Annual Groundwater Monitoring Report

Appalachian Power Company
John E. Amos Plant
Landfill CCR Management Unit
Winfield, West Virginia

January 2022

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Abbreviations:
ASD – Alternate Source Demonstration
CCR – Coal Combustion Residual
GWPS – Groundwater Protection Standard
SSI – Statistically Significant Increase
SSL – Statistically Significant Level
AMLF – Amos Landfill

I. Overview

This *Annual Groundwater Monitoring and Corrective Action Report* (Report) has been prepared to report the status of activities for the preceding year for an existing Landfill CCR unit at Appalachian Power Company's, a wholly-owned subsidiary of American Electric Power Company (AEP), John E. Amos Power Plant. The USEPA's CCR rules require that the Annual Groundwater Monitoring Report be posted to the operating record for the preceding year no later than January 31.

In general, the following activities were completed:

- Groundwater data underwent various validation tests, including tests for completeness, valid values, transcription errors, and consistent units.
- Groundwater data summary tables, groundwater velocity, and flow direction maps are included in **Appendix 1**.
- The Amos Landfill (AMLF) continued in detection monitoring throughout all of 2021.
- The Statistical Analysis Plan (SAP) for AMLF that was developed in accordance with the CCR Rule requirements in January 2017 was revised in January 2021 and subsequently posted to the operating record and publically available AEP CCR website.
- A Statistically significant increase (SSI) was confirmed at MW-4 and MW-1802 for chloride from the November 2020 detection monitoring event which included re-sampling in January 2021 in accordance with the statistical analysis plan. Statistical analysis for this event was completed in February 2021. An alternative source demonstration (ASD) was successfully completed in May 2021. The AMLF continued in detection monitoring.
- A SSI was confirmed at MW-4, MW-1801, and MW-1802 for chloride from the May 2021 detection monitoring event which included re-sampling in July 2021 in accordance with the statistical analysis plan. Statistical analysis for this event was completed in August 2021. An ASD was successfully completed in November 2021. The AMLF continued in detection monitoring.
- A detection monitoring event was conducted at the AMLF in November 2021. From the initial sampling, potential SSI's have been noted. Those are:
    - MW-2: Fluoride
    - MW-4: Chloride
    - MW-1801: Chloride
    - MW-1802: Calcium

  A re-sampling event will occur in the first quarter of 2022 for the above mentioned parameters and well locations in accordance with the statistical analysis plan. If any of the above potential SSI's are confirmed following statistical analysis, an ASD will be completed to determine if the unit can remain in detection monitoring or if it must transition to assessment monitoring in accordance with the CCR rule.

- Statistical analysis reports completed in 2021 for the above mentioned events (November 2020 and May 2021) are included in **Appendix 2**. The November 2021 event re-sampling and statistical analysis is still on-going.
- Alternative source demonstrations completed in 2021 are included in **Appendix 3**.

The major components of this annual report, to the extent applicable at this time, are presented in sections that follow:

- A map/aerial photograph showing the Amos Landfill CCR management unit, all groundwater monitoring wells, and monitoring well identification numbers.
- All of the monitoring data collected, including the rate and direction of groundwater flow, plus a summary showing the number of samples collected per monitoring well, the dates the samples were collected and whether the sample was collected as part of detection monitoring or assessment monitoring programs (**Appendix 1**).
- Statistical comparison of monitoring data to determine if there have been SSI(s) or SSL(s) (Attached as **Appendix 2**, where applicable);
- Discussion of the alternative source demonstrations (**Appendix 3**).
- A summary of any transition between monitoring programs or an alternate monitoring frequency, for example the date and circumstances for transitioning from detection monitoring to assessment monitoring, in addition to identifying the constituents detected at a statistically significant increase over background concentrations, if applicable (Appendix 4). This is not applicable to this report
- Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a statement as to why that happened (Appendix 5). This is not applicable to this report.
- Other information required to be included in the annual report such as assessment of corrective measures, if applicable.

In addition, this report summarizes key actions completed, and where applicable, describes any problems encountered and actions taken to resolve those problems. The report includes a projection of key activities for the upcoming year.

II. Groundwater Monitoring Well Locations and Identification Numbers

Figure 1 depicts the PE-certified groundwater monitoring network, the monitoring well locations, and their corresponding identification numbers. The groundwater monitoring well network was updated in 2020. MW-1801 and MW-1802 replaced MW-1 and MW-5. Additional information regarding this change to the monitoring well network can be found at https://aep.com/Assets/docs/requiredpostings/ccr/2020/AM-JEALF-GWMonitoringSystemDesignConstructionCert-052820.pdf

The monitoring well distribution adequately covers downgradient and upgradient areas as detailed in the revised *Groundwater Monitoring Network Evaluation Report*, referenced above, that was placed on the American Electric Power CCR public internet site on June 5, 2020.The groundwater quality monitoring network includes the following:

- Five upgradient wells: MW-6, MW-7R, MW-8, MW-9, and MW-10; and
- Four downgradient wells: MW-1801, MW-1802, MW-2, and MW-4.

Legend

⊕ Upgradient Sampling Location

⊕ Downgradient Sampling Location

▭ FGD Landfill

Notes

- Monitoring well coordinates provided by AEP.

700 350 0 700 Feet

Site Layout
FGD Landfill

AEP Amos Generating Plant
Winfield, West Virginia

Geosyntec consultants

Columbus, Ohio

2022/01/26

Figure

1

P:\Projects\AEP\Groundwater Statistical Evaluation - CHA8423\Groundwater Mapping\GIS Files\MXD\Amos\AEP-Amos_Landfill_Site_Layout_v2.mxd. ASoltero. 1/26/2022. CHA8423/04/08.

III. Monitoring Wells Installed or Decommissioned

No monitoring wells were installed or decommissioned in 2021.

IV. Groundwater Quality Data and Static Water Elevation Data, With Flow Rate and Direction Calculations and Discussion

Appendix 1 contains tables showing the groundwater quality data collected since initiating CCR background sampling through results received in 2021. Static water elevation data from each monitoring event in 2021 are also shown in **Appendix 1**, along with the groundwater velocity calculations, groundwater flow direction, and potentiometric maps developed after each sampling event.

V. Groundwater Quality Data Statistical Analysis

Statistical analysis of the November 2020 detection monitoring samples was completed in February 2021. An SSI in the Appendix III parameter of chloride at MW-4 and MW-1802 was documented in the February 2021 *Evaluation of Detection Monitoring Data at Amos Plant's Landfill* memorandum (**Appendix 2**). An alternative source demonstration was undertaken for this parameter at these monitoring wells and it was successful. That demonstration is discussed in the next section of this report.

Statistical analysis of the May 2021 detection monitoring samples was completed in August 2021. An SSI in the Appendix III parameter of chloride at MW-4, MW-1801, and MW-1802 was documented in the August 2021 *Evaluation of Detection Monitoring Data at Amos Plant's Landfill* memorandum (**Appendix 2**). An alternative source demonstration was undertaken for this parameter and was successful. That demonstration is discussed in the next section of this report.

The November 2021 detection monitoring samples received indicate potential SSI's at the following:

- MW-2: Fluoride
- MW-4: Chloride
- MW-1801: Chloride
- MW-1802: Calcium

The re-sampling event, in accordance with the statistical analysis plan, will be completed in the first quarter of 2022 and the final statistical analysis will follow. If any SSI's are confirmed, an ASD will be attempted. If successful, the AMLF will remain in detection monitoring. However, if unsuccessful, the AMLF will transition into assessment monitoring.

Additionally, the AMLF Statistical Analysis Plan (SAP) was updated in January 2021. The revised SAP that has been posted to the AEP publically available CCR website is included in **Appendix 2** and includes a record of revisions.

VI. Alternative Source Demonstrations

An alternative source demonstration (ASD) relative to the Appendix III SSI's (MW-4 and MW-1802: Chloride) resulting from the November 2020 detection monitoring event was completed in May 2021. The demonstration concluded that the groundwater quality and Appendix III indicator parameter SSI's identified in the statistical evaluation is attributable to an alternative source. The successful ASD for the Appendix III parameter is attached in **Appendix 3**.

An alternative source demonstration (ASD) relative to the Appendix III SSI's (MW-4, MW-1801, and MW-1802: Chloride) resulting from the May 2021 detection monitoring event was completed in November 2021. The demonstration concluded that the groundwater quality and Appendix III indicator parameter SSI's identified in the statistical evaluation is attributable to an alternative source. The successful ASD for the Appendix III parameter is attached in **Appendix 3**.

VII. Discussion About Transition Between Monitoring Requirements or Alternate Monitoring Frequency

As of this annual report date there has been no transition between detection monitoring and assessment monitoring. Detection monitoring will continue in 2022 pending the results of the aforementioned statistical analysis regarding the November 2021 groundwater sampling event. If the statistical analysis confirms any SSIs, an ASD will be performed if applicable. The sampling frequency of twice per year will be maintained for the Appendix III parameters upon a successful alternative source demonstration. If necessary, a transition to the assessment monitoring program will occur.

Regarding defining an alternate monitoring frequency, the groundwater velocity and monitoring well production are high enough at this facility that no modification to the semiannual assessment monitoring frequency is needed.

VIII. Other Information Required

As required by the CCR detection monitoring rules in 40 CFR 257.94, sampling all CCR wells for the Appendix III parameters was completed in 2021. All required information has been included in this annual groundwater monitoring report.

IX. Description of Any Problems Encountered in 2021 and Actions Taken

No significant problems were encountered. The low flow sampling effort went smoothly and the schedule was met to support the 2021 annual groundwater report preparation covering the groundwater monitoring activities in 2021.

X. A Projection of Key Activities for the Upcoming Year

Key activities for 2022 include:

- Complete the resampling event and statistical evaluation for the November 2021 detection monitoring potential SSI's.
- Perform an ASD, if necessary, for the November 2021 detection monitoring event if any SSI's are confirmed. If the ASD if necessary and is unsuccessful, the CCR unit will transition into assessment monitoring. If it is successful or no SSI's are confirmed, the CCR unit will continue detection monitoring on a semi-annual basis.
- Respond to any new data received in light of what the CCR rule requires.
- Preparation of the 2022 annual groundwater report.

APPENDIX 1

Figures and Tables showing the groundwater monitoring network, data collected, and the rate and direction of groundwater flow.

Table 1 - Groundwater Data Summary: MW-1
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/23/2016	Background	0.044	31.1	3.45	0.09 J	6.2	30.6	182
10/18/2016	Background	0.060	29.0	3.31	0.09	6.5	30.8	232
11/9/2016	Background	0.076	29.9	3.42	0.10	6.5	31.3	194
12/13/2016	Background	0.065	29.3	3.08	0.07 J	6.1	27.7	250
2/9/2017	Background	0.050	26.8	3.16	0.09	6.3	27.9	234
3/16/2017	Background	0.046	28.4	3.32	0.09	7.5	29.4	216
5/23/2017	Background	0.123	30.2	3.19	0.09	6.6	28.5	215
6/21/2017	Background	0.037	28.1	4.94	0.08	6.4	31.9	204
11/1/2017	Detection	0.047	28.7	3.08	0.10	6.4	30.2	224
5/2/2018	Detection	0.134	27.2	3.22	0.10	6.5	29.9	194
11/29/2018	Detection	0.143	26.4	3.07	0.11	6.7	27.8	191
12/18/2018	Detection	0.07 J	--	--	--	6.5	--	--
6/11/2019	Detection	0.04 J	28.1	2.86	0.11	7.0	29.9	184
11/6/2019	Detection	0.04 J	30.1	3.20	0.10	6.2	29.4	193

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL) followed by a 'U' flag.
J: Estimated value. Parameter was detected at concentration below the reporting limit
- -: Not analyzed
MW-1 was removed from the groundwater monitoring network in 2020.

Table 1 - Groundwater Data Summary: MW-1
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/23/2016	Background	0.04 J	0.27	207	0.024	0.02 J	0.3	0.097	0.0848	0.09 J	0.186	0.017	< 0.002 U	0.04 J	0.9	0.01 J
10/18/2016	Background	0.04 J	0.62	206	0.050	0.03	0.627	0.306	1.24	0.09	0.567	0.017	0.002 J	0.08 J	1.4	0.05 J
11/9/2016	Background	0.04 J	0.44	210	0.036	0.03	0.564	0.200	1.001	0.10	0.450	0.020	< 0.002 U	0.14	1.3	0.088
12/13/2016	Background	0.05 J	1.09	232	0.100	0.01 J	2.16	0.613	0.6701	0.07 J	1.45	0.027	< 0.002 U	0.11	1.7	0.02 J
2/9/2017	Background	0.03 J	0.37	184	0.026	0.02 J	0.401	0.174	0.836	0.09	0.340	0.015	< 0.002 U	0.21	1.6	0.02 J
3/16/2017	Background	0.06	0.67	200	0.057	0.06	0.993	0.393	0.73	0.09	1.03	0.012	0.003 J	0.10	1.1	0.02 J
5/23/2017	Background	0.08	0.40	211	0.032	0.05	0.555	0.292	3.243	0.09	0.697	0.026	< 0.002 U	0.11	1.1	0.01 J
6/21/2017	Background	0.07	0.43	200	0.031	0.06	0.547	0.289	1.379	0.08	0.753	0.013	< 0.002 U	0.10	1.2	0.02 J

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
<: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL) followed by a 'U' flag.
J: Estimated value. Parameter was detected at concentration below the reporting limit
- -: Not analyzed
pCi/L: picocuries per liter
MW-1 was removed from the groundwater monitoring network in 2020.

Table 1 - Groundwater Data Summary: MW-2
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/23/2016	Background	0.201	1.99	4.00	1.34	8.7	12.0	362
10/17/2016	Background	0.198	1.53	4.21	1.26	9.1	11.8	354
11/8/2016	Background	0.216	1.46	4.13	1.30	8.2	11.3	378
12/13/2016	Background	0.217	1.65	2.99	1.19	8.5	7.6	350
2/8/2017	Background	0.190	1.56	2.66	1.33	8.7	7.4	374
3/14/2017	Background	0.184	1.81	3.91	1.20	8.4	7.7	354
5/23/2017	Background	0.187	1.42	4.23	1.17	8.7	8.1	354
6/21/2017	Background	0.189	1.56	3.47	1.19	8.5	7.4	356
11/1/2017	Detection	0.202	1.88	2.34	1.46	8.8	8.6	394
1/8/2018	Detection	0.251	--	--	1.07	8.4	--	353
5/1/2018	Detection	0.241	3.50	3.90	1.45	8.5	9.4	344
6/19/2018	Detection	0.338	1.79	--	1.28	8.5	--	--
9/24/2018	Detection	0.215	--	--	--	--	--	--
11/28/2018	Detection	0.235	1.84	5.09	1.15	8.5	8.5	355
12/17/2018	Detection	--	--	--	--	8.6	--	--
1/24/2019	Detection	0.218	--	--	--	--	--	--
6/11/2019	Detection	0.215	1.80	3.26	1.63	8.7	9.4	379
7/22/2019	Detection	--	--	--	1.41	8.7	--	--
11/6/2019	Detection	0.203	1.73	3.44	1.66	8.6	9.5	379
2/11/2020	Detection	--	--	--	1.37	8.5	--	--
5/5/2020	Detection	0.174	2.76	5.08	1.37	8.6	7.8	368
7/7/2020	Detection	--	2.74	--	--	8.5	--	--
11/3/2020	Detection	0.179	1.69	4.31	1.45	8.8	9.0	378
5/4/2021	Detection	0.220	2.04	3.60	1.62	8.7	8.2	386
7/21/2021	Detection	--	--	--	1.41	8.4	--	--
11/2/2021	Detection	0.221	1.8	2.85	1.70	8.6	6.97	380

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-2
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/23/2016	Background	0.03 J1	6.57	51.8	0.129	0.14	1.3	1.02	0.904	1.34	1.24	0.009	< 0.002 U1	6.04	0.2 J1	0.03 J1
10/17/2016	Background	0.01 J1	3.94	25.7	0.040	0.005 J1	0.592	0.290	0.208	1.26	0.258	0.010	< 0.002 U1	3.70	0.09 J1	0.067
11/8/2016	Background	0.01 J1	3.54	23.7	0.02 J1	< 0.004 U1	0.295	0.107	0.8825	1.30	0.077	0.008	< 0.002 U1	3.84	0.05 J1	< 0.01 U1
12/13/2016	Background	0.01 J1	4.36	27.1	0.009 J1	< 0.004 U1	0.952	0.075	0.288	1.19	0.068	0.011	< 0.002 U1	6.11	0.05 J1	< 0.01 U1
2/8/2017	Background	< 0.01 U1	4.09	25.5	0.032	0.005 J1	0.571	0.287	1.109	1.33	0.279	0.009	< 0.002 U1	5.55	0.1	0.02 J1
3/14/2017	Background	0.02 J1	3.72	31.9	0.071	0.02	1.01	0.573	2.863	1.20	0.651	0.010	0.002 J1	3.46	0.2	0.02 J1
5/23/2017	Background	0.03 J1	3.59	27.2	0.043	0.009 J1	0.605	0.341	0.796	1.17	0.333	0.010	< 0.002 U1	3.70	0.1	< 0.01 U1
6/21/2017	Background	0.03 J1	3.80	27.7	0.028	0.01 J1	0.490	0.234	1.1188	1.19	0.229	0.004	0.003 J1	4.57	0.08 J1	0.03 J1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-4
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/23/2016	Background	0.173	0.914	14.1	1.49	9.9	10.7	368
10/18/2016	Background	0.165	0.807	13.9	1.33	9.8	11.7	386
11/7/2016	Background	0.203	0.842	14.6	1.44	9.5	11.1	376
12/13/2016	Background	0.180	0.836	15.7	1.34	9.0	8.0	372
2/8/2017	Background	0.170	0.807	14.9	1.40	9.3	8.0	412
3/14/2017	Background	0.173	0.855	14.5	1.46	8.8	7.4	381
5/23/2017	Background	0.190	0.750	15.3	1.38	9.2	7.9	390
6/20/2017	Background	0.161	0.814	15.1	1.36	9.1	7.6	392
11/1/2017	Detection	0.194	0.766	14.2	1.36	9.4	9.3	404
1/8/2018	Detection	0.145	--	--	1.37	3.3	--	--
5/1/2018	Detection	0.199	0.783	14.9	1.47	9.2	9.0	380
11/27/2018	Detection	0.188	0.807	14.1	1.42	8.8	8.8	383
6/12/2019	Detection	0.167	0.788	14.4	1.46	8.6	9.0	415
11/6/2019	Detection	0.173	0.761	14.9	1.49	9.2	9.4	382
5/5/2020	Detection	0.150	0.790	15.2	1.37	9.2	8.4	397
11/3/2020	Detection	0.157	0.783	17.1	1.53	9.4	9.7	397
1/5/2021	Detection	--	--	18.0	1.48	9.4	--	--
5/4/2021	Detection	0.168	0.695	19.7	1.50	9.2	8.8	410
7/21/2021	Detection	--	--	20.8	--	9.0	--	--
11/4/2021	Detection	0.167	0.7	21.8	1.40	9.1	7.86	390

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-4
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/23/2016	Background	0.01 J1	9.61	24.1	0.020	0.11	0.9	0.158	0.444	1.49	0.371	0.008	< 0.002 U1	8.82	0.09 J1	< 0.01 U1
10/18/2016	Background	< 0.01 U1	8.81	20.2	< 0.005 U1	0.006 J1	0.064	0.014	0.152	1.33	0.021	0.002	< 0.002 U1	8.01	< 0.03 U1	0.03 J1
11/7/2016	Background	< 0.01 U1	9.07	21.5	< 0.005 U1	< 0.004 U1	1.68	0.029	1.56	1.44	0.007 J1	0.003	< 0.002 U1	8.14	< 0.03 U1	< 0.01 U1
12/13/2016	Background	< 0.01 U1	9.44	22.4	< 0.005 U1	< 0.004 U1	0.169	0.011	0.16	1.34	0.009 J1	0.007	< 0.002 U1	8.94	< 0.03 U1	0.02 J1
2/8/2017	Background	< 0.01 U1	8.78	19.2	0.006 J1	< 0.004 U1	0.122	0.043	0.567	1.40	0.064	0.006	< 0.002 U1	8.15	< 0.03 U1	0.03 J1
3/14/2017	Background	< 0.01 U1	10.1	20.4	0.005 J1	0.005 J1	0.523	0.041	1.456	1.46	0.114	0.006	< 0.002 U1	9.70	< 0.03 U1	< 0.01 U1
5/23/2017	Background	0.02 J1	8.96	21.1	< 0.004 U1	< 0.005 U1	0.104	0.008 J1	0.872	1.38	0.01 J1	0.012	< 0.002 U1	8.21	< 0.03 U1	< 0.01 U1
6/20/2017	Background	0.02 J1	9.15	21.8	0.004 J1	0.005 J1	0.157	0.037	0.905	1.36	0.039	0.005	< 0.002 U1	7.86	0.05 J1	< 0.01 U1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-5
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/23/2016	Background	0.032	18.4	3.59	0.14	9.9	29.3	124
10/18/2016	Background	0.034	15.6	3.61	0.12	6.4	29.3	148
11/8/2016	Background	0.034	14.3	3.52	0.11	6.3	25.5	92
12/13/2016	Background	0.015	14.6	3.61	0.07	8.2	24.3	100
2/8/2017	Background	0.030	14.1	3.54	0.09	6.4	24.0	126
3/16/2017	Background	0.026	15.9	3.72	0.09	7.0	24.9	158
5/23/2017	Background	0.032	13.7	3.70	0.09	6.3	24.2	108
6/20/2017	Background	0.017	14.5	3.66	0.08	6.0	27.8	102
11/1/2017	Detection	0.046	15.6	4.09	0.09	6.1	28.4	136
1/8/2018	Detection	--	--	4.22	--	6.7	--	--
5/2/2018	Detection	0.123	14.3	4.39	0.09	6.2	26.3	122
6/20/2018	Detection	0.126	--	4.61	--	6.1	--	--
11/29/2018	Detection	0.122	14.1	4.86	0.13	7.4	24.5	113
12/17/2018	Detection	--	--	4.77	--	6.2	--	--
6/12/2019	Detection	0.02 J	16.2	4.60	0.11	6.1	26.4	132
7/22/2019	Detection	--	--	4.61	--	6.0	--	--
11/6/2019	Detection	0.03 J	18.3	5.21	0.10	6.0	28.3	131
2/11/2020	Detection	--	18.5	--	--	5.8	--	--

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL) followed by a 'U' flag.
J: Estimated value. Parameter was detected at concentration below the reporting limit
- -: Not analyzed
MW-5 was removed from the groundwater monitoring network in 2020.

