

**C-404 Hazardous Waste Landfill
November 2018 Semiannual
Groundwater Report
(April 2018–September 2018),
Paducah Gaseous Diffusion Plant,
Paducah, Kentucky**



This document is approved for public release per review by:

David Hayden
FRNP Classification Support

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Date

**C-404 Hazardous Waste Landfill
November 2018 Semiannual
Groundwater Report
(April 2018–September 2018),
Paducah Gaseous Diffusion Plant,
Paducah, Kentucky**

Date Issued—November 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 November 2018 Semiannual Groundwater Report (April 2018–September 2018)*, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, FRNP-RPT-0026/V2, 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 second reporting period 2018 covers April through September 2018 and includes analytical data from the August 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. Arsenic and trichloroethene concentrations in compliance well MW84 and lead and uranium concentrations in compliance well MW87 were statistically different from concentrations in the background wells. The 2007 *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2 (PRS 2007) demonstrated that the C-404 Landfill was not the source of the historical, statistically significant background exceedance of trichloroethene in MW84. MW84 arsenic exceedance is consistent with the 2007 Alternate Source Demonstration. The trend of arsenic concentrations in MW84 is similar to the historical TCE trend in the same well. This determination for arsenic in MW84 fulfills Section II.K.8 of the Hazardous Waste Management Facility Permit, which allows for demonstrating that the exceedance is consistent with the findings in the 2007 Alternate Source Demonstration and also allows for the demonstration to be submitted within the semiannual report.

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

The leachate in the C-404 Landfill leachate collection system is monitored and, at a minimum, is removed and sampled when the level exceeds 3 ft in depth. On April 16, 2018, the leachate level in the C-404 Landfill leachate collection system was measured at 39 inches and the leachate was sampled. On April 17, 2018, 1,150 gal was removed. Leachate analytical data from the sample collected February 27, 2018, during the previous reporting period are provided in this report because the laboratory results were not available by the regulatory deadline of the previous report.

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1. INTRODUCTION

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

Groundwater analytical results are provided in Appendix A. The statistical analyses and qualification statement are provided in Appendix B. The annual groundwater flow rate and direction determination is provided in Appendix C. Landfill leachate analytical results are provided in Appendix D.

1.1 BACKGROUND

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

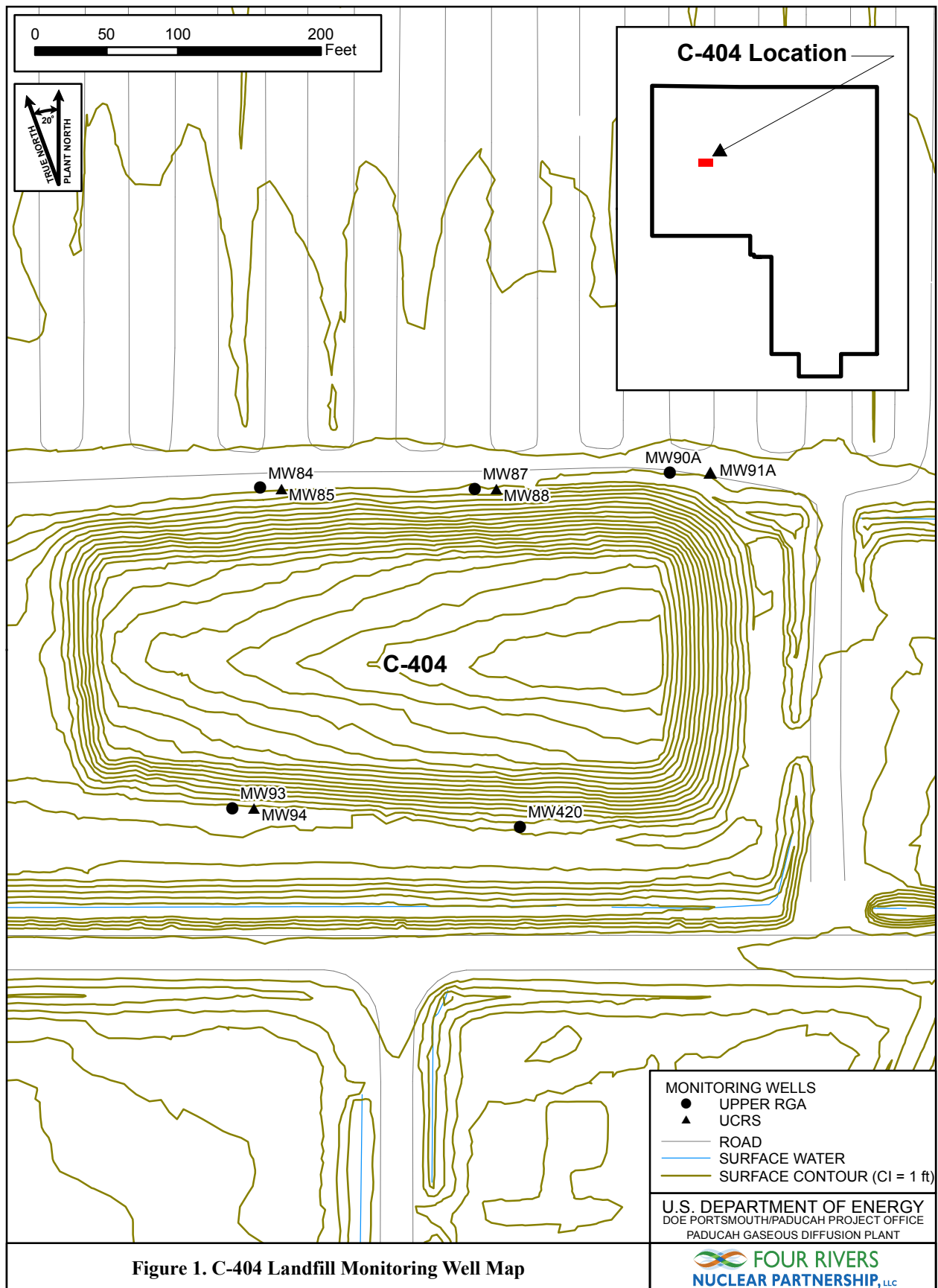
In 1986, the disposal of waste at the C-404 Landfill was halted, and a portion of the disposed-of waste was found to be Resource Conservation and Recovery Act (RCRA)-hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987. It currently is regulated under RCRA as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

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

1.2 MONITORING PERIOD ACTIVITIES

1.2.1 Groundwater Monitoring

Groundwater sampling was conducted in August 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. A map of the MW locations is provided in Figure 1.



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Table 1 presents the well numbers for URGAs 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 URGAs.

Table 1. Monitoring Well Locations

UCRS	
Located south of C-404 Landfill, adjacent to upgradient URGAs background well MW93	MW94
Located north of C-404 Landfill, adjacent to downgradient URGAs 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.

This table refers to these UCRS wells as being adjacent to an “upgradient” or “downgradient” URGAs well location, identified relative to the URGAs 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 URGAs; therefore, UCRS wells are not considered “upgradient” or “downgradient” of other wells in the area.

Table 2 presents the Assembled Kentucky Groundwater (AKGWA) numbers for each MW. 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 Part VIII.E of the 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 August 2018 semiannual sampling event. Appendix B of this report contains the statistical analyses.

Per Permit Specific Condition II.K.4.a, the groundwater flow rate and direction are evaluated annually and reported in each November report. For this report, potentiometric maps have been included in Appendix C using data from sampling performed in January and August 2018. Depth-to-water was measured on January 29, 2018, and August 21, 2018, from several wells at the perimeter of the C-404 Landfill. Water level measurements in 11 vicinity well locations define the potentiometric surface for the URGAs (see Table C.1). Groundwater flow direction beneath the C-404 Landfill generally trends northeastward, but commonly varies from northeast to north. On January 29, 2018 and August 21, 2018, groundwater flow was toward the northeast (see Figures C.1 and C.2).

1.2.2 Landfill Leachate

In accordance with Section 1.2 of the Permit, the quantity of liquid in the leachate collection system is monitored (at least monthly) and, at a minimum, will be “removed when the quantity exceeds 3 ft in depth.” Once the leachate depth 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, April to September 2018, was 1,150 gal. The leachate was sampled on April 16, 2018. Leachate analytical data from the sample collected February 27, 2018, during the previous reporting period are provided in this report because the laboratory results were not available by the regulatory deadline of the previous report. Analytical results are included in Appendix D.

2. STATISTICAL SYNOPSIS

The statistical analyses conducted on the data collected from C-404 Landfill were performed in accordance with procedures in the Permit, Part VIII.E, reissued in July 2015. Appendix B of this report contains the statistical analyses performed for this reporting period. Data utilized for statistical analyses included data from the URGA background wells, MW93 and MW420, and URGA compliance wells, MW84, MW87, and MW90A. For these statistical analyses, the reporting period data set includes data from July 2016, January 2017, July 2017, January 2018, and August 2018.

Arsenic and TCE concentrations in compliance well MW84 and lead and uranium concentrations in compliance well MW87 were statistically different from concentrations in the background wells. Appendix B provides a summary of the statistical analyses performed. The statistical tests on all other parameters showed no statistical difference between concentrations in the compliance (downgradient) and background (upgradient) wells.

STATISTICALLY SIGNIFICANT EXCEEDANCE OF BACKGROUND IN MW84

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

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

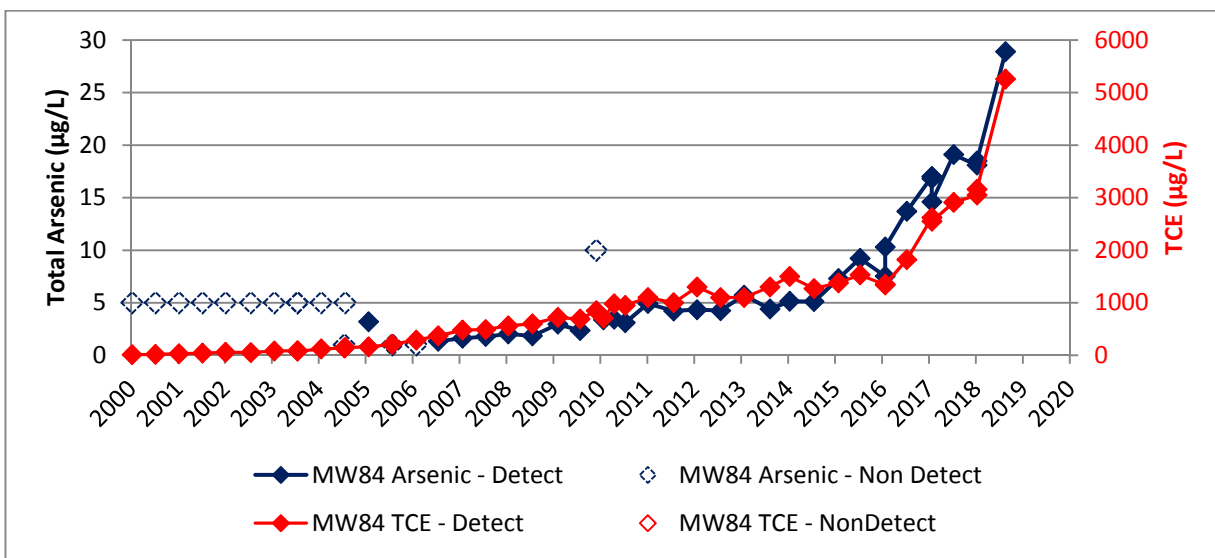


Figure 2. Arsenic and TCE Trend in MW84

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

First, until the January 2015 sampling event, the westernmost upgradient well (MW93) typically had higher arsenic concentrations than the downgradient well MW84 (see Figure 3). Since then, the MW84 arsenic concentrations have increased steadily, potentially reflecting increasing proximity to the core of the upgradient source. This condition is similar to the pattern of TCE concentrations historically seen in these same wells and is attributed to a source upgradient/crossgradient of the C-404 Landfill in the 2007 Alternate Source Demonstration. Similar, but slightly delayed, arsenic and TCE trends also are evident in neighboring (east) downgradient well MW87 (see Figure 4). The TCE detections¹ over time in MW333, located approximately 106 ft southwest of the C-404 Landfill, are depicted in Figure 5.

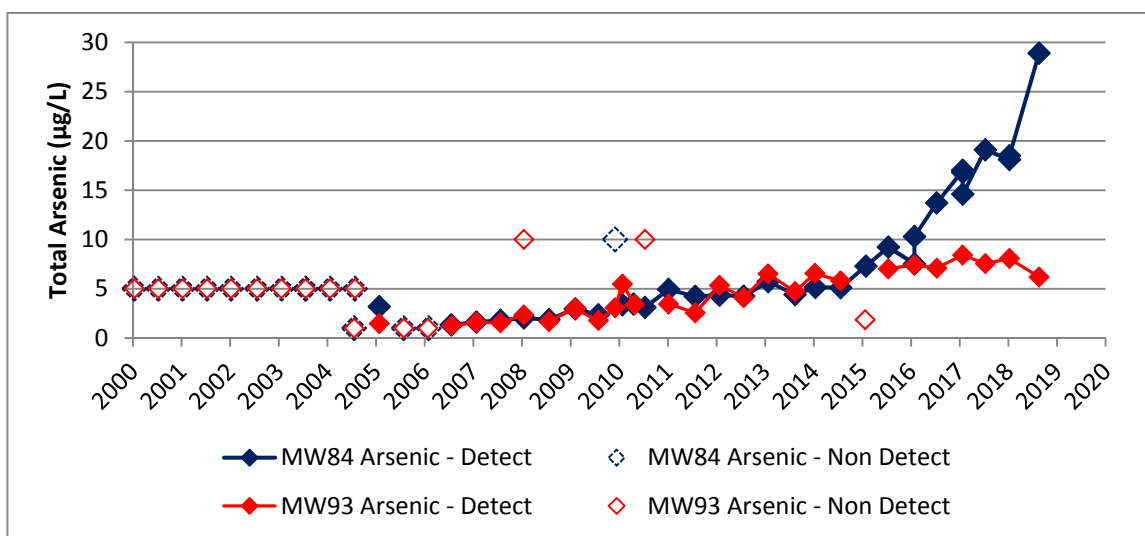


Figure 3. Arsenic Trend in MW84 and MW93

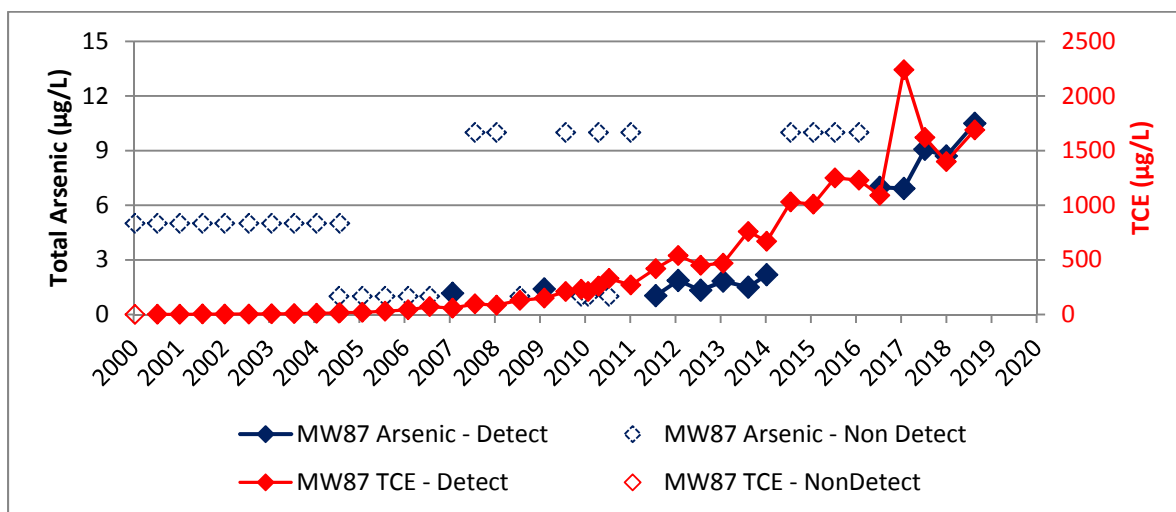


Figure 4. Arsenic and TCE Trend in MW87

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

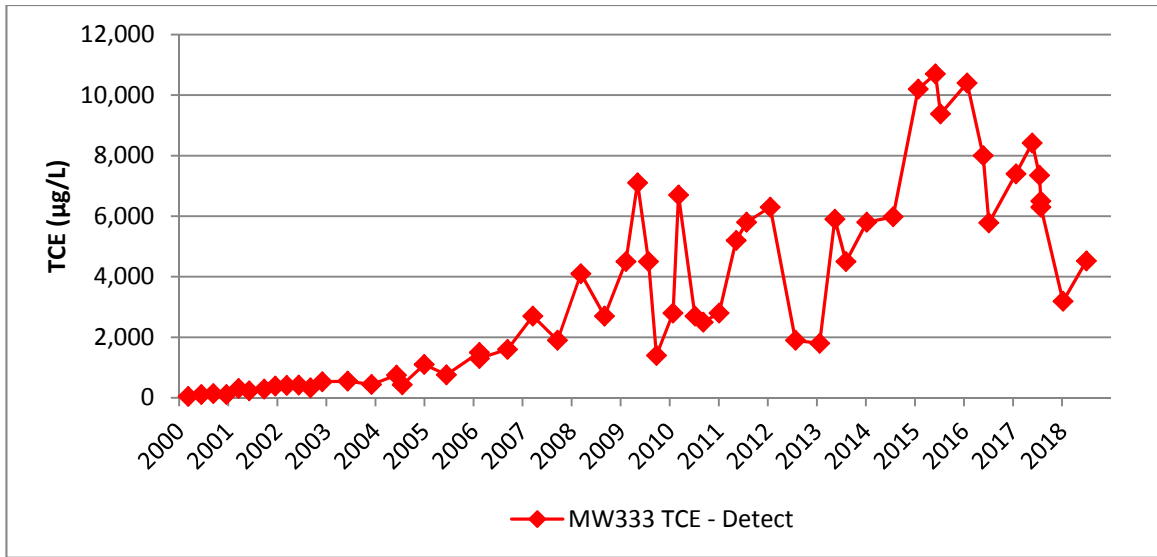


Figure 5. TCE Trend in MW333

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

Finally, most of the leachate samples collected over the years have had no detectable arsenic (dissolved arsenic is not required by the Permit for leachate) and the measureable concentrations are well below concentrations recently detected in RGA groundwater at MW84. Of the 25% (17 of 67) of leachate samples with measureable arsenic concentrations, the maximum concentration of 6.32 µg/L in leachate is below the August 2018 arsenic concentration of 28.9 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 August 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 during each semiannual sampling event. Equipment rinseate blanks, field blanks, field duplicates, and trip blanks are obtained to ensure quality control and are reported in the Analytical Results in Appendix A. Laboratory quality control samples, such as matrix spikes, matrix spike duplicates, and method blanks, are performed by the laboratory and reported in the laboratory report. Both field and laboratory quality control sample results are reviewed as part of the data validation process.

