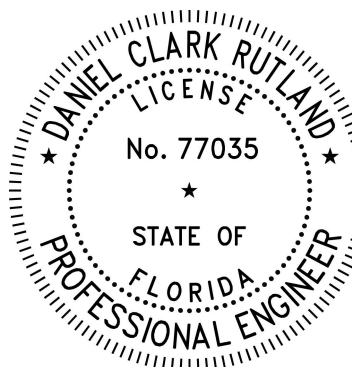


2021 Annual Groundwater Monitoring and Corrective Action Report: OUC Stanton Energy Center CCR

PREPARED FOR: Orlando Utility Commission
PREPARED BY: CH2M HILL Engineers, Inc.
DATE: January 28, 2022
PROJECT NUMBER: D3292400.A.PN.OE.08_DR

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Purpose

On April 17, 2015, the United States Environmental Protection Agency (EPA) published the final rule for the Coal Combustion Residuals (CCR) Rule, Subtitle D of 40 Code of Federal Regulations (CFR) 257. The CCR Rule established national minimum criteria for CCR disposal and became effective October 19, 2015. The Orlando Utilities Commission (OUC) must comply with this rule when managing the disposal of CCR material generated at Stanton Energy Center (SEC). This technical memorandum fulfills the reporting requirements associated with the annual groundwater monitoring and corrective action report, Section 257.90 (2)(e), CFR.

The CCR Rule includes: deadlines for the establishment of a groundwater monitoring system, sampling and analysis of groundwater requirements, the statistical analysis of the groundwater quality data, and specifying corrective actions (if necessary) for facilities disposing of CCR. The CCR Groundwater Monitoring and Corrective Action program is described in Sections 257.90 through 257.98 of the CCR Rule:

- Applicability (§257.90)
- Groundwater Monitoring Systems (§257.91)
- Groundwater Sampling and Analysis Requirements (§257.93)
- Detection Monitoring Program (§257.94)
- Assessment Monitoring Program (§257.95)
- Assessment of Corrective Measures (§257.96)
- Selection of Remedy (§257.97)
- Implementation of Corrective Action Program (§257.98)

Monitoring requirements for compliance are included in §257 sub-sections. How OUC met the requirements of the CCR program is described in the first annual report (CH2M 2018). The 2017 annual report contained the results of the Groundwater Monitoring and Corrective Action program from July 2015 through December 2017. Subsequent OUC SEC annual reports were intended to only describe the status of the program for the given year in accordance with §257.90(e) (Table 1). This technical memorandum provides the required 2021 documentation to demonstrate the OUC SEC's compliance with the CCR Rule annual groundwater monitoring and corrective action report.

Table 1. Annual Groundwater Monitoring and Corrective Action Report (§257.90(e))

2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

Requirement	Response
A map, aerial image, or diagram showing the CCR unit and the background (or up-gradient) and downgradient monitoring wells, to include the well identification numbers, that are part of the groundwater monitoring program for the CCR unit.	These are shown in Figures 2 and 3 in the background section
Identification of any monitoring wells that were installed or decommissioned during the preceding year, along with a narrative description of why those actions were taken.	No changes to the wells during this period
In addition to the monitoring data obtained under §257.90 through §257.98, a summary including the number of groundwater samples that were collected for analysis for each background and downgradient well, the dates the samples were collected, and whether the sample was required by the detection monitoring or assessment monitoring programs.	See results section
A narrative discussion of any transition between monitoring programs (e.g., the date and circumstances for transitioning from detection monitoring to assessment monitoring in addition to identifying the constituent(s) detected at a statistically significant increase over background levels).	See discussion section
Other information required to be included in the annual report as specified in §257.90 through §257.98.	Part of discussion and conclusions

Background and Setting

SEC is located 12 miles southeast of Orlando, Florida. OUC has been operating SEC since 1987 and dry-managing CCRs in landfills on the west side of the property. The original, now closed, landfill received CCR from July 1987 through August 28, 2015. From the period of May 28 through August 15, 2015, the CCR directed to the closed landfill was used to form part of the landfill cap. The cap was completed with 2 feet of soil and then sodded to stabilize the soil. The old landfill is exempt from the CCR Rule because it ceased operations prior to its implementation. The old landfill is closed (hereinafter “closed landfill”) and is undergoing post-closure monitoring under OUC's Conditions of Certification with the Florida Department of Environmental Protection (FDEP). The closed landfill has a 6.42-megawatt solar power generation farm installed over its top.

The new landfill (hereinafter “active landfill”) began receiving CCR on May 28, 2015 as a monofill that receives CCR produced by the SEC coal-fired power generating process. The new landfill is positioned immediately west of and adjacent to the closed landfill and immediately east of the road Innovation Way, which is the approximate SEC western property boundary (Figure 1). The Orange County municipal solid waste landfill is immediately west of SEC. The design standards for the active landfill are compliant with Florida's municipal solid waste landfill requirements under Chapter 62-701, Florida Administrative Code. The active landfill is fully double-lined and does not discharge into the surficial groundwater.

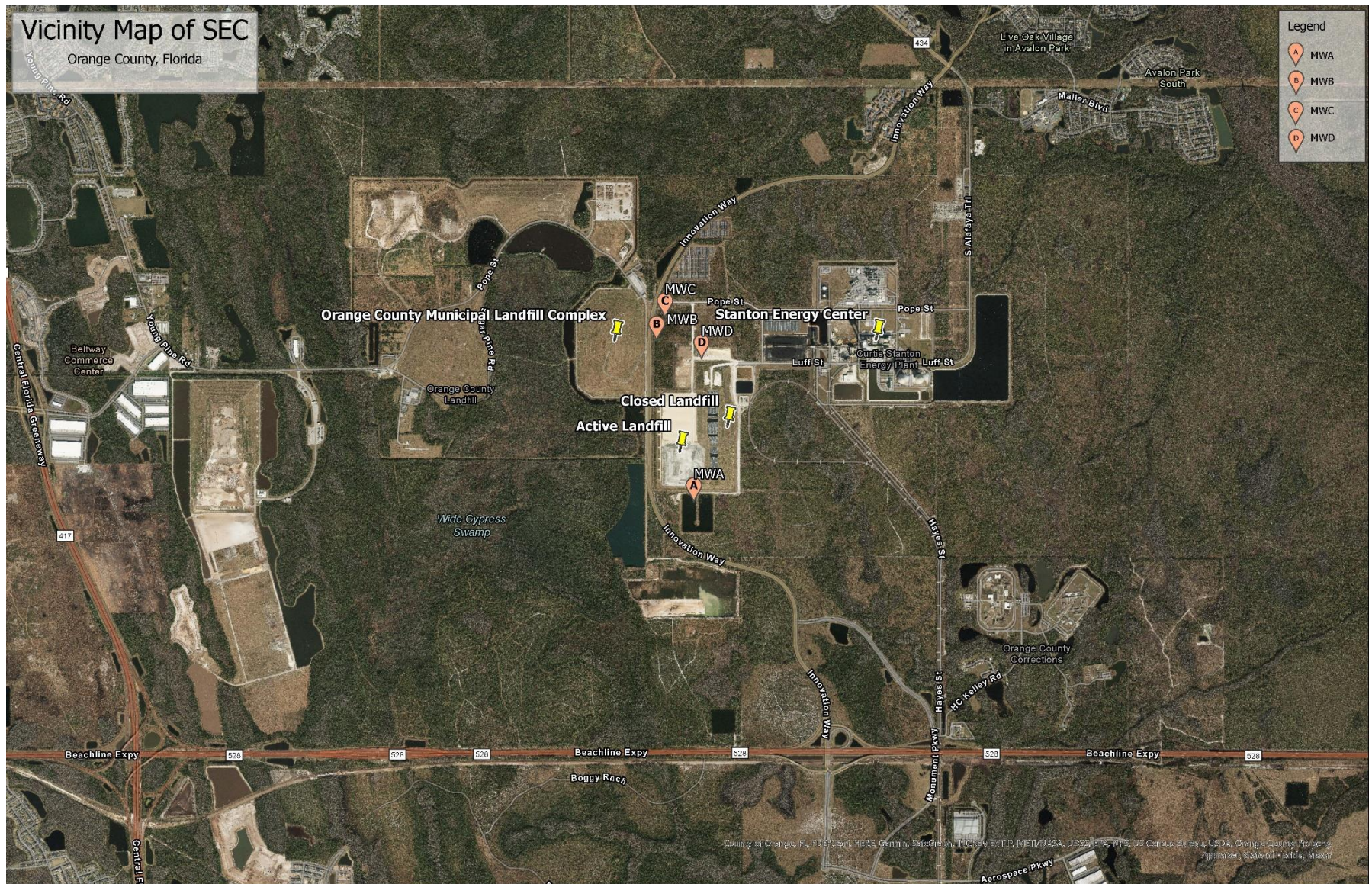


Figure 1. General Vicinity Map of OUC SEC and Landfills
2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

Groundwater conditions at SEC are regulated under two separate programs: the FDEP Power Plant Siting Act and the U.S. Environmental Protection Agency (EPA) CCR Rule. The FDEP monitoring program has been active since August 1986, while the CCR monitoring program began in October 2015. OUC has made a conscious effort to keep these programs separate because different regulatory requirements, different groundwater quality standards, and different monitored constituents. However, the groundwater under the two adjacent landfills is common.

Monitoring well locations were selected based on the groundwater gradient characteristics, the positions of the active and closed landfills, and were also constrained by the western site boundary. The physical constraints, the history of FDEP's groundwater monitoring and other investigation results were used to locate the monitoring wells for the CCR program. The western property boundary is the regional groundwater up-gradient edge at the SEC site (Figures 2 and 3). The surficial aquifer groundwater near the SEC CCR active landfill is generally flowing outward from an apparent local groundwater level high under the adjacent closed coal residual landfill (this is especially evident at the end of the wet season in Figure 3). Even though the surficial groundwater gradient is toward the southwest initially from this local high, the overall groundwater gradient is still toward the east and northeast. Consequently, the groundwater quality conditions near the active landfill that are monitored for the CCR program do not represent unaffected background conditions. The CCR Rule groundwater data represent conditions since the beginning of the CCR monitoring program.

Some constituents were statistically out of range in the September 2020 sampling event (CH2M 2021a). Because of unexpected staff changes, resampling could not be done until it was time to complete the normally scheduled March 2021 event. Otherwise, the 2021 monitoring proceeded as required. Key program activities for 2021 were to review if the observed high levels of chlorides, calcium, sulfate, and total dissolved solids (TDS) in the results could be attributed a source other than the CCR-regulated landfill, update statistical baseline and trend analysis, prepare an annual report and upload the document to the OUC CCR website by January 31, 2022, and continue with CCR detection monitoring.

CCR Groundwater Data Screening and Decision Process through the Assessment Monitoring Program

The groundwater data and screening and decision process was derived from §257.90 through §257.98 of the CCR Rule. A summary of the monitoring process is:

1. Collect CCR period background water quality data, Appendix III and IV constituents. This step occurred between September 9, 2015 and July 20, 2017 at SEC and is completed.
2. Identify method(s) to evaluate the data for statistically significant trend changes for each well and constituent for Appendix III and IV constituents by well. This step was completed and documented in an October 2017 report (CH2M 2017a).
3. Quantify criteria that define the limits for statistically significant change from background for each Appendix III and IV constituent by well. This was completed and documented in the 2017 annual report and has been updated for the 2022 monitoring year and is included for reference in Appendix A.
4. Establish a groundwater protection standard for each Appendix IV constituent [§257.95(h)] detected in groundwater. Note that the CCR Rule does not list Appendix III constituents to establish groundwater protection standards. This was completed and documented in the 2017 annual report.
5. Collect detection program water quality data, Appendix III constituents (§257.94). The detection monitoring program sampling results are presented in the 2017 through 2021 annual reports.



Figure 2. 2021 First Semi-Annual Event Groundwater Levels
2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

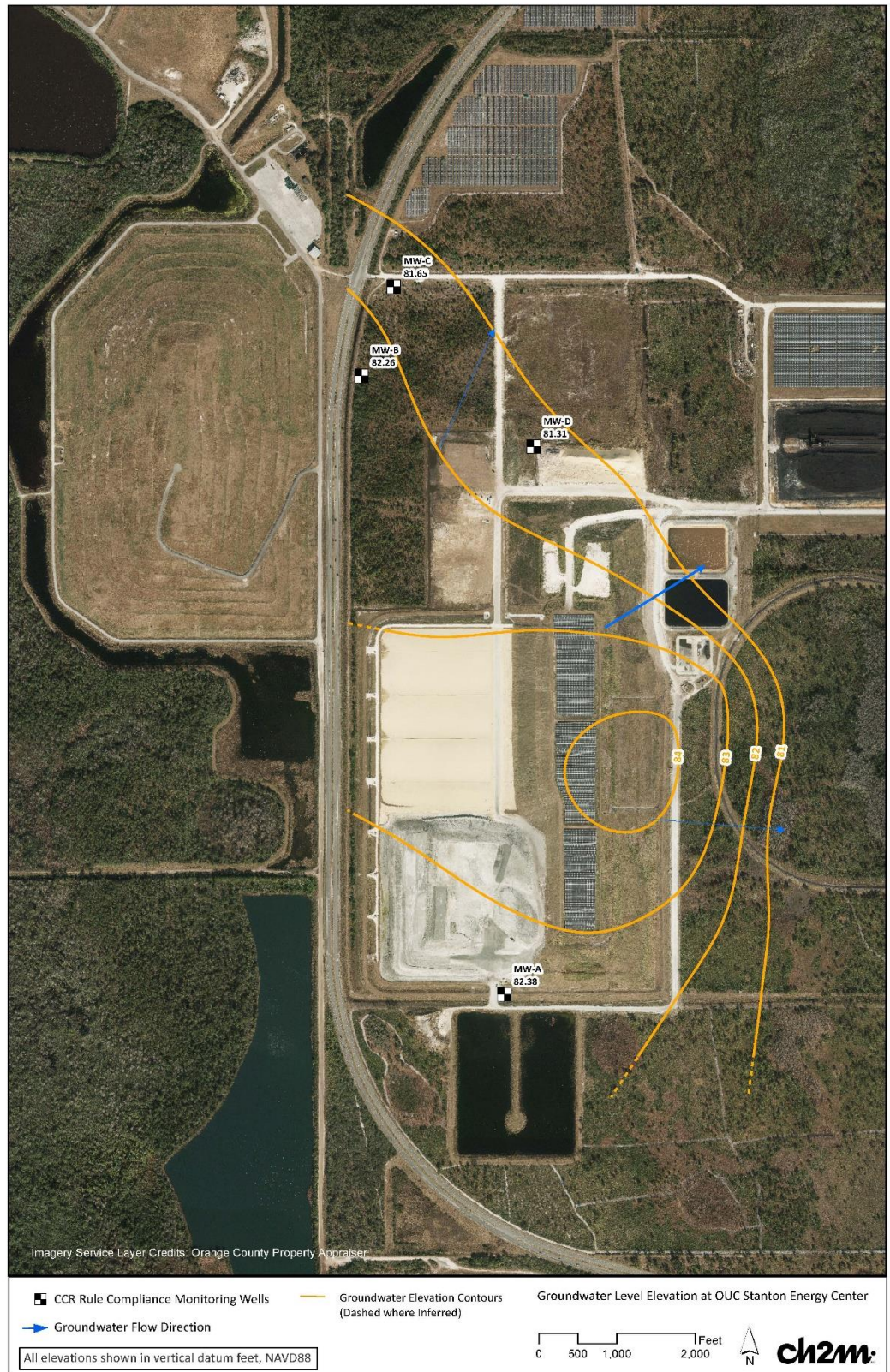


Figure 3. 2021 Second Semi-Annual Event Groundwater Levels
 2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

6. Assess groundwater flow direction and rate. The detection monitoring program sampling results are presented in the 2017 through 2021 annual reports.
7. Compare detection program water quality data to the statistical trend criteria to evaluate for no significant trend change, or a significant trend change, from the background water quality data.
 - a. If the result is no significant trend change then continue with detection program monitoring
 - b. If the result is a significant trend change may be indicated, then resample within 90 days
 - i. Compare data to the statistical criteria for no significant trend change or significant trend change
 1. If the result is no significant trend change then continue with detection program monitoring
 2. If the result is significant trend change of one or more constituents at the waste boundary [§257.94(e)]
 - a. Establish an assessment monitoring program and post a notification on the CCR Web site that an assessment monitoring program has been established, or
 - b. Demonstrate that a source other than the CCR unit caused the significant increase within 90 days. Continue with the detection monitoring program.
 - c. After approximately 3 years of detection program monitoring reassess the statistical analyses of the groundwater water quality trends against the background data to identify if changes are needed.
8. Assessment monitoring program (§257.95)
 - a. Within 90 days of establishing an assessment monitoring program sample the groundwater for Appendix IV constituents, and then sample annually thereafter.
 - b. The number of samples, N, needs to be sufficient to support the statistical evaluation of the data [§257.93(e)]. The owner may demonstrate that an alternative sampling frequency is necessary during the active life and post-closure of the CCR unit based on site conditions; however, sample no less frequently than annually.
 - c. After obtaining the results from the above, within 90 days sample all wells for Appendix III and IV constituents, at least semi-annually. The number of samples, N, needs to be sufficient to support the statistical evaluation of the data [§257.93(e)].
 - i. Establish groundwater protection standards consistent with [§257.95(h)] as described in Item 4, above.
 - ii. If the sampling results for the Appendix III and IV constituents are below the established groundwater protection standards for two consecutive sampling events, the monitoring program may return to detection monitoring (Appendix III constituents). Notification that the detection monitoring program is resuming must be posted on the CCR Web site.
 - iii. If concentrations of one or more constituents are above background but below the groundwater protection standard continue with the assessment monitoring program.

- iv. If concentrations of one or more constituents are statistically significant concentrations above the groundwater protection standard, post a notification on the CCR Web site [§257.95(g)] and characterize the nature of the release [§257.95(g)(1)].

The 2017 and 2018 results and analysis indicated that calcium, chloride, pH (low) and TDS from MW-B, and calcium and chloride from MW-D fell outside the statistical confidence intervals. This did not mean that there was a problem, but continued scrutiny was needed to assess site conditions. Continued detection monitoring proceeded in 2019. High levels of chlorides, calcium, sulfate, and TDS were observed in the 2019, 2020, and 2021 results. A closer review of the potential sources was conducted during 2020 and 2021 (Appendix B). These reviews indicated that the source was not from the CCR-regulated landfill and detection monitoring could continue.

Results of the Detection Monitoring Program – 2021

Monitoring Wells

The SEC CCR active landfill groundwater monitoring system consists of four surficial aquifer monitoring wells. These wells are named MW-A, MW-B, MW-C, and MW-D. The monitoring wells are about 20 to 25 feet deep into the surficial aquifer. MW-A has an approximate 10-foot deeper installation depth because the land surface elevation at its location is approximately 10 feet higher than at the other wells. The horizon for the monitoring interval for MW-A is the same as the interval for MW-B, MW-C, and MW-D. MW-A is considered the regional up-gradient well and the other wells are downgradient based on local groundwater levels.

Groundwater Levels and Flow

Groundwater levels in the monitoring wells were collected with each sampling event and groundwater level elevation maps were prepared. Table 2 presents the well location and water level data. Figure 4 shows a chart of the semi-annual groundwater elevations. The semi-annual groundwater level maps are provided in Figures 2 and 3. In general, there are no major changes in groundwater levels and flow patterns across the site since 2015. The 2018 values were like those measured in 2016, while 2017 showed some larger variations. The 2019 levels were about 0.3- to 0.7-foot higher than 2018 levels for the dry and wet seasons, respectively. Water levels in October 2021 were the highest recorded to date after a very wet summer. These levels were similar to the fall 2017 and fall 2020 levels and within the range monitored during the entire program, since 2015 (Figure 4). Overall, there is no substantial trend in groundwater levels as the fall 2021 levels were similar to the fall 2017 and fall 2020 levels (less than 0.4-foot difference).

Table 2. Background and Operations Period Groundwater Levels – MW-A, MW-B, MW-C, and MW-D, OUC Stanton Energy Center

2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

DATE	Well	Florida State Plane East Zone (901)		Elevation TOC (feet, NAVD88)	Depth to Water (feet)	Water Level Elevation (feet, NAVD88)
		Northing (feet)	Easting (feet)			
10/30/2015	MW-A	1504260.1	597643.8	95.77	13.6	82.17
4/29/2016					13.96	81.81
10/31/2016					13.53	82.24
4/25/2017					15.64	80.13
10/31/2017					13.31	82.46
4/27/2018					15.16	80.61

Table 2. Background and Operations Period Groundwater Levels – MW-A, MW-B, MW-C, and MW-D, OUC Stanton Energy Center

2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

DATE	Well	Florida State Plane East Zone (901)		Elevation TOC (feet, NAVD88)	Depth to Water (feet)	Water Level Elevation (feet, NAVD88)
		Northing (feet)	Easting (feet)			
10/30/2018					14.20	81.57
4/29/2019					14.82	80.95
10/31/2019					13.94	81.83
4/29/2020					15.28	80.49
10/29/2020					13.35	82.42
3/17/2021					14.47	81.30
10/13/2021					13.39	82.38
10/30/2015	MW-B	1508750.3	596609.8	86.05	4.86	81.19
4/29/2016					5.20	80.85
10/31/2016					4.90	81.15
4/25/2017					7.25	78.80
10/31/2017					4.41	81.64
4/27/2018					6.17	79.88
10/30/2018					5.59	80.46
4/29/2019					5.74	80.31
10/31/2019					4.72	81.33
4/29/2020					6.54	79.51
10/31/2020					4.21	81.84
3/17/2021					5.60	80.45
10/13/2021					3.79	82.26
10/30/2015	MW-C	1509397.7	596841.6	86.84	6.22	80.62
4/29/2016					6.56	80.28
10/31/2016					6.14	80.70
4/25/2017					8.36	78.48
10/31/2017					5.67	81.17
4/27/2018					7.35	79.49
10/30/2018					6.90	79.94
4/29/2019					6.95	79.89
10/31/2019					5.94	80.90
4/29/2020					7.80	79.04
10/31/2020					5.50	81.34
3/17/2021					6.98	79.86
10/13/2021					5.19	81.65
10/30/2015					4.89	80.21
4/29/2016					5.58	79.52
10/31/2016					5.14	79.96

Table 2. Background and Operations Period Groundwater Levels – MW-A, MW-B, MW-C, and MW-D, OUC Stanton Energy Center

2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

DATE	Well	Florida State Plane East Zone (901)		Elevation TOC (feet, NAVD88)	Depth to Water (feet)	Water Level Elevation (feet, NAVD88)
		Northing (feet)	Easting (feet)			
4/25/2017	MW-D	1508237.4	597858.3	85.10	7.44	77.66
10/31/2017					3.96	81.14
4/27/2018					5.79	79.31
10/30/2018					5.43	79.67
4/29/2019					5.65	79.45
10/31/2019					4.60	80.50
4/29/2020					5.85	79.25
10/29/2020					3.97	81.13
3/17/2021					4.45	80.65
10/13/2021					3.79	81.31

TOC - Top of casing

NAVD88 - North American Vertical Datum of 1988

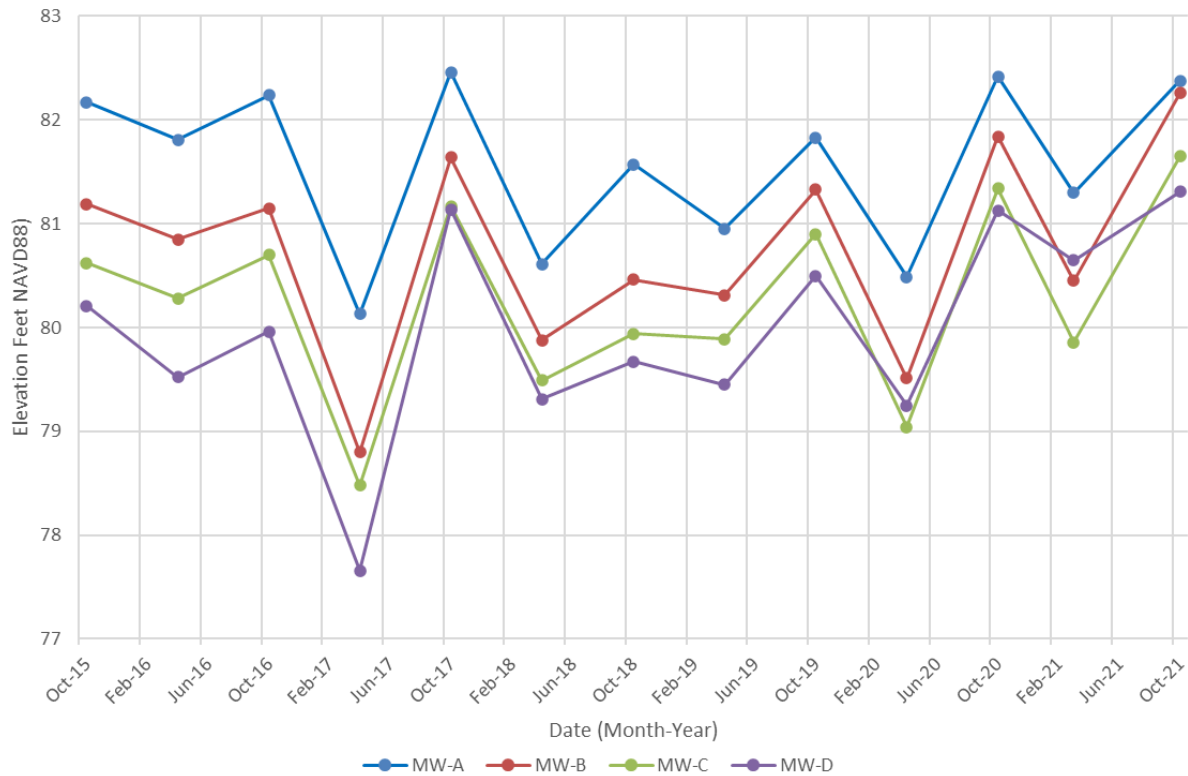


Figure 4. Quarterly Groundwater Levels

2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

Groundwater Sampling and Laboratory Analysis

The detection monitoring program began with establishing background groundwater quality conditions that consisted of collecting and analyzing quarterly samples between September 2015 and July 2017 for Appendix III and IV constituents. Sampling events to establish background water quality conditions were completed by October 17, 2017 in accordance with §257.94(b). MW-A is the background well and MW-B, MW-C, and MW-D are the three wells to monitor for compliance with the CCR.

Based on the October 2017 results, OUC resampled MW-B for calcium, chloride, pH (low), and TDS; and MW-D for calcium and chloride on January 25, 2018. The resampled data were evaluated against the October 30, 2017 background sample results to determine the next action. Two parameters were confirmed to be a potential statistically significant increase (SSI), pH and total dissolved solids (TDS) in MW-B. The apparently confirmed well-constituent pairs identified for an SSI at well MW-B may not be an SSI due to lack of a sufficient quantity of background data.

Several parameters being monitored had trends noted during the CCR background period. In the past, the upper probability limits (UPL, and lower probability limit [LPL] for pH) were tested by modifying the baseline UPL/LPL with the trend parameter. This made the limits slope with time, and in some instances the limits approached zero - which is not feasible. Because it was difficult to see the change over time when both the observed data and probability limits vary, starting with the 2019 annual report the UPL/LPL were held constant and the observed data were adjusted by the trend parameters (that is, “detrended” by applying the slope parameter to the observed data as shown by example on the bottom of Table 3). Time series plots were created to show the change in the observations over time against a constant limit. These plots are discussed further in the next section.

The 2021 semi-annual sampling results are shown in Table 4 (and Appendix C). The following results are noted:

- The March 7, 2021 compliance monitoring sampling event resulted in the identification of potential SSIs at 3 wells for similar constituent pairs. For constituents that resulted in potential SSIs relative to detrended UPL, resampling was completed on June 28, 2021 for the following wells and constituents:
 - Well MW-B for calcium, chloride, pH, and TDS. Retesting was done because the sampled concentrations were high when compared to the baseline data and were outside of their limits because of the trend adjustment. The detrended retest values were similarly outside of their respective probability limits. Observed pH was measured within acceptable levels, but the negative trend established for statistical baseline analysis needs to be reevaluated.
 - Well MW-C for calcium, pH, and TDS. Retesting was conducted and calcium was below the detrended UPL while both pH and TDS remained above the detrended UPL. Additional discussion is included below on alternative sources.
 - Well MW-D for calcium, chloride, pH, fluoride, sulfate, and TDS. The detrended retest values were similarly outside of their respective probability limits. Also, observed pH was lower than the LPL which was also part of a longer-term trend at the site that should be re-evaluated with additional data. Fluoride values were high, but because of high dissolved solids, it is possible that fluoride may not be accurately represented in low concentrations.
- The September 14, 2021 compliance monitoring sampling event resulted in the identification of potential SSIs of similar constituents at 3 wells. For constituents that resulted in potential SSIs relative to detrended UPL, resampling was completed on October 26, 2021 for the following wells and constituents:
 - Well MW-B for calcium, chloride, pH, and TDS. The detrended retest values were similarly outside of their respective probability limits. Observed pH was measured

within acceptable levels, but the negative trend established for statistical baseline analysis needs to be reevaluated.

- Well MW-C for calcium, pH, and TDS; with levels similar to the March sampling. The detrended retest values were similarly outside of their respective probability limits.
- Well MW-D for calcium, chloride, pH, fluoride, sulfate, and TDS. While the chloride, fluoride, sulfate, and TDS observed values were lower than the spring sampling event, calcium and pH remained approximately the same. The retest values were higher than originally collected, except for fluoride, which was undetected.

Table 3. Detection Monitoring Parameters Tolerance Limits and Trend Parameters

2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

Well	Constituent	UPL	LPL	Unit	Limit Trend Slope	Detrended
MW-B	Boron	41.2		ug/L	0.1064	Y
	Calcium	30,000		ug/L	-37.26	Y
	Chloride	123,000		ug/L	-127.1	Y
	Fluoride	230		ug/L		
	pH	4.55	3.87	pH Units	0.0008951	Y
	Sulfate	61,300		ug/L		
	TDS	292,000		ug/L	-195.8	Y
MW-C	Boron	31.1		ug/L		
	Calcium	8,370		ug/L		
	Chloride	8,550		ug/L	12.5	Y
	Fluoride	100		ug/L		
	pH	5.73	5.03	pH Units	-0.0004337	Y
	Sulfate	2,370		ug/L		
	TDS	70,800		ug/L		
MW-D	Boron	32.6		ug/L		
	Calcium	5,730		ug/L	-3.194	Y
	Chloride	18,000		ug/L	11.3	Y
	Fluoride	120		ug/L		
	pH	6.23	4.92	pH Units	-0.002029	Y
	Sulfate	330		ug/L		
	TDS	114,000		ug/L		

UPL and LPL are the upper and lower probability limits. These are also referred to as the tolerance levels.

µg/L = micrograms per liter

“Detrended” means that the data need to be adjusted for the trend. The trend is applied to the days since the baseline period began (9/9/2015) to the observed data. The trend’s case is opposite when applied to the data; for example, boron March 28, 2019 adjustment is $-0.1064 \times 1296 \text{ days} = -138 \text{ ug/L}$. The detrended March 2019 boron value is $112 - 138 = -26 \text{ ug/L}$.

Table 4. Summary of the 2021 Annual Data Detection Monitoring Results
2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

Well	Constituents Units LPL UPL Trend					First Semi-Annual Sampling Event on 3/7/2021 and Retesting on 6/28/2021						Second Semi-Annual Sampling Event on 9/14/2021 and associated Retesting on 10/26/2021							
						Observed Value	Detrended / Observed Value	Within Compliance	Is Retesting Required?	Retest Values	Detrended Retest Value	SSI	Observed Value	Detrended / Observed Value	Within Compliance	Is Retesting Required?	Retest Values	Detrended Retest Value	SSI Confirmed
MW-B	Boron	ug/L		41.2	Y	147.0	-66.4	Yes					99.0	-135.0	Yes			NA	
	Calcium	ug/L		30,000	Y	4,340	79,084	No	Yes	2,350	81,304	Yes	6,950	88,810	No	Yes	7,470	90,895	Yes
	Chloride	ug/L		123,000	Y	20,100	275,063	No	Yes	13,000	282,325	Yes	29,300	308,539	No	Yes	28,900	313,477	Yes
	pH	pH Units	3.87	4.55	Y	4.68	2.88	No	Yes	4.49	2.59	Yes	4.30	2.33	No	Yes	4.42	2.42	Yes
	Fluoride	ug/L		230		60	60	Yes					80	80	Yes				NA
	Sulfate	ug/L		61,300		34,300	34,300	Yes					32,200	32,200	Yes				NA
	TDS	ug/L		292,000	Y	121,000	513,775	No	Yes	99,000	513,900	Yes	136,000	566,173	No	Yes	125,000	563,396	Yes
MW-C	Boron	ug/L		31.1		11.0	11.0	Yes					10.0	10.0	Yes				NA
	Calcium	ug/L		8,370		10,100	10,100	No	Yes	8,190	8,190	No	10,300	10,300	No	Yes	11,200	11,200	Yes
	Chloride	ug/L		8,550	Y	24,900	-175	Yes					26,000	-1,463	Yes				NA
	pH	pH Units	5.03	5.73	Y	5.27	6.14	No	Yes	4.99	5.91	Yes	4.93	5.88	No	Yes	5.15	6.12	Yes
	Fluoride	ug/L		100		100	100	Yes					100	100	Yes				NA
	Sulfate	ug/L		2,370		310	310	Yes					210	210	Yes				NA
	TDS	ug/L		70,800		107,000	107,000	No	Yes	96,000	96,000	Yes	102,000	102,000	No	Yes	95,000	95,000	Yes
MW-D	Boron	ug/L		32.6		17.0	17.0	Yes					16.0	16.0	Yes				NA
	Calcium	ug/L		5,730	Y	776,000	782,407	No	Yes	742,000	748,768	Yes	775,000	782,017	No	Yes	1,040,000	1,047,151	Yes
	Chloride	ug/L		18,000	Y	2,420,000	2,397,332	No	Yes	2,320,000	2,296,055	Yes	1,920,000	1,895,174	No	Yes	2,760,000	2,734,699	Yes
	pH	pH Units	4.92	6.23	Y	4.20	8.27	No	Yes	4.22	8.52	Yes	4.42	8.88	No	Yes	4.15	8.69	Yes
	Fluoride	ug/L		120		440	440	No	Yes	200	200	Yes	270	270	No	Yes	ND	ND	No
	Sulfate	ug/L		330		153,000	153,000	No	Yes	154,000	154,000	Yes	149,000	149,000	No	Yes	218,000	218,000	Yes
	TDS	ug/L		114,000		6,450,000	6,450,000	No	Yes	6,960,000	6,960,000	Yes	5,980,000	5,980,000	No	Yes	7,320,000	7,320,000	Yes

SSI - statistically significant increase; LPL - lower probability limit; UPL - upper probability limit

Data Discussion

Considering the original baseline date and the 2017 through 2021 data, the original trends estimated on the smaller background dataset seemed to be inaccurate for some constituents at MW-B: boron, pH, and sulfate. Figure 5 shows the detrended data over time. Since these few parameters have consistent trends after adjustment, it is probable that their original baseline trend analysis was not representative. For accurate trends, the time series plots of the detrended data should be relatively flat, like it is for MW-C pH and sulfate. MW-B pH and sulfate had no trend in the original analysis, but it appears to be trending given the larger dataset. Concurrent with the development of this annual report, the 2015 through 2021 dataset was statistically reanalyzed to update baseline conditions and more accurately represent groundwater quality trends for each constituent. A summary of this analysis is included in Appendix A.

For other data, the time series plot indicated that there could have been a change occurring around 2017. The chlorides, calcium, sulfate, and TDS concentrations started to raise in mid-2017 in MW-B and MW-D by 2018 (Figures 5 and 6). However, during 2020 there was a significant increase in these four parameters which indicated that there is a potential new source or introduction of inorganic minerals in the shallow groundwater. The previous annual reports and alternative source evaluation demonstrated a likely alternative source, like the limerock storage pile located near MW-D (CH2M 2020b). While water quality data in fall of 2020 indicated a decreasing trend after the removal of the limerock storage area, increasing trends are noted in both spring and fall 2021 results.

Potential Alternative Sources Review

MW-B and MW-D are not close to the new, double-lined CCR landfill subject to this regulation. MW-B is approximately 3,125 linear feet and MW-D is about 2,600 linear feet from the new landfill. MW-C is further north. The rise in calcium, chloride, sulfate, and TDS concentrations measured in these monitoring wells started in mid-2017, approximately 780 days from the initiation of storing CCR material in the active landfill. The calculated groundwater flow rate in the western part of the site is between 0.105 and 0.405 feet per day under the typical groundwater gradient measured on site. The groundwater travel time from the northern edge of active cell of the new landfill to any compliance monitoring well is expected to be greater than 17 years (Appendix B).