Table 1 - Groundwater Data Summary: MW-5
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/23/2016	Background	0.04 J	0.47	93.3	0.02 J	0.07	0.3	0.188	1.025	0.14	0.263	0.006	< 0.002 U	0.17	0.1	0.01 J
10/18/2016	Background	0.04 J	0.34	82.5	0.02 J	0.02	0.546	0.198	0.353	0.12	0.250	0.005	< 0.002 U	0.16	0.2	0.03 J
11/8/2016	Background	0.04 J	0.49	80.1	0.050	0.05	0.945	0.446	1.847	0.11	0.698	< 0.0002 U	< 0.002 U	0.14	0.1	0.01 J
12/13/2016	Background	0.04 J	0.51	80.9	0.033	0.03	0.622	0.339	1.18	0.07	0.442	0.010	< 0.002 U	0.18	0.2	0.070
2/8/2017	Background	0.02 J	0.30	70.2	0.022	0.02 J	0.465	0.217	0.5868	0.09	0.257	0.005	< 0.002 U	0.14	0.1	0.02 J
3/16/2017	Background	0.09	2.32	121	0.183	0.21	4.43	2.92	1.096	0.09	3.77	0.002	0.008	0.40	0.9	0.04 J
5/23/2017	Background	0.06	0.21	77.7	0.01 J	0.02	0.248	0.072	1.312	0.09	0.093	0.011	< 0.002 U	0.14	0.09 J	< 0.01 U
6/20/2017	Background	0.02 J	0.25	80.6	0.01 J	0.03	0.291	0.092	1.141	0.08	0.097	< 0.0002 U	< 0.002 U	0.09 J	0.09 J	< 0.01 U

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
<: Non-detect value. Parameters which were not detected are shown as less than the method detection limit (MDL) followed by a 'U' flag.
J: Estimated value. Parameter was detected at concentration below the reporting limit
- -: Not analyzed
pCi/L: picocuries per liter
MW-5 was removed from groundwater monitoring network in 2020.

Table 1 - Groundwater Data Summary: MW-6
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/24/2016	Background	0.095	40.7	7.78	0.26	7.6	41.3	408
10/19/2016	Background	0.093	39.8	7.67	0.23	7.9	51.1	438
11/7/2016	Background	0.147	42.7	7.76	0.25	7.7	51.6	426
12/12/2016	Background	0.109	44.4	8.17	0.20	7.5	54.0	414
2/7/2017	Background	0.122	36.7	7.20	0.23	7.5	31.1	380
3/16/2017	Background	0.098	37.1	7.09	0.24	7.9	29.1	388
5/22/2017	Background	0.171	33.7	6.89	0.23	7.7	24.7	359
6/19/2017	Background	0.154	37.2	7.01	0.21	7.4	33.1	386
11/2/2017	Detection	0.159	41.3	7.77	0.22	7.5	51.8	440
5/1/2018	Detection	0.163	33.4	6.94	0.26	7.4	24.7	358
11/28/2018	Detection	0.156	35.8	6.85	0.24	7.6	22.9	333
6/12/2019	Detection	0.08 J1	32.8	6.85	0.28	7.7	21.9	363
11/6/2019	Detection	0.100	39.8	8.00	0.24	7.4	33.2	390
5/7/2020	Detection	0.092	37.0	6.61	0.21	7.6	14.9	349
11/4/2020	Detection	0.088	38.4	7.63	0.28	7.7	32.5	375
5/4/2021	Detection	0.101	34.7	7.33	0.27	7.5	19.0	354
11/4/2021	Detection	0.093	35.1	7.51	0.25	7.4	22.1	360

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-6
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/24/2016	Background	0.04 J1	6.03	245	0.036	0.03	0.5	0.183	2.318	0.26	0.461	0.015	< 0.002 U1	0.77	0.09 J1	0.138
10/19/2016	Background	0.02 J1	6.42	235	0.033	0.005 J1	0.413	0.148	0.697	0.23	0.381	0.015	< 0.002 U1	0.36	0.09 J1	0.02 J1
11/7/2016	Background	0.01 J1	6.64	250	0.009 J1	< 0.004 U1	0.160	0.023	2.7	0.25	0.053	0.011	< 0.002 U1	0.36	< 0.03 U1	< 0.01 U1
12/12/2016	Background	0.01 J1	7.36	246	0.006 J1	0.01 J1	0.104	0.020	1.878	0.20	0.039	0.023	< 0.002 U1	0.39	0.04 J1	0.03 J1
2/7/2017	Background	< 0.01 U1	5.47	199	0.02 J1	< 0.004 U1	0.207	0.073	1.151	0.23	0.160	0.013	< 0.002 U1	0.44	0.05 J1	0.01 J1
3/16/2017	Background	0.03 J1	4.44	224	< 0.005 U1	0.005 J1	0.498	0.028	1.844	0.24	0.048	0.009	0.003 J1	0.53	0.03 J1	< 0.01 U1
5/22/2017	Background	0.04 J1	4.58	218	0.02 J1	0.009 J1	0.175	0.063	2.4	0.23	0.117	0.019	< 0.002 U1	0.50	0.04 J1	0.01 J1
6/19/2017	Background	0.03 J1	4.86	233	0.01 J1	< 0.005 U1	0.274	0.051	1.617	0.21	0.136	0.011	< 0.002 U1	0.44	0.04 J1	< 0.01 U1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-7R
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/24/2016	Background	0.106	31.0	4.13	0.36	7.7	228	678
10/18/2016	Background	0.083	30.9	3.86	0.32	8.0	229	706
11/8/2016	Background	0.102	33.5	3.78	0.31	7.0	209	618
12/14/2016	Background	0.084	32.2	3.94	0.26	7.6	217	606
2/9/2017	Background	0.071	37.7	3.45	0.22	7.6	186	542
3/14/2017	Background	0.078	33.6	3.79	0.30	7.7	215	640
5/24/2017	Background	0.072	30.4	3.80	0.29	7.6	226	663
6/21/2017	Background	0.092	32.5	3.60	0.26	7.6	246	680
11/2/2017	Detection	0.109	31.7	3.59	0.28	7.6	211	636
5/1/2018	Detection	0.145	30.3	4.09	0.36	7.7	239	688
11/28/2018	Detection	0.118	44.4	3.65	0.26	7.4	201	627
6/12/2019	Detection	0.1 J1	36.8	3.75	0.35	7.4	226	700
11/6/2019	Detection	0.099	26.6	4.15	0.34	7.5	217	655
5/6/2020	Detection	0.079	41.7	3.68	0.28	7.5	208	629
11/3/2020	Detection	0.077	37.9	3.93	0.35	7.6	247	731
5/4/2021	Detection	0.096	33.0	3.86	0.37	7.6	220	708
11/4/2021	Detection	0.090	29.0	3.76	0.33	7.5	210	730

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-7R
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/24/2016	Background	0.11	8.37	60.8	0.155	0.04	1.0	0.368	1.043	0.36	1.52	0.016	0.004 J1	25.7	0.4	0.061
10/18/2016	Background	0.07	7.13	51.4	0.111	0.01 J1	0.760	0.279	0.959	0.32	0.961	0.012	0.002 J1	23.2	0.3	0.03 J1
11/8/2016	Background	0.08	5.81	42.2	0.026	0.02	2.82	0.084	1.895	0.31	0.261	0.013	< 0.002 U1	17.5	0.2	0.01 J1
12/14/2016	Background	0.09	7.33	44.3	0.028	0.01 J1	1.73	0.103	0.962	0.26	0.249	0.014	< 0.002 U1	24.6	0.2	0.02 J1
2/9/2017	Background	0.05	4.21	41.7	0.01 J1	0.01 J1	0.217	0.065	0.0996	0.22	0.156	0.012	< 0.002 U1	11.7	0.08 J1	0.02 J1
3/14/2017	Background	0.08	7.02	40.2	0.01 J1	0.01 J1	0.234	0.064	2.735	0.30	0.154	0.010	< 0.002 U1	24.6	0.1	0.02 J1
5/24/2017	Background	0.10	7.48	42.0	0.01 J1	0.01 J1	0.242	0.080	0.3888	0.29	0.171	0.016	< 0.002 U1	25.7	0.2	0.01 J1
6/21/2017	Background	0.08	6.69	39.1	0.006 J1	0.006 J1	0.154	0.043	1.497	0.26	0.064	0.010	< 0.002 U1	22.9	0.1	0.01 J1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-8
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/24/2016	Background	0.021	141	13.3	0.16	7.0	73.6	578
10/19/2016	Background	0.037	135	12.6	0.15	7.2	66.5	538
11/9/2016	Background	0.029	137	5.12	0.07	6.9	26.1	532
12/14/2016	Background	0.017	136	14.2	0.13	6.8	59.7	504
2/8/2017	Background	0.092	132	12.9	0.15	6.9	67.5	540
3/15/2017	Background	0.074	151	13.5	0.16	7.2	74.5	623
5/24/2017	Background	0.031	137	13.9	0.14	6.8	73.2	596
6/20/2017	Background	0.034	139	12.6	0.13	6.9	77.2	574
11/2/2017	Detection	0.031	125	12.1	0.15	6.8	63.1	526
5/1/2018	Detection	0.065	136	13.1	0.17	6.9	78.8	592
11/29/2018	Detection	0.05 J1	126	13.2	0.17	6.8	58.8	558
6/12/2019	Detection	0.03 J1	125	8.58	0.20	7.6	54.5	540
11/6/2019	Detection	< 0.02 U1	134	21.2	0.16	6.8	78.6	613
5/7/2020	Detection	< 0.02 U1	115	15.3	0.15	7.0	98.4	590
11/4/2020	Detection	< 0.02 U1	112	9.87	0.20	6.8	87.3	549
5/4/2021	Detection	0.02 J1	94.1	6.32	0.20	7.1	73.8	472
11/3/2021	Detection	< 0.09 U1	111	60.9	0.18	7.0	64.9	570

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-8
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/24/2016	Background	0.04 J1	0.41	221	0.021	0.04	0.4	0.270	0.776	0.16	0.393	0.013	< 0.002 U1	0.40	0.2	0.03 J1
10/19/2016	Background	0.03 J1	0.35	195	0.01 J1	0.04	0.158	0.140	0.746	0.15	0.279	0.006	< 0.002 U1	0.07 J1	0.2	0.02 J1
11/9/2016	Background	0.02 J1	0.25	209	0.008 J1	< 0.004 U1	0.164	0.082	1.113	0.07	0.028	0.004	< 0.002 U1	0.08 J1	0.2	0.02 J1
12/14/2016	Background	0.03 J1	0.32	212	0.008 J1	0.008 J1	0.097	0.083	1.582	0.13	0.062	0.013	< 0.002 U1	0.10	0.2	0.02 J1
2/8/2017	Background	0.03 J1	0.37	192	0.01 J1	0.007 J1	0.131	0.059	1.223	0.15	0.109	0.007	< 0.002 U1	0.47	0.1	0.136
3/15/2017	Background	0.05 J1	1.44	270	0.069	0.02 J1	2.39	1.02	3.405	0.16	1.43	0.011	0.003 J1	0.28	0.4	0.02 J1
5/24/2017	Background	0.07	0.47	201	0.02 J1	0.009 J1	0.354	0.201	1.257	0.14	0.260	0.016	< 0.002 U1	0.11	0.2	0.01 J1
6/20/2017	Background	0.03 J1	0.35	182	0.02 J1	0.007 J1	0.192	0.077	1.065	0.13	0.142	0.005	< 0.002 U1	0.07 J1	0.3	0.02 J1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-9
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/24/2016	Background	0.064	80.1	6.30	0.24	7.3	37.3	414
10/19/2016	Background	0.042	103	6.09	0.18	7.5	36.4	444
11/9/2016	Background	0.076	90.6	6.11	0.22	7.2	34.5	420
12/13/2016	Background	0.057	94.4	6.59	0.18	7.1	35.1	390
2/8/2017	Background	0.052	99.0	6.22	0.16	7.1	34.9	382
3/15/2017	Background	0.093	99.1	6.26	0.22	7.4	35.8	402
5/23/2017	Background	0.084	86.4	6.21	0.18	7.1	34.8	438
6/20/2017	Background	0.079	93.8	6.17	0.15	7.0	38.4	424
11/2/2017	Detection	0.075	79.1	5.97	0.20	7.1	33.1	404
5/1/2018	Detection	0.200	73.1	6.14	0.26	7.2	30.9	402
11/29/2018	Detection	0.09 J1	78.8	6.08	0.21	7.1	31.6	412
6/11/2019	Detection	0.04 J1	97.6	6.03	0.20	7.3	37.9	436
11/7/2019	Detection	0.04 J1	85.8	6.11	0.19	7.3	38.2	442
5/6/2020	Detection	0.03 J1	80.3	2.53	0.22	7.2	22.4	333
11/4/2020	Detection	0.056	61.5	2.73	0.30	7.1	28.4	362
5/4/2021	Detection	0.064	57.0	3.96	0.28	7.2	29.8	396
11/3/2021	Detection	0.054	72.7	4.47	0.23	7.2	28.2	410

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-9
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/24/2016	Background	0.07	1.45	443	0.025	0.03	0.8	0.464	1.831	0.24	0.565	0.017	< 0.002 U1	0.48	0.2	0.03 J1
10/19/2016	Background	0.04 J1	3.75	441	0.025	0.01 J1	0.625	0.372	3.035	0.18	0.478	0.010	< 0.002 U1	0.27	0.1	0.03 J1
11/9/2016	Background	0.05 J1	1.12	491	< 0.005 U1	0.02 J1	0.207	0.020	1.735	0.22	0.046	0.008	< 0.002 U1	0.41	0.1	0.03 J1
12/13/2016	Background	0.04 J1	1.23	497	< 0.005 U1	0.04	0.540	0.032	0.39	0.18	0.084	0.019	< 0.002 U1	0.56	0.2	< 0.01 U1
2/8/2017	Background	0.02 J1	1.78	388	< 0.005 U1	0.03	0.078	0.033	1.448	0.16	0.058	0.012	< 0.002 U1	0.27	0.1	0.02 J1
3/15/2017	Background	0.04 J1	4.40	603	0.074	0.04	1.43	1.51	2.365	0.22	1.81	0.009	0.002 J1	0.37	0.5	0.04 J1
5/23/2017	Background	0.07	0.96	425	< 0.004 U1	0.02 J1	0.117	0.021	2.173	0.18	0.063	0.021	< 0.002 U1	0.37	0.2	0.02 J1
6/20/2017	Background	0.05 J1	1.35	441	< 0.004 U1	0.03	0.094	0.066	1.992	0.15	0.038	0.014	< 0.002 U1	0.33	0.07 J1	0.02 J1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-10
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
8/24/2016	Background	0.087	1.68	5.54	0.89	9.0	19.1	512
10/19/2016	Background	0.081	1.09	4.49	0.72	9.6	18.0	504
11/9/2016	Background	0.118	2.31	5.46	0.92	8.9	16.9	546
12/13/2016	Background	0.076	1.24	4.15	0.38	8.7	14.1	482
2/8/2017	Background	0.113	1.37	4.24	0.57	9.1	14.4	504
3/14/2017	Background	0.125	1.18	4.60	0.50	8.7	13.3	499
5/24/2017	Background	0.081	1.16	4.19	0.43	8.9	14.3	467
6/20/2017	Background	0.078	1.04	4.11	0.44	8.6	14.9	492
11/2/2017	Detection	0.095	1.12	5.08	0.55	9.2	17.0	508
5/2/2018	Detection	0.157	1.74	5.67	0.69	9.2	16.7	522
11/29/2018	Detection	0.174	1.03	5.27	0.59	8.7	15.3	506
6/11/2019	Detection	0.08 J1	1.03	5.12	0.72	9.0	16.0	524
11/6/2019	Detection	0.076	1.43	5.62	0.52	8.7	16.8	490
5/6/2020	Detection	0.074	1.25	4.90	0.60	8.6	13.0	526
11/4/2020	Detection	0.071	1.18	5.77	0.73	8.9	16.5	523
5/4/2021	Detection	0.081	0.916	5.48	0.73	9.0	14.7	519
11/5/2021	Detection	0.257	0.9	16.4	4.88	8.8	17.8	490

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-10
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
8/24/2016	Background	0.36	24.5	105	0.058	0.26	0.5	0.367	0.769	0.89	1.11	0.010	0.003 J1	3.08	0.5	0.01 J1
10/19/2016	Background	0.26	19.4	62.4	0.02 J1	0.01 J1	0.373	0.102	0.0283	0.72	0.357	0.008	< 0.002 U1	2.58	0.4	0.082
11/9/2016	Background	0.38	21.5	144	0.264	0.05	3.96	1.66	0.168	0.92	3.41	0.007	0.004 J1	2.53	1.1	0.057
12/13/2016	Background	0.63	17.1	69.8	0.029	0.20	1.63	0.212	0.0992	0.38	0.895	0.019	< 0.002 U1	2.79	0.7	< 0.01 U1
2/8/2017	Background	0.38	22.8	92.9	0.124	0.04	2.28	0.850	0.14643	0.57	1.89	0.008	0.003 J1	2.76	1.9	0.071
3/14/2017	Background	0.32	21.2	69.0	0.039	0.01 J1	0.965	0.280	2.089	0.50	0.635	0.010	0.003 J1	3.38	2.3	0.02 J1
5/24/2017	Background	0.23	9.07	55.6	0.022	0.02 J1	0.500	0.151	1.06	0.43	0.469	0.011	< 0.002 U1	3.52	0.5	0.01 J1
6/20/2017	Background	0.30	17.7	61.7	0.025	0.01 J1	0.577	0.170	0.1376	0.44	0.448	0.004	< 0.002 U1	2.40	1.0	0.01 J1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-1801
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
12/18/2018	Background	0.273	1.76	10.4	5.01	8.9	8.1	498
1/24/2019	Background	0.247	1.59	10.8	5.19	8.9	7.2	490
2/21/2019	Background	0.219	1.38	11.0	5.26	9.0	6.8	550
3/13/2019	Background	0.251	1.55	11.1	5.32	9.0	6.6	509
4/23/2019	Background	0.246	1.50	11.3	5.35	9.1	8.2	507
6/11/2019	Background	0.260	1.45	10.4	5.03	9.4	6.5	506
7/23/2019	Background	0.246	1.41	10.8	5.47	8.8	7.2	502
11/5/2019	Background	0.255	1.46	11.7	5.36	8.7	7.0	501
5/7/2020	Detection	0.252	1.65	11.6	4.98	8.9	6.8	541
11/4/2020	Detection	0.215	1.52	12.5	5.34	9.0	7.5	535
1/5/2021	Detection	--	--	11.7	--	9.0	--	--
5/5/2021	Detection	0.250	1.65	13.1	5.24	8.8	9.1	542
7/21/2021	Detection	--	--	13.1	--	8.6	7.63	--
11/4/2021	Detection	0.245	1.5	13.5	5.13	8.7	6.31	530

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-1801
Amos - LF
Appendix IV Constituents

Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**pCi/L**	**mg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
12/18/2018	Background	0.30	13.5	39.3	0.113	0.07	3.30	0.876	0.816	5.01	0.966	< 0.009 U1	< 0.002 U1	58.4	0.3	< 0.1 U1
1/24/2019	Background	0.14	11.8	34.6	0.08 J1	< 0.01 U1	2.56	0.436	0.983	5.19	0.544	0.032	< 0.002 U1	64.5	0.2 J1	< 0.1 U1
2/21/2019	Background	0.14	10.4	28.7	0.02 J1	< 0.01 U1	0.585	0.162	0.175	5.26	0.272	< 0.009 U1	< 0.002 U1	66.3	0.1 J1	< 0.1 U1
3/13/2019	Background	0.1 J1	9.02	26.6	< 0.02 U1	< 0.01 U1	0.463	0.143	0.58	5.32	0.116	< 0.009 U1	< 0.002 U1	60.8	0.05 J1	< 0.1 U1
4/23/2019	Background	0.14	9.95	30.9	0.02 J1	< 0.01 U1	0.722	0.180	0.751	5.35	0.240	< 0.009 U1	< 0.002 U1	69.4	0.06 J1	< 0.1 U1
6/11/2019	Background	0.1 J1	7.80	25.4	< 0.02 U1	< 0.01 U1	0.336	0.120	0.208	5.03	0.09 J1	< 0.009 U1	< 0.002 U1	61.6	0.05 J1	< 0.1 U1
7/23/2019	Background	0.06 J1	7.95	26.2	< 0.02 U1	< 0.01 U1	0.229	0.092	0.569	5.47	0.07 J1	< 0.02 U1	< 0.002 U1	62.7	< 0.03 U1	< 0.1 U1
11/5/2019	Background	0.04 J1	7.74	25.9	< 0.02 U1	< 0.01 U1	0.483	0.073	0.29	5.36	0.07 J1	0.00829	< 0.002 U1	62.8	< 0.03 U1	< 0.1 U1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-1802
Amos - LF
Appendix III Constituents

Collection Date	Monitoring Program	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
		mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
12/17/2018	Background	0.267	0.821	8.33	4.79	9.1	20.6	482
1/25/2019	Background	0.249	0.924	8.87	4.82	9.1	20.3	451
2/21/2019	Background	0.233	0.840	8.94	4.87	9.3	20.1	532
3/13/2019	Background	0.234	0.860	9.21	4.75	9.3	18.8	477
4/24/2019	Background	0.242	0.910	9.13	5.04	9.2	21.2	478
6/12/2019	Background	0.253	0.876	9.01	4.54	9.0	19.1	476
7/23/2019	Background	0.236	0.865	8.80	5.16	9.0	20.7	476
11/5/2019	Background	0.254	0.892	9.90	4.84	8.9	19.7	460
5/7/2020	Detection	0.258	0.963	9.12	4.91	8.8	15.2	490
11/5/2020	Detection	0.223	0.974	10.7	4.89	9.2	19.0	494
1/5/2021	Detection	--	--	10.7	--	9.3	--	--
5/5/2021	Detection	0.258	0.800	11.5	4.88	9.1	17.9	508
7/22/2021	Detection	--	--	13.5	--	8.8	--	--
11/4/2021	Detection	0.082	1.0	5.47	0.73	9.0	13.2	510

Notes:
mg/L: milligrams per liter
SU: standard unit
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag.
In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit.
In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 1 - Groundwater Data Summary: MW-1802
Amos - LF
Appendix IV Constituents