FIELD DUPLICATE SAMPLE

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

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

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

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

In order to comply with the current Permit requirement until a Permit modification can be established, two field duplicates were collected during this reporting period. Both samples were collected from the same MW. A groundwater sample was collected from a MW along with a field duplicate sample prescribed

by the Permit. A separate groundwater sample was collected from the same MW along with a field duplicate sample prescribed by CP4-ES-2704. This process of collecting two field duplicates will be incorporated into future sampling events.

Table 3 provides a comparison of the analytical data for the four samples. The field duplicate sample for MW85 was collected as prescribed by the Permit. The field duplicate sample for MW85-2 was collected as prescribed by CP4-ES-2704. Concentrations of each parameter are consistent among the four samples with the exception of lead. Concentrations are consistent between the MW85 groundwater sample and the MW85 duplicate (Permit) except for TCE. Based on the estimated concentration in sample MW85 duplicate (Permit), the field duplicate TCE concentration was approximately one-third of the groundwater sample TCE concentration. Concentrations are consistent between the MW85-2 groundwater sample and the MW85-2 duplicate (procedure).

Table 3. Field Duplicate Sample Comparison

Analysis	Units	MW85		MW85 duplicate (Permit)		MW85-2		MW85-2 duplicate (procedure)	
		Results	Q	Results	Q	Results	Q	Results	Q
Arsenic	mg/L	0.00992		0.0101		0.0104		0.0106	
Arsenic, Dissolved	mg/L	0.005	U	0.005	U	0.005	U	0.00206	J
Cadmium	mg/L	0.001	U	0.001	U	0.001	U	0.001	U
Cadmium, Dissolved	mg/L	0.001	U	0.001	U	0.001	U	0.001	U
Chromium	mg/L	0.00963	J	0.0105		0.0049	J	0.00611	J
Chromium, Dissolved	mg/L	0.00337	J	0.01	U	0.01	U	0.01	U
Lead	mg/L	0.000917	J	0.000924	J	0.002	U	0.000554	J
Lead, Dissolved	mg/L	0.002	U	0.002	U	0.002	U	0.002	U
Mercury	mg/L	0.0002	U	0.0002	U	0.0002	U	0.0002	U
Mercury, Dissolved	mg/L	0.0002	U	0.0002	U	0.0002	U	0.0002	U
Selenium	mg/L	0.005	U	0.005	U	0.005	U	0.005	U
Selenium, Dissolved	mg/L	0.005	U	0.005	U	0.005	U	0.005	U
Technetium-99	pCi/L	52.6		64		50.5		64.3	
Total Organic Carbon (TOC)	mg/L	0.919	J	0.909	J	0.941	J	0.915	J
Trichloroethene	µg/L	1.24		0.41	J	1	U	1	U
Uranium	mg/L	0.000367		0.000372		0.000299		0.000301	
Uranium-234	pCi/L	0.0486	U	-0.39	U	0.315	U	0.545	U
Uranium-235	pCi/L	0.201	U	-0.0572	U	0.0548	U	0	U
Uranium-238	pCi/L	0.0913	U	-0.185	U	0.12	U	0.233	U

Q = qualifier

U = analyte analyzed for but not detected at or below the lowest concentration reported

J = estimated quantity

4. PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: *C-404 Hazardous Waste Landfill
November 2018 Semiannual Groundwater Report
(April 2018–September 2018),
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(FRNP-RPT-0026/V2)*

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



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R.R. Davis
11/14/18

Kenneth R. Davis
Kenneth R. Davis

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November 14, 2018
Date

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5. REFERENCES

- KDWM (Kentucky Division of Waste Management) 2017. Hazardous Waste Management Facility Permit for the U.S. Department of Energy, Paducah Gaseous Diffusion Plant, KY8-890-008-982, effective October 13.
- PRS (Paducah Remediation Services, LLC) 2007. *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, PRS-ENM-0031/R2, Paducah Remediation Services, LLC, Kevil, KY.

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APPENDIX A

**C-404 HAZARDOUS WASTE LANDFILL GROUNDWATER
ANALYTICAL RESULTS**

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**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

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

AKGWA Well Tag #: 8000-5233

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0289	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.9	Inches/Hg		8/20/2018				X
Cadmium	J	0.000323	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium		0.0752	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		417	umho/cm		8/20/2018				X
Depth to Water		48.92	ft		8/20/2018				X
Dissolved Oxygen		3.86	mg/L		8/20/2018				X
Lead		0.00319	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.01	Std Unit		8/20/2018				X
Redox		417	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	11.8	pCi/L	13.5	8/20/2018	8.2	8.31	DOE TC-02-RC	=
Temperature		68.4	deg F		8/20/2018				X
Trichloroethene		5260	ug/L	100	8/20/2018			SW846-8260B	=
Turbidity		137	NTU		8/20/2018				X
Uranium		0.000302	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	0.276	pCi/L	1.05	8/20/2018	0.605	0.608	HASL 300, U-02-RC M	=
Uranium-235	U	0.167	pCi/L	0.501	8/20/2018	0.469	0.47	HASL 300, U-02-RC M	=
Uranium-238	U	0.373	pCi/L	0.647	8/20/2018	0.537	0.539	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		0.00992	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.89	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	J	0.00963	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	J	0.00337	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		331	umho/cm		8/20/2018				X
Depth to Water		10.29	ft		8/20/2018				X
Dissolved Oxygen		3.48	mg/L		8/20/2018				X
Lead	J	0.000917	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.3	Std Unit		8/20/2018				X
Redox		393	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99		52.6	pCi/L	14.2	8/20/2018	10.1	11.7	DOE TC-02-RC	=
Temperature		69.7	deg F		8/20/2018				X
Trichloroethene		1.24	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		85.4	NTU		8/20/2018				X
Uranium		0.000367	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	0.0486	pCi/L	1.43	8/20/2018	0.675	0.675	HASL 300, U-02-RC M	=
Uranium-235	U	0.201	pCi/L	0.604	8/20/2018	0.566	0.567	HASL 300, U-02-RC M	=
Uranium-238	U	0.0913	pCi/L	1.21	8/20/2018	0.589	0.59	HASL 300, U-02-RC M	=

* The field duplicate sample associated with this sample is Sampling Point MW85 REP.

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

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

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0101	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.89	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium		0.0105	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		331	umho/cm		8/20/2018				X
Depth to Water		10.29	ft		8/20/2018				X
Dissolved Oxygen		3.48	mg/L		8/20/2018				X
Lead	J	0.000924	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.3	Std Unit		8/20/2018				X
Redox		393	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99		64	pCi/L	14.4	8/20/2018	10.6	12.8	DOE TC-02-RC	=
Temperature		69.7	deg F		8/20/2018				X
Trichloroethene	J	0.41	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		85.4	NTU		8/20/2018				X
Uranium		0.000372	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.39	pCi/L	1.77	8/20/2018	0.607	0.608	HASL 300, U-02-RC M	=
Uranium-235	U	-0.0572	pCi/L	1.14	8/20/2018	0.494	0.495	HASL 300, U-02-RC M	=
Uranium-238	U	-0.185	pCi/L	1.27	8/20/2018	0.429	0.43	HASL 300, U-02-RC M	=

* Field duplicate sample collected as prescribed in the Permit.

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

Sampling Point: 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		0.0104	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.89	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	J	0.0049	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		331	umho/cm		8/20/2018				X
Depth to Water		10.29	ft		8/20/2018				X
Dissolved Oxygen		3.48	mg/L		8/20/2018				X
Lead	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.3	Std Unit		8/20/2018				X
Redox		393	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99		50.5	pCi/L	14	8/20/2018	9.96	11.4	DOE TC-02-RC	=
Temperature		69.7	deg F		8/20/2018				X
Trichloroethene	U	1	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		85.4	NTU		8/20/2018				X
Uranium		0.000299	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	0.315	pCi/L	1.25	8/20/2018	0.713	0.716	HASL 300, U-02-RC M	=
Uranium-235	U	0.0548	pCi/L	1.2	8/20/2018	0.573	0.573	HASL 300, U-02-RC M	=
Uranium-238	U	0.12	pCi/L	0.759	8/20/2018	0.451	0.452	HASL 300, U-02-RC M	=

* The field duplicate sample associated with this sample is Sampling Point MW85 FR.

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

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

AKGWA Well Tag #: 8000-5234

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/- TPU)	Method	Validation	
Arsenic		0.0106	mg/L	0.005	8/20/2018		SW846-6020	=	
Arsenic, Dissolved	J	0.00206	mg/L	0.005	8/20/2018		SW846-6020	=	
Barometric Pressure Reading		29.89	Inches/Hg		8/20/2018			X	
Cadmium	U	0.001	mg/L	0.001	8/20/2018		SW846-6020	=	
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018		SW846-6020	=	
Chromium	J	0.00611	mg/L	0.01	8/20/2018		SW846-6020	=	
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018		SW846-6020	=	
Conductivity		331	umho/cm		8/20/2018			X	
Depth to Water		10.29	ft		8/20/2018			X	
Dissolved Oxygen		3.48	mg/L		8/20/2018			X	
Lead	J	0.000554	mg/L	0.002	8/20/2018		SW846-6020	=	
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018		SW846-6020	=	
Mercury	U	0.0002	mg/L	0.0002	8/20/2018		SW846-7470A	=	
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018		SW846-7470A	=	
pH		6.3	Std Unit		8/20/2018			X	
Redox		393	mV		8/20/2018			X	
Selenium	U	0.005	mg/L	0.005	8/20/2018		SW846-6020	=	
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018		SW846-6020	=	
Technetium-99		64.3	pCi/L	14.6	8/20/2018	10.8	12.9	DOE TC-02-RC	=
Temperature		69.7	deg F		8/20/2018				X
Trichloroethene	U	1	ug/L	1	8/20/2018		SW846-8260B	=	
Turbidity		85.4	NTU		8/20/2018				X
Uranium		0.000301	mg/L	0.0002	8/20/2018		SW846-6020	=	
Uranium-234	U	0.545	pCi/L	2.56	8/20/2018	1.4	1.41	HASL 300, U-02-RC M	=
Uranium-235	U	0	pCi/L	1.14	8/20/2018	0.764	0.767	HASL 300, U-02-RC M	=
Uranium-238	U	0.233	pCi/L	1.47	8/20/2018	0.874	0.876	HASL 300, U-02-RC M	=

* Field duplicate sample collected as prescribed by internal procedure.

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

Sampling Point: 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		0.0105	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.91	Inches/Hg		8/20/2018				X
Cadmium	J	0.000372	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium		0.275	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	J	0.005	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		339	umho/cm		8/20/2018				X
Depth to Water		48.86	ft		8/20/2018				X
Dissolved Oxygen		2.79	mg/L		8/20/2018				X
Lead		0.00682	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.05	Std Unit		8/20/2018				X
Redox		434	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	4.44	pCi/L	15	8/20/2018	8.8	8.81	DOE TC-02-RC	=
Temperature		68.3	deg F		8/20/2018				X
Trichloroethene		1690	ug/L	50	8/20/2018			SW846-8260B	=
Turbidity		215	NTU		8/20/2018				X
Uranium		0.000722	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.102	pCi/L	1.73	8/20/2018	0.73	0.731	HASL 300, U-02-RC M	=
Uranium-235	U	-0.119	pCi/L	1.37	8/20/2018	0.526	0.527	HASL 300, U-02-RC M	=
Uranium-238	U	0.208	pCi/L	1.32	8/20/2018	0.712	0.713	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		0.0101	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.91	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium		0.0108	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		652	umho/cm		8/20/2018				X
Depth to Water		9.69	ft		8/20/2018				X
Dissolved Oxygen		2.56	mg/L		8/20/2018				X
Lead		0.00353	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		5.84	Std Unit		8/20/2018				X
Redox		413	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99		19.5	pCi/L	14.5	8/20/2018	9.13	9.38	DOE TC-02-RC	=
Temperature		67.9	deg F		8/20/2018				X
Trichloroethene		13.3	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		136	NTU		8/20/2018				X
Uranium		0.000423	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.157	pCi/L	1.71	8/20/2018	0.668	0.669	HASL 300, U-02-RC M	=
Uranium-235	U	-0.0669	pCi/L	1.34	8/20/2018	0.577	0.578	HASL 300, U-02-RC M	=
Uranium-238	U	-0.162	pCi/L	1.38	8/20/2018	0.49	0.491	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	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.91	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		216	umho/cm		8/20/2018				X
Depth to Water		47.75	ft		8/20/2018				X
Dissolved Oxygen		3.49	mg/L		8/20/2018				X
Lead	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		5.98	Std Unit		8/20/2018				X
Redox		431	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	7.78	pCi/L	14.6	8/20/2018	8.71	8.76	DOE TC-02-RC	=
Temperature		69.6	deg F		8/20/2018				X
Trichloroethene		53.3	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		35.4	NTU		8/20/2018				X
Uranium	U	0.0002	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.954	pCi/L	2.61	8/20/2018	0.933	0.933	HASL 300, U-02-RC M	=
Uranium-235	U	-0.177	pCi/L	1.5	8/20/2018	0.534	0.535	HASL 300, U-02-RC M	=
Uranium-238	U	-0.278	pCi/L	1.72	8/20/2018	0.632	0.633	HASL 300, U-02-RC M	=

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

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

AKGWA Well Tag #: 8007-2917

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic		0.0168	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved		0.012	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.89	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	J	0.00538	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		1429	umho/cm		8/20/2018				X
Depth to Water		12.88	ft		8/20/2018				X
Dissolved Oxygen		4.11	mg/L		8/20/2018				X
Lead	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.22	Std Unit		8/20/2018				X
Redox		47	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99		37.6	pCi/L	14.8	8/20/2018	9.98	10.8	DOE TC-02-RC	=
Temperature		69.8	deg F		8/20/2018				X
Trichloroethene		34	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		14.9	NTU		8/20/2018				X
Uranium	J	0.000175	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.305	pCi/L	1.75	8/20/2018	0.625	0.625	HASL 300, U-02-RC M	=
Uranium-235	U	-0.0603	pCi/L	1.2	8/20/2018	0.52	0.521	HASL 300, U-02-RC M	=
Uranium-238	U	-0.195	pCi/L	1.34	8/20/2018	0.452	0.453	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		0.00619	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.87	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium		0.11	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		349	umho/cm		8/20/2018				X
Depth to Water		50.36	ft		8/20/2018				X
Dissolved Oxygen		1.82	mg/L		8/20/2018				X
Lead	J	0.000802	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.09	Std Unit		8/20/2018				X
Redox		333	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	4.61	pCi/L	14.7	8/20/2018	8.6	8.62	DOE TC-02-RC	=
Temperature		69.3	deg F		8/20/2018				X
Trichloroethene		1000	ug/L	25	8/20/2018			SW846-8260B	=
Turbidity		74.5	NTU		8/20/2018				X
Uranium	J	0.000113	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.362	pCi/L	1.56	8/20/2018	0.453	0.454	HASL 300, U-02-RC M	=
Uranium-235	U	0.252	pCi/L	0.756	8/20/2018	0.708	0.709	HASL 300, U-02-RC M	=
Uranium-238	U	-0.0896	pCi/L	1.51	8/20/2018	0.619	0.62	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	0.00318	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.87	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	J	0.00759	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		853	umho/cm		8/20/2018				X
Depth to Water		13.67	ft		8/20/2018				X
Dissolved Oxygen		2.52	mg/L		8/20/2018				X
Lead		0.00225	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.38	Std Unit		8/20/2018				X
Redox		307	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99		937	pCi/L	15.3	8/20/2018	27.9	107	DOE TC-02-RC	=
Temperature		68.9	deg F		8/20/2018				X
Trichloroethene		3.29	ug/L	1	8/20/2018			SW846-8260B	=
Turbidity		291	NTU		8/20/2018				X
Uranium		0.00238	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.18	pCi/L	2.83	8/20/2018	1.18	1.18	HASL 300, U-02-RC M	=
Uranium-235	U	-0.198	pCi/L	2.23	8/20/2018	0.836	0.839	HASL 300, U-02-RC M	=
Uranium-238	U	0.213	pCi/L	1.7	8/20/2018	0.937	0.939	HASL 300, U-02-RC M	=

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

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

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

AKGWA Well Tag #: 8005-3263

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-	TPU	Method	Validation
Arsenic	J	0.00304	mg/L	0.005	8/20/2018			SW846-6020	=
Arsenic, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Barometric Pressure Reading		29.89	Inches/Hg		8/20/2018				X
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Cadmium, Dissolved	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Chromium, Dissolved	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Conductivity		336	umho/cm		8/20/2018				X
Depth to Water		50.44	ft		8/20/2018				X
Dissolved Oxygen		1.71	mg/L		8/20/2018				X
Lead	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Lead, Dissolved	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Mercury, Dissolved	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
pH		6.01	Std Unit		8/20/2018				X
Redox		276	mV		8/20/2018				X
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Selenium, Dissolved	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	0.33	pCi/L	18.4	8/20/2018	10.6	10.6	DOE TC-02-RC	=
Temperature		69.3	deg F		8/20/2018				X
Trichloroethene		476	ug/L	5	8/20/2018			SW846-8260B	=
Turbidity		15.1	NTU		8/20/2018				X
Uranium	U	0.0002	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.0108	pCi/L	1.56	8/20/2018	0.698	0.698	HASL 300, U-02-RC M	=
Uranium-235	U	-0.0481	pCi/L	1.69	8/20/2018	0.722	0.723	HASL 300, U-02-RC M	=
Uranium-238	U	0.498	pCi/L	1.44	8/20/2018	0.887	0.89	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	8/20/2018			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Lead	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	0.835	pCi/L	15.6	8/20/2018	8.99	8.99	DOE TC-02-RC	=
Trichloroethene	U	1	ug/L	1	8/20/2018			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.111	pCi/L	1.51	8/20/2018	0.632	0.632	HASL 300, U-02-RC M	=
Uranium-235	U	-0.051	pCi/L	1.03	8/20/2018	0.443	0.444	HASL 300, U-02-RC M	=
Uranium-238	U	0.18	pCi/L	1.14	8/20/2018	0.616	0.616	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	8/20/2018			SW846-6020	=
Cadmium	U	0.001	mg/L	0.001	8/20/2018			SW846-6020	=
Chromium	U	0.01	mg/L	0.01	8/20/2018			SW846-6020	=
Lead	U	0.002	mg/L	0.002	8/20/2018			SW846-6020	=
Mercury	U	0.0002	mg/L	0.0002	8/20/2018			SW846-7470A	=
Selenium	U	0.005	mg/L	0.005	8/20/2018			SW846-6020	=
Technetium-99	U	-6.66	pCi/L	14.2	8/20/2018	7.82	7.82	DOE TC-02-RC	=
Trichloroethene	U	1	ug/L	1	8/20/2018			SW846-8260B	=
Uranium	U	0.0002	mg/L	0.0002	8/20/2018			SW846-6020	=
Uranium-234	U	-0.273	pCi/L	1.98	8/20/2018	0.738	0.739	HASL 300, U-02-RC M	=
Uranium-235	U	-0.072	pCi/L	1.44	8/20/2018	0.621	0.623	HASL 300, U-02-RC M	=
Uranium-238	U	-0.282	pCi/L	2.04	8/20/2018	0.764	0.765	HASL 300, U-02-RC M	=

**Paducah OREIS
GROUNDWATER MONITORING REPORT**

Facility: C-404 Landfill **County:** McCracken **Permit #:** KY8-890-008-982
Type of Sample: TB **Period:** Semiannual Report QC Samples
AKGWA Well Tag #: 0000-0000

Parameter	Qualifier	Result	Units	Reporting Limit	Date Collected	Counting Error (+/-)	TPU	Method	Validation
Trichloroethene	U	1	ug/L	1	8/20/2018			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.

