CCR Groundwater Statistical Analysis Plan

Black Dog Generating Plant

Burnsville, Minnesota

Prepared for
Northern States Power Company

April 2019

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Certifications

I hereby certify that I have examined the facility and, being familiar with the provisions of 40 CFR 257 Subpart D, attest that this Groundwater Statistical Analysis Plan has been prepared in accordance with good engineering practice, including consideration of applicable industry standards and the requirements of 40 CFR §257.93. I hereby certify that the plan is adequate for this facility and that procedures for recordkeeping and reporting have been established. I further certify that this report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Jeremy J. Gacnik, P.E.
PE #: 49292

April 15, 2019
Date

Acronyms

Acronym	Description
CCR	coal combustion residuals
GWPS	groundwater protection standard
KM	Kaplan-Meier
MCL	maximum contaminant level
ND	non-detect
QA	quality assurance
QC	quality control
SAP	sampling and analysis plan
SSI	statistically significant increase
UPL	upper prediction limit

1.0 Introduction

This Statistical Analysis Plan (Plan) describes part of the Sampling and Analysis Plan required by the Coal Combustion Residuals (CCR) Rule (EPA, 2015a) §257.93 Groundwater Sampling and Analysis Requirements. The Plan provides a description of the potential statistical methods that may be used to evaluate groundwater quality data collected from the monitoring network for the decommissioned CCR units at the Black Dog Generating Plant (Site). The Site is located in Burnsville, Minnesota (Figure 1), and is owned and operated by Northern States Power Company, a Minnesota corporation doing business as Xcel Energy (NSPM).

1.1 Site Background Information

The Black Dog plant ceased coal fired operations on April 16, 2015. The CCR units at the Site include three decommissioned CCR surface impoundments, referred to as Ponds 1, 2, and 3 (Figure 2). NSPM drained the impoundments and removed CCR in accordance with the Ash Pond Closure Plan (Barr, 2016) by December 12, 2016. Under the provision for closure by removal of CCR, §257.102(c) of the CCR Rule states that the CCR units will be considered closed when it is demonstrated that groundwater monitoring concentrations do not exceed groundwater protection standards (GWPS) established pursuant to §257.95(h) for constituents listed in appendix IV to the CCR Rule.

1.2 Data Collection

A multiunit groundwater monitoring system was established and baseline groundwater monitoring was completed in 2017 and 2018 (Barr, 2019). Baseline groundwater monitoring consisted of 8 or more sampling events at each background and downgradient CCR monitoring well, in accordance with the Baseline Sampling and Analysis Plan (Barr, 2017). Water levels were also collected during the baseline sampling for use in developing the hydrogeologic conceptual model for the Site and certifying the CCR well network (Barr, 2019a). The baseline sampling was completed after the CCR units were decommissioned and CCR had been removed.

Background groundwater quality is represented by baseline samples from the background well network, which was selected based on the hydrogeologic conditions at the Site, as described in the Groundwater Monitoring System Certification Report (Barr, 2019a). Post-baseline monitoring events will be conducted using the same methods as the baseline sampling, in accordance with the Sampling and Analysis Plan (Barr, 2019b).

1.3 Purpose

The purpose of the statistical analysis of the groundwater monitoring data for this Site is to assess whether groundwater monitoring concentrations meet GWPS as part of the closure requirements for the CCR units [§257.102(c)]. As stated in the CCR Rule (as modified by Amendments to the National Minimum Criteria (Phase One, Part One), July 30, 2018), GWPS are to be established in accordance with §257.95(h):

(h) The owner or operator of the CCR unit must establish a groundwater protection standard for each constituent in appendix IV to this part detected in the groundwater. The groundwater protection standard shall be:

(1) For constituents for which a maximum contaminant level (MCL) has been established under §§ 141.62 and 141.66 of this title, the MCL for that constituent;

(2) For the following constituents:

(i) Cobalt 6 micrograms per liter (μg/l);

(ii) Lead 15 μg/l;

(iii) Lithium 40 μg/l; and

(iv) Molybdenum 100 μg/l

(3) For constituents for which the background level is higher than the levels identified under paragraphs (h)(1) and (h)(2) of this section, the background concentration.

Therefore, to develop values for GWPS, the "background concentration" needs to be determined for each appendix IV constituent and compared to the MCL and the values in (h)(2) above. This report outlines the statistical methods that may be used to determine the background concentrations and to evaluate the CCR monitoring data in compliance with the CCR Rule.

2.0 Statistical Methods

The purpose of statistical evaluations for this Site is to determine background concentrations for appendix IV parameters, determine GWPS in accordance with §257.95(h), and compare future downgradient monitoring data to the GWPS to document closure requirements are met. Statistical methods may also be used for general review and characterization of the groundwater monitoring data.

Consistent with the CCR Rule, statistical methods may include more than one type of analysis depending on the data for each well/parameter combination. Statistical evaluations of groundwater sampling results will be conducted in accordance with CCR Rule Section 257.93 (f) and selected methods from the following technical guidance documents, as deemed appropriate by the qualified professional engineer:

- EPA, 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities: Unified Guidance. EPA 530/R-09-007. March 2009.
- ITRC, 2013. ITRC Guidance Document: Groundwater Statistics and Monitoring Compliance.
- EPA, 2015. ProUCL Version 5.1 Technical Guide: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041. October 2015.
- ASTM, 2017. D6312-17 Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs at Waste Disposal Facilities, ASTM International, West Conshohocken, PA, www.astm.org.