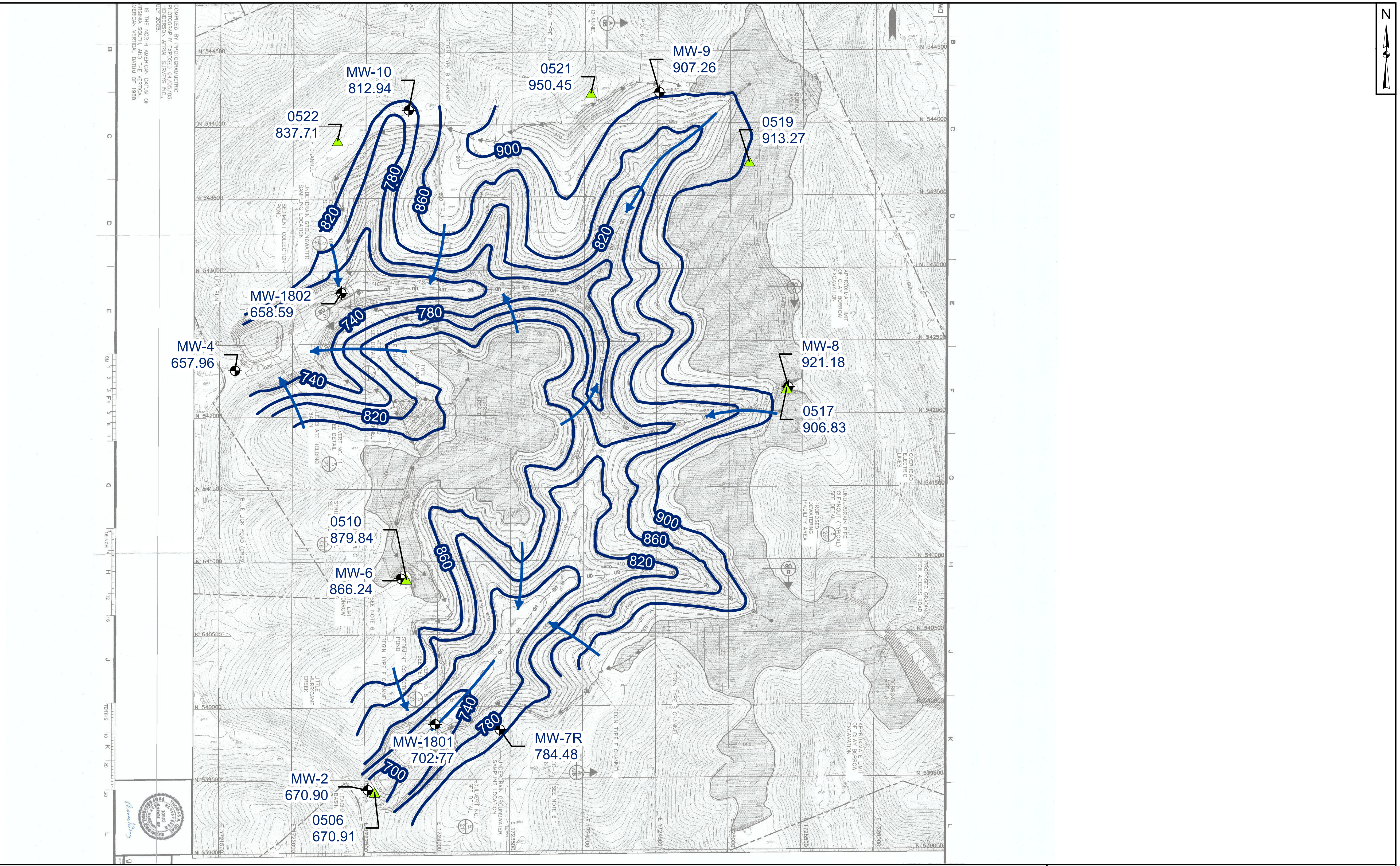
Collection Date	Monitoring Program	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Combined Radium	Fluoride	Lead	Lithium	Mercury	Molybdenum	Selenium	Thallium
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L
12/17/2018	Background	0.03 J1	6.08	15.5	< 0.02 U1	< 0.01 U1	0.296	0.081	0.445	4.79	0.1 J1	< 0.009 U1	< 0.002 U1	22.7	0.04 J1	< 0.1 U1
1/25/2019	Background	0.05 J1	6.00	17.1	0.03 J1	< 0.01 U1	0.497	0.219	0.522	4.82	0.214	0.03 J1	< 0.002 U1	23.1	0.05 J1	< 0.1 U1
2/21/2019	Background	0.03 J1	6.42	16.1	< 0.02 U1	< 0.01 U1	0.232	0.083	0.1739	4.87	0.08 J1	< 0.009 U1	< 0.002 U1	24.9	< 0.03 U1	< 0.1 U1
3/13/2019	Background	0.04 J1	6.28	15.2	< 0.02 U1	< 0.01 U1	0.269	0.074	0.0735	4.75	0.1 J1	< 0.009 U1	< 0.002 U1	23.9	< 0.03 U1	< 0.1 U1
4/24/2019	Background	0.08 J1	6.24	17.0	< 0.02 U1	< 0.01 U1	0.300	0.099	0.281	5.04	0.142	< 0.009 U1	< 0.002 U1	28.0	0.06 J1	< 0.1 U1
6/12/2019	Background	0.02 J1	5.66	13.6	< 0.02 U1	< 0.01 U1	0.08 J1	0.03 J1	0.418	4.54	0.04 J1	< 0.009 U1	< 0.002 U1	23.3	< 0.03 U1	< 0.1 U1
7/23/2019	Background	0.04 J1	6.43	15.5	< 0.02 U1	< 0.01 U1	0.281	0.071	0.0519	5.16	0.1 J1	< 0.02 U1	< 0.002 U1	26.9	0.05 J1	< 0.1 U1
11/5/2019	Background	0.04 J1	6.37	14.6	< 0.02 U1	< 0.01 U1	0.273	0.04 J1	0.2057	4.84	0.06 J1	0.00714	< 0.002 U1	26.8	0.05 J1	< 0.1 U1

Notes:
µg/L: micrograms per liter
mg/L: milligrams per liter
pCi/L: picocuries per liter
<: Non-detect value. Analytes which were not detected are shown as less than the method detection limit (MDL) followed by a 'U1' flag. In analytical data prior to 5/18/2021, U1 flags were reported as U in the analytical report.
- -: Not analyzed
J1: Concentration estimated. Analyte was detected between the method detection limit and the reporting limit. In analytical data prior to 5/18/2021, J1 flags were reported as J in the analytical report.

Table 2: Residence Time Calculation Summary
Amos Landfill

			2021-01[3]		2021-05		2021-07[3]		2021-11	
CCR Management Unit	Monitoring Well	Well Diameter (inches)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)	Groundwater Velocity (ft/year)	Groundwater Residence Time (days)
Landfill	MW-2 [2]	2.0	0.6	95	0.6	106	0.6	94	0.6	106
	MW-4 [2]	2.0	1.7	36	1.7	35	1.8	35	1.7	35
	MW-6 [1]	2.0	1.8	35	1.8	33	1.9	32	1.8	28
	MW-7R [1]	2.0	0.7	85	0.8	74	0.8	81	0.8	87
	MW-8 [1]	2.0	3.1	20	2.4	25	2.4	25	2.4	25
	MW-9 [1]	2.0	3.3	18	5.1	12	4.8	13	5.1	23
	MW-10 [1]	2.0	1.0	64	0.6	94	0.7	84	0.6	93
	MW-1801 [2]	2.0	2.3	27	2.3	26	2.3	26	2.3	27
	MW-1802 [2]	2.0	2.6	24	2.6	24	2.6	24	2.6	24

Notes:
[1] - Background Well
[2] - Downgradient Well
[3] - Two-of-two verification sampling



Legend

⊕ Groundwater Monitoring Well

△ Piezometer

→ Groundwater Flow Direction

— Groundwater Elevation Contour

Notes

- Monitoring well coordinates and water level data (collected on May 3, 2021) provided by AEP.
- Potentiometric surface contour interval is 40 feet.
- Topography and drainage system basemap from AEP Drawing No. 13-30500-05-A (topographic contour interval: 10 feet).
- Groundwater elevation units are feet above mean sea level.

700 350 0 700
Feet

Potentiometric Surface Map - Uppermost Aquifer
May 2021

AEP Amos Generating Plant
Winfield, West Virginia

Geosyntec consultants

Columbus, Ohio

2021/06/22

Figure

2

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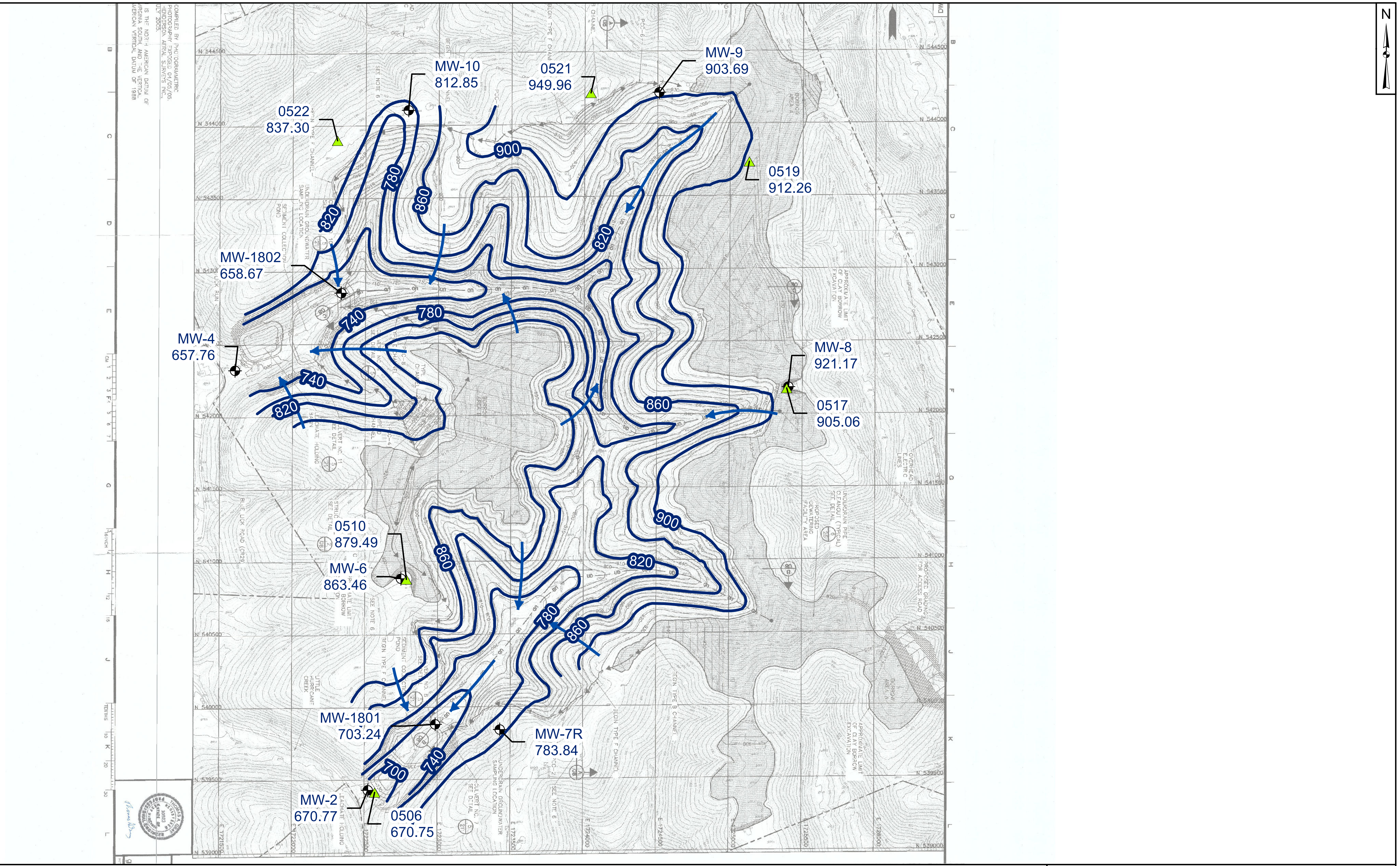

Legend

- ⯐ Groundwater Monitoring Well
- ▲ Piezometer
- ― Groundwater Elevation Contour
- → Groundwater Flow Direction

Notes

- Monitoring well coordinates and water level data (collected on November 1, 2021) provided by AEP.
- Potentiometric surface contour interval is 40 feet.
- Topography and drainage system basemap from AEP Drawing No. 13-30500-05-A (topographic contour interval: 10 feet).
- Groundwater elevation units are feet above mean sea level.

Potentiometric Surface Map - Uppermost Aquifer
November 2021

AEP Amos Generating Plant
Winfield, West Virginia

Geosyntec
consultants

Columbus, Ohio

2022/01/10

Figure
3

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APPENDIX 2

The statistical analysis reports completed in 2021 follow.

STATISTICAL ANALYSIS PLAN
APPALACHIAN POWER COMPANY
JOHN AMOS PLANT

Prepared in compliance with USEPA's Coal Combustion Residuals Rule, 40 CFR 257.93

Revision 0: January 2017

Revision 1: January 2021

STATISTICAL ANALYSIS PLAN

Submitted to

AMERICAN ELECTRIC POWER

1 Riverside Plaza
Columbus, Ohio 43215-2372

Submitted by

Geosyntec consultants

engineers | scientists | innovators

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Columbus, Ohio 43221

In collaboration with

Kristina Rayner
Groundwater Stats Consulting

and

Kirk M. Cameron, Ph.D.
MacStat Consulting, Ltd.

CHA8500

January 2021
Revision 1

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LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

Annual Report	Annual Groundwater Monitoring and Corrective Action Report
ANOVA	analysis of variance
CCR	coal combustion residuals
CFR	Code of Federal Regulations
GWPS	groundwater protection standard
LCL	lower confidence limit
MCL	maximum contaminant level
OLS	ordinary least-squares
ORP	oxidation-reduction potential
PQL	practical quantitation limit
QC	quality control
RCRA	Resource Conservation and Recovery Act
RL	reporting limit
ROS	regression on order statistics
SAP	Statistical Analysis Plan
SSI	statistically significant increase
SSL	statistically significant level
SWFPR	site-wide false positive rate
UCL	upper confidence limit
Unified Guidance	*Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (USEPA, 2009)
UPL	upper prediction limit
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit

SECTION 1

INTRODUCTION

In April 2015, the United States Environmental Protection Agency (USEPA) issued new regulations regarding the disposal of coal combustion residuals (CCR) in certain landfills and impoundments under 40 CFR 257, Subpart D, referred to as the “CCR rules.” Facilities regulated under the CCR rules are required to develop and sample a groundwater monitoring well network to evaluate if landfilled CCR materials are impacting downgradient groundwater quality. As part of the evaluation, the analytical data collected during the sampling events must undergo statistical analysis to identify statistically significant increases (SSIs) in analyte concentrations above background levels. A description of acceptable statistical programs is provided in USEPA’s document *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (USEPA, 2009), which is commonly referred to as the “Unified Guidance”.

The CCR rules are not prescriptive regarding what statistical analyses should be selected so that groundwater data are interpreted in a consistent manner and the results meet certification requirements. Geosyntec Consultants, Inc. (Geosyntec) prepared this Statistical Analysis Plan (SAP) on behalf of American Electric Power (AEP) to develop a logic process regarding the appropriate statistical analysis of groundwater data collected in compliance with the CCR rules. The SAP will provide a narrative description of the statistical approach and methods used in accordance with the CCR rule reporting requirements [40 CFR 257.93(f)(6)].

This SAP describes statistical procedures to be used to establish background conditions, implement detection monitoring, implement assessment monitoring (as needed), and implement corrective action monitoring (as needed).

Procedures for collecting, preserving, and shipping groundwater samples are not included in this SAP. It is assumed that samples are collected and handled in accordance with AEP’s draft *Groundwater Sampling and Analysis Plan* (AEP, 2016*)* and the requirements of 40 CFR 257.93 *et seq.*

SECTION 2

ANALYSES FOR REVIEWING AND PREPARING DATA

2.1 Physical Independence

Most statistical analyses require separate sampling events to be statistically independent. Statistical independence of groundwater samples is most likely to be realized when the samples are collected at time intervals that are sufficiently far apart that the samples are not from the same volume of groundwater. In such cases, the samples of groundwater are considered physically independent. To ensure physical independence, the minimum time between sampling events must be longer than the residence time of groundwater that would be collected in the monitoring well. The minimum time interval between sampling events (t_{min}) can be determined by calculating the groundwater velocity, as follows:

$$v = \frac{Ki}{n} \quad (1)$$

$$t_{min} = \frac{v}{D} \quad (2)$$

where:

$v =$ groundwater velocity
$K =$ hydraulic conductivity
$i =$ hydraulic gradient
$n =$ effective porosity
$t_{min} =$ minimum time interval between sampling events
$D =$ well bore volume (i.e., diameter of well and surrounding filter pack)

2.2 Testing for Normality

Many statistical analyses assume that the sample data are normally distributed. If such an analysis is used, the assumption of normality can be tested using the Shapiro-Wilk test (for sample sizes up to 50) or the Shapiro-Francía test (for sample sizes greater than 50). Normality can also be tested by less computationally intensive means such as graphing data on a probability plot. If the data appear not to be normally distributed (e.g., they are skewed in some fashion), then data may be transformed mathematically such that the transformed data do follow a normal distribution (e.g., lognormal distributions, Box-Cox transformations). Alternatively, a non-parametric test (i.e., a test that does not assume a particular distribution of the data) may be used. However, since non-parametric tests generally require large datasets to maintain an adequately low site-wide false positive rate (SWFPR), transforming the data is preferred.

2.3 Testing for Outliers

Outliers are extreme data points that may represent an anomaly or error. Data sets should be visually inspected for outliers using time series and/or box-and-whisker plots. While they are valuable as screening tools, visual methods are not foolproof. For example, if data are skewed according to a lognormal distribution, the boxplot screening may identify more outliers than actually exist. Typically, goodness-of-fit testing must be done on the non-outlier portion of the data to determine at what scale to test the possible outliers.

Potential outliers should be evaluated for potential sources of error (e.g., in transcription or calculation) or evidence that the data point is not representative (e.g., by examining quality control [QC] data, groundwater geochemistry, sampling procedures, etc.). Errors should be corrected prior to further statistical analysis, and data points that are flagged as non-representative should not be used in the statistical analysis. In addition, data points can be considered extreme outliers if they meet one of the following criteria:

$$x_i < \tilde{x}_{0.25} - 3 \times IQR \quad (3)$$

or

$$x_i > \tilde{x}_{0.75} + 3 \times IQR \quad (4)$$

where:

$x_i =$ individual data point
$\tilde{x}_{0.25} =$ first quartile
$\tilde{x}_{0.75} =$ third quartile
$IQR =$ the interquartile range $= \tilde{x}_{0.75} - \tilde{x}_{0.25}$

Extreme outliers may be excluded from the statistical analysis based on professional judgment. Goodness-of-fit testing may be needed to corroborate the classification of data points as extreme outliers. Flagged data and extreme outliers should still be maintained in the database and should be reevaluated as new data are collected.

2.4 Handling Duplicate or Replicate Data

Duplicate or replicate samples are often collected for QC purposes. Averaging the parent sample and duplicate sample results may give a more accurate representation of the constituent concentration at the time, but doing so would reduce the sample variability. Since many statistical tests assume that data are homoscedastic (i.e., the population variance does not change across samples), this technique is not recommended. Unless there is reason to suspect that either the parent sample or the duplicate sample is more representative of site groundwater, one of the samples should be selected at random and that value should be used in the subsequent statistical analysis. However, it should be reported when parent sample and duplicate sample results are different from a decision-making perspective, e.g., when the duplicate sample exceeds the groundwater protection standard (GWPS) but the parent sample does not.

2.5 Handling Non-Detect Data

If non-detect data are infrequent (less than 15%), half of the reporting limit (RL) can be used in place of these data without significantly altering the results of a statistical test. The RL may be either the laboratory practical quantification limit (PQL) or an established project limit which is less than the maximum contaminant level (MCL) or CCR rule-specified screening level for constituents that do not have an MCL. If non-detect data are more frequent, parametric methods that explicitly consider non-detects or non-parametric methods insensitive to the presence of non-detect data should be used. Where available, estimated results less than the RL (i.e., “J-flagged” data) should be used, and these data should be considered detections for the purposes of statistical analysis.

2.6 Deseasonalizing Data

Most statistical tests assume that data are independent and identically distributed. Datasets with seasonal or cyclic patterns violate this assumption. If seasonal trends are not corrected, the variance of the data will be overestimated, lessening the statistical power of the test. False positives may also be identified for elevated results that are caused by seasonal variation instead of a release.

At the same time, deseasonalizing data inherently assumes that the seasonal pattern will continue into the future, so care should be taken when correcting for seasonality. There should be a physical explanation for the seasonal pattern, and the seasonal pattern should be observed for at least three cycles before deseasonalizing data.

To evaluate whether a seasonal pattern exists, data should first be visually inspected on a time series plot. Observing parallel or antiparallel patterns for the same constituent across multiple wells or for multiple constituents within a single well provides greater assurance of a seasonal pattern and may be used to infer a physical explanation.

If a seasonal pattern is observed, the dataset should undergo a statistical test for seasonality before deseasonalizing the data. First, results are categorized into seasons based on the observed seasonal pattern and the frequency of sampling (e.g., summer or winter; dry season or wet season; first, second, third, or fourth quarter; etc.). Then, the Kruskal-Wallis test can be applied to the various seasonal datasets to test whether the different seasons are statistically significantly different from one another.

To deseasonalize the data, a seasonal mean should be calculated for each season based on the categorization for the dataset, and a grand mean (i.e., the overall mean of all data) should be calculated. Each result should then be corrected based on the difference between the grand mean and the seasonal mean for that result’s season. Similar to transforming apparently non-normal data, statistics should be calculated based on the deseasonalized data.

SECTION 3

DETECTION MONITORING

3.1 Establishing Background

By October 17, 2017, eight independent background samples should be collected from each monitoring well in the CCR unit groundwater monitoring system as part of the initial monitoring period [40 CFR 257.94(b)]. Background wells do not necessarily need to be hydraulically upgradient of the CCR unit, but they must not be affected by a release from the CCR unit [40 CFR 257.91(a)(1)]. The sampling frequency should be such that samples are physically independent, as described in **Section 2.1**. Samples should be analyzed for the Appendix III and Appendix IV constituents listed in **Table 1**.

Once analytical data are received, summary statistics (e.g., mean and variance) should be calculated for the background datasets. Initially, analysis should be done independently for each constituent at each well. As part of our protocol in such situations, time series plots and box plots will be prepared along with the summary statistics. The Kaplan-Meier method or robust regression on order statistics (ROS) can be used to compute summary statistics when there are large fractions (i.e., 15% to 50%) of non-detects; these methods are discussed below. If more than 50% of the data are non-detect, then summary statistics cannot be reliably calculated. Procedures for evaluating future data against these background datasets are described in **Section 3.2.1** (for detection monitoring) and **Section 4.1.1** (for assessment monitoring and corrective action monitoring).

Background data will be evaluated for statistically significant temporal trends using (a) ordinary least-squares (OLS) linear regression with a *t*-test ($\alpha = 0.01$) on the slope and/or (b) the non-parametric Theil-Sen slope estimator with Mann-Kendall trend test ($\alpha = 0.05$, or 0.01 for larger datasets). Non-detect data are replaced with half the RL for these analyses. The OLS linear regression or Theil-Sen slope estimator will be used to estimate the rate of change (increasing, no change, or decreasing) over time for each constituent at each well. The *t*-test or Mann-Kendall statistic will be used to determine whether a trend is statistically significant. OLS linear regression should only be used when at most 15% of the data are non-detect, when regression residuals are normally distributed, and when the variance from the regression line does not change over time. The Theil-Sen/Mann-Kendall analysis requires at least five observations for meaningful results; at least eight observations are recommended. Note that a statistically significant increasing trend in background data (or a statistically significant decreasing trend in pH) could indicate an existing release from the CCR unit or another source, and further investigation may be needed to determine the source of this trend.

Background data will also be evaluated for statistically significant seasonal patterns and, if present, will be deseasonalized using the procedure described in **Section 2.6**.

If the trend analysis does not indicate a statistically significant trend, the proposed background data will be tested for normality using one of the methods outlined in **Section 2.2**. When data follow a normal or transformed-normal distribution (e.g. lognormal or other Box-Cox transformation), parametric methods are applied. If fewer than 15% of the data are non-detect, non-detect data may be replaced with half the RL and the mean and variance can be calculated normally. If 15% to 50% of the data are non-detect, two methods – the Kaplan-Meier or Robust ROS method – can be used to determine the sample mean and variance. Kaplan-Meier should not be used if all non-detect data have the same RL or if the maximum detected value is less than the highest RL of the non-detect data. When data do not follow a normal or transformed-normal distribution, or when more than 50% of the data are non-detect, nonparametric methods may be used.

Once the sample mean and variance are calculated for each constituent at each well (assuming no significant trends over time), the data from background wells should be compared for each constituent. The purpose of this exercise is to test for significant spatial variation and to decide between interwell and intrawell approaches. First, the equality of variance across background wells should be tested visually using box-and-whisker plots and/or analytically using Levene's test ($\alpha = 0.01$). If the variances appear equal, then one-way, parametric analysis of variance (ANOVA) should be conducted across background wells ($\alpha = 0.05$). If there are no statistically significant differences among the background wells, then interwell comparisons may be appropriate to evaluate SSIs.

