Prepared for

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DETECTION MONITORING STATISTICAL METHODS CERTIFICATION REPORT

FEDERAL CCR RULE
LOT 15 LANDFILL
BALTIMORE, MARYLAND

Prepared by

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1. INTRODUCTION

Geosyntec Consultants (Geosyntec) has prepared this document for the Fort Armistead Road - Lot 15 Industrial Landfill (the Site), located in Baltimore, Maryland. The purpose of this document is to summarize the statistical methods that will be used to evaluate Site groundwater quality data to meet requirements of the Federal Coal Combustion Residuals (CCR) Rule prescribed in 40 Code of Federal Regulations (CFR) Part 257.93. As detailed in 40 CFR 257.93(f)(6), the owner or operator must obtain certification from a qualified Professional Engineer (P.E.) stating that the selected statistical method is appropriate for evaluating the groundwater monitoring data for the CCR management area. It is intended that this document will be placed in the facility operating record as required by 40 CFR 257.105(h)(4).

2. FEDERAL CCR RULE STATISTICAL METHOD REQUIREMENTS

The requirements for statistical analysis of groundwater quality data collected under the CCR Rule are given in 40 CFR 257.93(f)-(h). A summary of those requirements is provided below.

The owner or operator must:

- (f) Select one (1) of the statistical methods specified in the Section to evaluate the data. Those statistical methods include: (i) a parametric analysis of variance (ANOVA); (ii) an ANOVA based on ranks; (iii) a tolerance or prediction interval procedure; (iv) a control chart approach, (v) or other statistical test method meeting the performance standards of 40 CFR 257.93(g);
- (g) The statistical method chosen must comply with the following performance standards, as appropriate:
    - Be appropriate for the data distribution (e.g. normal, non-normal, or log-normal);
    - Use specified levels for Type I errors for ANOVA test, if selected;
    - Unless an ANOVA is the chosen statistical method, the selected test and associated statistical parameters must be as effective as any other approach in the section for evaluating the data;
    - Account for non-detect data; and
    - If necessary, include procedures to control or correct for seasonal variation, spatial variability, and temporal correlation.
- (h) Using the selected statistical method, determine if there is a statistically significant increase over background values for each Appendix III constituent.

3. GROUNDWATER MONITORING NETWORK

As described in the *Groundwater Monitoring Network Certification Report* (Geosyntec, 2017), the Site's CCR groundwater monitoring system consists of two (2) upgradient background monitoring wells (MW-06 and MW-08) and eight (8) downgradient compliance monitoring wells (MW-07, MW-09R, and MW-10 through MW-15). Additional details regarding the monitoring network are provided in the Report.

4. CCR RULE GROUNDWATER QUALITY DATA

In accordance with Section 257.94 of the CCR Rule, baseline concentrations of Appendix III and IV CCR constituents were measured at each Site monitoring well, except MW-09R, during eight (8) quarterly sampling events conducted since December 2015. MW-09R, which was installed in February 2017 to replace the damaged and leaking well casing discovered at MW-09, was sampled monthly from March 2017 to October 2017 to obtain the required eight (8) samples. Low-flow sampling techniques were used to collect the baseline samples at each monitoring well.

Prior to December 2015, groundwater monitoring was conducted at MW-06 through MW-11 on a semi-annual basis since 1993 to comply with Maryland Department of the Environment (MDE) requirements. As a result, historical data for some Appendix III constituents are available at those locations. MDE did not require monitoring for all Appendix III constituents; therefore, data are not available for every Appendix III constituent for the entire record. Although historical Appendix III data are available at MW-06 through MW-11, it should be noted that those data were collected using a three (3) well-volume sampling approach, which is different than the low-flow sampling techniques that were used to collect the eight (8) baseline samples summarized above.

5. STATISTICAL ANALYSIS

After review of the Appendix III groundwater quality data, interwell prediction intervals were selected as the statistical method to evaluate if there is a statistically significant increase over background for each Appendix III constituent. Prediction intervals are an approved CCR Rule statistical method listed in 40 CFR 257.93(f)(3).

Prediction limits will be used to predict the upper limit of possible future values for each Appendix III constituent as well as the lower limit for pH, based on the upgradient monitoring well dataset and a specified number of future statistical comparisons. The calculated upper limit is termed the upper prediction limit (UPL) and the lower limit the lower prediction limit (LPL). Data collected from each downgradient compliance monitoring well will then be compared to the UPL and LPL (for pH) to evaluate the statistical significance. If a downgradient well result is greater than the UPL, then the analysis suggests that groundwater concentrations are above background levels. If pH in a downgradient well is below the LPL, then the analysis suggest pH is below background levels.

