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Statistical Analysis Plan

Baldwin Energy Complex
Havana Power Station
Hennepin Power Station
Wood River Power Station

Dynegy Midwest Generation, LLC

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Natural Resource Technology
AN OBG COMPANY

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ACRONYMS AND ABBREVIATIONS

Annual Report	Annual Groundwater Monitoring and Corrective Action Report
ANOVA	analysis of variance
ASD	alternative source demonstration
CCR	Coal Combustion Residuals
CUSUM	cumulative sum
COCs	constituents of concern
GWPS	groundwater protection standard
LCL	lower confidence limit
LPL	lower prediction limit
MCL	maximum contaminant level
MSE	mean squared error
RCRA	Resource Conservation and Recovery Act
RL	reporting limit
ROS	regression on order statistics
SSI	statistically significant increase
SSL	statistically significant level
SWFPR	site-wide false positive rate
Unified Guidance	Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance (USEPA, 2009)
UPL	upper prediction limit
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit

1. INTRODUCTION

In April 2015, the United States Environmental Protection Agency (USEPA) issued a final rule for the regulation and management of Coal Combustion Residuals (CCR) in certain landfills and impoundments under Subtitle D of the Resource Conservation and Recovery Act (RCRA) [40 CFR 257 Subpart D; published in 80 FR 21302-21501, April 17, 2015, referred to hereafter as the CCR Rule]. Facilities regulated under the CCR Rule are required to develop and sample a groundwater monitoring well network to evaluate if landfilled (including within an impoundment) CCR materials are impacting downgradient groundwater quality. The groundwater quality evaluation must include selection and certification by a qualified professional engineer of the statistical procedures to be used by a qualified professional engineer. The procedures described in the evaluation will be used to establish background conditions and implement detection, assessment, and corrective action monitoring as necessary and required by 40 CFR §257.93-257.95. This Statistical Analysis Plan was prepared in accordance with the requirements of 40 CFR §257.93, with reference to the acceptable statistical procedures provided in USEPA's Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance (March 2009), and is intended to provide a logical process and framework for conducting the statistical analysis of the data obtained during groundwater monitoring.

This Statistical Analysis Plan does not include procedures for groundwater sample collection and analysis, as these activities are conducted in accordance with the Sampling and Analysis Plan prepared for each CCR unit in accordance with 40CFR 257.93. This Statistical Analysis Plan will be used as the primary reference for evaluating groundwater quality before and after closure of CCR landfills and surface impoundments.

1.1 STATISTICAL ANALYSIS OBJECTIVES

This Statistical Analysis Plan is intended to provide a framework for conducting the statistical analyses of data obtained during groundwater monitoring conducted in accordance with the Sampling and Analysis Plan for each CCR unit. The Statistical Analysis Plan will enable a qualified professional engineer to certify that the selected statistical methods are appropriate for evaluating the groundwater monitoring data for CCR management areas.

1.2 STATISTICAL ANALYSIS PLAN APPROACH

The main sections of this Statistical Analysis Plan should be viewed as a "generic" outline of statistical methods for each CCR unit and required constituent. The statistical analysis of the groundwater monitoring data however, will be conducted on an individual-constituent basis, and may involve the use of appropriate statistical procedures depending on multiple factors such as detection frequency and normality distributions.

The CCR Rule outlines four phases of groundwater monitoring:

- Background Monitoring in accordance with 40 CFR 257.90(b)(iii) and 257.94(b)
- Detection Monitoring in accordance with 40 CFR 257.94
- Assessment Monitoring in accordance with 40 CFR 257.95
- Corrective Action Monitoring in accordance with 40 CFR 257.95(g) and 257.98.

Each phase of the groundwater monitoring program requires specific statistical procedures to accomplish the intended purpose. During the first phase, background groundwater quality will be established, utilizing upgradient and background wells. Detection Monitoring is then initiated through the evaluation of the downgradient groundwater monitoring data for statistically significant increases (SSI) over background levels for seven selected constituents. If an SSI is confirmed for any constituent at any downgradient well, Assessment Monitoring must be conducted. In addition to continued monitoring of the seven constituents used in Detection Monitoring, Assessment Monitoring will then evaluate whether exceedances occur for 15 additional constituents relative to the groundwater protection standard (GWPS). If an exceedance is confirmed, Corrective Action

Monitoring will then be initiated to respond to and control a release. The developed statistical analysis plan will be implemented for each monitoring phase, following the requirements of the CCR Rule, and in accordance with the statistical procedures.

2. BACKGROUND MONITORING AND DATA PREPARATION

At least one upgradient or background monitoring well, and three downgradient monitoring wells (located at the edge of the CCR unit boundary) were sampled and analyzed for constituents, as listed in Appendix III (boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids) and Appendix IV (antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, radium 226 and 228 combined) of Part 257, during the first phase of the groundwater monitoring program.

The upgradient or background monitoring well(s) were placed upgradient of the CCR unit, or at an alternative background location, where they are not affected by potential leakage from the CCR unit. Downgradient monitoring wells were placed at the waste boundary of the CCR unit, along the same groundwater flow path. As the CCR Rule 257.91(a)(2) specifies, the location of these wells ensures that wells in the uppermost aquifer accurately represent the quality of groundwater, while downgradient wells monitor potential contaminant pathways.

To account for both seasonal and spatial variability in groundwater quality, eight independent sampling events were completed on a quarterly or greater frequency between November 2015 and August 2017. As outlined, groundwater sampling procedures included sampling of the upgradient, background, and downgradient wells using low-flow sampling methods, the collection of one field quality control sample per event, and groundwater samples that were not field-filtered before laboratory analysis of total recoverable metals.

Following completion of the eight baseline (quarterly) sampling events, background groundwater quality will be established for Appendix III and IV constituents. Groundwater monitoring will then be conducted at least semiannually for the life of the facility unless there is inadequate groundwater flow and a longer interval is required between sample events.

The following subsections outline the statistical tests and procedures (methods) that will be utilized to evaluate data collected for each constituent in both background and downgradient wells for Background, Detection, Assessment, and Corrective Action Monitoring. When necessary and contingent upon equivalent statistical power, an alternative test not included in this Statistical Analysis Plan may be chosen due to site-specific data requirements.

2.1 SAMPLE INDEPENDENCE

Independence of sample results is a major assumption for most statistical analyses. To ensure physical independence of groundwater sampling results, the minimum time between sampling events must be longer than the time required for groundwater to move through the monitoring well. Therefore, the minimum time interval between sampling events is a function of the groundwater velocity and well bore volume (diameter of the well and surrounding filter pack).

