FRNP-RPT-0026/V1

C-404 Hazardous Waste Landfill May 2018 Semiannual Groundwater Report (October 2017–March 2018), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

This document is approved for public release per review by:

David Hayden — 5-22-18

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C-404 Hazardous Waste Landfill May 2018 Semiannual Groundwater Report (October 2017–March 2018), Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—May 2018

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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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
UTL	upper tolerance limit

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EXECUTIVE SUMMARY

This report, *C-404 Hazardous Waste Landfill May 2018 Semiannual Groundwater Report (October 2017–March 2018), Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, FRNP-RPT-0026/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 reporting period covers October 2017 through March 2018 and includes analytical data from the January 2018 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. Only the arsenic concentration in compliance well MW84 was statistically different from concentrations in the background wells. The MW84 arsenic exceedance is consistent with the 2007 Alternate Source Demonstration (PRS 2007), which demonstrates that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of trichloroethene in MW84. 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 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 and, at a minimum, is removed and sampled when the level exceeds 3 ft in depth. On February 26, 2018, the leachate level in the C-404 Landfill leachate collection system was measured at 39 inches. On February 27, 2018, 1,000 gal was removed and sampled. Analytical data were not available for inclusion in this report by the regulatory deadline. The analytical data for the February 27, 2018, leachate sample will be included in the next semiannual report.

During this reporting period, MW91 was abandoned and replaced with MW91A (DOE 2017). Downhole camera inspections of MW91, as part of the site well maintenance program, revealed significant corrosion and some biofouling as well as a hole in the well riser. The integrity of the well riser had deteriorated to a point that it no longer was suitable for its intended purpose. MW91A was placed 10 ft north of MW91 and screened at the same depth interval. MW91A was sampled during this reporting period, and analytical data for this replacement well are included in this 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 (the permit) (KDWM 2015), Specific Condition II.K.6.d—Recordkeeping, Reporting, and Response. The period covered by this report is October 2017 through March 2018.

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

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 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 2015).

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.

1.2 MONITORING PERIOD ACTIVITIES

1.2.1 Groundwater Monitoring

Groundwater sampling was conducted in January 2018 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. There are nine monitoring wells (MWs) sampled under this permit for the C-404 Landfill: four Upper Continental Recharge System (UCRS) wells and five Upper Regional Gravel Aquifer (URGA) wells.

During this reporting period, MW91 was abandoned and replaced with MW91A (DOE 2017). Downhole camera inspections of MW91, conducted in 2017 as part of the site well maintenance program, revealed significant corrosion and some biofouling as well as a hole in the well riser. The integrity of the well riser had deteriorated to a point that it no longer was suitable for its intended purpose. MW91 is a UCRS well

located in the northeast monitoring well cluster for the C-404 Landfill (Figure 1). MW91A was placed 10 ft north of MW91 and screened at the same depth interval. Downhole camera inspections of all other C-404 Landfill wells of the same age—MW84, MW85, MW87, MW88, MW93, and MW94 (installed in 1988)—did not reveal casing failures.

Table 1 presents the well numbers 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 these UCRS wells as being adjacent to an "upgradient" or "downgradient" URGA well location, identified relative to the 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 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 presents the Assembled Kentucky Groundwater (AKGWA) numbers for each MW. A map of the MW locations is provided in Figure 1. All of the MWs listed in Tables 1 and 2 were sampled during this reporting period, and the samples were analyzed for parameters required by Attachment E of the Hazardous Waste Management Facility Permit.

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

Appendix A of this report contains the analytical results from the wells that were sampled during the January 2018 semiannual sampling event. Appendix B of this report contains the statistical analyses.

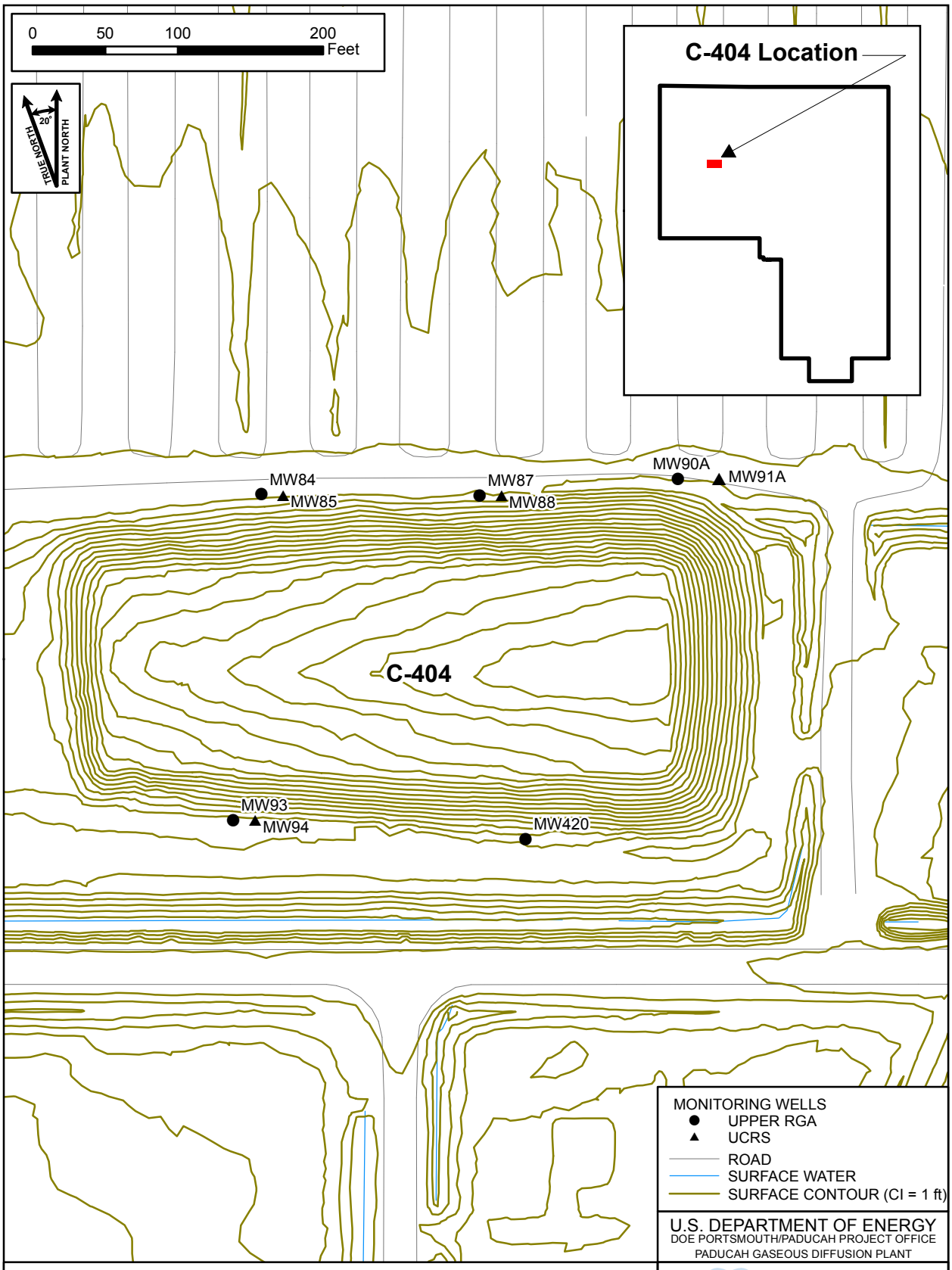

Figure 1. C-404 Landfill Monitoring Well Map

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3/19/2018

1.2.2 Landfill Leachate

In accordance with Section 1.2 of the Hazardous Waste Management Facility 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 reached 3 ft, the leachate was pumped into a mobile tank. The leachate then was 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 2017 to March 2018, was 1,000 gal. The leachate was sampled on February 27, 2018. Analytical data were not available for inclusion in this report by the regulatory deadline. The analytical data for the February 27, 2018, 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 Hazardous Waste Management Facility Permit, Attachment Part 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 2016, July 2016, January 2017, July 2017, and January 2018.

Only the arsenic concentration in compliance well MW84 was statistically different from concentrations in the background wells (see Appendix B). The statistical tests on all other parameters, including dissolved arsenic, showed no statistical difference between concentrations in the compliance (downgradient) and background (upgradient) wells.

Since the nonparametric ANOVA test for arsenic identified a statistically significant difference between concentrations in the compliance well, MW84, and concentrations in background wells, in accordance with the permit provisions, the data were evaluated further by comparing the most recent compliance analytical data to a 95% upper tolerance limit (UTL) using the five most recent sets of data for each background well. Results of the comparison showed concentrations in compliance well MW84 were higher than the UTL for the paired background concentrations. Analytical data were then evaluated using paired (parametric) ANOVA of wells in the same direction relative to the landfill (e.g., compare upgradient westernmost well MW93 analytical data to downgradient well MW84 analytical data). The paired ANOVA, could not be used for arsenic because there was no evidence of equality of variance. Thus, the paired ANOVA was abandoned, and the nonparametric ANOVA, was performed. Results of the nonparametric ANOVA identified there to be a significant difference between upgradient and downgradient wells. An additional intra-well evaluation of trend was then performed for arsenic in MW84 using the Mann-Kendall statistical test. The Mann-Kendall statistical test identified a positive trend in MW84 over the past eight semiannual events.