2.1 Preliminary Data Evaluation

Considerations regarding the methods for calculating the background concentration will be based on preliminary data evaluation. The data will be evaluated using standard hydrogeologic methods to consider overall flow directions, well screen depths, locations, and likely flow paths relative to the former CCR units. The data set will be reviewed for data quality, and may be characterized with summary statistics, distribution tests, outlier testing, and visual plots. If applicable to the Site, media geochemical results, source water comparisons, and dissolved metals comparisons may be completed to assess the unique aspects of the Site and provide visual representations of the data (Stiff, Piper, and time series plots). The preliminary data evaluation methods are described in further detail below.

2.1.1 Data Summary Statistics

The summary statistics may include number of observations, number of values below the detection limit (non-detects), minimums, maximums, means, medians, measures of variability, and quantiles. Graphical displays, such as box plots and Q-Q plots, may be utilized to visually evaluate the data, including the presence and degree of any outlier(s).

2.1.2 Non-Detect Data

Laboratory reporting limits will be those that are reliably achieved within the laboratory's acceptable precision and accuracy limits during routine operating conditions. Statistical software used will account for non-detect data with statistical methods consistent with EPA guidance (EPA, 2009). Substitution methods will not be used to handle non-detect data used in statistical tests for determining background concentrations unless non-detect observations comprise below 15% of the data. The Kaplan-Meier method will be used for data sets with between 15 and 50% non-detects. Data sets with more than 50% of the observations below detection will be assessed using non-parametric methods.

2.1.3 Duplicates

Duplicate samples are typically collected as a quality control check on field sampling and laboratory methods, not for data analysis purposes. If Barr conducts a QA/QC review of the data and the results of a duplicate sample do not sufficiently match that of the original sample, a qualifier is typically applied and, based on the type of qualifier, the original data may be excluded from further analysis. Duplicate sample results will not be used in data evaluations beyond QA/QC review.

2.1.4 Data Distribution

The type of distribution (normal, log-normal, non-parametric, etc.) will be determined for each parameter at each well before selecting the appropriate statistical test method. A Goodness-of-Fit test (e.g., Shapiro-Wilk or Shapiro-Francia) will be performed at a significance level of 0.05. Data distribution determinations will be updated each time statistical analyses are conducted. As required by the CCR Rule §257.93 (g)(1), data sets that do not fit a normal distribution will be transformed, or a distribution-free (non-parametric) test will be used.

2.1.5 Time Series Plots and Trend Testing

Time series plots are useful graphical representations of the water quality over time; they can assist in visual evaluations of trends over time as well as to identify potential outliers. Trend testing provides a tool to evaluate whether the groundwater concentrations at a given location are stable or exhibit statistically significant evidence of an upward or downward trend. Various trend tests, including but not limited to Sen’s Slope or Mann-Kendall trend tests, may be used to assess for the presence of statistically significant increasing or decreasing trends. Trend tests, if used, will be applied in accordance with the EPA Unified Guidance (EPA, 2009).

The Mann-Kendall test does not require that the data follow a specific distribution, and it can handle datasets with non-detect data. However, the Mann-Kendall test cannot account for multiple detection limits for non-detect data within a given data set. In the case of multiple detection limits, all values below the highest detection limit (including any detected measurements) should be censored at a single value less than or equal to the highest detection limit. The censored data set will only be used to conduct Mann-Kendall trend analysis. Similarly, Sen’s slope assumes a synthetic distribution of the data.

2.1.6 Outlier Testing

Outlier testing can be conducted on data sets that are normally distributed. Outliers will be evaluated by the Dixon and Rosner test methods, both of which are outlined in the EPA Unified Guidance (EPA, 2009). For non-parametric data sets, outlier screening can be conducted using the Tukey method, as described in the EPA Unified Guidance (EPA, 2009). The presence of a statistical outlier will not necessarily result in that value being removed from the data set. Outliers will generally be kept in the data set unless determined to be unrepresentative of the groundwater quality based on an identified data quality issue or a shift in groundwater data population.

2.1.7 Stiff and Piper Plots

Both Stiff and Piper plots use major cations and anion concentrations to create visualizations of the groundwater geochemistry. Stiff diagrams represent water chemistry as shapes where the resultant shape reflects the geochemical fingerprint of each water sample and allows for a visual comparison of water types. Piper diagrams are plots of relative major ion chemistry of water samples that are used to differentiate between water types and to identify potential mixing of water types (Helsel and Hirsch, 2002). These types of comparisons are most useful in those instances where source water samples have been collected and analyzed for the same major ions as the monitoring samples. Source waters can be upgradient groundwater, surface waters, pond water, leachate, leach test, or other sample data. These plots can also be viewed to evaluate changes or trends in data over time.