SAMPLE METHOD Codes

GR Grab

SAMPLING POINT Codes

UCRS Upper Continental Recharge System

URGA Upper Regional Gravel Aquifer

SAMPLE TYPE Codes

FB Field Blank

FR Field Duplicate as defined in sampling procedure.

REP Field Duplicate as defined in permit.

REG Regular

RI QC Equipment Rinseate/Decon

TB Trip Blank

VALIDATION Codes

= Validated result, no qualifier is necessary.

X Not validated.

APPENDIX B

C-404 HAZARDOUS WASTE LANDFILL STATISTICAL ANALYSES

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GROUNDWATER STATISTICAL SUMMARY

Introduction

The statistical analyses conducted on the data collected from C-404 Hazardous Waste Landfill (C-404 Landfill) were performed in accordance with procedures provided in Appendix E of the Hazardous Waste Management Facility Permit, reissued by the Kentucky Division of Waste Management (KDWM) in July 2015. The percent of censored (nondetected) data points for individual parameters was calculated for the combined analytical data from the most recent five sampling events. The percent of censored data was used to select the types of statistical analyses to determine whether compliance well concentrations differed from background well concentrations. Data points were used in the statistical analysis for analyte results close to the sample quantitation limit that were judged to be below that limit by the data validator. For the second reporting period 2018 semiannual report, the reporting period data set includes data from July 2016, January 2017, July 2017, January 2018, and August 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 the second reporting period 2018 semiannual report, the reporting period data set from July 2016 through August 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 required by Part VIII.E of the Permit.

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

Parameters	Observations	Missing Observations*	Censored Observations (Nondetects)	Uncensored Observations (Detects)
URGA				
Arsenic	25	0	8	17
Cadmium	25	0	16	9
Chromium	25	0	9	16
Lead	25	0	9	16
Mercury	25	0	25	0
Selenium	25	0	21	4
Technetium-99	25	0	23	2
Trichloroethene	25	0	0	25
Uranium (Metals)	25	0	11	14
Uranium-234	25	0	25	0
Uranium-235	25	0	25	0
Uranium-238	25	0	25	0

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

Parameter	Total Samples (Nonmissing)	Uncensored (Detects)	Censored (Nondetects)	Percent Censored	Statistical Test Set*
URGA					
Arsenic	25	17	8	32.00	3
Cadmium	25	9	16	64.00	2
Chromium	25	16	9	36.00	3
Lead	25	16	9	36.00	3
Mercury	25	0	25	100.00	1
Selenium	25	4	21	84.00	2
Technetium-99	25	2	23	92.00	1
Trichloroethene	25	25	0	0.00	4/3**
Uranium (Metals)	25	14	11	44.00	3
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 C-404 Landfill statistical analyses for the second reporting period 2018, including the statistical tests performed, the attachment number, well type, parameter, and results of each statistical test. Results of Statistical Test 2, Statistical Test 3, and Statistical Test 4 are presented in Attachments B1 through B7. The statistician qualification statement is presented in Attachment B8.

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

Parameter	LOD Values	½ LOD Values
URGA		
Mercury (mg/L)	0.0002	0.0001
Technetium-99 (pCi/L)	18.4	9.2
Uranium-234 (pCi/L)	2.61	1.305
Uranium-235 (pCi/L)	1.69	0.845
Uranium-238 (pCi/L)	1.72	0.86

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

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

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

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

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

Statistical Test 3, Nonparametric ANOVA, for lead in the URGAs 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 and MW87) results to upgradient westernmost well (MW93) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and no trend was identified for lead in MW84 while a positive trend was identified for lead in MW87.

Statistical Test 3, Nonparametric ANOVA, for uranium in the URGAs 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 and MW87) results to upgradient westernmost well (MW93) results]. Results of the paired (parametric) ANOVA identified there to be a significant difference between upgradient and downgradient wells. A Mann-Kendall test was performed to further evaluate the data, and no trend was identified for uranium in MW84 while a positive trend was identified for uranium in MW87.

Statistical Test 4, Parametric ANOVA, could not be used for trichloroethene in the URGAs because there was no evidence of equality of variance. Thus, Statistical Test 4 was abandoned and Statistical Test 3, Nonparametric ANOVA, was performed. Nonparametric ANOVA identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells; therefore, the data were evaluated further by comparing results to the UTL. The 95% UTL indicated a statistically significant difference between concentrations in downgradient wells and concentrations in

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

Table B.5. Summary of Conclusions from the C-404 Hazardous Waste Landfill Statistical Analyses for the Second Reporting Period 2018

Attachment	RGA Well Type	Parameter	Applied Statistical Test	Results
B1	URGA	Arsenic	Statistical Test 3, Nonparametric ANOVA with 95% UTL, paired ANOVA (MW84 vs. MW93), Mann-Kendall, and data review	Because Nonparametric ANOVA indicated a statistically significant difference between concentrations in downgradient wells and concentrations in background wells for compliance well MW84, a comparison to the 95% UTL, paired ANOVA, Mann-Kendall, and an attempt to review data was performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified a positive trend in MW84.
B2	URGA	Cadmium	Statistical Test 2, Test of Proportions with Statistical Test 3, Nonparametric ANOVA and 95% UTL	Because Test of Proportions indicated statistically significant evidence that the proportion of detects in one group of data exceeds the proportion of detects in the other group, Statistical Test 3, Nonparametric ANOVA, and a comparison to the 95% UTL were performed. Results of the comparison to the 95% UTL have not identified a statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B3	URGA	Chromium	Statistical Test 3, Nonparametric ANOVA	No statistically significant difference between concentrations in downgradient wells and concentrations in background wells.
B4	URGA	Lead	Statistical Test 3, Nonparametric ANOVA with 95% UTL and paired ANOVA (MW84 vs. MW93, MW87 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 wells MW84 and MW87, a comparison to the 95% UTL, paired ANOVA, Mann-Kendall, and an attempt to review data were performed, as required by the Hazardous Waste Management Facility Permit. Results of the paired ANOVA have identified there is a significant difference between upgradient and downgradient wells. The Mann-Kendall identified no trend in MW84 and a positive trend in MW87.
B5	URGA	Selenium	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 C-404 Hazardous Waste Landfill Statistical Analyses for the Second Reporting Period 2018 (Continued)

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

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ATTACHMENT B1

ARSENIC

STATISTICAL TEST 3

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**Attachment B1: Arsenic URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.00619	0.00304	0.0289	0.0105	0.0025
Sum	0.0499		0.09720	0.04217	0.0125
n _i	10		5	5	5
(x _i) _{avg}	0.00499		0.01944	0.00843	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 $\bar{x}_{..}$ = 0.00807

N =	25	N = the total number of samples
p =	4	p = the number of n _i groups
$\bar{x}_{..}$ =	0.20	$\bar{x}_{..}$ = the sum of the total number of samples

**Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Arsenic (mg/L)	Adjusted Rank	Tie Number
1	0	4.5	Tie 1
2	0	4.5	
3	0	4.5	
4	0	4.5	
5	0	4.5	
6	0	4.5	
7	0	4.5	
8	0	4.5	
9	0.00207	9	
10	0.00304	10	
11	0.00619	11	
12	0.00692	12	
13	0.00698	13	
14	0.00709	14	
15	0.00755	15	
16	0.00807	16	
17	0.00842	17	
18	0.0087	18	
19	0.00907	19	
20	0.0105	20	
21	0.0137	21	
22	0.017	22	
23	0.0185	23	
24	0.0191	24	
25	0.0289	25	

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

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

$$\begin{aligned}
 n_{\text{tie}} & \quad \text{Adjustment for Ties: } (n_{\text{tie}}^3 - n_{\text{tie}}) \\
 8 & \quad \text{Tie 1} = \quad 504 \\
 & \quad \Sigma T_i = \quad 504
 \end{aligned}$$

Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Sums of Ranks and Averages

Arsenic (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.00619	0.00304	0.0289	0.0105	0

Observation Ranks for Arsenic					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	14	4.5	21	13	4.5
Jan-17	17	4.5	22	12	4.5
Jul-17	15	9	24	19	4.5
Jan-18	16	4.5	23	18	4.5
Aug-18	11	10	25	20	4.5
R_i	105.5		115	82	22.5
$(R_i)_{avg}$	10.6		23.0	16.4	4.5
R_i^2/n_i	1113.0		2645.0	1344.8	101.3

$$\Sigma R_i^2/n_i = 5204.1$$

$$K = 4$$

$$N = 25$$

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.

Calculation of Kruskal-Wallis Statistic

$$H = 18.075 \quad \text{Kruskal-Wallis Statistic} \quad H = [12/N(N+1) \cdot \Sigma R_i^2/n_i] - 3(N+1)$$

$$H' = 18.679 \quad \text{Corrected Kruskal-Wallis} \quad H' = H/[1 - (\Sigma T_i/N^3 - N)]$$

$$\chi^2_{crit} = 7.815 \quad 3 \quad \text{degrees of freedom at the 5\% significance level}$$

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.

$$K-1 = 3 \quad \alpha/(K-1) = 0.01667 \quad Z(\alpha/(K-1))^{**} = 2.1280$$

$$\alpha = 0.05 \quad 1-(\alpha/(K-1)) = 0.983$$

NOTE:

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

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

**Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Calculate Critical Values

Average Background Ranking = 10.6

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	12.5	evidence of contamination
	MW87	8.578	5.9	not contaminated
	MW90A	8.578	-6.1	not contaminated

mg/L = milligrams per liter

BG = background

DL = detection limit

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

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

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

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

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW87 and MW90A, there is no statistically significant difference from the C-404 Landfill 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).

**Attachment B1: Arsenic URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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.

**August 2018 Data, Second Reporting Period
Observations (mg/L)**

Well No.						
MW93	0.00709	0.00842	0.00755	0.00807	0.00619	Upgradient Well ¹
MW420	0.0025	0.0025	0.00207	0.0025	0.00304	Upgradient Well ¹
						Current Data
MW84	X: Mean Value =		0.0050			0.0289
MW87	S: Standard Deviation =		0.0027			0.0105
MW90A	K* factor =		2.911 (for n = 10)			0.0025
	CV = S/X		0.5365 <1, assume normal distribution			
	Upper Tolerance Interval: TL = X + (KxS) =		0.0128 (mg/L)			

¹ = Data from previous 5 sampling events.

CV = coefficient of variation

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

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

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

Attachment B1: Arsenic URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

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	
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
Aug-18	0.00619	0.0289	0.0000383	0.0008352
Sum (x_i)	0.0373	0.09720	0.1345	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	0.00746	0.01944		
$(x_i)^2$	0.00139	0.00945		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ = 0.01345

N = 10

N = the total number of samples

p = 2

p = the number of n_i groups

$x_{..}$ = 0.1345

$x_{..}$ = 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
Jul-16	-0.00037	-0.00574
Jan-17	0.00096	-0.00244
Jul-17	0.00009	-0.00034
Jan-18	0.00061	-0.00094
Aug-18	-0.00127	0.00946

X: Mean Value = 0.00E+00

S: Standard Deviation = 0.00384

K* Factor = 2.911 (for n = 10)

CV = S/X = #DIV/0! #DIV/0!

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

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

If the coefficient of variation (CV) is < 1, the data are normally distributed.

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

**Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 0.1345$
n_i = number of data points per well	$(x_{avg})_{..} = 0.01345$
N = total sample size	$n_i = 5$
S^2 = the square of the standard deviation	$p = 2$
$\ln(S_i^2)$ = natural logarithm of each variance	$N = 10$
f = total sample size minus the number of wells (groups)	$f_i = 4$
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.00087	0.00000076288	-14.086	5	0.0000031	-56.3
0.00569	0.00003234800	-10.339	5	0.0001294	-41.4

$$\sum(S_i^2) = 0.00003 \qquad \sum f_i \ln(S_i^2) = -97.70049$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 S_p^2 &= 0.0000166 \\
 \ln S_p^2 &= -11.009 \\
 \chi^2 &= 9.630 \quad (\text{If calculated } \chi^2 \leq \text{tabulated } \chi^2_{\text{crit}}, \text{ then variances are equal at the given} \\
 &\qquad \qquad \qquad \text{significance level).} \\
 \chi^2_{\text{crit}} &= 3.841 \quad \text{at a 5\% significance level with } 1 \quad \text{degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

**Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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

ln[Arsenic (mg/L)]				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
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
Aug-18	-5.08	-3.54	25.86	12.56
Sum (x_i)	-24.52	-19.86	-44.37	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	-4.90	-3.97		
$(x_i)^2$	601.08	394.30		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ = -4.44

N = 10

N = the total number of samples

p = 2

p = the number of n_i groups

$x_{..}$ = -44.37

$x_{..}$ = 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
Jul-16	-0.05	-0.32
Jan-17	0.13	-0.10
Jul-17	0.02	0.01
Jan-18	0.08	-0.02
Aug-18	-0.18	0.43

X: Mean Value = 0.00E+00

S: Standard Deviation = 0.20

K* Factor = 2.911 (for n = 10)

CV = S/X = #DIV/0! #DIV/0!

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

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

If the coefficient of variation is < 1, the residuals are normally distributed.

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

**Attachment B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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

p = number of wells	$x_{..} = -44.37$
n_i = number of data points per well	$(x_{avg})_{..} = -4.44$
N = total sample size	$n_i = 5$
S^2 = the square of the standard deviation	$p = 2$
$\ln(S_i^2)$ = natural logarithm of each variance	$N = 10$
f = total sample size minus the number of wells (groups)	$f_i = 4$
$f_i = n_i - 1$	

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.12	0.01	-4.23	5	0.06	-16.9
0.27	0.07	-2.60	5	0.30	-10.4

$$\sum(S_i^2) = 0.09 \qquad \sum f_i \ln(S_i^2) = -27.34$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 Sp^2 &= 0.04 \\
 \ln Sp^2 &= -3.12 \\
 \chi^2 &= 2.39 \quad \text{(If calculated } \chi^2 \leq \text{tabulated } \chi^2_{crit}, \text{ then variances are equal at the given} \\
 &\qquad \qquad \qquad \text{significance level).} \\
 \chi^2_{crit} * &= 3.841 \quad \text{at a 5\% significance level with } 1 \quad \text{degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

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

**Attachment B1: Arsenic URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Between Well Sum of Squares

Source of	Sums of Squares	Degrees of	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{\text{wells}} = 2.17154$	1	2.17154	49.09	5.32
Error	$SS_{\text{Error}} = 0.35390$	8	0.044237		
Total	$SS_{\text{Total}} = 2.52544$	9			

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

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

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

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

Attachment B1: Arsenic URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Mann-Kendall Statistical Analysis for Arsenic in MW84

Input Data

Date Collected	Result (mg/L)
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
Aug-18	0.0289

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation	ProUCL 5.19/27/2018 3:32:43 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	0.95
Level of Significance	0.05

MW84_arsenic 3Q

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	0.0073
Maximum	0.0289
Mean	0.0155
Geometric Mean	0.0142
Median	0.0154
Standard Deviation	0.00698
Coefficient of Variation	0.45

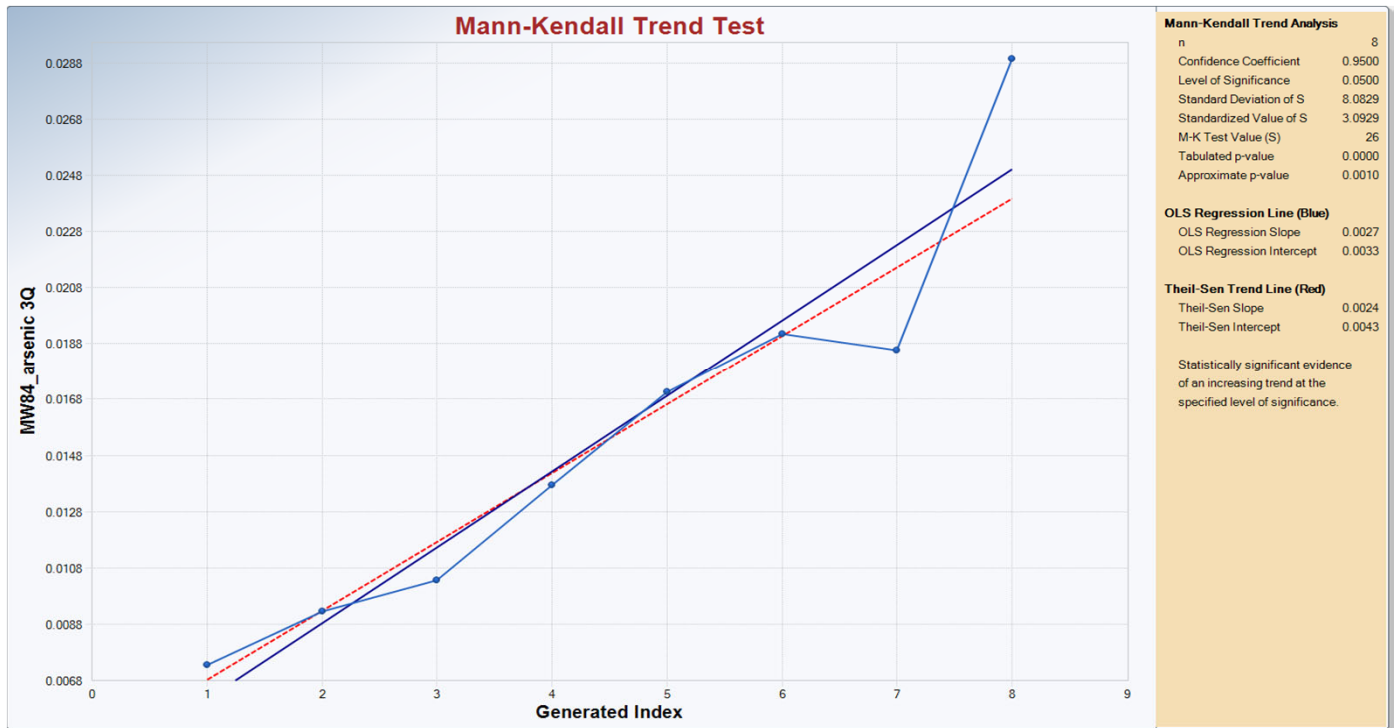
Mann-Kendall Test

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 B1: Arsenic URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Mann-Kendall Statistical Analysis for Arsenic in MW84



ATTACHMENT B2

CADMIUM
STATISTICAL TEST 2

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**Attachment B2: Cadmium URGAs, Statistical Test 2, Test of Proportions,
Second Reporting Period 2018**

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.0005	0.0005	0.000323	0.000372	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 =	1	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 =	0.360	P = (x+y)/n
nP =	9	n = n _b +n _c
n(1-P) =	16	

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 =	0.533	P _c = proportion of detects in compliance wells
S _D =	0.196	S _D = standard error of difference in proportions
Z =	-2.211	Z = (P _b -P _c)/S _D
absolute value of Z =	2.211	

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

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

¹ Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

**Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.0005	0.0005	0.000323	0.000372	0.0005
Sum	0.0047		0.00213	0.00200	0.0025
n _i	10		5	5	5
(x _i) _{avg}	0.00047		0.00043	0.00040	0.0005

mg/L = milligrams per liter

BG = background

DL = detection limit

All data sets represent 1/2 DL values for nondetects.

