Department of Energy

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MAY 29 2019

Ms. Lauren Linehan
Division of Waste Management
Kentucky Department for Environmental Protection
625 Hospital Drive
Madisonville, Kentucky 42431

PPPO-02-5541521-19B

Ms. April Webb
Hazardous Waste Branch Manager
Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Boulevard, 2nd Floor
Frankfort, Kentucky 40601

Dear Ms. Linehan and Ms. Webb:

C-404 HAZARDOUS WASTE LANDFILL MAY 2019 SEMIANNUAL GROUNDWATER REPORT (OCTOBER 2018–MARCH 2019), PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, FRNP-RPT-0086/V1, HAZARDOUS WASTE MANAGEMENT FACILITY PERMIT NO. KY8-890-008-982, AGENCY INTEREST ID NO. 3059

Enclosed is the subject report for the first reporting period of fiscal year 2019. This report is required in accordance with Part II, Specific Condition II.K.6.d, of Hazardous Waste Management Facility Permit No. KY8-890-008-982 (Permit).

Results of the statistical analyses indicate that compliance well concentrations of Permit-required parameters are not statistically different from those in background wells, except for trichloroethene (TCE) and arsenic in monitoring well MW84. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, demonstrated that the C-404 Hazardous Waste Landfill was not the source of the historical, statistically significant background exceedance of TCE in MW84. The trend of arsenic concentrations in MW84 is similar to the historical TCE trend in the same well; therefore, the arsenic exceedance is consistent with findings in the 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, and is not attributable to a release from the C-404 Hazardous Waste Landfill.

Notification of the statistically significant difference for arsenic and TCE in MW84 was submitted, pursuant to Part II, Specific Condition II.K.6.a, to your department under separate correspondence.

If you have any questions or require additional information, please contact David Dollins at (270) 441-6819.

Sincerely,

Jennifer Woodard

Jennifer Woodard
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:
1. Certification Page
2. C-404 Hazardous Waste Landfill May 2019 Semiannual Groundwater Report, FRNP-RPT-0086/V1

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CERTIFICATION

Document Identification: ***C-404 Hazardous Waste Landfill May 2019 Semiannual Groundwater Report (October 2018–March 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0086/V1, Permit No. KY8-890-008-982, Agency Interest ID No. 3059, dated May 2019**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Four Rivers Nuclear Partnership, LLC

Myrna E. Redfield, Deputy Program Manager
Four Rivers Nuclear Partnership, LLC

5/28/19
Date Signed

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy

Jennifer Woodard, Paducah Site Lead
Portsmouth/Paducah Project Office
U.S. Department of Energy

5/28/19
Date Signed

FRNP-RPT-0086/V1

C-404 Hazardous Waste Landfill May 2019 Semiannual Groundwater Report (October 2018–March 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

This document is approved for public release per review by:

David Hayden
FRNP Classification Support

5-14-19
Date

FRNP-RPT-0086/V1

C-404 Hazardous Waste Landfill May 2019 Semiannual Groundwater Report (October 2018–March 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—May 2019

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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FIGURES

TABLES

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ACRONYMS

AKGWA	Assembled Kentucky Groundwater
MW	monitoring well
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
UCRS	Upper Continental Recharge System
URGA	Upper Regional Gravel Aquifer

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EXECUTIVE SUMMARY

This report, *C-404 Hazardous Waste Landfill May 2019 Semiannual Groundwater Report (October 2018–March 2019), Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* FRNP-RPT-0086/V1, is being submitted by the U.S. Department of Energy in accordance with requirements in Kentucky Division of Waste Management Hazardous Waste Management Facility Permit, KY8-890-008-982. The first reporting period 2019 covers October 2018 through March 2019 and includes analytical data from the January 2019 sampling of monitoring wells (MWs) located in the vicinity of the closed C-404 Hazardous Waste Landfill (C-404 Landfill). In 1986, disposal of waste at C-404 Landfill was halted and a portion of the disposed-of waste was found to be Resource Conservation and Recovery Act (RCRA) hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987.

The groundwater monitoring analytical data were subjected to statistical analyses. The analyses were conducted in accordance with the Hazardous Waste Management Facility Permit. Arsenic and trichloroethene (TCE) concentrations in compliance well MW84 were statistically different from concentrations in the background wells. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* PRS-ENM-0031/R2 (PRS 2007) demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of TCE in MW84. MW84 arsenic exceedance is consistent with the 2007 Alternate Source Demonstration. The trend of arsenic concentrations in MW84 is similar to the historical TCE trend in the same well. This determination for arsenic in MW84 fulfills Section II.K.8 of the Hazardous Waste Management Facility Permit, which allows for demonstrating that the exceedance is consistent with the findings in the 2007 Alternate Source Demonstration and also allows for the demonstration to be submitted within the semiannual report.

For the remaining parameters, concentrations in the downgradient (compliance) wells were not statistically different from the concentrations in upgradient (background) wells.

The leachate in the C-404 Landfill leachate collection system is monitored (at least monthly) and, at a minimum, is removed and sampled when the level exceeds 3 ft in depth. The volume of leachate removed from the sump during this reporting period, October 2018 to March 2019, was 3,300 gal. The leachate was sampled on November 28, 2018; February 8, 2019; and March 21, 2019. Analytical results for the November 2018 and February 2019 leachate samples are provided in this report. Analytical results for the March 2019 leachate sample were not available for inclusion in this report by the regulatory deadline. The analytical data for the March 2019 leachate sample will be included in the next semiannual report.

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1. INTRODUCTION

This report contains the statistical evaluation of data from groundwater sampling and analysis for the closed C-404 Hazardous Waste Landfill (C-404 Landfill) at the U.S. Department of Energy Paducah Site (Paducah Site), Paducah, Kentucky. This semiannual report is required by the Kentucky Division of Waste Management Hazardous Waste Management Facility Permit, KY8-890-008-982 (Permit) (KDWM 2017), Specific Condition II.K.6.d—Recordkeeping, Reporting, and Response. The period covered by this report is October 2018 through March 2019.

Groundwater analytical results are provided in Appendix A. The statistical analyses and qualification statement are provided in Appendix B. Landfill leachate analytical results are provided in Appendix C.

1.1 BACKGROUND

The closed C-404 Landfill is located in the west-central portion of the Paducah Site secured area. The 1.2-acre facility operated as a surface impoundment from approximately 1952 until early 1957. During this time, influents to the impoundment originated from the C-400 Cleaning Building. In 1957, the impoundment was converted to a solid waste disposal facility for uranium-contaminated solid waste. When the impoundment was converted into a disposal facility, a sump was installed at the former weir to collect the leachate from the facility. Leachate is pumped from the sump, as needed, into a mobile tank. Then the leachate is transferred to a permitted hazardous waste storage facility on-site prior to characterization and transferred off-site for treatment.

In 1986, the disposal of waste at the C-404 Landfill was halted, and a portion of the disposed-of waste was found to be Resource Conservation and Recovery Act (RCRA)-hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987. It currently is regulated under RCRA as a land disposal unit and compliance is monitored under the current Hazardous Waste Management Facility Permit (KDWM 2017).

Previous groundwater monitoring documented that concentrations in compliance wells were statistically different from background wells for trichloroethene (TCE). The *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007) documented that the source of the differences from background concentrations in compliance wells is not from the C-404 Landfill, but rather, the source is located upgradient/crossgradient of the C-404 Landfill.

Previous groundwater monitoring of monitoring well (MW) 87 documented that concentrations in the compliance well were statistically different from background wells for lead and uranium. The *C-404 Hazardous Waste Landfill Alternate Source Demonstration—Source of Lead and Uranium in MW87 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FRNP 2019) concluded that the statistical differences were a result of infiltration of Upper Continental Recharge System (UCRS) groundwater into the Regional Gravel Aquifer (RGA) well due to compromised integrity of the well.

1.2 MONITORING PERIOD ACTIVITIES

1.2.1 Groundwater Monitoring

There are nine MWs sampled under the Permit for the C-404 Landfill: four UCRS wells and five Upper Regional Gravel Aquifer (URGA) wells. A map of the MW locations is provided in Figure 1.

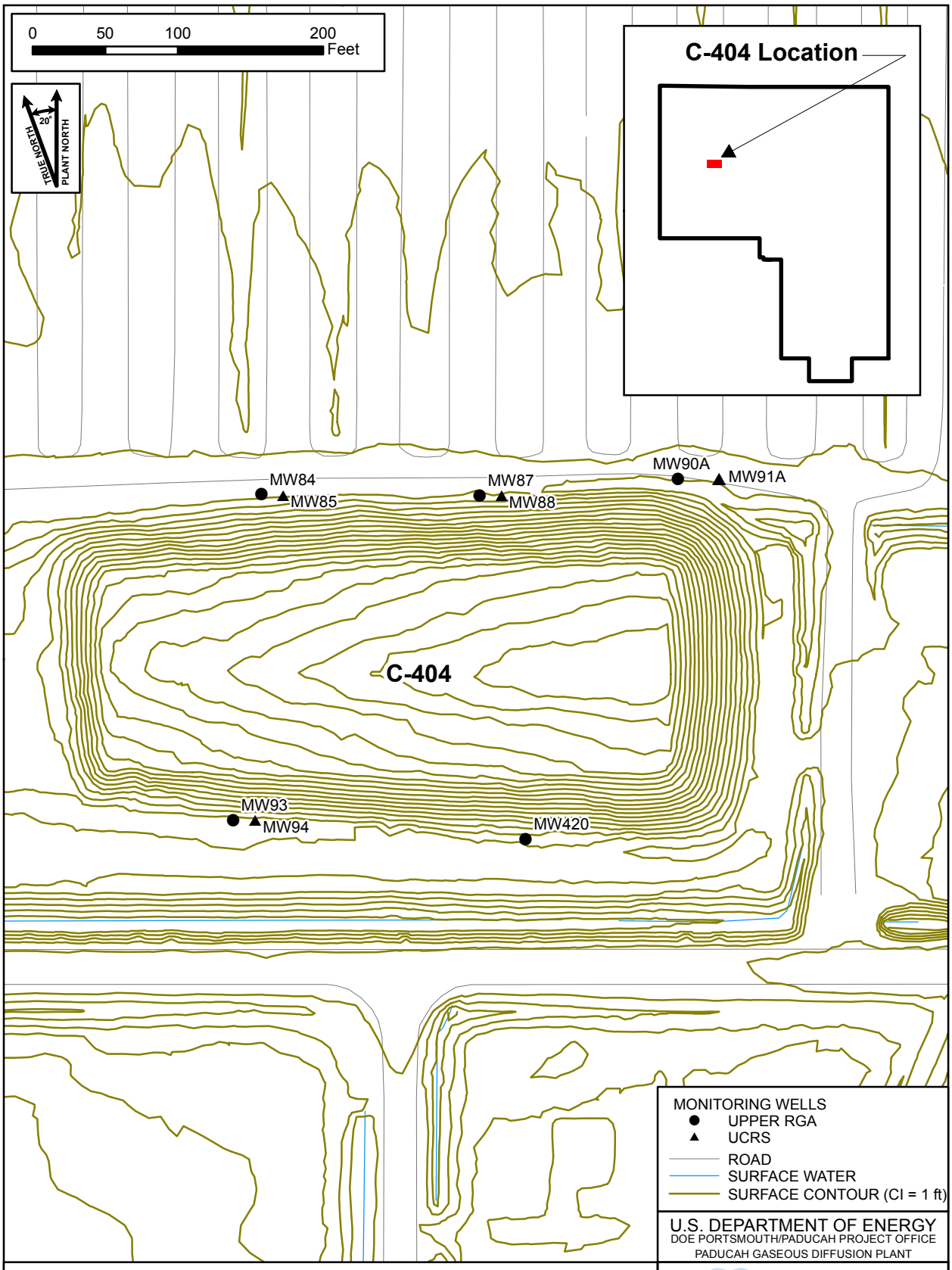

Figure 1. C-404 Landfill Monitoring Well Map

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3/19/2018

Table 1 presents the well number for URGA wells located upgradient and downgradient of the C-404 Landfill. Table 1 also presents the well numbers for the UCRS wells located in proximity to the URGA wells. This table refers to the UCRS wells as being adjacent to an upgradient or downgradient URGA well location identified relative to these URGA groundwater flow direction. The conceptual model for the C-404 Landfill indicates that groundwater in the UCRS wells flows primarily vertically until it reaches the URGA; therefore, UCRS wells are not considered "upgradient" or "downgradient" of other wells in the area. Table 2 presents the Assembled Kentucky Groundwater (AKGWA) numbers for each MW.

Table 1. Monitoring Well Locations

UCRS	
Located south of C-404 Landfill, adjacent to upgradient URGA background well MW93	MW94
Located north of C-404 Landfill, adjacent to downgradient URGA compliance wells	MW85, MW88, MW91A*
URGA	
Upgradient background wells	MW93, MW420
Downgradient compliance wells	MW84, MW87, MW90A*

*MW90 was abandoned in 2001 and replaced with MW90A. MW91 was abandoned in 2017 and replaced with MW91A.

Table 2. Assembled Kentucky Groundwater Numbers

Paducah Site Well Number	AKGWA Number
MW84	8000-5233
MW85	8000-5234
MW87	8000-5236
MW88	8000-5237
MW90A	8004-0357
MW91A	8007-2917
MW93	8000-5102
MW94	8000-5103
MW420	8005-3263

All nine MWs were sampled in January 2019 during this reporting period, and the samples were analyzed for parameters required by Part VIII.E of the Permit. Groundwater sampling was conducted using procedure CP4-ES-2101, *Groundwater Sampling*. Appropriate sample containers and preservatives were used. The laboratory that performed the analyses used U.S. Environmental Protection Agency-approved methods, as applicable. Appendix A of this report contains the analytical results. Appendix B of this report contains the statistical analyses.

1.2.2 Landfill Leachate

In accordance with Section 1.2 of the Permit, the quantity of liquid in the leachate collection system is monitored (at least monthly) and, at a minimum, will be "removed when the quantity exceeds 3 ft in depth." Once the leachate depth reaches 3 ft, the leachate is pumped into a mobile tank. The leachate then is transferred to a permitted hazardous waste storage facility on-site prior to characterization and transferred off-site for treatment. The volume of leachate removed from the sump during this reporting period, October 2018 to March 2019, was 3,300 gal. The leachate was sampled on November 28, 2018; February 8, 2019; and March 21, 2019. Analytical results for the November 2018 and February 2019

leachate samples are included in Appendix C. Analytical data for the March 2019 leachate sample were not available for inclusion in this report by the regulatory deadline. The analytical data for the March 2019 leachate sample will be included in the next semiannual report.

2. STATISTICAL SYNOPSIS

The statistical analyses conducted on the data collected from C-404 Landfill were performed in accordance with procedures in the Permit, Part VIII.E, reissued in July 2015. Appendix B of this report contains the statistical analyses performed for this reporting period. Data utilized for statistical analyses included data from the URGA background wells, MW93 and MW420, and URGA compliance wells, MW84, MW87, and MW90A. For these statistical analyses, the reporting period data set includes data from January 2017, July 2017, January 2018, August 2018, and January 2019.

Arsenic and TCE concentrations in compliance well MW84 were statistically different from concentrations in the background wells. Appendix B provides a summary of the statistical analyses performed. The statistical tests on all other parameters showed no statistical difference between concentrations in the compliance (downgradient) and background (upgradient) wells.

STATISTICALLY SIGNIFICANT EXCEEDANCE OF BACKGROUND IN MW84

An alternate source demonstration previously was conducted for TCE in MW84. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, (PRS 2007) demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of TCE in MW84. The 2007 demonstration found that the statistically significant increase of TCE in downgradient well MW84 appeared to be due to an upgradient source whose TCE is migrating through the C-404 Landfill area.

The exceedance in arsenic concentration over background concentrations is consistent with the findings in the 2007 Alternate Source Demonstration (PRS 2007). The trend of arsenic concentrations in MW84 is similar to the historical TCE trend in the same well, as demonstrated in Figure 2. This determination fulfills Section II.K.8 of the Hazardous Waste Management Facility Permit, which allows for demonstrating that the exceedance is consistent with the findings in the 2007 Alternate Source Demonstration and allows for the demonstration to be submitted within the semiannual report.

