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Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

Groundwater Monitoring Statistical Methods, Revision 1
Update from 2017 Certification
North Rail Loop (NRL) Landfill
TVA Gallatin Fossil Plant
Gallatin, Tennessee

1. Introduction

This letter documents AECOM's updated certification of the statistical methods for use in the Tennessee Valley Authority (TVA) Coal Combustion Residuals (CCR) Rule Groundwater Quality Monitoring Program at the Gallatin Fossil Plant North Rail Loop (NRL) Landfill. The NRL Landfill groundwater monitoring system was designed as a multi-unit monitoring system covering all three of the constructed/proposed landfill cells (existing Cells 1 and 2, and proposed Cell 3). The statistical methods described below are appropriate for evaluating the groundwater monitoring data for the NRL Landfill, as required by the CCR Rule at 40 CFR § 257.93, 257.94, and 257.95. This is an update from the previous certification dated November 2017.

Revision Log

Revision	Date	Details
0	11/14/2017	Initial certification in accordance with 40 CFR 257.93(f)(6)
1	12/15/2022	Update to reflect the transition to Assessment monitoring and for consistency with the statistical methods used at other TVA fossil plants

2. Description of Statistical Methods

The statistical methods presented here are subject to change based on data that may be collected in the future and/or for different phases of monitoring. Changes to the statistical methods will need re-certification.

2.1 Detection Monitoring (257.93, 257.94)

The statistical evaluations for Detection Monitoring at the NRL Landfill are based on an intra-well approach, where monitoring data from each downgradient well is compared to a background concentration calculated at that well. At the NRL Landfill, the groundwater chemistry in the upgradient and background wells is different than in the downgradient wells, a condition that

existed prior to construction of the landfill. As groundwater moves along its flow path away from its location of recharge, it has increasing contact with the geological materials it flows through. This contact results in some common patterns of geochemical evolution in groundwater (e.g., Freeze & Cherry, 1979). For example, the concentrations of dissolved species and total dissolved solids (TDS) tend to increase with greater distances from recharge sources and increased contact with geologic materials. At the NRL Landfill, the wells east of the landfill are the most downgradient and so the farthest from recharge areas. The chemistry in these wells shows the effects of this chemical evolution. They have higher TDS, higher pH, and/or sodium-dominated major ions compared to calcium-dominated in the wells further to the west. All of these changes are consistent with commonly recognized patterns (e.g., Freeze and Cherry, 1979).

According to the US Environmental Protection Agency's (USEPA) Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 530/R-09-007; March 2009), in situations where groundwater chemistry is spatially variable, such as at the NRL Landfill, intra-well statistical methods are preferred to inter-well methods. Intra-well statistics account for the spatial differences in groundwater chemistry between wells by utilizing the data collected prior to landfill operation to compare to the concentrations during landfill operation. In this way, statistical changes from conditions prior to landfill operation can be identified, which may represent a release from the unit.

The statistical methods described below are used during Detection Monitoring at the NRL Landfill to identify statistically significant increases (SSIs) over background at downgradient wells in accordance with 257.93(h).

- Background concentrations of Appendix III constituents are calculated using an Upper Prediction Limit (UPL) statistic. The UPL is one of the statistical methods specifically identified in the CCR Rule at 257.93(f)(3) and 257.93(g)(4).
- The UPLs are calculated with a 99% confidence, consistent with the US Environmental Protection Agency's (USEPA) Unified Guidance for Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (EPA 530/R-09-007; March 2009).
- Intra-well background UPLs are calculated for each Appendix III constituent in each of the downgradient wells, which are listed on Table 1 of the Groundwater Monitoring System Certification dated June 13, 2018 (Revision 1).
- Background UPLs are calculated using ProUCL, a software tool developed by the USEPA. ProUCL also evaluates the distribution of the data, so that a distribution-appropriate UPL is calculated for each constituent, as required by 257.93(g)(1). ProUCL may identify a distribution as normal, log-normal, gamma, or distribution-free (i.e., non-parametric). Due to the relatively small size of the datasets at each well, each dataset was assumed to be normally distributed unless identified by ProUCL as not normal or approximately normal.
- In situations with less than four detected results, ProUCL issues a warning on the reliability of the statistical calculation. In these cases, either the highest detected value or the most common reporting limit is used for the UPL (whichever is highest). This is consistent with statistical methods of calculating non-parametric UPLs, which default to the maximum value.
- ProUCL is also designed to handle results below the limit of detection, as required by 257.93(g)(5).
- For the original monitoring network, UPLs are calculated using data from samples collected from these wells prior to waste being placed in the landfill. Specifically, the background dataset is based on the data collected from these wells between April 2015 and May 2016,

which represents a minimum of eight pre-waste sampling events for most constituents. Operation of the landfill started in June 2016, so the data from these samples cannot be affected by waste placed in the landfill.

- Downgradient well NRL230 was installed in 2018, after the landfill was in operation. As a result, there is no pre-waste analytical data available for this well. UPLs are calculated for NRL230 using the same statistical methods described above, using the baseline data from the well collected from April 2018 to November 2018, representing a minimum of eight samples.
- For pH, a Lower Prediction Limit (LPL) with 99% confidence is also calculated.
- During Detection Monitoring (257.94), to identify potential statistically significant increases over background, the results from each downgradient well are compared to the pre-waste background UPL for each constituent at that well (257.93(f)(3) and 257.93(h)). For pH, the Detection monitoring results from the downgradient wells are compared to both the UPL and LPL to identify both statistically significant increases and decreases in pH compared to pre-waste background levels.