If ANOVA indicates statistically significant differences among background wells, then spatial variability can be concluded. As with temporal trends, the existence of spatial variability could indicate an existing release from the CCR unit or another source, and further investigation may be needed to determine the source of this variability. If the spatial variability is not caused by a release from the CCR unit, then intrawell comparisons would be appropriate to evaluate SSIs.

3.2 Evaluating Statistically Significant Increases (SSIs)

After the initial eight rounds of background sampling, groundwater sampling and analysis should be conducted on a semiannual basis. The statistical evaluation of each groundwater monitoring event must be completed within 90 days of receiving the analytical results from the laboratory [40 CFR 257.93(h)(2)].

The CCR rules only require analysis of the Appendix III constituents; however, analyzing additional constituents should be considered. Turbidity, dissolved oxygen, and oxidation-reduction potential (ORP), should be measured in the field in addition to pH. Other geochemical parameters, such as alkalinity, magnesium, potassium, sodium, iron, and manganese, should also be analyzed in the laboratory periodically (e.g., once every one to four years). Both the field and laboratory geochemical parameters can help identify the cause of any apparent change in groundwater quality. Additionally, analyzing for the Appendix IV constituents periodically should be considered to ensure the background dataset for these constituents is complete and current should assessment monitoring be needed. Statistical analyses should still be limited to the Appendix III constituents to help meet the dual goals of a SWFPR less than 10% per year and an adequate statistical power.

The CCR rules specifically list four methods acceptable for statistical analysis: ANOVA, tolerance intervals, prediction intervals, and control charts [40 CFR 257.93(f)]. Of these, the Unified Guidance recommends prediction limits combined with retesting for maintaining a low SWFPR while providing high statistical power (USEPA, 2009). Control charts are also acceptable as long as parametric methods can be used (i.e., the data or transformed data are normally distributed and the frequency of non-detects is at most 50%), as there is no nonparametric counterpart to the control chart. ANOVA is not recommended as the CCR rules mandate a minimum Type I error (α) of 0.05, at which it would be difficult to maintain an annual SWFPR less than 10%.

Prediction intervals and control charts can be used for both interwell and intrawell comparisons. For interwell comparisons, the pooled data from background monitoring wells should be used for the background dataset; for intrawell comparisons, the background dataset should be a subset of historical data at each monitoring well. (See **Section 3.4** below for procedures for updating background datasets.) Interwell comparisons are preferable, but they should only be used when there are no trends and no statistically significant population differences among background wells; otherwise, a significant test result may only indicate natural spatial variability instead of an SSI.

For prediction intervals, the upper prediction limit (UPL) is calculated according to the following formula:

$$\mathrm{UPL} = \bar{x} + ks \quad (5)$$

where:

$\bar{x} =$ mean concentration of the background dataset
$s =$ standard deviation of the background dataset
$k =$ multiplier based on the characteristics of the site and the statistical test

Values for k are chosen to maintain an SWFPR less than 10% and depend on the following: (1) number of wells, (2) number of constituents being evaluated, (3) size of the background dataset, (4) retesting regime, and (5) whether intrawell or interwell comparisons are being used. Values for k are listed in Tables 19-1, 19-2, 19-10, and 19-11 in Appendix D of the Unified Guidance (USEPA, 2009). If the k value that precisely matches site conditions does not appear in these tables, it can be estimated using the provided values by linear interpolation.

A one-of-two or one-of-three testing regime should be employed; i.e., if at least one sample in a series of two or three (respectively) does not exceed the UPL, then it can be concluded that an SSI has not occurred. In practice, if the initial result does not exceed the UPL, then no resampling is needed. If the initial result does exceed the UPL, then a resample should be collected prior to the next regularly scheduled sampling event at the monitoring well(s) and for the constituent(s) exceeding the UPL. Additional geochemical parameters, such as alkalinity, magnesium, potassium, sodium, iron, and manganese, should also be analyzed during resampling to help identify the source of the apparent increase. Enough time should elapse between the initial sample and each resample so that the samples are physically independent (**Section 2.1**). If both the initial result and the subsequent resample(s) exceed the UPL, then an SSI can be concluded.

Choosing between a one-of-two and a one-of-three testing regime should be done before conducting the statistical analysis, as the UPL calculation depends on the resampling regime selected. The choice should depend on site conditions and the size of the background dataset. First, if three physically independent samples cannot be collected in a six-month period, then a one-of-two testing regime should be used. A one-of-two testing regime may also be considered (a) if the background dataset has at least 16 data points or (b) if the CCR unit's monitoring well network has nine or fewer downgradient monitoring wells and a background dataset of at least 8 data points. Otherwise, a one-of-three testing regime should be employed to achieve an acceptably high statistical power and an acceptably low SWFPR.

If two physically independent samples cannot be collected in a six-month period, then a reduced monitoring frequency may be warranted. In this case, a demonstration must be made documenting the need for – and effectiveness of – a reduced monitoring frequency. This demonstration must be certified by a qualified professional engineer, and monitoring must still be done on at least an annual basis [40 CFR 257.94(d)].

The above procedure can be used wherever a mean and variance can be calculated for background data, including datasets that are transformed-normal and datasets where the mean and variance are calculated using the Kaplan-Meier or Robust ROS method. (Note that if data are transformed-normal, prediction intervals or control limits should first be calculated for the transformed data and then be transformed back into concentration terms.) Methods for determining prediction intervals where more than half of the background data are non-detect, where background data are neither normal nor transformed-normal, or where statistically significant trends or seasonal patterns exist are described below.

Different analyses can and should be used for different constituents and different monitoring wells within a CCR unit depending on the background data. For instance, if background wells have similar chloride data but different pH data, then interwell comparisons may be considered for chloride analysis and intrawell comparisons may be considered for pH analysis. If boron data are stable above the RL at MW-1 and mostly non-detect at MW-2, then it would be appropriate to use parametric prediction limits at MW-1 and non-parametric prediction limits at MW-2.

3.2.1 Most Background Data Are Non-Detect

If at least half of the data are non-detect, non-parametric prediction intervals with retesting should be used. In this method, the UPL is set either at the highest or at the second-highest concentration observed in the background dataset. A sufficiently large background dataset is paramount for this procedure to achieve an acceptably low SWFPR. To this end, the Kruskal-Wallis test should be performed on all background monitoring wells where at least 50% of the data for the constituent are non-detect to evaluate spatial variability. If the Kruskal-Wallis test indicates that there is no significant spatial variability among background wells, then the data from the background wells should be pooled to form a larger background dataset and thus to run an interwell test.

The choice between a one-of-two and a one-of-three testing regime should be based on the same criteria used for parametric testing, as described in **Section 3.2**. Choosing between using the highest or second-highest observed concentration as the UPL should depend in part on the size of the background dataset and the number of monitoring wells around the CCR unit. Assuming a one-of-three testing regime is used, the highest observed concentration should be used when the background dataset has fewer than 32 data points and the monitoring network has twelve or fewer wells. If there are at least thirteen wells, the highest observed concentration should be used when the background dataset has fewer than 48 data points. The second-highest observed concentration may be used for larger datasets.

If a one-of-two testing regime must be used due to aquifer conditions, then the highest observed concentration should be used (a) when the background dataset has fewer than 64 data points if there are fifteen or fewer wells or (b) when the background dataset has fewer than 88 data points if there are at least sixteen wells. The second-highest observed concentration may be used for larger data sets.

3.2.2 All Background Data Are Non-Detect

If all of the background data are non-detect, then the Double Quantification Rule should be used. According to this rule, if a sample and verification resample both exceed the PQL, then an SSI can be concluded. This can be thought of as setting the UPL at the PQL with a one-of-two testing regime. The possibility of false positives from this rule does not count against the calculated SWFPR because the false positive risk is small when all previous background data have been non-detect.

3.2.3 Background Data Are neither Normal nor Transformed-Normal

If background data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution, then non-parametric prediction intervals with retesting should be used. In this method, the UPL is set either at the highest or at the second-highest concentration observed in the background dataset. A sufficiently large background dataset is paramount for this procedure to achieve an acceptably low SWFPR. To this end, the Kruskal-Wallis test should be performed on all background monitoring wells where at least 50% of the data for the constituent are non-detect to evaluate spatial variability. If the Kruskal-Wallis test indicates that there is no significant spatial variability among background wells, then the data from the background wells should be pooled to form a larger background dataset and thus to run an interwell test.

The choice between a one-of-two and a one-of-three testing regime should be based on the same criteria used for parametric testing, as described in **Section 3.2**. The choice between using the highest or second-highest observed concentration as the UPL should be based on the same considerations described in **Section 3.2.1**.

3.2.4 A Significant Temporal Trend Exists

True temporal trends in background data (i.e., absent a release from the facility or another source) are considered unlikely. Thus, a truncated dataset that does not exhibit a statistically significant trend may be used. In these cases, UPLs would be calculated as described in the previous sections.

Alternatively, if there is a significant temporal trend in the background data that is not attributable to a release, prediction limits can be constructed around a trend line. A trend line can be constructed parametrically using OLS linear regression. OLS linear regression should only be used when at most 15% of the data are non-detect, when regression residuals are normally distributed, and when the variance from the regression line does not change over time. If OLS linear regression is used, the UPL can be calculated according to the following equation:

$$\mathrm{UPL} = \widehat{x_0} + t_{1-\alpha,n-2} * s_e * \sqrt{1 + \frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2}} \quad (6)$$

where:

$\widehat{x_0} =$ regression-line estimate of the mean concentration at time t_0
$t_{1-\alpha,n-2} =$ one-tailed *t*-value at a confidence of 1 – α and n – 2 degrees of freedom
$s_e =$ standard error of the regression line
$n =$ number of samples in the background dataset
$t_0 =$ date the groundwater sample being compared to the UPL was collected
$\bar{t} =$ mean of the sampling dates in the background dataset
$s_t =$ standard deviation of the sampling dates in the background dataset

The choice between a one-of-two and a one-of-three testing regime should be based on the same criteria used when there is no significant trend, as described in **Section 3.2**. The choice of α depends on the retesting regime and the number of wells within the monitoring network. If a one-of-two testing regime is employed, an α = 0.02 is recommended if there are eighteen or fewer wells and an α = 0.01 is recommended if there are at least nineteen wells within the monitoring network. If a one-of-three testing regime is employed, an α = 0.05 should be used.

3.2.5 A Significant Seasonal Pattern Exists

If a statistically significant seasonal pattern exists and if there is a physical explanation for the seasonality, the background data should be deseasonalized using the procedure described in **Section 2.6**. The background UPL should be calculated based on the deseasonalized data. Results should then be deseasonalized by subtracting the difference between the seasonal mean and the grand mean before comparing results to the UPL.

3.3 Responding to an Identified SSI

If the statistical evaluation indicates that an SSI is present, the data should be evaluated to assess whether the SSI is caused by a release from the CCR unit. If it can be shown that the SSI resulted from a release from another source, from an error in sampling or analysis, or from natural variability, then a demonstration of this must be made in writing and certified by a qualified professional engineer within 90 days of completing the statistical evaluation [40 CFR 257.94(e)(2)]. (The statistical evaluation itself must be completed within 90 days of receiving the analytical data from the laboratory.) If this demonstration is not made within 90 days of completing the statistical evaluation, then the site must begin assessment monitoring [40 CFR 257.94(e)(1)].

3.4 Updating Background

As recommended in the Unified Guidance, background values should be updated every four to eight measurements, assuming no confirmed SSI is identified (USEPA, 2009). (See **Section 4.4** for procedures for updating background if an SSI has been identified.) A Student's *t*-test or the nonparametric Mann-Whitney test (also known as the Wilcoxon rank-sum test) should be conducted to compare the set of new data points against the existing background dataset, as appropriate. An $\alpha = 0.05$ is recommended given the relatively small size of the datasets, particularly if background is updated every four measurements and particularly if the nonparametric Mann-Whitney test is used. However, an α as low as 0.01 may be used if the existing background dataset is sufficiently large (i.e., contains at least five data points) or if Student's *t*-test is used.

If the *t*-test or Mann-Whitney test does not indicate significant differences, the new data should be combined with the existing background data to calculate an updated UPL. Increasing the size of the background dataset will increase the power of subsequent statistical tests.

If the *t*-test or Mann-Whitney test indicates a statistically significant difference between the two populations, then the data should not be combined with the existing background data until further review determines the cause of the difference. If the differences appear to be caused by a release, then the previous background dataset should continue to be used. Absent evidence of a release, the new dataset should be considered more representative of present-day groundwater conditions and used for background. Note that the *t*-test or Mann-Whitney test is used to compare new data to the existing background dataset for the purposes of updating background. The tests are not used to determine whether an SSI is present or whether a release has occurred.

Periodically, spatial variability among background wells may be re-assessed to determine whether using an interwell or intrawell comparison is appropriate on a constituent-by-constituent basis, as outlined in **Section 3.1**.

SECTION 4

ASSESSMENT MONITORING

A CCR unit must begin assessment monitoring if an SSI is identified and is not attributed to some cause besides a release from the CCR unit. Assessment monitoring must begin within 90 days of identifying the SSI. During this 90-day period, the monitoring well network must be sampled for all Appendix IV constituents [40 CFR 257.95(b)]. Within 90 days of obtaining the results from this sampling event, all of the CCR unit wells must be sampled for all Appendix III constituents and those Appendix IV constituents that were detected during the initial assessment monitoring event [40 CFR 257.95(d)(1)].

After these initial assessment monitoring events, the CCR unit wells must be sampled for all Appendix III constituents and previously detected Appendix IV constituents on a semiannual basis [40 CFR 257.95(d)(1)]. Additionally, the CCR unit wells must be sampled for all Appendix IV constituents on an annual basis [40 CFR 257.95(b)].

As with detection monitoring, if physically independent samples cannot be collected on a semiannual basis, then a reduced monitoring frequency may be warranted. A demonstration must be made documenting the need for – and effectiveness of – a reduced monitoring frequency. This demonstration must be certified by a qualified professional engineer, and monitoring must still be done on at least an annual basis [40 CFR 257.95(c)].

GWPSs must be established for each detected Appendix IV constituent. The GWPS shall be the greater of the background concentration and the MCL established by the USEPA for that constituent. There is no established MCL for cobalt, lead, lithium, and molybdenum. For these constituents, the CCR rules specify a screening level that can be used in place of the MCL. For these constituents, the GWPS shall be the greater of the background concentration and the CCR rule-specified screening level [40 CFR 257.95(h)]. An upper tolerance limit (UTL) with 95% confidence and 95% coverage is often used as the representative background concentration.

A single site-wide GWPS would be recommended for each constituent based on pooled background data, even if natural spatial variability exists. If background data are not pooled, background concentrations and consequently GWPSs would vary from well to well. One difficulty with this approach is that concentrations at one monitoring well may exceed the location-specific GWPS and still be below levels considered as natural background at other locations within the site. The pooled background is often more interpretable and less cumbersome for developing a single background-based GWPS per constituent.

To determine whether a move to corrective action is warranted, a confidence interval constructed on recent data at each compliance monitoring well should be compared to the site-wide GWPS. When the lower confidence limit (LCL) of this interval exceeds the GWPS, an assessment of corrective measures may be justified.

When corrective action is not warranted, to return from assessment monitoring to detection monitoring, the CCR rules specify that all Appendix III and IV constituents must be at or below background levels for two consecutive sampling events [40 CFR 257.95(e)]. Procedures for comparing results to background are described in **Section 4.2**.

4.1 Comparing Data to the GWPS

As stated in **Section 4**, the GWPS is set at the MCL (or CCR rule-specified screening level for cobalt, lead, lithium, and molybdenum) or a value based on background data, whichever is greater. The UTL calculated from the background dataset is often used as the background value.

Tolerance intervals are similar to prediction intervals. However, whereas prediction intervals represent a range where a future result is expected to lie, tolerance intervals represent a range where a proportion of the population is expected to lie. Tolerance intervals have both an associated coverage (i.e., the proportion of the population covered by the tolerance interval) and an associated confidence. A coverage of 95% ($\gamma = 0.95$) and a confidence of 95% ($\alpha = 0.05$) are typically used.

The UTL is calculated similarly to the UPL:

$$\mathrm{UTL} = \bar{x} + \tau s \quad (7)$$

Similar to the UPL calculation, $\bar{x}$ is the mean concentration and s is the standard deviation of the background dataset. However, in this case the multiplier τ is different from that of the UPL calculation and is a function of the chosen coverage and confidence and the size of the background dataset. Values of τ are tabulated in Table 17-3 in Appendix D of the Unified Guidance (USEPA, 2009). As with prediction limits, if the τ value that precisely matches site conditions does not appear in these tables, it can be estimated using the provided values by linear interpolation.

Once a GWPS is established, new data must be evaluated to determine whether they are statistically significantly higher than the GWPS. The statistical analyses listed in 40 CFR 257.93(f) are appropriate for comparing new data to a background dataset but are not appropriate for comparing new data to a fixed standard. For these cases, the Unified Guidance recommends using confidence intervals around the mean or median (USEPA, 2009).

Evaluations should be done for each detected Appendix IV constituent at each well. Data from different wells should not be pooled. When selecting which data to include in the recent dataset, time series plots of concentration data at each well should be created and visually inspected. Only data that exhibit the same behavior as recent data should be included. For instance, if the last eight arsenic results cluster around 9 µg/L and the previous eight results cluster around 4 µg/L, then only the eight most recent results should be used in the statistical analysis. Similarly, if chromium concentrations steadily increased over the last ten samples and were stable previously, then the statistical analysis should only use the ten most recent results and (since they are steadily increasing) should involve constructing a confidence interval around a trend line.

At the same time, datasets should also be sufficiently large to maintain statistical power. As many data points that exhibit the same behavior as recent data as possible should be included, including data collected prior to assessment monitoring (e.g., during the initial eight monitoring events). Ideally, datasets should have at least eight data points; in no case should a dataset have fewer than four data points.

If at least 50% of the recent dataset is non-detect, then a parametric confidence interval should not be used, and the procedure in **Section 4.1.1** should be followed.

New data will be evaluated for statistically significant temporal trends using (1) OLS linear regression with a *t*-test ($\alpha = 0.01$) on the slope and/or (2) the non-parametric Theil-Sen slope estimator with Mann-Kendall trend test ($\alpha = 0.05$, or 0.01 for larger datasets). Non-detect data are replaced with half the RL for these analyses. The OLS linear regression or Theil-Sen slope estimator will be used to estimate the rate of change (increasing, no change, or decreasing) over time for each constituent at each well. The *t*-test or Mann-Kendall statistic will be used to determine whether a trend is statistically significant. OLS linear regression should only be used when at most 15% of the data are non-detect, when regression residuals are normally distributed, and when the variance from the regression line does not change over time. The Theil-Sen/Mann-Kendall analysis requires at least five observations for meaningful results; at least eight observations are recommended. If a significant temporal trend exists, then a confidence interval around the trend line should be constructed as outlined in **Section 4.1.3**.

If the trend analysis does not indicate a statistically significant trend, then the mean and variance should be calculated. If fewer than 15% of the data are non-detect, then the non-detect data can be replaced with half the RL and the mean and variance can be calculated normally. Tolerance intervals are sensitive to the choice of population distribution. Normality should be confirmed using the Shapiro-Wilk (or Shapiro-Francía) test and/or probability plots, as described in **Section 2.2**. If data appear not to be normally distributed, data should be transformed so that the transformed data are normally distributed.

Two methods – the Kaplan-Meier or Robust ROS method – can be used to determine the sample mean and variance when 15% to 50% of the data are non-detect. Kaplan-Meier should not be used if all non-detect data have the same RL or if the maximum detected value is less than the highest RL of the non-detect data.

When most of the data are detections, data are normally distributed, and there is no significant temporal trend, the LCL is calculated according to the following equation:

$$\text{LCL} = \bar{x} - t_{1-\alpha,n-1} * \frac{s}{\sqrt{n}} \quad (8)$$

where:

$\bar{x} =$ mean concentration of the recent dataset
$t_{1-\alpha,n-1} =$ one-tailed t-value at a confidence of $1 - \alpha$ and at $n - 1$ degrees of freedom
$s =$ standard deviation of the recent dataset
$n =$ number of samples in the recent dataset

The *t* value must be chosen in such a way to balance the competing goals of a low false-positive rate and a high statistical power. The Unified Guidance recommends that the statistical test have at least 80% power ($1 - \beta = 0.8$) when the underlying mean concentration is twice the MCL (USEPA, 2009). Values of the minimum α (from which *t* values can be determined) are tabulated for this criterion for various values of *n* in Table 22-2 in Appendix D of the Unified Guidance (USEPA, 2009). The selected α should be the maximum of the value in Table 22-2 and 0.01.

If data are transformed normal, the LCL should first be calculated for the transformed data and then be transformed back into concentration terms. Correction factors are available but are not expected to be required. Alternatively, a non-parametric LCL can be used, as described in **Section 4.1.2**.

If data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution, then a non-parametric LCL should be used, as described in **Section 4.1.2**.

If the LCL exceeds the GWPS, then a statistically significant exceedance can be concluded. If this occurs, the owner/operator is required to take several actions, including potentially moving the facility to corrective action, as described in **Section 4.3**.

4.1.1 Most Data Are Non-Detect

If background data are mostly non-detect, non-parametric tolerance intervals should be used. In these cases, the UTL is set at either the highest or second-highest concentration observed in the background dataset. If all background data are non-detect, then the UTL would default to the RL. The highest or second-highest observed concentration (or RL) effectively becomes the GWPS when this value is greater than the MCL (or CCR rule-specified screening level for cobalt, lead, lithium, and molybdenum). However, if most background data are non-detect, then detected concentrations are likely less than the MCL (or CCR rule-specified screening level), and the GWPS will be set at the MCL (or CCR rule-specified screening level).

If recent data are mostly non-detect, non-parametric confidence intervals can be constructed around the median by ranking the data from least to greatest and setting the LCL equal to one of the lower values of data. The confidence can be calculated based on the rank of the data point used and the sample size. Confidence values are tabulated in Table 21-11 in Appendix D of the Unified Guidance for sample sizes up to 20 (USEPA, 2009).

However, if most of the recent data are non-detect, then the data point selected for the LCL will also be non-detect. If the RL is less than the GWPS, then no statistically significant exceedance has occurred.

GWPSs should only be determined for detected Appendix IV constituents [40 CFR 257.95(d)(2)]. If all the data for a constituent are non-detect, no statistical evaluation need be performed.

4.1.2 Data Are neither Normal nor Transformed-Normal

If background data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution, then non-parametric tolerance intervals should be used. In these cases, the UTL is set at either the highest or second-highest concentration observed in the background dataset.

If recent data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution, non-parametric confidence intervals can be constructed around the median by ranking the data from least to greatest and setting the LCL equal to one of the lower values of data. The confidence can be calculated based on the rank of the data point used and the sample size. Confidence values are tabulated in Table 21-11 in Appendix D of the Unified Guidance for sample sizes up to 20 (USEPA, 2009).