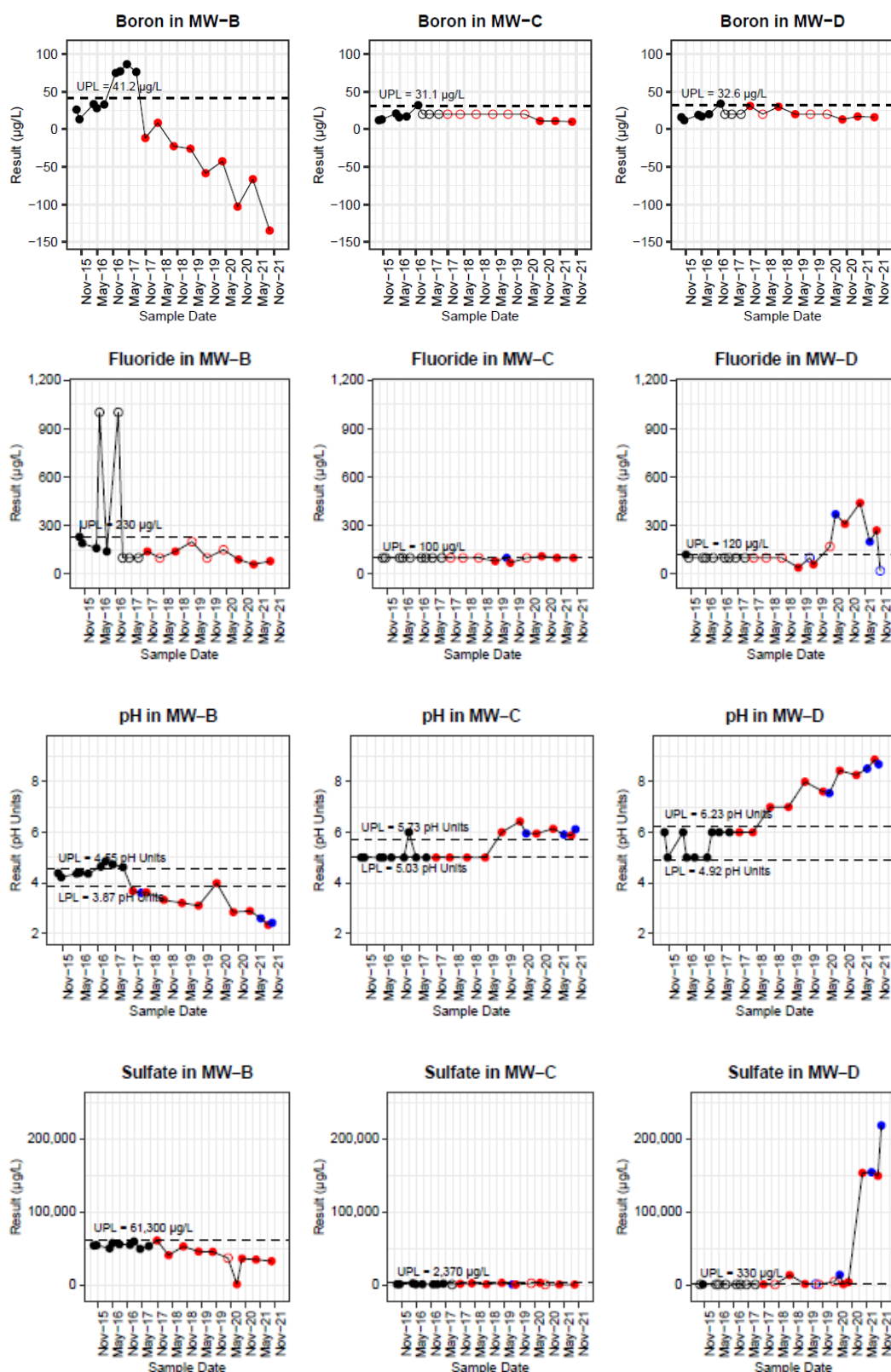
MW-B is closer to the western boundary of the property than MW-D and the water level elevation in MW-B is consistently about 0.2- to 1.0-foot higher than the elevation in MW-D (Table 2 and Figure 4). Since MW-B chlorides, calcium, and TDS concentrations appeared to rise sooner than at MW-D, it is possible that there is an influence entering offsite from the west. MW-D is not directly downgradient of MW-B. MW-C is closer to MW-B and is downgradient, yet it is not experiencing a similar rise in calcium, chlorides, sulfate, or TDS (a slight rise, but not as much). Consequently, the very high constituents in MW-D do not appear to be coming from the west or northwest.

Sample results from the first semi-annual sampling event conducted on March 7, 2021 required retesting for identified potential SSIs at wells MW-B, MW-C, and MW-D for pH, fluoride, sulfate, calcium, chloride, and total dissolved solids (requirements varied per well). After checking the results with the lab and retesting on June 28, 2021, the potential SSIs were confirmed at MW-D for calcium, chloride, pH, fluoride, sulfate, and TDS. In fact, some of the detrended concentrations for these parameters were orders of magnitude different from the baseline data (60 to 130 times the upper limit). The pH was also greater than the upper limit when the baseline detrend was applied, but the value of 4.22 standard units is not a water quality issue. The fluoride concentration at MW-D was also higher than the statistical upper limit. However, because of high dissolved solids, it is possible that fluoride may not be accurately represented by laboratory analysis when measured in low concentrations. The detrended calcium, chloride, pH and TDS concentrations were also potential SSIs at MW-B in the retest results (potential

SSIs), but only about 2.5 times the upper limit. At MW-C resampling was completed for pH and TDS. The pH retest value was 5.27 standard units and while that was a potential SSI when detrended with baseline information, it was not a water quality issue. The TDS retest concentration was approximately the same as the March concentration and remained a potential SSI.

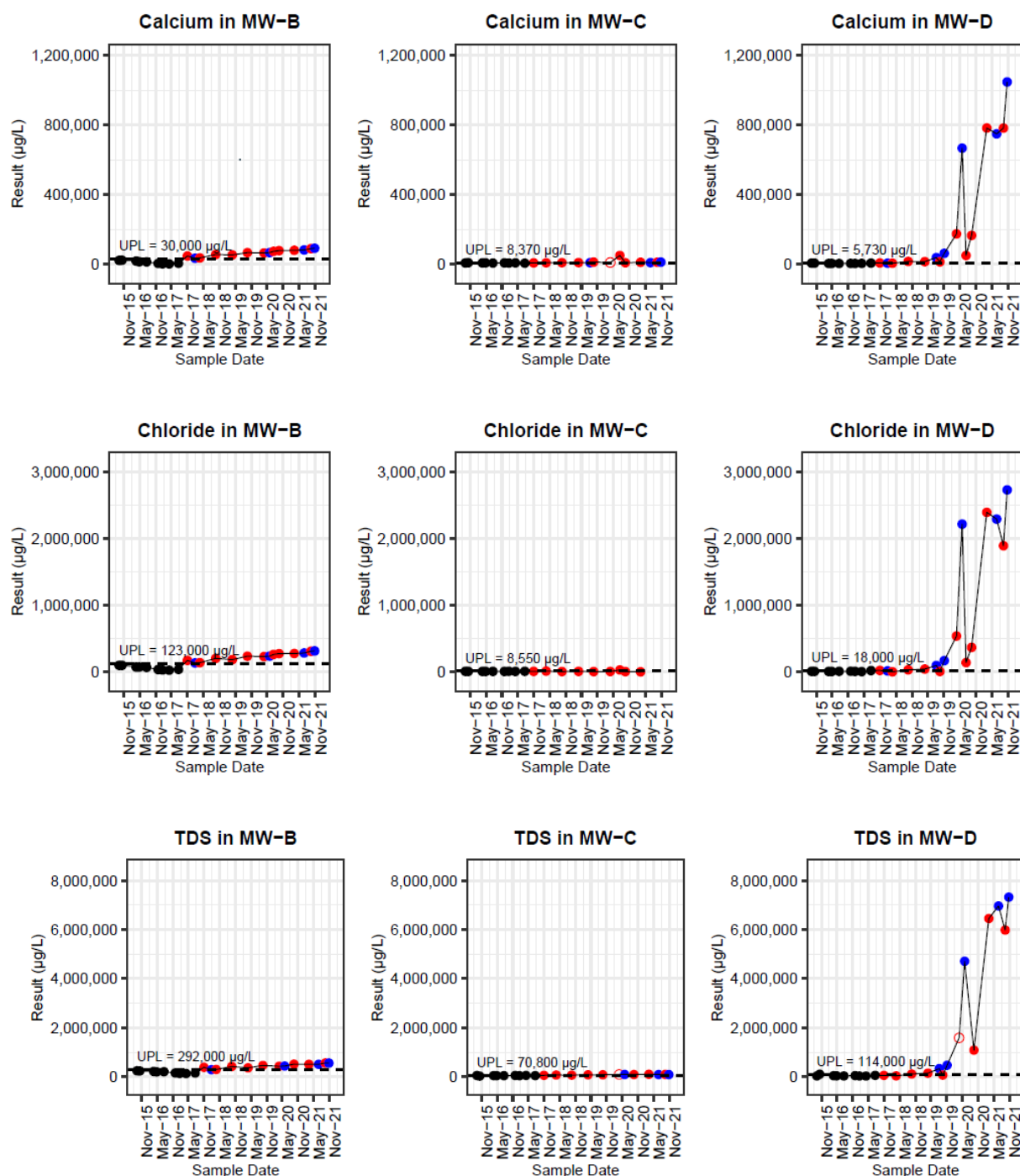
The results of the September 14, 2021 second semi-annual sampling event also indicated potential SSIs for calcium, chloride, pH, fluoride, sulfate, and TDS at the three wells. Retesting results collected on October 26, 2021 identified potential statistically significant increases for calcium, chloride, pH, sulfate, and TDS (results vary by well). It was determined that the elevated concentrations at MW-D for calcium, chloride, pH, sulfate, and TDS could not be explained by statistical analysis alone. Detrended concentrations for these parameters were orders of magnitude different from the baseline data (60 to 180 times the upper limit). The pH was also greater than the upper limit when the baseline trend was applied, but the value of 4.15 standard units is not a water quality issue. The fluoride concentration at MW-D was also higher than the statistical upper limit for the September 14, 2021 sample but was not detected in the resample. The detrended calcium, chloride, pH, and TDS concentrations were also exceeded their respective UPLs at MW-B in the retest results (potential SSIs), but only about 2.5 times the upper limit. At MW-C resampling was completed for calcium, pH, and TDS. The calcium concentration measured in the September sample was elevated compared to both UPL and the March sampling event. Retest results confirmed that elevated calcium concentrations represent a potential statistically significant increase. The pH retest value was 5.15 standard units and while that was high compared to baseline, it was not a quality issue. The TDS retest concentration was similar to the September concentration and remained a potential statistically significant increase.

The statistical baseline and trend analysis was repeated in 2021 (Appendix A) to update the original trend estimates that were made with the limited initial data set (as required by the CCR Rule). The results of this 2021 analysis provided updated UPL and LPL (for pH) that characterize each well over a longer period (September 2015 to September 2021). The updated baseline trend analysis resulted in revised thresholds for UPLs that would have eliminated the SSI categorization of the 2021 sampling data for calcium, chloride, pH, and TDS in MW-B and MW-C. The same analysis would have eliminated SSIs at MW-D for pH and fluoride. As a result, the updated statistical baseline analysis better characterizes the historical data and trends at each well in the CCR monitoring program.



Black dots are background data; red dots are detection data; blue dots are resampled data

Figure 5. Well-Constituent Results that are Candidates for Updated Trend and Limit Analysis
2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report



Black dots are background data; red dots are detection data; blue dots are resampled data

Figure 6. Candidate Well-Constituent Pairs that are Candidates Additional Analysis for Alternative Sources
 2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

During 2020, after SSIs were monitored, a demonstration was made that these were from an alternate source (CH2M 2020b). As discussed in the 2020 Annual Report, there was limerock stored near MW-D which could be a source of the type of constituents observed rising. Identifying an alternative source other than the CCR landfill met the requirement of the CCR Rule to continue in the Detection Monitoring program. Since the concentrations in MW-D elevated relative to than at the other MWs, and it is primarily calcium, chloride, sulfate, and TDS at issue, the discussion focuses primarily on these four

constituents. High calcium, chloride, and sulfate values would contribute to the high TDS values, as well as other dissolved salts and minerals.

Additional groundwater samples from the four CCR MWs have been collected since July 13, 2020 for a suite of major anions and cations for a geochemical analysis to identify if the groundwaters at the MWs are from different sources. These parameters for geochemical pattern analysis included: bicarbonate/carbonate (HCO_3/CO_3), chloride (Cl), sulfate (SO_4), calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na).

Site Conditions near MW-D

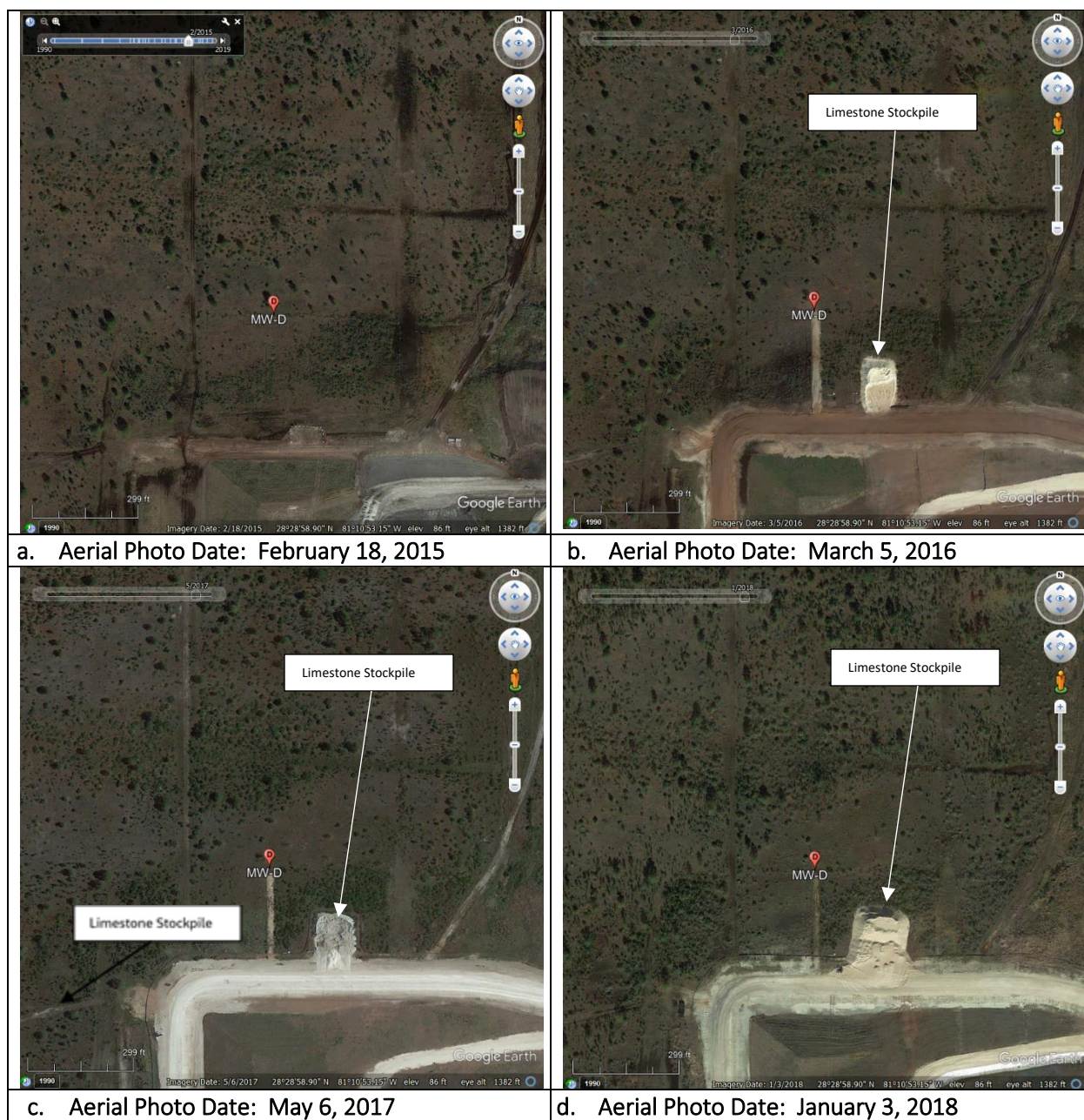
During the CCR monitoring history a stockpile of crushed limestone (also called limerock) to support landfill operations was placed near MW-D. Aerial photographs of presence and positions of the stockpile at six different times are presented in Figures 7a through 7f. The MWs wells were installed in August 2015 and the limestone stockpile was not observed during the time of MW construction; therefore, the February 18, 2015 aerial photograph represents the preconstruction condition at the site. Over time the stockpile grew and the position of the northwest corner of the stockpile came within approximately 75 feet of MW-D. It was hypothesized that stormwater runoff from the pile could have impacted groundwater quality at MW-D through direct infiltration and groundwater transport, or overland flow then infiltration and groundwater transport around the general area. The stockpile was removed in January 2020 (Figures 7g and 7h). The spike in TDS-related data occurred in 2020, so it is possible that there was a residual influence of the near-surface groundwater from the stockpile, or perhaps, the removal efforts mixed limerock into the surface soil causing the spike in concentrations. The concentrations of calcium and chloride dropped in September of 2020 nearly as precipitously as they increased but returned to potential SSIs in March and September of 2021. Additional site investigations were completed as part of an alternative source analysis (Appendix B).

This 2021 alternative source analysis focused on the hydrogeologic conditions on the western portion of the site between MW-D and the active landfill. New hydrogeologic data for the surficial aquifer was collected near the MWs. The results of this investigation found that groundwater travel time from the northern edge of active cell of the new landfill to either monitoring well is expected to be greater than 17 years. Because the active CCR landfill cell is relatively new (6 years old) and located far away from the compliance MWs, is highly unlikely that the groundwater at MW-B, MW-C, and MW-D is from the active cell of the CCR landfill. As a result, additional monitoring is needed to identify longer term residual groundwater quality trends at MW-D.

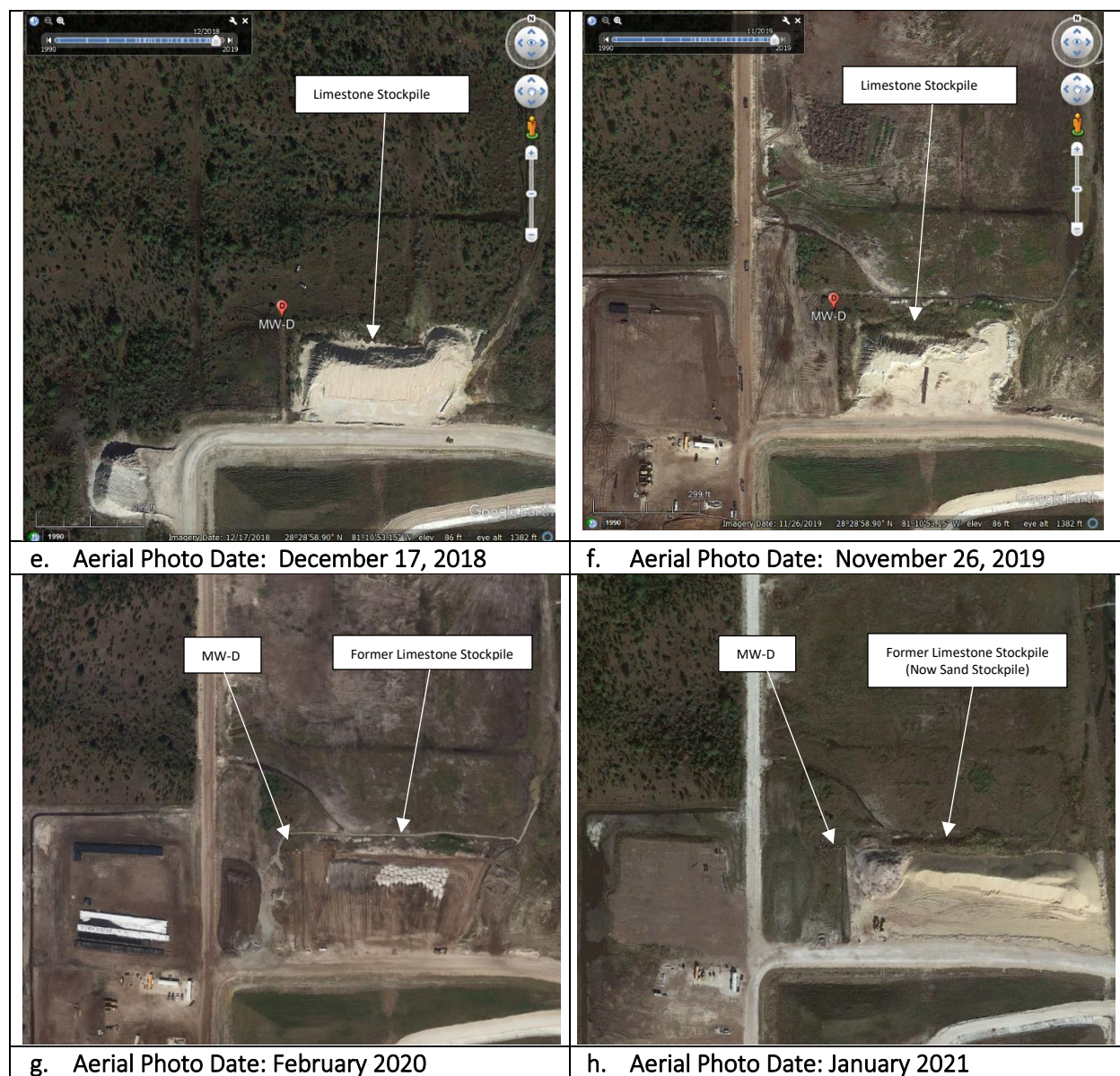
From 2019 to 2021 OUC constructed a new CCR landfill cell adjacent to and north of the current one. Like the existing cell, it is lined in accordance to state municipal solid waste rules. The land to the southwest and west of MW-D was cleared and grubbed to support this construction, which also could have had hydrologic impacts to the near-surface groundwater during 2020. The groundwater table is approximately 2-feet below land surface in this area and the MWs are 30 feet deep with the screened intervals from 20 to 30 feet deep (screens fully submersed in the groundwater). As the new cell was excavated (since fall 2019) additional rainfall and runoff could have been retained and percolated into the ground between the CCR landfill and the MWs. Now that the new cell is lined, this area should cease contributing stormwater and recharge but there could be a time lag. MW-D is over 2,600 feet from the north side of existing cell and 1,200 feet from the north side of the new cell. The work staging area was built about 300 feet from MW-D and a new haul road is adjacent to it (Figure 7f). MW-B, which also had elevated TDS, is about 3,200 feet from the existing CCR cell and 1,700 feet from the new cell excavation. MW-C is the furthest north and away from the existing landfill (about 3,800 feet) and disturbed soils, and it had the lowest elevated TDS concentrations.

A longer sampling period of CCR Appendix III Constituents for Detection Monitoring plus major ions is necessary to evaluate if the nature of the results is temporary.

Figures 7a through 7h. OUC CCR Groundwater Monitoring MW-D Area Over Time
2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report



Figures 7a through 7h. OUC CCR Groundwater Monitoring MW-D Area Over Time
2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report



Geochemical Pattern Analysis

During sampling events starting in July of 2020, OUC has sampled the four CCR MWs for a suite of major ions for geochemical pattern analysis using the method described by Piper (1944). The results of the March 2021 sampling are presented in Table 5. The results from the September 2021 sampling are shown in Table 6. The low percent difference between the total cations and anions indicate that the basic geochemistry constituents are in balance at each MW and suitable to use for the pattern analysis.

Piper's graphical method plots the equivalent concentration results (milliequivalents per liter, meq/L) of the sampled common water ions over a diamond grid. Sample results that plot close to one another are geochemically similar indicating a possible common source; sample results that do not plot close to one another are geochemically dissimilar indicating different sources.

The equivalent ion concentrations were plotted (percent meq/L) and aligned to a geochemical facies pattern, as presented by hatari labs (2018). The overlay of the OUC CCR results and the facies pattern are presented in Figures 8 through 11 for MW-A, MW-B, MW-C, and MW-D, respectively. The data were very similar between sampling events, except for MW-D. The results of the procedure show that the position of the MW-D groundwater (as indicated by the inverted magenta triangle) plot away from the positions of the groundwater from the other three monitoring wells but are slowly trending toward the position of MW-A. The results indicate that groundwater at MW-D plots as calcium-chloride-type water, while MW-A and MW-C plot as transitional mixed type and sodium-chloride-type water and MW-B plots as sodium-chloride-type water.

Table 5. March 7, 2021 Geochemical Sampling Results with Ion Balances*2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report*

Well	Anions				Cations			
	Cl	CO ₃	HCO ₃	SO ₄	Ca	Mg	Na	K
	Concentration (mg/L)							
MW-A	18,400	0.0	0.0	1,160	5,010	3.8	4,860	1,490
MW-B	20.1	0.0	3.0	34.3	4.3	2.3	12.9	9.7
MW-C	24.9	0.0	15.0	0.3	10.1	0.8	9.2	1.0
MW-D	2,420	0.0	0.0	153.0	776.0	15.9	564	190
	Concentration (meq/L)							
MW-A	519	0.0	0.0	24.2	250.0	0.3	211	38.1
MW-B	0.6	0.0	0.1	0.7	0.2	0.2	0.6	0.2
MW-C	0.7	0.0	0.3	0.0	0.5	0.1	0.4	0.0
MW-D	68.3	0.0	0.0	3.2	38.7	1.3	24.5	4.9
	Percentage of meq/L							
MW-A	96%	0%	0%	4%	50%	0%	42%	8%
MW-B	42%	0%	4%	53%	18%	16%	46%	20%
MW-C	70%	0%	30%	1%	51%	7%	40%	3%
MW-D	96%	0%	0%	4%	56%	2%	35%	7%
Well	Ion Balance							
	Sum of Anions	Sum of Cations	Ion Balance					
MW-A	543.1	499.8	4.2%					
MW-B	1.3	1.2	4.9%					
MW-C	1.0	1.0	0.5%					
MW-D	71.4	69.4	1.4%					

Notes:

Bicarbonate (HCO₃), carbonate (CO₃), chloride (Cl), sulfate (SO₄), calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na)
 mg/L= milligram per liter; meq/L = milliequivalents per liter

Percentage meq is the percent of the sum of the four anions/cations listed

The ion balance was calculated (in meq/L) as the total dissolved-anions concentration minus the total dissolved-cation concentration divided by the total concentration of ions

Table 6. September 14, 2021 Geochemical Sampling Results with Ion Balances*2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report*

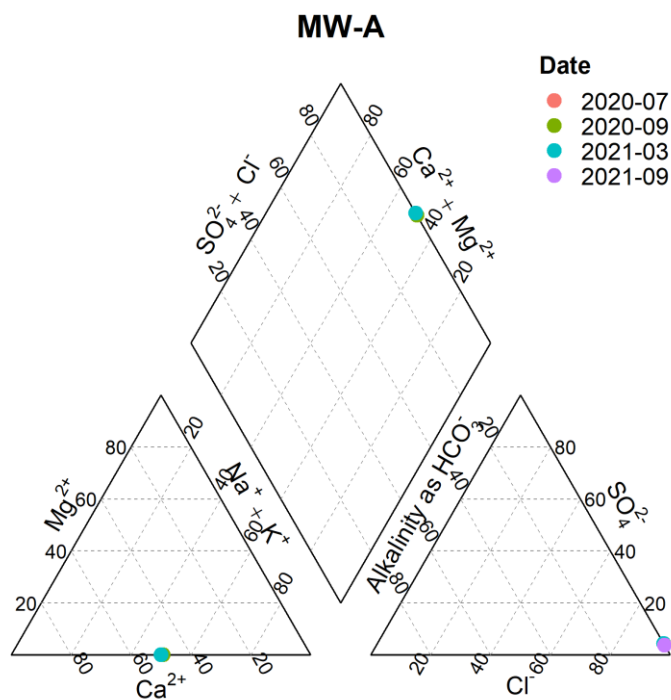
Well	Anions				Cations			
	Cl	CO ₃	HCO ₃	SO ₄	Ca	Mg	Na	K
	Concentration (mg/L)							
MW-A	17,800	0.0	1.0	977	5,580	4	5,090	1,510
MW-B	29.3	0.0	3.0	32.2	6.95	2.49	20.6	3.13
MW-C	26.0	0.0	15.0	0.21	10.3	0.99	9.87	1.17
MW-D	1,920	0.0	1.0	149	775	27.9	383	25.3
	Concentration (meq/L)							
MW-A	502	0.0	0.02	20.34	278.46	0.33	221.40	38.62
MW-B	0.83	0.0	0.06	0.67	0.35	0.20	0.90	0.08
MW-C	0.73	0.0	0.30	0.00	0.51	0.08	0.43	0.03
MW-D	54.16	0.0	0.02	3.10	38.67	2.30	16.66	0.65
	Percentage of meq/L							
MW-A	96%	0%	0%	4%	52%	0%	41%	7%
MW-B	53%	0%	4%	43%	23%	13%	59%	5%
MW-C	71%	0%	29%	0%	49%	8%	41%	3%
MW-D	95%	0%	0%	5%	66%	4%	29%	1%
Well	Ion Balance							
	Sum of Anions	Sum of Cations	Ion Balance					
MW-A	522.4	538.8	-1.5%					
MW-B	1.6	1.5	0.9%					
MW-C	1.0	1.1	-0.8%					
MW-D	57.3	58.3	-0.9%					

Notes:

Bicarbonate (HCO₃), carbonate (CO₃), chloride (Cl), sulfate (SO₄), calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na)
 mg/L= milligram per liter; meq/L = milliequivalents per liter

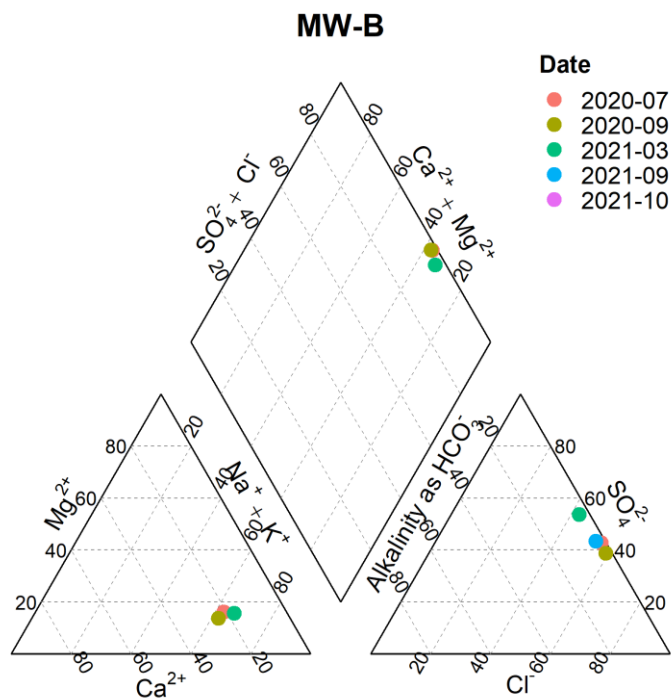
Percentage meq is the percent of the sum of the four anions/cations listed

The ion balance was calculated (in meq/L) as the total dissolved-anions concentration minus the total dissolved-cation concentration divided by the total concentration of ions



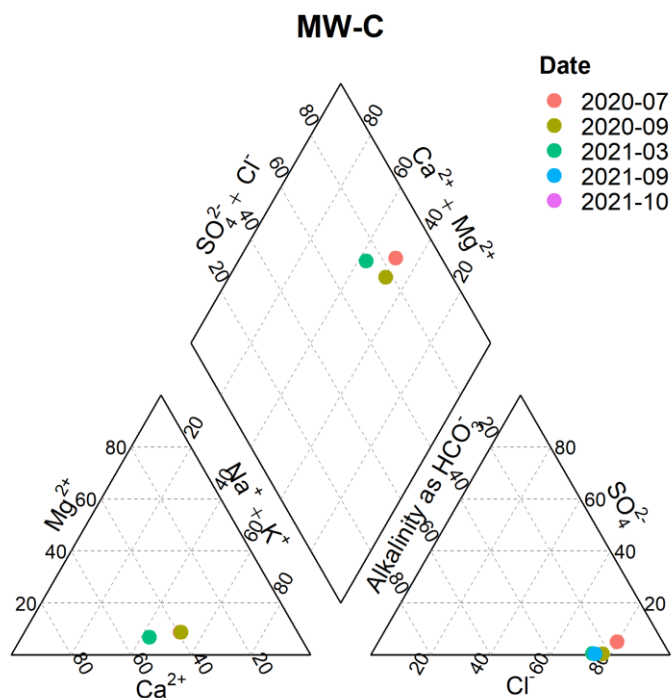
Note that data points overlap and may not be seen.

Figure 8. MW-A Results of Geochemical Facies Pattern and Analysis Results (after hatari labs 2018)
 2020 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report



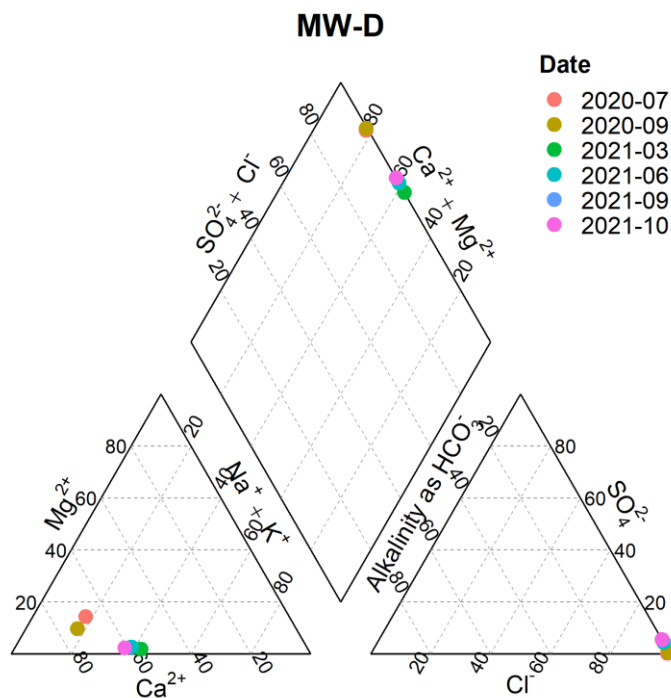
Note that data points overlap and may not be seen.

Figure 9. MW-B Results of Geochemical Facies Pattern and Analysis Results (after hatari labs 2018)
 2020 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report



Note that data points overlap and may not be seen.

Figure 10. MW-C Results of Geochemical Facies Pattern and Analysis Results (after hatari labs 2018)
 2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report



Note that data points overlap and may not be seen.

Figure 11. MW-D Results of Geochemical Facies Pattern and Analysis Results (after hatari labs 2018)
 2021 Coal Combustion Residuals Annual Groundwater Monitoring and Corrective Action Report

Conclusion

The general purpose of the 2021 annual report is to document the results of the CCR detection monitoring conducted at OUC SEC. The results indicated that analyses of several parameter fell outside the expected statistical significance interval based on the original background analysis of the CCR data. These statistically significant increases are derived from a comparison of the results to a statistical analysis of a limited number of background readings.

The statistical baseline and trend analysis was repeated in 2021 (Appendix A) to update the original trend estimates that were made with the limited-sized data set. The results of this 2021 analysis provided updated UPL and LPL (for pH) that characterize each well over a longer period (September 2015 to September 2021). The updated baseline trend analysis resulted in revised thresholds for UPLs that would have eliminated the SSI categorization of the 2021 sampling data for calcium, chloride, pH, and TDS in MW-B and MW-C. The same analysis would have eliminated SSIs at MW-D for pH and fluoride. As a result, the updated statistical baseline analysis better characterizes the historical data and trends at each well in the CCR monitoring program. Starting in 2022, the detection monitoring results will be conducted using the updated baseline prediction limits.

If a potential SSI is verified using the detection monitoring program, the site assessment monitoring program must be initiated for all monitoring wells within 90 days and continue at semiannual frequency. Alternately, the owner of the facility must demonstrate that a source other than the CCR unit is responsible for the increase. The CCR landfill is relatively new (6 years old) and located away from the compliance MWs. Groundwater does not move very quickly along the low gradient landscape at OUC SEC. Additional site investigations were completed as part of an Alternative Source Analysis (Appendix B). This analysis focused on the hydrogeologic conditions on the western portion of the site between MW-D and the active landfill and found that groundwater travel time from the northern edge of the active landfill cell to either monitoring well is expected to be greater than 17 years. Results of this analysis indicated that the groundwater quality at MW-D cannot yet be influenced by the new CCR landfill and that an alternate source is responsible for the water quality at MW-D.

A review of the site conditions indicates that a limerock pile was a possible contributor to concentration increases in MW-D. From this analysis it is concluded that the groundwater at MW-D is of different geochemical type of a different source of that from MW-A, MW-B, and MW-C. The limerock was a potential alternative source located near MW-D for several years and the analysis supports a potential alternate source for the statistically significant increases at MW-D and MW-B. The limerock pile located near MW-D was removed January 2020 and land restored. MW-C data indicate the results are in range of natural variability. Because calcium and chloride are mobile dissolved ions, there could have been a widespread groundwater influence from the clearing and grubbing of the area for the new construction. High TDS is associated with these high ion concentrations too.

Based on the review of the data against projected trends, potential sources of constituents from surrounding land uses, and the principal component analysis (PCA) conducted in 2018, it is concluded that statistically significant increases of constituents are not verified to be from the CCR and it is not appropriate to proceed to assessment monitoring. There is reasonable documentation that the high concentration of dissolved ions is from an alternative source and that continued Detection Monitoring is recommended with additional ionic groundwater data collection so this situation can continue to be reviewed.

References

For detailed discussions of multivariate statistical methods and underlying mathematical theory, the reader is referred to the books by Jolliffe (1986) and Johnson and Wichern (2007).

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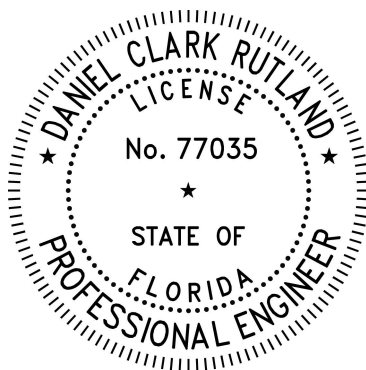
Appendix A
Update of Background Water Quality Concentrations for
the OUC SEC CCR Landfill Detection Monitoring Program

Update of Background Water Quality Concentrations for the Orlando Utilities Commission Stanton Energy Center CCR Landfill Detection Monitoring Program

PREPARED FOR: Orlando Utility Commission
PREPARED BY: CH2M HILL Engineers, Inc.
DATE: January 28, 2022
PROJECT NUMBER D3292400

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Objective

This technical memorandum (TM) documents the analysis to update the existing groundwater quality background limits used at the Orlando Utilities Commission (OUC) Stanton Energy Center (SEC) by incorporating the detection monitoring data collected since the last background water quality was established in 2017. The objective of this work is to develop appropriate statistical methods so that the future detection monitoring samples can be tested against limits that best represent the current background conditions.

Background

The Coal Combustion Residuals (CCR) Rule created three phases of groundwater monitoring that include: detection, assessment, and corrective action. The main objective of this report is to update background values for the detection monitoring phase. The detection monitoring phase assumes that groundwater is clean or not impacted under the CCR Rule. The main objective of detection monitoring is to determine if a statistically significant increase (SSI) greater than background concentrations for Appendix III constituents have been observed. Therefore, detection monitoring continues until an SSI above background is observed. An observed SSI must be large enough to account for the inherent uncertainty and variability in the data.

The detection monitoring consists of the seven constituents listed in Appendix III of the CCR Rule. Specifically, detection monitoring is performed for the following constituents:

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

The focus of background development and detection monitoring is limited to the selected detection monitoring constituents. Monitoring data for other constituents may be collected and reported, but they are not directly incorporated into the formal CCR Rule detection monitoring assessment. By limiting the statistically evaluated constituents to the most useful indicators, the overall number of statistical tests can be reduced to help meet the site-wide false-positive rate (SWFPR). Fewer tests also imply a lower single test false negative error rate, and therefore an improvement in statistical power.

