	1	1	2	1				1		
83338_C1		1	WSA								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		
83338_C3		1	WSA												1		1	1	1	1	1	1	1	1	1	1		
83340_C1		1	WSA												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		

Note: Shading indicates well is outside the current Operational Design remediation footprint.

^aA "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.

^bWSA = Waste Storage Area.

SE = South Field

D/DP = Direct/Plume Boundary for EPL Exceedences

P/PB = Property/Plume Boundary for FRL Exceedance

^d Prior to 2017, P/PB included OSDE monitoring results for some constituents.

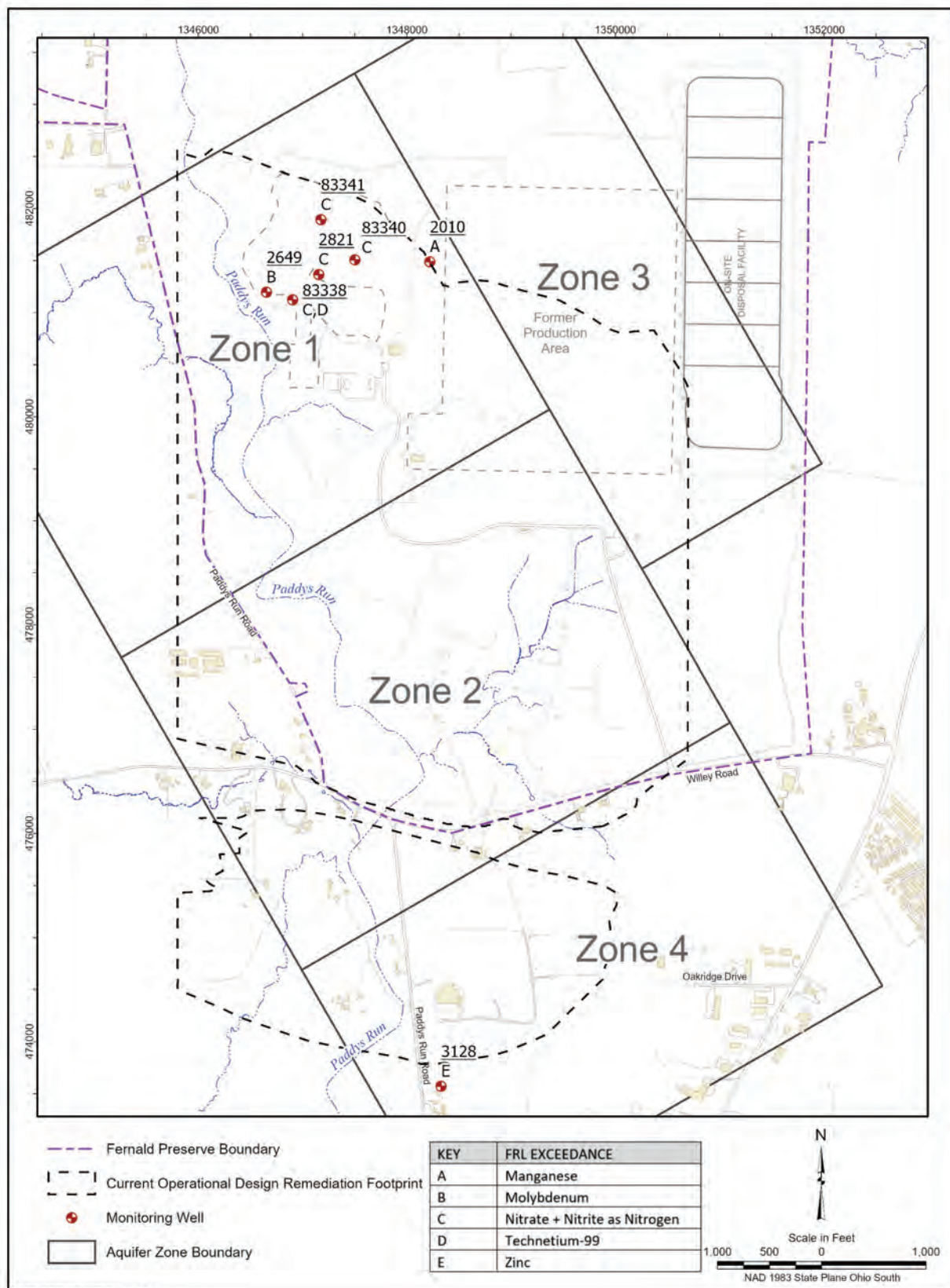
^b Beginning in 2017, monitoring frequency for P/PB and PRRS projects changed from semi-annual to annual.

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

Constituent	Monitoring Well	Monitoring Program	Pertinent 2020 Results	2021 FRL Exceedance	Evaluation Results for 2021	Figure Number
Zinc	22205	P/PB	Additional routine data required	No	Not persistent	A.4-2
Zinc	3128	P/PB	Not Applicable	Yes	Additional routine data required	A.4-3

^a FRL = Final Remediation Level, P/PB = Property/Plume Boundary



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Figure A.4-1. Non-Uranium Constituent Locations with 2021 Results Above FRLs

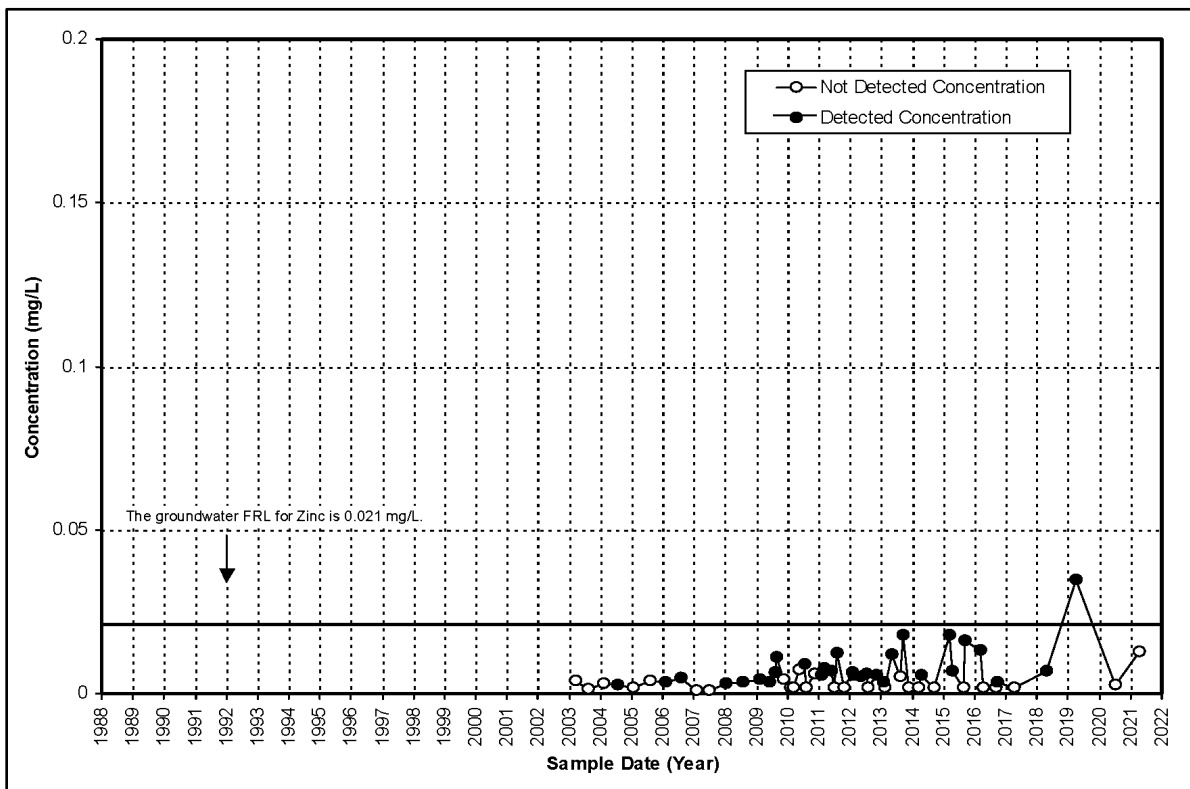


Figure A.4-2. Zinc Concentration Versus Time Plot for Monitoring Well 22205

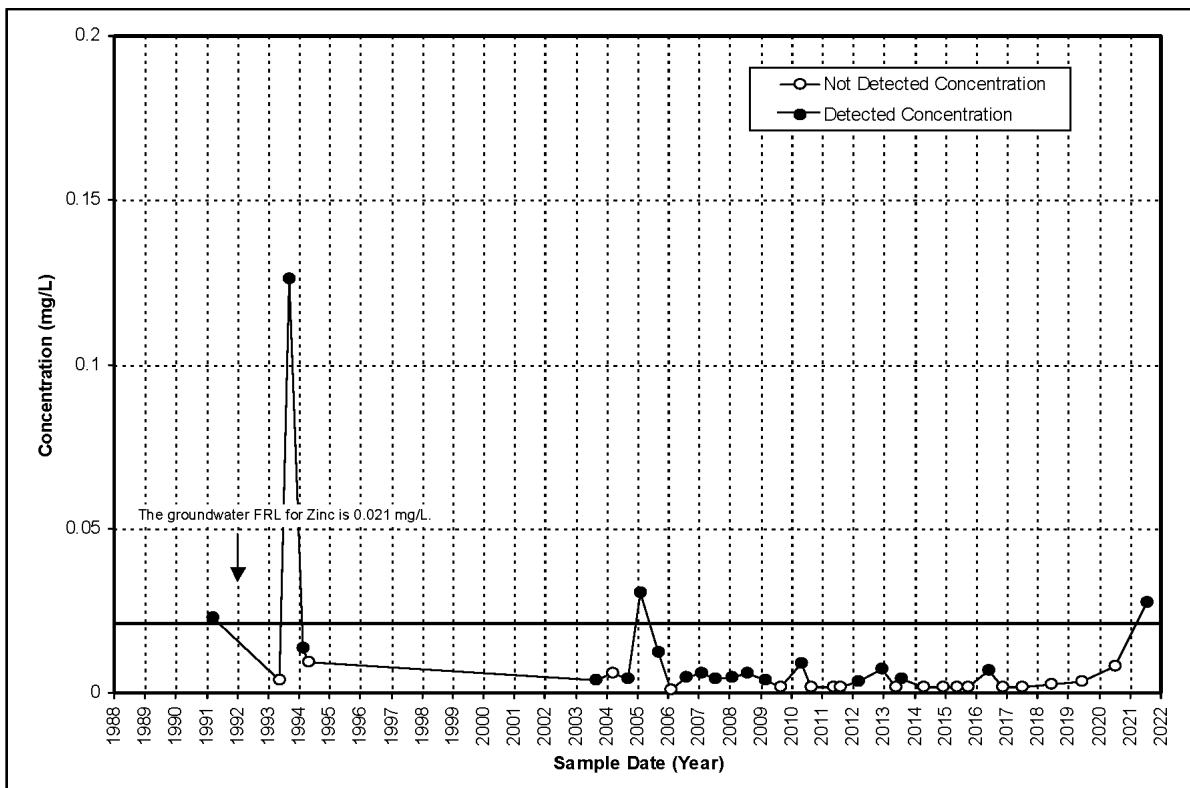


Figure A.4-3. Zinc Concentration Versus Time Plot for Monitoring Well 3128

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Attachment A.5

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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	<i>Comprehensive Legacy Management and Institutional Controls Plan</i>
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

ft	feet
gpad	gallons per acre per day
µg/L	micrograms per liter

A.5.0 On-Site Disposal Facility Monitoring Results

This attachment provides results for the On-Site Disposal Facility (OSDF) leak detection and leachate monitoring program at the Fernald Preserve, Ohio, Site. Monitoring and sampling were conducted in accordance with the *Comprehensive Legacy Management and Institutional Controls Plan* (LMICP), Attachment C, “Groundwater/Leak Detection and Leachate Monitoring Plan” (GWLMP) (DOE 2019a). The objective of the GWLMP is to meet regulatory requirements for groundwater detection monitoring in the Great Miami Aquifer (GMA) and perched groundwater system and to provide leachate monitoring information.

Facility Description

The OSDF is in the northeast area of the Fernald Preserve. It has a capacity of 2.96 million cubic yards and a maximum height of approximately 65 feet (ft). A security fence surrounds the OSDF and defines a footprint that occupies approximately 100 acres. The facility consists of eight individual cells. All eight cells were completely full and capped by October 2006.

Protection of the GMA and the overlying perched groundwater system includes the following measures for each of the eight cells (refer to Figure A.5-1 for a cross section of the liner system):

- Multilayer composite cap system
- Leachate collection system (LCS)
- Leak detection system (LDS)
- Multilayer composite liner system

The LCS consists of a gravel layer installed beneath the encapsulated waste to collect rainwater that came in contact with the waste during cell construction and additional moisture that is draining from the waste following capping. The LDS is located beneath both the LCS and the primary geosynthetic liner system and provides a mechanism for collecting and monitoring leakage through the primary liner layer of the OSDF prior to any releases to the environment. Both systems drain to the west and extend beyond the synthetic liner systems into valve houses, where leachate is collected in tanks for sampling.

The base of each cell liner also slopes toward the centerline of the cell, and the centerline of the base is sloped toward the west. Leachate moving along the top of a liner would first travel toward the centerline and then west along the centerline to be drained from the cell via piping at the penetration box, which is the lowest elevation point of the cell.

Each cell is monitored below the penetration box with a horizontal till well (HTW), which represents the first monitoring point for a potential release from a cell. HTWs provide monitoring of the perched groundwater quality beneath the point where the LCS and LDS pipes exit the liner system. The GMA is monitored by both an upgradient and a downgradient monitoring well for each cell. Figure A.5-2 identifies the well locations associated with the OSDF. Table A.5-1 identifies specific dates for the following cell activities:

- Sample initiation for each monitoring horizon
- Waste placement initiation

- LDS volume measurement initiation
- Cap geomembrane layer completion
- Cap completion (through seeding)

A construction quality assurance and quality control program was executed for each cell of the OSDF. The synthetic liners and caps of each cell were inspected and tested for defects at the time of installation. Given the attention to quality assurance and quality control during the installation of the OSDF liner system, it is doubtful that a breach in the liner would have gone unnoticed, but it is possible that a breach could develop. Such a breach would provide a potential pathway for leachate migration, but adequate hydraulic head is needed to drive leachate through the breach and clay liner into the underlying horizon.

The GWLMP summarizes the principal geologic, hydrogeologic, and subsurface contaminant conditions in the OSDF area that had a direct bearing on the development of the monitoring program for the OSDF facility. As discussed in the GWLMP, the conceptual flow path/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 2021 OSDF leak detection and leachate monitoring information is organized into the following sections:

- Flow and Hydraulic Performance (Section A.5.1)
- Water Quality: Data Presentations and Evaluations (Section A.5.2)
- Cell Cap Inspections (Section A.5.3)
- Summary of Overall Performance and Findings and Recommendations (Section A.5.4)

Subattachments A.5.1 through A.5.8 provide cell-specific information for Cells 1 through 8.

A.5.1 Flow and Hydraulic Performance

A.5.1.1 Overall LCS Volumes

Capacitance probes are used to measure water levels in each LCS tank. The water levels in the tanks are communicated to the Converted Advanced Wastewater Treatment (CAWWT) facility via radio signal. When the water level in the tank reaches 1.86 ft, the tank is approximately 80% full, and the pump automatically starts to pump water from the tank to the leachate lift station. The water in the lift station is pumped to the CAWWT facility backwash basin. To determine the volume of leachate pumped, the change in water level after pumping is converted to gallons using an equation from the tank manufacturer. If communication to the CAWWT facility is not functioning, tanks are pumped manually when tanks are between 40% and 80% full of water. In this case, volumes pumped are recorded manually on the leachate round sheet. Tanks are also pumped manually after each sampling event.

Leachate volumes have been measured since waste placement began. Figure A.5-3 is a graph showing monthly leachate volumes from October 2006 through December 2021. Figure A.5-4 is a graph that shows the annual leachate volume from 2007 through 2021.

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 table below. Contingencies for closing the valves are provided in the GWLMP in the 2019 LMICP (DOE 2019a). No line closures occurred in 2021.

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 discussed in Attachment A.1. The valves were shut for a period within the calendar year and did not affect the reporting of the volume in the same way as in 2017 and 2018.

Leachate volumes reported for 2019 reflect accumulation over the entire calendar year with the leachate valves being open 253 days (January 1 through August 13, and December 3 through December 31, 2019), during which time a total of 113,350 gallons of leachate were collected and pumped to the CAWWT backwash basin for subsequent treatment at the CAWWT facility.

Leachate volumes for 2021 reflect the entire calendar year with the valves open, during which time a total of 105,874 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 2021 was approximately 62.4 million gallons (42.50 inches over 54.1 acres). The facility cap was designed to inhibit water from infiltrating the OSDF. Leachate collected in 2021 (105,874 gallons) represents approximately 0.17% of the 62.4 million gallons. This value indicates that in 2021 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 [gpac]) and accumulation volumes (in gallons) for each cell's LDS. As explained below, the method of measuring flow in the LDS (for those cells that still have flow) has changed in response to the decreasing flow.

The GWLMP states that trend analysis of the LDS flow monitoring measurements will be conducted for capped cells to provide an indication of changes in system performance. Monthly accumulation volumes for Cells 1 through 8 are provided and graphically displayed in Subattachments A.5.1 through A.5.8. The graphs indicate that LDS flows are trending asymptotic at or near zero.

Through 2017, capacitance probes were used in the tank of each LDS to measure the water level within the tank. The capacitance probes can measure within hundredths of a foot of water in the bottom of the tank. Measured water levels were used to calculate the accumulation rate for each cell. Although water may register via the probes, there may not be enough water present to

physically obtain a sample. Pump out of the tank can occur automatically if an LDS tank water level reaches 80% of its capacity (1.86 ft of water). Pump out also occurs after semiannual sampling is completed to remove any water that remains after sampling, to ensure newer water is sampled for the next semiannual sampling event.

In 2021, LDS tanks for Cells 1, 2, 3, 5, and 7 were too dry to collect semiannual samples, so no pump out occurred in these LDS tanks, resulting in an accumulation rate of 0.0 gpad. The LDS tanks in Cells 4, 6, and 8 accumulated enough water to collect routine semiannual samples in 2021. However, the amount of water accumulated in each of those LDS tanks in 2021 was very low, so accumulation rates are estimated by tracking the volume of water manually pumped out of each LDS tank and the amount of time between pump outs. To be conservative, a volume of 1 gallon was assumed for each sampling event. The calculation for estimated maximum accumulation rates based on tank pump outs is summarized below.

Cell	Estimated Volume Pumped from LDS (gallons)	Estimated Maximum Accumulation Rate (gpac)
4	1	0.0002
6	30	0.015
8	2	0.0006

The *On-Site Disposal Facility Final Design Calculation Package* (DOE 1997) defines an initial response leakage rate for individual cells of 200 gpac. As a best management practice, the U.S. Department of Energy (DOE) imposed two lower leakage rates:

1. Initial Response Leakage Rate of 20 gpac
2. Low-Flow Response Leakage Rate of 2 gpac

The highest estimated maximum accumulation rate determined for 2021 (0.015 gpac in Cell 6) is only 0.75% of the low-flow response leakage rate of 2 gpac.

The 2021 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	2021 Estimated Maximum LDS Accumulation Rate Calculated from Tank Pump Outs (gpac)	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	0.0002	0.001	0.01
5	0.00	0.0	0.0
6	0.015	0.075	0.75
7	0.00	0.0	0.0
8	0.0006	0.003	0.03

These estimated LDS accumulation rates indicate that the liner systems for the cells are performing well and within the specifications outlined in the approved OSDF design, as illustrated in Figure A.5-5. The initial response leakage rate of 20 gpac 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.

In 2021, the LDS tanks in 5 of the 8 cells (Cells 1, 2, 3, 5, and 7) were dry (0.0 gpad). The estimated maximum accumulation rate measured for the remaining three cells that had flow in the LDS in 2021 (Cells 4, 6, and 8) was only 0.015 gpad. The current LDS tanks hold approximately 300 gallons of water, making them oversized for current LDS flow conditions. In the 2018 Site Environmental Report, DOE reported plans to install tubing at an existing sampling port upstream of the LDS tank to provide a means to divert any future flow into a 5-gallon container. The thought was that the smaller container would better facilitate future sampling events and LDS flow measurement capabilities. Given that the LDS systems continue to dry up, DOE decided not to install the sampling ports.

Over the years, several small, very minor leaks have occurred in the valve house piping that so far have been easily repaired. The liquid is being contained within the valve house. The leaks are the result of galvanic corrosion between two different types of metal components of the piping system. Rather than wait for more leaks to develop, DOE is investigating replacing the metal piping inside the valve houses that connects the leachate lines to the collection tanks with plastic piping before the metal components further deteriorate. This presents the opportunity to also replace the sampling ports on these lines, as previously discussed above. DOE is reviewing these modifications with the U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) and plans to make the approved modifications to the valve house piping and sampling ports during 2022.

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 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 matched the very low historical total uranium concentrations in the perched groundwater in the area; therefore, the liquid in the valve house is attributed to water leaking into the valve house from outside the valve house at the point where the LCS line system penetrates through the valve house wall. Any liquid that enters the valve house via this pathway is being directed to the LCS tank within the valve house until repairs can be made. It should be noted that the small amount of liquid entering the LCS tanks via this pathway will temporarily impact the volume and quality of water collected from the Cell 7 LCS tank. The impact is expected to be minimal. DOE is moving forward with a planned repair in 2022.

A.5.1.3 Liner Efficiencies

Cell-specific apparent liner hydraulic efficiencies are calculated using the following equation:

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

Apparent liner hydraulic efficiency is a measure of how a cell's liner is performing. The above equation considers *all* the LDS volume to be leakage through the primary liner, which

is a conservative measure. In the *Report on the 1995 Workshop on Geosynthetic Clay Liners* (EPA 1996), several sources of flow from leak detection layers were identified. These sources include:

- Top liner leakage.
- Construction water and compression water.
- Consolidation water.
- Water from groundwater infiltration.

As stated previously, the LDSs in Cells 1, 2, 3, 5, and 7 were dry in 2021, resulting in an LDS volume equal to 0 for the purposes of calculating the liner efficiency. Since 2019, liner efficiencies of only those cells that had LDS volumes greater than 0 are reported (Cells 4, 6, and 8 for 2021). Cells 4 and 8 in 2021 are reported at 100% because, although a sample was collected, no pumping occurred from the tanks.

Apparent Liner Efficiency (Percent), Quarterly for 2021

Quarter	Cell 4	Cell 6	Cell 8
First	100.00	100.00	100.00
Second	100.00	99.26	100.00
Third	100.00	100.00	100.00
Fourth	100.00	100.00	100.00

A.5.1.4 HTW Water Yields

HTW water yields are monitored at each cell to document trends in perched-water purge volumes. In 2021, 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. 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 2021

Location ID	Cell	First Half Purge March 2, 2021 (Gallons)	Second Half Purge September 8, 2021 (Gallons)	Annual Total (Gallons)	Annual Average (Gallons)
12338	Cell 1	820	280	1,100	550
12339	Cell 2	810	800	1,610	805
12340	Cell 3	710	725	1,435	718
12341	Cell 4	610	550	1,160	580
12342	Cell 5	1,050	1,050	2,100	1,050
12343	Cell 6	415	275	690	345
12344	Cell 7	200	760	960	480
12345	Cell 8	Dry	Dry	Dry	Dry
Totals		4,615	4,440	9,055	Not Applicable

A.5.2 Water Quality: Data Presentations and Evaluations

The water quality and data presentations and evaluations presented in this report consist of the following:

- 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. Concentrations-versus-time plots, bivariate plots, and control charts are used to help interpret and present results. Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell. With EPA and Ohio EPA concurrence, monitoring changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017 (total uranium, boron, sodium, sulfate, calcium, lithium, magnesium, nitrate + nitrite as nitrogen, potassium, selenium, technetium-99, total dissolved solids, and total organic halogens). All 13 parameters are sampled in the GMA wells; 4 of the 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW for each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was eliminated beginning in January 2017 with EPA and Ohio EPA concurrence.

Summary statistics for all the parameters monitored semiannually are provided in Subattachments A.5.1 through A.5.8 (Tables A.5.1-1 through A.5.8-1). The information provided in each summary table is based on a standardized quarterly sampling frequency. Baseline data are included in the summary statistics. A discussion of data collected for the OSDF is provided in the “Groundwater/Leak Detection and Leachate Monitoring Plan” (Attachment C of the LMICP).

The 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). ChemStat software is also used to perform the statistical analysis of groundwater monitoring data at Resource Conservation and Recovery Act facilities. The website for the software is www.pointstar.com.

Data set distributions were checked using the Shapiro-Wilk Test (95% confidence interval) for data sets with fewer than 50 samples and the Shapiro-Francia Test (95% confidence interval) for data sets 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 LMICP “Groundwater/Leak Detection and Leachate Monitoring Plan” (DOE 2019a), monitoring accumulation rates from the LDS against established design and agreed-to administrative action rates is a much better approach.

A.5.2.2 Concentration Plots

Concentration plots for the parameters monitored semiannually in 2021 are presented in Subattachments A.5.1 through A.5.8. The plots are presented with a common vertical y scale based on the parameter. Outliers identified in Subattachments A.5.1 through A.5.8 in Tables A.5.1-1 through A.5.8-1 are not plotted on the concentration plots.

Table A.5.3 provides an OSDF Groundwater, Leachate, and LDS Monitoring Summary. As shown in Table A.5-3 and listed below, three sampling locations had new high total uranium concentrations in 2021; two were in the LDS, and one was in the GMA.

- **GMA of Cell 3:** A new high of 18.5 micrograms per liter ($\mu\text{g/L}$) was measured in the first half of 2021 in the upgradient GMA well (22203). The previous high was 15.4 $\mu\text{g/L}$. The concentration measured in the second half of 2021 was 8.08 $\mu\text{g/L}$.
- **LDS of Cell 6:** Two new highs were measured in 2021. In the first half of 2021, a concentration of 149 $\mu\text{g/L}$ was measured. In the second half of 2021, a concentration of 152 $\mu\text{g/L}$ was measured. The previous high was 144 $\mu\text{g/L}$.
- **LDS of Cell 8:** A new high of 315 $\mu\text{g/L}$ was measured in the second half of 2021. The previous high was 209 $\mu\text{g/L}$. The concentration measured in the first half of 2021 was 180 $\mu\text{g/L}$.

Bivariate plot results reported in Section A.5.2.4 continue to support the interpretation that chemical signatures for the different monitoring horizons are separate and distinct, indicating that mixing between the horizons is not occurring; therefore, new high uranium concentrations measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.

The new high uranium concentrations measured in the LDS of Cells 6 and 8 in 2021 are not attributed to communication with the LCS. A new high uranium concentration measured in the LDS is attributed to the impact that decreasing flow can have on the uranium concentration left in fluid remaining in the LDS as the LDS dries up. Uranium concentration versus time plots for each cell are provided in Subattachments A.5.1 through A.5.8. As shown in those figures, with the exception of Cell 3 LDS, an increasing uranium concentration trend was clearly observed in the LDS of other cells as they were drying up (Cells 1, 2, 5, and 7). For Cell 3, the last sample collected showed an increasing uranium concentration, but the overall trend in the Cell 3 LDS leading up to the last sample was not increasing. The LDS of each cell is expected to dry up over time, and this indicates that the facility continues to operate as designed.

Figures A.5-7 through A.5-9 illustrates the trends observed at the three remaining cells that had enough fluid left in the LDS to sample in 2021. Each figure shows three graphs, with a general trend line. The upper graph is the total uranium concentration versus time in the LDS fluid. The middle graph is the accumulation of fluid in gallons in the LDS, and the lower graph is the mass of uranium contained within the accumulated volume of fluid. The graphs illustrate that as the LDS dries up (decreasing accumulation volume), the uranium concentrations increase, while the mass of uranium in the accumulated fluid does not show an overall increasing trend.

A.5.2.3 Control Charts

Intrawell control charts employ historical measurements from a compliance point as background. The *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities—Unified Guidance* (EPA 2009) defines the process of creating a Shewhart-cumulative sum (CUSUM) control chart. Appropriate background data are used to define a baseline for the well. The baseline parameters for the chart, estimates of the mean, and standard deviation are obtained from the background data. These baseline measurements characterize the expected background concentrations at the monitoring point. As future concentrations are measured, the baseline

parameters are used to standardize the newly gathered data. After these measurements are standardized and plotted, a control chart is declared “not in control” if future concentrations exceed the baseline control limit. This is indicated on the control chart when either the Shewhart or CUSUM plot traces begin to exceed a control limit. The limit is based on the rationale that if the monitoring point remains unchanged from the baseline condition, new standardized observations should not deviate substantially from the baseline mean. If a change occurs, the standardized values will deviate significantly from the baseline and tend to exceed the control limit. Usually, two parameters are used to interpret control charts: the decision value (h) and the Shewhart control limit (SCL).

A minimum of eight samples are recommended for use in ChemStat software to define the baseline for a control chart. Therefore, only sample sets with at least eight samples were selected for control charts. By default, the ChemStat software plots both a CUSUM control limit (h) and a Shewhart control limit (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-six Shewhart-CUSUM control charts were prepared in 2021 and are presented in Subattachments A.5.1 through A.5.8 for parameters monitored semiannually in the HTW and GMA wells in 2021 that had data sets that achieved control chart criteria (i.e., more than eight samples, normal or lognormal distribution, no trend, and no serial correlation). All of the 26 control charts exhibited “in control” conditions.

A.5.2.4 Bivariate Plots

Bivariate plots are used in an Alternate Source Determination capacity to show that water quality changes observed beneath the facility in HTW and GMA wells are not attributed to facility performance. Sodium and total uranium were selected because this combination provides a good distinction between LCS, LDS, and HTW. This combination was discovered during the Common Ion Study (DOE 2008). Although the sodium–uranium bivariate plot for Cell 8 provides a distinction between the LDS and HTW, the separation shown between the LDS and HTW is not as distinct as it is for the other seven cells; therefore, a sulfate–uranium bivariate plot is also provided for Cell 8. In 2020, the uranium concentration in the LCS of Cell 1 decreased enough to place it in the area of the bivariate plot occupied by HTW samples. The LDS of Cell 1 has been too dry to collect a sample from since 2011. An additional bivariate plot of sodium–sulfate is provided for Cell 1 to illustrate that the sodium and sulfate concentrations indicate that the LCS and HTW zones are not mixing. Other combinations may be added in the future, if deemed appropriate.

Bivariate plots are presented for each cell in Subattachments A.5.1 through A.5.8. The bivariate plots illustrate the concentration signatures in each monitoring horizon. Distinct clustering of

horizon concentrations indicates that the fluids in the different horizons are not mixing. In response to an Ohio EPA comment on the *Fernald Preserve 2009 Site Environmental Report* (DOE 2010) (Ohio EPA Comment Number 35), the closest points between monitoring horizons were dated until 2018. Beginning with the *Fernald Preserve 2018 Site Environmental Report* (DOE 2019b), an arrow is provided on the plots from the first to most recent sample result for each monitoring horizon. The dates of the first and most recent sample plotted are also posted for each sampling horizon.

An additional bivariate plot for sodium–sulfate is presented for Cell 1 in Subattachment A.5.1. The additional sodium–sulfate bivariate plot provides supporting information concerning the water chemistry signatures present in the LCS and HTW of Cell 1—specifically, that they are separate and distinct.

An additional bivariate plot for uranium–sulfate is presented for Cell 8 in Subattachment A.5.8. The additional uranium–sulfate bivariate plot provides supporting information concerning the water chemistry signatures present in the LDS and HTW of Cell 8—specifically, that they are separate and distinct.

The bivariate plots for 2021 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 2021 (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 if the continued use of bivariate plots with data from the LDS is still warranted. Assessment results indicated that bivariate plots continue to be a valuable tool for assessing whether the monitoring zones are mixing (Geochemical Consultants 2016).

A.5.2.5 Upward Concentration Trends in the HTW and GMA Wells

The HTW is located beneath the liner penetration box of each cell by design. This area of the liner penetration box is the lowest elevation point of each cell and potentially the weakest point in the cell design. If a leak were to develop, it should be detected beneath the liner penetration box first. Therefore, the water quality in the HTW represents the first line of evidence that a potential leak from the cell might be occurring. A leak would be indicated by an increasing concentration trend in the HTW.

GMA monitoring wells are positioned (and identified) for pre-aquifer-remediation flow conditions defined in the Operable Unit 5 Remedial Investigation Report (DOE 1995). Water level data reported in the Operable Unit 5 Remedial Investigation Report indicate that, prior to 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 2021 inspections were conducted in March, June, September, and December. A complete inspection of the cell cap is conducted annually. The inspection team typically includes representatives from Ohio EPA, Ohio Department of Health, and the site contractor. Issues identified during inspections typically include rocks that surface as topsoil settles, animal burrows and digging, the presence of woody vegetation, and noxious herbaceous species.

The issues are addressed as follows:

- Rocks greater than 4 inches in diameter that surface are removed, especially if they will interfere with mowing activities or may be a source location for erosion.
- Animal burrows and holes are filled in and reseeded, if necessary.
- Woody vegetation is cut and stumps are treated with herbicide.
- Herbicide is applied to noxious weeds.

Through 2021, following each inspection, a report is submitted to EPA and Ohio EPA documenting the inspection and issues and stating how issues will be addressed. These reports are available to the public on the Fernald Preserve website at <https://www.lm.doe.gov/fernaldd/sites.aspx>. In 2021, there were no visual signs that the integrity of the cap had been compromised in any way. Appendix C provides additional information regarding the OSDF cap inspections and findings.

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 2021 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 2021 was 0.22% less than in 2020 (approximately 105,874 gallons in 2021 compared with 106,103 gallons in 2020).
- In 2021 there was not enough water in the LDS of Cells 1, 2, 3, 5, and 7 to collect a water sample.
- LDS accumulation rates for 2021 in Cells 4, 6 and 8 indicate that the liner systems are performing as designed. The largest estimated LDS maximum accumulation rate calculated in 2021 was 0.015 gpad in Cell 6, approximately 0.075% of the initial response leakage rate of 20 gpad, and 0.75% of the low-flow response leakage rate of 2 gpad.
- Quarterly apparent liner efficiencies were consistently greater than 99% for all cells in 2021.
- Three sampling locations had new high total uranium concentrations in 2021. Two in the LDS, and one was in the GMA.
 - **GMA of Cell 3:** A new high of 18.5 µg/L was measured in the first half of 2021 in the upgradient GMA well (22203). The previous high was 15.4 µg/L. The concentration measured in the second half of 2021 was 8.08 µg/L.
 - **LDS of Cell 6:** Two new highs were measured in 2021. In the first half of 2021, a concentration of 149 µg/L was measured. In the second half of 2021, a concentration of 152 µg/L was measured. The previous high was 144 µg/L.
 - **LDS of Cell 8:** A new high of 315 µg/L was measured in the second half of 2021. The previous high was 209 µg/L. The concentration measured in the first half of 2021 was 180 µg/L.
- Bivariate plots continue to show that the chemical signatures for uranium, sulfate, and sodium in the LCS, LDS, and HTW are separate and distinct, indicating that:
 - Mixing between the horizons is not occurring; therefore, concentration changes measured beneath the cells in GMA wells are attributed to fluctuating ambient concentrations beneath the cell and are not related to cell performance.
 - New high uranium concentrations measured in the LDS are not attributed to communication with the LCS. The new high uranium concentrations measured in the LDS are attributed to the impact that decreasing flow can have on the uranium concentration left in water remaining in the LDS as the LDS dries up.

- In 2021, 26 datasets met the criteria for Shewhart-CUSUM control charts. All control charts exhibited “in control” conditions.
- In 2021, quarterly physical inspections of the OSDF revealed no visual signs that the integrity of the OSDF cap had been compromised.

A.5.5 References

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Table A.5-1. OSDF Initiation and Completion Dates

Cell	Sample Initiation per Horizon ^a	Waste Placement Initiation	LDS Volume Measurement Initiation ^b	Cap Geomembrane Layer Completion ^c	Cap Completion ^d
1	LCS: February 17, 1998 LDS: February 18, 1998 HTW: October 30, 1997 GMA-U: March 31, 1997 GMA-D: March 31, 1997	December 23, 1997	May 1999	August 17, 2001	December 20, 2001
2	LCS: November 23, 1998 LDS: December 14, 1998 HTW: June 29, 1998 GMA-U: June 30, 1997 GMA-D: June 25, 1997	November 12, 1998	May 1999	July 17, 2003	November 12, 2003
3	LCS: October 13, 1999 LDS: August 26, 2002 HTW: July 28, 1998 GMA-U: August 24, 1998 GMA-D: August 24, 1998	October 26, 1999	October 1999	July 16, 2004	September 20, 2004
4	LCS: November 4, 2002 LDS: November 4, 2002 HTW: February 26, 2002 GMA-U: November 6, 2001 GMA-D: November 5, 2001	November 08, 2002	November 2002	December 18, 2004	April 29, 2005
5	LCS: November 4, 2002 LDS: November 4, 2002 HTW: February 26, 2002 GMA-U: November 6, 2001 GMA-D: November 5, 2001	November 19, 2002	November 2002	June 22, 2005	August 29, 2005
6	LCS: October 27, 2003 LDS: October 27, 2003 HTW: March 14, 2003 GMA-U: December 16, 2002 GMA-D: December 16, 2002	November 18, 2003	January 2004	October 28, 2005	January 12, 2006

Table A.5-1. OSDF Initiation and Completion Dates (continued)

Cell	Sample Initiation per Horizon ^a	Waste Placement Initiation	LDS Volume Measurement Initiation ^b	Cap Geomembrane Layer Completion ^c	Cap Completion ^d
7	LCS: September 2, 2004 LDS: September 2, 2004 HTW: February 24, 2004 GMA-U: January 21, 2004 GMA-D: January 21, 2004	September 9, 2004	September 2004	July 2006	October 25, 2006
8	LCS: October 18, 2004 LDS: October 18, 2004 HTW: May 19, 2004 GMA-U: March 31, 2004 GMA-D: March 31, 2004 GMA-SW: August 22, 2005 GMA-SE: August 22, 2005	December 2, 2004	December 2004	September 24, 2006	October 25, 2006

^aLCS = 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

^bPrior to 1999, overall LDS volumes were measured. From 1999 on, LDS volumes were measured by cell.

^cThe cap geomembrane layer is made of high density polyethylene.

^dCap 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 distribution	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"					

^aNA=not applicable; ND=not detected

^bIf 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 2021 ^{a,c} (µg/L)	Second Half 2021 ^{a,c} (µg/L)	Historical Trend ^d (Year Last Sampled)
Cell 1 (Dec 1997)	12338C	LCS	Feb 17, 1998	76	ND–206	22.9	4.22	None (2021)
	12338D	LDS	Feb 18, 1998	37	1.50–37.0	DRY	DRY	Up (2011)
	12338	Glacial Till	Oct 30, 1997	85	ND–19	7.28	6.71	Up (2021)
	22201	Great Miami Aquifer	Mar 31, 1997	92	ND–12.4	9.58	6.09	Up (2021)
	22198	Great Miami Aquifer	Mar 31, 1997	140	0.540–15.2	3.28	3.07	Down (2021)
Cell 2 (Nov 1998)	12339C	LCS	Nov 23, 1998	72	4.51–686	120	195	Up (2021)
	12339D	LDS	Dec 14, 1998	29	4.08–25.8 ^e	DRY	DRY	None (2013)
	12339	Glacial Till	Jun 29, 1998	96	ND–36.9	16.0	16.5	Up (2021)
	22200	Great Miami Aquifer	Jun 30, 1997	87	ND–4.69	0.487	1.53	Up (2021)
	22199	Great Miami Aquifer	Jun 25, 1997	117	ND–12.1	0.439	1.15	Down (2021)
Cell 3 (Oct 1999)	12340C	LCS	Oct 13, 1999	70	9.27–206	140	117	Up (2021)
	12340D	LDS	Aug 26, 2002	20	8.90–27.7 ^e	DRY	DRY	Down (2007)
	12340	Glacial Till	Jul 28, 1998	89	ND–58.5	16.4	18.2	None (2021)
	22203	Great Miami Aquifer	Aug 24, 1998	82	ND– 18.5	18.5	8.08	Up (2021)
	22204	Great Miami Aquifer	Aug 24, 1998	112	ND–22.9	3.80	3.57	Up (2021)
Cell 4 (Nov 2002)	12341C	LCS	Nov 04, 2002	56	4.41–234	145	108	None (2021)
	12341D	LDS	Nov 04, 2002	41	5.74–55.9	DRY	29.9	Up (2021) ^f
	12341	Glacial Till	Feb 26, 2002	69	3.40 –7.91	3.40	3.45	Down (2021)
	22206	Great Miami Aquifer	Nov 06, 2001	73	ND–5.78	1.26	2.23	Up (2021)
	22205	Great Miami Aquifer	Nov 05, 2001	99	0.446–19.7	1.76	3.16	None (2021)
Cell 5 (Nov 2002)	12342C	LCS	Nov 04, 2002	58	3.39–285	129	116	None (2021)
	12342D	LDS	Nov 04, 2002	40	2.93–27.1	DRY	DRY	Down (2013)
	12342	Glacial Till	Feb 26, 2002	70	7.45–21.1	7.82	8.77	Down (2021)
	22207	Great Miami Aquifer	Nov 06, 2001	73	ND–4.48	0.399	ND	Down (2021)
	22208	Great Miami Aquifer	Nov 05, 2001	98	ND–2.1	0.442	0.364	None (2021)

Table A.5-3. (continued) 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 2021 ^{a,c} (µg/L)	Second Half 2021 ^{a,c} (µg/L)	Historical Trend ^d (Year Last Sampled)
Cell 6 (Nov 2003)	12343C	LCS	Oct 27, 2003	55	8.03–276	113	109	Down (2021)
	12343D	LDS	Oct 27, 2003	54	3.1– 152	149	152	Up (2021)
	12343	Glacial Till	Mar 14, 2003	62	ND–24.2	9.34	9.47	None (2021)
	22209	Great Miami Aquifer	Dec 16, 2002	68	ND–2.43	0.560	ND	Down (2021)
	22210	Great Miami Aquifer	Dec 16, 2002	93	ND–1.02	0.716	0.889	None (2021)
Cell 7 (Sep 2004)	12344C	LCS	Sep 02, 2004	51	4.72–355	37.6	63.4	Down (2021)
	12344D	LDS	Sep 02, 2004	29	12.2–169 ^e	DRY	DRY	Up (2015)
	12344	Glacial Till	Feb 24, 2004	59	0.674–12.1	4.10	3.81	Up (2021)
	22212	Great Miami Aquifer	Jan 21, 2004	61	ND–5.53	0.517	ND	None (2021)
	22211	Great Miami Aquifer	Jan 21, 2004	83	ND–4.31	0.298	0.891	None (2021)
Cell 8 (Dec 2004)	12345C	LCS	Oct 18, 2004	48	1.51–335	136	167	None (2021)
	12345D	LDS	Oct 18, 2004	45	9.38– 315	180	315	Up (2021)
	12345	Glacial Till	May 19, 2004	20	3.48–7.3	DRY	DRY	Up (2008)
	22213	Great Miami Aquifer	Mar 31, 2004	60	ND–0.71	0.429	ND	Up (2021)
	22214	Great Miami Aquifer	Mar 31, 2004	83	ND–2.95	0.428	1.21	Down (2021)
	22215	Great Miami Aquifer	Aug 22, 2005	51	ND–16.4	0.435	ND	None (2021)
	22217 ^g	Great Miami Aquifer	Aug 22, 2005	50	ND–18.3	3.28	7.17	Down (2021)

Note: The data on this table represent the raw data from the database. However, data presented in the Attachment A.5 subattachments has gone through a statistical processing and analysis. In regard to the statistical processing, the data was quarterized (normalized to one result per quarter) and outliers were removed to arrive at an accurate distribution model. Because of the processing, the total number of samples and range of concentrations on this table might not match the text, tables, and figures in Attachment A.5. The rules used for the statistical processing and analysis in Attachment A.5 are discussed in Section A.5.2.1, and the results are summarized in Table A.5-2.

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

^a **Bold text** indicates a new high or low detected in 2021.

^b ND = not detected.

^c Where there are more than two data points for the half year, the higher result is used.

^d The trends presented here are based on nonparametric Mann-Kendall procedure and come from the tables in Attachment A.5 subattachments for each cell. See Tables A.5.1-1, A.5.2-1, A.5.3-1, A.5.4-1, A.5.5-1, A.5.6-1, A.5.7-1, and A.5.8-1.

^e Some data are not considered representative of LDS in Cell 2 (December 14, 1998, through May 23, 2000, data set) due to malfunction in Cell 2 leachate pipeline and resulting mixing of individual flows. It is suspected that some November 2004 samples were switched (i.e., 12339C with 12339D, and 12340C with 12340D). If data from these events were included above, maximum total uranium concentrations would be 71 µg/L for 12339D and 72.4 µg/L for 12340D. It is suspected that samples were switched in 2014 (i.e., 12344D with the field duplicate for 12345C). If the data point from this sampling event was not included above, maximum total uranium concentration for 12344D would be 37.6 µg/L.

^f The Cell 4 LDS was dry, resulting in no data from fourth quarter 2011 through 2016.

^g Monitoring location 22216 was plugged and abandoned in April 2006. Monitoring location 22217 is its replacement. The results listed for location 22217 also include the results for location 22216.

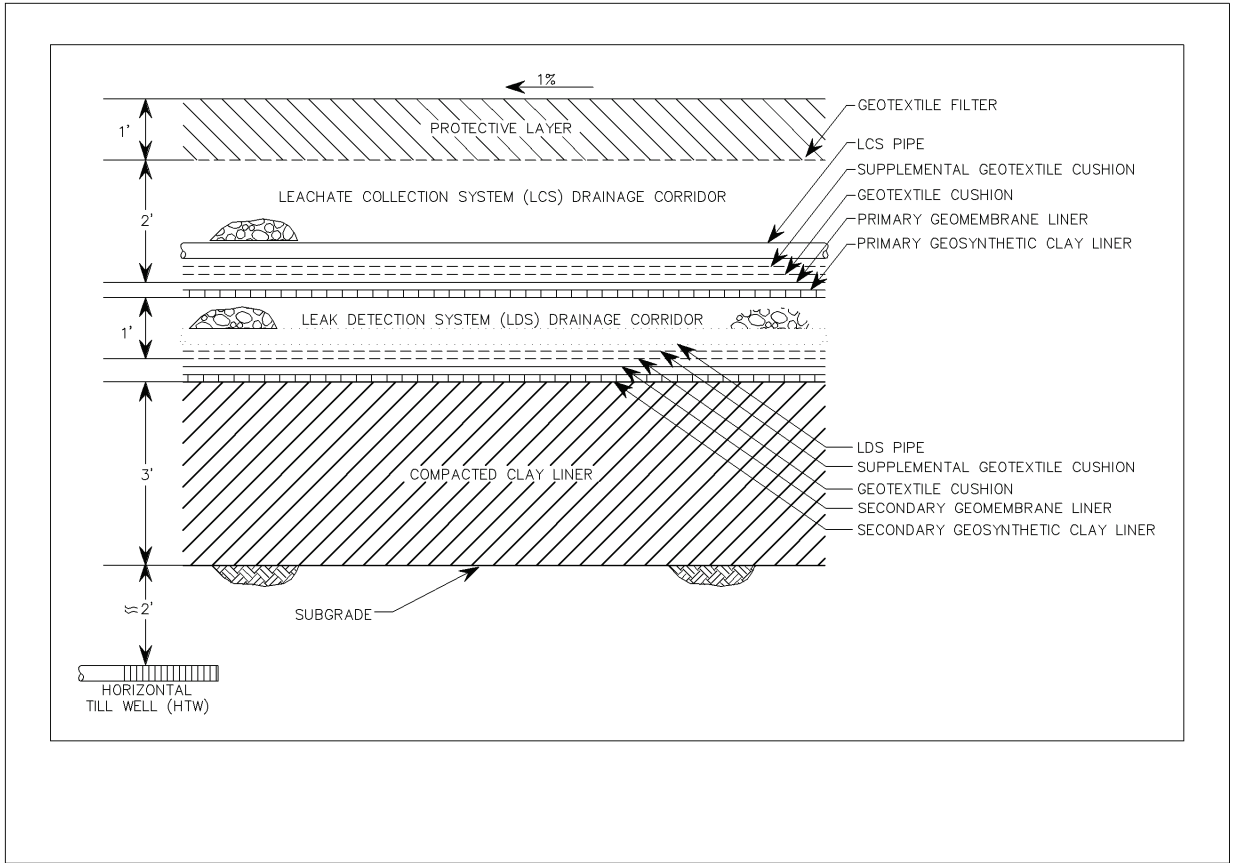


Figure A.5-1. Cross Section of OSDF Liner System with HTW at the Drainage Corridor

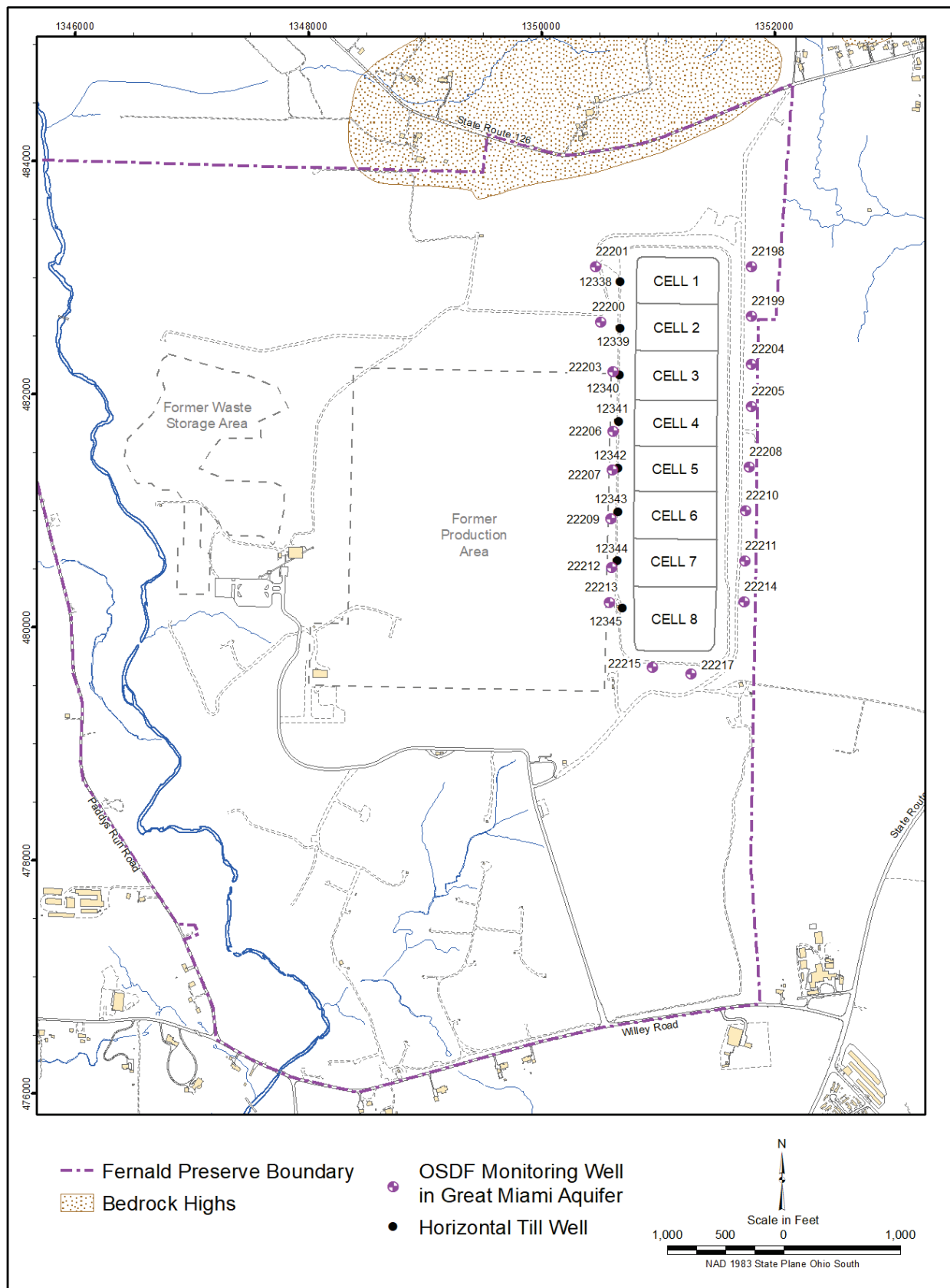


Figure A.5-2. OSDF Footprint and Monitoring Well Locations

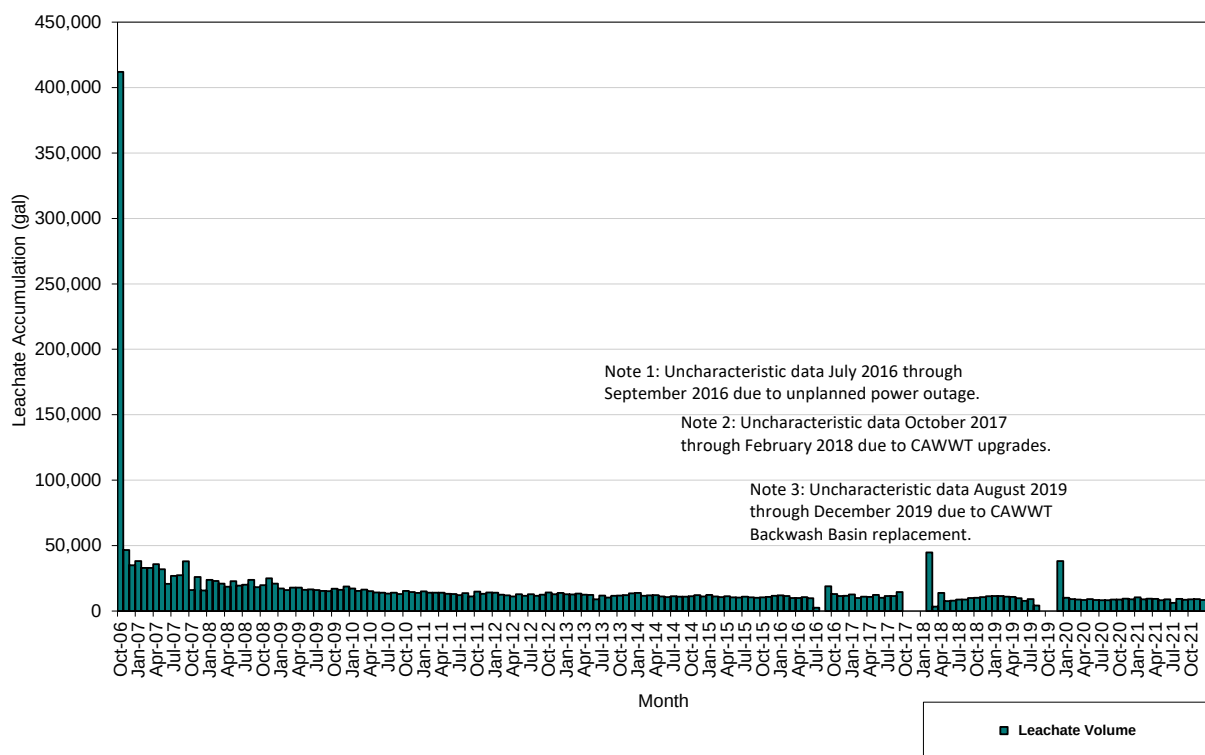


Figure A.5-3. OSDF Monthly LCS Flow (October 2006 Through December 2021)

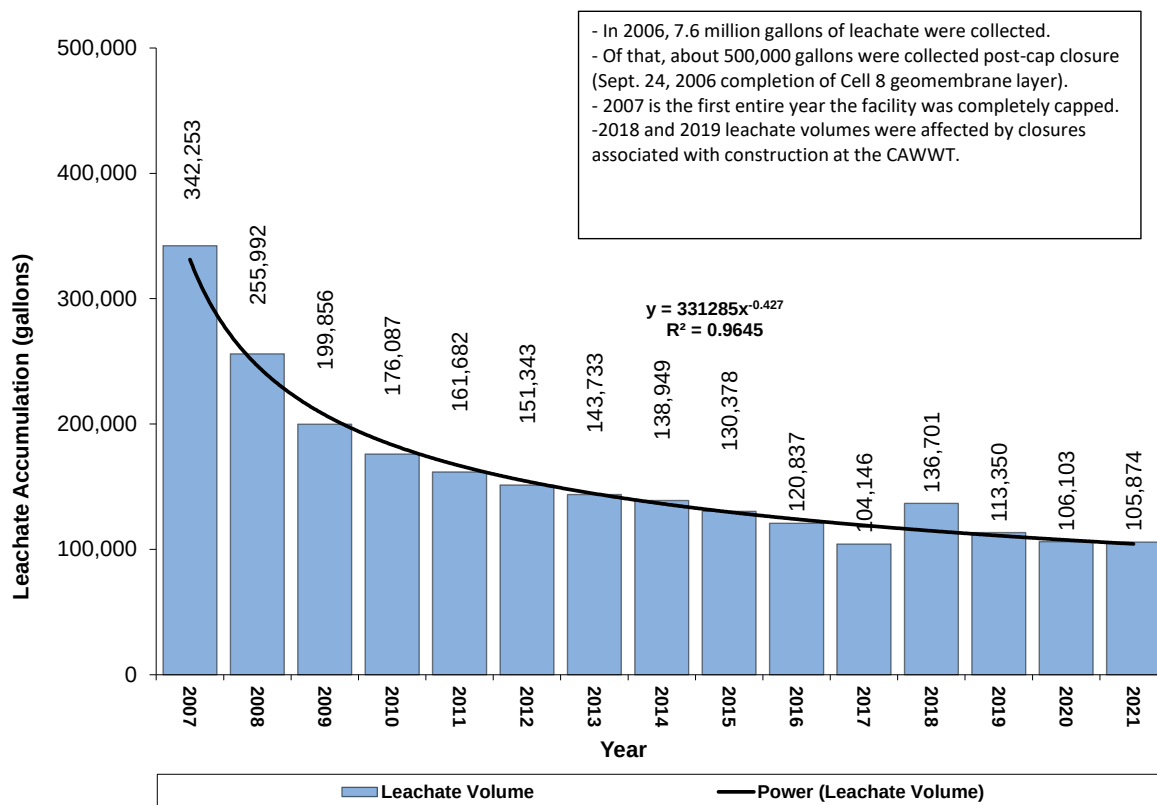


Figure A.5-4. OSDF Annual LCS Flow (2007 Through 2021)

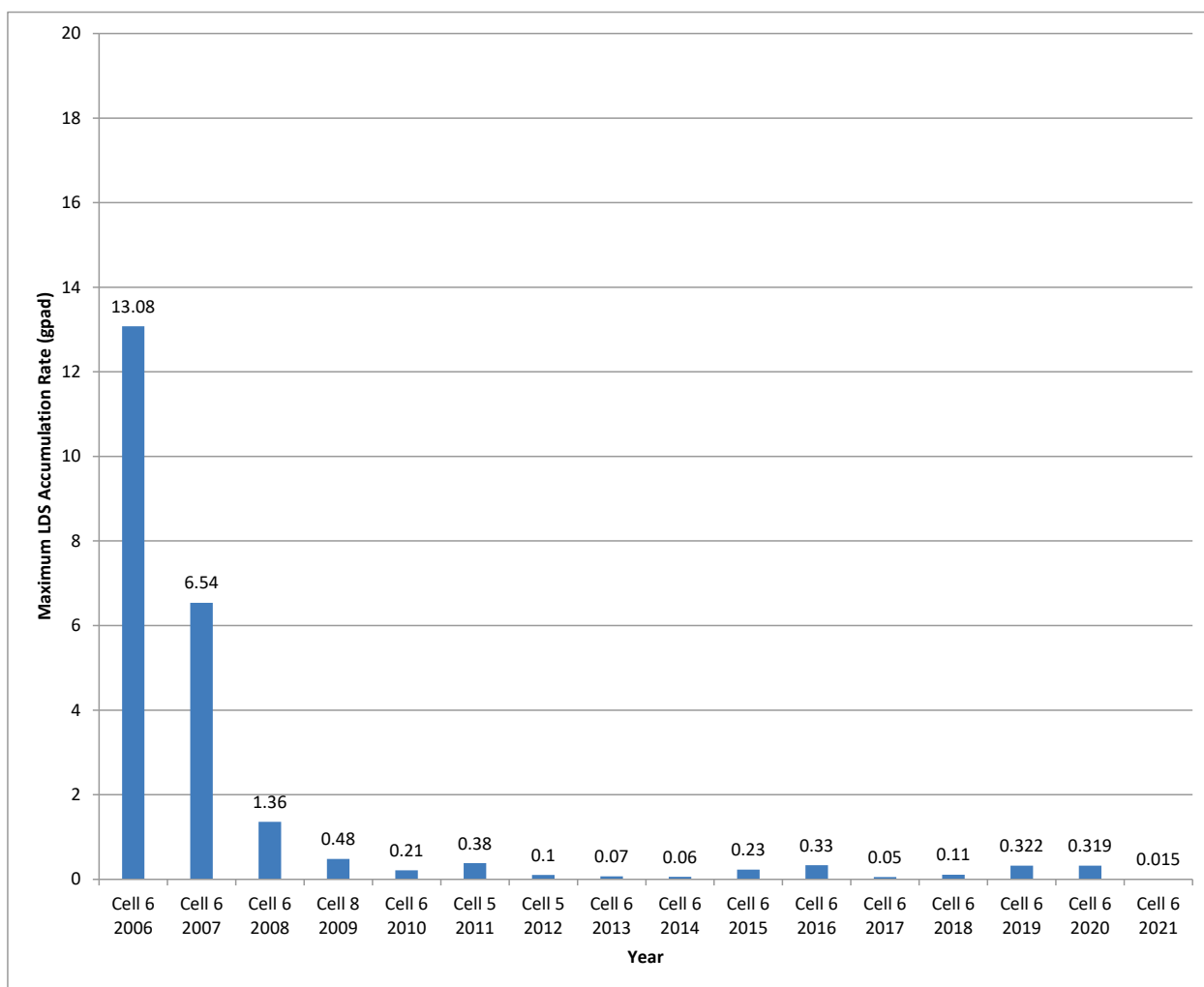


Figure A.5-5. Maximum LDS Accumulation Rate Between 2006 and 2021

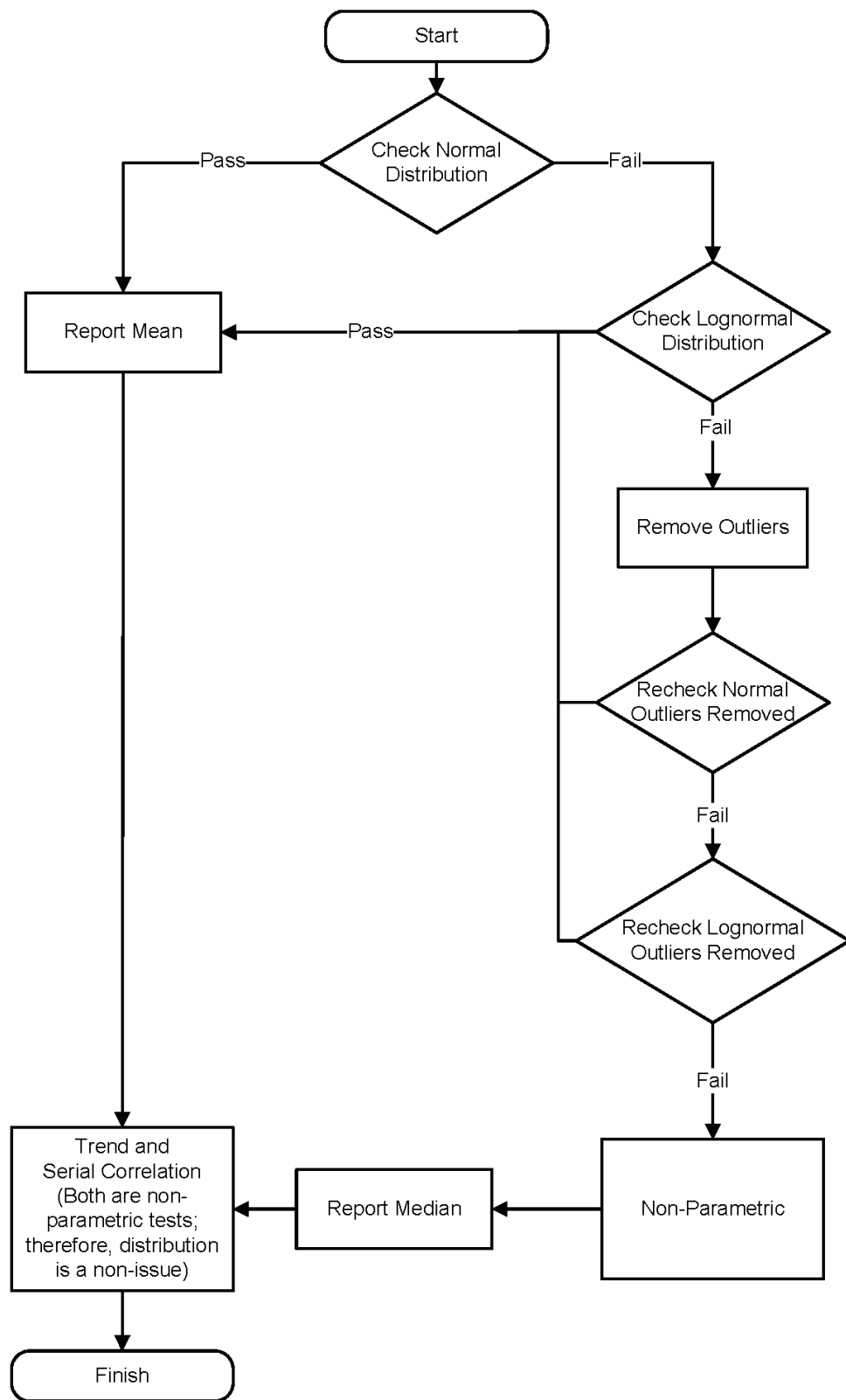


Figure A.5-6. OSDF Statistical Evaluation Process

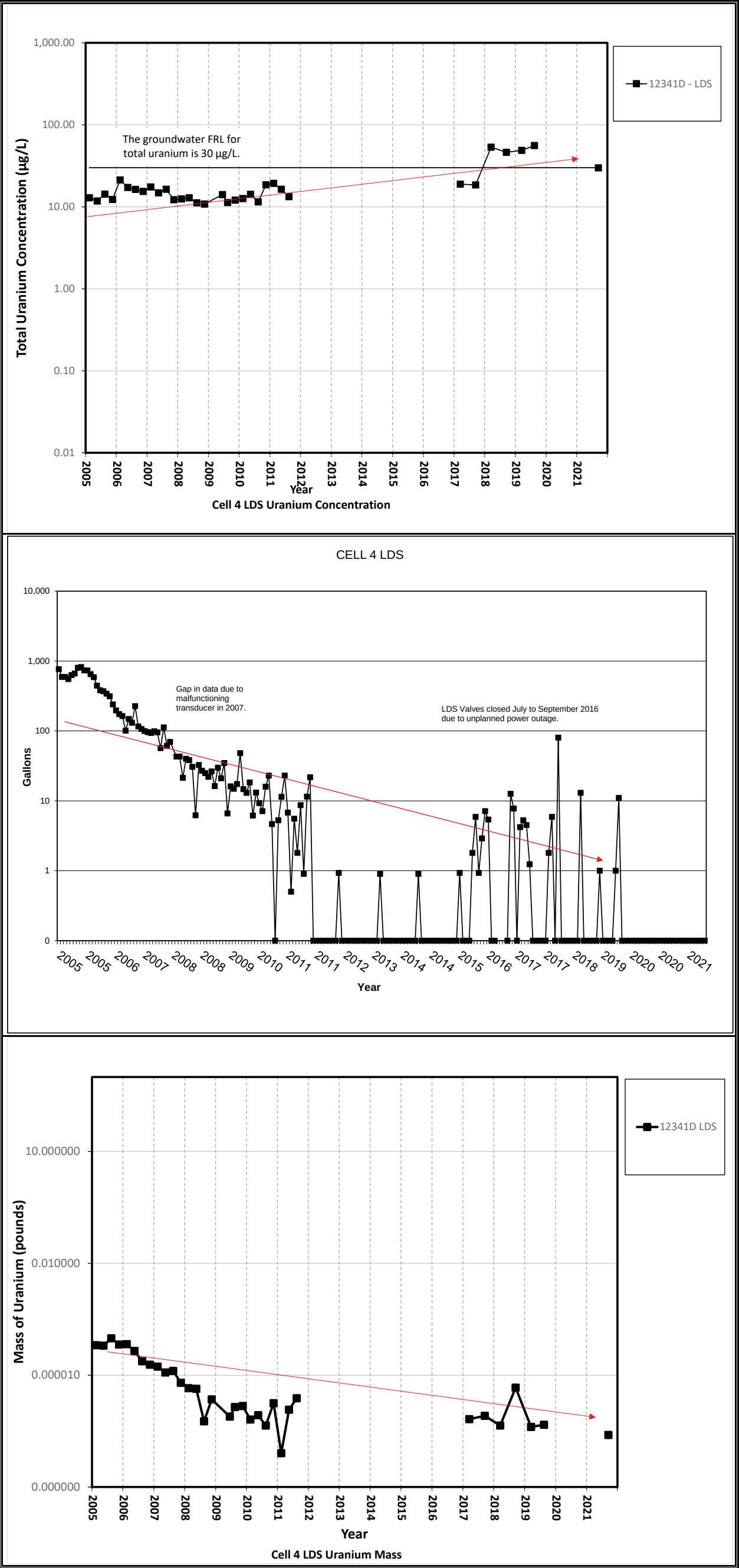


Figure A.5-7. Cell 4 LDS Concentration, Accumulation Rate, and Uranium Mass Comparison

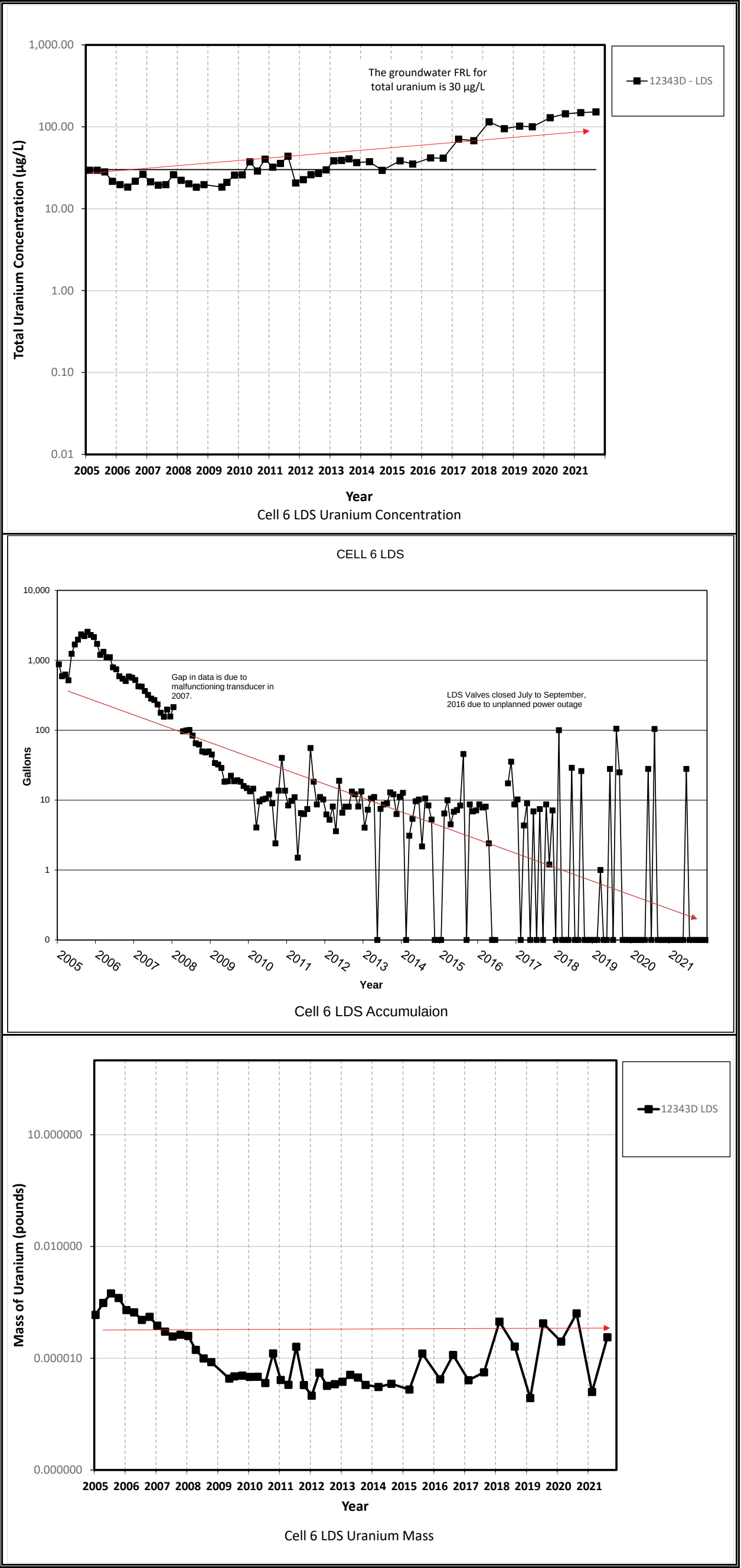


Figure A.5-8. Cell 6 LDS Concentration, Accumulation Rate, and Uranium Mass Comparison

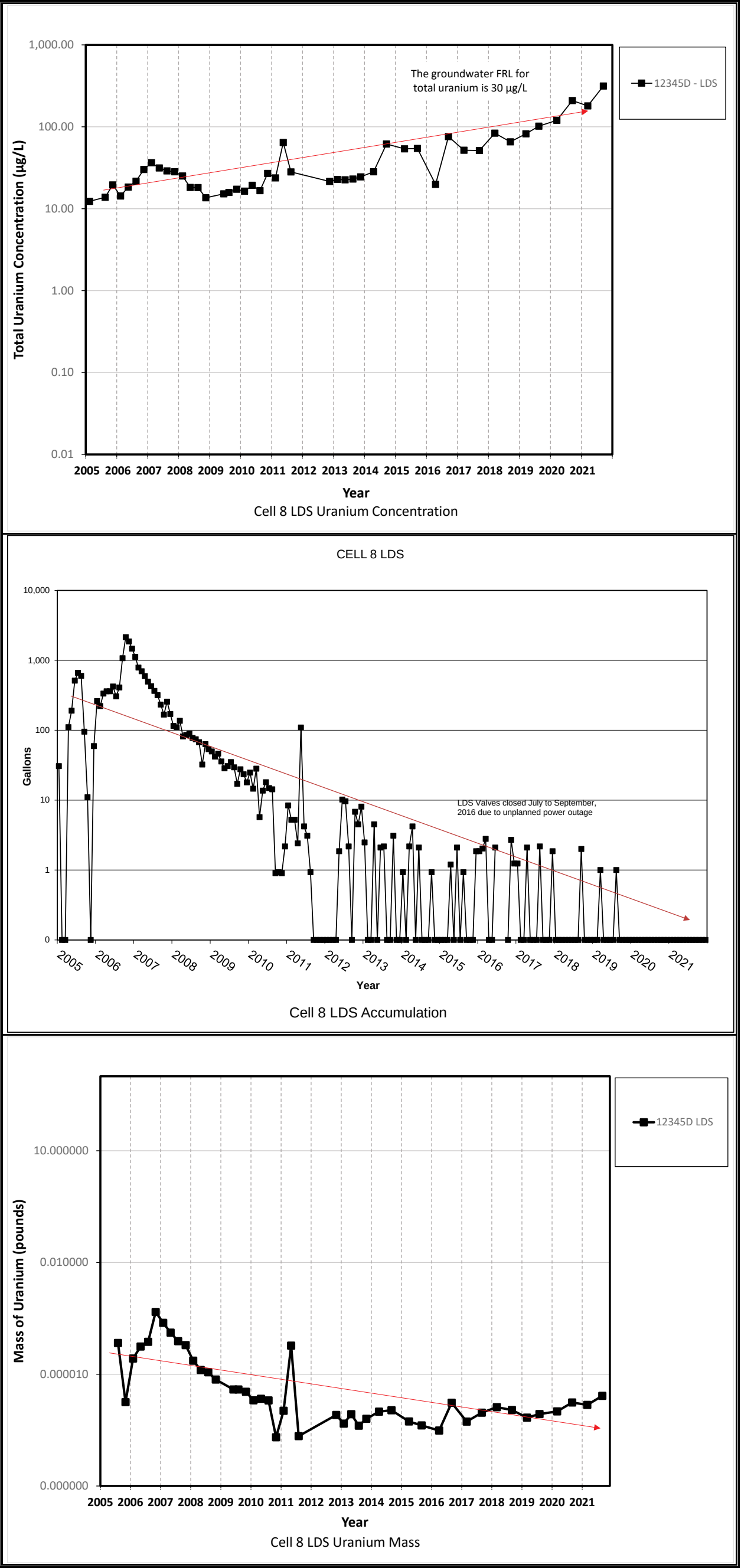


Figure A.5-9. Cell 8 LDS Concentration, Accumulation Rate, and Uranium Mass Comparison

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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	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.1-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.1-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.1-2)
- OSDF horizontal till well (HTW) 12338 water yield (refer to Table A.5.1-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.1-3 and A.5.1-4)
- Plots of concentration versus time (refer to Figures A.5.1-5A through A.5.1-17)
- A bivariate plot for total uranium–sodium (refer to Figure A.5.1-18)
- A bivariate plot for sodium–sulfate (refer to Figure A.5.1-19)
- Control charts (refer to Figures A.5.1-20 and A.5.1-21)

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 the 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW for each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was 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 (sodium and sulfate) in 2021 have upward trends in the LCS and/or LDS based on the Mann-Kendall test for trend. No new high concentrations were measured in the LCS of Cell 1 in 2021. The volume of water in the LDS tank of Cell 1 has been insufficient to collect a sample since 2011.

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

Parameter	LCS 12338C 2021 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 and/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^a

Parameter	HTW 12338	GMA-U ^b 22201	GMA-D ^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 2021 shows that the uranium concentrations measured in the LCS were 22.9 micrograms per liter (µg/L) and 4.22 µg/L. These uranium concentrations in the LCS are similar to uranium concentrations measured in the HTW in 2021. In 2021, the uranium concentrations measured in the HTW were 7.28 µg/L and 6.71 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 2021. Since 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 hCL on the control charts. For interpretation purposes, the hCL value will be regarded as the CUSUM control limit (h).

As shown in Table A.5.1-1 in gray shading and as summarized below, two parameters in the HTW and GMA wells of Cell 1 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.5.1-20 and A.5.1-21). The two control charts for Cell 1 indicate “in control” conditions for calcium and lithium.

Parameter	Monitoring Point ^a	Well Number	Assessment	Figure Number
Calcium	GMA-U	22201	In Control	A.5.1-20
Lithium	GMA-U	22201	In Control	A.5.1-21

^a GMA-U = upgradient Great Miami Aquifer.

A.5.1.3 Summary and Conclusions

- Two parameters monitored semiannually within the facility in 2021 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 2021.
- 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.

- Two control charts were constructed for Cell 1 parameters for monitoring horizons beneath the facility (HTW and GMA wells). The two control charts for Cell 1 indicate “in control” conditions for calcium and 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	77	78	98.7	ND	159	77.8	36.9	Normal	None (2021)	Detected	206(Q4-10)
	LDS	12338D	37	37	100	1.50	37.0	10.8	6.8	Undefined	Up (2011)	Detected	
	HTW	12338	74	76	97.4	ND	12.7	8.17	3.48	Undefined	Up (2021)	Detected	
	GMA-U	22201	79	83	95.2	ND	12.4	4.99	3.34	Undefined	Up (2021)	Detected	
	GMA-D	22198	90	90	100	0.574	15.2	4.70	2.52	Undefined	Down (2021)	Detected	
Boron (mg/L)	LCS	12338C	78	79	98.7	ND	1.72	0.973	0.317	Undefined	Down (2021)	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	56	59	94.9	ND	0.271	0.141	0.062	Normal	None (2021)	Detected	
	GMA-U	22201	81	83	97.6	ND	0.158	0.122	0.026	Undefined	Up (2021)	Detected	
	GMA-D	22198	78	82	95.1	ND	0.131	0.0547	0.0158	Ln Normal	Down (2021)	Detected	
Sodium (mg/L)	LCS	12338C	52	52	100	11.7	22.0	19.1	2.6	Undefined	Up (2021)	Detected	29.3(Q3-05)
	LDS	12338D	9	9	100	335	896	571	216	Normal	Up (2011)	Not Detected	
	HTW	12338	44	44	100	8.72	23.8	13.2	3.7	Undefined	Down (2021)	Detected	
	GMA-U	22201	35	35	100	25.7	65.5	43.4	13.3	Undefined	Down (2021)	Detected	
	GMA-D	22198	36	36	100	9.93	17.1	13.3	2.0	Normal	Down (2021)	Detected	
Sulfate (mg/L)	LCS	12338C	64	64	100	707	3,360	1,830	680	Undefined	Up (2021)	Detected	
	LDS	12338D	19	19	100	675	3,500	1,590	780	Ln Normal	Up (2011)	Detected	
	HTW	12338	54	54	100	400	907	628	125	Normal	Down (2021)	Detected	
	GMA-U	22201	59	59	100	91.8	735	258	147	Ln Normal	None (2021)	Detected	1,980(Q4-04)
	GMA-D	22198	59	59	100	101	506	159	91	Undefined	Down (2021)	Detected	
Calcium (mg/L)	GMA-U	22201	28	28	100	143	334	205	41	Ln Normal	None (2021)	Not Detected	
	GMA-D	22198	28	28	100	133	192	153	15	Normal	Down (2021)	Not Detected	
Lithium (mg/L)	GMA-U	22201	35	35	100	0.00665	0.0153	0.0108	0.0025	Normal	None (2021)	Not Detected	
	GMA-D	22198	35	35	100	0.00624	0.0107	0.00920	0.00081	Undefined	None (2021)	Not Detected	
Magnesium (mg/L)	GMA-U	22201	28	28	100	36.1	82.2	49.6	9.5	Ln Normal	Up (2021)	Not Detected	
	GMA-D	22198	28	28	100	36.2	47.8	40.4	3.1	Normal	Down (2021)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22201	22	28	78.6	ND	1.44	0.270	0.484	Undefined	Up (2021)	Not Detected	
	GMA-D	22198	9	48	18.8	ND	0.550	0.0125	0.177	Undefined	Down (2021)	Detected	
Potassium (mg/L)	GMA-U	22201	28	28	100	2.28	3.97	2.92	0.46	Normal	Down (2021)	Not Detected	
	GMA-D	22198	29	29	100	1.24	2.07	1.62	0.23	Normal	Down (2021)	Detected	
Selenium (mg/L)	GMA-U	22201	2	35	5.7	ND	0.0189	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22198	5	55	9.1	ND	0.0153	0.0030	0.0028	Undefined	Up (2021)	Detected	
Technetium-99 (pCi/L)	GMA-U	22201	1	32	3.1	ND	3.86	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22198	2	33	6.1	ND	8.30	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22201	35	35	100	594	1,600	927	198	Ln Normal	Down (2021)	Not Detected	
	GMA-D	22198	35	35	100	561	805	623	63	Undefined	Down (2021)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22201	36	83	43.4	ND	0.0319	0.00645	0.00684	Undefined	Down (2021)	Not Detected	0.078(Q1-97), 0.308(Q2-2000)
	GMA-D	22198	18	82	22.0	ND	0.0235	0.00182	0.00530	Undefined	Down (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

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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

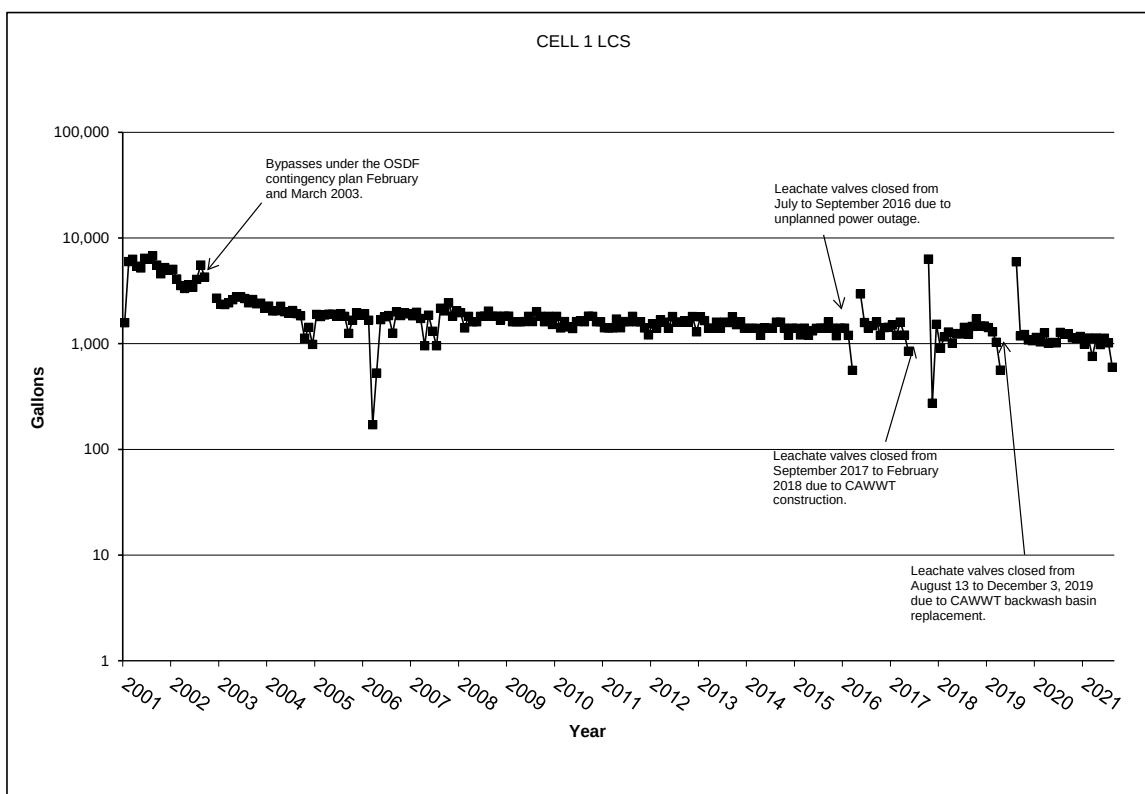


Figure A.5.1-1. Monthly Accumulation Volumes for Cell 1 LCS

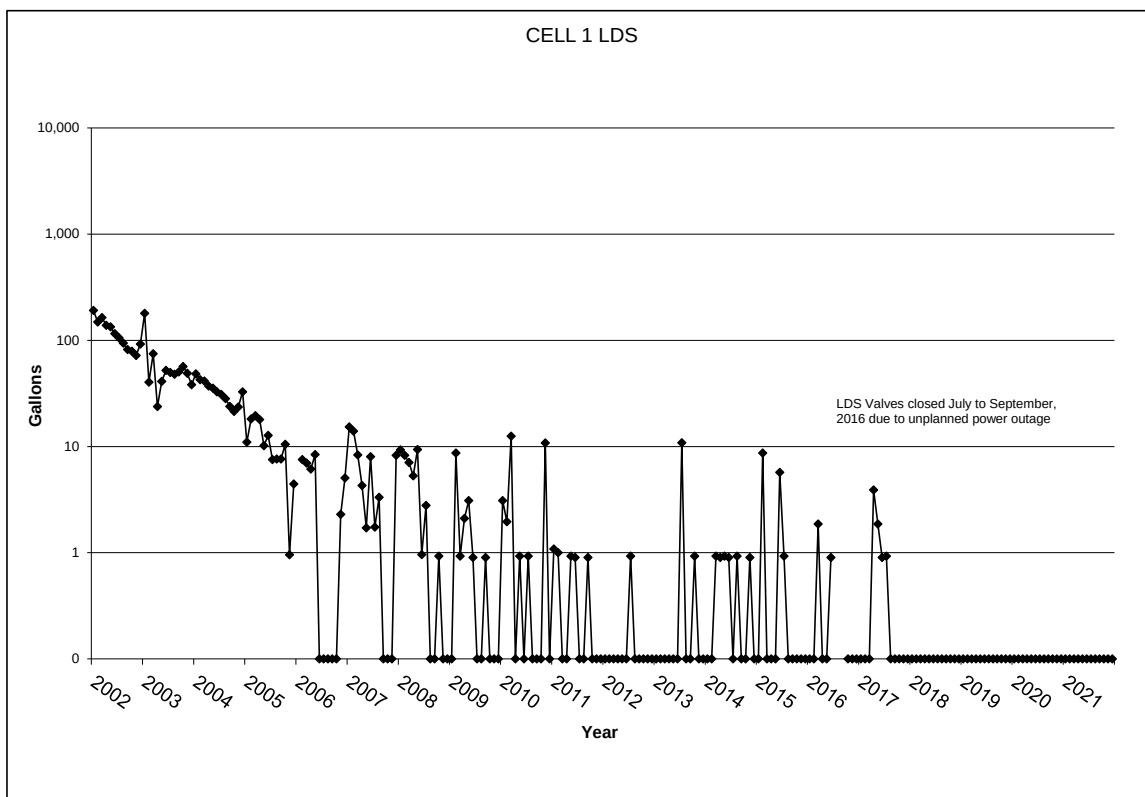


Figure A.5.1-2. Monthly Accumulation Volumes for Cell 1 LDS

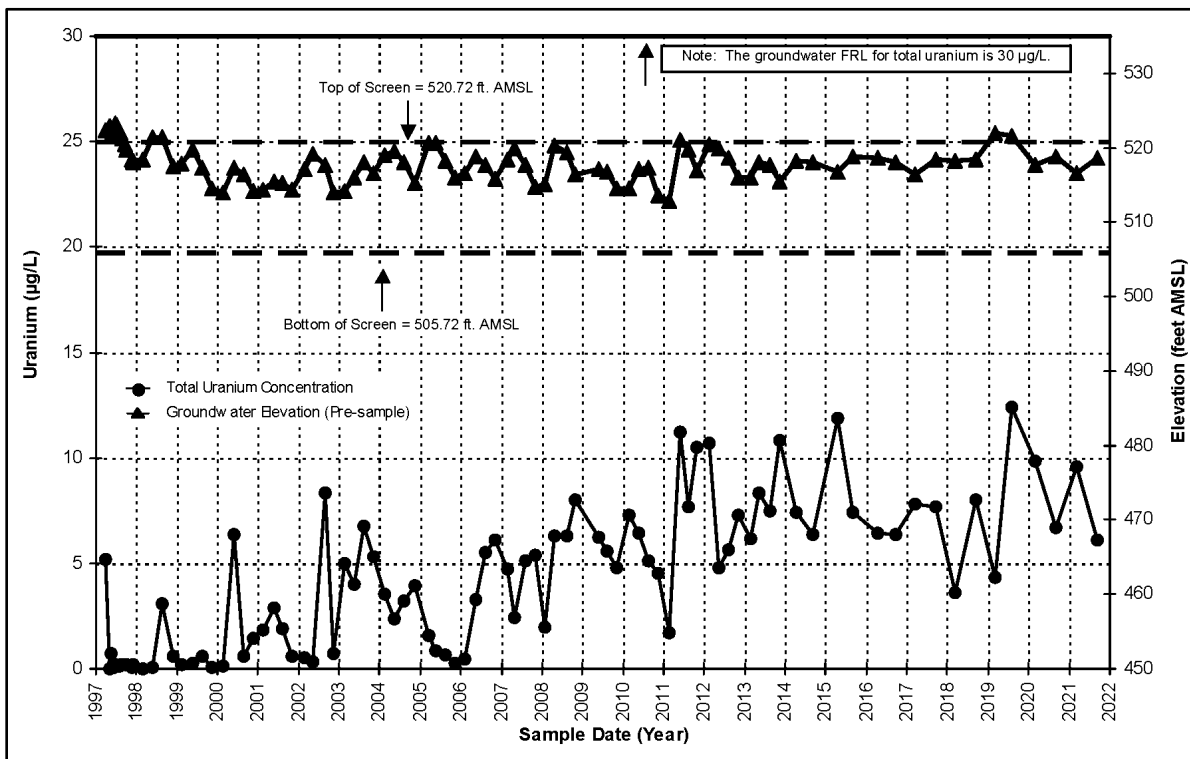


Figure A.5.1-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 1 Upgradient Monitoring Well 22201

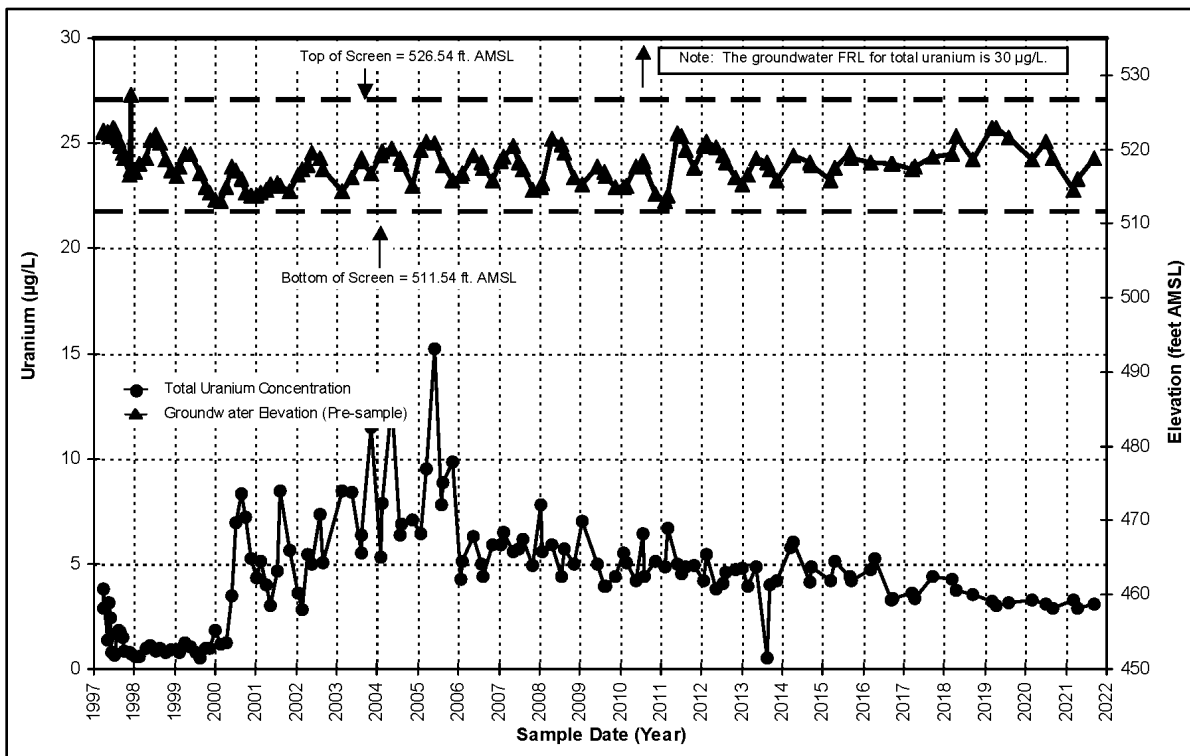


Figure A.5.1-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 1 Downgradient Monitoring Well 22198

