

# ***Evaluation of Statistical Outliers and Statistically Significant Trends in Ground Water Quality Data***

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## **PURPOSE**

This educational guideline provides guidance to the regulated community on evaluation of statistical outliers and statistically significant trends in background ground water quality data from an Ohio EPA-regulated solid waste facility. Statistical evaluation of outliers and trends is generally part of a broader evaluation of a statistical analysis plan or update to the statistical analysis plan as part of the ground water monitoring program.

## **APPLICABLE RULES**

MSW: OAC 3745-27-10(C)(1), (C)(6) & (C)(7)

ISW: OAC 3745-29-08(C)(5) & (C)(6)

RSW: OAC 3745-30-08(C)(5) & (C)(6)

## **APPLICABILITY**

This document is only applicable to background ground water sample data from an Ohio EPA-regulated solid waste facility.

## **DETAILED DISCUSSION**

### Background

Solid waste rules require that ground water sample results and associated statistical methods used to determine the statistical background of a ground water monitoring program be “protective of human health and the environment,” which includes a requirement that the results be “representative” of the background ground water quality of the geologic unit(s) being monitored. However, at least two common factors may confound the representativeness of a sample result: 1) error in sampling, laboratory analysis or statistical analysis; 2) a

recent or historic release of constituents from the monitored waste unit into ground water.

An outlier in ground water monitoring can be generally defined as “a measurement that is very different from other values in the data set.” Statistical analysis of background ground water quality data occasionally confirms that a data point is *statistically* different from the rest of the data set (i.e. a statistical outlier if conducting an outlier test). Such data may be erroneous and not representative of true background ground water quality (i.e. the population).

Removing or restricting a statistical outlier from the background data set would tend to increase statistical power to detect an actual release in downgradient wells. But high values may represent actual extreme values in the background population rather than an error, so removing them from the background data set may increase the false positive rate at a facility.

The 2009 US EPA Unified Guidance recommends that “testing of outliers be performed on background data, but they generally not be removed unless some basis for a likely error or discrepancy can be identified. Such possible errors or discrepancies could include data recording errors, unusual sampling and laboratory procedures or conditions, inconsistent sample turbidity, and values significantly outside the historical ranges of background data,” but also includes that “because of these concerns, it may be advisable at times to remove high-magnitude outliers in background even if the reasons for these apparently extreme observations are not known.”

Additionally, if a release of waste-derived constituents into ground water occurred at the facility prior to or during collection of intrawell background ground water samples, a slow, steady change in concentration (or pH) over time can mask an indication of the release in post-background intrawell sampling results. Such slow, steady changes in data can often be identified through statistical trend tests or visual inspection of graphs and/or charts. However, trends also frequently occur for naturally-occurring parameters in ground water where no release has occurred. Therefore, a trend in data does not automatically indicate a release from the waste unit has occurred.

Therefore, the following guidance was developed to promote the objective of being protective of human health and the environment and concurrently promote the use of professional judgment as a key component in evaluating the representativeness of statistically significant outliers and trends in background data.

### Guidance

The steps described below outline a process for an owner or operator to evaluate potential background data prior to establishing or updating the background data set. The Ohio EPA considers this process to be in accordance with solid waste rules [OAC 3745-27-10(C)(1), (C)(6), & (C)(7), and OAC 3745-30-08(C)(5) & (C)(6)]. However, other methods may be available to the owner or operator that, upon evaluation, are also deemed by Ohio EPA to be in accordance with these solid waste rules.

Step 1. Outlier Tests (see Flowchart #1 and Flowchart #2 attached to this document for an outline of the statistical outlier determination process described in this step). Perform an outlier test on the entire background data set (i.e. the original or existing background data set, or if updating, the data set

consisting of both the original/existing data set and the data proposed to be updated) in accordance with the following:

- A. If censored<sup>1</sup> data comprise less than seventy-five percent<sup>2</sup> of the background data set, a statistical outlier should be determined as follows:
  - (1) Perform a statistical outlier test such as Dixon's, Rosner's, Grubb's (ASTM E178-75 in 1989 Interim Final Guidance), or other appropriate, standard statistical outlier test (as described in the statistical analysis plan) on high and low suspect values at a type I error rate of not less than 0.01 for each parameter at each sample location to determine if a statistical outlier or multiple statistical outliers is/are present. Controls for the problems of "masking" and "swamping" of outliers should also be implemented, as appropriate.
  - (2) In addition to the standard outlier test described above in this Step, if the highest value data point in the background data set exceeds by an order of magnitude the value of the second highest data point, the highest data point should be considered a statistical outlier.
- B. If censored data comprise greater than or equal to seventy-five percent of the background data set, a statistical outlier should be determined as follows:
  - (1) If there is a single detection greater than or equal to the practical quantitation limit (PQL) and detections greater than or equal to the method detection limit (MDL) comprise greater than or equal to fifty percent of the background data set, any value greater than or equal to two times the median PQL of the background data set should be considered a statistical outlier<sup>3</sup>.
  - (2) If there is a single detection greater than or equal to the PQL and detections greater than or equal to the MDL comprise less than fifty percent of the background data set, any value greater than or equal to the highest PQL among the background data should be considered a statistical outlier.