These methods are subject to change based on data that may be collected in the future. In addition, the pre-waste datasets are small (approximately 8 samples), and it may be appropriate at some point to improve the statistical robustness and develop more representative UPLs by expanding the dataset used in the statistical calculations. Changes to the statistical methods will need re-certification.

2.2 Assessment Monitoring (257.95)

There are two aspects of Assessment Monitoring that may involve statistics. Where background concentrations of an Appendix IV constituent are above the published Groundwater Protection Standard (GWPS), statistics may be used to calculate a site-specific GWPS based on background (257.94(h)). Statistics are also used to identify Statistically Significant Levels (SSLs) above GWPSs. The statistical methods used in Assessment Monitoring are described below.

2.2.1 Site-Specific GWPS

Where background concentrations are above published GWPSs for Appendix IV constituents, a site-specific GWPS based on background (257.95(h)(3)) is developed based on an upper tolerance limit (UTL). The UTL is one of the statistical methods specifically identified in the CCR Rule at 257.93(f)(3) and 257.93(g)(4).

- The UTL is calculated with 95% confidence (α=0.05) and 95% coverage, consistent with recommendations in the USEPA's Unified Guidance.
- UTLs are calculated for each of the monitoring wells in the certified monitoring network. For the upgradient and downgradient wells, the background/pre-waste datasets are used as described above for calculating UPLs.
- UTLs are also calculated at the four background wells. Data from these wells is not used in the intra-wells methods for identifying SSIs during Detection Monitoring. For calculating UTLs at the background wells, the current full dataset is used (November 2016 to September 2022). The UTLs may be recalculated and updated, as additional data is obtained from these wells in subsequent sampling events.
- Background UTLs are calculated using ProUCL. ProUCL also evaluates the distribution of the data, so that a distribution-appropriate UTL is calculated for each constituent, as required

by 257.93(g)(1). ProUCL may identify a distribution as normal, log-normal, gamma, or distribution-free (i.e., non-parametric).

- ProUCL is designed to handle results below the limit of detection, as required by 257.93(g)(5). Non-detect results with a detection limit greater than the maximum detected concentration were omitted from the datasets. Other non-detect results were retained.
- UTLs are calculated for each well in the monitoring network. The maximum UTL (from representative wells) is then used as the GWPS applicable to the CCR unit.

2.2.2 GWPS Exceedances

During assessment monitoring, 40 CFR 257.95(g) requires statistically significant levels (SSLs) of Appendix IV constituents above GWPSs to be identified. The identification of SSLs is performed in a step-wise process:

- At each downgradient well, the sampling result for each Appendix IV constituent is compared directly to the GWPS. When the concentration is below the GWPS, no SSL is identified.
- Where sampling results may exceed the GWPS, verification re-sampling may be used to confirm the sampling results. If the verification sampling concentration is below the GWPS (i.e., the exceedance is not confirmed), no SSL is identified.
- Where the direct comparison indicates a concentration above the GWPS, further statistical analysis is performed to identify levels statistically greater than the GWPS, using procedures recommended in the USEPA's Unified Guidance, and described below.
- The additional statistical evaluations use all available data for the constituent at the relevant well since monitoring started (April 2015 or November 2016 for most wells). At some point in time, it may be appropriate to focus only on more recent data to conduct these evaluations.
- Non-detect results with elevated detection limits may be omitted from these calculations where the result could bias the outcome.
- A linear regression analysis is used to identify whether there is a statistically significant concentration trend over time for the Appendix IV constituent in the well that exceeds the GWPS. A trend is considered statistically significant when the slope of the regression line is greater than zero with 95% confidence (α=0.05).
- If there is not a statistically significant trend, the 99% upper and lower confidence levels (UCL, LCL, respectively) on the mean concentration in that monitoring well are calculated. As recommended in the Unified Guidance, when both the UCL and LCL exceed the GWPS, an SSL is identified. If the LCL and/or UCL is below the GWPS, no SSL is identified.
- Where there is a statistically significant trend, a confidence band approach is used instead. A 98% confidence band is constructed around the regression line, resulting in a 99% upper and a 99% lower confidence band around the mean. If, for the most recent sample, both the upper and lower confidence bands are above the GWPS, an SSL is identified.
- If either the lower and/or the upper confidence band around the most recent sample is below the GWPS, no SSL is identified.

3. Qualified Professional Engineer Certification

I, David E. Skeggs, PE, being a Registered Professional Engineer in good standing in the State of Tennessee, do hereby certify, to the best of my knowledge, information, and belief that the information contained in this certification is prepared in accordance with the accepted practice of engineering; that the information contained herein is accurate as of the date of my signature below; and that the statistical methods described above are appropriate for evaluating the groundwater monitoring data at the Gallatin Fossil Plant NRL Landfill in accordance with 40 CFR § 257.93. Opinions relating to environmental, geologic, and hydrogeologic conditions or other estimates are based on available data; actual conditions may vary from those encountered at the times and locations where data are obtained, despite the use of due care.

SIGNATURE: _____ DATE: 12/15/2022

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