The specific prediction limit procedures that will be used for statistical data analysis are summarized in the sections below. The procedures were developed in accordance with the prediction limit calculation methods detailed in *Statistical Analysis of Groundwater Monitoring*

Data at RCRA Facilities – Unified Guidance [Unified Guidance] (USEPA, 2009). ChemStat©, Version 6.3, developed by Starpoint Software, Inc. of Cincinnati, Ohio, will be used to perform the statistical analysis. ChemStat© contains statistical and graphical capabilities that were developed specifically for evaluation of groundwater quality data.

Although interwell prediction limits and ChemStat© have been selected for Site data analysis, other statistical analysis methods approved under 40 CFR 257.93(f), such as analysis of variance, control charts, or intrawell analyses, or alternate statistical software packages may be used to evaluate Site data, if necessary. Procedures used for those analyses will be consistent with CCR rule requirements and the Unified Guidance.

5.1 Prediction Limits

5.1.1 Background Dataset

Data collected from upgradient monitoring wells MW-06 and MW-08 will be used to establish the initial interwell background groundwater prediction limit(s) for each constituent. Appendix III data available at MW-06 and MW-08 are summarized on **Table 1**. Although historical data is available at MW-06 and MW-08 for Appendix III constituents, only data collected during the eight (8) baseline CCR monitoring events will be used to establish background levels for initial prediction limit calculation. Those eight (8) monitoring events are being used because the samples were collected using a low-flow sampling approach. Historical results prior to December 2015 were collected using a three (3) well-volume sampling approach. Because of the different sampling methodology, data prior to 2015 have the potential to be a source of variation; therefore, it will not be included in the statistical analysis. Additionally, the most recent baseline results are the most pertinent for the statistical evaluation and should be considered more representative of current groundwater quality than historical data.

As additional samples are collected in the future, prediction limits for the background dataset will be periodically updated. As recommended in the Unified Guidance, background predictions limits will be updated every four (4) to eight (8) measurements (i.e., every two to four years if samples are collected semi-annually). Before accepting new data into the background dataset, a statistical test such as a Student's t-test or Mann-Whitney test will be performed to compare new data to existing data. If the comparison test does not indicate a statistical difference, the new data can be pooled with existing background data to calculate updated prediction limits. If a statistically significant difference between the datasets is detected, the data should be reviewed to evaluate the cause of the difference and identify which dataset is more representative of background conditions at the time. Unless a release is the suspected cause, the new dataset should be considered more representative of existing groundwater conditions than historical data.

5.1.2 Data Preparation and Review

The procedures detailed below will be used to prepare the background dataset for each Appendix III constituent for prediction limit calculation.

Handling Non-Detect Data

To prepare background and compliance well data for statistical analysis, non-detect results will be replaced with a numerical value. The numerical value for each non-detect result will be the laboratory reporting limit (RL). The RL is considered the lowest level that can be reasonably achieved by the laboratory within specified limits of precision and accuracy during routine operating conditions. Replacing non-detect values with the RL is a conservative estimate of the sample concentration. The laboratory reported value for estimated concentrations (J-flagged) will be retained in all datasets. Blind duplicate results will not be incorporated into the dataset for statistical analysis.

Equality of Variance and Trends

When combining data from two background locations, the data from each location should be evaluated for equality of variance to assess if the data can be pooled for parametric analysis. To assess equality of variance between MW-06 and MW-08, the data will be tested with Levene's test. If Levene's test does not indicate a significant difference, the data will be pooled for parametric analysis. If the test detects a significant difference, the data will be pooled but only non-parametric prediction limit calculations will be performed.

In addition, the data from each location will be evaluated for trends using a two-sided Mann-Kendall test at a 99% level of significance. Seasonality in the dataset will be tested using Seasonal Kendall Analysis at a 99% significance level. If a significant trend is detected, consideration will be given to removing the trending data or transforming the dataset, if possible, before proceeding with analysis. If trending data are removed or transformed, Levene's test will be repeated.

Outlier Identification

Potential outliers in the pooled background dataset for each constituent will be evaluated using Dixon's Outlier test, if there are 25 or less data points, or Rosner's Outlier Test, if there are more than 25 data points, at a 99% level of significance. If the test does not identify outlier concentrations, the dataset will be approved for prediction limit calculation. If an outlier is identified by the tests, consideration will be given to removing it from the dataset. However, as discussed in the Unified Guidance, care should be taken in removing outliers from the dataset. An outlier will only be removed if multiple lines of evidence suggest it is truly an outlier concentration not representative of background groundwater quality.