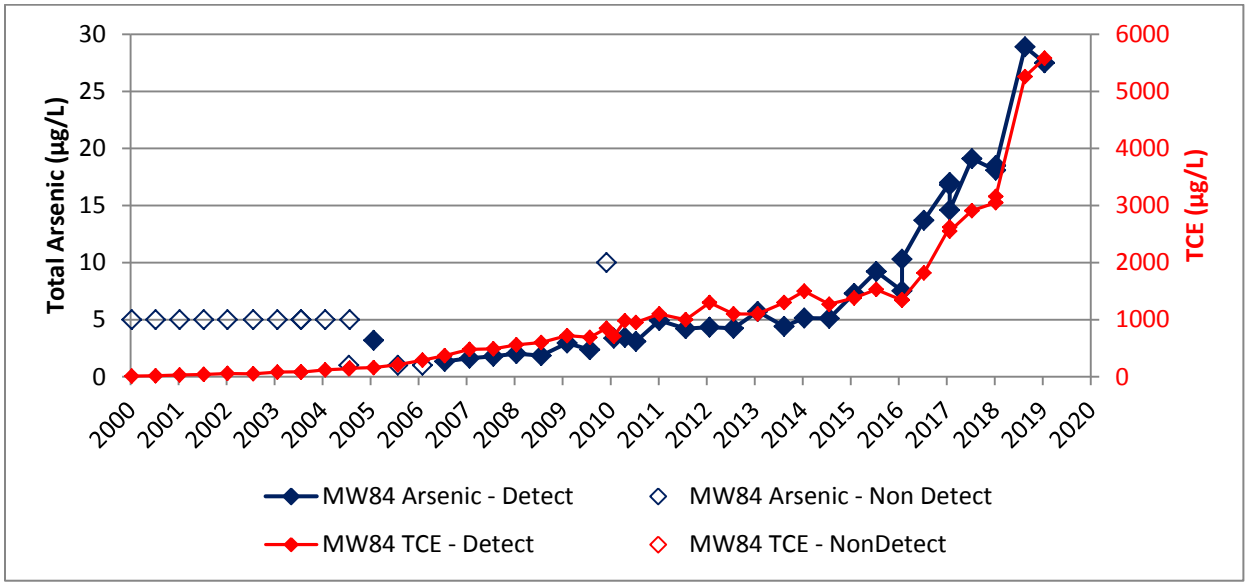

Figure 2. Arsenic and TCE Trend in MW84

Trending of groundwater data gathered in the vicinity and upgradient of the C-404 Landfill supports and supplements the finding in the 2007 Alternate Source Demonstration, as follows.

First, until the January 2015 sampling event, the westernmost upgradient well (MW93) typically had higher arsenic concentrations than the downgradient well MW84 (see Figure 3). Since then, the MW84 arsenic concentrations have increased steadily, potentially reflecting increasing proximity to the core of the upgradient source. This condition is similar to the pattern of TCE concentrations historically seen in these same wells and is attributed to a source upgradient/crossgradient of the C-404 Landfill in the 2007 Alternate Source Demonstration. Similar, but slightly delayed, arsenic and TCE trends also are evident in neighboring (east) downgradient well MW87 (see Figure 4). The TCE detections[1] over time in MW333, located approximately 106 ft southwest of the C-404 Landfill, are depicted in Figure 5.

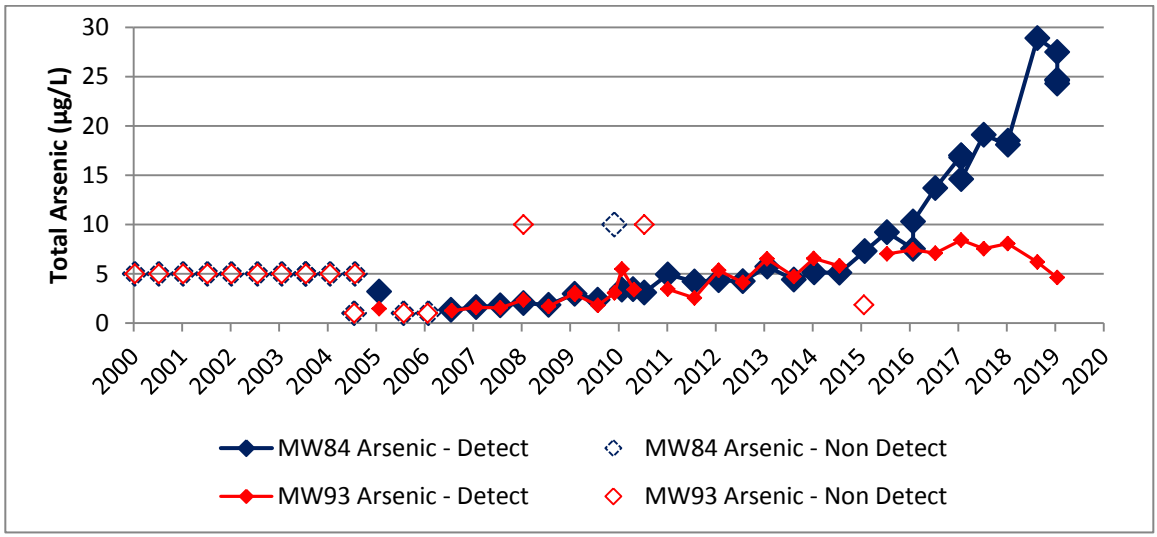

Figure 3. Arsenic Trend in MW84 and MW93

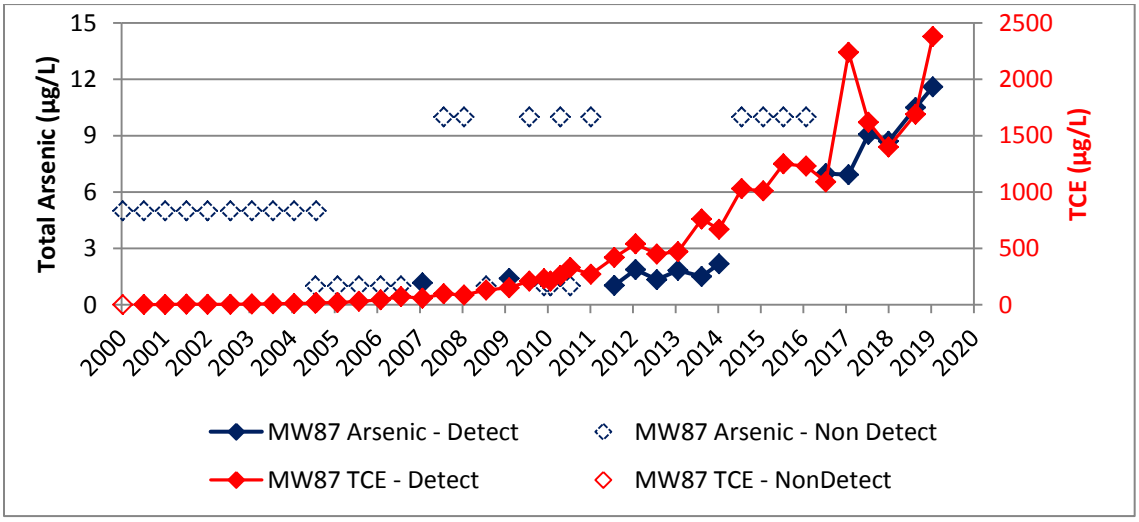

Figure 4. Arsenic and TCE Trend in MW87

[1] There is only one arsenic data point for MW333. The sample collected July 20, 2004, had a detectable concentration of 2.90 µg/L.

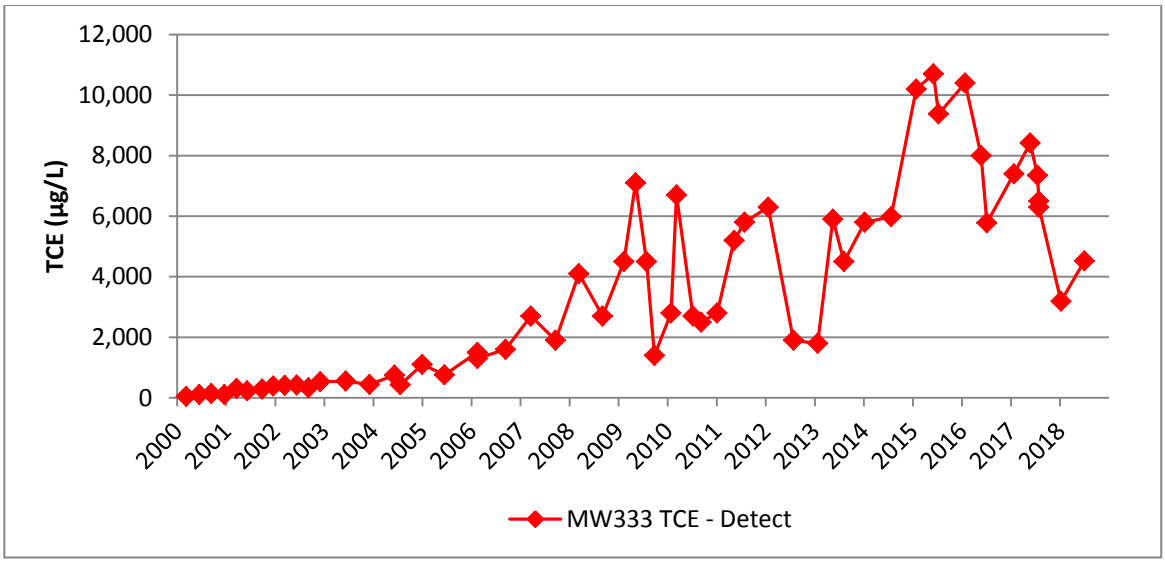

Figure 5. TCE Trend in MW333

Second, groundwater flow directions are to the northeast—similarly indicating an upgradient, non-C-404 Landfill source of MW84 impacts. This condition is consistent with flow patterns found in 2007 during the Alternate Source Demonstration.

Finally, most of the leachate samples collected over the years have had no detectable arsenic (dissolved arsenic is not required by the Permit for leachate) and the measureable concentrations are well below concentrations recently detected in RGA groundwater at MW84. Of the 29% (20 of 70) of leachate samples with measureable arsenic concentrations, the maximum concentration of 6.32 µg/L in leachate is below the January 2019 arsenic concentration of 27.5 µg/L found in MW84; thus, the C-404 Landfill cannot be the source of the arsenic found in that well.

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3. DATA VALIDATION AND QA/QC SUMMARY

The data and the data validation qualifiers for the January 2019 data set are provided in Appendix A. All data for this data set were considered useable as reported. Data validation was performed on the analytical data by an independent, third-party validator.

Field quality control samples are collected during each semiannual sampling event. Equipment rinseate blanks, field blanks, field duplicates, and trip blanks are obtained to ensure quality control and are reported in the Analytical Results in Appendix A. Laboratory quality control samples, such as matrix spikes, matrix spike duplicates, and method blanks, are performed by the laboratory and reported in the laboratory report. Both field and laboratory quality control sample results are reviewed as part of the data validation process.

FIELD DUPLICATE SAMPLE

During a May 23, 2018, teleconference, the U.S. Department of Energy (DOE) discussed with KDWM the method used to collect duplicate samples from MWs at the C-404 Landfill. The collection method being used is defined in SW-846 as a collocated duplicate and differs from a definition in the Permit Part VIII.E, Appendix E3. In the teleconference, KDWM agreed that the collocated duplicate collection method was appropriate for precision monitoring at the C-404 Landfill. Additionally, there was a discussion about how this collection method is an acceptable practice under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and it is the type of duplicate sampling utilized in CERCLA sampling events at the Paducah Site.

Permit Part VIII.E, Appendix E3, Monitoring Well Requirements, Section 1.4, Field Quality Control, states that field duplicates consist of two aliquots of a sample (i.e., the primary sample and its duplicate) that are aliquoted into two containers from a single sample collection container or sample mixing container. Additionally, the Permit defines a duplicate sample as two or more separate samples taken from the same source during the same sampling event.

Procedure CP4-ES-2704, *Trip, Equipment, and Field Blank Preparation*, describes a field duplicate sample (collocated duplicate) as being collected at the same time, using the same procedures, the same type of equipment, and in the same types of containers as the original sample. The samples are placed in separate, but identical sample containers as the original sample. This is consistent with the Permit's definition of a duplicate sample (i.e., separate samples taken from the same source during the same sampling event).

The Permit's description for collection of a field duplicate sample is similar to the field replicate sample identified in CP4-ES-2704. Field replicate samples also are referred to as split samples in the procedure. The field replicate sample is described as being collected by initially collecting twice as much volume as is normally collected, homogenizing the material by mixing, and distributing into two sets of sample containers. Additionally, the procedure states that samples for volatile organic compounds are not mixed prior to subsampling. A field replicate sample is not commonly used due to volatile organic compounds being a contaminant of concern at the Paducah Site.

In order to comply with the current Permit requirement until a Permit modification can be established, two field duplicates were collected during this reporting period. Both samples were collected from the same MW. A groundwater sample was collected from a MW along with a field duplicate sample (MW84 REP) prescribed by the Permit. A separate groundwater sample was collected from the same MW along with a field duplicate sample (MW84 FR) prescribed by CP4-ES-2704. See Appendix A for data.

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4. PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: *C-404 Hazardous Waste Landfill*
May 2019 Semiannual Groundwater Report
(October 2018–March 2019),
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(FRNP-RPT-0086/V1)

Stamped and signed pursuant to my authority as a duly registered geologist under the provisions of *KRS* Chapter 322A.

PG113927
K. Davis
5-14-19

Kenneth R. Davis
Kenneth R. Davis

PG113927

May 14, 2019
Date

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5. REFERENCES

FRNP (Four Rivers Nuclear Partnership, LLC) 2019. *C-404 Hazardous Waste Landfill Alternate Source Demonstration—Source of Lead and Uranium in MW87 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0078, Four Rivers Nuclear Partnership, LLC, Kevil, KY.

KDWM (Kentucky Division of Waste Management) 2017. Hazardous Waste Management Facility Permit for the U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY8-890-008-982, effective October 13.

PRS (Paducah Remediation Services, LLC) 2007. *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, Paducah Remediation Services, LLC, Kevil, KY.

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APPENDIX A

C-404 HAZARDOUS WASTE LANDFILL GROUNDWATER ANALYTICAL RESULTS

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Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW84 REG* Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5233

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0243	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00234	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.26	Inches/Hg		1/16/2019				X
Cadmium	J	0.000415	mg/L	0.001	1/16/2019			SW846-6020	J
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium		0.0251	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		416	umho/cm		1/16/2019				X
Depth to Water		50.34	ft		1/16/2019				X
Dissolved Oxygen		3.76	mg/L		1/16/2019				X
Lead		0.00204	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		5.91	Std Unit		1/16/2019				X
Redox		436	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		6.33	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99		25.6	pCi/L	15.2	1/16/2019	9.57	9.98	DOE TC-02-RC	=
Temperature		49.7	deg F		1/16/2019				X
Trichloroethene		4670	ug/L	100	1/16/2019			SW846-8260B	=
Turbidity		68.4	NTU		1/16/2019				X
Uranium	J	0.000186	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	0.305	pCi/L	1.53	1/16/2019	0.834	0.836	HASL 300, U-02-RC M	=
Uranium-235	U	0.172	pCi/L	1.08	1/16/2019	0.645	0.646	HASL 300, U-02-RC M	=
Uranium-238	U	0.6	pCi/L	1.12	1/16/2019	0.82	0.824	HASL 300, U-02-RC M	=

* The field duplicate sample associated with this sample is Sampling Point MW84 REP.

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW84 REP* Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5233

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0246	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00239	mg/L	0.005	1/16/2019			SW846-6020	=
Cadmium	J	0.000325	mg/L	0.001	1/16/2019			SW846-6020	J
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium		0.0225	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Lead	J	0.00187	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		6.31	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99		28.8	pCi/L	14.8	1/16/2019	9.41	9.94	DOE TC-02-RC	=
Trichloroethene		5060	ug/L	100	1/16/2019			SW846-8260B	=
Uranium	J	0.000172	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	0.944	pCi/L	1.43	1/16/2019	1.02	1.03	HASL 300, U-02-RC M	=
Uranium-235	U	-0.201	pCi/L	1.38	1/16/2019	0.465	0.466	HASL 300, U-02-RC M	=
Uranium-238	U	0.724	pCi/L	1.03	1/16/2019	0.827	0.833	HASL 300, U-02-RC M	=

* Field duplicate sample collected as prescribed in the Permit.

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW84 REG* Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5233

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0275	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.0024	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.26	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium		0.0216	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		427	umho/cm		1/16/2019				X
Depth to Water		50.34	ft		1/16/2019				X
Dissolved Oxygen		3.53	mg/L		1/16/2019				X
Lead	J	0.00169	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		5.86	Std Unit		1/16/2019				X
Redox		431	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		6.3	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99		27.8	pCi/L	15.5	1/16/2019	9.79	10.3	DOE TC-02-RC	=
Temperature		50.6	deg F		1/16/2019				X
Trichloroethene		5580	ug/L	100	1/16/2019			SW846-8260B	=
Turbidity		64.7	NTU		1/16/2019				X
Uranium	J	0.000193	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	-0.147	pCi/L	1.88	1/16/2019	0.78	0.781	HASL 300, U-02-RC M	=
Uranium-235	U	1.25	pCi/L	1.26	1/16/2019	1.27	1.28	HASL 300, U-02-RC M	=
Uranium-238	U	1.24	pCi/L	1.78	1/16/2019	1.29	1.3	HASL 300, U-02-RC M	=

* The field duplicate sample associated with this sample is Sampling Point MW84 FR.

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW84 FR* Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5233

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0247	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00233	mg/L	0.005	1/16/2019			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium		0.0209	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Lead	J	0.00163	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		6.33	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99		23.1	pCi/L	15.1	1/16/2019	9.41	9.75	DOE TC-02-RC	=
Trichloroethene		5570	ug/L	100	1/16/2019			SW846-8260B	=
Uranium	J	0.00016	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	0.609	pCi/L	1.53	1/16/2019	0.927	0.932	HASL 300, U-02-RC M	=
Uranium-235	U	0.517	pCi/L	0.897	1/16/2019	0.744	0.747	HASL 300, U-02-RC M	=
Uranium-238	U	0.0908	pCi/L	1.31	1/16/2019	0.639	0.639	HASL 300, U-02-RC M	=

* Field duplicate sample collected as prescribed by internal procedure.