Bolded values indicate a detected result.

Overall mean x_{..} = 0.00045

N =	25	N = the total number of samples
p =	4	p = the number of n _i groups
x _{..} =	0.01	x _{..} = the sum of the total number of samples

**Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Cadmium (mg/L)	Adjusted Rank	Tie Number
1	0	8.5	Tie 1
2	0	8.5	
3	0	8.5	
4	0	8.5	
5	0	8.5	
6	0	8.5	
7	0	8.5	
8	0	8.5	
9	0	8.5	
10	0	8.5	
11	0	8.5	
12	0	8.5	
13	0	8.5	
14	0	8.5	
15	0	8.5	
16	0	8.5	
17	0.000199	17	
18	0.000292	18	
19	0.000304	19	
20	0.000323	20	
21	0.000372	21	
22	0.000375	22	
23	0.000396	23	
24	0.000451	24	
25	0.000619	25	

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

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

n_{tie} Adjustment for Ties: $(n_{tie}^3 - n_{tie})$

16 Tie 1 = 4080

$\sum T_i =$ 4080

Attachment B2: Cadmium URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Sums of Ranks and Averages

Cadmium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	0.000199	0	0.000292	0.000451	0
Jan-17	0	0	0.000619	0	0
Jul-17	0	0	0.000396	0.000304	0
Jan-18	0	0	0	0.000375	0
Aug-18	0	0	0.000323	0.000372	0

Observation Ranks for Cadmium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	17	8.5	18	24	8.5
Jan-17	8.5	8.5	25	8.5	8.5
Jul-17	8.5	8.5	23	19	8.5
Jan-18	8.5	8.5	8.5	22	8.5
Aug-18	8.5	8.5	20	21	8.5
R_i	93.5		94.5	94.5	42.5
$(R_i)_{avg}$	9.4		18.9	18.9	8.5
R_i^2/n_i	874.2		1786.1	1786.1	361.3

$$\sum R_i^2/n_i = 4807.6$$

mg/L = milligrams per liter

K = the number of n_i groups

BG = background

N = the total number of samples

DL = detection limit

Bolded values indicate a detected result.

$$K = 4$$

$$N = 25$$

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

Calculation of Kruskal-Wallis Statistic

$$H = 10.755$$

Kruskal-Wallis Statistic

$$H = [12/N(N+1) * \sum R_i^2/n_i] - 3(N+1)$$

$$H' = 14.564$$

Corrected Kruskal-Wallis

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

$$\chi^2_{crit} = 7.815$$

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.

$$K-1 = 3$$

$$\alpha = 0.05$$

$$\alpha/(K-1) = 0.01667$$

$$1 - (\alpha/(K-1)) = 0.983$$

$$Z(\alpha/(K-1))^{**} = 2.1280$$

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

Attachment B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Calculate Critical Values

Average Background Ranking = 9.4

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	9.55	evidence of contamination
	MW87	8.578	9.55	evidence of contamination
	MW90A	8.578	-0.85	not contaminated

mg/L = milligrams per liter

BG = background

DL = detection limit

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

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

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

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

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW90A, there is no statistically significant difference between compliance test wells and background wells at the C-404 Landfill; 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 B2: Cadmium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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.

**August 2018 Data, Second Reporting Period
Observations (mg/L)**

Well No.						
MW93	0.000199	0.0005	0.0005	0.0005	0.0005	Upgradient Well [!]
MW420	0.0005	0.0005	0.0005	0.0005	0.0005	Upgradient Well [!]
						Current Data
MW84	X: Mean Value =		0.0005			0.000323
MW87	S: Standard Deviation =		0.0001			0.000372
MW90A	K* factor =		2.911	(for n = 10)		0.0005
	CV = S/X		0.2026	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =		0.0007	(mg/L)		

[!] = Data from previous 5 sampling events.

CV = coefficient of variation

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

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

ATTACHMENT B3

CHROMIUM
STATISTICAL TEST 3

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**Attachment B3: Chromium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.11	0.005	0.0752	0.275	0.005
Sum	1.1820		0.37270	1.93770	0.0238
n _i	10		5	5	5
(x _i) _{avg}	0.11820		0.07454	0.38754	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 $\bar{x}_{..}$ = 0.14065

N =	25	N = the total number of samples
p =	4	p = the number of n _i groups
$\bar{x}_{..}$ =	3.52	$\bar{x}_{..}$ = the sum of the total number of samples

**Attachment B3: Chromium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Chromium (mg/L)	Adjusted Rank	Tie Number
1	0	5	Tie 1
2	0	5	
3	0	5	
4	0	5	
5	0	5	
6	0	5	
7	0	5	
8	0	5	
9	0	5	
10	0.00381	10	
11	0.0206	11	
12	0.0309	12	
13	0.0557	13	
14	0.0752	14	
15	0.103	15	
16	0.11	16	
17	0.143	17	
18	0.151	18	
19	0.165	19	
20	0.207	20	
21	0.261	21	
22	0.262	22	
23	0.275	23	
24	0.428	24	
25	1.18	25	

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

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

n_{tie} Adjustment for Ties: $(n_{tie}^3 - n_{tie})$

9 Tie 1 = 720

$\sum T_i =$ 720

Attachment B3: Chromium URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Sums of Ranks and Averages

Chromium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.11	0	0.0752	0.275	0

Observation Ranks for Chromium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	20	5	11	19	5
Jan-17	24	5	12	22	5
Jul-17	21	5	15	13	5
Jan-18	18	5	17	25	10
Aug-18	16	5	14	23	5
R_i	124		69	102	30
$(R_i)_{avg}$	12.4		13.8	20.4	6.0
R_i^2/n_i	1537.6		952.2	2080.8	180.0

$$\sum R_i^2/n_i = 4750.6$$

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.

$$K = 4$$

$$N = 25$$

Calculation of Kruskal-Wallis Statistic

$$H = 9.703 \quad \text{Kruskal-Wallis Statistic} \quad H = [12/N(N+1) * \sum R_i^2/n_i] - 3(N+1)$$

$$H' = 10.173 \quad \text{Corrected Kruskal-Wallis} \quad H' = H/[1 - (\sum T_i^3/N^3) - N]$$

$$\chi^2_{crit} = 7.815 \quad 3 \quad \text{degrees of freedom at the 5\% significance level}$$

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.

$$\begin{array}{llll} K-1 = & 3 & \alpha/(K-1) = & 0.01667 \\ \alpha = & 0.05 & 1-(\alpha/(K-1)) = & 0.983 \end{array} \quad Z(\alpha/(K-1))^{**} = 2.1280$$

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

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

Attachment B3: Chromium URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Calculate Critical Values

Average Background Ranking = 12.4

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	1.40	not contaminated
	MW87	8.578	8.00	not contaminated
	MW90A	8.578	-6.40	not contaminated

mg/L = milligrams per liter

BG = background

DL = detection limit

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

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

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

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

ATTACHMENT B4

LEAD

STATISTICAL TEST 3

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**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.000802	0.001	0.00319	0.00682	0.001
Sum	0.0132		0.01491	0.02793	0.0046
n _i	10		5	5	5
(x _i) _{avg}	0.00132		0.00298	0.00559	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.. = 0.00243

N = 25

N = the total number of samples

p = 4

p = the number of n_i groups

x.. = 0.06

x.. = the sum of the total number of samples

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Lead (mg/L)	Adjusted Rank	Tie Number
1	0	5	Tie 1
2	0	5	
3	0	5	
4	0	5	
5	0	5	
6	0	5	
7	0	5	
8	0	5	
9	0	5	
10	0.000634	10	
11	0.000802	11	
12	0.00155	12	
13	0.00181	13	
14	0.00186	14	
15	0.00191	15	
16	0.00213	16	
17	0.00239	17	
18	0.00267	18	
19	0.00319	19	
20	0.00439	20	
21	0.00475	21	
22	0.00533	22	
23	0.0056	23	
24	0.00579	24	
25	0.00682	25	

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

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

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Sums of Ranks and Averages

Lead (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.000802	0	0.00319	0.00682	0

Observation Ranks for Lead					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	13	5	17	23	5
Jan-17	12	5	21	20	5
Jul-17	16	5	18	22	5
Jan-18	14	5	15	24	10
Aug-18	11	5	19	25	5
R_i	91		90	114	30
$(R_i)_{avg}$	9.1		18.0	22.8	6.0
R_i^2/n_i	828.1		1620.0	2599.2	180.0

$$\Sigma R_i^2/n_i = 5227.3$$

mg/L = milligrams per liter K = the number of n_i groups
 BG = background N = the total number of samples
 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.

$$K = 4$$

$$N = 25$$

Calculation of Kruskal-Wallis Statistic

$$H = 18.504 \quad \text{Kruskal-Wallis Statistic} \quad H = [12/N(N+1) * \Sigma R_i^2/n_i] - 3(N+1)$$

$$H' = 19.399 \quad \text{Corrected Kruskal-Wallis} \quad H' = H/[1 - (\Sigma T_i/N^3 - N)]$$

$$\chi^2_{crit} = 7.815 \quad 3 \quad \text{degrees of freedom at the 5\% significance level}$$

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.

$$K-1 = 3 \quad \alpha/(K-1) = 0.01667 \quad Z(\alpha/(K-1))^{**} = 2.1280$$

$$\alpha = 0.05 \quad 1-(\alpha/(K-1)) = 0.983$$

NOTE:

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

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Calculate Critical Values

Average Background Ranking = 9.1

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	8.90	evidence of contamination
	MW87	8.578	13.70	evidence of contamination
	MW90A	8.578	-3.10	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 MW84 and MW87, there is a statistically significant difference between downgradient compliance test wells and background wells in MW84 and MW87 from the C-404 Landfill.

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

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW90A, there is no statistically significant difference from C-404 in this downgradient compliance test well; however, the negative value indicates that the background wells have elevated concentrations.

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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.

**August 2018 Data, Second Reporting Period
Observations (mg/L)**

Well No.						
MW93	0.00181	0.00155	0.00213	0.00186	0.000802	Upgradient Well [!]
MW420	0.001	0.001	0.001	0.001	0.001	Upgradient Well [!]
						Current Data
MW84	X: Mean Value =		0.0013			0.00319
MW87	S: Standard Deviation =		0.0005			0.00682
MW90A	K* factor =		2.911	(for n = 10)		0.001
	CV = S/X		0.3603	<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: MW84 and MW87 exceeded the UTL, which is statistically significant evidence that these compliance wells have elevated concentrations with respect to background data.

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

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Paired (Parametric) ANOVA - MW93 and MW84

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

Lead (mg/L)				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jul-16	0.00181	0.00239	0.0000033	0.0000057
Jan-17	0.00155	0.00475	0.0000024	0.0000226
Jul-17	0.00213	0.00267	0.0000045	0.0000071
Jan-18	0.00186	0.00191	0.0000035	0.0000036
Aug-18	0.000802	0.00319	0.0000006	0.0000102
Sum (x_i)	0.008	0.01491	0.0231	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	0.002	0.00298		
$(x_i)^2$	0.00007	0.00022		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ =	0.00231	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.0231	$x_{..}$ = 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
Jul-16	0.00018	-0.00059
Jan-17	-0.00008	0.00177
Jul-17	0.00050	-0.00031
Jan-18	0.00023	-0.00107
Aug-18	-0.00083	0.00021

X: Mean Value =	-1.95E-19
S: Standard Deviation =	0.00080
K* Factor =	2.911 (for n = 10)
CV = S/X =	-4.11E+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.

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 0.0231$
n_i = number of data points per well	$(x_{avg})_{..} = 0.00231$
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	$\ln(S_i^2)^\dagger$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)^\dagger$
0.000507	0.00000025682	-15.175	5	0.0000010	-60.7
0.00109	0.00000119152	-13.640	5	0.0000048	-54.6

$$\sum(S_i^2) = 0.000001448 \qquad \sum f_i \ln(S_i^2) = -115.26067$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 Sp^2 &= 0.0000007 \\
 \ln Sp^2 &= -14.138 \\
 \chi^2 &= 2.155 \\
 \chi_{crit}^2 &= 3.841
 \end{aligned}
 \quad
 \begin{aligned}
 &\text{(If calculated } \chi^2 \leq \text{tabulated } \chi_{crit}^2, \text{ then variances are equal at the given} \\
 &\text{significance level).} \\
 &\text{at a 5\% significance level with } 1 \text{ degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Between Well Sum of Squares

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{\text{wells}} = 0.000005$	1	0.000005	6.31	5.32
Error	$SS_{\text{Error}} = 0.000006$	8	0.000001		
Total	$SS_{\text{Total}} = 0.000010$	9			

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

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

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

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

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Mann-Kendall Statistical Analysis for Lead in MW84

Input Data

Date Collected	Result (mg/L)
Jan-15	0.00189
Jul-15	0.00088
Jan-16	0.00108
Jul-16	0.00239
Jan-17	0.00475
Jul-17	0.00267
Jan-18	0.00191
Aug-18	0.00319

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation ProUCL 5.19/28/2018 11:31:44 AM
 From File WorkSheet.xls
 Full Precision OFF
 Confidence Coefficient 0.95
 Level of Significance 0.05

MW84 Lead 3Q

General Statistics

Number or Reported Events Not Used 0
 Number of Generated Events 8
 Number Values Reported (n) 8
 Minimum 8.8000E-4
 Maximum 0.00475
 Mean 0.00235
 Geometric Mean 0.00207
 Median 0.00215
 Standard Deviation 0.00124
 Coefficient of Variation 0.528

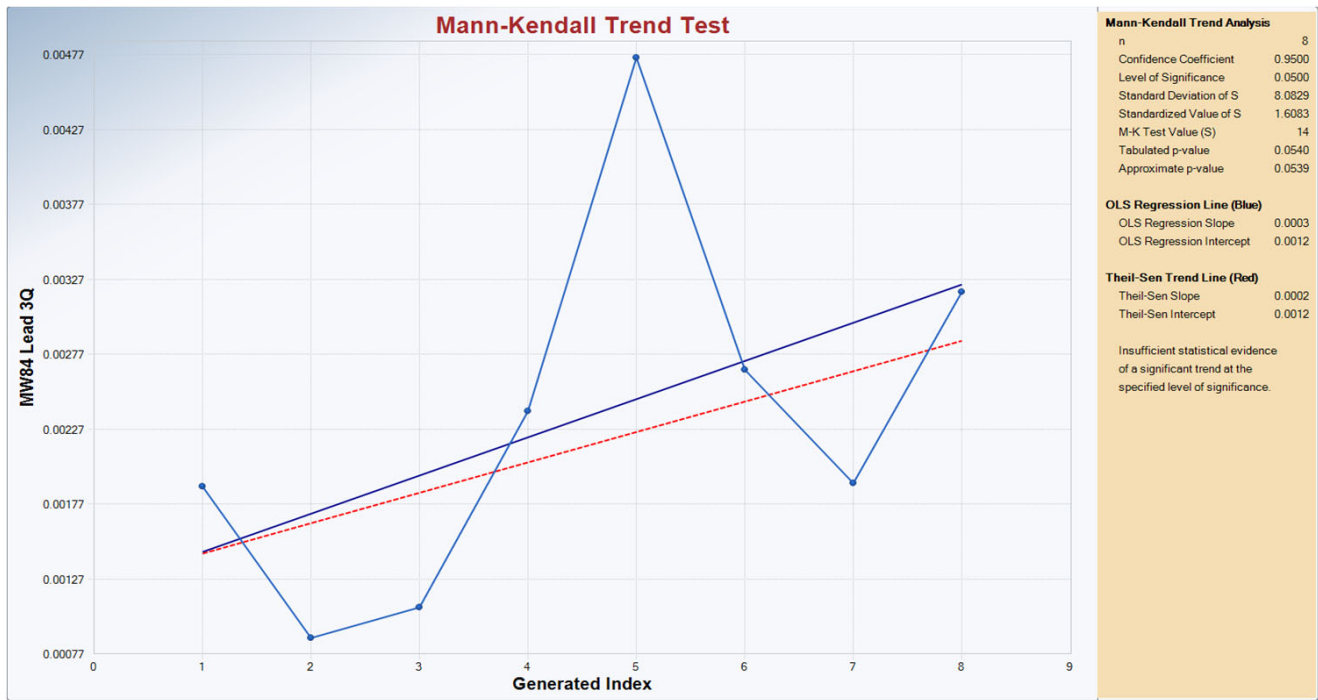
Mann-Kendall Test

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

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Mann-Kendall Statistical Analysis for Lead in MW84



Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Paired (Parametric) ANOVA - MW93 and MW87

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

Lead (mg/L)				
Date	Background	Compliance		
	MW93	MW87	n_i^2	
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
Aug-18	0.000802	0.00682	0.0000006	0.0000465
Sum (x_i)	0.008	0.02793	0.0361	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	0.002	0.00559		
$(x_i)^2$	0.00007	0.00078		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ =	0.00361	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	0.0361	$x_{..}$ = 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
Jul-16	0.00018	0.00001
Jan-17	-0.00008	-0.00120
Jul-17	0.00050	-0.00026
Jan-18	0.00023	0.00020
Aug-18	-0.00083	0.00123

X: Mean Value =	3.47E-19	
S: Standard Deviation =	0.00067	
K* Factor =	2.911	(for n = 10)
CV = S/X =	1.94E+15	≥ 1, data are NOT normally distributed

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

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

If the coefficient of variation is < 1, the data are normally distributed.