The basic assumption in detection monitoring is that the facility is not impacting groundwater unless statistically demonstrated otherwise. Statistical comparisons are made between background and downgradient detection wells (interwell comparisons), or over time in a single well (intrawell comparisons), to identify significant changes in groundwater quality that may be caused by the facility.

The initial step in developing a detection monitoring program is establishing background concentrations for the required constituents. Appropriate and representative background data is the single most important factor to a successful statistical groundwater monitoring program (EPA 2009). Representative background data show numerical characteristics closely matching those arising from the site-specific aquifer being evaluated. Background data must also be appropriate to the statistical test. All detection monitoring tests involve comparisons of detection point data against the established background limits. A minimum of 8 to 10 independent background samples are generally required for most parametric statistical tests, but as many background data points as possible are preferable to provide adequate statistical power to control false-positive and false-negative errors. Unlike parametric statistical tests, the nonparametric statistical tests require a large sample size to meet the false-positive and false-negative requirements (EPA 2009).

Because of natural temporal changes in ambient groundwater quality and the need for sufficiently large sample sizes for statistical analysis, background data should not be regarded as a single fixed quantity. If natural groundwater conditions change over time during the collection of detection monitoring data, comparisons against previously established backgrounds may not be appropriate. EPA (2009) recommends that background should be updated periodically.

Review of the Existing Data

EPA (2009) recommends that all observations designated as background should be evaluated periodically (2 to 3 years for semi-annual sampling) to ensure that they still adequately reflect the current natural or baseline groundwater conditions to help establish appropriate and representative background limits. In general, the set of new observations is statistically compared to the existing background data, as appropriate. If the data are found to be comparable, then the new data set is combined with the existing background data set to re-establish the statistical background limits. If the data are shown to be significantly different, then

the data will be reviewed to evaluate the cause of the difference. Absence evidence of a release, the new data should be considered more representative of present-day groundwater conditions and used for background. Thus, to update the background limits, both the initial background data and the detection data were reviewed so that an updated background data set representing the current conditions can be established. The available data comprised of:

- The OUC SEC CCR groundwater monitoring network is comprised of 4-wells, one upgradient well MW-A, and three downgradient wells (MA-B, MW-C, and MW-D). The background data consists of the data collected from the three downgradient wells.
- 9 rounds of initial background data collected over approximately 2 years (September 2015 to July 2017) from three detection monitoring wells in the network per the CCR Rule requirements, and
- 9 rounds of detection monitoring data collected over approximately 4 years (Oct. 2017 to September 2021).

Table 1 presents the basic descriptive statistics of the available data set (Sept. 2015 to Oct. 2021) for all 4-wells of the OUC groundwater monitoring network.

Summary of Alternative Source Demonstrations

After identification of an exceedance during each detection monitoring event, additional statistical evaluations were conducted to prepare alternate source demonstrations. A brief summary of the most recent alternative source demonstrations is given below:

- During the CCR detection monitoring history a stockpile of crushed limestone (also called limerock) to support landfill operations was placed near MW-D. Over time the stockpile grew and the position of the northwest corner of the stockpile came within approximately 75 feet of MW-D. It was hypothesized that stormwater runoff from the pile could have impacted surficial groundwater quality at MW-D through direct infiltration and groundwater transport, or overland flow then infiltration and groundwater transport around the general area. An alternative source demonstration was completed and found that the limerock stockpile was a potential alternative source for SSIs at MW-D and MW-B (CH2M 2020).
- The stockpile was removed in January 2020 (CH2M 2021). The spike in TDS-related data occurred in 2020, so it is possible that there was a residual influence of the near-surface groundwater from the stockpile, or perhaps, the removal efforts mixed limerock into the surface soil causing the spike in calcium, chloride, and TDS concentrations. The concentrations of calcium and chloride dropped in September of 2020 nearly as precipitously as they increased but returned to high levels in March and September of 2021.
- Additional site investigations were completed as part of an Alternative Source Analysis in the 2021 monitoring year (CH2M 2021). As part of this alternate source demonstration, additional groundwater data were collected in September 2021 to evaluate hydrogeologic conditions in the surficial aquifer. This additional analysis was focused on the hydrogeologic conditions on the western portion of the site between MW-D and the active landfill. New groundwater percolation data were collected near the MWs. The results of this investigation found that groundwater travel time from the northern edge of active cell of the new landfill to either monitoring well is expected to be greater than 17 years. Because the CCR active landfill cell is relatively new (6 years old) and located

Table 1: Summary Statistics (Before removal of Outliers)*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	Units	Total Samples	Detect Results	Nondetect Results	Detect Frequency (%)	Minimum Nondetect	Maximum Nondetect	KM Mean	KM Standard Deviation	KM CV	Minimum Detect	Maximum Detect	Mean Detect	Median Detect	Standard Deviation Detect	CV Detect
MW-A	Boron	mg/L	18	12	6	67	0.4	0.4	0.272	0.245	0.9	0.0575	1.01	0.32	0.352	0.283	0.885
MW-A	Calcium	mg/L	19	19	0	100	---	---	3787	977.9	0.258	2220	5580	3787	3830	977.9	0.258
MW-A	Chloride	mg/L	19	19	0	100	---	---	14670	2622	0.179	9730	18400	14670	14700	2622	0.179
MW-A	Fluoride	mg/L	18	1	17	6	0.1	100	1.182	3.421	2.895	12	12	12	12	---	---
MW-A	pH	SU	19	19	0	100	---	---	4.061	0.19	0.0467	3.81	4.52	4.061	4.01	0.19	0.0467
MW-A	Sulfate	mg/L	19	19	0	100	---	---	1119	214.2	0.192	674	1550	1119	1130	214.2	0.192
MW-A	TDS	mg/L	18	18	0	100	---	---	29517	8014	0.272	17100	45600	29517	28750	8014	0.272
MW-B	Boron	mg/L	18	18	0	100	---	---	0.078	0.0381	0.489	0.0133	0.147	0.078	0.0819	0.0381	0.489
MW-B	Calcium	mg/L	23	23	0	100	---	---	8.058	6.689	0.83	0.879	21.9	8.058	6.95	6.689	0.83
MW-B	Chloride	mg/L	23	23	0	100	---	---	41.96	25.96	0.619	13	97.7	41.96	33.7	25.96	0.619
MW-B	Fluoride	mg/L	18	9	9	50	0.1	1	0.113	0.0492	0.434	0.06	0.23	0.137	0.14	0.0541	0.396
MW-B	pH	SU	22	22	0	100	---	---	4.507	0.264	0.0586	4.22	5.47	4.507	4.415	0.264	0.0586
MW-B	Sulfate	mg/L	19	19	0	100	---	---	47.65	8.98	0.188	32.2	60.4	47.65	49.8	8.98	0.188
MW-B	TDS	mg/L	22	22	0	100	---	---	163.1	49.03	0.301	99	250	163.1	151	49.03	0.301
MW-C	Boron	mg/L	18	9	9	50	0.02	0.02	0.0144	0.00519	0.362	0.01	0.0324	0.0159	0.0133	0.00704	0.443
MW-C	Calcium	mg/L	22	22	0	100	---	---	7.802	1.671	0.214	5.09	11.2	7.802	7.48	1.671	0.214
MW-C	Chloride	mg/L	19	19	0	100	---	---	17.11	7.149	0.418	6.82	27.3	17.11	16.2	7.149	0.418
MW-C	Fluoride	mg/L	19	7	12	37	0.1	0.1	0.0821	0.0128	0.156	0.07	0.11	0.0943	0.1	0.014	0.148
MW-C	pH	SU	22	22	0	100	---	---	5.177	0.198	0.0383	4.93	5.71	5.177	5.155	0.198	0.0383
MW-C	Sulfate	mg/L	20	18	2	90	0.22	0.25	0.911	0.756	0.83	0.18	2.38	0.99	0.56	0.778	0.786
MW-C	TDS	mg/L	21	21	0	100	---	---	74.05	21.8	0.294	35	107	74.05	73	21.8	0.294
MW-D	Boron	mg/L	18	12	6	67	0.02	0.02	0.0187	0.0062	0.331	0.0123	0.0341	0.0203	0.0178	0.00724	0.357
MW-D	Calcium	mg/L	25	25	0	100	---	---	181	323.6	1.788	1.79	1040	181	7.93	323.6	1.788
MW-D	Chloride	mg/L	25	25	0	100	---	---	532.3	935.6	1.758	6.74	2760	532.3	29.2	935.6	1.758
MW-D	Fluoride	mg/L	22	9	13	41	0.02	0.1	0.113	0.123	1.089	0.04	0.44	0.22	0.2	0.138	0.627
MW-D	pH	SU	22	22	0	100	---	---	4.633	0.404	0.0871	4.05	5.54	4.633	4.565	0.404	0.0871
MW-D	Sulfate	mg/L	23	12	11	52	0.25	0.65	31.01	64.31	2.074	0.3	218	59.2	8.61	82.67	1.396
MW-D	TDS	mg/L	23	23	0	100	---	---	1558	2610	1.675	36	7320	1558	110	2610	1.675

Notes:

KM Mean = Corrected mean value using the Kaplan-Meier mehod

KM Standard Deviation = Corrected standard deviation value using the Kaplan-Meier mehod

% = percent

mg/L = milligrams per liter

SU = standard units

Update of Background Water Quality Concentrations for the Orlando Utilities Commission Stanton Energy Center CCR Landfill Detection Monitoring Program

far away from the compliance MWs, it is highly unlikely that the groundwater at MW-B, MW-C, and MW-D is from the active cell of the CCR landfill. Therefore, continued Detection Monitoring was recommended.

The above findings support the recommendation to periodically review the background concentration values using the background and detection data sets to see if they can be combined, creating a larger background sample size. To update the background limits, the initial background data, and the newly collected data (that is, the detection monitoring data) were combined to provide better statistical power to control false positive and false negative error rates.

Managing Duplicate Data

Duplicate groundwater samples have been collected from the CCR monitoring wells at the SEC for quality assurance and quality control (QA/QC) purposes. For statistical analysis of parameters with duplicate sample results, only the parent sample was used for statistical comparisons, assuming that review of all QA/QC data indicated that the original parent sample result was valid.

Data Qualifiers

Estimated concentrations (constituent concentrations denoted with the "J" qualifier) for the background groundwater monitoring data were treated as qualified detected concentrations for statistical analysis. No rejected data through analytical data validation were identified in the data set; therefore, no data were rejected from the data set that was used for statistical evaluation.

Statistical Evaluation

A stepwise approach was used for evaluating the OUC Landfill background groundwater monitoring data to determine its suitability for statistical analysis. These steps include data compilation, exploratory analysis and descriptive statistics, statistical outlier detection, evaluation of data independence and stationarity, and testing for parametric behavior. Unless stated differently, statistical tests conducted during the exploratory data evaluation stage were performed using a significance level of 5 percent (0.05). If the calculated probability from a test is below this significance level, a conclusion is drawn to reject the null hypothesis and instead determine that a significant test result exists. A significance level of 5 percent is often used to provide strong evidence against the null hypothesis. Using this significance level, there is a probability that 5 percent of the cases would be significant simply from random variability (false positives).

It is important to make sure that the data set used to determine background levels is representative of the site-specific anthropogenic background data set. Thus, before conducting statistical analysis for establishing background levels, it is desirable to determine if the background data set that represents a "single" population and possibly without any outliers.

Testing for Outliers According to the Unified Guidance

Statistical outliers are observations considered not from the same population set as the rest of the samples and violate the basic statistical assumption of identically and independently distributed measurements. The Unified Guidance (EPA 2009) recommends that testing for outliers be performed on background data, but that data generally should not be removed

unless some basis for a likely error or discrepancy is identified. As management of potential outliers carries both positive and negative risks, the Guidance suggests that these risks should be carefully understood while deciding removal of potential outliers. If a potential outlier is not removed from background prior to statistical testing, it may substantially raise the magnitude of both parametric and nonparametric background limit values. A subsequent compliance well test against this background limit will be much less likely to identify an exceedance, lowering the statistical power of the method and the overall quality of the statistical monitoring program. According to the Unified Guidance (USEPA 2009) and ProUCL Technical Guide (USEPA 2015), the presence of outliers distorts most statistics of interest [e.g., mean, standard deviation, upper confidence limits (UCLs), upper prediction limits (UPLs), and upper tolerance limits (UTLs)]. Because of these concerns, it may be advisable at times to remove high-magnitude outliers in background even if the reasons for these apparently extreme observations are not known (USEPA 2009). The overall impact of outlier removal will tend to improve the power of background limits, and thus result in a more environmentally protective program. While estimating the background limits, it is implicitly assumed that the background data set represents a single statistical population. Therefore, it is desirable to compute decision statistics based upon data sets representing the main population and not to compute distorted statistics by accommodating a few outlier results that have a low probability of representing natural variation (USEPA 2015).

Thus, prior to the calculation of background, the groundwater monitoring data were visually inspected for potential outliers using graphical presentations of the entire potential background data set, as previously described. Statistical outliers also were evaluated using Dixon's outlier test (1953). Dixon's test is valid for data sets with up to 25 observations and is recommended by EPA (2009) for outlier identification. The probability values (p-values) provided for Dixon's test were compared with a significance level of 0.05 (the most common significance level in most statistical works, including environmental statistics [EPA 2009]). A calculated probability lower than the significance level of 0.05 is defined as "statistically significant." Conversely, a calculated probability higher than or equal to the significance level of 0.05 is defined as "statistically insignificant."

Dixon's outlier test assumes that the data values (aside from those being tested as potential outliers) are normally distributed. Because environmental data tend to be right skewed, a test that relies on an assumption of a normal distribution may identify a relatively large number of statistical outliers. Thus, statistical outliers were further evaluated by applying a logarithmic transformation of the data to improve adherence to normality (EPA 2009). For data sets that do not comply with the normality assumption, interquartile range (IQR) and median absolute deviation (MAD) scores (Wilcox 2010) were calculated and used to assist in outlier identification. The EPA (2009) defines any observation that falls from 1.5 times to 3 times the IQR above the 3rd quartile or below the 1st quartile as a "mild" outlier and any value more than 3 times the IQR above the 3rd quartile or below the 1st quartile as an "extreme" outlier.

Attachment 1 presents scatter plots of the raw data by plotting observation numbers versus the observation values along with IQR and MAD score lines for each well-analyte pair. Based on the IQR and MAD scores, the identified outliers for various well-analyte data sets are also shown on these scatter plots. These preliminary identified outliers were candidates for further analyses using the parametric outlier tests. Table 2 presents results of outlier analyses showing p-values of the Dixon's test conducted using raw and log-transformed data along with the IQR and MAD scores for all well-analyte pairs. As the Dixon's test identify only a single outlier at a time, this

Table 2: Outlier Identification (Raw Data)*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	Sample Date	Result	Next Closest Value	Units	RPD	IQR Score	MAD Score	Dixon's Test P-Value	LogDixon's Test P-Value	Data normally distributed after removal of outlier(s)?
Statistical High Outliers											
MW-B	Boron	3/7/2021	0.147	0.134	mg/L	8.84	0.87	2.08	0.35	0.22	Yes
MW-B	Calcium	10/12/2015	21.9	21.1	mg/L	3.65	0.86	1.92	0.46	0.95	No
MW-B	Chloride	10/12/2015	97.7	97.1	mg/L	0.61	0.82	2.94	0.20	0.60	No
MW-B	Fluoride	4/27/2016	0.5	0.23	mg/L	54.00	3.37	6.07	0.00	0.25	No
MW-B	pH	3/25/2020	5.47	4.85	SU	11.33	3.92	11.86	0.00	0.00	Yes
MW-B	Sulfate	10/30/2017	60.4	59	mg/L	2.32	0.41	1.30	0.70	0.71	Yes
MW-B	TDS	9/9/2015	250	242	mg/L	3.20	0.48	2.02	0.90	0.94	No
MW-C	Boron	11/29/2016	0.0324	0.0205	mg/L	36.73	6.28	Inf	0.00	0.01	No
MW-C	Calcium	10/26/2021	11.2	11.1	mg/L	0.89	1.73	3.14	0.64	0.55	Yes
MW-C	Chloride	7/13/2020	27.3	26	mg/L	4.76	0.27	1.15	0.98	0.98	Yes
MW-C	Fluoride	9/14/2020	0.11	0.1	mg/L	9.09	0.50	Inf	0.70	0.66	No
MW-C	pH	3/25/2020	5.71	5.47	SU	4.20	1.66	2.77	0.08	0.11	Yes
MW-C	Sulfate	3/28/2019	2.38	2.36	mg/L	0.84	0.76	3.66	0.62	0.67	No
MW-C	TDS	3/7/2021	107	102	mg/L	4.67	0.26	1.09	0.74	0.84	Yes
MW-D	Boron	11/29/2016	0.0341	0.031	mg/L	9.09	1.50	2.44	0.66	0.85	No
MW-D	Calcium	10/26/2021	1040	776	mg/L	25.38	5.64	119.81	0.32	0.95	No
MW-D	Chloride	10/26/2021	2760	2420	mg/L	12.32	6.31	82.15	0.63	0.98	No
MW-D	Fluoride	3/7/2021	0.44	0.37	mg/L	15.91	2.63	Inf	0.18	0.03	No
MW-D	pH	9/9/2015	5.54	5.4	SU	2.53	2.73	4.24	0.66	0.71	Yes
MW-D	Sulfate	10/26/2021	218	154	mg/L	29.36	24.68	734.10	0.24	0.95	No
MW-D	TDS	10/26/2021	7320	6960	mg/L	4.92	4.62	68.49	0.78	1.00	No
Statistical Low Outliers											
MW-B	Boron	10/12/2015	0.0133	0.0261	mg/L	96.24	0.53	2.19	0.76	0.72	Yes
MW-B	Calcium	3/22/2018	0.879	1.01	mg/L	14.90	0.12	0.78	1.00	0.90	No
MW-B	Chloride	6/28/2021	13	16.6	mg/L	27.69	0.19	0.95	0.90	0.61	No
MW-B	Fluoride	1/18/2017	0.05	0.06	mg/L	20.00	0.02	0.67	1.00	1.00	No
MW-B	pH	10/12/2015	4.22	4.3	SU	1.90	0.63	2.19	0.61	0.58	No
MW-B	Sulfate	9/14/2021	32.2	34.3	mg/L	6.52	0.47	2.16	0.70	0.64	Yes
MW-B	TDS	6/28/2021	99	106	mg/L	7.07	0.28	1.06	0.88	0.76	No
MW-C	Boron	1/18/2017	0.01	0.011	mg/L	10.00	0.00	NA	1.00	1.00	No
MW-C	Calcium	7/20/2017	5.09	5.74	mg/L	12.77	1.04	2.02	0.71	0.76	Yes
MW-C	Chloride	10/12/2015	6.82	7.12	mg/L	4.40	0.30	0.97	0.93	0.71	Yes
MW-C	Fluoride	9/9/2015	0.05	0.07	mg/L	40.00	0.00	NA	1.00	1.00	Yes
MW-C	pH	3/28/2019	4.93	4.95	SU	0.41	0.34	1.12	0.97	0.96	Yes
MW-C	Sulfate	9/14/2020	0.11	0.125	mg/L	13.64	0.16	0.84	0.98	0.93	No
MW-C	TDS	10/12/2015	35	50	mg/L	42.86	0.45	1.22	0.41	0.14	No
MW-D	Boron	1/18/2017	0.01	0.0123	mg/L	23.00	0.00	0.77	1.00	1.00	No
MW-D	Calcium	3/22/2018	1.79	1.81	mg/L	1.12	0.01	0.71	1.00	0.98	No
MW-D	Chloride	9/9/2015	6.74	6.78	mg/L	0.59	0.01	0.68	1.00	1.00	No
MW-D	Fluoride	10/26/2021	0.01	0.04	mg/L	300.00	0.37	Inf	0.75	0.67	No
MW-D	pH	5/29/2020	4.05	4.15	SU	2.47	1.20	2.24	0.79	0.75	No
MW-D	Sulfate	9/9/2015	0.125	0.13	mg/L	4.00	0.00	0.67	1.00	1.00	No
MW-D	TDS	4/4/2017	36	37	mg/L	2.78	0.01	0.70	1.00	1.00	No

Notes:

mg/L = milligram per liter

IQR = interquartile range

MAD = median absolute deviation

mg/L = milligrams per liter

P-Value = probability of rejecting the null hypothesis when it is true

RPD = relative percent difference

SU = standard units

^(a) Detected concentration consistent with other results and within the expected range of variability.

Table 3: Outliers Removed*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	Sample Date	Result	Units	Outlier Removed
MW-B	Fluoride	4/27/2016	1	mg/L	Yes
MW-B	Fluoride	11/29/2016	1	mg/L	Yes
MW-B	pH	3/25/2020	5.47	SU	Yes
MW-C	Boron	11/29/2016	0.0324	mg/L	Yes
MW-D	Calcium	3/25/2020	168	mg/L	Yes
MW-D	Calcium	5/29/2020	661	mg/L	Yes
MW-D	Calcium	9/14/2020	159	mg/L	Yes
MW-D	Calcium	3/7/2021	776	mg/L	Yes
MW-D	Calcium	6/28/2021	742	mg/L	Yes
MW-D	Calcium	9/14/2021	775	mg/L	Yes
MW-D	Calcium	10/26/2021	1040	mg/L	Yes
MW-D	Chloride	3/25/2020	556	mg/L	Yes
MW-D	Chloride	5/29/2020	2240	mg/L	Yes
MW-D	Chloride	9/14/2020	387	mg/L	Yes
MW-D	Chloride	3/7/2021	2420	mg/L	Yes
MW-D	Chloride	6/28/2021	2320	mg/L	Yes
MW-D	Chloride	9/14/2021	1920	mg/L	Yes
MW-D	Chloride	10/26/2021	2760	mg/L	Yes
MW-D	Sulfate	3/7/2021	153	mg/L	Yes
MW-D	Sulfate	6/28/2021	154	mg/L	Yes
MW-D	Sulfate	9/14/2021	149	mg/L	Yes
MW-D	Sulfate	10/26/2021	218	mg/L	Yes
MW-D	TDS	3/25/2020	1590	mg/L	Yes
MW-D	TDS	5/29/2020	4710	mg/L	Yes
MW-D	TDS	9/14/2020	1090	mg/L	Yes
MW-D	TDS	3/7/2021	6450	mg/L	Yes
MW-D	TDS	6/28/2021	6960	mg/L	Yes
MW-D	TDS	9/14/2021	5980	mg/L	Yes
MW-D	TDS	10/26/2021	7320	mg/L	Yes

Notes:

mg/L = milligrams per liter

SU = standard units

test is repeated for datasets obtained after removing the confirmed outliers until the test results are negative (i.e., Dixon's test the $p\text{-value} \geq 0.05$).

A list of statistical outliers identified at the 5 percent significance level is provided in Table 3. Dixon's test was performed for all constituent/well combinations having their detection frequency greater than or equal to 50 percent. Based on outlier analysis, a total of 29 outliers (2 observations of fluoride and 1-observation of pH at MW-B, 1-observation of boron at MW-C, and 7-observations of calcium, chloride, and TDS each, and 4-observations of sulfate at MW-D) were confirmed as outliers and removed from the dataset before conducting further statistical analyses.

Summary Statistics and Graphical Presentation of the OUC Landfill Established Background Data

The dataset obtained after removing the confirmed statistical outliers is the established updated background data set. Summary statistics for the Appendix III constituents after removing 29 outliers are provided in Table 4. This table includes the total number of samples, frequency of detection, and the minimum and maximum concentrations for detected observations. Graphical presentations of the Appendix III constituents are generated using various statistical plotting methods to provide added insight (e.g., existence of extreme observations, data distributions and patterns, mixture populations, and visual comparison of two or more groups) into data sets that are not possible to visualize and understand by reviewing descriptive and test statistics and tabulated data. Graphical representation of the analysis is provided in attachments to this report, as referenced in the discussion below.

Statistical plotting methods include box-and-whisker plots, histograms, and probability plots as shown in Attachments 2 and 3. Box-and-whisker plots show the central tendency, degree of symmetry, range of variation, and potential outliers of a data set. The upper value of the box represents the 75th percentile for the data and the lower value of the box is the 25th percentile for the data. Thus, 50 percent of the data fall within the box. The top of the whisker represents the 75th percentile plus 1.5 times the interquartile range (IQR), where the IQR is the 75th percentile minus the 25th percentile. The bottom of the whisker is the 25th percentile minus 1.5 times the IQR. Any value outside of this range is considered a potential statistical outlier, which is represented by a dot on the plot.

The outlying concentrations of box-and-whisker plots only serve the definition of falling relatively far from the middle 50 percent of the data. If the data are drawn from a highly skewed distribution, or a symmetrical one with long tails, multiple observations of this type are expected. Although it is common vernacular to refer to these observations as outliers, they should not be confused with the outlier definitions described earlier in this report as part of the outlier evaluation discussion.

Normal probability plots show the ordered sample results versus the corresponding quantiles of a theoretical data distribution, such as the normal distribution, and is described as a quantile–quantile, or Q–Q, plot (e.g., normal Q–Q plot). Since quantiles are associated with cumulative probabilities, Q–Q plots are also referred to as probability plots. A normal probability plot is used to evaluate the normality of the distribution of a variable (i.e., whether, and to what extent, the distribution of the variable follows the normal distribution). If the data are not normally distributed, they will deviate systematically from a straight line. Variability in the data will cause the data to scatter randomly around the normality line, but the data will still appear to follow a single straight line. Outliers may also be evident in this plot. In addition to these plots, separate Q–Q plots showing the Shapiro-Wilk and Lilliefors normality test results are included in Attachment 3.

A histogram is a visual representation of the data collected into groups. The data range is divided into several bins, or classes, and the data is sorted into the bins. A histogram is a bar graph conveying the bins and the frequency of data points in each bin. Histograms provide a visual method of accessing location, shape, and spread of the data; the shape of a histogram helps determine whether the distribution is symmetric or skewed. The visual impression of a histogram is sensitive to the number of bins selected. A large number of bins will increase data detail, while fewer bins will increase the smoothness of the histogram.

Table 4: Summary Statistics (After removal of Outliers)*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	Units	Total Samples	Detect Results	Nondetect Results	Detect Frequency (%)	Minimum Nondetect	Maximum Nondetect	KM Mean	KM Standard Deviation	KM CV	Minimum Detect	Maximum Detect	Mean Detect	Median Detect	Standard Deviation Detect	CV Detect
MW-B	Boron	mg/L	18	18	0	100	---	---	0.078	0.0381	0.489	0.0133	0.147	0.078	0.0819	0.0381	0.489
MW-B	Calcium	mg/L	23	23	0	100	---	---	8.058	6.689	0.83	0.879	21.9	8.058	6.95	6.689	0.83
MW-B	Chloride	mg/L	23	23	0	100	---	---	41.96	25.96	0.619	13	97.7	41.96	33.7	25.96	0.619
MW-B	Fluoride	mg/L	16	9	7	56.25	0.1	0.2	0.113	0.0492	0.434	0.06	0.23	0.137	0.14	0.0541	0.396
MW-B	pH	SU	21	21	0	100	---	---	4.461	0.157	0.0351	4.22	4.85	4.461	4.41	0.157	0.0351
MW-B	Sulfate	mg/L	19	19	0	100	---	---	47.65	8.98	0.188	32.2	60.4	47.65	49.8	8.98	0.188
MW-B	TDS	mg/L	22	22	0	100	---	---	163.1	49.03	0.301	99	250	163.1	151	49.03	0.301
MW-C	Boron	mg/L	17	8	9	47.06	0.02	0.02	0.0133	0.00288	0.217	0.01	0.0205	0.0138	0.0129	0.00356	0.258
MW-C	Calcium	mg/L	22	22	0	100	---	---	7.802	1.671	0.214	5.09	11.2	7.802	7.48	1.671	0.214
MW-C	Chloride	mg/L	19	19	0	100	---	---	17.11	7.149	0.418	6.82	27.3	17.11	16.2	7.149	0.418
MW-C	Fluoride	mg/L	19	7	12	36.84	0.1	0.1	0.0821	0.0128	0.156	0.07	0.11	0.0943	0.1	0.014	0.148
MW-C	pH	SU	22	22	0	100	---	---	5.177	0.198	0.0383	4.93	5.71	5.177	5.155	0.198	0.0383
MW-C	Sulfate	mg/L	20	18	2	90	0.22	0.25	0.911	0.756	0.83	0.18	2.38	0.99	0.56	0.778	0.786
MW-C	TDS	mg/L	21	21	0	100	---	---	74.05	21.8	0.294	35	107	74.05	73	21.8	0.294
MW-D	Boron	mg/L	18	12	6	66.67	0.02	0.02	0.0187	0.0062	0.331	0.0123	0.0341	0.0203	0.0178	0.00724	0.357
MW-D	Calcium	mg/L	18	18	0	100	---	---	11.32	16.83	1.488	1.79	56.8	11.32	3.64	16.83	1.488
MW-D	Chloride	mg/L	18	18	0	100	---	---	39.18	51.87	1.324	6.74	185	39.18	13.2	51.87	1.324
MW-D	Fluoride	mg/L	22	9	13	40.91	0.02	0.1	0.113	0.123	1.089	0.04	0.44	0.22	0.2	0.138	0.627
MW-D	pH	SU	22	22	0	100	---	---	4.633	0.404	0.0871	4.05	5.54	4.633	4.565	0.404	0.0871
MW-D	Sulfate	mg/L	19	8	11	42.11	0.25	0.65	2.064	4	1.938	0.3	13.5	4.556	2.21	5.582	1.225
MW-D	TDS	mg/L	16	16	0	100	---	---	108.6	123.8	1.14	36	476	108.6	58	123.8	1.14

Notes:

KM Mean = Corrected mean value using the Kaplan-Meier method

KM Standard Deviation = Corrected standard deviation value using the Kaplan-Meier method

% = percent

mg/L = milligrams per liter

SU = standard units

Spatial Variability

Spatial variability refers to statistically identifiable differences in mean and variance levels across the well network. In the absence of any spatial variation, it is expected that each constituent in the monitoring well network should have approximately the same population mean and variance.

A nonparametric analysis of variance (ANOVA) method, the Kruskal-Wallis test, was applied to the data to test for spatial variability. This test considers the locations of monitoring wells as the relevant statistical factor. While the parametric ANOVA method is a statistical procedure used to determine whether there are statistically significant differences in mean concentrations among wells, the Kruskal-Wallis method tests for differences among average population ranks equivalent to the medians. Under the null hypothesis of no difference in concentrations among wells, the observations are assumed to arise from identical distributions with equal population variances. When the calculated probability (p-value) is greater than or equal to the common significance level of 0.05, the null hypothesis of no significant difference between wells is assumed. When the probability is below 0.05, a significant difference between the central tendency of at least one of the wells and the other multiple-well groups is suggested. The Levene test was conducted to test the underlying assumption for equality of variance for the validity of the Kruskal Wallis results. When the assumption for equality of variance was not met the Welch-F Test was used as an alternative test to the Kruskal-Wallis test.

Table 5 presents result of the spatial variability analysis obtained using the Kruskal-Wallis test. The results indicate that the background groundwater monitoring constituents exhibit significant spatial variation. This is shown graphically in the overlapping time series and box plots included in Attachment 4.

Temporal Variability

A stationary statistical distribution is one whose population characteristics do not change over time or space. A nonstationary distribution infers that either the mean, variance, or both are changing over time in any given well. Temporal variability exists when the distribution of measurements varies with the times at which sampling or analytical measurement occurs. The EPA (2009) distinguishes temporal variations from trends or seasonal effects by the lack of a regular or identifiable pattern.

The Kruskal-Wallis test was applied to the data to test for temporal variability for each well-analyte pair considering the sampling events as the relevant statistical factor. Table 6 presents the results of the temporal variability analysis using the Kruskal-Wallis test. The obtained results indicate that the background groundwater monitoring constituents do not exhibit significant temporal variation.

Table 5: Results of Spatial Variability Analysis*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Parameter	Levene P-Value	KW P-Value	WF P-Value	Conclusion
After Outliers are removed (All Wells)				
Boron	0.00	0.00	0.00	Significant
Calcium	0.00	0.00	0.00	Significant
Chloride	0.00	0.00	0.00	Significant
Fluoride	0.00	0.00	0.00	Significant
pH	0.00	0.00	0.00	Significant
Sulfate	0.00	0.00	0.00	Significant
TDS	0.00	0.00	0.00	Significant
After Outliers are removed (DG Wells)				
Boron	0.00	0.00	0.00	Significant
Calcium	0.00	0.23	0.68	Insignificant
Chloride	0.00	0.00	0.00	Significant
Fluoride	0.00	0.16	0.02	Significant
pH	0.00	0.00	0.00	Significant
Sulfate	0.00	0.00	0.00	Significant
TDS	0.00	0.00	0.00	Significant

Notes:

KW = Kruskal-Wallis Test

Levene = Levene Test for testing variance

NDs = nondetects

WF = Welch-F Test

P-Value = probability of rejecting the null hypothesis when it is true

Table 6: Results of Temporal Variability Analysis*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	KW P-Value	Conclusion
MW-B	Boron	0.22	Insignificant
MW-B	Calcium	0.15	Insignificant
MW-B	Chloride	0.13	Insignificant
MW-B	Fluoride	0.36	Insignificant
MW-B	pH	0.48	Insignificant
MW-B	Sulfate	0.12	Insignificant
MW-B	TDS	0.19	Insignificant
MW-C	Boron	0.94	Insignificant
MW-C	Calcium	0.37	Insignificant
MW-C	Chloride	0.54	Insignificant
MW-C	Fluoride	0.34	Insignificant
MW-C	pH	0.78	Insignificant
MW-C	Sulfate	0.38	Insignificant
MW-C	TDS	0.24	Insignificant
MW-D	Boron	0.57	Insignificant
MW-D	Calcium	0.34	Insignificant
MW-D	Chloride	0.54	Insignificant
MW-D	Fluoride	0.30	Insignificant
MW-D	pH	0.49	Insignificant
MW-D	Sulfate	0.43	Insignificant
MW-D	TDS	0.35	Insignificant

Notes:

KW = Kruskal-Wallis Test

NDs = nondetects

P-Value = probability of rejecting the null hypothesis when it is true

Seasonality Analysis

For each well-analyte pair, the observed data was divided into two seasons: data collected during January through June of each year was considered as the first season (normally dry), whereas the data collected during July through December in any year was considered as the second season (normally wet). Using this data and the Kruskal-Wallis test, seasonality was tested whether there are statistically significant seasonal effects in the data. Table 7 presents the results of seasonality analysis for all well-analyte pairs. Except for 4 well-analyte pairs (calcium, chloride, and TDS at well MW-B and sulfate at MW-C) from the total 21 well-analyte pairs, no other well-analyte pair shows significant seasonality effects at the 5 percent significance level. As the majority of the well-analyte pairs do not indicate any seasonal effects, it was decided not to make any seasonality corrections to the 4 well-analyte pairs that have indicated seasonal effects. It is unusual to have seasonal effects only for a few well-analyte pairs. It is possible the identified seasonality may be an artifact of some other unknown phenomenon.

Table 7: Results of Seasonality Analysis*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Constituents	Levene P-Value	KW P-Value	WF P-Value	Seasonality
MW-B	Boron	0.40	0.13	0.24	No
MW-B	Calcium	0.51	0.01	0.01	Yes
MW-B	Chloride	0.33	0.00	0.02	Yes
MW-B	Fluoride	0.20	0.15	0.10	No
MW-B	pH	0.11	0.18	0.15	No
MW-B	Sulfate	0.80	0.62	0.61	No
MW-B	TDS	0.40	0.01	0.01	Yes
MW-C	Boron	0.20	0.91	0.69	No
MW-C	Calcium	0.43	1.00	0.83	No
MW-C	Chloride	0.93	1.00	0.89	No
MW-C	Fluoride	0.91	0.96	0.99	No
MW-C	pH	0.25	0.51	0.38	No
MW-C	Sulfate	0.17	0.03	0.04	Yes
MW-C	TDS	0.81	0.53	0.45	No
MW-D	Boron	0.03	0.28	0.14	No
MW-D	Calcium	0.00	0.02	0.06	No
MW-D	Chloride	0.01	0.14	0.08	No
MW-D	Fluoride	0.12	0.59	0.34	No
MW-D	pH	0.91	0.25	0.29	No
MW-D	Sulfate	0.57	0.73	0.74	No
MW-D	TDS	0.08	0.08	0.15	No

Notes:

KW = Kruskal-Wallis Test

Levene = Levene Test for testing variance

NDs = nondetects

WF = Welch-F Test

P-Value = probability of rejecting the null hypothesis when it is true

Secular Trend Analysis

A secular trend at a well location indicates that the mean is not stationary but is changing over time. Secular trend analysis was performed using the nonparametric Mann-Kendall test (Gilbert 1996). As a nonparametric procedure, the Mann-Kendall test does not require the underlying data to follow a specific distribution. The test compares the relative change of sample data over time rather than the magnitude of data values. Non-detects were used by assigning them a common value that was less than the lowest measured value in the data set (EPA 2009).

The Mann-Kendall test statistic (S) is found by counting the number of "concordant observations", where the later-in-time observation has a larger value for the series and subtracting the number of "discordant observations", where the later-in-time observation has a smaller value for the series. This is done for all pairs of observations in the data set. The total difference is denoted by S. Positive values of S indicate an increase in constituent concentrations over time, whereas negative values indicate a decrease in constituent concentrations over time. The strength of the trend is proportional to the magnitude of S (i.e., the larger the absolute value of S, the stronger the evidence for a real trend).

The results for the Mann-Kendall test for each well-constituent pair are shown in Table 8. This table includes the calculated probability for a single-tailed test, which represents the probability that an observed trend would occur purely by chance (given the variability and sample size of the data set). Attachment 5 presents the trend plots for all well-analyte pairs. A significance level of 0.05 was used for comparisons with this probability and the resulting decisions are reported as significantly increasing or decreasing trends or a non-significant result (no trend).