4.1.3 A Significant Temporal Trend Exists

If recent data show a significant temporal trend, then an LCL below the trend line can be calculated according to the following equation:

$$\text{LCL} = \widehat{x_0} - \sqrt{2s_e^2 * F_{1-2\alpha,2,n-2} * \left(\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2}\right)} \quad (9)$$

where:

$\widehat{x_0} =$ regression-line estimate of the mean concentration at time t_0
$s_e =$ standard error of the regression line
$F_{1-2\alpha,2,n-2} =$ upper (1 - 2α)th percentage point from an *F*-distribution with 2 and n – 2 degrees of freedom
$n =$ number of samples in the recent dataset
$t_0 =$ date of the most recent groundwater sample
$\bar{t} =$ mean of the sampling dates in the recent dataset
$s_t =$ standard deviation of the sampling dates in the recent dataset

Note that the LCL is a function of time; to assess current compliance, the date of the most recent sample should be used for t_0. If and only if the LCL is greater than the GWPS at this time, then a statistically significant exceedance can be concluded. This equation can also be used to assess when the LCL will exceed the GWPS (assuming the current trend continues).

The same α that would have been selected if there were no significant trend (as described in **Section 4.1**) should be used here to determine the proper *F* value.

If the Theil-Sen method is used to determine the trend line, a computationally intensive technique known as bootstrapping can be used to determine the LCL. This procedure is described in Section 21.3.2 of the Unified Guidance (USEPA, 2009).

4.1.4 A Significant Seasonal Pattern Exists

If a statistically significant seasonal pattern exists in the background data and if there is a physical explanation for the seasonality, the background data should be deseasonalized using the procedure described in **Section 2.6**. The background-based UTL should be calculated based on the deseasonalized data, and the GWPS should be set at the MCL (or CCR rule-specified screening level) or the background-based UTL, whichever is greater.

Similarly, if a statistically significant seasonal pattern exists in compliance well data and if there is a physical explanation for the seasonality, the compliance well data should be deseasonalized using the procedure described in **Section 2.6**. The LCL to be compared to the GWPS should be calculated based on the deseasonalized compliance well data.

4.2 Comparing Data to Background

Assessment monitoring data must be compared to the GWPS (the higher of the MCL, CCR rule-specified level, or background level) to assess whether corrective action is warranted at the CCR unit (i.e. the LCL exceeds the GWPS). Additionally, assessment monitoring data may be compared to background data to assess whether the CCR unit can move from assessment monitoring back to detection monitoring.

To return from assessment monitoring to detection monitoring, the CCR rules specify that all Appendix III and IV constituents must be at or below background levels for two consecutive sampling events [40 CFR 257.95(e)]. However, the analysis of all Appendix III and IV constituents is not required for every monitoring event. Therefore, all Appendix III and IV constituents should be collected during two consecutive sampling events on a periodic basis (e.g., every two to four years) and/or when statistical evaluation of assessment monitoring data suggests groundwater concentrations are at or below background levels.

A UTL can be used to represent “a reasonable maximum on likely background concentrations” for Appendix III and IV constituents (USEPA, 2009). As described previously, UTLs can be determined parametrically or non-parametrically. For the parametric intervals, the UTL is calculated according to Equation 7. Non-parametric UTLs can be determined by setting the UTL to the highest or second-highest measured background value. If all background data are non-detect, then non-detect results in compliance wells can be considered statistically similar to background. If a temporal trend in background data exists and is not attributable to a release, background data can be truncated so that no significant temporal trend is evident.

To determine whether Appendix III and IV constituents are at or below background levels, a confidence interval constructed on recent data at each compliance monitoring well should be compared to the background UTL for each constituent. When the upper confidence limit (UCL) is below the background UTL, then it can be concluded that concentrations are at or below background. If UCLs are less than background UTLs for every constituent at every monitoring well for two consecutive events, then the CCR unit may return to detection monitoring.

When most of the data are detections, data are normally distributed, and there is no significant temporal trend, the UCL is calculated according to the following equation:

$$\mathrm{UCL} = \bar{x} + t_{1-\alpha,n-1} * \frac{s}{\sqrt{n}} \quad (10)$$

where:

$\bar{x} =$ mean concentration of the recent dataset
$t_{1-\alpha,n-1} =$ one-tailed t-value at a confidence of $1 - \alpha$ and at $n - 1$ degrees of freedom
$s =$ standard deviation of the recent dataset
$n =$ number of samples in the recent dataset

If recent data are mostly non-detect or are non-normal and cannot be transformed such that the transformed data follow a normal distribution, non-parametric confidence intervals can be constructed around the median by ranking the data from least to greatest and setting the UCL equal to one of the higher values of data. The confidence can be calculated based on the rank of the data point used and the sample size. Confidence values are tabulated in Table 21-11 in Appendix D of the Unified Guidance for sample sizes up to 20 (USEPA, 2009).

If recent data show a significant temporal trend, then a UCL above the trend line can be calculated according to the following equation:

$$\mathrm{UCL} = \widehat{x_0} + \sqrt{2s_e^2 * F_{1-2\alpha,2,n-2} * \left(\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2}\right)} \qquad (11)$$

where:

$\widehat{x_0} =$ regression-line estimate of the mean concentration at time t_0
$s_e =$ standard error of the regression line
$F_{1-2\alpha,2,n-2} =$ upper (1 - 2α)th percentage point from an F-distribution with 2 and $n - 2$ degrees of freedom
$n =$ number of samples in the recent dataset
$t_0 =$ date of the most recent groundwater sample
$\bar{t} =$ mean of the sampling dates in the recent dataset
$s_t =$ standard deviation of the sampling dates in the recent dataset

In all cases, the choice of τ and α (for parametric UTLs and UCLs, respectively), the choice of the highest or second-highest data point (for non-parametric UTLs and UCLs), etc. should be made based on sound statistical judgment and site characteristics (e.g., size of datasets, number of monitoring wells, etc.).

4.3 Required Responses to the Results of the Statistical Evaluation

If the statistical evaluation demonstrates that the concentrations of all Appendix III and Appendix IV constituents are at or below background levels for two consecutive sampling events, then the CCR unit may return to detection monitoring [40 CFR 257.95(e)]. A notification that the CCR unit is returning to detection monitoring must be placed in the facility's operating record.

If the statistical evaluation demonstrates that some Appendix III or Appendix IV constituents are at concentrations above background levels but there are no statistically significant exceedances of GWPSs, then the CCR unit must remain in assessment monitoring [40 CFR 257.95(f)].

If the statistical evaluation demonstrates that an Appendix IV constituent is present at a statistically significant level (SSL) above its GWPS (i.e., if the LCL exceeds the GWPS), then the owner/operator must:

- Include a notification in the facility's operating record that identifies the constituents exceeding GWPSs [40 CFR 257.95(g)];

- Characterize the nature and extent of the release, including installing monitoring wells needed to delineate the plume, installing a monitoring well at the downgradient property boundary, quantifying the nature and the amount of the release, and sampling all wells for Appendix III and detected Appendix IV constituents [40 CFR 257.95(g)(1)];

- If the plume has migrated off-site, notify property owners overlying the plume [40 CFR 257.95(g)(2)]; and

- Either begin an assessment of corrective measures or demonstrate that the SSL is not due to a release from the CCR unit within 90 days of completing the statistical evaluation [40 CFR 257.95(g)(3)]. This demonstration must be made in writing and certified by a qualified professional engineer. The CCR rules require the previous three actions to be taken even if it can be demonstrated that the SSL is not due to a release from the CCR unit.

Reporting requirements for assessment monitoring are summarized in **Section 6.2**.

4.4 Updating Background

Care should be taken when updating background during assessment monitoring since, by definition, an SSI over background has already occurred. Data that appear to be affected by a release from the CCR unit should not be included in updated background datasets. However, it may be possible to update some background datasets (e.g., constituents not associated with a release, wells upgradient of the CCR unit, etc.). Formal updating of Appendix III constituents may be considered when there are at least four new points.

Data should be reviewed every four to eight measurements to assess the possibility of updating background datasets. Professional judgment should first be applied; any data that appear to be affected by a release should be excluded from the background update, even if there is no statistically significant difference between the new data and the existing background data.

For data that appear not to be affected by a release, a Student's *t*-test or Mann-Whitney test should be conducted to compare the set of new data points against the existing background dataset. If the *t*-test or Mann-Whitney test corroborates that there are no significant differences, the new data should be combined with the existing background data to create an updated and expanded background dataset. Increasing the size of the background dataset will increase the power of subsequent statistical tests.

If the *t*-test or Mann-Whitney test indicates a statistically significant difference between the two datasets, then it should be considered that the difference results from a release and the existing background dataset should continue to be used. If and only if there is evidence to suggest that the difference is not related to a release from the CCR unit, then the newer set of measurements should be used for background so that resulting statistical limits are representative of present-day groundwater quality conditions.

Periodically, spatial variability among background wells may be re-assessed to determine whether using an interwell or intrawell comparison is appropriate on a constituent-by-constituent basis, as outlined in **Section 3.1**.

SECTION 5

CORRECTIVE ACTION MONITORING

A CCR unit must begin an assessment of corrective measures if an SSL is identified and is not attributed to some cause other than a release from the CCR unit. The assessment of corrective measures must begin within 90 days of identifying the SSL [40 CFR 257.95(g)(3)]. Based on the results of the corrective measures assessment, a remedy must be selected as soon as feasible [40 CFR 257.97(a)]. A schedule for implementing and completing the remedial activities must be included in the remedy selection [40 CFR 257.97(d)]. The owner/operator must begin remedial activities within 90 days of selecting a remedy, and a corrective action groundwater monitoring program must be implemented based on the schedule established as part of the remedy selection [40 CFR 257.98(a)].

The corrective action monitoring program must:

- Meet the requirements of an assessment monitoring program [40 CFR 257.98(a)(1)(i)];
- Document the effectiveness of the remedy [40 CFR 257.98(a)(1)(ii)]; and
- Demonstrate compliance with the GWPS [40 CFR 257.98(a)(1)(iii)].

The statistical methods used in corrective action monitoring are similar to those used in assessment monitoring. For each detected Appendix IV constituent, a GWPS is set at the MCL (or CCR rule-specified screening level for cobalt, lead, lithium, and molybdenum) or a value based on background data, whichever is greater. A confidence interval is constructed based on recent data at each compliance well, and the confidence interval is compared to the site-wide GWPS. However, in assessment monitoring, the presumption is that a release has not occurred, and a release is concluded when average concentrations are higher than the GWPS (i.e., when the *lower* confidence limit [LCL] is *greater* than the GWPS). If a CCR unit is in corrective action monitoring, then evidence of a release has already been identified. Therefore, in corrective action monitoring, the presumption is that a release has occurred, and the conclusion that the remedy has successfully decreased concentrations below the GWPS is made when average concentrations are less than the GWPS (i.e., when the *upper* confidence limit [UCL] is *less* than the GWPS). (Note that this presumption only applies to well-constituent pairs where an SSL has previously been identified. Well-constituent pairs in assessment monitoring where an SSL has not been identified effectively remain in assessment monitoring until the entire unit returns to detection monitoring.)

A remedy is considered complete when, among other things, confidence intervals constructed for Appendix IV constituents for wells identified with SSLs have not exceeded the GWPS for three consecutive years [40 CFR 257.98(c)(2)]. In this instance, a return to assessment monitoring would be warranted.

Upon completion of the remedy, the owner/operator must prepare a notification stating that the remedy is complete. The notification must be certified by a qualified professional engineer or approved by the State Director or USEPA and placed in the operating record [40 CFR 257.98(e)]. Otherwise, the owner/operator should follow the reporting requirements for assessment monitoring, as summarized in **Section 6.2**.

5.1 Comparing Data to the GWPS

As stated in **Section 5**, the GWPS is set at the MCL (or CCR rule-specified screening level for cobalt, lead, lithium, and molybdenum) or a value based on background data, whichever is greater. The UTL calculated from the background dataset is often used as the background value. The UTL is calculated as described in **Section 4.1**. Methods for updating background are described in **Section 4.4**.

For well-constituent pairs in corrective action monitoring, new data must be evaluated to determine whether they are statistically significantly lower than the GWPS. The statistical analyses listed in 40 CFR 257.93(f) are appropriate for comparing new data to a background dataset but are not appropriate for comparing new data to a fixed standard. For these cases, the Unified Guidance recommends using confidence intervals around the mean or median (USEPA, 2009).

When selecting which data to include in the recent dataset, time series plots of concentration data at each well should be created and visually inspected. Only data that exhibit the same behavior as recent data should be included. For instance, if the last eight arsenic results cluster around 9 µg/L and the previous eight results cluster around 4 µg/L, then only the eight most recent results should be used in the statistical analysis. Similarly, if chromium concentrations steadily increased over the last ten samples and were stable previously, then the statistical analysis should only use the ten most recent results and (since they are steadily increasing) should involve constructing a confidence interval around a trend line.

At the same time, datasets should also be sufficiently large to maintain statistical power. As many data points that exhibit the same behavior as recent data as possible should be included, including data collected prior to assessment monitoring (e.g., during the initial eight monitoring events). Ideally, datasets should have at least eight data points; in no case should a dataset have fewer than four data points.

If at least 50% of the recent dataset is non-detect, then a parametric confidence interval should not be used, and the procedure in **Section 5.1.1** should be followed.

New data will be evaluated for statistically significant temporal trends using (1) OLS linear regression with a *t*-test ($\alpha = 0.01$) on the slope and/or (2) the non-parametric Theil-Sen slope estimator with Mann-Kendall trend test ($\alpha = 0.05$, or 0.01 for larger datasets). Non-detect data are replaced with half the RL for these analyses. The OLS linear regression or Theil-Sen slope estimator will be used to estimate the rate of change (increasing, no change, or decreasing) over time for each constituent at each well. The *t*-test or Mann-Kendall statistic will be used to determine whether a trend is statistically significant. OLS linear regression should only be used when at most 15% of the data are non-detect, when regression residuals are normally distributed, and when the variance from the regression line does not change over time. The Theil-Sen/Mann-Kendall analysis requires at least five observations for meaningful results; at least eight observations are recommended. If a significant temporal trend exists, then a confidence interval around the trend line should be constructed as outlined in **Section 5.1.3**.

If the trend analysis does not indicate a statistically significant trend, then the mean and variance should be calculated. If fewer than 15% of the data are non-detect, then the non-detect data can be replaced with half the RL and the mean and variance can be calculated normally. Tolerance intervals are sensitive to the choice of population distribution. Normality should be confirmed using the Shapiro-Wilk (or Shapiro-Francía) test and/or probability plots, as described in **Section 2.2**. If data appear not to be normally distributed, data should be transformed so that the transformed data are normally distributed.

Two methods – the Kaplan-Meier or Robust ROS method – can be used to determine the sample mean and variance when 15% to 50% of the data are non-detect. Kaplan-Meier should not be used if all non-detect data have the same RL or if the maximum detected value is less than the highest RL of the non-detect data.

When most of the data are detections, data are normally distributed, and there is no significant temporal trend, the UCL is calculated according to the following equation:

$$\mathrm{UCL} = \bar{x} + t_{1-\alpha,n-1} * \frac{s}{\sqrt{n}} \quad (10)$$

where:

$\bar{x} =$ mean concentration of the recent dataset
$t_{1-\alpha,n-1} =$ one-tailed *t*-value at a confidence of 1 – α and at n – 1 degrees of freedom
$s =$ standard deviation of the recent dataset
$n =$ number of samples in the recent dataset

The *t* value must be chosen in such a way to balance the competing goals of a low false-positive rate and a high statistical power. The Unified Guidance recommends that the statistical test have at least 80% power ($1 - \beta = 0.8$) when the underlying mean concentration is twice the MCL (USEPA, 2009). Values of the minimum α (from which *t* values can be determined) are tabulated for this criterion for various values of *n* in Table 22-2 in Appendix D of the Unified Guidance (USEPA, 2009). The selected α should be the maximum of the value in Table 22-2 and 0.01.

If data are transformed normal, the UCL should first be calculated for the transformed data and then be transformed back into concentration terms. Correction factors are available but are not expected to be required. Alternatively, a non-parametric LCL can be used, as described in **Section 5.1.2**.

If data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution, then a non-parametric LCL should be used, as described in **Section 5.1.2**.

5.1.1 Most Data Are Non-Detect

If recent data are mostly non-detect, non-parametric confidence intervals can be constructed around the median by ranking the data from least to greatest and setting the UCL equal to one of the higher values of data. The confidence can be calculated based on the rank of the data point used and the sample size. Confidence values are tabulated in Table 21-11 in Appendix D of the Unified Guidance for sample sizes up to 20 (USEPA, 2009).

5.1.2 Data Are neither Normal nor Transformed-Normal

If recent data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution, non-parametric confidence intervals can be constructed around the median by ranking the data from least to greatest and setting the UCL equal to one of the higher values of data. The confidence can be calculated based on the rank of the data point used and the sample size. Confidence values are tabulated in Table 21-11 in Appendix D of the Unified Guidance for sample sizes up to 20 (USEPA, 2009).

5.1.3 A Significant Temporal Trend Exists

If recent data show a significant temporal trend, then a UCL above the trend line can be calculated according to the following equation:

$$\mathrm{UCL} = \widehat{x_0} + \sqrt{2s_e^2 * F_{1-2\alpha,2,n-2} * \left(\frac{1}{n} + \frac{(t_0 - \bar{t})^2}{(n-1)s_t^2}\right)} \quad (11)$$

where:

$\widehat{x_0} =$ regression-line estimate of the mean concentration at time t_0
$s_e =$ standard error of the regression line
$F_{1-2\alpha,2,n-2} =$ upper (1 - 2α)th percentage point from an *F*-distribution with 2 and *n* – 2 degrees of freedom
$n =$ number of samples in the recent dataset
$t_0 =$ date of the most recent groundwater sample
$\bar{t} =$ mean of the sampling dates in the recent dataset
$s_t =$ standard deviation of the sampling dates in the recent dataset

Note that the UCL is a function of time; to assess current compliance, the date of the most recent sample should be used for t_0. If and only if the UCL is less than the GWPS at this time, then it can be concluded that the remedy has successfully decreased concentrations below the GWPS. This equation can also be used to assess when the UCL will decrease below the GWPS (assuming the current trend continues).

The same α that would have been selected if there were no significant trend (as described in **Section 5.1**) should be used here to determine the proper *F* value.

If the Theil-Sen method is used to determine the trend line, a computationally intensive technique known as bootstrapping can be used to determine the UCL. This procedure is described in Section 21.3.2 of the Unified Guidance (USEPA, 2009).

5.1.4 A Significant Seasonal Pattern Exists

If a statistically significant seasonal pattern exists in compliance well data and if there is a physical explanation for the seasonality, the compliance well data should be deseasonalized using the procedure described in **Section 2.6**. The UCL to be compared to the GWPS should be calculated based on the deseasonalized compliance well data.

SECTION 6

REPORTING REQUIREMENTS

The CCR rule specifies reporting requirements throughout the monitoring process. Throughout the process, the required documentation is required to be posted both to the site's operating record and to a public internet set for review. As required by 40 CFR 257.93(f)(6), the chosen statistical methods described within this SAP are certified by a qualified professional engineer as appropriate for groundwater evaluation (**Section 7**).

By January 31 of each year, all existing facilities must submit an Annual Groundwater Monitoring and Corrective Action Report (Annual Report) [40 CFR 257.90(e)]. The Annual Report should be prepared and posted to both the site operating record and the public internet site. A notification should be sent to the State Director (and/or appropriate tribal authority) once the Annual Report is available.

The Annual Report should document site status, summarize key actions taken, describe problems encountered and their resolutions, and project key actions to be taken for the following year. The Annual Report should also include:

- A figure showing the CCR unit and the monitoring well network [40 CFR 257.90(e)(1)];
- An identification of monitoring wells installed or abandoned during the preceding year and the rationale for doing so [40 CFR 257.90(e)(2)];
- A summary of groundwater samples collected, which wells were sampled, what dates the samples were collected, and whether the samples were collected for detection monitoring, assessment monitoring, or corrective action monitoring [40 CFR 257.90(e)(3)]; and
- A discussion of any transition between monitoring programs (i.e., detection monitoring vs. assessment monitoring vs. corrective action monitoring) [40 CFR 257.90(e)(4)].

If appropriate, the Annual Report should detail a demonstration for an alternative groundwater sampling frequency. If no SSIs are identified during each sampling event, an updated Annual Report should be submitted yearly. If SSIs are identified, additional reporting requirements are summarized below.

6.1 Detection Monitoring

If SSIs are identified, the facility should demonstrate within 90 days of the detection, where possible, that SSIs over background are not due to a release from the facility, along with a certification by a qualified professional engineer that the information is accurate. If the SSIs over background are attributed to a release from the facility, the facility should prepare and place on the operating record within 90 days a notification stating that an assessment monitoring program has been established [40 CFR 257.94(e)(3)].

6.2 Assessment Monitoring

If an assessment monitoring program is in place, the Annual Report must also include [40 CFR 257.95(d)(3)]:

- Analytical results for Appendix III and detected Appendix IV constituents,
- Background concentrations for all Appendix III and Appendix IV constituents, and
- GWPSs established for detected Appendix IV constituents.

The semiannual analytical results for Appendix III and detected Appendix IV constituents must also be posted to the facility's operating record within 90 days of receipt [40 CFR 257.95(d)(1)].

If a constituent is detected at an SSL above its GWPS, a notification must be reported to the site's operating record. Additionally, the facility must notify any person who owns or resides on land that directly overlies any part of an off-site contaminant plume and record the notifications in the facility's operating record. Within 90 days, the facility must either initiate an assessment of corrective measures or demonstrate that the SSL is not due to a release from the CCR unit. The demonstration must be supported by a report certified by a qualified professional engineer [40 CFR 257.95(g)].

If statistics are performed by mid-October 2017 for the first compliance event, one or more resamples would normally be collected and re-analyzed within 90 days. By the end of January 2018, the initial exceedance will be either confirmed or determined to be a false positive. If it is confirmed, then assessment monitoring must be initiated within 90 days, which would fall at the same time as the next regular semi-annual event. In that case, the semi-annual event (March/April timeframe) would be for both assessment and detection monitoring (if assessment monitoring was initiated).

If the facility determines it may return to detection monitoring, the facility should issue a notification to the operating record and public site within 30 days.

6.3 Corrective Action Monitoring

If a corrective action monitoring program is in place, it must meet the requirements of an assessment monitoring program [40 CFR 257.98(a)(1)(i)]. Thus, the reporting requirements for corrective action monitoring will be similar to assessment monitoring, as described in **Section 6.2**. Upon completion of the remedy, the facility must prepare a notification that the remedy has been completed. The notification must be certified by a qualified professional engineer or approved by the State Director or USEPA and placed in the operating record [40 CFR 257.98(e)]

SECTION 7

CERTIFICATION BY QUALIFIED PROFESSIONAL ENGINEER

By means of this certification, I certify that I am a qualified professional engineer as defined in 40 CFR 257.53, that I have reviewed this SAP, and that the statistical methods described therein are appropriate and meet the requirements of 40 CFR 257.93.

DAVID ANTHONY MILLER

Printed Name of Qualified Professional Engineer

DAVID ANTHONY MILLER
22663

David Anthony Miller

Signature

22663	WEST VIRGINIA	01.22.2021
Registration No.	Registration State	Date

SECTION 8

REFERENCES

American Electric Power. 2016. Draft Groundwater Sampling and Analysis Plan. April 1, 2016.

Criteria for Classification of Solid Waste Disposal Facilities and Practices. 40 CFR §257. (2016).

Electric Power Research Institute. 2015. Groundwater Monitoring Guidance for the Coal Combustion Residuals Rule. Palo Alto, CA. 3002006287.

Environmental Protection Agency. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance. EPA 530/R-09-007.