2.2 NON-DETECT DATA PROCESSING

The reporting limit (RL) will be used as the lower level for the reporting of non-detected groundwater quality data. For all statistical test procedures, if the frequency of non-detect data are less than or equal to 15%, half of the RL will be substituted for these data. If the non-detect frequency is greater than 15%, up to 50% non-detect, either the Kaplan-Meier or robust regression on order statistics (ROS) will be used to estimate the mean and standard deviation adjusted for the presence of left-censored values. However, the Kaplan-Meier method will not be utilized if the RL is identical for all non-detects, as no variance in the data would result in simply RL substitution for each non-detect result. In this case, half the RL will be substituted for the non-detects. If the detection frequency is greater than 50%, a non-parametric test will be used. If only one background result is detected, that value will be used as the non-parametric upper prediction limit (UPL).

2.3 TESTING FOR NORMALITY

Many statistical analyses assume that sample data are normally distributed (parametric). However, environmental data are frequently non-normally distributed (nonparametric). The CCR Rule requires the knowledge of the background data distribution for comparison to downgradient results. The Unified Guidance document recommends the Shapiro-Wilk normality test for sample sizes of 50 or less, and the Shapiro-Francia normality test for sample sizes greater than 50. When possible, transformation of datasets to achieve normal distributions is preferred. Control charts (with the exception of XmR-charts) produced under the assumption of normality are also a valuable tool when datasets are parametric. They are used for detection monitoring and typically used for intrawell testing, though they can be structured for interwell. There is no non-parametric version of control charts.

2.4 TESTING FOR OUTLIERS

Appendix III and IV constituents will be screened for the existence of outliers using a method described by the Unified Guidance. Outliers are extreme data points that may represent an anomaly or erroneous data point. To test for outliers, one or more of the following outlier tests will be utilized:

- Dixon’s test, for well-constituent pairs with less than 25 samples, assumes normally distributed data.
- Grubb’s test for well-constituent pairs with seven or more samples, assumes normally distributed data.
- Time series, box-whisker plots, and probability plots provide visual tools to identify potential outliers, and evaluation of seasonal, spatial, or temporal variability for both normally and non-normally distributed data.

When necessary, a confirmatory sample will be collected to allow the facility to distinguish between an outlier and a true release from the facility. If re-sampling is necessary, this sample will be collected within 60 days following outlier identification. If the confirmatory sample indicates the original result as an outlier, it will be reported as such, and not as a release from the CCR unit. Data quality control, groundwater geochemistry, and sampling procedures will be evaluated as potential sources of error leading to an outlier result. Professional judgement will be used to exclude extreme outliers from further statistical analyses.

2.5 TREND ANALYSIS

Statistical analyses confirming the lack of trend are a fundamental step to confirm the assumption that groundwater quality values (constituent means) are stationary or constant over time at a CCR unit. These analyses allow for evaluation of variation in the background and downgradient data for each constituent over time. A statistically significant increasing trend in background data could indicate an existing release from the CCR unit or alternate source, requiring further investigation. In addition, statistically significant trending background data can result in increased standard deviation and, therefore, greater prediction or control limits. Consequently, the increased prediction or control limit will have less power or ability to identify a release from a CCR unit.

A linear regression, coupled with a t-test for slope significance, may be used on datasets for each constituent with few non-detects and a normally distributed variance of the mean to evaluate time trends. The Theil-Sen trend line, coupled with the Mann-Kendall test for slope significance, will be used for datasets with frequent non-detects or non-normal variance. Similarly, trend analyses could also be used on downgradient data to evaluate a possible release from the CCR unit.

2.6 SPATIAL VARIATION

Assuming no significant spatial trends exist, sample results may be compared between background wells for each constituent to confirm a lack of spatial variation. Box-and-whisker plots or an analytical evaluation, such as

Levene's test (α = 0.01), will be used to assure equality of variances across background wells. If variances are equal, a one-way analysis of variance (ANOVA, α = 0.05) will be computed across background wells. The Kruskall-Wallis test may be used to determine spatial variability for those constituents where at least 50% of the background data are non-detects. Similar to spatial trends, the occurrence of statistically significant spatial variation between background wells could indicate an existing release from a CCR unit. If the spatial variability is not due to an existing release, intrawell comparisons in downgradient wells may be used to more appropriately determine the occurrence of a future release from a CCR unit. Analyses may differ by constituents and wells, depending on spatial variability. For example, if spatial variability exists between background wells for boron but not for calcium, then intrawell comparisons may be used for boron and interwell comparisons may be used for calcium. Intrawell comparisons may be used as an appropriate alternative for existing CCR units that have not been in operation or for new CCR units that are being designed to put into service.

2.7 UPDATING BACKGROUND

Updating the background dataset periodically by adding recent results to an existing background dataset can improve the statistical power and accuracy of the statistical analysis, especially for non-parametric prediction intervals. The Unified Guidance recommends updating statistical limits (background) when at least four to eight new measurements (every 2 to 4 years under a semi-annual monitoring program), are available for comparison to historical data. Professional judgement will be used to evaluate whether any background data appear to be affected by a release and need to be excluded from a background update. A t-test for equal means (if normal data distribution) or medians (if non-normal data distribution) such as a Mann-Whitney (or Wilcoxon) rank-sum or box-whisker plots, will be conducted to verify that the two groups of background sample populations are statistically different prior to updating any background datasets. A 0.05 significance level will be utilized when evaluating the two populations, with the assumption that they have equal means or medians. In addition, time series graphs or other trend evaluation statistics will be conducted on the new background dataset to verify the absence of a release, or changing groundwater quality. If the tests indicate that there are no statistical differences between the two background populations, the new data will be combined with the existing dataset. If the two populations are found to be different, the data will be reviewed to evaluate the cause of the difference. If the differences appear to be caused by a release (if the new data are significantly higher, or lower for pH), then the previous background dataset may continue to be used. Furthermore, verified outliers will not be added to an existing background dataset. In accordance with the Unified Guidance, continual background updates will not be conducted due to the lack of sufficient samples for a statistical comparison. Spatial variability among background wells will also be assessed when background datasets are updated to whether pooling data and interwell comparisons are appropriate.

For intrawell evaluations, once an SSI has been identified for a constituent at a particular well, no additional updates of the baseline (background) datasets (for any parameter) will be allowed, unless the SSI is determined to be caused by something other than a release from the CCR unit. The baseline (background) dataset can only be updated with new data if the SSI is proven to be from the result of an alternate source.

3. DETECTION MONITORING PROGRAM

The second phase of the groundwater monitoring program is Detection Monitoring. Detection Monitoring is designed to monitor groundwater for evidence of a release by comparing Appendix III constituents in downgradient wells to background data to evaluate the possible occurrence of SSIs. Following initial monitoring to evaluate background groundwater quality, Detection Monitoring will begin with the collection of eight independent samples from each background and downgradient well. These samples will be analyzed for Appendix III constituents. Thereafter, samples will be collected and evaluated semi-annually. The selected Detection Monitoring statistical method used to evaluate groundwater data for each constituent, in comparison to the background data, will provide for adequate statistical power, limit the site-wide false positive rate (SWFPR), and be appropriate for the distribution and detection frequency of the background dataset.