Table 8: Mann-Kendall Trend Evaluation*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	No. of Samples	No. of Detects	Units	Detect Freq. (%)	MK Test Statistic (S)	MK p-value	TS Slope (per year)	Trend Analysis Result
MW-B	Boron	18	18	mg/L	100	111	0.000	0.02	Increasing
MW-B	Calcium	23	23	mg/L	100	-61	0.113	0.00	No Trend
MW-B	Chloride	23	23	mg/L	100	-123	0.001	-7.74	Decreasing
MW-B	Fluoride	16	9	mg/L	56	-38	0.080	0.00	No Trend
MW-B	pH	21	21	SU	100	25	0.467	0.00	No Trend
MW-B	Sulfate	19	19	mg/L	100	-105	0.000	-3.72	Decreasing
MW-B	TDS	22	22	mg/L	100	-132	0.000	-17.54	Decreasing
MW-C	Boron	17	8	mg/L	47	-29	---	0.00	---
MW-C	Calcium	22	22	mg/L	100	132	0.000	0.58	Increasing
MW-C	Chloride	19	19	mg/L	100	148	0.000	3.76	Increasing
MW-C	Fluoride	19	7	mg/L	37	91	---	0.01	---
MW-C	pH	22	22	SU	100	-67	0.062	0.00	No Trend
MW-C	Sulfate	20	18	mg/L	90	-22	0.495	0.00	No Trend
MW-C	TDS	21	21	mg/L	100	150	0.000	9.92	Increasing
MW-D	Boron	18	12	mg/L	67	-10	0.728	0.00	No Trend
MW-D	Calcium	18	18	mg/L	100	45	0.096	0.00	No Trend
MW-D	Chloride	18	18	mg/L	100	115	0.000	13.71	Increasing
MW-D	Fluoride	22	9	mg/L	41	91	---	0.01	---
MW-D	pH	22	22	SU	100	-120	0.001	-0.13	Decreasing
MW-D	Sulfate	19	8	mg/L	42	62	---	0.13	---
MW-D	TDS	16	16	mg/L	100	52	0.022	16.76	Increasing

Notes:

--- = values were not calculated due to Detection frequency < 50%

% = percent

Detect Freq. = frequency

MK = Mann-Kendall

TS Slope = slope of the fitted regression line using the Theil-Sen nonparametric procedure

p-value = probability value

Trend analysis performed using Mann Kendall single-tailed test at 0.05 significance level.

Of the 21 cases evaluated with the Mann-Kendall test, there were 10 cases (about 48 percent) with a significant calculated trend, 4 of them representing significantly decreasing trends and 6 significantly increasing trends. In 7 cases (33%), there were no trends and 4 cases couldn't be evaluated due to their detection frequencies being less than 50 percent.

Correcting for Linear Trends

If a data set exhibits a linear trend, the sample will exhibit temporal dependence. The Unified Guidance (USEPA 2009) recommends that these data sets should be detrended. The easiest way to detrend observations with a linear trend is to compute a linear regression on the data and then use the regression residuals instead of the original measurements for background calculations. Equation 1 is used to obtain the detrended data:

$$x_i^{\text{detrended}} = \alpha + [x_i - (\alpha + \beta t)] = x_i - \beta t \quad \text{Equation 1}$$

where, x_i represents the raw data, $x_i^{\text{detrended}}$ represents the detrended data, α is the regression line intercept, β is the slope (unit per year) of the fitted regression line, and t is time in years since September 2015. Table 8 includes the values of Theil-Sen slope for all well-constituent pairs. Using this information, the data sets for all well-constituent pairs identified for significant trends were detrended and background values were determined using the detrended data.

Goodness-of-Fit Testing

Determining the nature of the underlying population from which samples are drawn is important as it governs whether a parametric test procedure should be employed in subsequent statistical analyses. The ability to apply parametric statistical tests conveys higher statistical power, a lower false-positive error rate, and more robust conclusions overall.

Goodness-of-fit tests were performed to determine the probability that a particular background data set could have come from the tested distribution. Because a data set can pass a goodness-of-fit test for more than one distribution, the following hierarchy was used to choose a parametric distribution to calculate the background statistics:

- A normal distribution is used when a dataset passes the test for normality. Normal distribution was always selected over a lognormal or a gamma distribution.
- A gamma distribution is used when a dataset fails the test for normality but passes the test for the gamma distribution. A gamma distribution was always preferred over a lognormal distribution for background determination, if justified.
- A lognormal distribution is used when a dataset is neither normal nor gamma but passes the test for lognormality.
- Nonparametric methods are used when a dataset exhibited no discernible distribution, then the distribution-free nonparametric method is used to determine the background statistics.

EPA (2015) warns that use of a parametric lognormal distribution on a lognormally distributed data set may yield impractically large background values, especially when the standard deviation of the log-transformed data becomes greater than 1.0 for small data sets (less than 30 to 50 measurements). Because environmental data sets typically can be modeled by a gamma distribution, gamma distribution limits are given preference over lognormal distribution limits, where appropriate.

If the data do not appear to be normally distributed, the data may be transformed mathematically such that the transformed data follow a normal distribution; alternatively, a nonparametric method may be used. However, because nonparametric methods generally require large data sets to maintain an adequate low SWFPR, parametric methods are preferred. For mildly skewed, nonparametric data sets with a standard deviation of the log-transformed data less than 0.5, a normal distribution-based background estimation method was considered (EPA 2015). The results of the goodness-of-fit testing are provided in Table 9. All four cases, normal, gamma, lognormal, and nonparametric, exist in the updated background data.

Detection Monitoring Background Determination

Selection of Statistical Method

The CCR Rule specifically lists four methods acceptable for background determination. These methods are listed below and described in the following paragraphs.

- Tolerance or prediction interval procedure in which an interval for each parameter is established from the distribution of the background data, and the level of each parameter in each monitoring well is compared to the upper tolerance or prediction limit.

Table 9: Goodness-of-Fit Test Results*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Parameter	No. of Samples	P-Value for Normality	P-Value for Lognormality	P-Value for Gamma	Do data appear to be approximate normal?	Do data appear to be approximate gamma?	Do data appear to be approximate lognormal?	Approximate distribution of data
MW-B	Boron	18	0.19	---	---	Yes	---	---	Normal
MW-B	Calcium	23	0.02	0.09	0.20	No	Yes	Yes	Gamma
MW-B	Chloride	23	0.11	0.06	0.08	Yes	Yes	Yes	Normal
MW-B	Fluoride	9	0.76	0.61	0.74	Yes	Yes	Yes	KM Normal
MW-B	pH	21	0.05	0.07	0.06	Yes	Yes	Yes	Lognormal
MW-B	Sulfate	19	0.35	0.58	0.50	Yes	Yes	Yes	Normal
MW-B	TDS	22	0.15	0.11	0.13	Yes	Yes	Yes	Normal
MW-C	Boron	22	---	---	---	---	---	---	Nonparametric
MW-C	Calcium	22	0.87	0.94	0.96	Yes	Yes	Yes	Normal
MW-C	Chloride	19	0.21	0.07	0.17	Yes	Yes	Yes	Normal
MW-C	Fluoride	19	---	---	---	---	---	---	Nonparametric
MW-C	pH	22	0.13	0.19	0.17	Yes	Yes	Yes	Normal
MW-C	Sulfate	18	0.00	0.14	0.06	No	Yes	Yes	KM Lognormal
MW-C	TDS	21	0.68	0.44	0.54	Yes	Yes	Yes	Normal
MW-D	Boron	12	0.05	0.26	0.16	No	Yes	Yes	KM Gamma
MW-D	Calcium	18	0.00	0.01	0.00	No	No	No	Nonparametric
MW-D	Chloride	18	0.00	---	---	No	---	---	Nonparametric
MW-D	Fluoride	18	---	---	---	---	---	---	Nonparametric
MW-D	pH	22	0.19	0.26	0.23	Yes	Yes	Yes	Normal
MW-D	Sulfate	22	---	---	---	---	---	---	Nonparametric
MW-D	TDS	16	0.00	0.22	0.34	No	Yes	Yes	Gamma

Notes:

p = probability value

- Control chart approach that gives control limits for each parameter.
- Parametric ANOVA followed by multiple comparisons procedures to identify statistically significant evidence of contamination.
- Nonparametric ANOVA based on the ranks of the data followed by multiple comparisons procedures to identify statistically significant evidence of contamination.
- Additional statistical test that meets the performance standards listed in 40 CFR 297.93(g).

Parametric and Nonparametric ANOVA

The use of ANOVA assumes stringent assumptions that both background and detection monitoring data sets have similar distributions and equal variances, a condition that rarely occurs in practice. ANOVA procedures do not adjust for multiple comparisons due to multiple well-constituent combinations. Because the CCR Rule mandates a minimum Type I error of 0.05 for multiple comparisons (0.01 for individual monitoring well comparisons) when using ANOVA, it would be difficult to maintain EPA's (2009) recommended annual SWFPR of 10 percent for detection monitoring. Additionally, EPA (2009) reports that ANOVA is more sensitive to spatial variability than contamination. Spatial variability affects mean concentrations but typically not the variance; hence, small yet consistent differences will achieve statistical significance (Gibbons et al. 2009). In contrast, contamination affects both variability and mean concentration; therefore, a much larger effect is required to achieve statistical significance. While spatial variation is also a problem for prediction limits and tolerance limits for single future measurements, it is not nearly as severe a problem as for ANOVA because the distribution of the individual measurements is considered and not the more restrictive distribution of the sample mean. Based on these considerations, EPA (2009) does not recommend the use of ANOVA for detection monitoring.

Control Charts

Control charts are a viable alternative to parametric prediction limits for testing groundwater detection monitoring. Because control charts are a parametric method (there is no current nonparametric alternative), the data or transformed data must be normally distributed, and the frequency of non-detects (NDs) is less than 50 percent. The statistical performance (i.e., false-positive rates and statistical power) of control charts is not well understood because the control limit used to identify potential releases to groundwater is not based on a formula incorporating a desired false positive rate. Unlike prediction limits, the control limit cannot be precisely set to meet a pre-specified SWFPR unless the behavior of the control chart is modeled via Monte Carlo simulation; the same is true for assessing the statistical power (ability to detect a release if one occurs). Control charts usually provide less flexibility than prediction limits in designing a statistical monitoring program (EPA 2009).

Tolerance Limits

Although the construction of a tolerance limit is nearly identical to that of a prediction limit, tolerance limits lack the statistical properties that allow practitioners to modify the tests to control the SWFPR. As multiple comparisons of detection monitoring sample results are made to the background levels, the chance of falsely declaring a statistically significant release at the site increases when using tolerance limits. While simultaneous prediction limits consider the actual number of comparisons in defining exact false positive error rates, tolerance limit approaches

utilize an approximate and less precise pre-selected low level of probability. Thus, EPA (2009) recommends the use of prediction limits compared to tolerance limits for detection monitoring.

Prediction Limits

Of the statistical test methods listed in the CCR Rule, EPA (2009) recommends prediction limits for detection monitoring for their proven use of retesting strategies and ability to define an exact false positive error rate while maintaining high statistical power. The mathematical basis of retesting with prediction limits is well established, while those for retesting with tolerance limits or control charts are not. In contrast, to control charts, nonparametric prediction limits can be constructed as an alternative to parametric prediction limits for data exhibiting nonnormality.

Based on these reasons, prediction limits will be used as the preferred statistical method for detection monitoring at the OUC Landfill. Prediction intervals can be used for both interwell and intrawell comparisons. At sites where natural geochemical differences in groundwater quality exist between monitoring locations, the probability increases that statistically significant differences reported between upgradient, and downgradient locations are the result of spatial and/or hydrogeologic variability rather than the facility. In these situations, intrawell statistical methods minimize the likelihood that spatial variability will contribute to invalid statistical limits, assuming there has been no previous release.

For monitoring of the OUC Landfill, intrawell comparisons are used due to the statistically significant spatial variability that exists within the monitoring well network. The OUC Landfill CCR background monitoring program is comprised of 3 background detection monitoring wells: MW-B, MW-C, and MW-C. The step-by-step general procedure for background determination is as follows:

- For constituents composed of 100 percent NDs, the Double Quantification Rule (EPA 2009) will be evaluated by the following quasi-statistical rule: "A confirmed exceedance is registered if any well-constituent pair in the "100 percent ND" group exhibits quantified measurements (i.e., at or above the reporting limit [RL]) in two consecutive samples and resample events."
- For constituents exhibiting an ND frequency greater than 50 percent, a nonparametric upper prediction limit (UPL) was computed.
- For data sets containing at least 50 percent or fewer NDs, the detected results were used to attempt a fit to a distribution. If a reasonable fit was found, a prediction limit was calculated based on the estimated mean and standard deviation adjusted for the presence of left-censored values using the Kaplan-Meier (KM) product-limit estimator (Kaplan and Meier 1958).
- For constituent data sets that do not naturally fit a normal, a gamma, or a lognormal distribution, data were transformed using an appropriate transformation to comply with the normality assumption so that a parametric prediction limit could be constructed. The goal of data transformation is to find a transformation to approximate a normal distribution. The Box-Cox transformation technique is used to transform the dataset that does not fit any well-known distribution functions (EPA 2009).
- For constituents that could not be transformed to comply with normality assumption, a nonparametric prediction limit was computed.

Parametric Upper Prediction Limit

Assuming the background data are normally distributed or can be transformed to fit a normal distribution, the parametric upper prediction limit (UPL) is calculated using the following equation:

$$UPL = \bar{x} + Ks \quad \text{Equation 2}$$

where:

$\bar{x}$ = mean concentration of the background data set

s = standard deviation of the background data set

K = multiplier based on the characteristics of the site and the statistical test

Values for K are chosen to maintain the annual SWFPR at 10 percent. If data are transformed prior to determining the prediction limit, back-transformation in the original units should be performed to facilitate comparisons against detection point data. The K values selected for this location are discussed further below.

For pH, a lower prediction limit (LPL) and an upper prediction limit (UPL) is required; the following equation is used:

$$LPL, UPL = \bar{x} \pm Ks \quad \text{Equation 3}$$

Nonparametric Prediction Limit

Nonparametric prediction limits were considered when the background data were not normally distributed or could not be transformed to fit a normal distribution. A nonparametric UPL is constructed by setting the limit as a large order statistic selected from the background data (e.g., the maximum or second-largest background value). Unlike parametric limits, the confidence level for nonparametric limits is not adjustable but is fixed. To increase the confidence level, the number of future values to be predicted needs to be decreased or the number of background observations increased (EPA 2009).

The confidence probability for a prediction limit on one future measurement is equal to:

$$\text{Confidence} = (1 - \alpha) = j/(n + 1) \quad \text{Equation 4}$$

where:

α = false positive rate

n = sample size

j = rank of the prediction limit value

If the background maximum is taken as the UPL, the confidence level thus becomes $n/(n+1)$. Davis and McNichols (1999) developed a general formula to determine the confidence probability when the jth order statistic is taken as the UPL:

$$\text{Confidence} = (1 - \alpha) = \frac{(j+m-1) \cdot (j+m-2) \cdot \dots \cdot (j+1) \cdot j}{(n+m) \cdot (n+m-1) \cdot \dots \cdot (n+2) \cdot (n+1)} \quad \text{Equation 5}$$

To construct a prediction interval with sufficiently high confidence, more background observations are needed for a nonparametric prediction limit compared to a parametric-based limit. Parametric prediction intervals do not require as many background measurements because the form of the underlying distribution is assumed to be known.

Sitewide False Positive Rate and Statistical Power

EPA (2009) recommends an annual SWFPR of 10 percent, which is distributed equally among the total number of sampling events. An SWFPR of 5 percent is targeted for each semiannual sampling event. EPA also requires demonstration that the statistical methodology selected for a facility will provide adequate statistical power to detect a release, should one occur. EPA recommends a statistical power of at least 55 percent at 3 standard deviations and 80 percent at 4 standard deviations above the background mean.

Retesting Strategy

Retesting is an integral part of the statistical methodology for control of the SWFPR when multiple monitoring locations and parameters are being evaluated. EPA (2009) recommends that prediction limits be combined with retesting for maintaining a sufficiently low false-positive rate with the ability to detect a release if it occurs. Generally, a one-of-two or one-of-three retesting strategy is used to verify that an apparent detection exceeds the background. With this retesting approach, an apparent SSI cannot be confirmed until the retesting results have been obtained. If the initial detection result does not exceed the UPL, then no retesting is needed. If the initial detection result does exceed the UPL, then a retest should be conducted before the next regularly scheduled sampling event at the monitoring well(s) and for the constituent(s) exceeding the UPL. Resampling occurs after adequate time has elapsed to ensure physical independence between the initial sample and the resample. If a constituent-well combination passes the detection test based on the resampling results, detection monitoring continues. Otherwise, the owner must conduct further investigations to evaluate the reason for the potential SSI.

K-Multiplier Values

The K-multipliers for the prediction limits were computed using the EnvStats (Millard 2013) library run within the R language and environment for statistical computing (R Core Team 2014). The EPA (2009) includes R-code files for calculating exact K-multipliers and per-test false positive error rates. The exact K-multipliers were then verified using the K-multiplier tables in Appendix D of the Unified Guidance (EPA 2009). Values for K were chosen to maintain the annual SWFPR at 10 percent (EPA 2009), and are dependent upon the following:

- Number of detection wells (three at SEC)
- Number of constituents being evaluated (7 per the Appendix III list)
- Size of the background data set (ranges from 16 to 23)
- Number of statistical evaluations performed per year (2 for semiannual sampling)
- Retesting strategy

In general, the false positive rate increases in direct proportion to the number of comparisons being made, so a larger number of comparisons will increase the probability that a release will be indicated even though no release has occurred. Several options are available for limiting the SWFPR of a facility where multiple comparisons are made: (1) limit the number of comparisons, (2) decrease the per-test false positive rate, or (3) allow retesting in cases where statistical exceedances are noted.

The EPA (2009) recommends that detection monitoring programs be developed using a SWFPR of 10 percent over a 1-year period of testing. Using this criterion, the yearly SWFPR is fixed at

10 percent, and as such, the semiannual SWFPR is fixed at 5 percent. The magnitude of the per-test significance level (α -test) varies with the number of statistical tests required per semiannual evaluation. A cumulative false positive error rate α_{cum} is calculated as the probability of at least one statistically significant outcome for a total number of tests n_T in a calendar year at a single false positive error rate α -test using the properties of the Binomial distribution:

$$\alpha_{cum} = 1 - (1 - \alpha_{test})^{n_T} \quad \text{Equation 6}$$

By rearranging to solve for α -test and substituting the 10 percent design SWFPR for α -cum, the needed per-test false positive error rate is calculated as:

$$\alpha_{test} = 1 - (0.9)^{1/n_T} \quad \text{Equation 7}$$

The design of the retesting strategy is based on an assessment of its ability to meet the power standards provided by EPA (2009). In addition to specifying the annual SWFPR, the EPA (2009) also requires facilities to achieve adequate statistical power to detect a release, should one occur. More specifically, the EPA (2009) recommends a power of approximately 55 percent to 60 percent when concentration levels are 3 standard deviations above the background mean, or approximately 80 percent to 85 percent power at 4 standard deviations above the background mean.

Results of the power analysis for the intrawell parametric UPLs are shown in Table 10, as are the K-multipliers calculated for each background sample size. Sample sizes for the updated background data set ranged from 18 to 23 for the detection wells. As shown in Table 10, a one-of-two retesting strategy meets the recommended minimum power requirements as specified by the EPA (2009). The per-test significance level (α) is achieved based on how parametric prediction limits are developed. This is not necessarily the case for nonparametric prediction limits.

Table 10: Parametric Intrawell Prediction Limit Power Analysis

Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program

No. of Samples	Rule	Retesting Strategy	Tails	K Multiplier	Power at 3 SD	Power at 4 SD	Power Rating	Total Samples
23	k.of.m	1-of-2	1	1.87	0.92	1	Good	4
22	k.of.m	1-of-2	1	1.89	0.92	1	Good	4
21	k.of.m	1-of-2	1	1.9	0.91	1	Good	4
20	k.of.m	1-of-2	1	1.91	0.91	1	Good	4
19	k.of.m	1-of-2	1	1.93	0.9	1	Good	4
18	k.of.m	1-of-2	1	1.95	0.9	0.99	Good	4
17	k.of.m	1-of-2	1	1.97	0.89	0.99	Good	4
16	k.of.m	1-of-2	1	1.99	0.88	0.99	Good	4
22	k.of.m	1-of-2	2	2.11	0.86	0.99	Good	4
21	k.of.m	1-of-2	2	2.13	0.85	0.99	Good	4

Notes:

No. = number

SD = standard deviations

EPA (2009) recommends at least 55 to 60 percent annual power for detecting a 3 standard deviation increase and at least 80 to 85 percent annual power for detecting a 4 standard deviation increase above the true background mean.

Calculation of Prediction Limits

An intrawell UPL (and LPL for pH) was calculated for each of the Appendix III detection monitoring constituents at the three downgradient detection monitoring wells (MW-B, MW-C, and MW-D). Table 11 presents the prediction limits and supporting summary statistics, including the number of samples, the number of detections, and the percentage (frequency) of detection; the minimum and maximum detected values and the minimum and maximum reporting limits for non-detects; and the mean, median, standard deviation, and coefficient of variation along with corrected mean and standard deviation values using the KM method for datasets having less than 50 percent NDs. Also included in the table are the distributional assumptions used to calculate the prediction limits.

Future Background Updating

The basic assumption in detection monitoring is that the facility is not impacting groundwater unless statistically demonstrated otherwise. For intrawell testing, statistical comparisons are made over time at each detection well to identify significant changes in groundwater quality that may be caused by the facility.

Appropriate and representative background data is the most important factor for a successful statistical groundwater monitoring program. Representative background data show numerical characteristics closely matching those arising from the site-specific aquifer being evaluated. Background data must also be appropriate to the statistical test. All detection monitoring tests involve comparisons of detection point data against the established background limits. Due to temporal changes in ambient groundwater quality, background data should not be regarded as a single fixed quantity (that is, static). If natural groundwater conditions change over time during the collection of detection monitoring data, comparisons against previously established background may not be appropriate.

The EPA (2009) recommends that background data should be updated periodically so detection samples can be tested against data that best represent the current background conditions. There are however no firm rules on how often to update background data. The Unified Guidance (EPA, 2009) adopts the general principle that updating should occur when enough new measurements have been collected to allow a two-sample statistical comparison between the existing background data and a potential set of newer data. With quarterly sampling, at least 4 to 8 new measurements should be gathered to enable a two-sample statistical comparison; this implies that updating would take place every 1 to 2 years. With semi-annual sampling, the same principle would call for updating every 2 to 3 years assuming appropriate alternative source demonstrations are conducted for the confirmed SSIs. In cases when an SSI is confirmed and no alternative source demonstration is conducted, the background should not be updated; instead, appropriate regulatory action at the site will be taken.

Table 11: Intrawell Prediction Limits for Appendix III Constituents (Detection Monitoring)*Update of Background Water Quality Concentrations for the OUC CCR Landfill Detection Monitoring Program*

Well	Constituent	Units	Frequency of Detection			Minimum Values		Maximum Values		KM Mean	KM Standard Deviation	CV	Updated Background Values			
			Total Samples	Detect Results	Detect Freq. (%)	Non-Detect	Detect	Non-Detect	Detect				Trend Removal	LPL	UPL	Distribution
MW-B	Boron	mg/L	18	18	100	---	-0.0246	---	0.055	0.0273	0.0215	0.789	Yes		0.0692	Normal
	Calcium	mg/L	23	23	100	---	0.879	---	21.9	8.058	6.689	0.83	No		25.8	Gamma
	Chloride	mg/L	23	23	100	---	36.04	---	98.4	64.95	19.53	0.301	Yes		101	Normal
	Fluoride	mg/L	16	9	56	0.1	0.06	0.2	0.23	0.113	0.0492	0.434	No		0.211	KM Normal
	pH	SU	21	21	100	---	4.22	---	4.85	4.461	0.157	0.0351	No	4.14	4.8	Lognormal
	Sulfate	mg/L	19	19	100	---	49.71	---	68.35	57.3	4.62	0.0806	Yes		66.2	Normal
	TDS	mg/L	22	22	100	---	164.5	---	276.6	213.7	35.31	0.165	Yes		280	Normal
MW-C	Boron	mg/L	17	8	47	0.02	0.01	0.02	0.0205	0.0133	0.00288	0.217	---		0.0205	Nonparametric
	Calcium	mg/L	22	22	100	---	4.003	---	8.752	6.073	1.128	0.186	Yes		8.2	Normal
	Chloride	mg/L	19	19	100	---	3.373	---	12.27	7.349	1.966	0.267	Yes		11.1	Normal
	Fluoride	mg/L	19	7	37	0.1	0.07	0.1	0.11	0.0821	0.0128	0.156	---		0.11	Nonparametric
	pH	SU	22	22	100	---	4.93	---	5.71	5.177	0.198	0.0383	No	4.76	5.59	Normal
	Sulfate	mg/L	20	18	90	0.22	0.18	0.25	2.38	0.911	0.756	0.83	No		3.35	KM Lognormal
	TDS	mg/L	21	21	100	---	34.1	---	59	45.19	6.823	0.151	Yes		58.2	Normal
MW-D	Boron	mg/L	18	12	67	0.02	0.0123	0.02	0.0341	0.0187	0.0062	0.331	No		0.0313	KM Gamma
	Calcium	mg/L	18	18	100	---	1.79	---	56.8	11.32	16.83	1.488	No		56.8	Nonparametric
	Chloride	mg/L	18	18	100	---	-33.35	---	128	9.694	38.73	3.996	Yes		85.2	Nonparametric
	Fluoride	mg/L	22	9	41	0.02	0.04	0.1	0.44	0.113	0.123	1.089	---		0.44	Nonparametric
	pH	SU	22	22	100	---	4.568	---	5.54	5.019	0.288	0.0573	Yes	4.41	5.63	Normal
	Sulfate	mg/L	19	8	42	0.25	0.3	0.65	13.5	2.064	4	1.938	---		13.5	Nonparametric
	TDS	mg/L	16	16	100	---	0.56	---	406.3	75.66	109.8	1.452	Yes		320	Gamma

Notes:

"---" = not applicable

% = percent

CV = coefficient of variation

Detect Freq. = frequency

KM Mean = Corrected mean value using the Kaplan-Meier method

KM Standard Deviation = Corrected standard deviation value using the Kaplan-Meier method

LPL = lower prediction limit

mg/L = milligrams per liter

SU = standard units

UPL = upper prediction limit

UPLs were calculated using an annual Site-Wide False Positive Rate of 10 percent and a one-of-two retesting strategy.

Summary of Updated Background Set and Prediction Limits

Groundwater monitoring relies on comparing the results of sampling to statistically justified prediction limits derived from a set of background data. These limits need to be revisited periodically to remain current (EPA 2009). While updating the limits used for assessing potential SSI, the new observations must be statistically compared to the existing background data, as appropriate. If the data are found to be comparable, then the new data is to be combined with the existing background data set to re-compute the statistical background limits. If the data are shown to be different, then the data will be reviewed to evaluate the cause of the difference. Absence evidence of a release, the more recent data will be considered more representative of present-day groundwater conditions and used for the background.

This procedure was completed for the OUC SEC CCR Rule monitoring wells with monitored data collected through 2021. New trend analyses and UPL (and LPL for pH) were developed. Table 11 provides a summary of the new updated limits that will be applied going forward (starting in 2022). Some data will require trend adjustment prior to evaluation, as documented in Table 8. If there is an exceedance, then a resample will be collected prior to the next regularly scheduled event.

This background data set may be updated again in the future, in accordance with EPA guidance (EPA 2009).

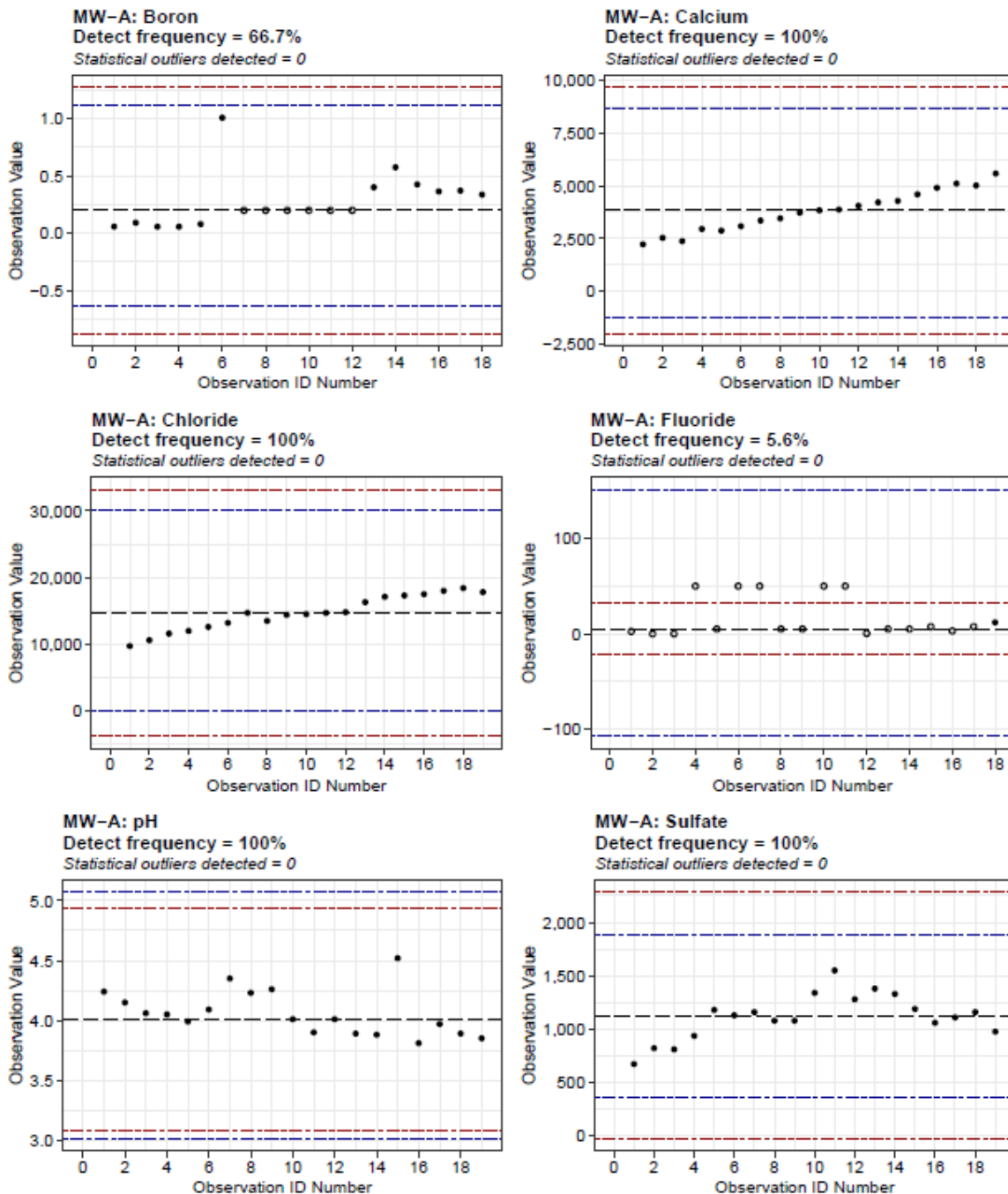
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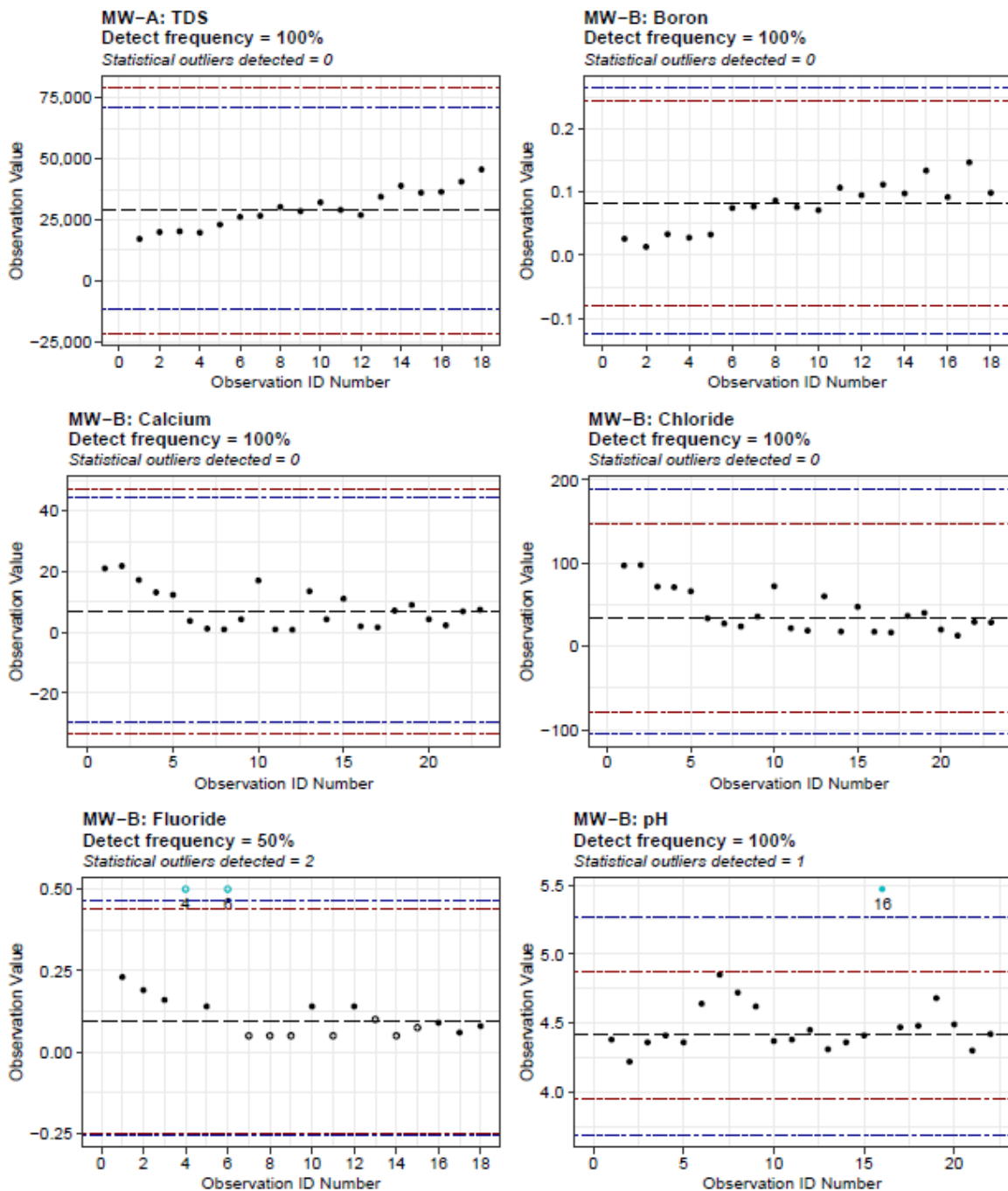
Attachment 1

Outlier Plots

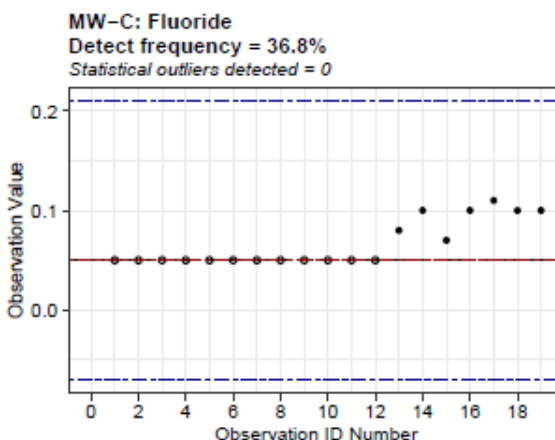
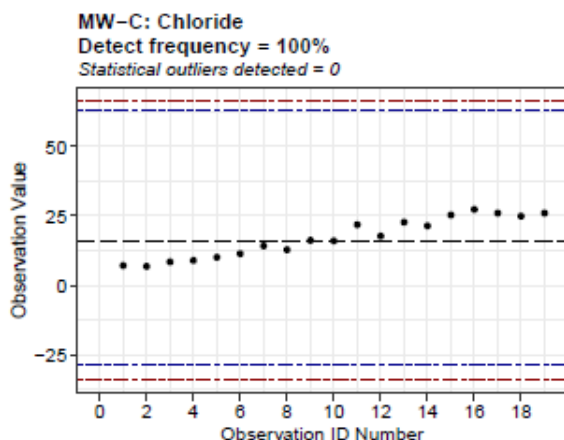
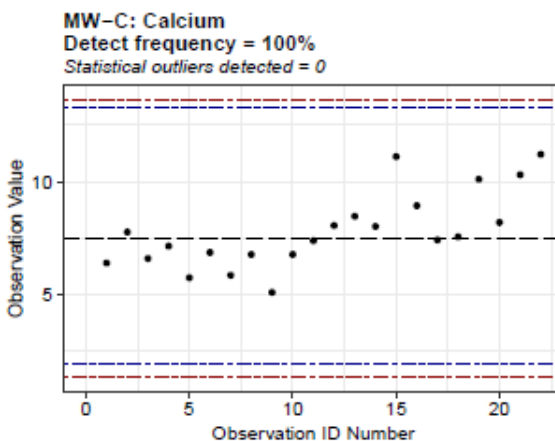
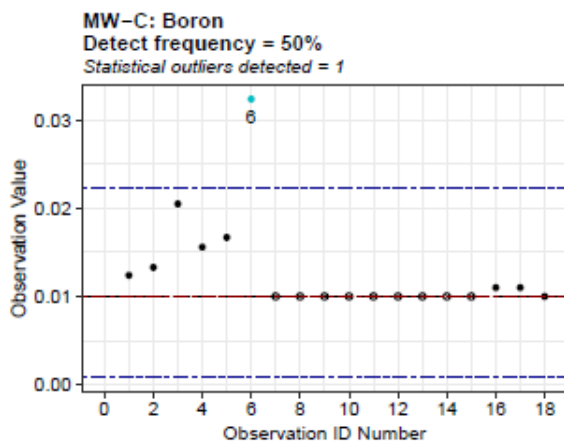
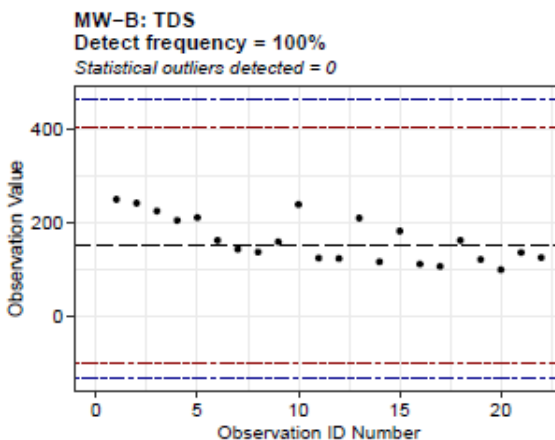
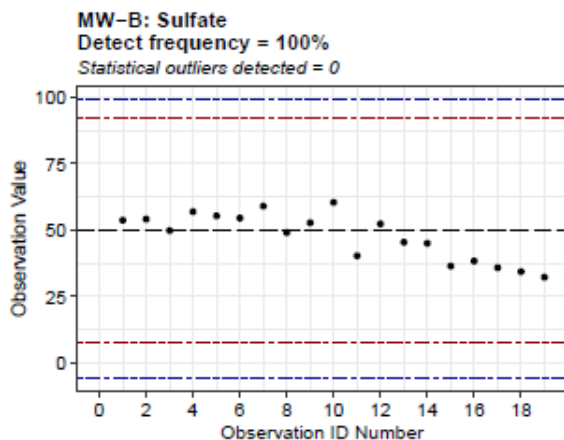
Outlier Plots for OUC Alluvium Data
 (lines represent median value [black], MAD limits [red], and IQR limits [blue])
 (nondetects are shown as open circles at MDL/2)