Table 1

Monitored Constituents Under the CCR Rules

Appendix III to 40 CFR 257 – Constituents for Detection Monitoring

Boron
Calcium
Chloride
Fluoride
pH
Sulfate
Total Dissolved Solids (TDS)

Appendix IV to 40 CFR 257 – Constituents for Assessment Monitoring

Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Fluoride
Lead
Lithium
Mercury
Molybdenum
Selenium
Thallium
Radium 226 and 228 combined

APPENDIX A

RECORD OF REVISIONS

Revision 1 (January 2021)

- Added statistical procedures used to implement corrective action monitoring (Section 5) and reporting requirements for corrective action monitoring (Section 6.3).

- Added references to CCR rule-specified screening levels for constituents that do not have an MCL (i.e., cobalt, lead, lithium, and molybdenum) in Sections 2.5, 4, 4.1, and 5.1.

- Removed text from Section 4 regarding a potential assessment monitoring approach for constituents that do not have an MCL because the CCR rule was revised to specify screening levels for these constituents.

- Added statistical procedures used to evaluate whether a seasonal pattern exists and to deseasonalize data (Sections 2.6, 3.2.5, 4.1.4, and 5.1.4).

- Specified that the Mann-Kendall trend test can use an α of 0.01 for sufficiently large datasets (Sections 3.1, 4.1, and 5.1).

- Removed references to control limits in Section 3.2 because prediction limits are generally being used to conduct detection monitoring.

- Removed references to using trend tests to evaluate SSIs at the end of Section 3.2 because prediction limits are generally being used to conduct detection monitoring.

- Clarified that non-parametric limits should be used when data are non-normal and cannot be transformed such that the transformed data do follow a normal distribution (Sections 3.2.3, 4.1.2, and 5.1.2).

- Referred to the Wilcoxon rank-sum/Mann-Whitney test as the Mann-Whitney test to match the statistical output from Sanitas (Sections 3.4 and 4.4).

- Clarified that a background dataset that contains at least five data points is sufficiently large to use an α as low as 0.01 to conduct the Mann-Whitney test as part of a background update, in line with recommendations in the Unified Guidance (Section 3.4).

- Clarified the procedure to be used if the Mann-Whitney test indicates a statistically significant difference between existing background data and newer data (Sections 3.4 and 4.4).

- Clarified that spatial variability among background wells may be assessed periodically as part of a background update because spatial variability is evaluated when background values are initially established (Sections 3.4 and 4.4).

- Clarified that UPLs are used to establish background values for Appendix III constituents and UTLs are used to establish background values for Appendix IV constituents (Section 4.2).

- Added statistical procedures to determine when Appendix III and Appendix IV concentrations are at or below background to evaluate whether units in assessment monitoring may return to detection monitoring (Section 4.2).

- Generally replaced “parameter” with “constituent”.

- Added references to the Unified Guidance and the CCR rule throughout the document.

- Made minor grammatical and stylistic changes throughout the document.

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Memorandum

Date:	February 5, 2021
To:	David Miller (AEP)
Copies to:	Benjamin Kepchar (AEP)
From:	Allison Kreinberg (Geosyntec)
Subject:	Evaluation of Detection Monitoring Data at Amos Plant's Landfill (LF)

In accordance with the United States Environmental Protection Agency's (USEPA's) regulations regarding the disposal of coal combustion residuals (CCR) in landfills and surface impoundments (40 CFR 257 Subpart D, "CCR rule"), the second semi-annual detection monitoring event at the Landfill (LF), an existing CCR unit at the Amos Power Plant located in Winfield, West Virginia was completed on November 3-4, 2020. Based on the results, verification sampling was completed on January 5, 2021.

Background values for the LF were previously calculated in January 2018. After a minimum of four detection monitoring events, the results of those events were compared to the existing background and the dataset was updated as appropriate. Revised upper prediction limits (UPLs) were calculated for each Appendix III parameter to represent background values. Lower prediction limits (LPLs) were also calculated for pH. Details on the calculation of these revised background values are described in Geosyntec's *Statistical Analysis Summary* report, dated February 27, 2020. In May 2020, monitoring wells MW-1 and MW-5 were removed from the groundwater monitoring network and replaced with wells MW-1801 and MW-1802. Following completion of eight background monitoring events, UPLs and LPLs were calculated for MW-1801 and MW-1802, as described in Geosyntec's *Statistical Analysis Summary – Background Update Calculations* report, dated July 8, 2020.

To achieve an acceptably high statistical power while maintaining a site-wide false-positive rate (SWFPR) of 10% per year or less, prediction limits were calculated based on a one-of-two retesting procedure. With this procedure, a statistically significant increase (SSI) is concluded only if both samples in a series of two exceed the UPL (or are below the LPL for pH). In practice, if the initial result did not exceed the UPL, a second sample was not collected or analyzed.

Detection monitoring results and the relevant background values are compared in Table 1 and noted exceedances are described in the list below.

- Chloride concentrations exceeded the intrawell UPL of 15.9 mg/L in both the initial (17.1 mg/L) and second (18.0 mg/L) samples collected at MW-4 and the intrawell UPL of 10.2 mg/L in both the initial (10.7 mg/L) and second (10.7 mg/L) samples collected at MW-1802. Thus, SSIs over background are concluded for chloride at MW-4 and MW-1802.

In response to the exceedance noted above, the Amos LF CCR unit will either transition to assessment monitoring or an alternative source demonstration (ASD) for chloride will be conducted in accordance with 40 CFR 257.94(e)(2). If the ASD is successful, the Amos LF will remain in detection monitoring.

The statistical analysis was conducted within 90 days of completion of sampling and analysis in accordance with 40 CFR 257.93(h)(2). A certification of these statistics by a qualified professional engineer is provided in Attachment A.

Table 1: Detection Monitoring Data Evalation
Amos Plant - Landfill

Analyte	Unit	Description	MW-2	MW-4		MW-1801		MW-1802	
			11/3/2020	11/3/2020	1/5/2021	11/4/2020	1/5/2021	11/4/2020	1/5/2021
Boron	mg/L	Intrawell Background Value (UPL)	0.247	0.214		0.306		0.276	
		Analytical Result	0.179	0.157	--	0.215	--	0.223	--
Calcium	mg/L	Intrawell Background Value (UPL)	2.10	0.912		1.83		0.978	
		Analytical Result	1.69	0.783	--	1.52	--	0.974	--
Chloride	mg/L	Intrawell Background Value (UPL)	5.40	15.9		12.1		10.2	
		Analytical Result	4.31	**17.1**	**18.0**	**12.5**	11.7	**10.7**	**10.7**
Fluoride	mg/L	Intrawell Background Value (UPL)	1.61	1.52		5.67		5.36	
		Analytical Result	1.45	**1.53**	1.48	5.34	--	4.89	--
pH	SU	Intrawell Background Value (UPL)	9.0	10.1		9.5		9.5	
		Intrawell Background Value (LPL)	8.2	8.3		8.5		8.7	
		Analytical Result	8.8	9.4	--	9.0	--	9.2	--
Sulfate	mg/L	Intrawell Background Value (UPL)	12.9	12.2		8.88		22.4	
		Analytical Result	9.0	9.7	--	7.5	--	19.0	--
Total Dissolved Solids	mg/L	Intrawell Background Value (UPL)	394	422		550		522	
		Analytical Result	378	397	--	535	--	494	--

Notes:
UPL: Upper prediction limit
LPL: Lower prediction limit
Bold values exceed the background value.
Background values are shaded gray.

ATTACHMENT A

Certification by a Qualified Professional Engineer

CERTIFICATION BY QUALIFIED PROFESSIONAL ENGINEER

I certify that the selected statistical method, described above and in the July 8, 2020 *Statistical Analysis Summary* report, is appropriate for evaluating the groundwater monitoring data for the Amos LF CCR management area and that the requirements of 40 CFR 257.93(f) have been met.

DAVID ANTHONY MILLER
Printed Name of Licensed Professional Engineer

DAVID ANTHONY MILLER
22663

David Anthony Miller
Signature

22663
License Number

WEST VIRGINIA
Licensing State

02.09.21
Date

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Memorandum

Date:	August 30, 2021
To:	David Miller (AEP)
Copies to:	Benjamin Kepchar (AEP)
From:	Allison Kreinberg (Geosyntec)
Subject:	Evaluation of Detection Monitoring Data at Amos Plant's Landfill (LF)

In accordance with the United States Environmental Protection Agency's (USEPA's) regulations regarding the disposal of coal combustion residuals (CCR) in landfills and surface impoundments (40 CFR 257 Subpart D, "CCR rule"), the first semi-annual detection monitoring event of 2021 at the Landfill (LF), an existing CCR unit at the Amos Power Plant located in Winfield, West Virginia was completed on May 4-5, 2021. Based on the results, verification sampling was completed on July 21, 2021.

Background values for the LF were previously calculated in January 2018. After a minimum of four detection monitoring events, the results of those events were compared to the existing background and the dataset was updated as appropriate. Revised upper prediction limits (UPLs) were calculated for each Appendix III parameter to represent background values. Lower prediction limits (LPLs) were also calculated for pH. Details on the calculation of these revised background values are described in Geosyntec's *Statistical Analysis Summary* report, dated February 27, 2020. In May 2020, monitoring wells MW-1 and MW-5 were removed from the groundwater monitoring network and replaced with wells MW-1801 and MW-1802. Following completion of eight background monitoring events, UPLs and LPLs were calculated for MW-1801 and MW-1802, as described in Geosyntec's *Statistical Analysis Summary – Background Update Calculations* report, dated July 8, 2020.

To achieve an acceptably high statistical power while maintaining a site-wide false-positive rate (SWFPR) of 10% per year or less, prediction limits were calculated based on a one-of-two retesting procedure. With this procedure, a statistically significant increase (SSI) is concluded only if both samples in a series of two exceed the UPL (or are below the LPL for pH). In practice, if the initial result did not exceed the UPL, a second sample was not collected or analyzed.

Detection monitoring results and the relevant background values are compared in Table 1 and noted exceedances are described in the list below.

- Chloride concentrations exceeded the intrawell UPL of 15.9 mg/L in both the initial (19.7 mg/L) and second (20.8 mg/L) samples collected at MW-4. Chloride concentrations exceeded the intrawell UPL of 12.1 mg/L in both the initial (13.1 mg/L) and second (13.1 mg/L) samples collected at MW-1801. Chloride concentartions also exceeded the intrawell UPL of 10.2 mg/L in both the initial (11.5 mg/L) and second (13.5 mg/L) samples collected at MW-1802. Thus, SSIs over background are concluded for chloride at MW-4, MW-1801, and MW-1802.

In response to the exceedance noted above, the Amos LF CCR unit will either transition to assessment monitoring or an alternative source demonstration (ASD) for chloride will be conducted in accordance with 40 CFR 257.94(e)(2). If the ASD is successful, the Amos LF will remain in detection monitoring.

The statistical analysis was conducted within 90 days of completion of sampling and analysis in accordance with 40 CFR 257.93(h)(2). A certification of these statistics by a qualified professional engineer is provided in Attachment A.

Table 1: Detection Monitoring Data Evalation
Amos - Landfill

Analyte	Unit	Description	MW-2		MW-4		MW-1801		MW-1802	
			5/4/2021	7/21/2021	5/4/2021	7/21/2021	5/5/2021	7/21/2021	5/5/2021	7/21/2021
Boron	mg/L	Intrawell Background Value (UPL)	0.247		0.214		0.306		0.276	
		Analytical Result	0.220	--	0.168	--	0.250	--	0.258	--
Calcium	mg/L	Intrawell Background Value (UPL)	2.10		0.912		1.83		0.978	
		Analytical Result	2.04	--	0.695	--	1.65	--	0.800	-
Chloride	mg/L	Intrawell Background Value (UPL)	5.40		15.9		12.1		10.2	
		Analytical Result	3.60	--	**19.7**	**20.8**	**13.1**	**13.1**	**11.5**	**13.5**
Fluoride	mg/L	Intrawell Background Value (UPL)	1.61		1.52		5.67		5.36	
		Analytical Result	**1.62**	1.41	1.50	--	5.24	--	4.88	--
pH	SU	Intrawell Background Value (UPL)	9.0		10.1		9.5		9.5	
		Intrawell Background Value (LPL)	8.2		8.3		8.5		8.7	
		Analytical Result	8.7	--	9.2	--	8.8	--	9.1	--
Sulfate	mg/L	Intrawell Background Value (UPL)	12.9		12.2		8.88		22.4	
		Analytical Result	8.2	--	8.8	--	**9.1**	7.63	17.9	--
Total Dissolved Solids	mg/L	Intrawell Background Value (UPL)	394		422		550		522	
		Analytical Result	386	--	410	--	542	--	508	--

Notes:
UPL: Upper prediction limit
LPL: Lower prediction limit
Bold values exceed the background value.
Background values are shaded gray.

ATTACHMENT A

Certification by a Qualified Professional Engineer

CERTIFICATION BY QUALIFIED PROFESSIONAL ENGINEER

I certify that the selected statistical method, described above and in the July 8, 2020 *Statistical Analysis Summary* report, is appropriate for evaluating the groundwater monitoring data for the Amos LF CCR management area and that the requirements of 40 CFR 257.93(f) have been met.

DAVID ANTHONY MILLER
Printed Name of Licensed Professional Engineer

David Anthony Miller
Signature

DAVID ANTHONY MILLER
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22663
License Number

WEST VIRGINIA
Licensing State

08.30.21
Date

APPENDIX 3

The alternative source demonstrations follow.

ALTERNATIVE SOURCE DEMONSTRATION REPORT FEDERAL CCR RULE

Amos Plant Landfill
Winfield, West Virginia

Submitted to

AMERICAN ELECTRIC POWER

1 Riverside Plaza
Columbus, Ohio 43215-2372

Submitted by

Geosyntec consultants

engineers | scientists | innovators

941 Chatham Lane, Suite 103
Columbus, Ohio 43221

May 6, 2021

CHA8495

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LIST OF ACRONYMS AND ABBREVIATIONS

AEP	American Electric Power
ASD	Alternative Source Demonstration
bgs	Below ground surface
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
LPL	Lower Prediction Limit
mg/L	Milligram per liter
QC	Quality Control
SSI	Statistically Significant Increase
UPL	Upper Prediction Limit
USEPA	United States Environmental Protection Agency

SECTION 1

INTRODUCTION AND SUMMARY

1.1 Introduction

This Alternative Source Demonstration (ASD) report has been prepared to address statistically significant increases (SSIs) for chloride at the Amos Plant Landfill (Landfill) following the second semi-annual detection monitoring event of 2020.

Following completion of four detection monitoring events, the previously calculated upper prediction limits (UPLs) for the Landfill were recalculated for each Appendix III parameter to represent background values (Geosyntec, 2020a). A lower prediction limit (LPL) was also recalculated for pH. The revised prediction limits were calculated based on a one-of-two retesting procedure in accordance with the Unified Guidance (USEPA, 2009) and the statistical analysis plan developed for the site (Geosyntec, 2020b). With this procedure, a statistically significant increase (SSI) is concluded only if both samples in a series of two exceed the UPL, or in the case of pH are below the LPL.

The second semi-annual detection monitoring event of 2020 was performed in November 2020 (initial sampling event) and January 2021 (verification sampling event) and the results were compared to the recalculated prediction limits. During this detection monitoring event, SSIs were identified for chloride at MW-4 and MW-1802 based on intrawell comparisons. A summary of the detection monitoring analytical results for all constituents listed in 40 CFR Part 257 Appendix III and the calculated prediction limits to which they were compared is provided in **Table 1**.

1.2 CCR Rule Requirements

In accordance with the United States Environmental Protection Agency (USEPA) regulations regarding the disposal of coal combustion residuals (CCR) in landfills and surface impoundments, Rule 40 CFR 257.94(e)(2) states the following:

> *The owner or operator may demonstrate that a source other than the CCR unit caused the statistically significant increase over background levels for a constituent or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. The owner or operator must complete the written demonstration within 90 days of detecting a statistically significant increase over background levels to include obtaining a certification from a qualified professional engineer verifying the accuracy of the information in the report.*

The second semi-annual detection monitoring event for 2020 was completed in November 2020 and January 2021 to identify SSIs over background limits. Pursuant to 40 CFR 257.94(e)(2), Geosyntec Consultants, Inc. (Geosyntec) has prepared this ASD report to identify whether the SSIs identified for chloride at MW-4 and MW-1802 are from a source other than the Landfill.

1.3 Demonstration of Alternative Sources

An evaluation was completed to assess possible alternative sources to which identified SSIs could be attributed. Alternative sources were identified amongst five types:

- ASD Type I: Sampling Causes;
- ASD Type II: Laboratory Causes;
- ASD Type III: Statistical Evaluation Causes;
- ASD Type IV: Natural Variation; and
- ASD Type V: Alternative Sources.

A demonstration was conducted to assess whether the increases in chloride at MW-4 and MW-1802 was based on a Type IV cause (Natural Variation) and not by a release from the Amos Plant Landfill.

SECTION 2

ALTERNATIVE SOURCE DEMONSTRATION

A brief description of the site geology, ASD evaluation methodology, and the proposed alternative source are described below.

2.1 Site Geology Summary

The Amos Plant Landfill site consists of a northern valley and southern valley, both of which are surrounded on all sides by bedrock ridges (**Figure 1**). A topographic high point separates the two valleys (Arcadis, 2020), as shown in **Figure 2**. MW-4 and MW-1802 are downgradient wells for the northern valley, which is hydrologically separate from the southern valley. Bedrock in the vicinity of MW-4 and MW-1802 consists of a combination of gray siltstone, silty shale, and red claystone. These lithologies make up part of the Pennsylvanian Monongahela and Conemaugh Formations. These formations contain a system of stress relief fractures that are associated with a decline in stress and erosion (Arcadis, 2020). Groundwater flows through these formations primarily in these stress fractures. Bedrock groundwater flow generally follows surface topography, flowing downslope of ridges towards valley floors (Arcadis, 2020).

2.2 Examination of Alternative Sources

Initial review of site geochemistry, site historical data, and laboratory QA/QC did not identify an ASD due to Type I (sampling) or Type II (laboratory) causes. A review of the statistical methods used did not identify any Type III (statistical) causes. Therefore, natural variation, which is a Type IV cause, was examined as a potential cause of the SSI. Based on the natural variation investigation (described below), Type V (anthropogenic) causes were not identified.

Chloride concentrations at upgradient well MW-8 have historically been above those observed MW-1802 and comparable to those observed at MW-4 (**Figure 3**). The chloride concentrations at MW-8 indicate that the native geologic material (which is predominantly claystone and sandstone) contains chloride that may be released into solution at concentrations higher than or comparable to those typically found at MW-4 and MW-1802. Thus, the changes in chloride concentration at MW-4 and MW-1802 are attributable to natural variation.

Boron is a conservative parameter due to its lack of attenuation by chemical processes in groundwater flow, and it functions as a 'tracer' for potential CCR unit releases due to its high relative concentration in CCR. The concentration of boron in a sample of Landfill leachate collected from the northern valley in August 2020 was 120 milligrams per liter (mg/L) and the concentrations of boron at MW-4 and MW-1802 are consistently less than 0.3 mg/L. Thus, if Landfill leachate, which has a boron concentration several orders of magnitude higher than the wells of interest, were impacting groundwater quality at downgradient monitoring wells, an increase in boron concentrations at MW-4 and MW-1802 would be expected. The current boron concentrations at both wells of interest do not display an increasing or decreasing trend (**Figure 4**), which suggests that groundwater quality changes cannot be attributed to a release from the Landfill.

Additionally, Piper diagrams, which visually represent the relative concentrations of major cations and anions in the groundwater and leachate analytical samples, were created to further illustrate the differences in groundwater geochemistry at MW-4 and MW-1802 compared to the geochemistry of the leachate (**Figure 5**). The data shown in these Piper diagrams captures the background and detection monitoring period (2017 through 2020). The groundwater geochemistry at both MW-4 and MW-1802 has remained unchanged throughout the monitoring period, as illustrated by the tight clustering of sample results for each well. Additionally, each well is distinct from the geochemistry of the leachate, illustrating a lack of influence from leachate on the groundwater composition. These observations support the conclusion that the SSIs identified for chloride cannot be attributed to a release from the Landfill and instead is caused by natural variation.

2.3 Sampling Requirements

The conclusions of this ASD support the determination that the identified SSI is from natural variation and not due to a release from the Landfill. Therefore, the unit will remain in the detection monitoring program. Groundwater at the unit will be sampled for Appendix III parameters on a semiannual basis.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

The preceding information serves as the ASD prepared in accordance with 40 CFR 257.94(e)(2) and supports the conclusion that the SSIs for chloride at MW-4 and MW-1802 are attributed to natural variation. Therefore, no further action is warranted, and the Amos Plant Landfill will remain in the detection monitoring program. Certification of this ASD by a qualified professional engineer is provided in **Attachment A**.

SECTION 4

REFERENCES

Arcadis, 2020. FGD Landfill – CCR Revised Groundwater Monitoring Well Network Evaluation. May.

Geosyntec Consultants, 2020a. Statistical Analysis Summary – Background Update Calculations. John E. Amos Plant Landfill. Winfield, West Virginia. February.

Geosyntec Consultants, 2020b. Statistical Analysis Plan – Revision 1. October.

USEPA, 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance. EPA 530/R-09-007. March

USEPA, 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities (Final Rule). Fed. Reg. 80 FR 21301, pp. 21301-21501, 40 CFR Parts 257 and 261, April.

TABLES

Table 1: Detection Monitoring Data Evalation
Amos Plant - Landfill

Analyte	Unit	Description	MW-2	MW-4		MW-1801		MW-1802	
			11/3/2020	11/3/2020	1/5/2021	11/4/2020	1/5/2021	11/4/2020	1/5/2021
Boron	mg/L	Intrawell Background Value (UPL)	0.247	0.214		0.306		0.276	
		Analytical Result	0.179	0.157	--	0.215	--	0.223	--
Calcium	mg/L	Intrawell Background Value (UPL)	2.10	0.912		1.83		0.978	
		Analytical Result	1.69	0.783	--	1.52	--	0.974	--
Chloride	mg/L	Intrawell Background Value (UPL)	5.40	15.9		12.1		10.2	
		Analytical Result	4.31	**17.1**	**18.0**	**12.5**	11.7	**10.7**	**10.7**
Fluoride	mg/L	Intrawell Background Value (UPL)	1.61	1.52		5.67		5.36	
		Analytical Result	1.45	**1.53**	1.48	5.34	--	4.89	--
pH	SU	Intrawell Background Value (UPL)	9.0	10.1		9.5		9.5	
		Intrawell Background Value (LPL)	8.2	8.3		8.5		8.7	
		Analytical Result	8.8	9.4	--	9.0	--	9.2	--
Sulfate	mg/L	Intrawell Background Value (UPL)	12.9	12.2		8.88		22.4	
		Analytical Result	9.0	9.7	--	7.5	--	19.0	--
Total Dissolved Solids	mg/L	Intrawell Background Value (UPL)	394	422		550		522	
		Analytical Result	378	397	--	535	--	494	--

Notes:
UPL: Upper prediction limit
LPL: Lower prediction limit
Bold values exceed the background value.
Background values are shaded gray.

FIGURES

Legend

- ⊕ Upgradient Sampling Location
- ⊕ Downgradient Sampling Location
- ▭ FGD Landfill Permitted Limits
- 🟩 Northern Valley
- 🟨 Southern Valley

Notes

- Monitoring well coordinates provided by AEP.
- Aerial imagery provided by DigitalGlobe and dated 8/30/2016.

