REPORT

GROUNDWATER MONITORING STATISTICAL METHODS CERTIFICATION

GERALD GENTLEMAN STATION ASH DISPOSAL FACILITY

Nebraska Public Power District

"Always there when you need us"

Submitted To: Nebraska Public Power District
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Table of Contents

1.0 INTRODUCTION

Golder Associates Inc. (Golder) has prepared this report to certify that the statistical methods selected for evaluating the groundwater quality data at the coal combustion residual (CCR) landfill located at Nebraska Public Power District's (NPPD's) Gerald Gentleman Station (GGS) are appropriate under the requirements of 40 CFR 257.93 (f) and (g).

2.0 STATISTICAL METHODOLOGY SUMMARY

40 CFR 257.93(f) includes a list of statistical methods from which to choose for evaluating the groundwater monitoring data from CCR management areas. The options include:

- A parametric analysis of variance followed by multiple comparison.
- An analysis of variance (ANOVA) based on ranks followed by multiple comparison procedures.
- A tolerance or prediction interval procedure, in which an interval for each constituent is established from the distribution of the background data and the level of each constituent in each compliance well is compared to the upper tolerance limit.
- A control chart approach that gives control limits for each constituent.
- Another method that complies with the performance standards of 40 CFR 257.93(g).

The statistical methodology for the site was developed based on the Environmental Protection Agency's (EPA's) Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA, 2009), and is described in detail in the Sampling and Analysis Plan (SAP), which can be found in the site Operating Record (Golder, 2017).

2.1 Baseline Statistical Analysis

Intra-well statistical methods will be used to evaluate the groundwater data for the Appendix III parameters listed in 40 CFR 257 during detection monitoring. The baseline statistical analysis will consist of a series of steps that are repeated for each parameter in each well, including:

- Initial data review;
- Data distribution (i.e., normality);
- Outlier analysis;
- Trend analysis;
- Seasonality;
- Statistical limit.

2.1.1 Initial Data Review

The initial data review will determine the frequency of detected and non-detected values for each parameter at each well, and will include compilation of minimum, maximum, mean (for normally distributed and transform-normally distributed data) and median concentrations. Additionally, data will be plotted on time-series graphs to assess the temporal variability of the data and to visually screen for potential outliers. Temporal variability can be caused by seasonality, changes to the analytical method, recalibration of instruments, and anomalies in the sampling method (EPA, 2009).

Non-detects will be replaced with an imputed value of one-half the laboratory reporting limit (PQL) for statistical analysis, as described in the Unified Guidance (EPA, 2009). Datasets with greater than 25% non-detects will be analyzed using non-parametric tests.

Prediction limits, which are the statistical methodology proposed for the site, assume concentrations do not demonstrate temporal correlation. Thus, prediction limits are not appropriate when temporal trends are present. If temporal trends are present in the dataset, the data will be adjusted to account for the trends (e.g., removal of seasonal trends), the time period used for the baseline will be reassessed, or an alternative statistical method will be used. In some cases, it may be possible that no adjustments or alternative methods are appropriate and a particular parameter may not be considered for statistical analysis.

As recommended in the Unified Guidance, any visually identified outliers will be further evaluated prior to inclusion in the statistical analysis. This evaluation will include reviewing the analytical laboratory reports, laboratory quality assurance/quality control (QA/QC) information (if available) and any available notes associated with the sampling event and the laboratory report to determine if any systematic errors were responsible for the noted anomalous readings. Occasionally, analytical values for a parameter at a specific well are not consistent with the remainder of the data. When these inconsistent values, or outliers, deviate significantly from the rest of the data, the data point will be removed from the dataset.

2.1.2 Data Distribution

Most parametric statistical tests are based on the assumption that the data are normally-distributed or can be transformed to a normal distribution. The distribution of the data will be tested for normality using the Shapiro-Wilk normality test with a 95 percent confidence level. Each parameter from each well will be analyzed separately. Datasets found to be non-normal will be tested for other distributions and transformed accordingly. Other distributions to be tested include log-normal and Ladder of Powers. Datasets found to exhibit other distributions will be transformed, and parametric analysis will be performed on the transform-normal data. Non-parametric statistics will be used for datasets that do not show normal or transform-normal distributions.

2.1.3 Outlier Analysis

Outliers will be evaluated and identified through visual inspection and EPA-recommended statistical analysis tests in the Unified Guidance. In accordance with the Unified Guidance, data points will be identified as outliers if the value was an "extreme, unusual-looking measurement" and "inconsistent with the distribution of the remaining measurements." Outliers will be deemed "inconsistent with the distribution of the remaining measurements" if: (1) inclusion of the outlier creates a non-normal data distribution but removal of the outlier results in a normal data distribution, (2) the result varied from the dataset and the value was unrealistic for the aquifer type, or (3) the value was visually identified as varying from the dataset.

Outliers will be managed as follows:

- Any suspected outlier identified by the outlier test or visual methods will be reviewed (i.e., reviewing the analytical report, lab narrative, and/or field notes) before removal from the dataset. Rejected data points will not be included in the baseline monitoring dataset.
- The rationale for the removal of any outliers will be documented in the statistical method summary for each well. The majority of the outliers will likely be isolated values that can be attributed to inconsistent sampling or analytical chemistry methodology resulting in laboratory contamination or other anomalies, or errors in the transcription of data values or decimal points.
- If an outlier is removed, the normality test will be rerun to determine if the dataset is normally-distributed without the outlier.