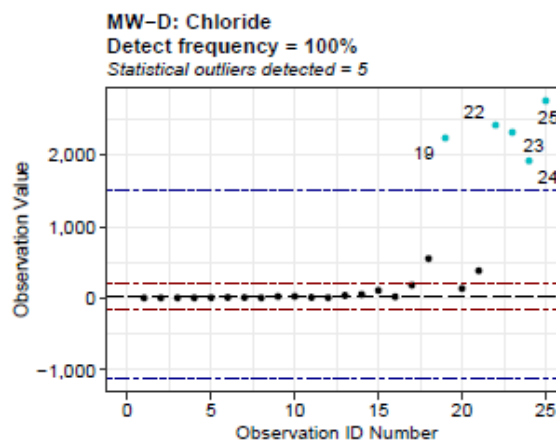
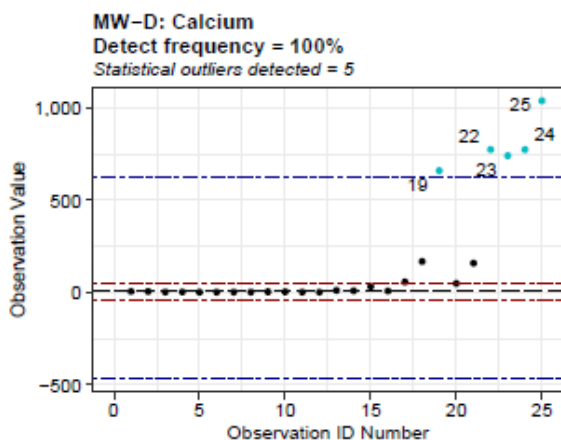
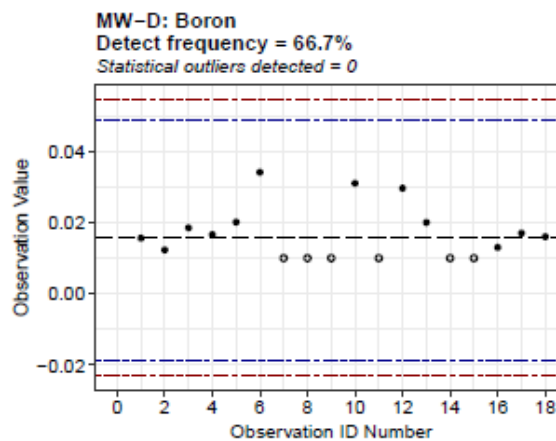
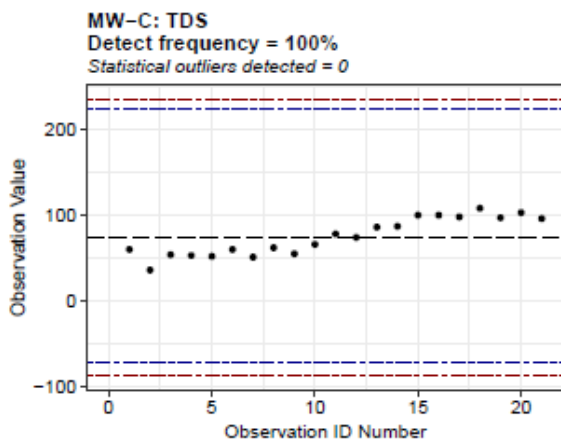
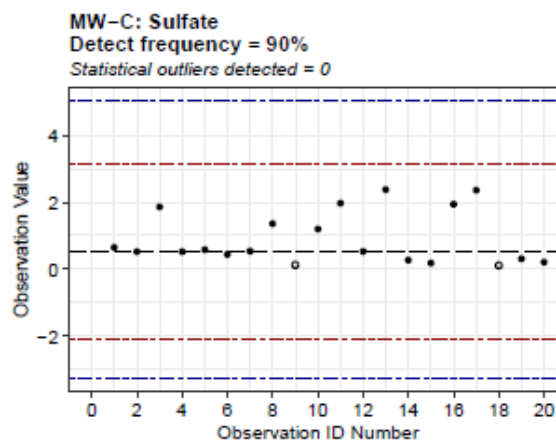
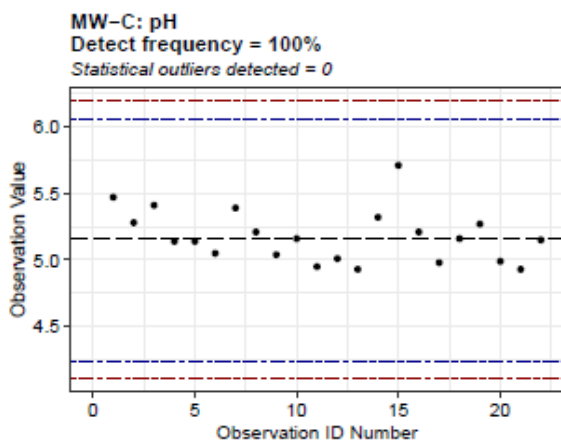
Outlier Plots for OUC Alluvium Data
(lines represent median value [black], MAD limits [red], and IQR limits [blue])
(nondetects are shown as open circles at MDL/2)



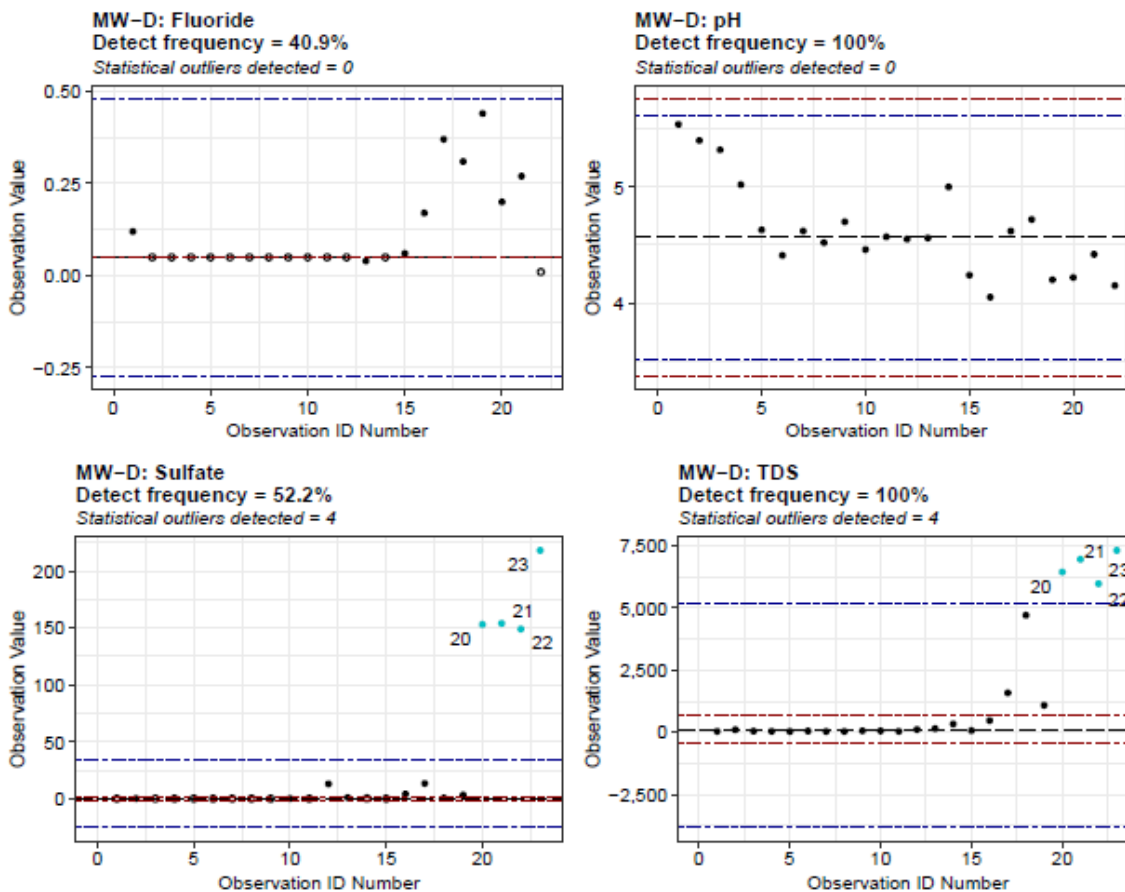
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 (lines represent median value [black], MAD limits [red], and IQR limits [blue])
 (nondetects are shown as open circles at MDL/2)



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 (nondetects are shown as open circles at MDL/2)



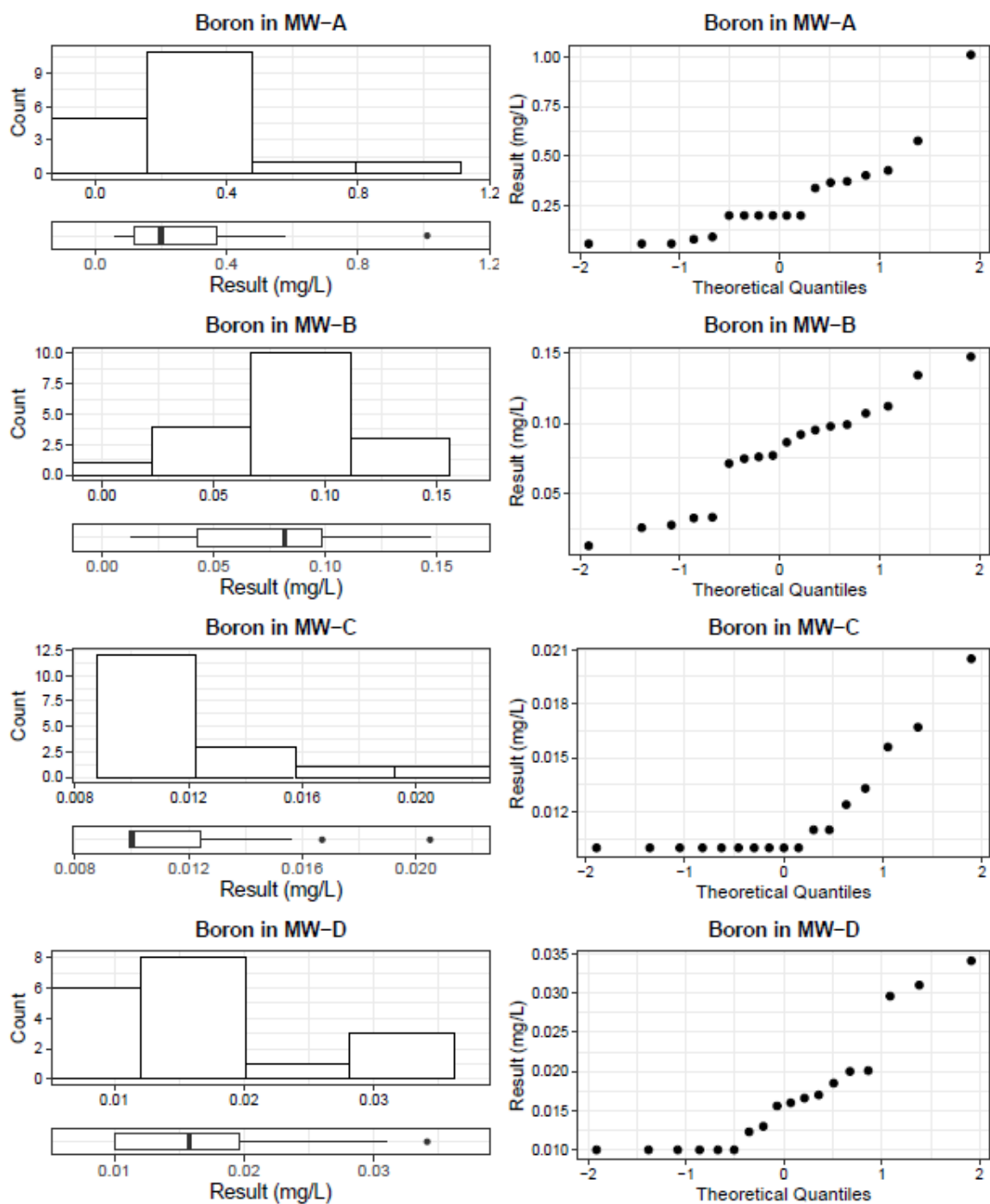
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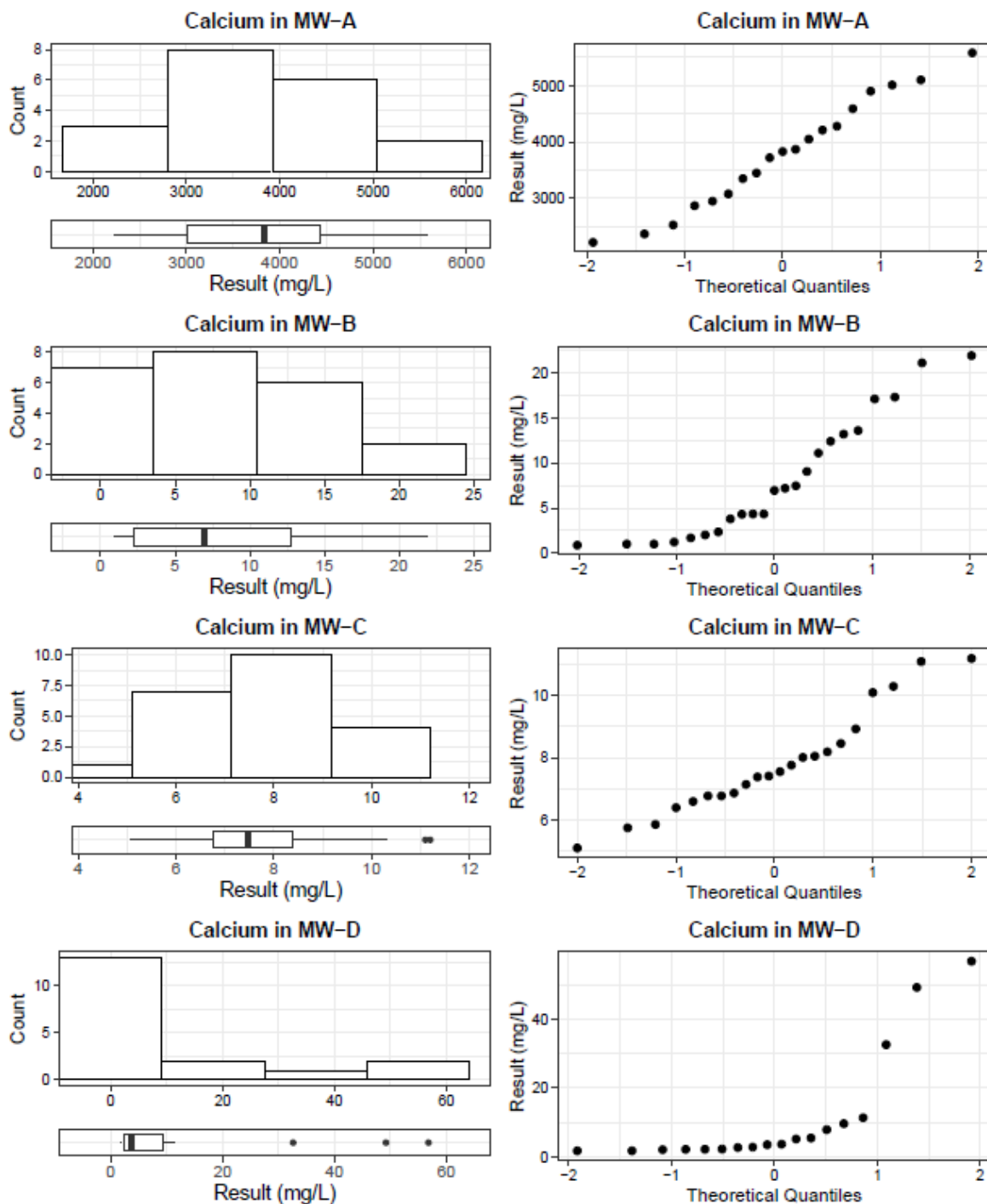
Attachment 2

Histograms, Bow Plots, and QQ Plots

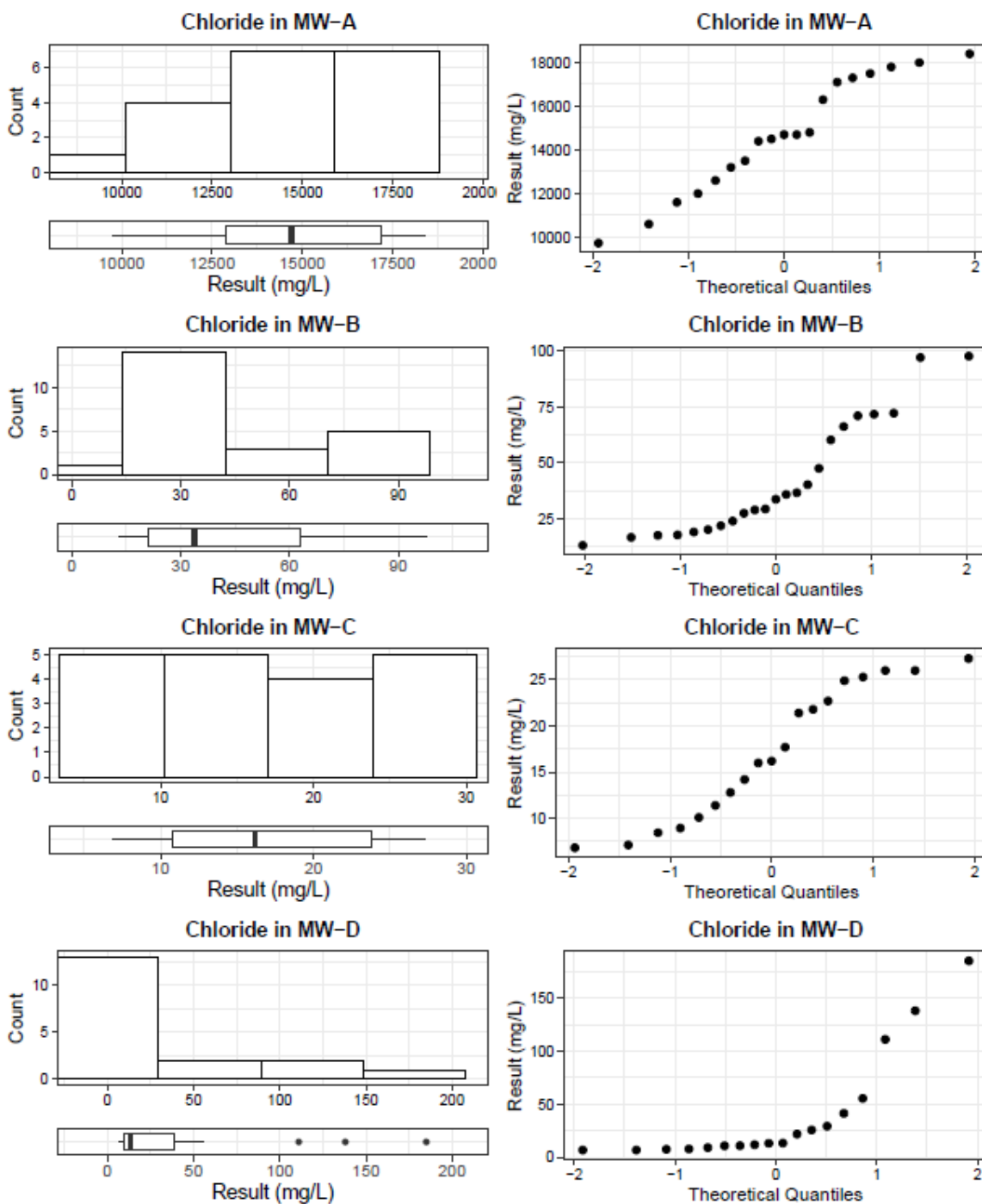
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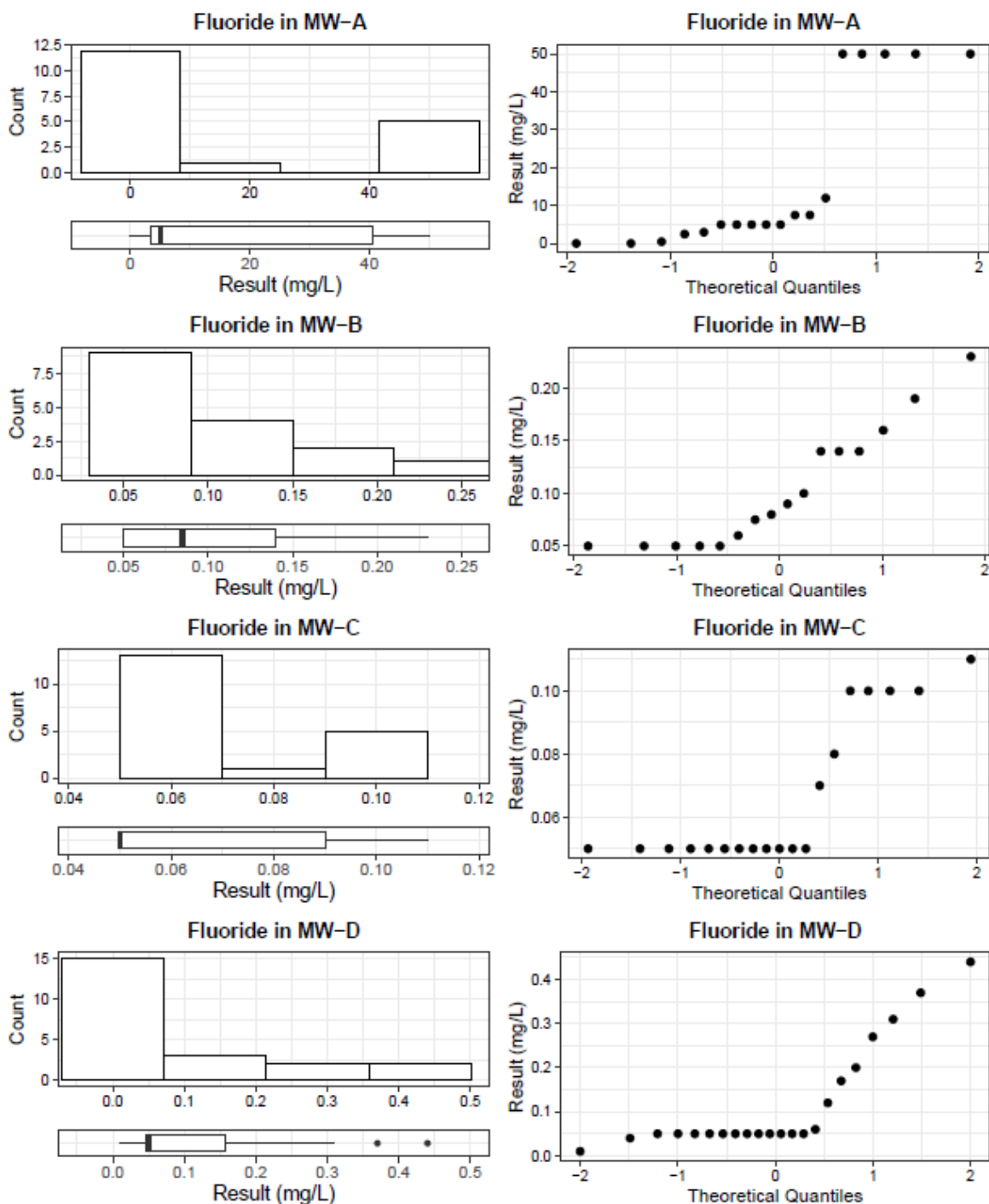
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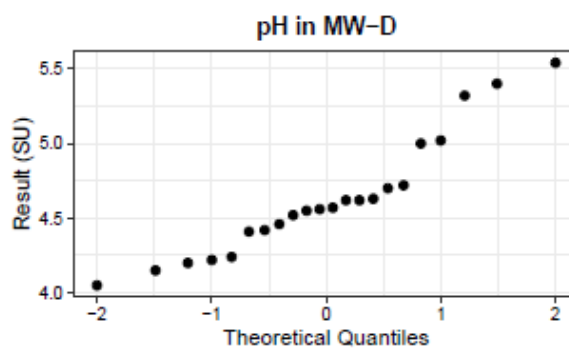
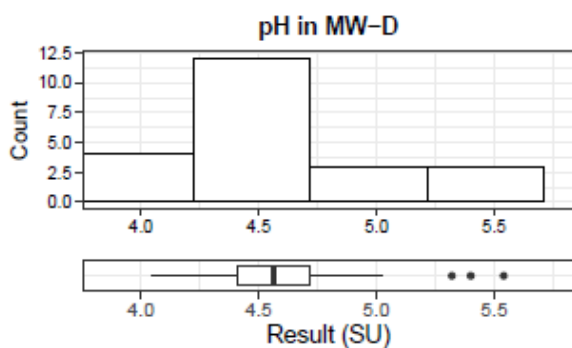
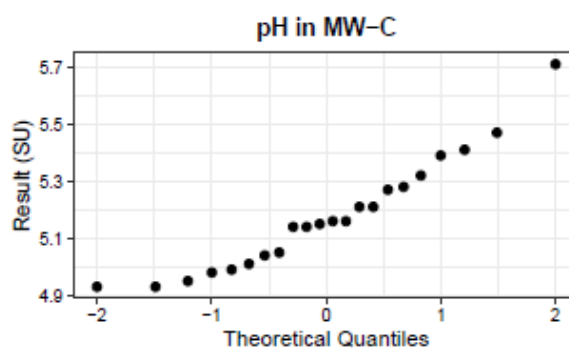
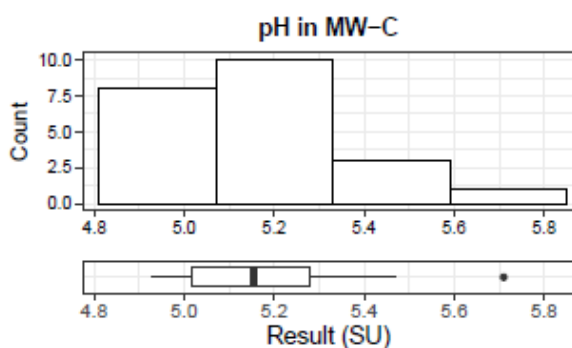
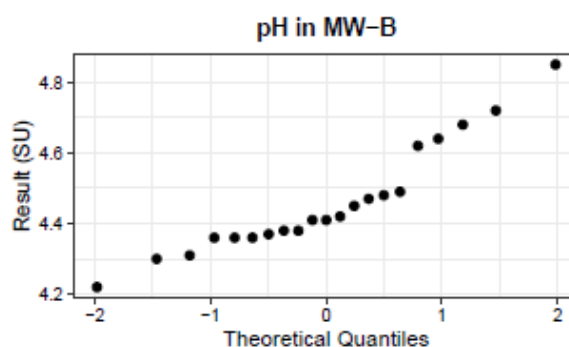
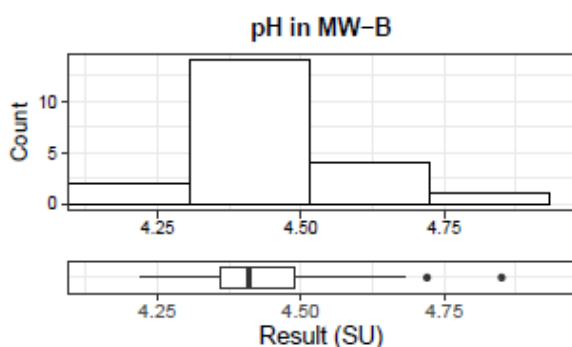
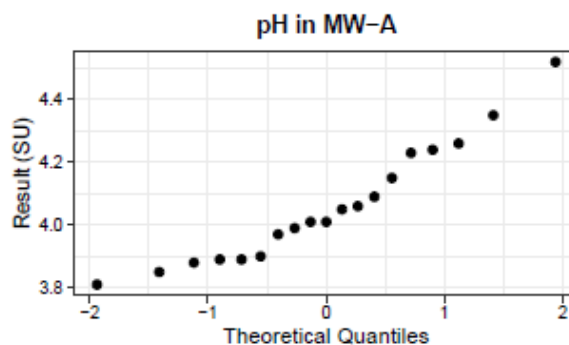
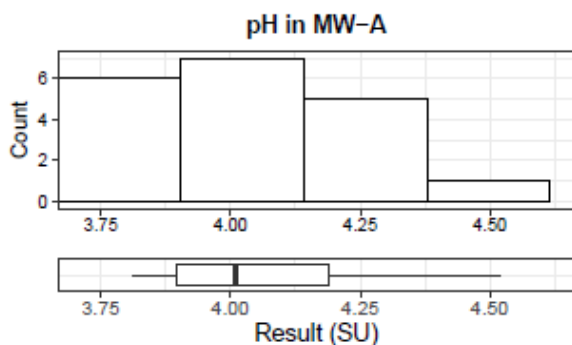
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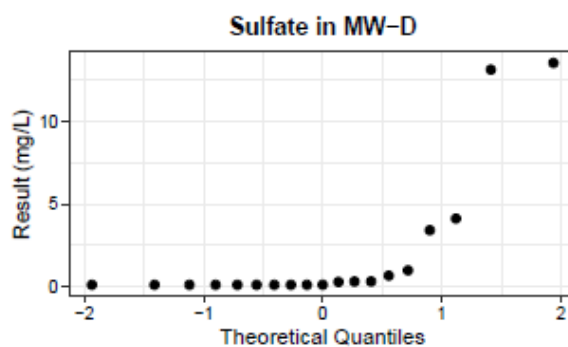
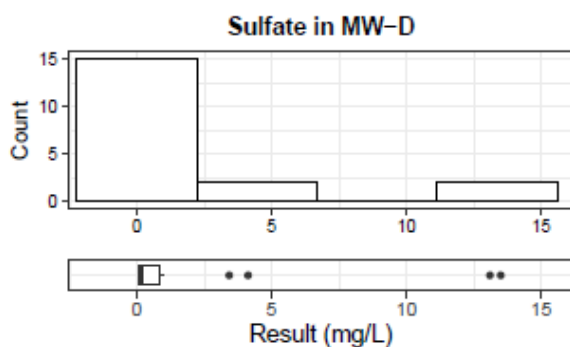
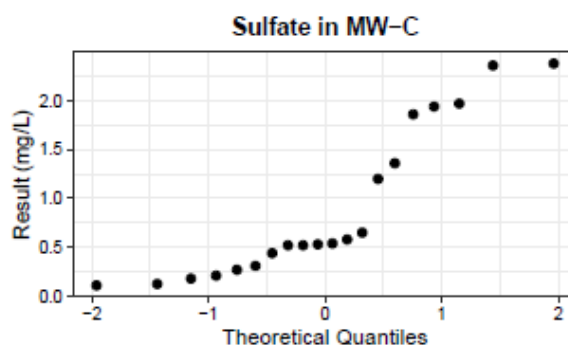
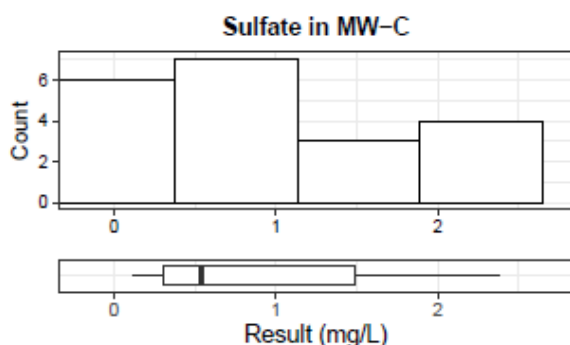
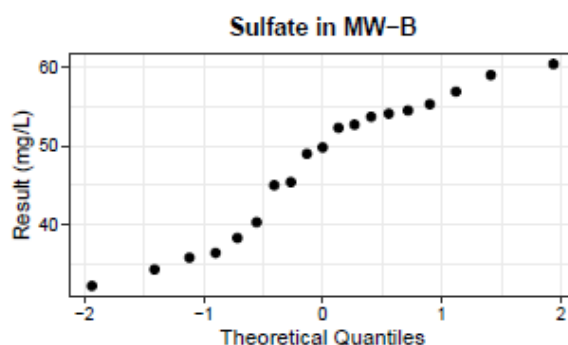
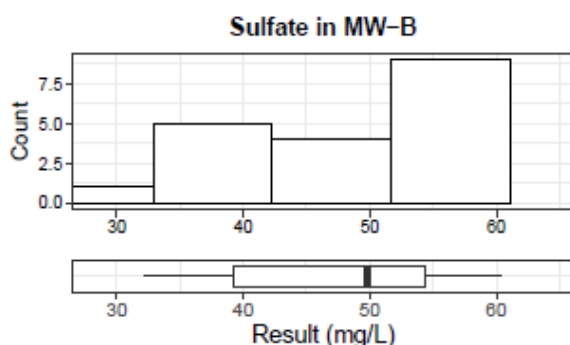
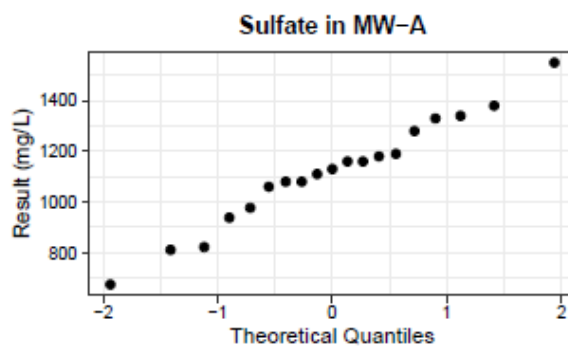
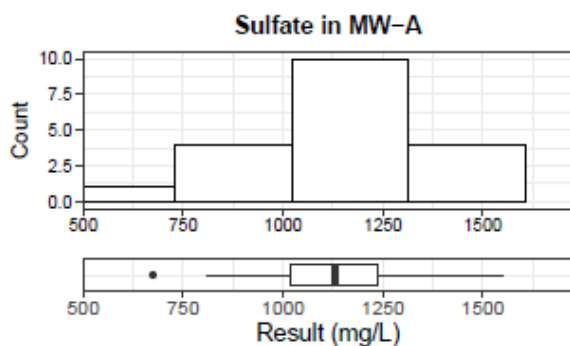
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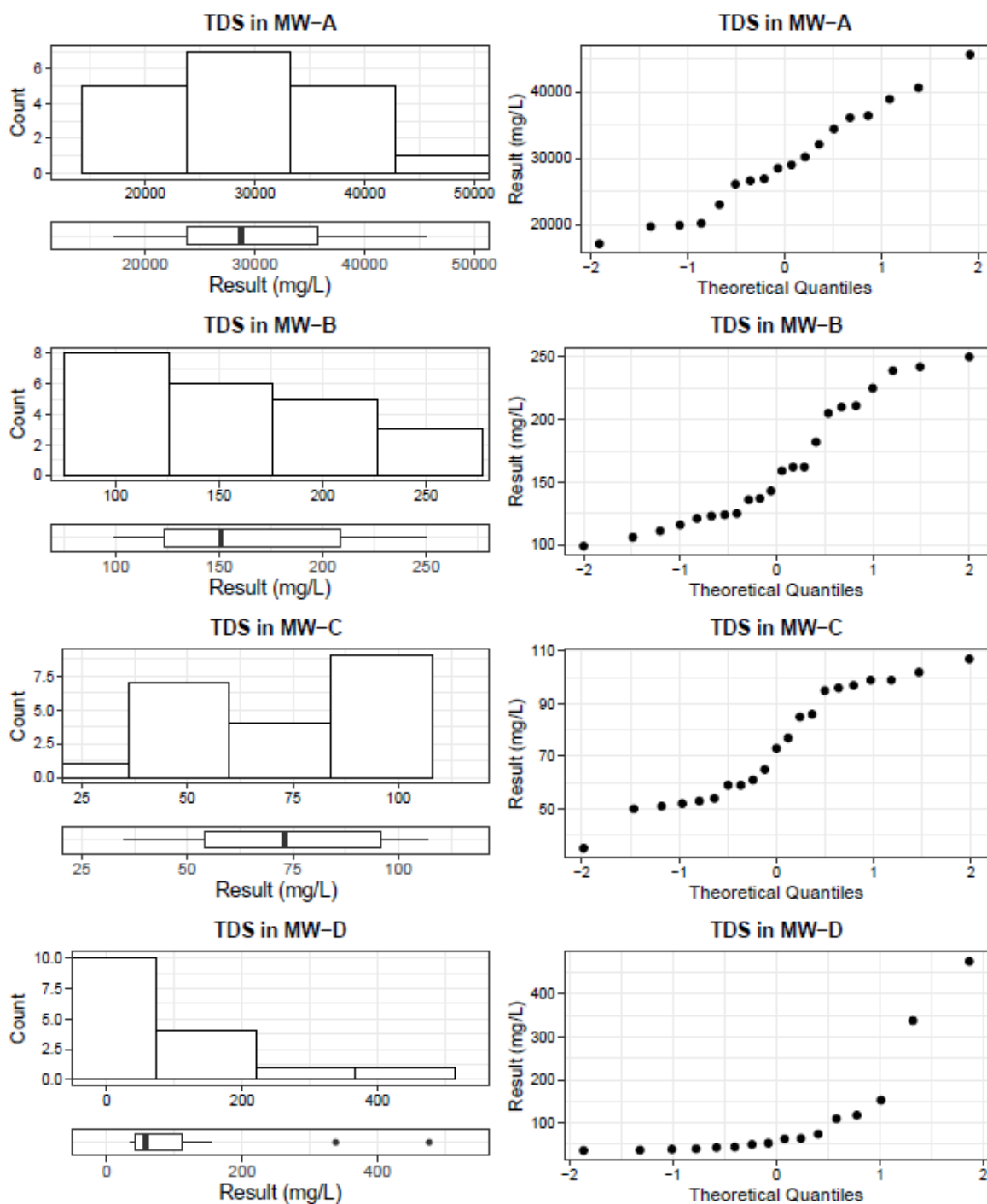
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OUC Landfill Histogram, QQ, and Box-Whisker Plots after Outlier Removal (nondetects assumed equal to one-half the MDL)