STATISTICALLY SIGNIFICANT EXCEEDANCE OF BACKGROUND

The exceedance in arsenic concentration over background concentrations is consistent with the findings in the 2007 Alternate Source Demonstration (PRS 2007). The 2007 demonstration found that the statistically significant increase of TCE in the downgradient well, MW84, appeared to be due to an upgradient source whose TCE is migrating through the C-404 Landfill area. 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.

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.

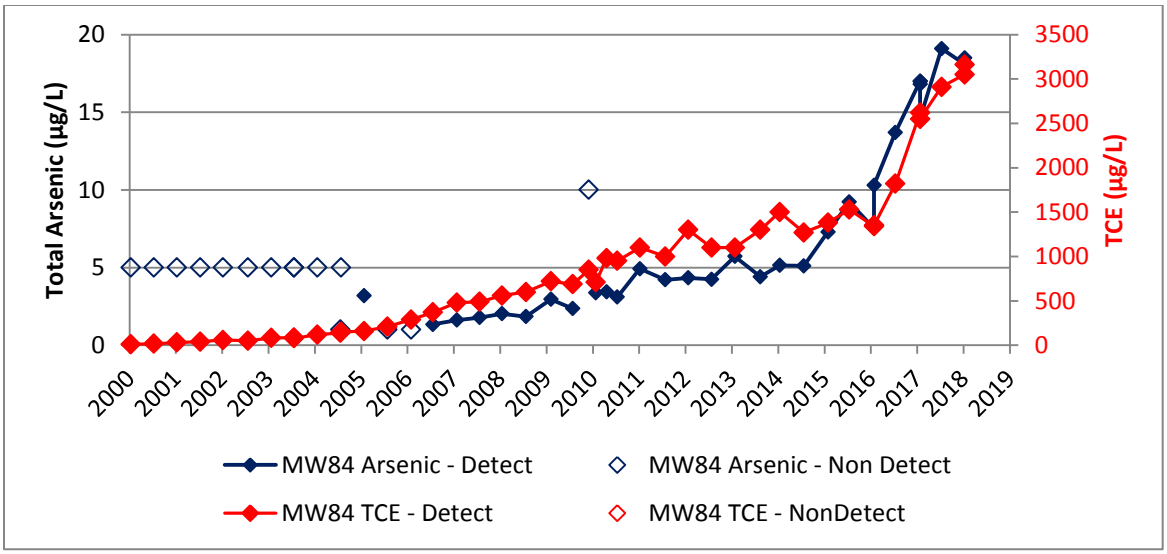

Figure 2. Arsenic and TCE Trend in MW84

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.

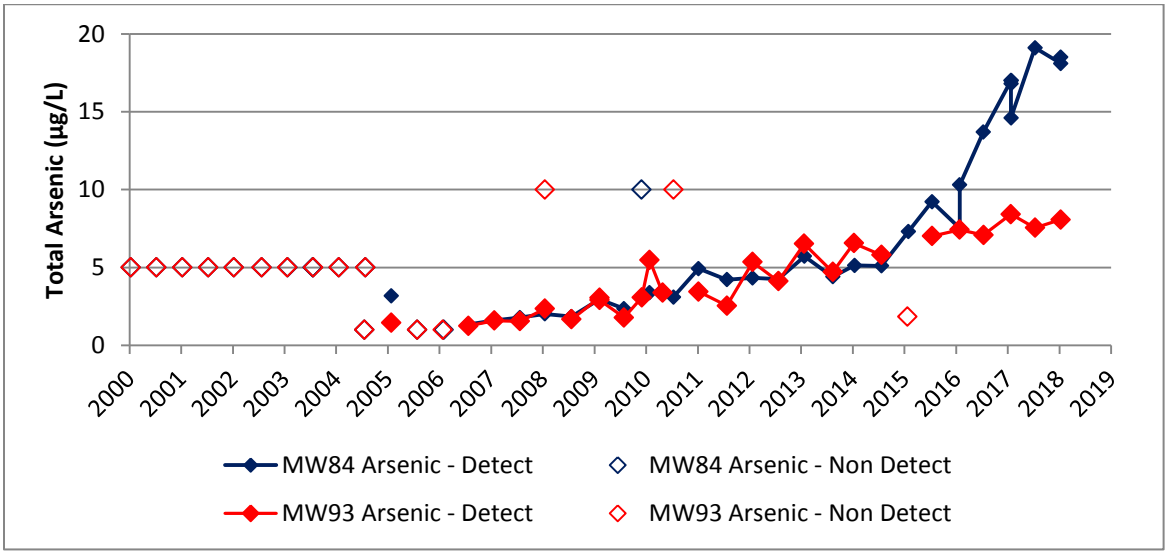

Figure 3. Arsenic Trend in MW84 and MW93

[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.

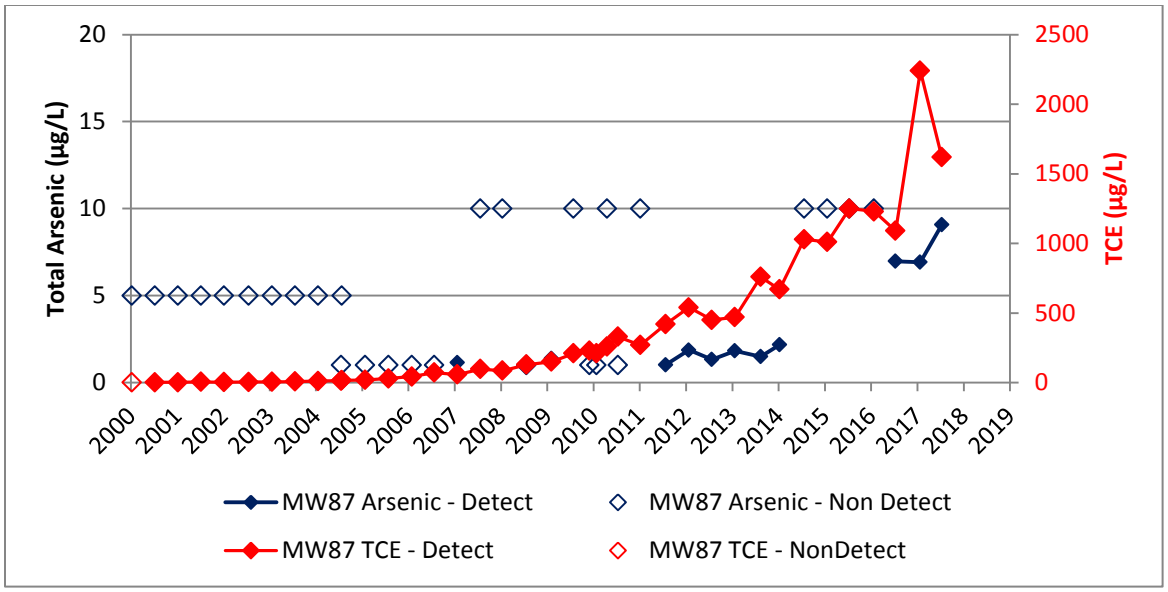

Figure 4. Arsenic and TCE Trend in MW87

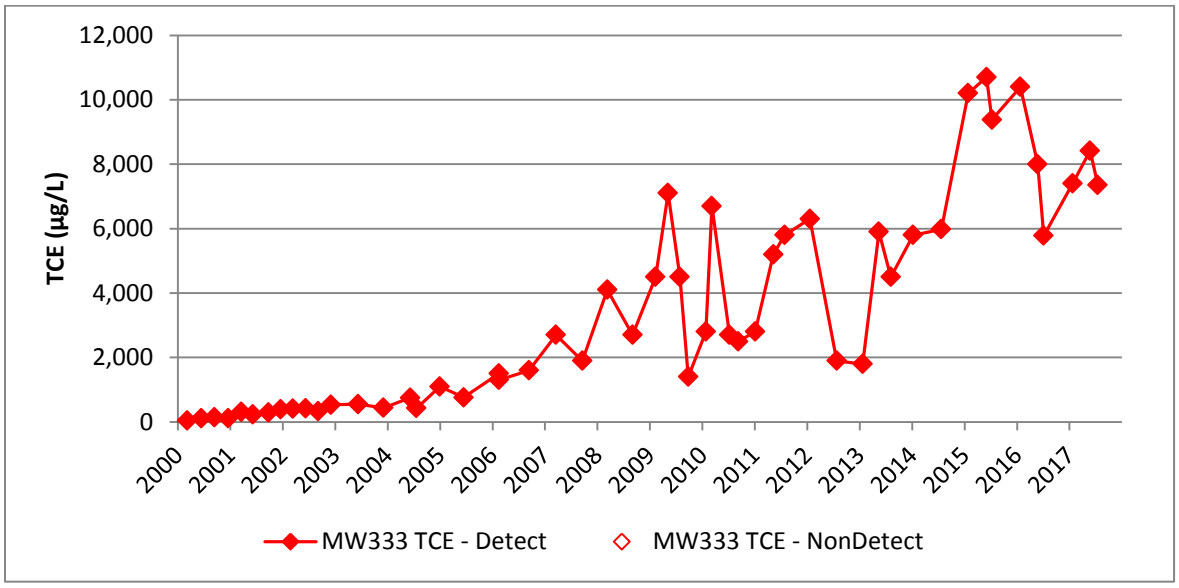

Figure 5. TCE Trend in MW333

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 do not contain arsenic concentrations that could be the source of the concentrations recently detected in RGA groundwater at MW84. Of the 26% (14 of 54) of leachate samples that do contain arsenic, the maximum concentration of 6.32 µg/L in leachate is below the January 2018 arsenic concentration of 18.5 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 2018 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 semiannually during each 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.