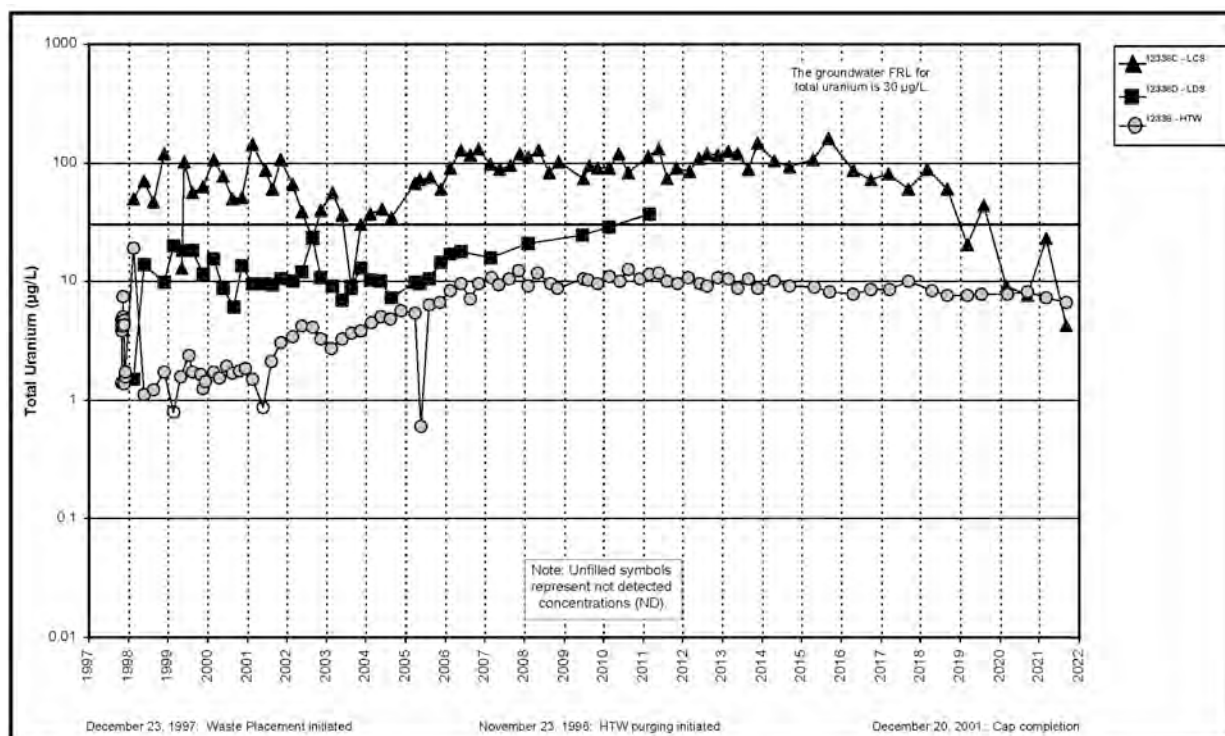


Figure A.5.1-5A. Cell 1 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

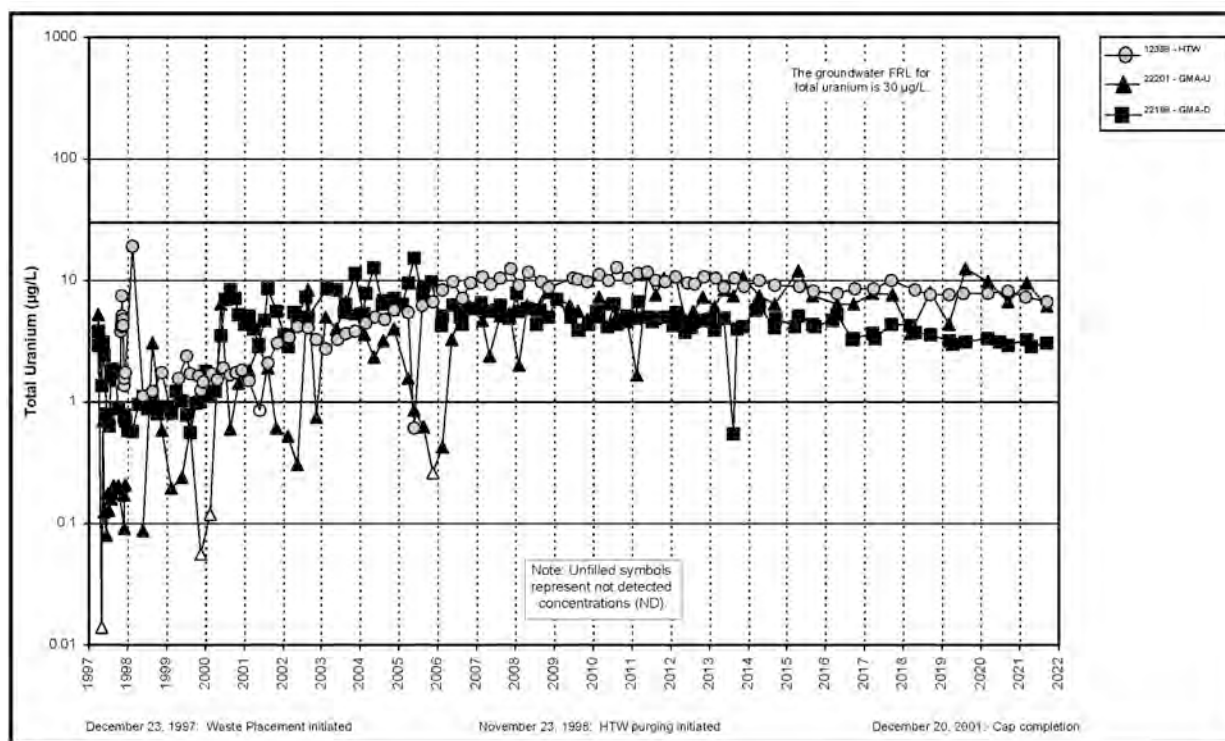


Figure A.5.1-5B. Cell 1 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

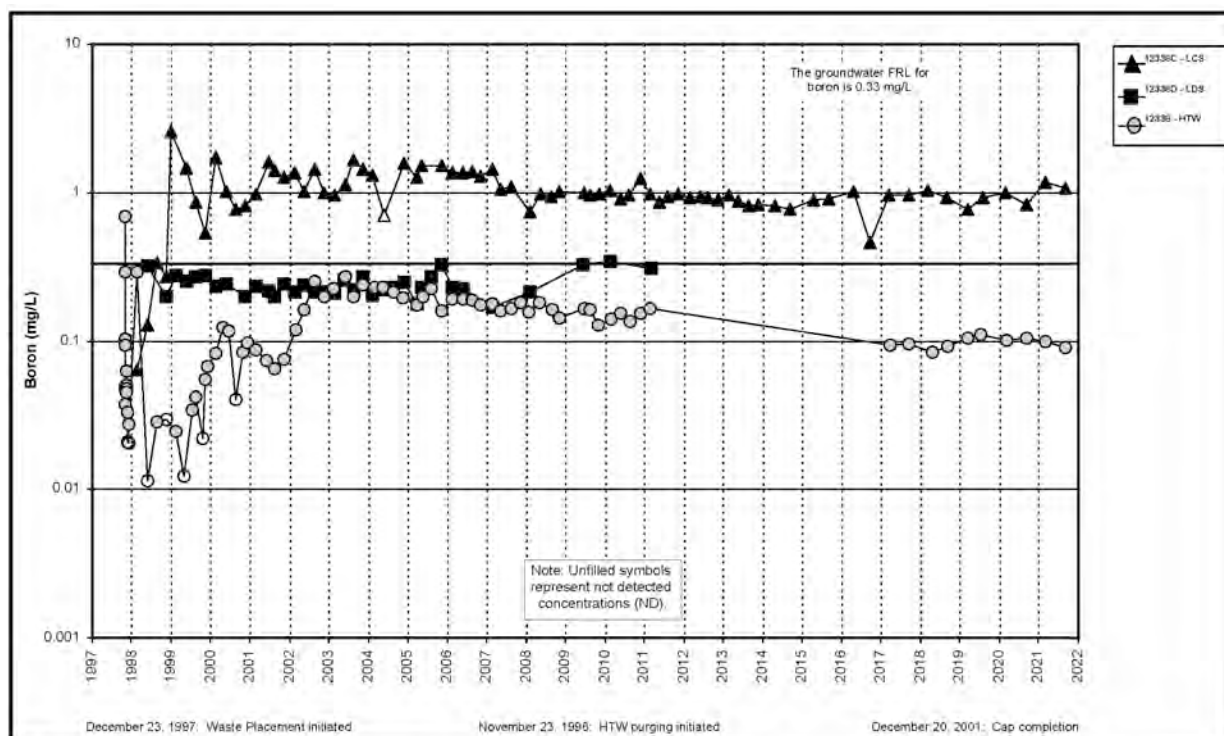


Figure A.5.1-6A. Cell 1 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

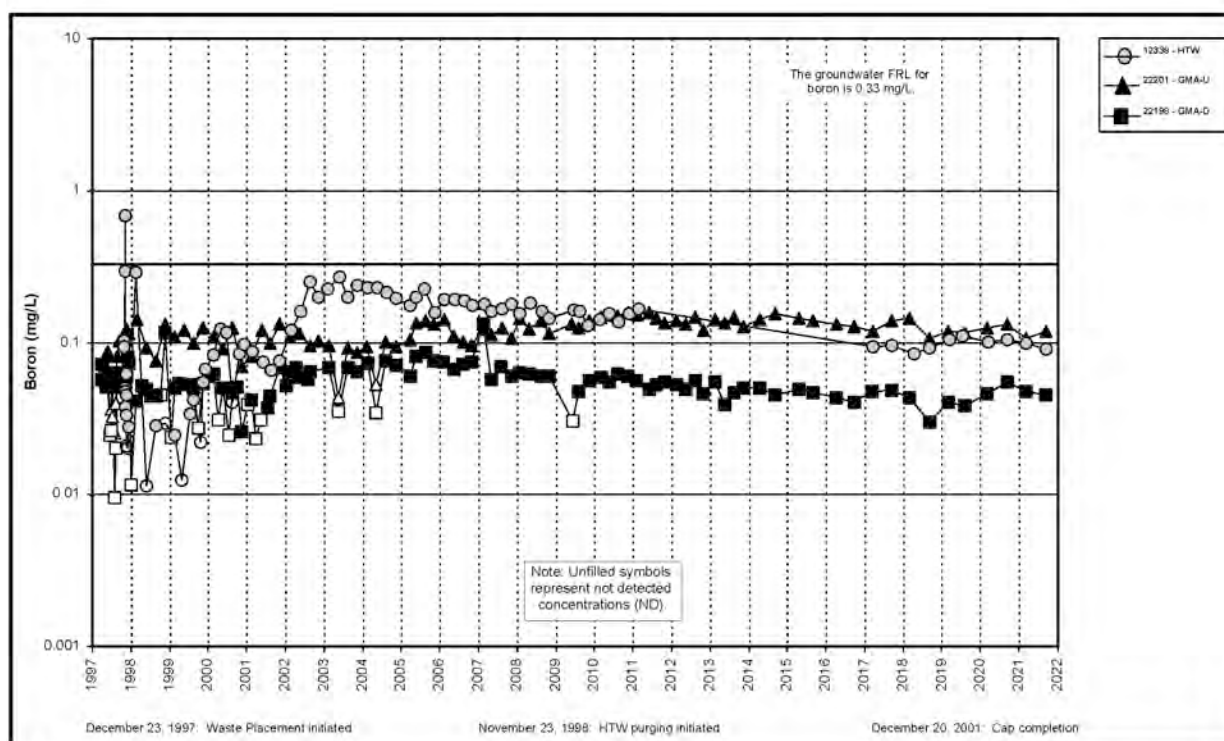


Figure A.5.1-6B. Cell 1 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

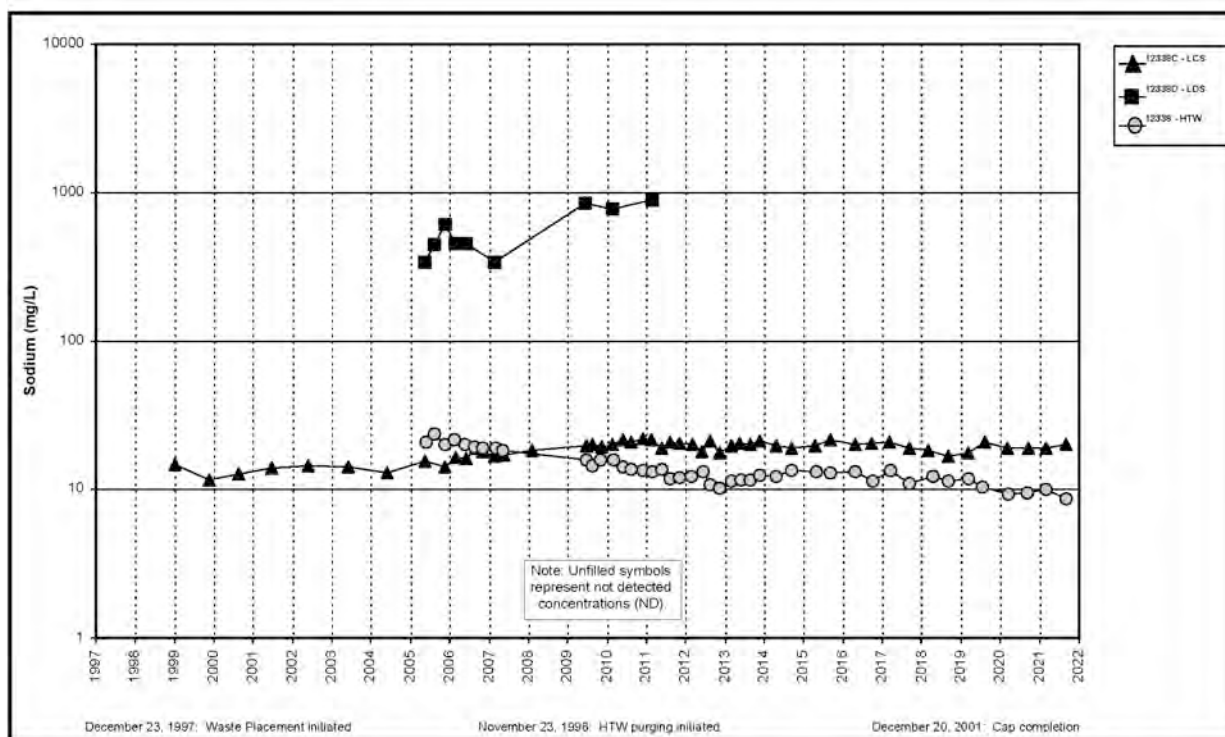


Figure A.5.1-7A. Cell 1 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

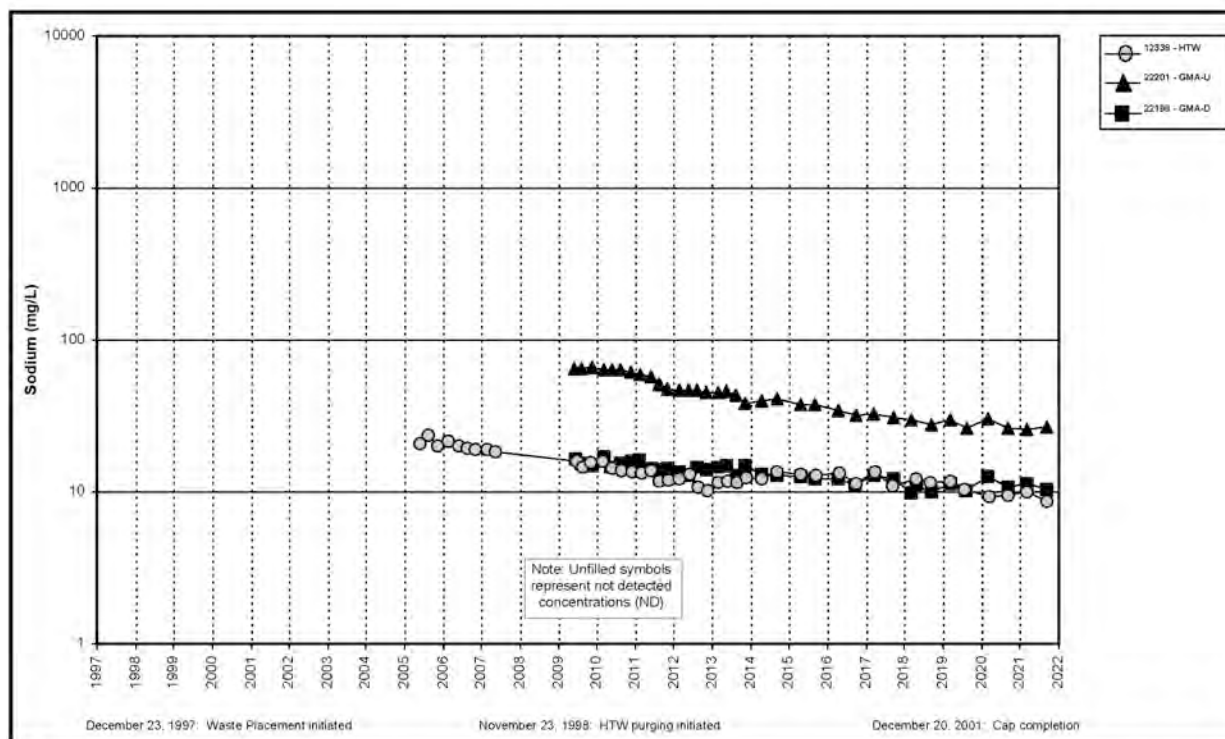


Figure A.5.1-7B. Cell 1 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

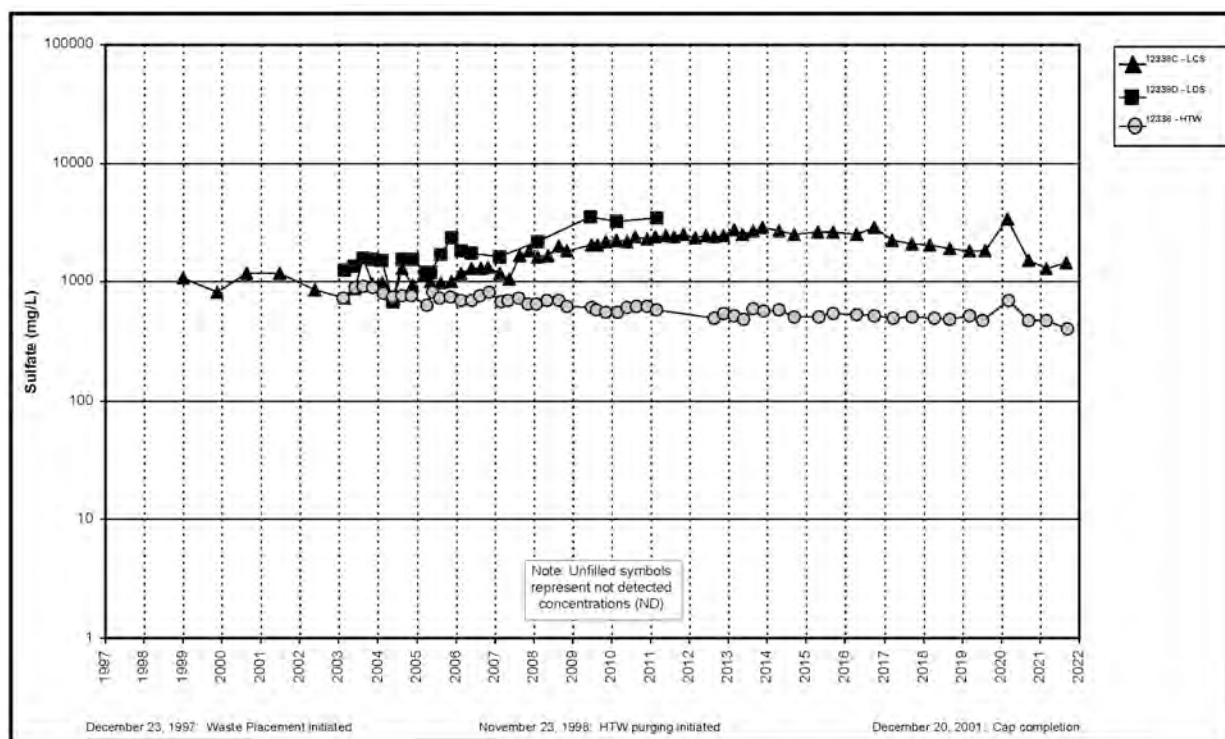


Figure A.5.1-8A. Cell 1 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

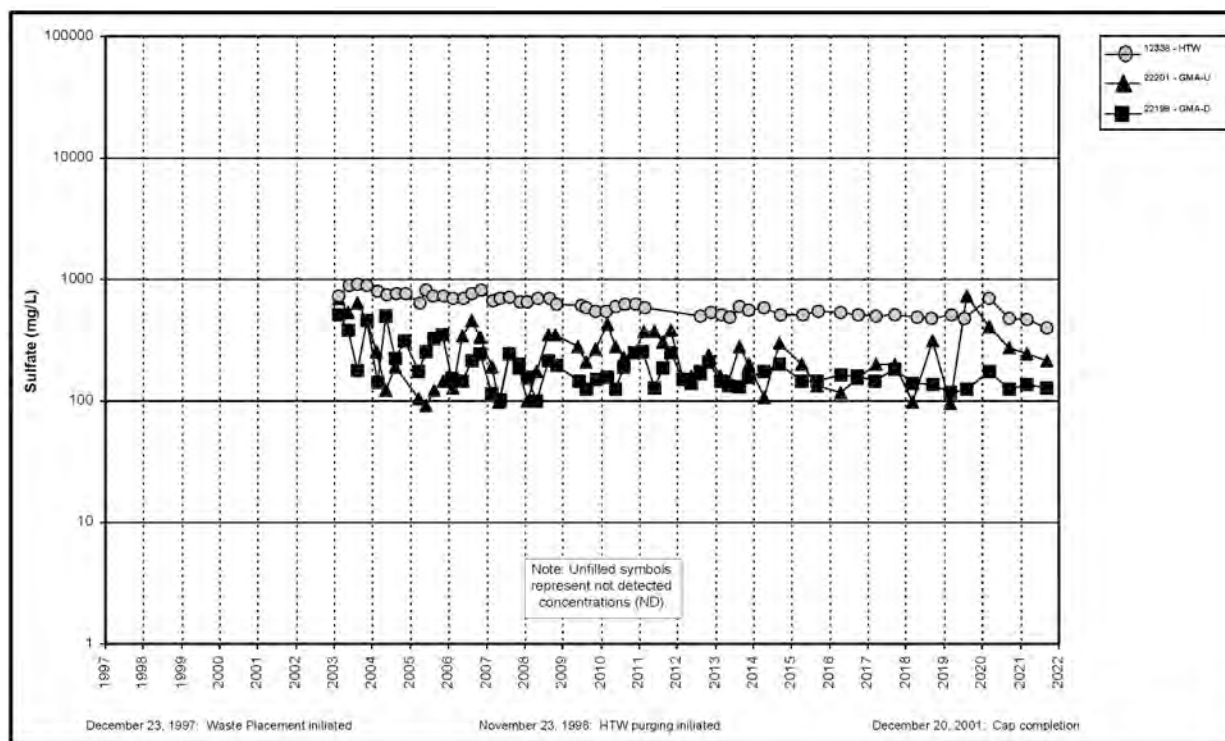


Figure A.5.1-8B. Cell 1 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

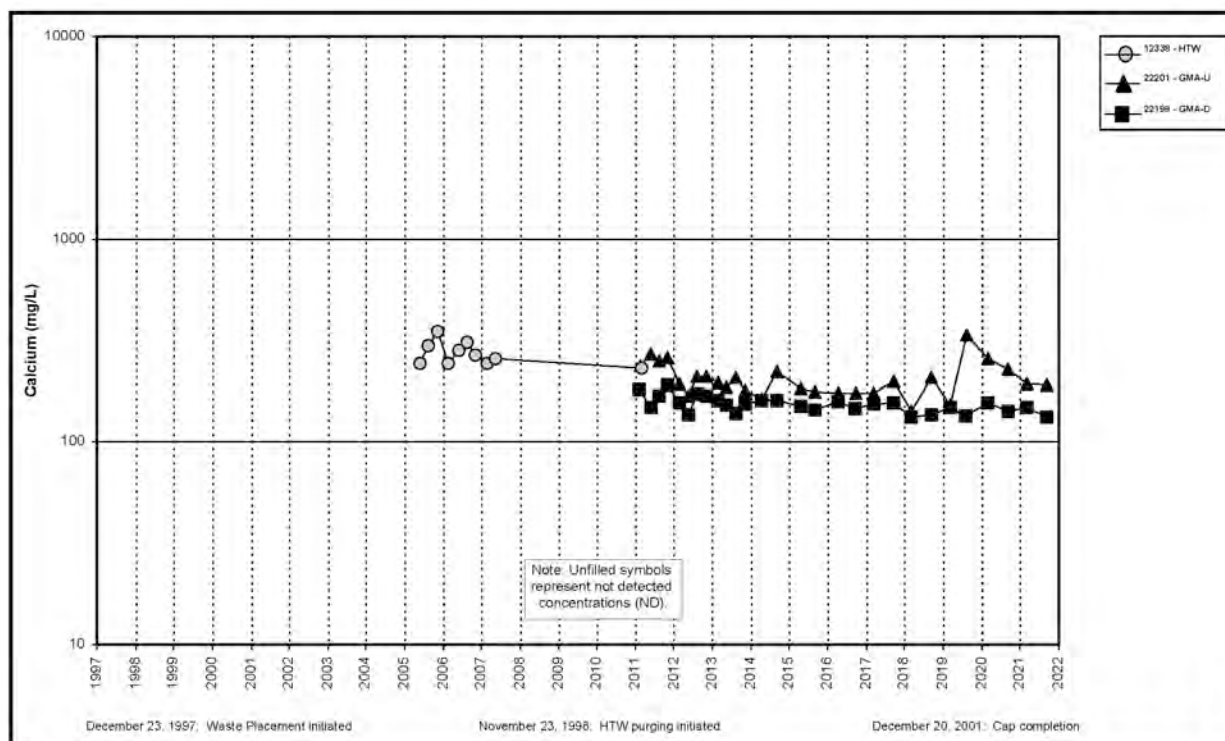


Figure A.5.1-9. Cell 1 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

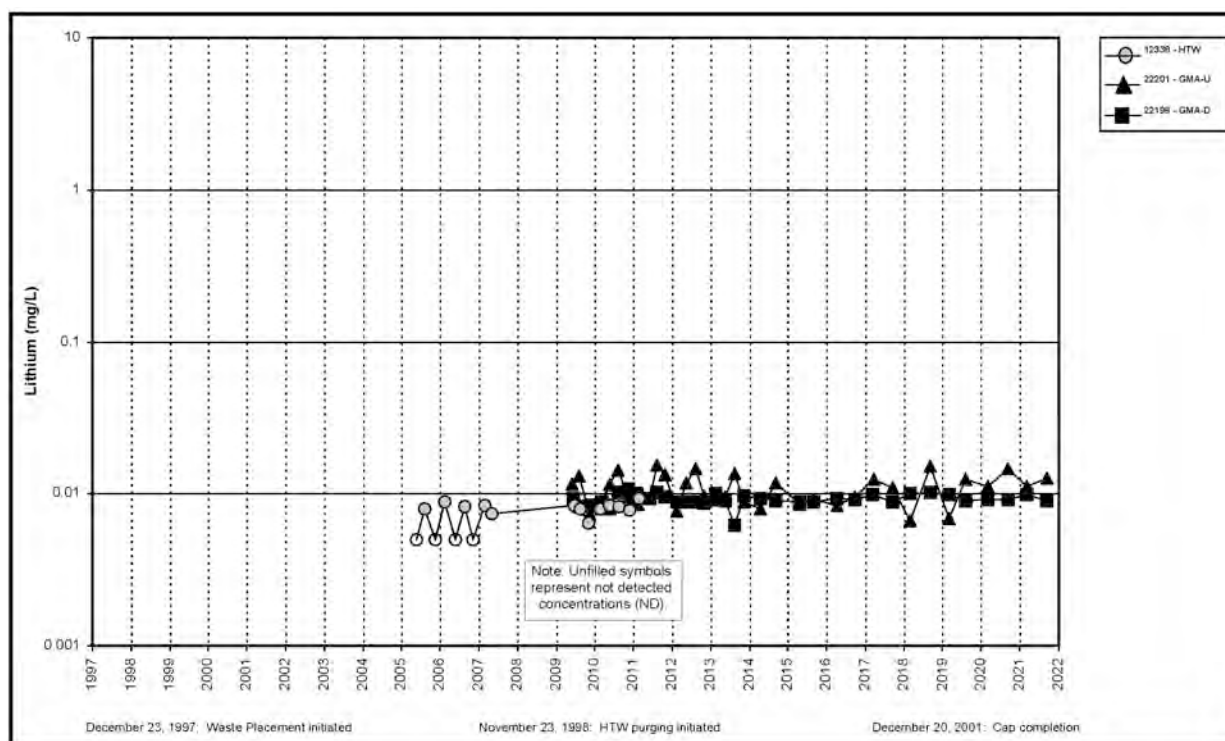


Figure A.5.1-10. Cell 1 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

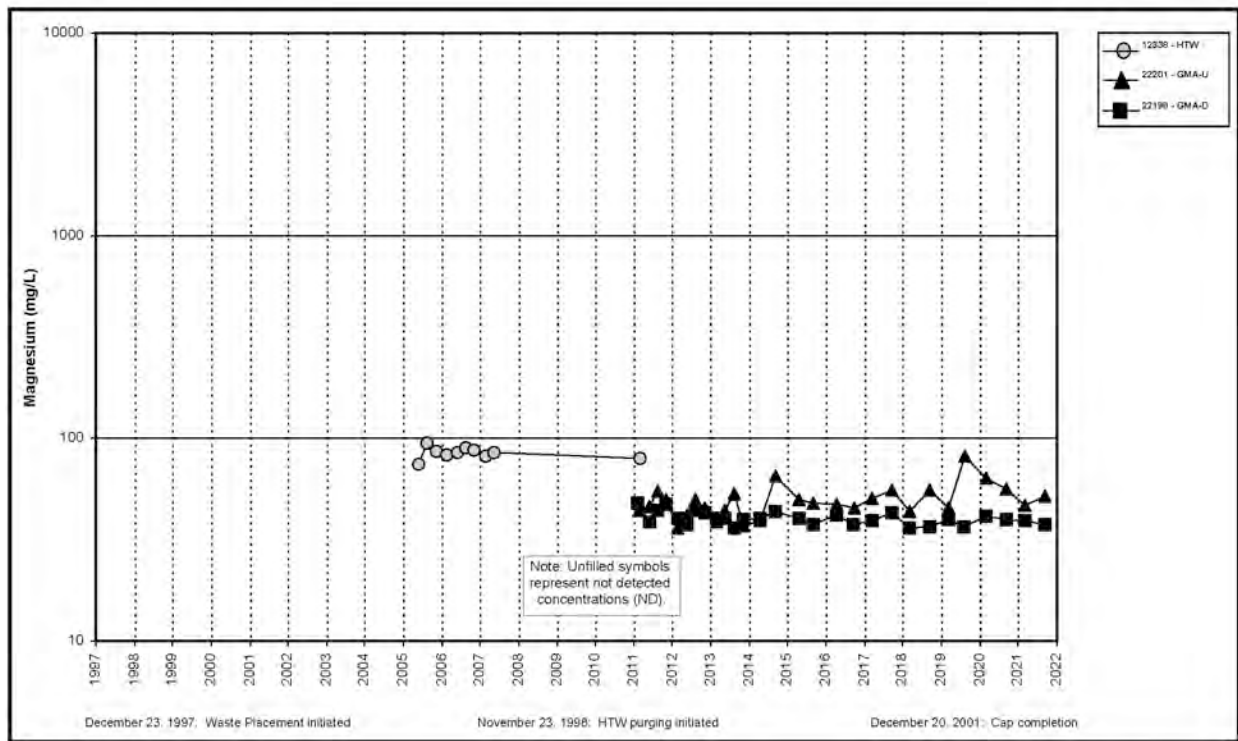


Figure A.5.1-11. Cell 1 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

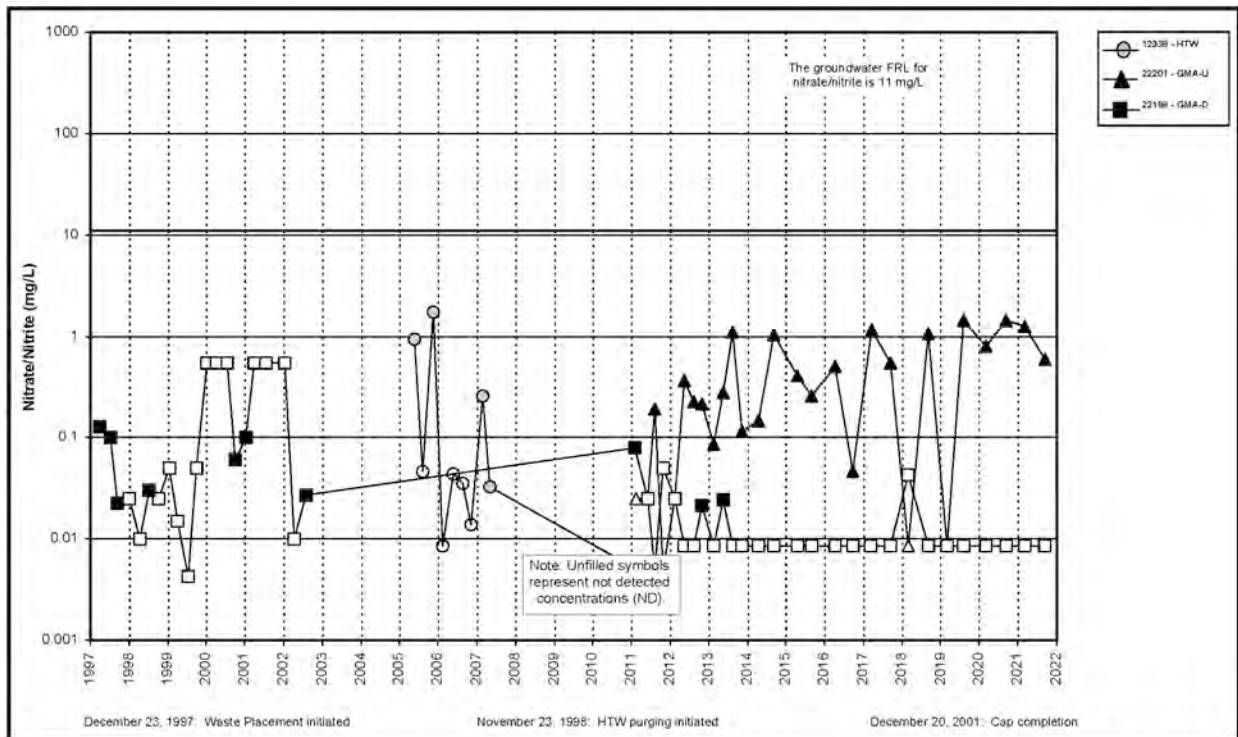


Figure A.5.1-12. Cell 1 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

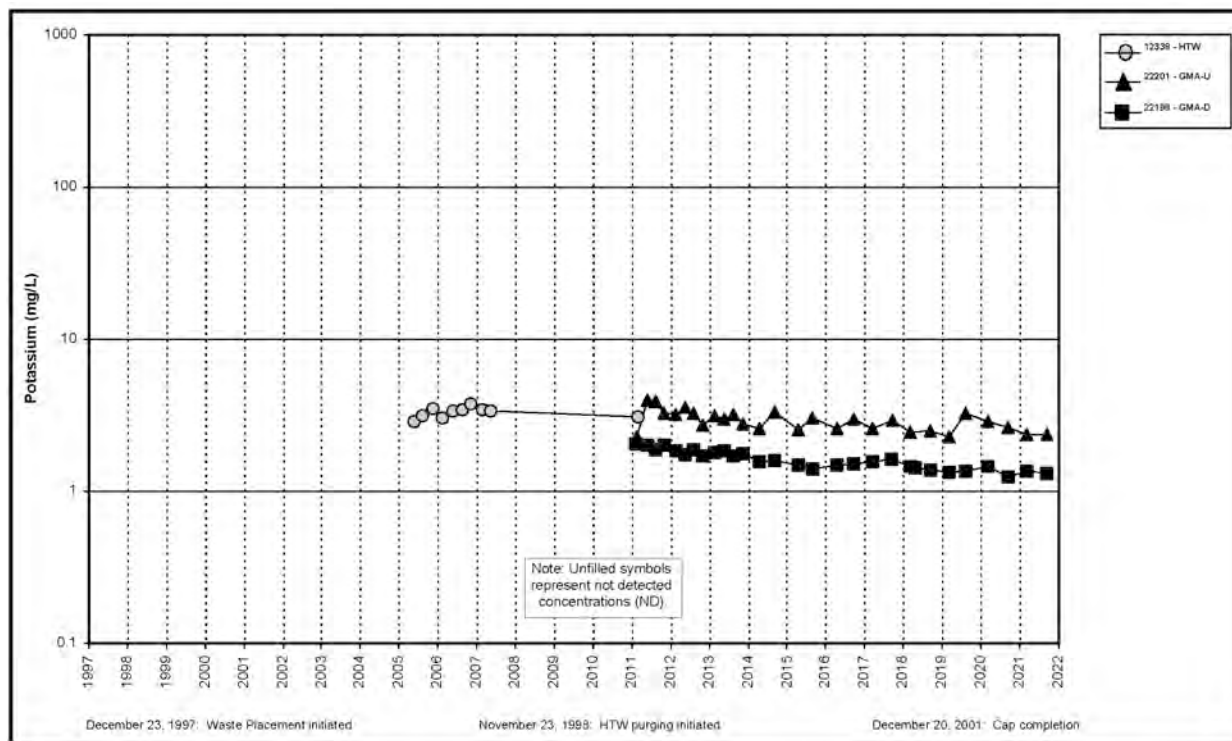


Figure A.5.1-13. Cell 1 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

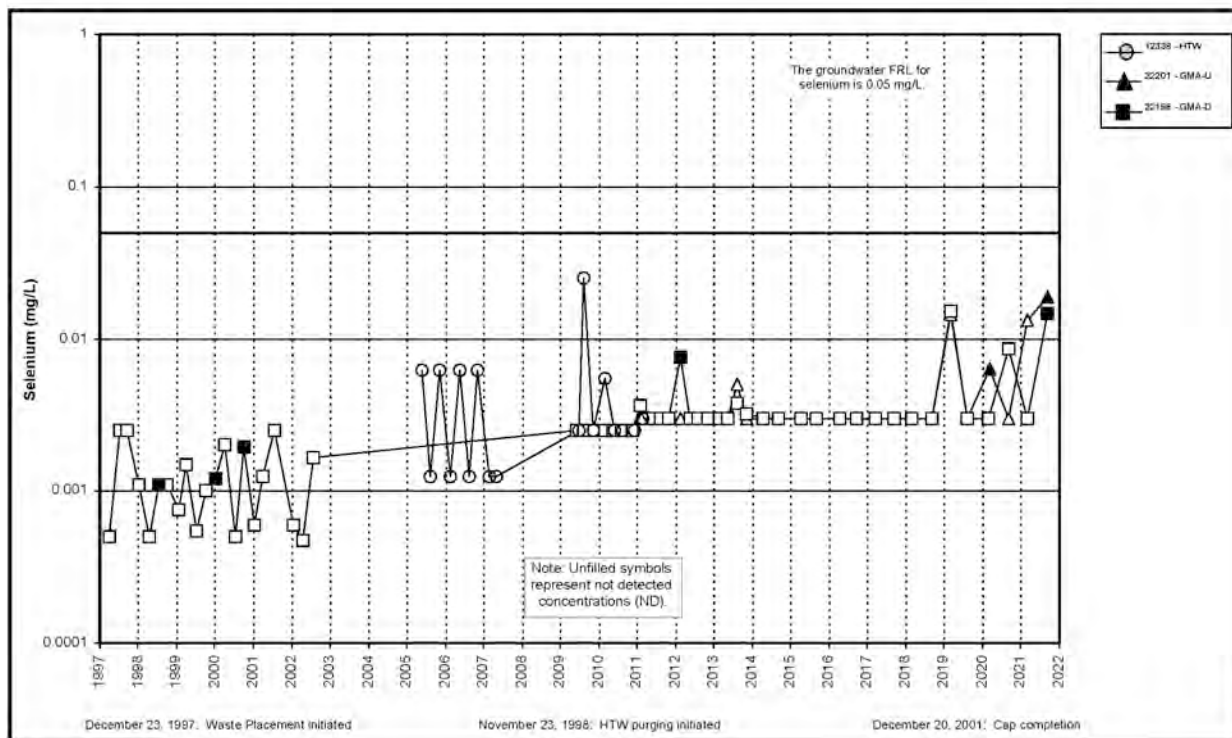


Figure A.5.1-14. Cell 1 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

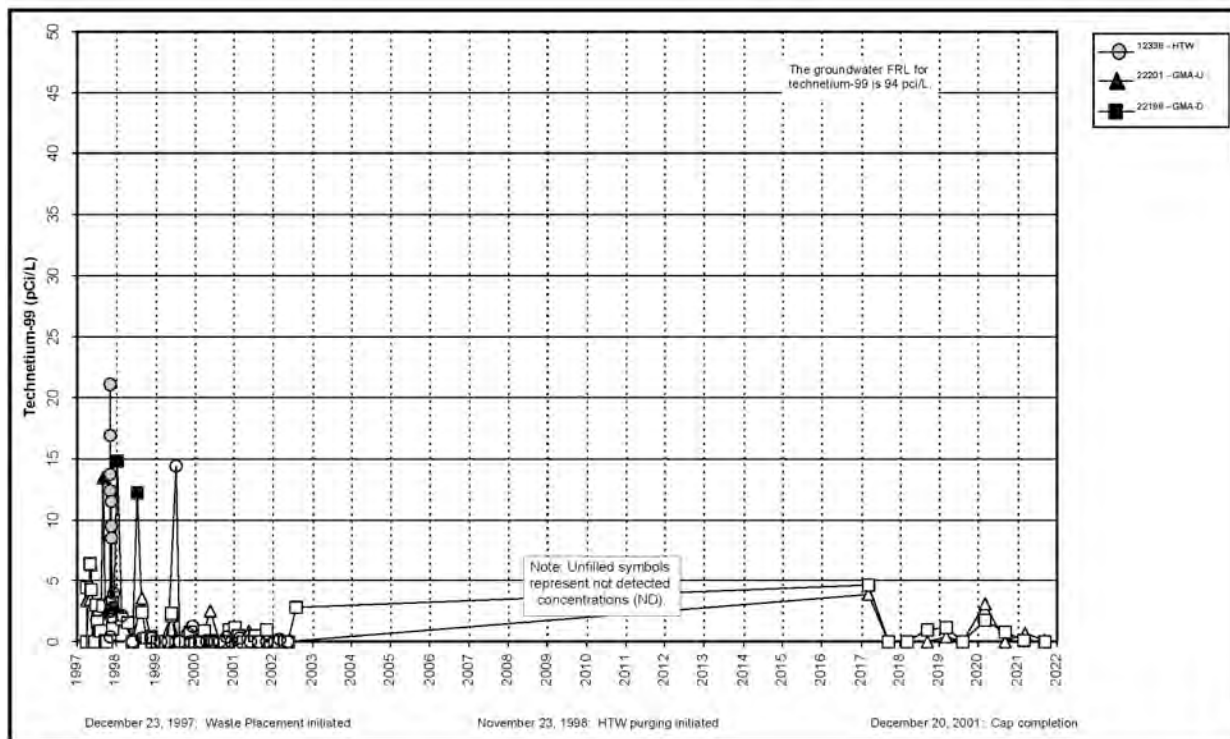


Figure A.5.1-15. Cell 1 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

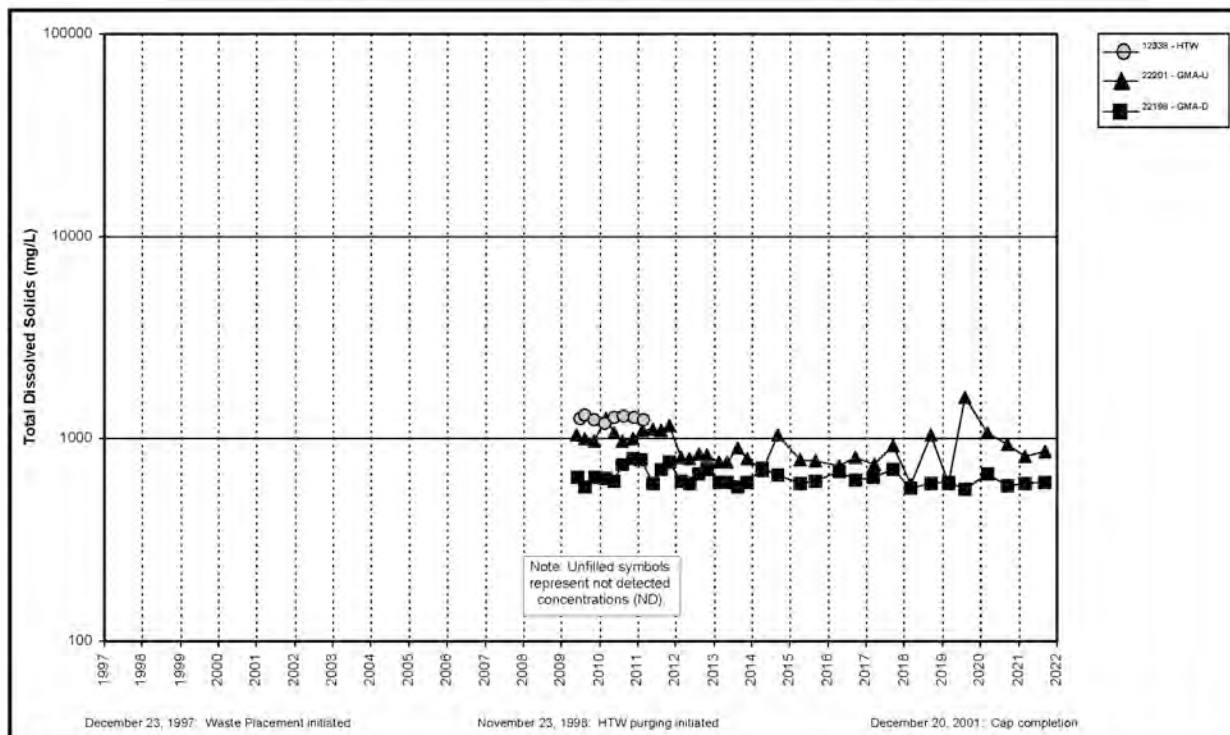


Figure A.5.1-16. Cell 1 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

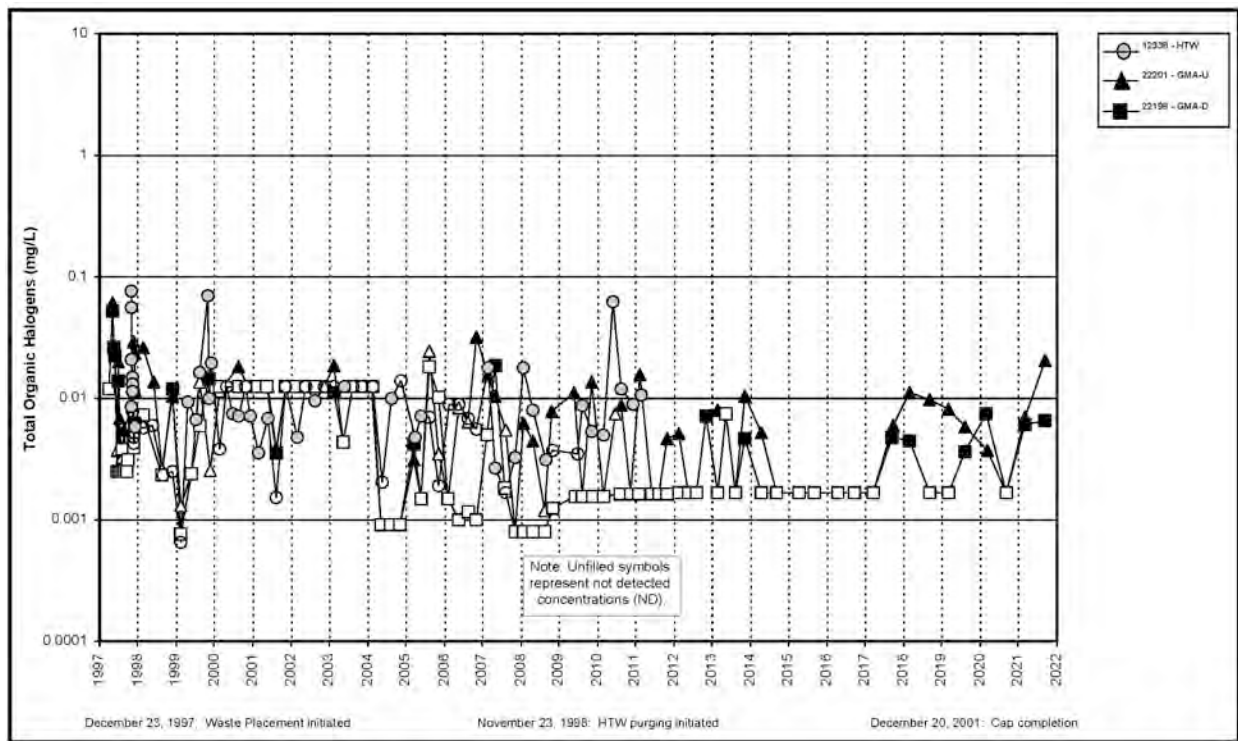


Figure A.5.1-17. Cell 1 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

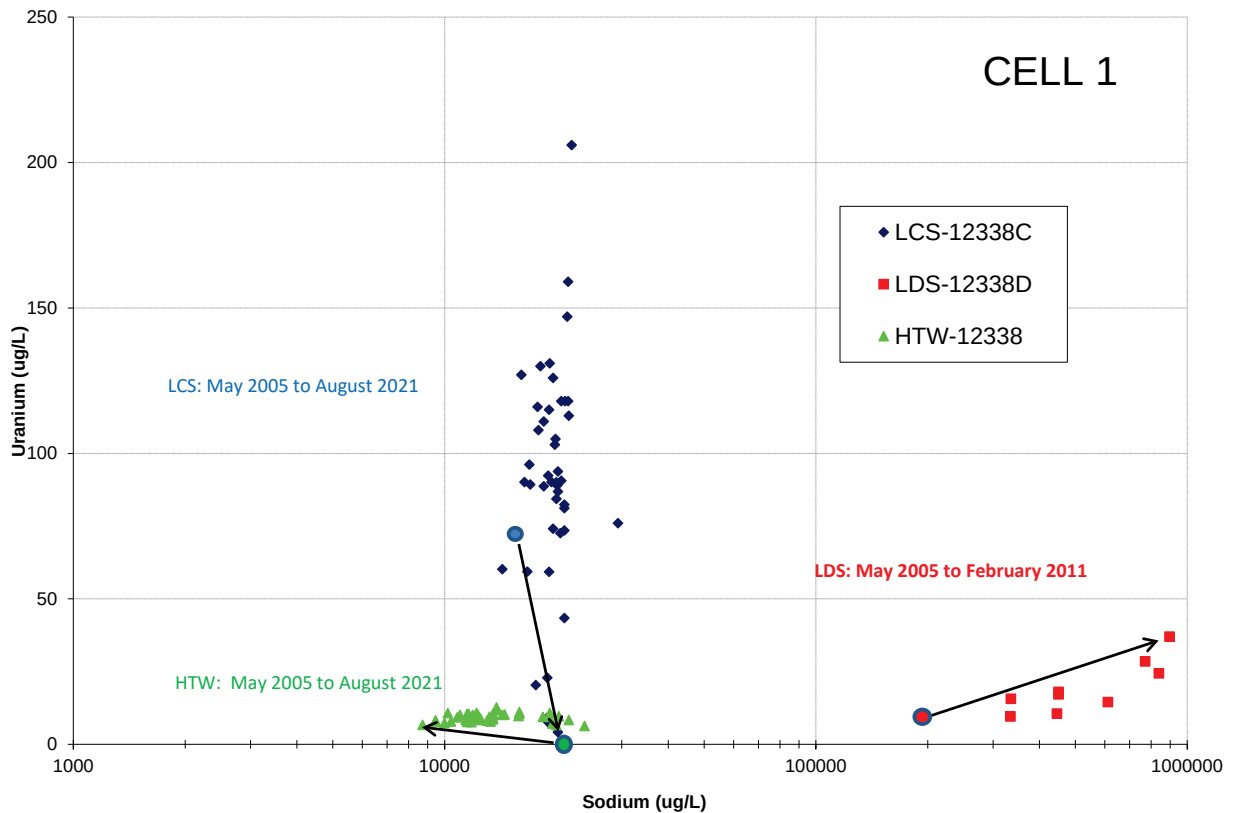


Figure A.5.1-18. Cell 1 Bivariate Plot for Uranium and Sodium

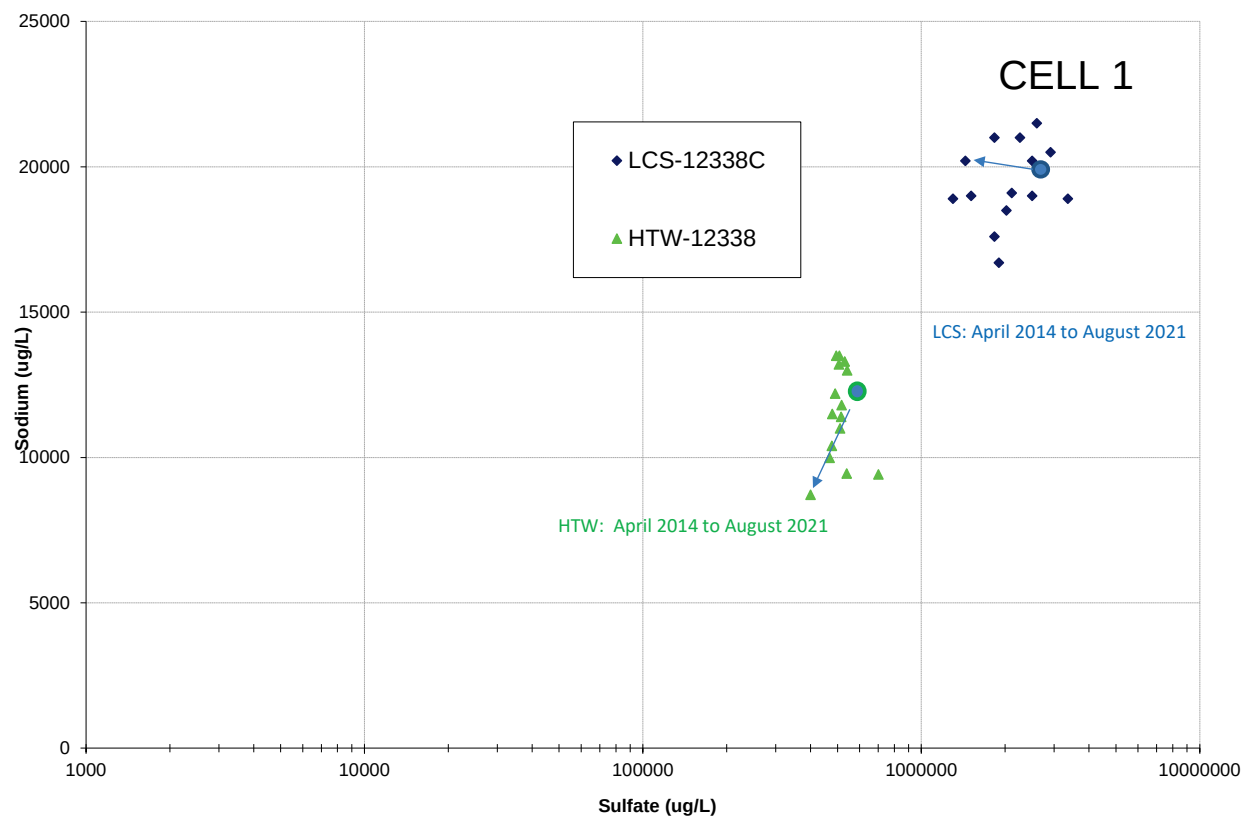


Figure A.5.1-19. Cell 1 Bivariate Plot for Sodium and Sulfate

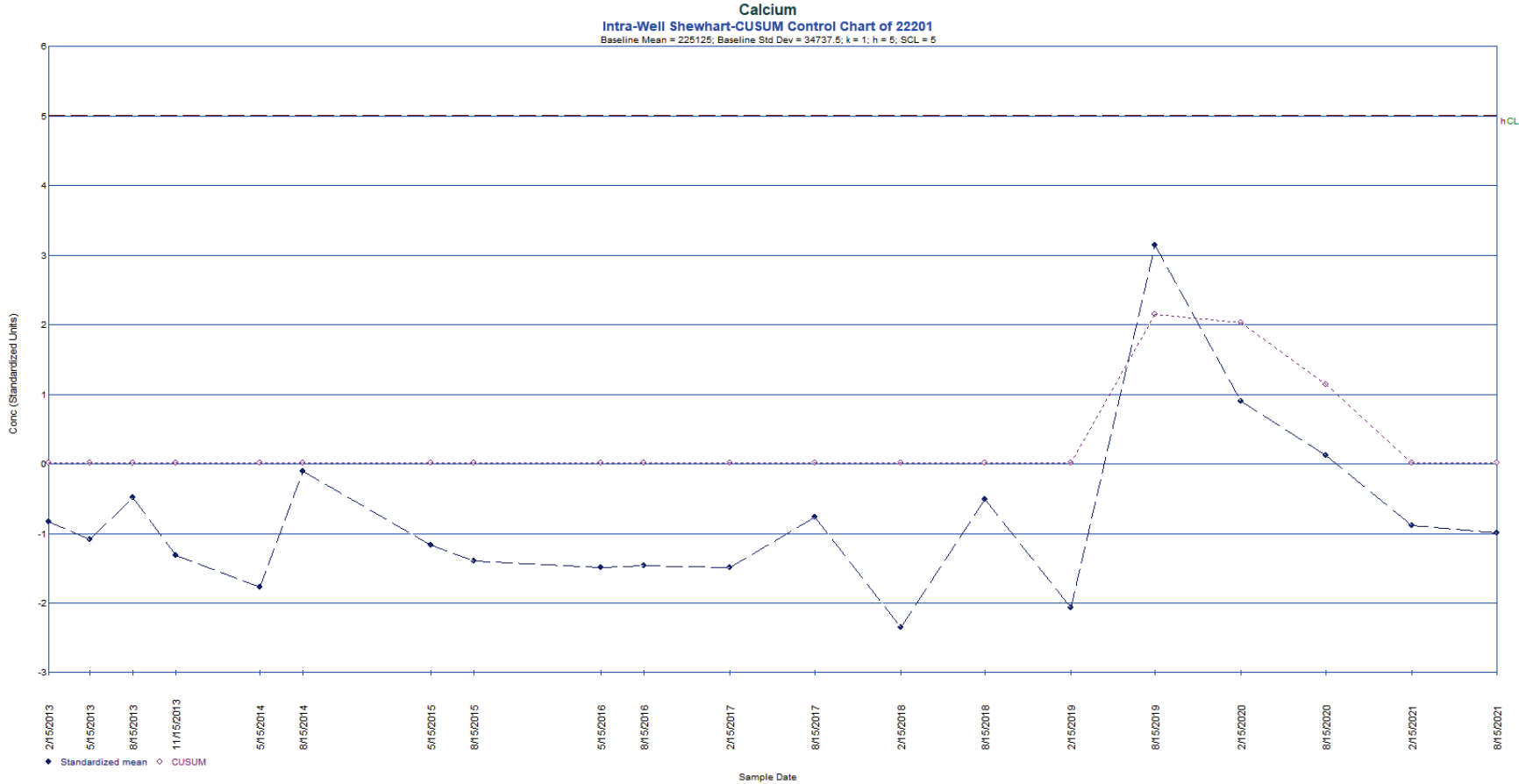


Figure A.5.1-20. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22201

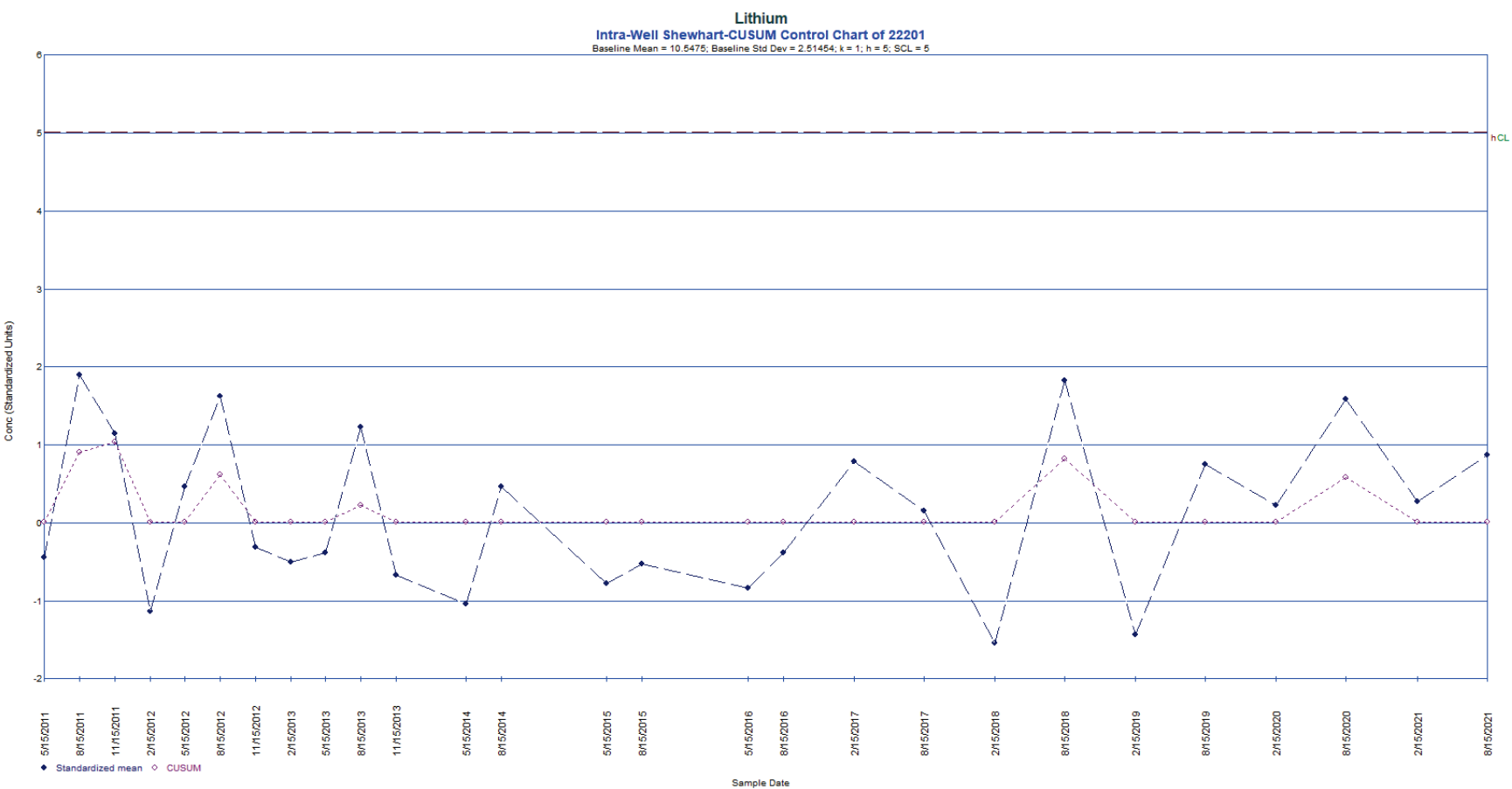


Figure A.5.1-21. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22201

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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	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.2-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.2-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.2-2)
- OSDF horizontal till well (HTW) 12339 water yield (refer to Table A.5.2-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.2-3 and A.5.2-4)
- Plots of concentration versus time (refer to Figures A.5.2-5A through A.5.2-17)
- A bivariate plot for uranium–sodium (refer to Figure A.5.2-18)
- Control charts (refer to Figure A.5.2-19)

A.5.2.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration-versus-time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining whether the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells: 4 of the 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW for each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was 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 2021 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 2021. 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 2021 Trend	LDS 12339D Trend (Year Last Sampled)
Total Uranium	Up	
Boron	Up	Up (2013)
Sodium	Up	Up (2013)
Sulfate	Up	Up (2013)

^a No entry indicates that the trend was not up.

A.5.2.1.2 HTW and Monitoring Well Results

As shown in Table A.5.2-1 and summarized below, five parameters in 2021 (total uranium, boron, lithium, potassium, and selenium) have upward trends in the HTW and/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^a

Parameter	HTW 12339	GMA-U^b 22200	GMA-D^b 22199
Total Uranium	Up	Up	
Boron	Up	Up	Up
Lithium		Up	Up
Potassium		Up	
Selenium		Up	

^a No entry indicates that the trend was not up.

^b GMA-U = upgradient Great Miami Aquifer; GMA-D = downgradient Great Miami Aquifer.

A.5.2.1.3 Discussion

The uranium–sodium bivariate plot for the Cell 2 LCS, LDS, and HTW is provided in Figure A.5.2-18. On the figure, the first sample ever collected from the monitoring horizon 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.5.2.2 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.5.2-1 in gray shading and as summarized below, one parameter in the HTW or GMA wells of Cell 2 meet the criteria for control charts (i.e., at least eight samples, normal or lognormal distribution, no trend, and no serial correlation), resulting in one control chart (Figures A.5.2-19). The control chart for Cell 2 indicates “in control” conditions for total dissolved solids.

Parameter	Monitoring Point ^a	Well Number	Assessment	Figure Number
Total Dissolved Solids	GMA-D	22199	In Control	A.5.2-19

^a GMA-U = upgradient Great Miami Aquifer; 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 2021: total uranium, boron, sodium, and sulfate. No new high concentrations were measured in the LCS of Cell 2 in 2021.
- The volume of water in the LDS tank of Cell 2 has been insufficient to collect a sample since 2013.
- Five parameters monitored semiannually in 2021 have an upward concentration trend in the HTW or GMA wells of Cell 2: total uranium, boron, lithium, potassium, and selenium. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 2 indicate that water is not mixing between the horizons. Therefore, upward concentration trends beneath Cell 2 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.
- One control chart was constructed for Cell 2 parameters. The control chart exhibits “in control” conditions.

A.5.2.4 References

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

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

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

Table A.5.2-1. Summary Statistics for Cell 2

Parameter	Horizon ^a	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum ^b	Maximum ^b	Average ^{c,d}	Standard Deviation ^d	Distribution Type ^{d,e}	Trend ^{d,f} (Year Last Sampled)	Serial Correlation ^{d,g}	Outliers ^{h,i}
Total Uranium (µg/L)	LCS	12339C	74	74	100	4.51	686	130	115	Ln Normal	Up (2021)	Detected	
	LDS	12339D	35	35	100	4.08	71.0	14.5	13.2	Undefined	None (2013)	Detected	
	HTW	12339	75	76	98.7	ND	36.9	11.3	6.6	Undefined	Up (2021)	Detected	
	GMA-U	22200	62	82	75.6	ND	4.69	0.300	0.582	Undefined	Up (2021)	Not Detected	
	GMA-D	22199	85	90	94.4	ND	12.1	0.637	2.18	Undefined	Down (2021)	Not Detected	
Boron (mg/L)	LCS	12339C	75	75	100	0.207	4.78	2.66	1.10	Undefined	Up (2021)	Detected	
	LDS	12339D	35	35	100	0.289	2.22	0.422	0.371	Undefined	Up (2013)	Detected	
	HTW	12339	56	59	94.9	ND	0.213	0.102	0.053	Undefined	Up (2021)	Detected	
	GMA-U	22200	70	82	85.4	ND	0.105	0.0572	0.0236	Undefined	Up (2021)	Detected	
	GMA-D	22199	73	82	89.0	ND	0.0899	0.0501	0.0148	Normal	Up (2021)	Detected	
Sodium (mg/L)	LCS	12339C	51	51	100	3.32	42.8	20.9	6.6	Undefined	Up (2021)	Detected	
	LDS	12339D	10	10	100	664	2,450	1,230	540	Normal	Up (2013)	Detected	
	HTW	12339	44	44	100	31.6	119	45.0	23.4	Undefined	Down (2021)	Detected	
	GMA-U	22200	35	35	100	20.4	32.9	26.6	3.4	Normal	Down (2021)	Detected	
	GMA-D	22199	36	36	100	7.94	19.5	13.3	3.3	Normal	Down (2021)	Detected	
Sulfate (mg/L)	LCS	12339C	63	63	100	155	1,960	1,600	320	Undefined	Up (2021)	Detected	
	LDS	12339D	18	18	100	2,290	13,000	3,780	2,680	Ln Normal	Up (2013)	Detected	
	HTW	12339	54	54	100	344	850	539	125	Undefined	Down (2021)	Detected	
	GMA-U	22200	59	59	100	61.1	434	136	94	Undefined	Down (2021)	Not Detected	
	GMA-D	22199	59	59	100	101	540	170	86	Undefined	None (2021)	Not Detected	
Calcium (mg/L)	GMA-U	22200	28	28	100	120	205	138	23	Undefined	None (2021)	Not Detected	
	GMA-D	22199	28	28	100	125	193	144	18	Undefined	None (2021)	Not Detected	
Lithium (mg/L)	GMA-U	22200	35	35	100	0.00345	0.00587	0.00423	0.00056	Ln Normal	Up (2021)	Not Detected	
	GMA-D	22199	35	35	100	0.00650	0.0101	0.00770	0.00078	Normal	Up (2021)	Detected	
Magnesium (mg/L)	GMA-U	22200	28	28	100	33.1	54.9	39.3	5.0	Undefined	None (2021)	Not Detected	
	GMA-D	22199	28	28	100	36.2	54.8	40.6	4.6	Undefined	None (2021)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22200	3	28	10.7	ND	0.200	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22199	2	28	7.1	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22200	28	28	100	1.50	2.14	1.86	0.19	Normal	Up (2021)	Detected	
	GMA-D	22199	29	29	100	1.28	1.75	1.46	0.11	Normal	Down (2021)	Not Detected	
Selenium (mg/L)	GMA-U	22200	5	35	14.3	ND	0.0134	0.00300	0.00276	Undefined	Up (2021)	Detected	
	GMA-D	22199	1	35	2.9	ND	0.0729	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22200	0	31	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22199	0	31	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22200	35	35	100	497	857	613	97	Undefined	None (2021)	Not Detected	
	GMA-D	22199	35	35	100	520	820	648	74	Normal	None (2021)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22200	30	82	36.6	ND	0.177	0.00437	0.0244	Undefined	Down (2021)	Detected	
	GMA-D	22199	19	82	23.2	ND	0.0775	0.00253	0.0117	Undefined	Down (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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 assumptions are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

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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

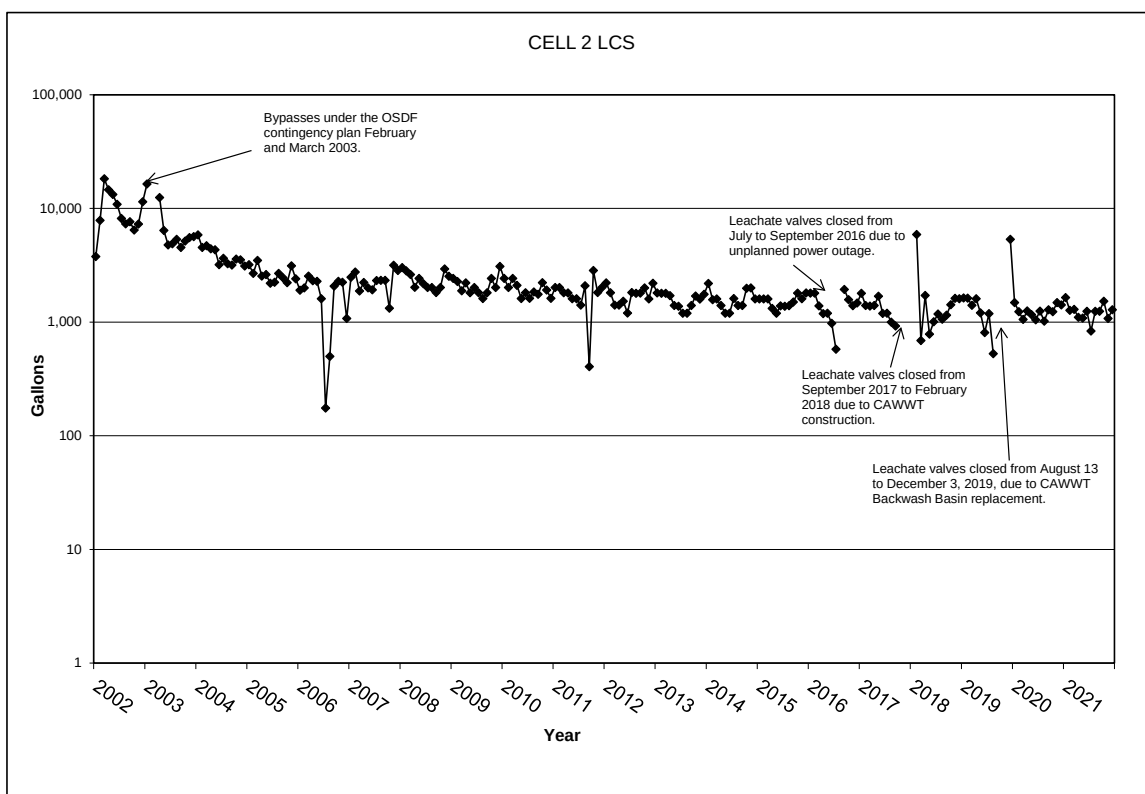


Figure A.5.2-1. Monthly Accumulation Volumes for Cell 2 LCS

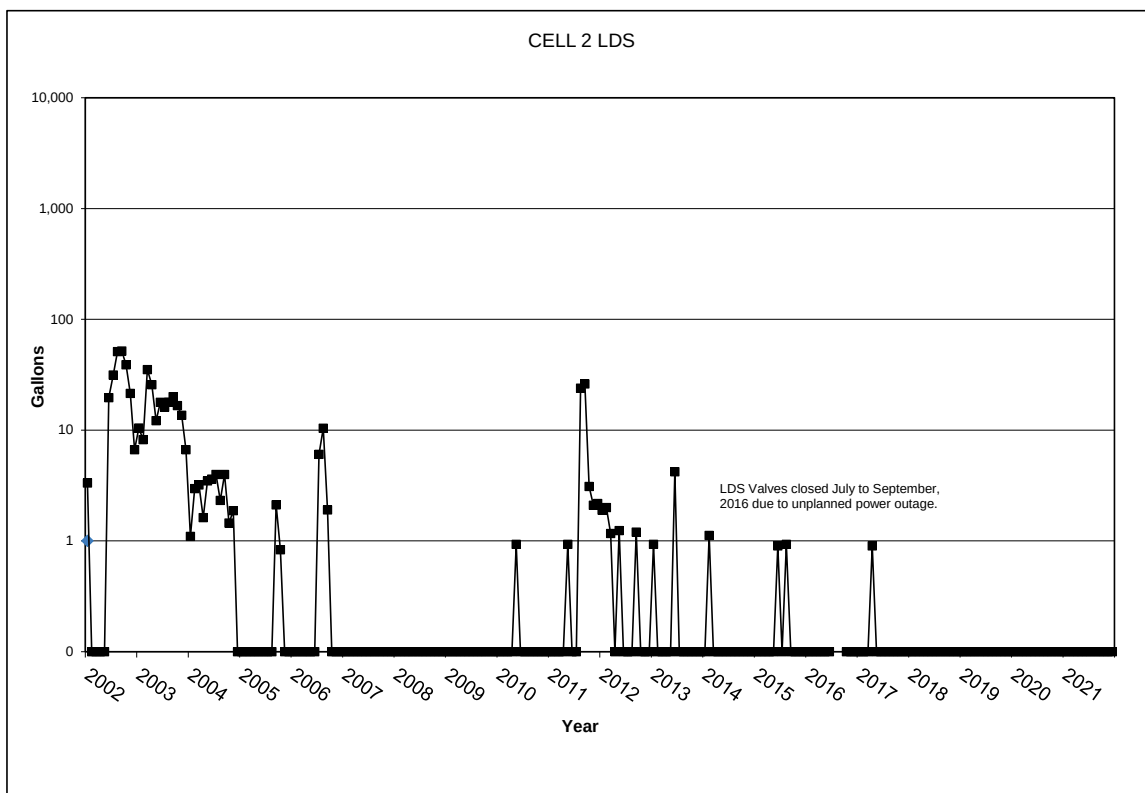


Figure A.5.2-2. Monthly Accumulation Volumes for Cell 2 LDS

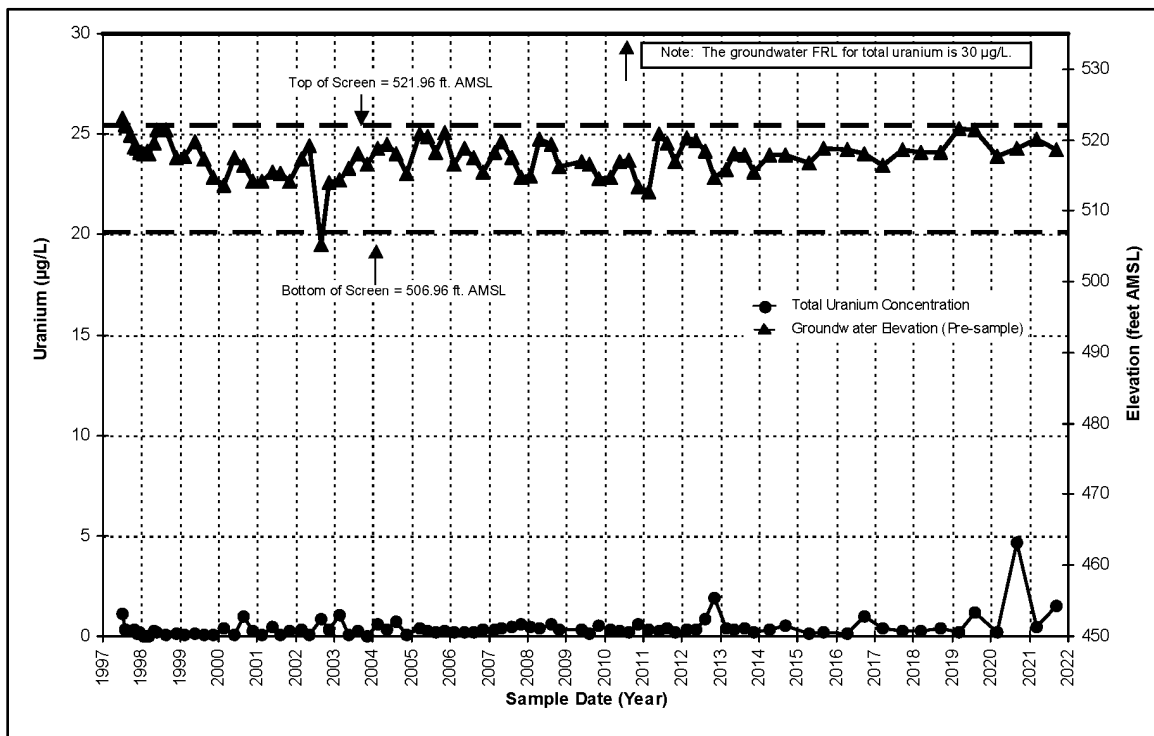


Figure A.5.2-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 2 Upgradient Monitoring Well 22200

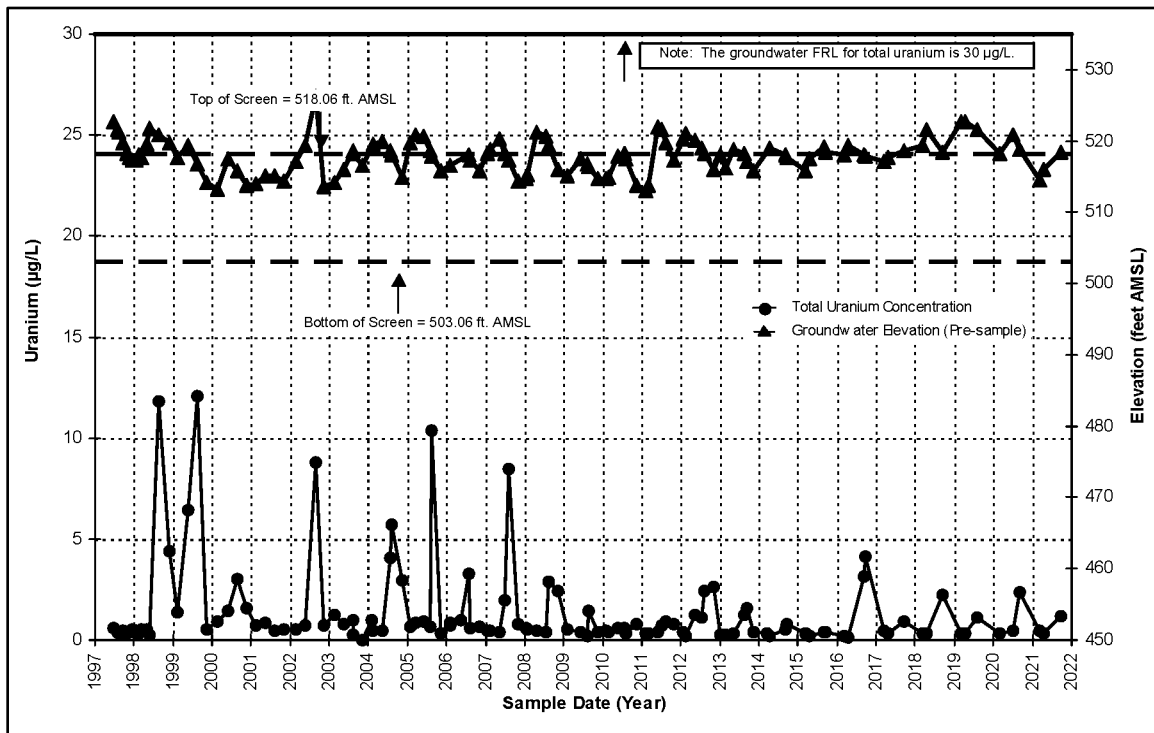


Figure A.5.2-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 2 Downgradient Monitoring Well 22199