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW85 REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0114	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00206	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.27	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium	J	0.00405	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	J	0.00359	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		404	umho/cm		1/16/2019				X
Depth to Water		9.9	ft		1/16/2019				X
Dissolved Oxygen		2.71	mg/L		1/16/2019				X
Lead	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		6.33	Std Unit		1/16/2019				X
Redox		427	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		10.8	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99		64	pCi/L	17.6	1/16/2019	12	13.9	DOE TC-02-RC	=
Temperature		54.1	deg F		1/16/2019				X
Trichloroethene		7.11	ug/L	1	1/16/2019			SW846-8260B	=
Turbidity		7.5	NTU		1/16/2019				X
Uranium		0.000338	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	0.129	pCi/L	2.21	1/16/2019	1.08	1.08	HASL 300, U-02-RC M	=
Uranium-235	U	0.135	pCi/L	1.44	1/16/2019	0.75	0.751	HASL 300, U-02-RC M	=
Uranium-238	U	-0.546	pCi/L	2.09	1/16/2019	0.703	0.704	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW87 REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5236

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0116	mg/L	0.005	1/15/2019			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/15/2019			SW846-6020	=
Barometric Pressure Reading		30.27	Inches/Hg		1/15/2019				X
Cadmium	J	0.000481	mg/L	0.001	1/15/2019			SW846-6020	J
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/15/2019			SW846-6020	=
Chromium		0.0424	mg/L	0.01	1/15/2019			SW846-6020	=
Chromium, Dissolved	J	0.00432	mg/L	0.01	1/15/2019			SW846-6020	=
Conductivity		337	umho/cm		1/15/2019				X
Depth to Water		50.03	ft		1/15/2019				X
Dissolved Oxygen		2.49	mg/L		1/15/2019				X
Lead		0.00502	mg/L	0.002	1/15/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/15/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/15/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/15/2019			SW846-7470A	=
pH		5.87	Std Unit		1/15/2019				X
Redox		432	mV		1/15/2019				X
Selenium	U	0.005	mg/L	0.005	1/15/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/15/2019			SW846-6020	=
Sulfate		6.28	mg/L	0.4	1/15/2019			SW846-9056	=
Technetium-99	U	1.88	pCi/L	19	1/15/2019	11.1	11.1	DOE TC-02-RC	=
Temperature		51.6	deg F		1/15/2019				X
Trichloroethene		2380	ug/L	50	1/15/2019			SW846-8260B	=
Turbidity		131	NTU		1/15/2019				X
Uranium		0.00042	mg/L	0.0002	1/15/2019			SW846-6020	=
Uranium-234	U	1.5	pCi/L	2.38	1/15/2019	1.66	1.68	HASL 300, U-02-RC M	=
Uranium-235	U	1.61	pCi/L	1.63	1/15/2019	1.64	1.66	HASL 300, U-02-RC M	=
Uranium-238	U	0.779	pCi/L	2.3	1/15/2019	1.38	1.38	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW88 REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5237

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.00669	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00221	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.24	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium		0.0175	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		660	umho/cm		1/16/2019				X
Depth to Water		9.46	ft		1/16/2019				X
Dissolved Oxygen		1.64	mg/L		1/16/2019				X
Lead	J	0.00149	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	J	0.000082	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		5.84	Std Unit		1/16/2019				X
Redox		396	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		127	mg/L	4	1/16/2019			SW846-9056	=
Technetium-99		19.1	pCi/L	18.2	1/16/2019	11.1	11.3	DOE TC-02-RC	=
Temperature		55.7	deg F		1/16/2019				X
Trichloroethene		3.81	ug/L	1	1/16/2019			SW846-8260B	=
Turbidity		68.4	NTU		1/16/2019				X
Uranium	J	0.000184	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	0.625	pCi/L	1.05	1/16/2019	0.751	0.758	HASL 300, U-02-RC M	=
Uranium-235	U	0.665	pCi/L	0.848	1/16/2019	0.784	0.789	HASL 300, U-02-RC M	=
Uranium-238	U	1.05	pCi/L	1.11	1/16/2019	0.907	0.917	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW90A REG Downgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8004-0357

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00217	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.29	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		221	umho/cm		1/16/2019				X
Depth to Water		48.49	ft		1/16/2019				X
Dissolved Oxygen		4.69	mg/L		1/16/2019				X
Lead	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		5.94	Std Unit		1/16/2019				X
Redox		424	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		4.33	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99	U	11.9	pCi/L	15.8	1/16/2019	9.49	9.58	DOE TC-02-RC	=
Temperature		54.8	deg F		1/16/2019				X
Trichloroethene		69.9	ug/L	1	1/16/2019			SW846-8260B	=
Turbidity		0	NTU		1/16/2019				X
Uranium	U	0.0002	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234		1.89	pCi/L	1.47	1/16/2019	1.42	1.45	HASL 300, U-02-RC M	=
Uranium-235	U	1	pCi/L	1.28	1/16/2019	1.18	1.19	HASL 300, U-02-RC M	=
Uranium-238	U	0.389	pCi/L	1.52	1/16/2019	0.883	0.885	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW91A REG Downgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8007-2917

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0168	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved		0.0159	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.22	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		1317	umho/cm		1/16/2019				X
Depth to Water		12.54	ft		1/16/2019				X
Dissolved Oxygen		0.58	mg/L		1/16/2019				X
Lead	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		6.23	Std Unit		1/16/2019				X
Redox		124	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		209	mg/L	8	1/16/2019			SW846-9056	=
Technetium-99	U	11.6	pCi/L	16.7	1/16/2019	10	10.1	DOE TC-02-RC	=
Temperature		57.5	deg F		1/16/2019				X
Trichloroethene		31.1	ug/L	1	1/16/2019			SW846-8260B	=
Turbidity		0	NTU		1/16/2019				X
Uranium	J	0.000092	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234		1.58	pCi/L	1.36	1/16/2019	1.2	1.22	HASL 300, U-02-RC M	=
Uranium-235	U	0.542	pCi/L	1.19	1/16/2019	0.861	0.864	HASL 300, U-02-RC M	=
Uranium-238		1.23	pCi/L	1.15	1/16/2019	1.04	1.05	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW93 REG Upgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5102

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic	J	0.00462	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00225	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.28	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium		0.0561	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	J	0.00401	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		367	umho/cm		1/16/2019				X
Depth to Water		51.59	ft		1/16/2019				X
Dissolved Oxygen		2.39	mg/L		1/16/2019				X
Lead	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		5.9	Std Unit		1/16/2019				X
Redox		382	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		7.36	mg/L	0.4	1/16/2019			SW846-9056	=
Technetium-99	U	8.75	pCi/L	22.1	1/16/2019	13.1	13.1	DOE TC-02-RC	=
Temperature		55.5	deg F		1/16/2019				X
Trichloroethene		1000	ug/L	25	1/16/2019			SW846-8260B	=
Turbidity		8.2	NTU		1/16/2019				X
Uranium	U	0.0002	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	1.05	pCi/L	1.37	1/16/2019	1.02	1.03	HASL 300, U-02-RC M	=
Uranium-235	U	0.199	pCi/L	0.597	1/16/2019	0.56	0.56	HASL 300, U-02-RC M	=
Uranium-238	U	0.812	pCi/L	1.06	1/16/2019	0.852	0.859	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW94 REG Upgradient UCRS **Period:** Semiannual Report

AKGWA Well Tag #: 8000-5103

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00233	mg/L	0.005	1/16/2019			SW846-6020	=
Barometric Pressure Reading		30.22	Inches/Hg		1/16/2019				X
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium	J	0.00814	mg/L	0.01	1/16/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Conductivity		864	umho/cm		1/16/2019				X
Depth to Water		13.28	ft		1/16/2019				X
Dissolved Oxygen		1.32	mg/L		1/16/2019				X
Lead	J	0.00189	mg/L	0.002	1/16/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
pH		6.39	Std Unit		1/16/2019				X
Redox		201	mV		1/16/2019				X
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Sulfate		81.4	mg/L	4	1/16/2019			SW846-9056	=
Technetium-99		992	pCi/L	18.2	1/16/2019	27.1	113	DOE TC-02-RC	=
Temperature		58.2	deg F		1/16/2019				X
Trichloroethene		2.19	ug/L	1	1/16/2019			SW846-8260B	=
Turbidity		76.9	NTU		1/16/2019				X
Uranium		0.00183	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	1.13	pCi/L	1.37	1/16/2019	1.03	1.04	HASL 300, U-02-RC M	=
Uranium-235	U	0.675	pCi/L	1.06	1/16/2019	0.855	0.86	HASL 300, U-02-RC M	=
Uranium-238	U	0.478	pCi/L	1.25	1/16/2019	0.777	0.779	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Sampling Point: MW420 REG Upgradient URGA **Period:** Semiannual Report

AKGWA Well Tag #: 8005-3263

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic	J	0.00414	mg/L	0.005	1/15/2019			SW846-6020	=
Arsenic, Dissolved	J	0.00222	mg/L	0.005	1/15/2019			SW846-6020	U
Barometric Pressure Reading		30.27	Inches/Hg		1/15/2019				X
Cadmium	U	0.001	mg/L	0.001	1/15/2019			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/15/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/15/2019			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/15/2019			SW846-6020	=
Conductivity		335	umho/cm		1/15/2019				X
Depth to Water		51.69	ft		1/15/2019				X
Dissolved Oxygen		1.99	mg/L		1/15/2019				X
Lead	U	0.002	mg/L	0.002	1/15/2019			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/15/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/15/2019			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/15/2019			SW846-7470A	=
pH		5.83	Std Unit		1/15/2019				X
Redox		441	mV		1/15/2019				X
Selenium	U	0.005	mg/L	0.005	1/15/2019			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/15/2019			SW846-6020	=
Sulfate		6.14	mg/L	0.4	1/15/2019			SW846-9056	=
Technetium-99	U	1.09	pCi/L	19	1/15/2019	11	11	DOE TC-02-RC	=
Temperature		55.9	deg F		1/15/2019				X
Trichloroethene		601	ug/L	10	1/15/2019			SW846-8260B	=
Turbidity		0	NTU		1/15/2019				X
Uranium	U	0.0002	mg/L	0.0002	1/15/2019			SW846-6020	=
Uranium-234	U	1.64	pCi/L	2.23	1/15/2019	1.66	1.68	HASL 300, U-02-RC M	=
Uranium-235	U	1.28	pCi/L	1.63	1/15/2019	1.51	1.52	HASL 300, U-02-RC M	=
Uranium-238	U	0.903	pCi/L	1.68	1/15/2019	1.23	1.24	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Type of Sample: FB **Period:** Semiannual Report QC Samples

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Lead	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Technetium-99	U	2.28	pCi/L	16.7	1/16/2019	9.73	9.73	DOE TC-02-RC	=
Trichloroethene	U	1	ug/L	1	1/16/2019			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	1.39	pCi/L	1.63	1/16/2019	1.22	1.24	HASL 300, U-02-RC M	=
Uranium-235	U	0.495	pCi/L	1.33	1/16/2019	0.876	0.879	HASL 300, U-02-RC M	=
Uranium-238	U	0.577	pCi/L	1.07	1/16/2019	0.788	0.792	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Type of Sample: RI **Period:** Semiannual Report QC Samples

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Arsenic	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	1/16/2019			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/16/2019			SW846-6020	=
Lead	U	0.002	mg/L	0.002	1/16/2019			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/16/2019			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	1/16/2019			SW846-6020	=
Technetium-99	U	2.99	pCi/L	15.5	1/16/2019	9.08	9.09	DOE TC-02-RC	=
Trichloroethene	U	1	ug/L	1	1/16/2019			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	1/16/2019			SW846-6020	=
Uranium-234	U	0.792	pCi/L	1.63	1/16/2019	1.04	1.05	HASL 300, U-02-RC M	=
Uranium-235	U	1.17	pCi/L	1.17	1/16/2019	1.11	1.12	HASL 300, U-02-RC M	=
Uranium-238	U	1.17	pCi/L	1.43	1/16/2019	1.09	1.1	HASL 300, U-02-RC M	=

Paducah OREIS
GROUNDWATER MONITORING REPORT

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982

Type of Sample: TB **Period:** Semiannual Report QC Samples

AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Trichloroethene	U	1	ug/L	1	1/15/2019			SW846-8260B	=
	U	1	ug/L	1	1/16/2019			SW846-8260B	=

MEDIA Codes

WG Groundwater

QUALIFIER Codes

U Analyte analyzed for, but not detected at or below the lowest concentration reported.
J Estimated quantitation.

SAMPLE METHOD Codes

GR Grab

SAMPLING POINT Codes

UCRS Upper Continental Recharge System
URGA Upper Regional Gravel Aquifer

SAMPLE TYPE Codes

FB Field Blank
FR Field Duplicate as defined in sampling procedure.
REP Field Duplicate as defined in permit.
REG Regular
RI QC Equipment Rinseate/Decon
TB Trip Blank

VALIDATION Codes

= Validated result, no qualifier is necessary.
J The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
U The analyte was analyzed for, but was not detected above the reported sample quantitation limit.
X Not validated.

APPENDIX B

C-404 HAZARDOUS WASTE LANDFILL STATISTICAL ANALYSES

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GROUNDWATER STATISTICAL SUMMARY

Introduction

The statistical analyses conducted on the data collected from C-404 Hazardous Waste Landfill (C-404 Landfill) were performed in accordance with procedures provided in Appendix E of the Hazardous Waste Management Facility Permit, reissued by the Kentucky Division of Waste Management (KDWM) in July 2015. The percent of censored (nondetected) data points for individual parameters was calculated for the combined analytical data from the most recent five sampling events. The percent of censored data was used to select the types of statistical analyses to determine whether compliance well concentrations differed from background well concentrations. Data points were used in the statistical analysis for analyte results close to the sample quantitation limit that were judged to be below that limit by the data validator. For the first reporting period 2019 semiannual report, the reporting period data set includes data from January 2017, July 2017, January 2018, August 2018, and January 2019.

Statistical Analysis Process

Utilizing the current data set and four previous data sets, the type of statistical test conducted for each chemical data set is a function of the number of samples and proportion of censored data (nondetects) to uncensored data (detects) in each group. The percent of censored (nondetected) data points for individual parameters was calculated for the combined analytical data. The statistical procedures applied to the data are summarized below.

- Determine the percentage of the censored data using the reporting period data set.
- Group by percentage of censored data where the following apply:
  - — If censored data are greater than or equal to 90%, determine the limit of detection (LOD) and half of the LOD (1/2 LOD). This is Statistical Test 1.
  - — If censored data are between 50% and 90%, perform a Test of Proportions. If the analysis indicates a significant proportional difference in compliance wells, further analyze through nonparametric Analysis of Variance (ANOVA) Test. This is Statistical Test 2.
  - — If censored data are between 15% and 50%, perform nonparametric ANOVA Test. If results exceed the critical value, compute the critical difference used to identify individual well concentrations, which are significantly elevated compared with background. This is Statistical Test 3.
  - — If censored data are less than 15%, actual data values are analyzed using parametric ANOVA procedures. If the wells exhibit equal variances, then the data are used as presented. If the wells do not exhibit equal variances, then the log of the data is taken and then used in the calculations. Where statistical testing indicates elevated compliance well concentrations, Bonferroni's Test of

Contrasts is performed. This is Statistical Test 4. If variances are found to be unequal even for log-transformed concentrations, Statistical Test 4 is abandoned and Statistical Test 3 is used to compare compliance wells with background wells. Statistical Test 4 is found in Section 5.2.1 of EPA guidance document, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (April 1989).

If the statistical method above indicates no statistical difference between concentrations in downgradient wells and concentrations in background wells, then there are no indications of statistically significant impacts on the groundwater from the C-404 Landfill. If the tiered statistical method above identifies a statistically significant difference between concentrations in downgradient wells and concentrations in background wells, then the data will be evaluated further to determine if the concentrations in downgradient wells are within statistically developed upper tolerance limit (UTL) for background concentrations or are consistent with the findings of the 2007 Alternate Source Demonstration (ASD), as follows:

(1) Compare the most recent downgradient sample results to a 95% UTL using the five most recent sets of data for each upgradient well as described below. If downgradient concentrations are lower than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

(2) Evaluate results using paired ANOVA of wells in the same direction relative to the landfill (e.g., compare upgradient westernmost well results to downgradient westernmost well results). If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

(3) If results show downgradient wells have statistically significant higher concentrations than upgradient wells, even when evaluated with respect to the ASD, additional intra-well evaluation of trend will be performed using the Mann-Kendall test for trend. If concentrations do not show an increasing trend, then there is no confirmed exceedance attributable to C-404.

(4) Review other Regional Gravel Aquifer (RGA) well results in vicinity to determine if they are consistent with ASD.

If the statistical analysis identifies downgradient well concentrations that are increasing, are higher than UTL, are higher than the upgradient well concentrations even when the ASD results are taken into account, this evaluation will identify a confirmed, statistically significant exceedance (in a compliance well) over background.

Data Analysis

Data from the upgradient background wells in the Upper Regional Gravel Aquifer (URGA) are included for comparison with three downgradient URGA wells. Figure 1 of this C-404 Landfill Groundwater Report provides a map of the well locations associated with the C-404 Landfill. Upper Continental Recharge System (UCRS) wells in Figure 1 are provided for reference only. Data from wells that are in the UCRS are not included in the statistical analyses.