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4. PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: *C-404 Hazardous Waste Landfill*
May 2018 Semiannual Groundwater Report
(October 2017–March 2018),
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(FRNP-RPT-0026/V1)

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

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K.R. Davis
5-23-18

Kenneth R. Davis
Kenneth R. Davis

PG113927

May 23, 2018
Date

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5. REFERENCES

DOE 2017. Letter from J. Woodard, U.S. Department of Energy, to A. Webb, Kentucky Department for Environmental Protection, "C-404 Landfill Report, Abandonment of MW91 and Replacement with MW91A, Per Hazardous Waste Management Facility Permit KY8-890-008-982, Conditions II.K.2.E and II.K.2.F; Hazardous Waste Permit Part E, 4.6.1; and 40 *CFR* § 264.97 (C); Agency Interest No. 3059," December 19.

KDWM (Kentucky Division of Waste Management) 2015. Hazardous Waste Management Facility Permit for the U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY8-890-008-982, effective July 26.

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		0.0181	mg/L	0.005	1/10/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Barometric Pressure Reading		30.07	Inches/Hg		1/10/2018				X
Cadmium	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Chromium		0.136	mg/L	0.01	1/10/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/10/2018			SW846-6020	=
Conductivity		393	umho/cm		1/10/2018				X
Depth to Water		53.32	ft		1/10/2018				X
Dissolved Oxygen		3.19	mg/L		1/10/2018				X
Lead	J	0.00173	mg/L	0.002	1/10/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/10/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
pH		5.91	Std Unit		1/10/2018				X
Redox		175	mV		1/10/2018				X
Selenium	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Selenium, Dissolved	J	0.00204	mg/L	0.005	1/10/2018			SW846-6020	=
Technetium-99		34.4	pCi/L	17.9	1/10/2018	11.5	12.1	HASL 300, Tc-02-RC M	=
Temperature		57.9	deg F		1/10/2018				X
Trichloroethene		3050	ug/L	50	1/10/2018			SW846-8260B	=
Turbidity		117	NTU		1/10/2018				X
Uranium	BJ	0.000199	mg/L	0.0002	1/10/2018			SW846-6020	U
Uranium-234	U	0.404	pCi/L	1.16	1/10/2018	0.752	0.757	HASL 300, U-02-RC M	=
Uranium-235	U	0.179	pCi/L	1.13	1/10/2018	0.671	0.672	HASL 300, U-02-RC M	=
Uranium-238	U	0.0991	pCi/L	1.06	1/10/2018	0.55	0.551	HASL 300, U-02-RC M	=

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		0.0185	mg/L	0.005	1/10/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Barometric Pressure Reading		30.07	Inches/Hg		1/10/2018				X
Cadmium	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Chromium		0.143	mg/L	0.01	1/10/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/10/2018			SW846-6020	=
Conductivity		393	umho/cm		1/10/2018				X
Depth to Water		53.32	ft		1/10/2018				X
Dissolved Oxygen		3.19	mg/L		1/10/2018				X
Lead	J	0.00191	mg/L	0.002	1/10/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/10/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
pH		5.91	Std Unit		1/10/2018				X
Redox		175	mV		1/10/2018				X
Selenium	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Technetium-99		33.3	pCi/L	17.7	1/10/2018	11.4	12	HASL 300, Tc-02-RC M	=
Temperature		57.9	deg F		1/10/2018				X
Trichloroethene		3160	ug/L	50	1/10/2018			SW846-8260B	=
Turbidity		117	NTU		1/10/2018				X
Uranium	B	0.0002	mg/L	0.0002	1/10/2018			SW846-6020	J
Uranium-234	U	0.283	pCi/L	1.32	1/10/2018	0.728	0.731	HASL 300, U-02-RC M	=
Uranium-235	U	0.35	pCi/L	0.953	1/10/2018	0.687	0.689	HASL 300, U-02-RC M	=
Uranium-238	U	0.244	pCi/L	0.89	1/10/2018	0.561	0.562	HASL 300, U-02-RC M	=