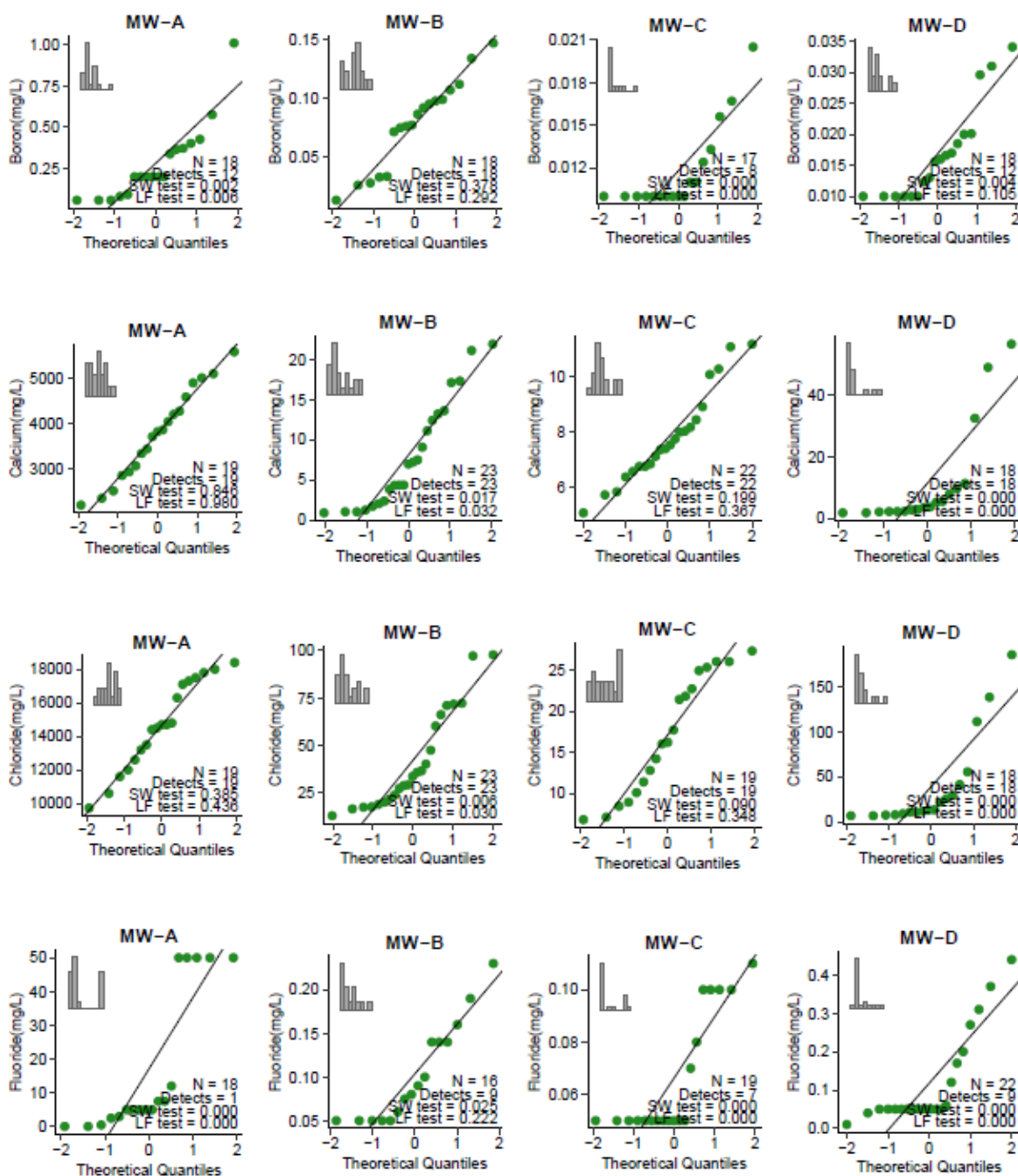
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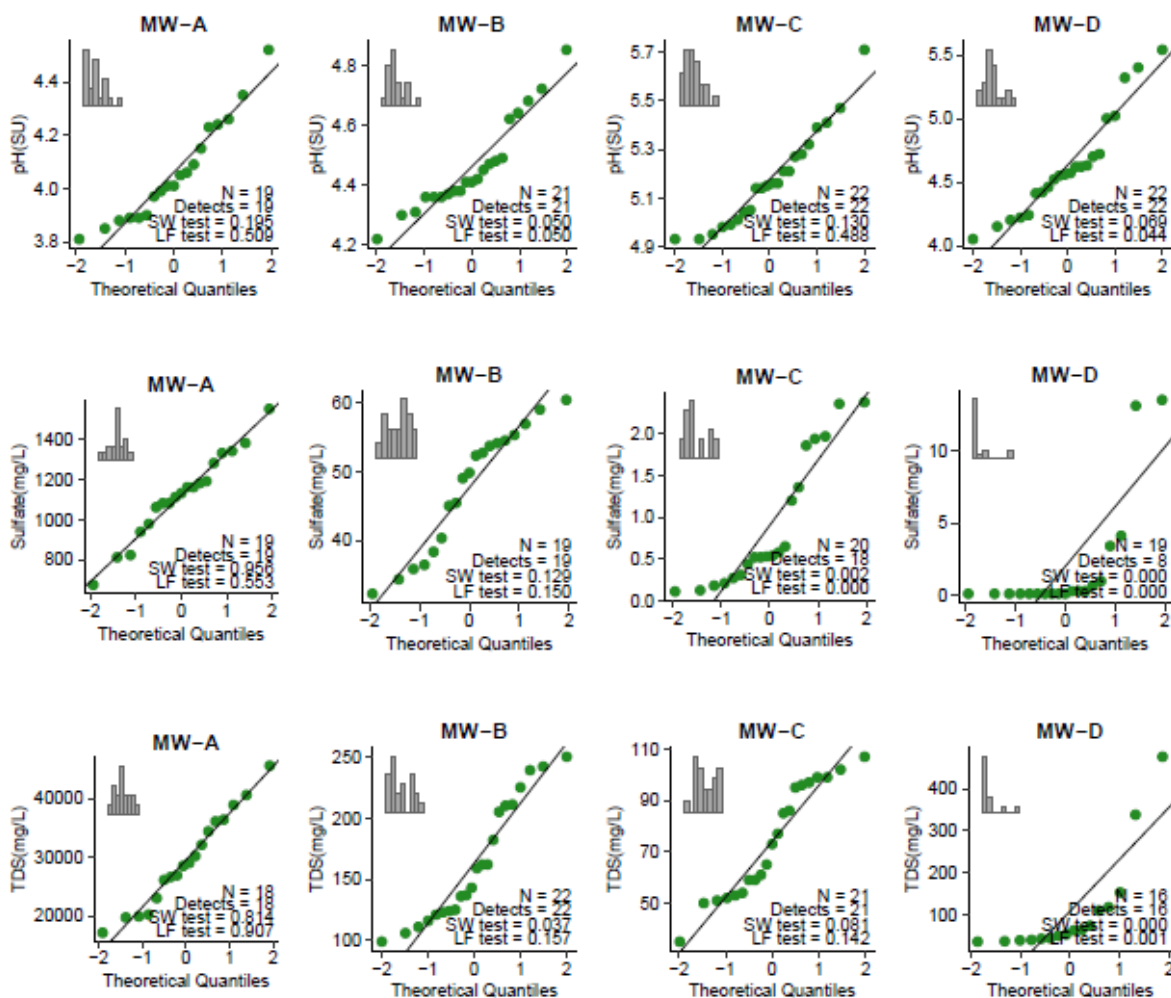
Attachment 3

QQ Plots with Normality Tests

Q-Q Plots, OUC Data
(nondetects assigned one-half the MDL)



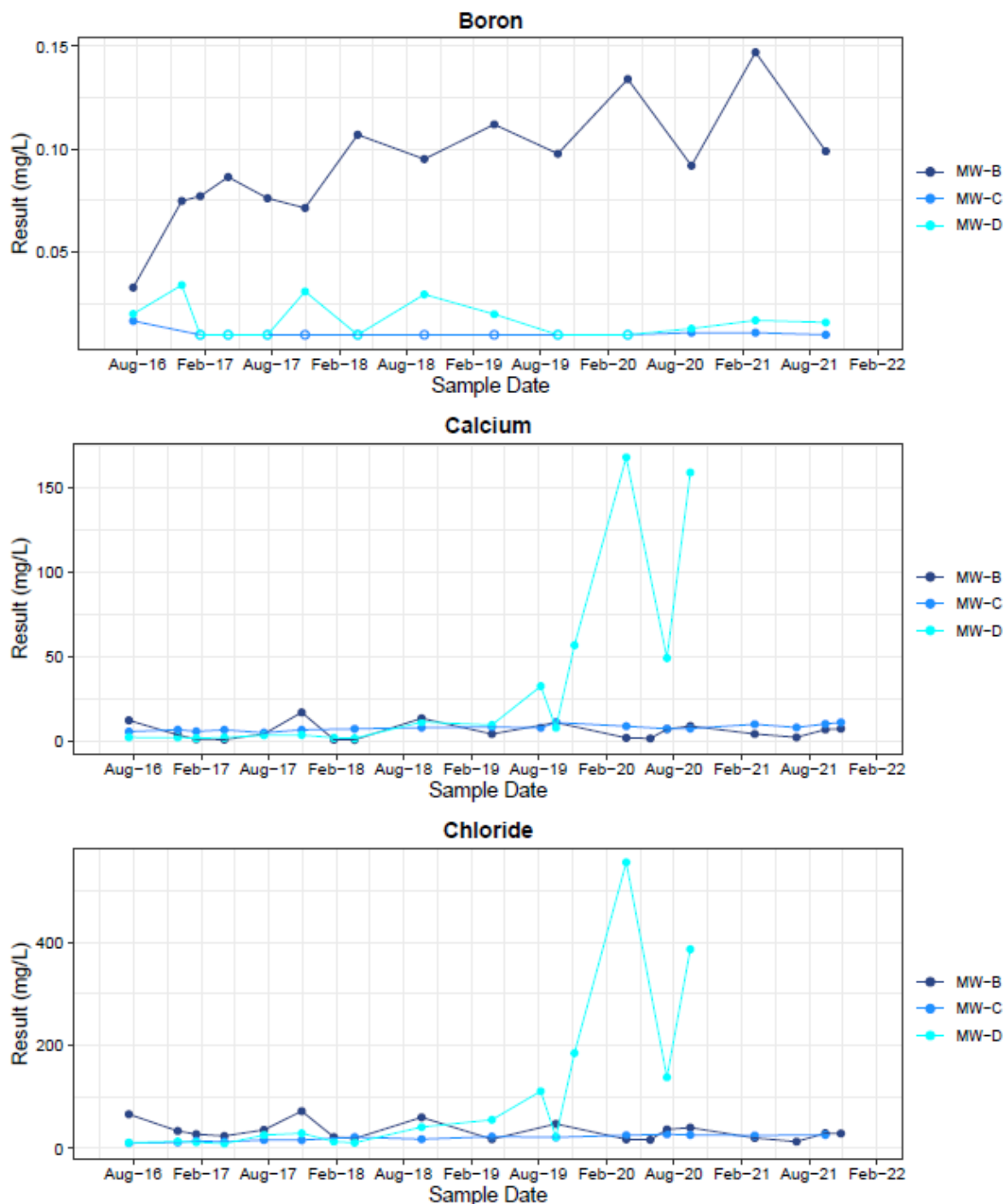
Q-Q Plots, OUC Data
(nondetects assigned one-half the MDL)



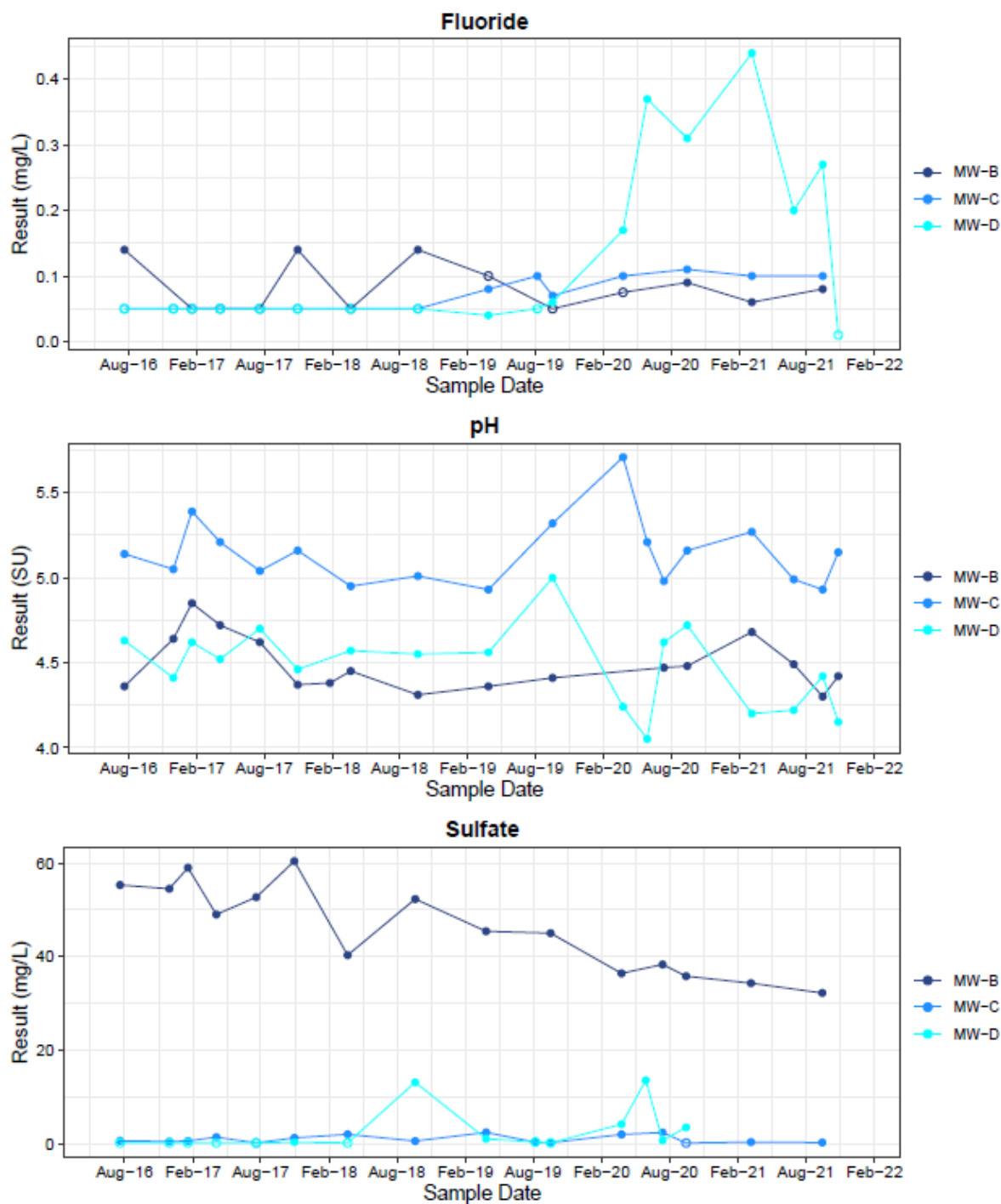
Attachment 4

Overlapping Timeseries Plots

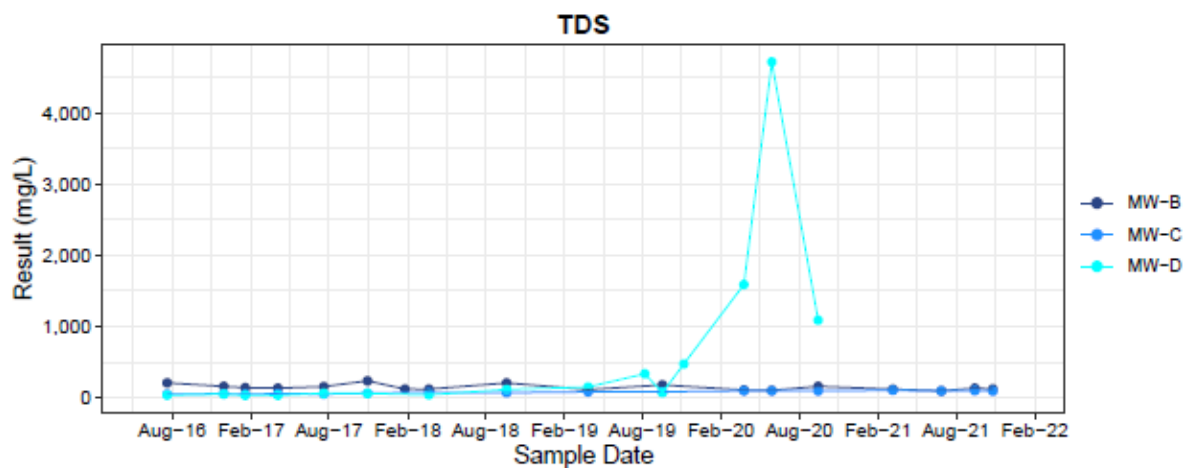
Overlapping Time Series Plots for OUC Landfill
(nondetects plotted using open symbols at one-half the reporting limit)



Overlapping Time Series Plots for OUC Landfill
(nondetects plotted using open symbols at one-half the reporting limit)



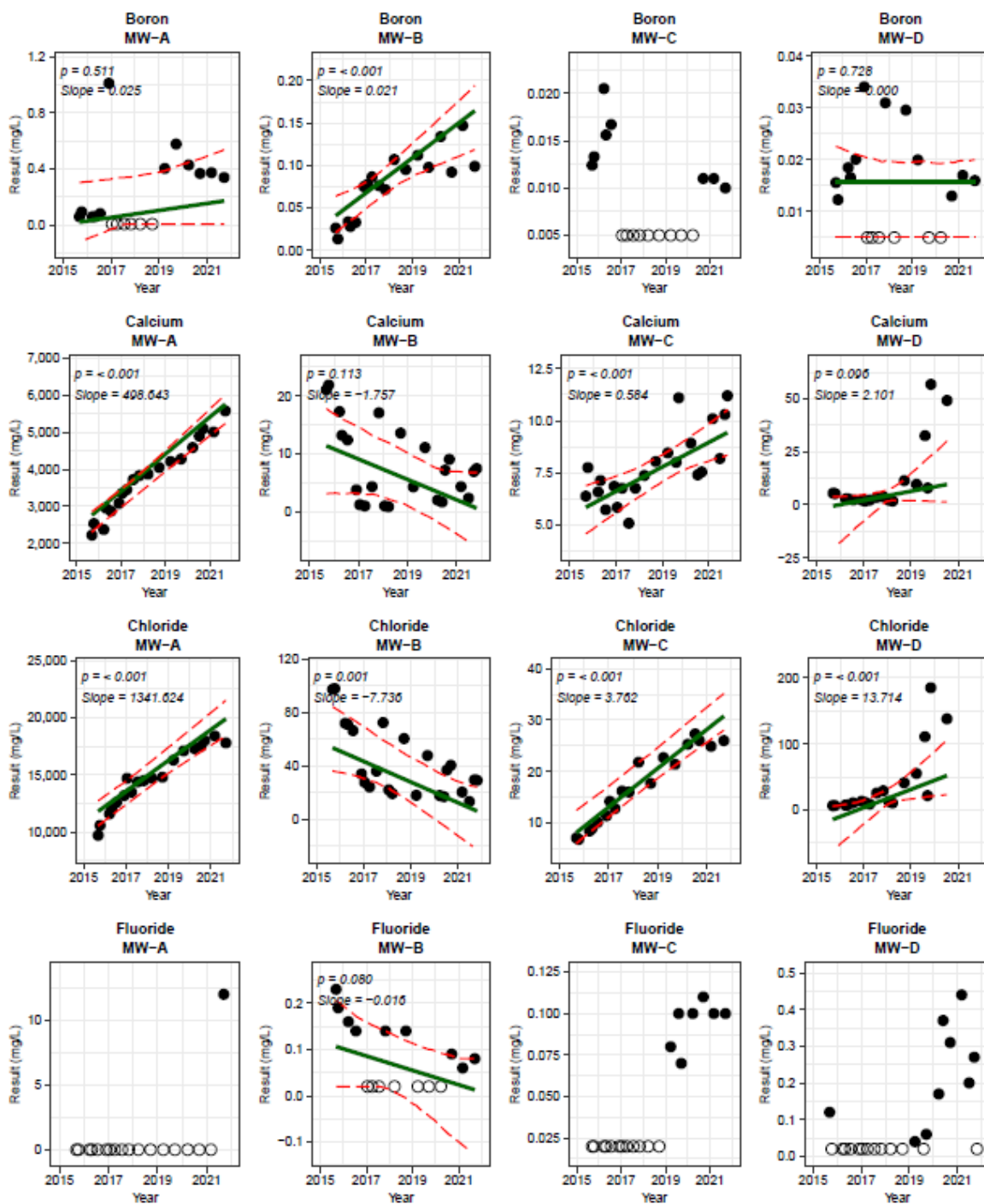
Overlapping Time Series Plots for OUC Landfill
(nondetects plotted using open symbols at one-half the reporting limit)



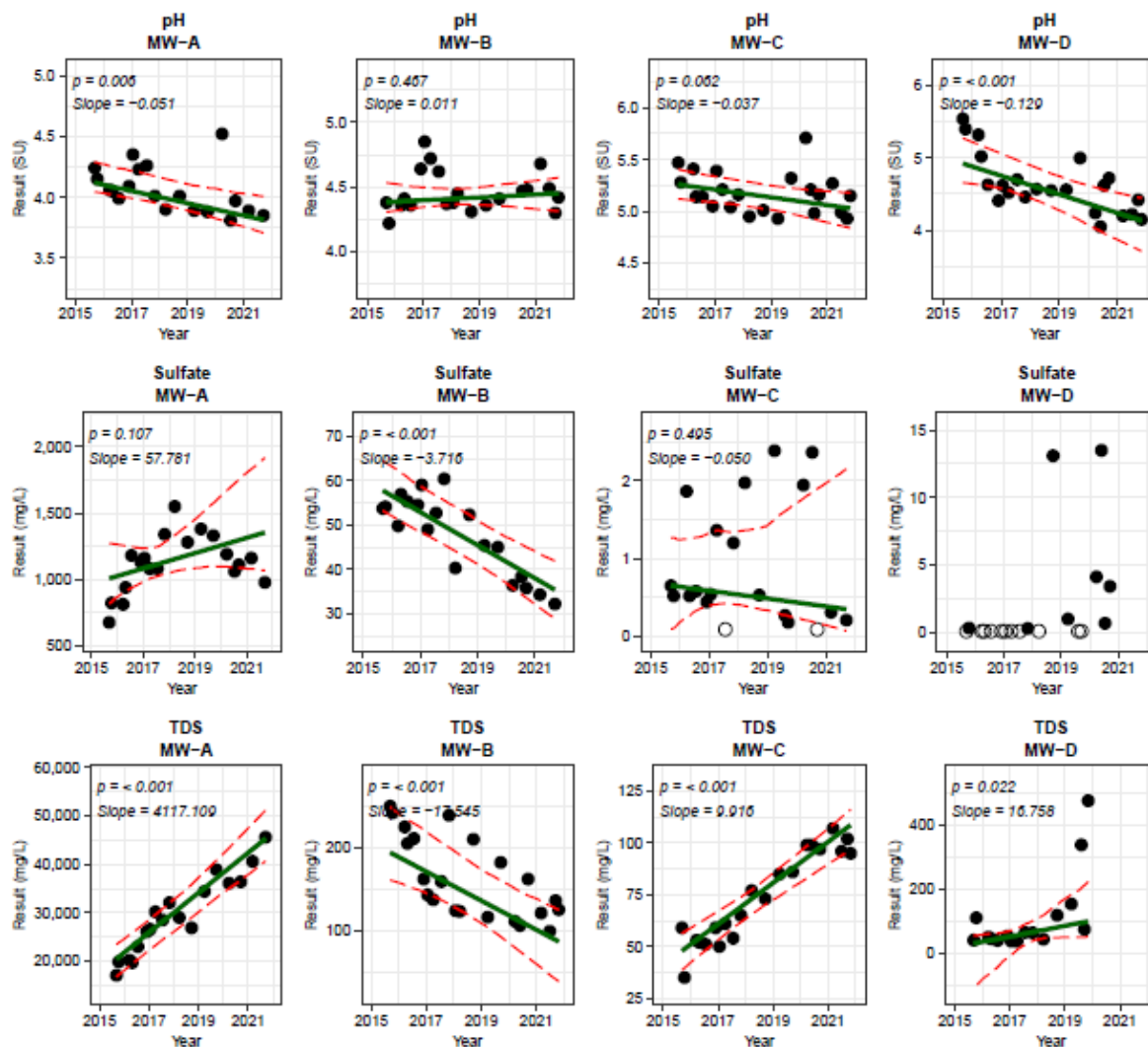
Attachment 5

Theil-Sen Trend Plots

Theil-Sen Trend Plots



Theil-Sen Trend Plots



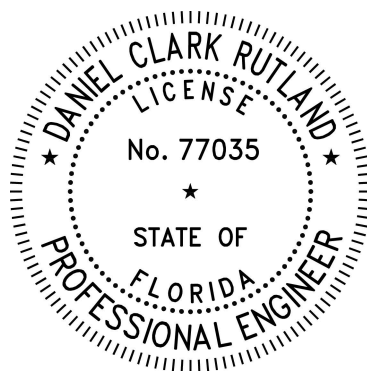
Appendix B
2021 Alternate Source Demonstration for CCR
Monitoring Wells: OUC Stanton Energy Center CCR

2021 Alternate Source Demonstration for CCR Monitoring Wells: OUC Stanton Energy Center CCR

PREPARED FOR: Orlando Utility Commission
PREPARED BY: CH2M HILL Engineers, Inc.
DATE: October 18, 2021
PROJECT NUMBER: D3292400

Daniel C. Rutland, P.E.
Florida P.E. No. 77035

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This report has been digitally sealed by Daniel C. Rutland, P.E. on the date adjacent to the seal.

Printed copies of this document are not considered signed and sealed and the signature must be verified on any electronic copy.

Executive Summary

The Orlando Utilities Commission (OUC) has been conducting groundwater monitoring associated with the new coal combustion residuals (CCR) landfill consistent with the United States Environmental Protection Agency's (EPA's) CCR Rule¹ since September 2015. Activities and results prior to 2021 have been documented and posted on OUC's CCR website, as required by the CCR Rule. The OUC CCR groundwater monitoring system consists of one background monitoring well (MW), MW-A, and three compliance MWs, MW-B, MW-C, and MW-D. Sample results from the first semi-annual sampling event conducted on March 17, 2021 required retesting for identified statistically significant increases (SSIs) at wells MW-B, MW-C, and MW-D for pH, fluoride (F), sulfate (SO₄), calcium (Ca), chloride (Cl), and total dissolved solids (TDS) (parameters varied per well).

After checking the results with the lab and retesting on June 28, 2021, it was determined that the data at MW-D for pH, F, SO₄, Ca, Cl, and TDS were confirmed as SSIs that could not be explained by statistical analysis alone. The SSIs at MW-B and MW-C were not as high as those at MW-D, but had similar parameters with high Cl, Ca, pH, and/or TDS levels.

The groundwater sampling and statistical analyses of the groundwater quality data sets from the four MWs will be presented in the 2021 annual groundwater monitoring and corrective action report for the OUC Stanton Energy Center. This document presents a demonstration that the confirmed SSIs identified at the MWs are from an alternate source; thus, meeting the requirement of the CCR Rule to continue in the Detection Monitoring program. Since the concentrations in MW-D have been higher than at the other MWs, and the constituents of concern are Ca, Cl, SO₄, and TDS, the discussion focuses primarily on these four analytes.

As part of this alternate source demonstration, additional groundwater data were collected in September 2021 to evaluate hydrogeologic conditions in the surficial aquifer and determine the

¹ <https://www.epa.gov/coalash/coal-ash-rule>, accessed October 6, 2021.

expected travel time of groundwater from the new CCR landfill to MW-D. The results of this analysis indicate that the groundwater velocity in the surficial aquifer is too low to have traveled from the new CCR landfill to MW-D since the beginning of the new CCR landfill operation approximately 6 years ago. Results of this analysis indicated that the groundwater quality at MW-D cannot yet be influenced by the new CCR landfill and indicates that an alternate source is responsible for the water quality at MW-D. This demonstration is documented in this memorandum. Subsequently, continued Detection Monitoring is recommended so this situation can continue to be evaluated.

Background

The Stanton Energy Center (SEC) is located 12 miles southeast of Orlando, Florida. OUC has been operating SEC since 1987 and dry-managing CCRs in landfills on the west side of the property. The original, now closed, landfill received CCR from July 1987 through August 28, 2015. From the period of May 28 through August 15, 2015, the CCR directed to the closed landfill was used to form part of the landfill cap. The cap was completed with 2 feet of soil and then sodded to stabilize the soil. The old landfill is exempt from the CCR Rule because it ceased operations prior the prescribed date of the CCR Rule, October 17, 2017. The old landfill has been closed (hereinafter “closed landfill”) and is undergoing post-closure monitoring under OUC’s Conditions of Certification with the Florida Department of Environmental Protection (FDEP). The closed landfill has a 6.42-megawatt solar power generation farm installed over its top.

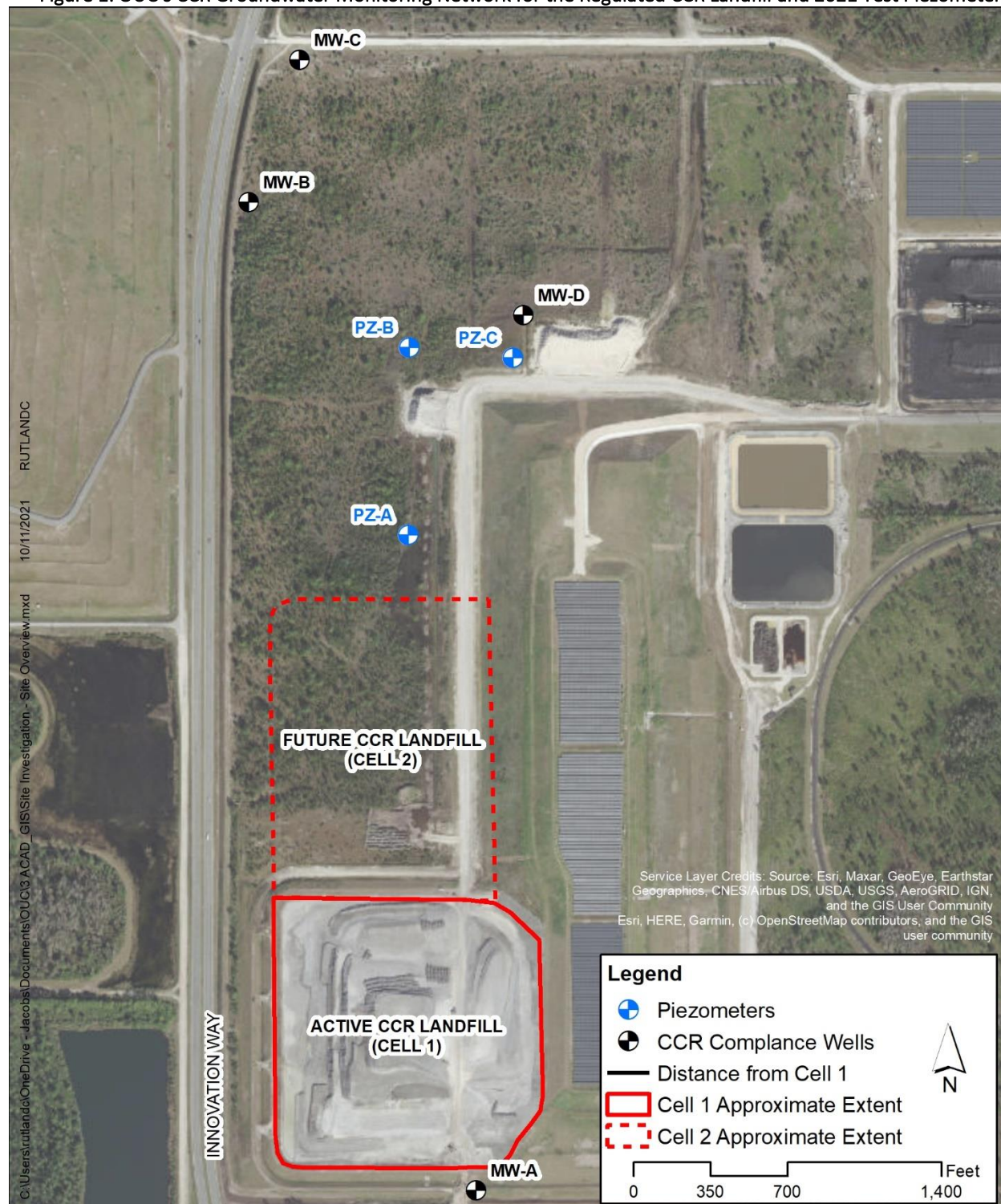
The new landfill (hereinafter “active landfill”) began receiving CCR on May 28, 2015 as a monofill that receives CCR produced by the SEC coal-fired power generating process. The new landfill is positioned immediately west of and adjacent to the closed landfill and immediately east of Innovation Way, which is the approximate SEC western property boundary. The design standards for the active landfill were compliant with Florida’s municipal solid waste landfill requirements under Chapter 62-701, Florida Administrative Code. The active landfill is fully double-lined and does not discharge into the surficial groundwater.

Groundwater conditions at SEC are regulated under two separate programs: the FDEP Power Plant Siting Act and the U.S. Environmental Protection Agency (EPA) CCR Rule. The FDEP monitoring program has been active since August 1986, while the CCR monitoring program began in October 2015. OUC has made a conscious effort to keep these programs separate because different regulatory requirements, different groundwater quality standards, and different monitored constituents. However, the groundwater conditions at the two adjacent landfills are common.

The CCR well monitoring network was installed in August 2015 and consisted of 4 MWs. MW-A is the background MW and MW-B, MW-C, and MW-D are compliance MWs (Figure 1). Background period groundwater quality sampling was performed from September 2015 through July 2017. Operational monitoring has been performed semi-annually beginning October 2017 to the present under the Detection Monitoring program of the CCR Rule. Data from the background monitoring period were used to establish statistically based evaluation criteria consistent with the CCR Rule. These baseline data established potential trends, when present, and statistical upper limits (and lower limit for pH) that are typically set at 95 percent confidence interval.

The March 17, 2021 semi-annual sampling and selective retest resampling on June 28, 2021 to confirm groundwater quality, determined that SSIs at the MWs associated with the active CCR unit were potentially present. When an SSI is determined from analysis of the data, the CCR Rule requires that the Detection Monitoring program convert to an Assessment Monitoring program unless the owner or operator demonstrates that the SSI resulted from an error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality, or was caused by a source other than the CCR unit. This analysis assessed the potential of an alternative source of contaminants in the groundwater.

Figure 1. OUC's CCR Groundwater Monitoring Network for the Regulated CCR Landfill and 2021 Test Piezometers



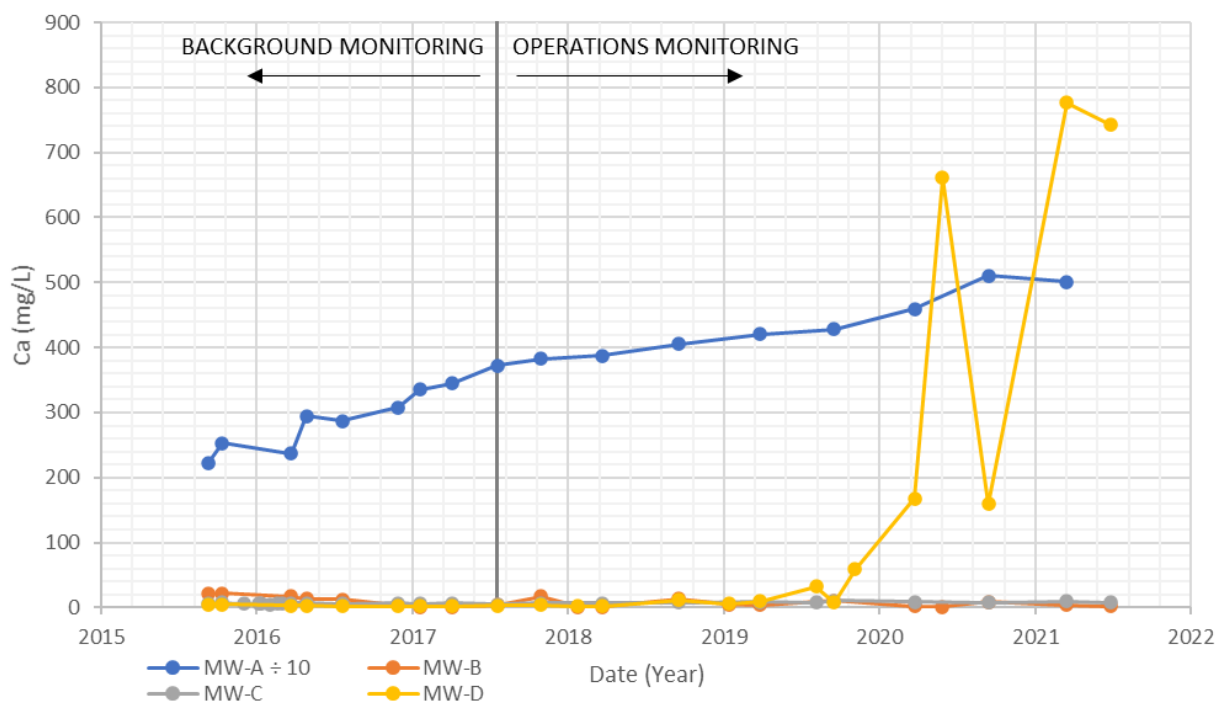
Groundwater Quality Data

Groundwater quality data for Ca, Cl, SO₄, and TDS are presented to show patterns among the MWs in Figures 2a through 2d. The background monitoring period is identified on the charts. Of interest are the concentrations of Ca and Cl at MW-D that began to increase on September 17, 2019 continued through the May 29, 2020 confirmatory selective resampling. The patterns show a sharp increase of concentrations in May. The September 14, 2020 sampling results in Figures 2a and 2b, respectively, had a sharp decrease of Ca and Cl concentrations. The March 17, 2021 sampling event showed elevated concentrations again, with confirmation sampling completed on June 28, 2021.