Table B.1 presents the C-404 Landfill upgradient or background wells and downgradient or compliance wells from the URGA. Data from the URGA compliance wells were compared with data from the URGA background wells.

Table B.1. Monitoring Well Locations

URGA	
Upgradient background wells	MW93, MW420
Downgradient compliance wells	MW84, MW87, MW90A*

*MW90 was abandoned in 2001 and replaced with MW90A.

For the first reporting period 2019 semiannual report, the reporting period data set from January 2017 through January 2019 consists of five sets of data.

Table B.2 lists the number of analyses (observations), nondetects (censored observations), detects (uncensored observations), and missing observations by parameter. When field duplicate data are available from a well, the higher of the two readings was retained for further evaluation.

Censoring Percentage and Statistical Analysis

The type of statistical test set applied to the data is a function of the number of nondetects (censored) versus detects (uncensored) in each of the parameter groups and among the wells. Table B.3 presents the percentage of censored data and type of statistical test chosen for each of the parameters required by Part VIII.E of the Permit.

Table B.2. Summary of Missing, Censored, and Uncensored Data Collected

Parameters	Observations	Missing Observations*	Censored Observations (Nondetects)	Uncensored Observations (Detects)
URGA				
Arsenic	25	0	7	18
Cadmium	25	0	17	8
Chromium	25	0	9	16
Lead	25	0	10	15
Mercury	25	0	25	0
Selenium	25	0	23	2
Technetium-99	25	0	22	3
Trichloroethene	25	0	0	25
Uranium (Metals)	25	0	12	13
Uranium-234	25	0	24	1
Uranium-235	25	0	25	0
Uranium-238	25	0	25	0

Table B.3. Percent Censored Report and Statistical Test Set Selected

Parameter	Total Samples (Nonmissing)	Uncensored (Detects)	Censored (Nondetects)	Percent Censored	Statistical Test Set*
URGA					
Arsenic	25	18	7	28.00	3
Cadmium	25	8	17	68.00	2
Chromium	25	16	9	36.00	3
Lead	25	15	10	40.00	3
Mercury	25	0	25	100.00	1
Selenium	25	2	23	92.00	1
Technetium-99	25	3	22	88.00	2
Trichloroethene	25	25	0	0.00	4/3**
Uranium (Metals)	25	13	12	48.00	3
Uranium-234	25	1	24	96.00	1
Uranium-235	25	0	25	100.00	1
Uranium-238	25	0	25	100.00	1

*A list of the constituents with greater than or equal to 90% censored data is included in Table B.4, which summarizes the results of Statistical Test 1.
**Because equality of variance could not be confirmed, Statistical Test 4, Parametric ANOVA, was abandoned, and Statistical Test 3, Nonparametric ANOVA, was performed.

SUMMARY OF CONCLUSIONS

The results for Statistical Test 1, LOD, are summarized in Table B.4. Table B.5 provides the summary of conclusions for the C-404 Landfill statistical analyses for the first reporting period 2019, including the statistical tests performed, the attachment number, well type, parameter, and results of each statistical test. Results of Statistical Test 2, Statistical Test 3, and Statistical Test 4 are presented in Attachments B1 through B7. The statistician qualification statement is presented in Attachment B8.

Table B.4. Statistical Test 1: Limit of Detection

Parameter	LOD Values	½ LOD Values
URGA		
Mercury (mg/L)	0.0002	0.0001
Selenium (mg/L)	0.005	0.0025
Uranium-234 (pCi/L)	2.38	1.19
Uranium-235 (pCi/L)	1.63	0.815
Uranium-238 (pCi/L)	2.3	1.15

In summary, Statistical Test 2, Test of Proportions, for technetium-99 in the URGA indicated no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Statistical Test 2, Test of Proportions, for cadmium in the URGA indicated a statistically significant evidence that the proportion of detects in one group of data exceeds the proportion of detects in the other

group. For cadmium, downgradient wells had a higher proportion of detects; therefore, the data were evaluated further using Nonparametric ANOVA. Nonparametric ANOVA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were compared to the UTL. The 95% UTL did not indicate a statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Statistical Test 3, Nonparametric ANOVA, for arsenic in the URGA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. Based on these results, the data were evaluated using paired (parametric) ANOVA of wells in the same direction relative to the landfill [e.g., performed a comparison of downgradient well (MW84) results to upgradient westernmost well (MW93) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and it identified an increasing trend for arsenic in MW84.

Statistical Test 3, Nonparametric ANOVA, for chromium in the URGA indicated no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Statistical Test 3, Nonparametric ANOVA, for lead in the URGA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL for MW84 did not indicate a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. The 95% UTL for MW87 indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. Based on these results, the data were evaluated using paired (parametric) ANOVA of wells in the same direction relative to the landfill [e.g., performed a comparison of downgradient well (MW87) results to upgradient westernmost well (MW93) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and no trend was identified for lead in MW87.

Statistical Test 3, Nonparametric ANOVA, for uranium in the URGA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL for MW84 did not indicate a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. The 95% UTL for MW87 indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. Based on these results, the data were evaluated using paired (parametric) ANOVA of wells in the same direction relative to the landfill [e.g., performed a comparison of downgradient well (MW87) results to upgradient westernmost well (MW93) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and no trend was identified for uranium in MW87.

Statistical Test 4, Parametric ANOVA, could not be used for trichloroethene in the URGA because there was no evidence of equality of variance. Thus, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Nonparametric ANOVA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells;

therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. Based on these results, the data were evaluated using paired (parametric) ANOVA of wells in the same direction relative to the landfill [e.g., performed a comparison of downgradient well (MW84) results to upgradient westernmost well (MW93) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and it identified an increasing trend for trichloroethene in MW84.

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the First Reporting Period 2019

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B1	URGA	Arsenic	Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW84 vs. MW93), Mann-Kendall, and data review	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, a comparison to the 95% UTL, paired ANOVA, Mann-Kendall, and an attempt to review data was performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified an increasing trend in MW84.
B2	URGA	Cadmium	Statistical Test 2, Test of Proportions with Statistical Test 3, Nonparametric ANOVA and 95% UTL	Because Test of Proportions indicated statistically significant evidence that the proportion of detects in one group of data exceeds the proportion of detects in the other group, Statistical Test 3, Nonparametric ANOVA, and a comparison to the 95% UTL were performed. Results of the comparison to the 95% UTL have not identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B3	URGA	Chromium	Statistical Test 3, Nonparametric ANOVA	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B4	URGA	Lead	Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW87 vs. MW93), and Mann-Kendall	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, a comparison to the 95% UTL was performed, as required by the Hazardous Waste Management Facility Permit. For MW84, results of the comparison to the 95% UTL have not identified a statistically significant difference between concentrations in downgradient wells or concentrations in background wells. Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the First Reporting Period 2019 (Continued)

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
				well MW87, a comparison to the 95% UTL, paired ANOVA, and Mann-Kendall were performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA for MW87 have identified that there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified no trend in MW87.
B5	URGA	Technetium-99	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B6	URGA	Trichloroethene	Statistical Test 4, Parametric ANOVA/Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW84 vs. MW93), Mann-Kendall, and data review	Because equality of variance could not be confirmed, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, a comparison to the 95% UTL, paired ANOVA, Mann-Kendall, and an attempt to review data were performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified an increasing trend in MW84.
B7	URGA	Uranium	Statistical Test 3, Nonparametric ANOVA, with 95% UTL, paired ANOVA (MW87 vs. MW93), and Mann-Kendall	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, a comparison to the 95% UTL was performed, as required by the Hazardous Waste Management Facility Permit. For MW84, results of the comparison to the 95% UTL have not identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells. Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW87, a comparison to the 95% UTL, paired ANOVA, and Mann-Kendall were performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified that there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified no trend in MW87.

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ATTACHMENT B1

ARSENIC
STATISTICAL TEST 3

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Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.00842**	0.0025	**0.017**	**0.00692**	0.0025
Jul-17	**0.00755**	**0.00207**	**0.0191**	**0.00907**	0.0025
Jan-18	**0.00807**	0.0025	**0.0185**	**0.0087**	0.0025
Aug-18	**0.00619**	**0.00304**	**0.0289**	**0.0105**	0.0025
Jan-19	**0.00462**	**0.00414**	**0.0275**	**0.0116**	0.0025
Sum	0.0491		0.11100	0.04679	0.0125
n_i	10		5	5	5
$(x_i)_{avg}$	0.00491		0.02220	0.00936	0.0025

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.00878

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.22	x.. = the sum of the total number of samples

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Arsenic (mg/L)	Adjusted Rank	Tie Number
1	0	4	
2	0	4	
3	0	4	
4	0	4	Tie 1
5	0	4	
6	0	4	
7	0	4	
8	**0.00207**	8	
9	**0.00304**	9	
10	**0.00414**	10	
11	**0.00462**	11	
12	**0.00619**	12	
13	**0.00692**	13	
14	**0.00755**	14	
15	**0.00807**	15	
16	**0.00842**	16	
17	**0.0087**	17	
18	**0.00907**	18	
19	**0.0105**	19	
20	**0.0116**	20	
21	**0.017**	21	
22	**0.0185**	22	
23	**0.0191**	23	
24	**0.0275**	24	
25	**0.0289**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
7	Tie 1 = 336
	$\sum T_i$ = 336

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Sums of Ranks and Averages

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.00842**	0	**0.017**	**0.00692**	0
Jul-17	**0.00755**	**0.00207**	**0.0191**	**0.00907**	0
Jan-18	**0.00807**	0	**0.0185**	**0.0087**	0
Aug-18	**0.00619**	**0.00304**	**0.0289**	**0.0105**	0
Jan-19	**0.00462**	**0.00414**	**0.0275**	**0.0116**	0

Observation Ranks for Arsenic					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	16	4	21	13	4
Jul-17	14	8	23	18	4
Jan-18	15	4	22	17	4
Aug-18	12	9	25	19	4
Jan-19	11	10	24	20	4
R_i	103		115	87	20
$(R_i)_{avg}$	10.3		23.0	17.4	4.0
R_i^2/n_i	1060.9		2645.0	1513.8	80.0

$\Sigma R_i^2/n_i$ = 5299.7

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.

K = the number of n_i groups
N = the total number of samples

K = 4
N = 25

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H =	19.841	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	20.277	Corrected Kruskal-Wallis	$H' = H/[1-(\sum T_i/N^3-N)]$
χ^2_{crit}* =	7.815	3 degrees of freedom at the 5% significance level	

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.

If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 =	3	α/(K-1) =	0.01667	Z(α/(K-1))** =	2.1280
α =	0.05	1-(α/K-1) =	0.983		

NOTE: *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 10.3

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	12.7	**evidence of contamination**
	MW87	8.578	7.1	not contaminated
	MW90A	8.578	-6.3	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87 and MW90A, there is no statistically significant difference between background wells and these downgradient compliance test wells; however, the negative value indicates that background wells have elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

January 2019 Data, First Reporting Period
Observations (mg/L)

Well No.						
MW93	**0.00842**	**0.00755**	**0.00807**	**0.00619**	**0.00462**	**Upgradient Well!**
MW420	0.0025	**0.00207**	0.0025	**0.00304**	**0.00414**	**Upgradient Well!**
						Current Data
MW84		X: Mean Value =	0.0049			**0.0275**
MW87		S: Standard Deviation =	0.0025			0.0116
MW90A		K* factor =	2.911	(for n = 10)		0.0025
		CV = S/X	0.5024	<1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**0.0121**	(mg/L)	

! = Data from previous 5 sampling events.
CV = coefficient of variation
* = Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Result: **MW84 exceeded the UTL, which is statistically significant evidence that this compliance well has elevated concentration with respect to background data.**

Because the 95% UTL indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the paired ANOVA was performed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Paired (Parametric) ANOVA

Evaluate results using paired ANOVA of wells in the same direction relative to the landfill [e.g., compare upgradient westernmost well results to downgradient westernmost well results]. If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

Arsenic (mg/L)				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jan-17	**0.00842**	**0.017**	0.0000709	0.0002890
Jul-17	**0.00755**	**0.0191**	0.0000570	0.0003648
Jan-18	**0.00807**	**0.0185**	0.0000651	0.0003423
Aug-18	**0.00619**	**0.0289**	0.0000383	0.0008352
Jan-19	**0.00462**	**0.0275**	0.0000213	0.0007563
Sum (x_i)	0.0349	0.11100	0.1459	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.00697	0.02220		
$(x_i)^2$	0.00121	0.01232		

mg/L = milligrams per liter
Bolded values indicate a detected result.

Overall mean x.. = 0.01459

N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.1459	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals ($x_i - x_{iavg}$)

Date	Background	Compliance
	MW93	MW84
Jan-17	0.00145	-0.00520
Jul-17	0.00058	-0.00310
Jan-18	0.00110	-0.00370
Aug-18	-0.00078	0.00670
Jan-19	-0.00235	0.00530

X: Mean Value =	0.00E+00	
S: Standard Deviation =	0.00385	
K* Factor =	2.911	(for n = 10)
CV = S/X =	#ΔIς/0!	#DIV/0!

†The Coefficient of Variability Test was not performed due to mean = 0 (i.e., division by 0 not possible).

*Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

If the coefficient of variation (CV) is < 1, the data are normally distributed.
If the coefficient of variation (CV) is > or = 1, data are not normally distributed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 0.1459$
n_i = number of data points per well	$(x_{avg})_{..} = 0.01459$
N = total sample size	$n_i = 5$
S^2 = the square of the standard deviation	p = 2
$\ln(S_i^2)$ = natural logarithm of each variance	N = 10
f = total sample size minus the number of wells (groups)	$f_i = 4$
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.00156	0.00000244495	-12.921	5	0.0000098	-51.7
0.00555	0.00003083000	-10.387	5	0.0001233	-41.5

$\sum(S_i^2)$ = 0.00003 $\sum f_i\ln(S_i^2)$ = -93.23403

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.0000166	
ln Sp^2 =	-11.004	
χ^2 =	5.203	(If calculated $\chi^2 \leq$ tabulated χ^2_{crit}, then variances are equal at the given significance level).
χ^2_{crit} * =	3.841	at a 5% significance level with 1 degrees of freedom (p-1)

NOTE: The variances are NOT equal. (i.e., calculated $\chi^2 > \chi^2_{crit}$)

Variances are not equal, transform the original data to lognormal (i.e., since calculated $\chi^2 > \chi^2_{crit}$).

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Paired (Parametric) ANOVA—Lognormal Data

ln[Arsenic (mg/L)]				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jan-17	**-4.78**	**-4.07**	22.82	16.60
Jul-17	**-4.89**	**-3.96**	23.88	15.67
Jan-18	**-4.82**	**-3.99**	23.23	15.92
Aug-18	**-5.08**	**-3.54**	25.86	12.56
Jan-19	**-5.38**	**-3.59**	28.92	12.91
Sum (x_i)	-24.95	-19.16	-44.11	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	-4.99	-3.83		
$(x_i)^2$	622.26	367.11		

mg/L = milligrams per liter **Bolded values indicate a detected result.**

Overall mean x.. =	-4.41	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	-44.11	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test—Lognormal Data

Table of Residuals (x_i-$x_i$avg) for Lognormal Data

Date	Background	Compliance
	MW93	MW84
Jan-17	0.21	-0.24
Jul-17	0.10	-0.13
Jan-18	0.17	-0.16
Aug-18	-0.10	0.29
Jan-19	-0.39	0.24

X: Mean Value =	1.33E-16	
S: Standard Deviation =	0.23	
K* Factor =	2.911	(for n = 10)
CV = S/X =	1.74E+15	≥1, data are NOT normally distributed

Data are not normally distributed (i.e., ≥1)

*Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

If the coefficient of variation is < 1, the residuals are normally distributed.
If the coefficient of variation is > or = 1, the residuals are not normally distributed.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Determine Equality of Variance—Lognormal Data

p = number of wells
n_i = number of data points per well
N = total sample size
S^2 = the square of the standard deviation
$\ln(S_i^2)$ = natural logarithm of each variance
f = total sample size minus the number of wells (groups)
$f_i = n_i - 1$

$x_{..} = -44.11$
$(x_{avg})_{..} = -4.41$
$n_i = 5$
$p = 2$
$N = 10$
$f_i = 4$

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.25	0.06	-2.80	5	0.24	-11.2
0.24	0.06	-2.82	5	0.24	-11.3

$\sum(S_i^2) =$ 0.12 $\sum f_i \ln(S_i^2) =$ -22.45

Equality of Variance: Bartlett's Test

$f =$ 8
$Sp^2 =$ 0.06
$\ln Sp^2 =$ -2.81
$\chi^2 =$ 0.00 (If calculated $\chi^2 \leq$ tabulated χ^2_{crit}, then variances are equal at the given significance level).
χ^2_{crit} * = 3.841 at a 5% significance level with 1 degrees of freedom (p-1)

NOTE: The variances are equal. (i.e., calculated $\chi^2 \leq \chi^2_{crit}$)

Since calculated $\chi^2 \leq \chi^2_{crit}$, then the analysis can proceed as normal.