Statistical power is the ability of a statistical test to detect a true SSI. For normalized background data, the Unified Guidance recommends that a test have at least 55 to 60% power to detect an increase of three standard deviations over background, or 80% power to detect a four standard deviation increase. Power curves can be used to measure statistical power of the selected statistical method. For Detection Monitoring, the power curve displays the probability of an individual comparison detecting a concentration increase relative to background.

Multiple comparisons inevitably occur during Detection Monitoring due to the seven constituents evaluated at three or more downgradient monitoring wells. This can lead to complications, as each individual comparison increases the SWFPR, or the potential that a statistical test will incorrectly identify an SSI on a site-wide scale. Although decreasing the false positive rate is desirable, all other things being equal, this also decreases the statistical power, which is undesirable. Therefore, the Unified Guidance recommends a statistical program have a SWFPR of 10% or less per year (5% per semi-annual sample event) to limit the occurrence of false positives, while maintaining sufficient statistical power to detect a true release from a CCR unit.

Detection Monitoring statistical analyses will begin within 60 days of receiving laboratory analytical results, and completed within 90 days. Prediction intervals will be calculated using background data for each constituent, unless an alternative site-specific method is utilized to provide increased power or to reduce the SWFPR.

The Double Quantification Rule will be used when all background data are non-detects for a particular constituent. This rule determines an SSI if any constituent in a sample and a verification resample are in exceedance, or two consecutive sampling events are in exceedance. This method reduces SWFPR, and enhances statistical power as downgradient well-constituent pairs analyzed using this rule are not included in comparisons for SWFPR calculations.

3.1 SSI DETERMINATION

One-sided upper prediction limits (UPL) will be calculated for each Appendix III constituent using the pooled background samples collected during the initial monitoring samples events. Individual values for each constituent detected in the downgradient monitoring wells will then be compared to the background UPL. An exceedance of the UPL for any constituent measured at any downgradient well constitutes an SSI. An exception to this method is pH, where two-sided (upper and lower) prediction intervals are established from the distribution of the background groundwater quality data. An exceedance of either the UPL or lower prediction limit (LPL) would constitute an SSI for pH.

3.1.1 The Parametric Upper Prediction Limit for Future Values

Parametric UPLs for future values will be utilized when background data contains less than 50% non-detects, and can be normalized. Parametric UPL for individual future values will be calculated from normally-distributed background data as follows:

$$UPL_{1-\alpha} = \overline{x} + \kappa s$$

$\bar{x}$ = sample mean of background data

s = standard deviation of background data

κ = multiplier based on the number of downgradient compliance wells to be tested (*w*), the background sample size (*n*) the number (*c*) of constituents of concern (COCs), the "1-of-*m*" retesting scheme, and the evaluation schedule (annual, semi-annual, quarterly). Tabulated in Table 19-1 in Appendix D of the Unified Guidance.

The number of downgradient compliance wells to be tested (*w*) will vary by CCR unit, with a minimum of three wells. The background sample size (*n*) will equate to 8 multiplied by the number of upgradient or background wells at each CCR unit. The number of constituents of concern (*c*) will be seven, as stated in the Appendix III parameters list. The retesting scheme will be a 1-of-2, whereby an SSI is confirmed if the original sample and the retest or optional verification sample(s) exceed the UPL. Lastly, the evaluation schedule will be semi-annual. When exact κ multiplier values are not specified in Table 19-1 of the Unified Guidance, the desired input points (w^* and n^*) that lie between the closest table entries as $w_1 < w^* < w_2$ and $n_1 < n^* < n_2$, will first be calculated as fractional terms.

$$f_w = \frac{(w^* - w_1)}{(w_2 - w_1)} \quad and \quad f_n = \frac{(n^* - n_1)}{(n_2 - n_1)}$$

The interpolated κ multiplier will then be computed as:

$$\kappa_{w^*,n^*} = (1 - f_w)(1 - f_n) \cdot \kappa_{w_1,n_1} + f_w(1 - f_n) \cdot \kappa_{w_2,n_1} + (1 - f_w) \cdot f_n \cdot \kappa_{w_1,n_2} + f_w \cdot f_n \cdot \kappa_{w_2,n_2}$$

3.1.2 The Parametric Shewhart-CUSUM Control Chart

Combined Shewhart-CUSUM control charts may also be used when pooled background data contains less than 50% non-detects, and can be normalized. This method can be used to determine whether downgradient data plotted on the control chart follow the same distribution as the background data used to compute the baseline control limit. Combined control charts use both the new individual measurement, and the cumulative sum (CUSUM) of past and current measurements at every sampling event. This technique gives control charts increased sensitivity to detect trends and shifts in concentration levels. The Shewhart portion of the chart is ideal for detecting sudden concentration increases, and the CUSUM portion is preferred for detecting slower, steady increases. Shewhart-CUSUM control charts will be constructed by first computing the standardized concentration (Z_i) based on compliance point measurement (x_i) collected on sampling event (T_i):

$$Z_i = (x_i - \bar{x}_B)/s_B$$

$\bar{x}_B$ = sample mean calculated from *n* background measurements

s_B = sample standard deviation calculated from *n* background measurements

The standardized CUSUM (S_i) will then be computed for each sampling event (T_i) as:

$$S_i = \max[0, (Z_i - k) + S_{i-1}]$$

k = half displacement or shift in standard deviations to be detected on the control chart. Will be set to 1 to rapidly detect upward concentration shifts of at least 2 standard deviations.

To plot the control chart in concentration units, compute the non-standardized CUSUMS (S_i^c) as:

$$S_i^c = \bar{x}_B + S_i \cdot s_B$$

The non-standardized control limit (h_c) will be computed to assess compliance of both future measurements (x_i) and non-standardized CUSUMS (U_i) as follows:

$$h_c = \overline{x}_B + h \cdot s_B$$

Control charts will be constructed by plotting both the compliance measurements (x_i) and the non-standardized CUSUMs (S_i^c) on the y-axis, and sampling events (T_i) along the x-axis. From the first plotted sampling event T_1, the control chart will be out-of-control if the trace of the non-standardized concentration exceeds h_c.

3.1.3 The Non-Parametric Upper Prediction Limit for Future Values

Non-parametric UPLs for future values will be utilized when background data cannot be normalized, or contains a large percentage of non-detects. To calculate the non-parametric UPL on a future value, the target per-constituent false positive rate (α_{const}) will be determined as follows:

$$\alpha_{const} = 1 - (1 - \alpha)^{1/c}$$

α = the SWFPR of 0.10

c = the number of monitoring constituents

For a target SWFPR of 10%, and seven monitoring constituents, the target per-constituent false positive rate (α_{const}) will be 0.015%.