Population Distribution Testing

The pooled background data will be tested for normality using Shapiro-Wilks (50 or less measurements) or Shapiro-Francia (more than 50 measurements) normality tests at a 95% significance level. If normally distributed at a 95% significance level, parametric prediction limits will be calculated. If not normally distributed, the data will first be transformed to a natural logarithm distribution and tested for a lognormal distribution at a 95% significance level. If lognormally distributed at 95%, parametric prediction limits will be calculated on the transformed data. If not lognormally distributed, non-parametric prediction limits will be calculated.

5.1.3 Calculating Prediction Limits

When normally or lognormally distributed, a 95% Upper Prediction Limit (UPL) will be calculated using a one-sided parametric prediction limit function for each Appendix III constituent, except pH. Because a CCR release has the potential to lower or raise groundwater pH, a two-sided parametric prediction limit function will be used to calculate a UPL and LPL for pH. For parametric prediction limit calculations, four (4) future observations, representing two (2) years of semi-annual detection monitoring events, will be used for each of the eight (8) downgradient compliance wells. Therefore, parametric prediction limits will be calculated based on 32 future samples.

When non-normally distributed, non-parametric prediction limits will be calculated. Per the Unified Guidance, the non-parametric UPL will be the maximum concentration detected in the background dataset. For pH only, the non-parametric LPL will be the minimum concentration detected in the background dataset.

5.2 Identifying Statistically Significant Increases

To identify a statistically significant increase above interwell background in downgradient compliance wells, the Appendix III data generated during each monitoring event from each downgradient monitoring well will be compared to the prediction limits. If an Appendix III constituent concentration is detected above the UPL, that concentration will be considered a potential statistically significant increase (SSI) above background. For pH, compliance well measurements will also be compared to the LPL. If below the LPL, the measurement will be considered a potential statistically significant decrease below background.

To conclude an interwell SSI or decrease (for pH), resampling of the downgradient monitoring well for the constituent with the occurrence will be conducted if the concentration measured during the previous monitoring event was not above the UPL or was not below the LPL. If the initial result and subsequent resample are above the UPL or below the LPL, then an interwell SSI or decrease will be respectively concluded. An interwell SSI will be concluded without resampling if the concentration during the previous monitoring event was above the UPL or below the LPL.

6. SUMMARY AND CONCLUSION

In accordance with 40 CFR 257.93(f), interwell prediction limits will be used to identify SSIs above background. The prediction limit methods presented herein were developed in accordance with the Unified Guidance and meet the CCR Rule statistical analysis performance standards. The P.E. certification required by 40 CFR 257.93(f)(6) is provided in **Appendix A.** This document should be placed in the facility operating record as required in 40 CFR 257.105(h)(4). The P.E. certification with a narrative description of the statistical method should be posted to the publicly accessible intranet Site as required by 40 CFR 257.105(h)(3).

7. REFERENCES

Geosyntec, 2017. Groundwater Monitoring Network Certification Report for Federal CCR Rule, Lot 15 Landfill, Baltimore, Maryland, October 2017.

Code of Federal Regulations (CFR), Title 40: Protection of the Environment. Part 257: Criteria for Classification of Solid Waste Disposal Facilities and Practices. Subpart D: Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments.

U.S Environmental Protection Agency (EPA), 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities – Unified Guidance, March 2009.