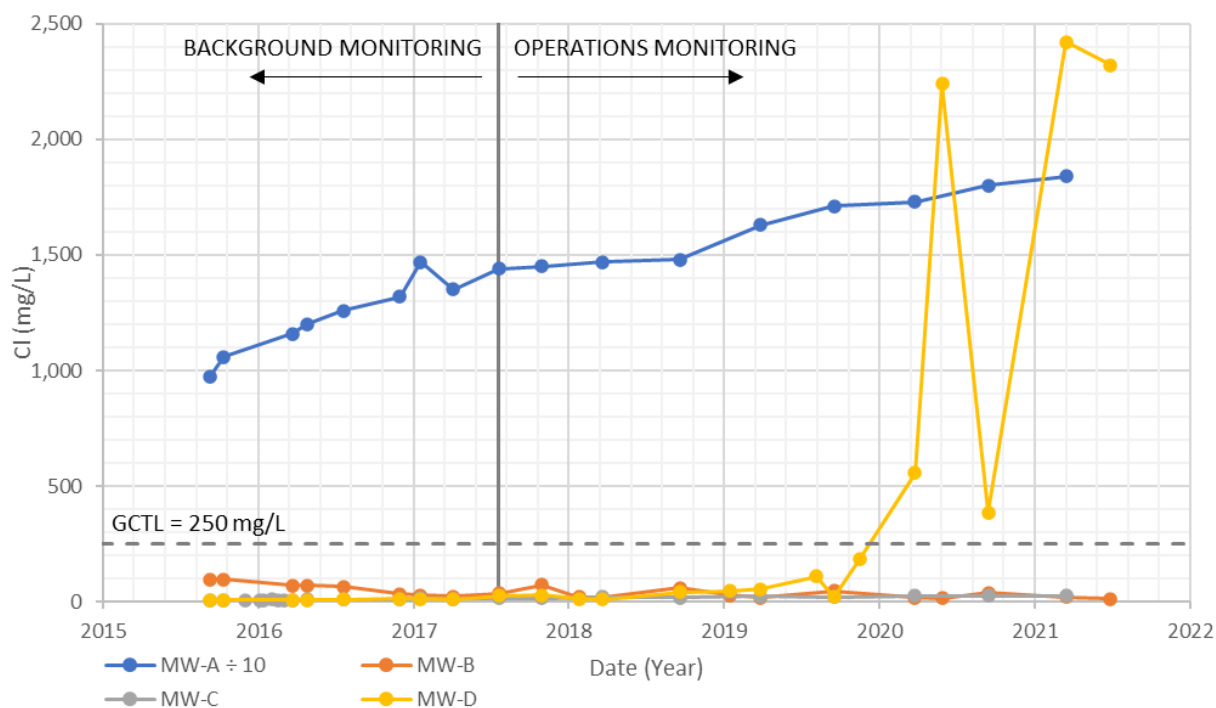
It was determined that the data at MW-D for pH, F, SO₄, Ca, Cl, and TDS were confirmed as SSIs that could not be explained by statistical analysis alone. The concentrations for these parameters were orders of magnitude different from the baseline data, approximately 1.3 to 470 times the statistical upper prediction limits (UPL). The pH was greater than the UPL when the baseline trend was applied, but the value of 4.22 standard units is not a water quality issue. The F and SO₄ concentrations at MW-D were greater than the UPL, but still below the primary and secondary maximum contaminant limits (MCL) of 4 mg/L and 250 mg/L, respectively.

The SSIs at MW-B and MW-C were not as high as those at MW-D, but had similar parameters with high Cl, Ca, pH, and/or TDS levels. The Cl and TDS analytes were approximately two times greater than the UPL at MW-B in the retest results. However, sampled values of Cl and TDS were below the secondary MCLs of 250 mg/L and 500 mg/L, respectively. At MW-C pH, Ca, and TDS were retested, but only pH and TDS were above the UPL. The pH retest value was 5.2 standard units and while that was high compared to baseline, it is not a water quality issue. While the TDS retest value was above the UPL, it was significantly below the secondary MCL.

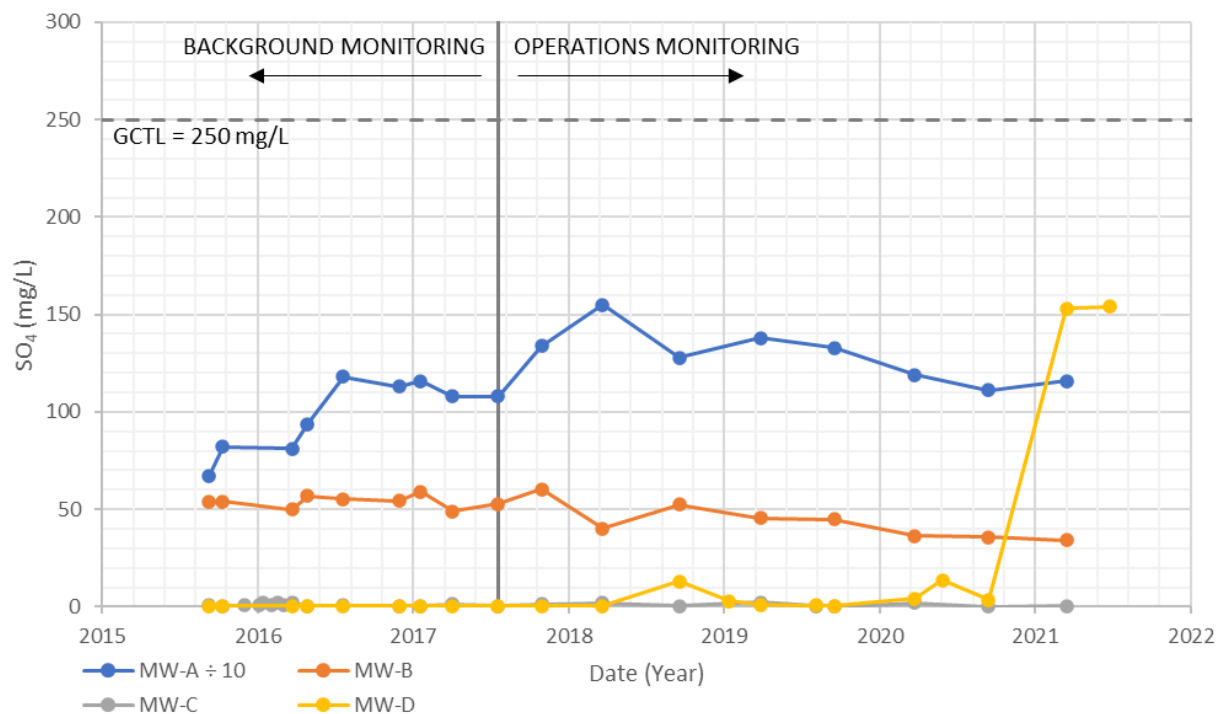
Figures 2a through 2d. Raw Groundwater Quality at the CCR Monitoring Wells



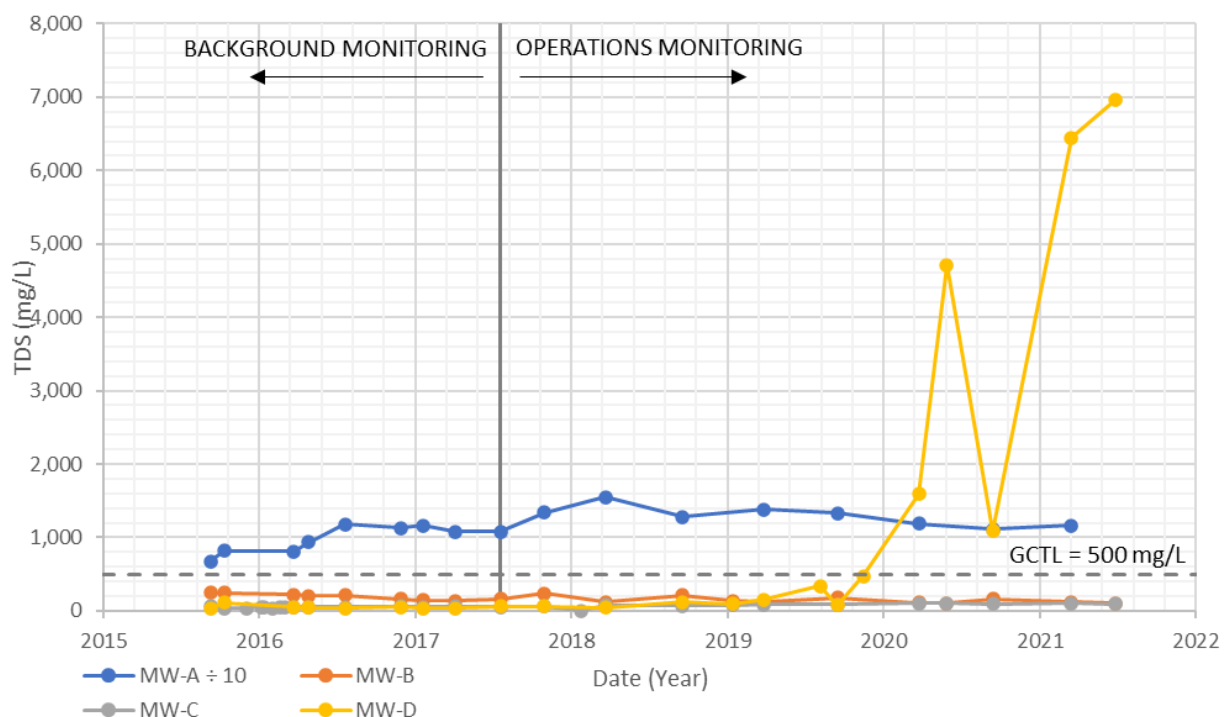
2a. Calcium



2b. Chloride



2c. Sulfate



2d. Total Dissolved Solids

Groundwater Monitoring Infrastructure and Testing

OUC has finished the construction of a new CCR landfill Cell 2 adjacent to and north of Cell 1 (Figure 1). The design standards for the horizontal expansion were compliant with Florida's municipal solid waste landfill requirements under Chapter 62-701, Florida Administrative Code. Cell 2 is fully double lined with a leachate collection system that pumps to the lined Combustion Waste Storage area (CWSA) Runoff Ponds and does not discharge into the surficial groundwater. It has not started receiving CCR materials.

The groundwater table north of the newly constructed cell is about 2.5 feet below land surface (bls) and the MWs are 30 feet bls with the screened intervals between 20 to 30 feet bls (screens fully submersed in the groundwater). MW-D is over 2,600 feet from the north side of the active landfill cell (Cell 1) and 1,200 feet from the north side of the new cell (Cell 2). MW-B is about 3,200 feet from the active landfill cell and 1,700 feet from the new cell. MW-C is the furthest north and away from the active landfill cell (about 3,800 feet) and disturbed soils.

Three new piezometers were installed on September 29, 2021 to measure the surficial aquifer properties in the area between the active landfill cell and MW-D (Figure 1). PZ-A is located approximately 320 feet north of the newly constructed landfill cell, over 1,600 feet north the active landfill cell, and approximately 1,100 feet southwest of MW-D. PZ-B is located over 1,110 feet north of the newly constructed landfill cell, over 2,500 feet north of the active landfill cell, and approximately 530 feet west of MW-D. PZ-C is located approximately 1,700 feet north of the newly constructed landfill cell, over 2,400 feet from the active landfill cell, and approximately 190 feet south of MW-D.

The soil lithology was continuously sampled to approximately 35 feet bls at each piezometer location prior to the casing installation. Soil sampling generally shows that approximately 30 to 35 feet of deep fine sands overlay a dense clay layer that has a thickness of greater than 5 feet. This clay layer provides an apparent shallow confining layer in the vicinity of the tested area. Detailed lithology results are included in Appendix A.

Each piezometer was installed above the clay layer to a depth of 30 feet bls utilizing a hollow stem auger. Piezometers were installed utilizing 2-inch schedule 40 PVC with a 10-foot screen interval (screened between 20 to 30 feet bls). A typical clean sand (20-40 silica sand) was used for the filter pack in the screen interval with approximately 1 to 2 feet of fine sand above the top of screen. All three wells were completed to the surface with neat cement grout and finished with a 2 ft by 2 ft by 4-inch concrete pad. Detailed well completion diagrams are included in Appendix B. Piezometer development was completed using a 2-inch submersible pump and surging.

After piezometer installation and development, slug tests were completed at each well to characterize the surficial aquifer hydraulic conductivity. Prior to slug testing, static water level data was collected from the new piezometers and existing monitoring wells in the vicinity of the active and newly constructed landfill cell. A summary of water levels and hydraulic gradient can be seen in Figure 3.

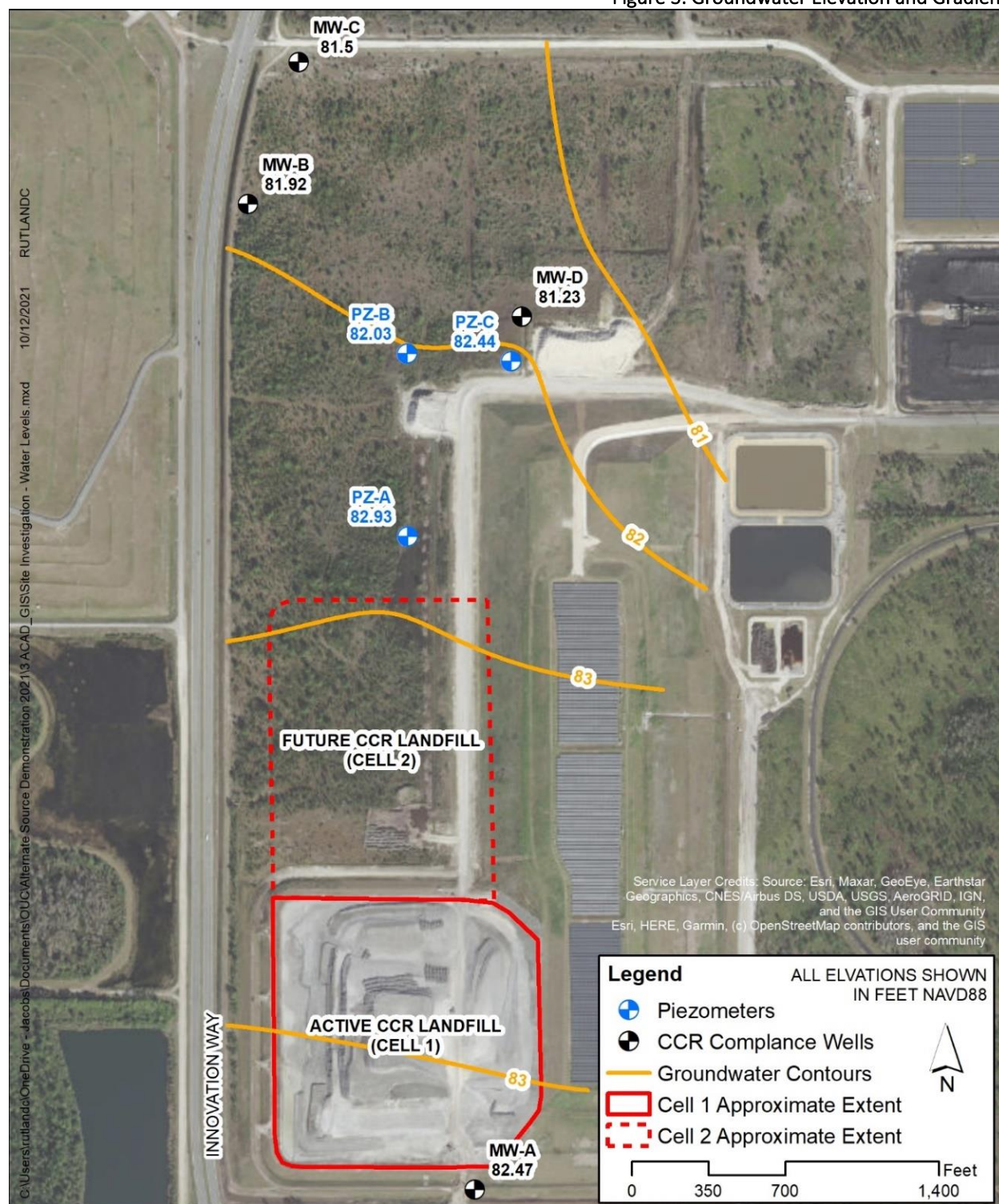
Slug tests were conducted using a vented pressure transducer and a 5-foot long 1.5-inch diameter positive displacement rod. Slug testing was conducted utilizing both rising head (slug-in) and falling head (slug-out) tests. The pressure transducer recorded depth every 250 milliseconds, allowing for the collection of detailed water level data within each piezometer during testing. Results were analyzed using the AQTESOLV program and the KGS Model solution and are summarized in Table 1 and Appendix C. Results at the new piezometers ranged from 7.1 to 20.9 feet/day.

These results are consistent with previously documented hydraulic conductivity testing completed on site. Previous testing found hydraulic conductivity of the surficial aquifer to range between 8.5 and 22.0 feet/day (Ardaman & Associates, Inc., 2011).

Table 1. Summary of Slug Test Results

Piezometer ID	Hydraulic Conductivity (ft/day)	
	Rising Head Test (slug-in)	Falling Head Test (slug-out)
PZ-A	7.2	7.2
PZ-B	20.9	19.7
PZ-C	11.8	12.0

Figure 3. Groundwater Elevation and Gradient



Groundwater Flow Analysis

The new information collected as part of the site investigative activities was used to calculate velocity and flow rate of the surficial aquifer in the area between the active landfill cell and MW-D. Utilizing Darcy's equation for flow through a porous medium (Equation 1), solving for specific discharge (Equation 2), and calculating soil pore space velocity (Equation 3), the velocity and travel times for groundwater originating from the edge of the active landfill cell can be estimated.

$$Q = KA(h_0 - h_1)/L \quad \text{Equation 1}$$

$$q = K(h_0 - h_1)/L \quad \text{Equation 2}$$

$$v = K(h_0 - h_1)/(nL) \quad \text{Equation 3}$$

Where:

Q = Flow (ft³/day)

q = Specific Discharge (ft/day)

v = Groundwater Velocity (ft/day)

K = Hydraulic Conductivity (ft/day)

h_0 = Upgradient Hydraulic Head (ft)

h_1 = Downgradient Hydraulic Head (ft)

L = Distance in Direction of Flow (ft)

n = Soil Porosity (dimensionless)

Based on the soil borings completed prior to piezometer installation, an estimated value for soil porosity for fine sand of 30 percent was utilized in Equation 3. The hydraulic gradient between the active landfill Cell 1 and MW-D was measured to be 0.0015 ft/ft. A more inclined gradient between PZ-C and MW-D was measured to be 0.0058 ft/ft. Using the range of hydraulic gradients relative to MW-D (0.0015 to 0.0058 ft/ft) and the highest measured hydraulic conductivity of 20.9 ft/day, it is estimated that groundwater travels at velocity between 0.105 and 0.405 ft/day. Based on these results, it will take between 7 and 26 years for groundwater to travel 1,000 feet, depending on groundwater gradient conditions. Therefore, the fastest conservative calculated travel time from the edge of the active landfill cell to MW-D would be greater than 16.9 years, as shown in Figure 4.

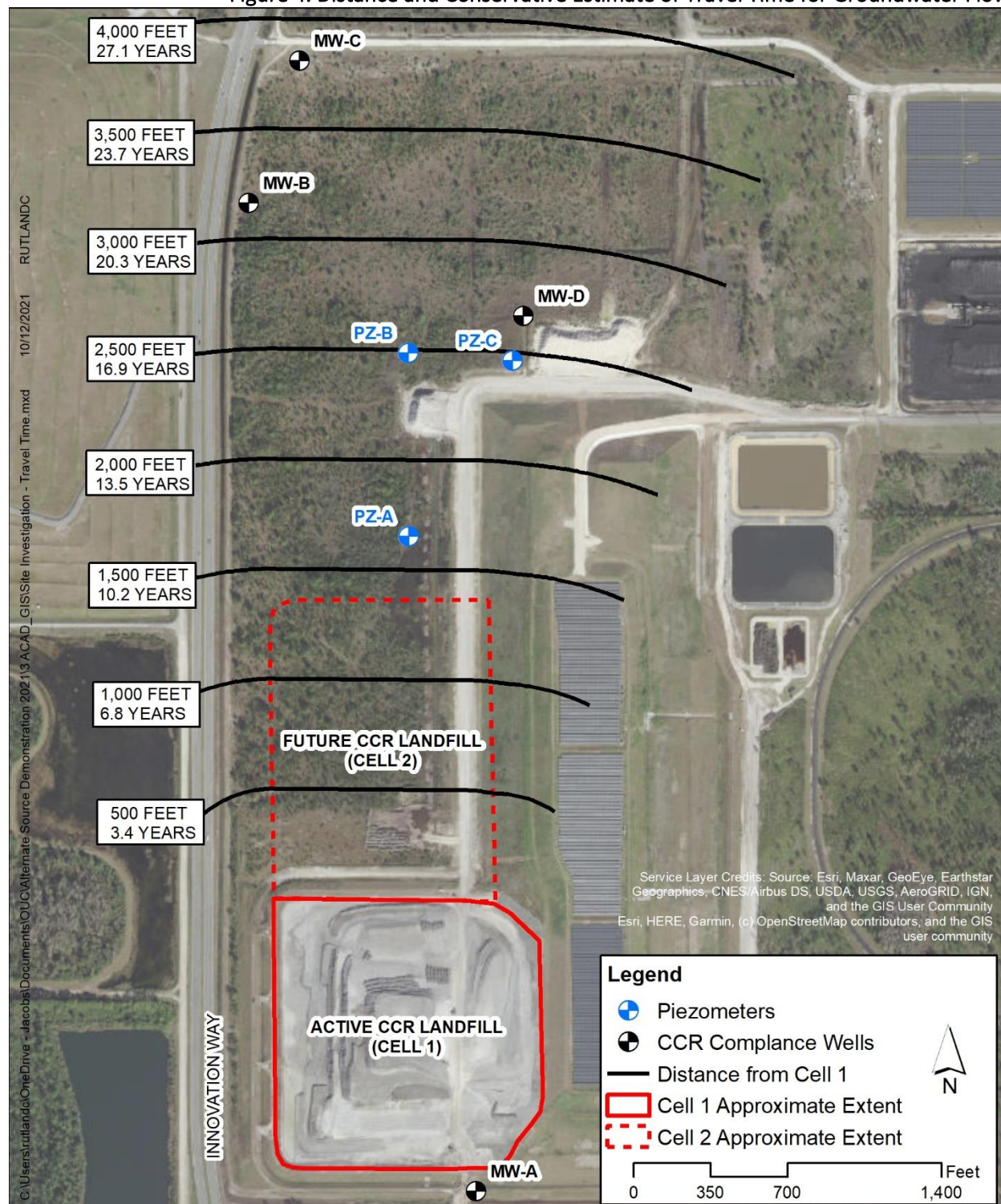
Conclusion

The CCR landfill active cell is relatively new (6 years old) and located far away from the compliance MWs. Groundwater does not move very quickly along the low gradient landscape at OUC Stanton Energy Center. From this analysis, utilizing new site-specific data, it is concluded to be highly unlikely that the groundwater at MW-B, MW-C, and MW-D is from the active cell of the CCR landfill. It is improbable that the lined CCR landfill would be a source of identified SSIs. Based on this new information, the changes in groundwater quality observed at MW-B, MW-C, and MW-D cannot yet be influenced by active CCR landfill activities. Therefore, an alternate source is likely influencing the groundwater quality at these wells.

Recommendations

1. OUC's CCR groundwater monitoring program should remain in the Detection Monitoring program.
2. Conduct additional field investigations to identify the source influencing water quality at MW-D.

Figure 4. Distance and Conservative Estimate of Travel Time for Groundwater Flow



References

Ardaman & Associates, Inc. 2021. Hydrogeological Report Proposed Horizontal Expansion of Combustion Waste Storage Area. Orlando Utilities Commission, Stanton Energy Center, Orange County Florida.

U.S. Environmental Protection Agency (EPA). 2020. Disposal of Coal Combustion Residuals from Electric Utilities Rulemakings. Website with history and linking rule and updates.

<https://www.epa.gov/coalash/coal-ash-rule>, Accessed September 2, 2020.

APPENDIX A Soil Boring Logs



PROJECT NUMBER
D3292400

BORING NUMBER
PZ-A

SOIL BORING LOG

PROJECT : OUC STANTON ENERGY CENTER LOCATION : OUC STANTON ENERGY CENTER, ORANGE COUNTY, FLORIDA
ELEVATION : N/A DRILLING CONTRACTOR : CUSTOM DRILLING SERVICES
DRILLING METHOD AND EQUIPMENT USED : SONIC
WATER LEVELS : N/A START : 9/29/21 @ 1715 END : 9/29/21 @ 1800 LOGGER : D. VANEGAS

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)		STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION	COMMENTS
	RECOVERY (FT)	#/TYPE		SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	DRILLER COMMENTS
5	10			TOP SOIL	
10	10			FINE SAND, TRACE ORGANICS, WELL SORTED, DARK REDDISH BROWN (5YR 2.5/2), LOOSE TO VERY DENSELY PACKED.	
20	10			FINE SAND, WELL SORTED, DARK BROWN (10YR 7/4), DENSELY PACKED.	
25	5			VERY FINE SAND, WELL SORTED, PALE BROWN (10YR 7/2), DENSELY PACKED.	

Jacobs

PROJECT NUMBER
D3292400

BORING NUMBER
PZ-A

SOIL BORING LOG

30

5

SANDY CLAY, GREENISH GRAY (5G 4/1), VERY
DENSE, MEDIUM PLASTICITY.

35

CLAY, DARK GREENISH GRAY (5G 4/1), VERY
DENSE, HIGH PLASTICITY.



PROJECT NUMBER
D3292400

BORING NUMBER
PZ-B

SOIL BORING LOG

PROJECT : OUC STANTON ENERGY CENTER LOCATION : OUC STANTON ENERGY CENTER, ORANGE COUNTY, FLORIDA

ELEVATION : N/A DRILLING CONTRACTOR : CUSTOM DRILLING SERVICES

DRILLING METHOD AND EQUIPMENT USED : SONIC

WATER LEVELS N/A START : 9/29/21 @ 0945 END : 9/29/21 @ 1115 LOGGER : D. VANEGAS

DEPTH BELOW SURFACE (FT)				STANDARD	SOIL DESCRIPTION	COMMENTS
	INTERVAL (FT)	RECOVERY (FT)		PENETRATION	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	DRILLER COMMENTS
		#/TYPE		TEST RESULTS		
				6"-6"-6"-6" (N)		
5					TOP SOIL	
10	10				FINE SAND, TRACE ORGANICS, WELL SORTED, DARK REDDISH BROWN (5YR 2.5/2), LOOSE TO VERY DENSELY PACKED.	
15						
20	10				FINE SAND, WELL SORTED, VERY PALE BROWN (10YR 7/4), DENSELY PACKED.	
25						
	5				VERY FINE SAND, WELL SORTED, VERY PALE BROWN (10YR 7/4), DENSELY PACKED.	

Jacobs					PROJECT NUMBER D3292400		BORING NUMBER PZ-B	
					SOIL BORING LOG			
30					SILT SAND, WELL SORTED, VERY PALE ORANGE (10YR 5/8), DENSELY PACKED.			
35		5			CLAY, DARK GREENISH GRAY (5G 4/1), VERY DENSE, HIGH PLASTICITY.			



PROJECT NUMBER
D3292400

BORING NUMBER
PZ-C

SOIL BORING LOG

PROJECT : OUC STANTON ENERGY CENTER

LOCATION : OUC STANTON ENERGY CENTER, ORANGE COUNTY, FLORIDA

ELEVATION : N/A

DRILLING CONTRACTOR : CUSTOM DRILLING SERVICES

DRILLING METHOD AND EQUIPMENT USED :

SONIC

WATER LEVELS : N/A

START : 9/29/21 @ 1355

END : 9/29/21 @ 1450

LOGGER : D. VANEGAS

DEPTH BELOW SURFACE (FT)

STANDARD

SOIL DESCRIPTION

COMMENTS

INTERVAL (FT)

PENETRATION

SOIL NAME, USCS GROUP SYMBOL, COLOR,
MOISTURE CONTENT, RELATIVE DENSITY,
OR CONSISTENCY, SOIL STRUCTURE,
MINERALOGY.

DRILLER COMMENTS

RECOVERY (FT)

#/TYPE

TEST
RESULTS

6"-6"-6"-6"
(N)

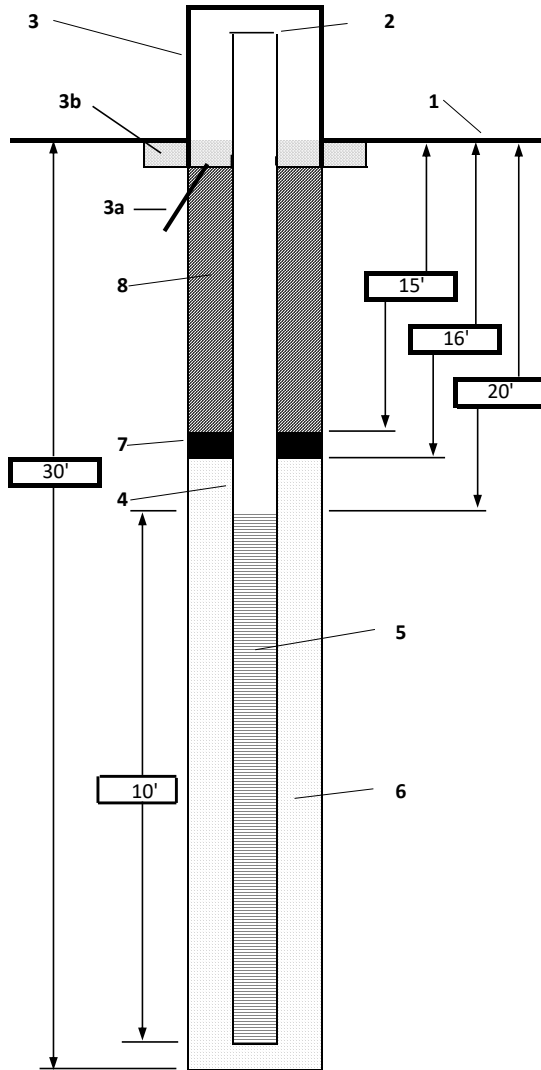
					TOP SOIL	
5						
10		10			FINE SAND, TRACE ORGANICS, WELL SORTED, DARK REDDISH BROWN (5YR 2.5/2), LOOSE TO VERY DENSELY PACKED.	
15						
20		10			VERY FINE SAND, WELL SORTED, VERY PALE BROWN (10YR 7/4), DENSELY PACKED.	
25					VERY FINE SAND, WELL SORTED, PALE BROWN (10YR 7/2), MODERATELY PACKED.	
		5			SILT SAND, WELL SORTED, VERY PALE ORANGE (10YR 5/8), DENSELY PACKED, TRACE CLAY	
					VERY FINE SAND, WELL SORTED, PALE BROWN (10YR 7/2), MODERATELY PACKED.	

Jacobs				PROJECT NUMBER D3292400		BORING NUMBER PZ-C	
				SOIL BORING LOG			
30					SANDY CLAY, GREENISH GRAY (5G 4/1), VERY DENSE, MEDIUM PLASTICITY.		
		5			CLAY, DARK GREENISH GRAY (5G 4/1), VERY DENSE, HIGH PLASTICITY.		
35							

APPENDIX B Well Completion Diagrams

PROJECT NUMBER D3292400	WELL NUMBER PZ-A
SHEET 1 OF 1	
WELL COMPLETION DIAGRAM	

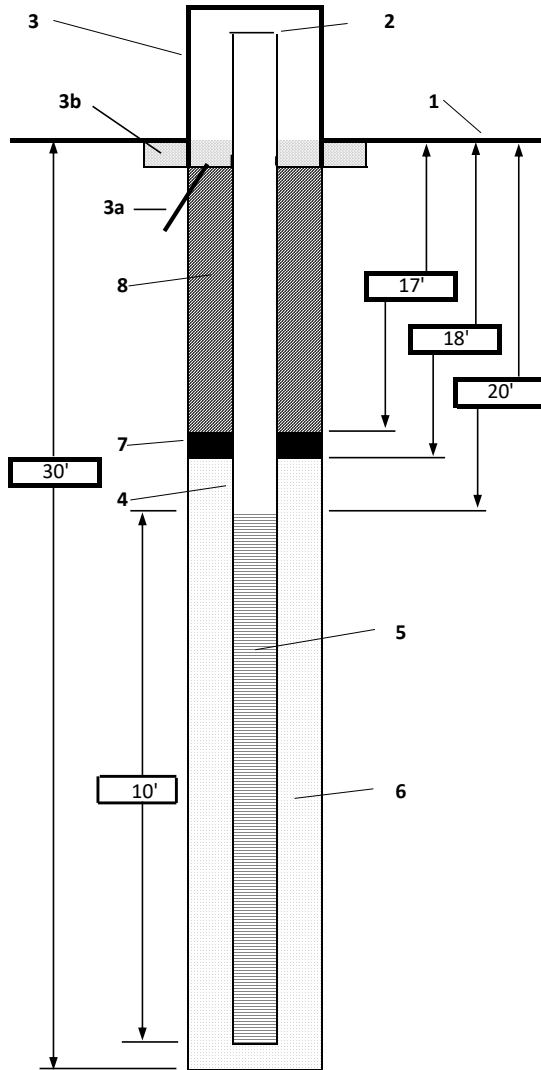
PROJECT : OUC STANTON ENERGY CENTER	LOCATION : OUC STANTON ENERGY CENTER - ORANGE COUNTY, FLORIDA
DRILLING CONTRACTOR : CUSTOM DRILLING SERVICES	
DRILLING METHOD AND EQUIPMENT USED : HOLLOW STEM AUGER	
WATER LEVELS : N/A	START : 9/30/2021 @0845 END : 9/30/21 @0955 LOGGER : D. VANEGAS



1- Ground elevation at well	N/A
2- Top of casing	3.4 FT ALS
3- Wellhead protection cover	ALUM ABOVE GND ENCLOSURE W/LOCKING CAP
a) drain tube?	NO
b) concrete pad dimensions	2' X 2' X 0.5'
4- Dia./type of well casing	2" SCH 40 PVC
5- Type/slot size of screen	0.01"
	MACHINED
6- Type screen filter	20-40 SILICA SAND
a) Quantity used	7 BAGS
7- Type of seal	FINE SAND
a) Quantity used	1 BAG
8- Grout	
a) Grout mix used	NEAT PORTLAND CEMENT
b) Method of placement	GRAVITY
c) Vol. of well casing grout	
Development method	SUBMERSIBLE PUMP (@2GPM)/SURGE
Development time	2.5 HOURS
Estimated purge volume	264 GALLONS
Comments	

PROJECT NUMBER D3292400	WELL NUMBER PZ-B
SHEET 1 OF 1	
WELL COMPLETION DIAGRAM	

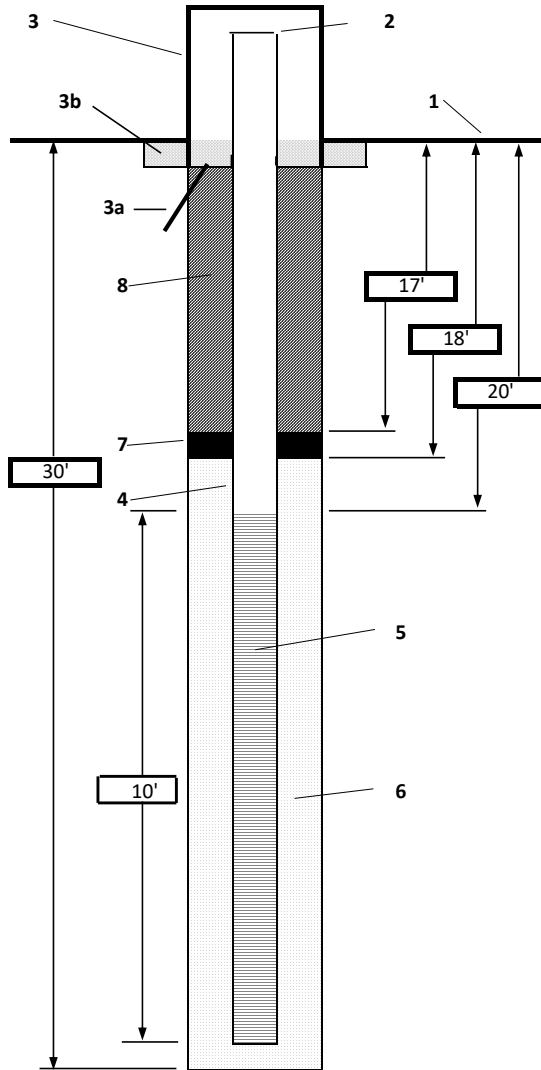
PROJECT : OUC STANTON ENERGY CENTER	LOCATION : OUC STANTON ENERGY CENTER - ORANGE COUNTY, FLORIDA
DRILLING CONTRACTOR : CUSTOM DRILLING SERVICES	
DRILLING METHOD AND EQUIPMENT USED : HOLLOW STEM AUGER	
WATER LEVELS : N/A	START : 9/29/2021 END : 9/29/21 LOGGER : D. VANEGAS



1- Ground elevation at well	N/A
2- Top of casing	3.7 FT ALS
3- Wellhead protection cover	ALUM ABOVE GND ENCLOSURE W/LOCKING CAP
a) drain tube?	NO
b) concrete pad dimensions	2' X 2' X 0.5'
4- Dia./type of well casing	2" SCH 40 PVC
5- Type/slot size of screen	0.01"
	MACHINED
6- Type screen filter	20-40 SILICA SAND
a) Quantity used	5 BAGS
7- Type of seal	FINE SAND
a) Quantity used	1 BAG
8- Grout	
a) Grout mix used	NEAT PORTLAND CEMENT
b) Method of placement	GRAVITY
c) Vol. of well casing grout	
Development method	SUBMERSIBLE PUMP (@2GPM)/SURGE
Development time	6 HOURS
Estimated purge volume	286 GALLONS
Comments	