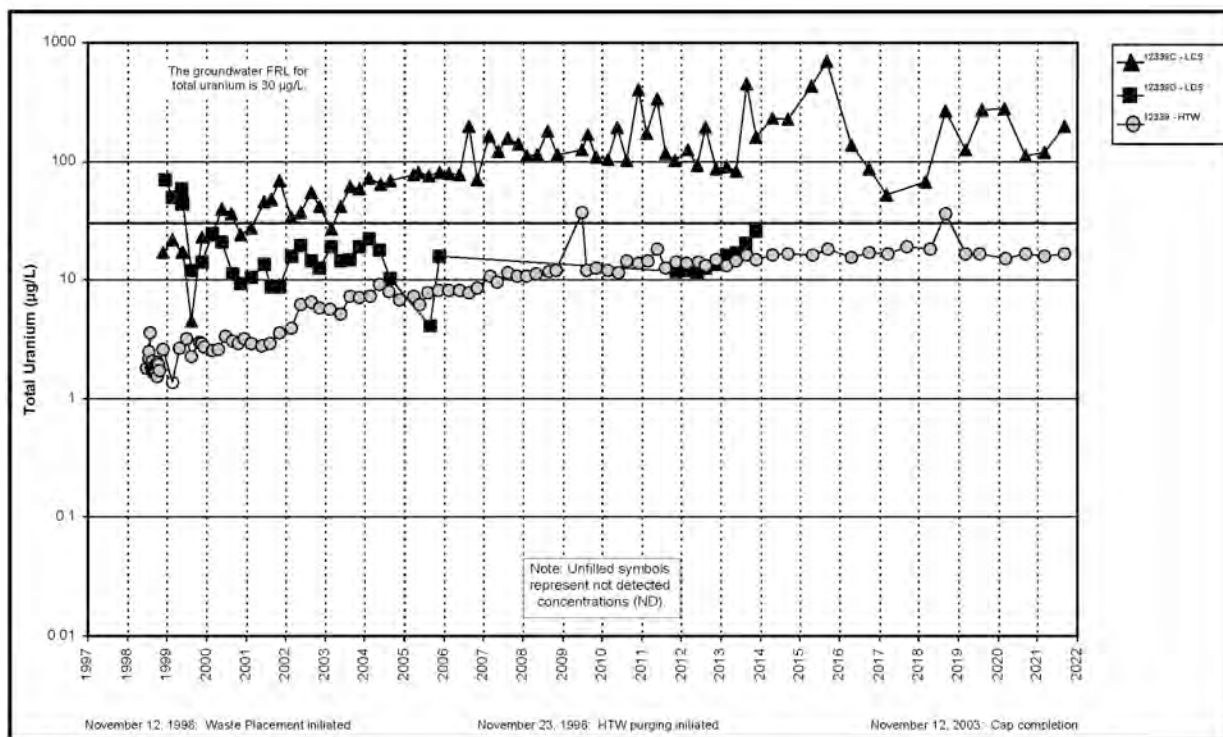


Figure A.5.2-5A. Cell 2 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

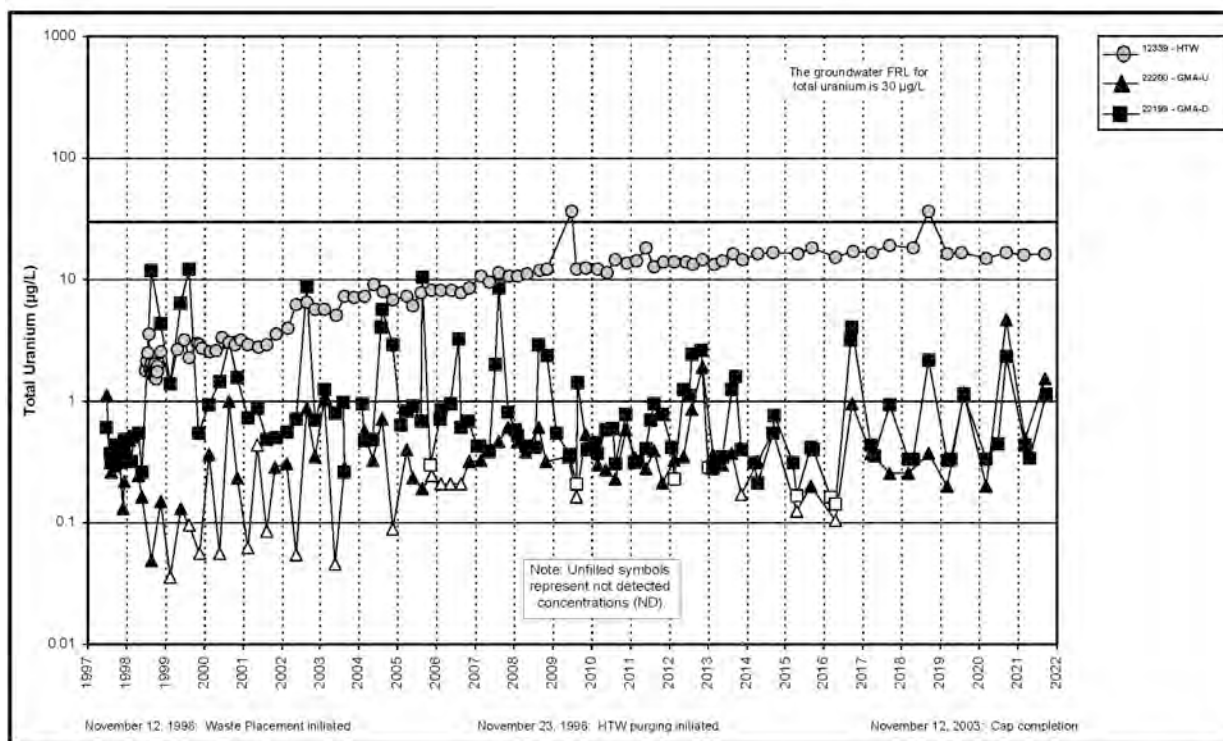


Figure A.5.2-5B. Cell 2 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

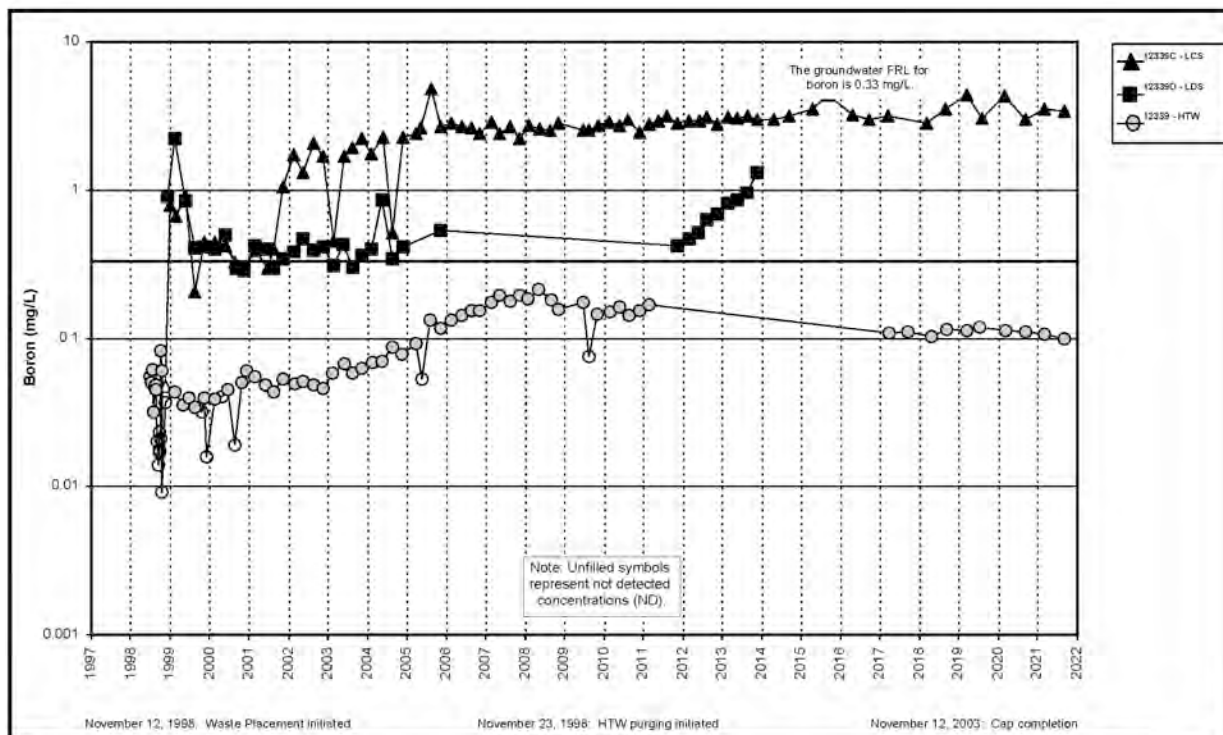


Figure A.5.2-6A. Cell 2 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

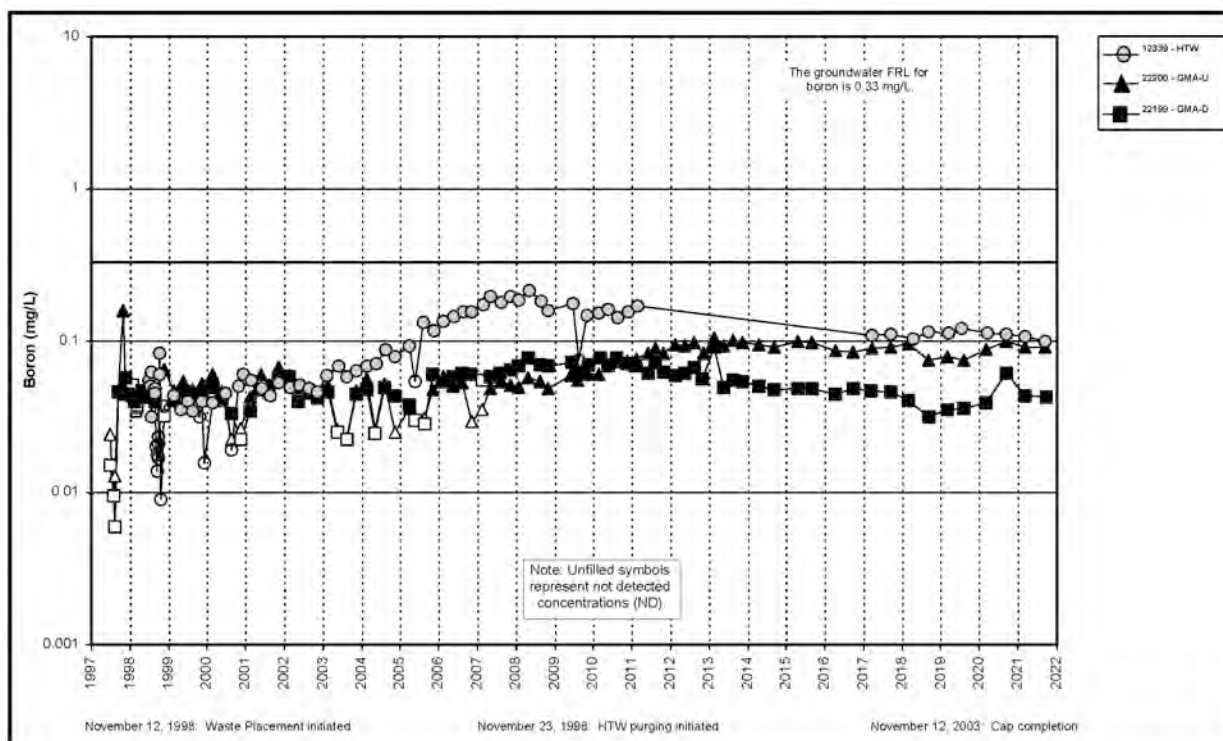


Figure A.5.2-6B. Cell 2 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

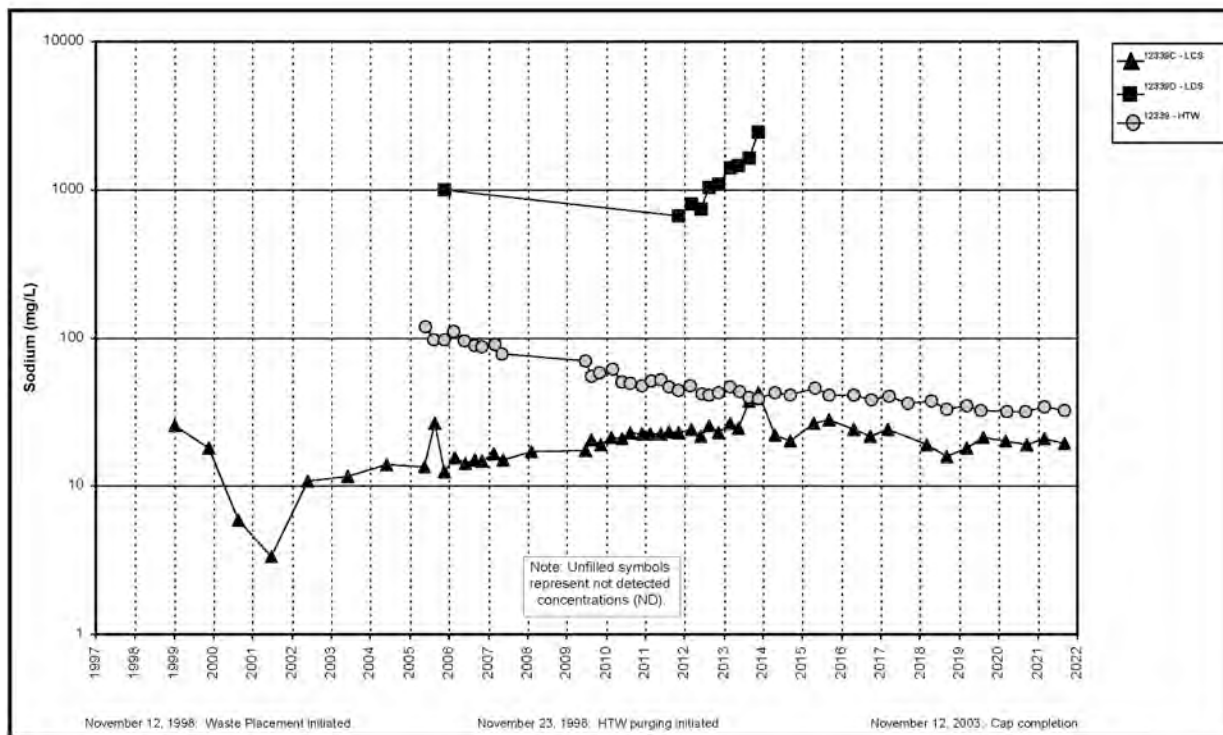


Figure A.5.2-7A. Cell 2 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

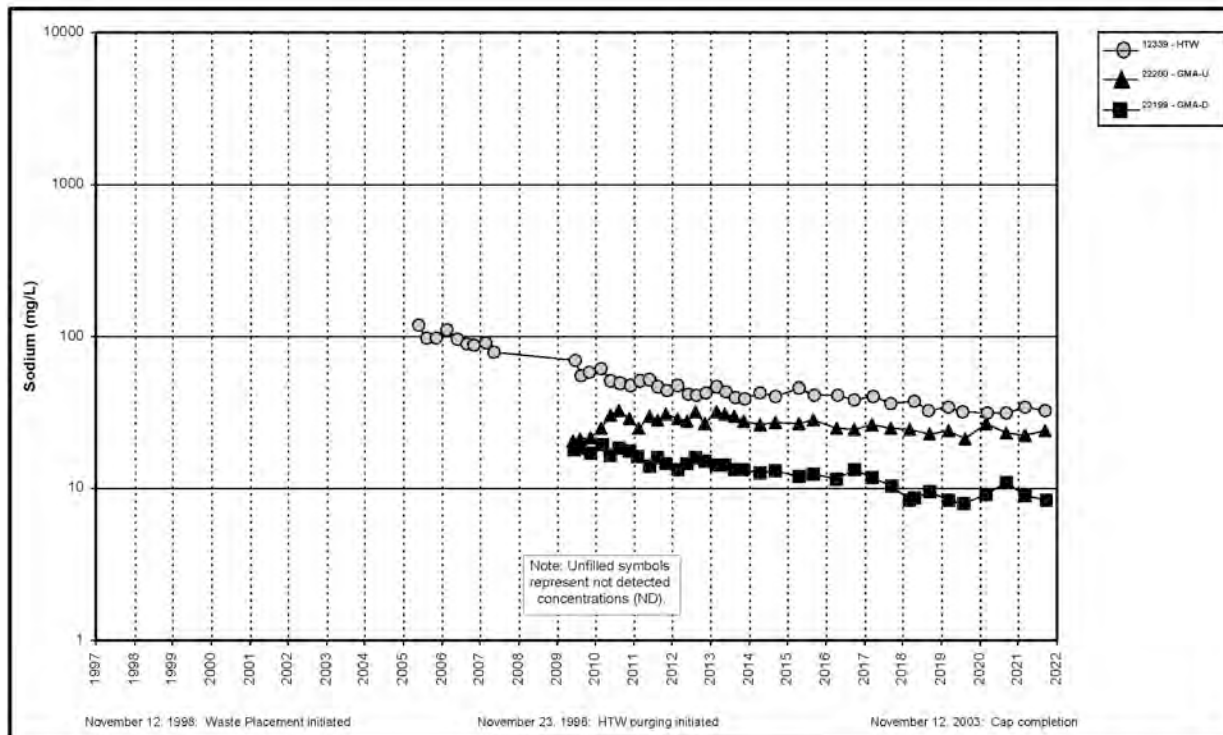


Figure A.5.2-7B. Cell 2 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

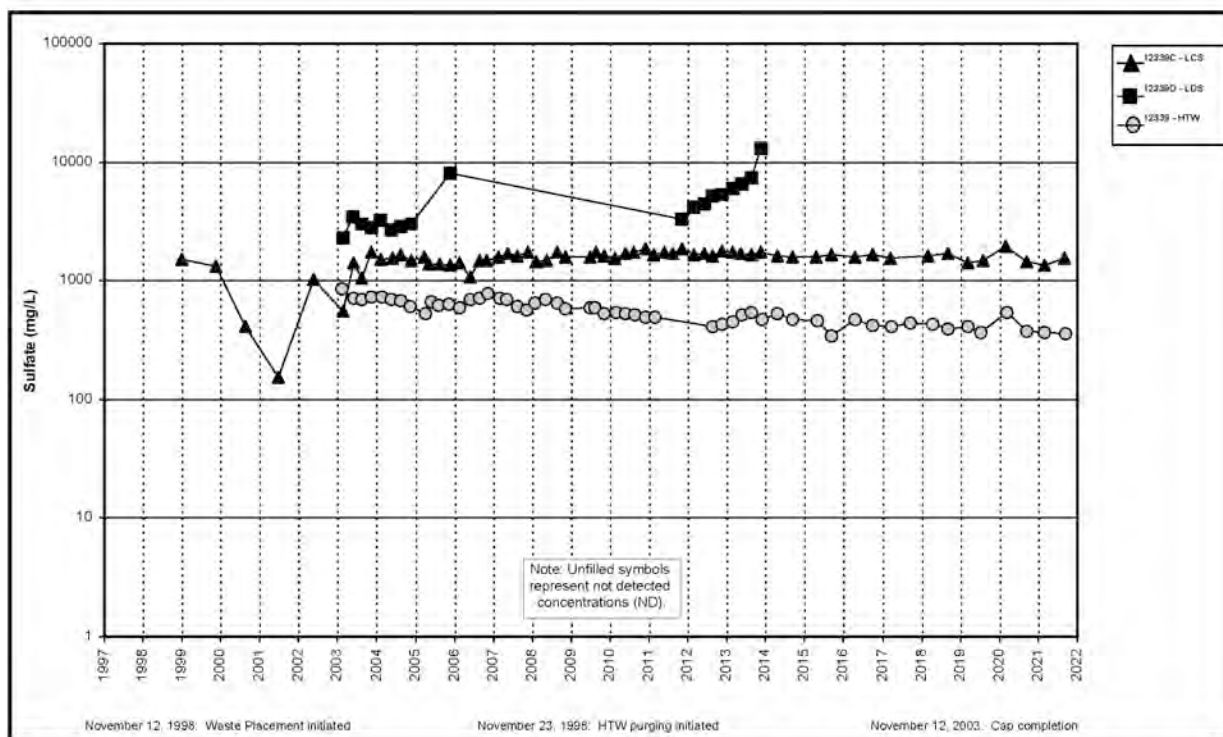


Figure A.5.2-8A. Cell 2 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

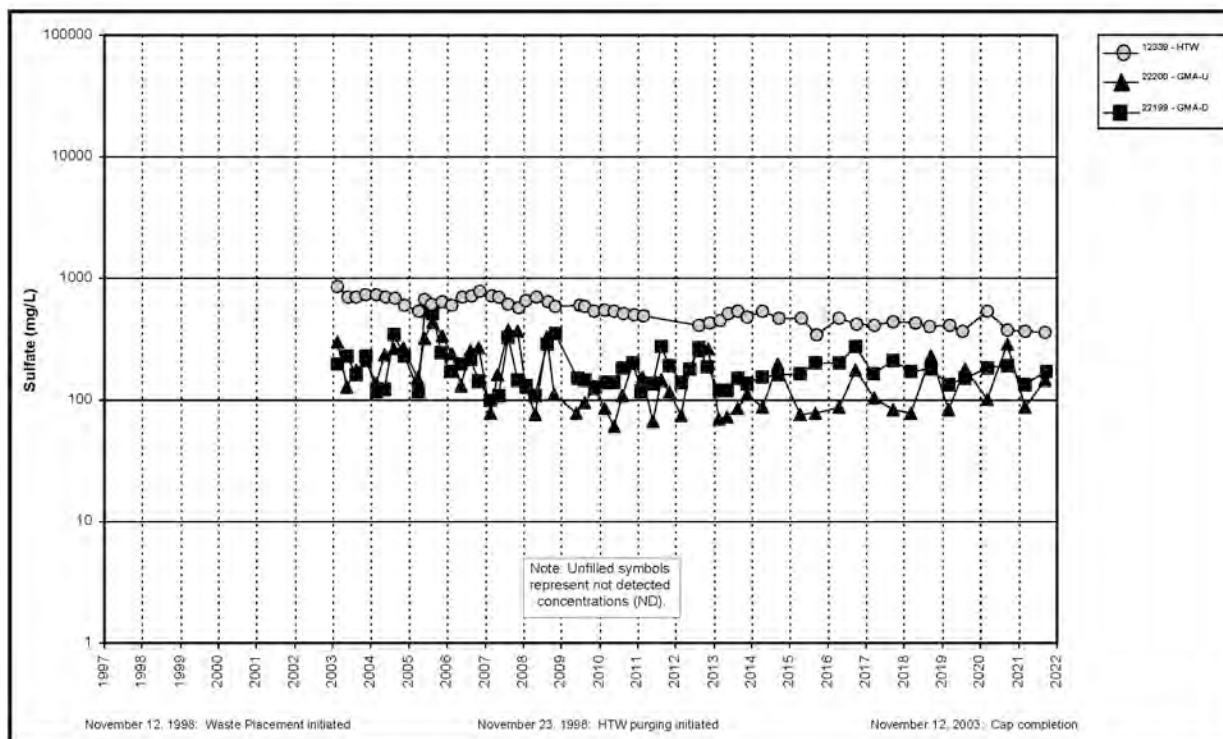


Figure A.5.2-8B. Cell 2 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

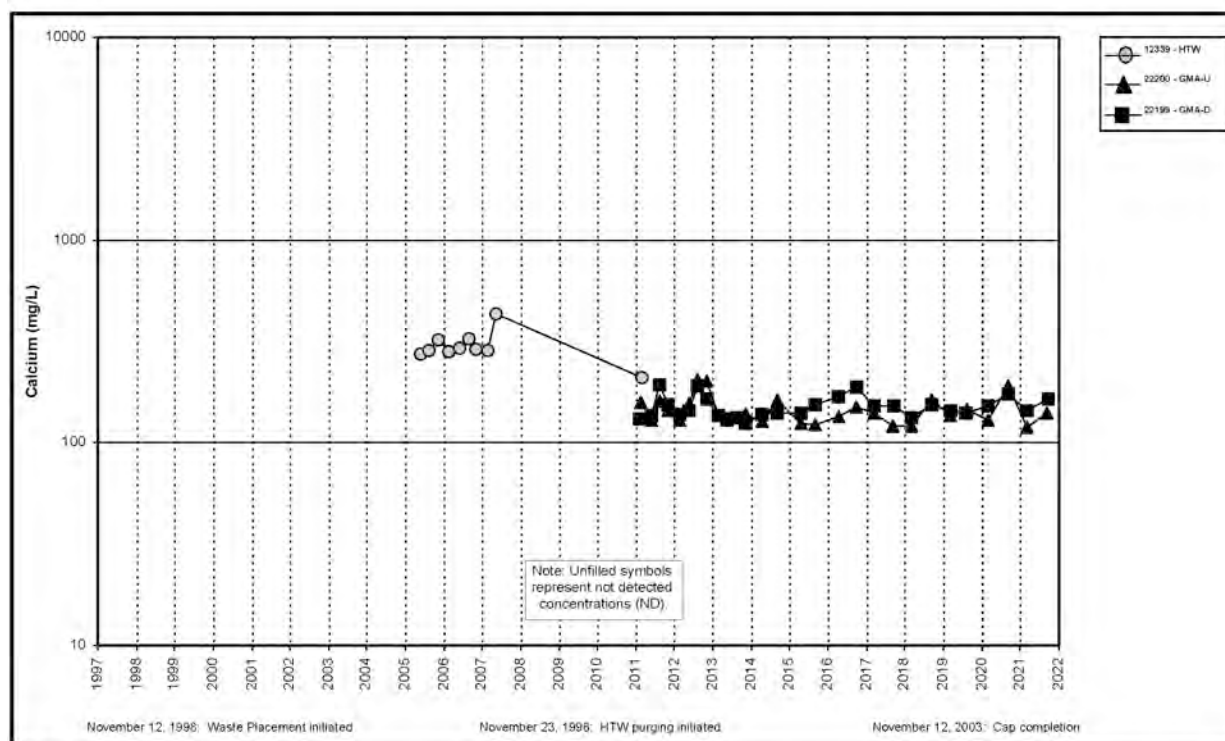


Figure A.5.2-9. Cell 2 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

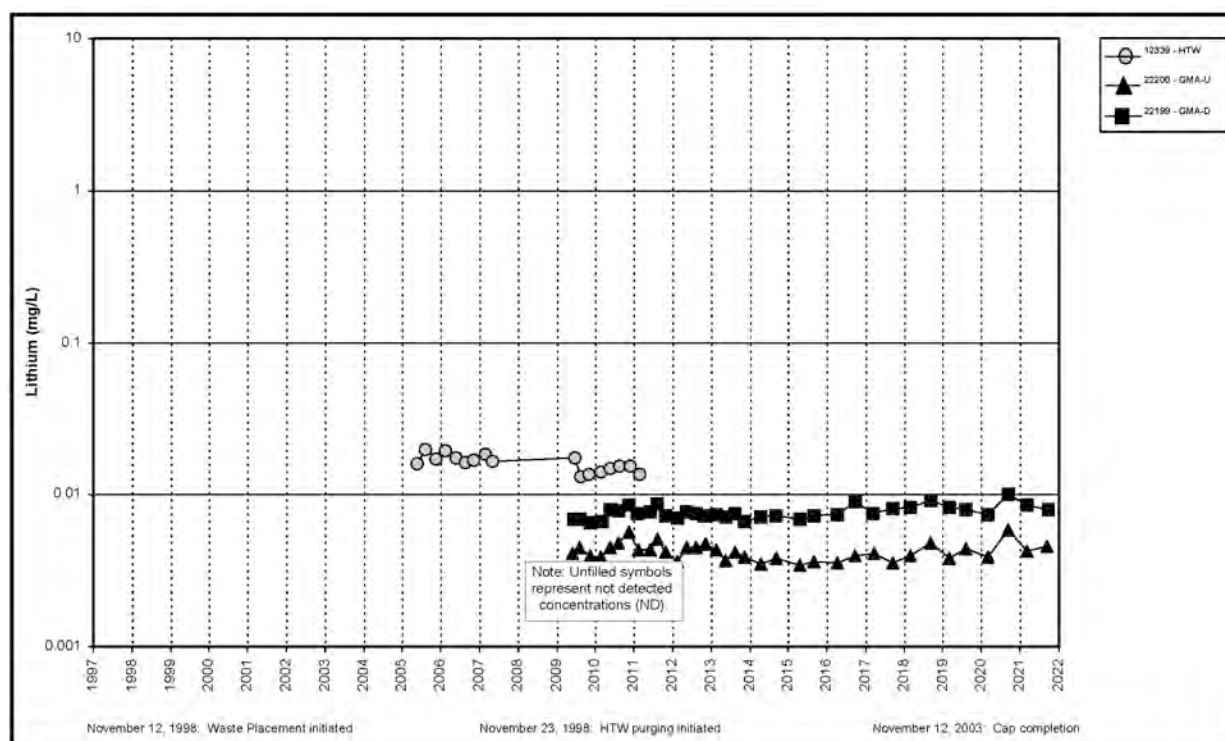


Figure A.5.2-10. Cell 2 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

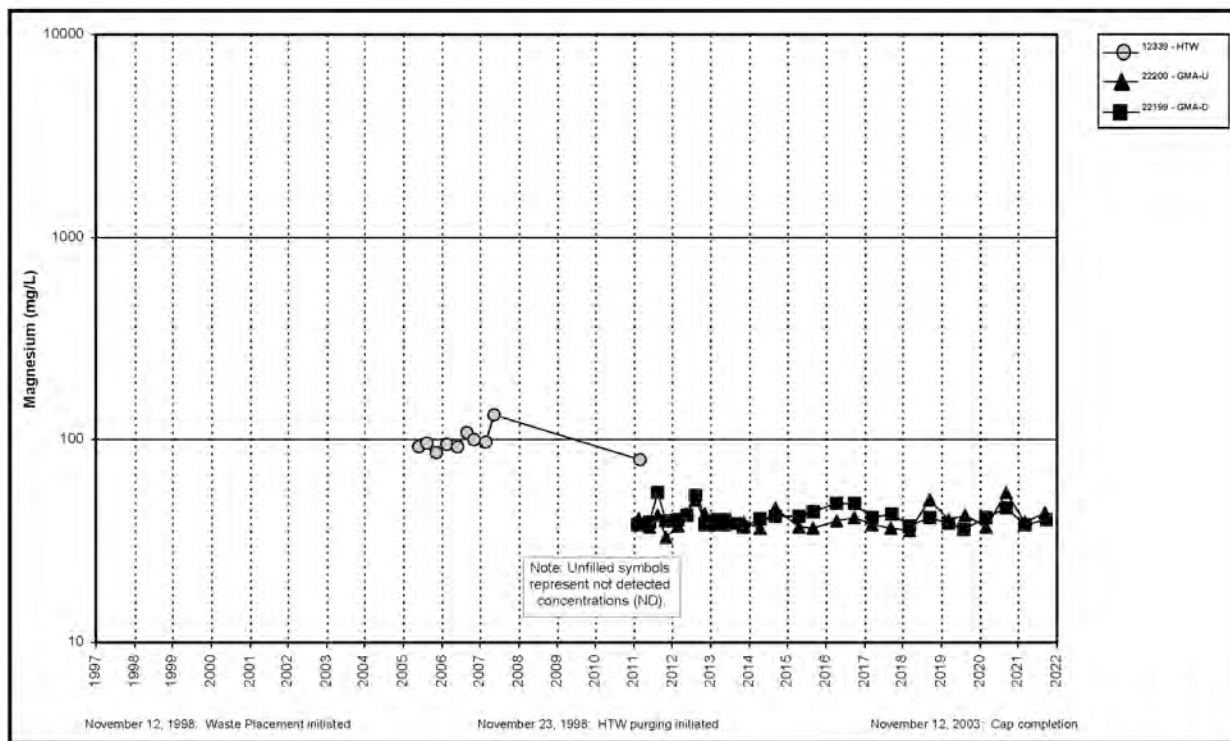


Figure A.5.2-11. Cell 2 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

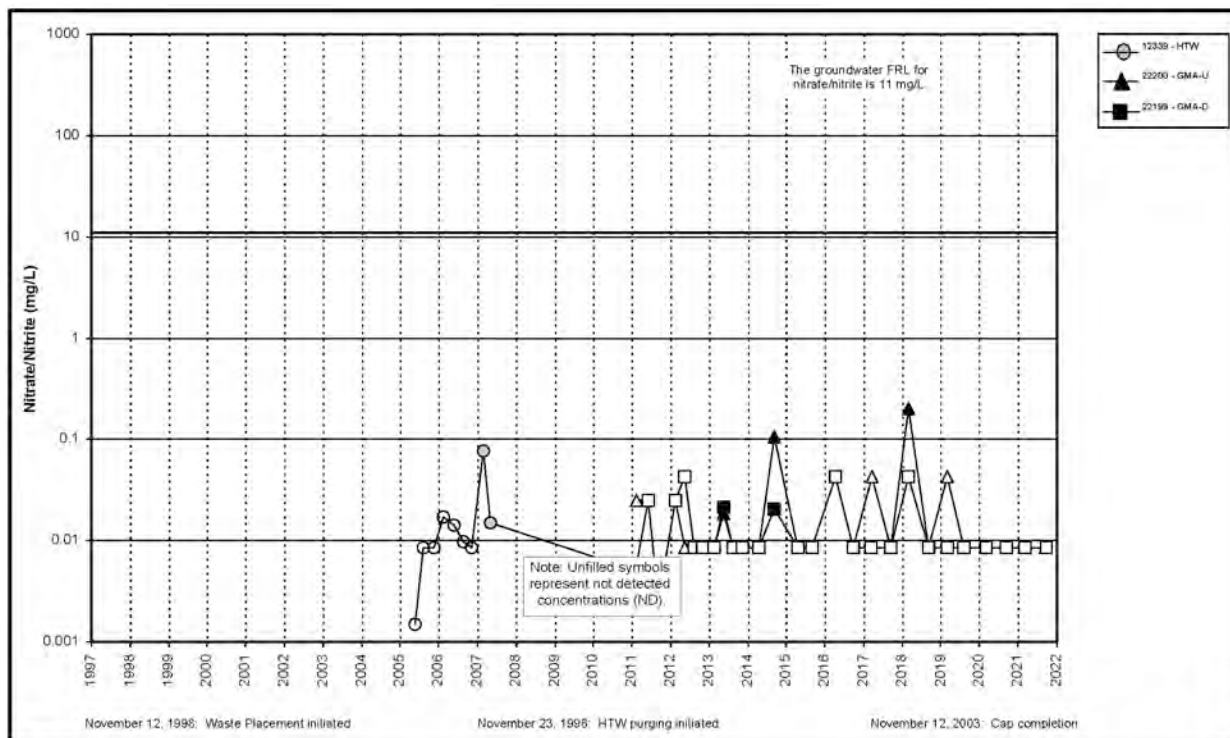


Figure A.5.2-12. Cell 2 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

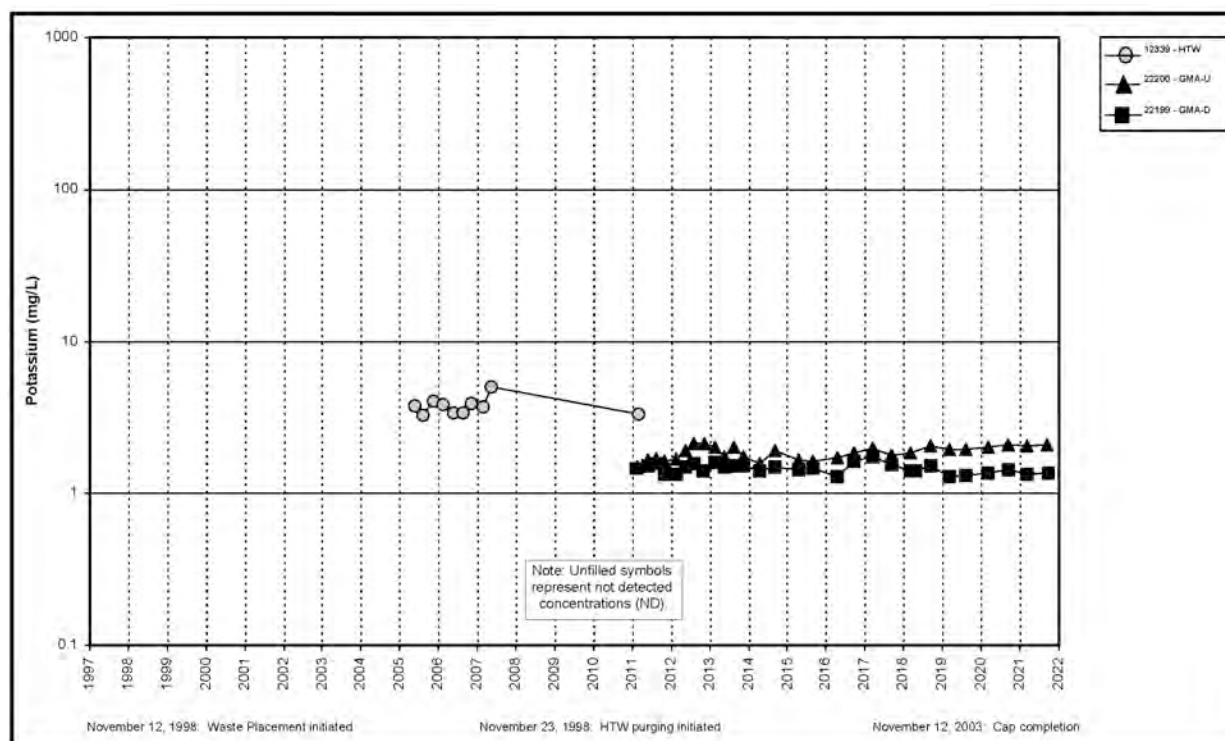


Figure A.5.2-13. Cell 2 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

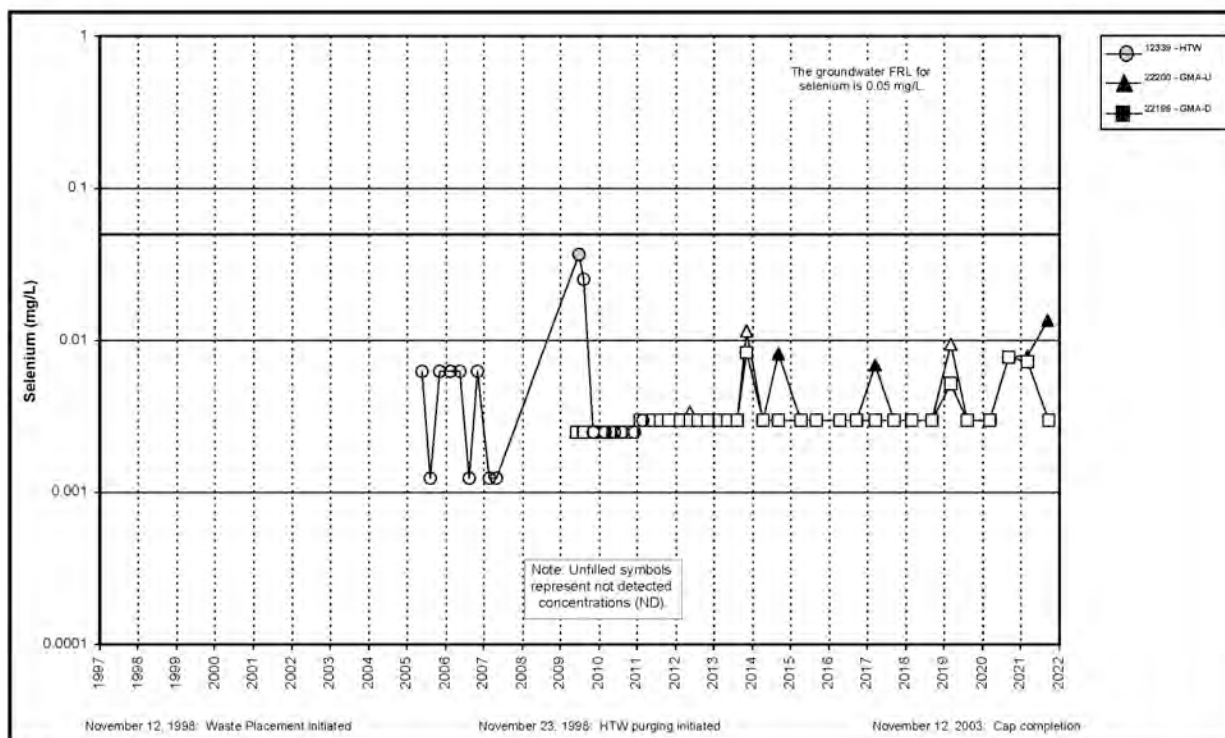


Figure A.5.2-14. Cell 2 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

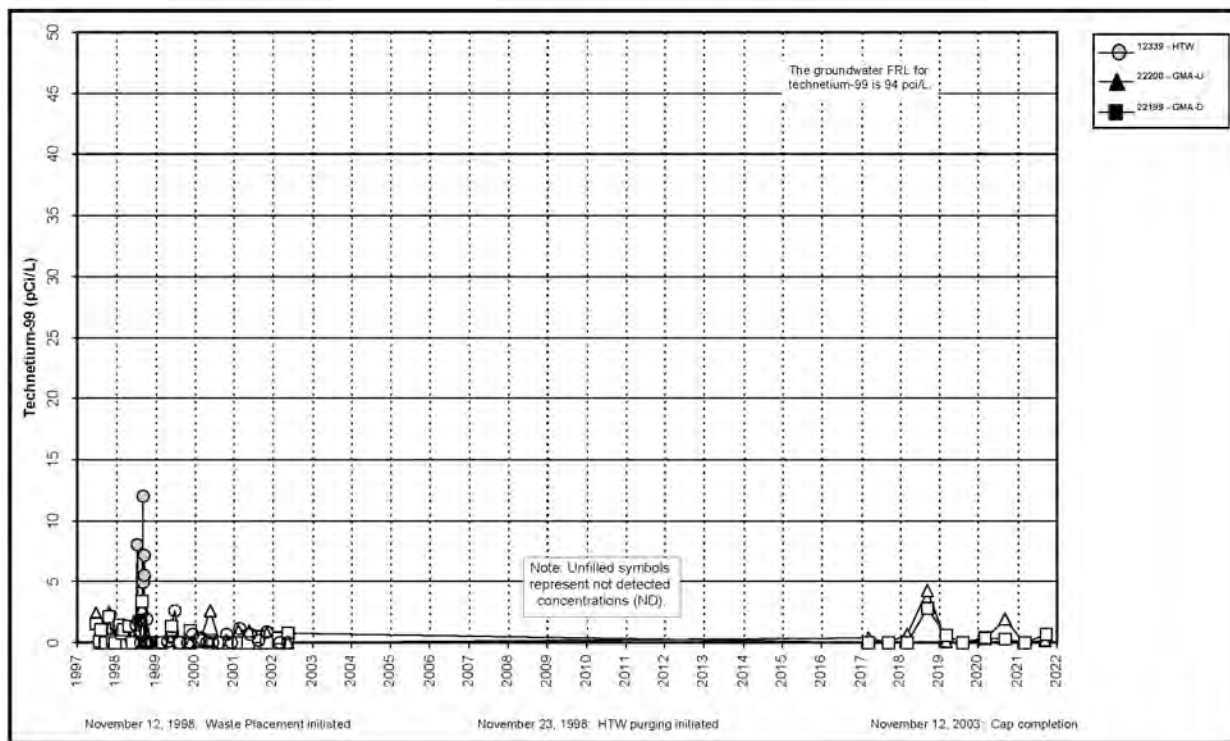


Figure A.5.2-15. Cell 2 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

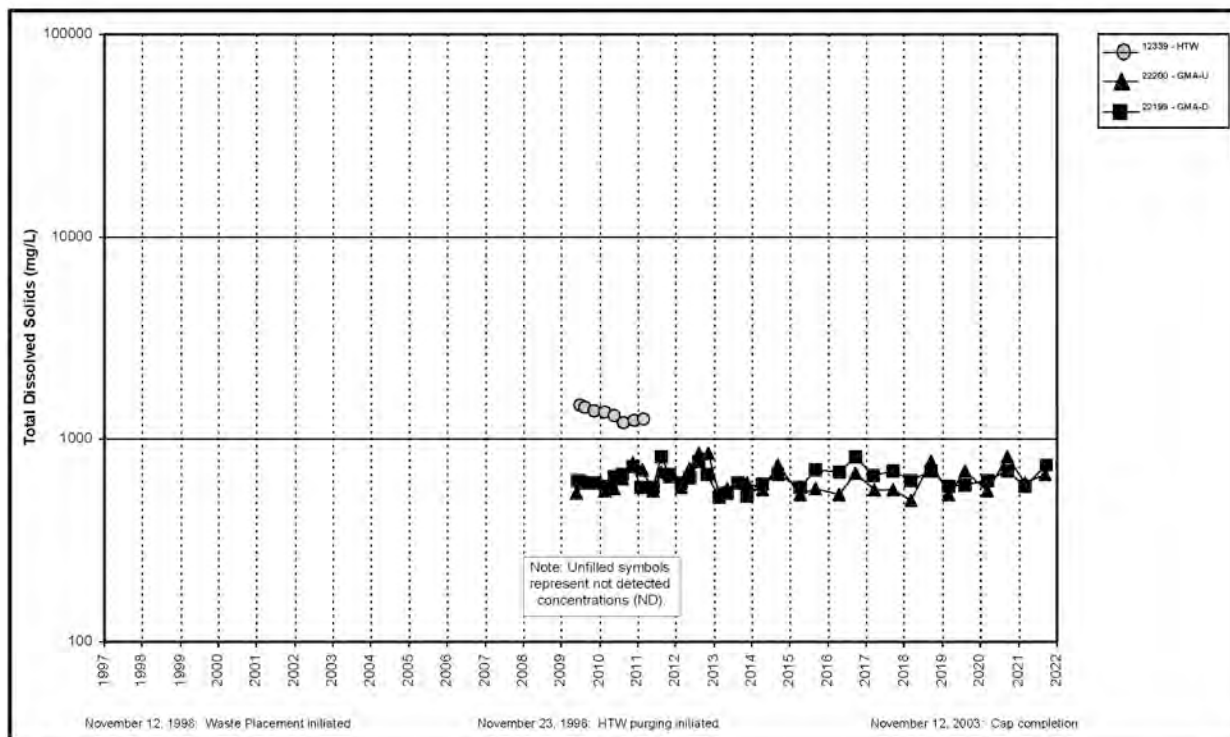


Figure A.5.2-16. Cell 2 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

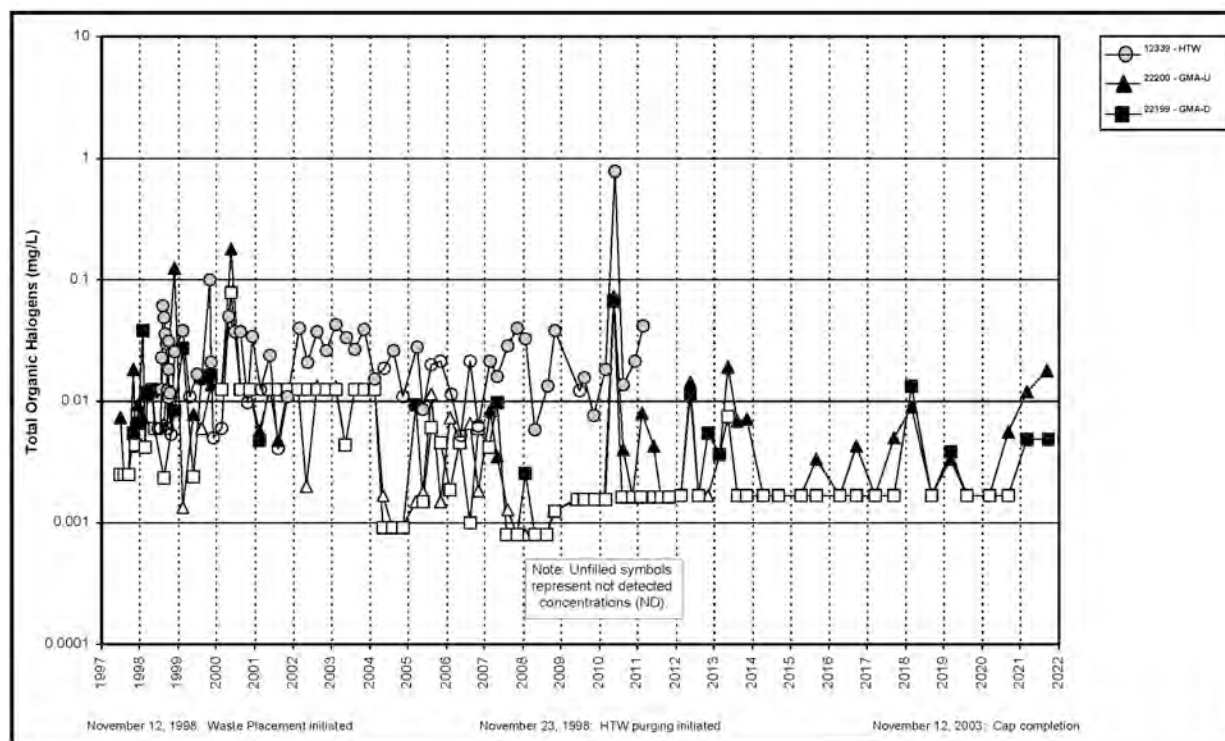


Figure A.5.2-17. Cell 2 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

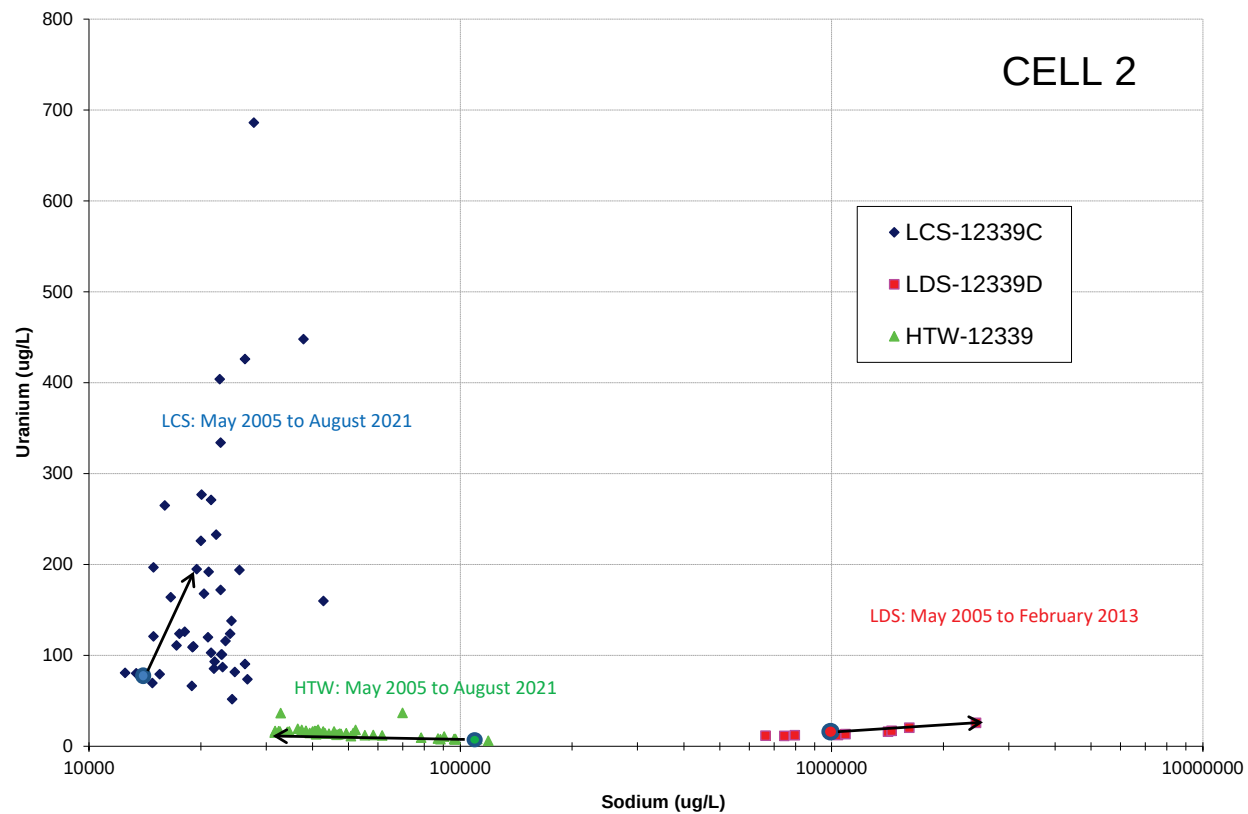


Figure A.5.2-18. Cell 2 Bivariate Plot for Uranium and Sodium

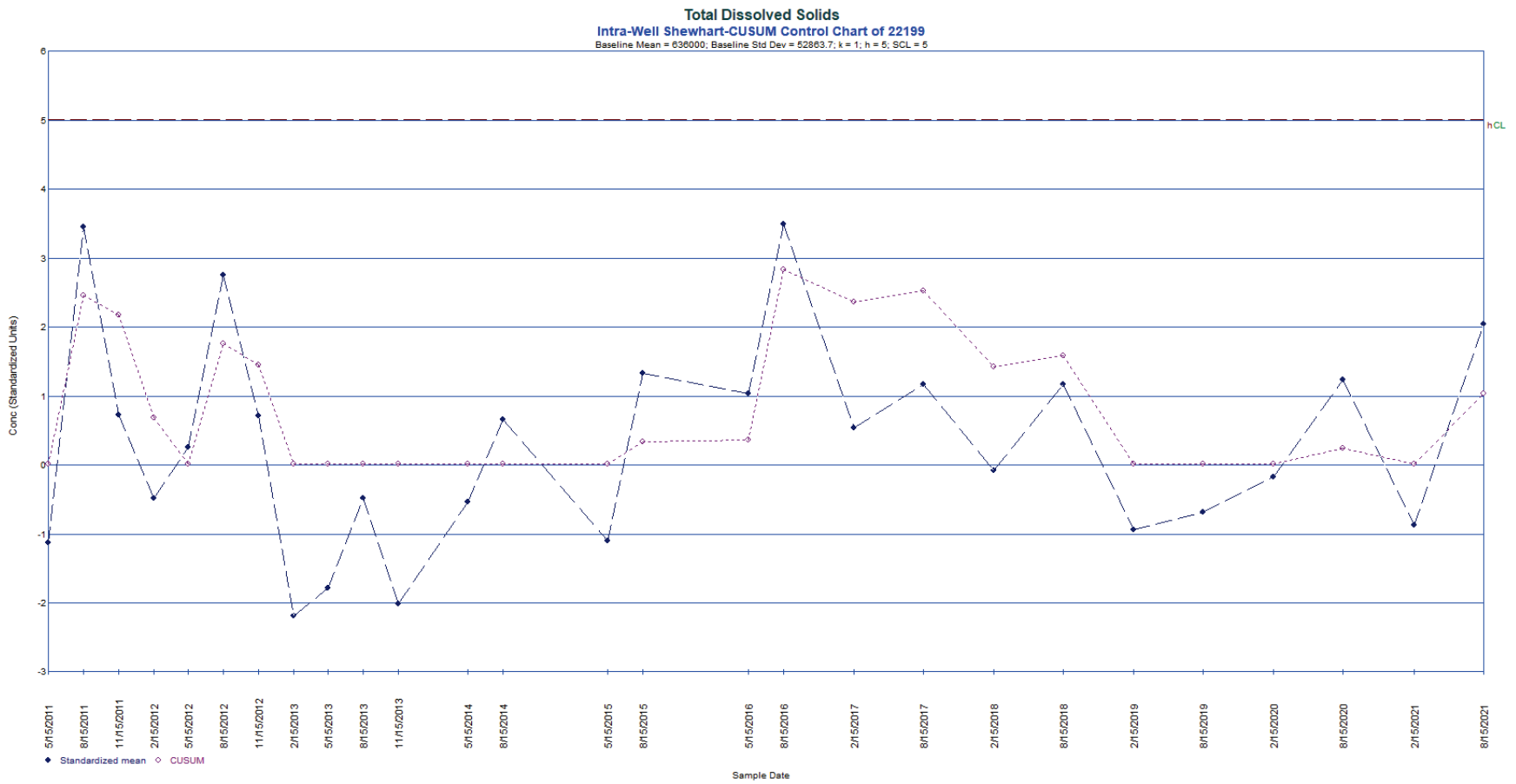


Figure A.5.2-19. Intra-Well Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22199

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	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.3-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.3-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.3-2)
- OSDF horizontal till well (HTW) 12340 water yield (refer to Table A.5.3-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.3-3 and A.5.3-4)
- Plots of concentration versus time (refer to Figures A.5.3-5A through A.5.3-17)
- A bivariate plot for uranium–sodium (refer to Figure A.5.3-18)
- Control charts (refer to Figures A.5.3-19 through A.5.3-21)

A.5.3.1 Water Quality Monitoring Results

Water quality within the cell is sampled in the LCS and LDS. Water quality beneath the cell is sampled in the HTW and GMA wells. Concentration-versus-time plots, bivariate plots, and control charts are used to help interpret and present the results.

Until 2014, quarterly water quality monitoring occurred in the LCS, LDS, HTW, and GMA wells of each cell for the purpose of determining if the OSDF is operating as designed. With U.S. Environmental Protection Agency (EPA) and Ohio Environmental Protection Agency (Ohio EPA) concurrence, the U.S. Department of Energy (DOE) changed from a quarterly sampling frequency to a semiannual sampling frequency at the start of 2014.

With EPA and Ohio EPA concurrence, DOE reduced the number of parameters sampled from 24 to 13 beginning in January 2017. All 13 parameters are sampled in the GMA wells; 4 of the 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 2021 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 2021. 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^a

Parameter	LCS 12340C 2021 Trend	LDS 12340D Trend (Year Last Sampled)
Total Uranium	Up	
Boron	Up	
Sodium	Up	
Sulfate	Up	

^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 below, seven parameters (total uranium, boron, lithium, magnesium, nitrate + nitrite as nitrogen, selenium, and total dissolved solids) have upward trends in the HTW and/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^a

Parameter	HTW 12340	GMA-U^b 22203	GMA-D^b 22204
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 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.5.3-1 in gray shading and as summarized below, three 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 three control charts (Figures A.5.3-19, A.5.3-20, and A.5.3-21). All three of the control charts for Cell 3 exhibit “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
Potassium	GMA-U	22203	In Control	A.5.3-21

^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 2021 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 2021.
- 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.

- Three control charts were constructed for Cell 3 parameters. All three of the 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	72	72	100	9.35	206	83.6	39.9	Normal	Up (2021)	Detected	
	LDS	12340D	21	21	100	8.90	27.7	17.0	5.0	Normal	Down (2007)	Not Detected	72.4 (Q4-04)
	HTW	12340	75	75	100	3.89	29.3	18.9	5.9	Undefined	None (2021)	Detected	58.5 (Q3-09), 42.1 (Q3-16)
	GMA-U	22203	74	77	96.1	0.118	18.5	3.90	4.04	Ln Normal	Up (2021)	Detected	
	GMA-D	22204	84	85	98.8	ND	22.9	3.81	4.63	Undefined	Up (2021)	Detected	
Boron (mg/L)	LCS	12340C	72	73	98.6	ND	9.19	4.50	1.84	Undefined	Up (2021)	Detected	
	LDS	12340D	20	21	95.2	ND	0.557	0.128	0.149	Undefined	Down (2007)	Detected	
	HTW	12340	58	58	100	0.0481	0.259	0.141	0.052	Normal	Up (2021)	Detected	0.960 (Q3-06)
	GMA-U	22203	66	77	85.7	ND	0.0870	0.0494	0.0170	Normal	Up (2021)	Detected	
	GMA-D	22204	69	77	89.6	ND	0.0887	0.0457	0.0152	Normal	Up (2021)	Detected	
Sodium (mg/L)	LCS	12340C	52	52	100	4.35	49.9	27.4	7.7	Undefined	Up (2021)	Detected	
	LDS	12340D	9	9	100	263	344	315	27	Normal	None (2007)	Not Detected	
	HTW	12340	44	44	100	12.0	74.1	35.7	17.0	Ln Normal	Down (2021)	Detected	
	GMA-U	22203	35	35	100	16.1	30.7	21.3	3.7	Normal	Down (2021)	Detected	
	GMA-D	22204	36	36	100	7.88	20.5	13.4	3.8	Normal	Down (2021)	Detected	
Sulfate (mg/L)	LCS	12340C	64	64	100	26.1	2,650	1,840	530	Undefined	Up (2021)	Detected	
	LDS	12340D	19	19	100	112	2,510	1,250	700	Undefined	Down (2007)	Not Detected	
	HTW	12340	54	54	100	352	958	628	159	Normal	Down (2021)	Detected	
	GMA-U	22203	59	59	100	64.2	738	251	149	Ln Normal	None (2021)	Detected	4,020 (Q3-12)
	GMA-D	22204	59	59	100	199	779	434	157	Normal	Down (2021)	Detected	
Calcium (mg/L)	GMA-U	22203	28	28	100	135	290	181	39	Ln Normal	None (2021)	Not Detected	
	GMA-D	22204	28	28	100	134	365	226	58	Normal	Down (2021)	Detected	
Lithium (mg/L)	GMA-U	22203	35	35	100	0.00577	0.0229	0.00956	0.00523	Undefined	Up (2021)	Not Detected	
	GMA-D	22204	35	35	100	0.00694	0.0102	0.00862	0.00088	Normal	None (2021)	Not Detected	
Magnesium (mg/L)	GMA-U	22203	28	28	100	32.5	65.6	47.5	9.6	Normal	Up (2021)	Not Detected	
	GMA-D	22204	28	28	100	37.2	66.6	49.1	8.3	Normal	Down (2021)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22203	15	28	53.6	ND	0.273	0.0250	0.0845	Undefined	Up (2021)	Not Detected	
	GMA-D	22204	1	28	3.6	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22203	28	28	100	2.07	3.50	2.59	0.35	Normal	None (2021)	Not Detected	
	GMA-D	22204	29	29	100	1.33	3.07	2.05	0.52	Normal	Down (2021)	Detected	
Selenium (mg/L)	GMA-U	22203	4	35	11.4	ND	0.0130	0.00300	0.00293	Undefined	Up (2021)	Detected	
	GMA-D	22204	4	35	11.4	ND	0.0178	0.00300	0.00299	Undefined	Up (2021)	Detected	
Technitium-99 (pCi/L)	GMA-U	22203	1	26	3.8	ND	8.44	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22204	0	26	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22203	35	35	100	524	1,410	689	199	Undefined	Up (2021)	Detected	
	GMA-D	22204	35	35	100	487	1,530	959	232	Normal	Down (2021)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22203	40	77	52.0	ND	0.213	0.00524	0.0253	Undefined	None (2021)	Detected	
	GMA-D	22204	15	77	19.5	ND	0.0270	0.00166	0.00546	Undefined	Down (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

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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

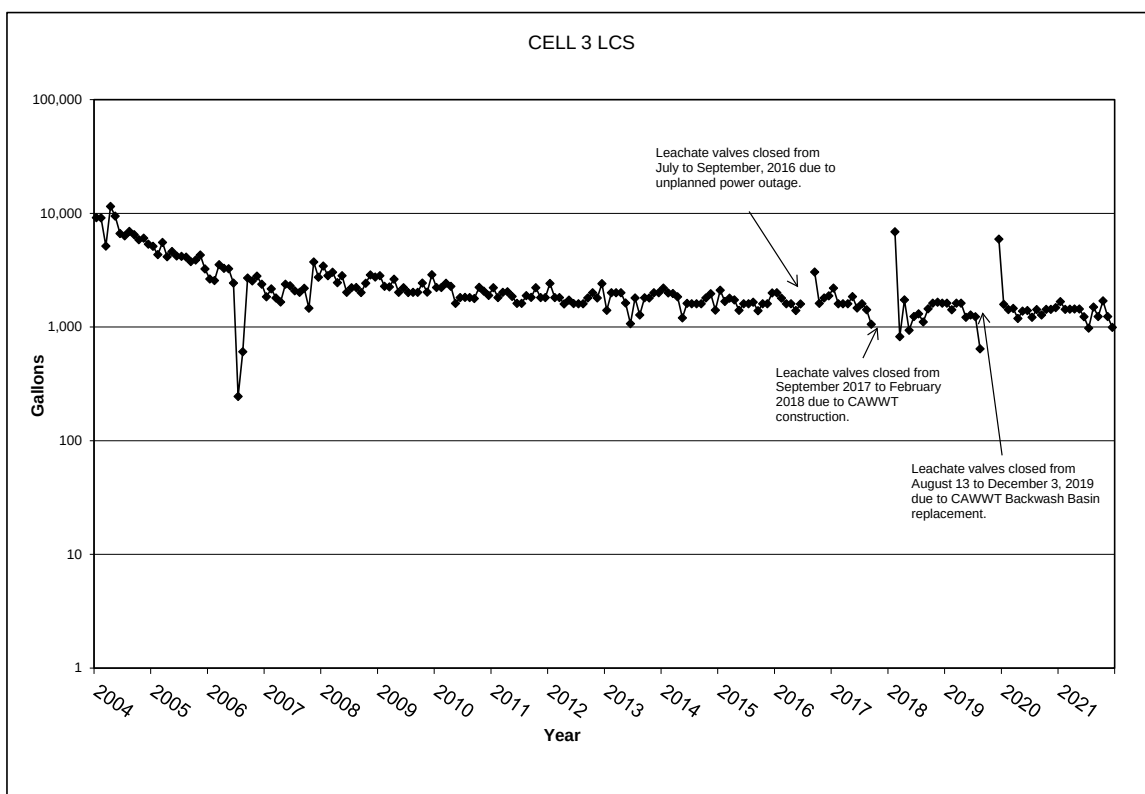


Figure A.5.3-1. Monthly Accumulation Volumes for Cell 3 LCS

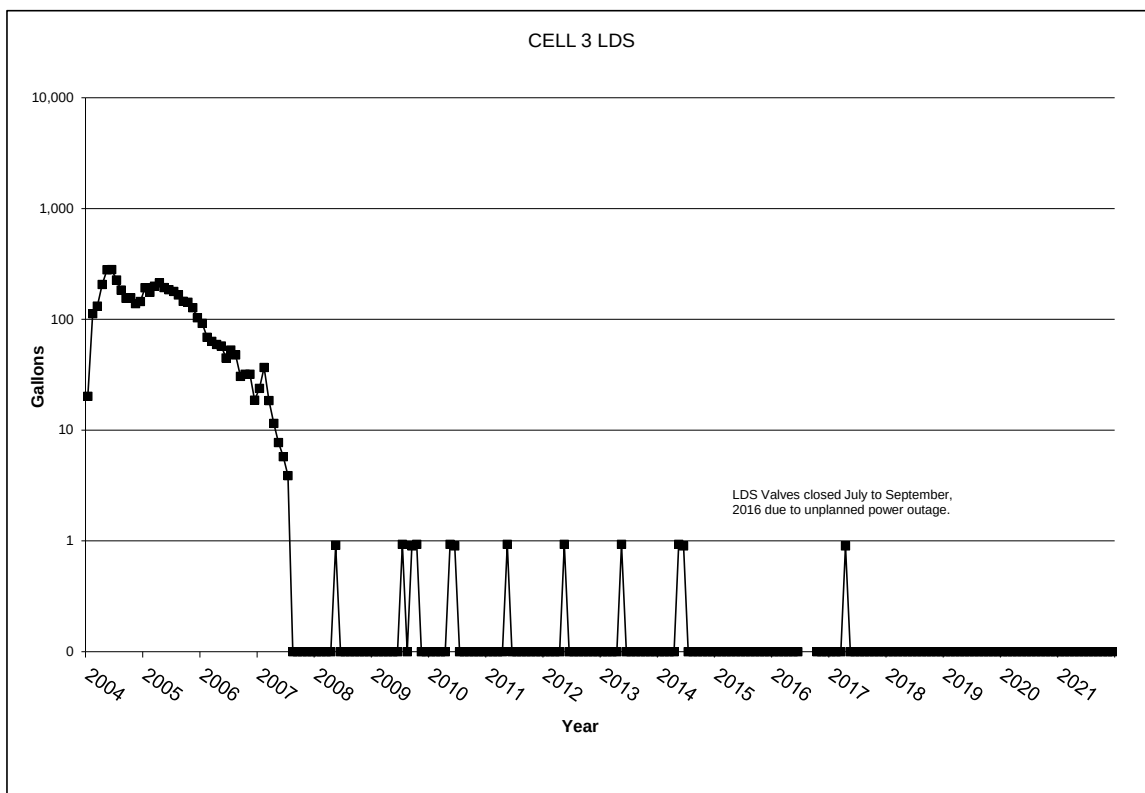


Figure A.5.3-2. Monthly Accumulation Volumes for Cell 3 LDS

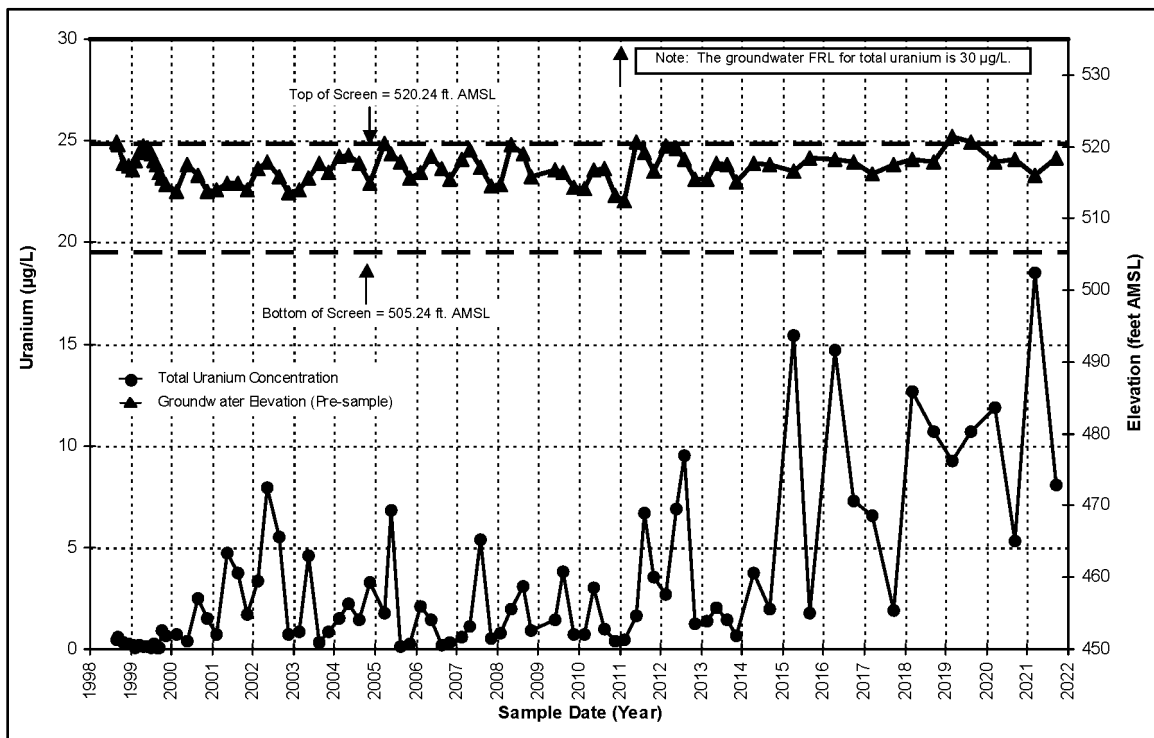


Figure A.5.3-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 3 Upgradient Monitoring Well 22203

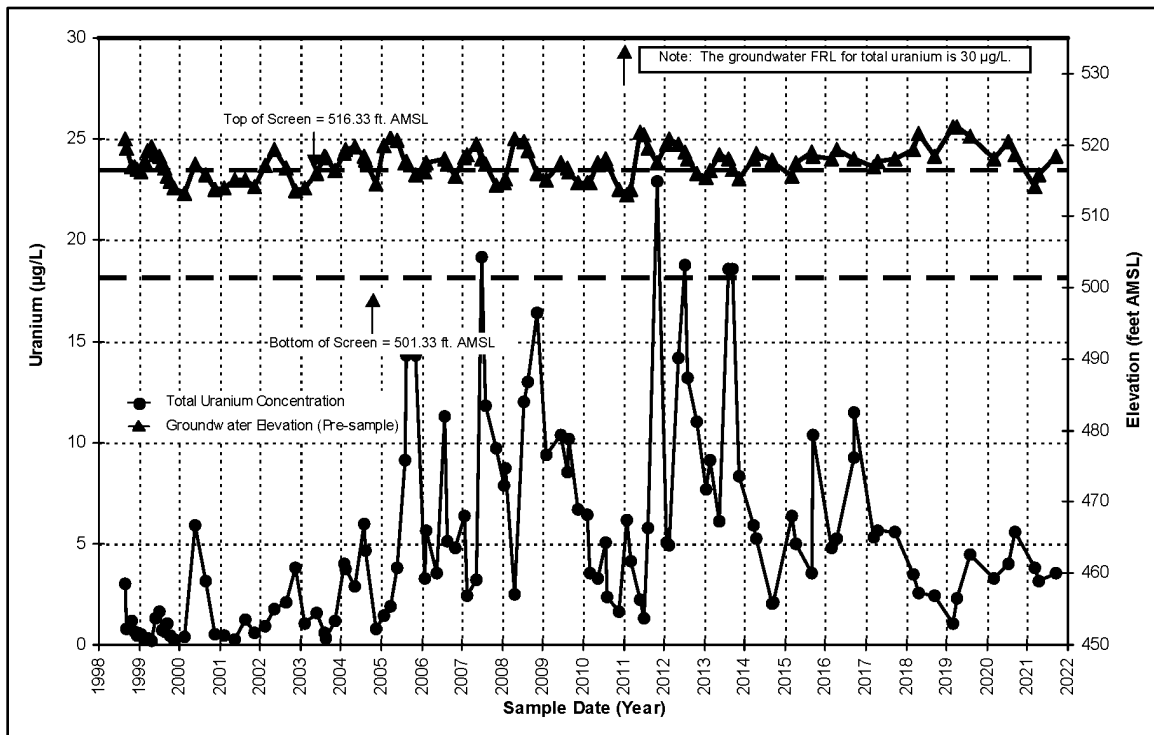


Figure A.5.3-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 3 Downgradient Monitoring Well 22204

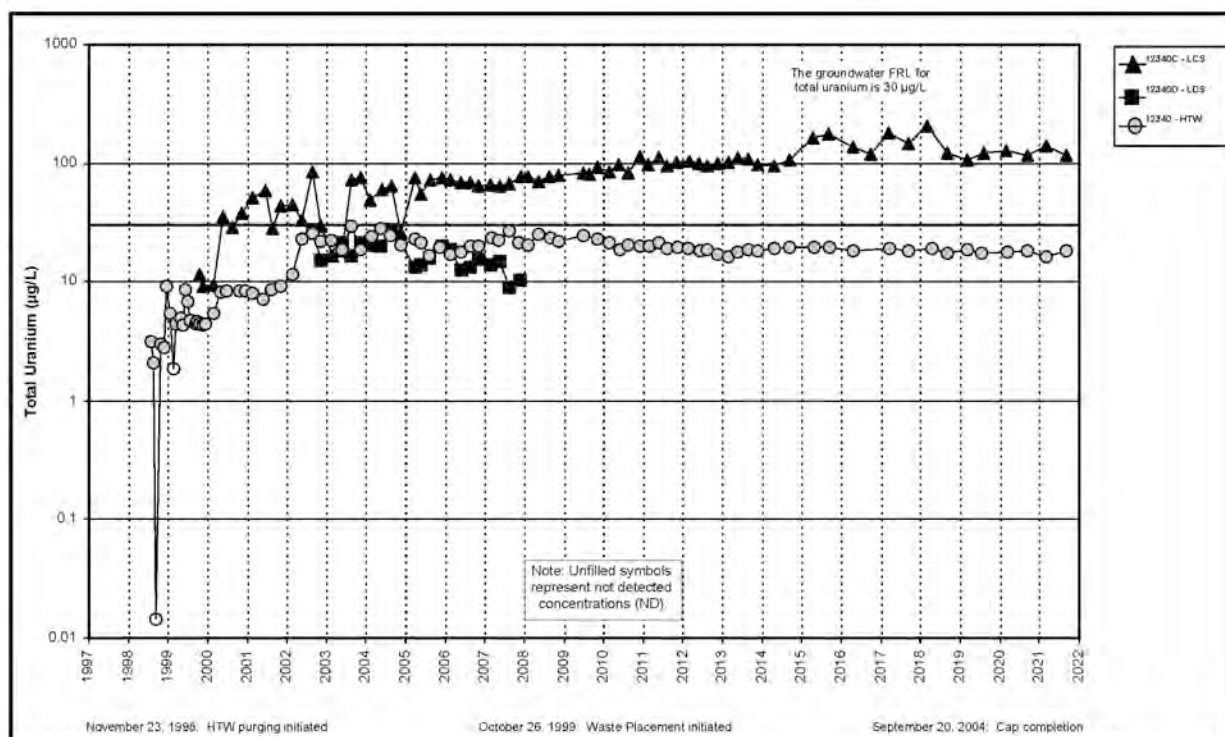


Figure A.5.3-5A. Cell 3 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

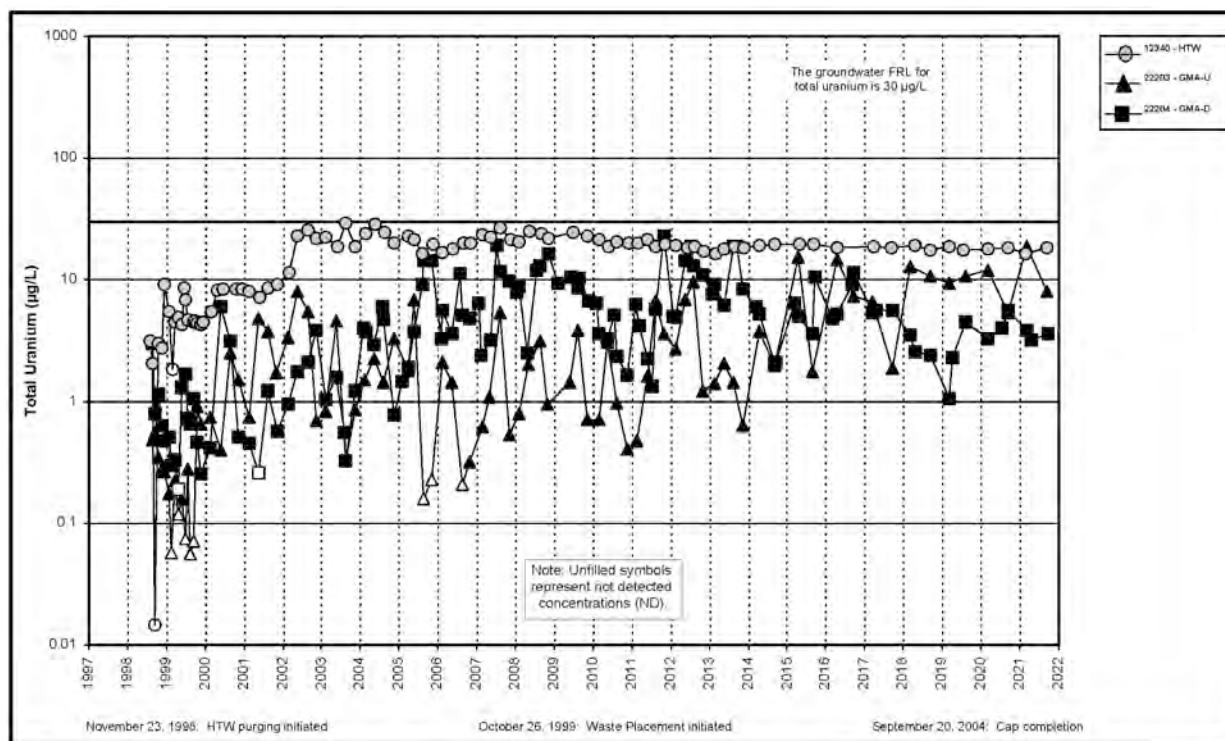


Figure A.5.3-5B. Cell 3 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

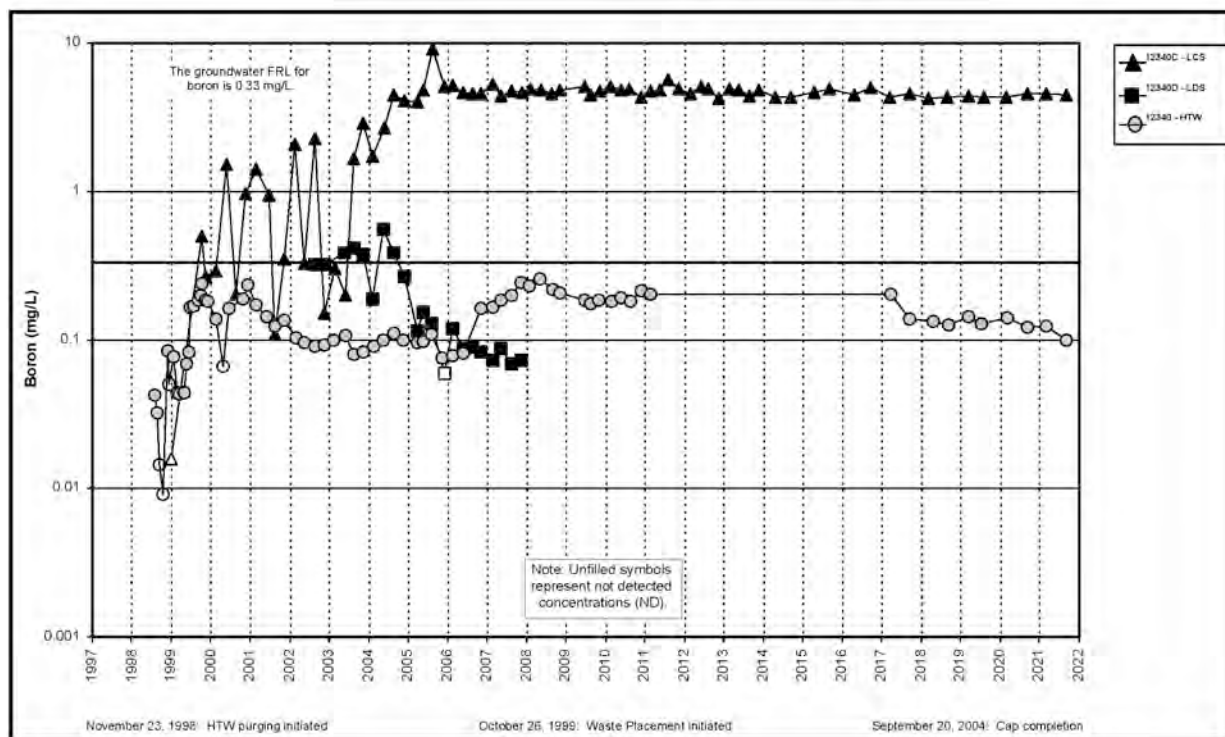


Figure A.5.3-6A. Cell 3 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

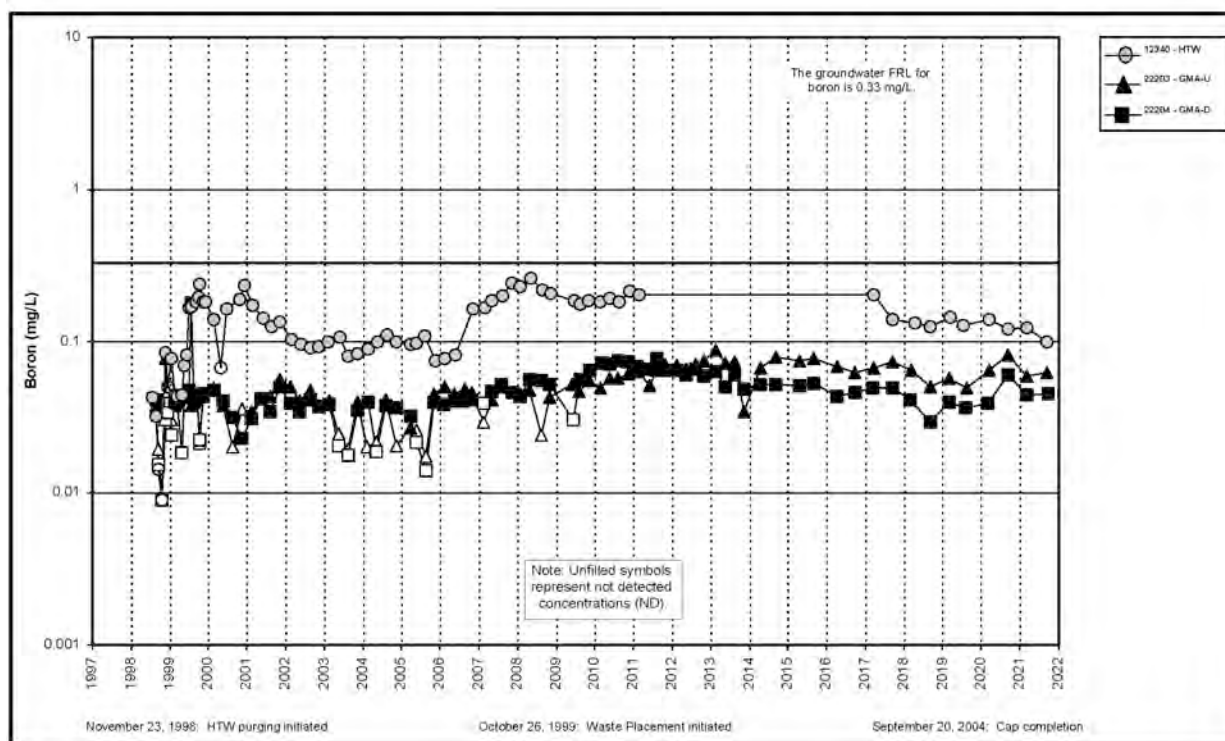


Figure A.5.3-6B. Cell 3 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

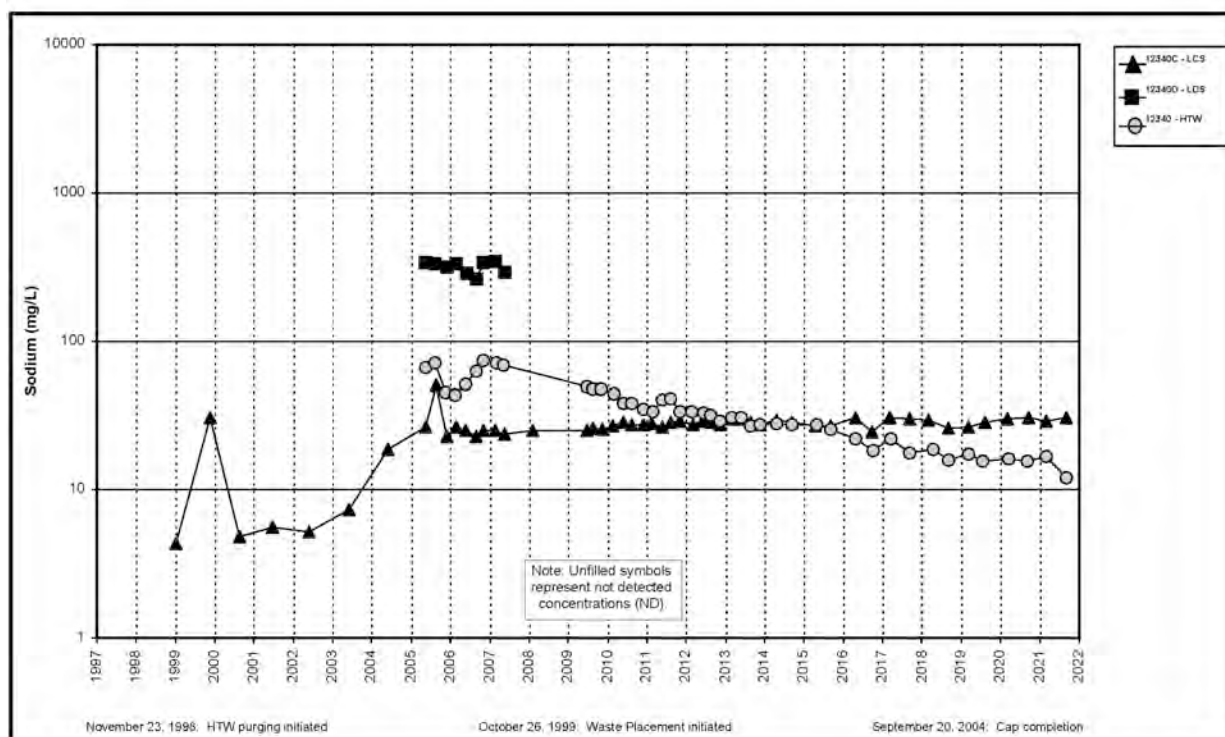


Figure A.5.3-7A. Cell 3 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

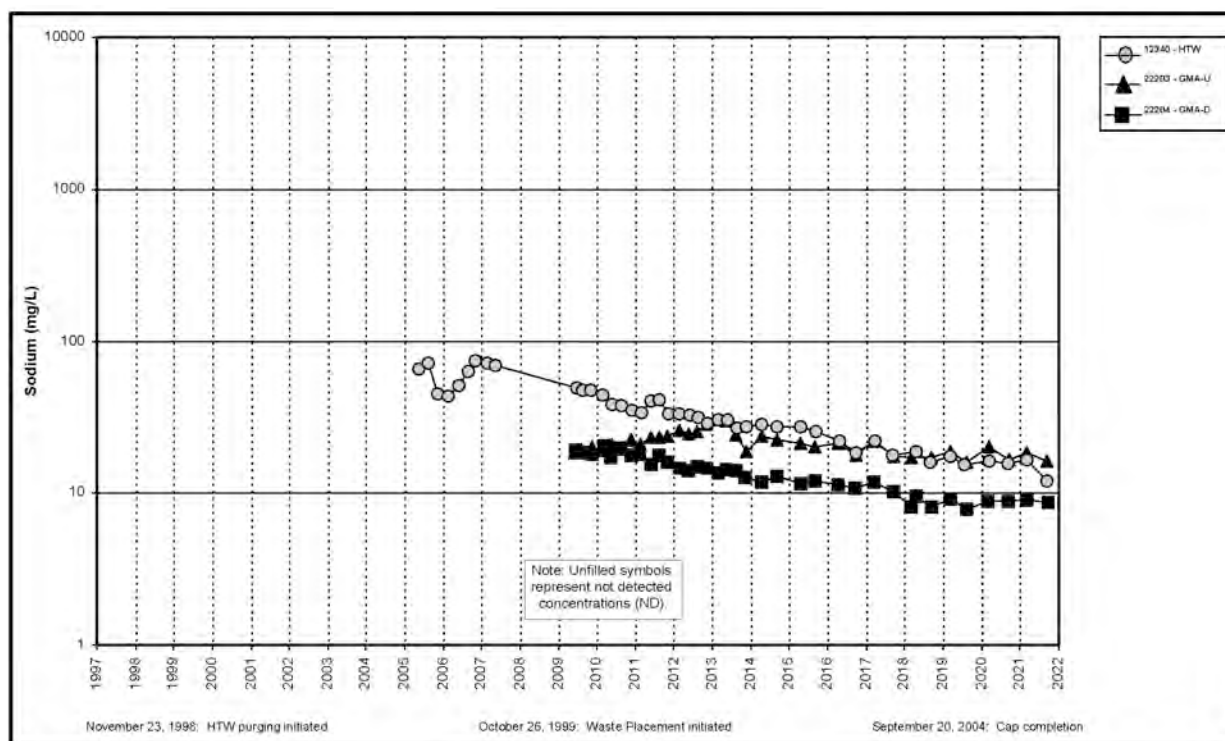


Figure A.5.3-7B. Cell 3 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

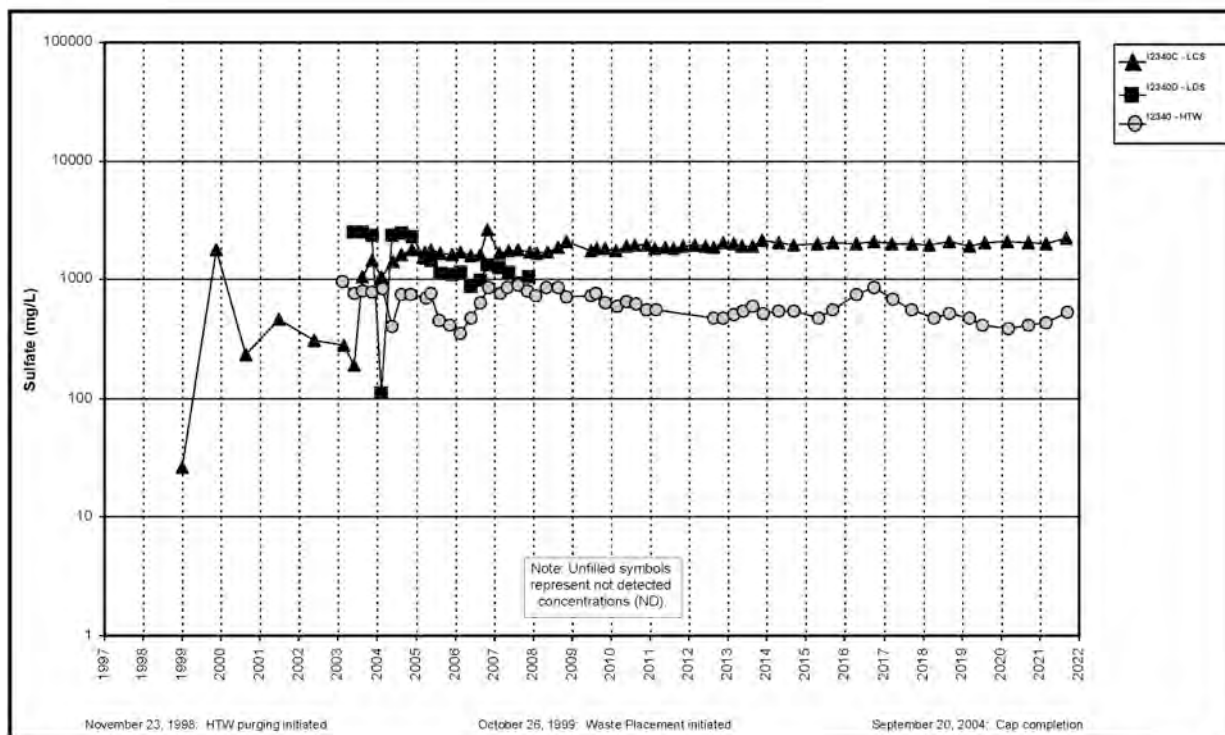


Figure A.5.3-8A. Cell 3 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

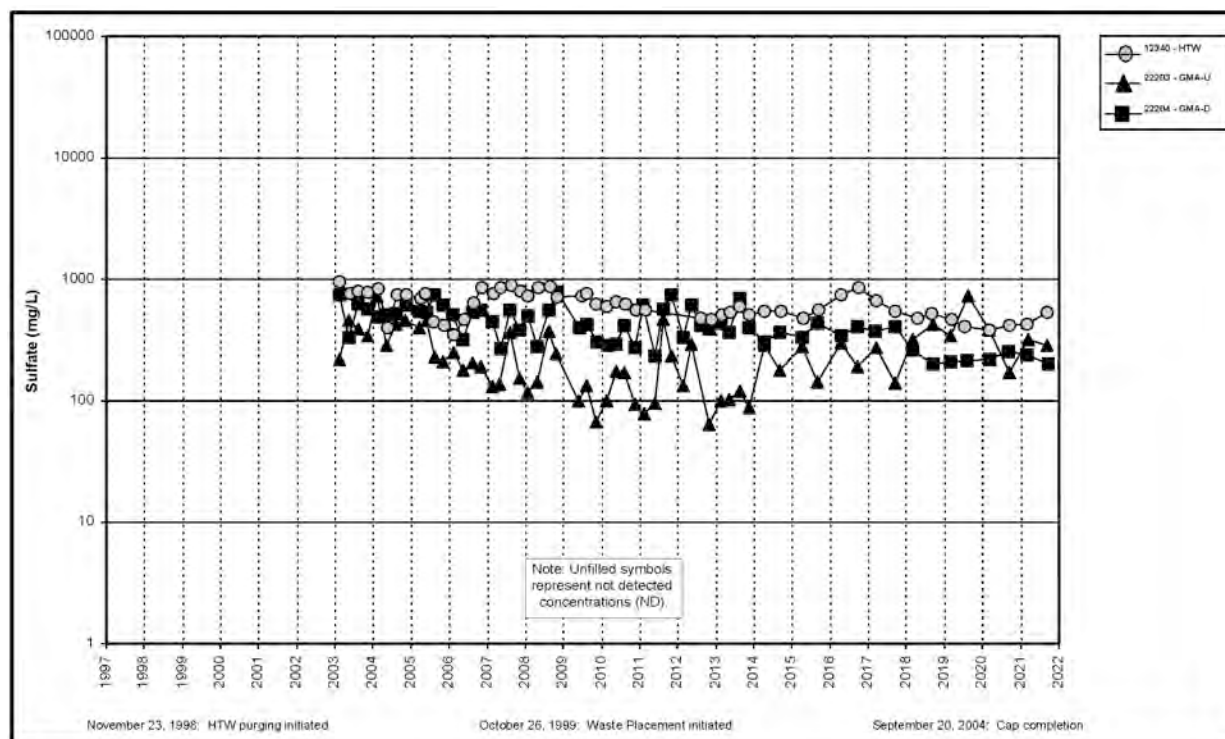


Figure A.5.3-8B. Cell 3 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

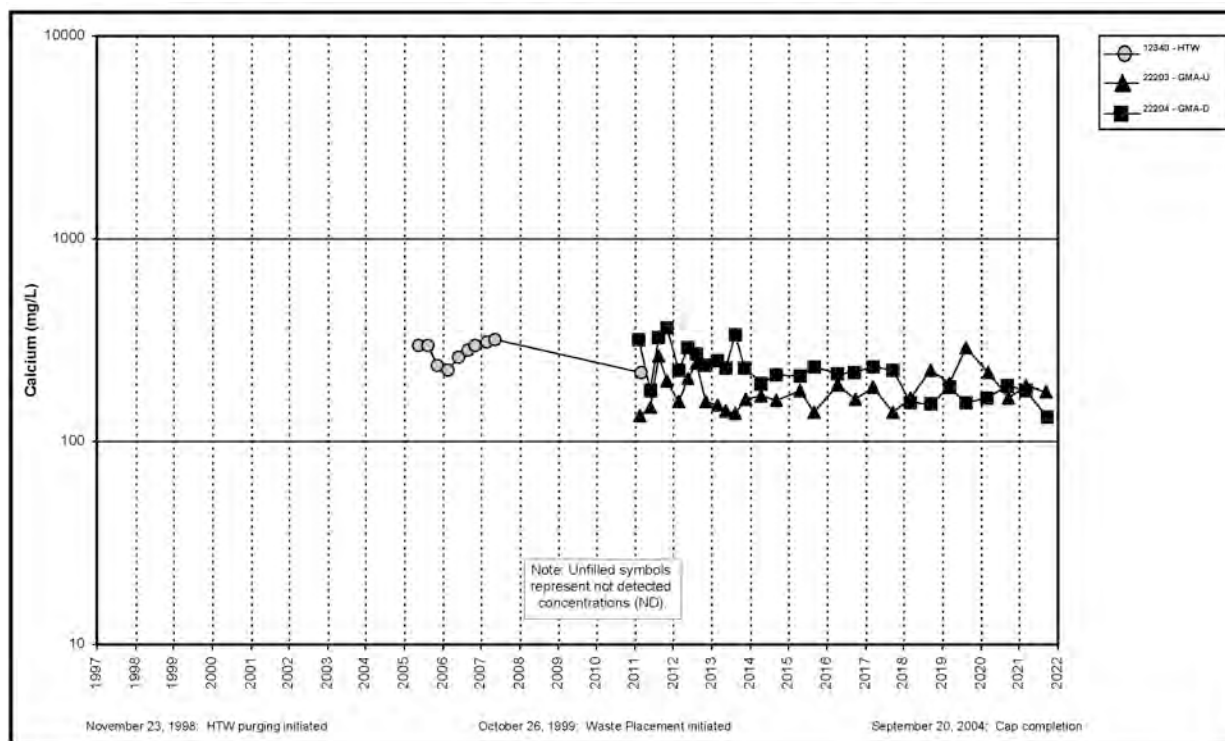


Figure A.5.3-9. Cell 3 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

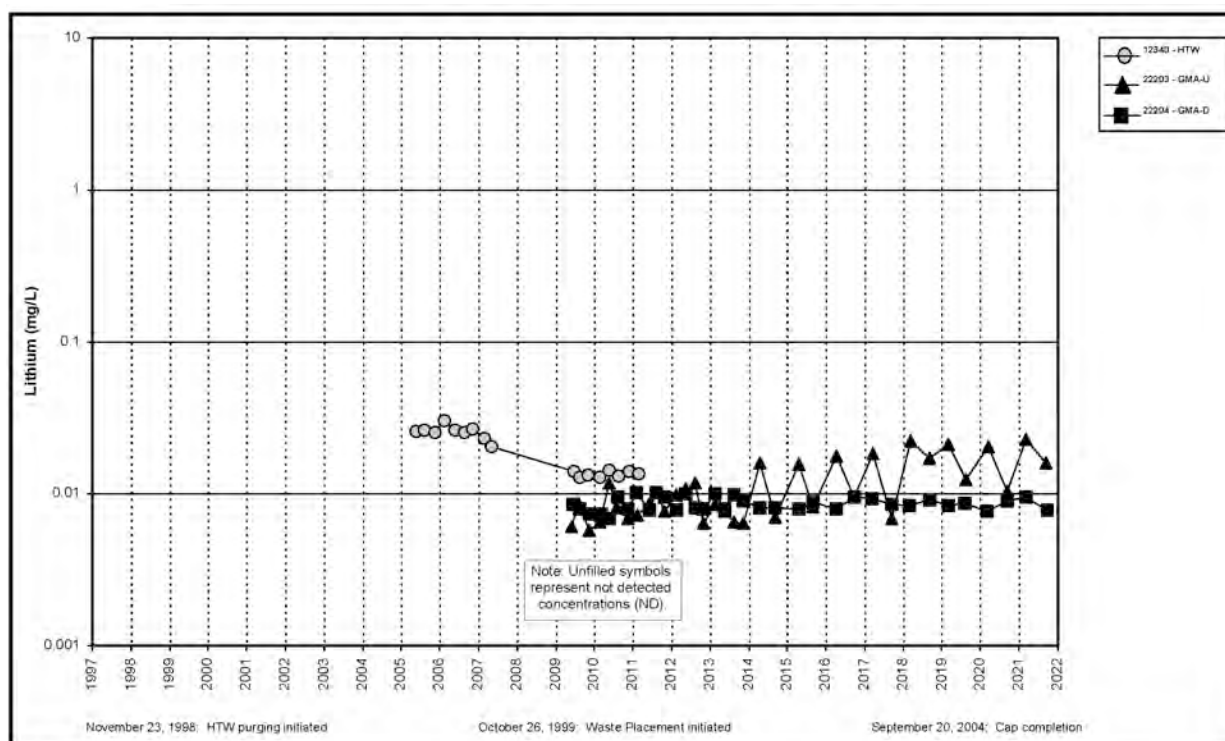


Figure A.5.3-10. Cell 3 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

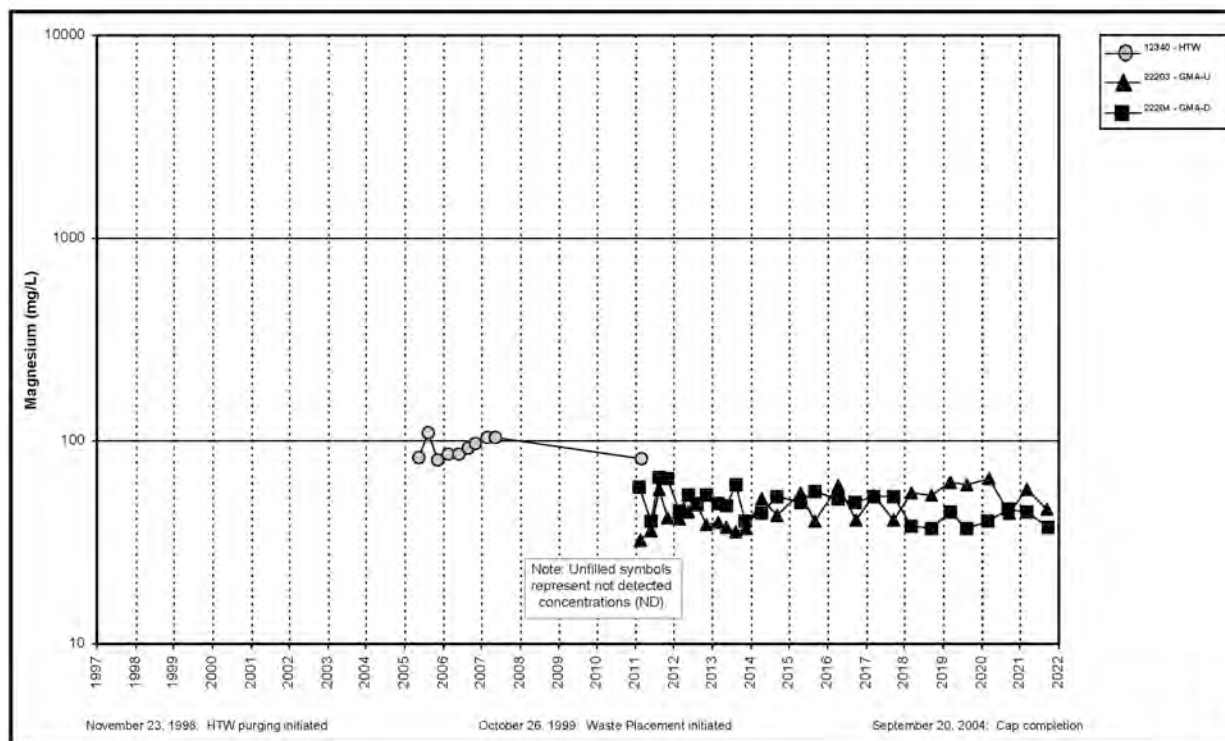


Figure A.5.3-11. Cell 3 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

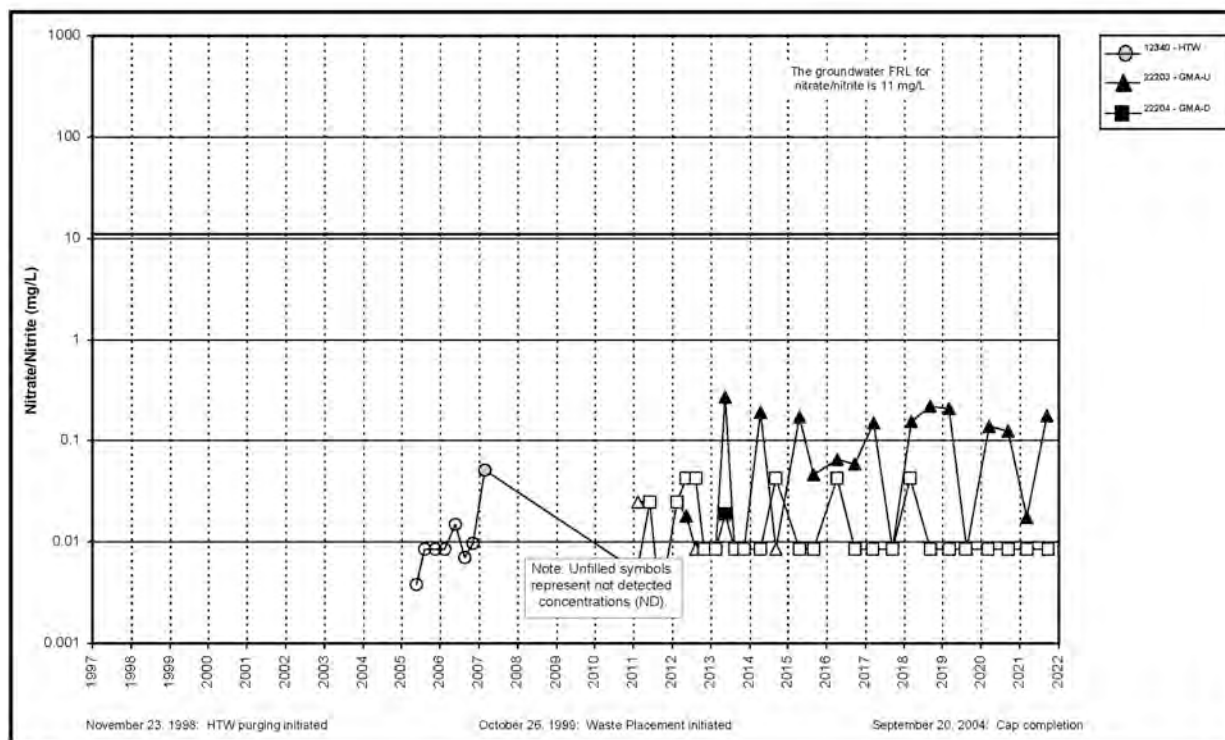


Figure A.5.3-12. Cell 3 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

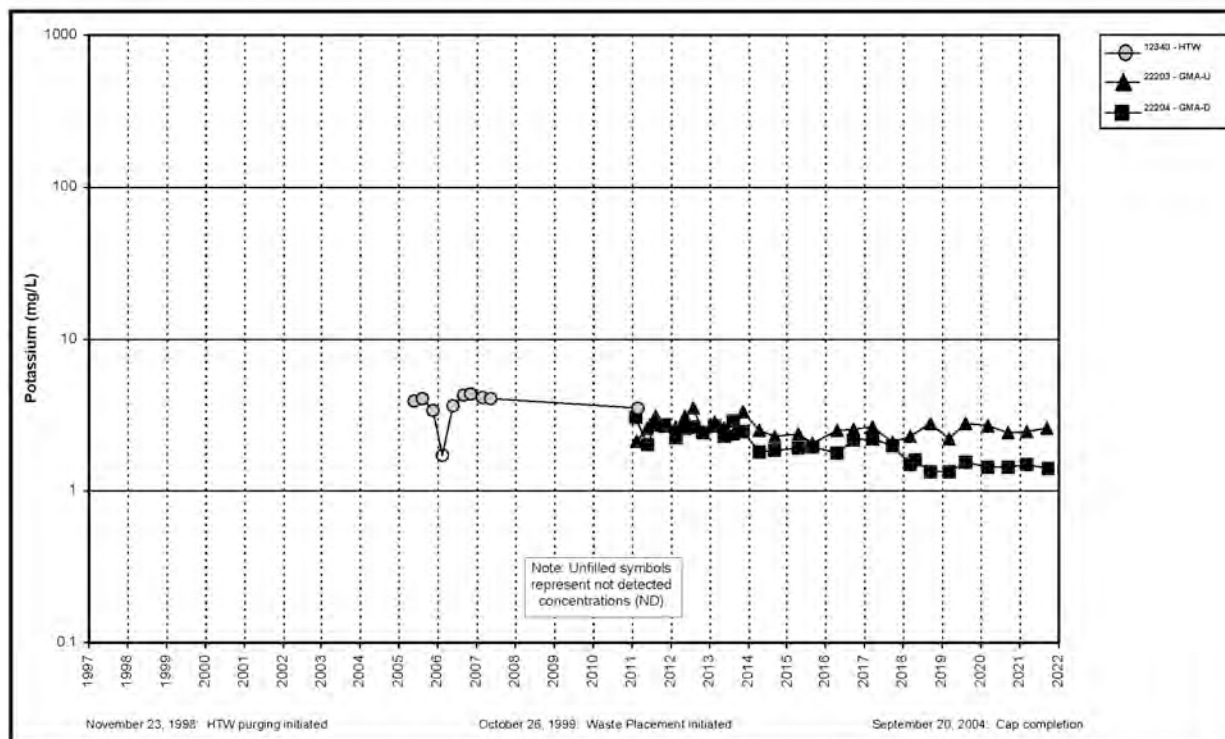


Figure A.5.3-13. Cell 3 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

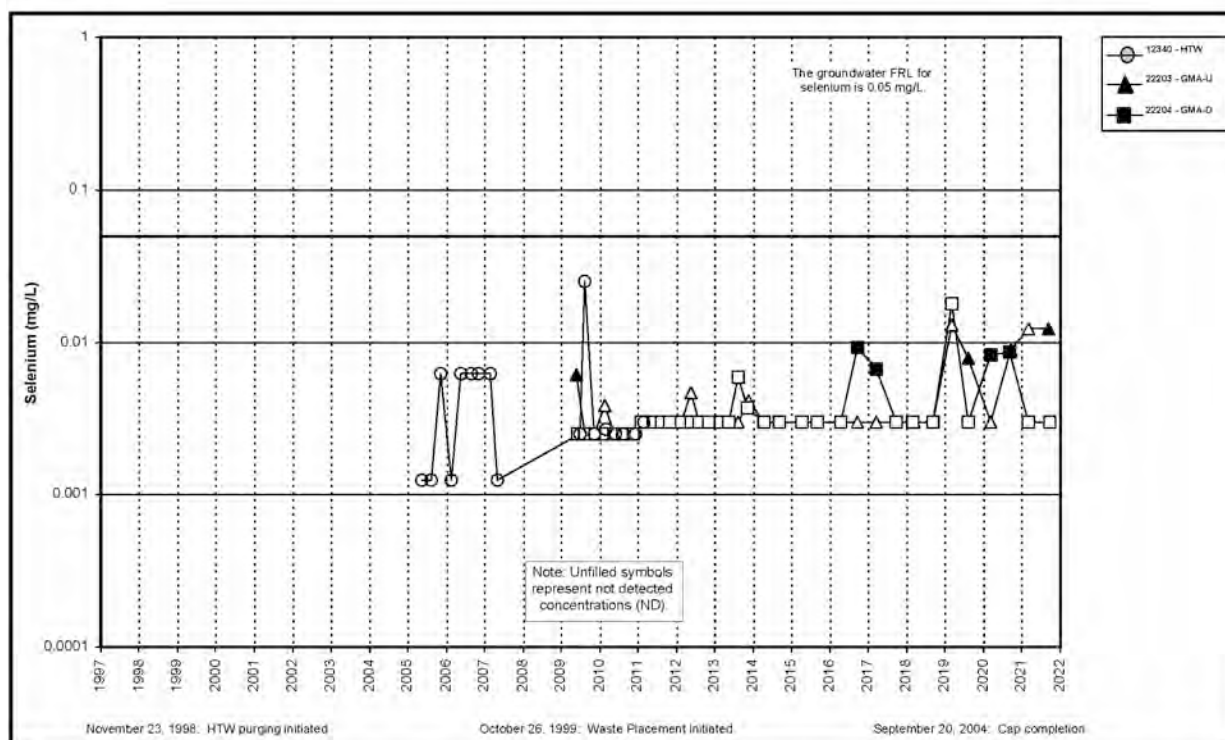


Figure A.5.3-14. Cell 3 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

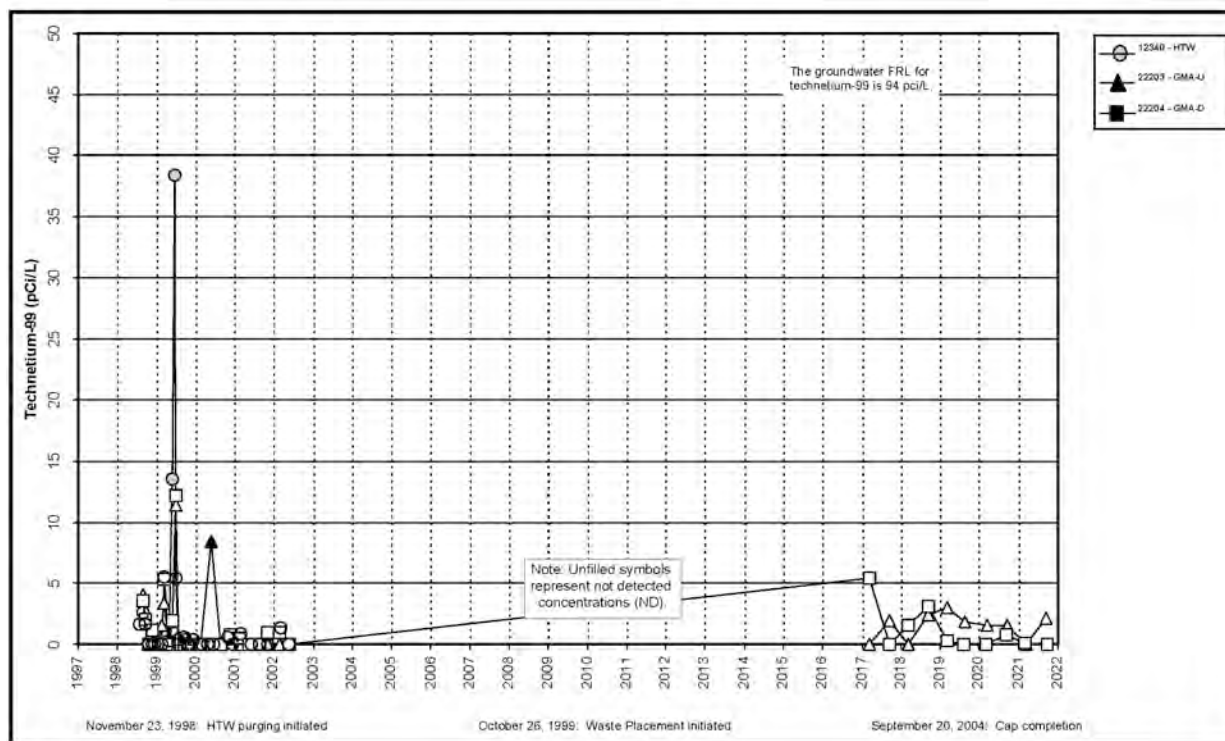


Figure A.5.3-15. Cell 3 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

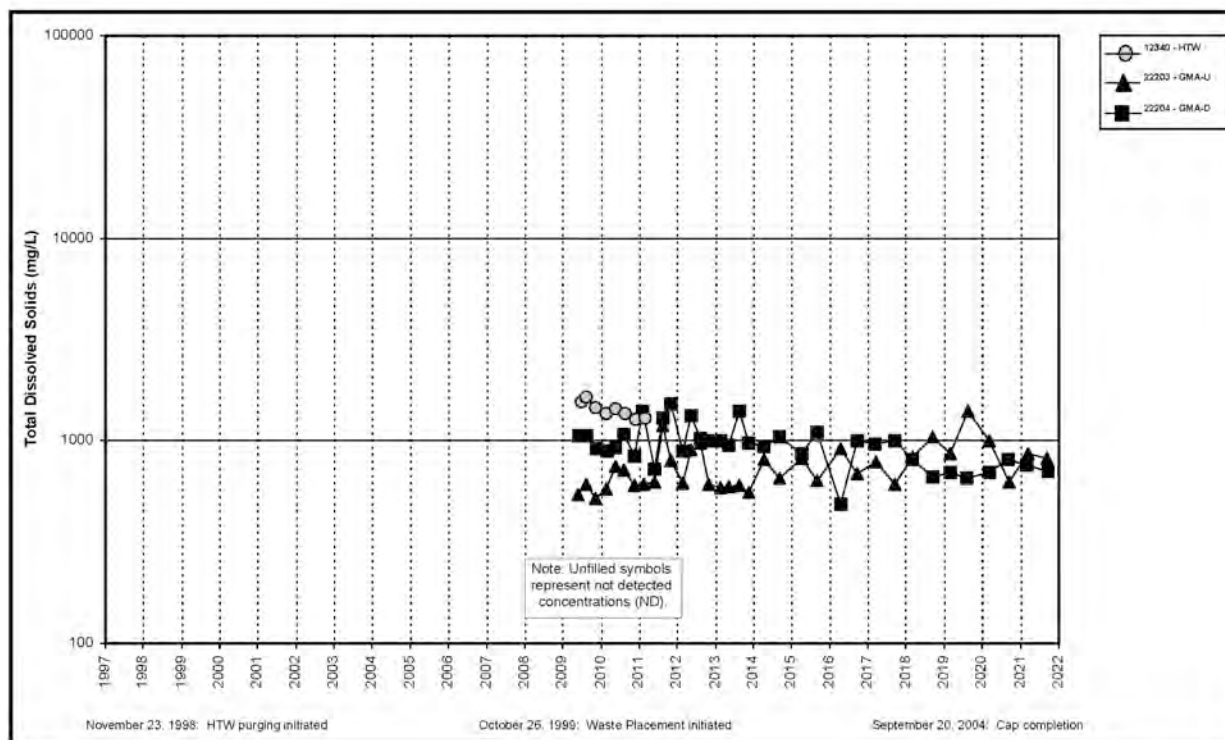


Figure A.5.3-16. Cell 3 Total Dissolved Solid Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

