ATTACHMENT 3

Mann-Kendall Test

The Mann-Kendall test is a non-parametric test for determining trends. It indicates whether a particular constituent has a statistically significant increasing or decreasing trend in an individual monitor well. The test will also indicate the absence of a statistically significant trend. Since the Mann-Kendall test is non-parametric, the sample data need not conform to a particular statistical distribution. Furthermore, missing values are allowed. Mann-Kendall can also use data reported as either a trace value or one less than the method detection limit by assigning a common value that is less than the lowest measured value. This is allowed because Mann-Kendall uses the relative magnitude of the values to determine a trend and not the measured values. The robustness and simplicity of the Mann-Kendall test reduces the chances for error during the statistical analysis. More detailed discussions of the Mann-Kendall test are presented by Gilbert (1987) and Singh and Singh (2013).

As stated by Singh and Singh (2013), "The M-K statistic, S, is computed by examining all possible distinct pairs of measurements in the time series data set and scoring each pair as follows. It should be noted that for a measurement data set of size, *n,* there are *n(n-1)/2* distinct pairs, (y_j, y_i) with $j>i$, which are being compared.

- If an earlier measurement, y_i, is less in magnitude than a later measurement, y_j, then that pair is assigned a score of 1;
- If an earlier measurement value is greater in magnitude than a later value, the pair is assigned a score of –1; and
- Pairs with identical ($y_i = y_j$) measurements values are assigned a score of 0.

"The M-K test statistic, S, equals the sum of scores assigned to all pairs. The following conclusions are derived based upon the values of the M-K statistic, S.

- A positive value of *S* implies that a majority of the differences between earlier and later measurements are positive suggesting the presence of a potential upward and increasing trend over time.
- A negative value for *S* implies that a majority of the differences between earlier and later measurements are negative suggesting the presence of a potential downward/ decreasing trend.
- A value of S close to zero indicates a roughly equal number of positive and negative scores assigned to all possible distinct pairs, (y_j, y_i) with $j>i$, suggesting that the data do not exhibit any evidence of an increasing or decreasing trend."

The statistical significance of the trend is determined by comparing the Mann-Kendall test statistic with tabulated p-values. Methods used for this statistical comparison are detailed by Singh and Singh (2013).

At the Chevron Salt Lake Refinery, trends in groundwater quality will be determined using a two-tailed Mann-Kendall test with a significance level alpha of 0.05 (i.e., a 95% confidence level). For determinations made in support of closure, a one-tailed test will be used, also with a significance level alpha of 0.05, to evaluate the lower limit. As long as the sample size being evaluated is at or below 22, the Mann-Kendall methodology for small sample size will be used.

However, when the sample size exceeds 22, the Mann-Kendall test for larger sample sizes will be used. All tests will be performed using ProUCL, version 5.0 (as updated) or other standard statistical software.

References

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold. New York, New York.

Singh, A. and A.K. Singh. 2013. ProUCL Version 5.0.00 Technical Guide: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041. U.S. Environmental Protection Agency, Office of Research and Development. Washington, D.C.