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 0.0361$
n_i = number of data points per well	$(x_{avg})_{..} = 0.00361$
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	$\ln(S_i^2)^\dagger$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)^\dagger$
0.000507	0.00000025682	-15.175	5	0.0000010	-60.7
0.00087	0.00000076513	-14.083	5	0.0000031	-56.3

$$\sum(S_i^2) = 0.000001022 \qquad \sum f_i \ln(S_i^2) = -117.03243$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 Sp^2 &= 0.0000005 \\
 \ln Sp^2 &= -14.487 \\
 \chi^2 &= 1.137 \\
 \chi_{crit}^2 &= 3.841
 \end{aligned}
 \quad
 \begin{aligned}
 &\text{(If calculated } \chi^2 \leq \text{tabulated } \chi_{crit}^2, \text{ then variances are equal at the given} \\
 &\text{significance level).} \\
 &\text{at a 5\% significance level with } 1 \text{ degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Between Well Sum of Squares

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{\text{wells}} = 0.000039$	1	0.000039	76.55	5.32
Error	$SS_{\text{Error}} = 0.000004$	8	0.000001		
Total	$SS_{\text{Total}} = 0.000043$	9			

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

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

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

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

Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Mann-Kendall Statistical Analysis for Lead in MW87

Input Data

Date Collected	Result (mg/L)
Jan-15	0.0009
Jul-15	0.002
Jan-16	0.00107
Jul-16	0.0056
Jan-17	0.00439
Jul-17	0.00533
Jan-18	0.00579
Aug-18	0.00682

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation ProUCL 5.110/1/2018 1:12:21 PM
 From File WorkSheet.xls
 Full Precision OFF
 Confidence Coefficient 0.95
 Level of Significance 0.05

MW87 lead 3Q

General Statistics

Number or Reported Events Not Used 0
 Number of Generated Events 8
 Number Values Reported (n) 8
 Minimum 9.0000E-4
 Maximum 0.00682
 Mean 0.00399
 Geometric Mean 0.00316
 Median 0.00486
 Standard Deviation 0.00232
 Coefficient of Variation 0.583

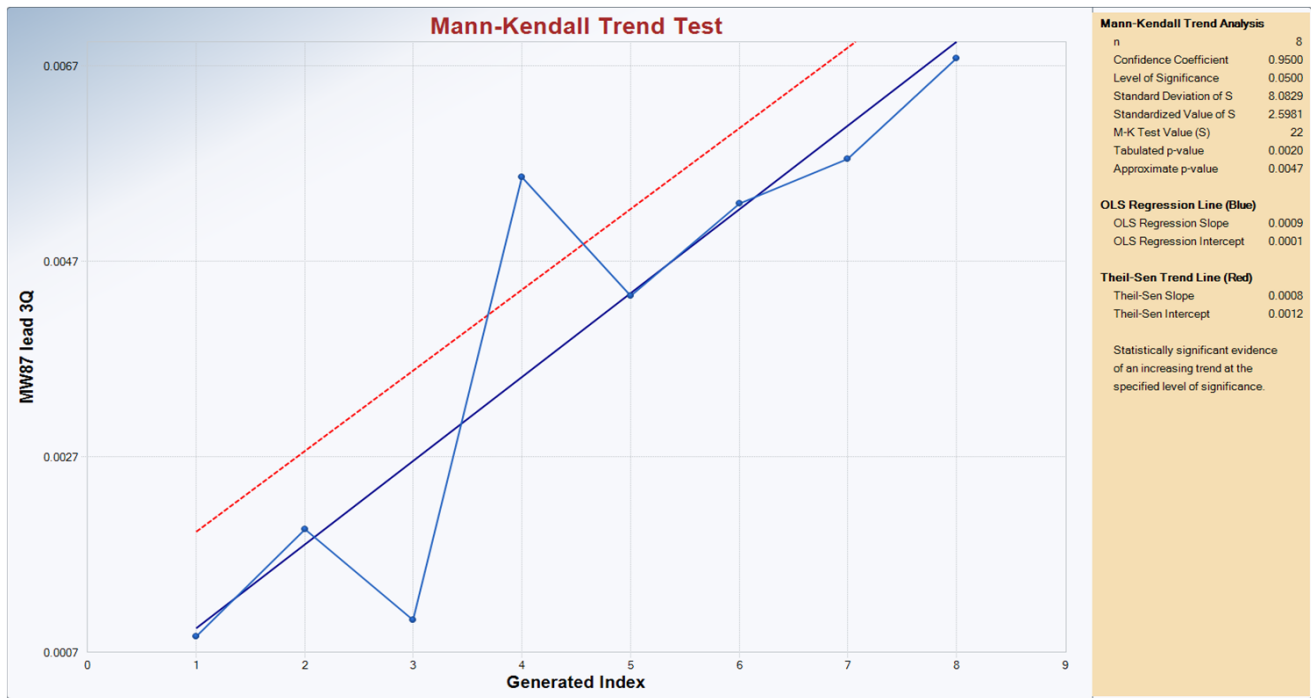
Mann-Kendall Test

M-K Test Value (S) 22
 Tabulated p-value 0.002
 Standard Deviation of S 8.083
 Standardized Value of S 2.598
 Approximate p-value 0.00469

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

**Attachment B4: Lead URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Mann-Kendall Statistical Analysis for Lead in MW87



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ATTACHMENT B5

SELENIUM
STATISTICAL TEST 2

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**Attachment B5: Selenium URGAs, Statistical Test 2, Test of Proportions,
Second Reporting Period 2018**

Selenium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.0025	0.0025	0.0025	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 =	0	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 =	0.160	P=(x+y)/n
nP =	4	n=n _b +n _c
n(1-P) =	21	

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 =	0.000	P _b = proportion of detects in background wells
P _c =	0.267	P _c = proportion of detects in compliance wells
S _D =	0.150	S _D = standard error of difference in proportions
Z =	-1.782	Z = (P _b -P _c)/S _D
absolute value of Z =	1.782	

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.**

¹Section 8.1.2, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA 1989).

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ATTACHMENT B6

**TRICHLOROETHENE
STATISTICAL TESTS 4/3**

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**Attachment B6: Trichloroethene URGAs, Statistical Test 4, Parametric ANOVA,
Second Reporting Period 2018**

Trichloroethene (TCE, µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	1000	476	5260	1690	53.3
n _i	10		5	5	5
Sum	9279		15770	8040	224.80
(x _i)avg	927.90		3154.00	1608.00	44.96

µg/L = micrograms per liter

Bolded values indicate a detected result.

Overall mean $\bar{x}_{..}$ = 1332.55

N = 25 N = the total number of samples

p = 4 p = the number of n_i groups

$\Sigma x_{..}$ = 33313.80 $\Sigma x_{..}$ = 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
Jul-16	1092.10	-758.90	-1334.00	-518.00	-9.66
Jan-17	1522.10	-653.90	-534.00	632.00	4.54
Jul-17	472.10	-663.90	-244.00	12.00	1.14
Jan-18	66.10	-695.90	6.00	-208.00	-4.36
Aug-18	72.10	-451.90	2106.00	82.00	8.34

X: Mean Value = -5.97E-15

S: Standard Deviation = 740.3

K* Factor = 2.292 (for n = 25)

CV = S/X = -1.24E+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.

**Attachment B6: Trichloroethene URGAs, Statistical Test 4, Parametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset

p = number of wells $\bar{x}_{..} = 33313.80$
 n_i = number of data points per well $(\bar{x}_{avg})_{..} = 1332.55$
 N = total sample size
 S^2 = the square of the standard deviation $p = 4$
 $\ln(S_i^2)$ = natural logarithm of each variance $N = 25$
 f = total sample size minus the number of wells (groups)
 $f_i = n_i - 1$

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
807.925	652742.77	13.389	10	5874684.9	120.5
1280.578	1639880.00	14.310	5	6559520.000	57.2
423.639	179470.00	12.098	5	717880.000	48.4
7.138	50.95	3.931	5	203.792	15.7

$$\sum(S_i^2) = 2472143.71 \qquad \sum f_i \ln(S_i^2) = 241.9$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 21 \\
 S_p^2 &= 626299.462 \\
 \ln S_p^2 &= 13.348 \\
 \chi^2 &= 38.444 \quad (\text{If } \chi^2 \leq \chi_{crit}^2, \text{ then variances are equal at the given} \\
 &\quad \text{significance level).} \\
 \chi_{crit}^2 * &= 7.815 \quad \text{at a 5\% significance level with} \quad 3 \quad \text{degrees of freedom}
 \end{aligned}$$

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

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

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

**Attachment B6: Trichloroethene URGAs, Statistical Test 4, Parametric ANOVA,
Second Reporting Period 2018**

Lognormal Data for TCE

ln[TCE (µg/L)]					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	6.91	6.17	8.57	7.43	3.98
\bar{x}_i	64.40		39.98	36.78	18.98
$(\bar{x}_i)_{avg}$	6.44		8.00	7.36	3.80

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
Jul-16	1.17	-1.31	-0.49	-0.36	-0.23
Jan-17	1.36	-0.83	-0.12	0.36	0.11
Jul-17	0.80	-0.86	-0.02	0.04	0.04
Jan-18	0.46	-0.99	0.06	-0.11	-0.09
Aug-18	0.47	-0.27	0.57	0.08	0.18

X: Mean Value = 1.07E-16
 S: Standard Deviation = 0.63
 K* Factor = 2.292 (for n = 25)
 CV = S/X = 5.90E+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)].

**Attachment B6: Trichloroethene URGAs, Statistical Test 4, Parametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset for Lognormal Data

p = number of wells (background wells considered as one group) $\bar{x}_{..} = 160.13$
 n_i = number of data points per well $(\bar{x}_{avg})_{..} = 6.41$
 N = total sample size
 S^2 = the square of the standard deviation $p = 4$
 $\ln(S_i^2)$ = natural logarithm of each variance $N = 25$
 f = total sample size minus the number of wells (groups)
 $f_i = n_i - 1$

Calculations for Equality of Variance: Bartlett's Test

S_i	S_i^2	$\ln(S_i^2)$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)$
0.973	0.946	-0.055	10	8.518	-0.5
0.383	0.147	-1.920	5	0.587	-7.7
0.264	0.070	-2.663	5	0.279	-10.7
0.164	0.027	-3.619	5	0.107	-14.5

$$\sum(S_i^2) = 1.19 \qquad \sum f_i \ln(S_i^2) = -33.3$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 21 \\
 S_p^2 &= 0.452 \\
 \ln S_p^2 &= -0.794 \\
 \chi^2 &= 16.626 \quad (\text{If } \chi^2 \leq \chi_{crit}^2, \text{ then variances are equal at the given} \\
 &\qquad \qquad \qquad \text{significance level).} \\
 \chi_{crit}^2 * &= 7.815 \quad \text{at a 5\% significance level with } 3 \text{ degrees of freedom}
 \end{aligned}$$

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

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

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

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

**Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	1000	476	5260	1690	53.3
n _i	10		5	5	5
x _i	9279		15770	8040	224.80
(x _i)avg	927.90		3154.00	1608.00	44.96

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 $\bar{x}_{..}$ = 1332.55

N = 25 N = the total number of samples

p = 4 p = the number of n_i groups

$\Sigma x_{..}$ = 33313.80 $\Sigma x_{..}$ = the sum of the total number of samples

**Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	TCE (µg/L)	Adjusted Rank	Tie Number
1	35.3	1	
2	40.6	2	
3	46.1	3	
4	49.5	4	
5	53.3	5	
6	169	6	
7	232	7	
8	264	8	
9	274	9	
10	476	10	
11	994	11	
12	1000	12	
13	1090	13	
14	1400	14.5	Tie 1
15	1400	14.5	
16	1620	16	
17	1690	17	
18	1820	18	
19	2020	19	
20	2240	20	
21	2450	21	
22	2620	22	
23	2910	23	
24	3160	24	
25	5260	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 B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Sums of Ranks and Averages

TCE (µg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	1000	476	5260	1690	53.3

Observation Ranks for TCE					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	19	6	18	13	1
Jan-17	21	9	22	20	4
Jul-17	14.5	8	23	16	3
Jan-18	11	7	24	14.5	2
Aug-18	12	10	25	17	5
R_i	117.5		112	80.5	15
$(R_i)_{avg}$	11.8		22.4	16.1	3
R_i^2/n_i	1380.6		2508.8	1296.1	45

$$\sum R_i^2/n_i = 5230.5$$

$$K = 4$$

$$N = 25$$

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.

K = the number of n_i groups

N = the total number of samples

Calculation of Kruskal-Wallis Statistic

$$H = 18.563 \quad \text{Kruskal-Wallis Statistic} \quad H = [12/N(N+1) * \sum R_i^2/n_i] - 3(N+1)$$

$$H' = 18.570 \quad \text{Corrected Kruskal-Wallis} \quad H' = H/[1 - (\sum T_i/N^3 - N)]$$

$$\chi^2_{crit} = 7.815 \quad 3 \quad \text{degrees of freedom at the 5% significance level}$$

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.

$$K-1 = 3 \quad \alpha/(K-1) = 0.01667 \quad Z(\alpha/(K-1))^{**} = 2.13$$

$$\alpha = 0.05 \quad 1-(\alpha/(K-1)) = 0.983$$

NOTE:

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

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

Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Calculate Critical Values

Average Background Ranking = 11.8

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	10.65	evidence of contamination
	MW87	8.578	4.35	not contaminated
	MW90A	8.578	-8.75	not contaminated

$\mu\text{g/L}$ = micrograms per liter

BG = background

DL = detection limit

CONCLUSION:

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

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

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

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

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

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

**Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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.

**August 2018 Data, Second Reporting Period
Observations (µg/L)**

Well No.						
MW93	2020	2450	1400	994	1000	Upgradient Well ¹
MW420	169	274	264	232	476	Upgradient Well ¹
						Current Data
MW84	X: Mean Value =		928			5260
MW87	S: Standard Deviation =		808			1690
MW90A	K* factor =		2.911	(for n = 10)		53.3
	CV = S/X		0.8707	<1, assume normal distribution		
	Upper Tolerance Interval: TL = X +(KxS) =		3280	(µg/L)		

¹ = Data from previous 5 sampling events.

CV = coefficient of variation

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

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

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

Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Paired (Parametric) ANOVA - MW93 and MW84

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

TCE (µg/L)				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jul-16	2020	1820	4080400	3312400
Jan-17	2450	2620	6002500	6864400
Jul-17	1400	2910	1960000	8468100
Jan-18	994	3160	988036	9985600
Aug-18	1000	5260	1000000	27667600
Sum (x_i)	7864	15770	23634	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	1573	3154		
$(x_i)^2$	61842496	248692900		

µg/L = micrograms per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ =	2363	
N =	10	N = the total number of samples
p =	2	p = the number of n_i groups
$x_{..}$ =	23634	$x_{..}$ = 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
Jul-16	447	-1334
Jan-17	877	-534
Jul-17	-173	-244
Jan-18	-579	6
Aug-18	-573	2106

X: Mean Value =	0.00E+00	
S: Standard Deviation =	956	
K* Factor =	2.911	(for n = 10)
CV = S/X =	#DIV/0!	#DIV/0!

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

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

If the coefficient of variation is < 1, the data are normally distributed.