<sup>1</sup> For statistical purposes data may be censored below the MDL and qualified (as an estimated value or "present") between the MDL and the PQL or data may be censored at the PQL. The owner or operator may propose either option in the statistical analysis plan, as appropriate.

<sup>2</sup> The 75% cutoff is based on extensive discussions among Ohio EPA, Kirk Cameron—statistician and author of the Unified Guidance, Robert Gibbons—statistician, and various consultants and owners and operators. The 75% cutoff is also consistent with fact that Dixon's test requires a minimum of 3 detects to run the test (Unified Guidance, page 12-9). Assuming a minimum background of 8 samples, 2 detects would equal 75% censored exactly, but if you had the minimum of 3 detects to use Dixon's this would equal less than 75% censored.

<sup>3</sup> See footnote #2. Also, at least two statistical software programs (DumpStat and Sanitas) have included a 2<sup>nd</sup> outlier criterion that an extreme value must exceed 3 times the background median to be considered a statistical outlier, even if that value fails a formal outlier test such as Dixon's. Kirk Cameron advised Ohio EPA that when data do not meet the normality assumption of a formal outlier test, a formal outlier test based on some order of statistics is still better than applying an arbitrary criterion of some multiple of the median if there are a sufficient number of detections to compute the formal outlier test. Ohio EPA agrees in principle that using a median-based outlier criteria may be appropriate for data sets where formal outlier testing is not possible (i.e.  $\geq 75\%$  censored). For example, if there is only one detection at/above the PQL in a sample data set ( $\geq 8$  samples), and that one detection represents the extreme upper portion of the same population as the censored data, it is reasonable to expect that approximately 50% of that population would lie at or above the MDL. Therefore, when  $\geq 50\%$  of sample data are at or above the MDL, Steps 1B(1) & (2) of this guidance direct that the outlier criterion should be twice the median (median would likely be the PQL), but if  $< 50\%$  of data are above the MDL, the outlier criterion would be equal to the PQL. Furthermore, as evidence increases that the true median is close to the PQL (i.e. two or more detections above the PQL with  $\geq 50\%$  detections above the MDL) the outlier criterion is increased to 3 times the median [Step 1B(3)].

- (3) If there are at least two detections greater than or equal to the PQL and detections greater than or equal to the MDL comprise greater than or equal to fifty percent of the background data set, any value greater than or equal to three times the median PQL of the background data set should be considered a statistical outlier.
  - (4) If there are at least two detections greater than or equal to the PQL and detections greater than or equal to the MDL comprise less than fifty percent of the background data set, any value greater than or equal to two times the median PQL of the background data set should be considered a statistical outlier.
- C. If the owner or operator intends to include in the background data set a value that was determined in accordance with Step 1A or Step 1B to be a statistical outlier, the owner or operator should submit justification that the outlier is representative of background ground water quality. The statistical outlier should not be included in the background data set unless representativeness is justified in consideration of the following evidences, as appropriate:
- 1) Consideration of potential close proximity in concentration of the statistical outlier to other detections at or above the PQL, or to available estimated data that is greater than or equal to the MDL but less than the PQL.
  - 2) Supporting evidence found in relevant, professional literature that the statistical outlier concentration is within the normal range of background concentrations expected for the parameter at the facility.
  - 3) A comparison of the statistical outlier concentration to background data from other sample locations located up or down gradient. The sampling locations must be unaffected by potential sources of contamination and the comparison must consider the range, standard deviation, and spatial variability present in background data at the facility and demonstrate that the statistical outlier concentration is within the normal range of background concentrations expected for the parameter at the facility.
  - 4) Use of an appropriate outlier testing procedure not previously identified in the statistical analysis plan demonstrating that the data point previously identified as a statistical outlier in accordance with the statistical analysis plan is not an outlier.

Step 2. Trend Tests. After performing outlier tests, statistical trend analyses should be performed on background data and in accordance with the following requirements:

- A. Trend analyses should be performed on the entire background data set for each parameter at each individual sample location.
- B. Trend analyses should be performed at a level of significance of 0.01 or higher for each parameter at each sample location.
- C. Trend analyses should be performed using "Sen's Estimate of Slope", "Spearman's Rank Correlation Test", "Mann-Kendall Trend Evaluation," or an equivalent, peer-reviewed trend analysis method.
- D. If the owner or operator intends to include in the background data set data that caused an

increasing trend determined in accordance with Step 2 of this document, the owner or operator should submit justification that the trend is representative of background ground water quality. The data should not be included in the background data set unless representativeness is justified in consideration of the following pieces of evidence:

- 1) Similarity of data to other site data and regional data (if available) that are unaffected by potential sources of contamination.
- 2) Information or data indicating an off-site source.
- 3) Results indicating a release from an on-site source that does not include a release from the limits of the waste management unit being monitored under the aforementioned rules.
- 4) Supporting evidence found in relevant, professional literature that the trend or data from the trend represents normal background concentrations expected for the parameter at the facility.

Additionally, OAC 3745-27-10(C)(7)(f) and 3745-30-08(C)(6)(f) state that when seasonal or spatial variability or temporal correlation exists in the data, that procedures to control or correct for the variability/correlation may be necessary.

## **REFERENCES**

US EPA, March 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance (Unified Guidance).

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## **DISCLAIMER**

The procedures set out in this document are intended solely for guidance of government personnel. The procedures are not intended and cannot be relied upon to create rights, substantive or procedural, enforceable by any party against Ohio EPA. While this guidance document is not legally binding, all statutes and rules referenced herein are binding and enforceable. Ohio EPA reserves the right to vary this guidance or to change it at any time without public notice and also reserves the right to deviate from this guidance on a case-by-case basis.

Chart #1 – Flow Chart for Outlier determination in Data Sets with Lower % of Censored Data

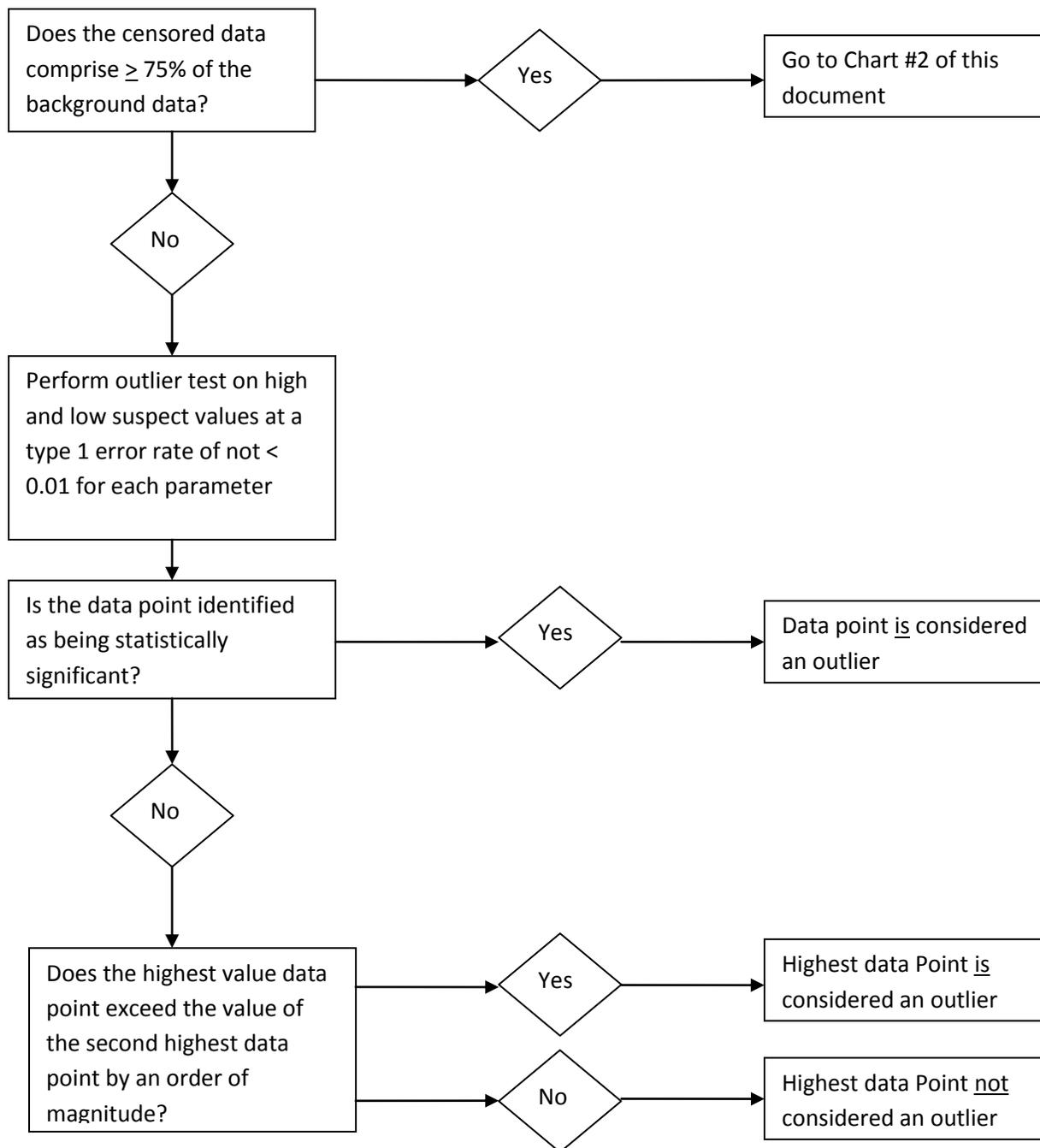


Chart #2 – Flow Chart for Outlier determination in Data Sets with High % of Censored Data