The number of yearly statistical evaluation (n_E) will be multiplied by the number of compliance wells (w) to calculate the look-up table entry, w^*. The background sample size (n) and w^* will be used to select an achievable per-constituent false positive rate value in Table 19-19 of Appendix D in the Unified Guidance that is no greater than the target per-constituent false positive rate (0.015%). The chosen achievable per-constituent false positive rate value will determine the type of non-parametric prediction limit (maximum or 2nd highest value in background) and a retesting scheme for individual observations. The background data will be sorted in ascending order, and the upper prediction limit will be set to the appropriate order statistic previously determined by the achievable per-constituent false positive rate value in Table 19-19. If all constituent measurements in a background sample are non-detect, the Double Quantification rule will be used.

Each initial measurement per compliance well will be compared to the UPL. One to three additional samples will be collected, depending on the retesting scheme chosen, for any constituent that exceeds the UPL. Again, SSI is confirmed if the original sample and the retest or verification sample(s) exceed the UPL.

When a mixture of test methods is needed (e.g., parametric prediction limits for some constituents, and non-parametric limits for other constituents), an annual SWFPR of 10% (equivalent to a semiannual SWFPR of 5%) will be maintained using a target SWFPR that is evenly proportioned across the list of constituents.

3.1.4 The Trend Comparison Test

If a significant trend is detected in pooled background data for a given constituent, a trend comparison test will be performed to determine whether the downgradient trend (if present) significantly differs from the trending pooled background data. A linear regression, coupled with a t-test for slope significance will be used to determine slope significance on datasets for each constituent with few non-detects and a normally distributed variance of the mean to evaluate time trends. The Theil-Sen trend line, coupled with the Mann-Kendall test will be used to determine slope significance for datasets with frequent non-detects or non-normal variance. An SSI will be confirmed if the slope is significantly greater in downgradient data.

In the event that statistical analyses identify a SSI for one or more parameters, the constituent-well pairs of concern may be re-sampled within the required timeframe (90 days from receipt of laboratory data). Detection Monitoring statistics will be updated using the downgradient verification resample results within 90 days of receiving laboratory analytical reports. If verification sample(s) confirm a SSI, results will be reported to the state director (and/or appropriate tribal authority, if applicable) and Assessment Monitoring will be initiated in the next scheduled semi-annual event. If applicable, an alternative source demonstration (ASD) indicating that the confirmed SSI was due to natural variability or an alternative release source other than the CCR unit facility will be completed within 90 days of the SSI confirmation. The ASD report must be certified by a qualified professional engineer and included with the annual groundwater monitoring report required by CCR Rule Part 257.90(e). If the ASD for a parameter is successful and there are no other SSIs, Detection Monitoring will continue; otherwise Assessment Monitoring will be initiated, as required by the CCR Rule Part 257.95. If the verification sample(s) do not confirm a SSI however, Detection Monitoring will continue. If an SSI is not identified for any Appendix III constituents in downgradient wells, Detection Monitoring will continue until the post-closure monitoring period. Table 1 below lists the statistical methods for Detection Monitoring.

Table 1. Statistical Methods for Detection Monitoring

<table>
<tr><th colspan="5">Detection Monitoring</th></tr>
<tr><th rowspan="2">Significant Trend?</th><th colspan="3">Background</th><th>Downgradient</th></tr>
<tr><th>% Non-Detects</th><th>Distribution</th><th>Test to Determine SSI</th><th>Comparison</th></tr>
<tr><td rowspan="4">No</td><td>≤50%</td><td rowspan="2">Normal</td><td rowspan="2">UPL for Future Values OR The Shewhart-CUSUM Control Chart</td><td rowspan="4">Individual Future Values</td></tr>
<tr><td rowspan="2">>50%</td></tr>
<tr><td>Non-Normal</td><td>The Non-Parametric Upper Prediction Limit for Future Values</td></tr>
<tr><td>100%</td><td>Non-Normal</td><td>Double Quantification Rule</td></tr>
<tr><td rowspan="2">Yes</td><td>≤50%</td><td>Normal</td><td>Linear Regression w/ t-test</td><td>Trend Comparison Test using Linear Regression w/ t-test</td></tr>
<tr><td>>50%</td><td>Non-Normal</td><td>Thiel-Sen trend line w/ Mann-Kendall</td><td>Trend Comparison Test using Thiel-Sen trend line w/ Mann-Kendall</td></tr>
</table>

4. ASSESSMENT MONITORING PROGRAM

The third phase of the groundwater monitoring program is Assessment Monitoring. Assessment Monitoring is performed after the confirmation of an SSI to evaluate whether downgradient concentrations are at statistically significant levels (SSL) relative to a GWPS. Groundwater sampling for all Appendix IV constituents will be conducted in the existing monitoring well network within 90 days of an SSI identification. Appendix III constituents, and those Appendix IV that were detected in groundwater will be sampled within 90 days of receiving laboratory results, and semi-annually thereafter. In addition, all Appendix IV constituents will be sampled on an annual basis. This annual sampling will likely coincide with the required semiannual sampling of Appendix III and detected Appendix IV constituents. Additional monitoring wells will be installed if an SSL is identified for any Appendix IV constituent at any downgradient well to evaluate the nature and extent of the plume. All Appendix III and Appendix IV constituents must be at or below background levels for two consecutive semi-annual sampling events for a CCR facility to return from Assessment to Detection Monitoring. If some Appendix III or Appendix IV constituents are at concentrations above background levels, but not statistically exceeding the GWPS, then the CCR facility must remain in Assessment Monitoring.

4.1 GWPS ESTABLISHMENT AND SSL DETERMINATION

A GWPS will be established for Appendix IV constituents detected in the downgradient monitoring wells. The GWPS will be the risk-based maximum contaminant level (MCL) established by the USEPA for each constituent. The first exception to this is when the background concentration is greater than the established MCL. The second exception occurs when the constituent does not have an MCL, such as for cobalt, lithium, molybdenum, and lead. For both of these exceptions, the background concentrations will be used to define the GWPS. The GWPS will be calculated using a parametric Upper Tolerance Limit (UTL), a parametric UPL for a future mean, or a non-parametric UPL for a future median.

4.1.1 The Upper Tolerance Limit

The UTL will be used to calculate the GWPS when pooled background data are normally distributed, with a non-detect frequency of 15% or less. When non-detect frequency is 15% or less, half the RL will be substituted for non-detects. The Unified Guidance recommends 95% confidence level and 95% coverage (95/95 tolerance interval). The non-detect data will be replaced with half the RL (simple substitution), and the normal mean and standard deviation will be calculated.

The Kaplan-Meier, or the ROS method, will be used when the detection frequency is between 15% and 50%. The Kaplan-Meier method assesses the linearity of a censored probability plot to determine whether the background sample can be approximately normalized. If so, then the Kaplan-Meier method will be used to compute estimates of the mean and standard deviation adjusted for the presence of left-censored values. The Kaplan-Meier or ROS estimate of the mean and standard deviation will be substituted for the sample mean and standard deviation. If background normality cannot be achieved, non-parametric UTLs will not be calculated until a minimum of 60 background samples have been collected (to achieve 95% coverage).

The Kaplan-Meier method will not be utilized if the RL are identical for all non-detects as there is no standard deviation (variance), resulting in simply substitution of the RL for each non-detect result. In this case, half the RL should be substituted for the non-detects.