700 350 0 700
Feet

Site Layout
FGD Landfill

AEP Amos Generating Plant
Winfield, West Virginia

Geosyntec
consultants

Figure
1

Columbus, Ohio
2021/04/29

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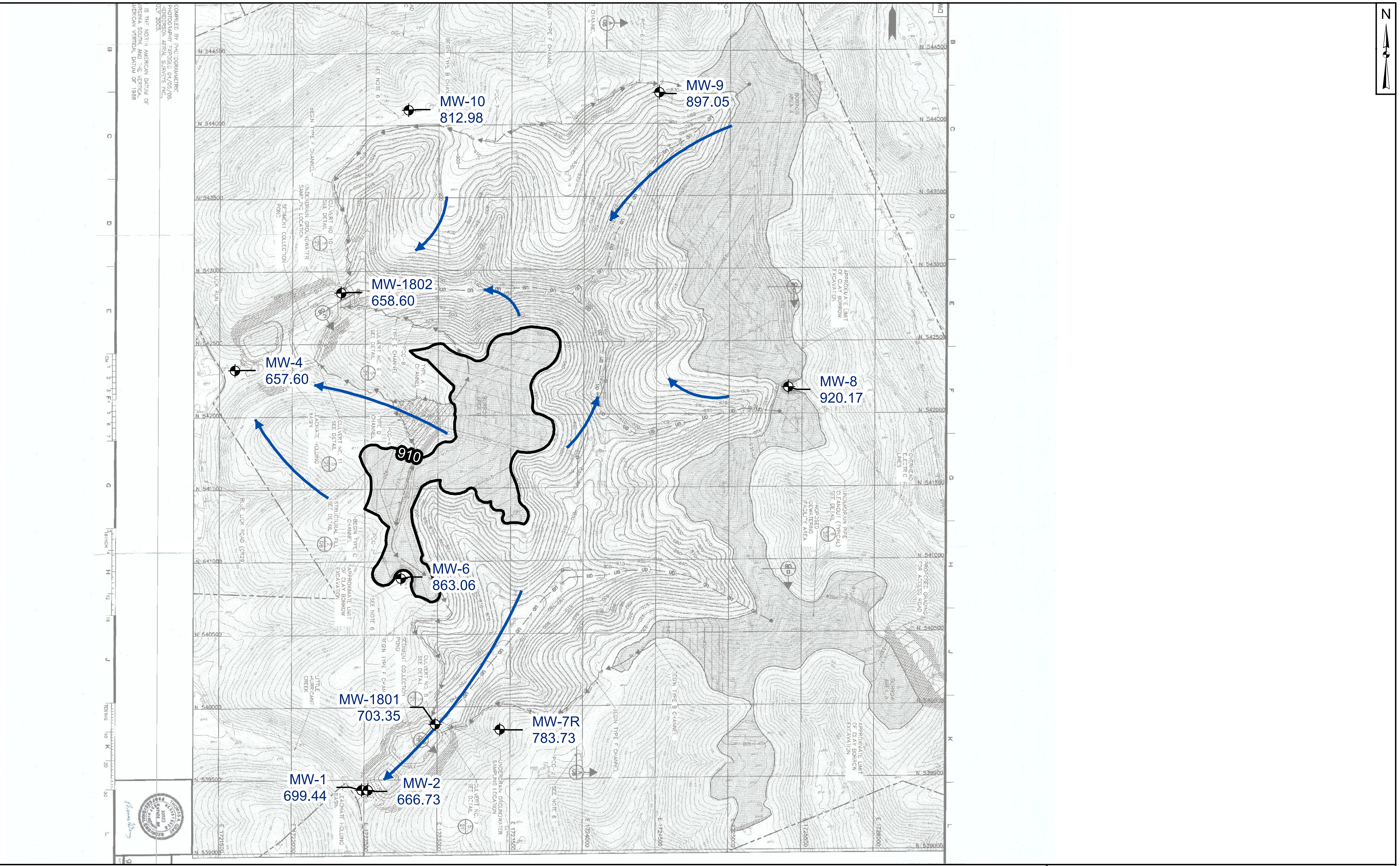

Legend

- ⊕ Groundwater Monitoring Well
- → Flow Direction
- — Ridge Peak Contour - Drainage Divide

Notes

- Monitoring well coordinates and water level data (collected on November 2, 2020) provided by AEP.
- Topography and drainage system basemap from AEP Drawing No. 13-30500-05-A (topographic contour interval: 10 feet).
- Groundwater elevation units are feet above mean sea level.
- The black line indicates the maximum elevation of the central ridge.

Groundwater Flow Direction Map
Uppermost Aquifer - November 2020

AEP Amos Generating Plant
Winfield, West Virginia

Geosyntec
consultants

Columbus, Ohio | 2021/03/18

Figure
2

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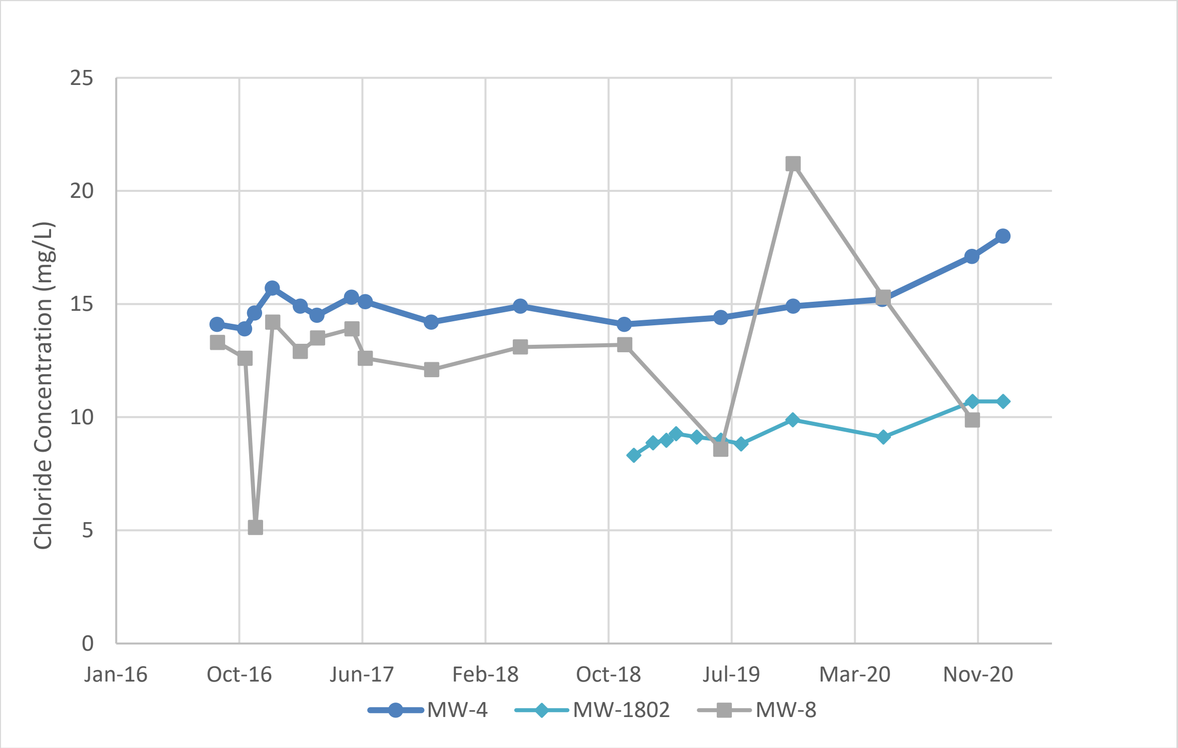


Notes: MW-8 is an upgradient monitoring location. Data was collected under the federal CCR rule and represent total chloride in groundwater. All three wells are screened in the Pennsylvanian Monongahela and Conemaugh Formations.

Chloride Time Series Graph

Amos Landfill

Geosyntec consultants

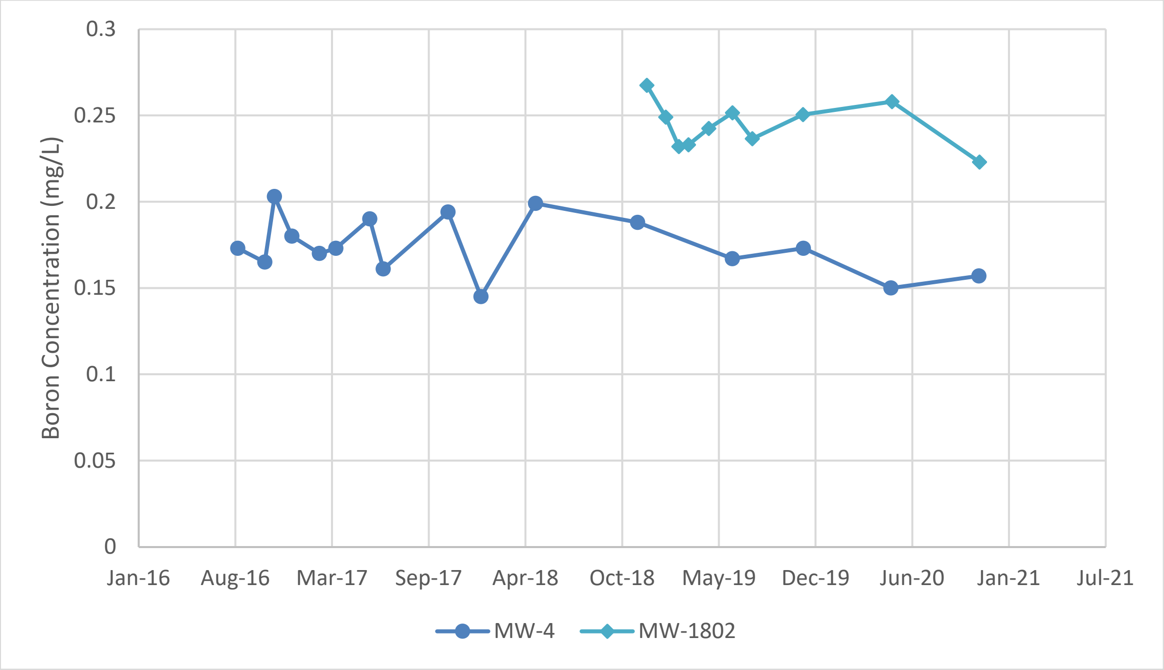
AMERICAN ELECTRIC POWER

Figure
3

Columbus, Ohio

20-April-2021

internal info: path, date revised, author



Notes: Data was collected under the federal CCR rule and represents total boron in groundwater.

Boron Time Series Graph

Amos Landfill

Geosyntec consultants

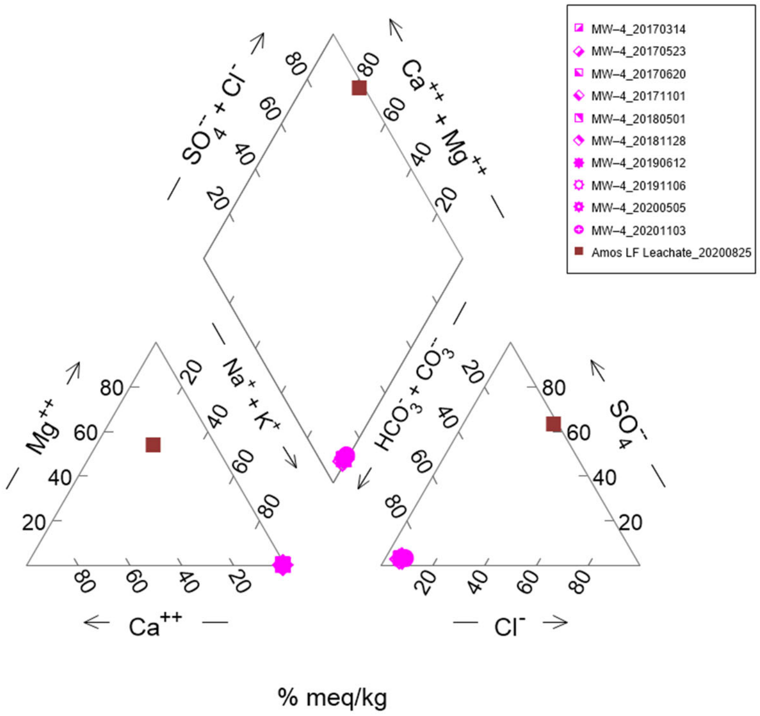
AMERICAN ELECTRIC POWER

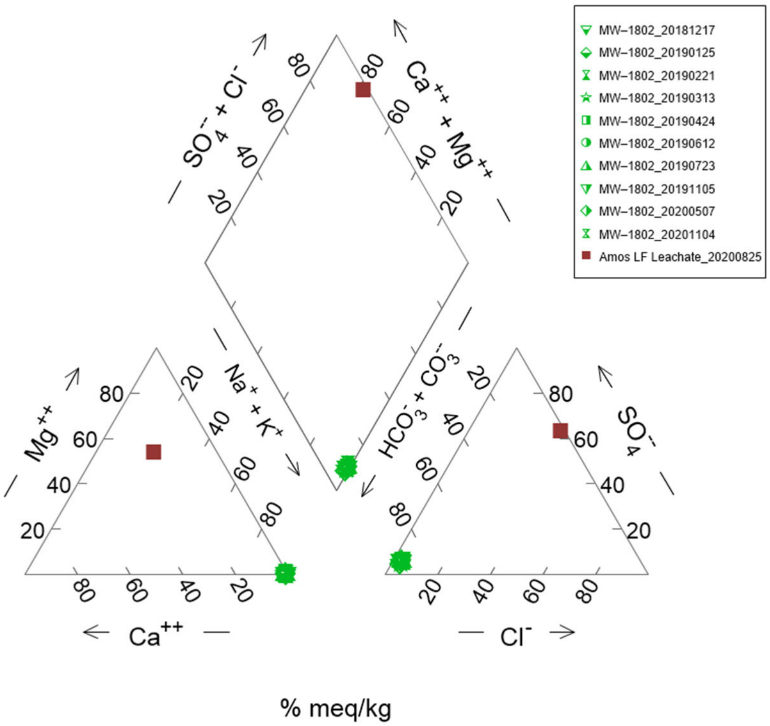
Figure

4

Columbus, Ohio

20-April-2021





Notes: The Landfill leachate sample was collected from the north valley header in August 2020.

Piper Diagrams – Leachate Comparison

Amos Landfill

Geosyntec consultants

AMERICAN ELECTRIC POWER

Figure

5

Columbus, Ohio

20-April-2021

internal info: path, date revised, author

ATTACHMENT A

Certification by Qualified Professional Engineer

CERTIFICATION BY A QUALIFIED PROFESSIONAL ENGINEER

I certify that the selected and above described alternative source demonstration is appropriate for evaluating the groundwater monitoring data for the Amos Plant Landfill CCR management area and that the requirements of 40 CFR 257.94(e)(2) have been met.

JOHN P. SEYMOUR
17091

John Seymour
Printed Name of Licensed Professional Engineer

Signature

017091
License Number

West Virginia
Licensing State

5/6/2021
Date

ALTERNATIVE SOURCE DEMONSTRATION REPORT FEDERAL CCR RULE

Amos Plant Landfill
Winfield, West Virginia

Submitted to

AMERICAN
ELECTRIC
POWER

1 Riverside Plaza
Columbus, Ohio 43215-2372

Submitted by

Geosyntec
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engineers | scientists | innovators

941 Chatham Lane, Suite 103
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November 22, 2021

CHA8495

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LIST OF ACRONYMS AND ABBREVIATIONS

AEP	American Electric Power
ASD	Alternative Source Demonstration
bgs	Below ground surface
CCR	Coal Combustion Residuals
CFR	Code of Federal Regulations
LPL	Lower Prediction Limit
mg/L	Milligram per liter
QC	Quality Control
SSI	Statistically Significant Increase
UPL	Upper Prediction Limit
USEPA	United States Environmental Protection Agency

SECTION 1

INTRODUCTION AND SUMMARY

1.1 Introduction

This Alternative Source Demonstration (ASD) report has been prepared to address statistically significant increases (SSIs) for chloride at the Amos Plant Landfill (Landfill) following the first semi-annual detection monitoring event of 2021.

Following completion of four detection monitoring events, the previously calculated upper prediction limits (UPLs) for the Landfill were recalculated for each Appendix III parameter to represent background values (Geosyntec, 2020a). A lower prediction limit (LPL) was also recalculated for pH. The revised prediction limits were calculated based on a one-of-two retesting procedure in accordance with the Unified Guidance (USEPA, 2009) and the statistical analysis plan developed for the site (Geosyntec, 2020b). With this procedure, a statistically significant increase (SSI) is concluded only if both samples in a series of two exceed the UPL, or in the case of pH are below the LPL.

The first semi-annual detection monitoring event of 2021 was performed in May 2021 (initial sampling event) and July 2021 (verification sampling event) and the results were compared to the recalculated prediction limits. During this detection monitoring event, SSIs were identified for chloride at MW-4, MW-1801, and MW-1802 based on intrawell comparisons. A summary of the detection monitoring analytical results for all constituents listed in 40 CFR Part 257 Appendix III and the calculated prediction limits to which they were compared is provided in **Table 1**.

1.2 CCR Rule Requirements

In accordance with the United States Environmental Protection Agency (USEPA) regulations regarding the disposal of coal combustion residuals (CCR) in landfills and surface impoundments, Rule 40 CFR 257.94(e)(2) states the following:

> *The owner or operator may demonstrate that a source other than the CCR unit caused the statistically significant increase over background levels for a constituent or that the statistically significant increase resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. The owner or operator must complete the written demonstration within 90 days of detecting a statistically significant increase over background levels to include obtaining a certification from a qualified professional engineer verifying the accuracy of the information in the report.*

The first semi-annual detection monitoring event for 2021 was completed in May and July 2021 to identify SSIs over background limits. Pursuant to 40 CFR 257.94(e)(2), Geosyntec Consultants, Inc. (Geosyntec) has prepared this ASD report to identify whether the SSIs identified for chloride at MW-4, MW-1801, and MW-1802 are from a source other than the Landfill.

1.3 Demonstration of Alternative Sources

An evaluation was completed to assess possible alternative sources to which identified SSIs could be attributed. Alternative sources were identified amongst five types:

- ASD Type I: Sampling Causes;
- ASD Type II: Laboratory Causes;
- ASD Type III: Statistical Evaluation Causes;
- ASD Type IV: Natural Variation; and
- ASD Type V: Alternative Sources.

A demonstration was conducted to assess whether the increases in chloride at MW-4, MW-1801 and MW-1802 were based on a Type IV cause (Natural Variation) and not by a release from the Amos Plant Landfill.

SECTION 2

ALTERNATIVE SOURCE DEMONSTRATION

A brief description of the site geology, ASD evaluation methodology, and the proposed alternative source are described below.

2.1 Site Geology Summary

The Amos Plant Landfill site consists of a northern valley and southern valley, both of which are surrounded on all sides by bedrock ridges (**Figure 1**). A topographic high point separates the two valleys (Arcadis, 2020), as shown in **Figure 2**. MW-4 and MW-1802 are downgradient wells for the northern valley, and MW-1801 is a downgradient well for the southern valley. The northern and southern valleys are hydrologically separated from each other.

Bedrock in the vicinity of MW-4, MW-1801, and MW-1802 consists of a combination of gray siltstone, silty shale, and red claystone. These lithologies make up part of the Pennsylvanian Monongahela and Conemaugh Formations. These formations contain a system of stress relief fractures that are associated with a decline in stress and erosion (Arcadis, 2020).

Groundwater flows through the stress relief fracture formations. Bedrock groundwater flow generally follows surface topography, flowing downslope of ridges towards valley floors (Arcadis, 2020).

2.2 Landfill Leachate Data Analysis

Initial review of site geochemistry, site historical data, and laboratory QA/QC did not identify an ASD due to Type I (sampling) or Type II (laboratory) causes. A review of the statistical methods used did not identify any Type III (statistical) causes. A preliminary review did not identify any Type V (anthropogenic) causes. Therefore, natural variation, which is a Type IV cause, was examined as a potential cause of the SSI.

Landfill leachate concentrations, including boron, major cations, and major anions, were examined to assess if it has similar geochemical characteristics as groundwater and whether it was a source. Piper diagrams, which visually represent the relative concentrations of major cations and anions in the groundwater and leachate analytical samples, were created to further illustrate the groundwater geochemistry at MW-4, MW-1801, and MW-1802 compared to the geochemistry of the leachate (**Figure 3**). The data shown in these Piper diagrams captures the background and detection monitoring periods: 2017 through 2021 for MW-4 and 2018 through 2021 for MW-1801 and MW-1802.

The groundwater geochemistry at MW-4, MW-1801, and MW-1802 has remained unchanged throughout the monitoring period, as illustrated by the tight clustering of sample results for each well on the Piper Diagrams. Each well is distinct from the geochemistry of the leachate, particularly for the relative percentages of each anion, illustrating a lack of influence from leachate on the groundwater composition. Instead, the relative percentages of anions at each of the downgradient wells of interest is more similar to background well MW-8 (**Figure 3**).

Boron and sulfate are conservative parameters due to their lack of attenuation by chemical processes in groundwater flow, and they function as a 'tracer' for potential CCR unit releases due to their high relative concentration in CCR. The concentration of boron in samples of Landfill leachate collected in October 2021 from the northern valley and southern valley were 95.8 milligrams per liter (mg/L) and 107 mg/L, respectively. The concentrations of boron at MW-4, MW-1801, and MW-1802 are consistently less than 0.3 mg/L (**Figure 4**). The October 2021 northern valley leachate and southern valley leachate sulfate concentrations were 14,400 mg/L and 18,400 mg/L, respectively. The concentrations of sulfate at MW-4, MW-1801, and MW-1802 are consistently less than 45 mg/L (**Figure 5**).

If Landfill leachate, which has boron and sulfate concentration several orders of magnitude higher than the wells of interest, were impacting groundwater quality at downgradient monitoring wells, an increase in boron and sulfate concentrations at MW-4, MW-1801, and MW-1802 would be expected. The current boron and sulfate concentrations at the wells of interest do not display increasing trends (**Figure 4** and **Figure 5,** respectively), which suggests that groundwater quality changes at these locations should not be attributed to a release from the Landfill.

2.3 Examination of Natural Variability

Chloride concentrations at upgradient well MW-8 have historically been above those observed at MW-1801 and MW-1802 and comparable to those observed at MW-4 (**Figure 6**). The chloride concentrations at MW-8 indicate that the native geologic material (which is predominantly claystone and sandstone) contains chloride that may be released into solution at concentrations higher than or comparable to those typically found at MW-4, MW-1801, and MW-1802. MW-8 is located hydraulically upgradient of the northern valley; wells MW-6 and MW-7, which are located hydraulically upgradient of the southern valley, have chloride concentrations that are lower than at MW-8 (**Figure 6**). Thus, the recent chloride concentrations are generally within the observed background chloride concentration range.

The results suggest changes in chloride concentration at the downgradient locations can be attributed to natural variations in the contribution of chloride from native geologic material.

2.4 Summary of Findings

A demonstration was conducted to assess whether the SSIs for chloride at MW-4, MW-1801 and MW-1802 were based on a Type IV cause (Natural Variation) and not by a release from the Amos Plant Landfill. The following is concluded:

1. The ASD is not a Type I (sampling error), Type II (laboratory), III (statistical), or V (anthropogenic) based on a review of the data.
2. Groundwater chemistry at the downgradient wells with chloride SSIs is generally unchanged and inconsistent with Landfill leachate.
3. Boron and sulfate concentrations at the downgradient wells with SSIs are generally unchanged. If impacts from Landfill leachate were occurring, increasing boron and sulfate groundwater concentrations would be expected.
4. The cause of chloride concentration increases in downgradient groundwater is from natural variation in contribution from the native geologic material.