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

**Section 5.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Between Well Sum of Squares

Source of	Sums of Squares		Degrees of	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	3.34669	1	3.34669	55.35	5.32
Error	SS_{Error} =	0.48367	8	0.060459		
Total	SS_{Total} =	3.83036	9			

If calculated F > F statistic, then reject the hypothesis of equal well means. If calculated F is less than or equal to F statistic, it can be concluded that there is no significant difference between concentrations; therefore, there is no evidence of well contamination.

CONCLUSION: **Calculated F > F statistic; therefore, ANOVA has identified a significant difference between background and downgradient wells.**

Because the paired ANOVA for the two wells indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, a Mann-Kendall statistical analysis was performed.

**Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989). F statistic taken at the 5% significance level.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for Arsenic in MW84

Input Data

Date Collected	Result (mg/L)
Jul-15	**0.00922**
Jan-16	**0.0103**
Jul-16	**0.0137**
Jan-17	**0.017**
Jul-17	**0.0191**
Jan-18	**0.0185**
Aug-18	**0.0289**
Jan-19	**0.0275**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	ProUCL 5.13/18/2019 12:23:28 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84 arsenic 1Q2019

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	0.00922
Maximum	0.0289
Mean	0.018
Geometric Mean	0.0168
Median	0.0178
Standard Deviation	0.00723
Coefficient of Variation	0.401

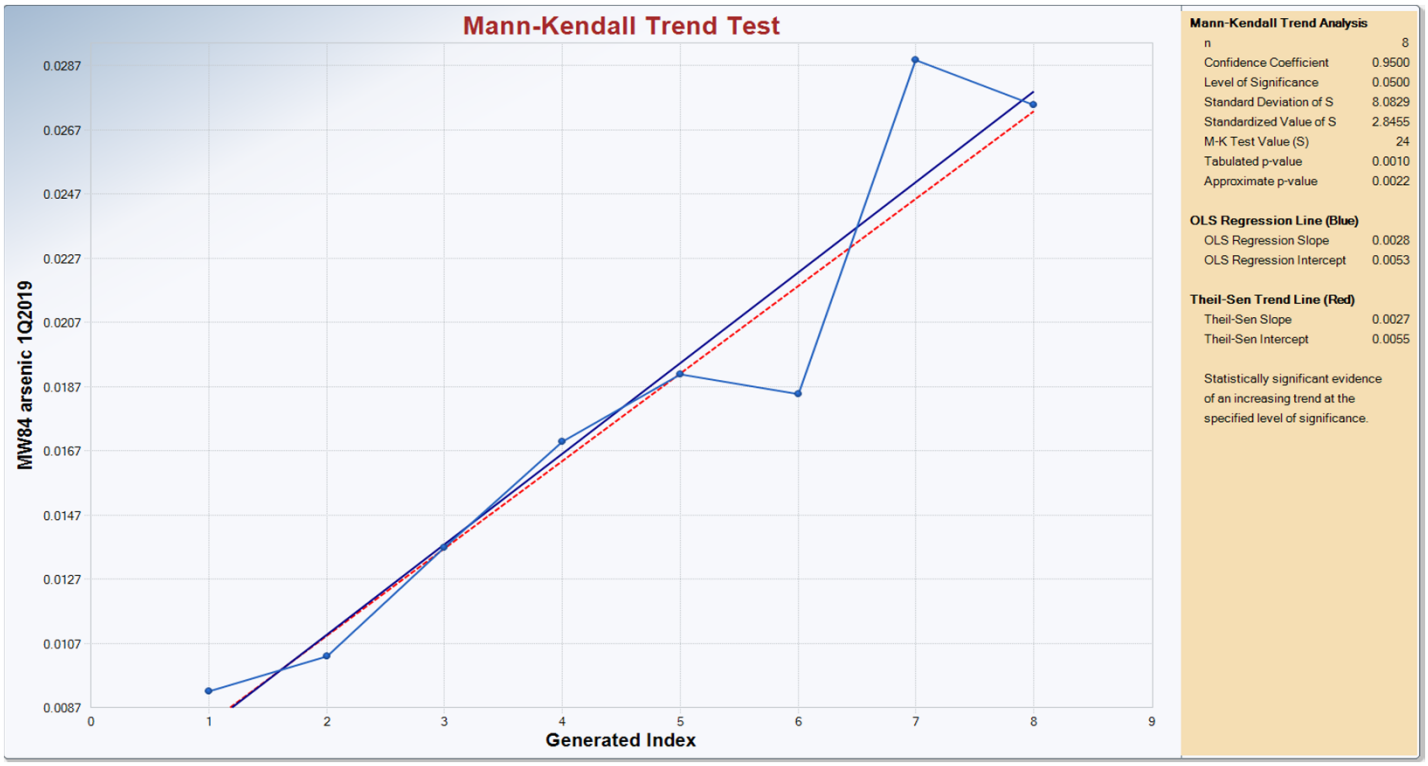
Mann-Kendall Test

M-K Test Value (S)	24
Tabulated p-value	0.001
Standard Deviation of S	8.083
Standardized Value of S	2.846
Approximate p-value	0.00222

Statistically significant evidence of an increasing trend at the specified level of significance.

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for Arsenic in MW84



ATTACHMENT B2

CADMIUM
STATISTICAL TEST 2

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Attachment B2: Cadmium URGA, Statistical Test 2, Test of Proportions, First Reporting Period 2019

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	0.0005	0.0005	**0.000619**	0.0005	0.0005
Jul-17	0.0005	0.0005	**0.000396**	**0.000304**	0.0005
Jan-18	0.0005	0.0005	0.0005	**0.000375**	0.0005
Aug-18	0.0005	0.0005	**0.000323**	**0.000372**	0.0005
Jan-19	0.0005	0.0005	**0.000415**	**0.000481**	0.0005

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

[!] **Test of Proportions**

Calculate the number of detections in background wells vs. compliance wells.

X =	0	X = number of samples above DL in background wells
Y =	8	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.320	P = (x+y)/n
nP =	8	$n = n_b+n_c$
n(1-P) =	17	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used.

P_b =	0.000	P_b = proportion of detects in background wells
P_c =	0.533	P_c = proportion of detects in compliance wells
S_D =	0.190	S_D = standard error of difference in proportions
Z =	-2.801	$Z = (P_b-P_c)/S_D$
absolute value of Z =	2.801	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: **Because the absolute value of Z is greater than 1.96, Nonparameteric ANOVA was performed.**

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	0.0005	0.0005	**0.000619**	0.0005	0.0005
Jul-17	0.0005	0.0005	**0.000396**	**0.000304**	0.0005
Jan-18	0.0005	0.0005	0.0005	**0.000375**	0.0005
Aug-18	0.0005	0.0005	**0.000323**	**0.000372**	0.0005
Jan-19	0.0005	0.0005	**0.000415**	**0.000481**	0.0005
Sum	0.0050		0.00225	0.00203	0.0025
n_i	10		5	5	5
$(x_i)_{avg}$	0.00050		0.00045	0.00041	0.0005

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.00047

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.01	x.. = the sum of the total number of samples

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Cadmium (mg/L)	Adjusted Rank	Tie Number
1	0	9	
2	0	9	
3	0	9	
4	0	9	
5	0	9	
6	0	9	
7	0	9	
8	0	9	
9	0	9	Tie 1
10	0	9	
11	0	9	
12	0	9	
13	0	9	
14	0	9	
15	0	9	
16	0	9	
17	0	9	
18	**0.000304**	18	
19	**0.000323**	19	
20	**0.000372**	20	
21	**0.000375**	21	
22	**0.000396**	22	
23	**0.000415**	23	
24	**0.000481**	24	
25	**0.000619**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3-n_{tie})$
17	Tie 1 = 4896
	$\sum T_i$ = 4896

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Sums of Ranks and Averages

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	0	0	**0.000619**	0	0
Jul-17	0	0	**0.000396**	**0.000304**	0
Jan-18	0	0	0	**0.000375**	0
Aug-18	0	0	**0.000323**	**0.000372**	0
Jan-19	0	0	**0.000415**	**0.000481**	0

Observation Ranks for Cadmium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	9	9	25	9	9
Jul-17	9	9	22	18	9
Jan-18	9	9	9	21	9
Aug-18	9	9	19	20	9
Jan-19	9	9	23	24	9
R_i	90		98	92	45
$(R_i)_{avg}$	9.0		19.6	18.4	9.0
R_i^2/n_i	810.0		1920.8	1692.8	405.0

$\Sigma R_i^2/n_i$ = 4828.6

K = 4

N = 25

mg/L = milligrams per liter

BG = background

DL = detection limit

K = the number of n_i groups

N = the total number of samples

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 11.143 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 16.240 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit}* = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.

If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 = 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280

α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE: *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 9.0

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	10.60	**evidence of contamination**
	MW87	8.578	9.40	**evidence of contamination**
	MW90A	8.578	0.00	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84 and MW87, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 and MW87 from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance wells MW84 and MW87, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

January 2019 Data, First Reporting Period
Observations (mg/L)

Well No.						
MW93	0.0005	0.0005	0.0005	0.0005	0.0005	**Upgradient Well!**
MW420	0.0005	0.0005	0.0005	0.0005	0.0005	**Upgradient Well!**
						Current Data
MW84		X: Mean Value =	0.0005			0.000415
MW87	S: Standard Deviation =		0.0000			0.000481
MW90A		K* factor =	2.911	(for n = 10)		0.0005
		CV = S/X	0.0000	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =			**0.0005**	(mg/L)	

! = Data from previous 5 sampling events.
CV = coefficient of variation
* = Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Result: **None of the Test Wells had exceeded the UTL, which is statistically significant evidence that these wells have no elevated concentration with respect to background data.**

ATTACHMENT B3

CHROMIUM
STATISTICAL TEST 3

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Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.428**	0.005	**0.0309**	**0.262**	0.005
Jul-17	**0.261**	0.005	**0.103**	**0.0557**	0.005
Jan-18	**0.151**	0.005	**0.143**	**1.18**	**0.00381**
Aug-18	**0.11**	0.005	**0.0752**	**0.275**	0.005
Jan-19	**0.0561**	0.005	**0.0251**	**0.0424**	0.005
Sum	1.0311		0.37720	1.81510	0.0238
n_i	10		5	5	5
$(x_i)_{avg}$	0.10311		0.07544	0.36302	0.0048

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.12989

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	3.25	x.. = the sum of the total number of samples

Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Chromium (mg/L)	Adjusted Rank	Tie Number
1	0	5	
2	0	5	
3	0	5	
4	0	5	
5	0	5	Tie 1
6	0	5	
7	0	5	
8	0	5	
9	0	5	
10	**0.00381**	10	
11	**0.0251**	11	
12	**0.0309**	12	
13	**0.0424**	13	
14	**0.0557**	14	
15	**0.0561**	15	
16	**0.0752**	16	
17	**0.103**	17	
18	**0.11**	18	
19	**0.143**	19	
20	**0.151**	20	
21	**0.261**	21	
22	**0.262**	22	
23	**0.275**	23	
24	**0.428**	24	
25	**1.18**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
9	Tie 1 = 720
	$\sum T_i$ = 720

Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Sums of Ranks and Averages

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.428**	0	**0.0309**	**0.262**	0
Jul-17	**0.261**	0	**0.103**	**0.0557**	0
Jan-18	**0.151**	0	**0.143**	**1.18**	**0.00381**
Aug-18	**0.11**	0	**0.0752**	**0.275**	0
Jan-19	**0.0561**	0	**0.0251**	**0.0424**	0

Observation Ranks for Chromium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	24	5	12	22	5
Jul-17	21	5	17	14	5
Jan-18	20	5	19	25	10
Aug-18	18	5	16	23	5
Jan-19	15	5	11	13	5
R_i	123		75	97	30
$(R_i)_{avg}$	12.3		15.0	19.4	6.0
R_i^2/n_i	1512.9		1125.0	1881.8	180.0

$\Sigma R_i^2/n_i$ = 4699.7

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.

K = 4
N = 25

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 8.764 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 9.188 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit}* = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.
If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 = 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280
α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE: *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B3: Chromium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 12.3

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	2.70	not contaminated
	MW87	8.578	7.10	not contaminated
	MW90A	8.578	-6.30	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW84, MW87, and MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill; however, the negative value indicates that background wells have elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

ATTACHMENT B4

LEAD
STATISTICAL TEST 3

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Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.00155**	0.001	**0.00475**	**0.00439**	0.001
Jul-17	**0.00213**	0.001	**0.00267**	**0.00533**	0.001
Jan-18	**0.00186**	0.001	**0.00191**	**0.00579**	**0.000634**
Aug-18	**0.000802**	0.001	**0.00319**	**0.00682**	0.001
Jan-19	0.001	0.001	**0.00204**	**0.00502**	0.001
Sum	0.0123		0.01456	0.02735	0.0046
n_i	10		5	5	5
$(x_i)_{avg}$	0.00123		0.00291	0.00547	0.0009

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.00236

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.06	x.. = the sum of the total number of samples

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Lead (mg/L)	Adjusted Rank	Tie Number
1	0	5.5	Tie 1
2	0	5.5	
3	0	5.5	
4	0	5.5	
5	0	5.5	
6	0	5.5	
7	0	5.5	
8	0	5.5	
9	0	5.5	
10	0	5.5	
11	**0.000634**	11	
12	**0.000802**	12	
13	**0.00155**	13	
14	**0.00186**	14	
15	**0.00191**	15	
16	**0.00204**	16	
17	**0.00213**	17	
18	**0.00267**	18	
19	**0.00319**	19	
20	**0.00439**	20	
21	**0.00475**	21	
22	**0.00502**	22	
23	**0.00533**	23	
24	**0.00579**	24	
25	**0.00682**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3-n_{tie})$	
10	Tie 1 =	990
	$\sum T_i$ =	990

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Sums of Ranks and Averages

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.00155**	0	**0.00475**	**0.00439**	0
Jul-17	**0.00213**	0	**0.00267**	**0.00533**	0
Jan-18	**0.00186**	0	**0.00191**	**0.00579**	**0.000634**
Aug-18	**0.000802**	0	**0.00319**	**0.00682**	0
Jan-19	0	0	**0.00204**	**0.00502**	0

Observation Ranks for Lead					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	13	5.5	21	20	5.5
Jul-17	17	5.5	18	23	5.5
Jan-18	14	5.5	15	24	11
Aug-18	12	5.5	19	25	5.5
Jan-19	5.5	5.5	16	22	5.5
R_i	89		89	114	33
$(R_i)_{avg}$	8.9		17.8	22.8	6.6
R_i^2/n_i	792.1		1584.2	2599.2	217.8

$\Sigma R_i^2/n_i$ = 5193.3

K = 4

N = 25

mg/L = milligrams per liter

BG = background

DL = detection limit

K = the number of n_i groups

N = the total number of samples

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 17.876 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 19.088 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit}* = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.
If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 = 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280

α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE: *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 8.9

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	8.90	**evidence of contamination**
	MW87	8.578	13.90	**evidence of contamination**
	MW90A	8.578	-2.30	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84 and MW87, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 and MW87 from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance wells MW84 and MW87, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW90A, there is no statistically significant difference between background wells and this downgradient compliance test well; however, the negative value indicates that the background wells have elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

January 2019 Data, First Reporting Period
Observations (mg/L)

Well No.						
MW93	**0.00155**	**0.00213**	**0.00186**	**0.000802**	0.001	**Upgradient Well**[!]
MW420	0.001	0.001	0.001	0.001	0.001	**Upgradient Well**[!]
						Current Data
MW84		X: Mean Value =	0.0012			0.00204
MW87		S: Standard Deviation =	0.0004			**0.00502**
MW90A		K* factor =	2.911	(for n = 10)		0.001
		CV = S/X	0.3633	<1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**0.0025**	(mg/L)	

! = Data from previous 5 sampling events.
CV = coefficient of variation
* = Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Result: **MW87 exceeded the UTL, which is statistically significant evidence that the compliance well has elevated concentrations with respect to background data.**

Because the 95% UTL indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW87, the paired ANOVA was performed.

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Paired (Parametric) ANOVA - MW93 and MW87

Evaluate results using paired ANOVA of wells in the same direction relative to the landfill [e.g., compare upgradient westernmost well results to downgradient westernmost well results]. If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

Lead (mg/L)				
Date	Background	Compliance		
	MW93	MW87	n_i^2	
Jan-17	**0.00155**	**0.00439**	0.0000024	0.0000193
Jul-17	**0.00213**	**0.00533**	0.0000045	0.0000284
Jan-18	**0.00186**	**0.00579**	0.0000035	0.0000335
Aug-18	**0.000802**	**0.00682**	0.0000006	0.0000465
Jan-19	0.001	**0.00502**	0.0000010	0.0000252
Sum (x_i)	0.007	0.02735	0.0347	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.001	0.00547		
$(x_i)^2$	0.00005	0.00075		

mg/L = milligrams per liter
Bolded values indicate a detected result.

Overall mean x.. =	0.00347	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.0347	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals ($x_i - x_{iavg}$)

Date	Background	Compliance
	MW93	MW87
Jan-17	0.00008	-0.00108
Jul-17	0.00066	-0.00014
Jan-18	0.00039	0.00032
Aug-18	-0.00067	0.00135
Jan-19	-0.00047	-0.00045

X: Mean Value =	-4.34E-20	
S: Standard Deviation =	0.00071	
K* Factor =	2.911	(for n = 10)
CV = S/X =	–1.64E+16	<1, data are normally distributed

Data are normally distributed (i.e., < 1).

*Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

If the coefficient of variation is < 1, the data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} =$ 0.0347
n_i = number of data points per well	$(x_{avg})_{..} =$ 0.00347
N = total sample size	$n_i =$ 5
S^2 = the square of the standard deviation	p = 2
$\ln(S_i^2)$ = natural logarithm of each variance	N = 10
f = total sample size minus the number of wells (groups)	f_i = 4
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$†	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$†
0.000562	0.00000031530	-14.970	5	0.0000013	-59.9
0.00091	0.00000082835	-14.004	5	0.0000033	-56.0

$\sum(S_i^2) =$ 0.000001144 $\sum f_i \ln(S_i^2) =$ -115.89425

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.0000006	
ln Sp^2 =	-14.374	
χ^2 =	0.899	(If calculated $\chi^2 \leq$ tabulated χ^2_{crit}, then variances are equal at the given significance level).
χ^2_{crit} * =	3.841	at a 5% significance level with 1 degrees of freedom (p-1)

NOTE: The variances are equal. (i.e., calculated $\chi^2 \leq \chi^2_{crit}$).

Since calculated $\chi^2 \leq \chi^2_{crit}$, then the analysis can proceed as normal.

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	0.000040	1	0.000040	70.01	5.32
Error	SS_{Error} =	0.000005	8	0.000001		
Total	SS_{Total} =	0.000045	9			

If calculated F > F statistic, then reject the hypothesis of equal well means. If calculated F is less than or equal to F statistic, it can be concluded that there is no significant difference between concentrations; therefore, there is no evidence of well contamination.

CONCLUSION: **Calculated F > F statistic; therefore, ANOVA has identified a significant difference between background and downgradient wells.**

Because the paired ANOVA for the two wells indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW87, a Mann-Kendall statistical analysis was performed.

**Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989). F statistic taken at the 5% significance level.

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for Lead in MW87

Input Data

Date Collected	Result (mg/L)
Jul-15	0.002
Jan-16	**0.00107**
Jul-16	**0.0056**
Jan-17	**0.00439**
Jul-17	**0.00533**
Jan-18	**0.00579**
Aug-18	**0.00682**
Jan-19	**0.00502**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	ProUCL 5.13/13/2019 3:02:58 PM
From File	MW87 lead ProUCL.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW87 lead 1Q2019

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	0.00107
Maximum	0.00682
Mean	0.0045
Geometric Mean	0.00392
Median	0.00518
Standard Deviation	0.00197
Coefficient of Variation	0.438

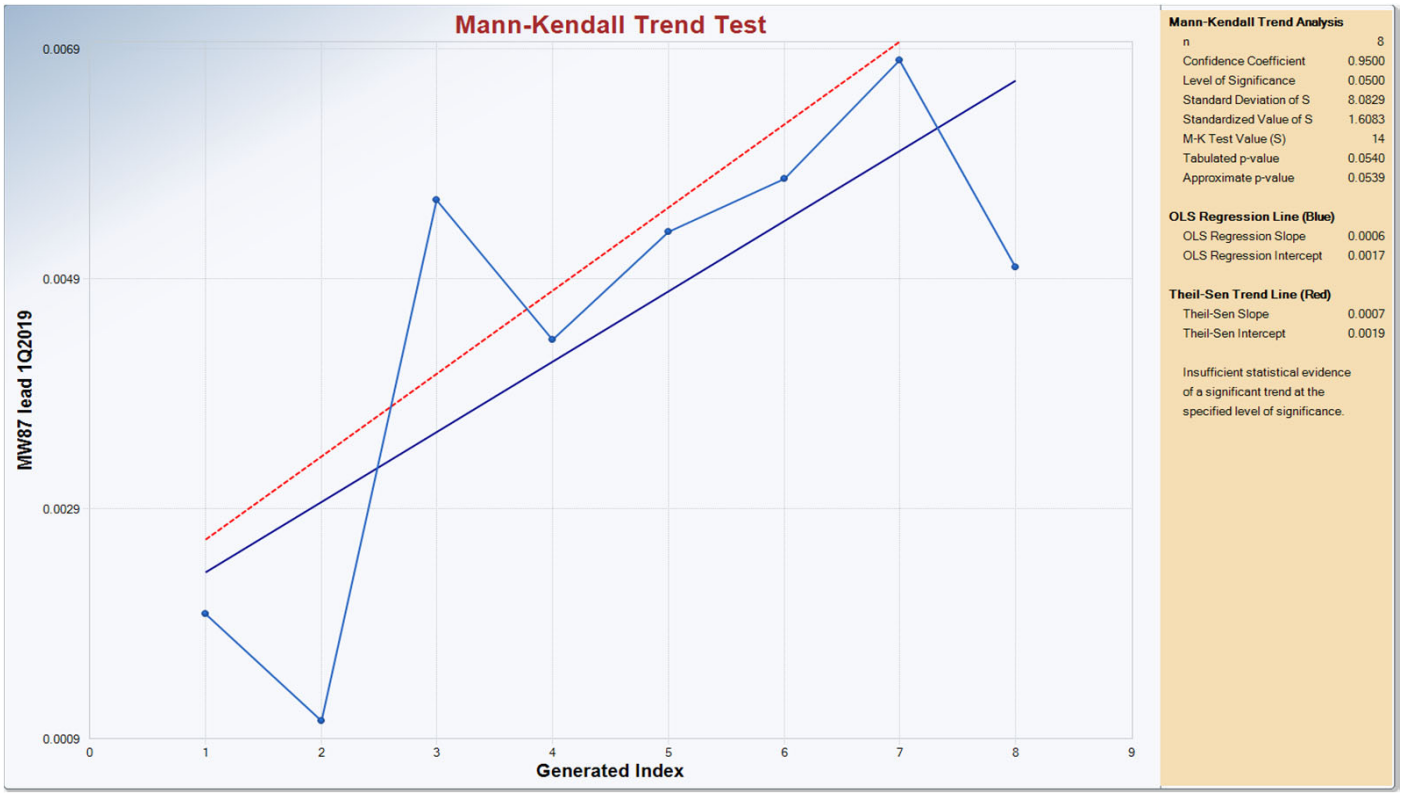
Mann-Kendall Test

M-K Test Value (S)	14
Tabulated p-value	0.054
Standard Deviation of S	8.083
Standardized Value of S	1.608
Approximate p-value	0.0539

Insufficient evidence to identify a significant trend at the specified level of significance.

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for Lead in MW87



ATTACHMENT B5

TECHNETIUM-99
STATISTICAL TEST 2

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Attachment B5: Technetium-99 URGA, Statistical Test 2, Test of Proportions, First Reporting Period 2019

Technetium-99 (pCi/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	6.75	6.8	8.15	6.9	7.2
Jul-17	9.85	9.7	10.05	9.9	9.55
Jan-18	9.4	**21.5**	**34.4**	9.45	9.2
Aug-18	7.35	9.2	6.75	7.5	7.3
Jan-19	11.05	9.5	**28.8**	9.5	7.9

pCi/L = picocuries per liter
BG = background
DL = detection limit
Nondetect values are 1/2 DL.
Bolded values indicate a detected result.

[!] **Test of Proportions**

Calculate the number of detections in background wells vs. compliance wells.

X =	1	X = number of samples above DL in background wells
Y =	2	Y = number of samples above DL in compliance wells
n_b =	10	n_b = count of background well results/samples analyzed
n_c =	15	n_c = count of compliance well results/samples analyzed
n =	25	n = total number of samples

P =	0.120	P=(x+y)/n
nP =	3	$n=n_b+n_c$
n(1-P) =	22	

NOTE: If nP and n(1-P) are both >= 5, then the normal approximation may be used; however, because nP < 5 and/or n(1-P) < 5, the test was continued to determine if the conclusion, along with a simple evaluation of the data would be similar.

P_b =	0.100	P_b = proportion of detects in background wells
P_c =	0.133	P_c = proportion of detects in compliance wells
S_D =	0.133	S_D = standard error of difference in proportions
Z =	-0.251	$Z = (P_b-P_c)/S_D$
absolute value of Z =	0.251	

If the absolute value of Z exceeds the 97.5th percentile value of 1.96 from the standard normal distribution, this provides statistically significant evidence at the 5% significance level that the proportion of detects in one group of data exceeds the proportion of detects in the other group.

CONCLUSION: **Because the absolute value of Z is less than 1.96, there is no statistical evidence that the proportion of samples with detected results differs between the background well and compliance well samples.**

[!] Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B6

TRICHLOROETHENE
STATISTICAL TESTS 4/3

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Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, First Reporting Period 2019

Trichloroethene (TCE, µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**2450**	**274**	**2620**	**2240**	**49.5**
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**
n_i	10		5	5	5
Sum	8691		19530	9330	259.40
(x_i)avg	869.10		3906.00	1866.00	51.88

µg/L = micrograms per liter
Bolded values indicate a detected result.

Overall mean x.. =	1512.42	
N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	37810.40	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals

Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	1580.90	-595.10	-1286.00	374.00	-2.38
Jul-17	530.90	-605.10	-996.00	-246.00	-5.78
Jan-18	124.90	-637.10	-746.00	-466.00	-11.28
Aug-18	130.90	-393.10	1354.00	-176.00	1.42
Jan-19	130.90	-268.10	1674.00	514.00	18.02

X: Mean Value =	1.93E-14	
S: Standard Deviation =	728.4	
K* Factor =	2.292	(for n = 25)
CV = S/X =	3.77E+16	> or = 1, data are not normally distributed

*K factor [from Table 5, Appendix B of *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

If the coefficient of variation is < 1, the data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, First Reporting Period 2019

Determine Equality of Variance of Dataset

p = number of wells
n_i = number of data points per well
N = total sample size
S^2 = the square of the standard deviation
$\ln(S_i^2)$ = natural logarithm of each variance
f = total sample size minus the number of wells (groups)
$f_i = n_i - 1$

$x_{..} =$ 37810.40
$(x_{avg})_{..} =$ 1512.42

p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
681.792	464840.10	13.049	10	4183560.9	117.4
1399.814	1959480.00	14.488	5	7837920.000	58.0
422.114	178180.00	12.091	5	712720.000	48.4
11.102	123.26	4.814	5	493.048	19.3

$\sum(S_i^2) =$ 2602623.36 $\sum f_i \ln(S_i^2) =$ 243.0

Equality of Variance: Bartlett's Test

$f =$ 21
$Sp^2 =$ 606413.998
$\ln Sp^2 =$ 13.315
$\chi^2 =$ 36.604 (If $\chi^2 \leq \chi^2_{crit}$, then variances are equal at the given significance level).
χ^2_{crit} * = 7.815 at a 5% significance level with 3 degrees of freedom

NOTE: The variances are NOT equal. (i.e., $\chi^2 > \chi^2_{crit}$)

Variances are not equal, transform the original data to lognormal (i.e., since $\chi^2 > \chi^2_{crit}$).

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, First Reporting Period 2019

Lognormal Data for TCE

ln[TCE (µg/L)]					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	7.80	5.61	7.87	7.71	3.90
Jul-17	7.24	5.58	7.98	7.39	3.83
Jan-18	6.90	5.45	8.06	7.24	3.70
Aug-18	6.91	6.17	8.57	7.43	3.98
Jan-19	6.91	6.40	8.63	7.77	4.25
x_i	64.97		41.10	37.56	19.66
(x_i)avg	6.50		8.22	7.51	3.93

µg/L = micrograms per liter

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals for Lognormal Data

Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	1.31	-0.88	-0.35	0.20	-0.03
Jul-17	0.75	-0.92	-0.24	-0.12	-0.10
Jan-18	0.41	-1.05	-0.16	-0.27	-0.23
Aug-18	0.41	-0.33	0.35	-0.08	0.04
Jan-19	0.41	-0.10	0.41	0.26	0.32

X: Mean Value = -8.88E-17
S: Standard Deviation = 0.52
K* Factor = 2.292 (for n = 25)
CV = S/X = –5.85E+15 <1, data are normally distributed

*K factor [from Table 5, Appendix B of *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Attachment B6: Trichloroethene URGA, Statistical Test 4, Parametric ANOVA, First Reporting Period 2019

Determine Equality of Variance of Dataset for Lognormal Data

p = number of wells (background wells considered as one group)
n_i = number of data points per well
N = total sample size
S^2 = the square of the standard deviation
$\ln(S_i^2)$ = natural logarithm of each variance
f = total sample size minus the number of wells (groups)
$f_i = n_i - 1$

$x_{..} =$ 163.28
$(x_{avg})_{..} =$ 6.53
p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	ni	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.790	0.624	-0.471	10	5.620	-4.2
0.351	0.124	-2.091	5	0.494	-8.4
0.225	0.051	-2.982	5	0.203	-11.9
0.203	0.041	-3.192	5	0.164	-12.8

$\sum(S_i^2) =$ 0.84 $\sum f_i\ln(S_i^2) =$ -37.3

Equality of Variance: Bartlett's Test

$f =$ 21
$Sp^2 =$ 0.309
$\ln Sp^2 =$ -1.176
$\chi^2 =$ 12.608 (If $\chi^2 \leq \chi^2_{crit}$, then variances are equal at the given significance level).
χ^2_{crit} * = 7.815 at a 5% significance level with 3 degrees of freedom

NOTE: The variances are NOT equal. (i.e., $\chi^2 > \chi^2_{crit}$)

Because variances are not equal, Statistical Test 3, Nonparametric ANOVA is performed.**

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

**Section 5.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989)].

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**2450**	**274**	**2620**	**2240**	**49.5**
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**
n_i	10		5	5	5
x_i	8691		19530	9330	259.40
(x_i)avg	869.10		3906.00	1866.00	51.88

µg/L = micrograms per liter
BG=background
DL=detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 1512.42

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	37810.40	x.. = the sum of the total number of samples

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	TCE (µg/L)	Adjusted Rank	Tie Number
1	**40.6**	1	
2	**46.1**	2	
3	**49.5**	3	
4	**53.3**	4	
5	**69.9**	5	
6	**232**	6	
7	**264**	7	
8	**274**	8	
9	**476**	9	
10	**601**	10	
11	**994**	11	
12	**1000**	12.5	Tie 1
13	**1000**	12.5	
14	**1400**	14.5	Tie 2
15	**1400**	14.5	
16	**1620**	16	
17	**1690**	17	
18	**2240**	18	
19	**2380**	19	
20	**2450**	20	
21	**2620**	21	
22	**2910**	22	
23	**3160**	23	
24	**5260**	24	
25	**5580**	25	

µg/L = micrograms per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$	
2	Tie 1 =	6
2	Tie 2 =	6
	$\sum T_i$ =	12

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Sums of Ranks and Averages

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**2450**	**274**	**2620**	**2240**	**49.5**
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
Aug-18	**1000**	**476**	**5260**	**1690**	**53.3**
Jan-19	**1000**	**601**	**5580**	**2380**	**69.9**

Observation Ranks for TCE					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	20	8	21	18	3
Jul-17	14.5	7	22	16	2
Jan-18	11	6	23	14.5	1
Aug-18	12.5	9	24	17	4
Jan-19	12.5	10	25	19	5
$R_{i.}$	110.5		115	84.5	15
$(R_i)_{avg}$	11.1		23.0	16.9	3
R_i^2/n_i	1221.0		2645.0	1428.1	45

$\Sigma R_i^2/n_i$ = 5339.1

K = 4

N = 25

µg/L = micrograms per liter
BG=background
DL=detection limit

K = the number of n_i groups
N = the total number of samples

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 20.568 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 20.583 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit} * = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.
If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 = 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280

α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE: *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (USEPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (USEPA 1989).

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 11.1

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	11.95	**evidence of contamination**
	MW87	8.578	5.85	not contaminated
	MW90A	8.578	-8.05	not contaminated

µg/L = micrograms per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84, there is a statistically significant difference between compliance test wells and background wells in MW84 at the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87 and MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill; however, the negative value indicates that background wells have elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

January 2019 Data, First Reporting Period
Observations (µg/L)

Well No.						
MW93	**2450**	**1400**	**994**	**1000**	**1000**	**Upgradient Well!**
MW420	**274**	**264**	**232**	**476**	**601**	**Upgradient Well!**
						Current Data
MW84		X: Mean Value =	869			**5580**
MW87		S: Standard Deviation =	682			2380
MW90A		K* factor =	2.911	(for n = 10)		69.9
		CV = S/X	0.7845	<1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**2854**	(µg/L)	

! = Data from previous 5 sampling events.
CV = coefficient of variation
* = Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Result: **MW84 exceeded the UTL, which is statistically significant evidence that this compliance well has elevated concentration with respect to background data.**

Because the 95% UTL indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, the paired ANOVA was performed.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Paired (Parametric) ANOVA - MW93 and MW84

Evaluate results using paired ANOVA of wells in the same direction relative to the landfill [e.g., compare upgradient westernmost well results to downgradient westernmost well results]. If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

TCE (µg/L)				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jan-17	**2450**	**2620**	6002500	6864400
Jul-17	**1400**	**2910**	1960000	8468100
Jan-18	**994**	**3160**	988036	9985600
Aug-18	**1000**	**5260**	1000000	27667600
Jan-19	**1000**	**5580**	1000000	31136400
Sum (x_i)	6844	19530	26374	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	1369	3906		
$(x_i)^2$	46840336	381420900		

µg/L = micrograms per liter
Bolded values indicate a detected result.