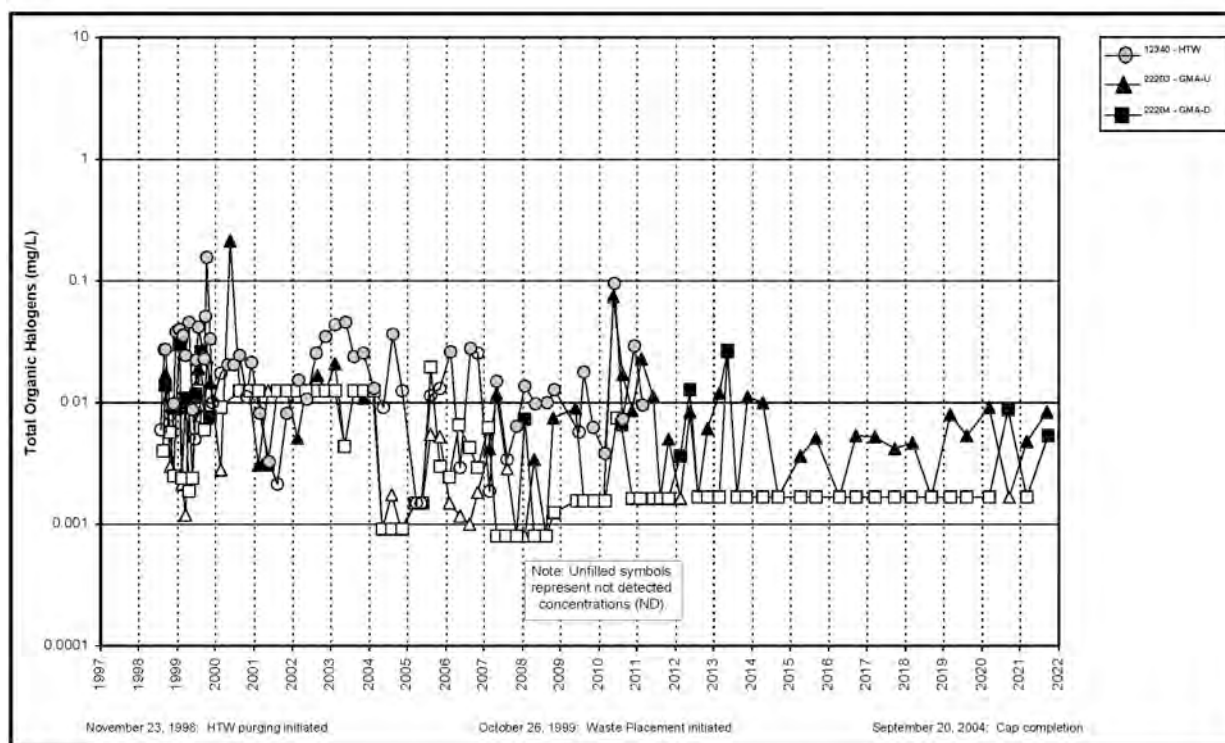


Figure A.5.3-17. Cell 3 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

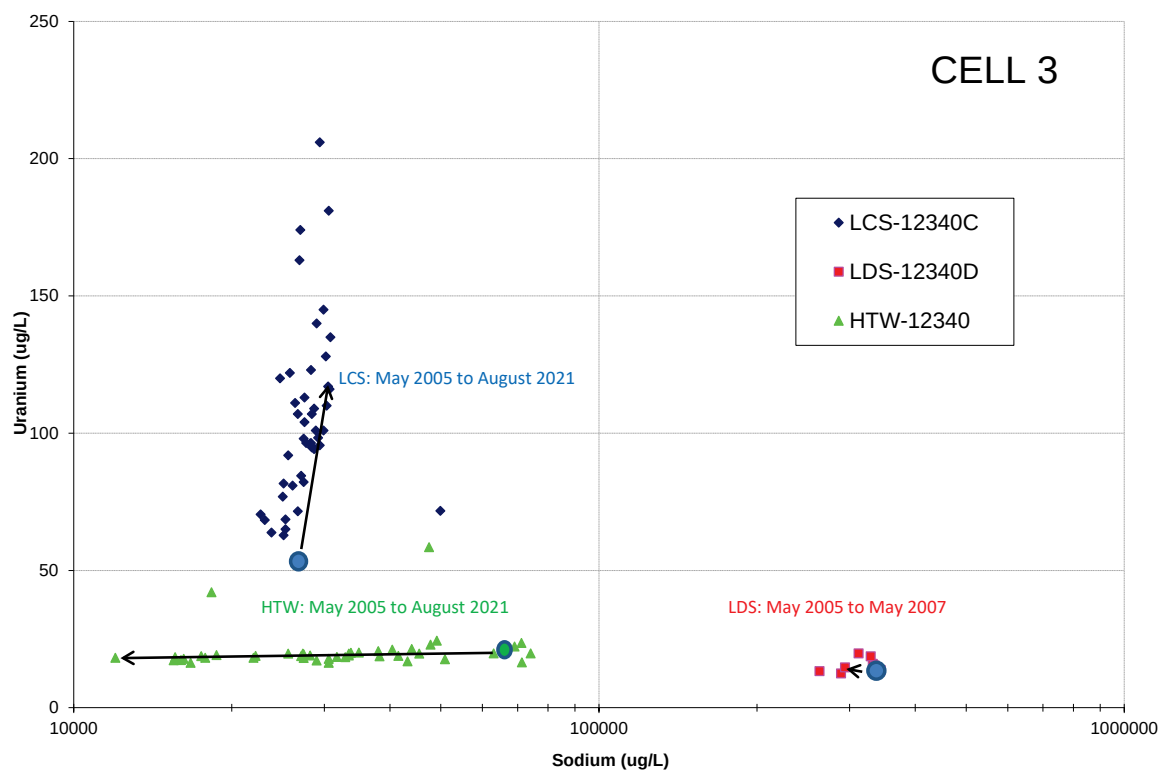


Figure A.5.3-18. Cell 3 Bivariate Plot for Uranium and Sodium

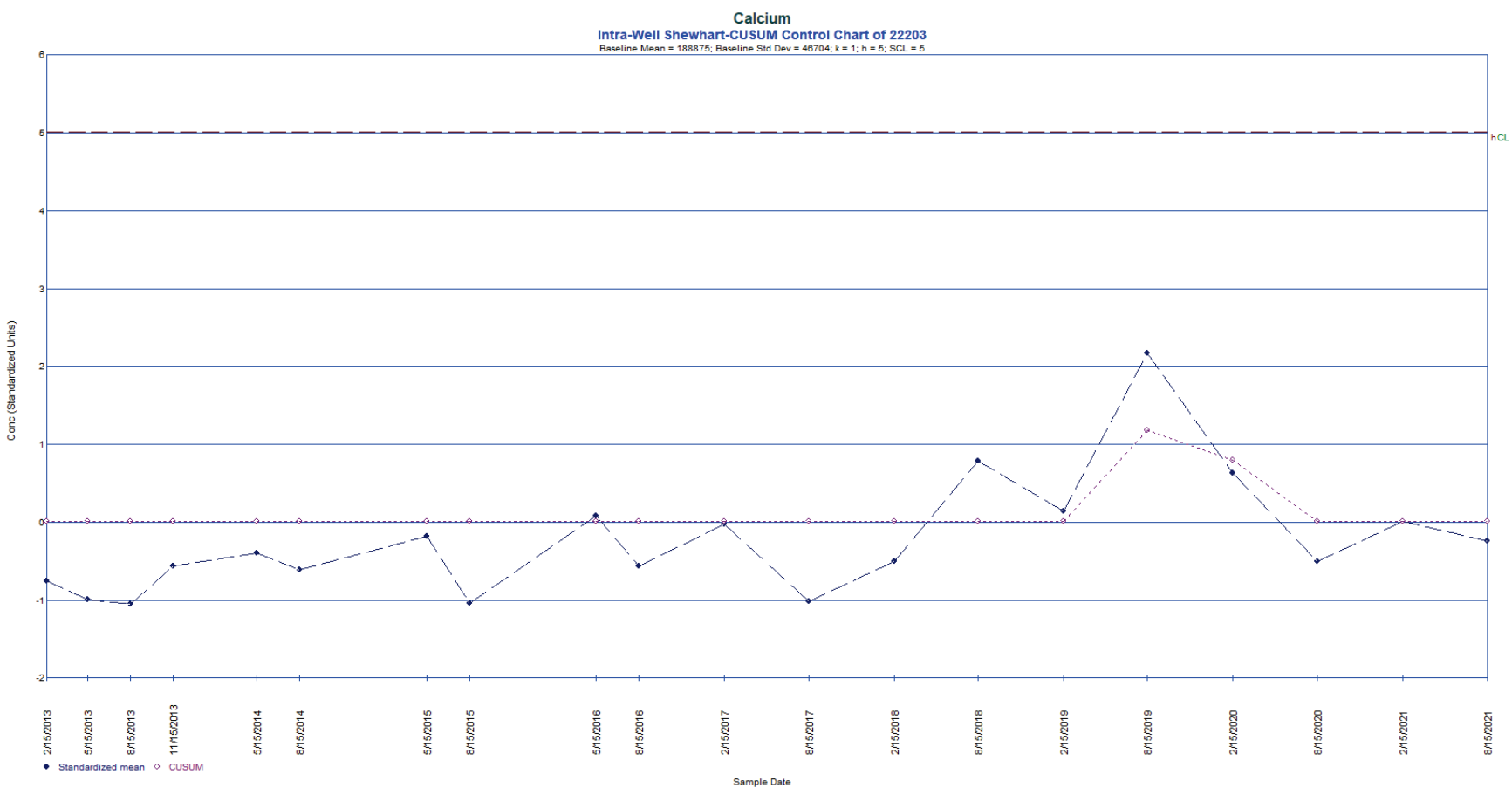


Figure A.5.3-19. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22203

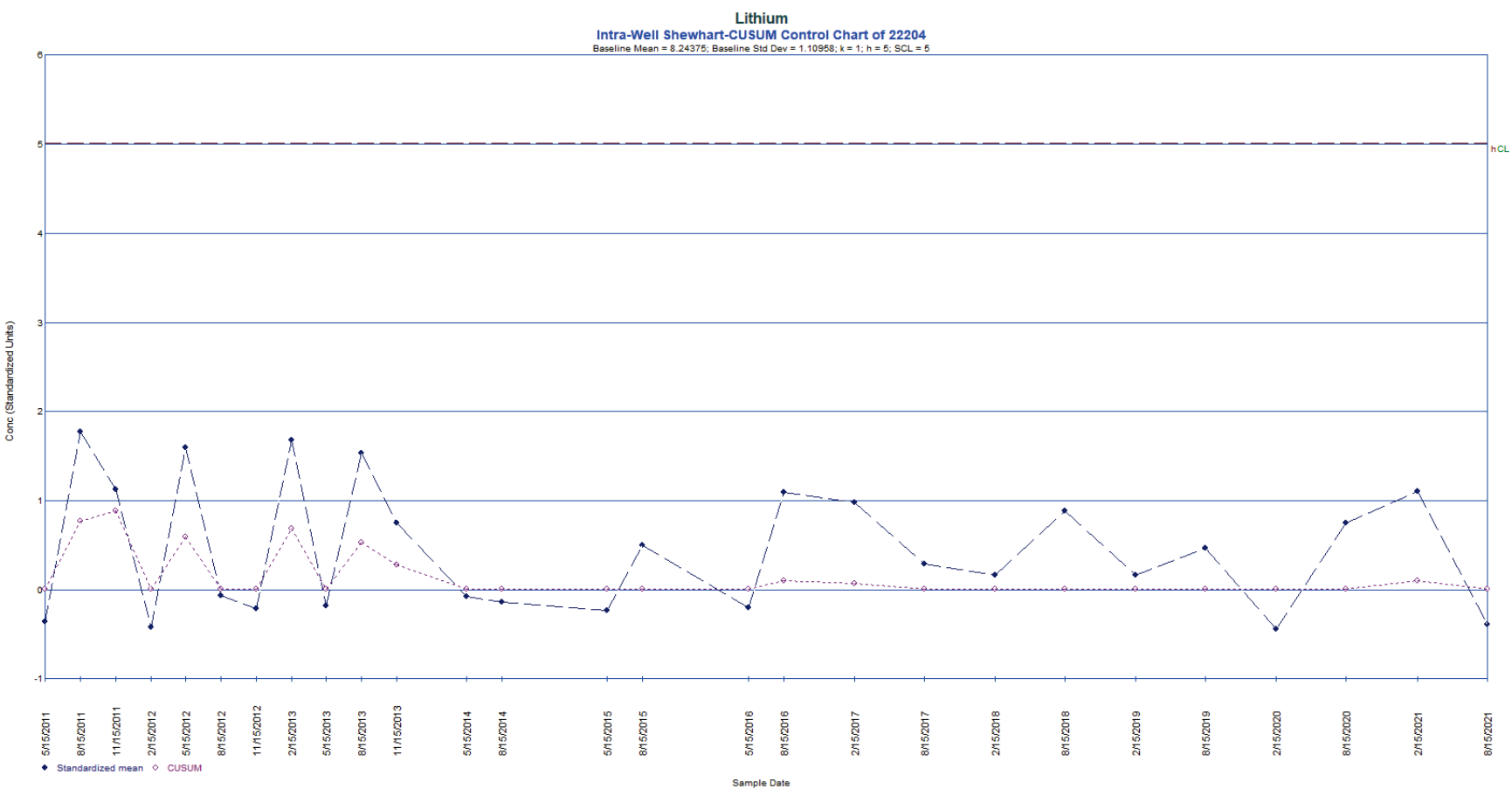


Figure A.5.3-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22204

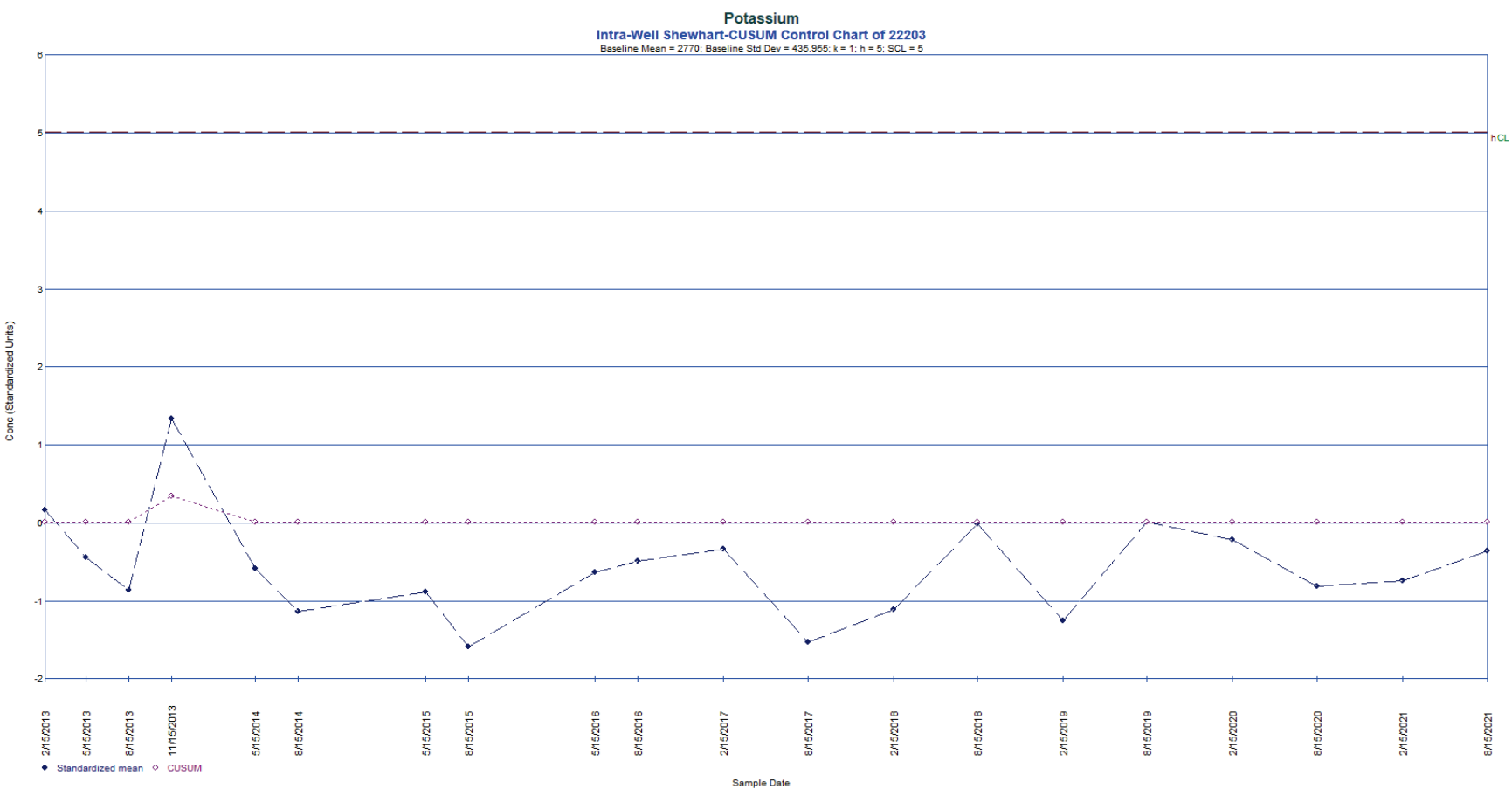


Figure A.5.3-21. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22203

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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	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.4-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.4-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.4-2)
- OSDF horizontal till well (HTW) 12341 water yield (refer to Table A.5.4-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.4-3 and A.5.4-4)
- Plots of concentration versus time (refer to Figures A.5.4-5A through A.5.4-17)
- A bivariate plot for uranium–sodium (refer to Figure A.5.4-18)
- Control charts (refer to 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 the 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.4.1.1 LCS and LDS Results

As shown in Table A.5.4-1 and summarized below, four parameters (total uranium, boron, sodium, and sulfate) have upward trends in the LCS and/or LDS based on the Mann-Kendall test for trend. In 2021, no new high concentrations were measured in the LCS of Cell 4.

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 been 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. New high concentrations of sodium [1,750 micrograms per liter (µg/L)] and sulfate (11,600 µg/L) were measured in the LDS of Cell 4 in 2021. The previous highs for sodium and sulfate were 1,420 µg/L and 9,010 µg/L, respectively.

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

Parameter	LCS 12341C 2021 Trend	LDS 12341D Trend (Year Last Sampled)
Total Uranium		Up (2021)
Boron		Up (2021)
Sodium	Up	Up (2021)
Sulfate	Up	Up (2021)

^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 and/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^a

Parameter	HTW 12341	GMA-U^b 22206	GMA-D^b 22205
Total Uranium		Up	
Boron		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; 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 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.5.4-1 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, HTW = horizontal till well.

A.5.4.3 Summary and Conclusions

- Four parameters in 2021 (total uranium, boron, sodium, and sulfate) have upward trends in the LCS and/or LDS based on the Mann-Kendall test for trend. New high concentrations of sodium (1,750 µg/L) and sulfate (11,600 µg/L) were measured in the LDS of Cell 4 in 2021. The previous highs for sodium and sulfate were 1,420 µg/L and 9,010 µg/L, respectively.
- Six parameters monitored semiannually have an upward concentration in the HTW or GMA wells of Cell 4: total uranium, boron, sodium, sulfate, lithium, and selenium. Separate and distinct chemical signatures for total uranium and sodium in the LCS, LDS, and HTW of Cell 4 indicate that water is not mixing between the horizons. Therefore, upward

concentration trends beneath Cell 4 (i.e., HTW or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance.

- Five control charts were constructed for Cell 4 parameters. All control charts exhibit “in control” conditions.

A.5.4.4 References

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

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

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

Table A.5.4-1. Summary Statistics for Cell 4

Parameter	Horizon ^a	Location	Number of Detected Samples	Total Number of Samples	Percent Detects	Minimum ^b	Maximum ^b	Average ^{c,d}	Standard Deviation ^d	Distribution Type ^{d,e}	Trend ^{d,f} (Year Last Sampled)	Serial Correlation ^{d,g}	Outliers ^{h,i}
Total Uranium (µg/L)	LCS	12341C	58	58	100	4.41	234	88.2	35.5	Undefined	None (2021)	Detected	
	LDS	12341D	41	41	100	5.74	55.9	14.8	11.6	Undefined	Up (2021)	Detected	
	HTW	12341	63	63	100	3.40	7.89	5.40	1.04	Normal	Down (2021)	Detected	
	GMA-U	22206	60	64	93.8	ND	4.67	1.37	0.97	Ln Normal	Up (2021)	Detected	
	GMA-D	22205	72	72	100	0.525	12.1	2.51	2.31	Ln Normal	None (2021)	Not Detected	
Boron (mg/L)	LCS	12341C	58	58	100	0.0626	1.93	0.854	0.267	Undefined	Down (2021)	Detected	
	LDS	12341D	41	41	100	0.415	2.89	0.697	0.654	Undefined	Up (2021)	Detected	
	HTW	12341	43	46	93.5	0.0284	1.24	0.0966	0.211	Undefined	Down (2021)	Detected	
	GMA-U	22206	59	64	92.2	ND	0.0817	0.0441	0.0133	Undefined	Up (2021)	Detected	
	GMA-D	22205	57	64	89.1	ND	0.0807	0.0460	0.0143	Normal	Up (2021)	Detected	
Sodium (mg/L)	LCS	12341C	48	48	100	22.0	117	54.2	12.9	Undefined	Up (2021)	Not Detected	
	LDS	12341D	27	27	100	307	1,750	495	342	Undefined	Up (2021)	Detected	
	HTW	12341	44	44	100	13.7	18.1	15.2	1.0	Normal	Down (2021)	Detected	
	GMA-U	22206	35	35	100	12.3	22.3	17.2	3.0	Normal	Up (2021)	Detected	
	GMA-D	22205	36	36	100	8.78	22.2	15.2	4.1	Undefined	Down (2021)	Detected	
Sulfate (mg/L)	LCS	12341C	58	58	100	140	3,940	2,750	766	Undefined	Up (2021)	Detected	
	LDS	12341D	41	41	100	1,470	11,600	2,630	2310	Undefined	Up (2021)	Detected	
	HTW	12341	54	54	100	153	531	278	118	Undefined	Up (2021)	Detected	
	GMA-U	22206	59	59	100	90.4	559	214	106	Ln Normal	Down (2021)	Detected	3,720 (Q3-12)
	GMA-D	22205	59	59	100	199	535	337	75	Normal	None (2021)	Not Detected	
Calcium (mg/L)	GMA-U	22206	28	28	100	137	217	150	22	Undefined	None (2021)	Not Detected	
	GMA-D	22205	28	28	100	168	268	219	22	Normal	Down (2021)	Not Detected	
Lithium (mg/L)	GMA-U	22206	35	35	100	0.00852	0.0175	0.0120	0.0024	Normal	Down (2021)	Detected	
	GMA-D	22205	35	35	100	0.00665	0.0167	0.00832	0.00225	Undefined	Up (2021)	Detected	
Magnesium (mg/L)	GMA-U	22206	28	28	100	30.2	43.8	35.9	3.6	Normal	None (2021)	Not Detected	
	GMA-D	22205	28	28	100	40.1	63.2	52.4	5.5	Normal	None (2021)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22206	2	28	7.1	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	4	28	14.3	ND	0.0818	0.00850	0.0173	Undefined	None (2021)	Not Detected	
Potassium (mg/L)	GMA-U	22206	28	28	100	3.04	4.39	3.67	0.37	Normal	Down (2021)	Detected	
	GMA-D	22205	29	29	100	1.71	3.22	2.33	0.40	Normal	Down (2021)	Detected	
Selenium (mg/L)	GMA-U	22206	3	35	8.6	ND	0.0294	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	5	35	14.3	ND	0.0180	0.00300	0.00378	Undefined	Up (2021)	Detected	
Technitium-99 (pCi/L)	GMA-U	22206	1	25	4.0	ND	8.54	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22205	0	25	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22206	35	35	100	551	877	626	82	Undefined	None (2021)	Not Detected	
	GMA-D	22205	35	35	100	726	1,180	938	101	Normal	None (2021)	Not Detected	
Total Organic Halogens (mg/L)	GMA-U	22206	23	64	35.9	ND	0.0640	0.00370	0.00957	Undefined	None (2021)	Detected	
	GMA-D	22205	15	64	23.4	ND	0.0142	0.00166	0.00392	Undefined	None (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

^jThe Cell 4 LDS was dry, resulting in no data from fourth quarter 2011 through 2016.

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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

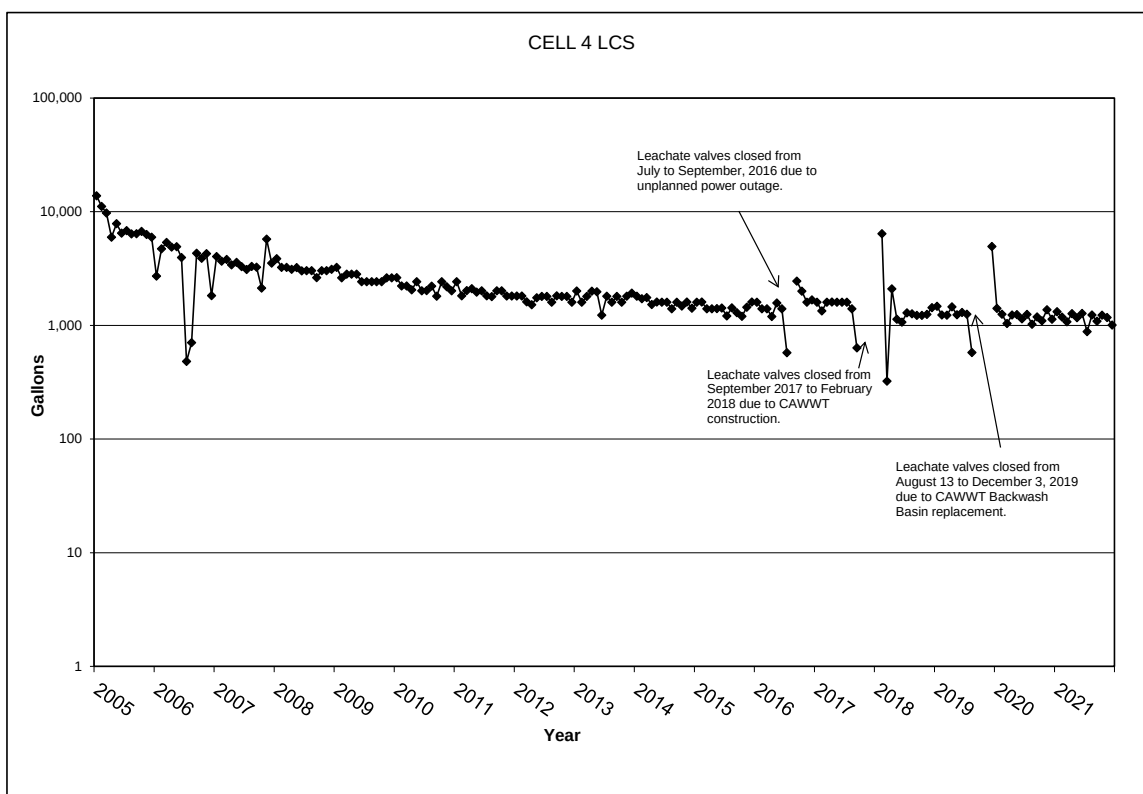


Figure A.5.4-1. Monthly Accumulation Volumes for Cell 4 LCS

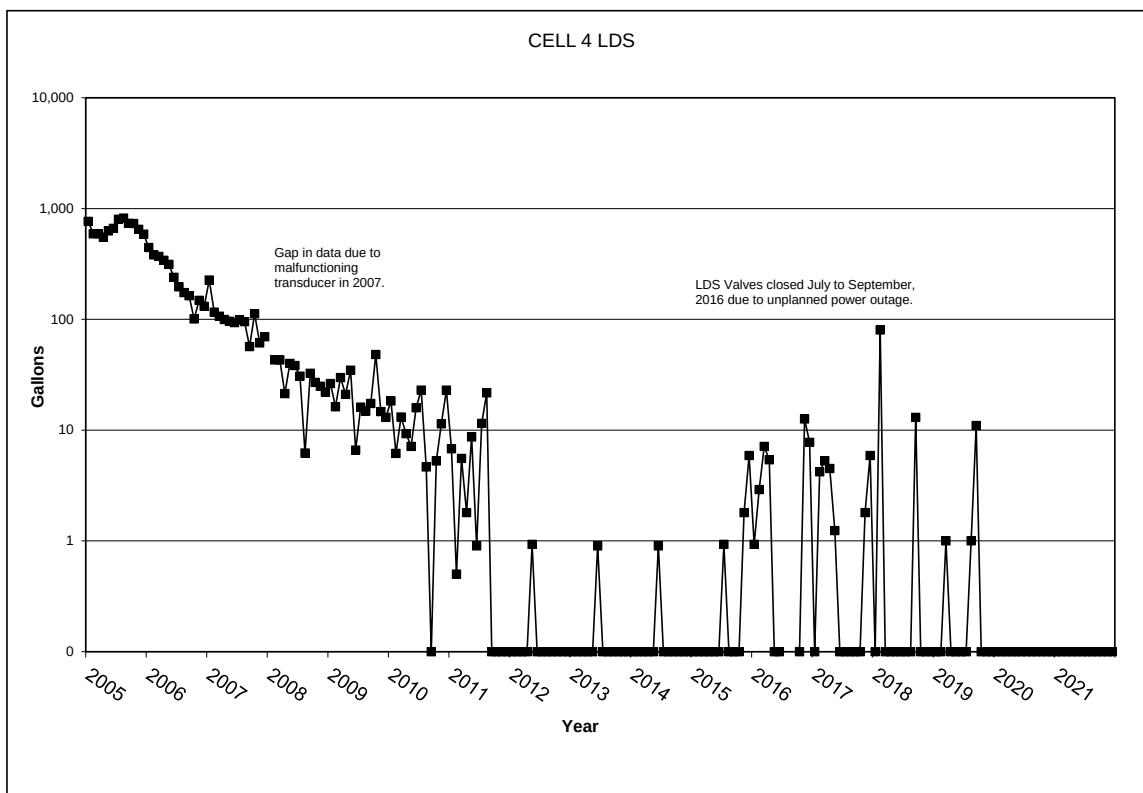


Figure A.5.4-2. Monthly Accumulation Volumes for Cell 4 LDS

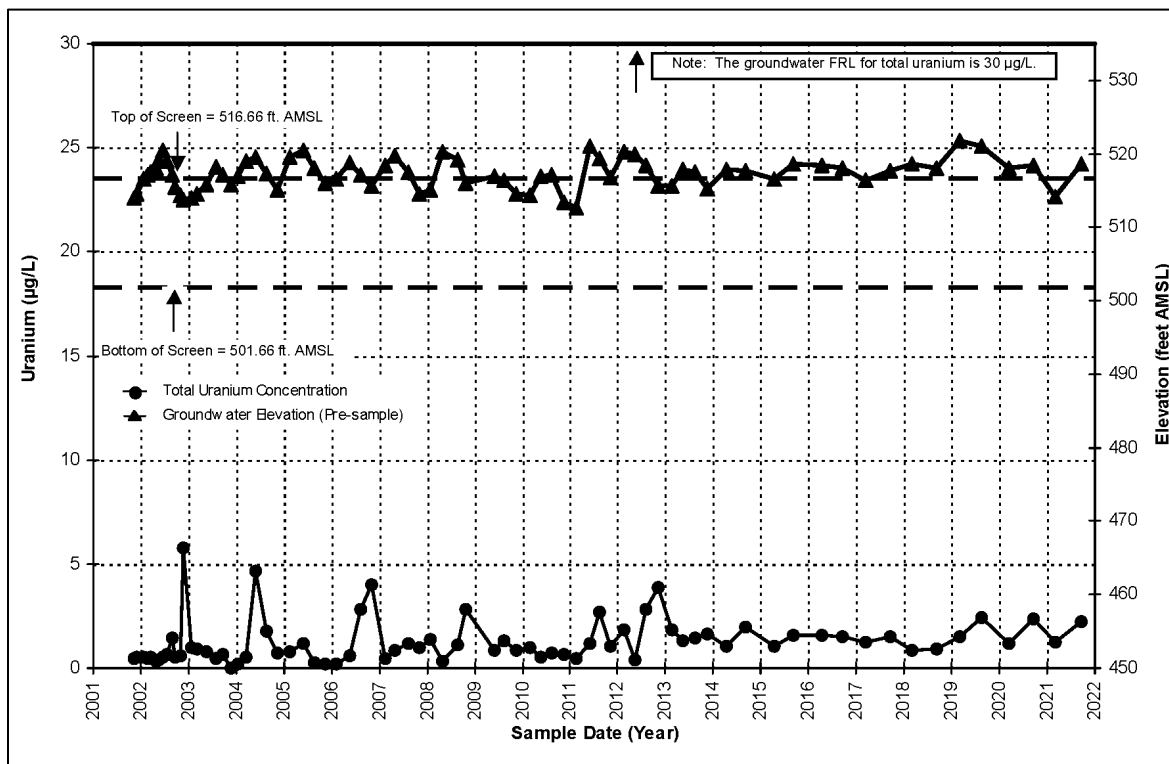


Figure A.5.4-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 4 Upgradient Monitoring Well 22206

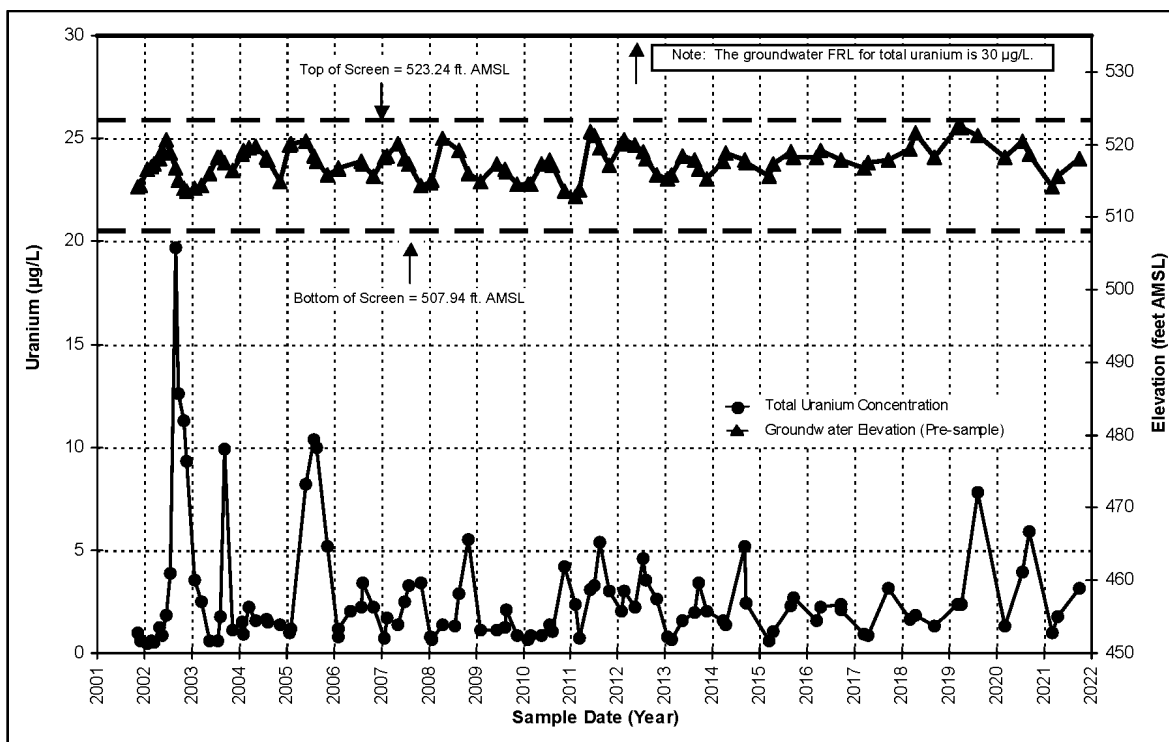


Figure A.5.4-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 4 Downgradient Monitoring Well 22205

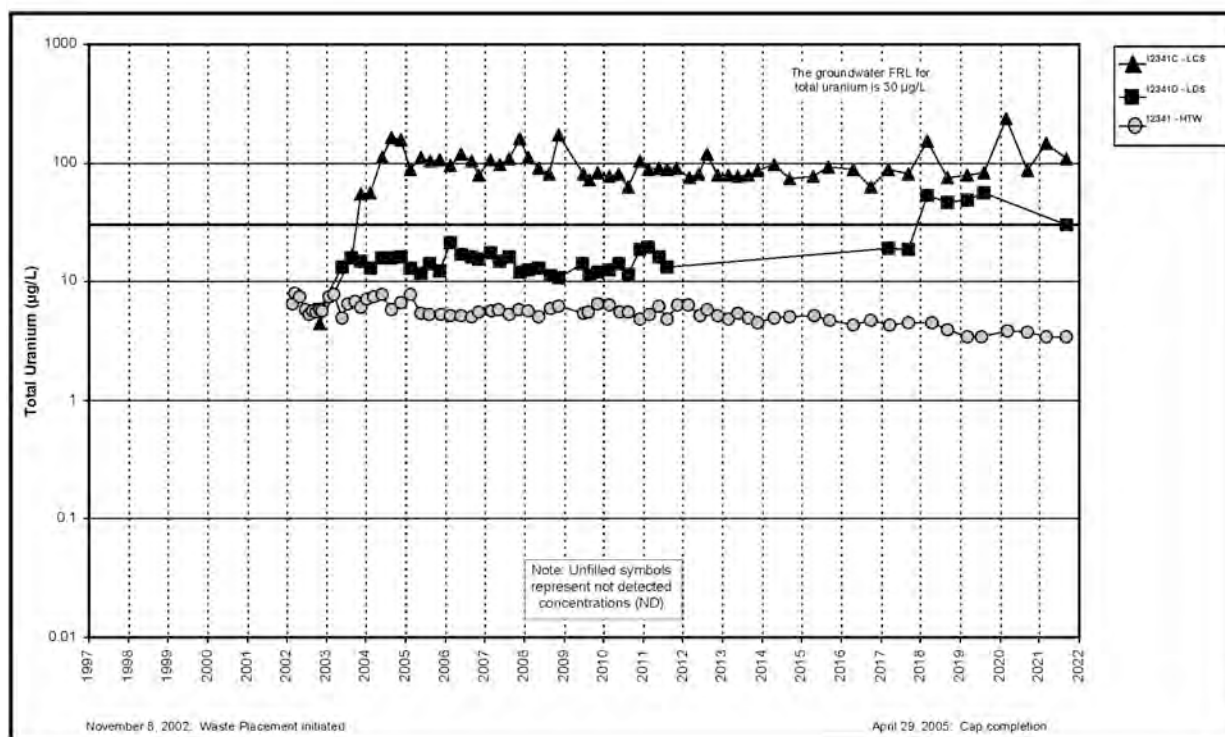


Figure A.5.4-5A. Cell 4 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

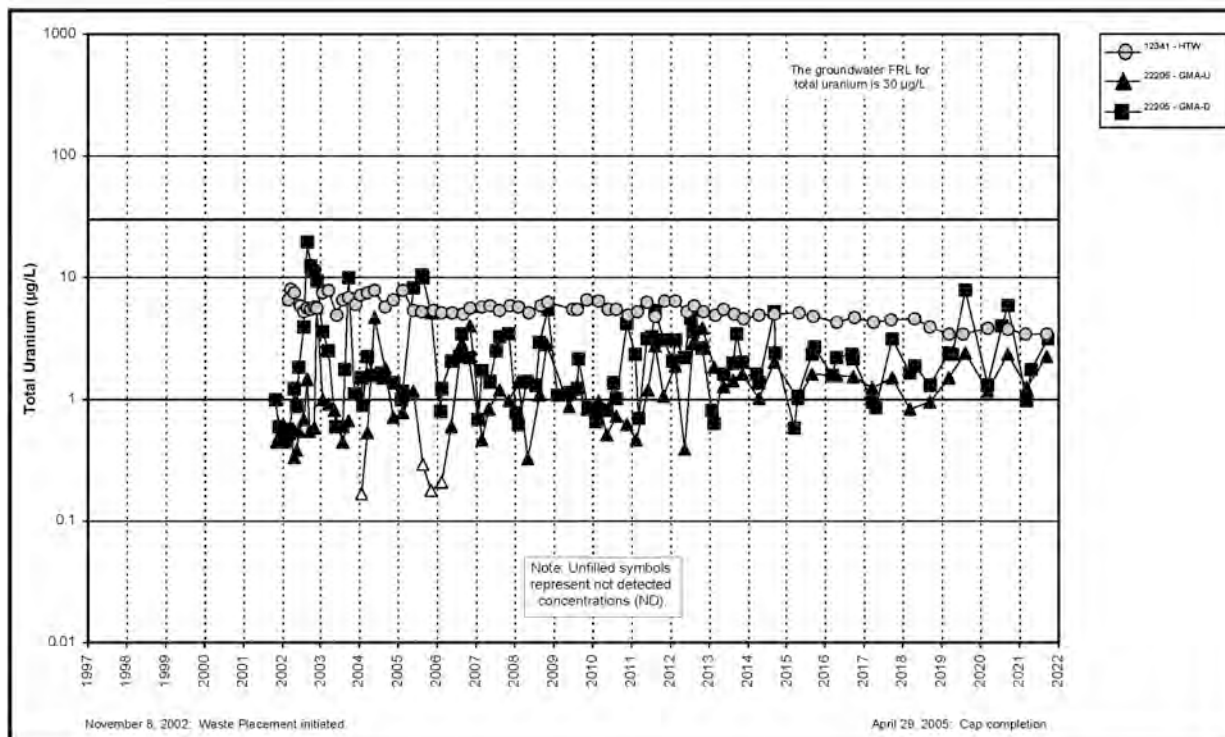


Figure A.5.4-5B. Cell 4 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

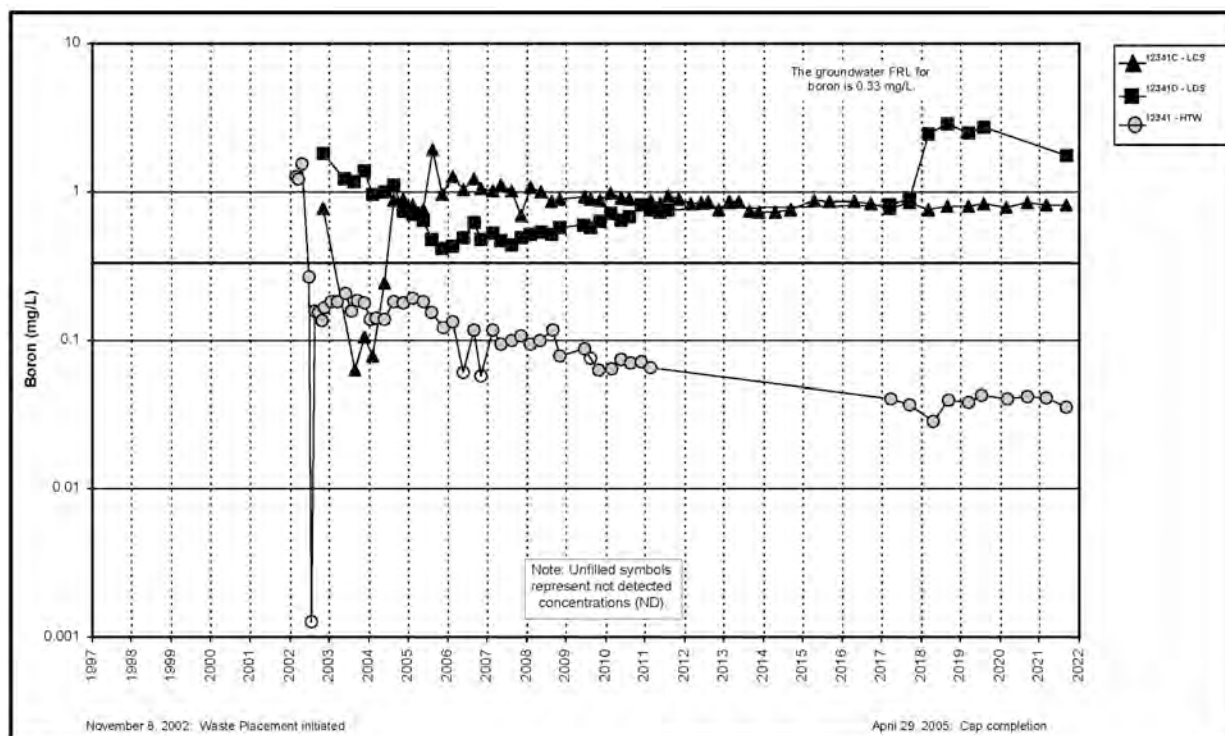


Figure A.5.4-6A. Cell 4 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

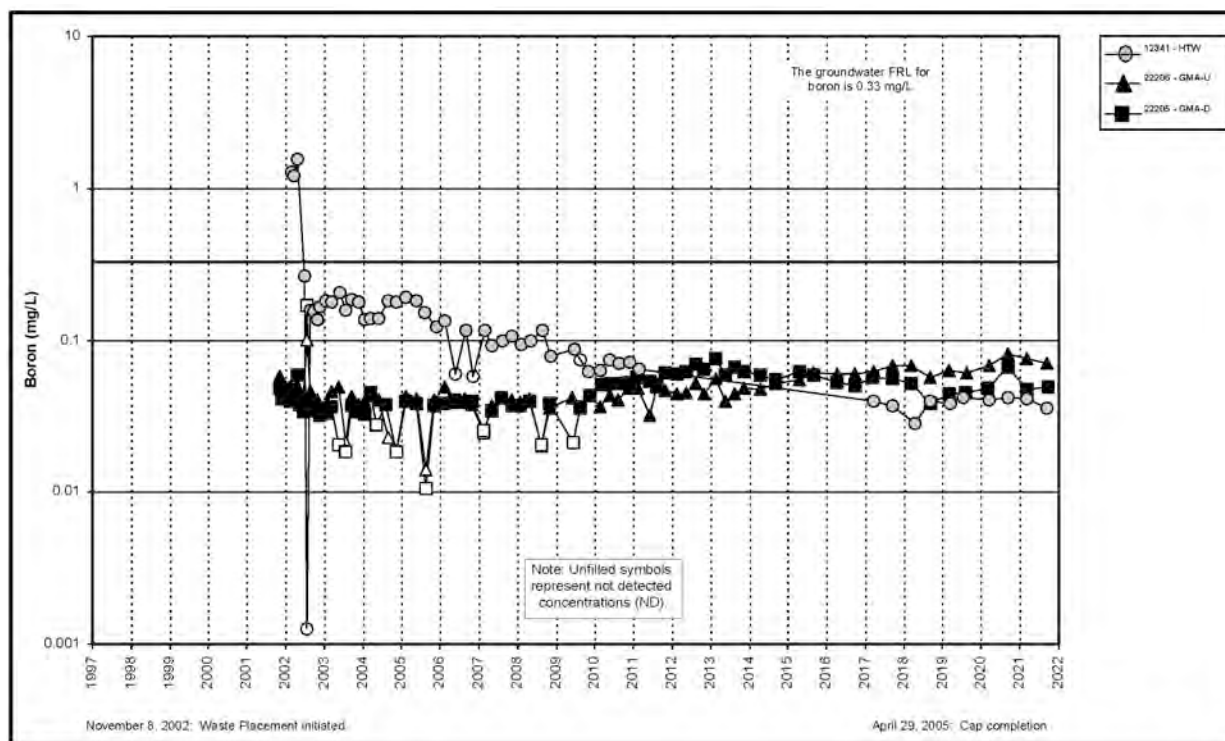


Figure A.5.4-6B. Cell 4 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

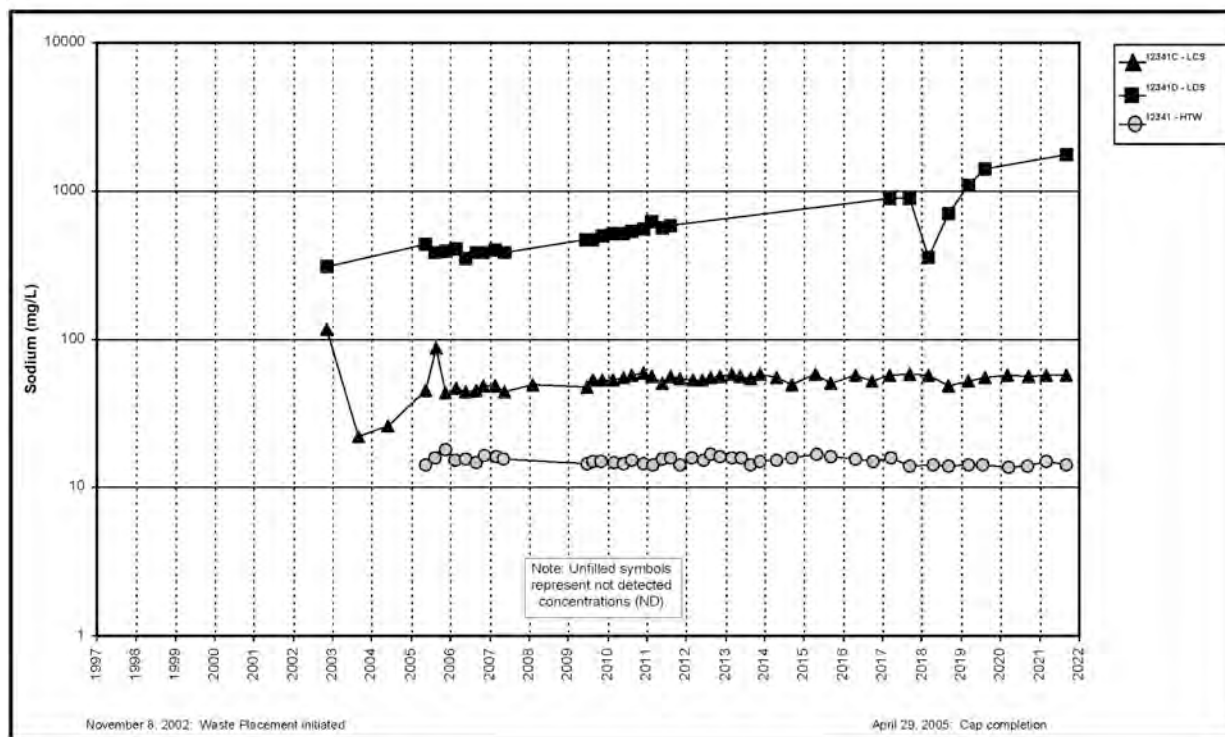


Figure A.5.4-7A. Cell 4 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

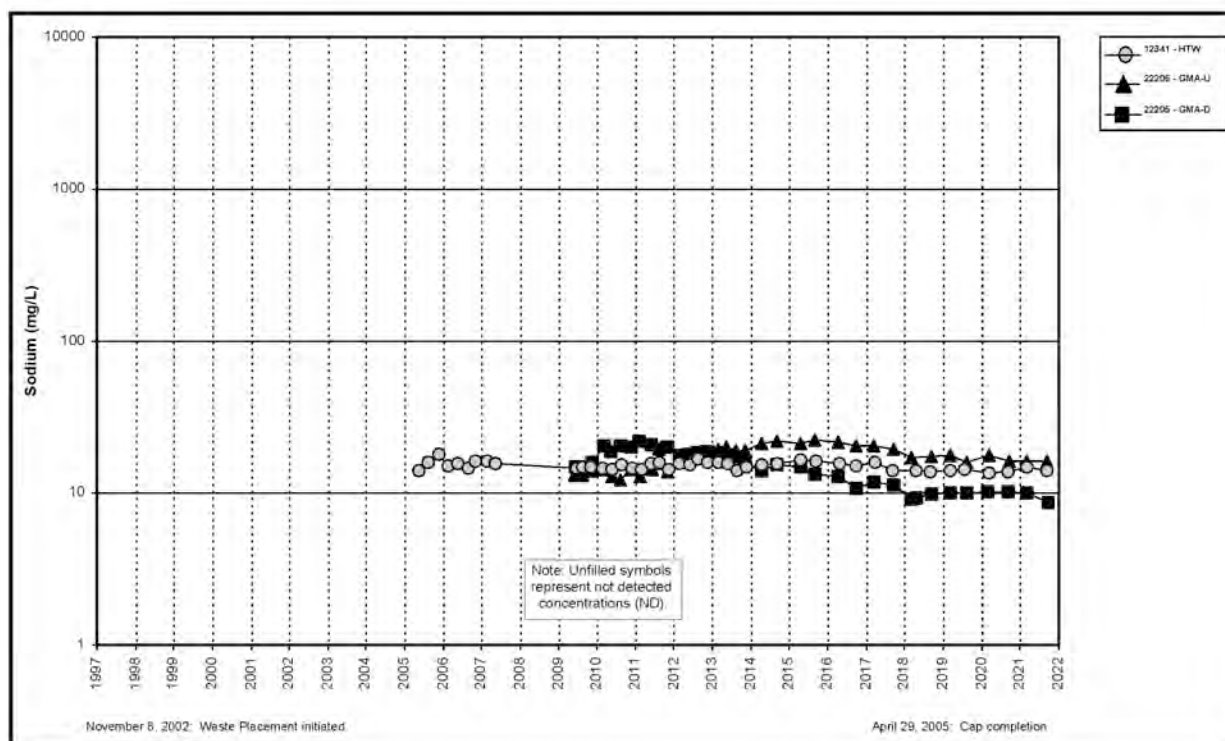


Figure A.5.4-7B. Cell 4 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

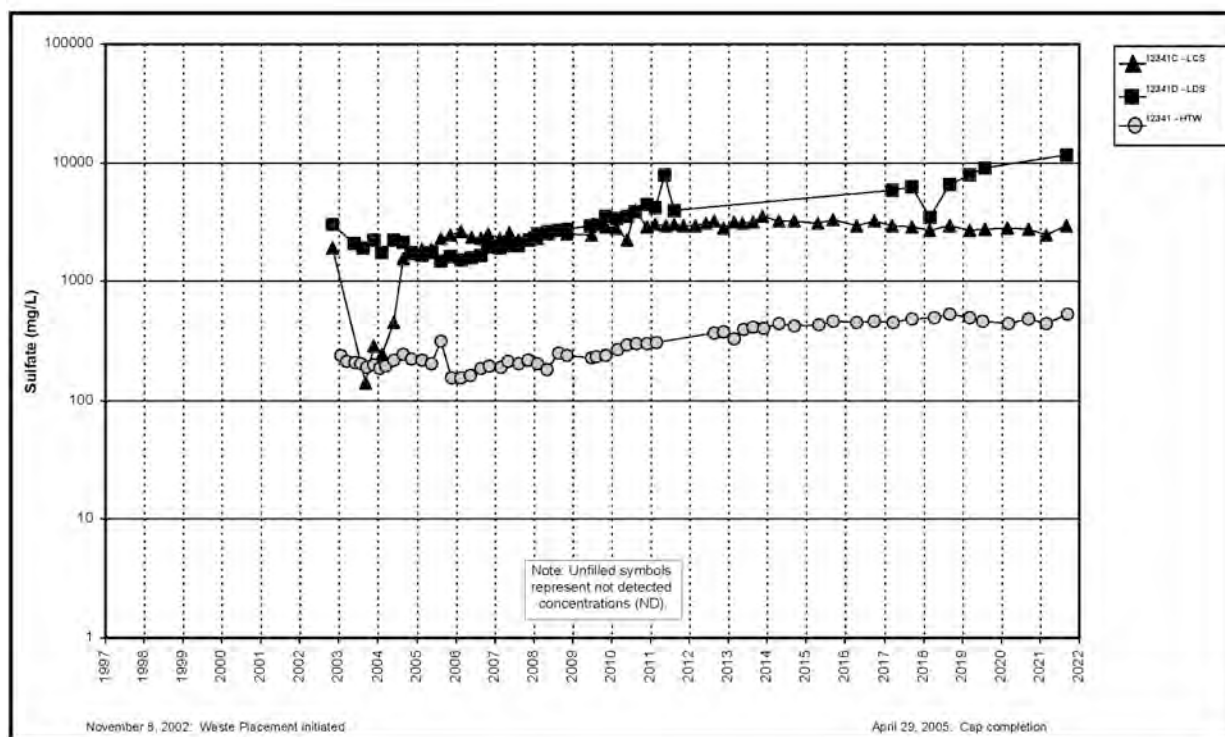


Figure A.5.4-8A. Cell 4 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

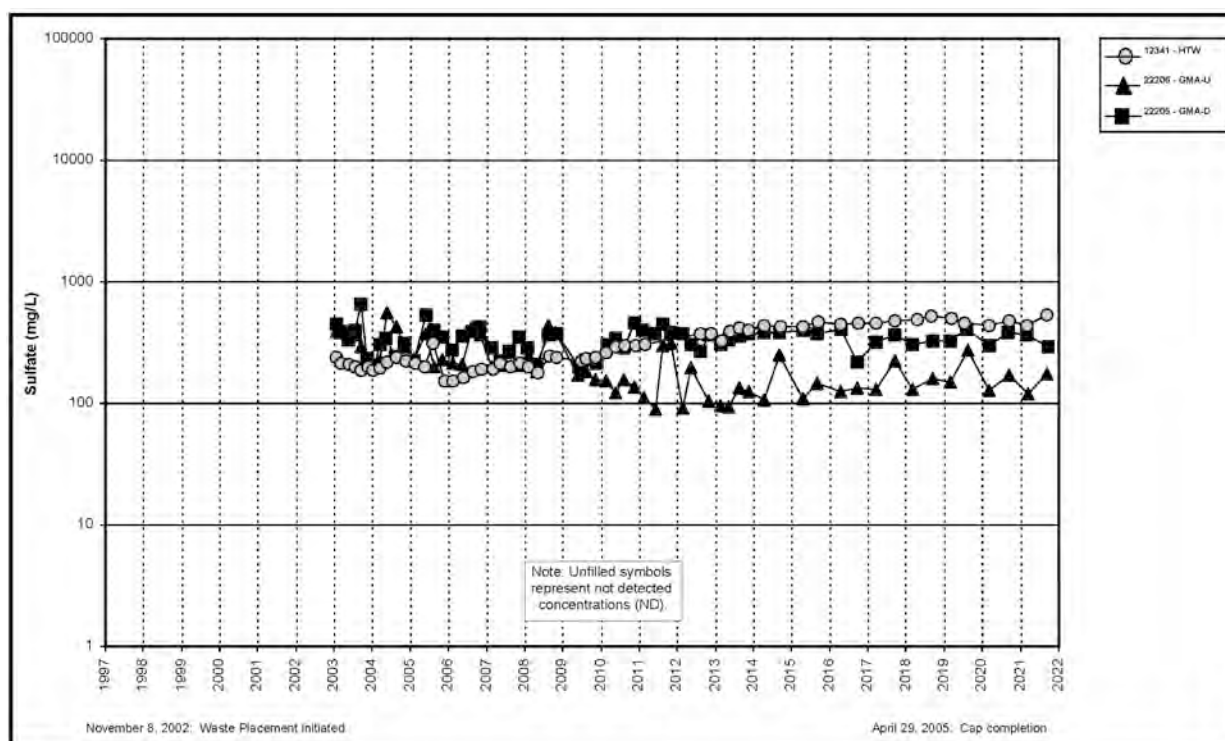


Figure A.5.4-8B. Cell 4 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

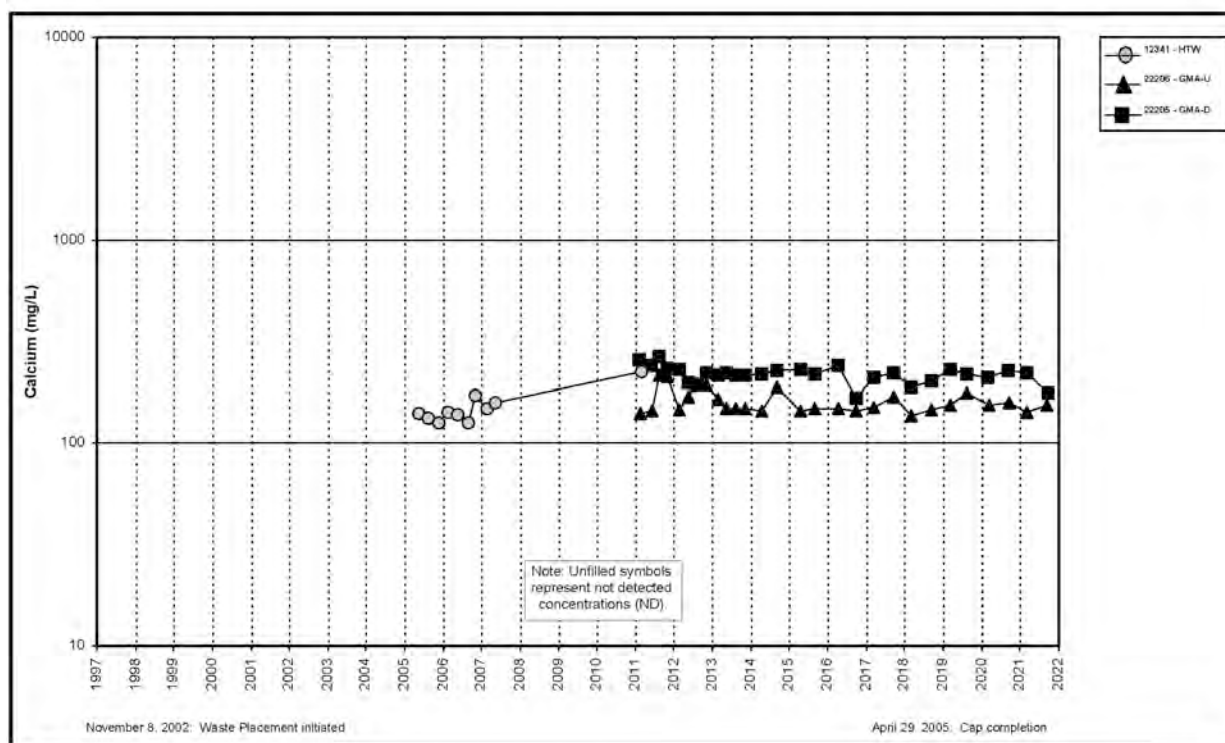


Figure A.5.4-9. Cell 4 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

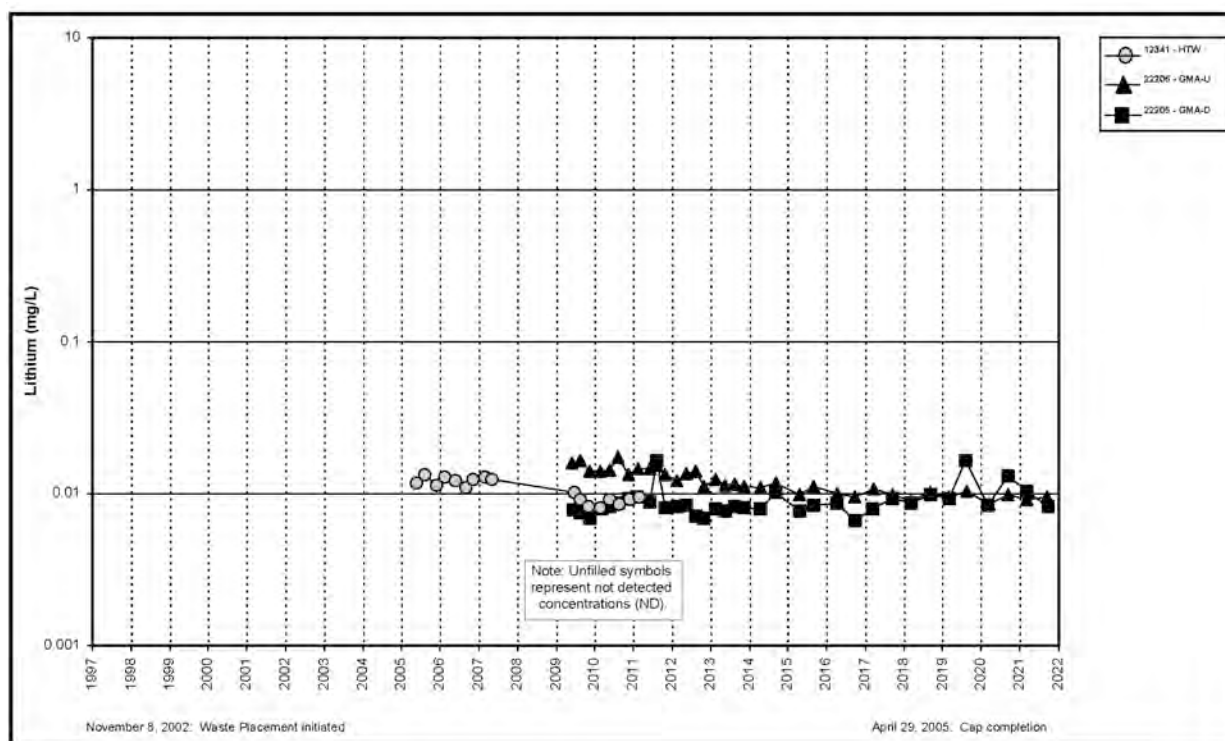


Figure A.5.4-10. Cell 4 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

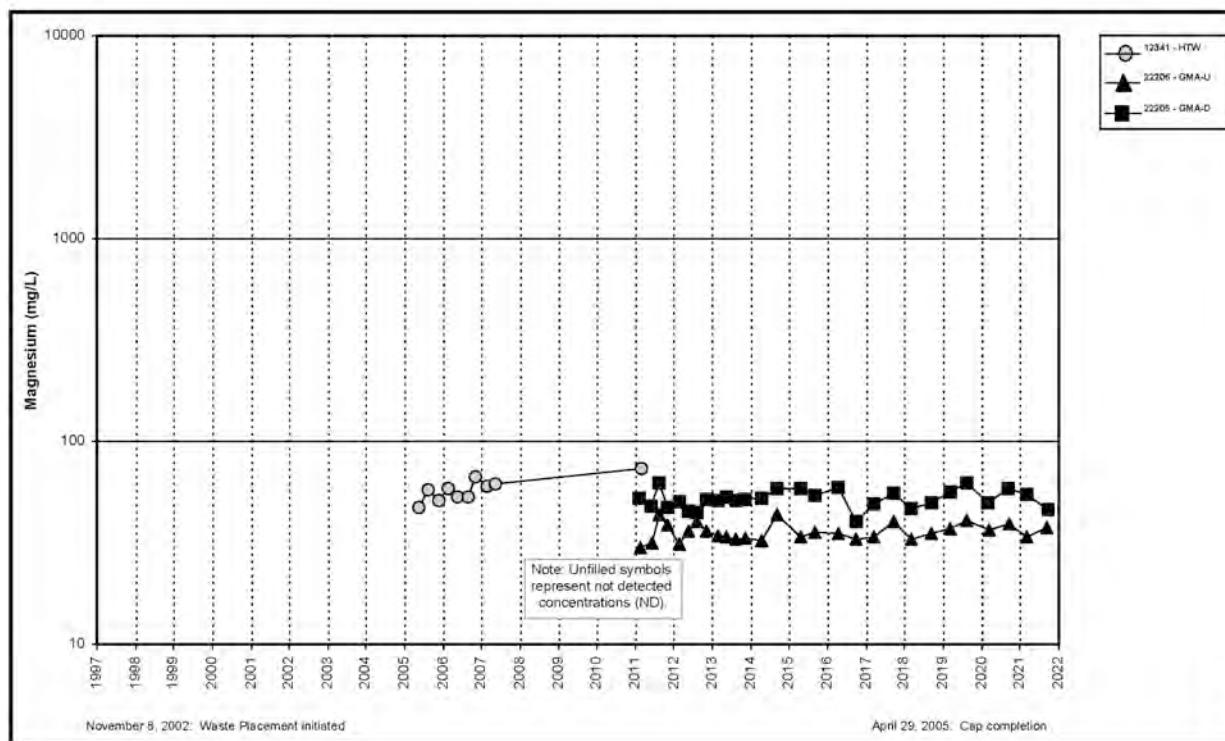


Figure A.5.4-11. Cell 4 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

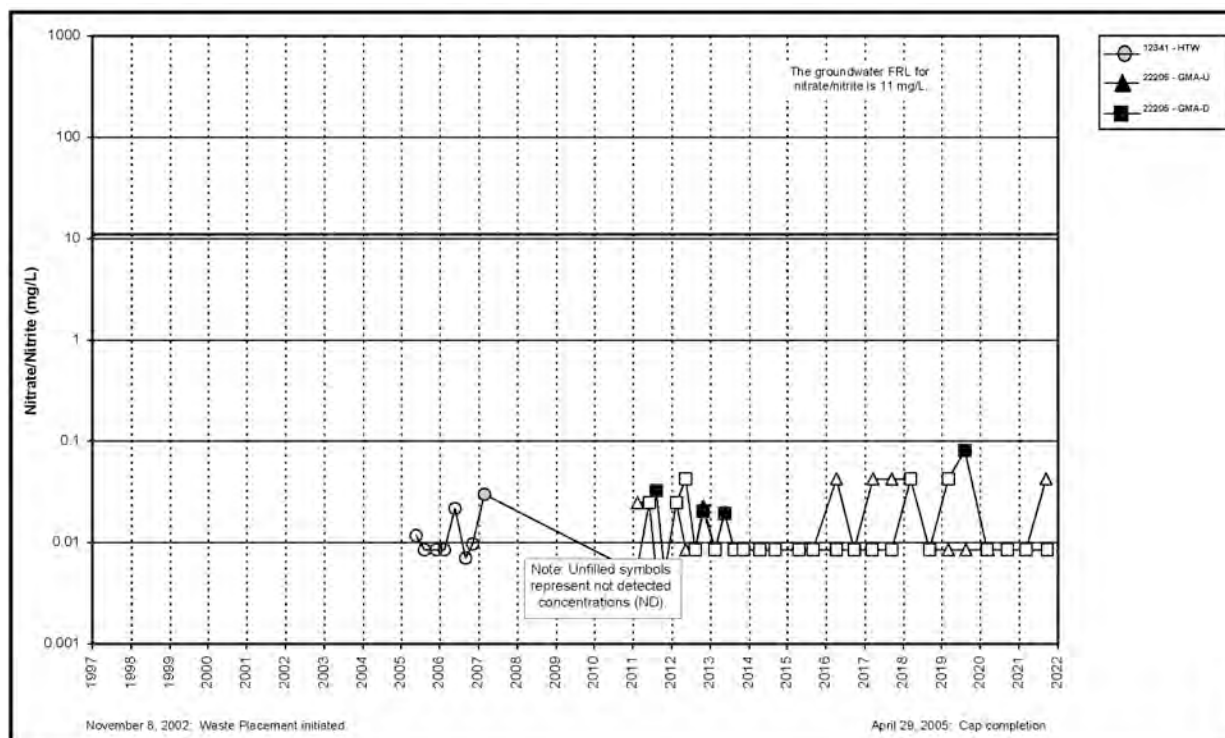


Figure A.5.4-12. Cell 4 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

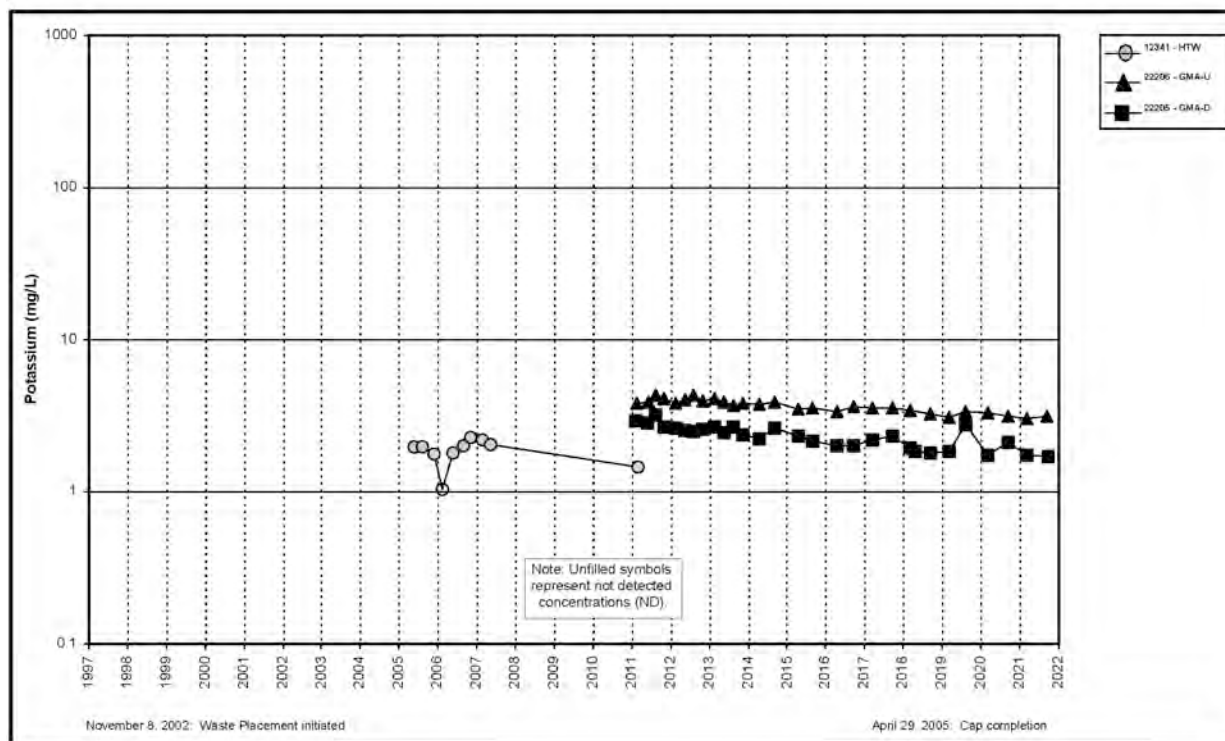


Figure A.5.4-13. Cell 4 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

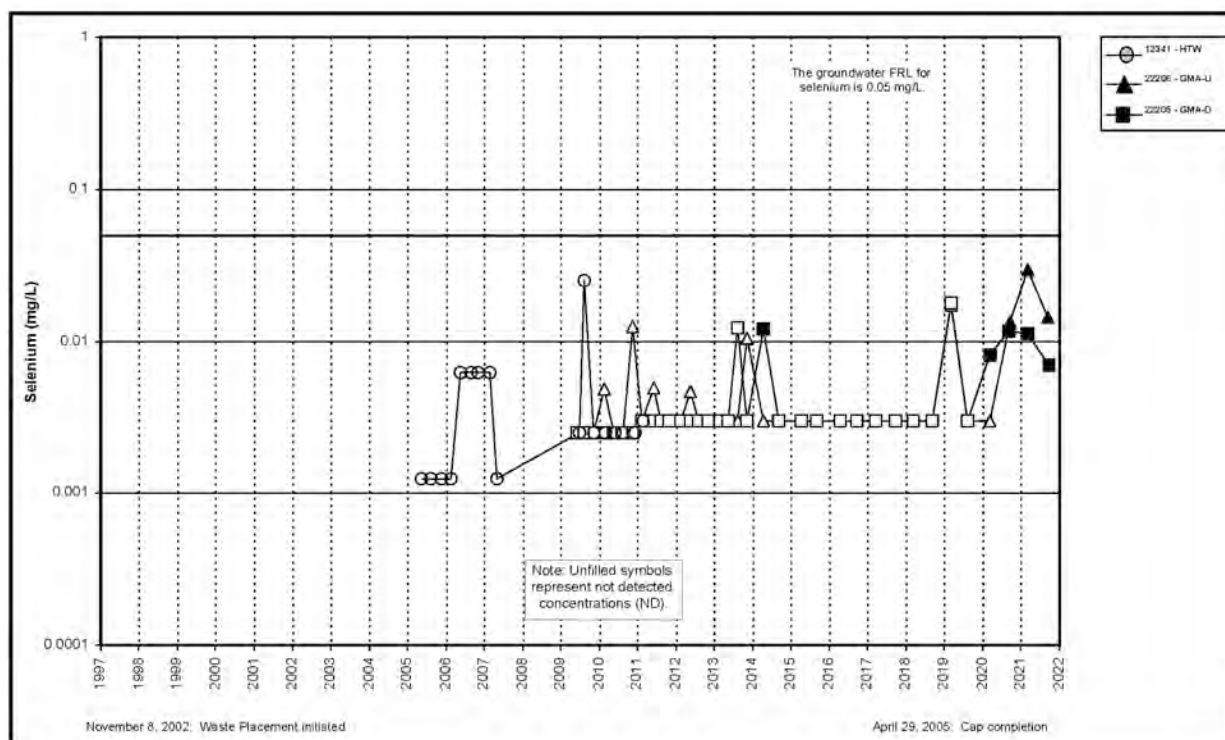


Figure A.5.4-14. Cell 4 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

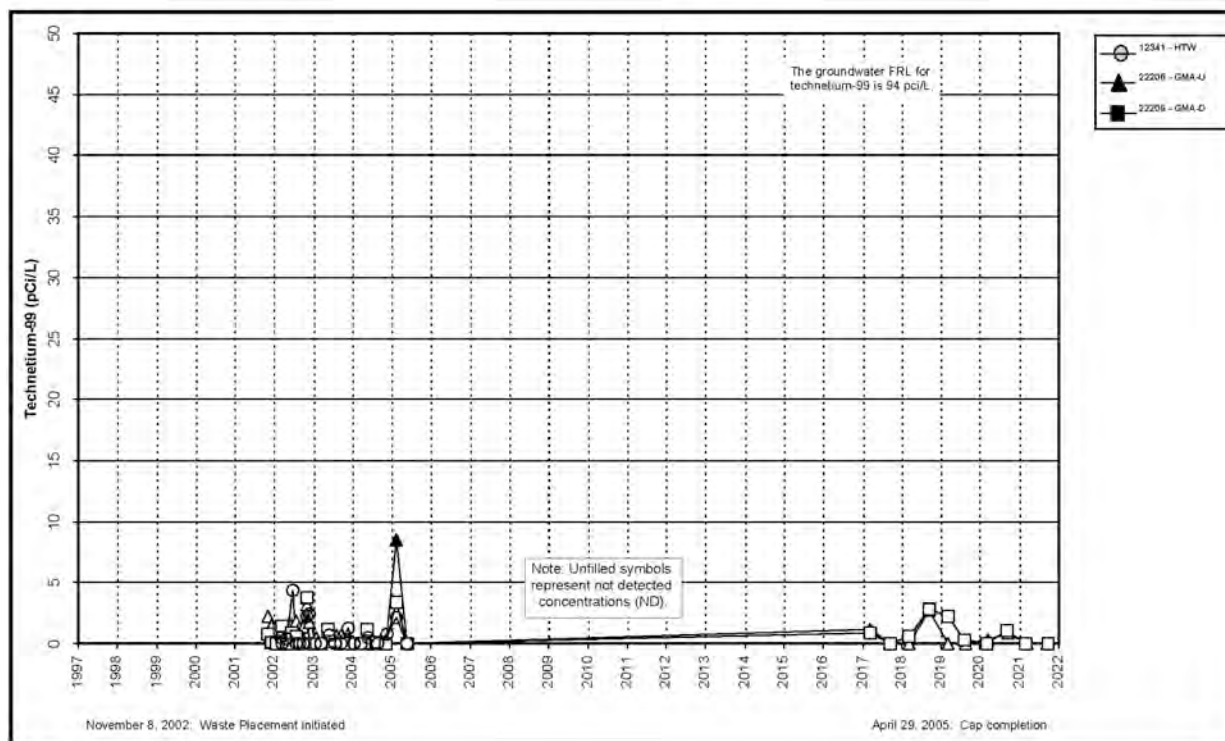


Figure A.5.4-15. Cell 4 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

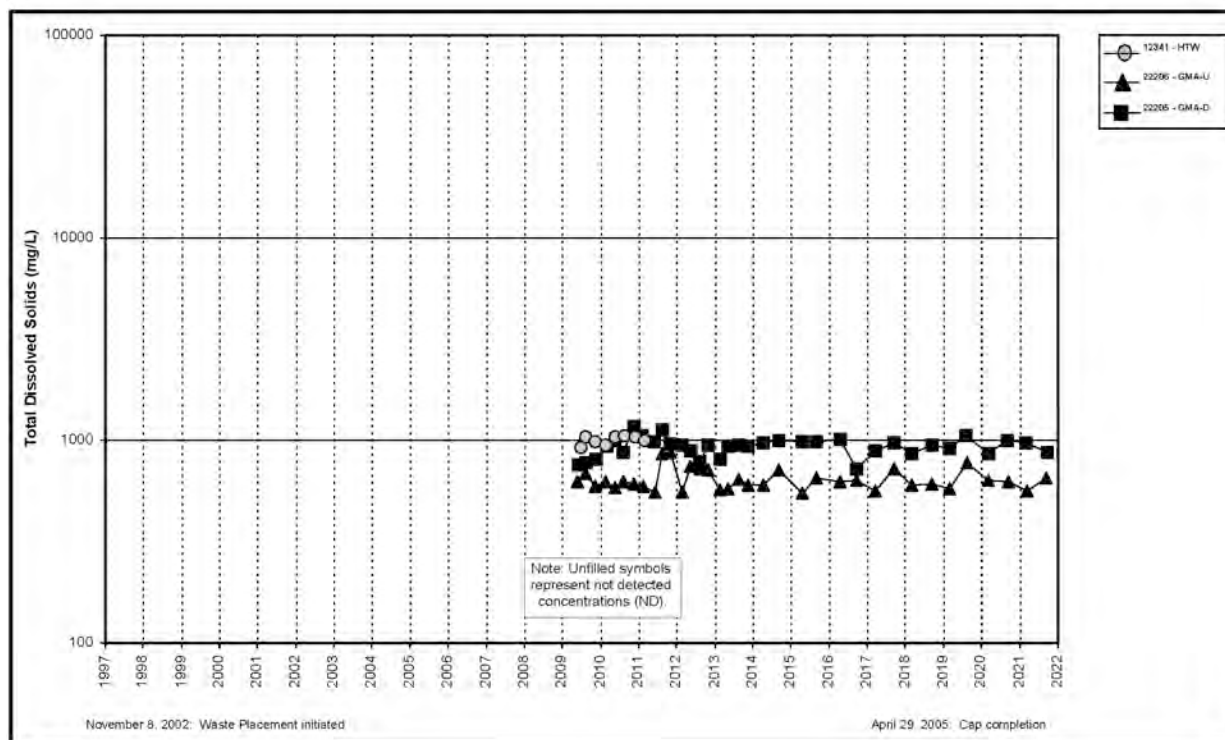


Figure A.5.4-16. Cell 4 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

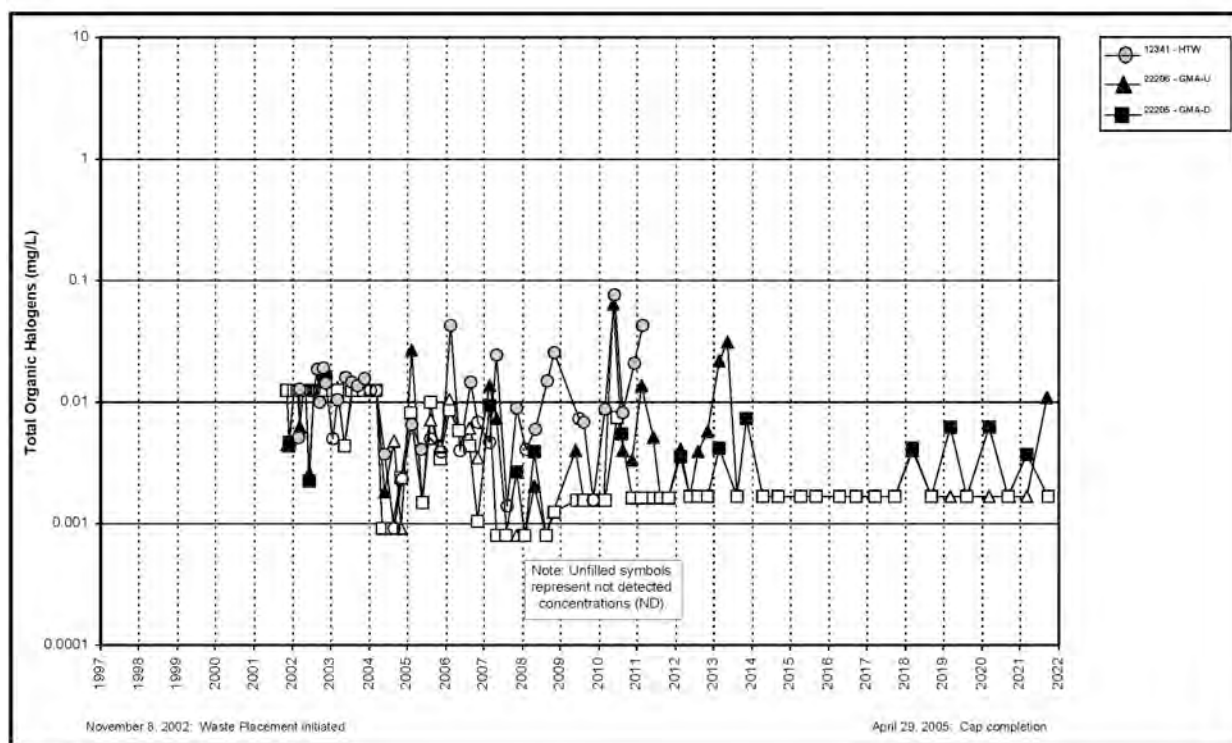


Figure A.5.4-17. Cell 4 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

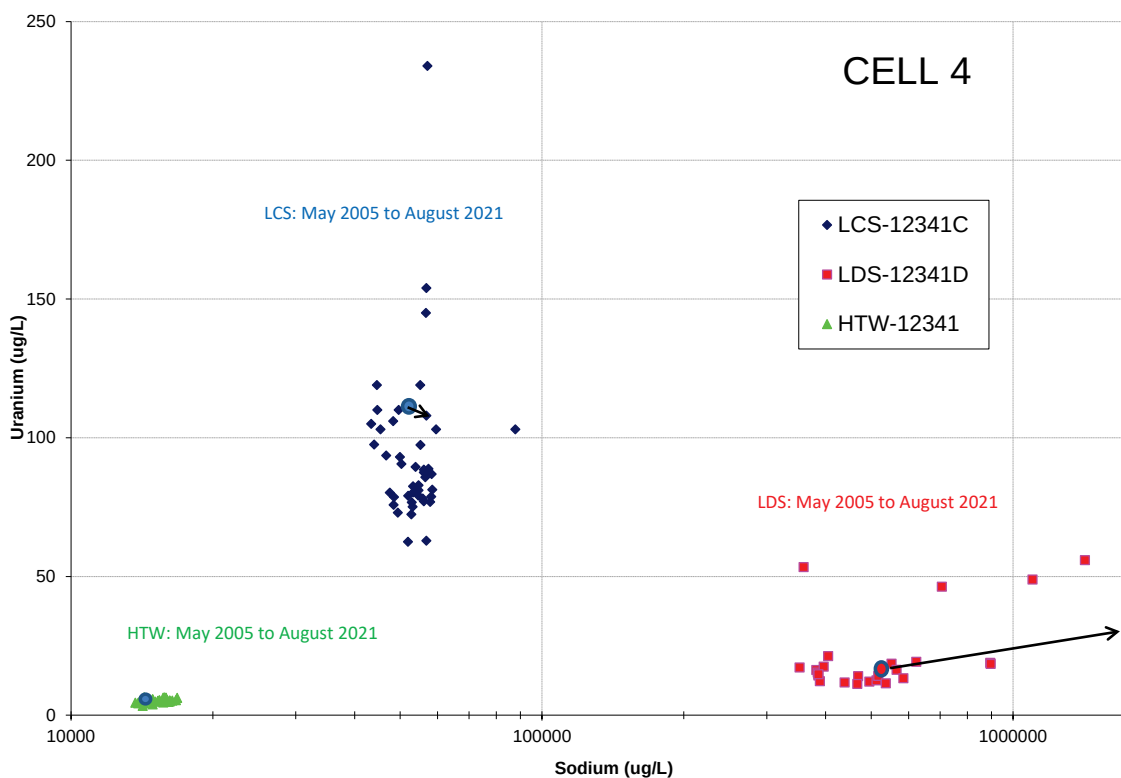


Figure A.5.4-18. Cell 4 Bivariate Plot for Uranium and Sodium

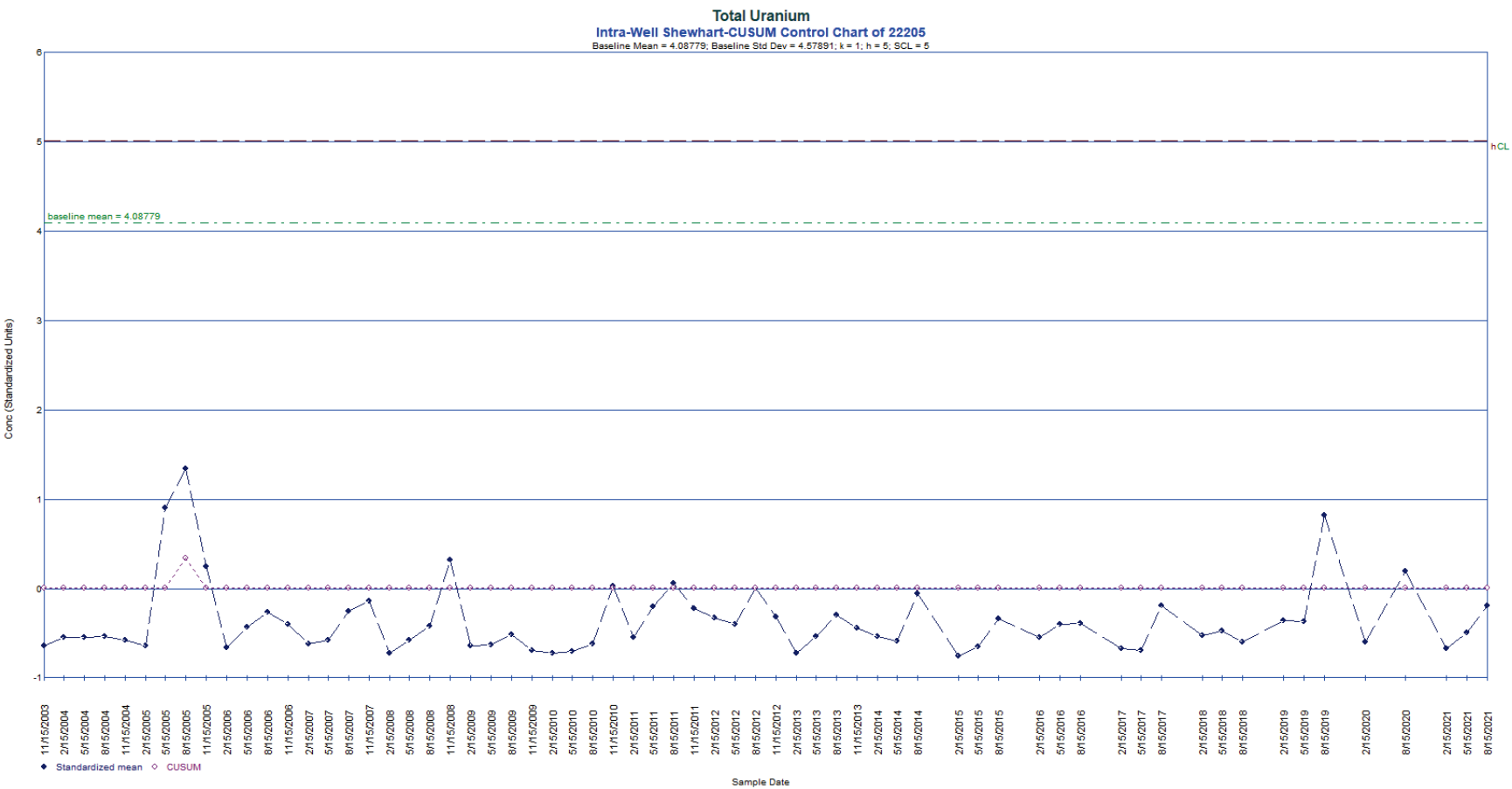


Figure A.5.4-19. Intrawell Shewhart-CUSUM Control Chart for Total Uranium in Monitoring Well 22205