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		0.0107	mg/L	0.005	1/10/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Barometric Pressure Reading		30.08	Inches/Hg		1/10/2018				X
Cadmium	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Chromium		0.0116	mg/L	0.01	1/10/2018			SW846-6020	=
Chromium, Dissolved	J	0.00538	mg/L	0.01	1/10/2018			SW846-6020	=
Conductivity		405	umho/cm		1/10/2018				X
Depth to Water		12.36	ft		1/10/2018				X
Dissolved Oxygen		2.44	mg/L		1/10/2018				X
Lead	J	0.00057	mg/L	0.002	1/10/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/10/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
pH		6.35	Std Unit		1/10/2018				X
Redox		226	mV		1/10/2018				X
Selenium	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Technetium-99		73.6	pCi/L	20.6	1/10/2018	14.4	16.5	HASL 300, Tc-02-RC M	=
Temperature		58.9	deg F		1/10/2018				X
Trichloroethene		10.5	ug/L	1	1/10/2018			SW846-8260B	=
Turbidity		31.6	NTU		1/10/2018				X
Uranium	B	0.000486	mg/L	0.0002	1/10/2018			SW846-6020	J
Uranium-234	U	0.0864	pCi/L	1.38	1/10/2018	0.669	0.669	HASL 300, U-02-RC M	=
Uranium-235	U	0.104	pCi/L	1.11	1/10/2018	0.581	0.581	HASL 300, U-02-RC M	=
Uranium-238	U	0.169	pCi/L	1.07	1/10/2018	0.578	0.578	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		0.0087	mg/L	0.005	1/9/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Barometric Pressure Reading		30.25	Inches/Hg		1/9/2018				X
Cadmium	J	0.000375	mg/L	0.001	1/9/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Chromium		1.18	mg/L	0.1	1/9/2018			SW846-6020	=
Chromium, Dissolved	J	0.00331	mg/L	0.01	1/9/2018			SW846-6020	=
Conductivity		345	umho/cm		1/9/2018				X
Depth to Water		53.42	ft		1/9/2018				X
Dissolved Oxygen		2.93	mg/L		1/9/2018				X
Lead		0.00579	mg/L	0.002	1/9/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
pH		6.3	Std Unit		1/9/2018				X
Redox		394	mV		1/9/2018				X
Selenium	J	0.00219	mg/L	0.005	1/9/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Technetium-99	U	4.48	pCi/L	18.9	1/9/2018	11.1	11.1	HASL 300, Tc-02-RC M	=
Temperature		56.7	deg F		1/9/2018				X
Trichloroethene	Y1	1400	ug/L	20	1/9/2018			SW846-8260B	=
Turbidity		269	NTU		1/9/2018				X
Uranium	B	0.000681	mg/L	0.0002	1/9/2018			SW846-6020	J
Uranium-234	U	0.721	pCi/L	1.91	1/9/2018	1.21	1.22	HASL 300, U-02-RC M	=
Uranium-235	U	0.0134	pCi/L	2.21	1/9/2018	0.992	0.994	HASL 300, U-02-RC M	=
Uranium-238	U	-0.119	pCi/L	2	1/9/2018	0.823	0.824	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		0.0103	mg/L	0.005	1/9/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Barometric Pressure Reading		30.26	Inches/Hg		1/9/2018				X
Cadmium	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Chromium		0.0129	mg/L	0.01	1/9/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/9/2018			SW846-6020	=
Conductivity		627	umho/cm		1/9/2018				X
Depth to Water		11.36	ft		1/9/2018				X
Dissolved Oxygen		2.13	mg/L		1/9/2018				X
Lead		0.00369	mg/L	0.002	1/9/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
pH		6.38	Std Unit		1/9/2018				X
Redox		345	mV		1/9/2018				X
Selenium	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Technetium-99		26.3	pCi/L	20.2	1/9/2018	12.6	12.9	HASL 300, Tc-02-RC M	=
Temperature		57.7	deg F		1/9/2018				X
Trichloroethene	Y1	7.17	ug/L	1	1/9/2018			SW846-8260B	=
Turbidity		107	NTU		1/9/2018				X
Uranium	B	0.000519	mg/L	0.0002	1/9/2018			SW846-6020	J
Uranium-234	U	0.147	pCi/L	1.75	1/9/2018	0.864	0.866	HASL 300, U-02-RC M	=
Uranium-235	U	-0.0728	pCi/L	1.45	1/9/2018	0.628	0.629	HASL 300, U-02-RC M	=
Uranium-238	U	-0.236	pCi/L	1.62	1/9/2018	0.546	0.547	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	1/9/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Barometric Pressure Reading		30.26	Inches/Hg		1/9/2018				X
Cadmium	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Chromium	J	0.00381	mg/L	0.01	1/9/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/9/2018			SW846-6020	=
Conductivity		221	umho/cm		1/9/2018				X
Depth to Water		52.26	ft		1/9/2018				X
Dissolved Oxygen		3.3	mg/L		1/9/2018				X
Lead	J	0.000634	mg/L	0.002	1/9/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
pH		6.45	Std Unit		1/9/2018				X
Redox		360	mV		1/9/2018				X
Selenium	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Technetium-99	U	4.69	pCi/L	18.4	1/9/2018	10.8	10.8	HASL 300, Tc-02-RC M	=
Temperature		59.4	deg F		1/9/2018				X
Trichloroethene	Y1	40.6	ug/L	1	1/9/2018			SW846-8260B	=
Turbidity		32.8	NTU		1/9/2018				X
Uranium	U	0.0002	mg/L	0.0002	1/9/2018			SW846-6020	=
Uranium-234	U	1.1	pCi/L	2.07	1/9/2018	1.45	1.47	HASL 300, U-02-RC M	=
Uranium-235	U	0.557	pCi/L	2.03	1/9/2018	1.28	1.28	HASL 300, U-02-RC M	=
Uranium-238	U	0.083	pCi/L	1.81	1/9/2018	0.867	0.869	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		0.00577	mg/L	0.005	1/10/2018			SW846-6020	=
Arsenic, Dissolved	J	0.00203	mg/L	0.005	1/10/2018			SW846-6020	=
Barometric Pressure Reading		30.06	Inches/Hg		1/10/2018				X
Cadmium	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Chromium		0.129	mg/L	0.01	1/10/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/10/2018			SW846-6020	=
Conductivity		1740	umho/cm		1/10/2018				X
Depth to Water		13.53	ft		1/10/2018				X
Dissolved Oxygen		1.52	mg/L		1/10/2018				X
Lead	J	0.00123	mg/L	0.002	1/10/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/10/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
pH		5.99	Std Unit		1/10/2018				X
Redox		-29	mV		1/10/2018				X
Selenium	J	0.00263	mg/L	0.005	1/10/2018			SW846-6020	=
Selenium, Dissolved	J	0.00403	mg/L	0.005	1/10/2018			SW846-6020	=
Technetium-99		60.5	pCi/L	19.5	1/10/2018	13.3	14.9	HASL 300, Tc-02-RC M	=
Temperature		58.4	deg F		1/10/2018				X
Trichloroethene		40.1	ug/L	1	1/10/2018			SW846-8260B	=
Turbidity		33.3	NTU		1/10/2018				X
Uranium	B	0.000467	mg/L	0.0002	1/10/2018			SW846-6020	J
Uranium-234	U	-0.303	pCi/L	1.72	1/10/2018	0.614	0.615	HASL 300, U-02-RC M	=
Uranium-235	U	0.494	pCi/L	0.74	1/10/2018	0.846	0.849	HASL 300, U-02-RC M	=
Uranium-238	U	1.01	pCi/L	1.32	1/10/2018	1.06	1.07	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		0.00807	mg/L	0.005	1/9/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Barometric Pressure Reading		30.28	Inches/Hg		1/9/2018				X
Cadmium	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Chromium		0.151	mg/L	0.01	1/9/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/9/2018			SW846-6020	=
Conductivity		377	umho/cm		1/9/2018				X
Depth to Water		55.01	ft		1/9/2018				X
Dissolved Oxygen		1.74	mg/L		1/9/2018				X
Lead	J	0.00186	mg/L	0.002	1/9/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
pH		6.55	Std Unit		1/9/2018				X
Redox		352	mV		1/9/2018				X
Selenium	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Selenium, Dissolved	J	0.00201	mg/L	0.005	1/9/2018			SW846-6020	=
Technetium-99	U	5.18	pCi/L	18.8	1/9/2018	11	11	HASL 300, Tc-02-RC M	=
Temperature		60.1	deg F		1/9/2018				X
Trichloroethene	Y1	994	ug/L	20	1/9/2018			SW846-8260B	=
Turbidity		103	NTU		1/9/2018				X
Uranium	BJ	0.000198	mg/L	0.0002	1/9/2018			SW846-6020	U
Uranium-234	U	-0.0837	pCi/L	2.2	1/9/2018	0.951	0.952	HASL 300, U-02-RC M	=
Uranium-235	U	-0.0774	pCi/L	1.55	1/9/2018	0.668	0.669	HASL 300, U-02-RC M	=
Uranium-238	U	0.522	pCi/L	0.783	1/9/2018	0.894	0.898	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	J	0.00425	mg/L	0.005	1/9/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Barometric Pressure Reading		30.28	Inches/Hg		1/9/2018				X
Cadmium	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Chromium		0.0301	mg/L	0.01	1/9/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/9/2018			SW846-6020	=
Conductivity		805	umho/cm		1/9/2018				X
Depth to Water		15.24	ft		1/9/2018				X
Dissolved Oxygen		1.01	mg/L		1/9/2018				X
Lead		0.00465	mg/L	0.002	1/9/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
pH		6.9	Std Unit		1/9/2018				X
Redox		351	mV		1/9/2018				X
Selenium	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Technetium-99		1110	pCi/L	20.8	1/9/2018	33.8	127	HASL 300, Tc-02-RC M	=
Temperature		61.7	deg F		1/9/2018				X
Trichloroethene	Y1	2.66	ug/L	1	1/9/2018			SW846-8260B	=
Turbidity		140	NTU		1/9/2018				X
Uranium	B	0.00228	mg/L	0.0002	1/9/2018			SW846-6020	J
Uranium-234	U	1.47	pCi/L	1.68	1/9/2018	1.41	1.43	HASL 300, U-02-RC M	=
Uranium-235	U	0	pCi/L	0.932	1/9/2018	0.626	0.628	HASL 300, U-02-RC M	=
Uranium-238	U	0.884	pCi/L	1.39	1/9/2018	1.12	1.13	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	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Barometric Pressure Reading		30.26	Inches/Hg		1/9/2018				X
Cadmium	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	1/9/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/9/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	1/9/2018			SW846-6020	=
Conductivity		285	umho/cm		1/9/2018				X
Depth to Water		55.1	ft		1/9/2018				X
Dissolved Oxygen		2.51	mg/L		1/9/2018				X
Lead	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	1/9/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	1/9/2018			SW846-7470A	=
pH		6.51	Std Unit		1/9/2018				X
Redox		372	mV		1/9/2018				X
Selenium	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	1/9/2018			SW846-6020	=
Technetium-99		21.5	pCi/L	18	1/9/2018	11.2	11.4	HASL 300, Tc-02-RC M	J
Temperature		56.7	deg F		1/9/2018				X
Trichloroethene	Y1	232	ug/L	5	1/9/2018			SW846-8260B	J
Turbidity		15.8	NTU		1/9/2018				X
Uranium	U	0.0002	mg/L	0.0002	1/9/2018			SW846-6020	=
Uranium-234	U	1.05	pCi/L	1.46	1/9/2018	1.05	1.07	HASL 300, U-02-RC M	=
Uranium-235	U	0.313	pCi/L	1.14	1/9/2018	0.718	0.719	HASL 300, U-02-RC M	=
Uranium-238	U	-0.2	pCi/L	1.17	1/9/2018	0.378	0.379	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	1/10/2018			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/10/2018			SW846-6020	=
Lead	U	0.002	mg/L	0.002	1/10/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Technetium-99	U	4.75	pCi/L	19.7	1/10/2018	11.5	11.5	HASL 300, Tc-02-RC M	=
Trichloroethene	U	1	ug/L	1	1/10/2018			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	1/10/2018			SW846-6020	=
Uranium-234	U	0.949	pCi/L	1.68	1/10/2018	1.17	1.18	HASL 300, U-02-RC M	=
Uranium-235	U	0.482	pCi/L	1.31	1/10/2018	0.947	0.95	HASL 300, U-02-RC M	=
Uranium-238	U	0.062	pCi/L	1.35	1/10/2018	0.648	0.649	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	1/10/2018			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	1/10/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	1/10/2018			SW846-6020	=
Lead	U	0.002	mg/L	0.002	1/10/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	1/10/2018			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	1/10/2018			SW846-6020	=
Technetium-99	U	-3.94	pCi/L	18.3	1/10/2018	10.4	10.4	HASL 300, Tc-02-RC M	=
Trichloroethene	U	1	ug/L	1	1/10/2018			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	1/10/2018			SW846-6020	=
Uranium-234	U	0.0744	pCi/L	1.75	1/10/2018	0.826	0.826	HASL 300, U-02-RC M	=
Uranium-235	U	0.218	pCi/L	1.38	1/10/2018	0.819	0.82	HASL 300, U-02-RC M	=
Uranium-238	U	-0.167	pCi/L	1.42	1/10/2018	0.505	0.506	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	UY1	1	ug/L	1	1/9/2018			SW846-8260B	=
	U	1	ug/L	1	1/10/2018			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.
B Compound found in blank as well as sample.
Y1 MS/MSD recovery outside acceptance criteria.

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 Replicate (Code used for Field Duplicate)
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 this report, the reporting period data set includes data from January 2016, July 2016, January 2017, July 2017, and January 2018.

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 this report, the reporting period data set from January 2016 through January 2018 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.

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	9	16
Arsenic, Dissolved	25	0	20	5
Cadmium	25	0	15	10
Cadmium, Dissolved	25	0	25	0
Chromium	25	0	9	16
Chromium, Dissolved	25	0	20	5
Lead	25	0	9	16
Lead, Dissolved	25	0	25	0
Mercury	25	0	25	0
Mercury, Dissolved	25	0	25	0
Selenium	25	0	19	6
Selenium, Dissolved	25	0	19	6
Technetium-99	25	0	22	3
Trichloroethene	25	0	0	25
Uranium (Metals)	25	0	14	11
Uranium-234	25	0	25	0
Uranium-235	25	0	25	0
Uranium-238	25	0	25	0

*Missing parameters that were dissolved metals were not analyzed when the parent total metals were not detected in prior sampling events.