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

Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Determine Equality of Variance of Dataset

p = number of wells	$x_{..} = 23634$
n_i = number of data points per well	$(x_{avg})_{..} = 2363$
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	$\ln(S_i^2)^\dagger$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)^\dagger$
645	415609	12.938	5	1662437	51.8
1281	1639880	14.310	5	6559520	57.2

$$\sum(S_i^2) = 2,055,489 \qquad \sum f_i \ln(S_i^2) = 109$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 Sp^2 &= 1027745 \\
 \ln Sp^2 &= 13.843 \\
 \chi^2 &= 1.752 \quad (\text{If calculated } \chi^2 \leq \text{tabulated } \chi^2_{\text{crit}}, \text{ then variances are equal at the given} \\
 &\qquad \qquad \qquad \text{significance level).} \\
 \chi^2_{\text{crit}} &= 3.841 \quad \text{at a 5\% significance level with } 1 \quad \text{degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

**Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Between Well Sum of Squares

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{\text{wells}} = 6250483.60$	1	6250483.60	6.08	5.32
Error	$SS_{\text{Error}} = 8221956.80$	8	1027744.60		
Total	$SS_{\text{Total}} = 14472440.40$	9			

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

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

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

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

Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Mann-Kendall Statistical Analysis for TCE in MW84

Input Data

Date Collected	Result (µg/L)
Jan-15	1380
Jul-15	1530
Jan-16	1350
Jul-16	1820
Jan-17	2620
Jul-17	2910
Jan-18	3160
Aug-18	5260

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation ProUCL 5.19/28/2018 9:36:51 AM

From File WorkSheet.xls

Full Precision OFF

Confidence Coefficient 0.95

Level of Significance 0.05

MW84 TCE Q3

General Statistics

Number or Reported Events Not Used	0
Number of Generated Events	8
Number Values Reported (n)	8
Minimum	1350
Maximum	5260
Mean	2504
Geometric Mean	2250
Median	2220
Standard Deviation	1321
Coefficient of Variation	0.528

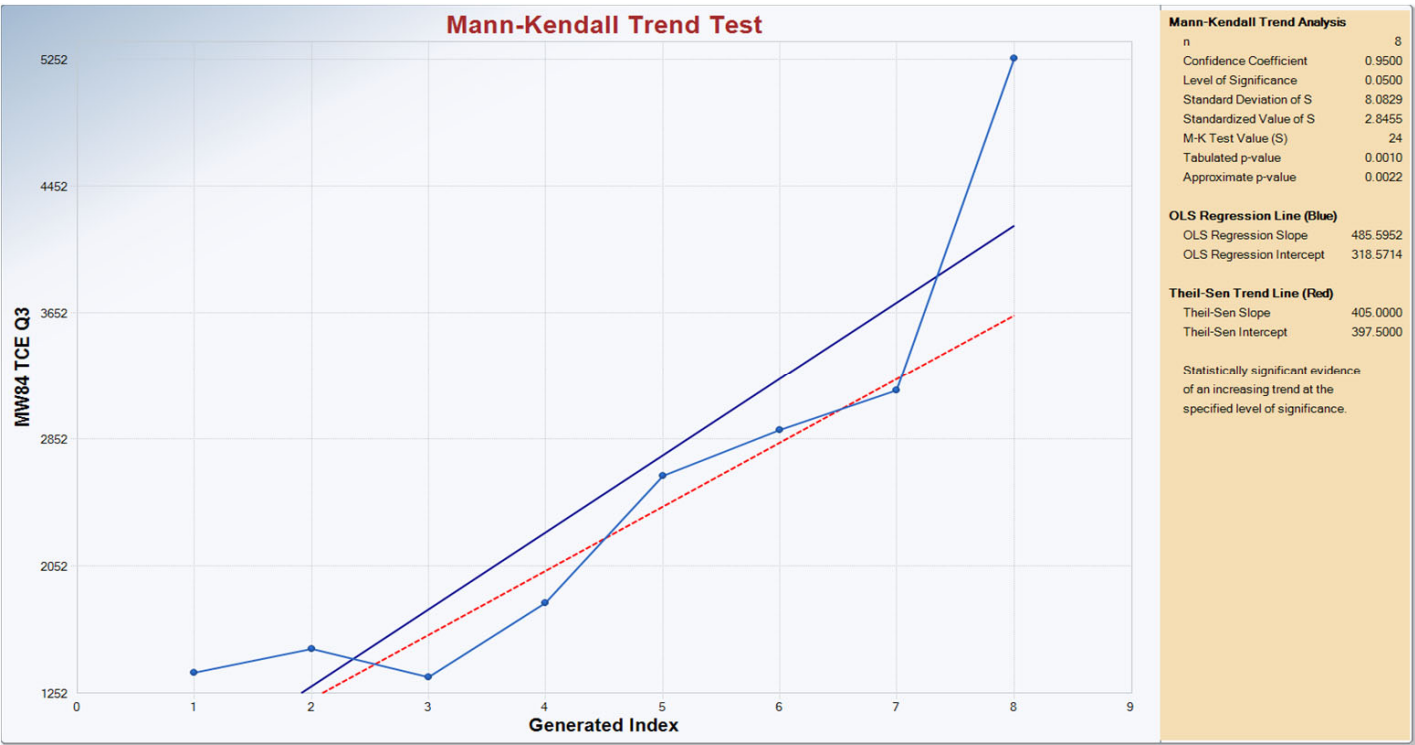
Mann-Kendall Test

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

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

Attachment B6: Trichloroethene URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018

Mann-Kendall Statistical Analysis for TCE in MW84



ATTACHMENT B7

**URANIUM
STATISTICAL TEST 3**

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**Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
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
Aug-18	0.000113	0.0001	0.000302	0.000722	0.0001
Sum	0.0013		0.00182	0.00306	0.0005
n _i	10		5	5	5
(x _i) _{avg}	0.00013		0.00036	0.00061	0.0001

mg/L = milligrams per liter

BG = background

DL = detection limit

All data sets represent 1/2 DL values for nondetects.

Bolded values indicate a detected result.

Overall mean $\bar{x}_{..}$ = 0.00027

N =	25	N = the total number of samples
p =	4	p = the number of n _i groups
$\bar{x}_{..}$ =	0.01	$\bar{x}_{..}$ = the sum of the total number of samples

**Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Statistical Test 3, Nonparametric ANOVA

Ranking of Observations

Sequence	Uranium (mg/L)	Adjusted Rank	Tie Number
1	0	6	Tie 1
2	0	6	
3	0	6	
4	0	6	
5	0	6	
6	0	6	
7	0	6	
8	0	6	
9	0	6	
10	0	6	
11	0	6	
12	0.000113	12	
13	0.000165	13	
14	0.0002	14	
15	0.000223	15	
16	0.000224	16	
17	0.000302	17	
18	0.000345	18	
19	0.000355	19	
20	0.000522	20	
21	0.000559	21	
22	0.000571	22	
23	0.000618	23	
24	0.000681	24	
25	0.000722	25	

mg/L = milligrams per liter

BG = background

DL = detection limit

Bolded values indicate a detected result.

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

$$\begin{aligned}
 n_{\text{tie}} & \quad \text{Adjustment for Ties: } (n_{\text{tie}}^3 - n_{\text{tie}}) \\
 11 & \quad \text{Tie 1} = \quad 1320 \\
 & \quad \Sigma T_i = \quad 1320
 \end{aligned}$$

Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Sums of Ranks and Averages

Uranium (mg/L)					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	0.000165	0	0.000345	0.000559	0
Jan-17	0.000223	0	0.000618	0.000522	0
Jul-17	0.000224	0	0.000355	0.000571	0
Jan-18	0	0	0.0002	0.000681	0
Aug-18	0.000113	0	0.000302	0.000722	0

Observation Ranks for Uranium					
Date	Background	Background	Compliance	Compliance	Compliance
	MW93	MW420	MW84	MW87	MW90A
Jul-16	13	6	18	21	6
Jan-17	15	6	23	20	6
Jul-17	16	6	19	22	6
Jan-18	6	6	14	24	6
Aug-18	12	6	17	25	6
R_i	92		91	112	30
$(R_i)_{avg}$	9.2		18.2	22.4	6.0
R_i^2/n_i	846.4		1656.2	2508.8	180.0

$$\Sigma R_i^2/n_i = 5191.4$$

$$K = 4$$

$$N = 25$$

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.

K = the number of n_i groups

N = the total number of samples

Calculation of Kruskal-Wallis Statistic

$$H = 17.841$$

$$H' = 19.490$$

$$\chi^2_{crit} = 7.815$$

Kruskal-Wallis Statistic

Corrected Kruskal-Wallis

3

degrees of freedom at the 5% significance level

$$H = [12/N(N+1) \cdot \Sigma R_i^2/n_i] - 3(N+1)$$

$$H' = H/[1 - (\Sigma T_i^3/N^3 - N)]$$

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.

$$K-1 = 3$$

$$\alpha = 0.05$$

$$\alpha/(K-1) = 0.01667$$

$$1 - (\alpha/(K-1)) = 0.983$$

$$Z(\alpha/(K-1))^{**} = 2.1280$$

NOTE:

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

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

**Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Calculate Critical Values

Average Background Ranking = 9.2

	Well No.	C_i	$(R_i)_{avg} - (R_b)_{avg}$	Conclusion
BG Well	MW93			
BG Well	MW420			
	MW84	8.578	9.00	evidence of contamination
	MW87	8.578	13.20	evidence of contamination
	MW90A	8.578	-3.20	not contaminated

mg/L = milligrams per liter

BG = background

DL = detection limit

CONCLUSION:

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

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

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

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

Since $(R_i)_{avg} - (R_b)_{avg} < C_i$ for MW90A, there is no statistically significant difference from C-404 in this downgradient compliance test well; however, the negative value indicates that the background wells have elevated concentrations.

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

**Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

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.

**August 2018 Data, Second Reporting Period
Observations (mg/L)**

Well No.						
MW93	0.000165	0.000223	0.000224	0.0001	0.000113	Upgradient Well [!]
MW420	0.0001	0.0001	0.0001	0.0001	0.0001	Upgradient Well [!]
						Current Data
MW84	X: Mean Value = 0.0001					0.000302
MW87	S: Standard Deviation = 0.0001					0.000722
MW90A	K* factor = 2.911 (for n = 10)					0.0001
	CV = S/X 0.3925 <1, assume normal distribution					
	Upper Tolerance Interval: TL = X +(KxS) = 0.0003 (mg/L)					

[!] = Data from previous 5 sampling events.

CV = coefficient of variation

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

Result: MW84 and MW87 exceeded the UTL, which is statistically significant evidence that these compliance wells have elevated concentrations with respect to background data.

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

Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Paired (Parametric) ANOVA - MW93 and MW84

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

Uranium (mg/L)				
Date	Background	Compliance		
	MW93	MW84	n_i^2	
Jul-16	0.000165	0.000345	0.00000003	0.00000001
Jan-17	0.000223	0.000618	0.00000005	0.00000004
Jul-17	0.000224	0.000355	0.00000005	0.00000001
Jan-18	0.0001	0.0002	0.00000001	0.00000004
Aug-18	0.000113	0.000302	0.00000001	0.00000001
Sum (x_i)	0.00083	0.00182	0.00265	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	0.00017	0.00036		
$(x_i)^2$	0.000001	0.000003		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ = 0.00026

N = 10

N = the total number of samples

p = 2

p = the number of n_i groups

$x_{..}$ = 0.0026

$x_{..}$ = 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
Jul-16	0.00000	-0.00002
Jan-17	0.00006	0.00025
Jul-17	0.00006	-0.00001
Jan-18	-0.00007	-0.00016
Aug-18	-0.00005	-0.00006

X: Mean Value = -2.03E-20

S: Standard Deviation = 0.00011

K* Factor = 2.911 (for n = 10)

CV = S/X = -5.43E+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.

**Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset

p = number of wells	$\bar{x}_{..} = 0.0026$
n_i = number of data points per well	$(\bar{x}_{avg})_{..} = 0.00026$
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	$\ln(S_i^2)^\dagger$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)^\dagger$
0.000059	0.00000000344	-19.487	5	0.0000000	-77.9
0.00015	0.00000002392	-17.548	5	0.0000001	-70.2

$$\sum(S_i^2) = 0.000000027 \qquad \sum f_i \ln(S_i^2) = -148.14056$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 Sp^2 &= 0.00000001 \\
 \ln Sp^2 &= -18.107 \\
 \chi^2 &= 3.284 \quad \text{(If calculated } \chi^2 \leq \text{tabulated } \chi^2_{\text{crit}}, \text{ then variances are equal at the given} \\
 &\qquad \qquad \qquad \text{significance level).} \\
 \chi^2_{\text{crit}} * &= 3.841 \quad \text{at a 5\% significance level with } 1 \quad \text{degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

**Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Between Well Sum of Squares

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{\text{wells}} = 0.0000001$	1	0.00000010	7.23	5.32
Error	$SS_{\text{Error}} = 0.0000001$	8	0.00000001		
Total	$SS_{\text{Total}} = 0.0000002$	9			

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

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

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

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

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Mann-Kendall Statistical Analysis for Uranium in MW84

Input Data

Date Collected	Result (mg/L)
Jan-15	0.00043
Jul-15	0.0002
Jan-16	0.0002
Jul-16	0.000345
Jan-17	0.000618
Jul-17	0.000355
Jan-18	0.0002
Aug-18	0.000302

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options
 Date/Time of Computation ProUCL 5.110/1/2018 8:32:04 AM
 From File WorkSheet.xls
 Full Precision OFF
 Confidence Coefficient 0.95
 Level of Significance 0.05

MW84 uranium 3Q

General Statistics

Number or Reported Events Not Used 0
 Number of Generated Events 8
 Number Values Reported (n) 8
 Minimum 2.0000E-4
 Maximum 6.1800E-4
 Mean 3.3125E-4
 Geometric Mean 3.0687E-4
 Median 3.2350E-4
 Standard Deviation 1.4406E-4
 Coefficient of Variation 0.435

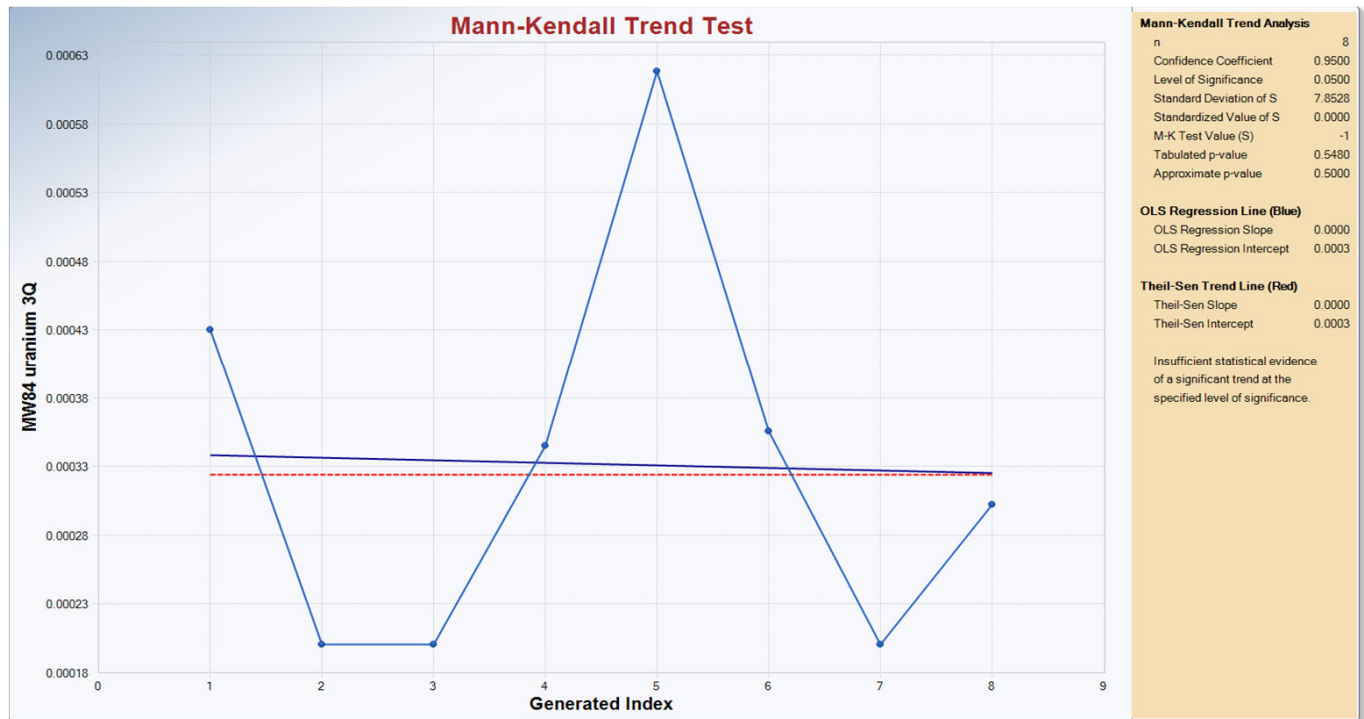
Mann-Kendall Test

M-K Test Value (S) -1
 Tabulated p-value 0.548
 Standard Deviation of S 7.853
 Standardized Value of S 0
 Approximate p-value 0.5

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

**Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Mann-Kendall Statistical Analysis for Uranium in MW84



Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Paired (Parametric) ANOVA - MW93 and MW87

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

Uranium (mg/L)				
Date	Background	Compliance		
	MW93	MW87	n_i^2	
Jul-16	0.000165	0.000559	0.00000003	0.00000003
Jan-17	0.000223	0.000522	0.00000005	0.00000003
Jul-17	0.000224	0.000571	0.00000001	0.00000003
Jan-18	0.0001	0.000681	0.00000001	0.00000005
Aug-18	0.000113	0.000722	0.00000001	0.00000005
Sum (x_i)	0.00083	0.00306	0.0039	Total Sum ($x_{..}$)
n_i	5	5		
$(x_i)_{avg}$	0.000165	0.00061		
$(x_i)^2$	0.000001	0.00001		

mg/L = milligrams per liter

Bolded values indicate a detected result.

Overall mean $x_{..}$ = 0.00039

N = 10

N = the total number of samples

p = 2

p = the number of n_i groups

$x_{..}$ = 0.0039

$x_{..}$ = 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
Jul-16	0.00000	-0.00005
Jan-17	0.00006	-0.00009
Jul-17	0.00006	-0.00004
Jan-18	-0.00007	0.00007
Aug-18	-0.00005	0.00011

X: Mean Value = -1.22E-20

S: Standard Deviation = 0.00007

K* Factor = 2.911 (for n = 10)

CV = S/X = -5.68E+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.

**Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Determine Equality of Variance of Dataset

p = number of wells	$\bar{x}_{..} = 0.0039$
n_i = number of data points per well	$(\bar{x}_{avg})_{..} = 0.00039$
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	$\ln(S_i^2)^\dagger$	n_i	$f_i S_i^2$	$f_i \ln(S_i^2)^\dagger$
0.000059	0.00000000344	-19.487	5	0.00000001	-77.9
0.00009	0.00000000736	-18.727	5	0.00000003	-74.9

$$\sum(S_i^2) = 0.000000011 \qquad \sum f_i \ln(S_i^2) = -152.85512$$

Equality of Variance: Bartlett's Test

$$\begin{aligned}
 f &= 8 \\
 S_p^2 &= 0.00000001 \\
 \ln S_p^2 &= -19.036 \\
 \chi^2 &= 0.564 \quad (\text{If calculated } \chi^2 \leq \text{tabulated } \chi_{crit}^2, \text{ then variances are equal at the given} \\
 &\quad \text{significance level).} \\
 \chi_{crit}^2 * &= 3.841 \quad \text{at a 5\% significance level with } 1 \quad \text{degrees of freedom (p-1)}
 \end{aligned}$$

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

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

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

**Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Between Well Sum of Squares

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	Calculated F	F Statistic**
Between Wells	$SS_{\text{wells}} = 0.0000005$	1	0.0000005	92.05	5.32
Error	$SS_{\text{Error}} = 0.00000004$	8	0.00000001		
Total	$SS_{\text{Total}} = 0.000001$	9			

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

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

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

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

Attachment B7: Uranium URGA, Statistical Test 3, Nonparametric ANOVA, Second Reporting Period 2018

Mann-Kendall Statistical Analysis for Uranium in MW87

Input Data

Date Collected	Result (mg/L)
Jan-15	0.00019
Jul-15	0.0002
Jan-16	0.0002
Jul-16	0.000559
Jan-17	0.000522
Jul-17	0.000571
Jan-18	0.000681
Aug-18	0.000722

Bolded values indicate a detected result.