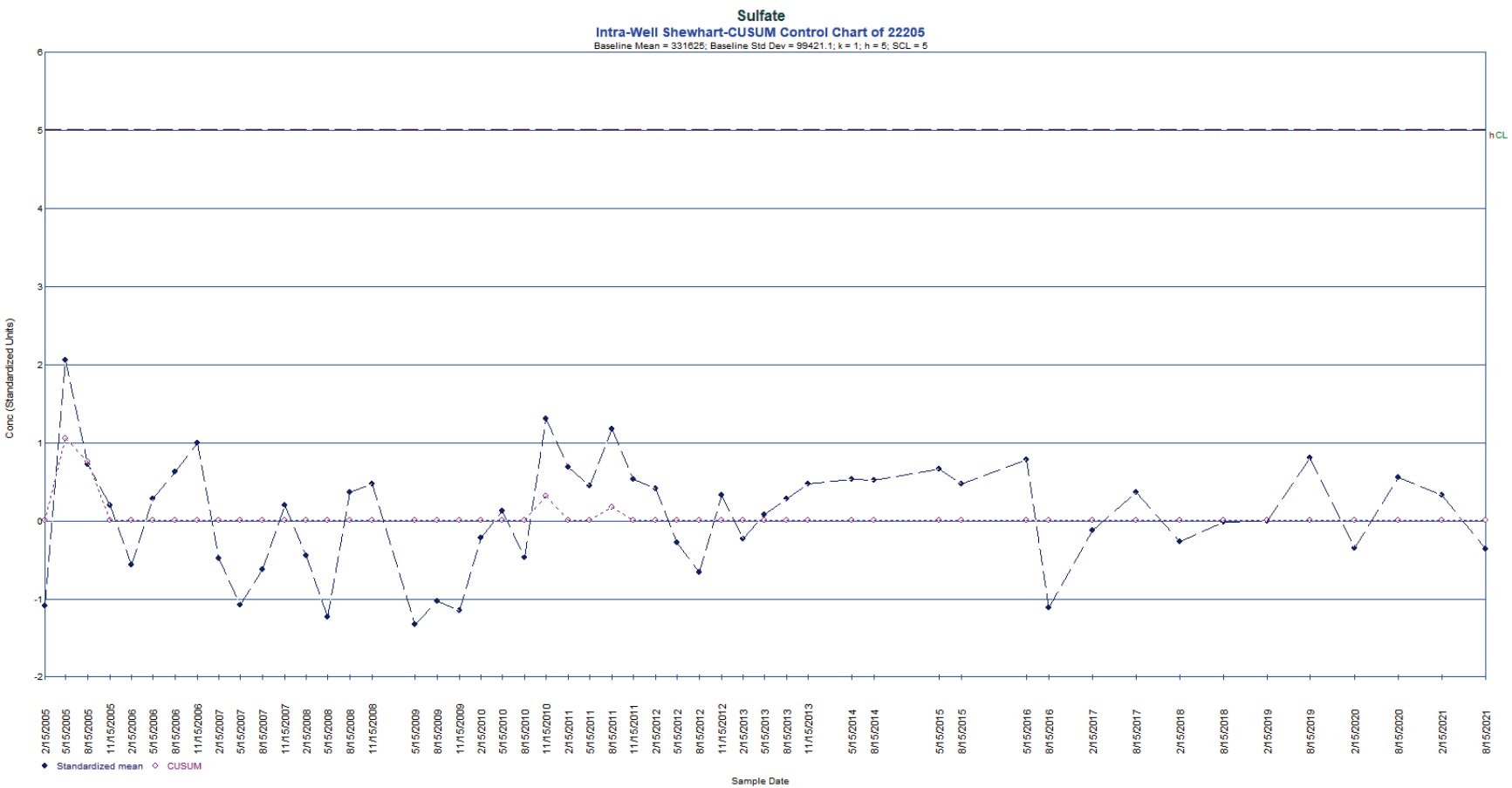


Figure A.5.4-20. Intrawell Shewhart-CUSUM Control Chart for Sulfate in Monitoring Well 22205

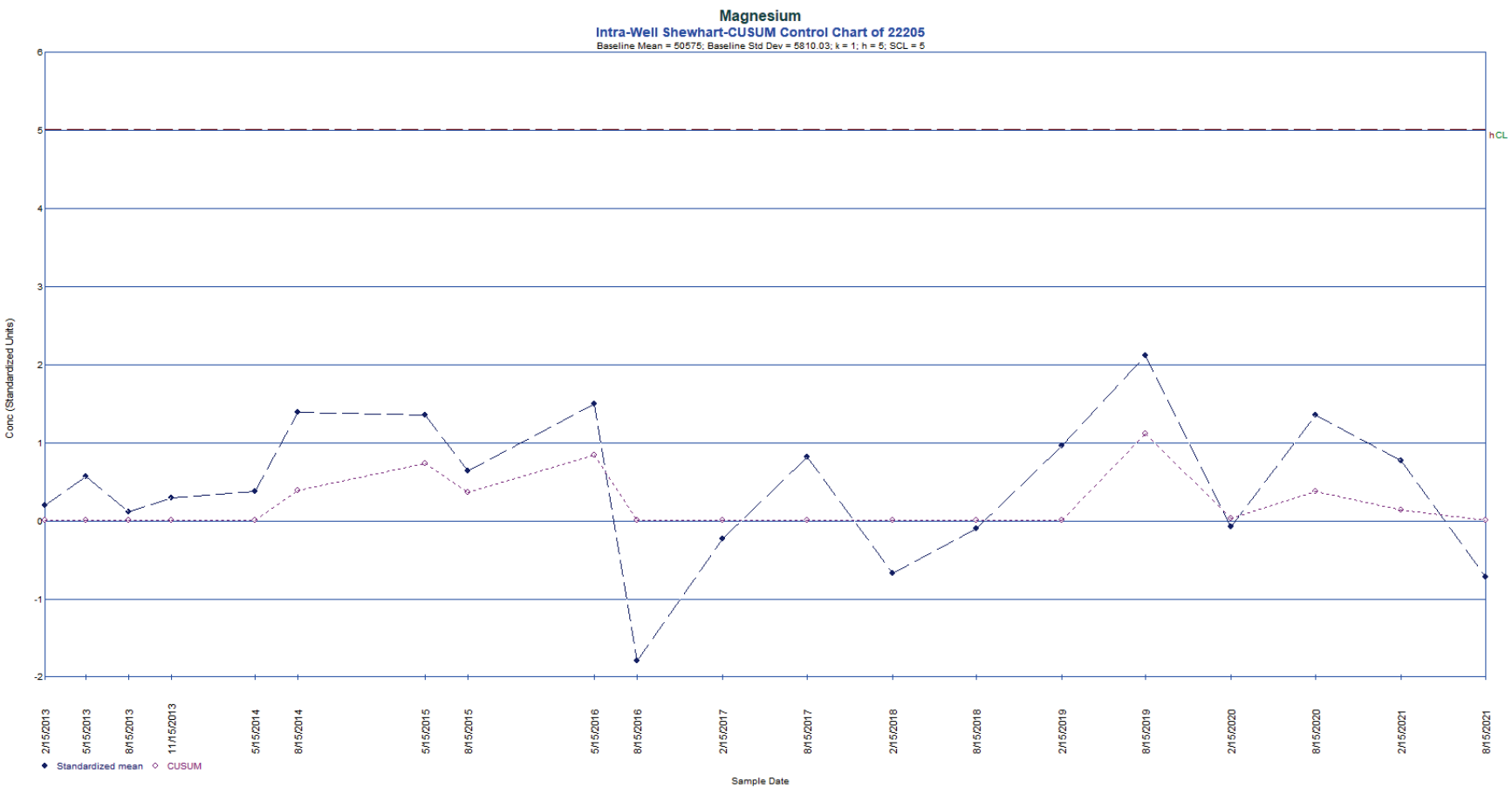


Figure A.5.4-21. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22205

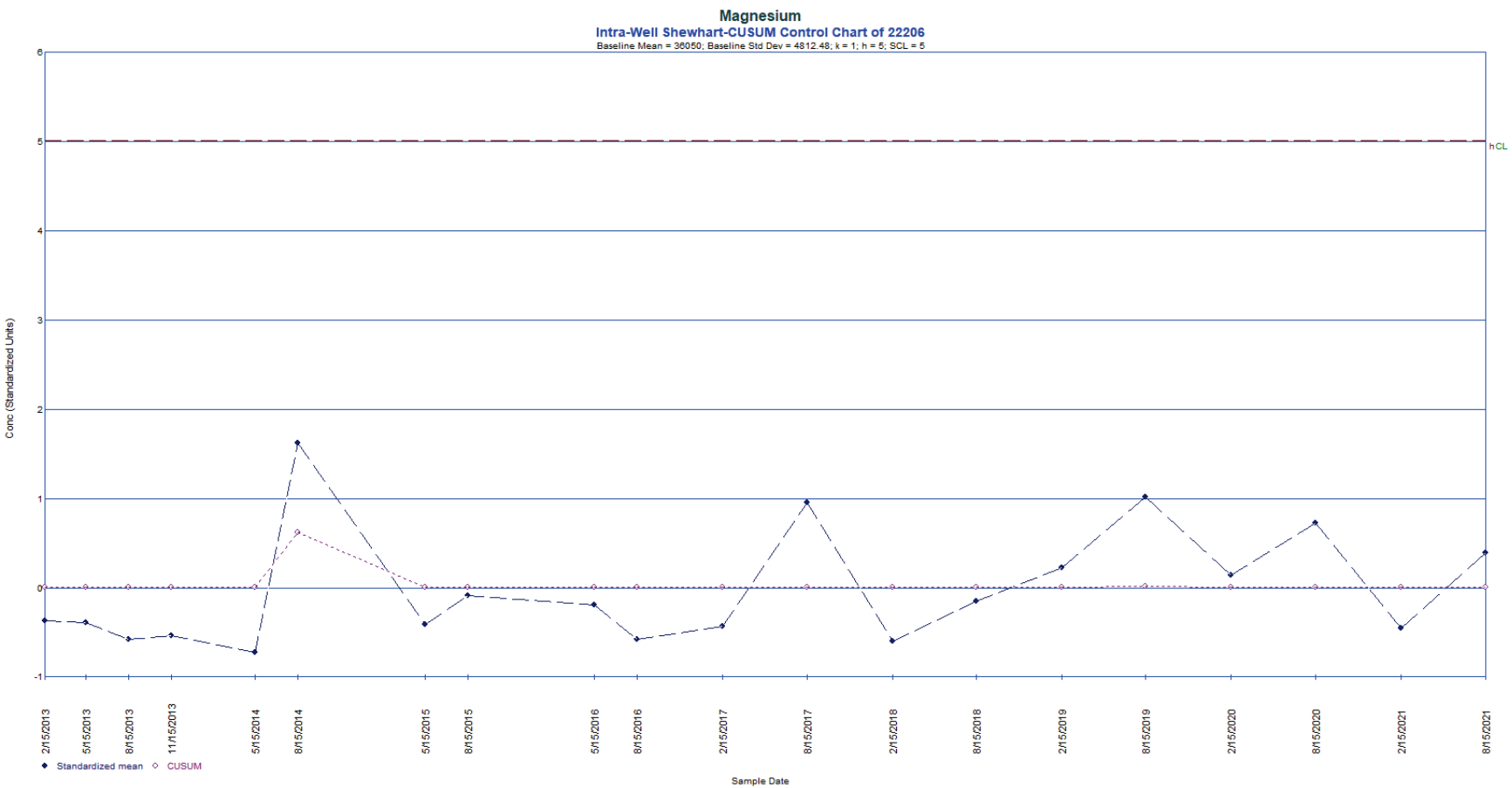


Figure A.5.4-22. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22206

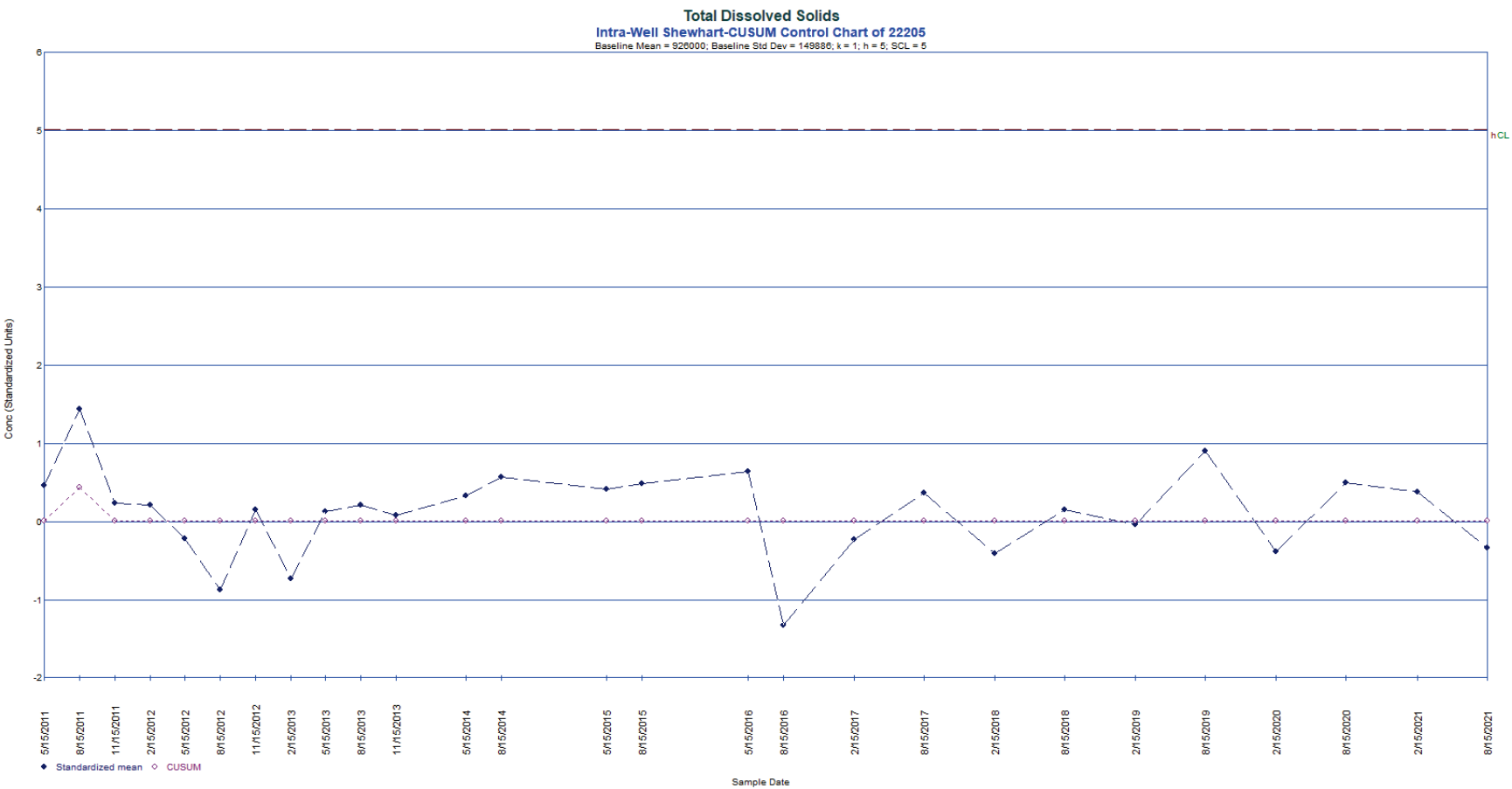


Figure A.5.4-23. Intrawell Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22205

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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	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.5-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.5-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.5-2)
- OSDF horizontal till well (HTW) 12342 water yield (refer to Table A.5.5-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.5-3 and A.5.5-4)
- Plots of concentration versus time (refer to Figures A.5.5-5A through A.5.5-17)
- A bivariate plot for uranium–sodium (refer to Figure A.5.5-18)
- Control chart (refer to 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 the 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 2021. The volume of water in the LDS tank of Cell 5 was insufficient to collect a sample in 2021.

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

Parameter	LCS 12342C	LDS 12342D
	2021 Trend	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, six parameters (boron, sodium, sulfate, lithium, magnesium, and potassium) have upward trends in the HTW and/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^a

Parameter	HTW 12342	GMA-U ^b 22207	GMA-D ^b 22208
Boron		Up	Up
Sodium		Up	
Sulfate	Up		
Lithium		Up	
Magnesium		Up	
Potassium		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 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 *hCL* on the control charts. For interpretation purposes, the *hCL* 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 (Figure A.5.5-19 thru A.5.21) which exhibits “in control” conditions.

Parameter	Monitoring Point	Well Number	Assessment	Figure Number
Calcium	GMA-U	22207	In Control	A.5.5-19
Lithium	GMA-D	22208	In Control	A.5.5-21
Uranium	GMA-D	22208	In Control	A.5.5-22

^aGMA-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 2021 based on the Mann-Kendall test for trend.
- The volume of water in the LDS tank of Cell 5 was insufficient to collect a sample in 2021.
- Six parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 5: boron, sodium, sulfate, lithium, magnesium, and potassium. 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 three 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*.

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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	60	60	100	3.39	285	122	46	Undefined	None (2021)	Detected	
	LDS	12342D	40	40	100	2.93	27.1	15.6	5.2	Normal	Down (2013)	Detected	
	HTW	12342	63	63	100	7.45	19.2	9.02	2.16	Undefined	Down (2021)	Detected	
	GMA-U	22207	53	64	82.8	ND	0.631	0.312	0.290	Ln Normal	Down (2021)	Not Detected	2.39 (Q3-02)
	GMA-D	22208	61	72	84.7	ND	0.540	0.340	0.092	Normal	None (2021)	Not Detected	2.10 (Q2-04); 0.800 (Q1-05); 0.006 (Q2-05); 0.710 (Q2-08)
Boron (mg/L)	LCS	12342C	58	60	96.7	ND	1.59	0.764	0.265	Undefined	None (2021)	Detected	
	LDS	12342D	40	40	100	0.202	1.20	0.398	0.272	Undefined	None (2013)	Detected	
	HTW	12342	44	46	95.6	ND	0.221	0.103	0.043	Ln Normal	Down (2021)	Detected	
	GMA-U	22207	59	64	92.2	ND	0.0912	0.0414	0.0132	Undefined	Up (2021)	Detected	
	GMA-D	22208	58	64	90.6	ND	0.0618	0.0365	0.0115	Normal	Up (2021)	Detected	
Sodium (mg/L)	LCS	12342C	47	48	97.9	57.0	79.7	68.1	4.9	Normal	Down (2021)	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	44	44	100	17.0	33.6	25.3	4.7	Normal	Down (2021)	Detected	
	GMA-U	22207	35	35	100	13.0	23.1	16.8	2.6	Normal	Up (2021)	Detected	
	GMA-D	22208	36	36	100	9.98	17.9	15.5	2.5	Undefined	Down (2021)	Detected	
Sulfate (mg/L)	LCS	12342C	60	60	100	218	5,910	3,500	1,250	Undefined	Up (2021)	Detected	
	LDS	12342D	40	40	100	1,130	6,100	2,160	1,030	Ln Normal	Up 2013)	Detected	
	HTW	12342	54	54	100	101	578	366	124	Undefined	Up (2021)	Detected	
	GMA-U	22207	59	59	100	97.8	552	209	100	Ln Normal	Down (2021)	Detected	770 (Q2-05)
	GMA-D	22208	59	59	100	98.1	671	362	102	Normal	Down (2021)	Detected	
Calcium (mg/L)	GMA-U	22207	28	28	100	124	187	153	12	Normal	None (2021)	Not Detected	
	GMA-D	22208	28	28	100	107	285	214	35	Normal	Down (2021)	Detected	
Lithium (mg/L)	GMA-U	22207	35	35	100	0.00642	0.0165	0.0141	0.0032	Undefined	Up (2021)	Detected	
	GMA-D	22208	35	35	100	0.00659	0.00985	0.00810	0.00069	Normal	None (2021)	Not Detected	0.00425 (Q1-17)
Magnesium (mg/L)	GMA-U	22207	28	28	100	26.1	38.5	33.4	3.1	Normal	Up (2021)	Detected	
	GMA-D	22208	28	28	100	53.6	66.4	53.6	6.2	Normal	Down (2021)	Detected	24.3 (Q1-17)
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22207	2	28	7.1	ND	0.0850	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	2	28	7.1	ND	0.0500	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22207	28	28	100	2.75	4.82	3.72	0.61	Normal	Up (2021)	Detected	
	GMA-D	22208	29	29	100	2.45	3.53	2.99	0.33	Normal	Down (2021)	Detected	
Selenium (mg/L)	GMA-U	22207	2	35	5.7	ND	0.0180	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	3	35	8.6	ND	0.0128	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22207	0	25	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22208	1	25	4.0	ND	6.40	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22207	35	35	100	552	770	636	49	Normal	None (2021)	Detected	987 (Q4-09)
	GMA-D	22208	35	35	100	456	1,290	943	153	Normal	Down (2021)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22207	22	64	34.4	ND	0.0470	0.00296	0.00736	Undefined	None (2021)	Detected	
	GMA-D	22208	18	64	28.1	ND	0.0260	0.00302	0.00523	Undefined	Down (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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 assumptionis are both rejected or there are less than 25 percent detected values. "Average" is defined as the Median of the data.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

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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

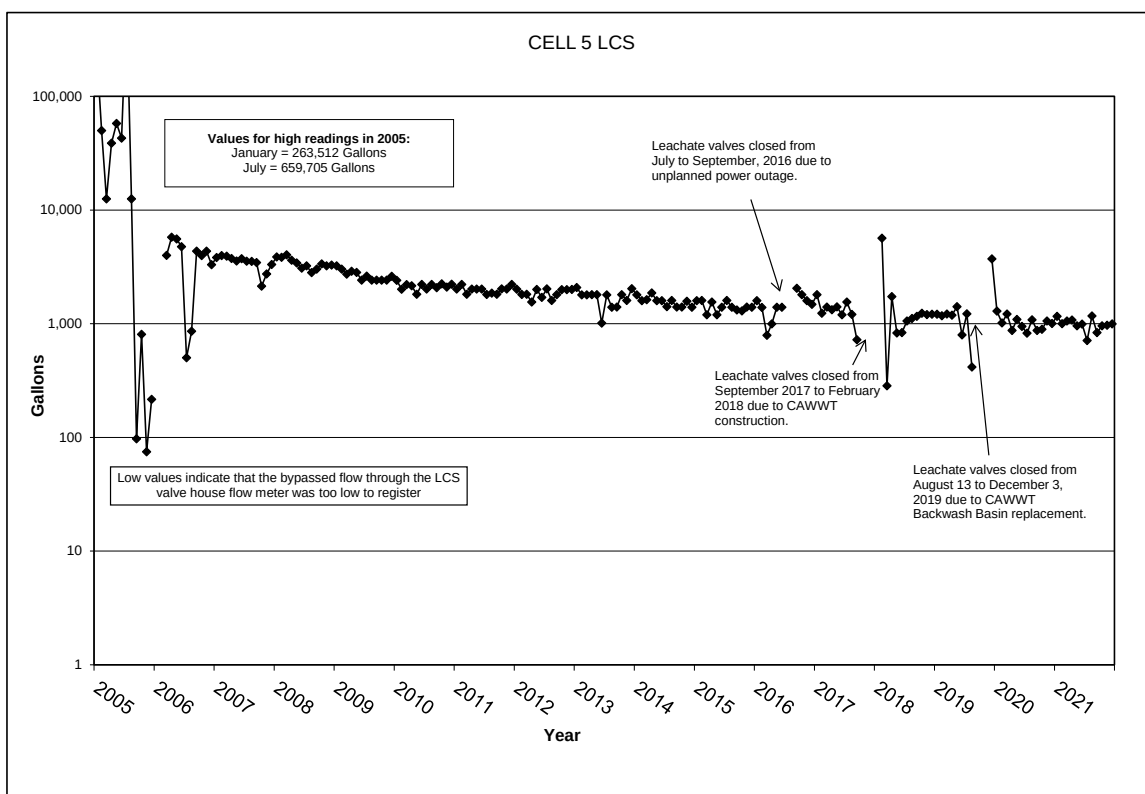


Figure A.5.5-1. Monthly Accumulation Volumes for Cell 5 LCS

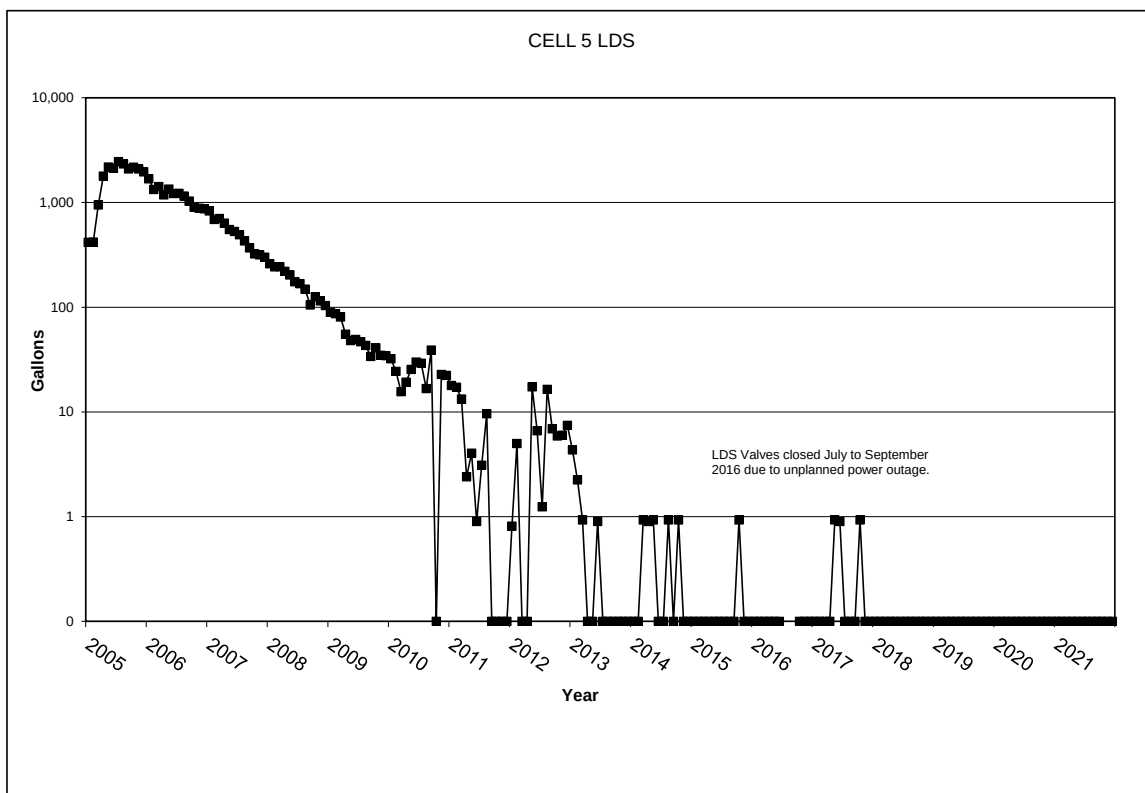


Figure A.5.5-2. Monthly Accumulation Volumes for Cell 5 LDS

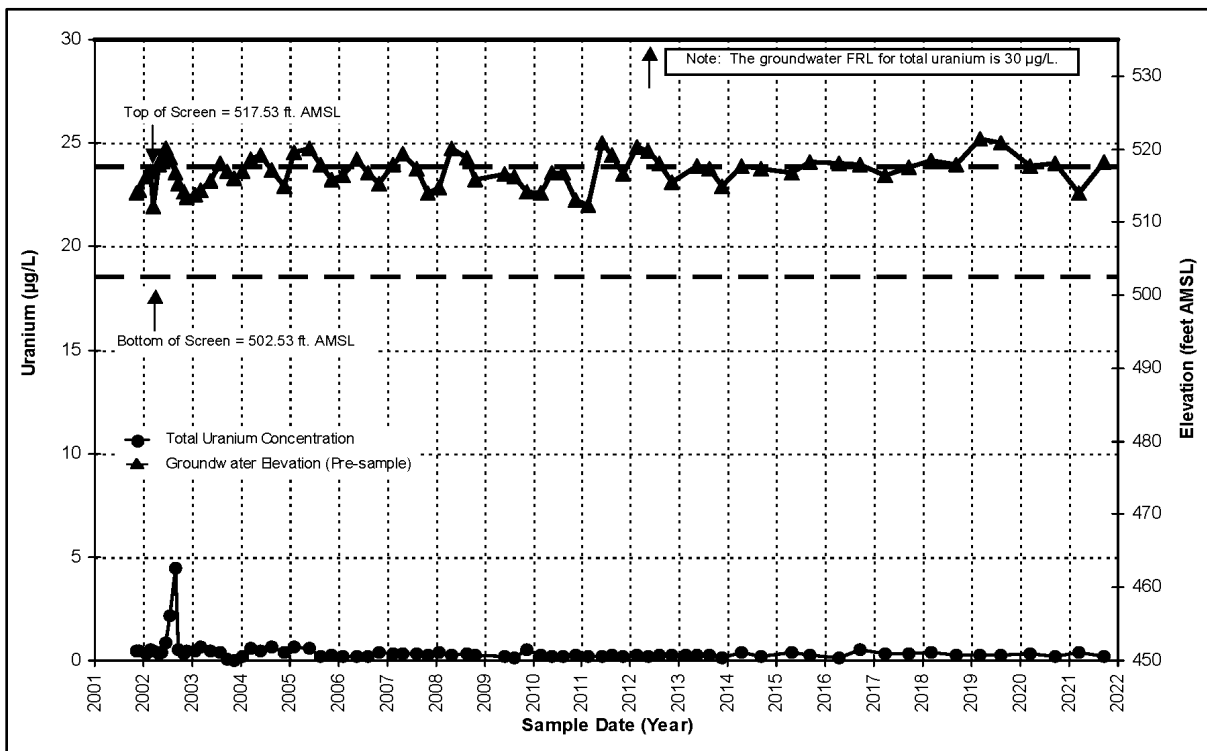


Figure A.5.5-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 5 Upgradient Monitoring Well 22207

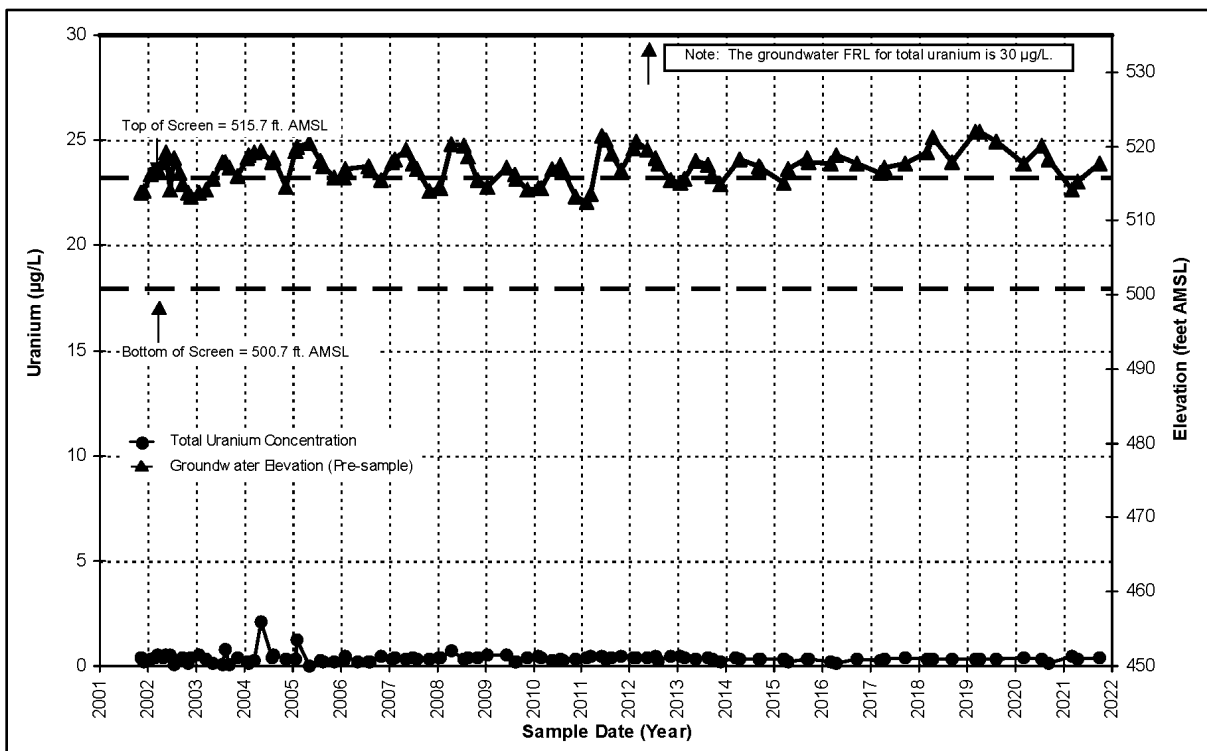


Figure A.5.5-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 5 Downgradient Monitoring Well 22208

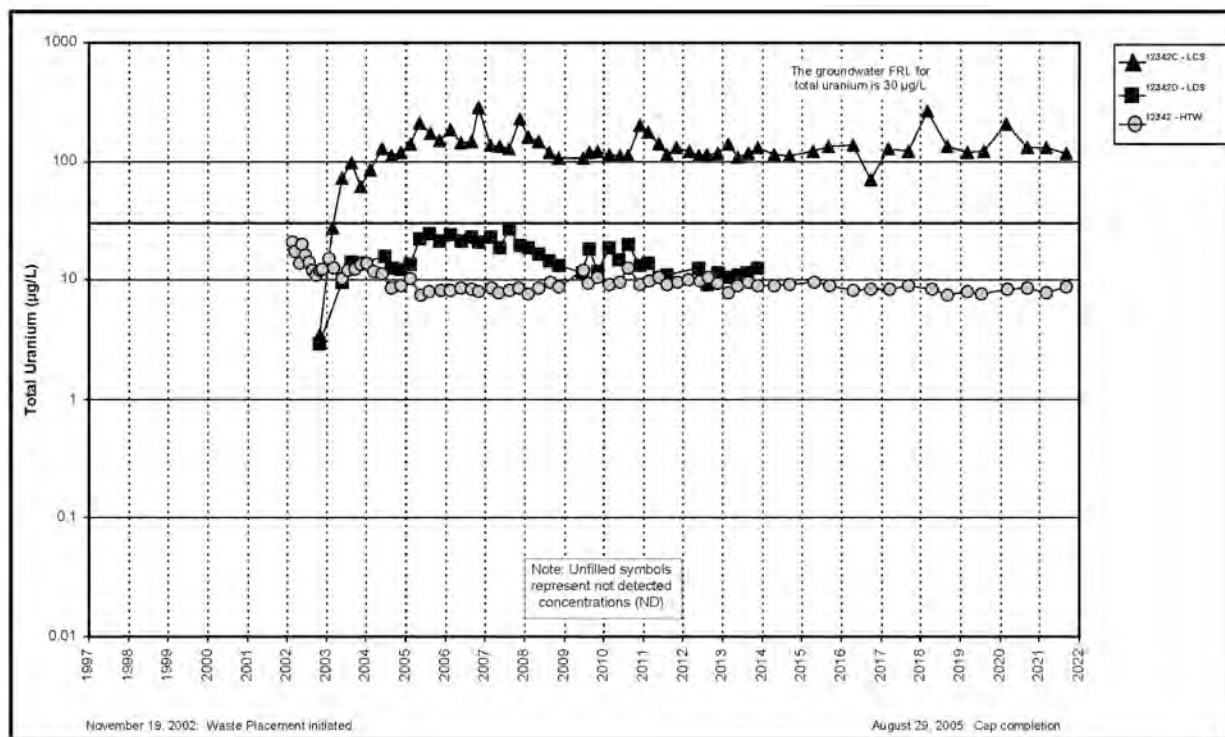


Figure A.5.5-5A. Cell 5 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

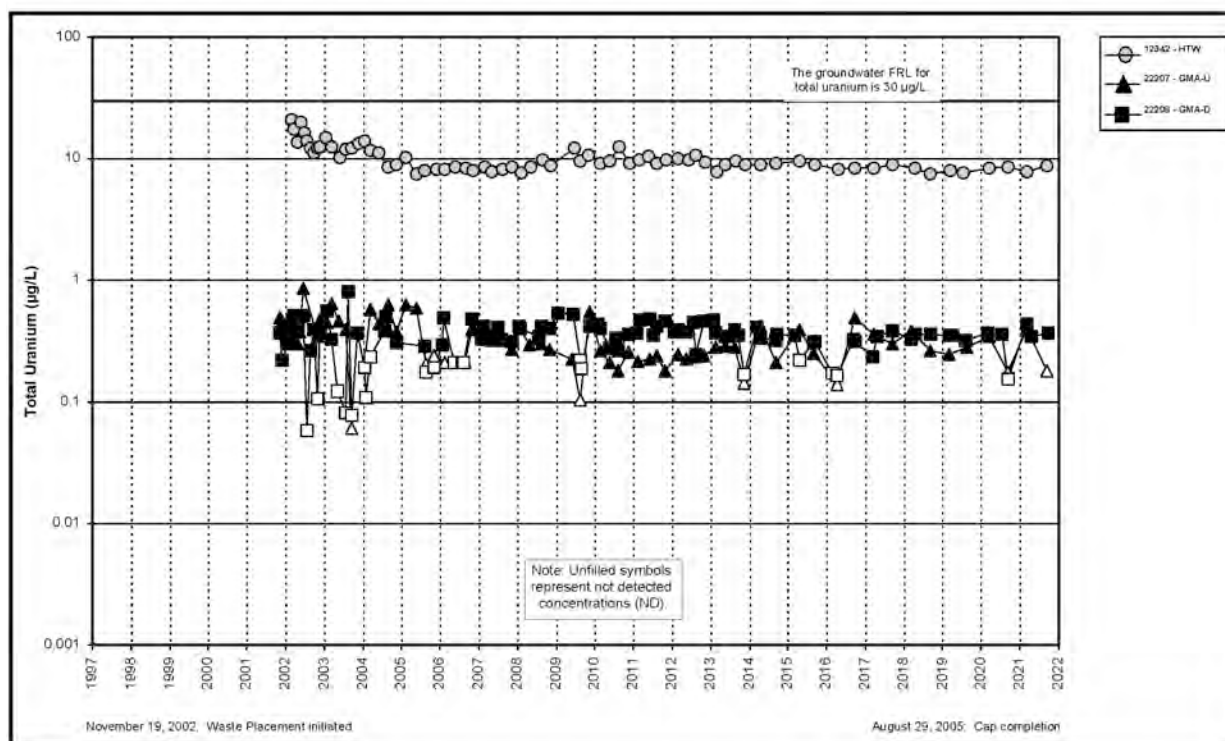


Figure A.5.5-5B. Cell 5 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

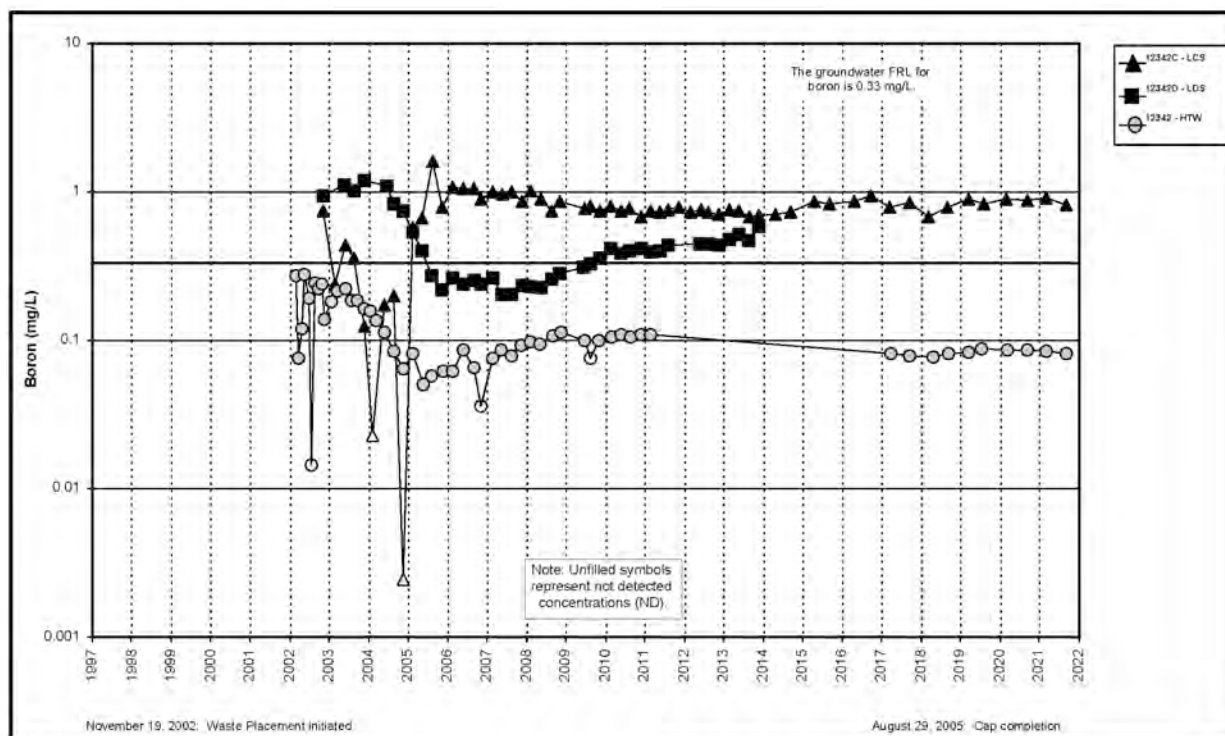


Figure A.5.5-6A. Cell 5 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

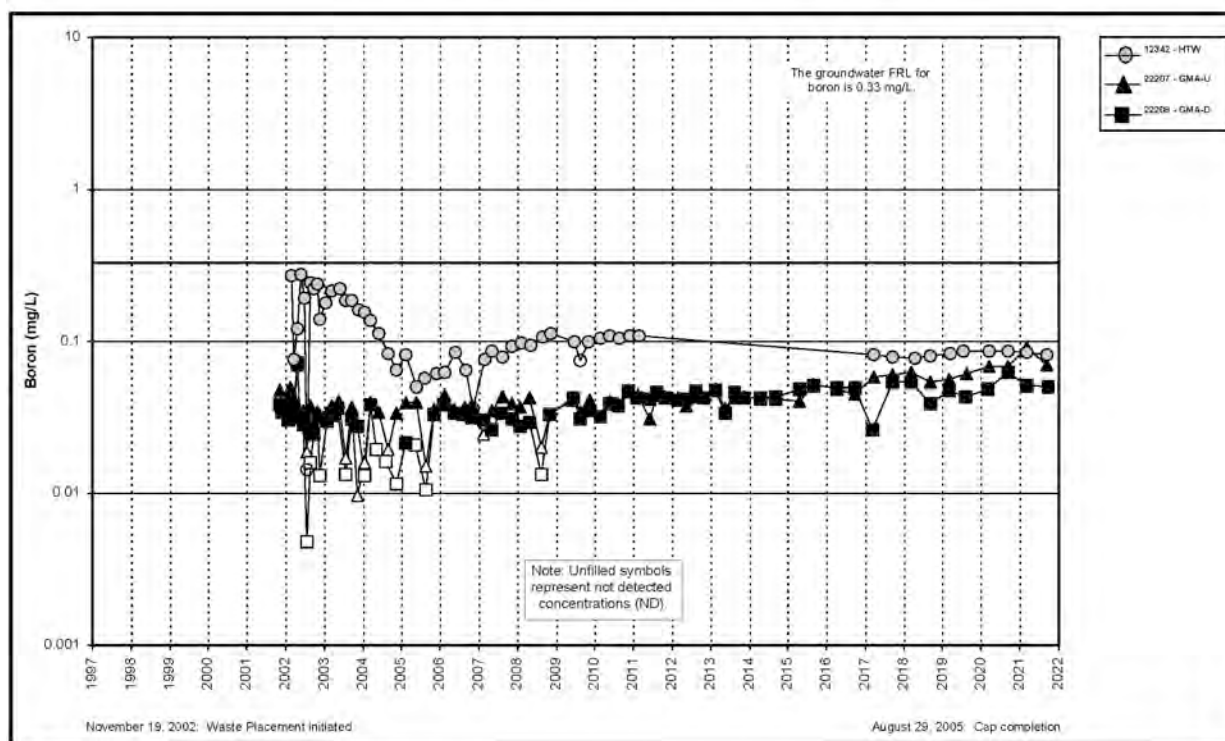


Figure A.5.5-6B. Cell 5 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

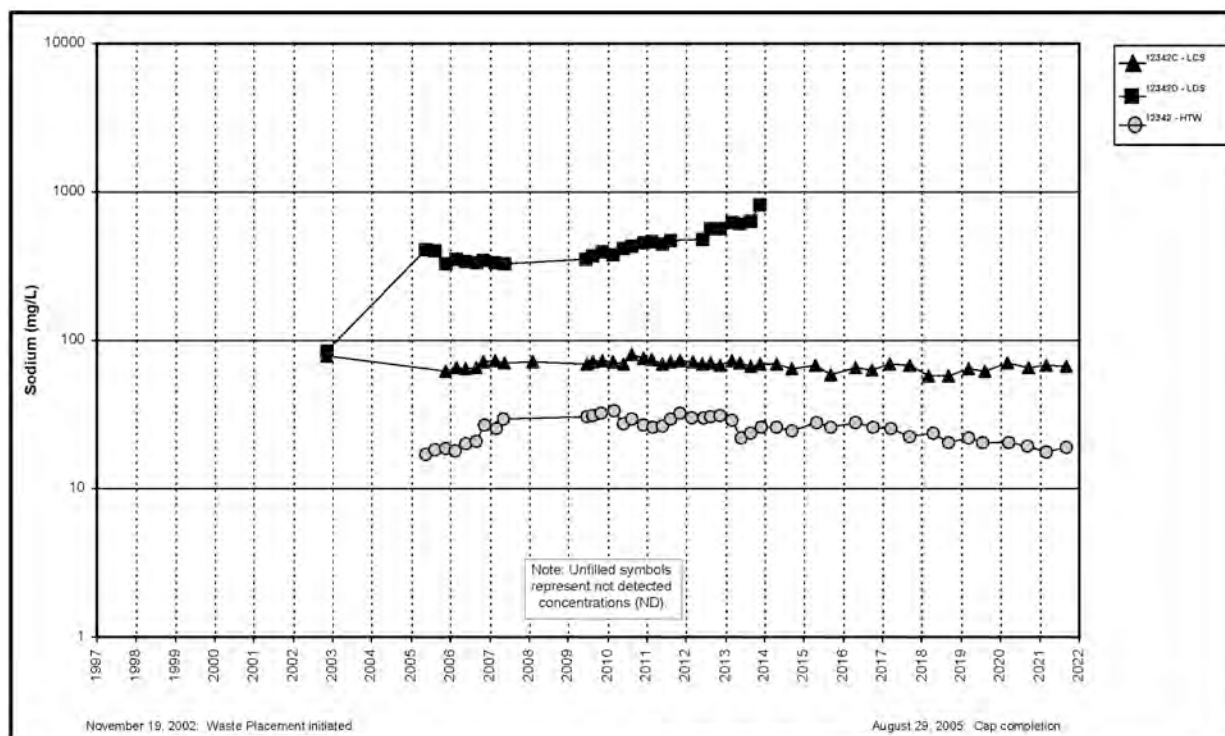


Figure A.5.5-7A. Cell 5 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

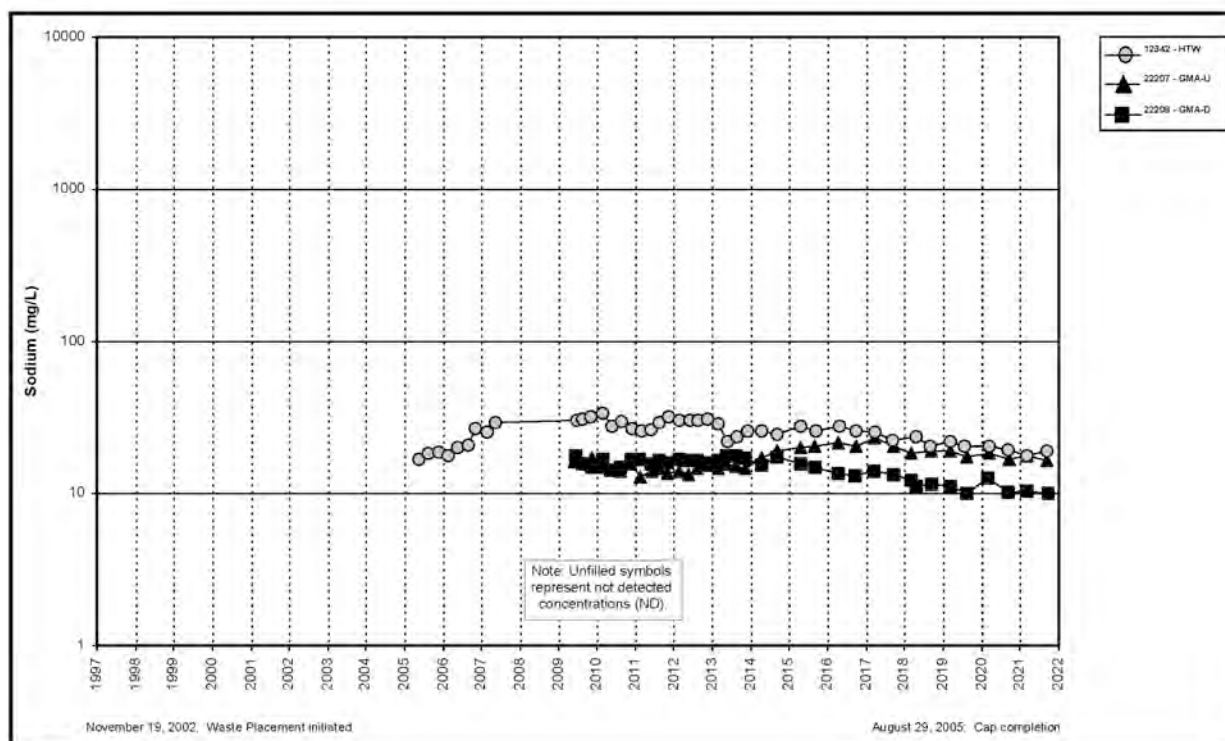


Figure A.5.5-7B. Cell 5 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

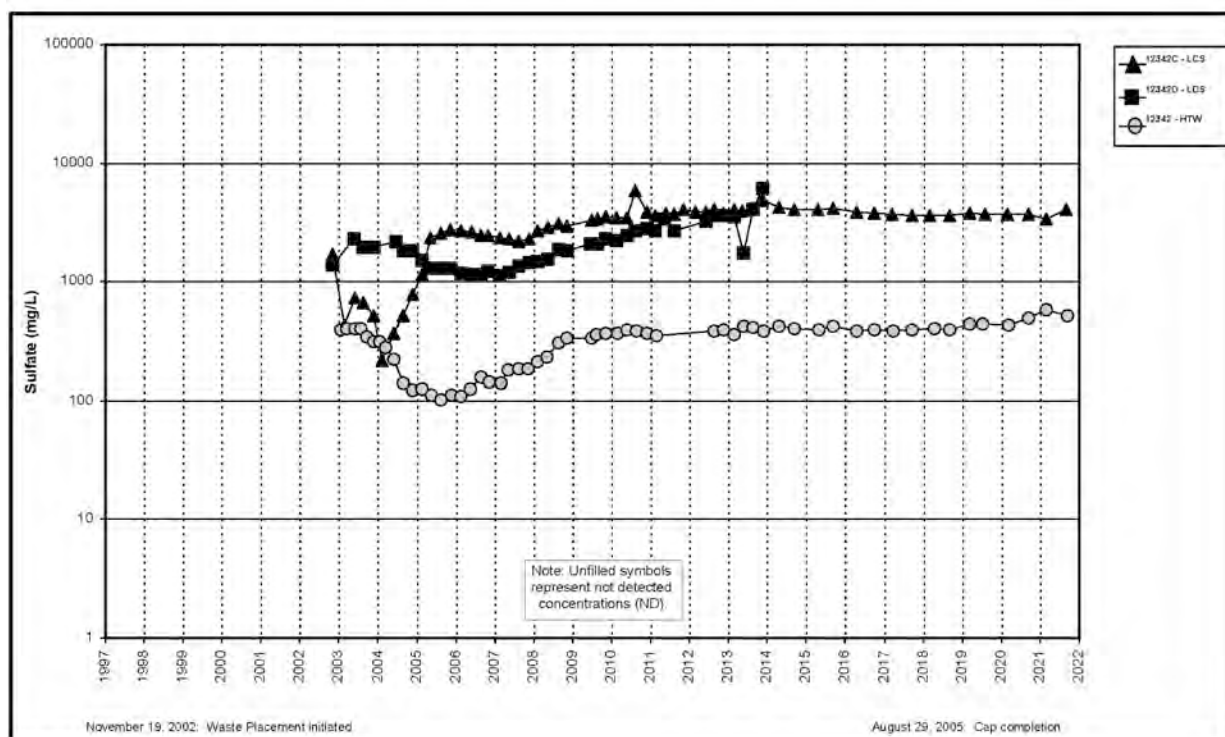


Figure A.5.5-8A. Cell 5 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

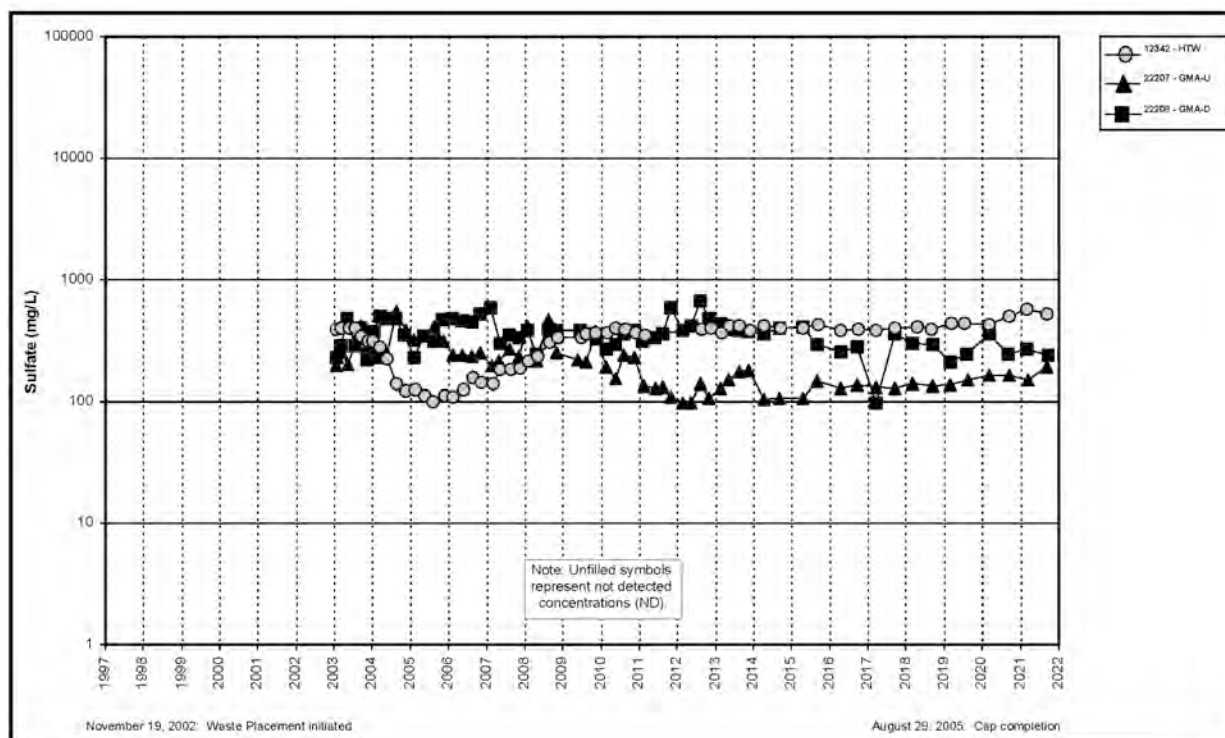


Figure A.5.5-8B. Cell 5 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

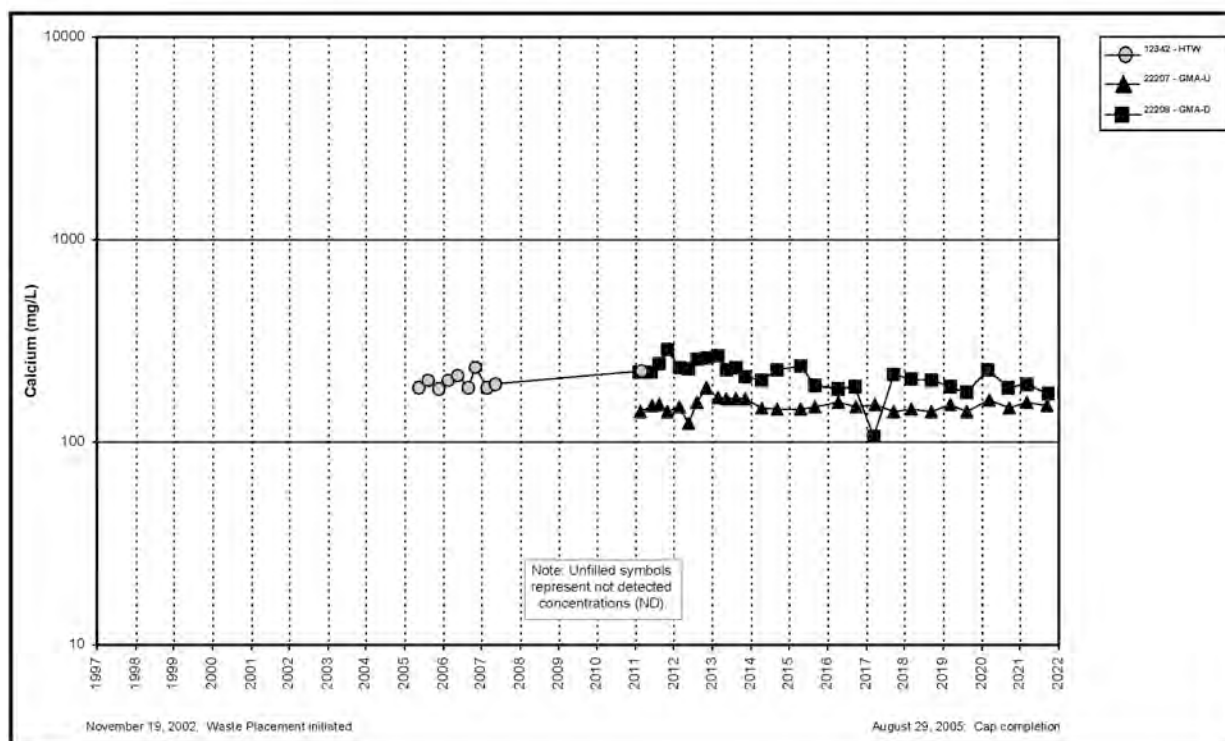


Figure A.5.5-9. Cell 5 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well



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

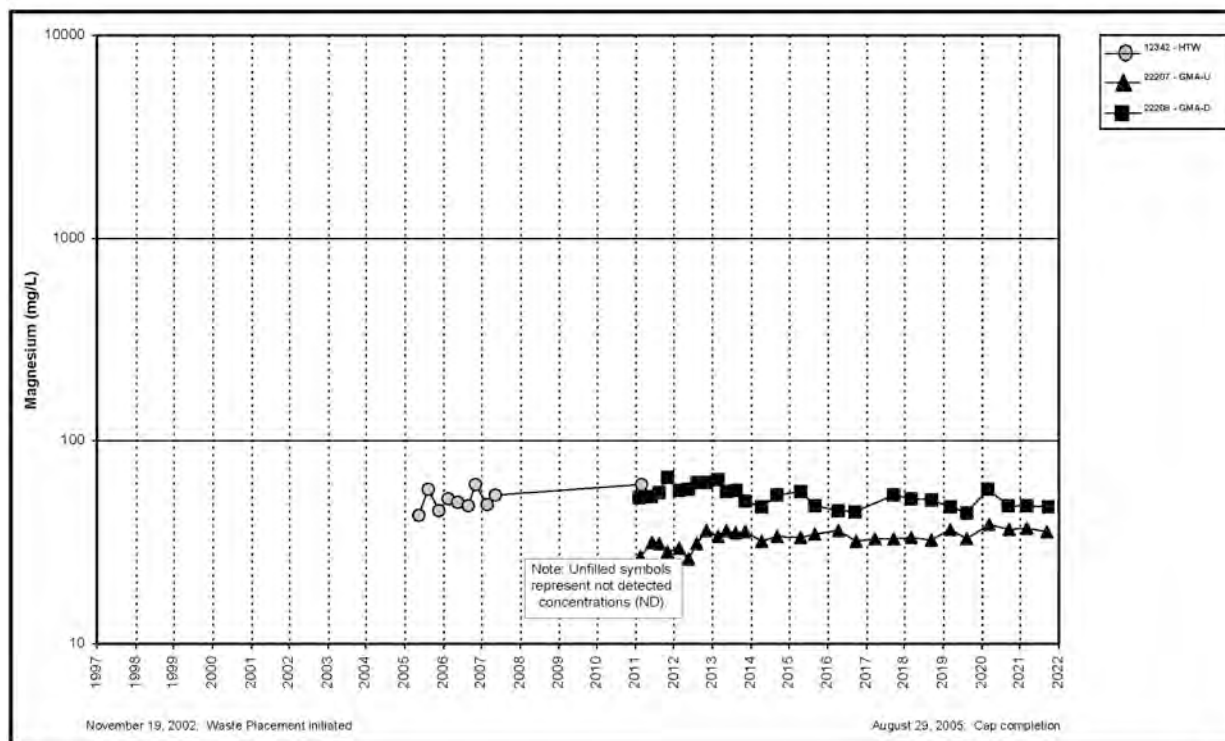


Figure A.5.5-11. Cell 5 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

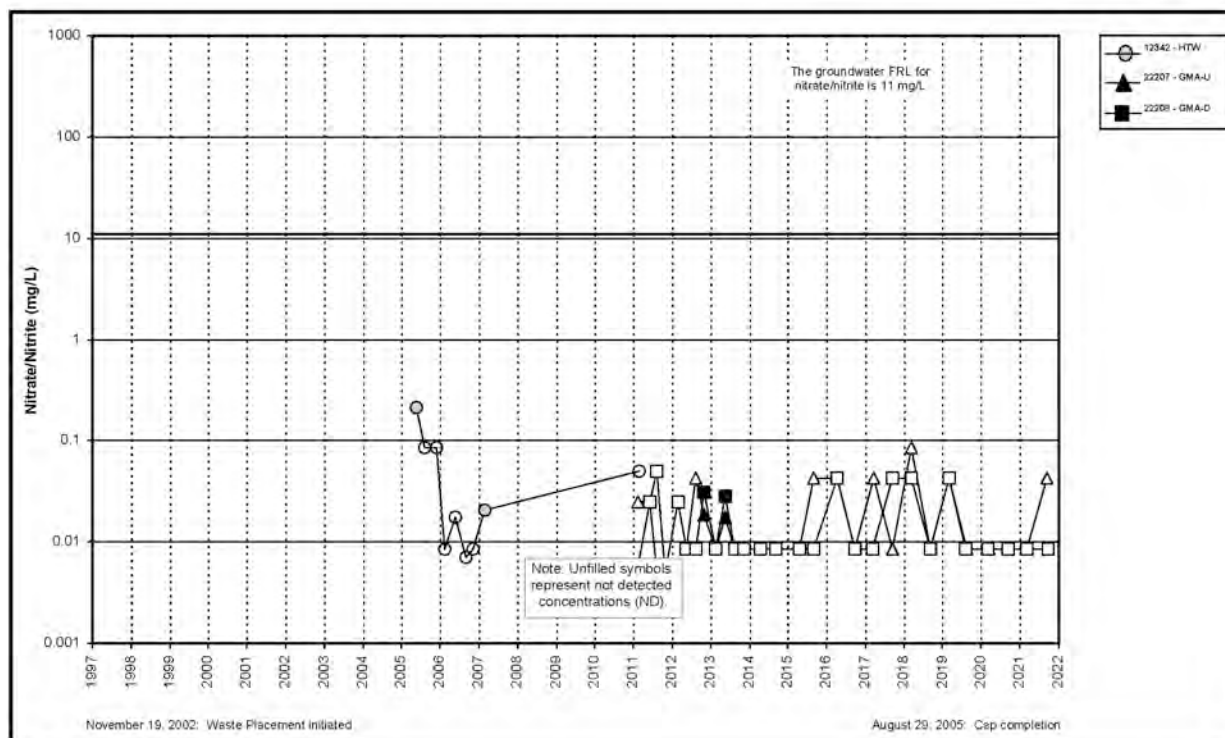


Figure A.5.5-12. Cell 5 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

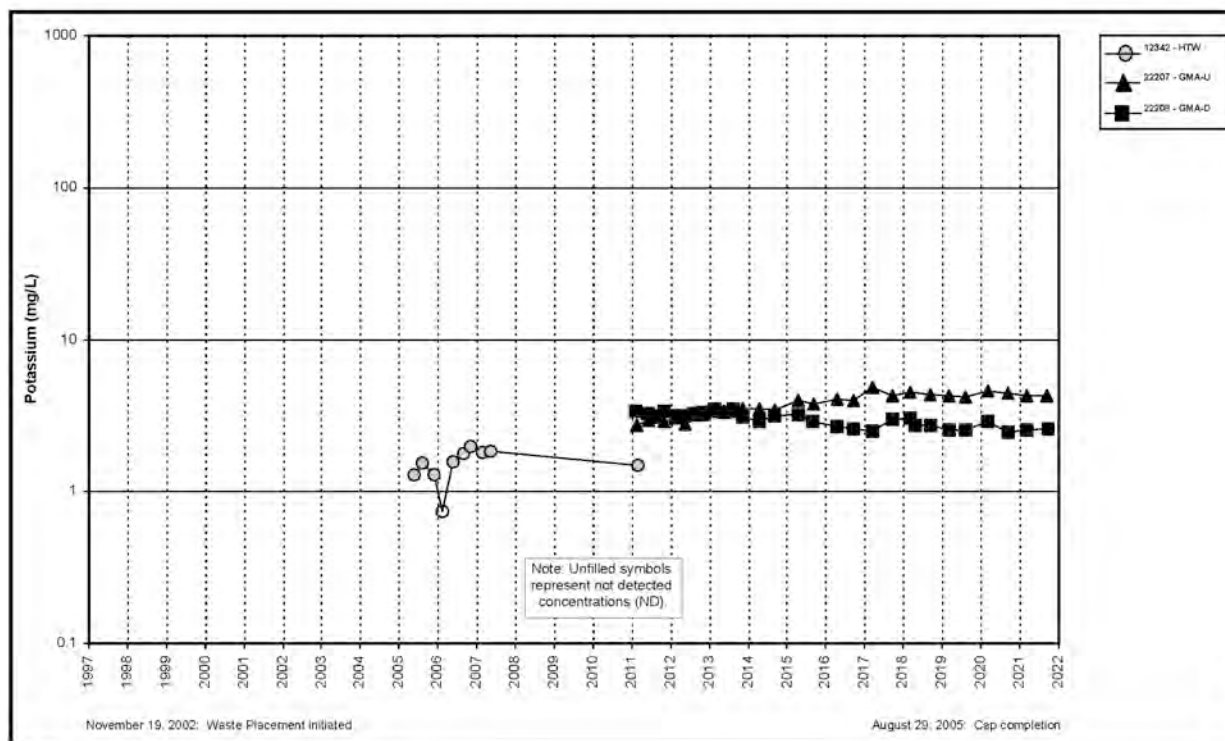


Figure A.5.5-13. Cell 5 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

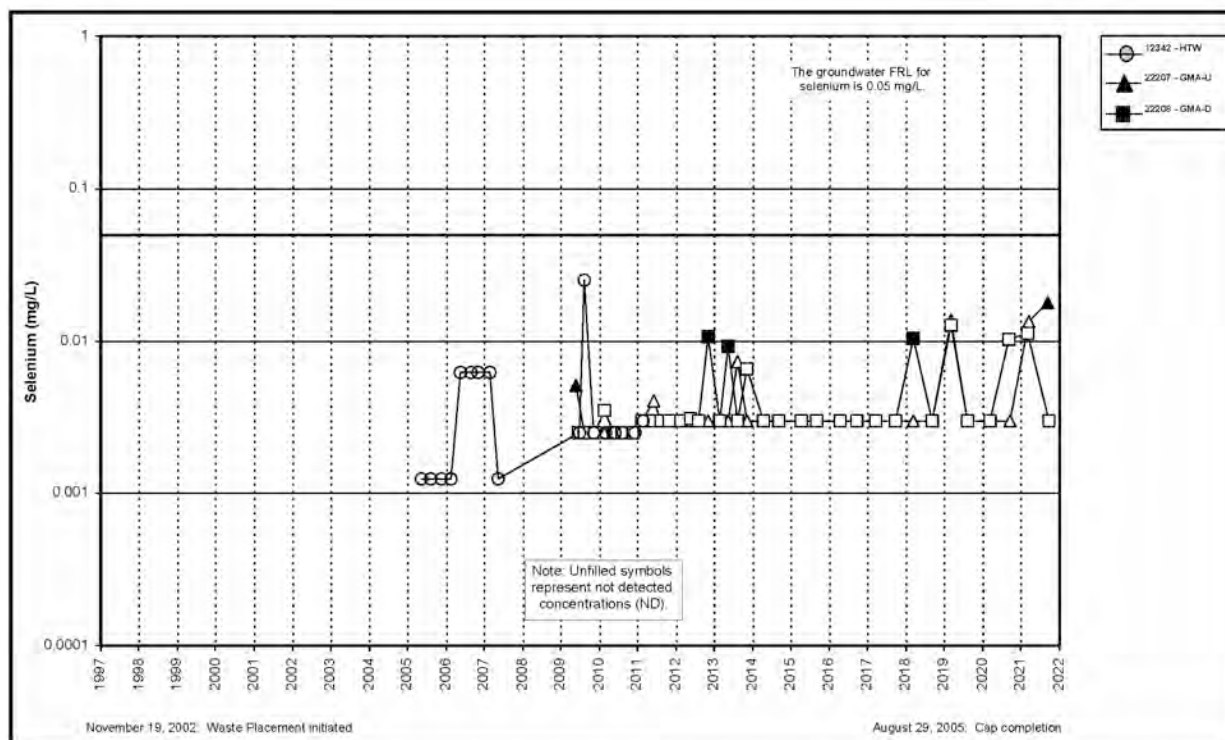


Figure A.5.5-14. Cell 5 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

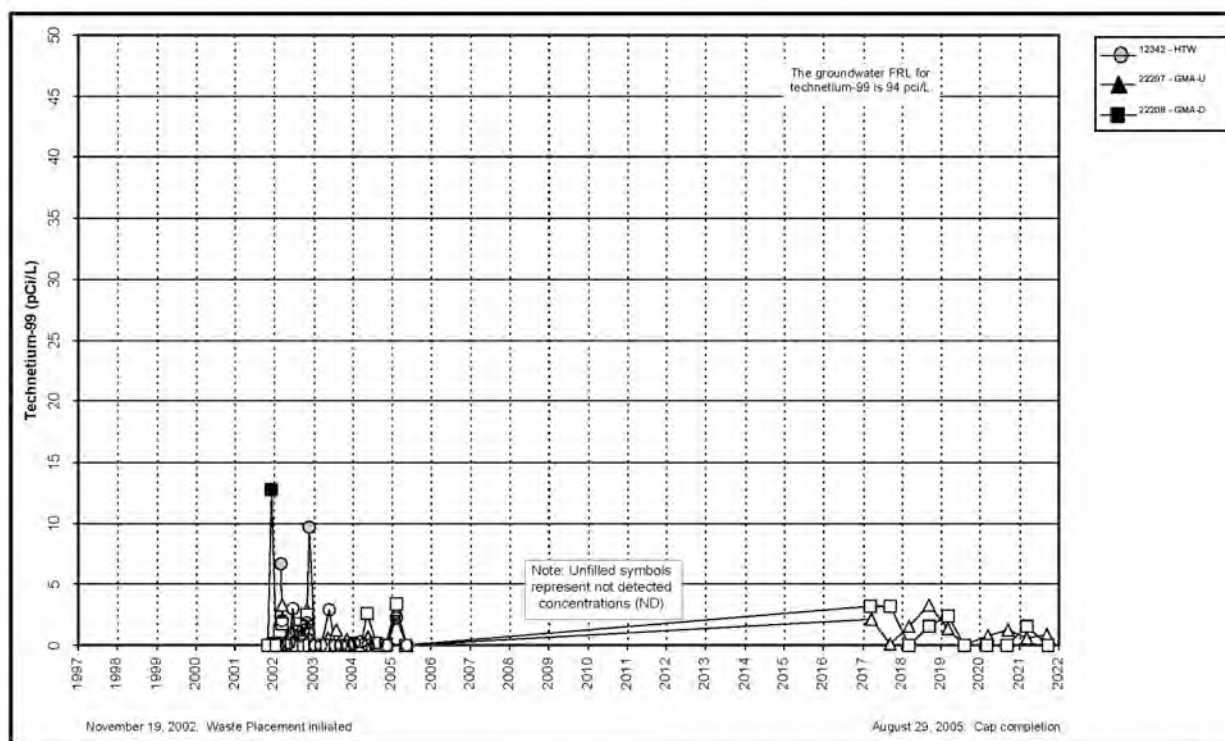


Figure A.5.5-15. Cell 5 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

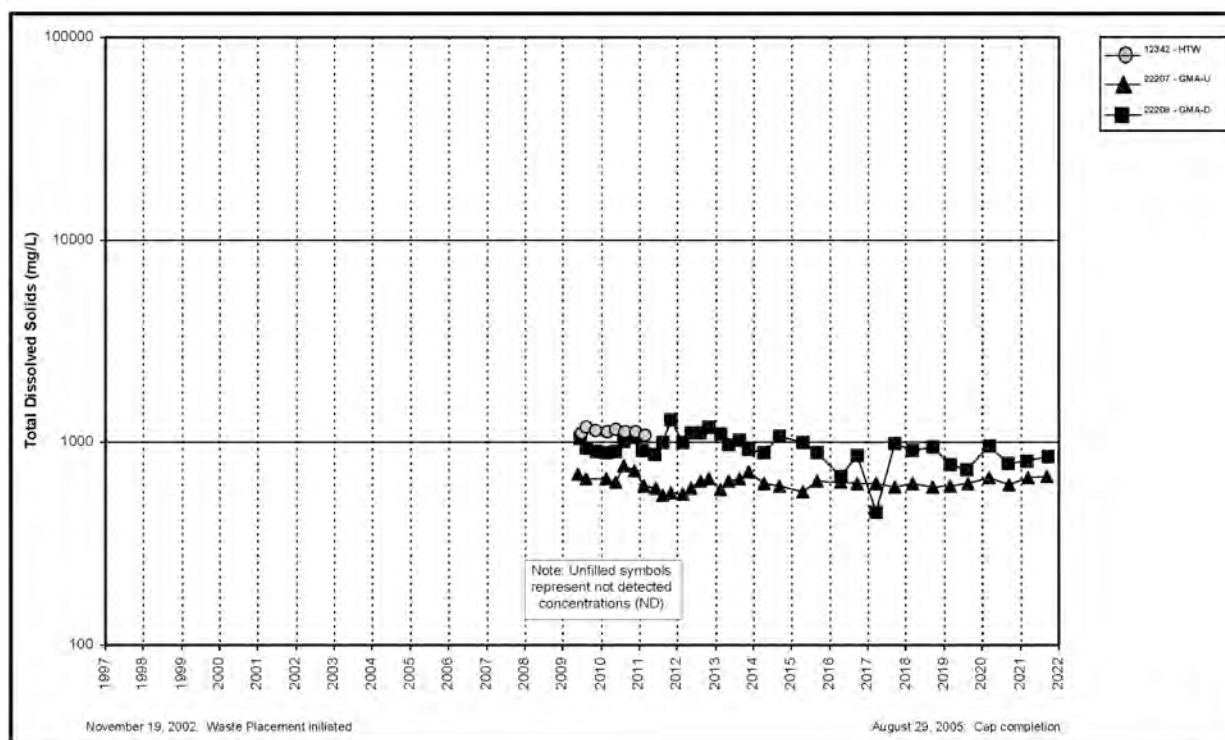


Figure A.5.5-16. Cell 5 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

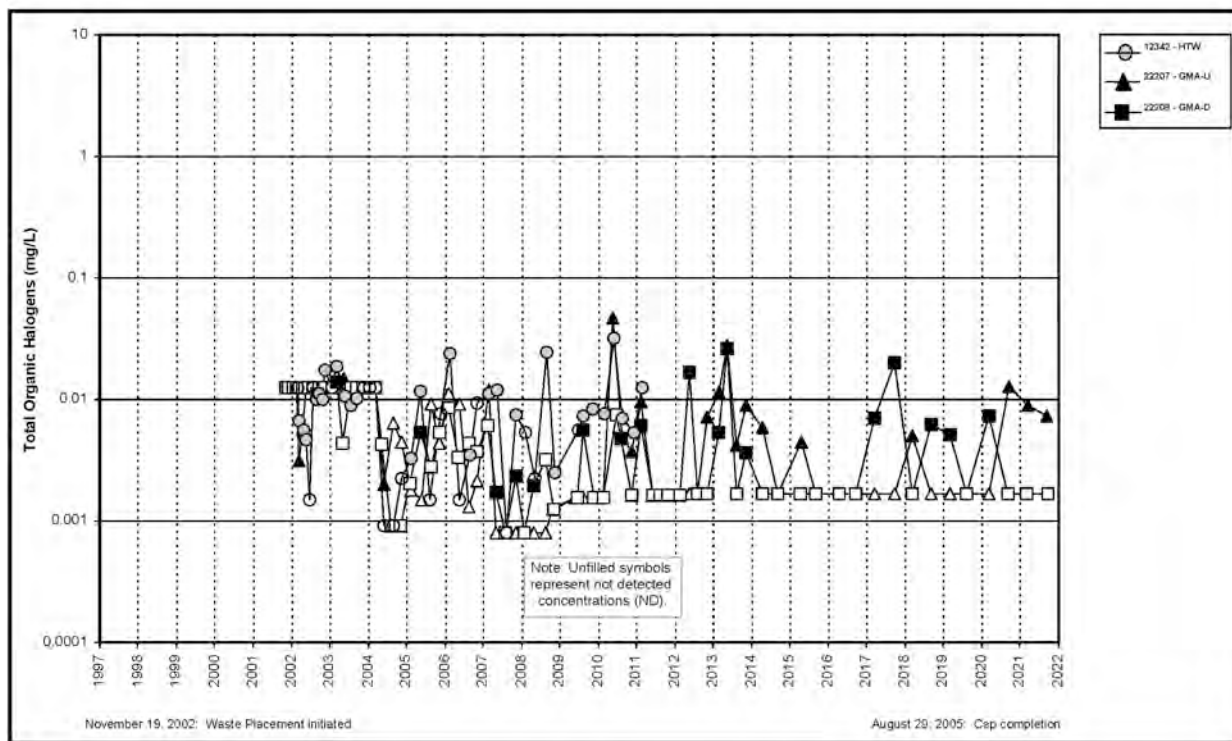


Figure A.5.5-17. Cell 5 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

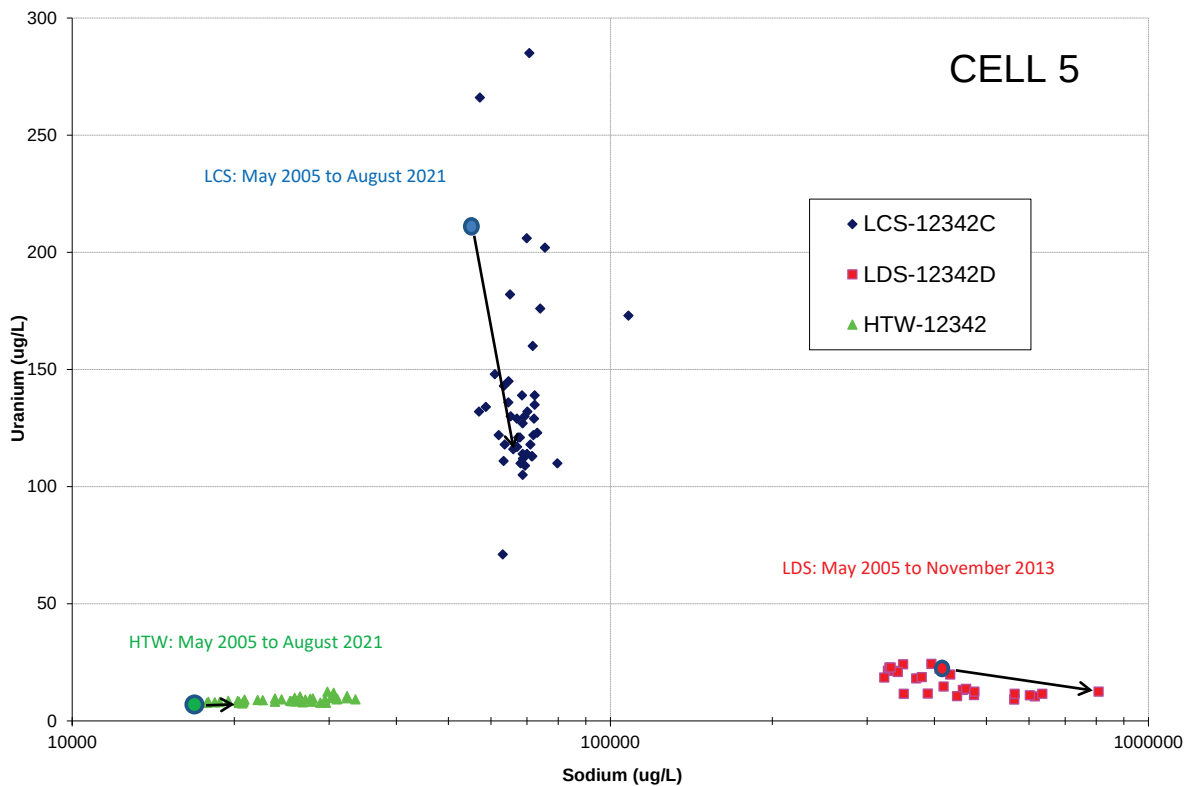


Figure A.5.5-18. Cell 5 Bivariate Plot for Uranium and Sodium

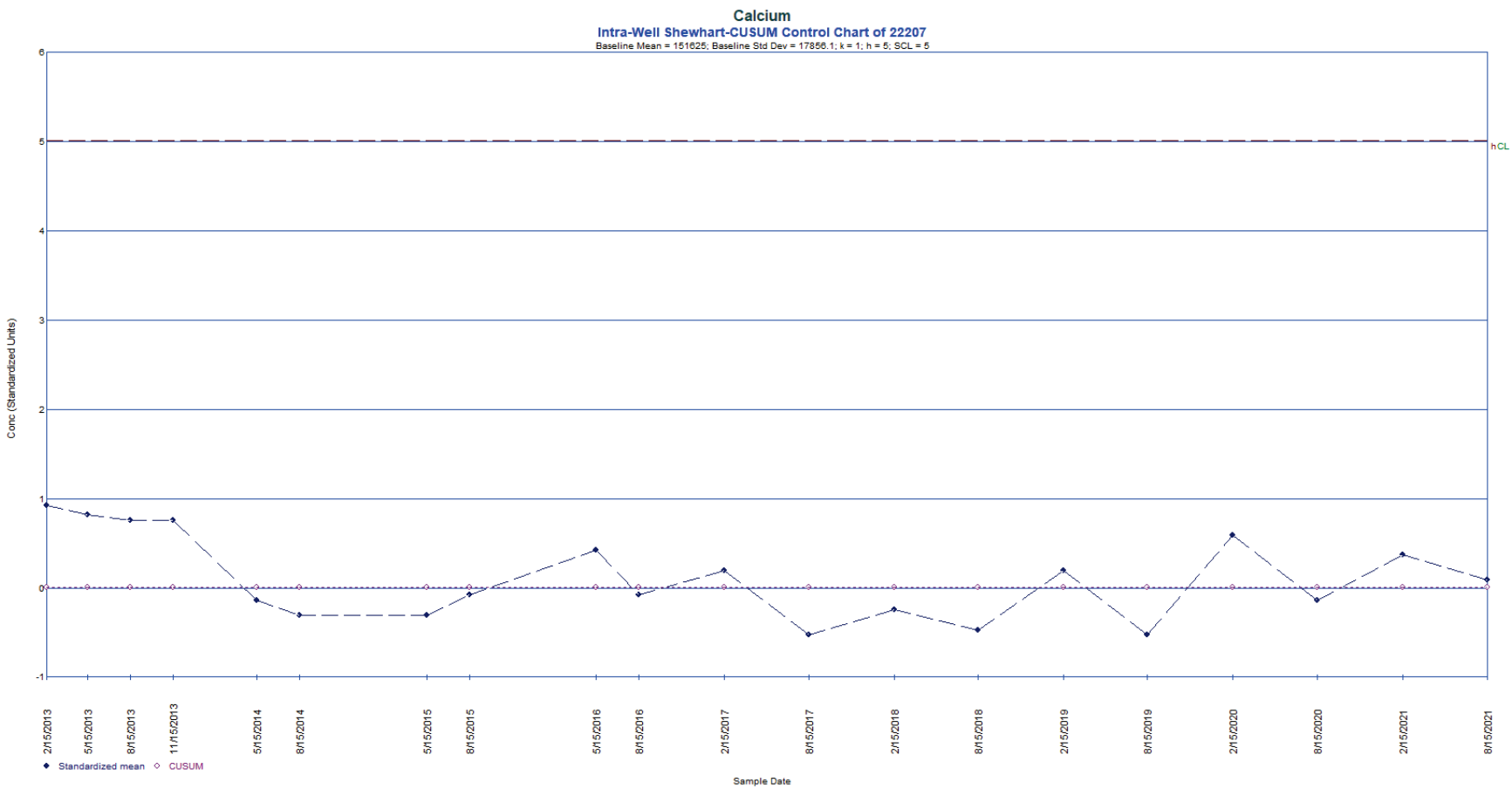


Figure A.5.5-19. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22207

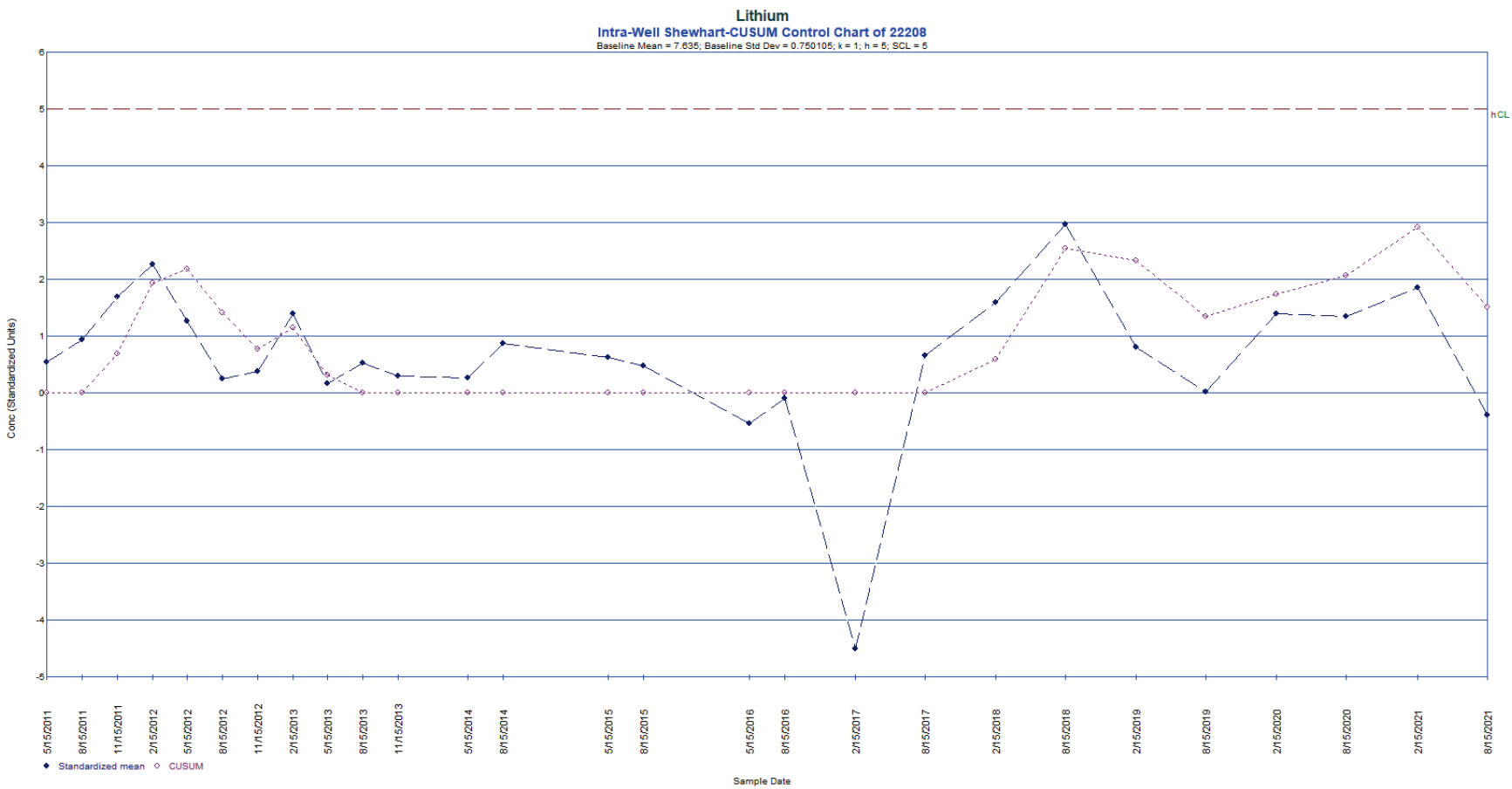


Figure A.5.5-20. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22208

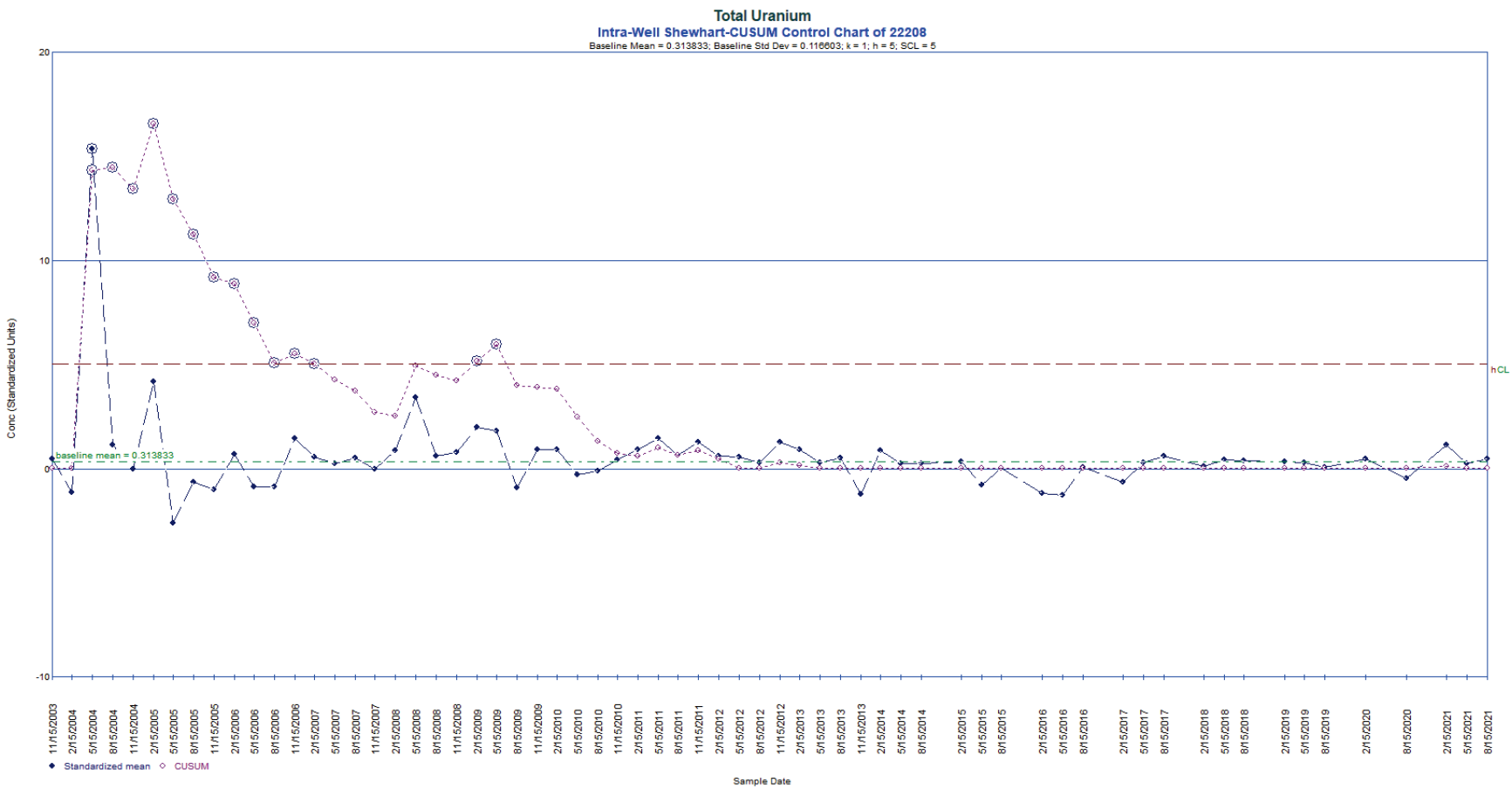


Figure A.5.5-21. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22208

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Subattachment A.5.6

Cell 6

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Abbreviations

CUSUM	Shewhart-cumulative sum
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMA	Great Miami Aquifer
GMA-D	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
HTW	horizontal till well
LCS	leachate collection system
LDS	leak detection system
Ohio EPA	Ohio Environmental Protection Agency
OSDF	On-Site Disposal Facility
SCL	Shewhart control limit

Measurement Abbreviations

amsl	above mean sea level
mg/L	milligrams per liter
µg/L	micrograms per liter

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This subattachment provides the following information about the On-Site Disposal Facility (OSDF) Cell 6:

- Semiannual monitoring summary statistics (refer to Table A.5.6-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.6-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.6-2)
- OSDF horizontal till well (HTW) 12343 water yield (refer to Table A.5.6-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.6-3 and A.5.6-4)
- Plots of concentration versus time (refer to Figures A.5.6-5A through A.5.6-17)
- A bivariate plot for uranium–sodium (refer to Figure A.5.6-18)
- Control charts (refer to Figures A.5.6-19 through A.5.6-23)

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 the 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 2021 have upward trends in the LCS and/or LDS based on the Mann-Kendall test for trend. In 2021, sufficient water was present in the LDS tank of Cell 6 to sample the tank twice. Three new concentration highs were measured in the LDS tank of Cell 6 in 2021 (uranium, sodium, and sulfate). The new high for uranium in the LDS was 152 micrograms per liter (µg/L). The previous high was 144 µg/L. The new high for sodium in the LDS was 856 mg/L. The previous high was 819 milligrams per liter (mg/L). The new high for sulfate in the LDS was 8,470 mg/L. The previous high was 6,510 mg/L.