These observations support the conclusion that the SSIs identified for chloride cannot be attributed to a release from the Landfill and instead is caused by natural variation.

2.5 Sampling Requirements

The conclusions of this ASD support the determination that the identified SSIs are from natural variation and not due to a release from the Landfill. Therefore, the unit will remain in the detection monitoring program. Groundwater at the unit will be sampled for Appendix III parameters on a semiannual basis.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

The preceding information serves as the ASD prepared in accordance with 40 CFR 257.94(e)(2) and supports the conclusion that the SSIs for chloride at MW-4, MW-1801, and MW-1802 are attributed to variation of natural groundwater quality. Therefore, no further action is warranted, and the Amos Plant Landfill will remain in the detection monitoring program. Certification of this ASD by a qualified professional engineer is provided in **Attachment A**.

SECTION 4

REFERENCES

Arcadis, 2020. FGD Landfill – CCR Revised Groundwater Monitoring Well Network Evaluation. May.

Geosyntec Consultants, 2020a. Statistical Analysis Summary – Background Update Calculations. John E. Amos Plant Landfill. Winfield, West Virginia. February.

Geosyntec Consultants, 2020b. Statistical Analysis Plan – Revision 1. October.

USEPA, 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance. EPA 530/R-09-007. March

USEPA, 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities (Final Rule). Fed. Reg. 80 FR 21301, pp. 21301-21501, 40 CFR Parts 257 and 261, April.

TABLES

Table 1: Detection Monitoring Data Evalation
Amos - Landfill

Analyte	Unit	Description	MW-2		MW-4		MW-1801		MW-1802	
			5/4/2021	7/21/2021	5/4/2021	7/21/2021	5/5/2021	7/21/2021	5/5/2021	7/21/2021
Boron	mg/L	Intrawell Background Value (UPL)	0.247		0.214		0.306		0.276	
		Analytical Result	0.220	--	0.168	--	0.250	--	0.258	--
Calcium	mg/L	Intrawell Background Value (UPL)	2.10		0.912		1.83		0.978	
		Analytical Result	2.04	--	0.695	--	1.65	--	0.800	-
Chloride	mg/L	Intrawell Background Value (UPL)	5.40		15.9		12.1		10.2	
		Analytical Result	3.60	--	**19.7**	**20.8**	**13.1**	**13.1**	**11.5**	**13.5**
Fluoride	mg/L	Intrawell Background Value (UPL)	1.61		1.52		5.67		5.36	
		Analytical Result	**1.62**	1.41	1.50	--	5.24	--	4.88	--
pH	SU	Intrawell Background Value (UPL)	9.0		10.1		9.5		9.5	
		Intrawell Background Value (LPL)	8.2		8.3		8.5		8.7	
		Analytical Result	8.7	--	9.2	--	8.8	--	9.1	--
Sulfate	mg/L	Intrawell Background Value (UPL)	12.9		12.2		8.88		22.4	
		Analytical Result	8.2	--	8.8	--	**9.1**	7.63	17.9	--
Total Dissolved Solids	mg/L	Intrawell Background Value (UPL)	394		422		550		522	
		Analytical Result	386	--	410	--	542	--	508	--

Notes:
UPL: Upper prediction limit
LPL: Lower prediction limit
Bold values exceed the background value.
Background values are shaded gray.

FIGURES

Legend

- Upgradient Sampling Location
- Downgradient Sampling Location
- FGD Landfill Permitted Limits
- 🟩 Northern Valley
- 🟨 Southern Valley

Notes

- Monitoring well coordinates provided by AEP.
- Aerial imagery provided by DigitalGlobe and dated 8/30/2016.

Site Layout
FGD Landfill

AEP Amos Generating Plant
Winfield, West Virginia

Geosyntec
consultants

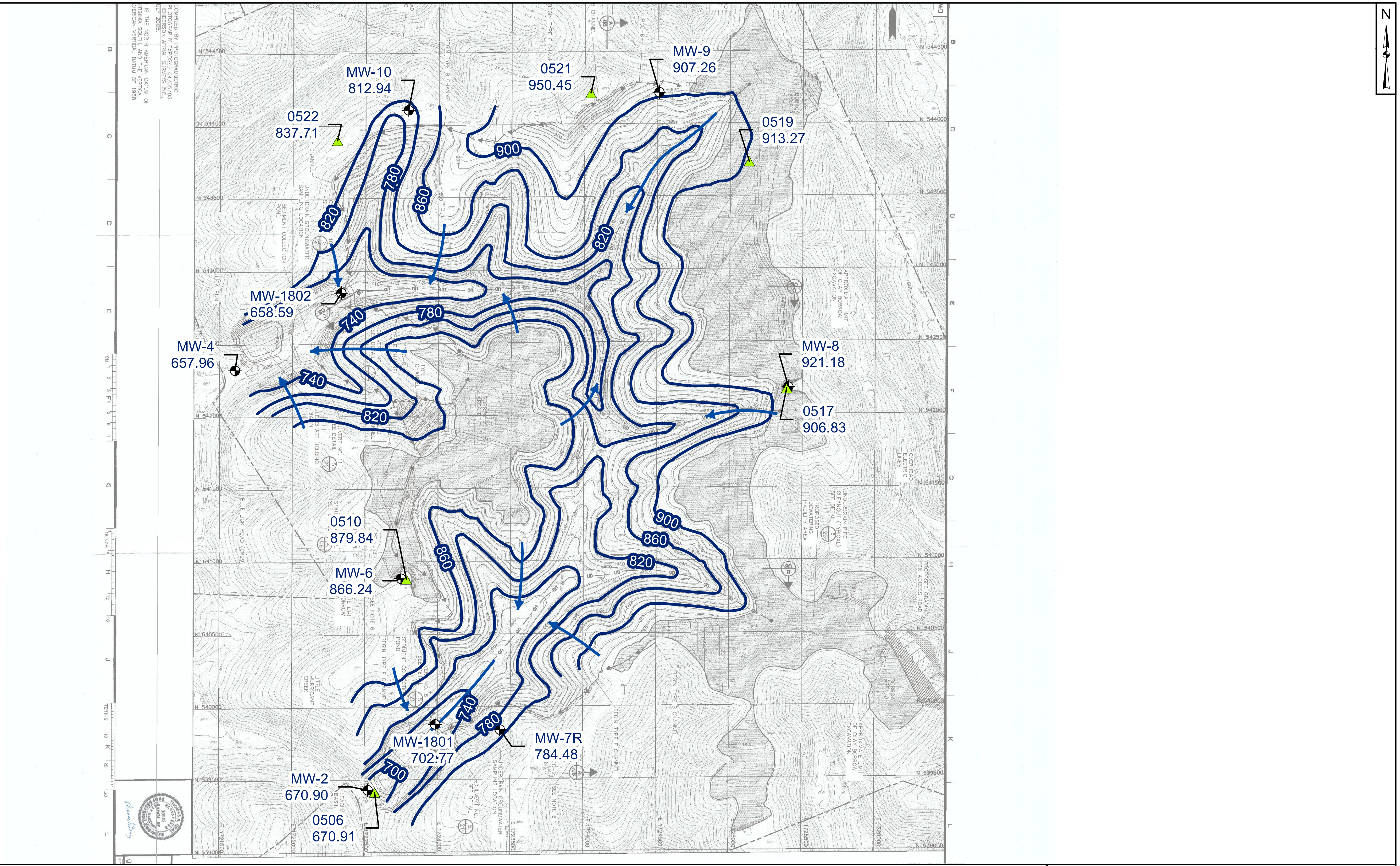
Columbus, Ohio

October 2021

Figure

1

P:\Projects\AEP\Groundwater Statistical Evaluation - CHA8423\Groundwater Mapping\GIS Files\MXD\Amos\AEP-Amos_Landfill_Site_Layout.mxd. ARevezzo. 4/29/2021. CHA8423/04/08.



700 350 0 700
Feet

Legend

- Groundwater Monitoring Well
- Piezometer
- Groundwater Flow Direction
- Groundwater Elevation Contour

Notes

- Monitoring well coordinates and water level data (collected on May 3, 2021) provided by AEP.
- Potentiometric surface contour interval is 40 feet.
- Topography and drainage system basemap from AEP Drawing No. 13-30500-05-A (topographic contour interval: 10 feet).
- Groundwater elevation units are feet above mean sea level.

Potentiometric Surface Map - Uppermost Aquifer
May 2021

AEP Amos Generating Plant
Winfield, West Virginia

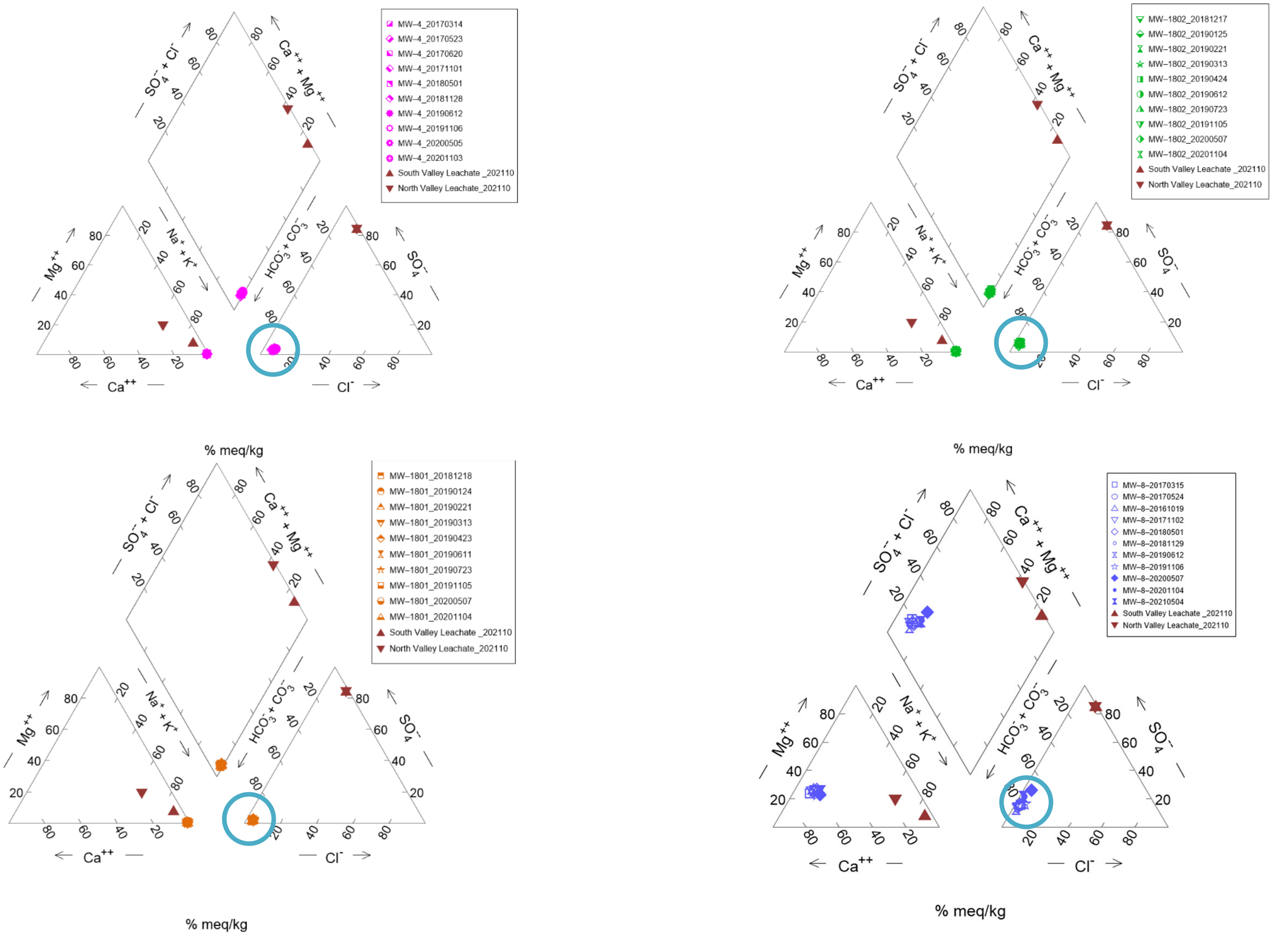
Geosyntec
consultants

Columbus, Ohio

October 2021

Figure
2

P:\Projects\AEP\Groundwater Statistical Evaluation - CHA8423\Groundwater Mapping\GIS Files\MXD\Amos\2021\AEP-Amos_Landfill_GW_2021-05.mxd. HDuff. 6/22/2021. CHA8423/04/08.



Piper Diagrams – Leachate Comparison

Amos Landfill

Notes: The Landfill leachate samples were collected on October 7, 2021. Leachate samples were not analyzed for potassium (K$^+$). Individual groundwater samples cannot be identified because of overlap of the symbology. All groundwater samples for each monitoring location are circled in blue on the anion distribution triangle. .

Geosyntec consultants

AMERICAN ELECTRIC POWER

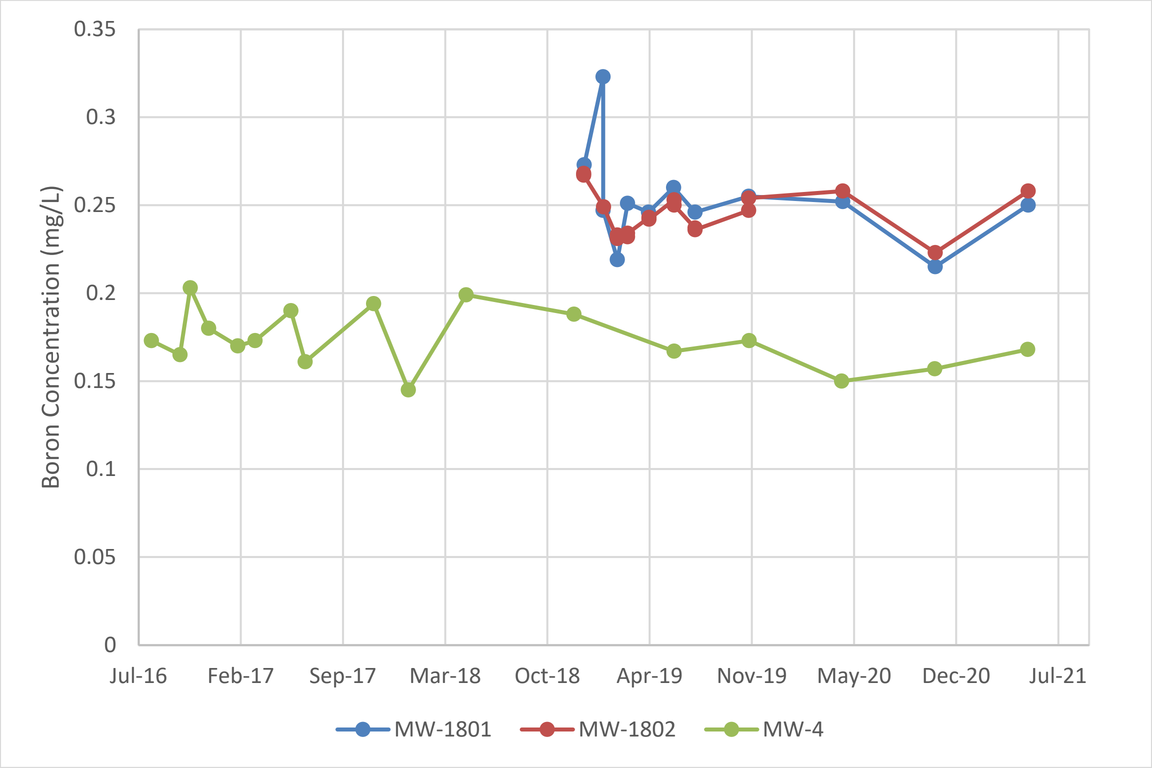
Columbus, Ohio

November 2021

Figure

3

\\annarbor-01\data\Projects\AEP\Legal Department - ASD Review\Amos\Landfill\2021-10 2021 1st Semiannual ASD Report\Figures



Notes: Data was collected under the federal CCR rule and represents total boron in groundwater.

Boron Time Series Graph

Amos Landfill

Geosyntec consultants

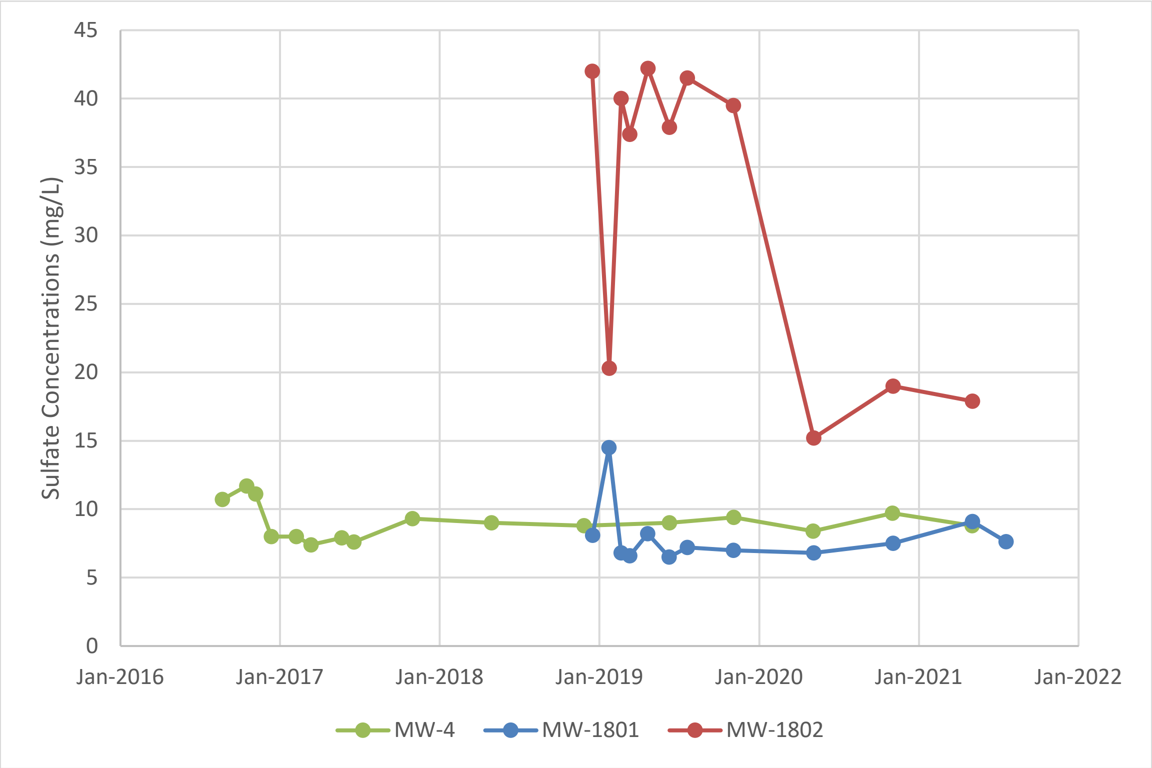
AMERICAN ELECTRIC POWER

Figure

4

Columbus, Ohio

October 2021



Notes: Data was collected under the federal CCR rule and represents total sulfate in groundwater.

Sulfate Time Series Graph

Amos Landfill

Geosyntec consultants

AMERICAN ELECTRIC POWER

Figure 5

Columbus, Ohio

November 2021

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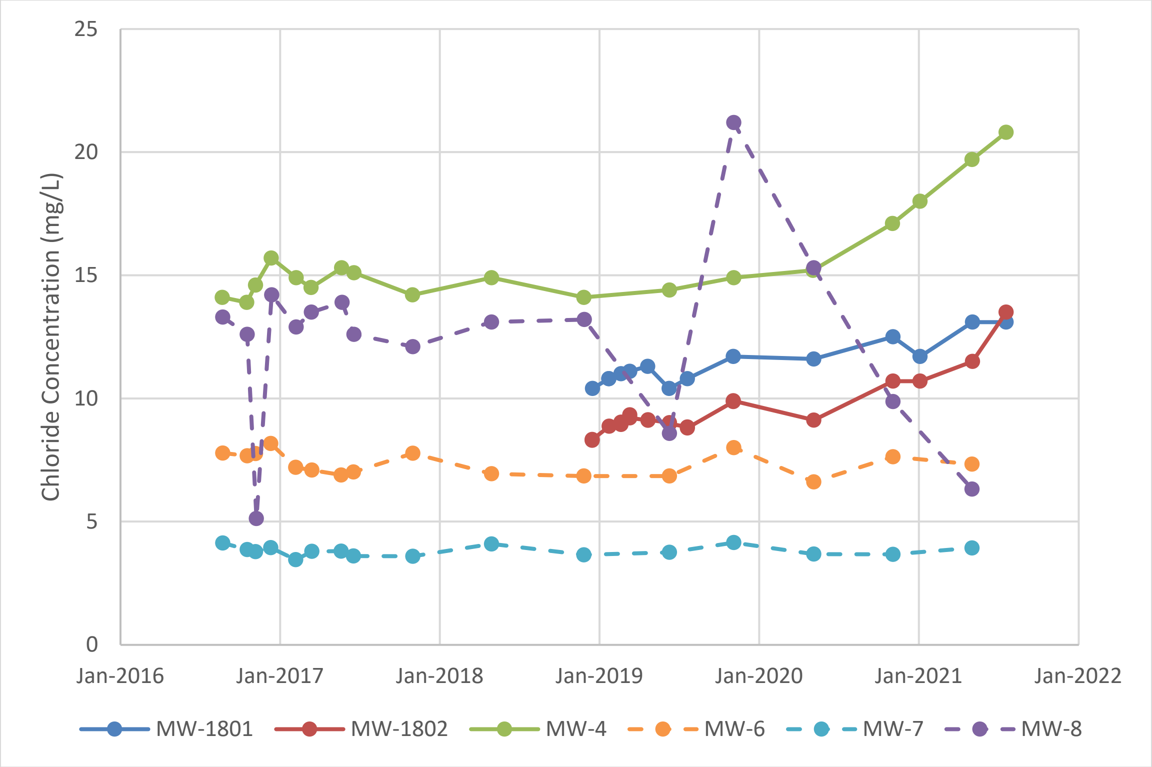

Notes: Upgradient monitoring locations MW-6, MW-7, and MW-8 are shown with dashed lines. Data was collected under the federal CCR rule and represent total chloride in groundwater.

Chloride Time Series Graph

Amos Landfill

Geosyntec consultants

AMERICAN ELECTRIC POWER

Figure
6

Columbus, Ohio

November 2021

ATTACHMENT A

Certification by Qualified Professional Engineer

CERTIFICATION BY A QUALIFIED PROFESSIONAL ENGINEER

I certify that the selected and above described alternative source demonstration is appropriate for evaluating the groundwater monitoring data for the Amos Plant Landfill CCR management area and that the requirements of 40 CFR 257.94(e)(2) have been met.

JOHN P. SEYMOUR
17091

John Seymour
Printed Name of Licensed Professional Engineer

John Seymour
Signature

017091
License Number

West Virginia
Licensing State

11/28/2021
Date

APPENDIX 4

Not applicable.

APPENDIX 5

Not applicable.