Mann-Kendall Trend Test Analysis

User Selected Options

Date/Time of Computation ProUCL 5.19/28/2018 3:14:42 PM
 From File WorkSheet.xls
 Full Precision OFF
 Confidence Coefficient 0.95
 Level of Significance 0.05

MW87 uranium 3Q

General Statistics

Number or Reported Events Not Used 0
 Number of Generated Events 8
 Number Values Reported (n) 8
 Minimum 1.9000E-4
 Maximum 7.2200E-4
 Mean 4.5563E-4
 Geometric Mean 3.9745E-4
 Median 5.4050E-4
 Standard Deviation 2.2405E-4
 Coefficient of Variation 0.492

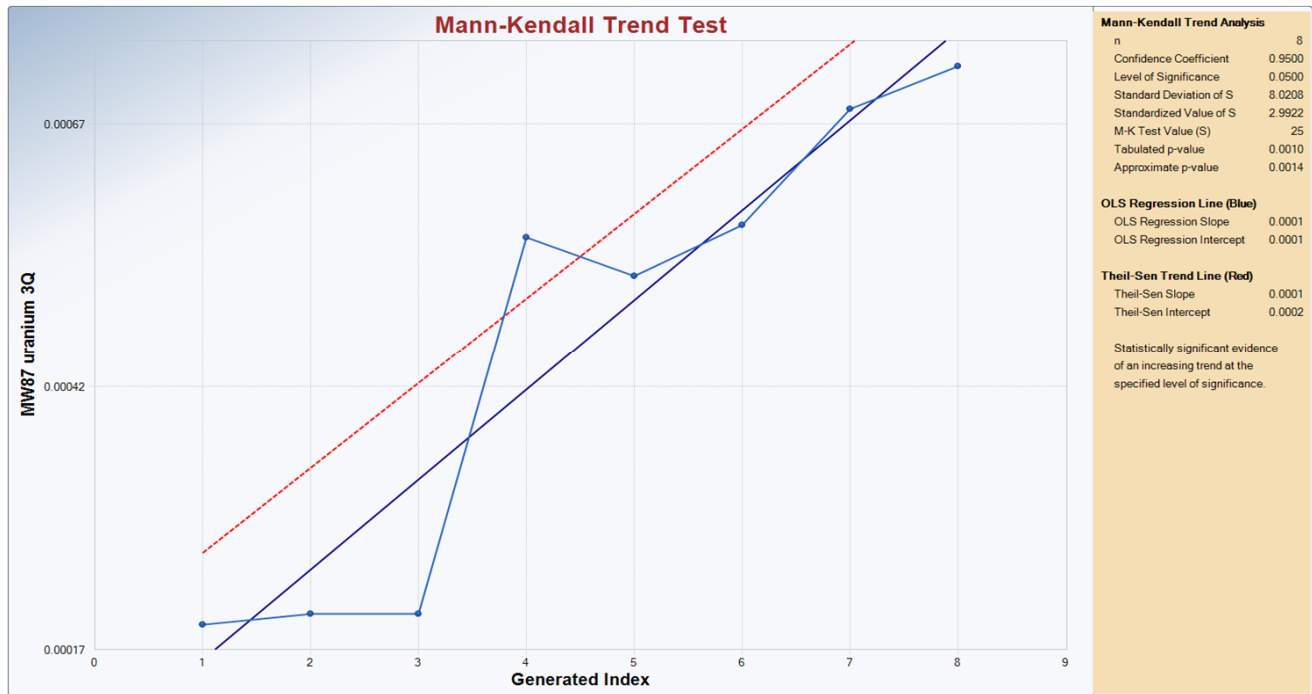
Mann-Kendall Test

M-K Test Value (S) 25
 Tabulated p-value 0.001
 Standard Deviation of S 8.021
 Standardized Value of S 2.992
 Approximate p-value 0.00138

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

**Attachment B7: Uranium URGAs, Statistical Test 3, Nonparametric ANOVA,
Second Reporting Period 2018**

Mann-Kendall Statistical Analysis for Uranium in MW87



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ATTACHMENT B8
STATISTICIAN STATEMENT

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October 4, 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 an Environmental Scientist, with a bachelor's degree in science, I have over 20 years of experience in reviewing and assessing laboratory analytical results associated with environmental sampling and investigation activities. For the generation of these statistical analyses, my work was observed and reviewed by a senior chemist and geologist with Four Rivers Nuclear Partnership, LLC.

For this project, the statistical analyses on groundwater data from July 2016 through August 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 (EPA's) ProUCL 5.1. The spreadsheets include the results for the following statistical tests:

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

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

Sincerely,



Jennifer R. Watson

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APPENDIX C

C-404 HAZARDOUS WASTE LANDFILL GROUNDWATER FLOW RATE AND DIRECTION

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2018 ANNUAL REPORT OF THE C-404 LANDFILL HYDRAULIC FLOW RATE AND DIRECTION

The Hazardous Waste Management Facility Permit, KY8-890-008-982, (Permit) requires annual determination of average hydraulic flow rate and direction of flow in the uppermost aquifer at the C-404 Hazardous Waste Landfill (C-404 Landfill). The uppermost aquifer below C-404 Landfill is the Regional Gravel Aquifer (RGA). Water level measurements currently are taken from several wells at the perimeter of the C-404 Landfill on a semiannual basis. The water levels used for this analysis (taken on January 29 and August 21, 2018) were measured as closely as possible and within a 24-hour period to ensure the comparability of the data. These measurements were used to plot the potentiometric surface of the upper RGA for the January and August 2018 semiannual sampling events.

Contours for each potentiometric surface were drawn after water level data were corrected for barometric pressure; groundwater hydraulic gradients then are calculated from the contours. The average of the gradients measured during this reporting period is the annual average groundwater hydraulic gradient for the upper RGA and is calculated at 1.08×10^{-3} ft/ft.

The hydraulic conductivity (K) values reported in the *Resource Conservation and Recovery Act (RCRA) Part B Permit Modification for Inclusion of C-404 Low-Level Radioactive/Hazardous Waste Landfill* (Clausen et al., 1992) were determined by multi-well testing and range from 21 to 140 ft/day (7.41×10^{-3} to 4.94×10^{-2} cm/s).

Multiplication of the hydraulic gradient (i) and the hydraulic conductivity (K) yields the specific discharge (q) for a unit area of the RGA. Annual average linear-flow velocity (v) is calculated by multiplying the hydraulic conductivity by the gradient and dividing by the porosity (n). It is assumed that (n) equals 25 percent in the RGA beneath the C-404 Landfill.

Table C.1 summarizes the annual average results of the calculations. Table C.2 presents the calculation information for the annual groundwater flow rate. The January and August potentiometric surface data of the upper RGA are presented in Tables C.3 and C.4, and potentiometric surface maps are presented in Figures C.1 and C.2. All water level measurements for January 29, 2018, were measured from alternate reference points compared to that specified in the Permit. As discussed in the May 23, 2018, meeting with The Kentucky Division of Waste Management, an attempt was made to collect the August 21, 2018, water level measurements using the reference point specified in the Permit. All water level measurements were taken using the reference points specified in the Permit with the exception of MW90A and MW420. The Permit specified these reference points as being the Well Wizard plate. Because the MWs no longer have a Well Wizard plate, an alternate reference point was needed.

The potentiometric contours depict the directions of hydraulic flow during each sampling event. Hydraulic flow direction beneath the C-404 Landfill generally trends northeastward, but commonly varies from northeast to north.

Table C.1. C-404 Landfill Annual Average Groundwater Flow Rate for 2018

Hydraulic Conductivity (K) Range	Annual Average Specific Discharge (q) ft/day (cm/s)	Annual Average Linear Flow Velocity (v) ft/day (cm/s)
High K	0.15 (5.3×10^{-5})	0.60 (2.1×10^{-4})
Low K	0.023 (8.0×10^{-6})	0.091 (3.2×10^{-5})

Table C.2. Calculation Information for the C-404 Landfill Annual Groundwater Flow Rate 2018

Upper RGA K = 21 ft/d					
	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
January 2018	-1.16E-03	0.024	8.6E-06	0.098	3.4E-05
August 2018	-9.94E-04	0.021	7.4E-06	0.084	2.9E-05
Annual Average	-1.08E-03	0.023	8.0E-06	0.091	3.2E-05
Upper RGA K = 140 ft/d					
	i (ft/ft)	q (ft/d)	q (cm/s)	v (ft/d)	v (cm/s)
January 2018	-1.16E-03	0.16	5.7E-05	0.65	2.3E-04
August 2018	-9.94E-04	0.14	4.9E-05	0.56	2.0E-04
Annual Average	-1.08E-03	0.15	5.3E-05	0.60	2.1E-04
$q = K \cdot i$ <div> where: q = specific discharge (per unit area) K = hydraulic conductivity i = hydraulic gradient (from potentiometric map) </div>					
$v = q/n$ <div> where: v = average linear velocity q = specific discharge n_e = porosity (assumed to be 25%) </div>					

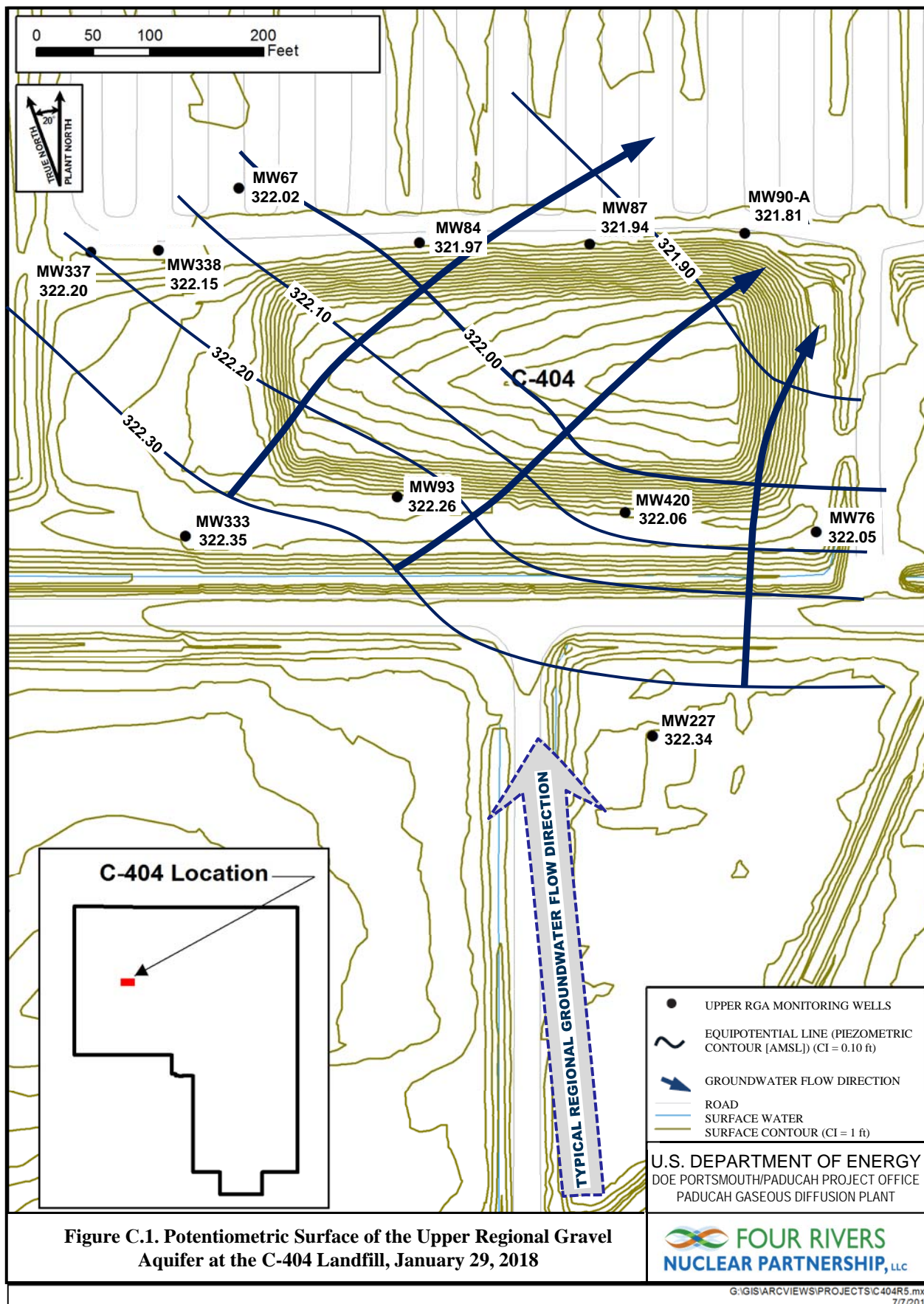
ft/ft = foot per foot
ft/d = foot per day
cm/s = centimeter/second

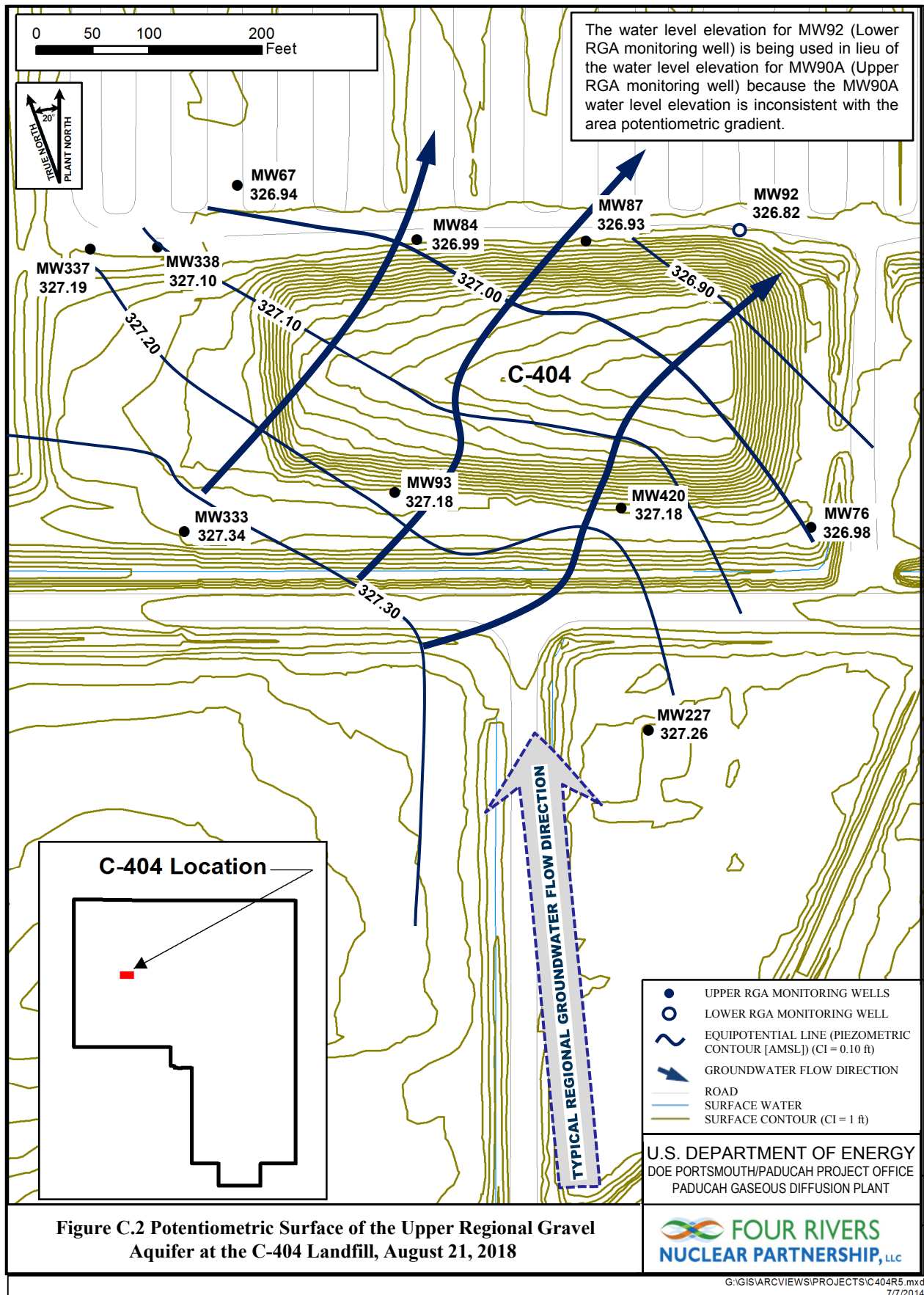
Table C.3. Barometric Pressure Corrections

C-404 Landfill (January 2018) Water Levels									
Date	Time	Well	Datum Elev*	BP	Delta BP	Raw Data		Corrected Data**	
						DTW	Elev	DTW	Elev
			(ft amsl)	(in Hg)	(ft H ₂ O)	(ft)	(ft amsl)	(ft)	(ft amsl)
1/29/2018	12:21	MW67	375.09	30.40	-0.01	53.08	322.01	53.07	322.02
1/29/2018	12:43	MW76	376.71	30.40	-0.01	54.67	322.04	54.66	322.05
1/29/2018	12:16	MW84	375.99	30.40	-0.01	54.03	321.96	54.02	321.97
1/29/2018	12:23	MW87	375.91	30.40	-0.01	53.98	321.93	53.97	321.94
1/29/2018	12:27	MW90A	374.43	30.40	-0.01	52.63	321.80	52.62	321.81
1/29/2018	12:37	MW93	377.80	30.40	-0.01	55.55	322.25	55.54	322.26
1/29/2018	12:46	MW227	378.81	30.40	-0.01	56.48	322.33	56.47	322.34
1/29/2018	12:40	MW333	377.35	30.40	-0.01	55.01	322.34	55.00	322.35
1/29/2018	12:18	MW337	374.67	30.40	-0.01	52.48	322.19	52.47	322.20
1/29/2018	12:19	MW338	374.86	30.40	-0.01	52.72	322.14	52.71	322.15
1/29/2018	12:31	MW420	378.23	30.40	-0.01	56.18	322.05	56.17	322.06
Initial Barometric Pressure			30.39						
Elev = elevation									
amsl = above mean sea level									
BP = barometric pressure									
DTW = depth to water in feet below datum									
*On 1/29/2018, water levels were measured from alternate reference points to those specified in the Permit (Well Wizard plate). Depth to water was measured from the Well Wizard rim in MW84, MW87, and MW93. Depth to water was measured from the top of outer casing in MW90A and MW420. MW90A and MW420 no longer have a Well Wizard plate.									
**Assumes a barometric efficiency of 1.0.									