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

Parameter	LCS 12343C 2021 Trend	LDS 12343D 2021 Trend
Total Uranium		Up
Boron		Up
Sodium	Up	Up
Sulfate	Up	Up

^aNo 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, five parameters (boron, sulfate, lithium, magnesium, and selenium) have upward trends in the HTW and/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^a

Parameter	HTW 12343	GMA-U ^b 22209	GMA-D ^b 22210
Boron		Up	Up
Sulfate	Up		Up
Lithium		Up	
Magnesium		Up	
Selenium		Up	Up

^aNo entry indicates that the trend was not up.

^bGMA-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 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.5.6-1 in gray shading and as summarized below, five parameters in the HTW or GMA wells of Cell 6 (total uranium, calcium, 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 five control charts (Figures A.5.6-19 through A.5.6-23). 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
Calcium	GMA-U	22209	In Control	A.5.6-20
Lithium	GMA-D	22210	In Control	A.5.6-21
Potassium	GMA-U	22209	In Control	A.5.6-22
Total Dissolved Solids	GMA-U	22209	In Control	A.5.6-23

^aGMA-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 and/or LDS of Cell 6: total uranium, boron, sodium, and sulfate. No new high concentrations were measured in 2021 in the Cell 6 LCS.
- Sufficient water was present in the LDS tank of Cell 6 to sample the tank twice in 2021. Three new concentration highs were measured in the LDS tank of Cell 6 in 2021 (i.e., uranium, sodium, and sulfate). The new high for uranium in the LDS was 152 µg/L. The previous high was 144 µg/L. The new high for sodium in the LDS was 856 mg/L. The

previous high was 819 mg/L. The new high for sulfate in the LDS was 8,470 mg/L. The previous high was 6,510 mg/L. The new high uranium sodium, and sulfate concentrations measured in the LDS are not attributed to communication with the LCS. They are attributed to the impact that decreasing flow can have on the concentrations left in water remaining in the LDS, as the LDS dries up. An additional discussion of this is presented in Attachment A.5, Section A.5.2.2.

- Five parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 6: boron, sulfate, 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.
- Five 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	56	56	100	43.3	276	124	33	Undefined	Down (2021)	Detectected	
	LDS	12343D	56	56	100	3.10	152	29.2	36.5	Undefined	Up (2021)	Detectected	
	HTW	12343	56	56	100	6.32	16.9	11.3	2.2	Normal	None (2021)	Detectected	24.2 (Q1-07); 21.4 (Q2-11)
	GMA-U	22209	54	60	90	ND	2.43	0.491	0.382	Undefined	Down (2021)	Not Detected	
	GMA-D	22210	66	68	97.1	ND	0.994	0.660	0.157	Ln Normal	None (2021)	Not Detected	
Boron (mg/L)	LCS	12343C	56	56	100	0.0566	1.37	0.734	0.194	Undefined	Down (2021)	Detectected	
	LDS	12343D	56	56	100	0.289	1.22	0.416	0.154	Undefined	Up (2021)	Detectected	2.38 (Q3-04)
	HTW	12343	35	39	89.7	ND	0.124	0.0899	0.0153	Normal	None (2021)	Detectected	0.0409 (Q2-06); 0.0360 (Q4-06)
	GMA-U	22209	55	60	91.7	ND	0.0668	0.0383	0.0096	Undefined	Up (2021)	Detectected	
	GMA-D	22210	57	60	95.0	ND	0.0616	0.0368	0.0090	Undefined	Up (2021)	Detectected	
Sodium (mg/L)	LCS	12343C	47	47	100	44.5	107	70.1	11.9	Normal	Up (2021)	Detectected	23.6 (Q2-04); 23.1 (Q2-05)
	LDS	12343D	45	45	100	109	856	513	138	Normal	Up (2021)	Detectected	
	HTW	12343	43	43	100	17.6	66.0	37.3	14.0	Undefined	Down (2021)	Detectected	
	GMA-U	22209	35	35	100	14.5	22.9	18.6	2.2	Normal	None (2021)	Detectected	
	GMA-D	22210	36	36	100	11.7	17.1	16.5	2.3	Undefined	Down (2021)	Detectected	
Sulfate (mg/L)	LCS	12343C	56	56	100	491	4,800	3,460	1,050	Undefined	Up (2021)	Detectected	
	LDS	12343D	55	55	100	1,300	8,470	3,450	1,570	Ln Normal	Up (2021)	Detectected	
	HTW	12343	50	51	98.0	ND	716	496	96	Normal	Up (2021)	Detectected	
	GMA-U	22209	59	59	100	2.07	406	162	67	Undefined	Down (2021)	Detectected	
	GMA-D	22210	59	59	100	127	392	276	72	Normal	Up (2021)	Detectected	578 (Q1-07)
Calcium (mg/L)	GMA-U	22209	28	28	100	136	184	151	12	Normal	None (2021)	Not Detected	242 (Q3-11); 231 (Q3-13)
	GMA-D	22210	28	28	100	176	239	208	19	Normal	Down (2021)	Detectected	
Lithium (mg/L)	GMA-U	22209	35	35	100	0.00486	0.0100	0.00660	0.00124	Ln Normal	Up (2021)	Detectected	
	GMA-D	22210	35	35	100	0.00631	0.00865	0.00738	0.00057	Normal	None (2021)	Not Detected	
Magnesium (mg/L)	GMA-U	22209	28	28	100	27.0	39.7	33.4	3.0	Normal	Up (2021)	Detectected	55.4 (Q3-13)
	GMA-D	22210	28	28	100	41.5	58.3	50.7	4.4	Normal	Down (2021)	Detectected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22209	3	29	10.3	ND	0.500	0.033	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22210	1	28	3.6	ND	0.0425	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22209	28	28	100	3.00	3.78	3.31	0.18	Normal	None (2021)	Not Detected	
	GMA-D	22210	29	29	100	2.79	3.62	3.18	0.23	Normal	Down (2021)	Detectected	
Selenium (mg/L)	GMA-U	22209	5	35	14.3	ND	0.0236	0.00300	0.00400	Undefined	Up (2021)	Detectected	
	GMA-D	22210	4	35	11.4	ND	0.0122	0.00300	0.00244	Undefined	Up (2021)	Detectected	
Technitium-99 (pCi/L)	GMA-U	22209	1	21	4.8	ND	8.61	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22210	1	21	4.8	ND	6.61	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22209	35	35	100	550	720	634	43	Normal	None (2021)	Not Detected	876 (Q3-11)
	GMA-D	22210	35	35	100	694	1,020	897	80	Normal	Down (2021)	Detectected	
Total Organic Halogens (mg/L)	GMA-U	22209	19	60	31.7	ND	0.0208	0.00166	0.00487	Undefined	None (2021)	Detectected	0.0365 (Q3-06); 0.0377 (Q1-11); 0.0432 (Q1-13)
	GMA-D	22210	17	60	28.3	ND	0.0590	0.00193	0.00837	Undefined	None (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

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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

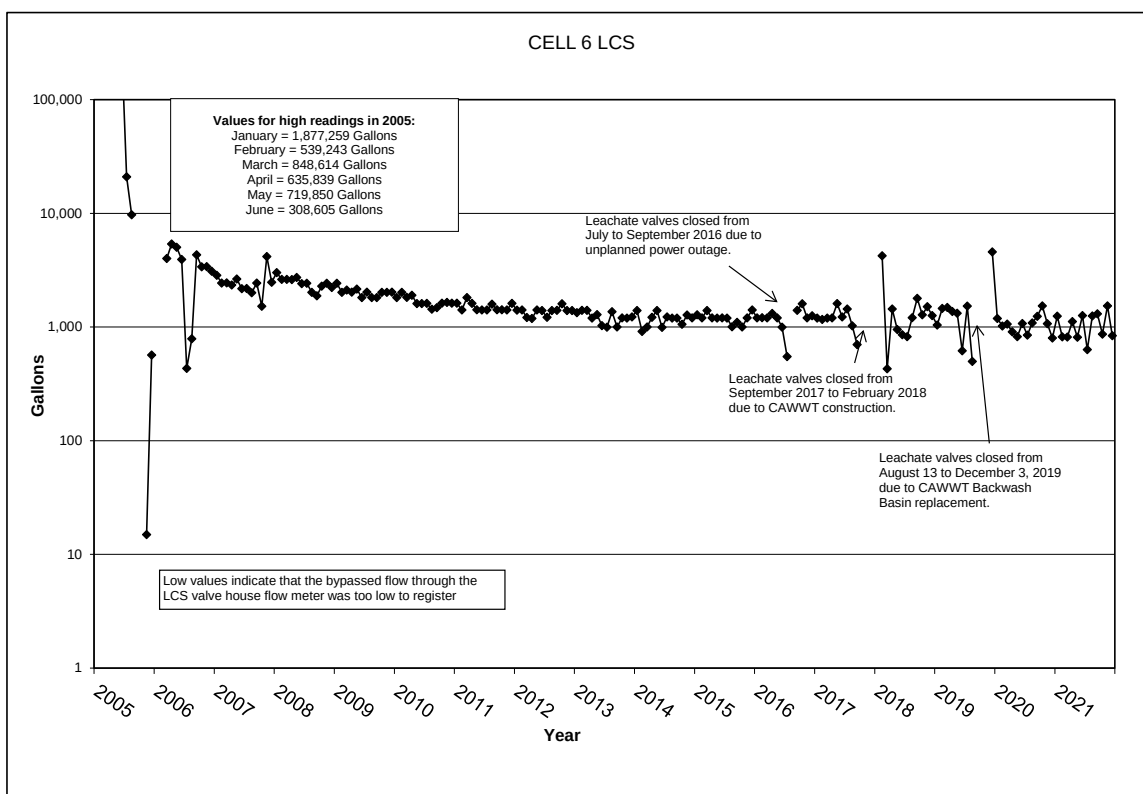


Figure A.5.6-1. Monthly Accumulation Volumes for Cell 6 LCS

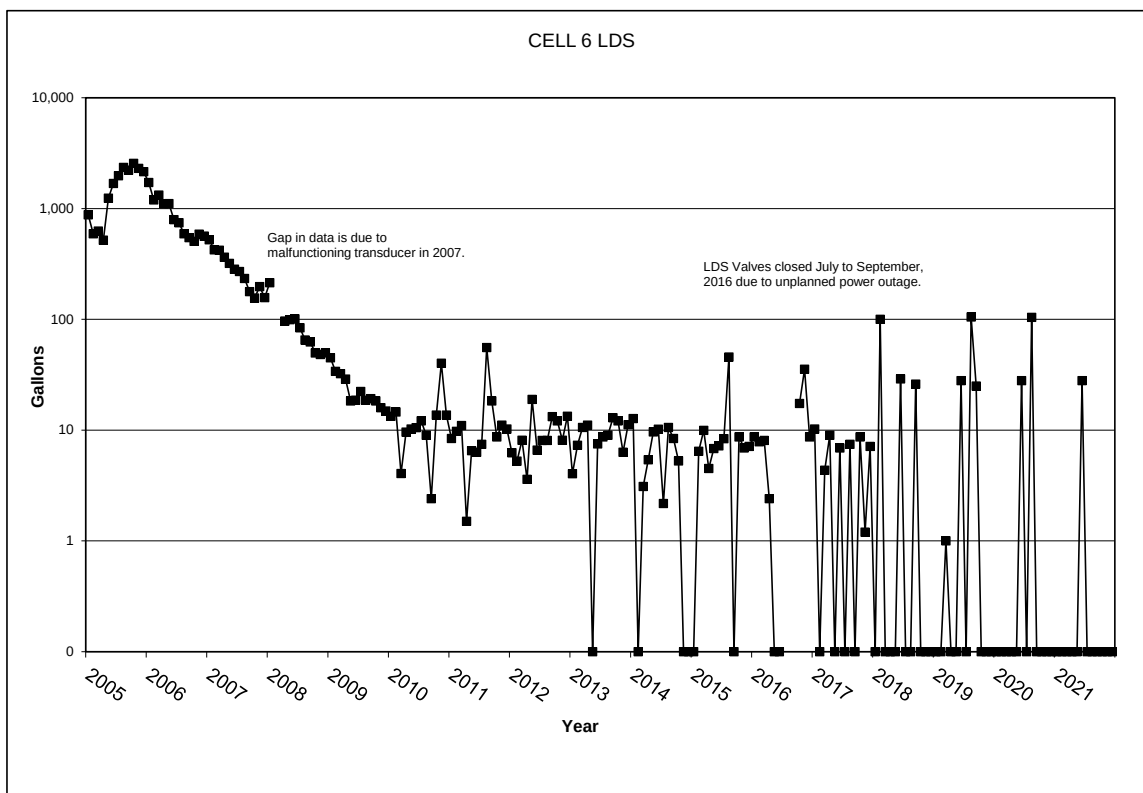


Figure A.5.6-2. Monthly Accumulation Volumes for Cell 6 LDS

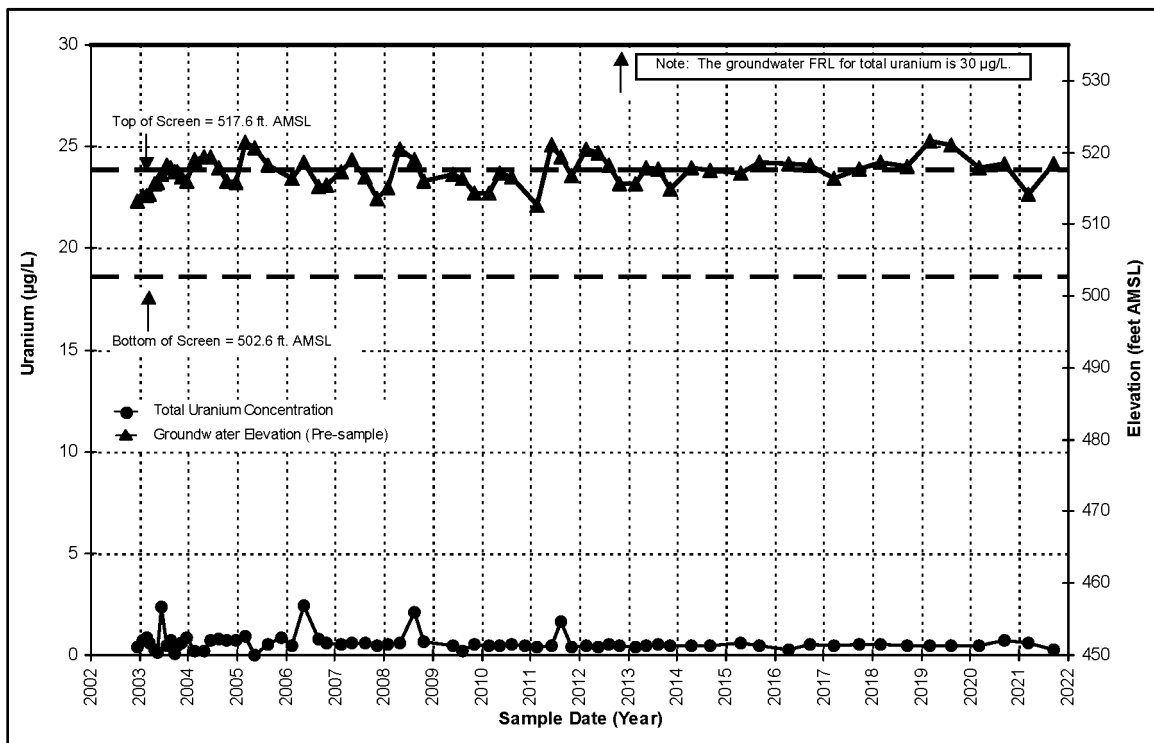


Figure A.5.6-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 6 Upgradient Monitoring Well 22209

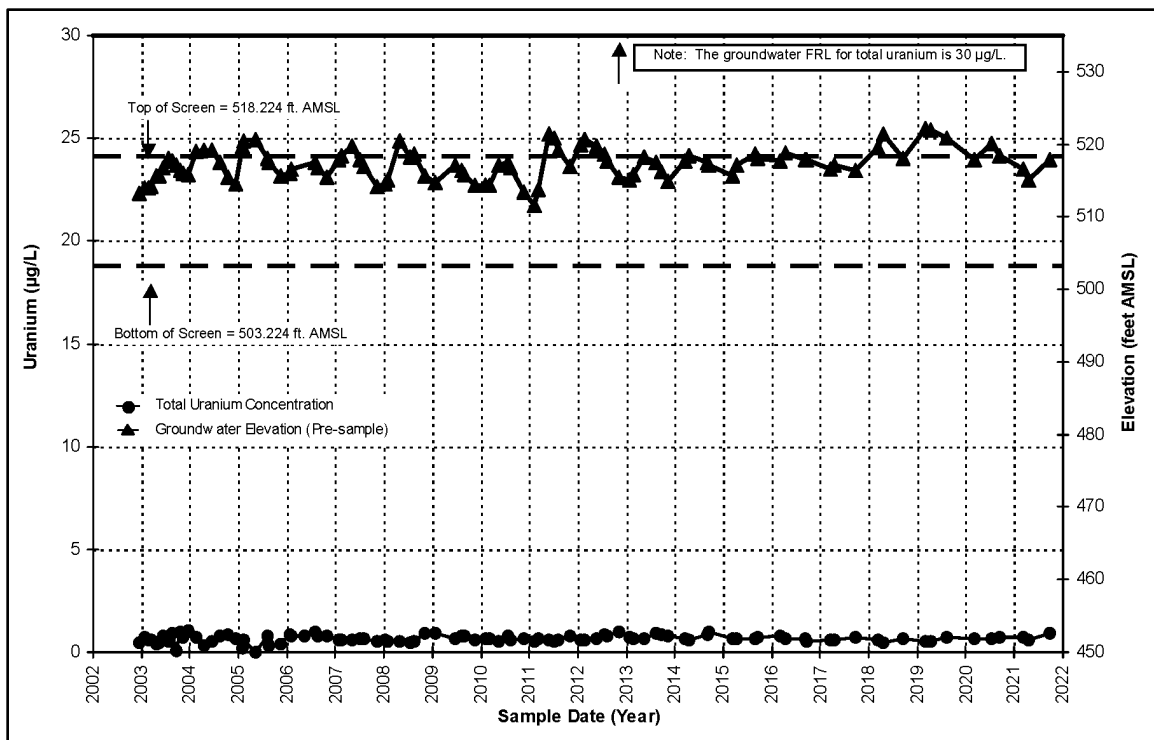


Figure A.5.6-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 6 Downgradient Monitoring Well 22210

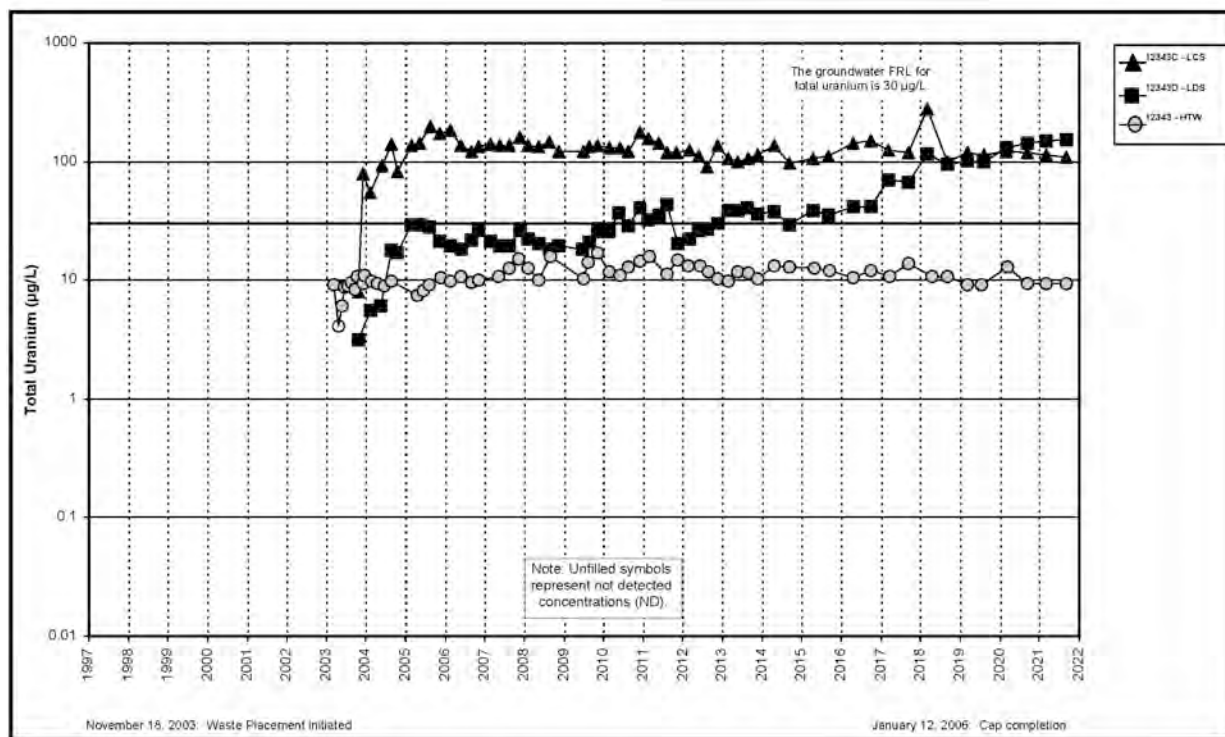


Figure A.5.6-5A. Cell 6 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

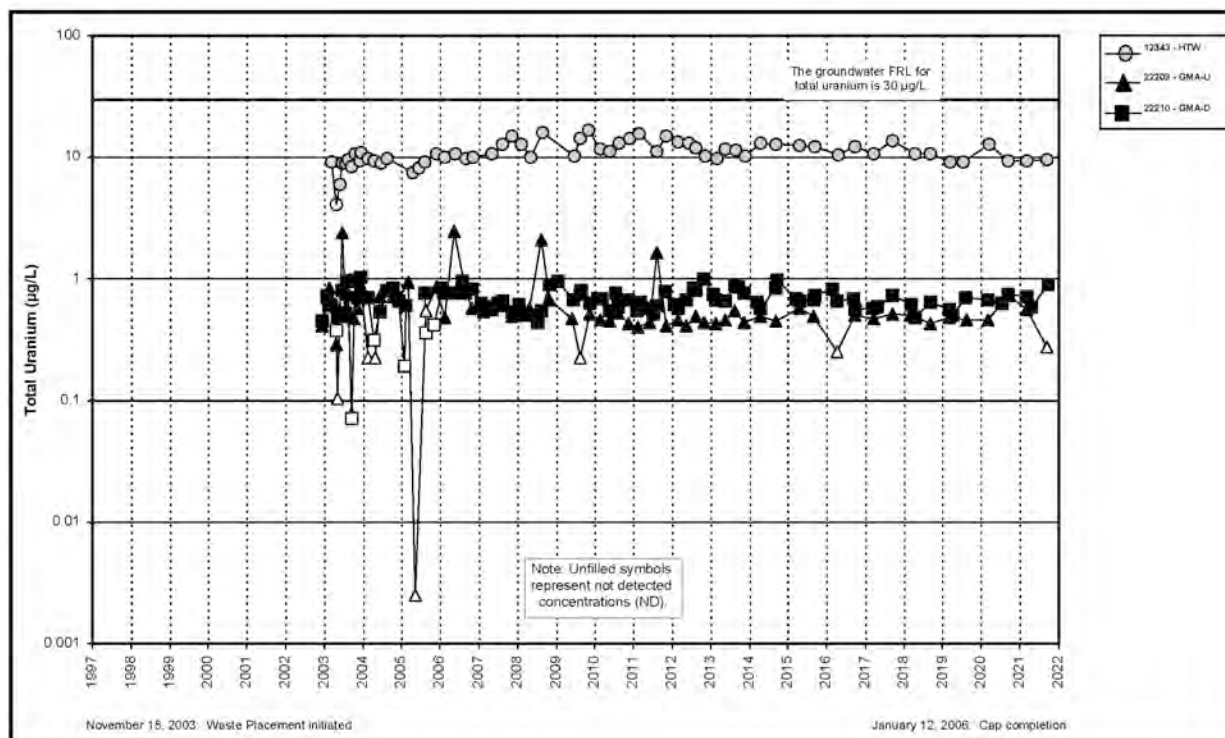


Figure A.5.6-5B. Cell 6 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

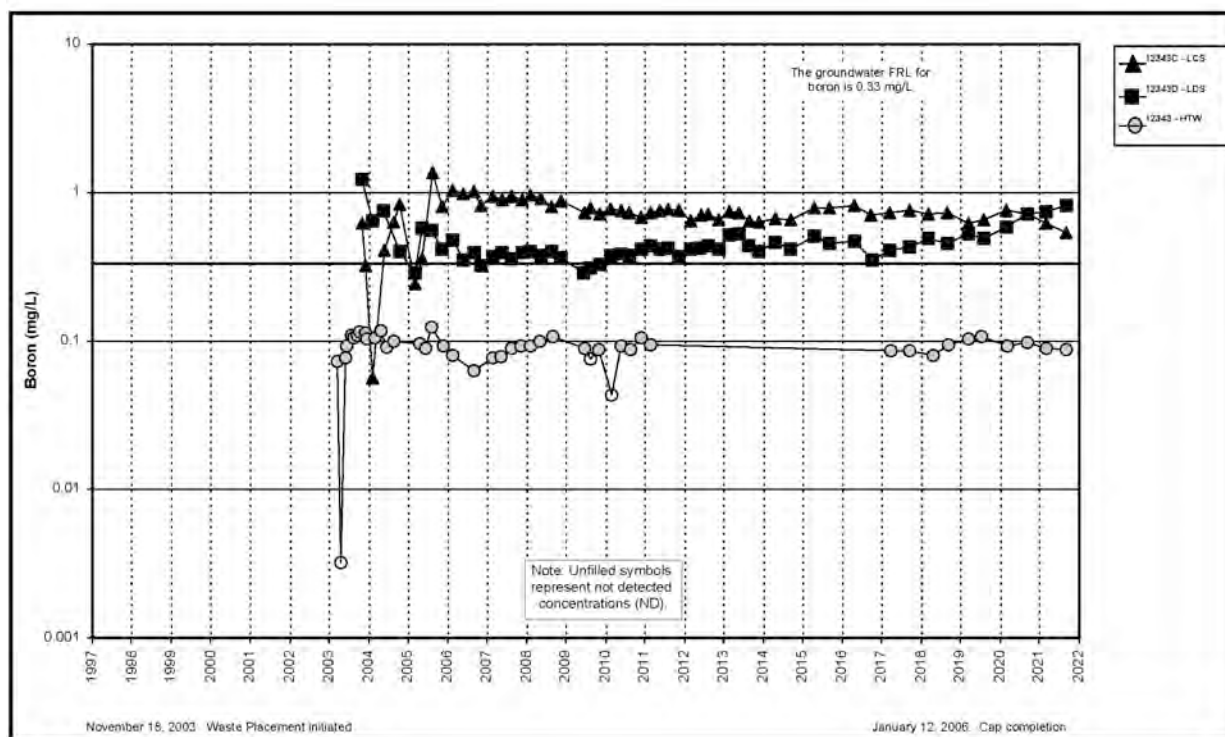


Figure A.5.6-6A. Cell 6 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

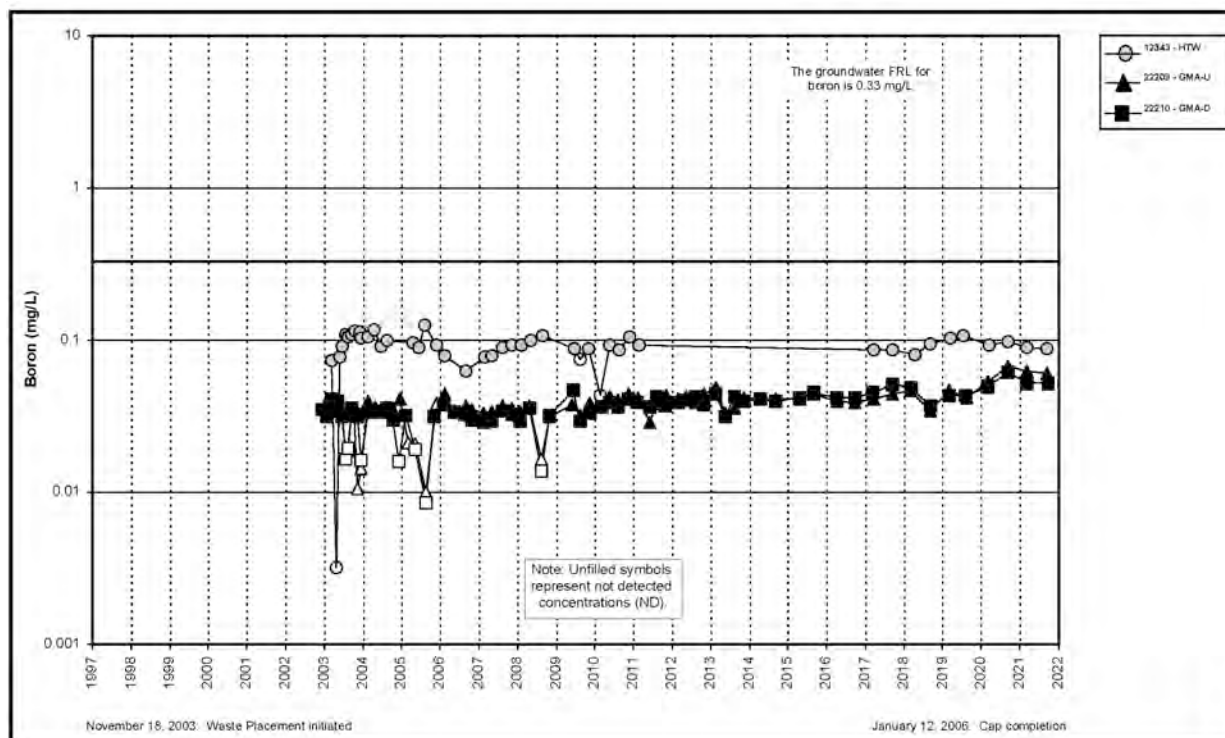


Figure A.5.6-6B. Cell 6 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

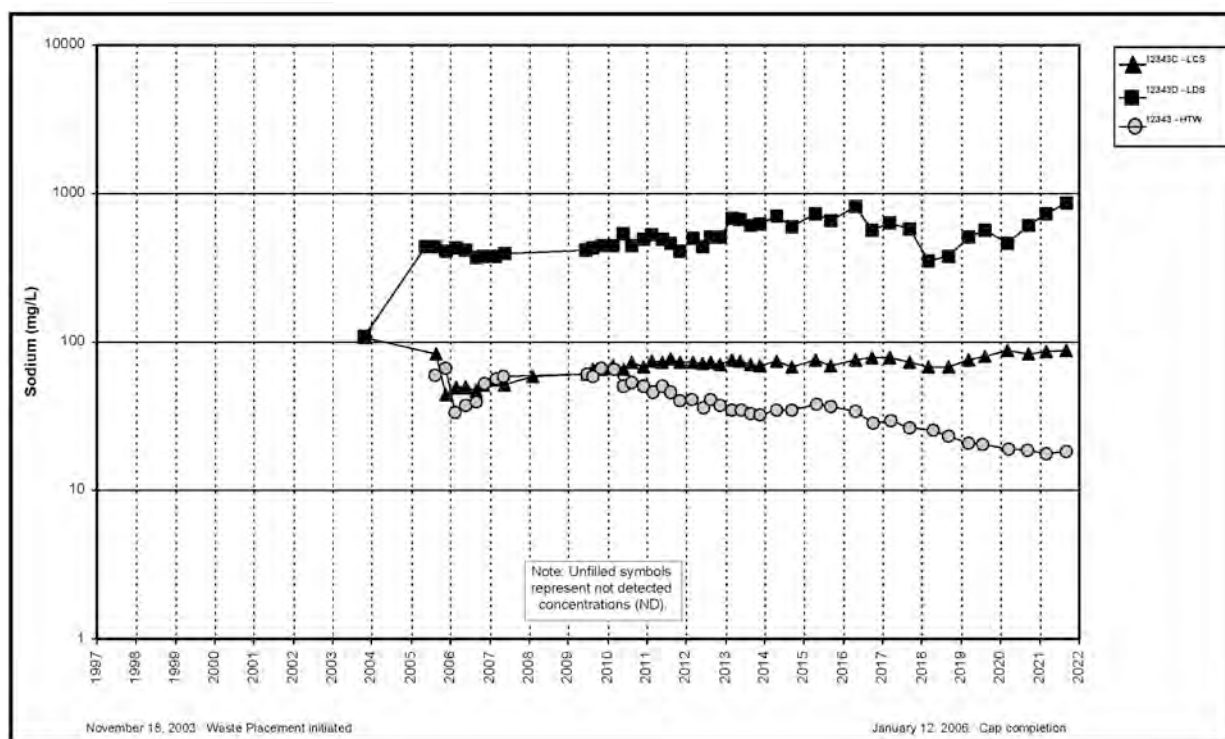


Figure A.5.6-7A. Cell 6 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

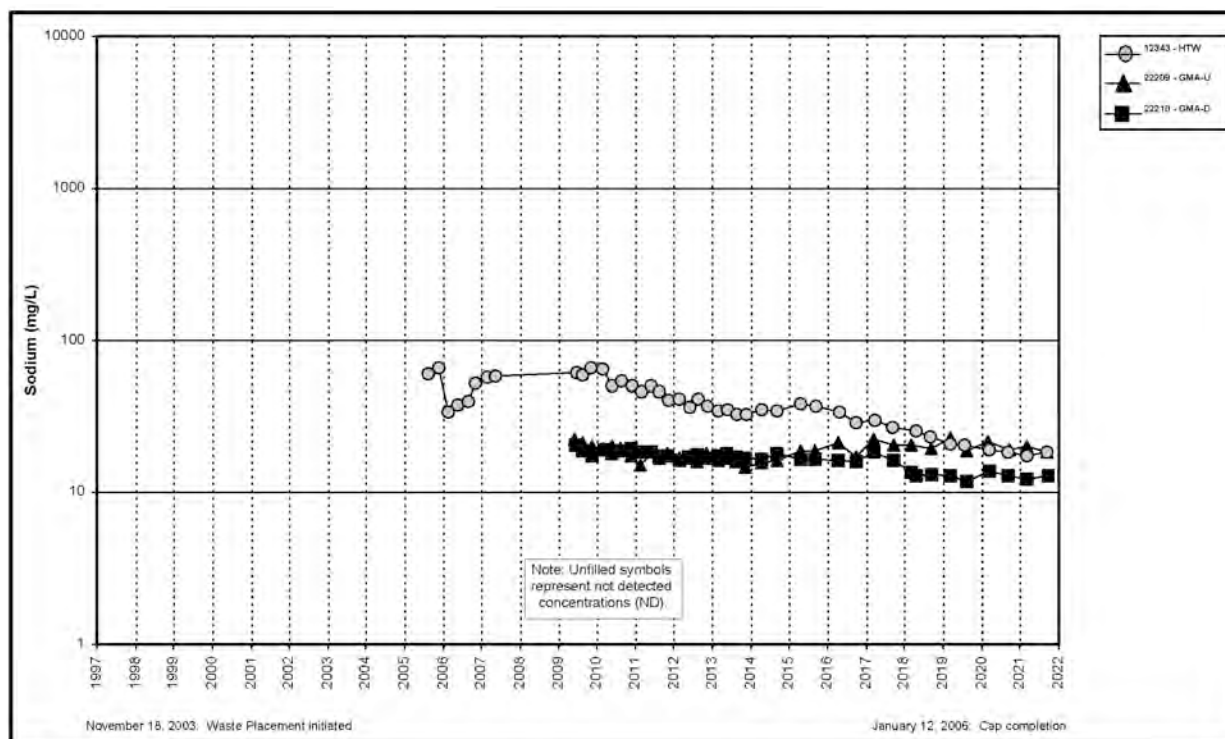


Figure A.5.6-7B. Cell 6 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

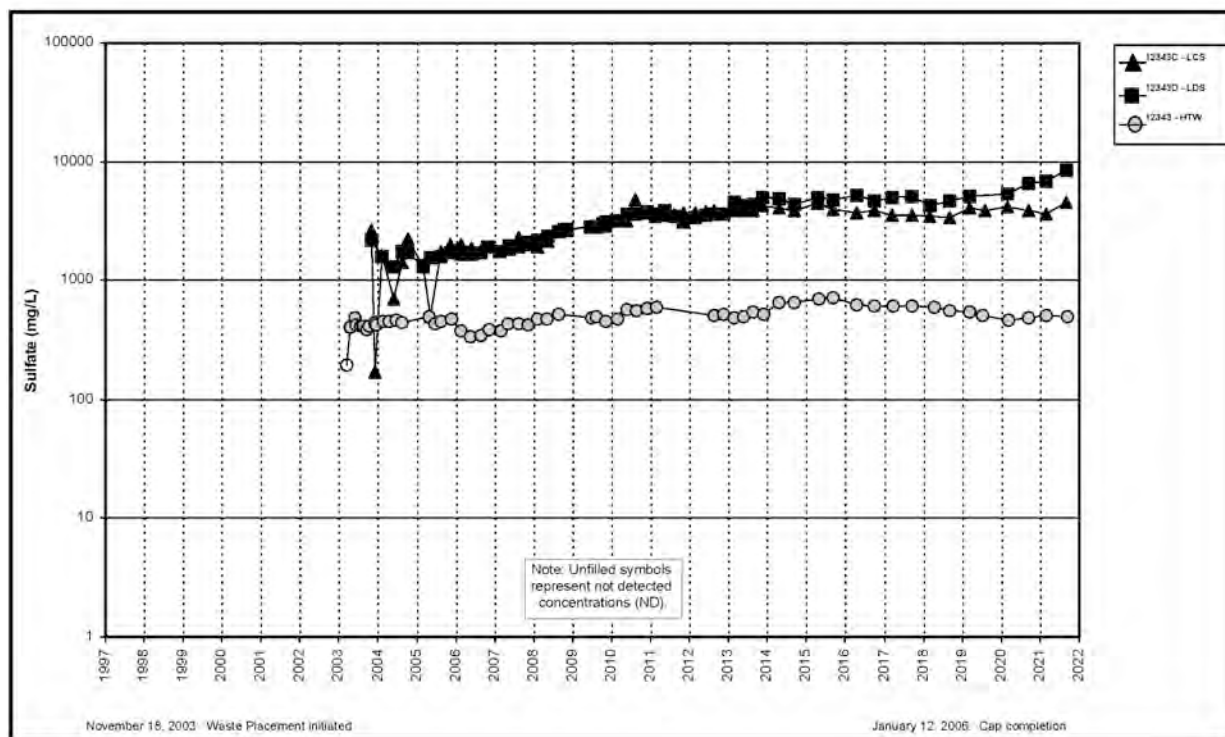


Figure A.5.6-8A. Cell 6 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

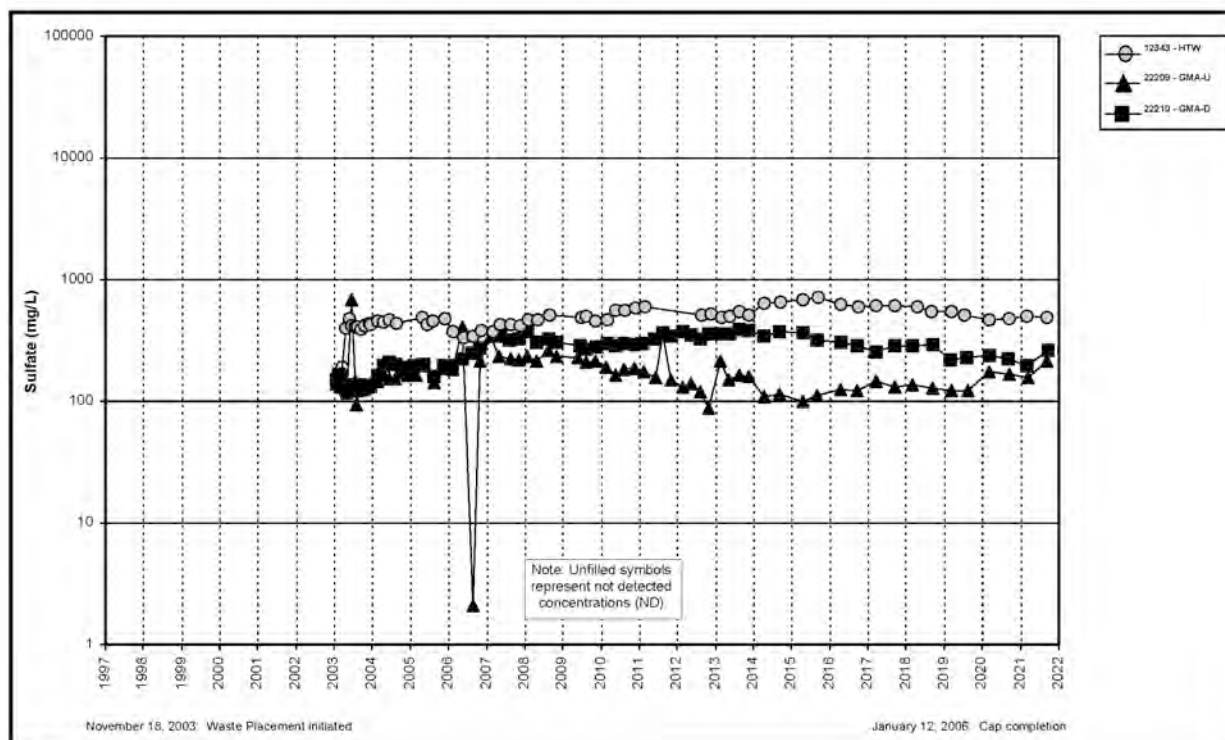


Figure A.5.6-8B. Cell 6 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

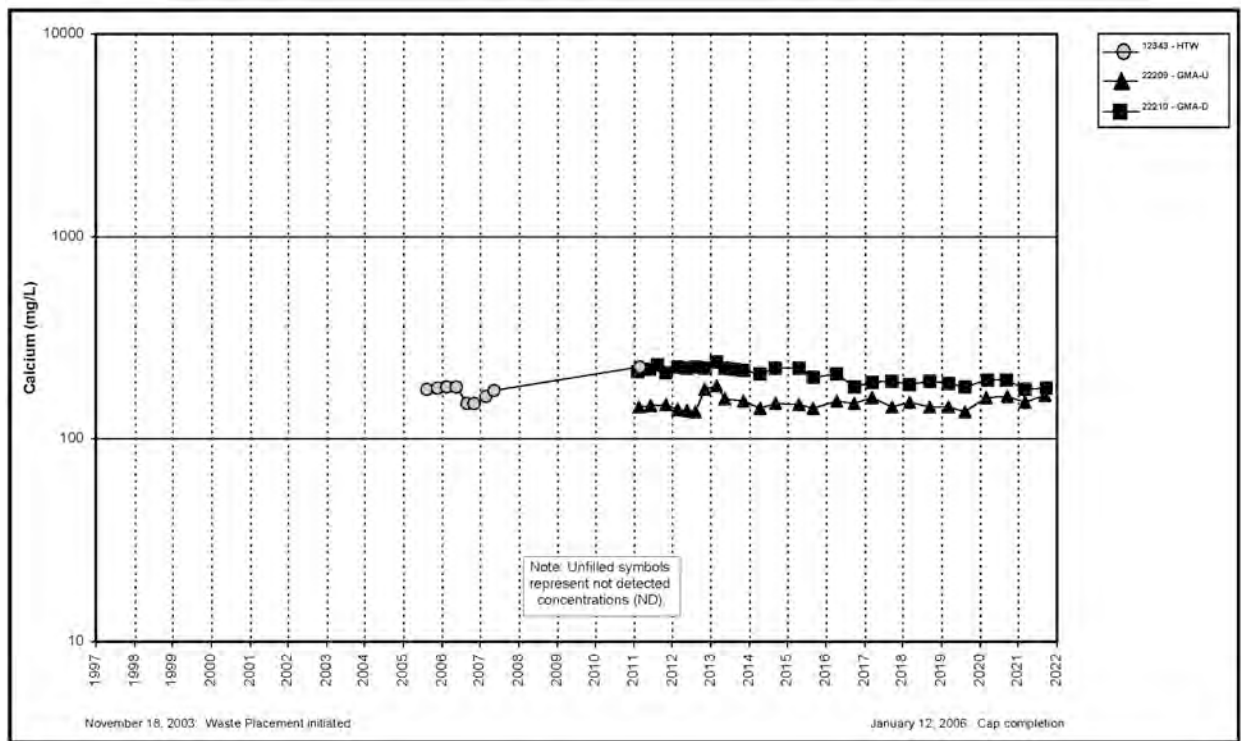


Figure A.5.6-9. Cell 6 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

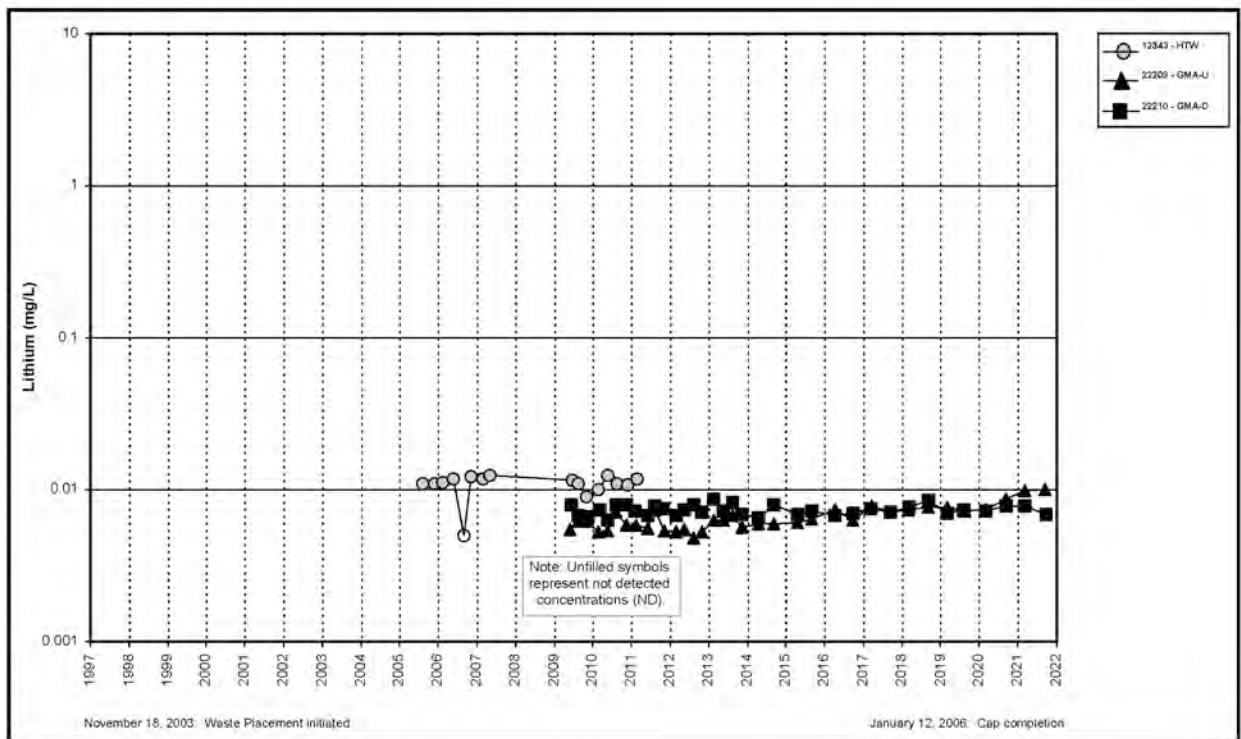


Figure A.5.6-10. Cell 6 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

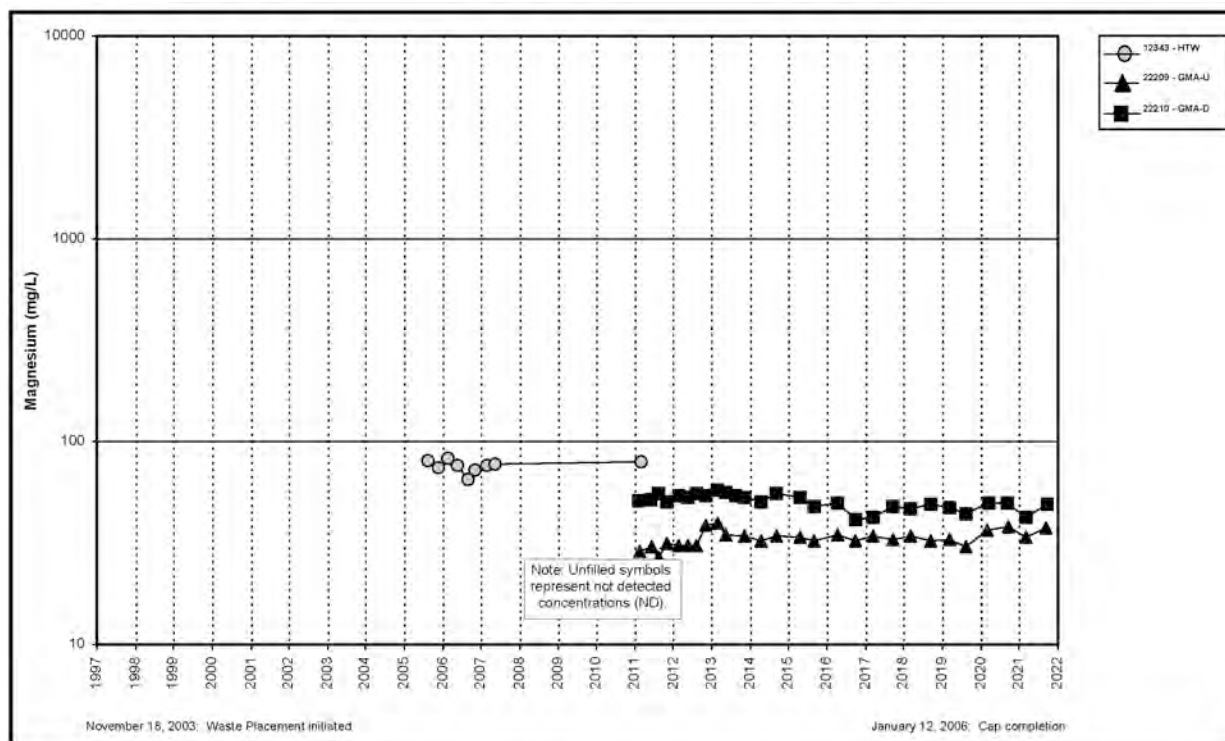


Figure A.5.6-11. Cell 6 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

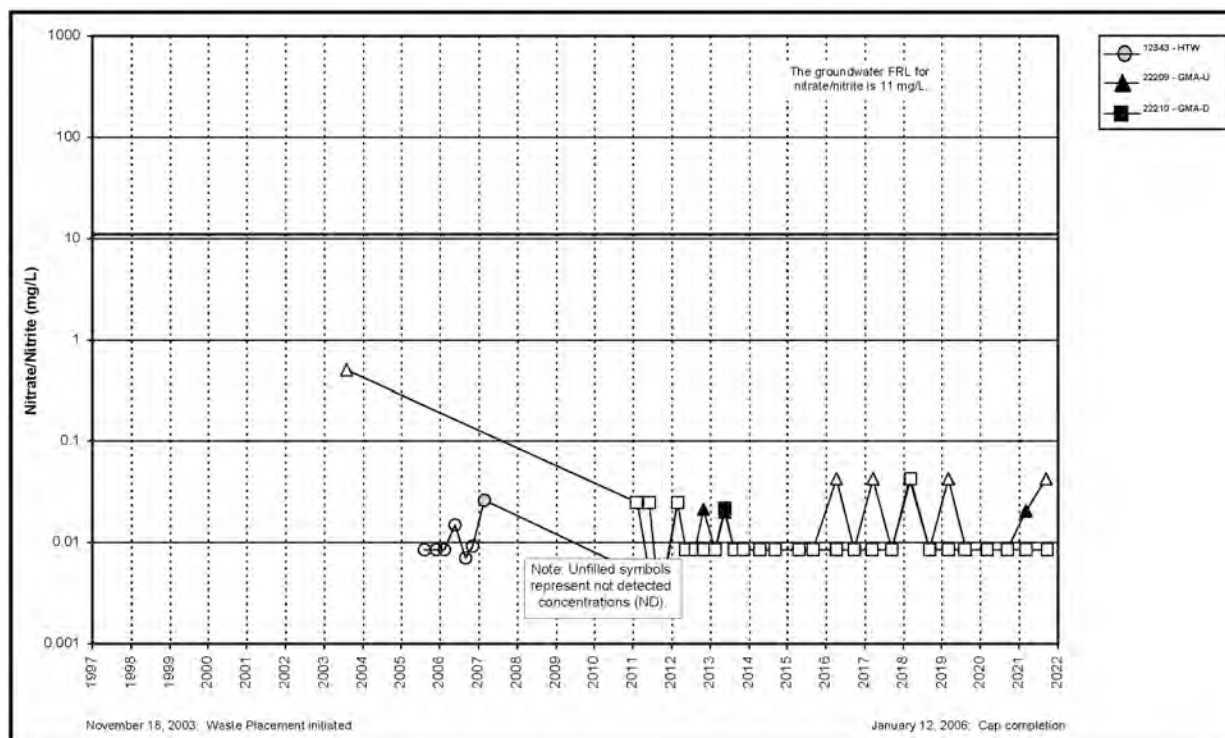


Figure A.5.6-12. Cell 6 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

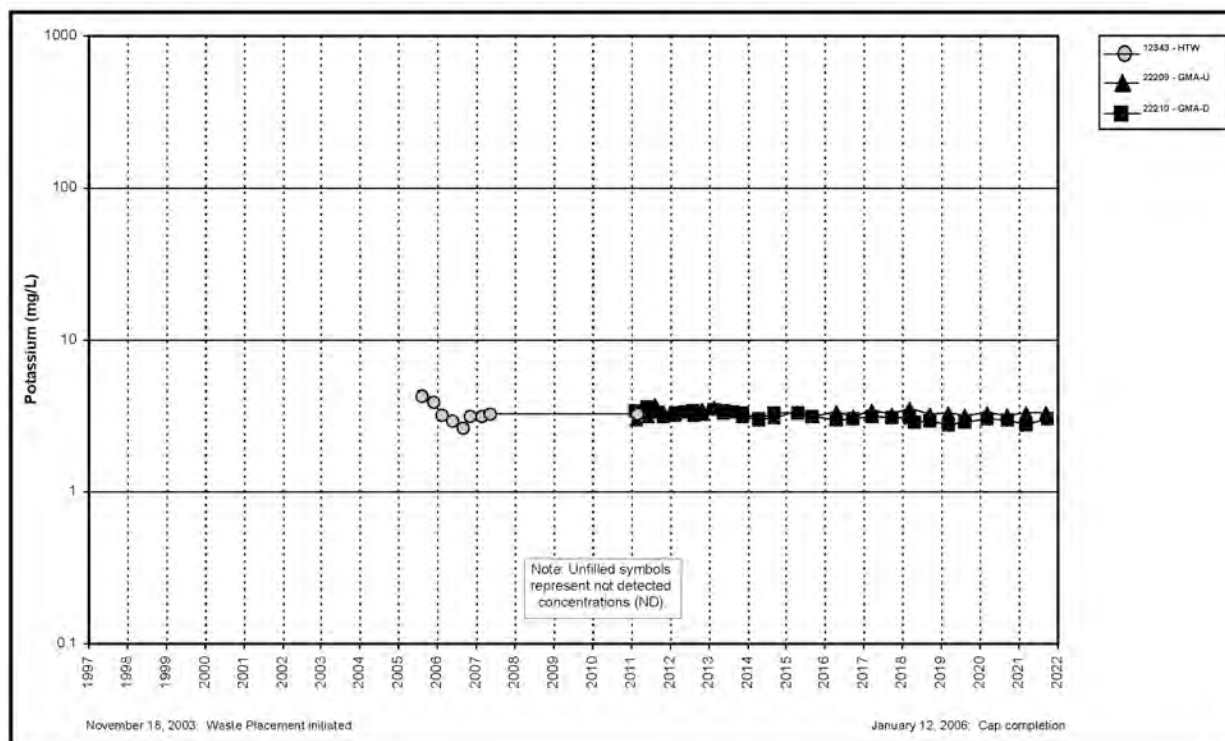


Figure A.5.6-13. Cell 6 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

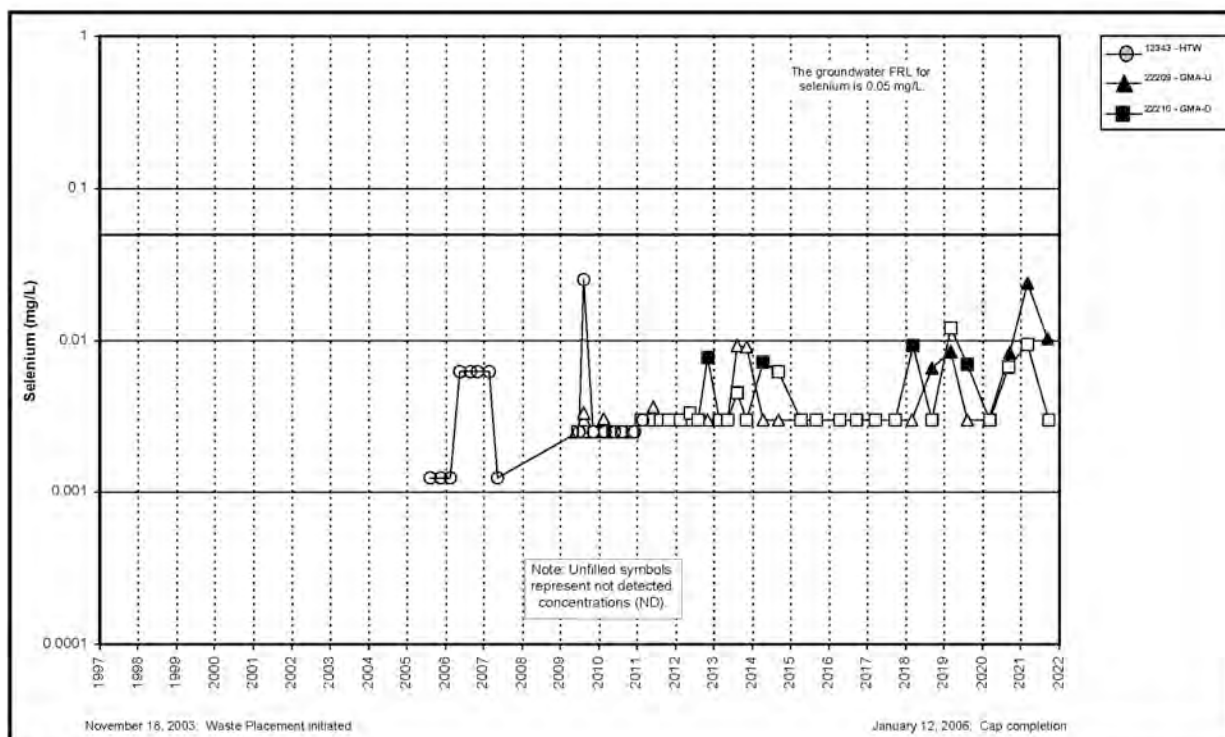


Figure A.5.6-14. Cell 6 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

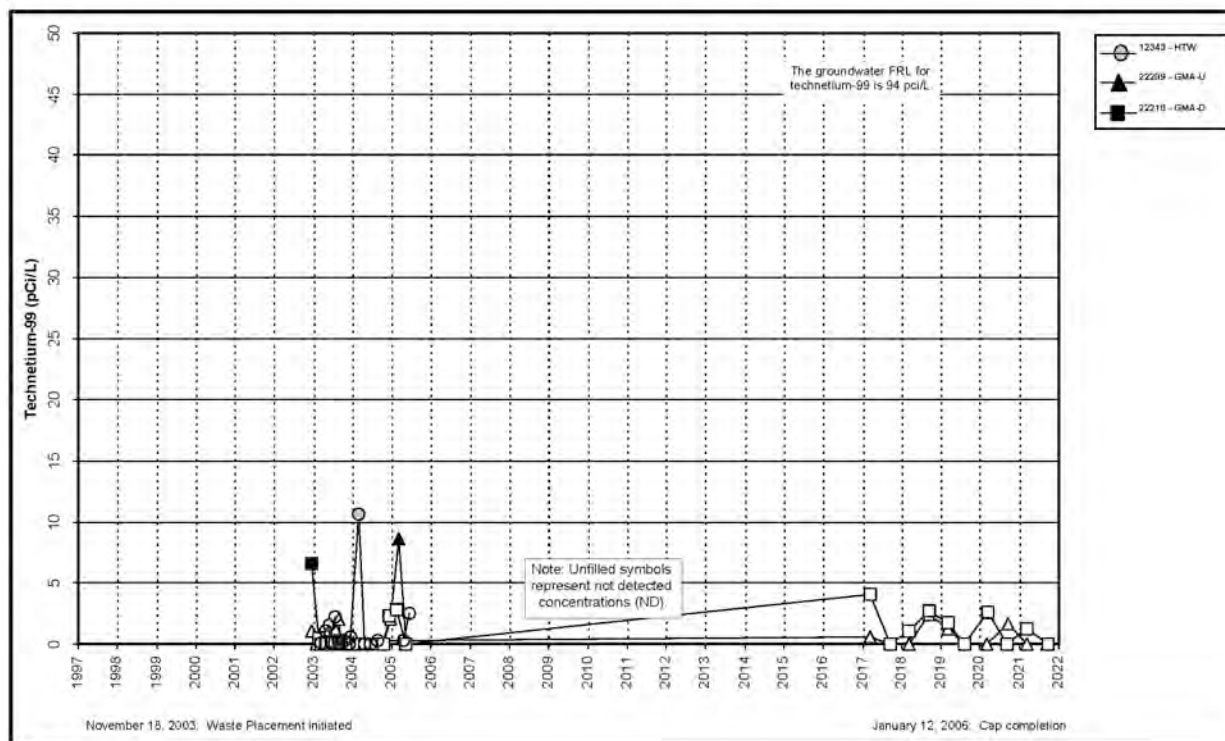


Figure A.5.6-15. Cell 6 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

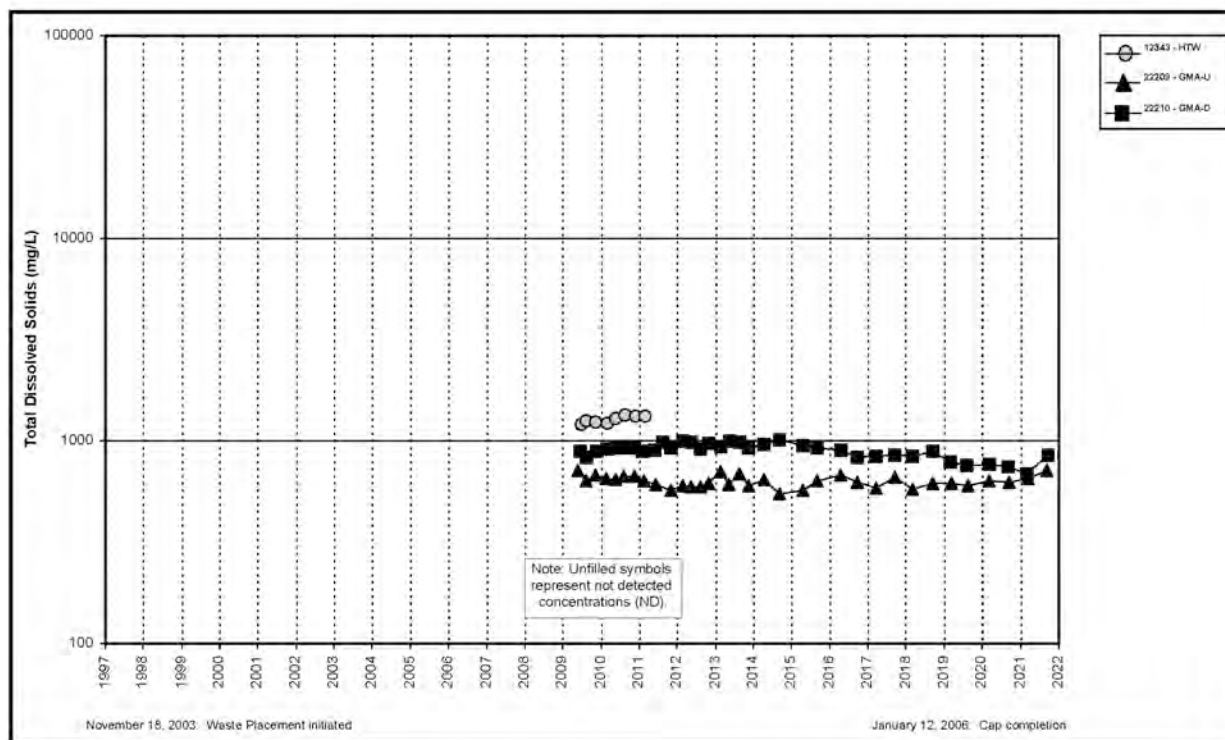


Figure A.5.6-16. Cell 6 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

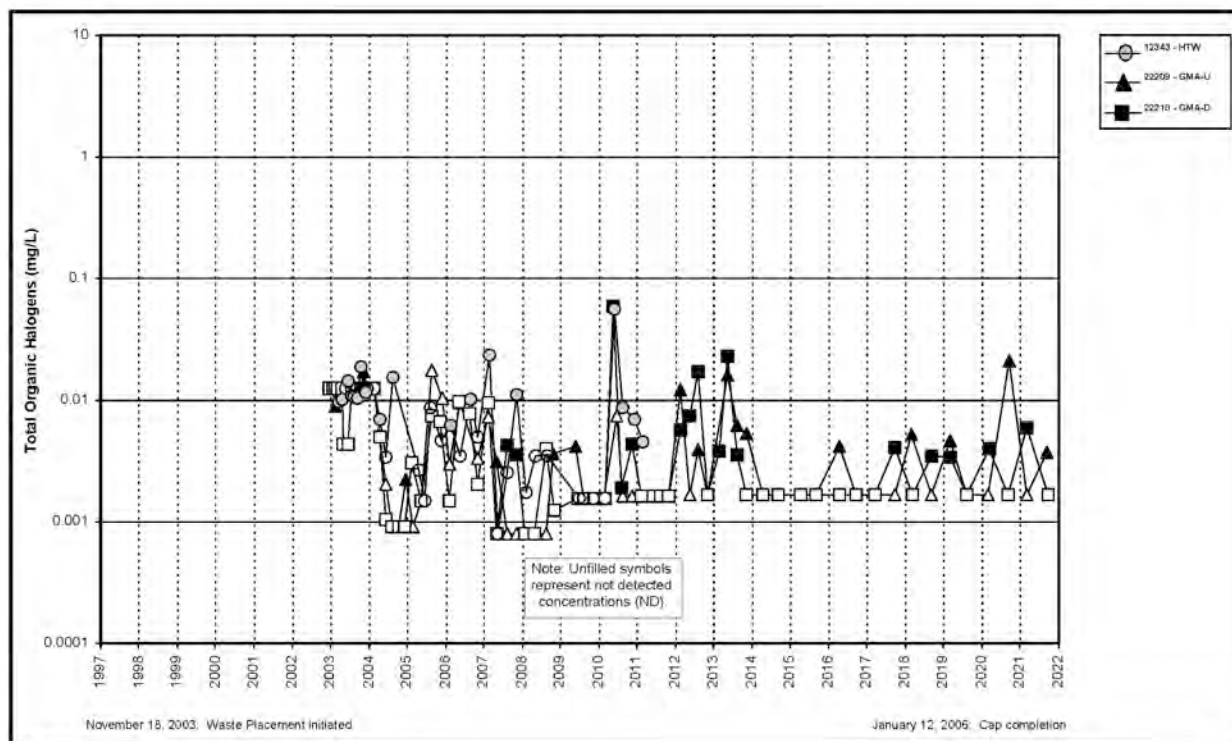


Figure A.5.6-17. Cell 6 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

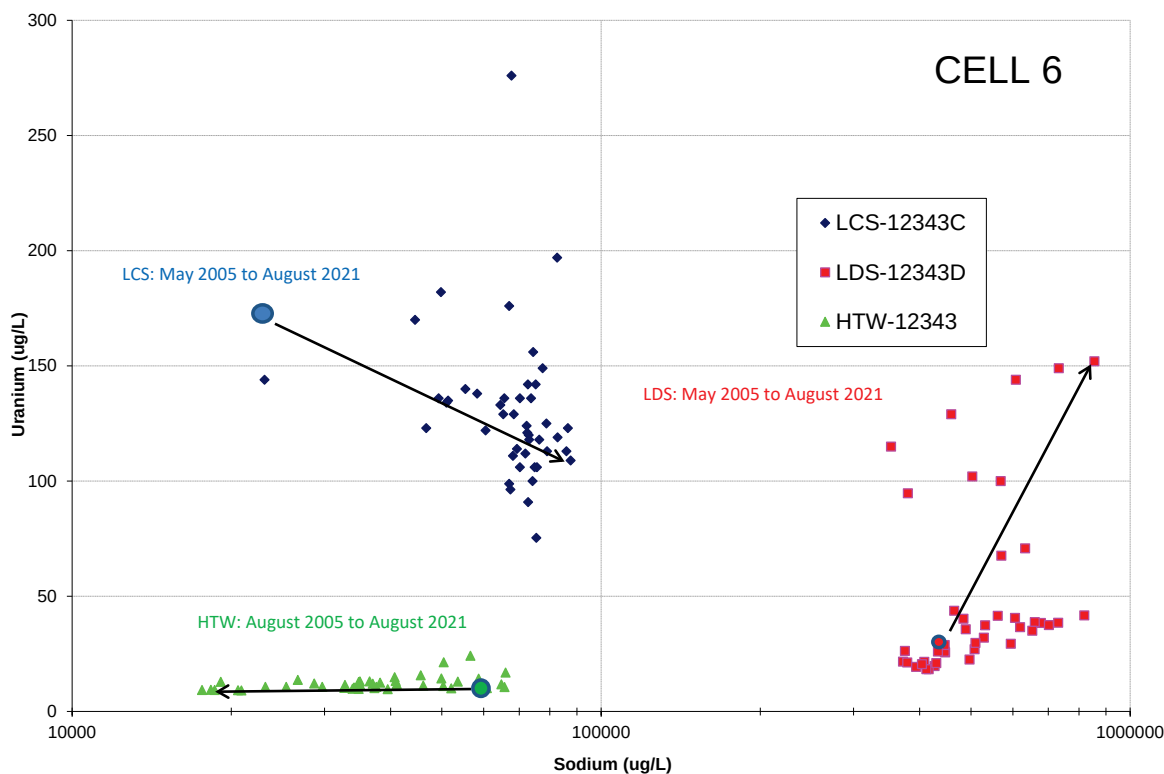


Figure A.5.6-18. Cell 6 Bivariate Plot for Uranium and Sodium

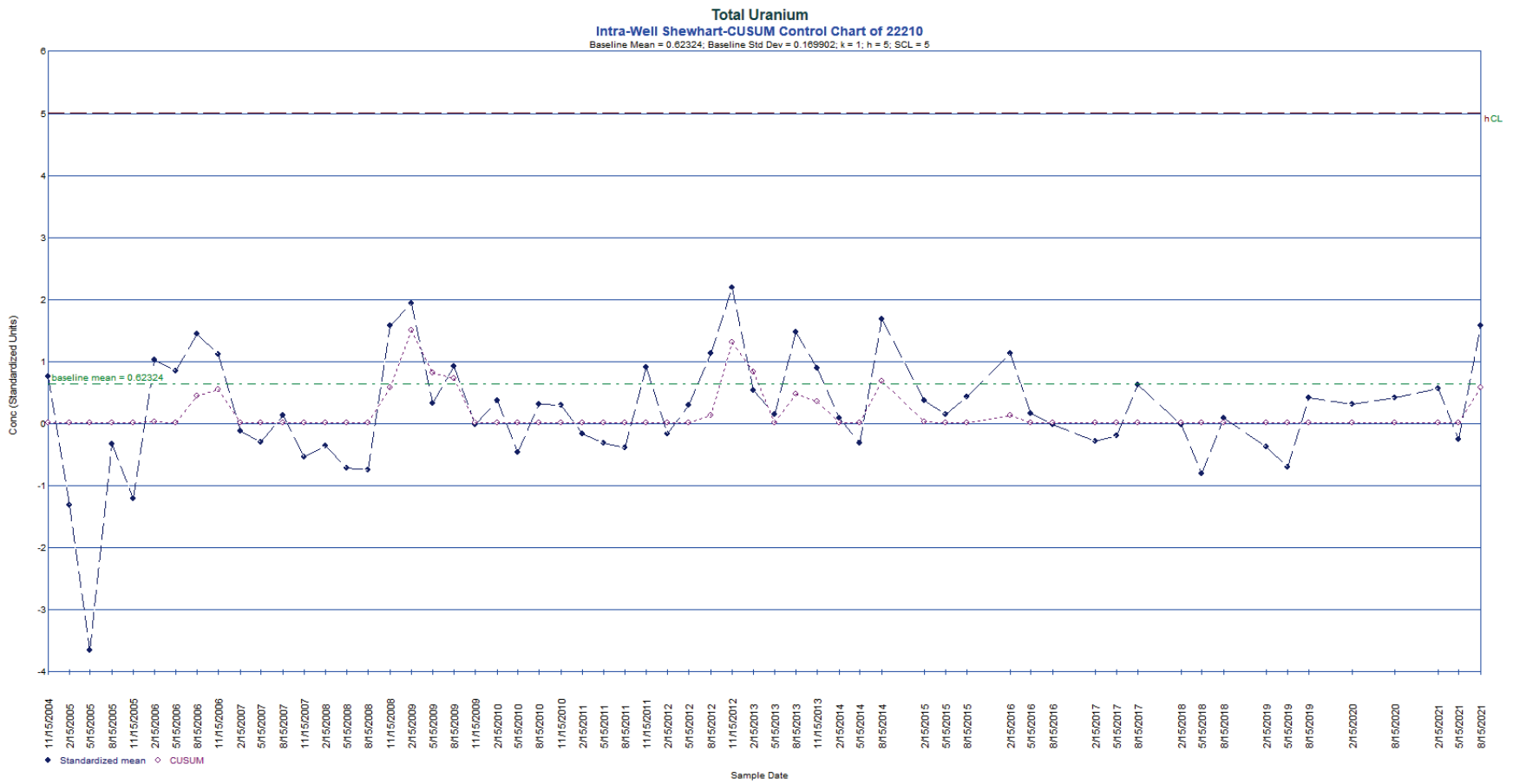


Figure A.5.6-19. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22210

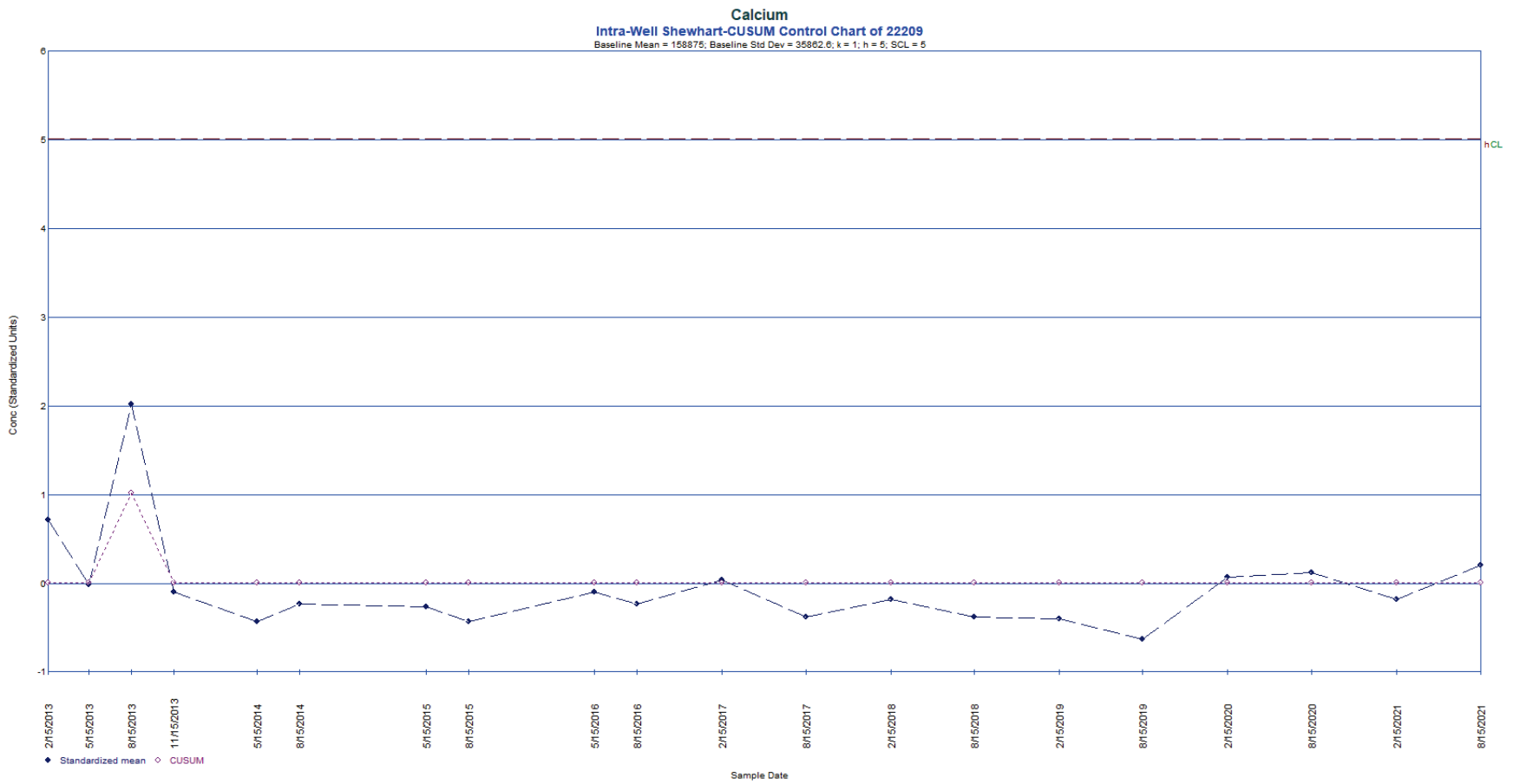


Figure A.5.6-20. Intrawell Shewhart-CUSUM Control Chart for Calcium in Monitoring Well 22209

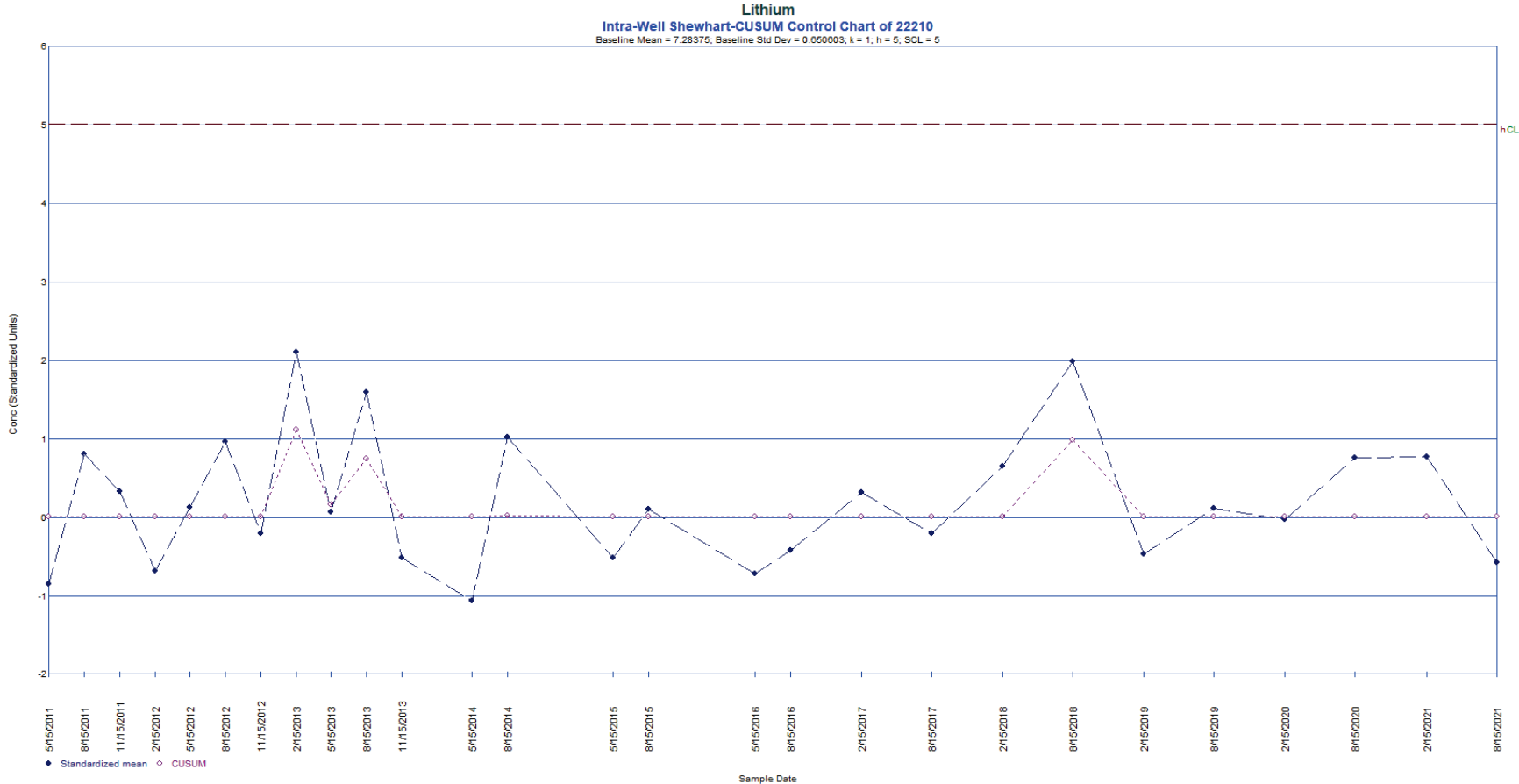


Figure A.5.6-21. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22210

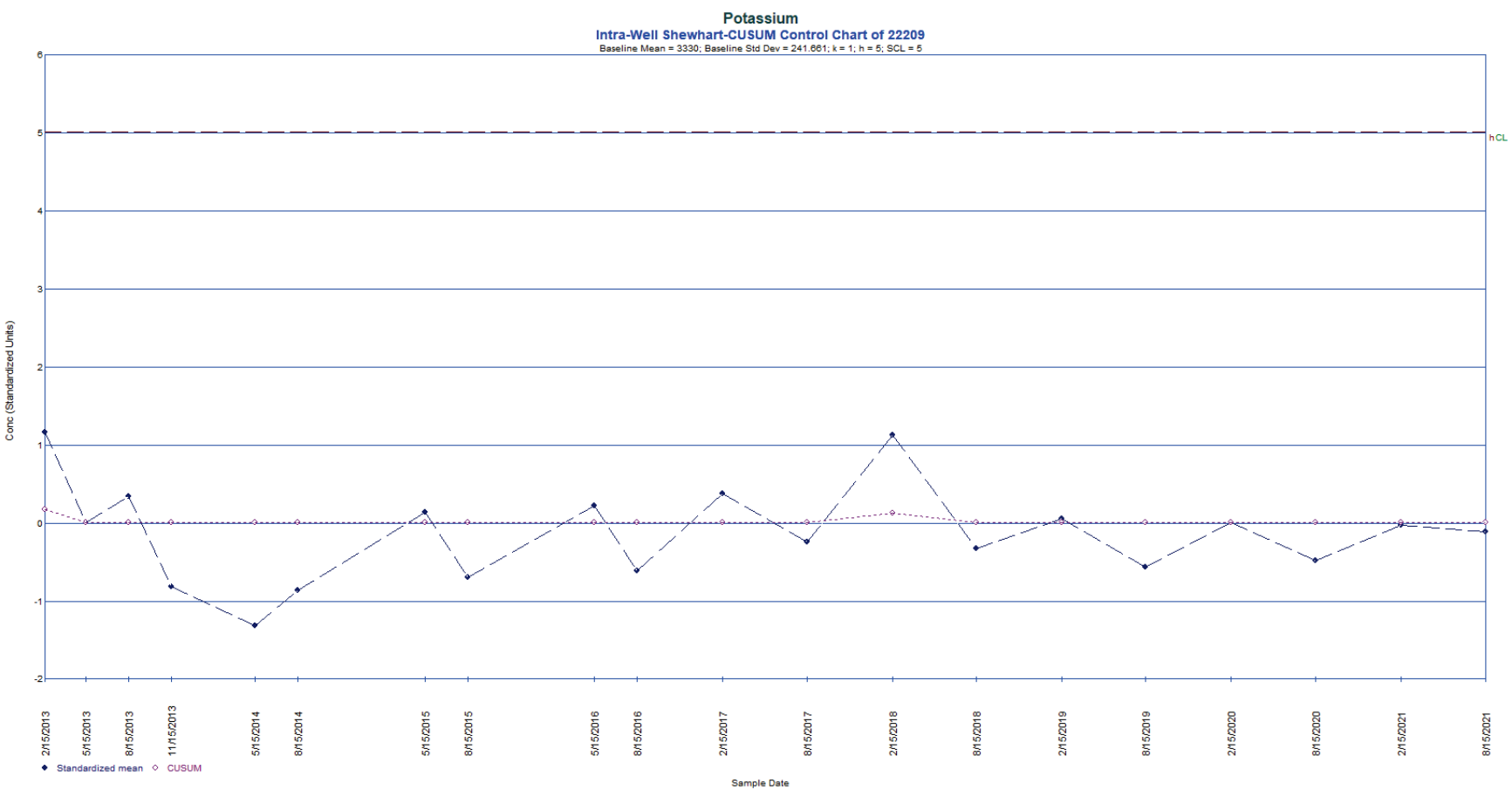


Figure A.5.6-22. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22209

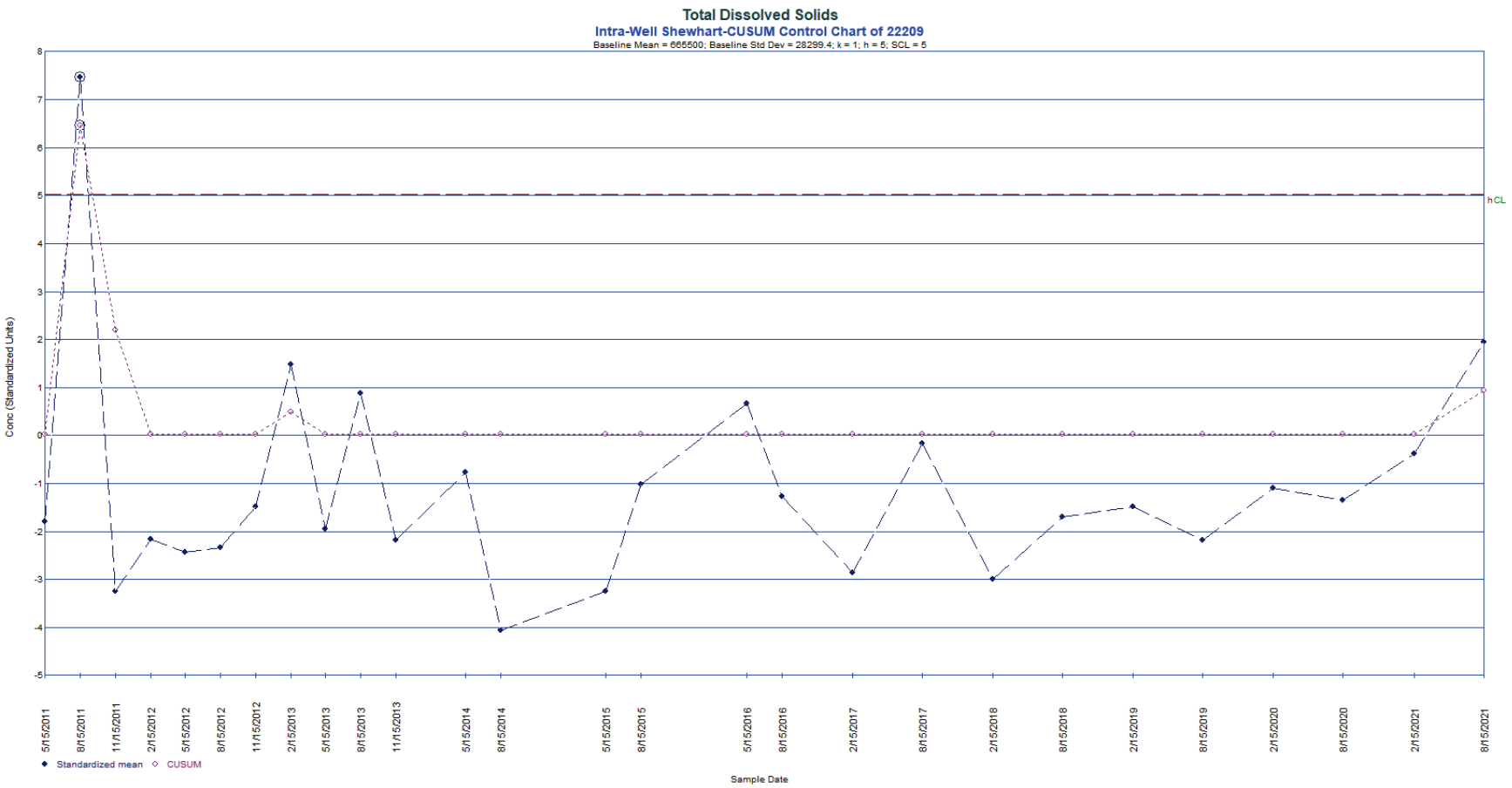


Figure A.5.6-23. Intra-Well Shewhart-CUSUM Control Chart for Total Dissolved Solids in Monitoring Well 22209

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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	Great Miami Aquifer–downgradient
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.7-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.7-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.7-2)
- OSDF horizontal till well (HTW) 12344 water yield (refer to Table A.5.7-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.7-3 and A.5.7-4)
- Plots of concentration versus time (refer to Figures A.5.7-5A through A.5.7-17)
- A bivariate plot for uranium–sodium (refer to Figure A.5.7-18)
- Control charts (refer to Figures A.5.7-19 through A.5.7-23)

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 the 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 (OAC 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 2021 have upward concentration trends in the LCS and/or LDS based on the Mann-Kendall test for trend. Two new high concentrations were measured in the LCS of Cell 7 in 2021 (sodium and sulfate). The new high for sodium was 131 milligrams per liter (mg/L). The previous high was 121 mg/L. The new high for sulfate was 5,470 mg/L. The previous high was 5,070 mg/L. The volume of water in the LDS tank of Cell 7 was insufficient to collect a sample in 2012 and 2013. Enough water was present to collect a sample in 2014 and 2015, but since 2015 the volume of water in the LDS tank of Cell 7 has been insufficient to collect a sample.