2.1.4 Trend Analysis

The Sen's Slope test is a non-parametric method for determining if an upward or downward trend exists in a dataset. The test involves examining all possible pairs of measurements in the dataset and scoring each pair to determine if a trend exists. The test will be conducted using a target confidence level of 95 percent. If a statistical limit cannot be established due to trending data, a trend analysis approach in accordance with the Unified Guidance will be used to evaluate the significance of an apparent change in water quality over time for the given parameter and well.

2.1.5 Seasonality

Seasonal temporal variability can mask changes in groundwater chemistry. Time-series plots will be observed for visual signs of seasonality, and once enough data has been collected, the data will be evaluated for seasonal variations using the seasonal Mann-Kendall trend test or a one-way ANOVA. The Mann-Kendall testing will be an intra-well evaluation performed on each parameter individually. Datasets found to have seasonality will be de-seasonalized for subsequent analysis.

2.1.6 Statistical Limits

Statistical analyses will be conducted using the software package WQStat Plus (Sanitas Technologies 2009), or equivalent, and using a user-defined confidence level based on a calculation of facility-wide false positive rates (typically α=0.05). For non-parametric prediction limits, the confidence level increases as the number of background observations increases, as described in Unified Guidance, Appendix D Table 18-1 (EPA, 2009).

Statistical limits will be established based on intrawell analysis. Review of the time series plots of the background data collected at GGS indicates spatial variability is present between the up-gradient wells. The Unified Guidance (EPA, 2009) recommends using intrawell testing when spatial variability is observed, stating that when using intrawell testing "confounding results due to spatial variability are eliminated."

Either a parametric or non-parametric method will be used to generate the baseline statistical limit for each constituent. The statistical method will vary between constituents and will be selected based on the percent of baseline non-detects (undetected concentrations) and baseline data distribution for each constituent in accordance with the Unified Guidance (EPA, 2009). In cases where the concentrations of a given analyte are normally or transformed-normally distributed and the well has equal to or greater than 25 percent detections, Shewhart-CUSUM parametric control charts will be used. In cases where the concentrations of a given analyte are not normally or transformed-normally distributed, a non-parametric prediction limit will be used. The non-parametric limit will be assigned at the highest detected value (excluding outliers) or the highest reporting limit, whichever is greater.

To reduce the likelihood of false positives, statistically significant increases will be verified by using "1 of 2" resampling. If the verification sample does not also show a statistically significant increase, the original result will be considered a false positive and will not result in a move to assessment monitoring.

2.2 Comparative Statistical Analysis

Once statistical limits have been established for the baseline data, the analytical results from each monitoring event will be compared to the statistical limits. When the statistical limit is exceeded, the data point will be identified as potentially statistically significant.

The following definitions will be used in discussion of the comparative statistical analysis:

- SSI – is a statistically significant increase and is defined as an analytical result that exceeds the parametric or non-parametric Prediction Limit established by the baseline statistical analysis.
- False-positive SSI – is defined as an analytical result that exceeds the statistical limit that can clearly be attributed to laboratory error, changes in analytical precision, or is invalidated through confirmatory re-sampling.
- Confirmatory re-sampling – is designated as the next scheduled sampling event.
- Verified exceedance – is interpreted as two consecutive SSIs (the original sample and the confirmatory re-sample) for the same parameter at the same well.

The detection monitoring program has been developed to identify potential statistically significant increases (SSI) over background values. This determination will be made within 90 days of the completion of laboratory analysis. A potential SSI will not be considered a verified exceedance until confirmatory re-sampling is performed. Confirmatory sampling will occur during the next scheduled sampling event.

If an SSI is identified and verified, NPPD shall establish an assessment monitoring program meeting the requirements of §257.96 of the CCR rule. In lieu of this, NPPD may demonstrate that a source other than the Ash Landfill caused the SSI or that the SSI resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. A report documenting this demonstration shall be

certified by a Professional Engineer registered in Nebraska and placed in the site's Operating Record within 90 days of the SSI determination. If a successful demonstration is made and documented, NPPD will continue detection monitoring. If, after 90 days, a successful demonstration is not made, NPPD shall initiate an assessment monitoring as described in the SAP (Golder, 2017).

3.0 CERTIFICATION

Based upon the review described in this report, the undersigned Professional Engineer registered in Nebraska certifies that the statistical method is appropriate for evaluating the groundwater monitoring data for the active CCR landfill at GGS, and meets the requirements of 40 CFR 257.93 (f) and (g).

4.0 REFERENCES

Golder, 2004. *Hydrogeologic Characterization Report for Gerald Gentleman Station*. Golder Associates Inc., October 15, 2004.

Golder, 2017. *Sampling and Analysis Plan for Gerald Gentleman Station*. Golder Associates Inc., October 10, 2017.

United States Environmental Protection Agency (EPA), 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, Office of Resource Conservation and Recovery, EPA-R-09-007, March 2009.

United States Environmental Protection Agency (EPA), 2015. Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; *Disposal of Coal Combustion Residuals from Electric Utilities*. April 17, 2015.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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