2.2 Establishing Background Concentrations

The statistical methods for establishing and comparing monitoring data to background concentrations will be in accordance with CCR Rule Section 257.93 (f) and the guidance documents listed in Section 2.1. The CCR Rule allows for several types of statistical evaluations to be conducted to determine if a statistically significant level over background concentration has occurred in downgradient monitoring wells. This includes the following tests, listed in 257.93(f):

1. Parametric analysis of variance (ANOVA) followed by multiple comparison procedures
2. Analysis of variance based on ranks followed by multiple comparison procedures
3. Tolerance or prediction interval
4. Control chart
5. Another statistical test method that meets the performance standards outlined in 257.93 (g).

It is not appropriate at this time to select which specific methods will be used for each constituent, as conditions may change and therefore the method best suited for the individual constituents may change with time. However, anticipated methods appropriate for the evaluation based on the statistical objectives are discussed below.

2.2.1 Background Calculation Methods

Background evaluations can be employed as interwell and intrawell tests; that is, they can evaluate spatial differences between well groups (i.e., interwell comparisons) or temporal differences within a single well (i.e., intrawell comparisons). Based on the CCR unit status at the time of baseline sampling (decommissioned, with CCR removed), interwell analysis (comparing downgradient and background well locations) are appropriate for comparing CCR unit monitoring data to background concentrations at the Site. The anticipated approach for establishing background concentrations is calculating an upper interval (upper tolerance limit or upper prediction limit) from the distribution of baseline background data [§257.93 (f)(3)]. However, other methods, if deemed appropriate based on the data and Site conditions, may also be utilized in lieu of or as a supplement to tolerance or prediction limits. The most appropriate statistical method(s) for each constituent in each monitoring well will be determined each time a statistical evaluation is conducted. Details regarding two background calculation method options are given below.

2.2.1.1 Upper Tolerance Limit

A tolerance interval is defined as the "concentration range designed to contain a pre-specified proportion of the underlying population from which the statistical sample is drawn (e.g., 95 percent of all possible population measurements)" (EPA 2009, pg. 17-14). A tolerance limit is a one-sided tolerance interval, of which the upper limit is the recommended value for constructing a background value for comparisons. The Unified Guidance recommends defining a fixed GWPS based on an upper tolerance limit with 95% coverage and a 95% confidence level (5% significance) for single-sample, point by point comparisons to a GWPS (p. 7-21 and 7-24). For a 95% Upper Tolerance Limit with 95% coverage, random observations from a distribution identical to background should exceed the upper tolerance limit less than 5% of the time. Tolerance limits can be calculated using either parametric or non-parametric methods, and the appropriate method will be selected for each parameter based on distribution fit testing results.

2.2.1.2 Upper Prediction Limit

Another option for developing a GWPS is use of an upper prediction limit on the background data. Prediction limits are utilized to predict the "upper limit of possible future values based on a background or baseline data set and comparing that limit to compliance point measurements or statistics … prediction limits explicitly account for the degree of variation in the background population and the size of the sample of measurements used to construct the limit" (ITRC 2013, pg. 87). Prediction limits are constructed to contain one or more future observations generated from the background population with a specified probability, known as the confidence level of the limit (EPA, 2009, pg. 18-3). While background data are used to construct the prediction limit, the probability that the limit contains all future observations is also based on the number of future measurements. For GWPS calculated based on an upper prediction limit, a 95% probability is recommended, and the number of future measurements will be the number of post-baseline samples collected.

Both parametric and non-parametric prediction limits can be determined. For parametric prediction limits, the mean and standard deviation of the background or baseline dataset is used whereas non-parametric prediction limits are based on order statistics (i.e., highest detected concentration; ITRC 2013, pg. 87).

2.2.2 Background Data Set

Background conditions are represented by wells screened in the uppermost aquifer which are unaffected by releases from the CCR units. These wells are identified and the rationale for their selection is included in the Groundwater Monitoring System Certification Report (Barr, 2019a). The background data set may consist of pooled baseline data from the background well network. Future background data collected may also be used to update the background data set over time in accordance with applicable guidance.

3.0 Groundwater Protection Standards

3.1 Establishing GWPS

Background concentrations will be compared to the values listed in §257.95(h)(1) (MCLs) or i §257.95(h)(2) (values for cobalt, lead, lithium and molybdenum) and the higher value selected as the GWPS for each appendix IV parameter, consistent with §257.95(h).

3.2 Compliance Determination

The results from monitoring events conducted after the baseline monitoring period will be used to assess whether the groundwater concentrations in samples from wells downgradient of the former CCR units meet closure requirements by comparing the concentration of each constituent to the GWPS.

A retesting strategy may also be utilized or another verification strategy as allowed under the Unified Guidance (EPA, 2009). For example, if a GWPS exceedance occurs, a verification resample(s) may be collected and compared to the GWPS. Further, GWPS based on upper prediction limits may be recalculated to account for a greater number of future values, if appropriate. Retesting may also be conducted if data quality or representativeness of the compliance data is unacceptable.

4.0 References

ASTM, 2017. D6312-17 Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs at Waste Disposal Facilities, ASTM International, West Conshohocken, PA, www.astm.org.

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