The parametric UTL on a future mean will be calculated from the background dataset as follows:

$$UTL = \overline{x} + \kappa\,(n, \gamma, \alpha - 1) \cdot s$$

$\overline{x}$ = background sample mean

s = background sample standard deviation

$\kappa\ (n, \gamma, \alpha - 1)$ =one-sided normal tolerance factor based on the chosen coverage (γ) and confidence level (α -1) and the size of the background dataset (n). Values are tabulated in Table 17-3 in Appendix D of the Unified Guidance. If exact values are not provided, then κ values can be estimated by linear interpolation similar to the method described in Section 3.

If the UTL is constructed on the logarithms of original observations to achieve normality, where $\overline{y}$ and s_y are the log-mean and log-standard deviation, the limit will be exponentiated for back-transformation to the concentration scale as follows:

$$TL = \exp\left[\overline{y} + \kappa\ (n, \gamma, \alpha - 1) \cdot s_y\right]$$

$\overline{y}$ = background sample log-mean

s_y = background sample log-standard deviation

When the GWPS is based on the MCL or a UTL derived from the background dataset, the confirmation of a SSL in downgradient compliance wells relative to the GWPS will be evaluated using confidence intervals. A confidence interval defines the upper and lower bound of the true mean of a constituent concentration in groundwater within a specified confidence range. Non-detects in downgradient data will be handled similarly to upgradient analyses, with half the RL substituted for non-detects when the frequency is 15% or less. The Kaplan-Meier, or the ROS method, will be used when the detection frequency is between 15% and 50% to compute estimates of the mean and standard deviation adjusted for the presence of left-censored values. These estimates will then be substituted for the sample mean and standard deviation. Once the GWPS is established for pooled background data using the UTL, either parametric or non-parametric confidence intervals will be computed for each constituent in downgradient wells to determine the occurrence of an SSL.

4.1.2 Parametric Confidence Intervals around a Mean

If downgradient data are approximately normal, one-sided parametric confidence intervals around a sample mean will be constructed for each constituent and well pair. The lower confidence limit (LCL) will be calculated as:

$$LCL_{1-\alpha} = \overline{x} - t_{1-\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

The upper confidence limit (UCL) will be calculated as:

$$UCL_{1-\alpha} = \overline{x} + t_{1-\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

$\overline{x}$ = downgradient sample mean

s = downgradient sample standard deviation

n = downgradient sample size

$t_{1-\alpha,n-1}$ = obtained from a Student's t-table with (n–1) degrees of freedom (Table 16-1 in Appendix D of the Unified Guidance)

The chosen *t* value will aim to achieve both a low false-positive rate, and high statistical power. Minimum α values are tabulated in Table 22-2 of Appendix D of the Unified Guidance. The selected minimum α value, from which the *t* value will be derived, will have at least 80% power (1-β = 0.8) when the underlying mean concentration is twice the MCL.

If downgradient data are distributionally lognormal, the LCL will be computed around the lognormal geometric mean as:

$$LCL_{1-\alpha} = \exp\left(\overline{y} + .5s_y^2 + \frac{s_y H_\alpha}{\sqrt{n-1}}\right)$$

The UCL will be computed around the lognormal geometric mean as:

$$UCL_{1-\alpha} = \exp\left(\overline{y} + .5s_y^2 + \frac{s_y H_{1-\alpha}}{\sqrt{n-1}}\right)$$

$\overline{y}$ = downgradient sample log-mean

s_y = downgradient sample log-standard deviation

H_α / $H_{1-\alpha}$ = bias-correction factor(s) found in Tables 21-1 through 21-8 in Appendix D of the Unified Guidance

4.1.3 Non-Parametric Confidence Intervals around a Median

Non-parametric confidence intervals around the median will be computed if the downgradient data contain greater than 50% non-detects or are non-normally distributed. The mathematical algorithm used to construct non-parametric confidence intervals is based on the probability *P* that any randomly-selected measurement in a sample of *n* concentration measurements will be less than an unknown *P* x 100th percentile of interest (where *P* is between 0 and 1). Then the probability that the measurement will exceed the *P* x 100th percentile is (1–*P*). The number of sample values falling below the *P* x 100th percentile out of a set of *n* should follow a binomial distribution with parameters *n* and success probability *P*, where 'success' is defined as the event that a sample measurement is below the *P* x 100th percentile. The probability that the interval formed by a given pair of order statistics will contain the percentile of interest will then be determined by a cumulative binomial distribution *Bin(x;n,p)*, representing the probability of *x* or fewer successes occurring in *n* trials with success probability *p*. *P* will be set to 0.50 for an interval around the median.

The sample size *n* will be ordered from least to greatest. Given *P* = 0.50, candidate interval endpoints will be chosen by ordered data values with ranks as close to product of (*n*+1) x 0.50. If the result of (*n*+1) x 0.50 is a fraction (for even-numbered sample sizes), the rank values immediately above and below will be selected as possible candidate endpoints. If the result of (*n*+1) x 0.50 is an integer (for odd-numbered sample sizes), one will be added and subtracted one to get the upper and lower candidate endpoints. The ranks of the endpoints will be denoted *L** and *U**. For a one-sided LCL, the confidence level associated with endpoint *L** will be computed as:

$$1-\alpha = Bin(L^* - 1; n, .50) = \sum_{x=L^*}^{n} \binom{n}{x} \left(\frac{1}{2}\right)^n$$

For a one-sided UCL, the confidence level associated with the endpoint *U** will be computed as:

$$1-\alpha = Bin(U^* - 1; n, .50) = \sum_{x=0}^{U^*-1} \binom{n}{x} \left(\frac{1}{2}\right)^n$$

If the candidate endpoint(s) do not achieve the desired confidence level, new candidate endpoints (*L**–1) and (*U**+1) and achieved confidence levels will be calculated. If one candidate endpoint equals the data minimum or maximum, only the rank of the other endpoint will be changed. Achievable confidence levels are tabulated using these equations in Table 21-11 in Appendix D of the Unified Guidance.

Both parametric and non-parametric confidence limits will then be compared to the GWPS (MCL or UTL if MCL is not available or background concentrations are above the MCL). The CCR site is considered to be in compliance if the LCL is equal to or lower than the GWPS for all detected Appendix IV constituents at all downgradient wells. An SSL is confirmed if the LCL exceeds the GWPS.