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	16	9	36.00	3
Arsenic, Dissolved	25	5	20	80.00	2
Cadmium	25	10	15	60.00	2
Cadmium, Dissolved	25	0	25	100.00	1
Chromium	25	16	9	36.00	3
Chromium, Dissolved	25	5	20	80.00	2
Lead	25	16	9	36.00	3
Lead, Dissolved	25	0	25	100.00	1
Mercury	25	0	25	100.00	1
Mercury, Dissolved	25	0	25	100.00	1
Selenium	25	6	19	76.00	2
Selenium, Dissolved	25	6	19	76.00	2
Technetium-99	25	3	22	88.00	2
Trichloroethene	25	25	0	0.00	4/3**
Uranium (Metals)	25	11	14	56.00	2
Uranium-234	25	0	25	100.00	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 statistical analyses for the C-404 Landfill, 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 B11. The statistician qualification statement is presented in Attachment B12.

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

Parameter	LOD Values	½ LOD Values
URGA		
Cadmium, Dissolved (mg/L)	0.001	0.0005
Lead, Dissolved (mg/L)	0.002	0.001
Mercury (mg/L)	0.0002	0.0001
Mercury, Dissolved (mg/L)	0.0002	0.0001
Uranium-234 (pCi/L)	2.2	1.1
Uranium-235 (pCi/L)	2.21	1.105
Uranium-238 (pCi/L)	2	1

In summary, Statistical Test 2, Test of Proportions, for dissolved arsenic, cadmium, dissolved chromium, selenium, dissolved selenium, technetium-99, and uranium in the URGA indicated no 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]. The paired ANOVA, could not be used for arsenic because there was no evidence of equality of variance. Thus, Statistical Test 4 was abandoned, and Statistical Test 3, Nonparametric ANOVA, was performed. Results of the Nonparametric 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 a positive 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 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]. The paired ANOVA could not be used for lead because there was no evidence of equality of variance. Thus, Statistical Test 4 was abandoned, and Statistical Test 3, Nonparametric ANOVA, was performed. Results of the Nonparametric ANOVA identified there was no significant difference between upgradient and downgradient wells.

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. Statistical Test 3 showed there was no statistically significant difference between concentrations in downgradient wells and concentrations in background wells for trichloroethene.

Table B.5. Summary of Conclusions from the Statistical Analyses for the C-404 Hazardous Waste Landfill for the January 2018 Data Set

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. Because equality of variance could not be confirmed on the paired ANOVA, it was abandoned, and Statistical Test 3, Nonparametric ANOVA, was performed. Results of the Nonparametric ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified a positive trend in MW84.
B2	URGA	Arsenic, Dissolved	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B3	URGA	Cadmium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B4	URGA	Chromium	Statistical Test 3, Nonparametric ANOVA	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B5	URGA	Chromium, Dissolved	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B6	URGA	Lead	Statistical Test 3, Nonparametric ANOVA with 95% UTL and paired ANOVA (MW87 vs. MW93)	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 and paired ANOVA was performed, as required by the Hazardous Waste Management Facility Permit. Because equality of variance could not be confirmed on the paired ANOVA, it was abandoned, and Statistical Test 3, Nonparametric ANOVA, was performed. Results of the Nonparametric ANOVA have identified there is no significant difference between upgradient and downgradient wells.
B7	URGA	Selenium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B8	URGA	Selenium, Dissolved	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

Table B.5. Summary of Conclusions from the Statistical Analyses for the C-404 Hazardous Waste Landfill for the January 2018 Data Set (Continued)

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B9	URGA	Technetium-99	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B10	URGA	Trichloroethene	Statistical Test 4, Parametric ANOVA/Statistical Test 3, Nonparametric ANOVA	Because equality of variance could not be confirmed, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Results of the Nonparametric ANOVA showed no statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B11	URGA	Uranium	Statistical Test 2, Test of Proportions	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.

ATTACHMENT B1

ARSENIC
STATISTICAL TEST 3

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Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.00743**	0.0025	**0.0103**	**0.00481**	0.0025
Jul-16	**0.00709**	0.0025	**0.0137**	**0.00698**	0.0025
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
Sum	0.0506		0.07860	0.03648	0.0125
n_i	10		5	5	5
$(x_i)_{avg}$	0.00506		0.01572	0.00730	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.. = 0.00713

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.18	x.. = the sum of the total number of samples

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Arsenic (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	**0.00207**	10	
11	**0.00481**	11	
12	**0.00692**	12	
13	**0.00698**	13	
14	**0.00709**	14	
15	**0.00743**	15	
16	**0.00755**	16	
17	**0.00807**	17	
18	**0.00842**	18	
19	**0.0087**	19	
20	**0.00907**	20	
21	**0.0103**	21	
22	**0.0137**	22	
23	**0.017**	23	
24	**0.0185**	24	
25	**0.0191**	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

Sums of Ranks and Averages

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.00743**	0	**0.0103**	**0.00481**	0
Jul-16	**0.00709**	0	**0.0137**	**0.00698**	0
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

Observation Ranks for Arsenic					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	15	5	21	11	5
Jul-16	14	5	22	13	5
Jan-17	18	5	23	12	5
Jul-17	16	10	25	20	5
Jan-18	17	5	24	19	5
R_i	110		115	75	25
$(R_i)_{avg}$	11.0		23.0	15.0	5.0
R_i^2/n_i	1210.0		2645.0	1125.0	125.0

$\Sigma R_i^2/n_i$ = 5105.0

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 =	16.246	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	17.032	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).

Calculate Critical Values

Average Background Ranking = 11.0

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	12.0	evidence of contamination
	MW87	8.578	4.0	not contaminated
	MW90A	8.578	-6.0	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 C-404.

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 from C-404 in these downgradient compliance test wells; however, the negative value indicates that background well has elevated concentrations.

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

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 2018 Data, First Reporting Period
Observations (mg/L)

Well No.						
MW93	**0.00743**	**0.00709**	**0.00842**	**0.00755**	**0.00807**	**Upgradient Well!**
MW420	0.0025	0.0025	0.0025	**0.00207**	0.0025	**Upgradient Well!**
						Current Data
MW84		X: Mean Value =	0.0051			**0.0185**
MW87		S: Standard Deviation =	0.0028			0.0087
MW90A		K* factor =	2.911	(for n = 10)		0.0025
		CV = S/X	0.5565	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =			**0.0133**	(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.

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-16	**0.00743**	**0.0103**	0.0000552	0.0001061
Jul-16	**0.00709**	**0.0137**	0.0000503	0.0001877
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
Sum (x_i)	0.0386	0.07860	0.1172	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.00771	0.01572		
$(x_i)^2$	0.00149	0.00618		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean x.. =	0.01172	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.1172	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-16	-0.00028	-0.00542
Jul-16	-0.00062	-0.00202
Jan-17	0.00071	0.00128
Jul-17	-0.00016	0.00338
Jan-18	0.00036	0.00278

X: Mean Value =	-1.04E-18	
S: Standard Deviation =	0.00248	
K* Factor =	2.911	(for n = 10)
CV = S/X =	–2.38E+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 (CV) is < 1, the data are normally distributed.
If the coefficient of variation (CV) is > or = 1, data are not normally distributed.

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)
$f_i = n_i - 1$

$x_{..} = 0.1172$
$(x_{avg})_{..} = 0.01172$
$n_i = 5$
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	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.00053	0.00000028052	-15.087	5	0.0000011	-60.3
0.00368	0.00001356200	-11.208	5	0.0000542	-44.8

$\sum(S_i^2)$ = 0.00001 $\sum f_i \ln(S_i^2)$ = -105.17944

Equality of Variance: Bartlett's Test

f = 8
Sp^2 = 0.0000069
ln Sp^2 = -11.881
χ^2 = 10.132 (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)

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

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).

Paired (Parametric) ANOVA—Lognormal Data for Arsenic in MW93 and MW84

ln[Arsenic (mg/L)]				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jan-16	**-4.90**	**-4.58**	24.03	20.94
Jul-16	**-4.95**	**-4.29**	24.49	18.41
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
Sum (x_i)	-24.33	-20.89	-45.22	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	-4.87	-4.18		
$(x_i)^2$	592.16	436.33		

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

Overall mean x.. =	-4.52	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	-45.22	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test—Lognormal Data for Arsenic in MW93 and MW84

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

Date	Background	Compliance
	MW93	MW84
Jan-16	-0.04	-0.40
Jul-16	-0.08	-0.11
Jan-17	0.09	0.10
Jul-17	-0.02	0.22
Jan-18	0.05	0.19

X: Mean Value =	1.33E-16	
S: Standard Deviation =	0.18	
K* Factor =	2.911	(for n = 10)
CV = S/X =	1.33E+15	≥1, data are NOT normally distributed

*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.