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

Parameter	LCS 12344C 2021 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, five parameters (total uranium, boron, sodium, sulfate, and selenium) have upward concentration trends in the HTW and/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^a

Parameter	HTW 12344	GMA-U ^b 22212	GMA-D ^b 22211
Total Uranium	Up		
Boron		Up	Up
Sodium	Up		Up
Sulfate	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 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.5.7-1 in gray shading and as summarized below, five parameters in the HTW and/or GMA wells of Cell 7 (total uranium, boron, 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 five control charts (Figures A.5.7-19 through A.5.7-23). All of the control charts exhibit “in control” conditions.

Parameter	Monitoring Point ^a	Monitoring Well	Assessment	Figure Number
Total Uranium	GMA-U	22212	In Control	A.5.7-19
Boron	HTW	12344	In Control	A.5.7-20
Lithium	GMA-D	22211	In Control	A.5.7-21
Magnesium	GMA-U	22212	In Control	A.5.7-22
Potassium	GMA-U	22212	In Control	A.5.7-23

^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 2021 have an upward concentration trend in the LCS of Cell 7: sodium and sulfate. Two new high concentrations were measured in the LCS of Cell 7 in 2021 (sodium and sulfate). The new high for sodium was 131 mg/L. The previous high was 121 mg/L. The new high for sulfate was 5,470 mg/L. The previous high was 5,070 mg/L.
- The volume of water in the LDS tank of Cell 7 was insufficient to collect a sample in 2021.
- Five parameters monitored semiannually have an upward concentration trend in the HTW or GMA wells of Cell 7: total uranium, boron, sodium, sulfate, 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 and/or GMA wells) are attributed to fluctuating ambient concentrations beneath the cell, and not to cell performance.
- Five 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	53	53	100	4.72	355	160	58	Undefined	Down (2021)	Detected	
	LDS	12344D	31	31	100	12.2	37.6	25.7	6.2	Normal	Up (2015)	Detected	169 (Q2-14)
	HTW	12344	53	53	100	2.00	8.61	3.80	1.50	Undefined	Up (2021)	Detected	12.1 (Q4-13)
	GMA-U	22212	49	55	89.1	ND	0.634	0.429	0.104	Normal	None (2021)	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	59	63	93.6	ND	4.06	0.346	0.663	Undefined	None (2021)	Not Detected	
Boron (mg/L)	LCS	12344C	53	53	100	0.0625	1.35	1.11	0.35	Undefined	Down (2021)	Detected	
	LDS	12344D	31	31	100	0.168	2.10	0.360	0.425	Undefined	Up (2015)	Detected	
	HTW	12344	29	37	78.4	ND	0.0750	0.0256	0.0120	Ln Normal	None (2021)	Not Detected	
	GMA-U	22212	53	55	96.4	ND	0.0486	0.0378	0.0077	Normal	Up (2021)	Detected	0.0151 (Q3-08); 0.0607 (Q3-20); 0.0603 (Q1-21)
	GMA-D	22211	52	55	94.6	ND	0.0622	0.0330	0.0098	Undefined	Up (2021)	Detected	
Sodium (mg/L)	LCS	12344C	46	46	100	51.8	131	95.0	18.1	Normal	Up (2021)	Detected	18.1 (Q2-05); 19.4 (Q3-05); 26.8 (Q4-05)
	LDS	12344D	24	24	100	186	1,590	587	374	Undefined	Up (2015)	Detected	
	HTW	12344	41	41	100	19.8	39.6	34.1	6.0	Undefined	Up (2021)	Detected	
	GMA-U	22212	35	35	100	15.5	27.0	20.3	2.9	Normal	Down (2021)	Detected	
	GMA-D	22211	36	36	100	10.1	19.2	14.2	2.5	Normal	Down (2021)	Detected	
Sulfate (mg/L)	LCS	12344C	53	53	100	122	5,470	3,630	1,280	Undefined	Up (2021)	Detected	
	LDS	12344D	31	31	100	1,280	7,370	1,770	1,880	Undefined	Up (2015)	Detected	
	HTW	12344	48	48	100	80.4	765	437	263	Undefined	Up (2021)	Detected	
	GMA-U	22212	55	55	100	96.6	731	202	112	Ln Normal	Down (2021)	Detected	
	GMA-D	22211	55	55	100	117	572	297	119	Ln Normal	None (2021)	Detected	3,640 (Q3-12)
Calcium (mg/L)	GMA-U	22212	28	28	100	140	177	155	10	Undefined	None (2021)	Not Detected	377 (Q3-11)
	GMA-D	22211	28	28	100	136	263	187	37	Normal	Down (2021)	Detected	
Lithium (mg/L)	GMA-U	22212	35	35	100	0.00474	0.00779	0.00548	0.00075	Undefined	None (2021)	Detected	0.00892 (Q3-10); 0.00810 (Q3-11)
	GMA-D	22211	35	35	100	0.00555	0.00930	0.00701	0.00086	Normal	None (2021)	Not Detected	
Magnesium (mg/L)	GMA-U	22212	28	28	100	28.6	41.5	34.7	2.6	Normal	None (2021)	Not Detected	54.6 (Q3-11)
	GMA-D	22211	28	28	100	34.6	64.7	46.8	8.4	Normal	Down (2021)	Not Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22212	3	28	10.7	ND	0.0431	0.0161	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22211	3	28	10.7	ND	0.0425	0.0167	Insufficient	Insufficient	Insufficient	Insufficient	
Potassium (mg/L)	GMA-U	22212	28	28	100	3.05	3.81	3.47	0.17	Normal	None (2021)	Not Detected	4.81 (Q3-11)
	GMA-D	22211	29	29	100	2.42	3.65	2.92	0.32	Normal	Down (2021)	Detected	
Selenium (mg/L)	GMA-U	22212	7	35	20.0	ND	0.0722	0.00300	0.0125	Undefined	Up (2021)	Detected	
	GMA-D	22211	2	35	5.7	ND	0.0124	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22212	1	20	5.0	ND	11.0	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22211	0	20	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22212	35	35	100	519	854	652	61	Ln Normal	None (2021)	Detected	1,130 (Q2-10); 1,270 (Q3-10); 1,510 (Q3-11)
	GMA-D	22211	35	35	100	583	1,350	886	214	Normal	Down (2021)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22212	21	55	38.2	ND	0.0125	0.00313	0.00289	Undefined	None (2021)	Not Detected	0.0500 (Q2-10); 0.0190 (Q2-13)
	GMA-D	22211	18	55	32.7	ND	0.0230	0.00166	0.00406	Undefined	None (2021)	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.

^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

^bND = not detected; NA = not applicable

^cAverages were determined based on the distribution assumption.

^dInsufficient is used for Distribution Type, Trend, or Serial Correlation whenever there is not enough data to run the test.

^eData 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.

^fTrend based on nonparametric Mann-Kendall procedure.

^gSerial correlation based on Rank Von Neumann test.

^hOutliers determined by Rosner's (for sample sizes greater than 25) or Dixon procedure (for sample sizes less than or equal to 25).

ⁱQ = quarter

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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

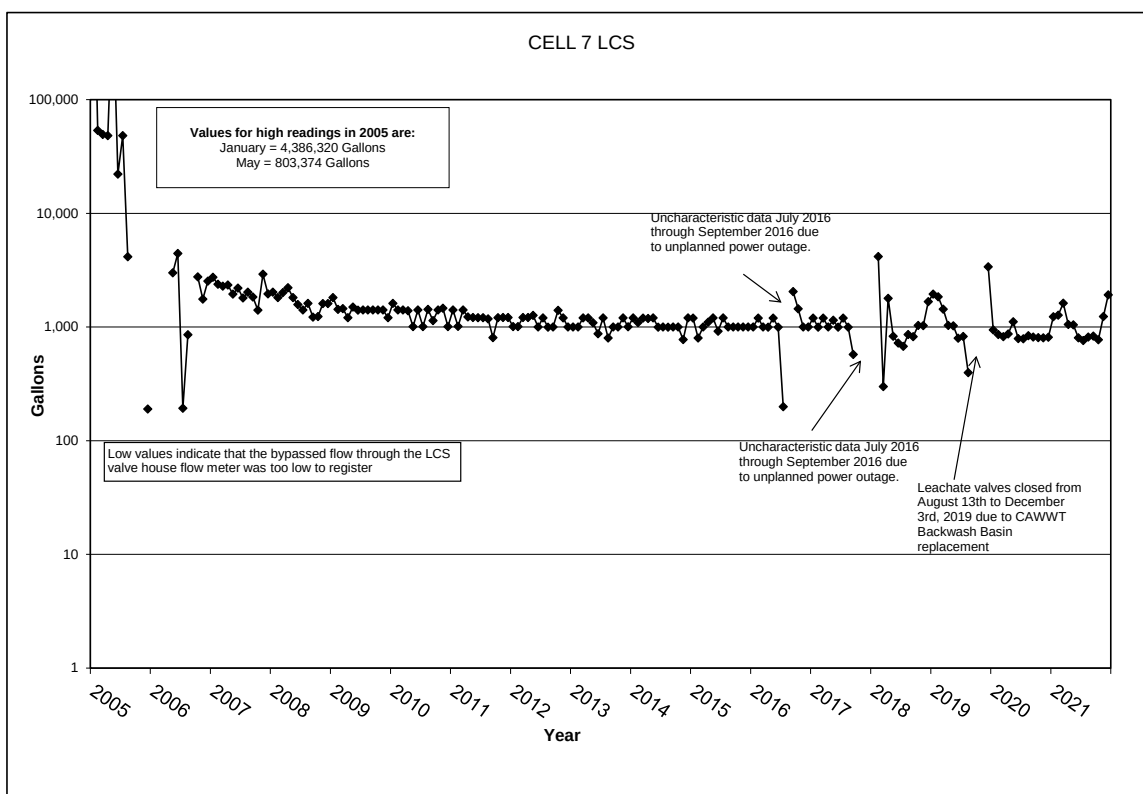


Figure A.5.7-1. Monthly Accumulation Volumes for Cell 7 LCS

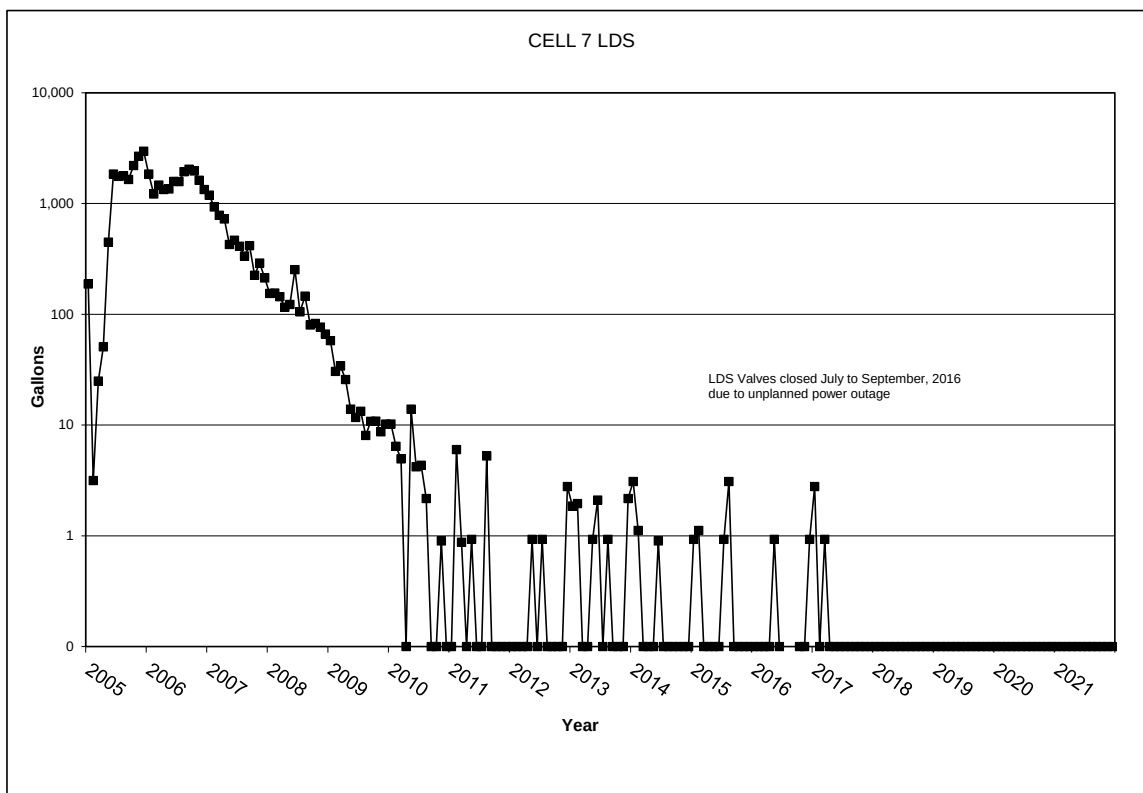


Figure A.5.7-2. Monthly Accumulation Volumes for Cell 7 LDS

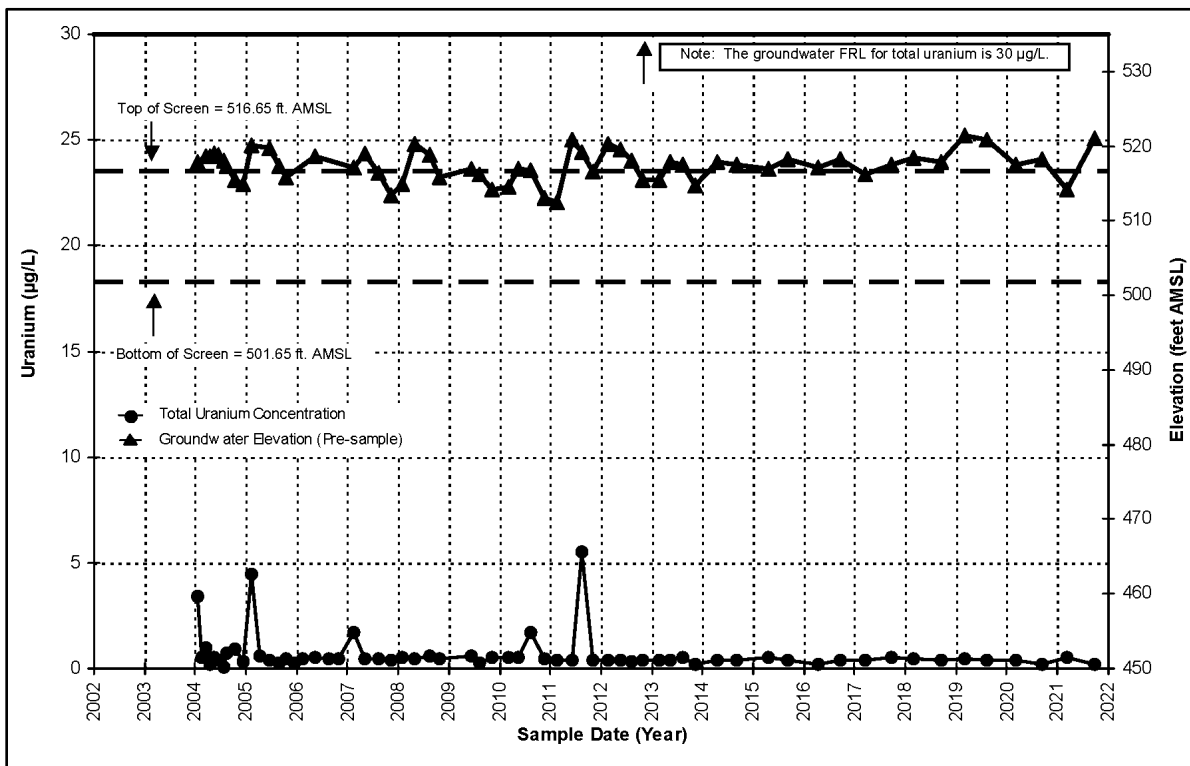


Figure A.5.7-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 7 Upgradient Monitoring Well 22212

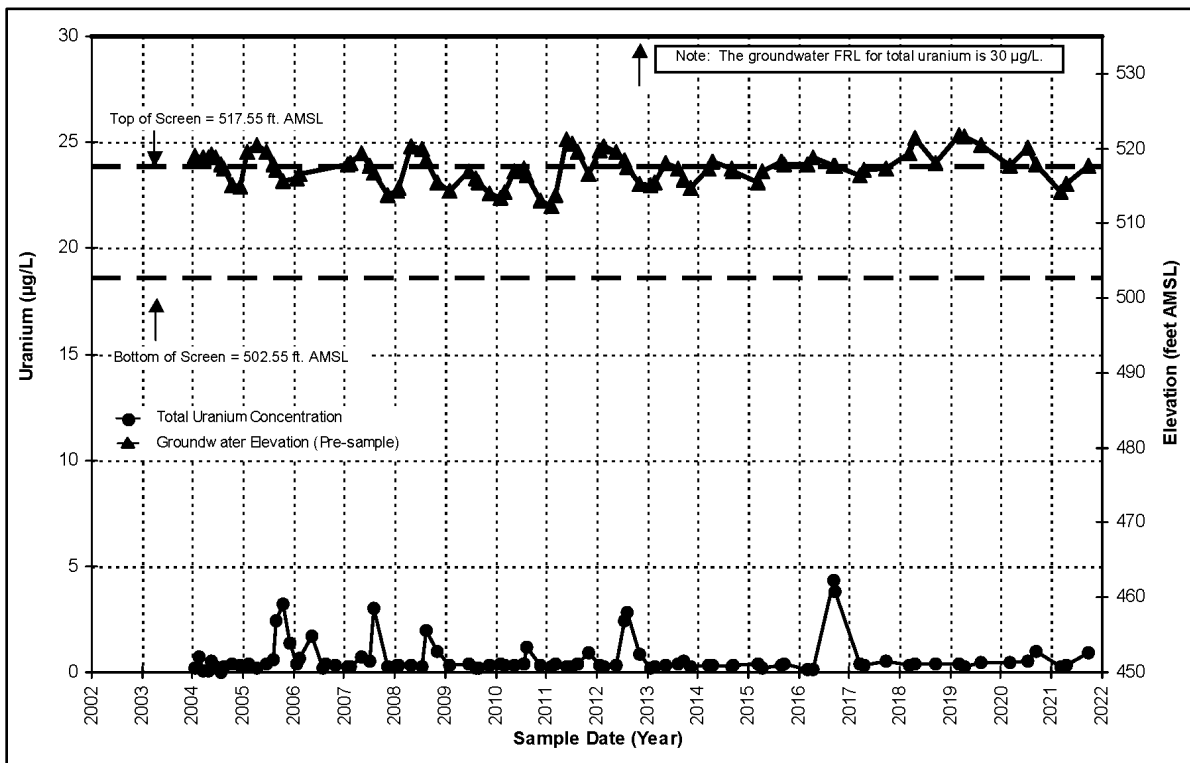


Figure A.5.7-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 7 Downgradient Monitoring Well 22211

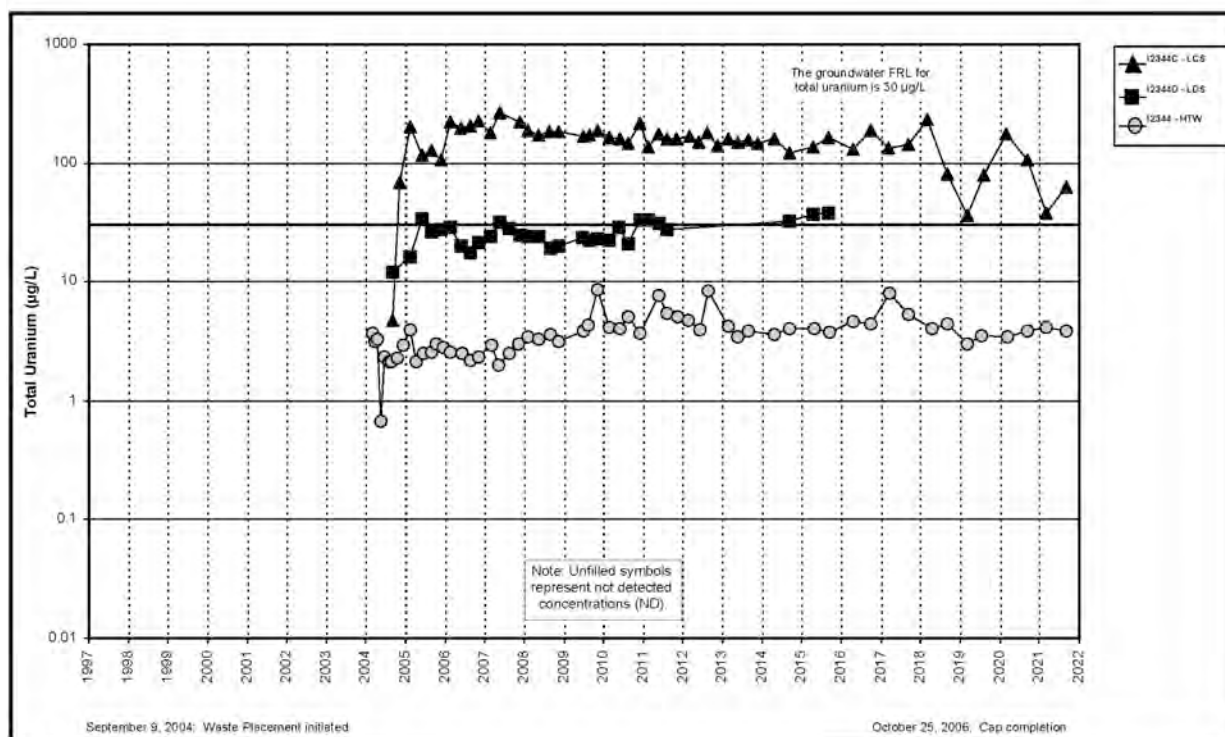


Figure A.5.7-5A. Cell 7 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

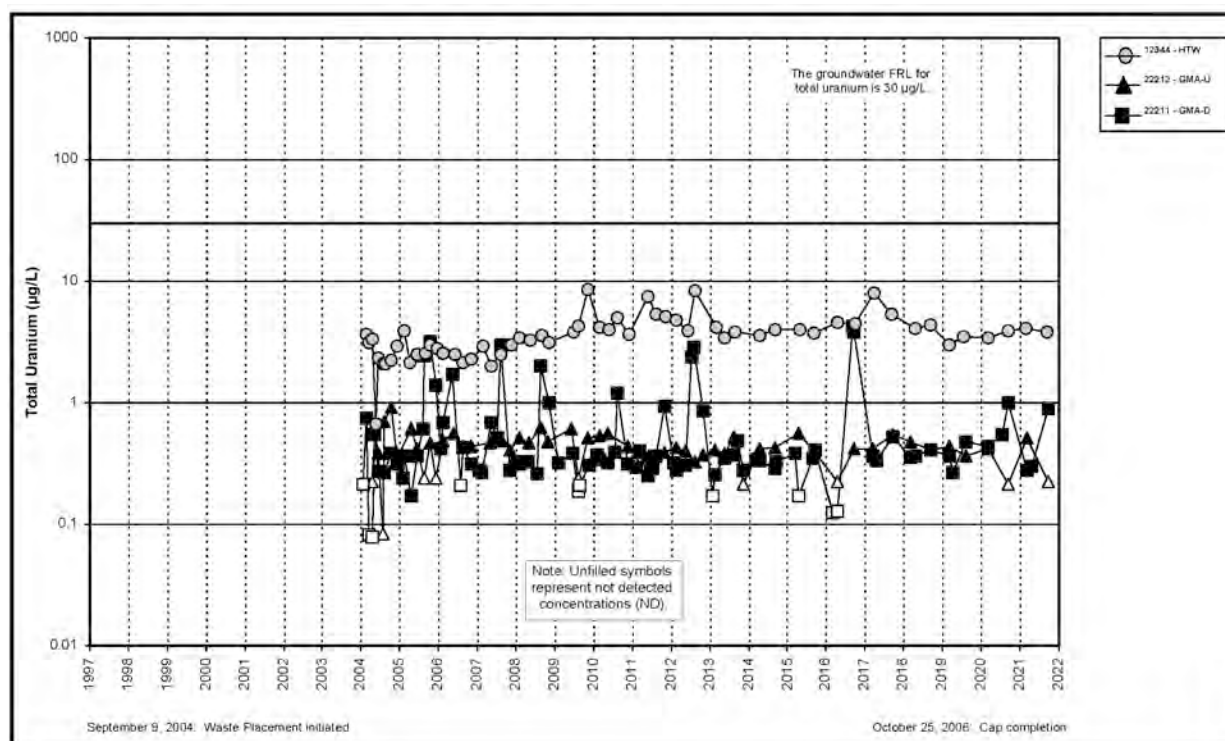


Figure A.5.7-5B. Cell 7 Total Uranium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

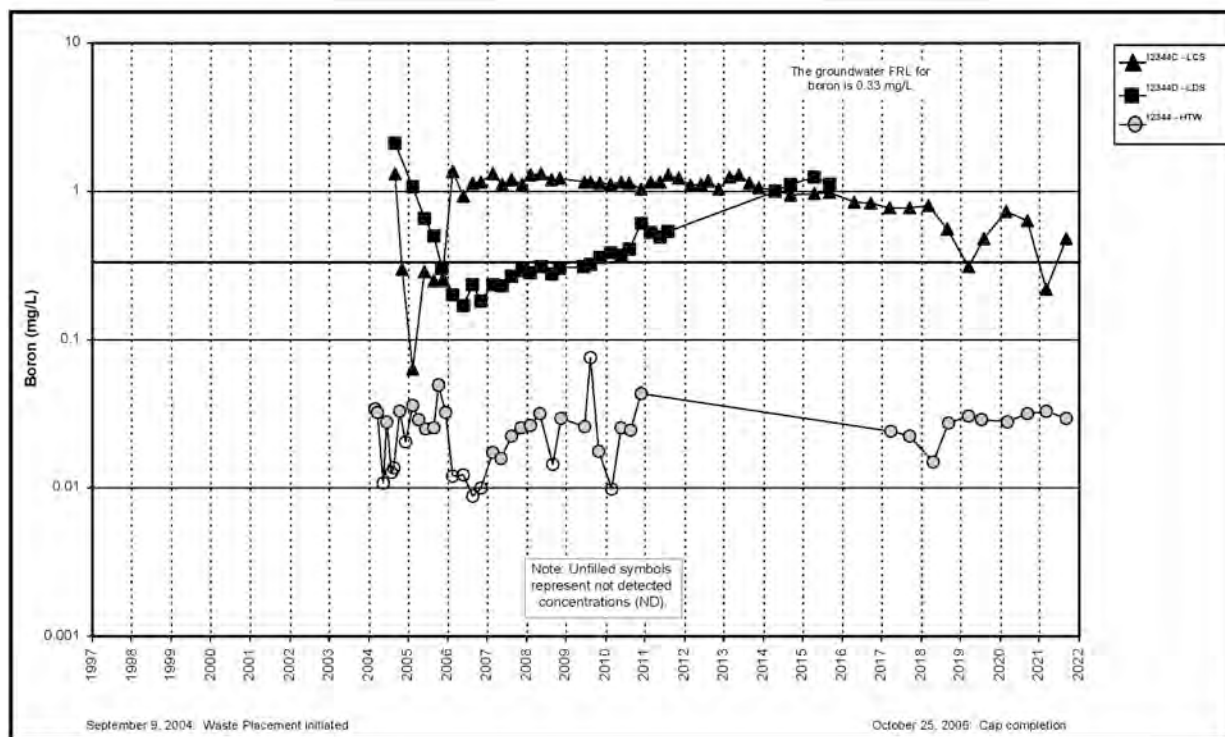


Figure A.5.7-6A. Cell 7 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

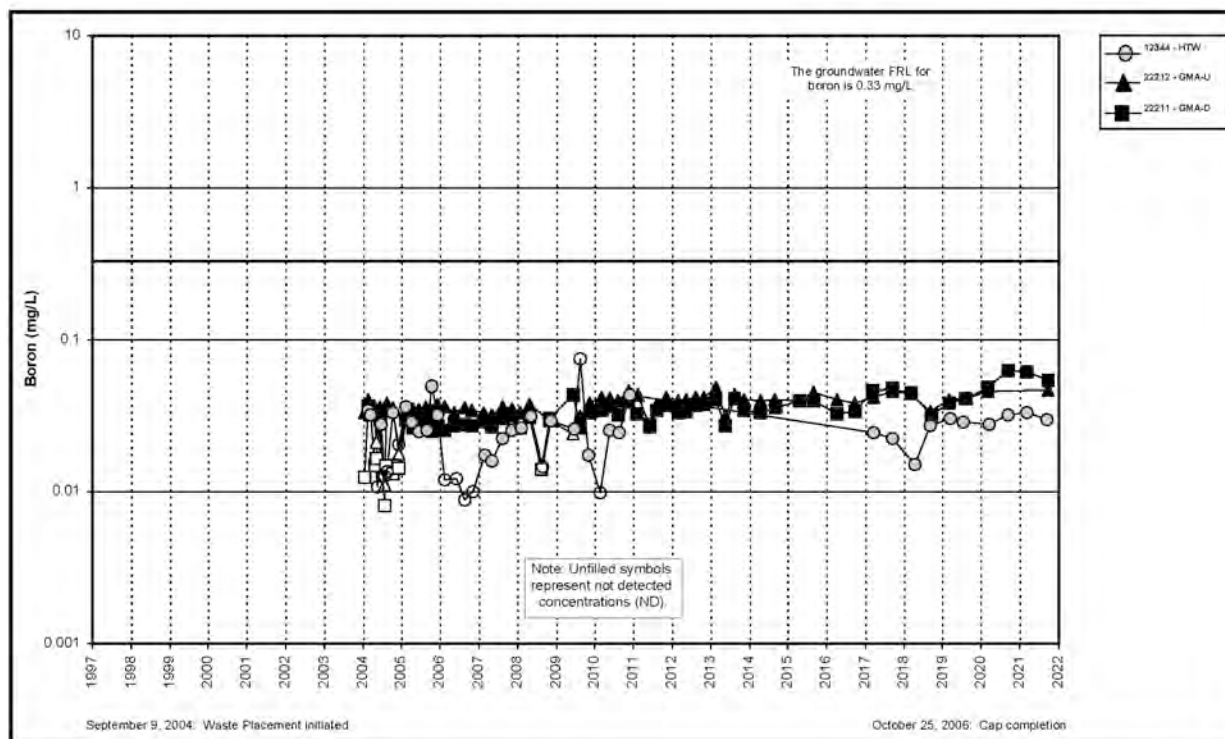


Figure A.5.7-6B. Cell 7 Boron Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

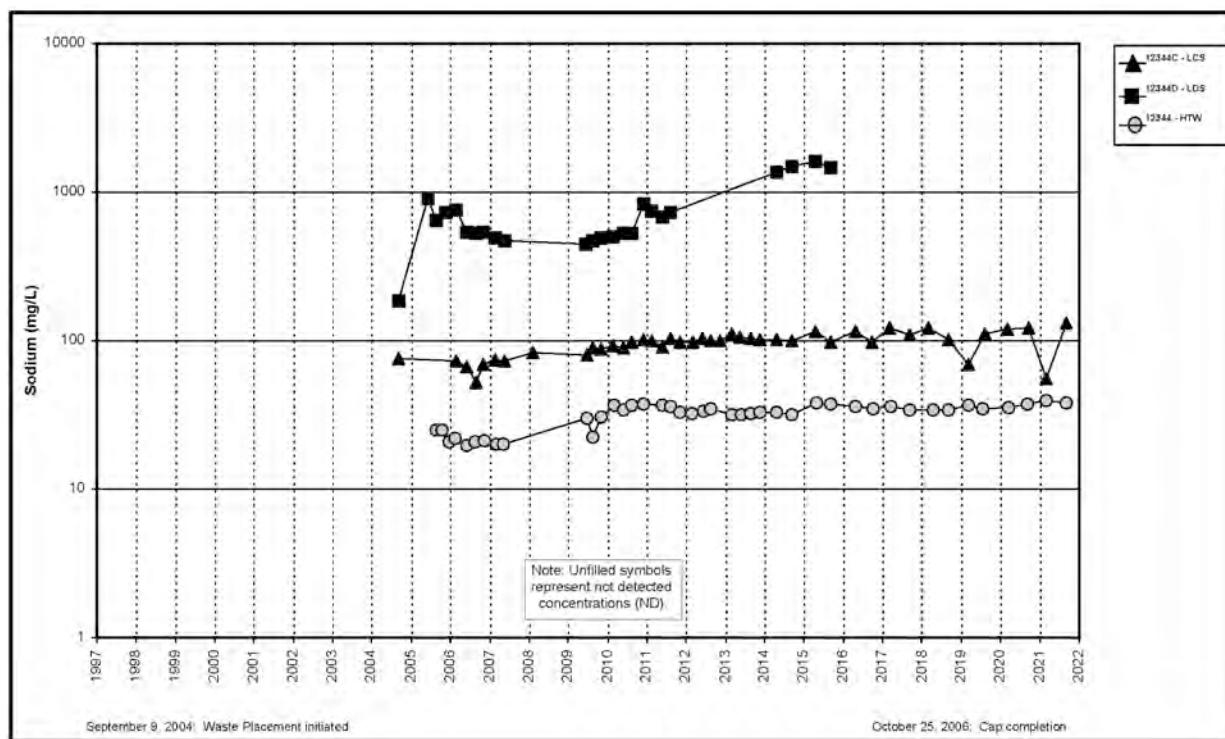


Figure A.5.7-7A. Cell 7 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

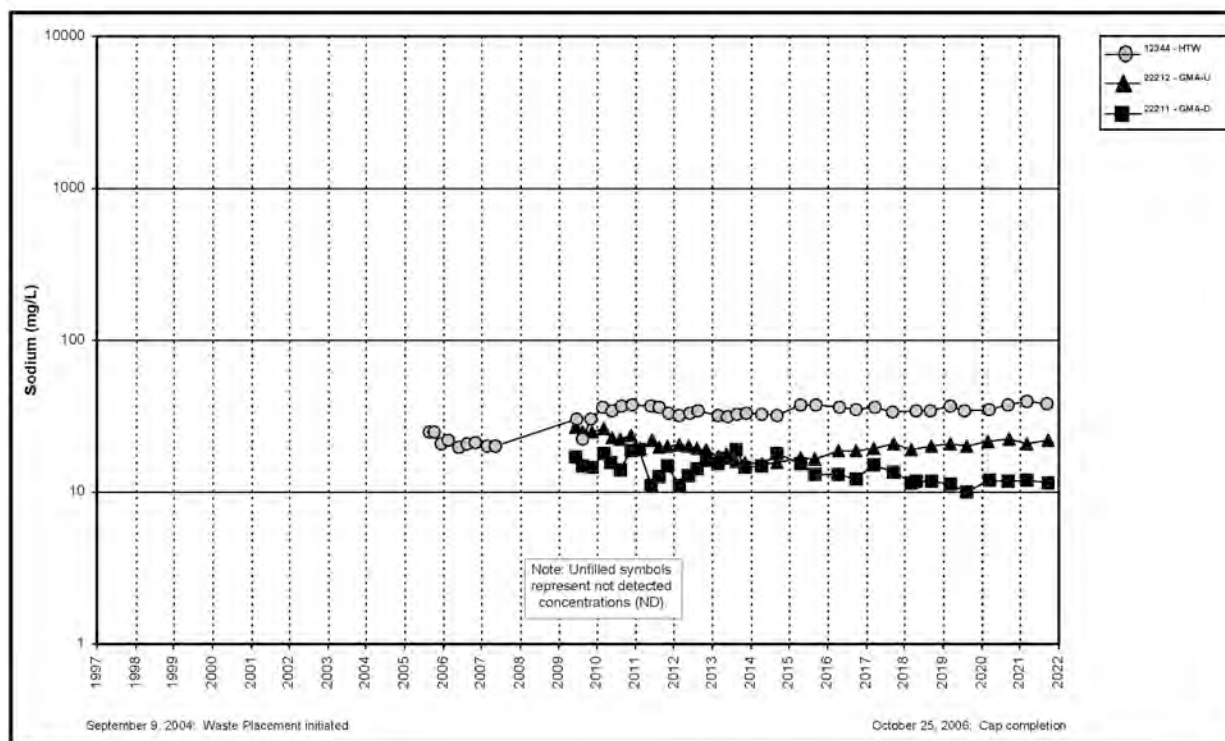


Figure A.5.7-7B. Cell 7 Sodium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

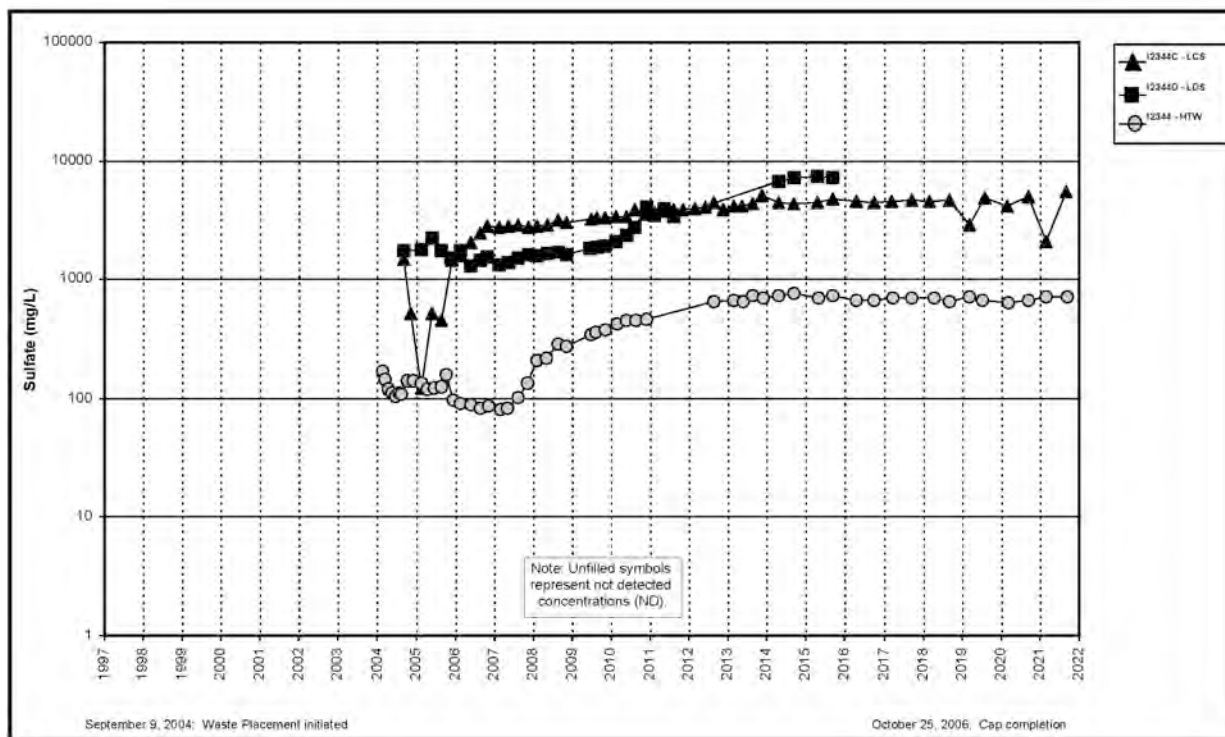


Figure A.5.7-8A. Cell 7 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

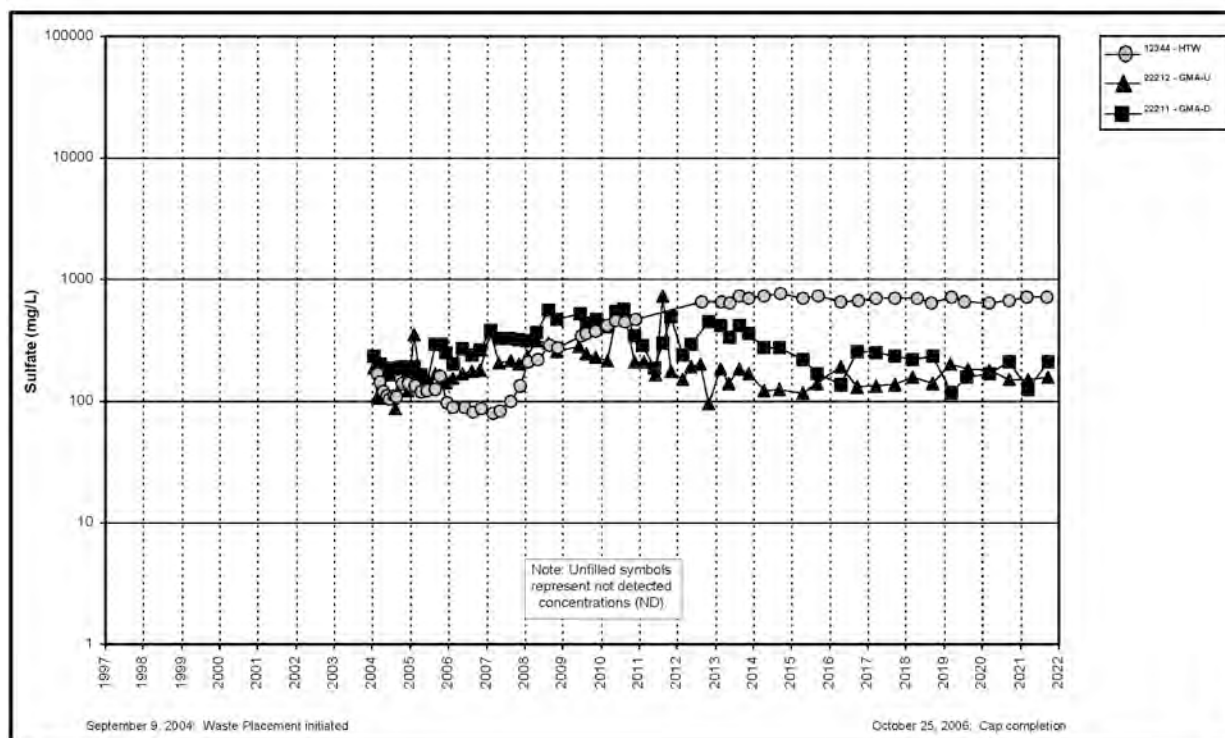


Figure A.5.7-8B. Cell 7 Sulfate Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

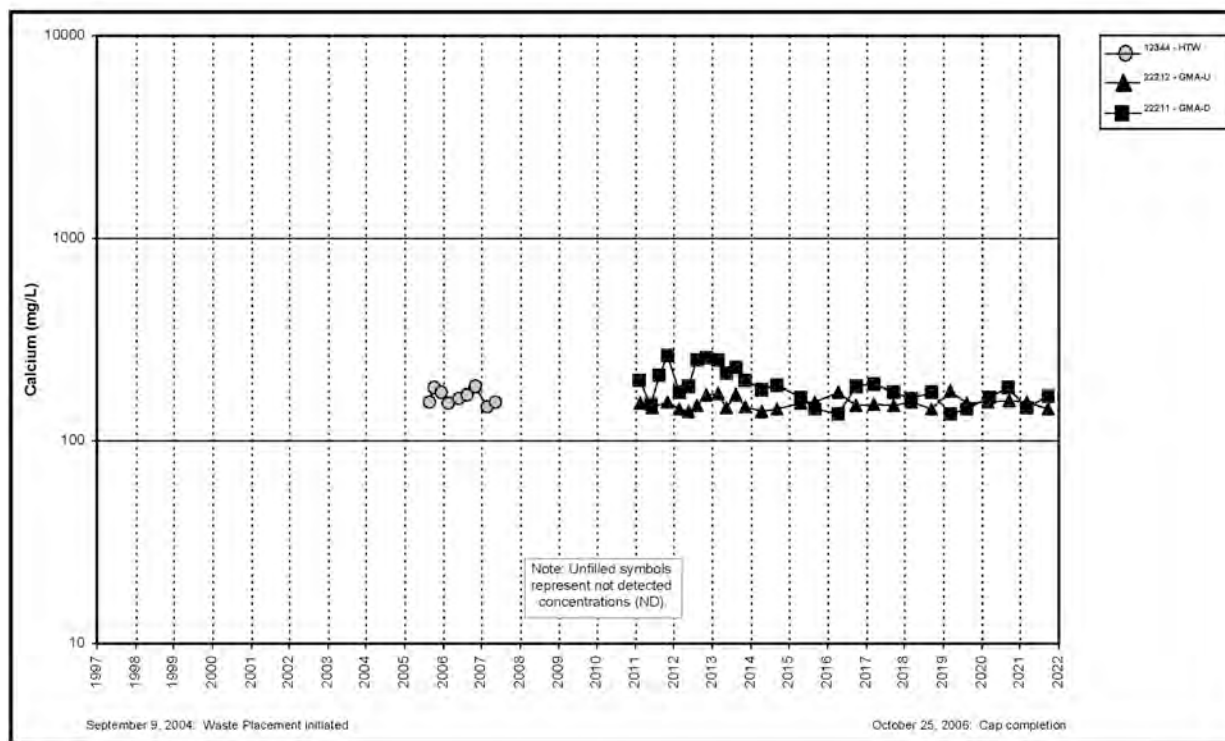


Figure A.5.7-9. Cell 7 Calcium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

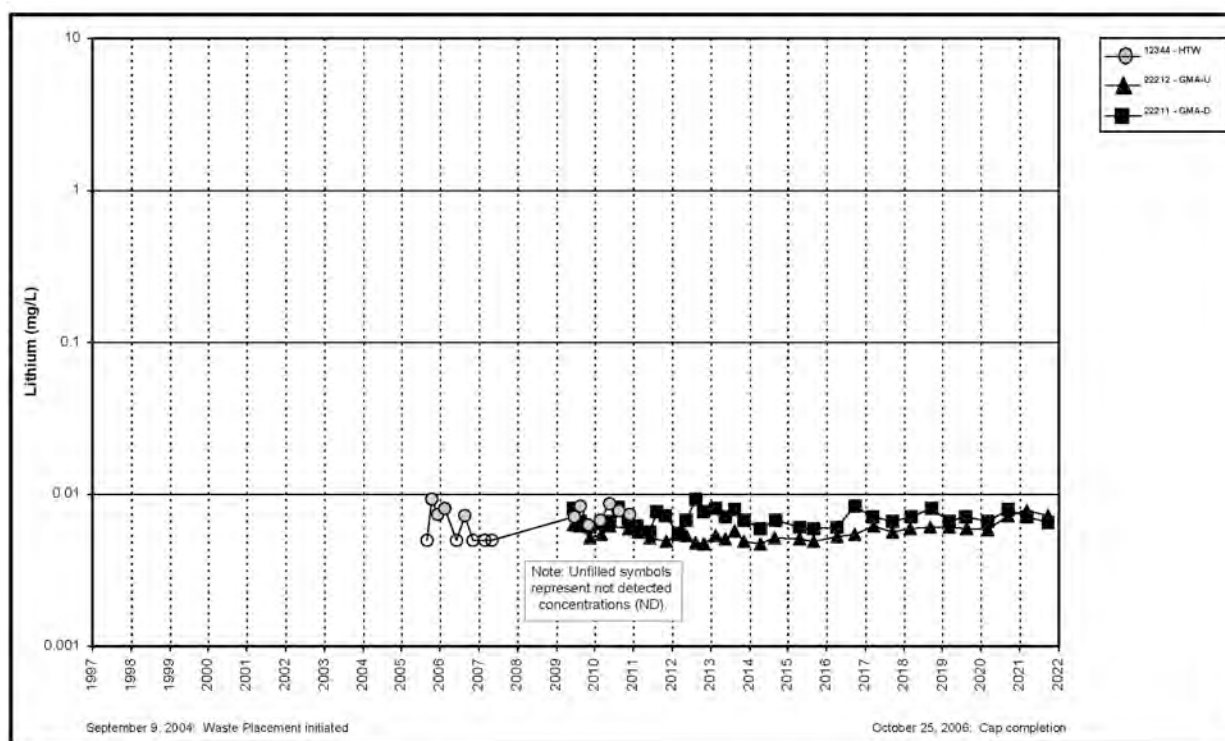


Figure A.5.7-10. Cell 7 Lithium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

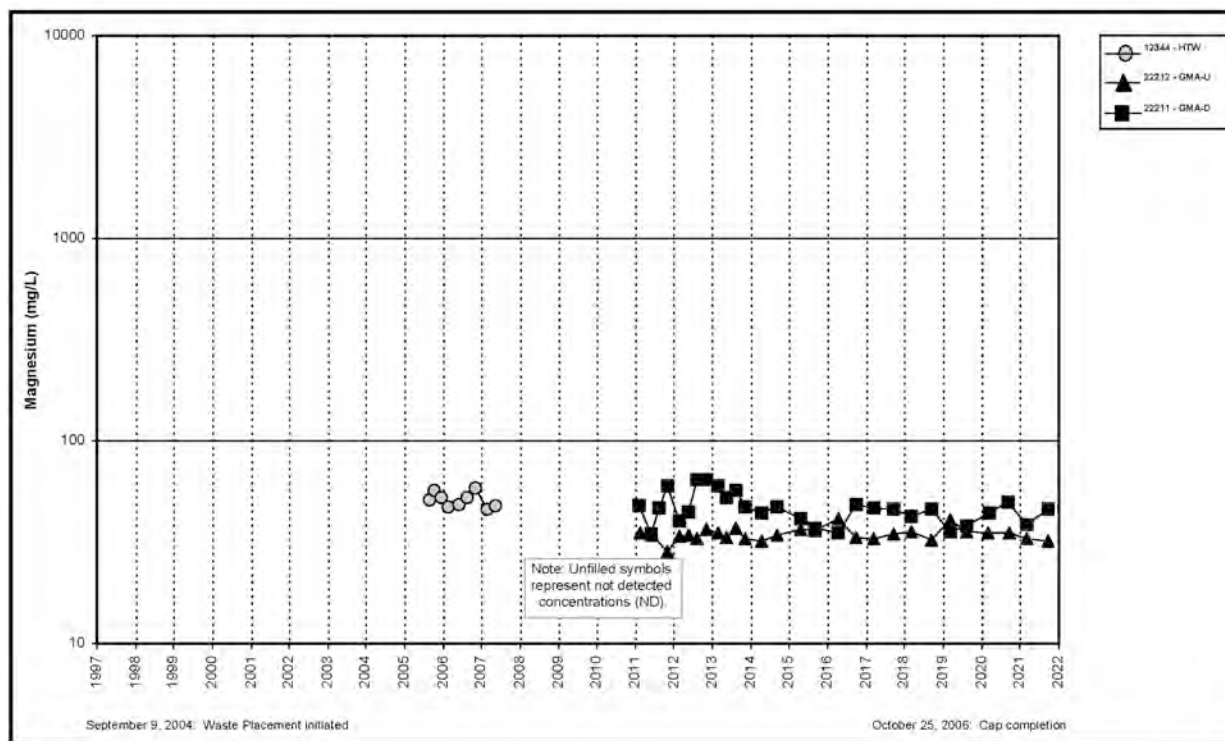


Figure A.5.7-11. Cell 7 Magnesium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

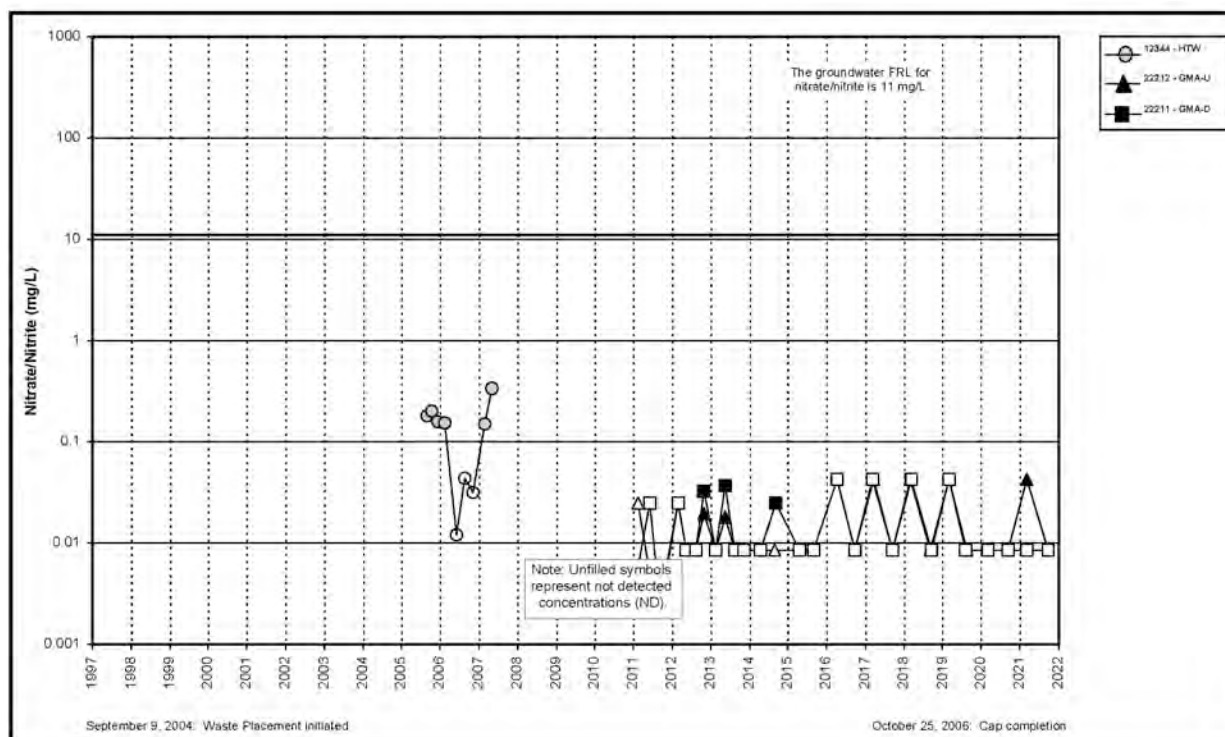


Figure A.5.7-12. Cell 7 Nitrate + Nitrite as Nitrogen Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

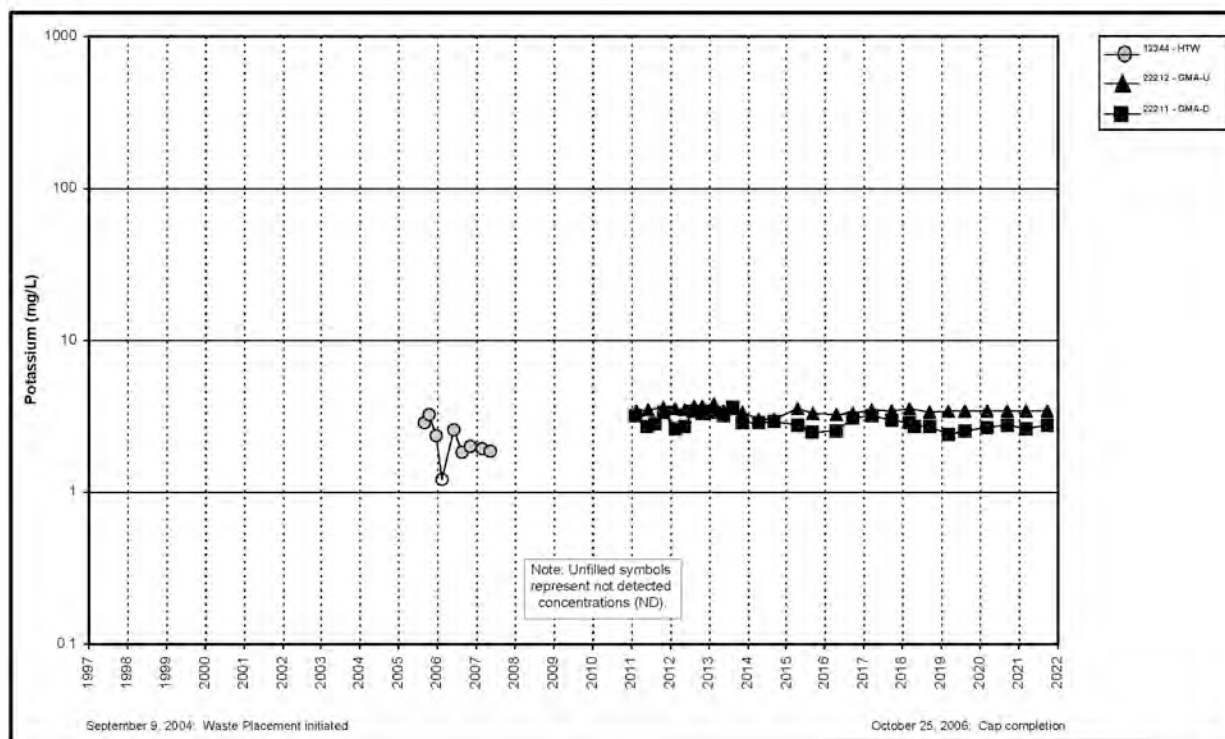


Figure A.5.7-13. Cell 7 Potassium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

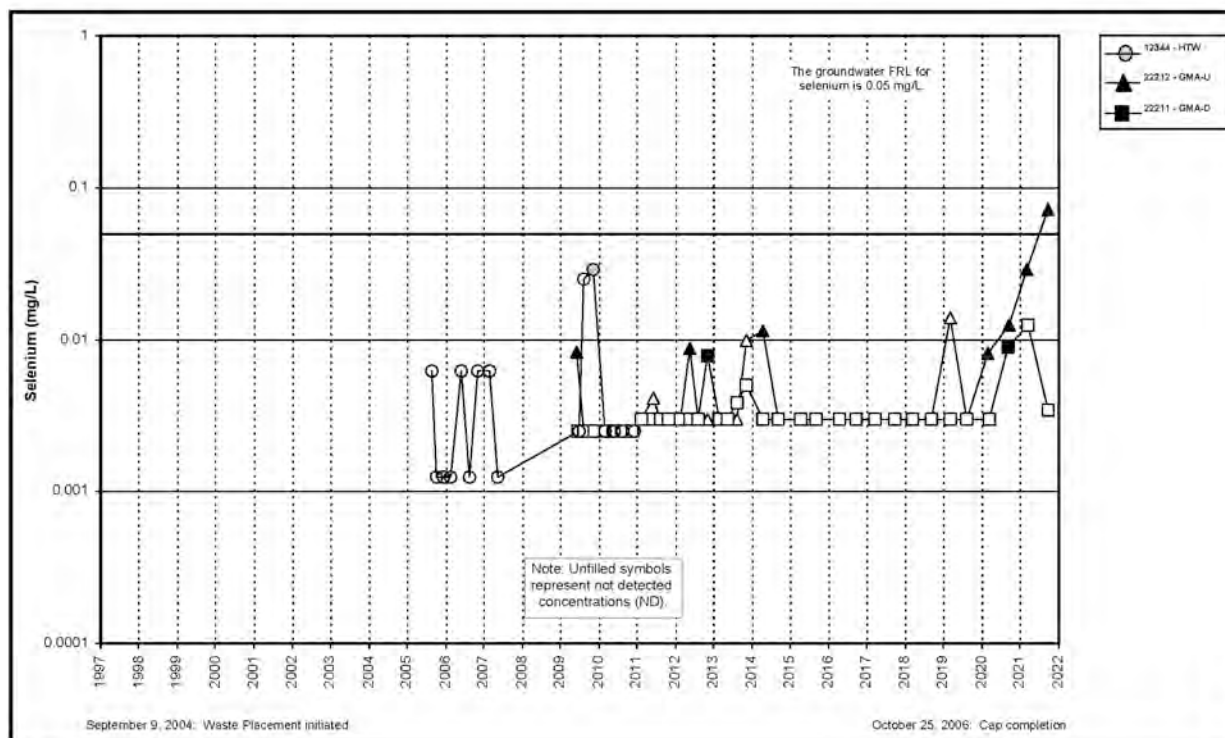


Figure A.5.7-14. Cell 7 Selenium Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

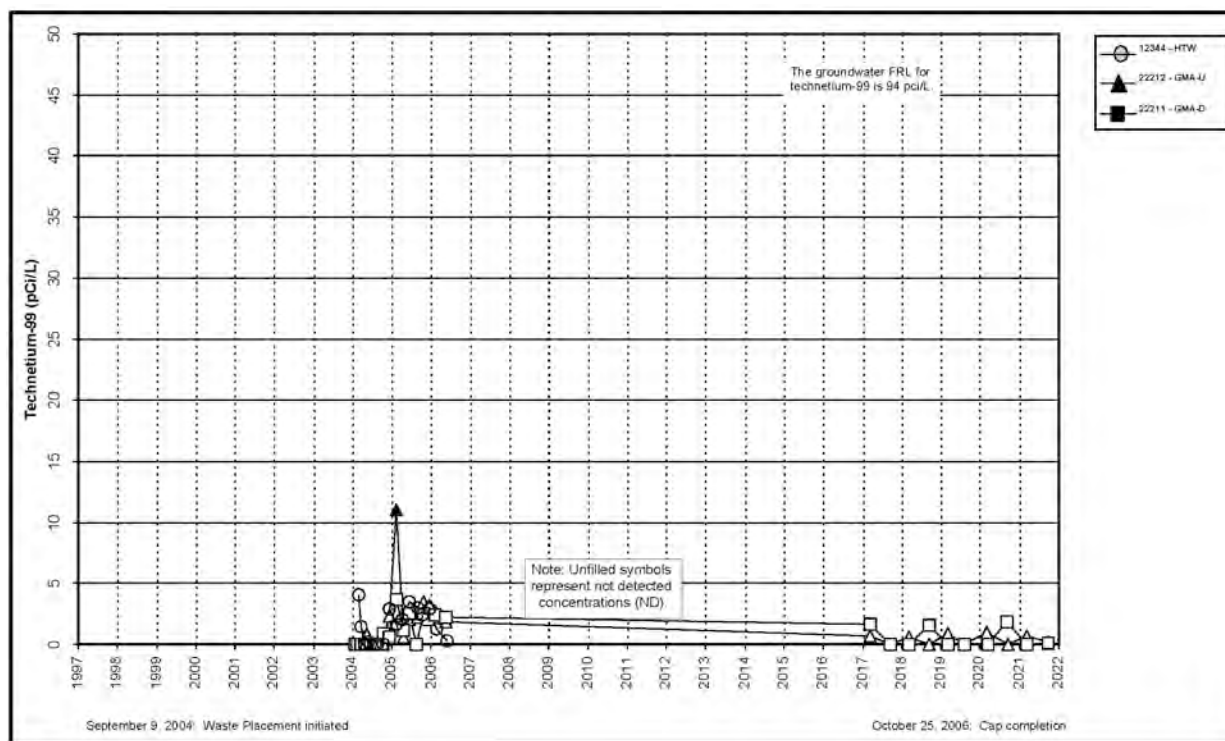


Figure A.5.7-15. Cell 7 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

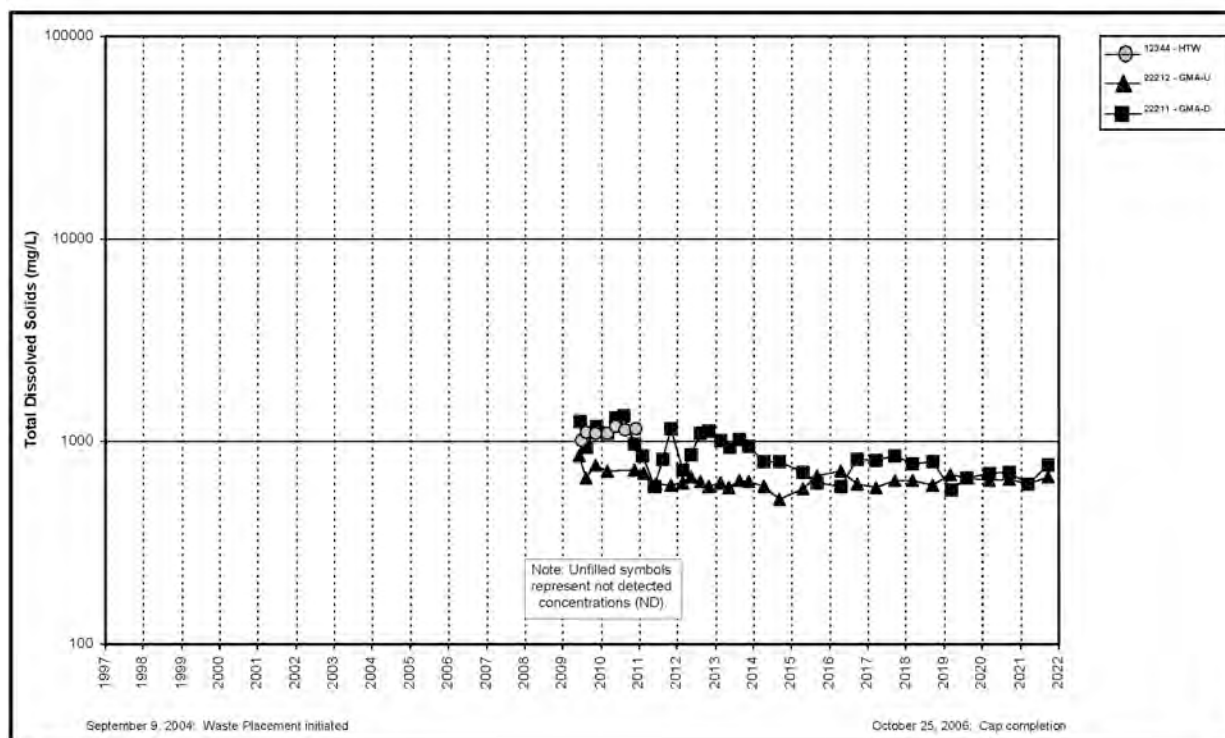


Figure A.5.7-16. Cell 7 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

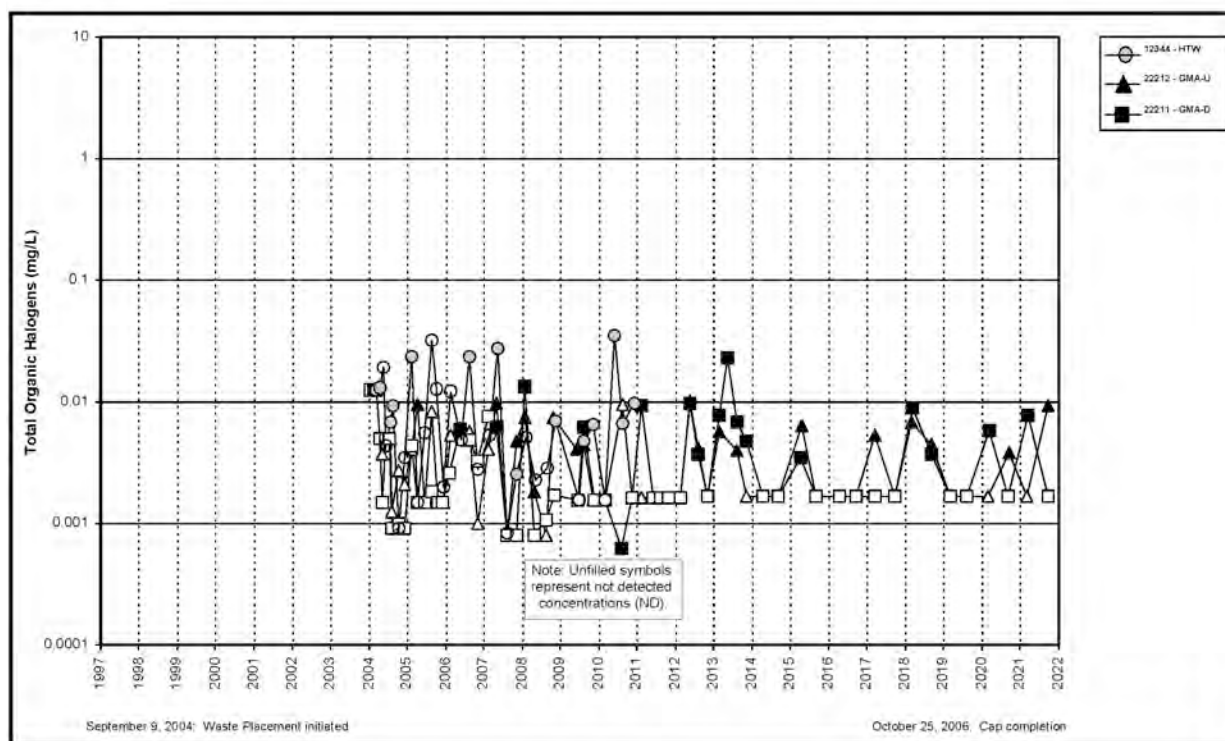


Figure A.5.7-17. Cell 7 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U Well, and GMA-D Well

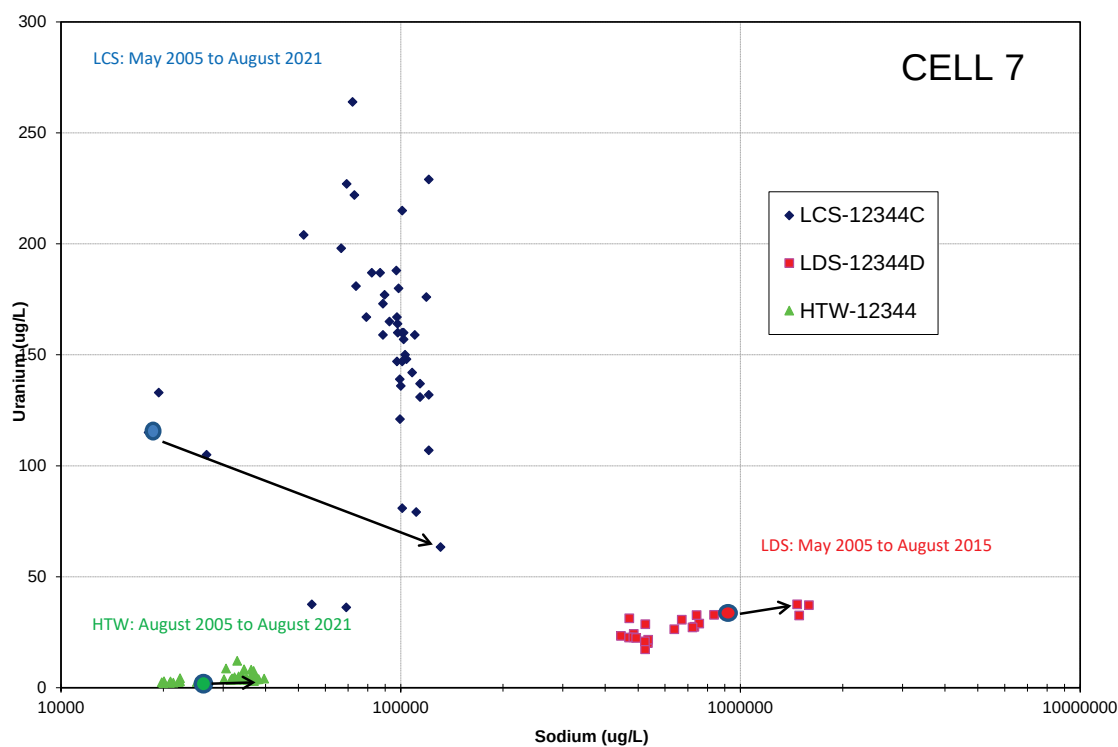


Figure A.5.7-18. Cell 7 Bivariate Plot for Uranium and Sodium

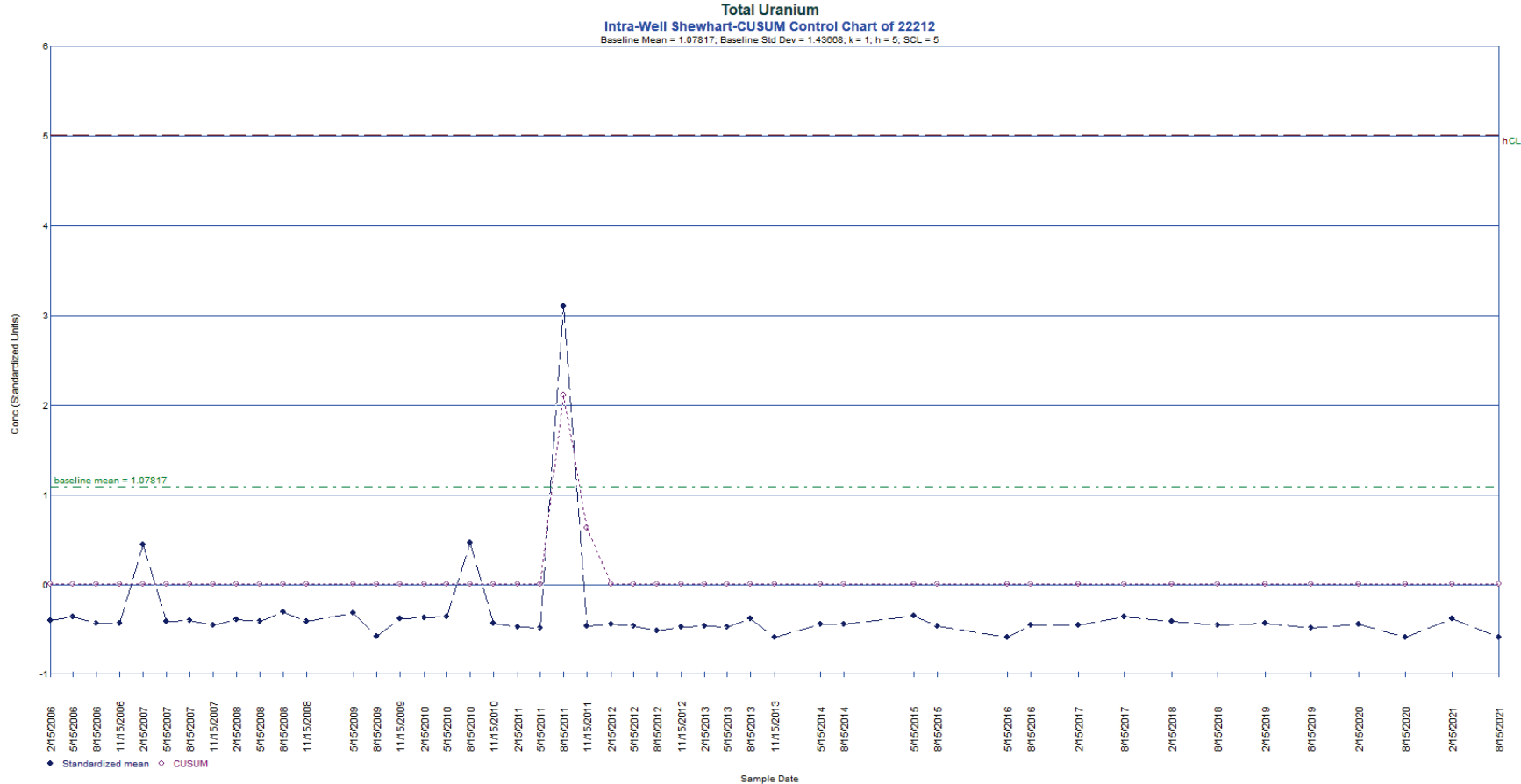


Figure A.5.7-19. Intrawell Shewhart-CUSUM Control Chart for Uranium in Monitoring Well 22212

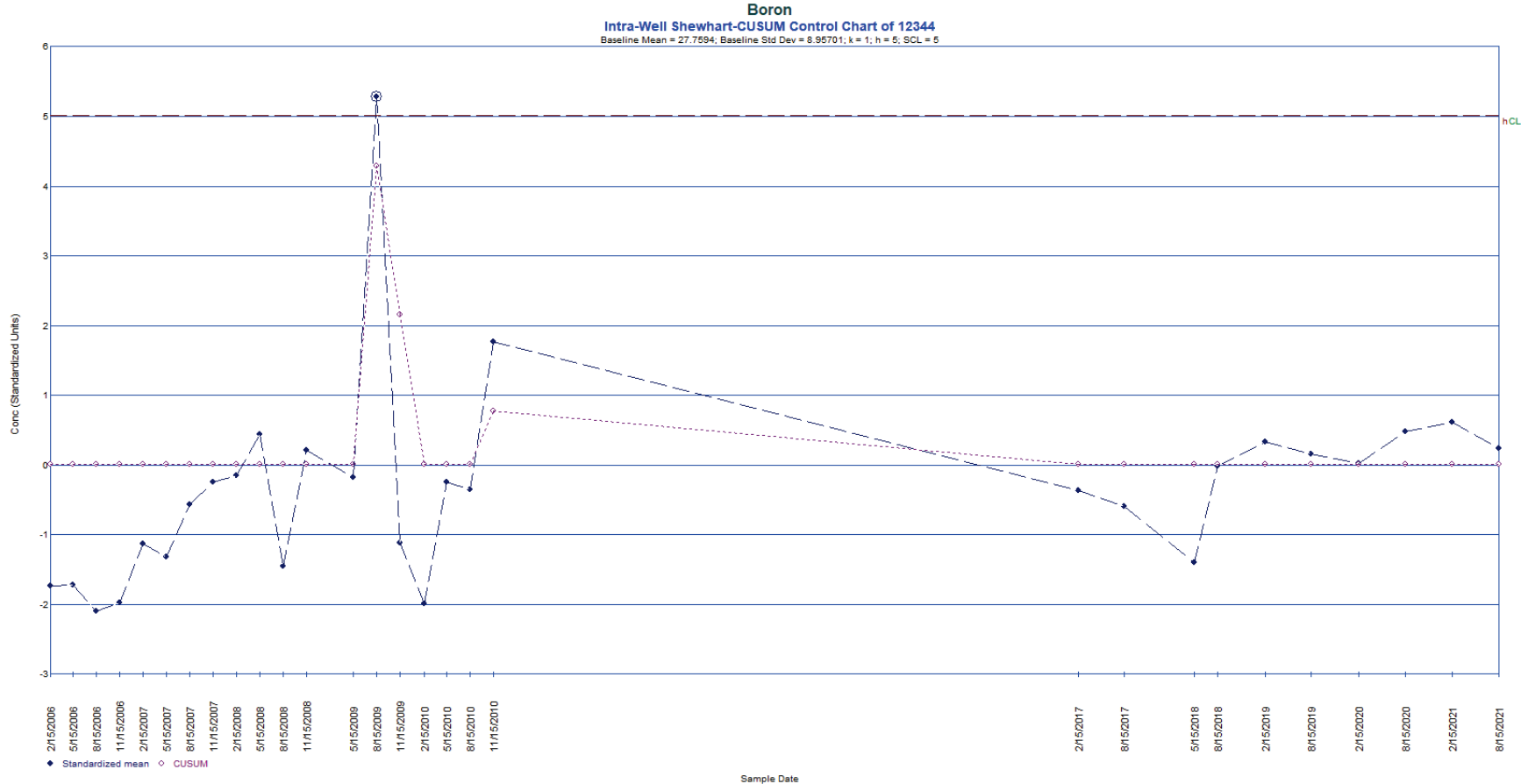


Figure A.5.7-20. Intrawell Shewhart-CUSUM Control Chart for Boron in Monitoring Well 12344

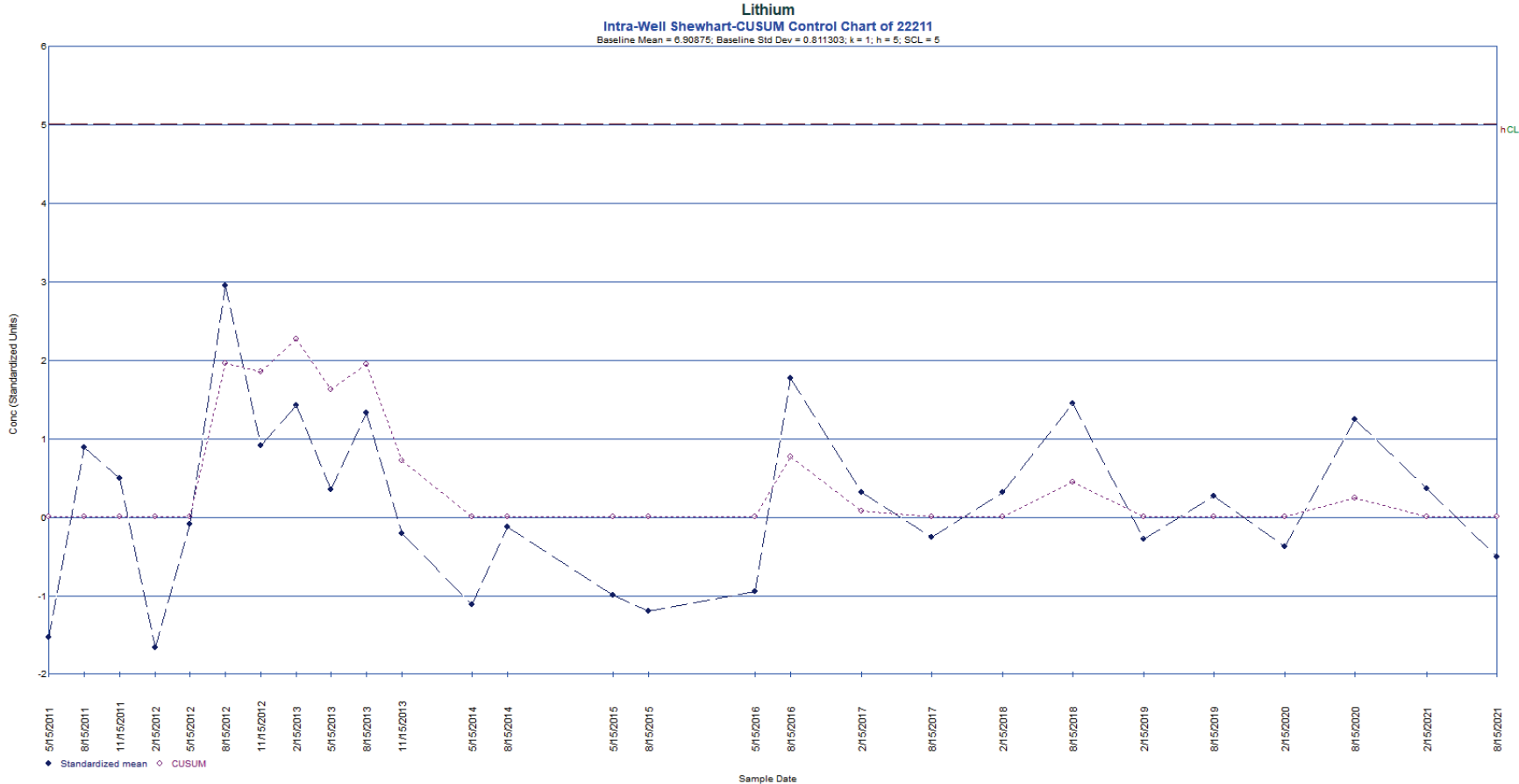


Figure A.5.7-21. Intrawell Shewhart-CUSUM Control Chart for Lithium in Monitoring Well 22211

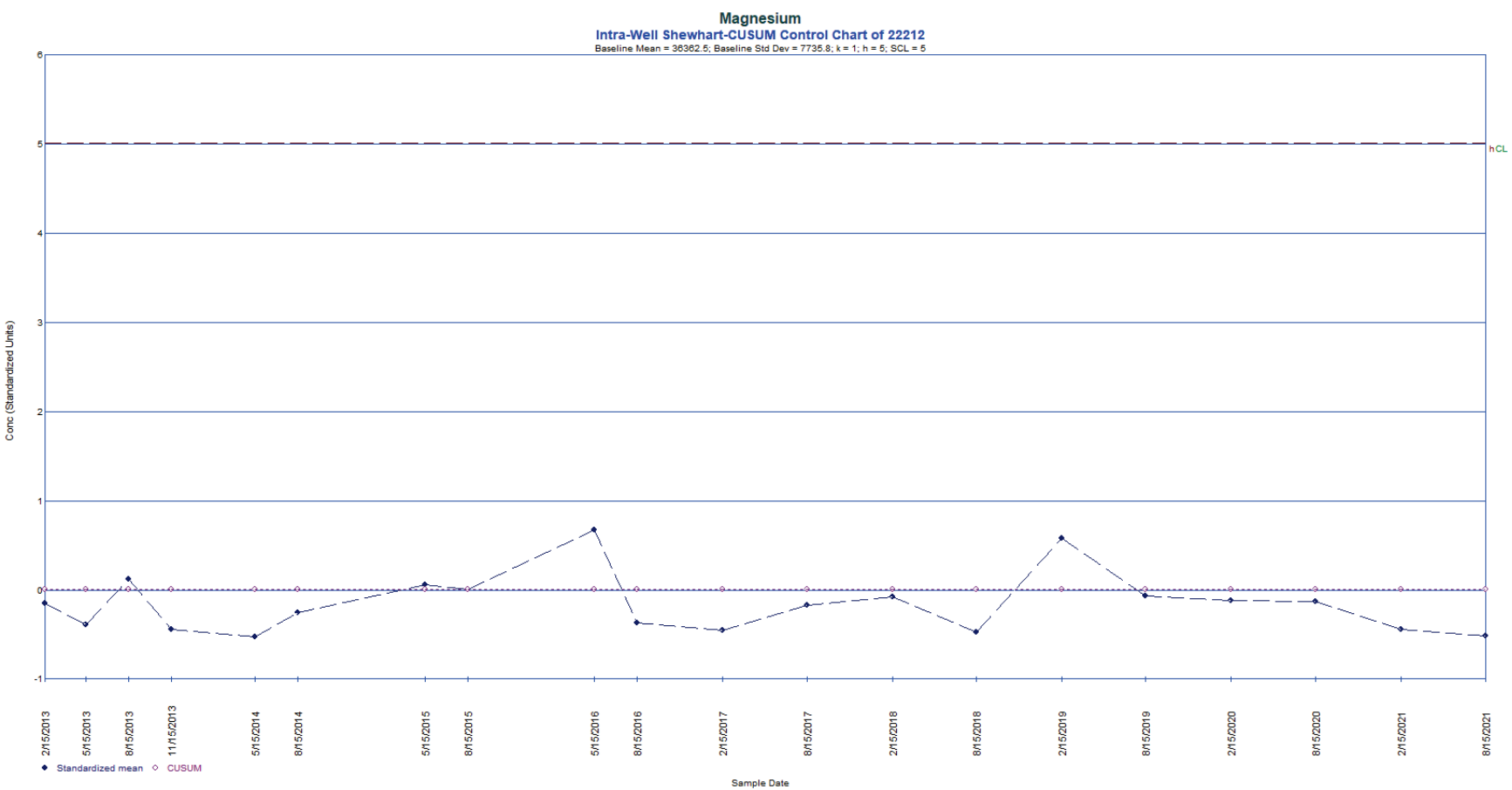


Figure A.5.7-22. Intrawell Shewhart-CUSUM Control Chart for Magnesium in Monitoring Well 22212

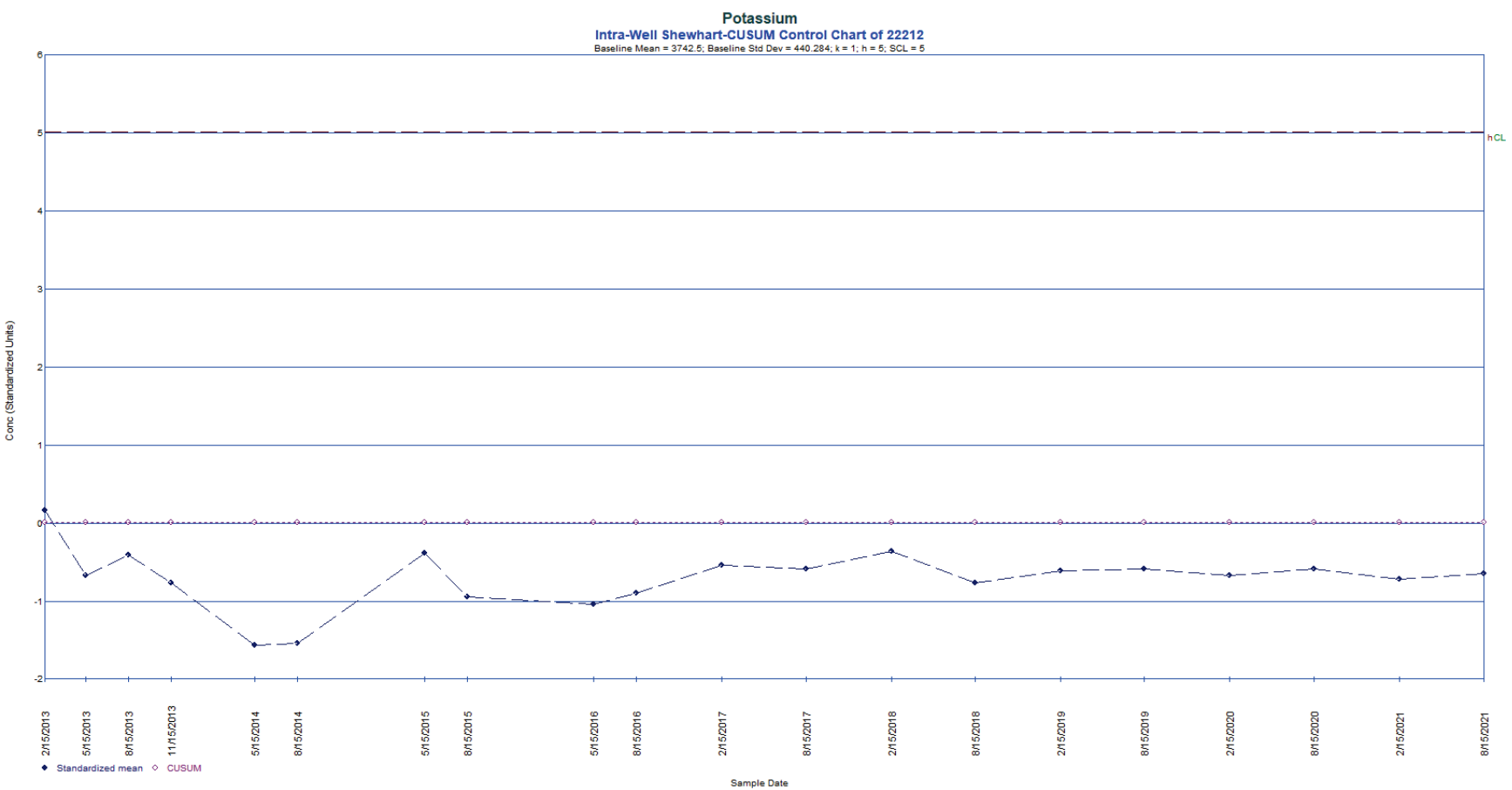


Figure A.5.7-23. Intrawell Shewhart-CUSUM Control Chart for Potassium in Monitoring Well 22212

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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	Great Miami Aquifer–downgradient
GMA-SE	Great Miami Aquifer–southeast
GMA-SW	Great Miami Aquifer–southwest
GMA-U	Great Miami Aquifer–upgradient
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 (refer to Table A.5.8-1)
- Leachate collection system (LCS) monthly accumulation volumes (refer to Figure A.5.8-1)
- Leak detection system (LDS) monthly accumulation volumes (refer to Figure A.5.8-2)
- OSDF horizontal till well (HTW) 12345 water yield (refer to Table A.5.8-2)
- Great Miami Aquifer (GMA) water levels and total uranium concentration versus time (refer to Figures A.5.8-3 through A.5.8-6)
- Plots of concentration versus time (refer to Figures A.5.8-7A through A.5.8-19)
- Bivariate plots for uranium–sodium and uranium–sulfate (refer to Figure A.5.8-20 and A.5.8-21)
- Control charts (refer to Figures A.5.8-22 through 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 the 13 parameters (total uranium, boron, sodium, and sulfate) are sampled in the LCS, LDS, and HTW of each cell. The annual sampling in the LCS of each cell for the abbreviated list of Appendix I parameters and polychlorinated biphenyls listed in *Ohio Administrative Code* 3745-27-10 was also eliminated beginning in January 2017 with EPA and Ohio EPA concurrence (DOE 2017).