4.1.4 The Upper Prediction Limit for a Future Mean

The parametric UPL for a future mean will be used to calculate the GWPS if the pooled background data contain 50-70% non-detects and normality can be achieved. The Kaplan-Meier or ROS methods to estimate the mean and standard deviation. The non-parametric UPL for a future median will be calculated as the GWPS if background samples cannot be normalized, or contain greater than 70% non-detects. The background, requirements, and assumptions for a prediction limit on future means of order *p* are essentially identical to those for prediction limits for future individual values used in Detection Monitoring. An order of 2*p* independent samples will be collected during each evaluation period to use a 1-of-2 retesting scheme. The parametric UPL for a future mean will be calculated from the background dataset at follows:

$$UPL_{1-\alpha} = \overline{x} + \kappa s$$

$\overline{x}$ = background sample mean

s = background standard deviation

κ = multiplier based on the order (*p*) of the future mean to be predicted, the number of downgradient compliance wells to be tested (*w*), the background sample size (*n*) the number (*c*) of constituents of concern (COCs), the "1-of-*m*" retesting scheme, and the evaluation schedule (annual, semi-annual, quarterly). Tabulated in 19-5 to 19-9 in Appendix D of the Unified Guidance.

The mean of order *p* will be computed for each well and compared against the UPL. For any compliance point mean that exceeds the limit, *p* additional resamples will be collected at that well for a 1-of-2 retesting scheme. Resample means will then be compared to the UPL. A SSL has been deemed to occur at a compliance well when the initial mean and *all* resample means exceed the UPL.

4.1.5 The Non-Parametric Upper Prediction Limit for a Future Median

The non-parametric UPL for a future median will be used to calculate the GWPS if the pooled background data contain greater than 70% non-detects and normality cannot be achieved. This approach is very similar to the method used non-parametric UPL for future values. The number of yearly statistical evaluation (n_E) will be multiplied by the number of compliance wells (*w*) to determine the look-up table entry, *w**. The background sample size (*n*) and *w** will be used to select an achievable per-constituent false positive rate value in Table 19-24 of Appendix D in the Unified Guidance that is no greater than the Appendix IV target per-constituent false positive rate (0.007 for 15 constituents). The chosen achievable per-constituent false positive rate value will determine the type of non-parametric prediction limit (maximum or 2nd highest value in background) and a retesting scheme for a future median. The background data will be sorted in ascending order, and the upper prediction limit will be set to the appropriate order statistic previously determined by the achievable per-constituent false positive rate value in Table 19-24. If all constituent measurements in a background sample are non-detect, the Double Quantification rule will be used (the RL becomes the GWPS if no MCL exists). The constituent will also be removed from calculations identifying the target false positive rate.

Two initial measurements per compliance well will be collected. If both do not exceed the upper prediction limit, a third initial measurement will not be collected since the median of order 3 will also not exceed the limit. If both exceed the prediction limit, a third initial measurement will not be collected since the median will also exceed the limit. If one initial measurement is above and one below the limit, a third initial observation may be collected to determine the position of the median relative to the UPL. Up to three resamples will be collected in order to assess the resample median. In all cases, if two or more of the compliance point observations are non-detect, the median will be set equal to the RL. The median value for each compliance well will be compared to the UPL. For the 1-of-2 retesting scheme, if any compliance point median exceeds the limit, up to three additional resamples will be collected from that well. The resample median will be computed and compared to the UPL. A SSL has been deemed to occur at a compliance well when either the initial median, or both the initial median and resample median exceed the UPL.

If all Appendix III and IV constituents are below the GWPS for two consecutive sampling events, the facility will return to Detection Monitoring. If the concentrations of detected constituents in Appendices III and IV are above background, but below the established GWPS, Assessment Monitoring will continue.

4.1.6 Parametric Linear Regression and Confidence Band

If the t-test detects a significant trend in the parametric linear regression line using either background or downgradient data for a particular constituent, confidence bands accounting for trends will be constructed to account for the trend-induced variation. If this is not accounted for, a wider confidence interval will inevitably be calculated for a given confidence level and sample size (n). A wider confidence interval will result in less statistical power, or ability to demonstrate an exceedance or return to compliance. When a linear trend line has been estimated, a series of confidence intervals is estimated at each point along the trend. This creates a simultaneous confidence band that follows the trend line. As the underlying population mean increases or decreases, the confidence band does also to reflect this change at that point in time.

Linear regression will be used when background or downgradient data are approximately normally distributed, with a constant sample variance around the mean, and the frequency of non-detects is low. The linear regression of concentration against sampling date (time) will be computed as follows:

$$\hat{b} = \sum_{i=1}^{n} (t_i - \bar{t}) \cdot x_i/(n-1) \cdot s_t^2$$

x_i = i^{th} concentration value and

t_i = i^{th} sampling date

$\bar{t}$ = sampling mean date

s_t^2 = variance of the sampling dates

This estimate leads to the following regression equation:

$$\hat{x} = \bar{x} + \hat{b} \cdot (\mathrm{t} - \bar{t})$$

$\bar{x}$ = mean concentration level

$\hat{x}$ = estimated mean concentration at time t

The regression residuals will also be computed at each sampling event to ensure uniformity and lack of significant skewness. Regression residuals will be computed at each sampling event as follows:

$$r_i = x_i - \hat{x}_i$$

The estimated variance around the regression line, or mean squared error (MSE) will be computed as follows:

$$s_e^2 = \frac{1}{n-2} \sum_{i=1}^{n} r_i^2$$

The confidence intervals around a linear regression trend line given confidence level (1-α) and a point in time (t_0), will be computed as follows:

$$LCL_{1-\alpha} = \hat{x}_0 - \sqrt{2s_e^2 \cdot F_{1-2\alpha,2,\mathrm{n}-1} \cdot \left[\frac{1}{n} + \frac{\left(t_0 - \bar{t}\right)^2}{(n-1) \cdot s_t^2}\right]}$$

$$UCL_{1-\alpha} = \hat{x}_0 - \sqrt{2s_e^2 \cdot F_{1-2\alpha,2,\mathrm{n}-2} \cdot \left[\frac{1}{n} + \frac{\left(t_0 - \bar{t}\right)^2}{(n-1) \cdot s_t^2}\right]}$$

$\hat{x}_0$ = estimated mean concentration from the regression equation at time t_0

$F_{1-2\alpha,2,n-2}$ = upper $(1\text{-}2\alpha)^{\text{th}}$ percentage point from an F-distribution with 2 and (n-2) degrees of freedom

For background data, the UCL around the linear regression line will be used as the GWPS for the trending constituent. For downgradient data, confidence bands around the linear regression line will be compared to the GWPS. The CCR site is considered to be in compliance if the LCL is equal to or lower than the GWPS for all detected Appendix IV constituents at all downgradient wells. An SSL is confirmed when the LCL based on the trend line first exceeds the GWPS.