Determine Equality of Variance—Lognormal Data for Arsenic in MW93 and MW84

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)
$f_i = n_i - 1$

$x_{..} =$ -45.22
$(x_{avg})_{..} =$ -4.52
$n_i =$ 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	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.07	0.00	-5.37	5	0.02	-21.5
0.26	0.07	-2.71	5	0.27	-10.9

$\sum(S_i^2) =$ 0.07 $\sum f_i\ln(S_i^2) =$ -32.32

Equality of Variance: Bartlett's Test

f = 8
$Sp^2 =$ 0.04
$\ln Sp^2 =$ -3.34
$\chi^2 =$ 5.61 (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)

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

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

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

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

Statistical Test 3, Nonparametric ANOVA

Arsenic (mg/L)		
Date	Background	Compliance
	MW93	MW84
Jan-16	**0.00743**	**0.0103**
Jul-16	**0.00709**	**0.0137**
Jan-17	**0.00842**	**0.017**
Jul-17	**0.00755**	**0.0191**
Jan-18	**0.00807**	**0.0185**
Sum	0.0386	0.07860
n_i	5	5
$(x_i)_{avg}$	0.00771	0.01572

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.. = 0.01172

N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
x.. =	0.11716	x.. = the sum of the total number of samples

Ranking of Observations

Sequence	Arsenic (mg/L)	Adjusted	Tie Number
1	**0.00709**	1	
2	**0.00743**	2	
3	**0.00755**	3	
4	**0.00807**	4	
5	**0.00842**	5	
6	**0.0103**	6	
7	**0.0137**	7	
8	**0.017**	8	
9	**0.0185**	9	
10	**0.0191**	10	

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

n_{tie}	Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
0	Tie 1 = 0
	$\sum T_i$ = 0

Sums of Ranks and Averages

Observation Ranks for Arsenic		
Date	Background	Compliance
	MW93	MW84
Jan-16	2	6
Jul-16	1	7
Jan-17	5	8
Jul-17	3	10
Jan-18	4	9
R_i	15	40
$(R_i)_{avg}$	3	8
R_i^2/n_i	45.0	320.0

$\Sigma R_i^2/n_i$ =	365
K =	2
N =	10

Calculation of Kruskal-Wallis Statistic

H =	6.818	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	6.818	Corrected Kruskal-Wallis	$H' = H/[1-(\sum T_i/N^3-N)]$
χ^2_{crit} * =	3.841	1	degrees of freedom at the 5% significance level

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

If $H' \leq \chi^2_{crit}$, the data from each well comes 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 =	1	$\alpha/(K-1)$ =	0.05000	$Z(\alpha/(K-1))$** =	1.6449
α =	0.05	$1-(\alpha/K-1)$ =	0.950		

*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).

Calculate Critical Values

Average Background Ranking = 3.000

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
	MW84	3.150	5.000	evidence of contamination

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 in this downgradient compliance test well.

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

Because the nonparametric 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.

Mann-Kendall Statistical Analysis for Arsenic in MW84

Input Data

Date Collected	Result (mg/L)
Jul-14	0.00511
Jan-15	0.0073
Jul-15	0.00922
Jan-16	0.0103
Jul-16	0.0137
Jan-17	0.017
Jul-17	0.0191
Jan-18	0.0185

Mann-Kendall Trend Test Analysis

User Selected Options	
Date/Time of Computation	ProUCL 5.13/28/2018 8:45:21 AM
From File	404 Arsenic MW84 DataPROUCL.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

RESULTS

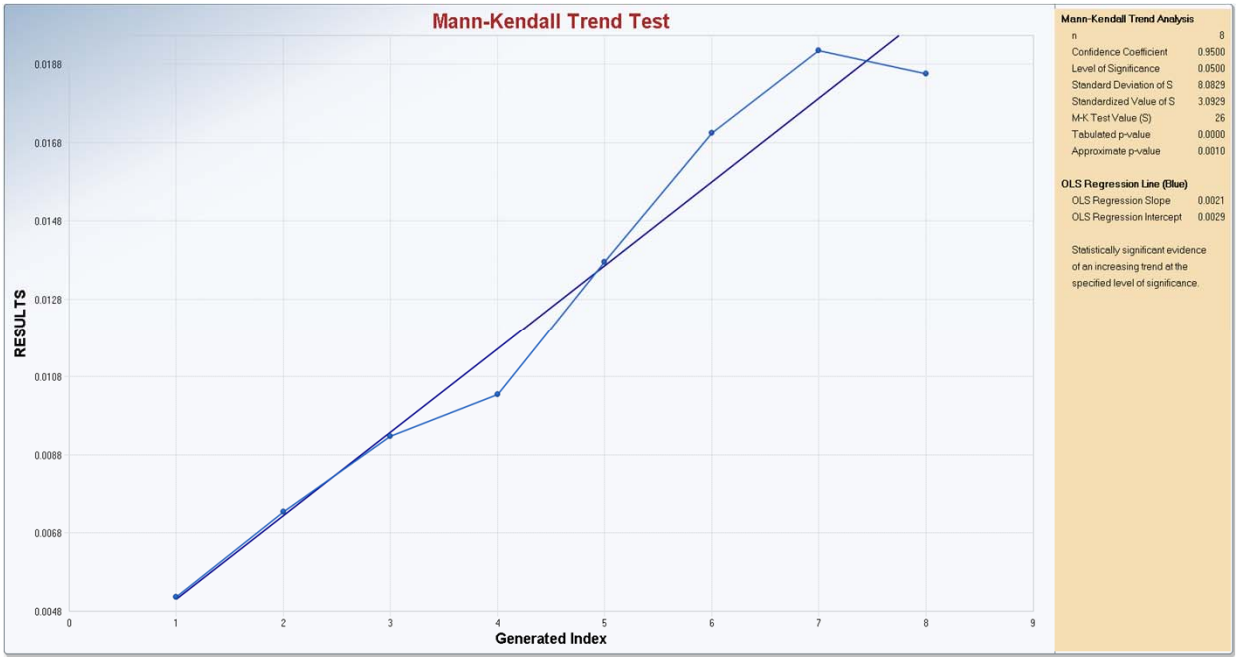
General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	0.00511
Maximum	0.0191
Mean	0.0125
Geometric Mean	0.0114
Median	0.012
Standard Deviation	0.00533
Coefficient of Variation	0.425

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 B2

ARSENIC (DISSOLVED)
STATISTICAL TEST 2

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Attachment B2: Statistical Test 2, Test of Proportions, January 2018
Arsenic, Dissolved URGA

Arsenic, Dissolved (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	0.0025	0.0025	0.0025	0.0025	0.0025
Jul-16	**0.00434**	0.0025	**0.00737**	**0.00282**	0.0025
Jan-17	**0.00254**	0.0025	**0.011**	0.0025	0.0025
Jul-17	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-18	0.0025	0.0025	0.0025	0.0025	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.

[!] **Test of Proportions**

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

X =	2	X = number of samples above DL in background wells
Y =	3	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 =	0.200	P = (x+y)/n
nP =	5	$n = n_b+n_c$
n(1-P) =	20	

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

P_b =	0.200	P_b = proportion of detects in background wells
P_c =	0.200	P_c = proportion of detects in compliance wells
S_D =	0.163	S_D = standard error of difference in proportions
Z =	0.000	$Z = (P_b-P_c)/S_D$
absolute value of Z =	0.000	

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 B3

CADMIUM
STATISTICAL TEST 2

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Attachment B3: Statistical Test 2, Test of Proportions, January 2018
Cadmium URGA

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.000152**	0.0005	**0.000179**	**0.000121**	0.0005
Jul-16	**0.000199**	0.0005	**0.000292**	**0.000451**	0.0005
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

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 =	2	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 =	0.400	P = (x+y)/n
nP =	10	$n = n_b+n_c$
n(1-P) =	15	

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

P_b =	0.200	P_b = proportion of detects in background wells
P_c =	0.533	P_c = proportion of detects in compliance wells
S_D =	0.200	S_D = standard error of difference in proportions
Z =	-1.667	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.667	

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 B4

CHROMIUM
STATISTICAL TEST 3

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Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.0401**	0.005	**0.0393**	**0.0266**	0.005
Jul-16	**0.207**	0.005	**0.0206**	**0.165**	0.005
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**
Sum	1.1121		0.33680	1.68930	0.0238
n_i	10		5	5	5
$(x_i)_{avg}$	0.11121		0.06736	0.33786	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.. = 0.12648

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	3.16	x.. = the sum of the total number of samples

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	**0.0206**	11	
12	**0.0266**	12	
13	**0.0309**	13	
14	**0.0393**	14	
15	**0.0401**	15	
16	**0.0557**	16	
17	**0.103**	17	
18	**0.143**	18	
19	**0.151**	19	
20	**0.165**	20	
21	**0.207**	21	
22	**0.261**	22	
23	**0.262**	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

Sums of Ranks and Averages

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.0401**	0	**0.0393**	**0.0266**	0
Jul-16	**0.207**	0	**0.0206**	**0.165**	0
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**

Observation Ranks for Chromium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	15	5	14	12	5
Jul-16	21	5	11	20	5
Jan-17	24	5	13	23	5
Jul-17	22	5	17	16	5
Jan-18	19	5	18	25	10
R_i	126		73	96	30
$(R_i)_{avg}$	12.6		14.6	19.2	6.0
R_i^2/n_i	1587.6		1065.8	1843.2	180.0

$\Sigma R_i^2/n_i$ = 4676.6

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.

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 = 8.337 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 8.741 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).