TABLE

TABLE 1
BACKGROUND GROUNDWATER RESULTS

Lot 15 Landfill
Baltimore, Maryland

	Analyte:	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
Well ID	**Sample Date**	mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
MW-6	1/1/1993	-	11.53	4	-	6.65	12	42
	7/1/1993	-	13.4	3	-	6.12	11	92
	1/1/1994	-	14.7	3	-	7	11	63
	7/1/1994	-	14.1	3	-	6.8	11	81
	1/1/1995	-	13.3	3	-	6.44	11	58.6
	7/1/1995	-	11.4	3	-	6.4	11	42
	1/1/1996	-	9.9	3	-	6.75	11	61
	7/1/1996	-	9.5	3	-	6.15	9	46
	1/1/1997	-	7.6	4	-	6.22	10	42
	7/1/1997	-	7.2	4	-	6.08	9	49
	1/1/1998	-	6.95	3	-	6.04	10	36
	7/1/1998	-	6.7	5	-	6.09	11	36
	1/1/1999	-	7.2	3	-	6.1	9	43
	7/1/1999	-	8.8	<1U	-	6	10	53
	1/1/2000	-	7	3	-	6.4	16	44
	7/1/2000	-	-	3	<0.1U	6	8	-
	1/1/2001	-	-	3.1	<0.1U	5.9	12	-
	7/1/2001	-	-	2.6	<0.1U	7	11	-
	1/1/2002	-	-	2.9	<0.1U	6.5	14	-
	7/1/2002	-	-	2.5	<0.1U	6	8.7	-
	1/1/2003	-	-	2.5	<0.1U	5.7	13	-
	7/1/2003	-	-	2.4	<0.1U	5.4	13	-
	1/1/2004	-	-	2.5	0.21	5.2	13	-
	7/1/2004	-	-	10	<0.1U	5	9.6	-
	1/1/2005	-	-	2	0.21	5.3	9.6	-
	7/1/2005	-	-	3	<0.1U	5.3	11	-
	1/1/2006	-	-	1.5	<0.1U	4.9	11	-
	7/1/2006	-	-	3.5	<0.1U	5.2	12	-
	1/1/2007	-	4.1	2.5	-	4.9	13	17
	7/1/2007	-	4.9	2	-	5.5	8.7	41
	1/1/2008	-	4.2	1.5	-	5.3	9.8	<10U
	7/1/2008	-	3.7	4.5	-	5.2	14	42
	1/1/2009	-	5.6	3	-	1.8	7.4	23
	7/1/2009	-	4.3	4	-	4.8	10	41
	1/1/2010	-	4.3	4	-	4.2	13	43
	7/1/2010	-	4.2	2	-	4.8	14	43
	1/1/2011	<0.02U	4.2	4	<0.1U	5.35	12	73
	7/1/2011	0.007	4.1	5	<0.1U	-	12	42
	1/1/2012	<0.01U	4	4.5	0.68	5.4	12	48
	7/1/2012	<0.01U	4	5	<0.1U	4.92	13	10
	1/1/2013	<0.01U	3.6	6	0.11	4.9	12	53
	7/1/2013	<0.01U	3.7	4.5	0.14	5.2*	10	<40U
	1/1/2014	<0.02U	3.6	2.5	-	4.99*	9.6	43
	7/1/2014	0.021	3.1	3.5	-	4.99*	59	54
	1/1/2015	<0.02U	3.4	3	-	4.3*	10	28
	7/1/2015	<0.02U	3.2	3.5	-	4.8*	12	44
	12/29/2015	<0.05U	6.18	3.8	<0.5U	5.26*	15.3	47.5J
	3/29/2016	<0.05U	5.25	4.2	<0.5U	5.29	13.2	41.5
	7/11/2016	<0.05UJ	5.66	3.5	<0.5U	5.8	13	55
	10/13/2016	<0.05U	6.49	3.9	<0.5U	5.9	14.5	38
	12/29/2016	<0.05U	7.57	4.3	<0.5U	5.8	14.7	46
	3/23/2017	<0.05U	5.74	3.8	<0.5U	6.1J	13.3	52.5
	6/22/2017	<0.05U	6.32	6.9	<0.5U	5.8	15.8	52.5
	9/7/2017	<0.05U	5.59	3.9	<0.5U	6	12.6	48.5

Notes:
J - The constituent was detected and the associated numerical value is estimated
U - The constituent was analyzed for, but was not detected at a level greater than or equal to the method detection limit (MDL)
Analytes not detected shown as < Reporting Limit
* Laboratory pH was not analzyed, result replaced with field pH measurement.
mg/L - milligrams per liter
SU - standard units
- not analyzed