4.1.7 Non-Parametric Thiel-Sen Trend Line and Confidence Band

If the Mann-Kendall test detects a significant trend in the non-parametric Thiel-Sen line using either background or downgradient data for a particular constituent, confidence bands accounting for trends will be constructed to account for the trend-induced variation. The Thiel-Sen trend line will be used as a non-parametric alternative to linear regression when trend residuals cannot be normalized or if there are a higher percentage of non-detects in either background or downgradient data. The Thiel-Sen trend line estimates the median concentration over time by combining the median pairwise slope with the median concentration value and the median sample date. To compute the Thiel-Sen line, the data will first be ordered by sampling event x_1, x_2, x_n. All possible distinct pairs of measurements (x_i, x_j) for $j > i$ will be considered and the simple pairwise slope estimate will be computed for each pair as follows:

$$m_{ij} = (x_j - x_i)/(j - i)$$

With a sample size of n, there will be a total of $N = n(n\text{-}1)/2$ pairwise estimates m_{ij}. If a given observation is a non-detect, half the RL will be substituted. The N pairwise slope estimates (m_{ij}) will be ordered from least to greatest (renamed $m_{(1)}$, $m_{(2)}$,..$m_{(N)}$). The Thiel-Sen estimate of slope (Q) will be calculated as the median value of the list depending on whether N is even or odd as follows:

$$Q = \begin{cases} m_{([N+1]/2)} \ if\ N\ is\ odd \\ (m_{(N/2)} + m_{([N+2]/2)})/2\ if\ N\ is\ even \end{cases}$$

The sample concentration magnitude will be ordered from least to greatest, $x_{(1)}$, $x_{(2)}$, to $x_{(n)}$ and the median concentration will be calculated as follows:

$$\tilde{x} = \begin{cases} x_{([n+1]/2)} \ if\ n\ is\ odd \\ (x_{(n/2)} + x_{([n+2]/2)})/2\ if\ n\ is\ even \end{cases}$$

The median sampling date ($\tilde{t}$) with ordered times ($t_{(1)}$, $t_{(2)}$, to $t_{(n)}$) will also be determined in this way. The Thiel-Sen trend line will then be computed for an estimate at any time (t) of the expected median concentration (x) as follows:

$$x = \tilde{x} + Q \cdot (\mathrm{t} - \tilde{t}) = (\tilde{x} - Q \cdot \tilde{t}) + Q \cdot \mathrm{t}$$

To construct a confidence band around the Thiel-Sen line, sample pairs (t_i, x_i) will be formed with a sample date (t_i) and the concentration measurement from that date (x_i). Bootstrap samples (B) will be formed by repeatedly sampling n pairs at random with replacement from the original sample pairs. This will be repeated 500 times. For each bootstrap sample, a Thiel-Sen trend line will be constructed using the equation above. A series of equally spaced time points (t_j) will be identified along the range of sampling dates represented in the original sample, j =1 to m. The Thiel-Sen trend line associated with each bootstrap replicate will be used to compute an estimated concentration ($\hat{x}_j^B$). An LCL will be constructed for the lower αth percentile $\hat{x}_j^{[\alpha]}$from the distribution of estimated concentrations at each time point (t_j). For an UCL, compute the upper (1-α)th percentile, $\hat{x}_j^{[1-\alpha]}$ at each time point (t_j).

For background data, the UCL around the Thiel-Sen trend line will be used as the GWPS for the trending constituent. For downgradient data, confidence bands around the Thiel-Sen trend line will be compared to the GWPS. The CCR site is considered to be in compliance if the LCL is equal to or lower than the GWPS for all detected Appendix IV constituents at all downgradient wells. An SSL is confirmed when the LCL based on the trend line first exceeds the GWPS.

4.3 ALTERNATIVE SOURCE DEMONSTRATION

If an SSL is confirmed, an ASD may be conducted to indicate a source other than the CCR unit as the cause of contamination. The ASD may also identify the SSL to be a result of error in sampling procedures, laboratory procedures, statistical analyses, or natural variation in groundwater quality. Any such demonstration must be supported by a report that includes the factual or evidentiary basis for any conclusions and must be certified by a qualified professional engineer. The demonstration must be included in the annual groundwater monitoring report and corrective action report.

4.4 REQUIRED RESPONSE ACTION

In the event of a confirmed SSL, the following actions will be taken:

- A notification of the GWPS exceedance will be placed in the operating record within 30 days of the SSL, and on the public internet site within 30 days of placement in the operating record.
- Additional monitoring wells will be installed to characterize the nature and extent of the release, including a minimum of one at the property boundary.
- Property owners will be notified within 30 days if a plume has extended off-site, as identified by the characterization of the nature and extent of the release.
- An ASD will be submitted within 90 days of the SSL determination. If an ASD is not submitted, assessment of corrective action measures will be initiated within 90 days of the SSL determination, including the required notification and closure or retrofitting, if the facility is an unlined impoundment.

Table 2 below lists the statistical methods for Assessment Monitoring.

Table 2. Statistical Methods for Assessment Monitoring

Assessment Monitoring						
Significant Trend?	Background			Downgradient		
	% Non-Detects	Distribution	GWPS Determination	% Non-Detects	Distribution	Test to Determine SSL
No	0 ≤ 50%	Normal	MCL or The Upper Tolerance Limit	≤75%	Normal	Parametric Lower Confidence Interval around a Normal Mean
				≤75%	Log-Normal	Parametric Lower Confidence Interval around a Lognormal Geometric Mean
				NA	Non-Normal	Non-Parametric Lower Confidence Interval around a Median
				>75%	Unknown/Cannot be determined	
	50 ≤ 70%	Normal	The Upper Prediction Limit for a Future Mean	NA	NA	Future mean
	>70%	Non-Normal	Upper Prediction Limit for a Future Median	NA	NA	Future median
	100%	Non-Normal	Double Quantification Rule	NA	NA	Individual Retesting Values
Yes	0 ≤ 50%	Normal	UCL of Confidence Band around Linear Regression	≤75%	Residuals after subtracting trend are normal, equal variance	Lower Confidence Band around Linear Regression
	50 ≤ 100%	Non-Normal	UCL of Confidence Band around Thiel-Sen trend line	≤75%	Residuals not normal	Lower Confidence Band around Thiel-Sen

5. CORRECTIVE ACTION MONITORING PROGRAM

The fourth phase of the groundwater monitoring program is Corrective Action. Corrective Action Monitoring is performed after a corrective action remedy has been selected and implemented. The CCR Rule specifies that the corrective action program must meet all the requirements of an Assessment Monitoring program, address any interim measures that might be needed to reduce the contaminants leaching from the CCR unit, and document the effectiveness of the selected remedy. While both Appendix III and Appendix IV constituents are analyzed in Corrective Action Monitoring, compliance with the GWPS will be based only on Appendix IV constituents detected in the Corrective Action Monitoring wells. During this monitoring phase, Detection Monitoring and Assessment Monitoring will continue. Data evaluation for Corrective Action Monitoring however, will be conducted separately. Assessment of corrective measure(s) will be initiated within 90 days of a confirmed Appendix IV SSL to prevent further releases, as well as begin remediation to restore the affected area to original conditions. Corrective Action does not use the same monitoring system as Detection and Assessment Monitoring. The Corrective Action Monitoring system will include all or a subset of the monitoring wells installed to evaluate the nature and extent of the plume after a SSL is documented.