Calculate Critical Values

Average Background Ranking = 12.6

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	2.00	not contaminated
	MW87	8.578	6.60	not contaminated
	MW90A	8.578	-6.60	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 B5

CHROMIUM, DISSOLVED
STATISTICAL TEST 2

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Attachment B5: Statistical Test 2, Test of Proportions, January 2018
Chromium, Dissolved URGA

Chromium, Dissolved (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	0.005	0.005	0.005	0.005	0.005
Jul-16	**0.0021**	0.005	0.005	**0.00438**	0.005
Jan-17	**0.0116**	0.005	0.005	0.005	0.005
Jul-17	**0.00474**	0.005	0.005	0.005	0.005
Jan-18	0.005	0.005	0.005	**0.00331**	0.005

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 =	3	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 =	0.200	P = (x+y)/n
nP =	5	$n = n_b+n_c$
n(1-P) =	20	

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

P_b =	0.300	P_b = proportion of detects in background wells
P_c =	0.133	P_c = proportion of detects in compliance wells
S_D =	0.163	S_D = standard error of difference in proportions
Z =	1.021	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.021	

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

LEAD
STATISTICAL TEST 3

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Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.00144**	0.001	**0.00108**	**0.00107**	0.001
Jul-16	**0.00181**	0.001	**0.00239**	**0.0056**	0.001
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**
Sum	0.0138		0.01280	0.02218	0.0046
n_i	10		5	5	5
$(x_i)_{avg}$	0.00138		0.00256	0.00444	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.. = 0.00214

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	0.05	x.. = the sum of the total number of samples

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Lead (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	**0.000634**	10	
11	**0.00107**	11	
12	**0.00108**	12	
13	**0.00144**	13	
14	**0.00155**	14	
15	**0.00181**	15	
16	**0.00186**	16	
17	**0.00191**	17	
18	**0.00213**	18	
19	**0.00239**	19	
20	**0.00267**	20	
21	**0.00439**	21	
22	**0.00475**	22	
23	**0.00533**	23	
24	**0.0056**	24	
25	**0.00579**	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

Sums of Ranks and Averages

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.00144**	0	**0.00108**	**0.00107**	0
Jul-16	**0.00181**	0	**0.00239**	**0.0056**	0
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**

Observation Ranks for Lead					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	13	5	12	11	5
Jul-16	15	5	19	24	5
Jan-17	14	5	22	21	5
Jul-17	18	5	20	23	5
Jan-18	16	5	17	25	10
R_i	101		90	104	30
$(R_i)_{avg}$	10.1		18.0	20.8	6.0
R_i^2/n_i	1020.1		1620.0	2163.2	180.0

$\Sigma R_i^2/n_i$ = 4983.3

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 = 13.999 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 14.677 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).

Calculate Critical Values

Average Background Ranking = 10.1

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	7.90	not contaminated
	MW87	8.578	10.70	evidence of contamination
	MW90A	8.578	-4.10	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 MW87, there is a statistically significant difference between downgradient compliance test wells and background wells in MW87 from C-404.

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

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW84 and MW90A, there is no statistically significant difference from C-404 in these downgradient compliance test wells; 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).

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 2018 Data, First Reporting Period
Observations (mg/L)

Well No.						
MW93	**0.00144**	**0.00181**	**0.00155**	**0.00213**	**0.00186**	**Upgradient Well!**
MW420	0.001	0.001	0.001	0.001	0.001	**Upgradient Well!**
						Current Data
MW84		X: Mean Value =	0.0014			0.00191
MW87		S: Standard Deviati	0.0004			**0.00579**
MW90A		K* factor =	2.911	(for n = 10)		0.000634
		CV = S/X	0.3181	<1, assume normal distribution		
		Upper Tolerance Interval: TL = X +(KxS) =		**0.0027**	(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 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 MW87, the paired ANOVA was performed.

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.

Lead (mg/L)				
Date	Background	Compliance		
	MW93	MW87	n_i^2	
Jan-16	**0.00144**	**0.00107**	0.0000021	0.0000011
Jul-16	**0.00181**	**0.0056**	0.0000033	0.0000314
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
Sum (x_i)	0.009	0.02218	0.0310	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	0.002	0.00444		
$(x_i)^2$	0.00008	0.00049		

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

Overall mean x.. =	0.00310	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.0310	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-16	-0.00032	-0.00337
Jul-16	0.00005	0.00116
Jan-17	-0.00021	-0.00005
Jul-17	0.00037	0.00089
Jan-18	0.00010	0.00135

X: Mean Value =	-5.85E-19	
S: Standard Deviation =	0.00132	
K* Factor =	2.911	(for n = 10)
CV = S/X =	–2.25E+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	$x_{..} =$ 0.0310
n_i = number of data points per well	$(x_{avg})_{..} =$ 0.00310
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	$f_iS_i^2$	$f_i\ln(S_i^2)$†
0.000272	0.00000007397	-16.420	5	0.0000003	-65.7
0.00196	0.00000382988	-12.473	5	0.0000153	-49.9

$\sum(S_i^2) =$ 0.000003904 $\sum f_i\ln(S_i^2) =$ -115.56913

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.0000020	
ln Sp^2 =	-13.147	
χ^2 =	10.396	(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)

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

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).

Paired (Parametric) ANOVA—Lognormal Data for Lead in MW93 and MW87

ln[Lead (mg/L)]				
Date	Background	Compliance		
	MW93	MW87	n_i^2	
Jan-16	**-6.54**	**-6.84**	42.81	46.79
Jul-16	**-6.31**	**-5.18**	39.87	26.88
Jan-17	**-6.47**	**-5.43**	41.85	29.47
Jul-17	**-6.15**	**-5.23**	37.84	27.40
Jan-18	**-6.29**	**-5.15**	39.53	26.54
Sum (x_i)	-31.77	-27.84	-59.61	Total Sum (x..)
n_i	5	5		
$(x_i)_{avg}$	-6.35	-5.57		
$(x_i)^2$	1009.07	775.04		

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

Overall mean x.. =	-5.96	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..} =$	-59.61	x.. = the sum of the total number of samples

Determine Normality of Dataset

Coefficient of Variability Test—Lognormal Data for Lead in MW93 and MW87

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

Date	Background	Compliance
	MW93	MW87
Jan-16	-0.19	-1.27
Jul-16	0.04	0.38
Jan-17	-0.12	0.14
Jul-17	0.20	0.33
Jan-18	0.07	0.42

X: Mean Value =	-6.22E-16	
S: Standard Deviation =	0.49	
K* Factor =	2.911	(for n = 10)
CV = S/X =	–7.89E+14	<1, data are normally distributed

*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.

Determine Equality of Variance of Lognormal Dataset for Lead in MW93 and MW87

p = number of wells	$x_{..} =$ -59.61
n_i = number of data points per well	$(x_{avg})_{..} =$ -5.96
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	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.15	0.02	-3.73	5	0.10	-14.9
0.72	0.52	-0.66	5	2.07	-2.6

$\sum(S_i^2)$ = 0.54 $\sum f_i\ln(S_i^2)$ = -17.55

Equality of Variance: Bartlett's Test

f =	8	
Sp^2 =	0.27	
ln Sp^2 =	-1.31	
χ^2 =	7.10	(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)

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

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

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

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

Statistical Test 3, Nonparametric ANOVA

Lead (mg/L)		
Date	Background	Compliance
	MW93	MW87
Jan-16	**0.00144**	**0.00107**
Jul-16	**0.00181**	**0.0056**
Jan-17	**0.00155**	**0.00439**
Jul-17	**0.00213**	**0.00533**
Jan-18	**0.00186**	**0.00579**
Sum	0.0088	0.02218
n_i	5	5
$(x_i)_{avg}$	0.00176	0.00444

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.. = 0.00310

N = 10 N = the total number of samples
p = 2 p = the number of n_i groups
x.. = 0.03097 x.. = the sum of the total number of samples

Ranking of Observations

Sequence	Lead (mg/L)	Adjusted Rank	Tie Number
1	**0.00107**	1	
2	**0.00144**	2	
3	**0.00155**	3	
4	**0.00181**	4	
5	**0.00186**	5	
6	**0.00213**	6	
7	**0.00439**	7	
8	**0.00533**	8	
9	**0.0056**	9	
10	**0.00579**	10	

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

n_{tie} Adjustment for Ties: $(n_{tie}^3 - n_{tie})$
0 Tie 1 = 0
$\sum T_i$ = 0

Sums of Ranks and Averages

Observation Ranks for Lead		
Date	Background	Compliance
	MW93	MW87
Jan-16	2	1
Jul-16	4	9
Jan-17	3	7
Jul-17	6	8
Jan-18	5	10
R_i	20	35
$(R_i)_{avg}$	4	7
R_i^2/n_i	80.0	245.0

$\Sigma R_i^2/n_i$ = 325
K = 2
N = 10

Calculation of Kruskal-Wallis Statistic

H =	2.455	Kruskal-Wallis Statistic	$H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$
H' =	2.455	Corrected Kruskal-Wallis	$H' = H/[1-(\sum T_i/N^3-N)]$
χ^2_{crit} * =	3.841	1	degrees of freedom at the 5% significance level

NOTE: H' < χ2crit.

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

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

Calculate Critical Values

NOTE: Not required due to H' < χ^2_{crit}.

Since H' < $\chi 2_{crit}$, there is no statistically significfant evidence of a difference between background wells and compliance wells.