A.5.8.1.1 LCS and LDS Results

As shown in Table A.5.8-1, and summarized below, four parameters (total uranium, boron, sodium, and sulfate) in 2021 have upward concentration trends in the LCS and/or LDS based on the Mann-Kendall test for trend. Enough water was present in the LDS of Cell 8 to collect semiannual samples twice in 2021. Six new high concentrations were measured in the LCS and or LDS of Cell 8 in 2021 (i.e., uranium, boron, sodium, and sulfate). The new high total uranium concentration measured in the LDS of Cell 8 in 2021 was 315 micrograms per liter (µg/L), up from 209 µg/L in 2020. The new high boron concentration measured in the LDS of Cell 8 in 2021 was 9.2 milligrams per liter (mg/L), up from 7.02 mg/L in 2020. The new high sodium concentrations measured in the LCS and LDS of Cell 8 in 2021 were 150 and 4,590 mg/L

respectively, up from 148 and 2,260 mg/L, respectively in 2020. The new high sulfate concentrations measured in the LCS and LDS of Cell 8 in 2021 were 4,190 and 36,300 mg/L, respectively, up from 4,020 and 20,900 mg/L, respectively, in 2020.

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

Parameter	LCS 12345C 2021 Trend	LDS 12345D 2021 Trend
Total Uranium		Up
Boron		Up
Sodium	Up	Up
Sulfate	Up	Up

^a No entry indicates that the trend was not up.

A.5.8.1.2 HTW and Monitoring Well Results

As shown in Table A.5.8-1 and summarized below, nine parameters sampled in 2021 (total uranium, boron, sodium, sulfate, lithium, magnesium, selenium, total dissolved solids, and total organic halogens) have upward concentration trends in the HTW and/or GMA wells based on the Mann-Kendall test for trend. Cell 8 is unique in that it has four GMA wells (GMA-U, GMA-D, GMA-SW, and GMA-SE). The Cell 8 HTW did not contain enough water to collect a sample in 2021.

Parameters with Upward Concentration Trends in the HTW and GMA Wells of Cell 8^a

Parameter	HTW 12345 Trend (Year Last Sampled)	GMA-U ^b 22213	GMA-D ^b 22214	GMA-SW ^b 22215	GMA-SE ^b 22217
Total Uranium	Up (2008)	Up			
Boron		Up		Up	
Sodium			Up	Up	
Sulfate	Up (2008)			Up	
Lithium				Up	
Magnesium				Up	
Selenium			Up	Up	
Total Dissolved Solids				Up	
Total Organic Halogens		Up			Up

^a No entry indicates that the trend was not up. Magnesium, selenium, total dissolved solids, and total organic halogen are not horizontal till well 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.

The new high uranium concentrations measured in the LDS are not attributed to communication with the LCS. The new high uranium concentration measured in the LDS are attributed to the impact that decreasing flow can have on the uranium concentration left in water remaining in the LDS, as the LDS dries up. An additional discussion of this is presented in Attachment A.5, Section A.5.2.5.

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 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.5.8-22 and A.5.8-23) that exhibit “in control” conditions.

Parameter	Monitoring Point ^a	Monitoring Well	Assessment	Figure Number
Boron	HTW	12345	In Control	A.5.8-22
Potassium	GMA-SW	22215	In Control	A.5.8-23

^a GMA-SW = southwest Great Miami Aquifer; GMA-SE = southeast Great Miami Aquifer, HTW = horizontal till well.

A.5.8.3 Summary and Conclusions

- Four parameters monitored semiannually have an upward concentration trend in the LCS and/or LDS of Cell 8: total uranium, boron, sodium, and sulfate.
- Six new high concentrations were measured in the LCS and or LDS of Cell 8 in 2021 (uranium, boron, sodium, and sulfate). The new high total uranium concentration measured in the LDS of Cell 8 in 2021 was 315 µg/L, up from 209 µg/L in 2020. The new high boron concentration measured in the LDS of Cell 8 in 2021 was 9.2 mg/L, up from 7.02 mg/L in 2020. The new high sodium concentrations measured in the LCS and LDS of Cell 8 in 2021 were 150 and 4,590 mg/L, respectively, up from 148 and 2,260 mg/L, respectively in 2020. The new high sulfate concentrations measured in the LCS and LDS of Cell 8 in 2021 were 4,190 and 36,300 mg/L, respectively, up from 4,020 and 20,900 mg/L, respectively, in 2020. The new high concentrations measured in the LDS are not attributed to communication with the LCS and are attributed to the impact that decreasing flow can have on the uranium concentration left in water remaining in the LDS, as the LDS dries up.
- The Cell 8 HTW did not contain enough water to collect a sample in 2021.
- Nine parameters monitored semiannually are increasing in either the HTW or GMA wells of Cell 8 (total uranium, boron, sodium, sulfate, lithium, magnesium, selenium, total dissolved solids, and total organic halogens). The chemical signatures for uranium–sodium and uranium–sulfate in the LCS of Cell 8 are separate and distinct from the signatures seen in the LDS and HTW. The signature for uranium–sodium in the HTW is also separate and distinct from the LDS signature, but low total uranium concentrations in both horizons have the clusters closer than what is seen in the other seven cells. The signature for uranium–sulfate in the HTW is separate and distinct from the LDS signature. Separate and distinct chemical signatures in the LCS, LDS, and HTW indicate that water is not mixing between the horizons. Concentration increases in the HTW and GMA wells of Cell 8 are attributed to fluctuating ambient concentrations beneath the cell and not to cell performance. The HTW of Cell 8 has been dry since the third quarter of 2008, providing additional evidence that the secondary liner is not leaking.
- Two control charts were constructed for Cell 8 parameters. Both exhibit “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*.

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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	52	52	100	1.51	335	168	58	Normal	None (2021)	Detected	
	LDS	12345D	47	47	100	9.38	315	25.1	57.4	Undefined	Up (2021)	Detected	
	HTW	12345	16	16	100	3.67	7.3	5.02	0.99	Normal	Up (2008)	Not Detected	
	GMA-U	22213	47	55	85.4	ND	0.717	0.391	0.120	Normal	Up (2021)	Detected	
	GMA-D	22214	60	63	95.2	ND	2.37	0.414	0.492	Undefined	Down (2021)	Not Detected	
	GMA-SW	22215	44	49	89.8	ND	16.4	0.480	2.53	Undefined	None (2021)	Not Detected	
	GMA-SE	22217	45	45	100	0.898	18.3	6.91	4.19	Normal	Down (2021)	Detected	
Boron (mg/L)	LCS	12345C	52	52	100	0.0681	0.776	0.612	0.165	Undefined	None (2021)	Detected	
	LDS	12345D	47	47	100	0.582	9.2	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	52	55	94.6	ND	0.0583	0.0389	0.0075	Undefined	Up (2021)	Detected	
	GMA-D	22214	53	55	96.4	ND	0.0524	0.029	0.0073	Undefined	None (2021)	Not Detected	
	GMA-SW	22215	47	49	95.9	ND	0.0746	0.0350	0.0091	Undefined	Up (2021)	Detected	
	GMA-SE	22217	43	45	95.6	ND	0.0447	0.0279	0.0061	Normal	None (2021)	Detected	
Sodium (mg/L)	LCS	12345C	44	44	100	16.8	150	116	35	Undefined	Up (2021)	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	35	35	100	18.3	30.3	21.9	3.7	Undefined	Down (2021)	Detected	
	GMA-D	22214	36	36	100	9.83	16.8	12.4	1.6	Normal	Up (2021)	Detected	
	GMA-SW	22215	35	35	100	13.5	26.0	18.6	2.6	Normal	Up (2021)	Detected	
	GMA-SE	22217	35	35	100	11.0	17.6	13.7	1.8	Undefined	None (2021)	Detected	
Sulfate (mg/L)	LCS	12345C	52	52	100	146	4,190	2,900	1,010	Undefined	Up (2021)	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	55	55	100	90.2	284	181	54	Normal	None (2021)	Detected	
	GMA-D	22214	55	55	100	76.1	457	215	92	Normal	Down (2021)	Detected	
	GMA-SW	22215	48	49	98.0	ND	911	252	169	Ln Normal	Up (2021)	Detected	
	GMA-SE	22217	45	45	100	113	1,320	360	209	Ln Normal	Down (2021)	Detected	
Calcium (mg/L)	GMA-U	22213	28	28	100	141	186	160	11	Normal	None (2021)	Detected	
	GMA-D	22214	28	28	100	89.8	230	142	39	Ln Normal	Down (2021)	Detected	
	GMA-SW	22215	28	28	100	127	446	192	70	Undefined	None (2021)	Not Detected	
	GMA-SE	22217	28	28	100	121	334	195	51	Normal	Down (2021)	Detected	
Lithium (mg/L)	GMA-U	22213	35	35	100	0.00434	0.00728	0.00542	0.0006	Normal	None (2021)	Detected	
	GMA-D	22214	35	35	100	0.00372	0.00858	0.00513	0.00104	Ln Normal	None (2021)	Detected	
	GMA-SW	22215	35	35	100	0.00467	0.00828	0.00593	0.00084	Normal	Up (2021)	Detected	
	GMA-SE	22217	35	35	100	0.00432	0.00799	0.00592	0.00097	Normal	Down (2021)	Detected	
Magnesium (mg/L)	GMA-U	22213	28	28	100	31.7	42	36.3	2.6	Normal	None (2021)	Detected	
	GMA-D	22214	28	28	100	22.0	53.2	33.8	8.5	Normal	Down (2021)	Detected	
	GMA-SW	22215	28	28	100	32.5	66.8	43.9	7.7	Ln Normal	Up (2021)	Not Detected	74.5 (Q2-11)
	GMA-SE	22217	28	28	100	27.5	63.3	42.4	8.8	Normal	Down (2021)	Detected	
Nitrate + Nitrite, as Nitrogen (mg/L)	GMA-U	22213	0	28	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-D	22214	1	28	3.6	ND	0.0500	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SW	22215	2	28	7.1	ND	0.0850	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SE	22217	6	28	21.4	ND	0.0850	0.019621	0.018184	Undefined	None (2021)	Not Detected	
Potassium (mg/L)	GMA-U	22213	28	28	100	3.36	4.14	3.68	0.17	Normal	Down (2021)	Detected	
	GMA-D	22214	29	29	100	2.14	3.23	2.54	0.29	Normal	Down (2021)	Detected	
	GMA-SW	22215	28	28	100	3.18	3.87	3.51	0.17	Normal	None (2021)	Not Detected	4.73 (Q2-11); 5.01 (Q3-11); 2.30 (Q4-13)
	GMA-SE	22217	28	28	100	2.36	4.09	3.02	0.41	Normal	Down (2021)	Detected	

Table A.5.8-1. Summary Statistics for Cell 8 (continued)

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}
Selenium (mg/L)	GMA-U	22213	3	35	8.6	ND	0.0260	0.00461	Insufficient	Insufficient	Insufficient	Detected	
	GMA-D	22214	4	35	11.4	ND	0.0194	0.00300	0.00389	Undefined	Up (2021)	Detected	
	GMA-SW	22215	8	35	22.9	ND	0.0432	0.00300	0.00732	Undefined	Up (2021)	Detected	
	GMA-SE	22217	3	35	8.6	ND	0.0174	0.00443	Insufficient	Insufficient	Insufficient	Insufficient	
Technitium-99 (pCi/L)	GMA-U	22213	6	46	13.0	ND	24.8	0.398	4.29	Undefined	Down (2021)	Detected	
	GMA-D	22214	4	46	8.7	ND	11.8	0.015	2.41	Undefined	None (2021)	Not Detected	
	GMA-SW	22215	0	40	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
	GMA-SE	22217	0	36	0	ND	NA	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	
Total Dissolved Solids (mg/L)	GMA-U	22213	35	35	100	429	843	672	84	Undefined	Down (2021)	Detected	
	GMA-D	22214	35	35	100	386	1,020	621	160	Normal	Down (2021)	Detected	
	GMA-SW	22215	35	35	100	457	1,800	821	268	Undefined	Up (2021)	Detected	
	GMA-SE	22217	35	35	100	514	1,550	886	253	Normal	Down (2021)	Detected	
Total Organic Halogens (mg/L)	GMA-U	22213	13	55	23.6	ND	0.0560	0.00166	0.00831	Undefined	Up (2021)	Not Detected	
	GMA-D	22214	12	55	21.8	ND	0.0590	0.00166	0.00880	Undefined	None (2021)	Not Detected	
	GMA-SW	22215	14	49	28.6	ND	0.0460	0.00166	0.00788	Undefined	None (2021)	Not Detected	
	GMA-SE	22217	16	45	35.6	ND	0.0730	0.00166	0.0112	Undefined	Up (2021)	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 (gallon)	Number of Months Purged	Average Volume Purged (gallon)
2004	4,020	5	804
2005	1,050	6	175
2006	3,375	4	844
2007	1,000	4	250
2008	135	4	34
2009	0	2	0
2010	0	2	0
2011	0	2	0
2012	0	2	0
2013	0	2	0
2014	0	2	0
2015	0	2	0
2016	0	2	0
2017	0	2	0
2018	0	2	0
2019	0	2	0
2020	0	2	0
2021	0	2	0

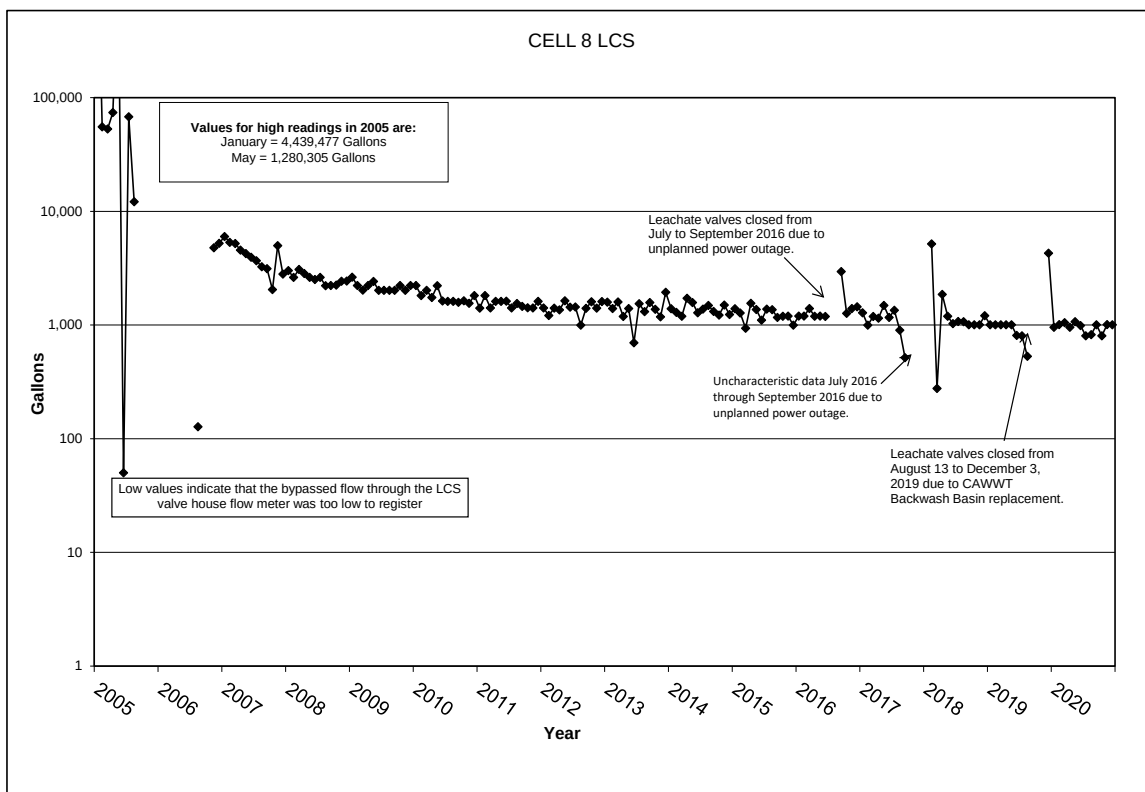


Figure A.5.8-1. Monthly Accumulation Volumes for Cell 8 LCS

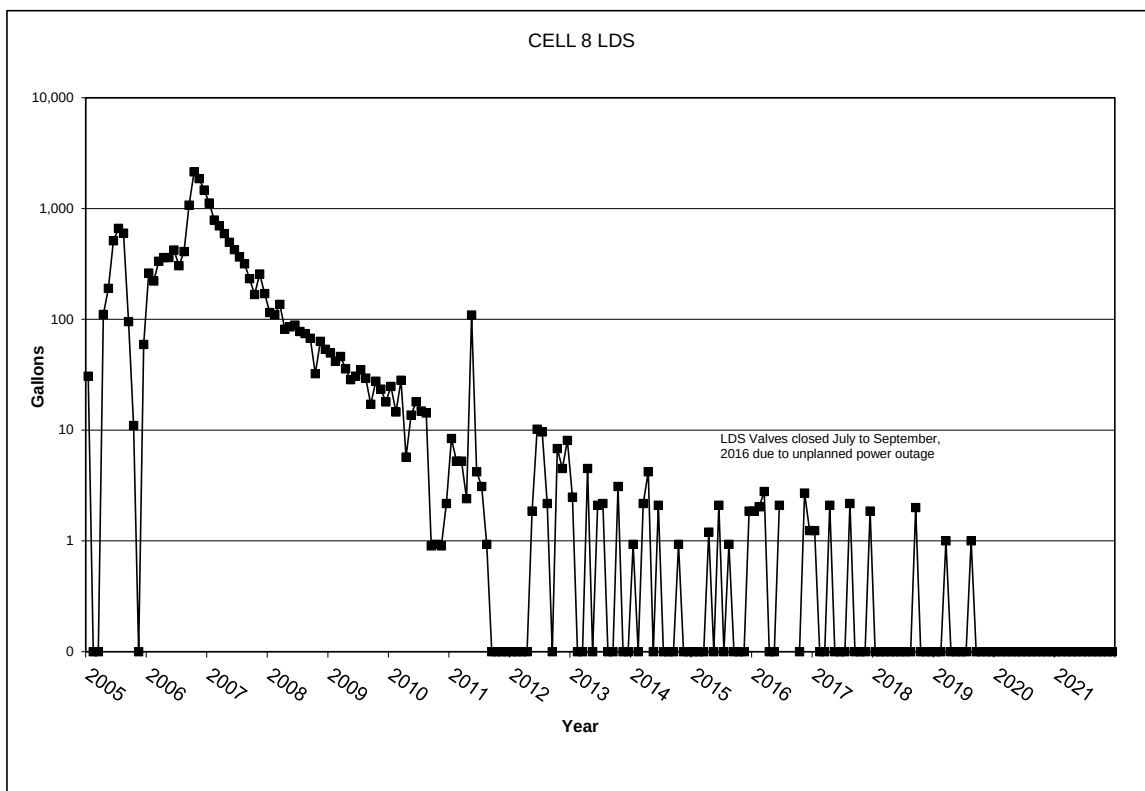


Figure A.5.8-2. Monthly Accumulation Volumes for Cell 8 LDS

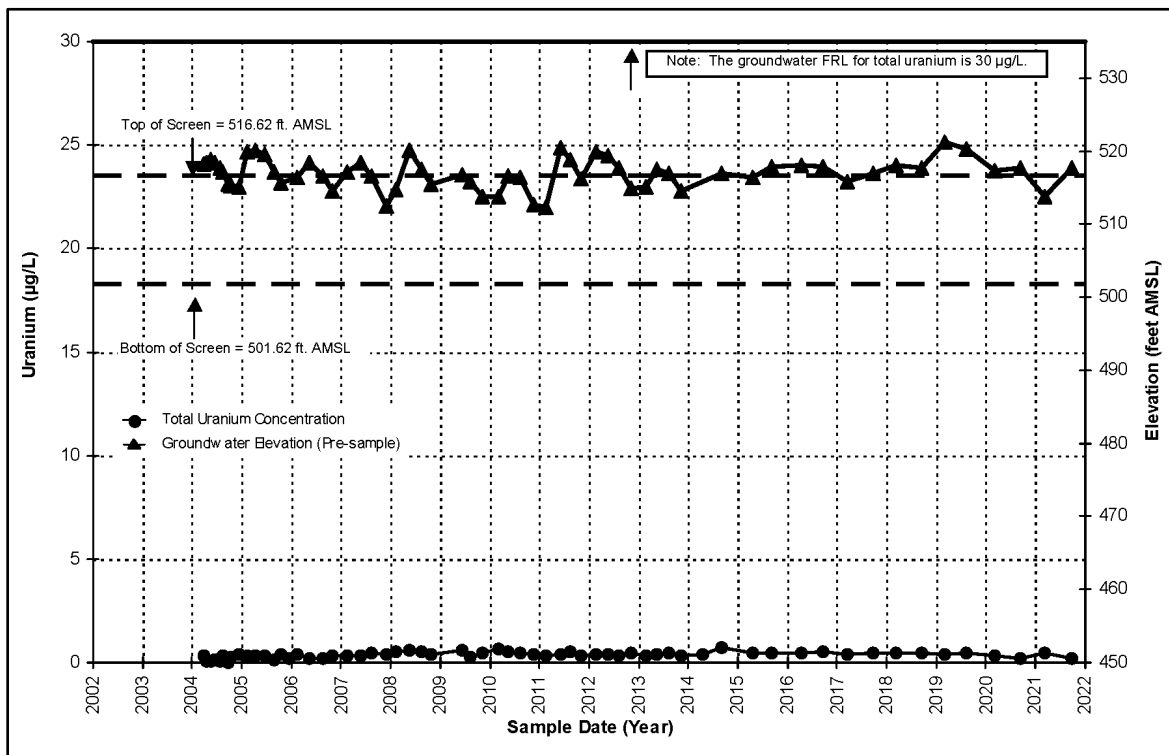


Figure A.5.8-3. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Upgradient Monitoring Well 22213

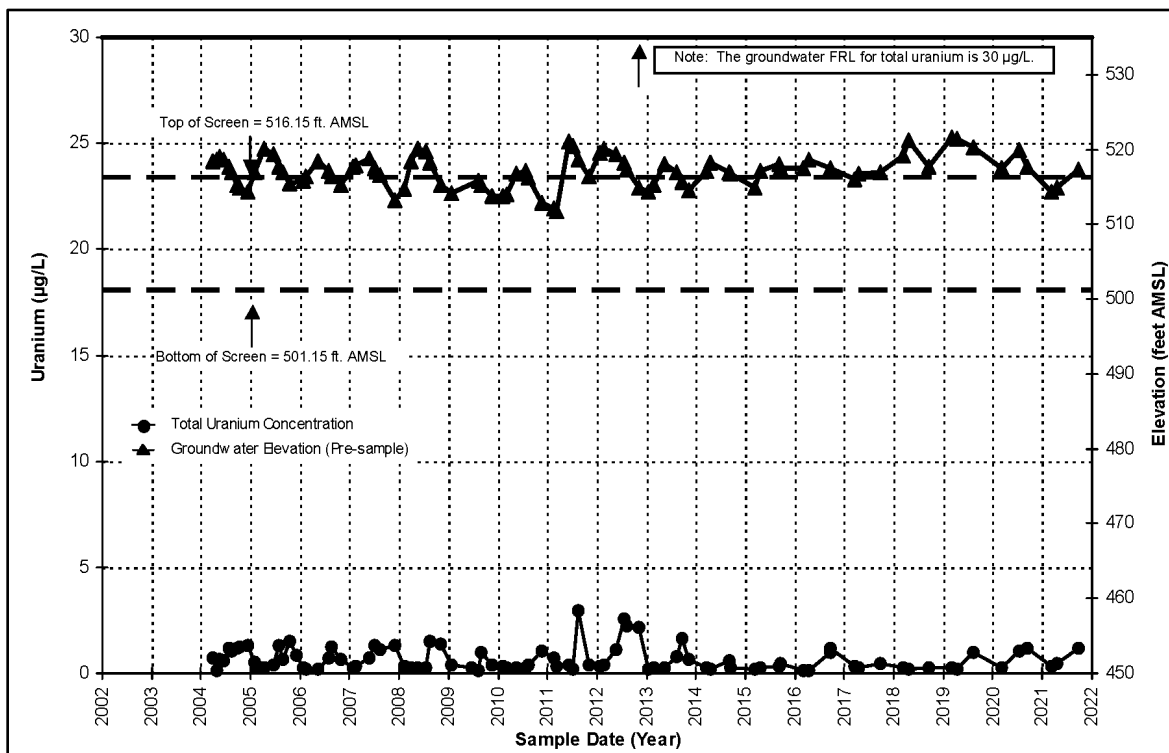


Figure A.5.8-4. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22214

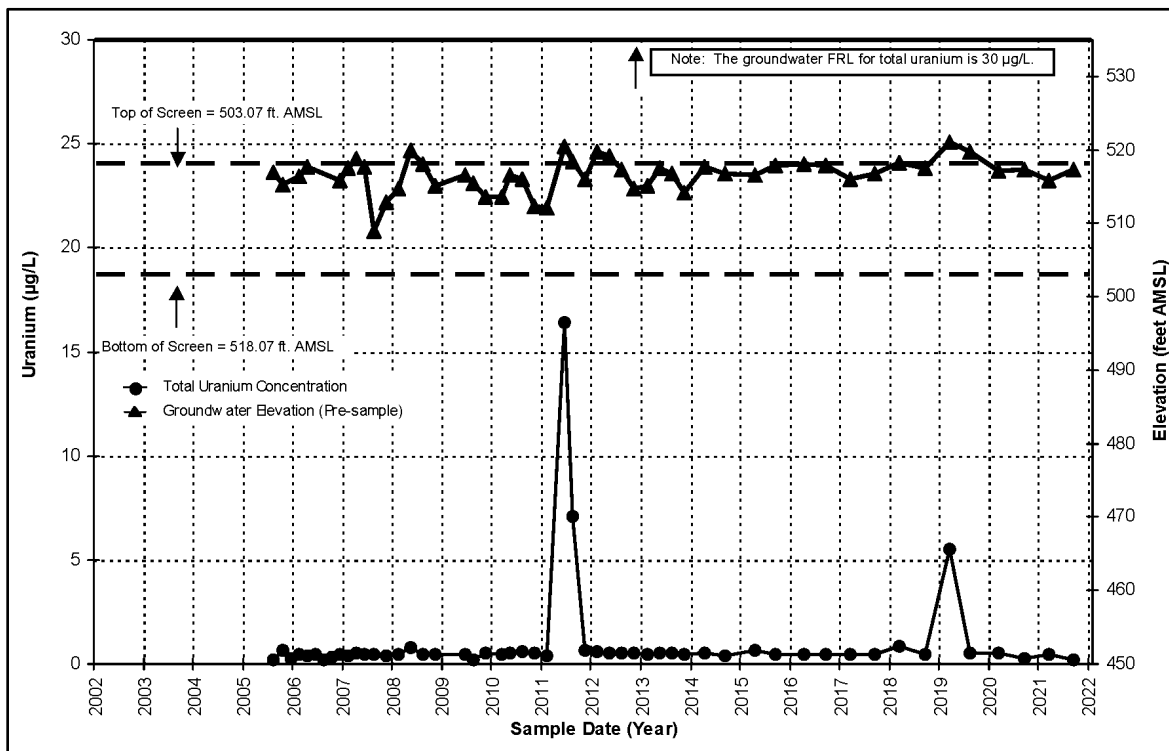


Figure A.5.8-5. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22215

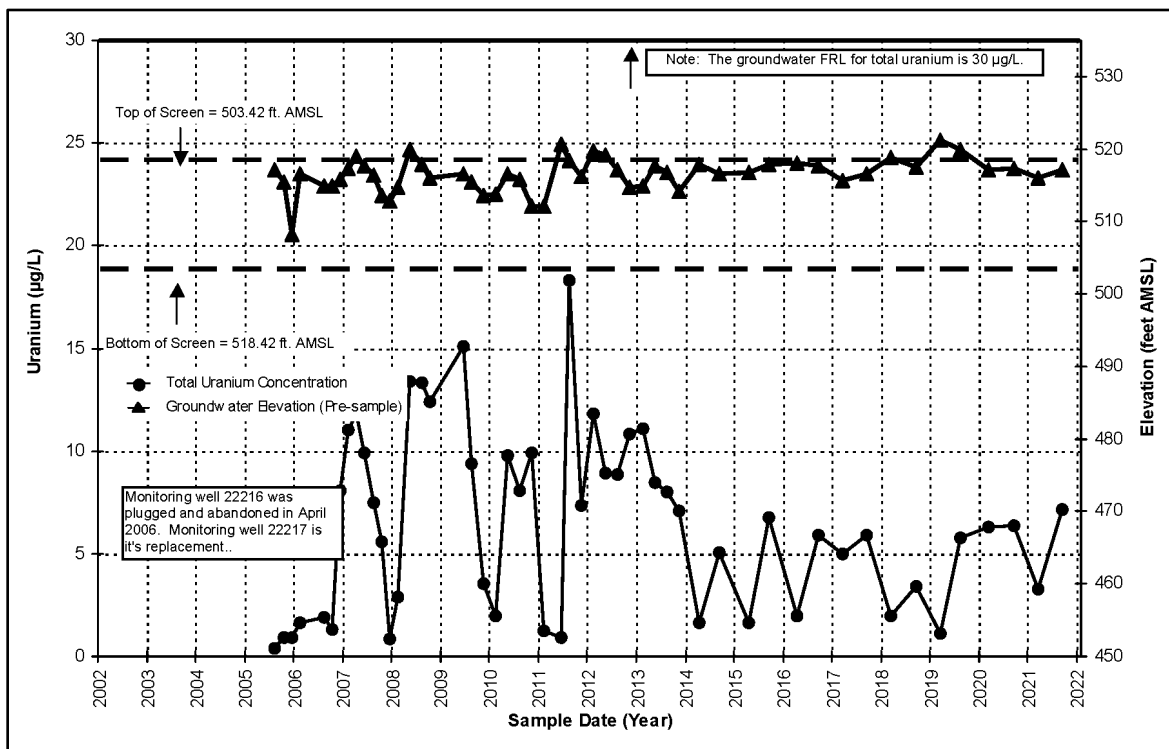


Figure A.5.8-6. Total Uranium Concentration and Groundwater Elevation Versus Time Plot for Cell 8 Downgradient Monitoring Well 22216/22217

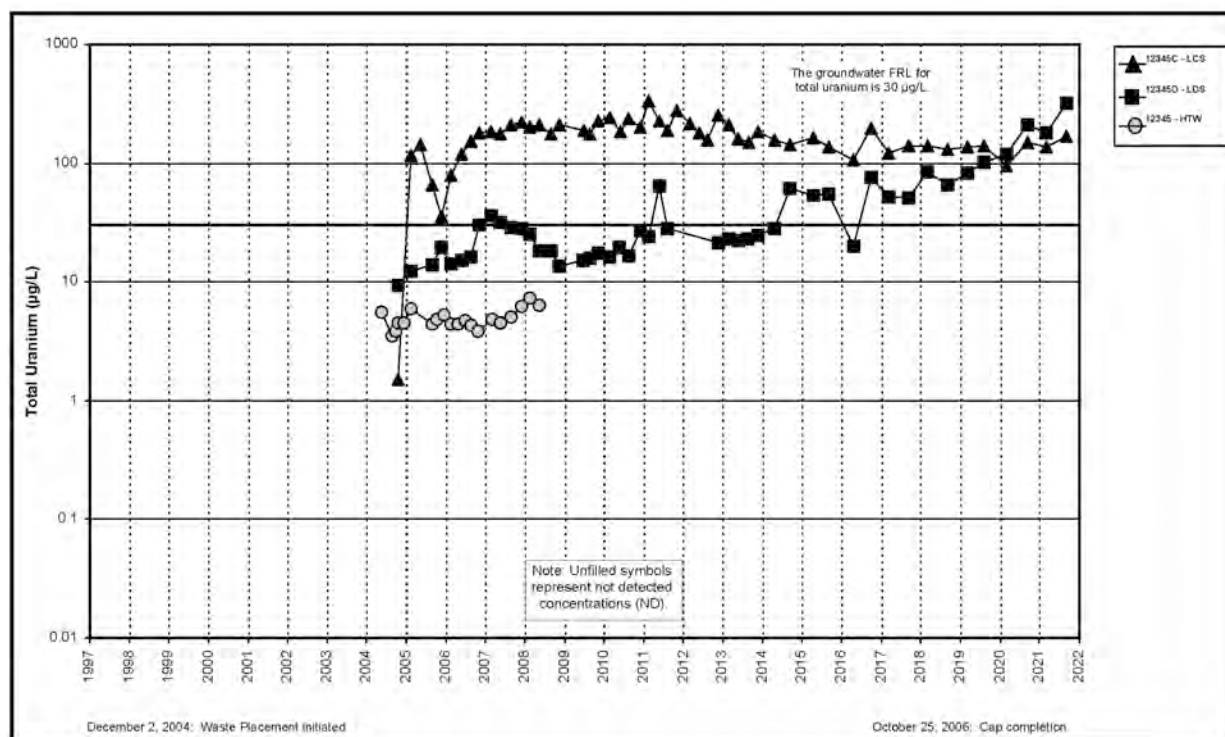


Figure A.5.8-7A. Cell 8 Total Uranium Concentration Versus Time Plot for LCS, LDS, and HTW

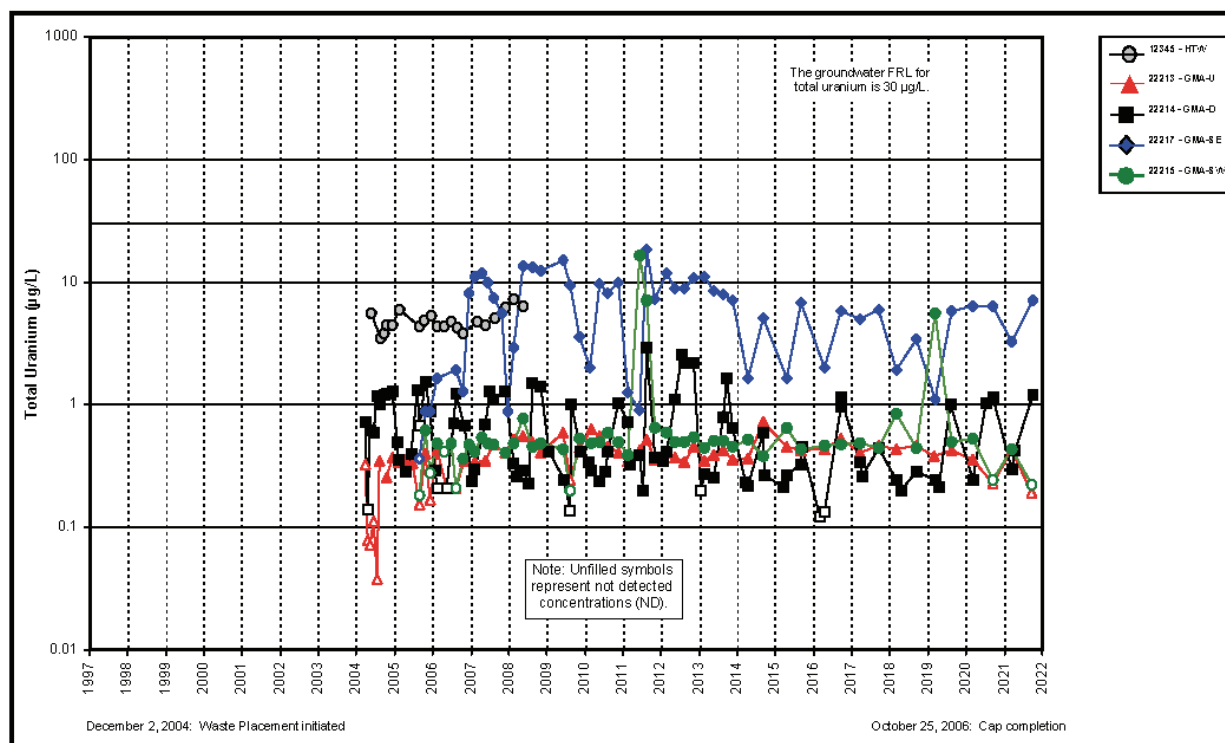


Figure A.5.8-7B. Cell 8 Total Uranium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

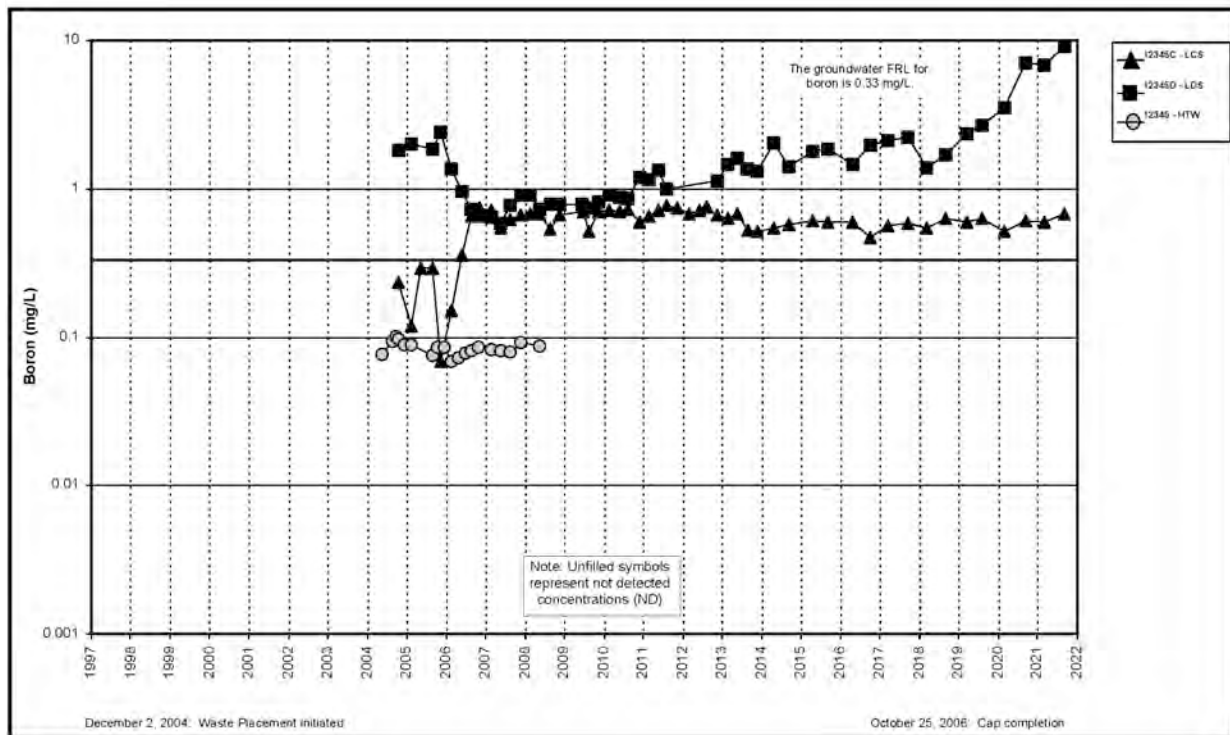


Figure A.5.8-8A. Cell 8 Boron Concentration Versus Time Plot for LCS, LDS, and HTW

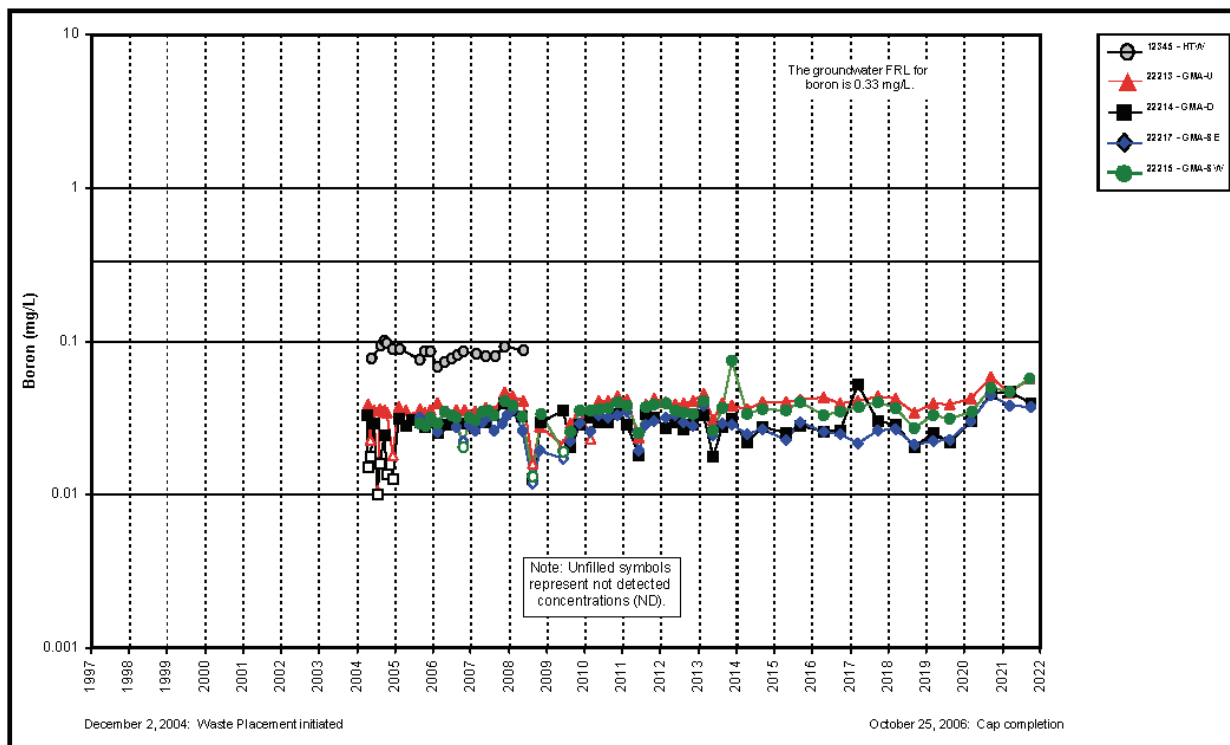


Figure A.5.8-8B. Cell 8 Boron Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

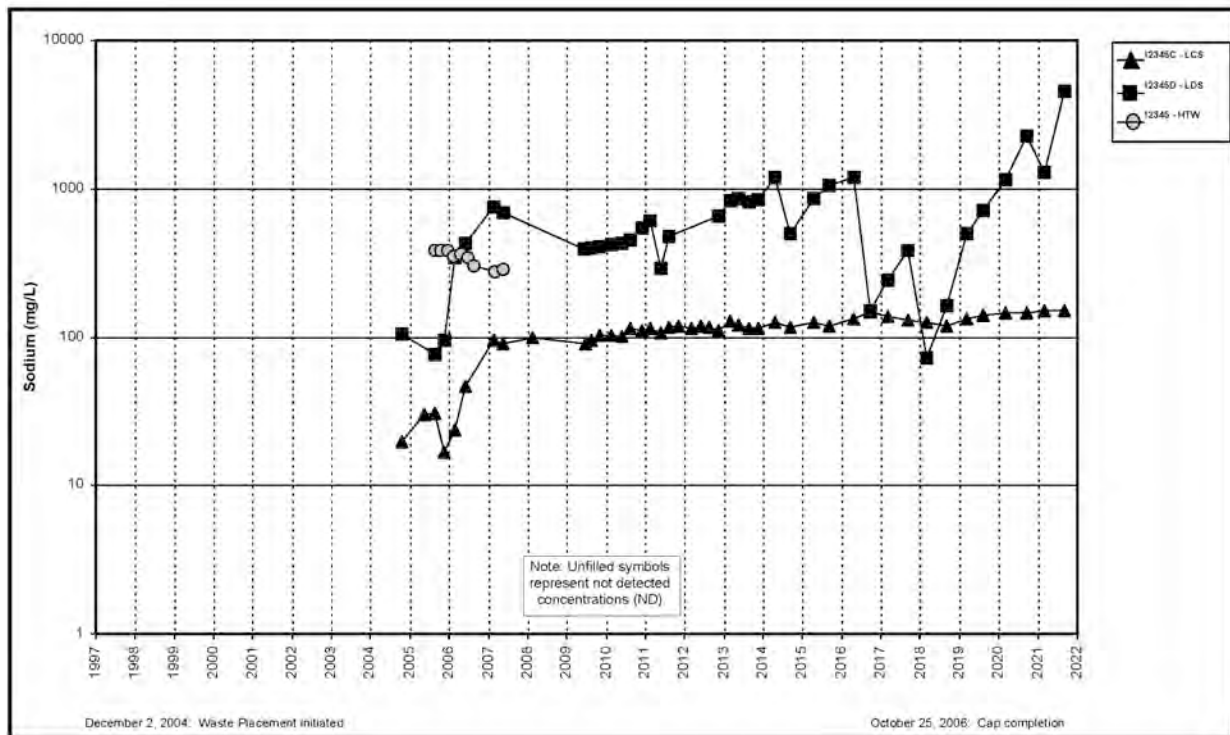


Figure A.5.8-9A. Cell 8 Sodium Concentration Versus Time Plot for LCS, LDS, and HTW

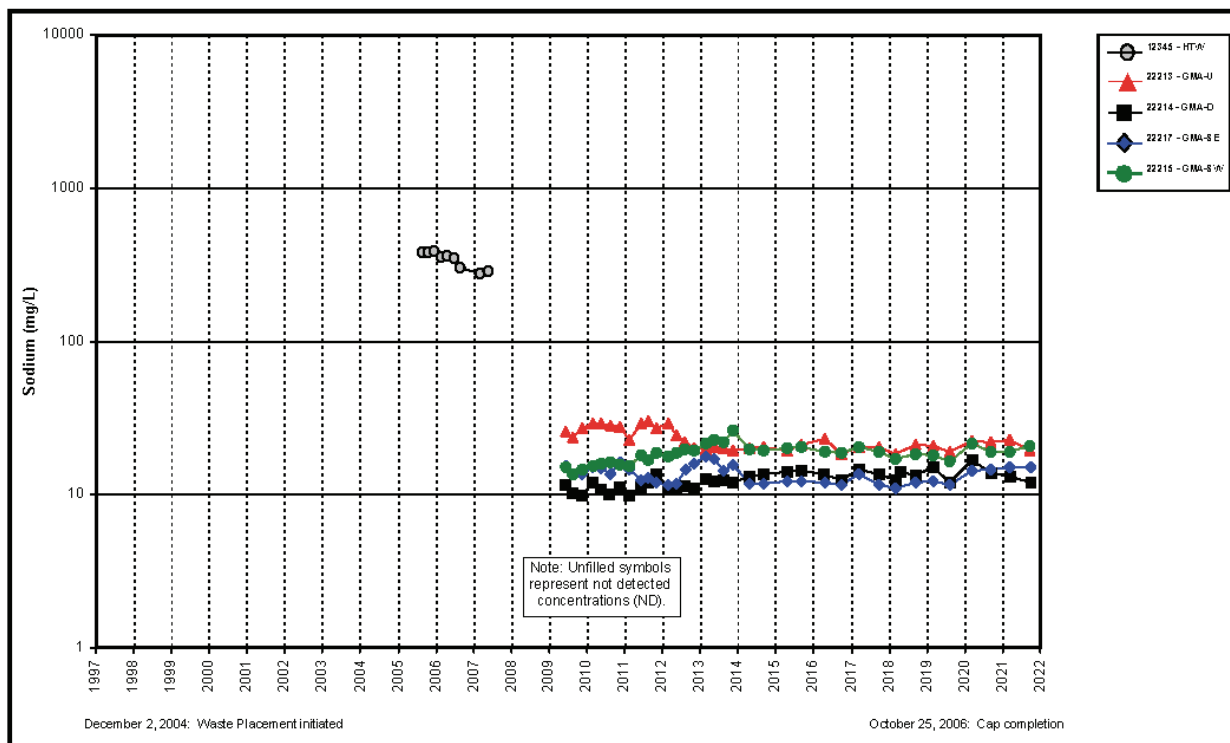


Figure A.5.8-9B. Cell 8 Sodium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

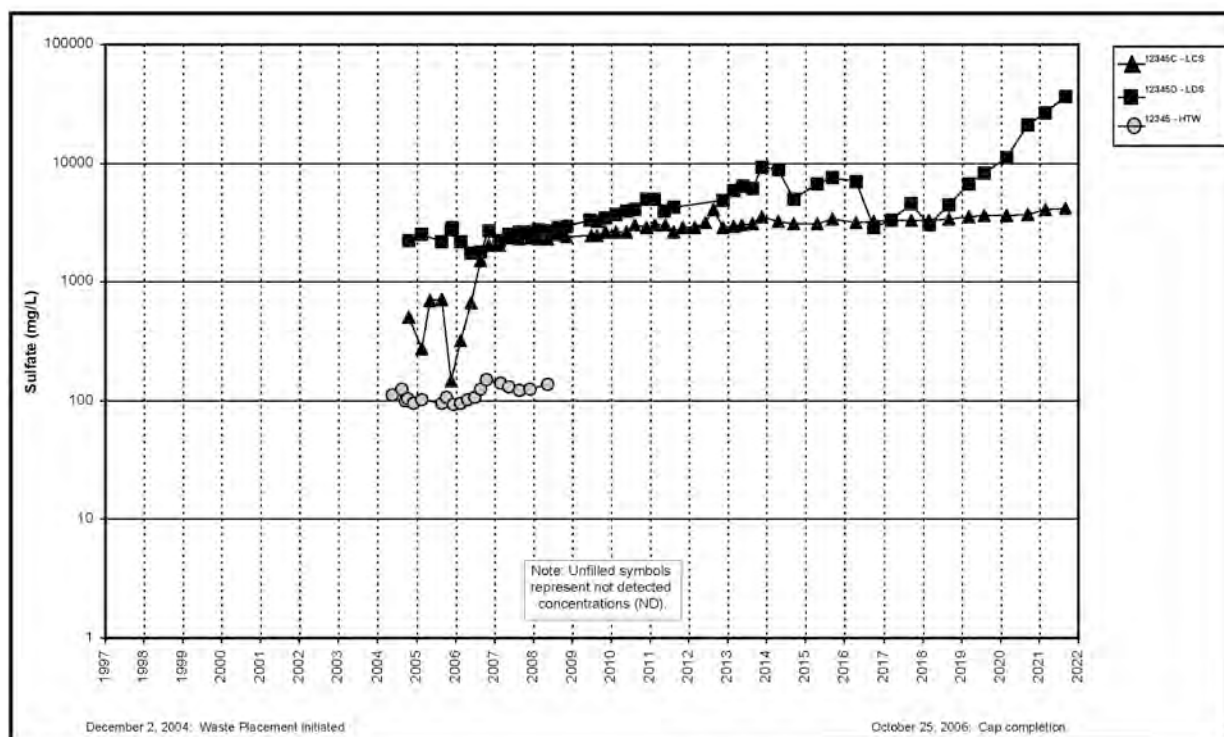


Figure A.5.8-10A. Cell 8 Sulfate Concentration Versus Time Plot for LCS, LDS, and HTW

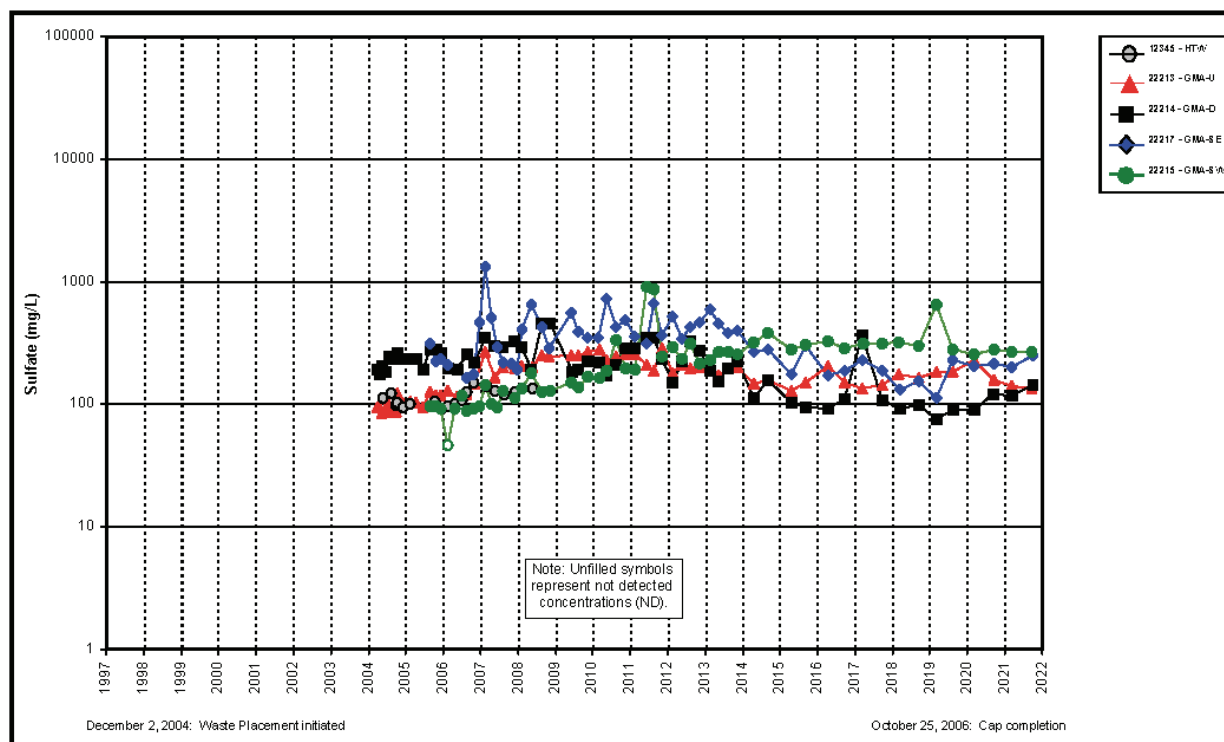


Figure A.5.8-10B. Cell 8 Sulfate Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

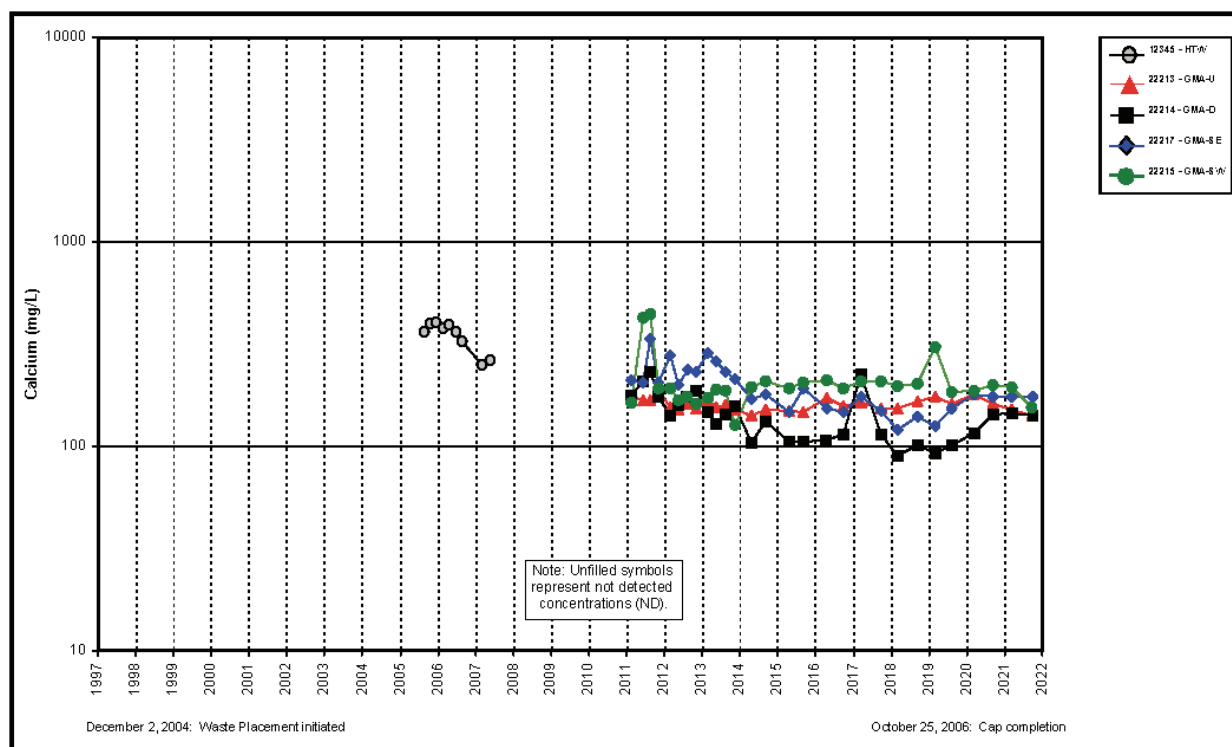


Figure A.5.8-11. Cell 8 Calcium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

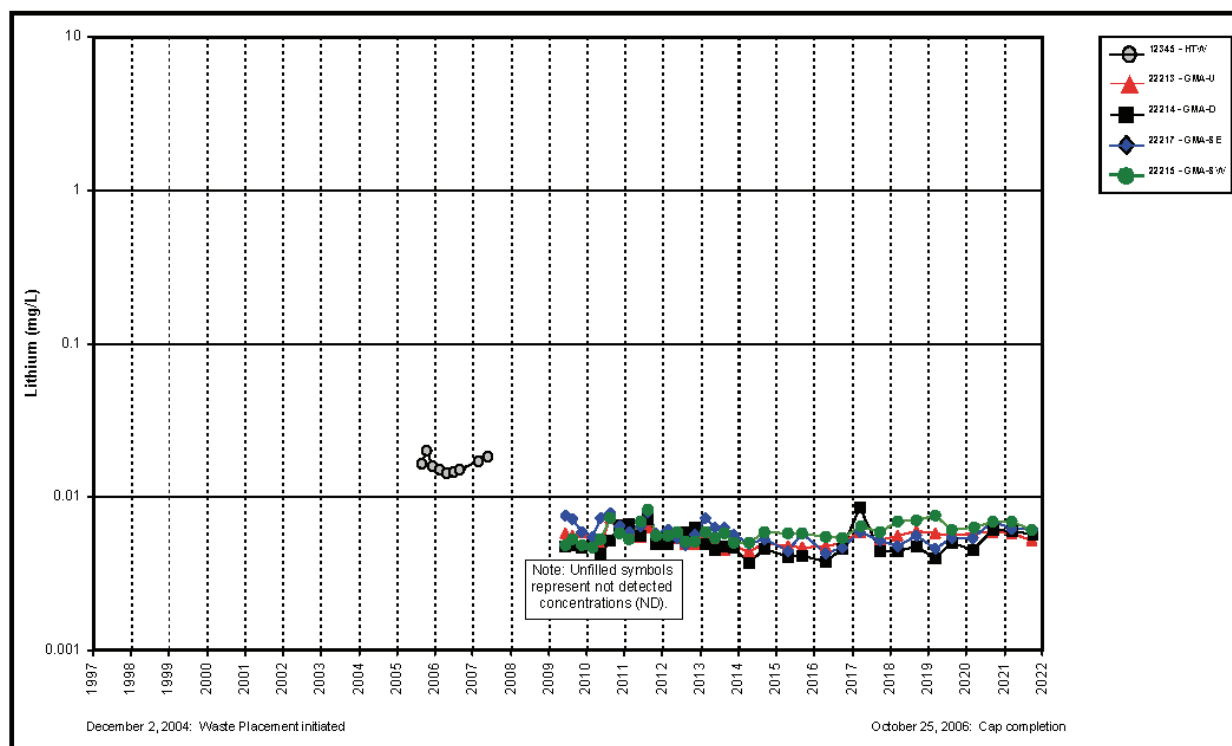


Figure A.5.8-12. Cell 8 Lithium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

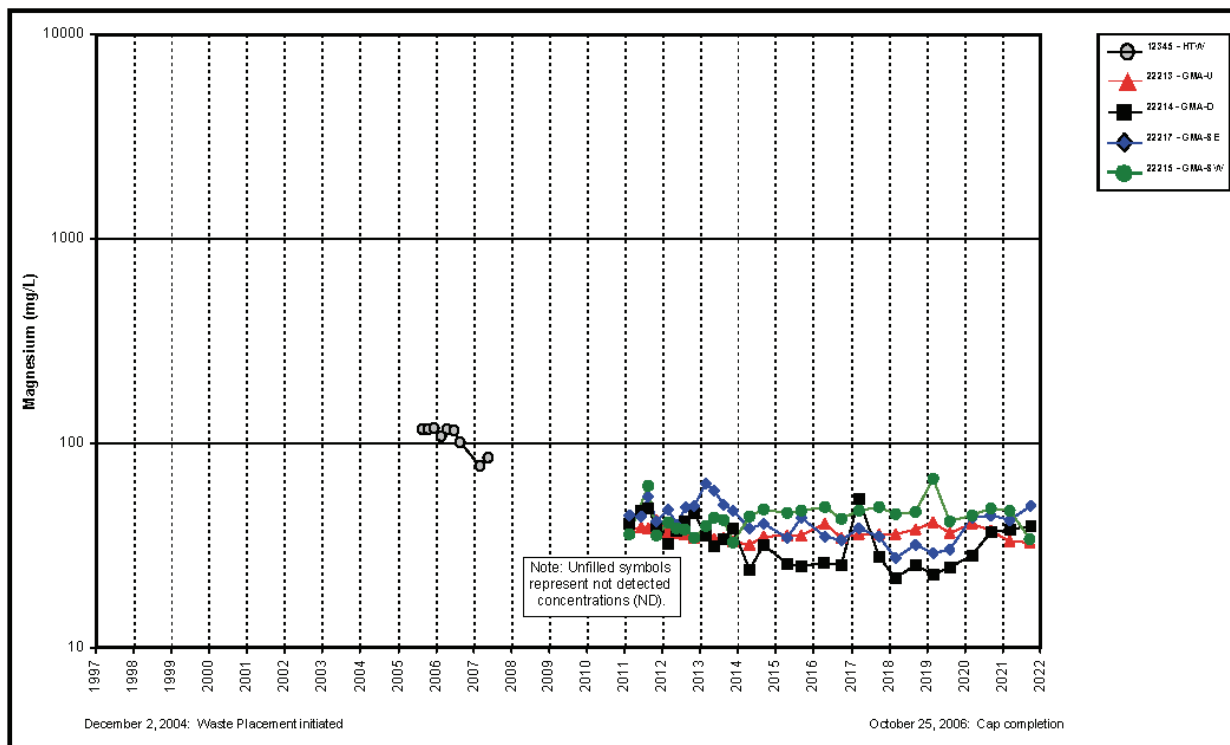


Figure A.5.8-13. Cell 8 Magnesium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

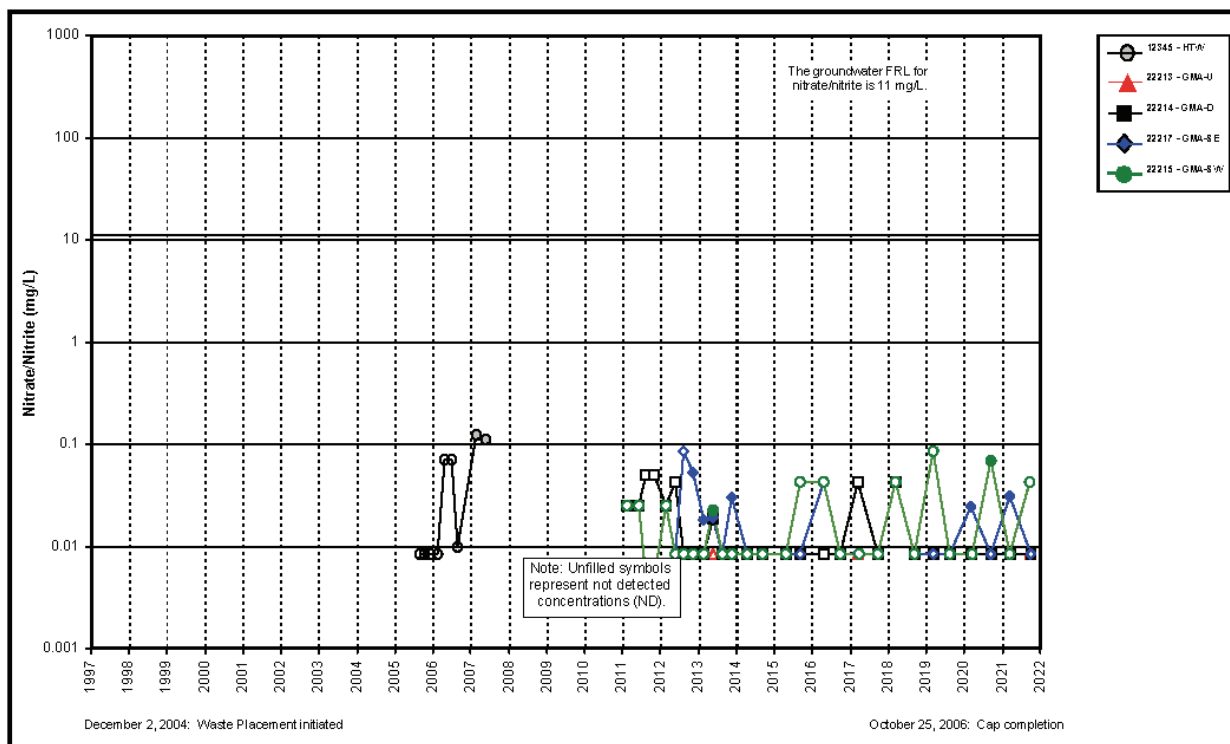


Figure A.5.8-14. Cell 8 Nitrate + Nitrate as Nitrogen Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

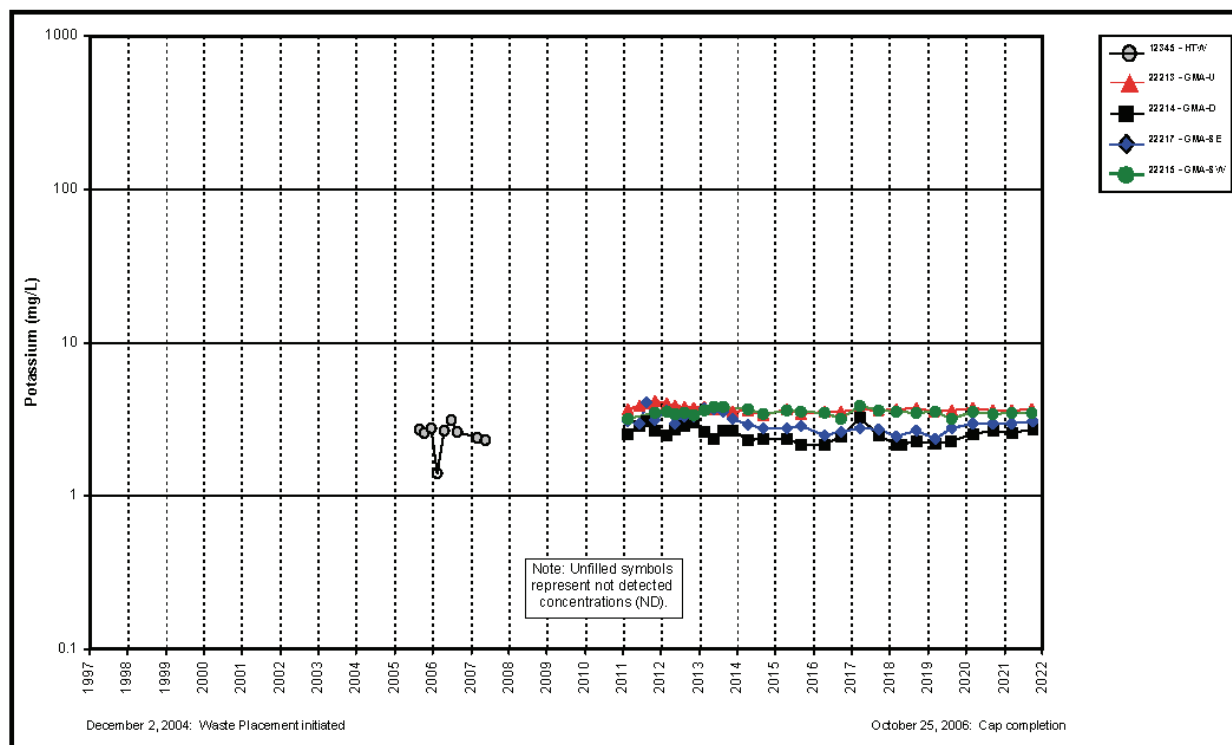


Figure A.5.8-15. Cell 8 Potassium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

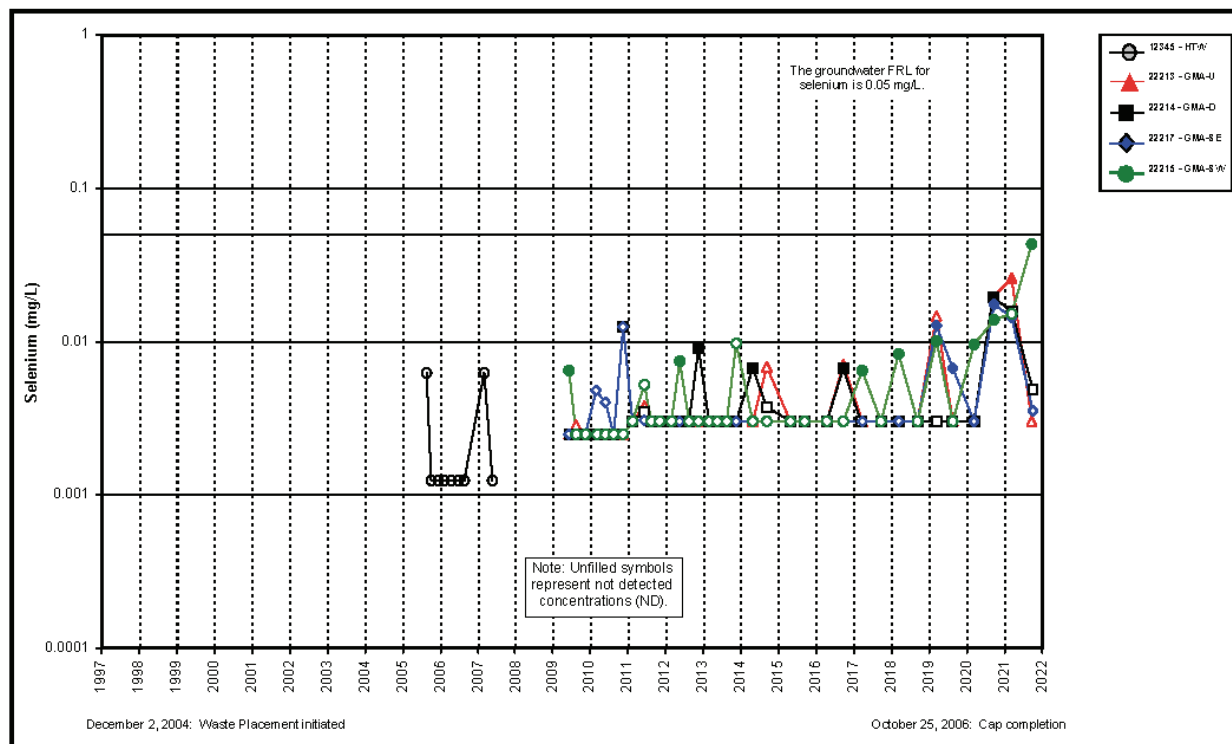


Figure A.5.8-16. Cell 8 Selenium Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

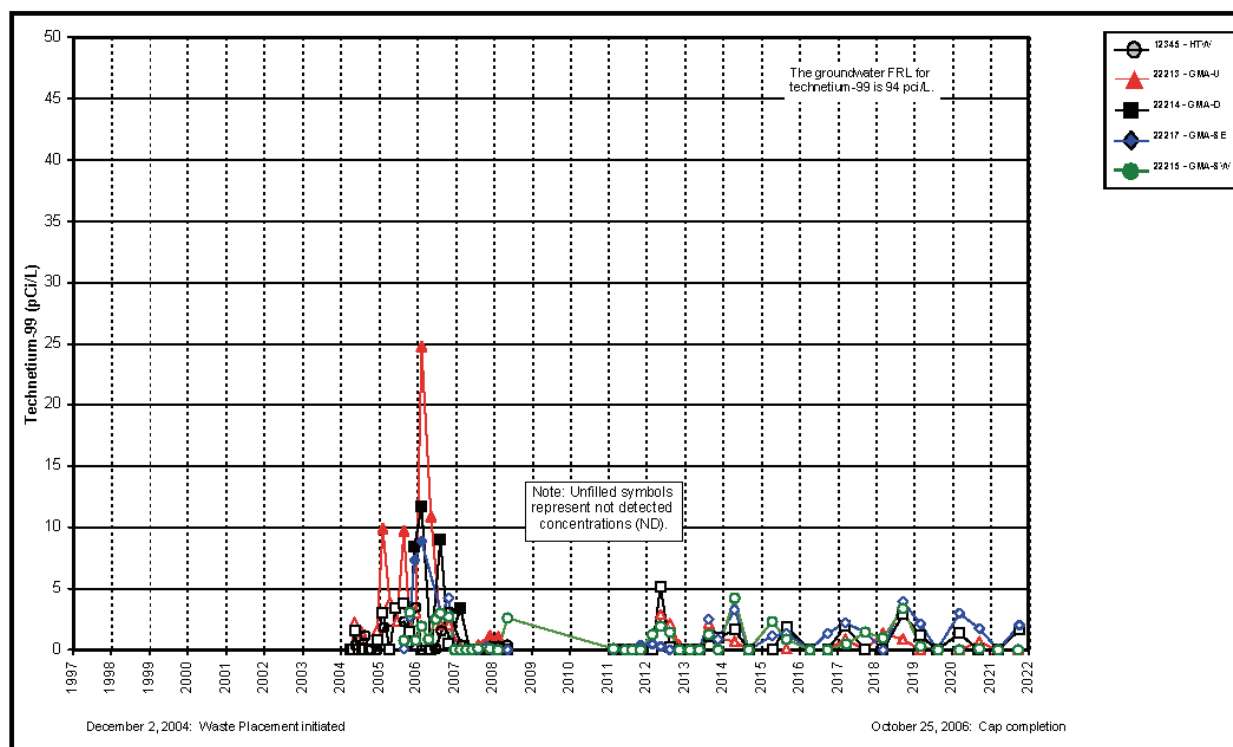


Figure A.5.8-17. Cell 8 Technetium-99 Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

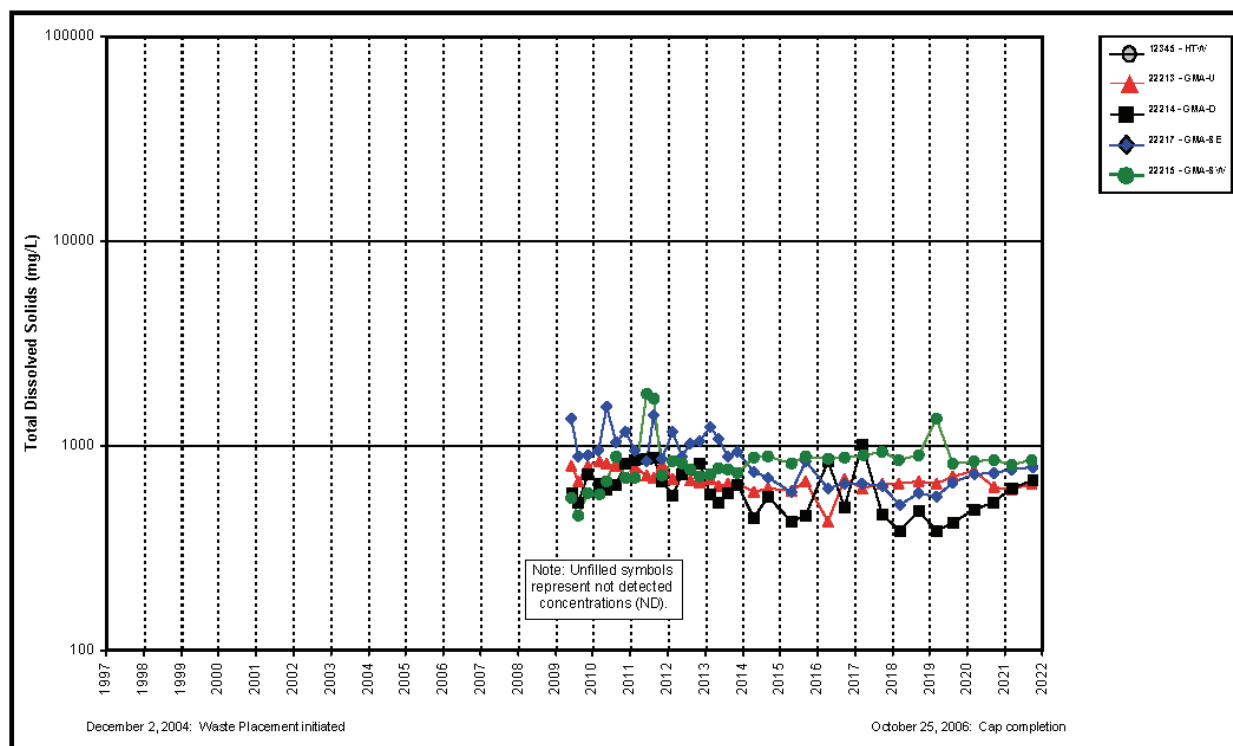


Figure A.5.8-18. Cell 8 Total Dissolved Solids Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

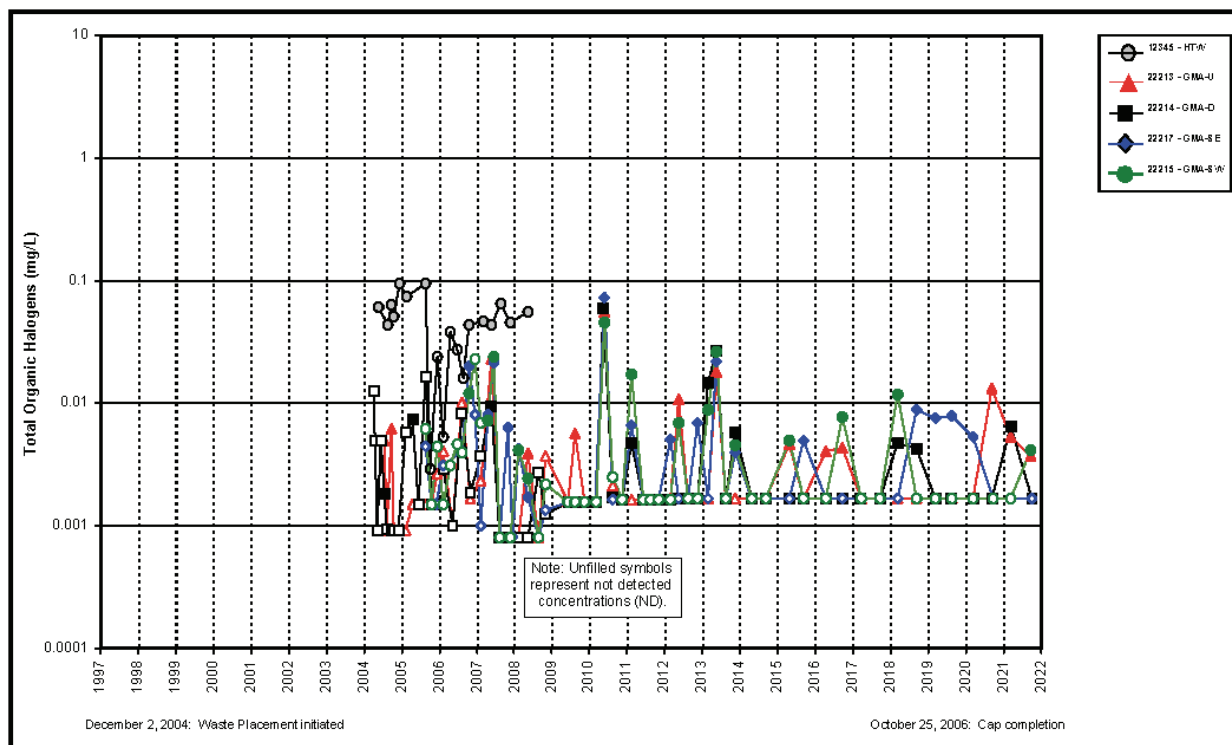


Figure A.5.8-19. Cell 8 Total Organic Halogens Concentration Versus Time Plot for HTW, GMA-U, GMA-D, GMA-SE, and GMA-SW Wells

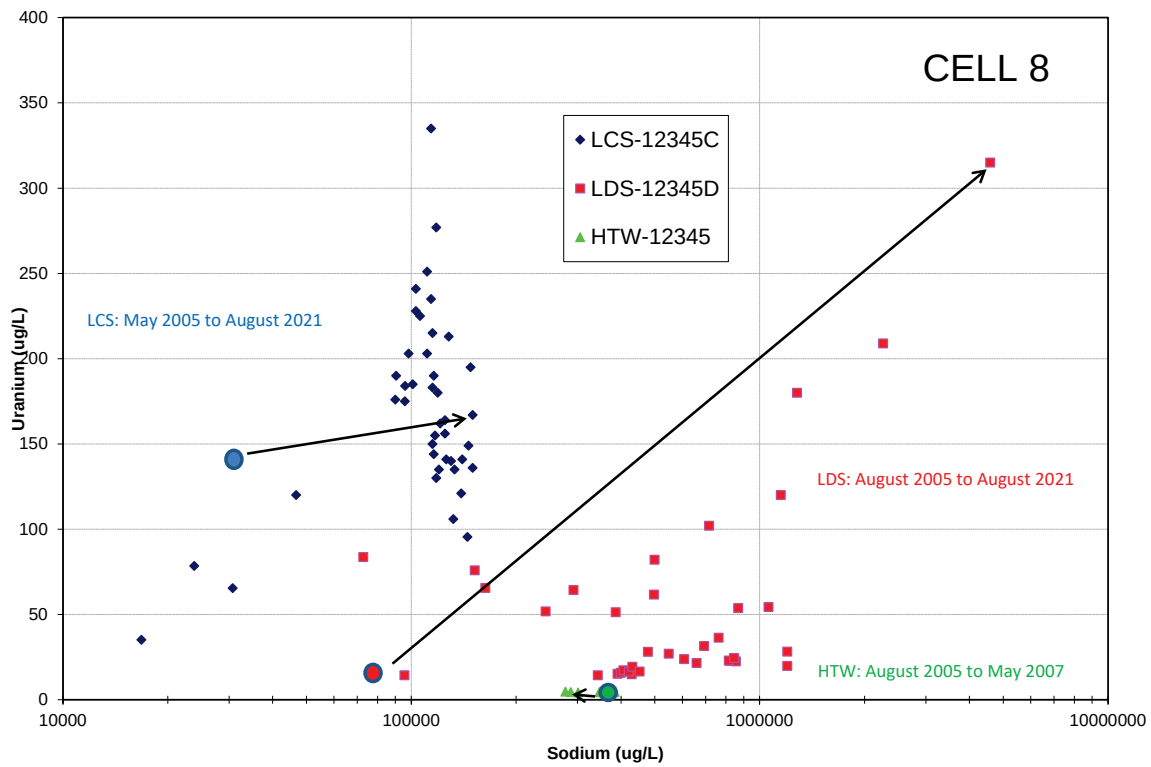


Figure A.5.8-20. Cell 8 Bivariate Plot for Uranium and Sodium

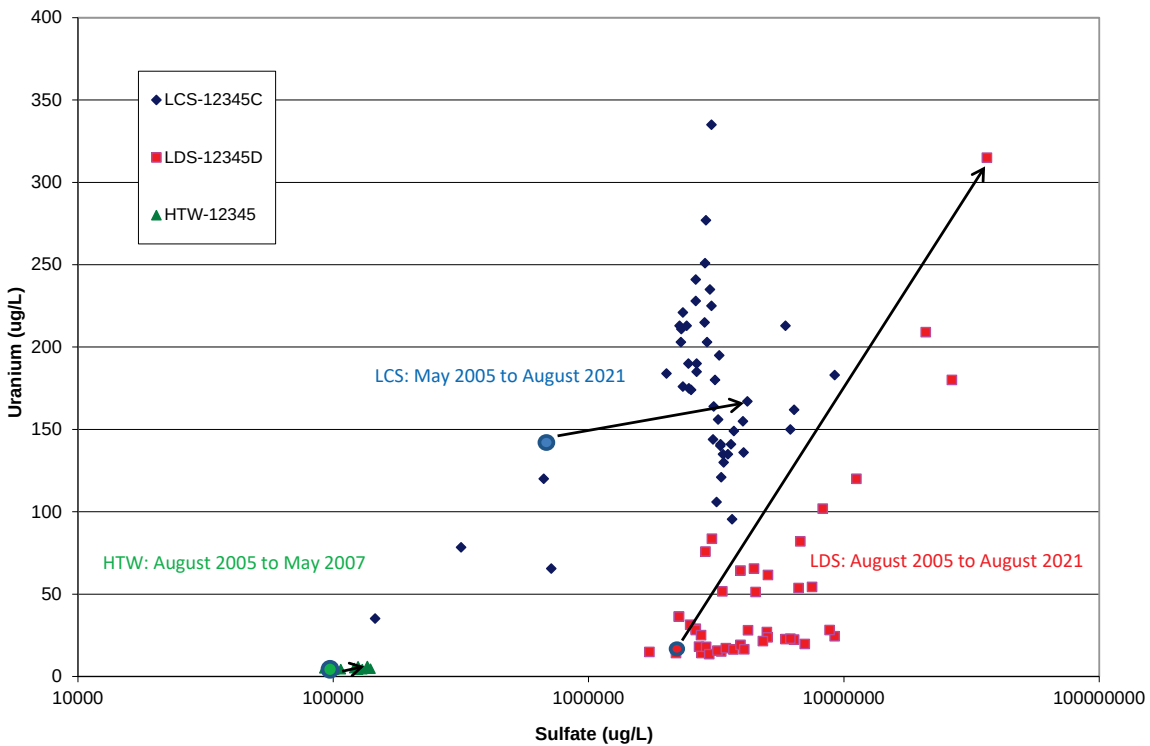


Figure A.5.8-21. Cell 8 Bivariate Plot for Uranium and Sulfate

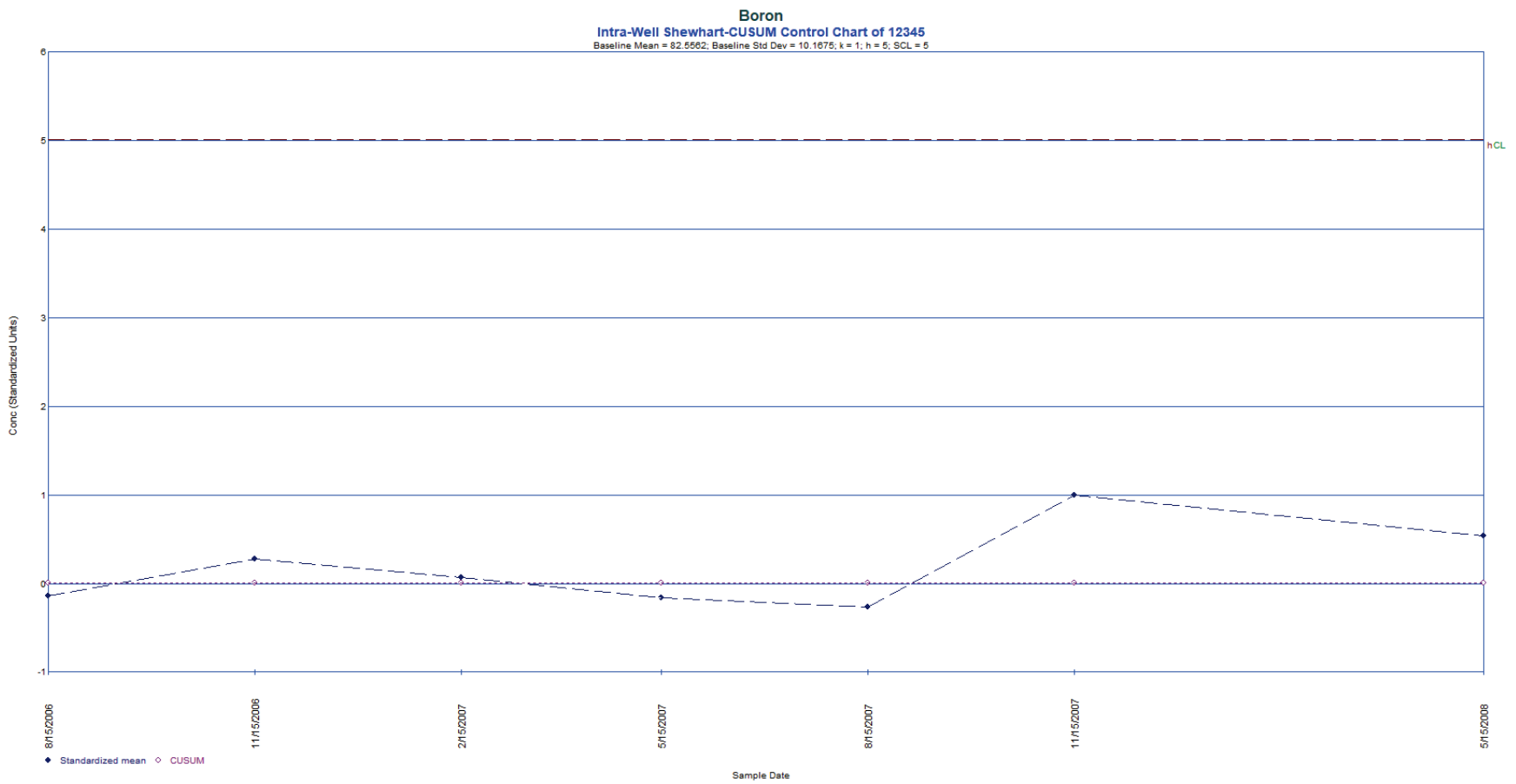
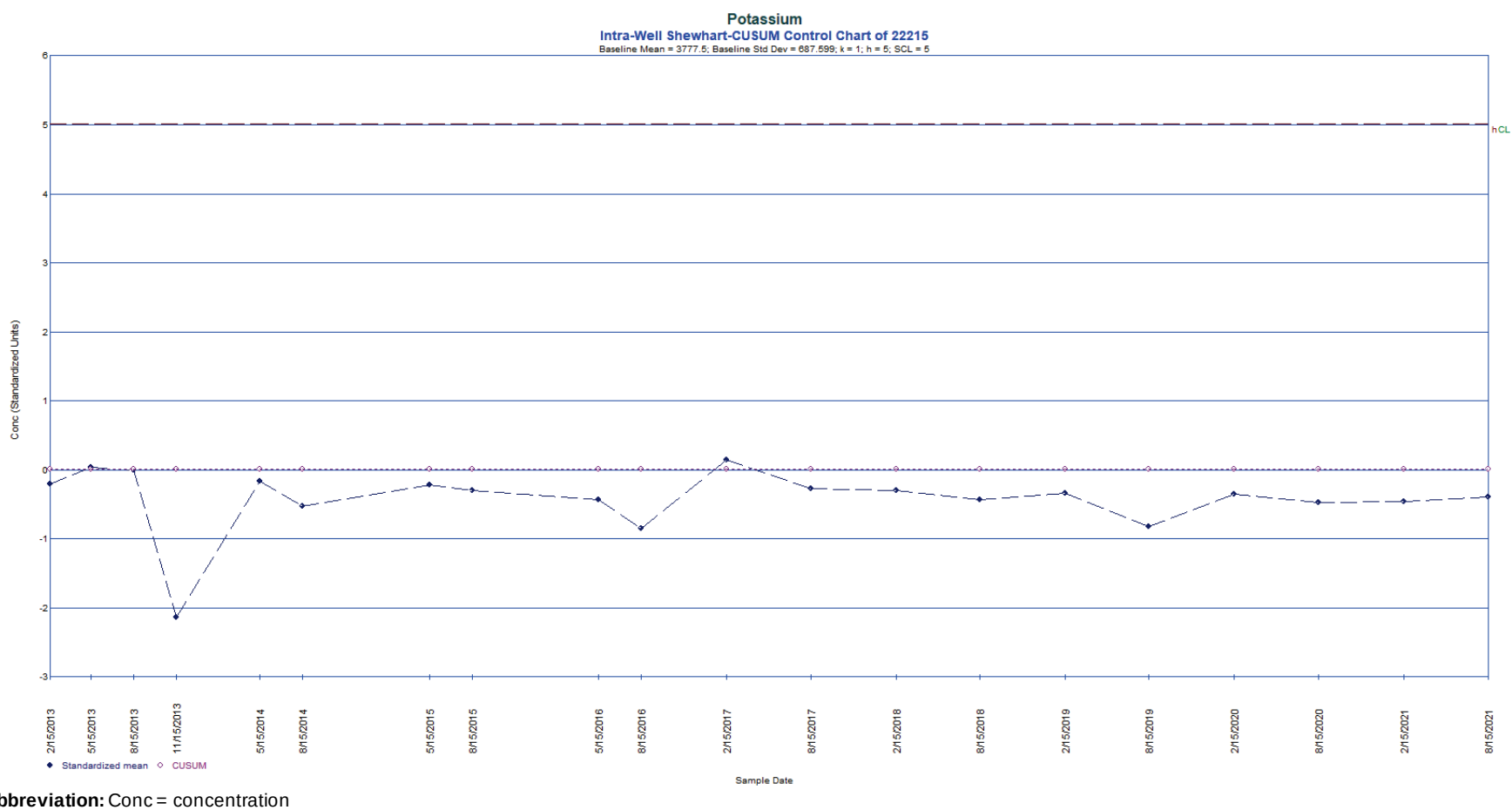


Figure A.5.8-22. Intrawell Shewhart-CUSUM Control Chart for Boron in Monitoring Well 12345



Abbreviation: Conc = concentration

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