Statistical methods used for Corrective Action Monitoring data will be similar to those used for Assessment Monitoring. One major exception to these analyses is the use of the UCL (when the GWPS is based on the MCL or UTL) to evaluate whether a well is in compliance, rather than the LCL as used in Assessment Monitoring. A facility is considered to be in compliance when the UCL is lower than the GWPS for all detected Appendix IV constituents at all Corrective Action Monitoring wells for 3 consecutive years. Corrective Action Monitoring will continue if the UCL for any Appendix IV constituent at any Corrective Action Monitoring well is equal to or higher than the GWPS.

When the GWPS is based on a UPL for a future mean or median, the facility will be considered to be in compliance when all Corrective Action Monitoring well means or medians (depending on the use of parametric or non-parametric UPLs) are lower than the GWPS for all detected Appendix IV constituents for 3 consecutive years. Corrective Action Monitoring will continue if the mean or median for any Appendix IV constituent at any Corrective Action Monitoring well is higher than the GWPS.

Table 3 below lists the statistical methods for Corrective Action Monitoring.

Table 3. Statistical Methods for Corrective Action Monitoring

Corrective Action Monitoring						
Significant Trend?	Background			Downgradient		
	% Non-Detects	Distribution	GWPS Determination	% Non-Detects	Distribution	Test to Determine SSL
No	0 ≤ 50%	Normal	MCL or The Upper Tolerance Limit	≤75%	Normal	Parametric Upper Confidence Interval around a Normal Mean
				≤75%	Log-Normal	Parametric Upper Confidence Interval around a Lognormal Geometric Mean
				NA	Non-Normal	Non-Parametric Upper Confidence Interval around a Median
				>75%	Unknown/Cannot be determined	
	50 ≤ 70%	Normal	The Upper Prediction Limit for a Future Mean	NA	NA	Future mean
	>70%	Non-Normal	Upper Prediction Limit for a Future Median	NA	NA	Future median
	100%	Non-Normal	Double Quantification Rule	NA	NA	Individual Retesting Values
Yes	0 ≤ 50%	Normal	UCL of Confidence Band around Linear Regression	≤75%	Residuals after subtracting trend are normal, equal variance	Upper Confidence Band around Linear Regression
	50 ≤ 100%	Non-Normal	UCL of Confidence Band around Thiel-Sen trend line	≤75%	Residuals not normal	Upper Confidence Band around Thiel-Sen

6. SUMMARY AND REPORTING REQUIREMENTS

6.1 PRIOR TO DETECTION MONITORING

The following records will be completed and placed in the operating record no later than October 17th, 2017 or prior to first receipt of CCR for new facilities:

- Monitoring well records including all documentation on design, installation, development, decommissioning, piezometers, measurement, sampling, and analytical devices.
- Monitoring system certifications
- Statistical method certifications

6.2 ALL MONITORING PHASES

The "Annual Groundwater Monitoring and Corrective Action Report" (Annual Report) will be placed in the operating record by January 31, 2018 for existing facilities, or January 31 of the year following first receipt of CCR for new facilities, and annually thereafter. For the preceding calendar year, the Annual Report will include:

- The status of the groundwater monitoring program phase for the CCR unit
- Key activities planned for the upcoming year
- A map, aerial image, or diagram indicating the CCR unit and monitoring well network
- Identification and explanation of monitoring wells installed or abandoned during the preceding year
- Summary of wells and dates for groundwater sampling for detection, assessment, or corrective action monitoring, depending on the current phase of the groundwater monitoring program
- Analytical results (Appendix III for Detection Monitoring and both Appendix III and Appendix IV for Assessment and Corrective Action Monitoring)
- Reasoning for transitions between phases of the groundwater monitoring program (detection vs. assessment vs corrective action monitoring)
- A demonstration for alternative groundwater sampling frequency, if needed

6.3 DETECTION MONITORING

Detection Monitoring includes the collection of eight initial samples from both background/upgradient and downgradient monitoring wells. When the collection period for these initial samples is complete, an SSI determination for Appendix III constituents will be conducted with subsequent semi-annual monitoring and statistical analyses. If there is an SSI that cannot be attributed to an ASD, the facility will initiate Assessment Monitoring. In addition to those items listed in section 6.2, the Annual Report will include:

- Explanation and certification of an SSI attributed to an ASD by a qualified professional engineer, when appropriate

Notifications of establishing an Assessment Monitoring program or of a return to Detection Monitoring will also be placed in the operating record within 30 days of the event.

6.4 ASSESSMENT MONITORING

Assessment Monitoring will include both Appendix III and Appendix IV constituents, on the same monitoring wells as Detection Monitoring. Under Assessment Monitoring, a facility is assumed to be in compliance until an SSL is confirmed. If an SSL of an Appendix IV constituent is confirmed, a notification and an assessment of the nature and extent of the release will be placed in the operating record regardless of whether an ASD is identified. If an ASD is identified, no further action is required and the facility will remain in Assessment Monitoring. If the release cannot be attributed to an ASD, Corrective Action will be triggered. Additional monitoring wells will then be installed to monitor the performance of the Corrective Action Remedy. In addition to items listed in sections 6.2 and 6.3, the Annual Report will include:

- Background concentrations for Appendix III and Appendix IV constituents
- Analytical results for Appendix III and detected Appendix IV constituents
- GWPS established for detected Appendix IV constituents
- Explanation and certification of *new* SSI concentrations attributed to an ASD by a qualified professional engineer, when appropriate
- Explanation and certification of an SSL attributed to an ASD by a qualified professional engineer, when appropriate
- Demonstration and certification by a qualified professional engineer that more than 90 days are needed to complete an evaluation of corrective measures to prevent future releases

Semi-annual analytical results for Appendix III and detected Appendix IV constituents will be placed in the facility's operating record within 90 days of receipt. Notifications of an SSL and initiation of assessment of Corrective Actions will also be placed in the operating record within 30 days of determination of an SSL above the GWPS.

6.5 CORRECTIVE ACTION MONITORING

Detection monitoring and Assessment Monitoring continue during the Corrective Action Monitoring period. Similar to Assessment Monitoring, Appendix III constituents are monitored and Appendix IV constituents are used as the basis for compliance. Corrective Action Monitoring will use a different set of monitoring wells, likely located downgradient of the Detection and Assessment Monitoring well system. Under Corrective Action Monitoring, a release is assumed to have had occurred at a facility. Therefore, the null hypothesis is reversed and a facility is considered to be out of compliance until all constituents at Corrective Action Monitoring wells are statistically lower than the GWPS for 3 consecutive years. In addition to the items listed in sections 6.2, 6,3, and 6.4, the following additional items will be included in the Annual Report:

- A list of GWPS for both Assessment and Corrective Action Monitoring
- Explanation and certification of *new* SSL concentrations attributed to an ASD by a qualified professional engineer, when appropriate

Notifications of *new* SSLs and the completion of the Corrective Action remedy, as certified by a qualified professional engineer, will also be placed in the operating record within 30 days of determination of the *new* SSLs or completing the remedy.

7. REFERENCES

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

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