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ATTACHMENT B7

SELENIUM
STATISTICAL TEST 2

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Attachment B7: Statistical Test 2, Test of Proportions, January 2018
Selenium URGA

Selenium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.00165**	0.0025	0.0025	0.0025	**0.00231**
Jul-16	0.0025	0.0025	0.0025	**0.00159**	**0.0017**
Jan-17	0.0025	0.0025	**0.00294**	0.0025	0.0025
Jul-17	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-18	0.0025	0.0025	0.0025	**0.00219**	0.0025

mg/L = milligrams 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 =	5	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 =	0.240	P=(x+y)/n
nP =	6	$n=n_b+n_c$
n(1-P) =	19	

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

P_b =	0.100	P_b = proportion of detects in background wells
P_c =	0.333	P_c = proportion of detects in compliance wells
S_D =	0.174	S_D = standard error of difference in proportions
Z =	-1.338	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.338	

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 B8

SELENIUM, DISSOLVED
STATISTICAL TEST 2

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Attachment B8: Statistical Test 2, Test of Proportions, January 2018
Selenium, Dissolved URGA

Selenium, Dissolved (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**0.00225**	0.0025	0.0025	**0.00199**	**0.00197**
Jul-16	0.0025	0.0025	0.0025	0.0025	**0.00157**
Jan-17	0.0025	0.0025	0.0025	0.0025	0.0025
Jul-17	0.0025	0.0025	0.0025	0.0025	0.0025
Jan-18	**0.00201**	0.0025	**0.00204**	0.0025	0.0025

mg/L = milligrams 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 =	2	X = number of samples above DL in background wells
Y =	4	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 =	0.240	P = (x+y)/n
nP =	6	$n = n_b+n_c$
n(1-P) =	19	

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

P_b =	0.200	P_b = proportion of detects in background wells
P_c =	0.267	P_c = proportion of detects in compliance wells
S_D =	0.174	S_D = standard error of difference in proportions
Z =	-0.382	$Z = (P_b-P_c)/S_D$
absolute value of Z =	0.382	

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 B9

TECHNETIUM-99
STATISTICAL TEST 2

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Attachment B9: Statistical Test 2, Test of Proportions, January 2018
Technetium-99 URGA

Technetium-99 (pCi/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	10.45	9.3	**170**	10.55	10.3
Jul-16	8.4	8.7	8.65	9	9.15
Jan-17	6.75	6.8	6.75	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

mg/L = milligrams 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 B10

TRICHLOROETHENE
STATISTICAL TESTS 4/3

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Trichloroethene (TCE, µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**2490**	**222**	**1350**	**1230**	**39.8**
Jul-16	**2020**	**169**	**1820**	**1090**	**35.3**
Jan-17	**2450**	**274**	**2620**	**2240**	**49.5**
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
n_i	10		5	5	5
Sum	10515		11860	7580	211.30
(x_i)avg	1051.50		2372.00	1516.00	42.26

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

Overall mean x.. = 1206.65
N = 25 N = the total number of samples
p = 4 p = the number of n_i groups
x.. = 30166.30 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-16	1438.50	-829.50	-1022.00	-286.00	-2.46
Jul-16	968.50	-882.50	-552.00	-426.00	-6.96
Jan-17	1398.50	-777.50	248.00	724.00	7.24
Jul-17	348.50	-787.50	538.00	104.00	3.84
Jan-18	-57.50	-819.50	788.00	-116.00	-1.66

X: Mean Value = -1.14E-15
S: Standard Deviation = 694.7
K* Factor = 2.292 (for n = 25)
CV = S/X = -6.11E+17 < 1, the 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)].

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
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)
$f_i = n_i - 1$

$x_{..} =$ 30166.30
$(x_{avg})_{..} =$ 1206.65

p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
969.018	938994.94	13.753	10	8450954.5	123.8
761.755	580270.00	13.271	5	2321080.000	53.1
450.478	202930.00	12.221	5	811720.000	48.9
5.577	31.10	3.437	5	124.412	13.7

$\sum(S_i^2) =$ 1722226.05 $\sum f_i \ln(S_i^2) =$ 239.5

Equality of Variance: Bartlett's Test

f = 21
$Sp^2 =$ 551613.282
$\ln Sp^2 =$ 13.221
$\chi^2 =$ 38.143 (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

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

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).

Lognormal Data for TCE

ln[TCE (µg/L)]					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	7.82	5.40	7.21	7.11	3.68
Jul-16	7.61	5.13	7.51	6.99	3.56
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
x_i	64.55		38.62	36.46	18.68
(x_i)avg	6.45		7.72	7.29	3.74

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-16	1.37	-1.05	-0.52	-0.18	-0.05
Jul-16	1.16	-1.33	-0.22	-0.30	-0.17
Jan-17	1.35	-0.84	0.15	0.42	0.17
Jul-17	0.79	-0.88	0.25	0.10	0.09
Jan-18	0.45	-1.01	0.33	-0.05	-0.03

X: Mean Value =	2.31E-16	
S: Standard Deviation =	0.71	
K* Factor =	2.292	(for n = 25)
CV = S/X =	3.07E+15	≥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)].

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)
$f_i = n_i - 1$

$x_{..} =$ 158.31
$(x_{avg})_{..} =$ 6.33
p = 4
N = 25

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	ni	$f_iS_i^2$	$f_i\ln(S_i^2)$
1.116	1.245	0.219	10	11.203	2.0
0.357	0.128	-2.059	5	0.510	-8.2
0.279	0.078	-2.556	5	0.310	-10.2
0.132	0.017	-4.047	5	0.070	-16.2

$\sum(S_i^2) =$ 1.47 $\sum f_i\ln(S_i^2) =$ -32.7

Equality of Variance: Bartlett's Test

$f =$ 21
$Sp^2 =$ 0.576
$\ln Sp^2 =$ -0.552
$\chi^2 =$ 21.087 (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

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

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

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

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

Attachment B10: Statistical Test 3, Nonparametric ANOVA, January 2018 Trichloroethene URGA

Statistical Test 3, Nonparametric ANOVA

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**2490**	**222**	**1350**	**1230**	**39.8**
Jul-16	**2020**	**169**	**1820**	**1090**	**35.3**
Jan-17	**2450**	**274**	**2620**	**2240**	**49.5**
Jul-17	**1400**	**264**	**2910**	**1620**	**46.1**
Jan-18	**994**	**232**	**3160**	**1400**	**40.6**
n_i	10		5	5	5
x_i	10515		11860	7580	211.30
(x_i)avg	1051.50		2372.00	1516.00	42.26

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.. = 1206.65

N =	25	N = the total number of samples
p =	4	p = the number of n_i groups
x.. =	30166.30	x.. = the sum of the total number of samples

Attachment B10: Statistical Test 3, Nonparametric ANOVA, January 2018 Trichloroethene URGA

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	TCE (µg/L)	Adjusted Rank	Tie Number
1	**35.3**	1	
2	**39.8**	2	
3	**40.6**	3	
4	**46.1**	4	
5	**49.5**	5	
6	**169**	6	
7	**222**	7	
8	**232**	8	
9	**264**	9	
10	**274**	10	
11	**994**	11	
12	**1090**	12	
13	**1230**	13	
14	**1350**	14	
15	**1400**	15.5	Tie 1
16	**1400**	15.5	
17	**1620**	17	
18	**1820**	18	
19	**2020**	19	
20	**2240**	20	
21	**2450**	21	
22	**2490**	22	
23	**2620**	23	
24	**2910**	24	
25	**3160**	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: $(ntie^3 - ntie)$
2	Tie 1 = 6
	$\sum T_i$ = 6

Attachment B10: Statistical Test 3, Nonparametric ANOVA, January 2018 Trichloroethene URGA

Sums of Ranks and Averages

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	**2520**	**191**	**1530**	**1250**	**37.9**
Jul-16	**2490**	**222**	**1350**	**1230**	**39.8**
Jan-17	**2020**	**169**	**1820**	**1090**	**35.3**
Jul-17	**2450**	**274**	**2620**	**2240**	**49.5**
Jan-18	**1400**	**264**	**2910**	**1620**	**46.1**

Observation Ranks for TCE					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	22	7	14	13	2
Jul-16	19	6	18	12	1
Jan-17	21	10	23	20	5
Jul-17	15.5	9	24	17	4
Jan-18	11	8	25	15.5	3
$R_{i.}$	128.5		104	77.5	15
$(R_i)_{avg}$	12.9		20.8	15.5	3
R_i^2/n_i	1651.2		2163.2	1201.3	45

$\Sigma R_i^2/n_i$ = 5060.7

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 = 15.428 Kruskal-Wallis Statistic $H = [12/N(N+1)*\Sigma R_i^2/n_i] - 3(N+1)$

H' = 15.434 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 $Z(\alpha/(K-1))$** = 2.128

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 B10: Statistical Test 3, Nonparametric ANOVA, January 2018 Trichloroethene URGA

Calculate Critical Values

Average Background Ranking = 12.9

	Well No.	C_i	$(R_i)_{avg}$ - $(R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	7.95	not contaminated
	MW87	8.578	2.65	not contaminated
	MW90A	8.578	-9.85	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, 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 B11

URANIUM
STATISTICAL TEST 2

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Attachment B11: Statistical Test 2, Test of Proportions, January 2018 Uranium URGA

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jan-16	0.0001	0.0001	0.0001	0.0001	0.0001
Jul-16	**0.000165**	0.0001	**0.000345**	**0.000559**	0.0001
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

mg/L = milligrams 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=	3	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 =	0.440	P=(x+y)/n
nP =	11	$n=n_b+n_c$
n(1-P) =	14	

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

P_b =	0.300	P_b =proportion of detects in background wells
P_c =	0.533	P_c =proportion of detects in compliance wells
S_D =	0.203	S_D=standard error of difference in proportions
Z =	-1.151	$Z = (P_b-P_c)/S_D$
absolute value of Z =	1.151	

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 B12

STATISTICIAN STATEMENT

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

March 28, 2018

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 a Chemist, with a Bachelor of Science degree in chemistry and a minor in biology, 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 Geosyntec Consultants.

For this project, the statistical analyses on groundwater data from January 2016 through January 2018 were performed in accordance with the Hazardous Waste Management Facility Permit, Appendix E using Microsoft Excel 2010 and U.S. Environmental Protection Agency's (USEPA'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 USEPA *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance* (1989).

Sincerely,

Jennifer R. Blewett

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