TABLE 1
BACKGROUND GROUNDWATER RESULTS

Lot 15 Landfill
Baltimore, Maryland

	Analyte:	Boron	Calcium	Chloride	Fluoride	pH	Sulfate	Total Dissolved Solids
Well ID	**Sample Date**	mg/L	mg/L	mg/L	mg/L	SU	mg/L	mg/L
MW-8	1/1/1993	-	1.34	4	-	5.93	5	14
	7/1/1993	-	1.61	4	-	5.58	5	17
	1/1/1994	-	1.86	4	-	5.95	5	26
	7/1/1994	-	1.12	4	-	5.77	5	39
	1/1/1995	-	1.99	4	-	5.78	5	31
	7/1/1995	-	1.8	4	-	5.67	4	25
	1/1/1996	-	1.82	4	-	5.47	5	34
	7/1/1996	-	1.97	4	-	5.78	5	29
	1/1/1997	-	1.68	4	-	5.9	6	22
	7/1/1997	-	1.92	4	-	5.42	6	30
	1/1/1998	-	1.8	4	-	5.45	6	26
	7/1/1998	-	1.71	6	-	5.55	12	46
	1/1/1999	-	2	5	-	5.3	5	36
	7/1/1999	-	2	<1U	-	5.5	5	33
	1/1/2000	-	1.9	3	-	4.7	6	22
	7/1/2000	-	-	3	<0.1U	5.7	5	-
	1/1/2001	-	-	3.2	<0.1U	5.6	3.8	-
	7/1/2001	-	-	3.2	<0.1U	6	12	-
	1/1/2002	-	-	3.5	<0.1U	5.6	11	-
	7/1/2002	-	-	2.5	<0.1U	5.6	9	-
	1/1/2003	-	-	3.5	<0.1U	5.6	9.7	-
	7/1/2003	-	-	3.5	<0.1U	4.8	9.7	-
	1/1/2004	-	-	4	<0.1U	5	10	-
	7/1/2004	-	-	4.5	<0.1U	5.1	5.6	-
	1/1/2005	-	-	5	<0.1U	5.9	3.6	-
	7/1/2005	-	-	4.5	0.05	5	5.5	-
	1/1/2006	-	-	<1U	<0.1U	5.1	7.1	-
	7/1/2006	-	-	4	<0.1U	4.8	7.8	-
	1/1/2007	-	1.5	3.5	-	4.5	9.1	48
	7/1/2007	-	1.5	2	-	5.4	5.9	84
	1/1/2008	-	1.5	3.5	-	5.8	6.8	<10U
	7/1/2008	-	1.4	5	-	5.2	8.3	8.3
	1/1/2009	-	1.7	2.5	-	4.8	5.4	16
	7/1/2009	-	1.7	4.5	-	4.6	7.7	33
	1/1/2010	-	2.1	4	-	4.1	8.5	40
	7/1/2010	-	1.6	2	-	4.6	9.1	25
	1/1/2011	<0.02U	1.7	4	<0.1U	4.99	10	<10U
	7/1/2011	0.0068	1.9	5	<0.1U	-	11	32
	1/1/2012	<0.01U	1.8	4.5	<0.1U	4.75	8.7	20
	7/1/2012	<0.01U	1.9	5	<0.1U	5.21	17	15
	1/1/2013	<0.01U	1.7	6	0.11	4.7	6.9	43
	7/1/2013	<0.01U	1.7	4.5	0.14	5.4*	5.8	22
	1/1/2014	<0.02U	1.9	3	-	5.23*	6.3	33
	7/1/2014	<0.02U	1.8	2.5	-	5.2*	37	46
	1/1/2015	<0.02U	1.6	3	-	4.3*	7	39
	7/1/2015	<0.02U	1.6	3.5	-	5.1*	7.1	21
	12/30/2015	0.0127J	4.08	3.6	<0.5U	5.36*	13.7	36.5
	3/29/2016	0.0088J	3.64	3.2	<0.5U	5.46*	12.2	31.5
	7/8/2016	0.0205J	3.63	3.2	<0.5U	5.7	11.8	<30U
	10/13/2016	0.0193J	3.96	2.8	<0.5U	5.6	15.9	47
	12/27/2016	0.0162J	3.8J	3	<0.5U	5.7	13.3	34.5
	3/22/2017	0.0112J	4.09	3	<0.5U	6.1	12.8	74J
	6/21/2017	0.0141J	4.48	2.5	<0.5U	6.2	14.4	53.5
	9/7/2017	0.0101J	3.71	2.5	<0.5U	5.7	12.4	38

Notes:
J - The constituent was detected and the associated numerical value is estimated
U - The constituent was analyzed for, but was not detected at a level greater than or equal to the method detection limit (MDL)
Analytes not detected shown as < Reporting Limit
* Laboratory pH was not analzyed, result replaced with field pH measurement.
mg/L - milligrams per liter
SU - standard units
 - not analyzed

APPENDIX A

P.E. CERTIFICATION

Certification for Selected Statistical Methods

CCR Unit: Lot 15 Landfill, Baltimore, Maryland

Certification:

I, **Thomas B. Ramsey**, a qualified professional engineer registered in the state of **Maryland**, have reviewed the information in the *Detection Monitoring Statistical Methods Certification Report, Lot 15 Landfill, Baltimore, Maryland* and based on my review, in my professional opinion find that, the selected statistical methods are appropriate for evaluating groundwater monitoring data for this CCR unit as described in 40 CFR §257.93(f) and (g).

Printed Name: Thomas B. Ramsey

PE License Number: 29452 State: Maryland

Signature: [signature]

Date: 17 October 2017 Seal: STATE OF MARYLAND ★ THOMAS B. RAMSEY ★ NO. 29452 REGISTERED ★ PROFESSIONAL ENGINEER