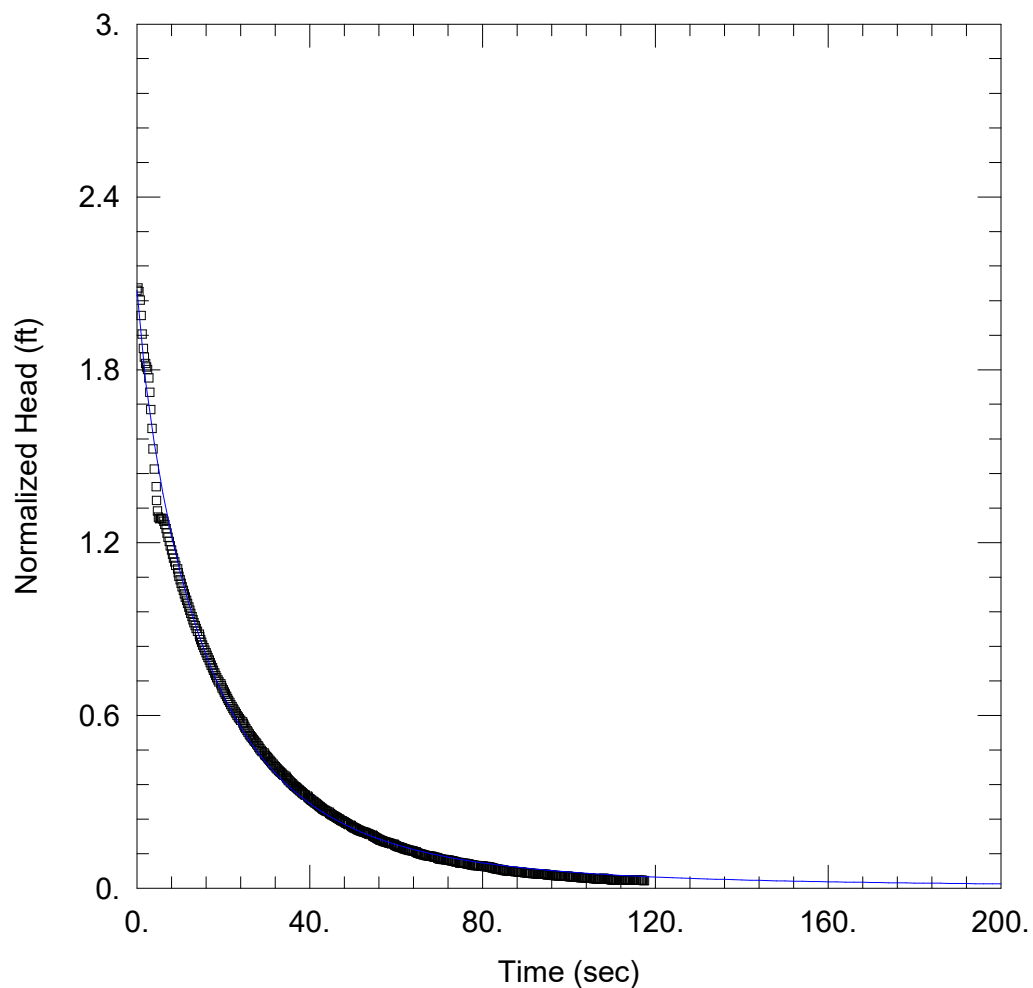
PROJECT NUMBER D3292400	WELL NUMBER PZ-C
SHEET 1 OF 1	
WELL COMPLETION DIAGRAM	

PROJECT : OUC STANTON ENERGY CENTER	LOCATION : OUC STANTON ENERGY CENTER - ORANGE COUNTY, FLORIDA
DRILLING CONTRACTOR : CUSTOM DRILLING SERVICES	
DRILLING METHOD AND EQUIPMENT USED : HOLLOW STEM AUGER	
WATER LEVELS : N/A	START : 9/29/2021 END : 9/29/21 LOGGER : D. VANEGAS



1- Ground elevation at well	N/A
2- Top of casing	3.3 FT ALS
3- Wellhead protection cover	ALUM ABOVE GND ENCLOSURE W/LOCKING CAP
a) drain tube?	NO
b) concrete pad dimensions	2' X 2' X 0.5'
4- Dia./type of well casing	2" SCH 40 PVC
5- Type/slot size of screen	0.01"
	MACHINED
6- Type screen filter	20-40 SILICA SAND
a) Quantity used	5 BAGS
7- Type of seal	FINE SAND
a) Quantity used	1 BAG
8- Grout	
a) Grout mix used	NEAT PORTLAND CEMENT
b) Method of placement	GRAVITY
c) Vol. of well casing grout	
Development method	SUBMERSIBLE PUMP (@2GPM)/SURGE
Development time	2 HOURS
Estimated purge volume	220 GALLONS
Comments	

APPENDIX C Slug Test Analysis and Results



WELL TEST ANALYSIS

Data Set: C:\Users\DV052933\Documents\OUC SEC MW - Dan\Slug Tests\PZ-A SlugIN.aqt
 Date: 10/11/21 Time: 13:52:15

PROJECT INFORMATION

Company: Jacobs
 Client: OUC
 Location: OUC SEC
 Test Well: PZ-A
 Test Date: 10/1/2021

AQUIFER DATA

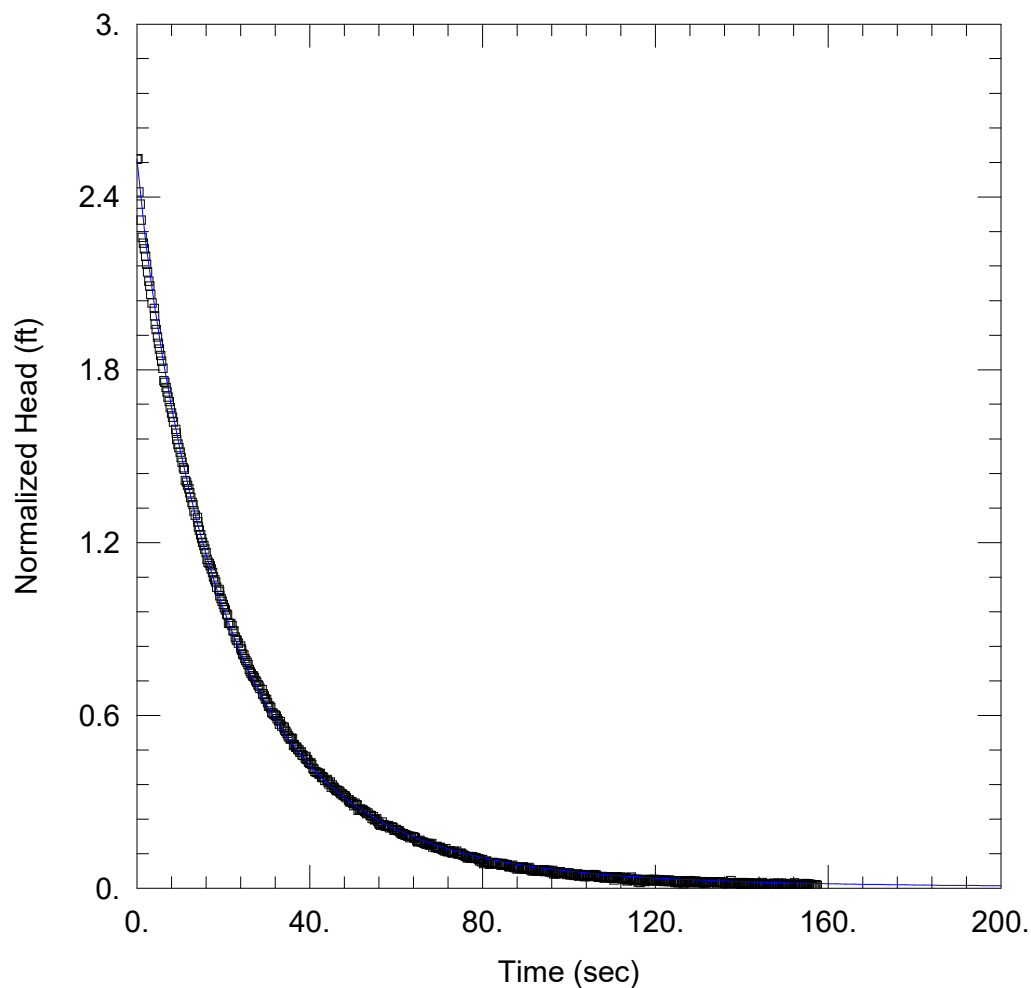
Saturated Thickness: 35. ft

WELL DATA (PZ-A)

Initial Displacement: <u>2.076 ft</u>	Static Water Column Height: <u>26.47 ft</u>
Total Well Penetration Depth: <u>30. ft</u>	Screen Length: <u>10. ft</u>
Casing Radius: <u>0.083 ft</u>	Well Radius: <u>0.083 ft</u>

SOLUTION

Aquifer Model: <u>Unconfined</u>	Solution Method: <u>KGS Model</u>
Kr = <u>7.149 ft/day</u>	Ss = <u>7.05E-5 ft⁻¹</u>
Kz/Kr = <u>0.1059</u>	



WELL TEST ANALYSIS

Data Set: C:\Users\DV052933\Documents\OUC SEC MW - Dan\Slug Tests\PZ-A SlugOUT.aqt
 Date: 10/11/21 Time: 13:55:17

PROJECT INFORMATION

Company: Jacobs
 Client: OUC
 Location: OUC SEC
 Test Well: PZ-A
 Test Date: 10/1/2021

AQUIFER DATA

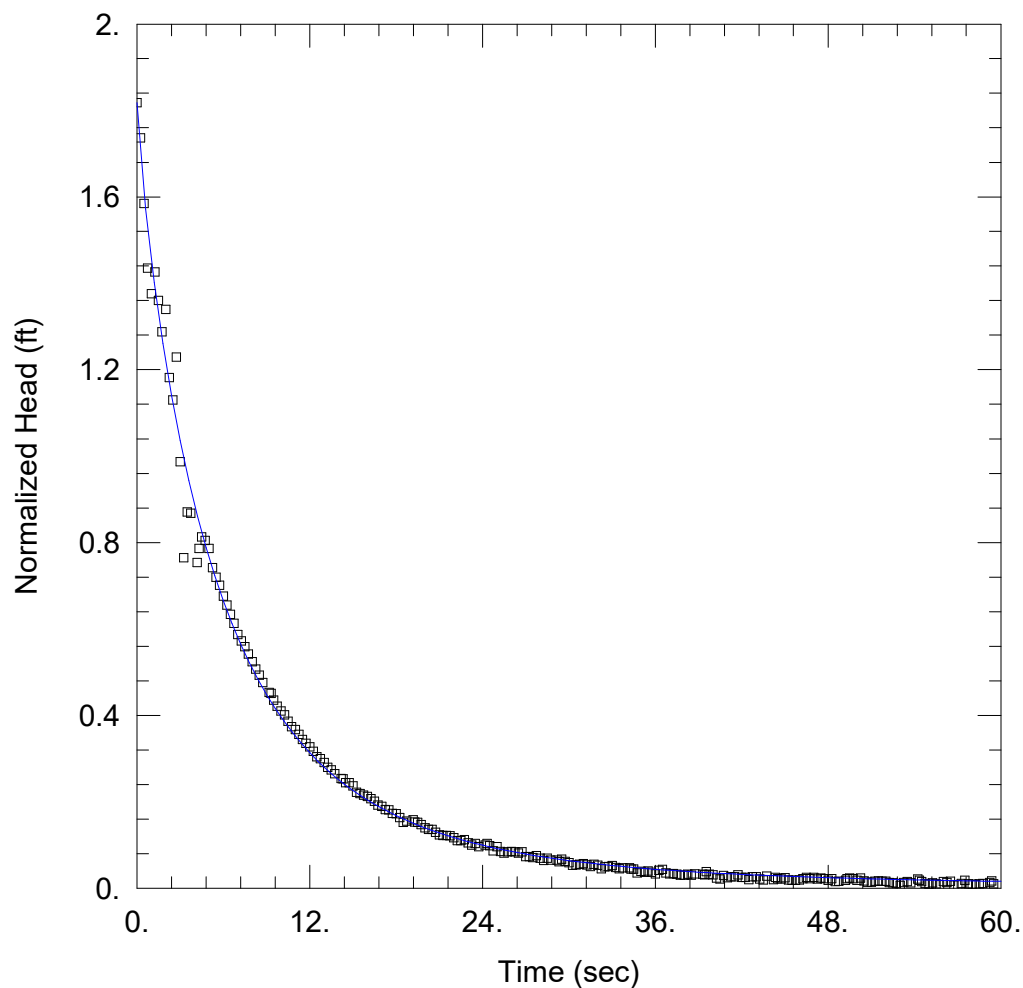
Saturated Thickness: 35. ft

WELL DATA (PZ-A)

Initial Displacement: <u>2.531 ft</u>	Static Water Column Height: <u>26.47 ft</u>
Total Well Penetration Depth: <u>30. ft</u>	Screen Length: <u>10. ft</u>
Casing Radius: <u>0.083 ft</u>	Well Radius: <u>0.083 ft</u>

SOLUTION

Aquifer Model: <u>Unconfined</u>	Solution Method: <u>KGS Model</u>
Kr = <u>7.216 ft/day</u>	Ss = <u>5.035E-6 ft⁻¹</u>
Kz/Kr = <u>0.1059</u>	



WELL TEST ANALYSIS

Data Set: C:\Users\DV052933\Documents\OUC SEC MW - Dan\Slug Tests\PZ-B SlugIN.aqt
 Date: 10/11/21 Time: 13:55:48

PROJECT INFORMATION

Company: Jacobs
 Client: OUC
 Location: OUC SEC
 Test Well: PZ-B
 Test Date: 10/1/2021

AQUIFER DATA

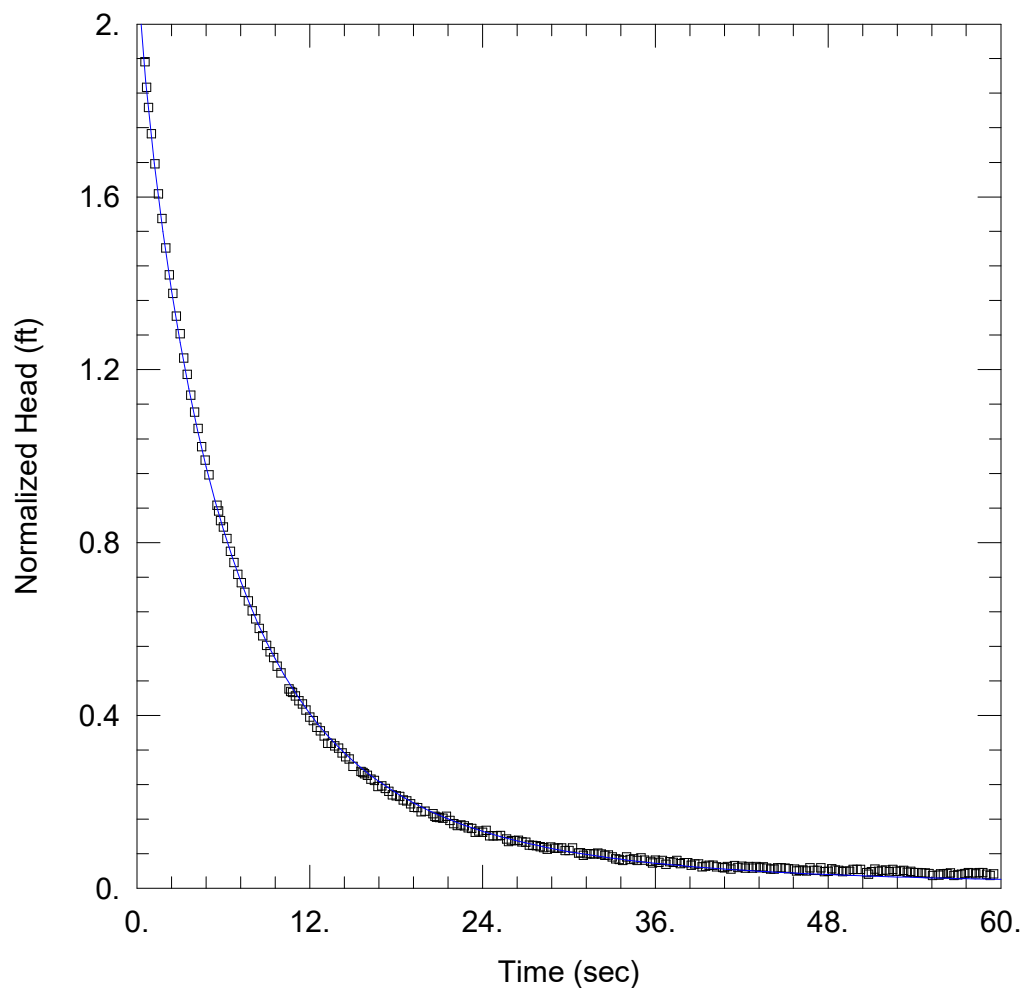
Saturated Thickness: 35. ft

WELL DATA (PZ-B)

Initial Displacement: <u>1.818 ft</u>	Static Water Column Height: <u>28.49 ft</u>
Total Well Penetration Depth: <u>30. ft</u>	Screen Length: <u>10. ft</u>
Casing Radius: <u>0.083 ft</u>	Well Radius: <u>0.083 ft</u>

SOLUTION

Aquifer Model: <u>Unconfined</u>	Solution Method: <u>KGS Model</u>
Kr = <u>20.93 ft/day</u>	Ss = <u>6.113E-5 ft⁻¹</u>
Kz/Kr = <u>0.1059</u>	



WELL TEST ANALYSIS

Data Set: C:\Users\DV052933\Documents\OUC SEC MW - Dan\Slug Tests\PZ-B SlugOUT.aqt
 Date: 10/11/21 Time: 13:56:31

PROJECT INFORMATION

Company: Jacobs
 Client: OUC
 Location: OUC SEC
 Test Well: PZ-B
 Test Date: 10/1/2021

AQUIFER DATA

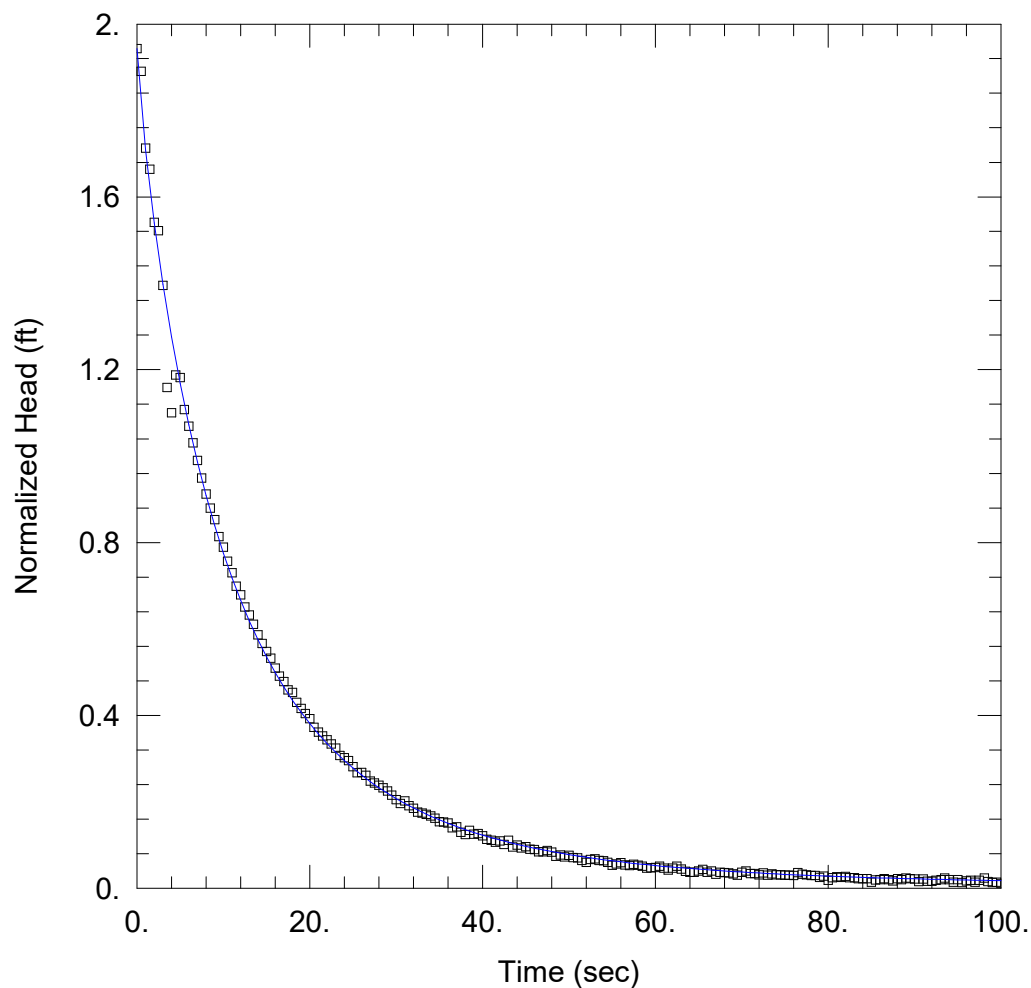
Saturated Thickness: 35. ft

WELL DATA (PZ-B)

Initial Displacement: <u>2.141</u> ft	Static Water Column Height: <u>28.49</u> ft
Total Well Penetration Depth: <u>30</u> . ft	Screen Length: <u>10</u> . ft
Casing Radius: <u>0.083</u> ft	Well Radius: <u>0.083</u> ft

SOLUTION

Aquifer Model: <u>Unconfined</u>	Solution Method: <u>KGS Model</u>
Kr = <u>19.74</u> ft/day	Ss = <u>5.407E-5</u> ft ⁻¹
Kz/Kr = <u>0.1059</u>	



WELL TEST ANALYSIS

Data Set: C:\Users\DV052933\Documents\OUC SEC MW - Dan\Slug Tests\PZ-C SlugIN.aqt
 Date: 10/11/21 Time: 13:57:29

PROJECT INFORMATION

Company: Jacobs
 Client: OUC
 Location: OUC SEC
 Test Well: PZ-A
 Test Date: 10/1/2021

AQUIFER DATA

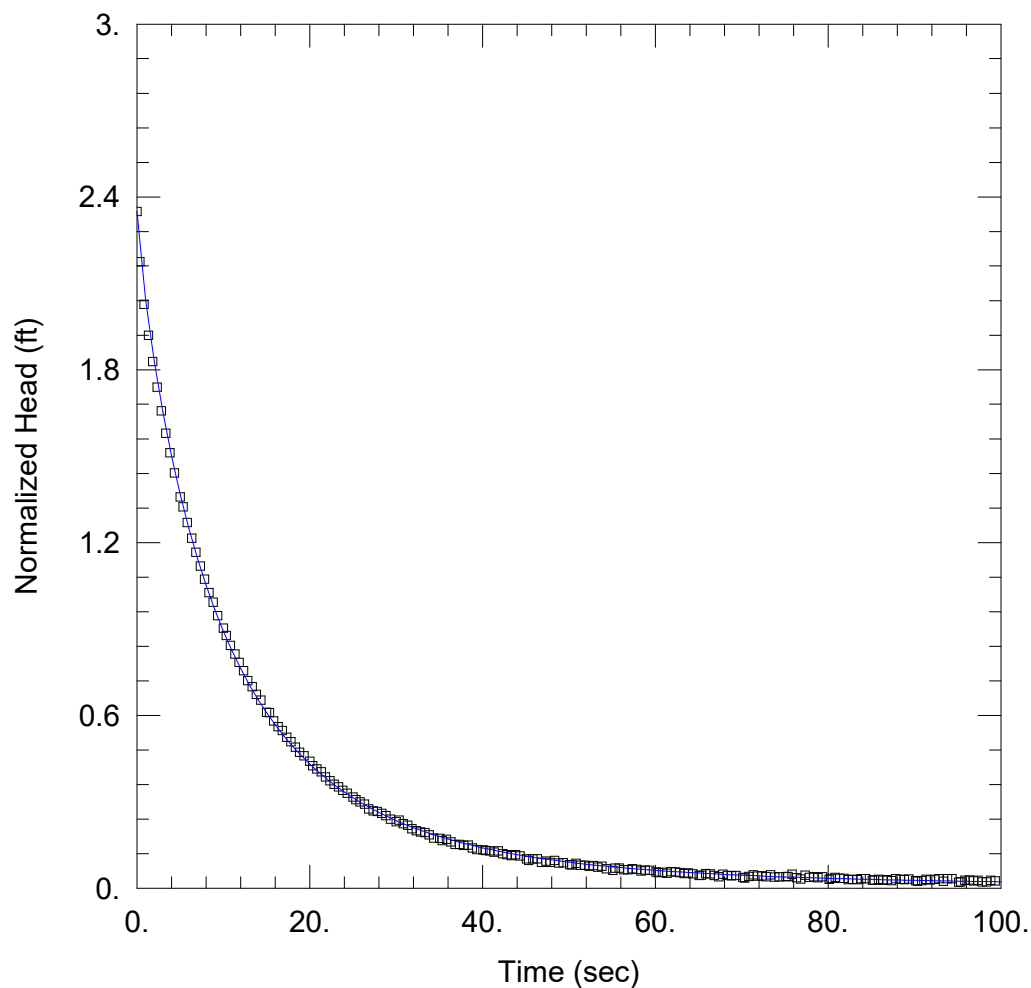
Saturated Thickness: 35. ft

WELL DATA (PZ-C)

Initial Displacement: <u>1.943 ft</u>	Static Water Column Height: <u>30. ft</u>
Total Well Penetration Depth: <u>30. ft</u>	Screen Length: <u>10. ft</u>
Casing Radius: <u>0.083 ft</u>	Well Radius: <u>0.083 ft</u>

SOLUTION

Aquifer Model: <u>Unconfined</u>	Solution Method: <u>KGS Model</u>
Kr = <u>11.77 ft/day</u>	Ss = <u>4.011E-5 ft⁻¹</u>
Kz/Kr = <u>0.1059</u>	



WELL TEST ANALYSIS

Data Set: C:\Users\DV052933\Documents\OUC SEC MW - Dan\Slug Tests\PZ-C SlugOUT.aqt
 Date: 10/11/21 Time: 13:58:07

PROJECT INFORMATION

Company: Jacobs
 Client: OUC
 Location: OUC SEC
 Test Well: PZ-A
 Test Date: 10/1/2021

AQUIFER DATA

Saturated Thickness: 35. ft

WELL DATA (PZ-C)

Initial Displacement: <u>2.349 ft</u>	Static Water Column Height: <u>30. ft</u>
Total Well Penetration Depth: <u>30. ft</u>	Screen Length: <u>10. ft</u>
Casing Radius: <u>0.083 ft</u>	Well Radius: <u>0.083 ft</u>

SOLUTION

Aquifer Model: <u>Unconfined</u>	Solution Method: <u>KGS Model</u>
Kr = <u>12.01 ft/day</u>	Ss = <u>6.022E-5 ft⁻¹</u>
Kz/Kr = <u>0.1059</u>	

Table C-1 Slug Test Raw Data Summary

Time (s)	PZ-A		PZ-B		PZ-C	
	Rising Head	Falling Head	Rising Head	Falling Head	Rising Head	Falling Head
	Displacement (ft)	Displacement (ft)	Displacement (ft)	Displacement (ft)	Displacement (ft)	Displacement (ft)
0	2.08	2.53	1.82	2.14	1.82	2.35
0.25	2.08	2.53	1.74	1.91	1.74	--
0.5	2.07	2.42	1.59	1.85	1.59	2.18
0.75	2.04	2.38	1.44	1.81	1.44	--
1	1.99	2.32	1.38	1.75	1.38	2.03
2	1.82	2.19	1.34	1.48	1.34	1.83
3	1.72	2.09	0.99	1.28	0.99	1.66
4	1.45	1.99	0.75	1.10	0.75	1.51
5	1.29	1.89	0.79	0.96	0.79	1.36
6	1.28	1.81	0.68	0.84	0.68	1.27
7	1.23	1.72	0.59	0.73	0.59	1.17
8	1.17	1.65	0.52	0.64	0.52	1.07
9	1.12	1.58	0.45	0.56	0.45	0.99
10	1.07	1.51	0.41	0.50	0.41	0.90
20	0.69	0.99	0.14	0.18	0.14	0.44
30	0.46	0.66	0.06	0.09	0.06	0.23
40	0.31	0.43	0.03	0.05	0.03	0.13
50	0.21	0.29	0.02	0.04	0.02	0.08
60	0.15	0.20	--	--	--	0.06
70	0.10	0.14	--	--	--	0.04
80	0.08	0.10	--	--	--	0.03
90	0.05	0.07	--	--	--	0.03
100	0.04	0.05	--	--	--	0.02
110	0.03	0.04	--	--	--	--
120	0.03	0.02	--	--	--	--

1 Data was collected in 0.25 second increments and has been summarized for formatting purposes

2 Data collected on October 1, 2021 by David Varegas and Daniel Rutland, PE

3 Data was collected using a Insitu Level TROLL 700

C-2 Analysis of Travel Times with Gradient Conditions Between PZ-A and MW-D

h ₀	h ₁	L ₁	L ₂	thickness	width	Porosity
ft	ft	ft	ft	ft	ft	%
82.93	81.23	0	1,127	1	1	30

Delta H	1.7	ft
Delta L	1127	ft
A	1	ft ²
Gradient	0.0015	ft/ft

Test ID	k	Q	q	v	Travel Time (1,127 Feet)		Travel Time (500 feet)		Travel Time (1,000 feet)		Travel Time (1,500 feet)		Travel Time (2,000 feet)		Travel Time (2,500 feet)		Travel Time (2,600 feet)		Travel Time (3,000 feet)		Travel Time (3,500 feet)		Travel Time (4,000 feet)	
	ft/day	ft ³ /day	ft/day	ft/day	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years
PZ-A	7.149	0.011	0.011	0.036	31,353	85.9	13,910	38.1	27,820	76.2	41,729	114.3	55,639	152.4	69,549	190.5	72,331	198.2	83,459	228.7	97,369	266.8	111,278	304.9
PZ-A Recovery	7.216	0.011	0.011	0.036	31,062	85.1	13,781	37.8	27,561	75.5	41,342	113.3	55,123	151.0	68,903	188.8	71,659	196.3	82,684	226.5	96,465	264.3	110,245	302.0
PZ-B	20.93	0.032	0.032	0.105	10,709	29.3	4,751	13.0	9,502	26.0	14,253	39.1	19,005	52.1	23,756	65.1	24,706	67.7	28,507	78.1	33,258	91.1	38,009	104.1
PZ-B Recovery	19.74	0.030	0.030	0.099	11,355	31.1	5,038	13.8	10,075	27.6	15,113	41.4	20,150	55.2	25,188	69.0	26,195	71.8	30,225	82.8	35,263	96.6	40,300	110.4
PZ-C	11.77	0.018	0.018	0.059	19,043	52.2	8,449	23.1	16,897	46.3	25,346	69.4	33,795	92.6	42,243	115.7	43,933	120.4	50,692	138.9	59,141	162.0	67,590	185.2
PZ-C Recovery	12.01	0.018	0.018	0.060	18,663	51.1	8,280	22.7	16,560	45.4	24,840	68.1	33,119	90.7	41,399	113.4	43,055	118.0	49,679	136.1	57,959	158.8	66,239	181.5

C-3 Analysis of Travel Times with Gradient Conditions Between PZ-C and MW-D

h ₀	h ₁	L ₁	L ₂	thickness	width	Porosity
ft	ft	ft	ft	ft	ft	%
82.44	81.23	0	208.57	1	1	30

Delta H	1.21	ft
Delta L	208.57	ft
A	1	ft ²
Gradient	0.0058	ft/ft

Test ID	k	Q	q	v	Travel Time (208.57 feet)		Travel Time (500 feet)		Travel Time (1,000 feet)		Travel Time (1,500 feet)		Travel Time (2,000 feet)		Travel Time (2,500 feet)		Travel Time (2,600 feet)		Travel Time (3,000 feet)		Travel Time (3,500 feet)		Travel Time (4,000 feet)	
	ft/day	ft ³ /day	ft/day	ft/day	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years	Days	Years
PZ-A	7.149	0.041	0.041	0.138	1,509	4.1	3,617	9.9	7,233	19.8	10,850	29.7	14,467	39.6	18,083	49.5	18,807	51.5	21,700	59.5	25,317	69.4	28,934	79.3
PZ-A Recovery	7.216	0.042	0.042	0.140	1,495	4.1	3,583	9.8	7,166	19.6	10,749	29.5	14,332	39.3	17,916	49.1	18,632	51.0	21,499	58.9	25,082	68.7	28,665	78.5
PZ-B	20.93	0.121	0.121	0.405	515	1.4	1,235	3.4	2,471	6.8	3,706	10.2	4,941	13.5	6,177	16.9	6,424	17.6	7,412	20.3	8,647	23.7	9,883	27.1
PZ-B Recovery	19.74	0.115	0.115	0.382	546	1.5	1,310	3.6	2,620	7.2	3,929	10.8	5,239	14.4	6,549	17.9	6,811	18.7	7,859	21.5	9,169	25.1	10,479	28.7
PZ-C	11.77	0.068	0.068	0.228	916	2.5	2,197	6.0	4,394	12.0	6,590	18.1	8,787	24.1	10,984	30.1	11,423	31.3	13,181	36.1	15,377	42.1	17,574	48.1
PZ-C Recovery	12.01	0.070	0.070	0.232	898	2.5	2,153	5.9	4,306	11.8	6,459	17.7	8,611	23.6	10,764	29.5	11,195	30.7	12,917	35.4	15,070	41.3	17,223	47.2

Appendix C

Laboratory Analysis Results

OUC Stanton CCR Monitoring Well Results, 2021								
Location ID	Sample Date	Parameter Name	MCL	Final Result Text	Final Result Units	Final Reporting Limit	Final Detection Limit	Qualifier Flag
MW-B	3/7/2021	Boron		147	µg/L	5	2	
MW-B	3/7/2021	Calcium		4,340	µg/L	500	40	
MW-B	3/7/2021	Chloride	250,000	20,100	µg/L	1,000	120	
MW-B	3/7/2021	Fluoride	4,000	60	µg/L	100	30	I
MW-B	3/7/2020	pH	6.5 to 8.5	4.68	pH Units			
MW-B	3/7/2020	Sulfate	250,000	34,300	µg/L	3,300	1,100	
MW-B	3/7/2020	TDS	500,000	121,000	µg/L	5,000	5,000	
MW-B	6/28/2021	Calcium		2,350	µg/L	500	40	
MW-B	6/28/2021	Chloride	250,000	13,000	µg/L	5,000	950	
MW-B	6/28/2021	pH	6.5 to 8.5	4.49	pH Units			
MW-B	6/28/2021	TDS	500,000	99,000	µg/L	5,000	5,000	
MW-B	9/14/2021	Boron		99	µg/L	5	2	
MW-B	9/14/2021	Calcium		6,950	µg/L	500	40	
MW-B	9/14/2021	Chloride	250,000	29,300	µg/L	5,000	550	
MW-B	9/14/2021	Fluoride	4,000	80	µg/L	100	20	I
MW-B	9/14/2021	pH	6.5 to 8.5	4.30	pH Units			
MW-B	9/14/2021	Sulfate	250,000	32,200	µg/L	2,320	780	
MW-B	9/14/2021	TDS	500,000	136,000	µg/L	5,000	5,000	
MW-B	10/26/2021	Calcium		7,470	µg/L	500	40	
MW-B	10/26/2021	Chloride	250,000	28,900	µg/L	1,000	110	
MW-B	10/26/2021	pH	6.5 to 8.5	4.42	pH Units			
MW-B	10/26/2021	TDS	500,000	125,000	µg/L	5,000	5,000	
MW-C	3/7/2021	Boron		11	µg/L	5	2	
MW-C	3/7/2021	Calcium		10,100	µg/L	500	40	
MW-C	3/7/2021	Chloride	250,000	24,900	µg/L	1,000	120	
MW-C	3/7/2021	Fluoride	4,000	100	µg/L	100	30	
MW-C	3/7/2021	pH	6.5 to 8.5	5.27	pH Units			
MW-C	3/7/2021	Sulfate	250,000	310	µg/L	660	220	
MW-C	3/7/2021	TDS	500,000	107,000	µg/L	5,000	5,000	
MW-C	6/28/2021	Calcium		8190	µg/L	500	40	
MW-C	6/28/2021	pH	6.5 to 8.5	4.99	pH Units			
MW-C	6/28/2021	TDS	500,000	96,000	µg/L	5,000	5,000	
MW-C	9/14/2021	Boron		10	µg/L	5	2	
MW-C	9/14/2021	Calcium		10,300	µg/L	500	40	
MW-C	9/14/2021	Chloride	250,000	26,000	µg/L	1,000	110	
MW-C	9/14/2021	Fluoride	4,000	100	µg/L	100	20	

OUC Stanton CCR Monitoring Well Results, 2021								
Location ID	Sample Date	Parameter Name	MCL	Final Result Text	Final Result Units	Final Reporting Limit	Final Detection Limit	Qualifier Flag
MW-C	9/14/2021	pH	6.5 to 8.5	4.93	pH Units			
MW-C	9/14/2021	Sulfate	250,000	210	µg/L	460	160	I
MW-C	9/14/2021	TDS	500,000	102,000	µg/L	5,000	5,000	
MW-C	10/26/2021	Calcium		11,200	ug/L	500	40	
MW-C	10/26/2021	pH	6.5 to 8.5	5	pH Units			
MW-C	10/26/2021	TDS	500,000	95,000	µg/L	5,000	5,000	
MW-D	3/7/2021	Boron		17	µg/L	5	2	
MW-D	3/7/2021	Calcium		776,000	µg/L	10,000	800	
MW-D	3/7/2021	Chloride	250,000	2,420,000	µg/L	200,000	24,600	
MW-D	3/7/2021	Fluoride	4,000	440	µg/L	100	30	
MW-D	3/7/2021	pH	6.5 to 8.5	4.2	pH Units			
MW-D	3/7/2021	Sulfate	250,000	153,000	µg/L	13,200	4,400	
MW-D	3/7/2021	TDS	500,000	6,450,000	µg/L	5,000	5,000	
MW-D	6/28/2021	Calcium		742,000	µg/L	12,500	1,000	
MW-D	6/28/2021	Chloride	250,000	2,320,000	µg/L	100,000	12,300	
MW-D	6/28/2021	Fluoride	4,000	200	µg/L	100	30	
MW-D	6/28/2021	pH	6.5 to 8.5	4.22	pH Units			
MW-D	6/28/2021	Sulfate	250,000	154,000	µg/L	66,000	22,000	
MW-D	6/28/2021	TDS	500,000	6,960,000	µg/L	5,000	5,000	
MW-D	9/14/2021	Boron		16	µg/L	5	2	
MW-D	9/14/2021	Calcium		775,000	µg/L	10,000	800	
MW-D	9/14/2021	Chloride	250,000	1,920,000	µg/L	100,000	11,000	
MW-D	9/14/2021	Fluoride	4,000	270	µg/L	100	20	
MW-D	9/14/2021	pH	6.5 to 8.5	4.42	pH Units			
MW-D	9/14/2021	Sulfate	250,000	149,000	µg/L	9,300	3,100	
MW-D	9/14/2021	TDS	500,000	5,980,000	µg/L	5,000	5,000	
MW-D	10/26/2021	Calcium		1,040,000	µg/L	20,000	1,600	
MW-D	10/26/2021	Chloride	250,000	2,760,000	µg/L	100,000	11,000	
MW-D	10/26/2021	Fluoride	4,000	20	µg/L	100	20	U
MW-D	10/26/2021	pH	6.5 to 8.5	4.15	pH Units			
MW-D	10/26/2021	Sulfate	250,000	218,000	µg/L	46,500	15,500	
MW-D	10/26/2021	TDS	500,000	7,320,000	µg/L	5,000	5,000	

Flags: U = Results below method detection limit; I = The reported value is greater than or equal to the laboratory method detection limit but less than the laboratory practical quantitation limit.