Table C.4. Barometric Pressure Corrections

C-404 Landfill (August 2018) Water Levels									
Date	Time	Well	Datum Elev*	BP	Delta BP	Raw Data		Corrected Data**	
						DTW	Elev (ft amsl)	DTW	Elev (ft amsl)
8/21/2018	8:01	MW67	374.95	29.90	0.00	48.01	326.94	48.01	326.94
8/21/2018	9:28	MW76	376.71	29.90	0.00	49.73	326.98	49.73	326.98
8/21/2018	8:31	MW84	375.91	29.90	0.00	48.92	326.99	48.92	326.99
8/21/2018	7:58	MW87	375.79	29.90	0.00	48.86	326.93	48.86	326.93
8/21/2018	7:53	MW90A	374.18	29.90	0.00	47.45	326.73	47.45	326.73
8/21/2018	8:36	MW92***	374.54	29.90	0.00	47.72	326.82	47.72	326.82
8/21/2018	9:21	MW93	377.59	29.90	0.00	50.41	327.18	50.41	327.18
8/21/2018	7:43	MW227	378.81	29.88	0.02	51.53	327.28	51.55	327.26
8/21/2018	9:23	MW333	377.35	29.90	0.00	50.01	327.34	50.01	327.34
8/21/2018	8:04	MW337	374.67	29.90	0.00	47.48	327.19	47.48	327.19
8/21/2018	8:06	MW338	374.86	29.90	0.00	47.76	327.10	47.76	327.10
8/21/2018	9:17	MW420	377.70	29.90	0.00	50.52	327.18	50.52	327.18
Initial Barometric Pressure			29.90						
Elev = elevation									
amsl = above mean sea level									
BP = barometric pressure									
DTW = depth to water in feet below datum									
*On 8/21/2018, water levels were measured from alternate reference points to those specified in the Permit (Well Wizard plate) for MW90A and MW420. Depth to water was measured from the top of inside casing in MW90A and MW420. MW90A and MW420 no longer have a Well Wizard plate.									
**Assumes a barometric efficiency of 1.0.									
***The water level measurement for MW92 (Lower RGA well) is being used in lieu of the water level measurement in MW90A (Upper RGA well) for this quarter. The derived water level elevation for MW90A is inconsistent with the area potentiometric gradient.									





APPENDIX D

C-404 HAZARDOUS WASTE LANDFILL LEACHATE ANALYTICAL RESULTS

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Paducah OREIS Report for 404L18-01

L1404L1-18

from: C404L

on 2/27/2018

Media: WW

SmpMethod: GR

Comments:

Samplers used a peristaltic pump to retrieve samples. Teflon tubing was raised up & down to achieve a vertical profile. 5.3 ft is the water level from the top of the leachate. CB 2-27-18 Due to a delay by FedEx, the VOA aliquot for this sample was not delivered to the lab until 3-7-18. HLN 3-7-18

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	8.61	mg/L			0.5			SW846-9056	GEL	1 / X /
FS										
Conductivity	889	umho/cm						FS	FS	/ /
Dissolved Oxygen	8.86	mg/L						FS	FS	/ /
pH	7.27	Std Unit						FS	FS	/ /
Redox	426	mV						FS	FS	/ /
Temperature	53.9	deg F						FS	FS	/ /
METAL										
Arsenic	0.00515	mg/L			0.005			SW846-6020	GEL	/ X /
Barium	0.163	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.00172	mg/L			0.001			SW846-6020	GEL	/ X /
Chromium	0.0514	mg/L			0.01			SW846-6020	GEL	/ X /
Copper	0.211	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	16.6	mg/L	E		0.1			SW846-6020	GEL	/ X /
Lead	0.0233	mg/L			0.002			SW846-6020	GEL	/ X /
Mercury	0.000406	mg/L			0.0002			SW846-7470A	GEL	/ X /
Nickel	0.243	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.00138	mg/L			0.001			SW846-6020	GEL	/ X /
Uranium	126	mg/L			0.6			SW846-6020	GEL	1 / X /
Zinc	0.165	mg/L	N		0.01			SW846-6020	GEL	/ X /
PPCB										
PCB-1016	1	ug/L	LUY1		1			SW846-8082	GEL	/ X /
PCB-1221	1	ug/L	U		1			SW846-8082	GEL	/ X /
PCB-1232	1	ug/L	U		1			SW846-8082	GEL	/ X /
PCB-1242	1	ug/L	U		1			SW846-8082	GEL	/ X /
PCB-1248	8.65	ug/L	Y2		1			SW846-8082	GEL	/ X / FDUP-OUT
PCB-1254	4.03	ug/L	Y2		1			SW846-8082	GEL	/ X / FDUP-OUT
PCB-1260	0.854	ug/L	JLY1Y2		1			SW846-8082	GEL	/ X / FDUP-OUT
Polychlorinated biphenyl	13.5	ug/L	Y2		1			SW846-8082	GEL	1 / X / FDUP-OUT
RADS										
Cesium-137	0.944	pCi/L	U		12.7	6.78	6.79	EPA-901.1	GEL	/ X /
Neptunium-237	6.26	pCi/L			1.26	2.02	2.14	ASTM-1475-00aM	GEL	/ X / FDUP-OUT
Plutonium-239/240	6.43	pCi/L			1.74	2.89	3.19	HASL 300, Pu-11-RC M	GEL	S / X / FDUP-OUT
Technetium-99	1020	pCi/L			18.7	30.5	120	DOE TC-02-RC	GEL	IS / X / FDUP-OUT
Thorium-230	108	pCi/L			1.48	8.93	23.8	HASL 300, Th-01-RC M	GEL	/ X / FDUP-OUT
Uranium-234	4060	pCi/L			787	1330	1490	HASL 300, U-02-RC M	GEL	/ X / FDUP-OUT
Uranium-235	36.6	pCi/L	U		799	383	383	HASL 300, U-02-RC M	GEL	/ X / FDUP-OUT
Uranium-238	39100	pCi/L			742	4000	7430	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.155	mg/L	B		0.05			EPA-350.1	GEL	/ X /

Paducah OREIS Report for 404L18-01

L1404LD1-18

from: C404L

on 2/27/2018

Media: WW

SmpMethod: GR

Comments:

Samplers used a peristaltic pump to retrieve samples. Teflon tubing was raised up & down to achieve a vertical profile. 5.3 ft is the water level from the top of the leachate. CB 2-27-18 Due to a delay by FedEx, the VOA aliquot for this sample was not delivered to the lab until 3-7-18. HLN 3-7-18

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	8.74	mg/L			0.5			SW846-9056	GEL	1 / X /
FS										
Conductivity	889	umho/cm						FS	FS	/ /
Dissolved Oxygen	8.86	mg/L						FS	FS	/ /
pH	7.27	Std Unit						FS	FS	/ /
Redox	426	mV						FS	FS	/ /
Temperature	53.9	deg F						FS	FS	/ /
METAL										
Arsenic	0.00272	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0778	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.00705	mg/L	J		0.01			SW846-6020	GEL	S / X /
Copper	0.0311	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	2.43	mg/L	E		0.1			SW846-6020	GEL	/ X /
Lead	0.0025	mg/L			0.002			SW846-6020	GEL	/ X /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.0348	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.000371	mg/L	J		0.001			SW846-6020	GEL	S / X /
Uranium	122	mg/L			0.6			SW846-6020	GEL	1 / X /
Zinc	0.0222	mg/L	N		0.01			SW846-6020	GEL	/ X /
PPCB										
PCB-1016	0.1	ug/L	UY1		0.1			SW846-8082	GEL	/ X /
PCB-1221	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1232	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1242	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1248	1.52	ug/L	Y2		0.1			SW846-8082	GEL	/ X / FDUP-OUT
PCB-1254	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X / FDUP-OUT
PCB-1260	0.0578	ug/L	JPY1Y		0.1			SW846-8082	GEL	/ X / FDUP-OUT
Polychlorinated biphenyl	1.58	ug/L	Y2		0.1			SW846-8082	GEL	1 / X / FDUP-OUT
RADS										
Cesium-137	1.59	pCi/L	U		10.3	5.4	5.45	EPA-901.1	GEL	/ X /
Neptunium-237	2.34	pCi/L			1.32	1.33	1.36	ASTM-1475-00aM	GEL	/ X / FDUP-OUT
Plutonium-239/240	0.33	pCi/L	U		1.56	0.869	0.871	HASL 300, Pu-11-RC M	GEL	/ X / FDUP-OUT
Technetium-99	421	pCi/L			18.6	21.3	52.4	DOE TC-02-RC	GEL	S / X / FDUP-OUT
Thorium-230	4.34	pCi/L			1.86	1.95	2.15	HASL 300, Th-01-RC M	GEL	/ X / FDUP-OUT
Uranium-234	3130	pCi/L			592	956	1050	HASL 300, U-02-RC M	GEL	/ X / FDUP-OUT
Uranium-235	565	pCi/L			480	486	492	HASL 300, U-02-RC M	GEL	/ X / FDUP-OUT
Uranium-238	42600	pCi/L			543	3390	6790	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.106	mg/L	B		0.05			EPA-350.1	GEL	/ X /

Paducah OREIS Report for 404L18-01

FB404L1-18

from: QC

on 2/27/2018

Media: WQ

SmpMethod:

Comments:

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	0.1	mg/L	U		0.1			SW846-9056	GEL	/ x /
METAL										
Arsenic	0.005	mg/L	U		0.005			SW846-6020	GEL	/ x /
Barium	0.002	mg/L	U		0.002			SW846-6020	GEL	/ x /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ x /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ x /
Copper	0.001	mg/L	U		0.001			SW846-6020	GEL	/ x /
Iron	0.1	mg/L	UE		0.1			SW846-6020	GEL	/ x /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ x /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ x /
Nickel	0.002	mg/L	U		0.002			SW846-6020	GEL	/ x /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ x /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ x /
Uranium	0.000107	mg/L	J		0.0002			SW846-6020	GEL	/ x /
Zinc	0.01	mg/L	UN		0.01			SW846-6020	GEL	/ x /
PPCB										
PCB-1016	0.0952	ug/L	UY1		0.0952			SW846-8082	GEL	/ x /
PCB-1221	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1232	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1242	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1248	0.0952	ug/L	UY2		0.0952			SW846-8082	GEL	/ x /
PCB-1254	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1260	0.0952	ug/L	UY1Y2		0.0952			SW846-8082	GEL	/ x /
Polychlorinated biphenyl	0.0952	ug/L	UY2		0.0952			SW846-8082	GEL	/ x /
RADS										
Cesium-137	0.0566	pCi/L	U		8.79	4.56	4.56	EPA-901.1	GEL	/ x /
Neptunium-237	-0.124	pCi/L	U		0.848	0.286	0.287	ASTM-1475-00aM	GEL	/ x /
Plutonium-239/240	-0.0844	pCi/L	U		0.974	0.373	0.374	HASL 300, Pu-11-RC M	GEL	/ x /
Technetium-99	-4.09	pCi/L	U		17.7	10	10	DOE TC-02-RC	GEL	/ x /
Thorium-230	0.33	pCi/L	U		2.16	1.13	1.14	HASL 300, Th-01-RC M	GEL	/ x /
Uranium-234	1.38	pCi/L	U		1.61	1.23	1.25	HASL 300, U-02-RC M	GEL	/ x /
Uranium-235	0.864	pCi/L	U		1.1	1.02	1.03	HASL 300, U-02-RC M	GEL	/ x /
Uranium-238	0.803	pCi/L	U		1.44	0.995	1	HASL 300, U-02-RC M	GEL	/ x /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ x /
WETCHEM										
Ammonia as Nitrogen	0.0939	mg/L	B		0.05			EPA-350.1	GEL	/ x /

Paducah OREIS Report for 404L18-01

RI404L1-18

from: QC

on 2/27/2018

Media: WQ

SmpMethod:

Comments:

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	0.1	mg/L	U		0.1			SW846-9056	GEL	/ x /
METAL										
Arsenic	0.005	mg/L	U		0.005			SW846-6020	GEL	/ x /
Barium	0.002	mg/L	U		0.002			SW846-6020	GEL	/ x /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ x /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ x /
Copper	0.001	mg/L	U		0.001			SW846-6020	GEL	/ x /
Iron	0.1	mg/L	UE		0.1			SW846-6020	GEL	/ x /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ x /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ x /
Nickel	0.002	mg/L	U		0.002			SW846-6020	GEL	/ x /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ x /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ x /
Uranium	0.0002	mg/L	U		0.0002			SW846-6020	GEL	/ x /
Zinc	0.01	mg/L	UN		0.01			SW846-6020	GEL	/ x /
PPCB										
PCB-1016	0.0952	ug/L	UY1		0.0952			SW846-8082	GEL	/ x /
PCB-1221	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1232	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1242	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1248	0.0952	ug/L	UY2		0.0952			SW846-8082	GEL	/ x /
PCB-1254	0.0952	ug/L	U		0.0952			SW846-8082	GEL	/ x /
PCB-1260	0.0952	ug/L	UY1Y2		0.0952			SW846-8082	GEL	/ x /
Polychlorinated biphenyl	0.0952	ug/L	UY2		0.0952			SW846-8082	GEL	/ x /
RADS										
Cesium-137	-0.0524	pCi/L	U		8.25	4.39	4.39	EPA-901.1	GEL	/ x /
Neptunium-237	0.00501	pCi/L	U		0.826	0.372	0.372	ASTM-1475-00aM	GEL	/ x /
Plutonium-239/240	0.14	pCi/L	U		0.881	0.524	0.525	HASL 300, Pu-11-RC M	GEL	/ x /
Technetium-99	-0.777	pCi/L	U		18.6	10.7	10.7	DOE TC-02-RC	GEL	/ x /
Thorium-230	0.237	pCi/L	U		1.32	0.702	0.707	HASL 300, Th-01-RC M	GEL	/ x /
Uranium-234	0.384	pCi/L	U		1.46	0.828	0.831	HASL 300, U-02-RC M	GEL	/ x /
Uranium-235	-0.0986	pCi/L	U		1.14	0.436	0.437	HASL 300, U-02-RC M	GEL	/ x /
Uranium-238	0.213	pCi/L	U		1.01	0.585	0.586	HASL 300, U-02-RC M	GEL	/ x /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ x /
WETCHEM										
Ammonia as Nitrogen	0.0732	mg/L	B		0.05			EPA-350.1	GEL	/ x /

TB404L1-18

from: QC

on 2/27/2018

Media: WQ

SmpMethod:

Comments:

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

Paducah OREIS Report for 404L18-02

L1404L2-18

from: C404L

on 4/16/2018

Media: WW

SmpMethod: GR

Comments:

Samplers used a peristaltic pump to collect sample. Teflon tubing was raised up & down to obtain a vertical profile. The water level is 4.7 ft from the top of leachate. CB 4-16-18

Analysis	Results	Units	Result Qual	Foot Note	Reporting Limit	Counting Error	TPU	Method	LabCode	V/V/A*
ANION										
Fluoride	7.1	mg/L			0.2			SW846-9056	GEL	1 / X /
FS										
Conductivity	542	umho/cm						FS	FS	/ /
Dissolved Oxygen	8.41	mg/L						FS	FS	/ /
pH	7.04	Std Unit						FS	FS	/ /
Redox	324	mV						FS	FS	/ /
Temperature	52.9	deg F						FS	FS	/ /
METAL										
Arsenic	0.00272	mg/L	J		0.005			SW846-6020	GEL	/ X /
Barium	0.0758	mg/L			0.002			SW846-6020	GEL	/ X /
Cadmium	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Chromium	0.01	mg/L	U		0.01			SW846-6020	GEL	/ X /
Copper	0.00682	mg/L			0.001			SW846-6020	GEL	/ X /
Iron	0.096	mg/L	J		0.1			SW846-6020	GEL	/ X /
Lead	0.002	mg/L	U		0.002			SW846-6020	GEL	/ X /
Mercury	0.0002	mg/L	U		0.0002			SW846-7470A	GEL	/ X /
Nickel	0.00395	mg/L			0.002			SW846-6020	GEL	/ X /
Selenium	0.005	mg/L	U		0.005			SW846-6020	GEL	/ X /
Silver	0.001	mg/L	U		0.001			SW846-6020	GEL	/ X /
Uranium	83.1	mg/L			0.2			SW846-6020	GEL	1 / X /
Zinc	0.00507	mg/L	J		0.01			SW846-6020	GEL	S / X /
PPCB										
PCB-1016	0.1	ug/L	UY1		0.1			SW846-8082	GEL	/ X /
PCB-1221	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1232	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1242	0.1	ug/L	U		0.1			SW846-8082	GEL	/ X /
PCB-1248	1.11	ug/L			0.1			SW846-8082	GEL	/ X /
PCB-1254	0.321	ug/L			0.1			SW846-8082	GEL	/ X /
PCB-1260	0.0625	ug/L	J		0.1			SW846-8082	GEL	/ X /
Polychlorinated biphenyl	1.49	ug/L			0.1			SW846-8082	GEL	1 / X /
RADS										
Cesium-137	-0.688	pCi/L	U		8.58	4.76	4.77	EPA-901.1	GEL	/ X /
Neptunium-237	-0.37	pCi/L	U		3.06	1.06	1.06	ASTM-1475-00aM	GEL	/ X /
Plutonium-239/240	0.79	pCi/L	U		1.64	1.1	1.11	HASL 300, Pu-11-RC M	GEL	/ X /
Technetium-99	148	pCi/L			17.6	15.6	22.6	DOE TC-02-RC	GEL	/ X /
Thorium-230	1.79	pCi/L	U		2.7	2.11	2.19	HASL 300, Th-01-RC M	GEL	/ X /
Uranium-234	2570	pCi/L			539	880	953	HASL 300, U-02-RC M	GEL	/ X /
Uranium-235	538	pCi/L			269	467	473	HASL 300, U-02-RC M	GEL	/ X /
Uranium-238	31700	pCi/L			509	2980	5320	HASL 300, U-02-RC M	GEL	/ X /
VOA										
Trichloroethene	1	ug/L	U		1			SW846-8260B	GEL	/ X /
WETCHEM										
Ammonia as Nitrogen	0.0251	mg/L	JN		0.05			EPA-350.1	GEL	S / X /

Paducah OREIS Report for 404L18-02

TB404L2-18

from: QC

on 4/16/2018

Media: WQ

SmpMethod:

Comments:

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