Overall mean x.. =	2637	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	26374	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals ($x_i - x_{iavg}$)

Date	Background	Compliance
	MW93	MW84
Jan-17	1081	-1286
Jul-17	31	-996
Jan-18	-375	-746
Aug-18	-369	1354
Jan-19	-369	1674

X: Mean Value =	0.00E+00	
S: Standard Deviation =	1023	
K* Factor =	2.911	(for n = 10)
CV = S/X =	#ΔIς/0!	#DIV/0!

†The Coefficient of Variability Test was not performed due to mean = 0 (i.e., division by 0 not possible).

*Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

If the coefficient of variation is < 1, the data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} =$ 26374
n_i = number of data points per well	$(x_{avg})_{..} =$ 2637
N = total sample size	$n_i =$ 5
S^2 = the square of the standard deviation	p = 2
$\ln(S_i^2)$ = natural logarithm of each variance	N = 10
f = total sample size minus the number of wells (groups)	f_i = 4
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$†	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$†
629	395617	12.888	5	1582469	51.6
1400	1959480	14.488	5	7837920	58.0

$\sum(S_i^2) =$ 2,355,097 $\sum f_i \ln(S_i^2) =$ 110

Equality of Variance: Bartlett's Test

f =	8	
$Sp^2 =$	1177549	
$\ln Sp^2 =$	13.979	
$\chi^2 =$	2.326	(If calculated $\chi^2 \leq$ tabulated χ^2_{crit}, then variances are equal at the given significance level).
χ^2_{crit} * =	3.841	at a 5% significance level with 1 degrees of freedom (p-1)

NOTE: The variances are equal. (i.e., calculated $\chi^2 \leq \chi^2_{crit}$)

Since calculated $\chi^2 \leq \chi^2_{crit}$, then the analysis can proceed as normal.

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	16093459.60	1	16093459.60	13.67	5.32
Error	SS_{Error} =	9420388.80	8	1177548.60		
Total	SS_{Total} =	25513848.40	9			

If calculated F > F statistic, then reject the hypothesis of equal well means. If calculated F is less than or equal to F statistic, it can be concluded that there is no significant difference between concentrations; therefore, there is no evidence of well contamination.

CONCLUSION: **Calculated F > F statistic; therefore, ANOVA has identified a significant difference between background and downgradient wells.**

Because the paired ANOVA for the two wells indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW84, a Mann-Kendall statistical analysis was performed.

**Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989). F statistic taken at the 5% significance level.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for TCE in MW84

Input Data

Date Collected	Result (µg/L)
Jul-15	**1530**
Jan-16	**1350**
Jul-16	**1820**
Jan-17	**2620**
Jul-17	**2910**
Jan-18	**3160**
Aug-18	**5260**
Jan-19	**5580**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options	
Date/Time of Computation	ProUCL 5.13/14/2019 9:05:35 AM
From File	MW84 TCE ProUCL.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84 TCE 1Q2019

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	1350
Maximum	5580
Mean	3029
Geometric Mean	2680
Median	2765
Standard Deviation	1613
Coefficient of Variation	0.533

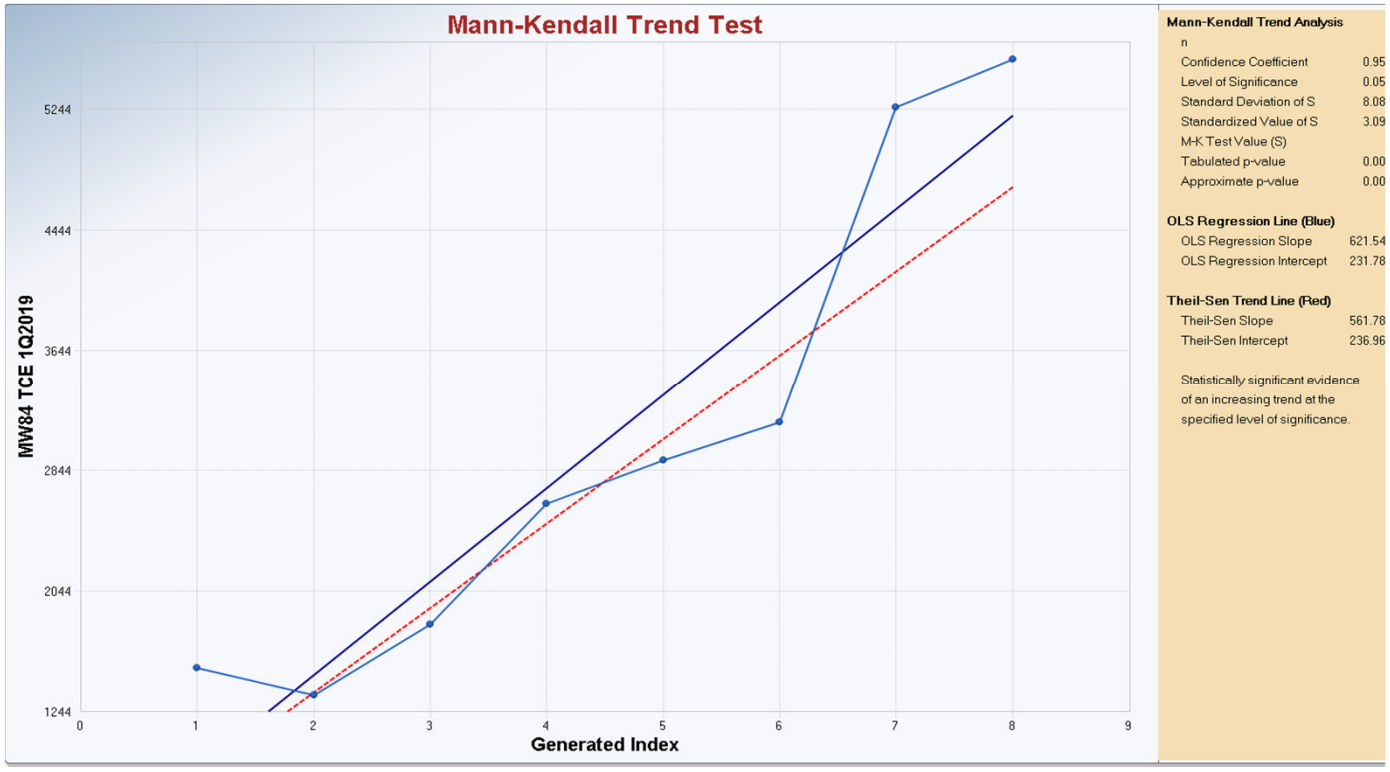
Mann-Kendall Test

M-K Test Value (S)	26
Tabulated p-value	0
Standard Deviation of S	8.083
Standardized Value of S	3.093
Approximate p-value	9.9089E-4

Statistically significant evidence of an increasing trend at the specified level of significance.

Attachment B6: Trichloroethene URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for TCE in MW84



ATTACHMENT B7

URANIUM
STATISTICAL TEST 3

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Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.000223**	0.0001	**0.000618**	**0.000522**	0.0001
Jul-17	**0.000224**	0.0001	**0.000355**	**0.000571**	0.0001
Jan-18	0.0001	0.0001	**0.0002**	**0.000681**	0.0001
Aug-18	**0.000113**	0.0001	**0.000302**	**0.000722**	0.0001
Jan-19	0.0001	0.0001	**0.000193**	**0.00042**	0.0001
Sum	0.0013		0.00167	0.00292	0.0005
n_i	10		5	5	5
$(x_i)_{avg}$	0.00013		0.00033	0.00058	0.0001

mg/L = milligrams per liter
BG = background
DL = detection limit
All data sets represent 1/2 DL values for nondetects.
Bolded values indicate a detected result.

Overall mean x.. = 0.00025

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.01	x.. = the sum of the total number of samples

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Uranium (mg/L)	Adjusted Rank	Tie Number
1	0	6.5	Tie 1
2	0	6.5	
3	0	6.5	
4	0	6.5	
5	0	6.5	
6	0	6.5	
7	0	6.5	
8	0	6.5	
9	0	6.5	
10	0	6.5	
11	0	6.5	
12	0	6.5	
13	**0.000113**	13	
14	**0.000193**	14	
15	**0.0002**	15	
16	**0.000223**	16	
17	**0.000224**	17	
18	**0.000302**	18	
19	**0.000355**	19	
20	**0.00042**	20	
21	**0.000522**	21	
22	**0.000571**	22	
23	**0.000618**	23	
24	**0.000681**	24	
25	**0.000722**	25	

mg/L = milligrams per liter
BG = background
DL = detection limit
Bolded values indicate a detected result.
NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

n_{tie}	Adjustment for Ties: $(n_{tie}^3-n_{tie})$	
12	Tie 1 =	1716
	$\sum T_i$ =	1716

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Sums of Ranks and Averages

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	**0.000223**	0	**0.000618**	**0.000522**	0
Jul-17	**0.000224**	0	**0.000355**	**0.000571**	0
Jan-18	0	0	**0.0002**	**0.000681**	0
Aug-18	**0.000113**	0	**0.000302**	**0.000722**	0
Jan-19	0	0	**0.000193**	**0.00042**	0

Observation Ranks for Uranium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-17	16	6.5	23	21	6.5
Jul-17	17	6.5	19	22	6.5
Jan-18	6.5	6.5	15	24	6.5
Aug-18	13	6.5	18	25	6.5
Jan-19	6.5	6.5	14	20	6.5
R_i	91.5		89	112	32.5
$(R_i)_{avg}$	9.2		17.8	22.4	6.5
R_i^2/n_i	837.2		1584.2	2508.8	211.3

$\Sigma R_i^2/n_i$ = 5141.5

K = 4

N = 25

mg/L = milligrams per liter

BG = background

DL = detection limit

K = the number of n_i groups

N = the total number of samples

Bolded values indicate a detected result.

NOTE: For this method, observations below the detection limit that are considered nondetects (i.e., U qualified data) are reported as a concentration of 0.

Calculation of Kruskal-Wallis Statistic

H = 16.920 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 19.011 Corrected Kruskal-Wallis $H' = H/[1-(\sum T_i/N^3-N)]$

χ^2_{crit}* = 7.815 3 degrees of freedom at the 5% significance level

NOTE: $H' > \chi^2_{crit}$

If $H' \leq \chi^2_{crit}$, the data from each well come from the same continuous distribution and hence have the same median concentrations of a specific constituent.
If $H' > \chi^2_{crit}$, reject the null hypothesis and calculate the critical difference for well comparisons to the background.

K-1 = 3 $\alpha/(K-1)$ = 0.01667 $Z(\alpha/(K-1))$** = 2.1280

α = 0.05 $1-(\alpha/K-1)$ = 0.983

NOTE: *Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).
**Table 4, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Calculate Critical Values

Average Background Ranking = 9.2

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	8.65	**evidence of contamination**
	MW87	8.578	13.25	**evidence of contamination**
	MW90A	8.578	-2.65	not contaminated

mg/L = milligrams per liter
BG = background
DL = detection limit

CONCLUSION: If $(R_i)_{avg} - (R_b)_{avg} > C_i$, then there is evidence that the compliance well is contaminated.

If $(R_i)_{avg} - (R_b)_{avg} < C_i$ for wells, there is no evidence of a statistically significant difference between concentrations in downgradient compliance test wells and background wells.

Since $(R_i)_{avg} - (R_b)_{avg} > C_i$ for MW84 and MW87, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 and MW87 from the C-404 Landfill.

Because nonparametric ANOVA indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance wells MW84 and MW87, the 95% UTL was performed.

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW90A, there is no statistically significant difference between background wells and this downgradient compliance test well; however, the negative value indicates that the background wells have elevated concentrations.

Section 5.2.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

95% Upper Tolerance Limit (UTL)

Compare the most recent downgradient sample results to a calculated 95% UTL using the five most recent sets of data for each upgradient well, as described below. If downgradient concentration is less than the UTL for the paired upgradient concentrations, then there is no confirmed exceedance.

January 2019 Data, First Reporting Period
Observations (mg/L)

Well No.						
MW93	**0.000223**	**0.000224**	0.0001	**0.000113**	0.0001	**Upgradient Well**[!]
MW420	0.0001	0.0001	0.0001	0.0001	0.0001	**Upgradient Well**[!]
						Current Data
MW84		X: Mean Value =	0.0001			0.000193
MW87		S: Standard Deviation =	0.0001			**0.00042**
MW90A		K* factor =	2.911	(for n = 10)		0.0001
		CV = S/X	0.4091	<1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**0.0003**	(mg/L)	

! = Data from previous 5 sampling events.
CV = coefficient of variation
* = Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Result: **MW87 exceeded the UTL, which is statistically significant evidence that the compliance well has elevated concentrations with respect to background data.**

Because the 95% UTL indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW87, the paired ANOVA was performed.

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Paired (Parametric) ANOVA - MW93 and MW87

Evaluate results using paired ANOVA of wells in the same direction relative to the landfill [e.g., compare upgradient westernmost well results to downgradient westernmost well results]. If ANOVA does not identify a statistically significant difference between upgradient and downgradient wells, then the results are consistent with the historical ASD.

Uranium (mg/L)				
Date	Background	Compliance		
	MW93	MW87	n_i^2	
Jan-17	**0.000223**	**0.000522**	0.00000005	0.0000003
Jul-17	**0.000224**	**0.000571**	0.00000005	0.0000003
Jan-18	0.0001	**0.000681**	0.0000000	0.0000005
Aug-18	**0.000113**	**0.000722**	0.00000001	0.0000005
Jan-19	0.0001	**0.00042**	0.00000001	0.0000002
Sum (x_i)	0.00076	0.00292	0.0037	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.000152	0.00058		
$(x_i)^2$	0.000001	0.00001		

mg/L = milligrams per liter
Bolded values indicate a detected result.

Overall mean x.. =	0.00037	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.0037	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test

Table of Residuals ($x_i - x_{iavg}$)

Date	Background	Compliance
	MW93	MW87
Jan-17	0.00007	-0.00006
Jul-17	0.00007	-0.00001
Jan-18	-0.00005	0.00010
Aug-18	-0.00004	0.00014
Jan-19	-0.00005	-0.00016

X: Mean Value =	-5.96E-20	
S: Standard Deviation =	0.00009	
K* Factor =	2.911	(for n = 10)
CV = S/X =	–1.55E+15	<1, data are normally distributed

Data are normally distributed (i.e., < 1).

*Table 5, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

If the coefficient of variation is < 1, the data are normally distributed.
If the coefficient of variation is > or = 1, data are not normally distributed.

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 0.0037$
n_i = number of data points per well	$(x_{avg})_{..} = 0.00037$
N = total sample size	$n_i = 5$
S^2 = the square of the standard deviation	p = 2
$\ln(S_i^2)$ = natural logarithm of each variance	N = 10
f = total sample size minus the number of wells (groups)	$f_i = 4$
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$†	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$†
0.000065	0.00000000429	-19.267	5	0.00000002	-77.1
0.00012	0.00000001484	-18.026	5	0.00000006	-72.1

$\sum(S_i^2)$ = 0.000000019 $\sum f_i \ln(S_i^2)$ = -149.17315

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.00000001	
ln Sp^2 =	-18.465	
χ^2 =	1.451	(If calculated $\chi^2 \leq$ tabulated χ^2_{crit}, then variances are equal at the given significance level).
χ^2_{crit} * =	3.841	at a 5% significance level wit 1 degrees of freedom (p-1)

NOTE: The variances are equal. (i.e., calculated $\chi^2 \leq \chi^2_{crit}$).

Since calculated $\chi^2 \leq \chi^2_{crit}$, then the analysis can proceed as normal.

*Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989).

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Between Well Sum of Squares

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	SS_{wells} =	0.0000005	1	0.0000005	48.60	5.32
Error	SS_{Error} =	0.00000008	8	0.00000001		
Total	SS_{Total} =	0.000001	9			

If calculated F > F statistic, then reject the hypothesis of equal well means. If calculated F is less than or equal to F statistic, it can be concluded that there is no significant difference between concentrations; therefore, there is no evidence of well contamination.

CONCLUSION: **Calculated F > F statistic; therefore, ANOVA has identified a significant difference between background and downgradient wells.**

Because the paired ANOVA for the two wells indicated a statistically significant difference between compliance test wells and background wells at the C-404 Landfill in compliance well MW87, a Mann-Kendall statistical analysis was performed.

**Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance* (EPA 1989). F statistic taken at the 5% significance level.

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, First Reporting Period 2019

Mann-Kendall Statistical Analysis for Uranium in MW87

Input Data

Date Collected	Result (mg/L)
Jul-15	0.0002
Jan-16	0.0002
Jul-16	**0.000559**
Jan-17	**0.000522**
Jul-17	**0.000571**
Jan-18	**0.000681**
Aug-18	**0.000722**
Jan-19	**0.00042**

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	ProUCL 5.13/13/2019 3:34:41 PM
From File	MW87 uranium ProUCL.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW87 uranium 1Q2019

General Statistics

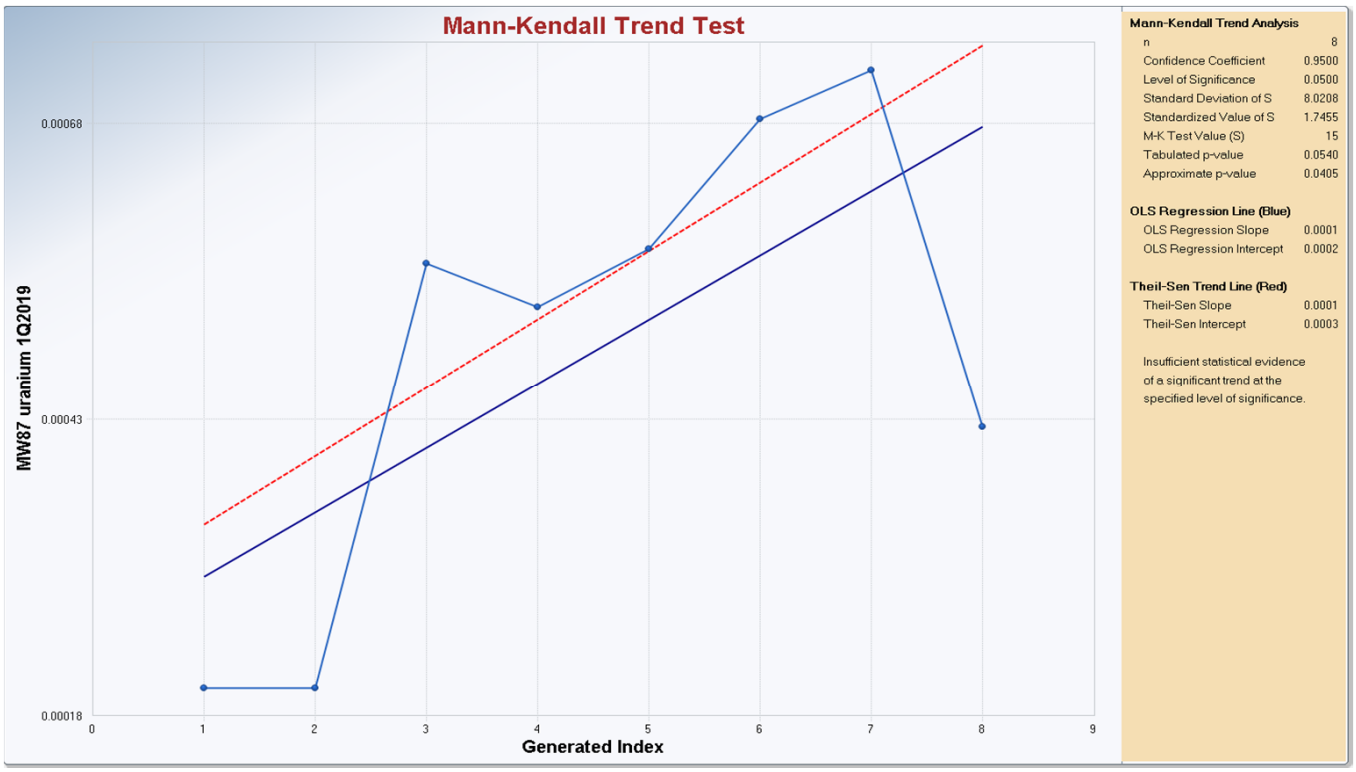
Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	2.0000E-4
Maximum	7.2200E-4
Mean	4.8438E-4
Geometric Mean	4.3887E-4
Median	5.4050E-4
Standard Deviation	1.9839E-4
Coefficient of Variation	0.41

Mann-Kendall Test

M-K Test Value (S)	15
Tabulated p-value	0.054
Standard Deviation of S	8.021
Standardized Value of S	1.745
Approximate p-value	0.0405

Insufficient evidence to identify a significant trend at the specified level of significance.

Mann-Kendall Statistical Analysis for Uranium in MW87



ATTACHMENT B8

STATISTICIAN STATEMENT

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Four Rivers Nuclear Partnership, LLC
5511 Hobbs Road
Kevil, KY 42053
www.fourriversnuclearpartnership.com

March 18, 2019

Ms. Kelly Layne
Four Rivers Nuclear Partnership, LLC
5511 Hobbs Road
Kevil, KY 42053

Dear Ms. Layne:

I am submitting this statement as a supplementary document to the completed statistical analysis I performed on the groundwater data for the C-404 Landfill at the Paducah Gaseous Diffusion Plant.

As an Environmental Scientist, with a bachelor's degree in science, I have over 20 years of experience in reviewing and assessing laboratory analytical results associated with environmental sampling and investigation activities. For the generation of these statistical analyses, my work was observed and reviewed by a senior chemist and geologist with Four Rivers Nuclear Partnership, LLC.

For this project, the statistical analyses on groundwater data from January 2017 through January 2019 were performed in accordance with the Hazardous Waste Management Facility Permit, Appendix E using Microsoft Excel 2010 and U.S. Environmental Protection Agency's (EPA's) ProUCL 5.1. The spreadsheets include the results for the following statistical tests:

- Test of Proportions
- Parametric Analysis of Variance (ANOVA)
- Nonparametric ANOVA
- 95% Upper Tolerance Limit
- Mann-Kendall

The statistical analyses procedures were based on EPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance* (1989).

Sincerely,

Jennifer R. Watson

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APPENDIX C

C-404 HAZARDOUS WASTE LANDFILL LEACHATE ANALYTICAL RESULTS

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November 28, 2018
Leachate Analytical Results

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Paducah OREIS Report for 404L19-01

L1404L1-19 from: C404L on 11/28/2018 Media: WW SmpMethod: GR

Comments: 5.11' is the measurement from the top of manhole to the top of leachate water. CB 11-28-18

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	7.28	mg/L	W		0.2			SW846-9056	GEL	I / X / J
FS										
Conductivity	534	umho/cm						FS	FS	/ /
Dissolved Oxygen	5.51	mg/L						FS	FS	/ /
pH	6.77	Std Unit						FS	FS	/ /
Redox	498	mV						FS	FS	/ /
Temperature	54.9	deg F						FS	FS	/ /
METAL										
Arsenic	0.00239	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0745	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
Copper	0.00927	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	0.1	mg/L	U		0.1			SW846-6020	GEL	/ X /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ X /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.00432	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Uranium	61.1	mg/L			0.2			SW846-6020	GEL	I / X /
Zinc	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
PPCB										
PCB-1016	0.0962	ug/L	UY1		0.0962			SW846-8082	GEL	/ X /
PCB-1221	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1232	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1242	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1248	1.24	ug/L			0.0962			SW846-8082	GEL	/ X /
PCB-1254	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
PCB-1260	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	1.24	ug/L			0.0962			SW846-8082	GEL	I / X /
RADS										
Cesium-137	8.78	pCi/L	U		10.7	14.5	14.5	EPA-901.1	GEL	/ X /
Neptunium-237	0.778	pCi/L	U		1.45	0.934	0.937	ASTM-1475-00aM	GEL	/ X /
Plutonium-239/240	-0.0373	pCi/L	U		1.31	0.56	0.561	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	240	pCi/L			18.1	17.6	31.8	DOE TC-02-RC	GEL	/ X /
Thorium-230	0.0709	pCi/L	U		2.03	0.968	0.969	HASL 300, Th-01-RC M	GEL	/ X / FDUP-OUT
Uranium-234	2200	pCi/L			132	400	601	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	367	pCi/L			68.7	185	200	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	28900	pCi/L			88.9	1440	6040	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.0839	mg/L			0.05			EPA-350.1	GEL	/ X / BH-FB,BH-RI

*Verification/Validation/Assessment

Paducah OREIS Report for 404L19-01

L1404LD1-19 from: C404L on 11/28/2018 Media: WW SmpMethod: GR

Comments: 5.11' is the measurement from the top of manhole to the top of leachate water. CB 11-28-18

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	7.39	mg/L	W		0.2			SW846-9056	GEL	I / X / J
FS										
Conductivity	534	umho/cm						FS	FS	/ /
Dissolved Oxygen	5.51	mg/L						FS	FS	/ /
pH	6.77	Std Unit						FS	FS	/ /
Redox	498	mV						FS	FS	/ /
Temperature	54.9	deg F						FS	FS	/ /
METAL										
Arsenic	0.00265	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0762	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
Copper	0.00928	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	0.1	mg/L	U		0.1			SW846-6020	GEL	/ X /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ X /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.00391	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Uranium	55.7	mg/L			0.2			SW846-6020	GEL	I / X /
Zinc	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
PPCB										
PCB-1016	0.1	ug/L	UY1		0.1			SW846-8082	GEL	/ X /
PCB-1221	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1232	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1242	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1248	1.23	ug/L			0.1			SW846-8082	GEL	/ X /
PCB-1254	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1260	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	1.23	ug/L			0.1			SW846-8082	GEL	I / X /
RADS										
Cesium-137	1.72	pCi/L	U		9.67	5.03	5.09	EPA-901.1	GEL	/ X /
Neptunium-237	0.864	pCi/L	U		1.63	1.03	1.03	ASTM-1475-00aM	GEL	/ X /
Plutonium-239/240	0.284	pCi/L	U		1.03	0.651	0.652	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	222	pCi/L			17.5	16.7	29.6	DOE TC-02-RC	GEL	/ X /
Thorium-230	1.77	pCi/L			1.51	1.37	1.41	HASL 300, Th-01-RC M	GEL	/ X / FDUP-OUT
Uranium-234	1870	pCi/L			64.7	276	407	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	269	pCi/L			62.1	119	127	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	23600	pCi/L			50.2	974	3900	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.0493	mg/L	J		0.05			EPA-350.1	GEL	S / X / BH-FB,BH-RI

*Verification/Validation/Assessment

Paducah OREIS Report for 404L19-01

FB404L1-19 from: QC on 11/28/2018 Media: WQ SmpMethod:

Comments:

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	0.0607	mg/L	JW		0.1			SW846-9056	GEL	/x/
METAL										
Arsenic	0.005	mg/L	U		0.005			SW846-6020	GEL	/x/
Barium	0.002	mg/L	U		0.002			SW846-6020	GEL	/x/
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/x/
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/x/
Copper	0.000317	mg/L	J		0.001			SW846-6020	GEL	/x/
Iron	0.1	mg/L	U		0.1			SW846-6020	GEL	/x/
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/x/
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/x/
Nickel	0.002	mg/L	U		0.002			SW846-6020	GEL	/x/
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/x/
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/x/
Uranium	0.0002	mg/L	U		0.0002			SW846-6020	GEL	/x/
Zinc	0.01	mg/L	U		0.01			SW846-6020	GEL	/x/
PPCB										
PCB-1016	0.0962	ug/L	UY1		0.0962			SW846-8082	GEL	/x/
PCB-1221	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
PCB-1232	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
PCB-1242	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
PCB-1248	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
PCB-1254	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
PCB-1260	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
Polychlorinated biphenyl	0.0962	ug/L	U		0.0962			SW846-8082	GEL	/x/
RADS										
Cesium-137	0.108	pCi/L	U		6.9	3.61	3.61	EPA-901.1	GEL	/x/
Neptunium-237	-0.233	pCi/L	U		1.08	0.329	0.329	ASTM-1475-00aM	GEL	/x/
Plutonium-239/240	-0.0408	pCi/L	U		0.815	0.352	0.353	HASL 300, Pu-11-RC M	GEL	/x/
Technetium-99	-1.59	pCi/L	U		17.4	9.93	9.93	DOE TC-02-RC	GEL	/x/
Thorium-230	-0.0253	pCi/L	U		1.37	0.603	0.604	HASL 300, Th-01-RC M	GEL	/x/
Uranium-234	3.18	pCi/L	U		3.57	2.84	2.89	HASL 300, U-02-RC M	GEL	/x/
Uranium-235	-0.401	pCi/L	U		3.4	1.21	1.21	HASL 300, U-02-RC M	GEL	/x/
Uranium-238	0.469	pCi/L	U		2.97	1.6	1.6	HASL 300, U-02-RC M	GEL	/x/
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/x/
WETCHEM										
Ammonia as Nitrogen	0.0528	mg/L			0.05			EPA-350.1	GEL	/x/

*Verification/Validation/Assessment

Paducah OREIS Report for 404L19-01

RI404L1-19 from: QC on 11/28/2018 Media: WQ SmpMethod:

Comments:

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	0.1	mg/L	UW		0.1			SW846-9056	GEL	/X/
METAL										
Arsenic	0.005	mg/L	U		0.005			SW846-6020	GEL	/X/
Barium	0.002	mg/L	U		0.002			SW846-6020	GEL	/X/
Cadmium	0.000321	mg/L	J		0.001			SW846-6020	GEL	/X/
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/X/
Copper	0.001	mg/L	U		0.001			SW846-6020	GEL	/X/
Iron	0.1	mg/L	U		0.1			SW846-6020	GEL	/X/
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/X/
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/X/
Nickel	0.002	mg/L	U		0.002			SW846-6020	GEL	/X/
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/X/
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/X/
Uranium	0.0002	mg/L	U		0.0002			SW846-6020	GEL	/X/
Zinc	0.01	mg/L	U		0.01			SW846-6020	GEL	/X/
PPCB										
PCB-1016	0.0935	ug/L	UY1		0.0935			SW846-8082	GEL	/X/
PCB-1221	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
PCB-1232	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
PCB-1242	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
PCB-1248	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
PCB-1254	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
PCB-1260	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
Polychlorinated biphenyl	0.0935	ug/L	U		0.0935			SW846-8082	GEL	/X/
RADS										
Cesium-137	-0.413	pCi/L	U		11.3	6.06	6.06	EPA-901.1	GEL	/X/
Neptunium-237	-0.22	pCi/L	U		1.2	0.431	0.432	ASTM-1475-00aM	GEL	/X/
Plutonium-239/240	0	pCi/L	U		0.517	0.348	0.348	HASL 300, Pu-11-RC M	GEL	/X/
Technetium-99	-0.349	pCi/L	U		20.2	11.6	11.6	DOE TC-02-RC	GEL	/X/
Thorium-230	0.184	pCi/L	U		1.49	0.762	0.764	HASL 300, Th-01-RC M	GEL	/X/
Uranium-234	0.422	pCi/L	U		6.88	3.29	3.29	HASL 300, U-02-RC M	GEL	/X/
Uranium-235	3.08	pCi/L	U		5.94	4.61	4.65	HASL 300, U-02-RC M	GEL	/X/
Uranium-238	1.32	pCi/L	U		5.38	3.25	3.26	HASL 300, U-02-RC M	GEL	/X/
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/X/
WETCHEM										
Ammonia as Nitrogen	0.0502	mg/L			0.05			EPA-350.1	GEL	/X/

TB404L1-19 from: QC on 11/28/2018 Media: WQ SmpMethod:

Comments:

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/X/

*Verification/Validation/Assessment

February 8, 2019
Leachate Analytical Results

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Paducah OREIS Report for 404L19-02

L1404L2-19 from: C404L on 2/8/2019 Media: WW SmpMethod: GR

Comments: Leachate level is @ 4.35' from top of manhole. SM 2-8-19

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	15.3	mg/L			1			SW846-9056	GEL	IS / X /
FS										
Conductivity	560	umho/cm						FS	FS	/ /
Dissolved Oxygen	11.09	mg/L						FS	FS	/ /
pH	7.06	Std Unit						FS	FS	/ /
Redox	441	mV						FS	FS	/ /
Temperature	39.3	deg F						FS	FS	/ /
METAL										
Arsenic	0.00284	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.08	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
Copper	0.0107	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	0.112	mg/L			0.1			SW846-6020	GEL	/ X /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ X /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.00387	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Uranium	74.1	mg/L			0.01			SW846-6020	GEL	I / X /
Zinc	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
PPCB										
PCB-1016	0.098	ug/L	U		0.098			SW846-8082	GEL	/ X /
PCB-1221	0.098	ug/L	U		0.098			SW846-8082	GEL	/ X /
PCB-1232	0.098	ug/L	U		0.098			SW846-8082	GEL	/ X /
PCB-1242	0.098	ug/L	U		0.098			SW846-8082	GEL	/ X /
PCB-1248	2.8	ug/L			0.098			SW846-8082	GEL	/ X /
PCB-1254	1.29	ug/L	P		0.098			SW846-8082	GEL	/ X /
PCB-1260	0.293	ug/L			0.098			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	4.38	ug/L			0.098			SW846-8082	GEL	I / X /
RADS										
Cesium-137	-2.56	pCi/L	U		9.91	5.87	5.99	EPA-901.1	GEL	/ X /
Neptunium-237	1.55	pCi/L	U		1.56	1.41	1.42	ASTM-1475-00aM	GEL	/ X /
Plutonium-239/240	-0.189	pCi/L	U		1.98	0.815	0.816	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	334	pCi/L			18.4	19.8	41.8	DOE TC-02-RC	GEL	/ X /
Thorium-230	3.73	pCi/L			1.14	1.59	1.72	HASL 300, Th-01-RC M	GEL	/ X /
Uranium-234	1860	pCi/L			138	333	426	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	335	pCi/L			122	164	170	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	22000	pCi/L			105	1130	3300	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.0889	mg/L	B		0.05			EPA-350.1	GEL	/ X /

*Verification/Validation/Assessment

Paducah OREIS Report for 404L19-02

TB404L2-19 from: QC on 2/8/2019 Media: WQ SmpMethod:

Comments:

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /