CSM Development: Background and Off-site Sources

6.1 Introduction

Sometimes all or part of the contamination at a site is not a result of site activities. For example, contamination may be naturally occurring, or may originate from off-site sources. The origin of contamination is important because the Indiana Department of Environmental Management (IDEM) does not routinely ask responsible parties to address contamination that did not arise from the subject site's activities.

There are many possible approaches to background evaluations, and IDEM will evaluate each demonstration for sound methodology and scientific validity consistent with United States Environmental Protection Agency (U.S. EPA) guidance (U.S. EPA 2002, 2007). This section provides example procedures and general guidelines for background and off-site source demonstrations.

These procedures rely critically on an adequate understanding of the site, as reflected in a conceptual site model. Essentially, they compare chemical concentrations found on-site with those found off-site. It is usually appropriate to eliminate a site from consideration as a source when chemical concentrations on-site are less than or equal to background concentrations. Conversely, on-site concentrations that exceed background concentrations suggest that the site may be a source.

6.2 Applicability

Most sites will not require a background or off-site source demonstration. However, this section may prove useful when attempting to show that contamination at a site did not arise from site activities. Guidance in this section may also apply when evaluating naturally-occurring site characteristics (e.g., soil fraction of organic carbon, soil pH, etc.) important in calculating site-specific screening levels.

While some of the guidance provided in this section may be applicable to the design of studies to develop regional or state-wide background screening levels, it was not written with that purpose in mind. IDEM recognizes the potential value of regional or state-wide background studies as a cost-effective approach for many smaller sites, and welcomes the opportunity to collaborate with stakeholders in the design and execution of such studies.

6.3 Definitions

There are two types of background: naturally occurring background and anthropogenic background. U.S. EPA (2002) defines **naturally occurring background** as substances present in the environment in forms that have not been influenced by human activity (e.g., arsenic in New Albany shale). U.S. EPA (2002) defines **anthropogenic background** as natural and human-made substances present in the environment as a result of human activities not specifically related to the site in question [e.g., lead and polyaromatic hydrocarbons (PAHs) deposited onto urban soil by vehicular exhaust]. The **background threshold value** (BTV) is an upper limit estimate of the background contaminant concentration (either naturally occurring or anthropogenic) used to represent environmental contaminants not specifically related to the site under investigation.

An **off-site source** is an identifiable localized point source outside the site of interest that contributed contamination to the site. (e.g., chlorinated solvents from a dry cleaner impacting a neighboring business that has no history of using those solvents). An off-site source demonstration employs the CSM approach to show that the site is not the source or is not the sole source of the contamination under investigation.

6.4 Background in Soils

Methods used to characterize background concentrations do not generally depend on the type of background substance (U.S. EPA, 2002). Therefore, this guidance does not differentiate between suggested procedures according to naturally occurring or anthropogenic substances.

6.4.1 Background in Soils: Selecting a Background Reference Area

A **background reference area** is the area where background samples are collected for comparison with samples collected on site. The background reference area should have physical, chemical, and geological characteristics similar to those of the site under investigation. It should also have virtually no impacts from site activities (U.S. EPA, 2002).

Possible background reference areas, subject to landowner approval, include public lands, woodlots, permanent pasture, or unused portions of cemeteries. Background reference areas are not necessarily limited to natural areas undisturbed by human activities. It may be difficult to find a suitable background reference area in an industrial complex. While background reference areas are normally selected from off-site areas, in some cases a non-impacted on-site area may be suitable as a background reference area (U.S. EPA, 2002). Because selection of a background sampling location is a matter of professional judgment, it is advisable to obtain concurrence from IDEM staff prior to obtaining background samples. It is not appropriate to bias the background data by sampling locations suspected to have high contaminant concentrations. For instance, soil lead concentrations along a major highway may not be representative of anthropogenic lead concentrations in a residential neighborhood. However, it is appropriate to collect some (but not all) background samples along roadways of a size typical for the site location (e.g., along a residential street if the site is in or adjacent to a residential neighborhood).

IDEM recommends using background reference areas within a two-mile radius for small to medium-sized sites if relevant background locations are present within this radius, although a greater radius may be necessary for larger sites. Samples collected beyond that distance may not have similar physical, chemical, or geological characteristics, and they may have been subject to different anthropological influences than the source area.

The following may not be suitable as background reference areas:

- Areas where hazardous substances, petroleum, solid or hazardous waste or waste waters are known or suspected to have been managed, treated, handled, stored, or disposed.
- Areas affected by roadway or parking lot runoff or road spray when evaluating chemicals associated with motor vehicles (e.g., lead or PAHs).
- Railroad tracks, right-of-ways or other areas affected by their runoff when evaluating chemicals associated with railroads and right-of-way maintenance.
- Storm drains or ditches presently or historically receiving industrial or urban runoff.
- Fill areas - unless the site under investigation is on similar fill, or IDEM agrees that the fill area is a valid background reference area.[42]

6.4.2 Background in Soils: Sampling Background Reference Areas

IDEM follows U.S. EPA in recommending eight to ten or more samples for determining a BTV (U.S. EPA, 2007). In some cases, more than ten samples may be necessary to support a background demonstration, depending on methodology and site characteristics. Investigators should document that the number of samples is adequate to support the selected method. Because the data evaluation process sometimes reduces the size of the set of background samples, it may be prudent to collect extra samples during the initial sampling effort.[43]

Representative background samples should come from equivalent stratigraphic positions in background reference areas comparable to the site. Suitable areas are (1) free of the influence of nearby sources of the contaminants under investigation, and (2) underlain by the same soil layers as the source area.

[42] Fill in this context refers only to clean fill or fill that is excluded from the requirements of the solid or hazardous waste management regulations. Waste fill is beyond the scope of this guidance.
[43] Sometimes it is possible for the laboratory to hold samples for future analysis, subject to need and method holding times.

6.4.3 Background in Soils: General Statistical Considerations

Many different statistical methods can be applied to background demonstrations. IDEM will evaluate statistical treatments of background data for sound methodology and scientific validity using the following general considerations:

- Does the statistic used to calculate a BTV provide an appropriate standard of comparison considering the on-site sampling scheme (e.g., judgmental versus systematic)? For example, a BTV calculated as the 90th percentile (upper end of background range) provides a suitable value for point-by-point comparison to on-site samples judgmentally selected to represent the upper range of on-site concentrations (see example in Section 6.4.5). Similarly, the maximum non-outlier value of a small sample set provides an estimated BTV representing the upper end of the background range for comparison to judgmental on-site samples (see Section 6.4.7). Alternatively, a BTV calculated as the 95% upper confidence limit of the mean (UCL) provides an apples to apples comparison to the 95% UCL of the mean of systematic on-site samples (see Section 6.4.6).
- Are the requirements of the statistical test met? For example, verifying that data are normally distributed is a necessary precursor to using many parametric statistical tests (U.S. EPA 2002, 2007).
- Do multiple independent statistical methods that compare the site versus background support the conclusions of the demonstration? For example, U.S. EPA (2007) notes that statistical methods should always be supplemented with appropriate graphical displays.
- Are data transformations and back-transformations applied appropriately? For example, data sets with nondetect values can have unacceptably large transformation bias and lead to incorrect decisions (U.S. EPA 2007).
- Has the statistical methodology been shown to have sufficient power to support decision making?

ProUCL[44] addresses many of these considerations and recommends the appropriate statistic based on the characteristics of the data set.

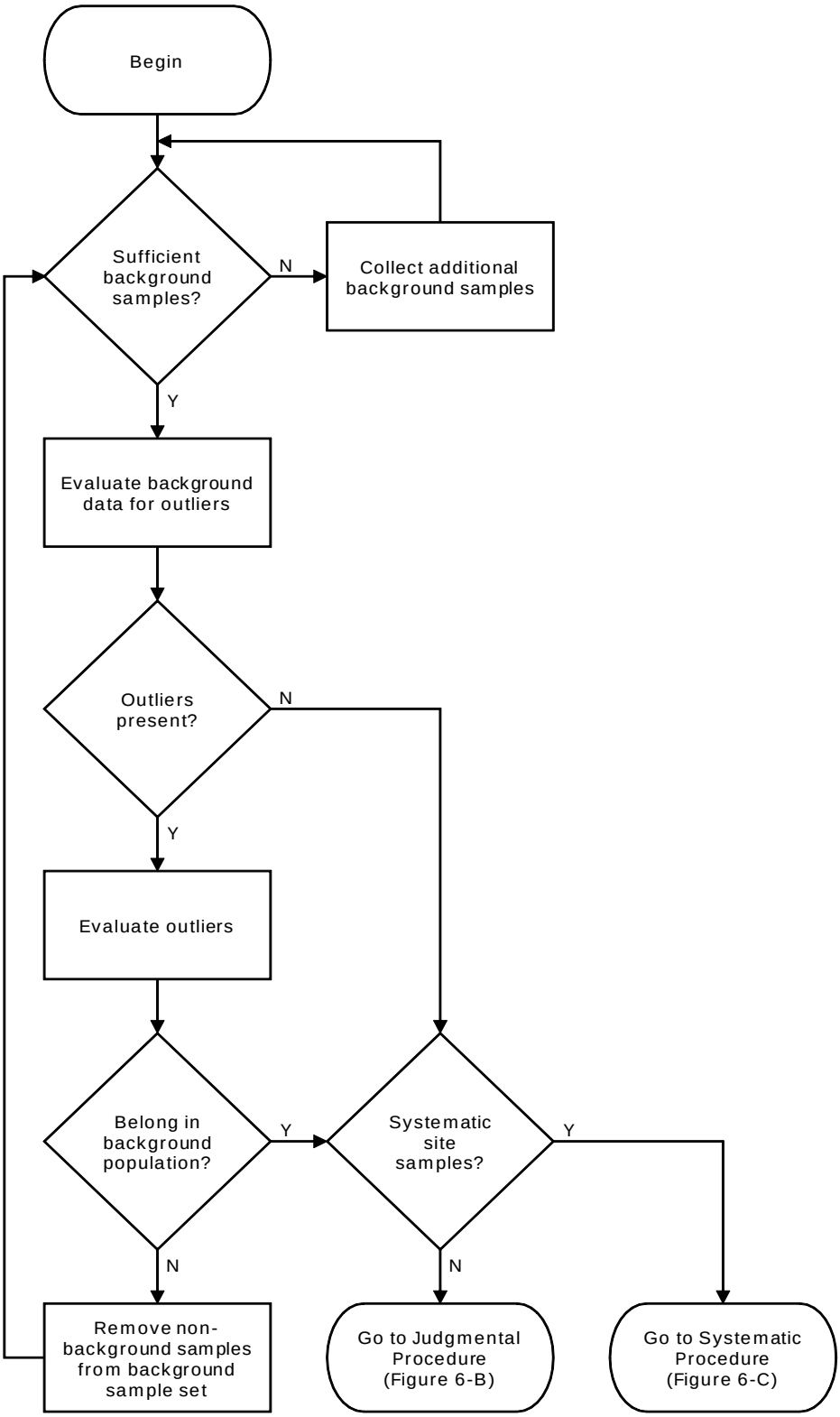
6.4.4 Background in Soils: Background Data Outlier Test

Analysis of background data begins with an outlier test (Figure 6-A). It is important to verify the presence of outliers using appropriate outlier tests and graphical displays before making a final decision to remove them. Graphical displays of a data set (e.g. Q-Q plot) may provide insight that may not otherwise be clear by looking at simple test statistics (U.S. EPA 2007). IDEM will evaluate outlier tests consistent with recent EPA guidance (U.S. EPA 2002, 2007).

A BTV is calculated from the remaining background data using the appropriate methodology according to the sample collection scheme for site samples - judgmental sampling (Section 6.4.5) or systematic sampling (Section 6.4.6). As always, IDEM will evaluate alternative proposals on their merits.

[44] *ProUCL* is a software application that can perform the necessary calculations and recommend an appropriate UCL. *ProUCL* is available for free download at the U.S. EPA website. Whatever the approach, IDEM review of UCL calculations will require submission of algorithm inputs and outputs.

Figure 6-A: Outlier Evaluation



6.4.5 Background in Soils: BTV Comparison to Judgmental Samples

Figure 6-B illustrates an example procedure for comparing a background data set to site samples collected under judgmental sampling. IDEM will evaluate alternative approaches consistent with recent U.S. EPA guidance (U.S. EPA 2002, 2007).

Example Procedure:

The BTV is the 90th percentile of the background sample set *after* addressing outliers. See the example calculation below. Compare the BTV to each on-site sample. If no on-site sample exceeds the BTV, it is reasonable to conclude that the on-site contaminants are background. On-site samples that exceed the BTV warrant further evaluation. Exceedances may indicate an area contaminated by site activities above background levels - particularly if they are significantly higher than the BTV or spatially concentrated. Samples only minimally above the BTV and scattered across the site may still be within the range of background.

The results of this comparison should be presented in the CSM along with the basis for any professional judgment and interpretation.

Example Calculation:

Calculate the 90th percentile of the background data set as follows:

1. Multiply the number of data points by 0.9 to find the position of the 90th percentile.

   Example: 12 data points X 0.9 = 10.8 (position of the 90th percentile)

2. Arrange the individual data points in ascending order of their concentration values

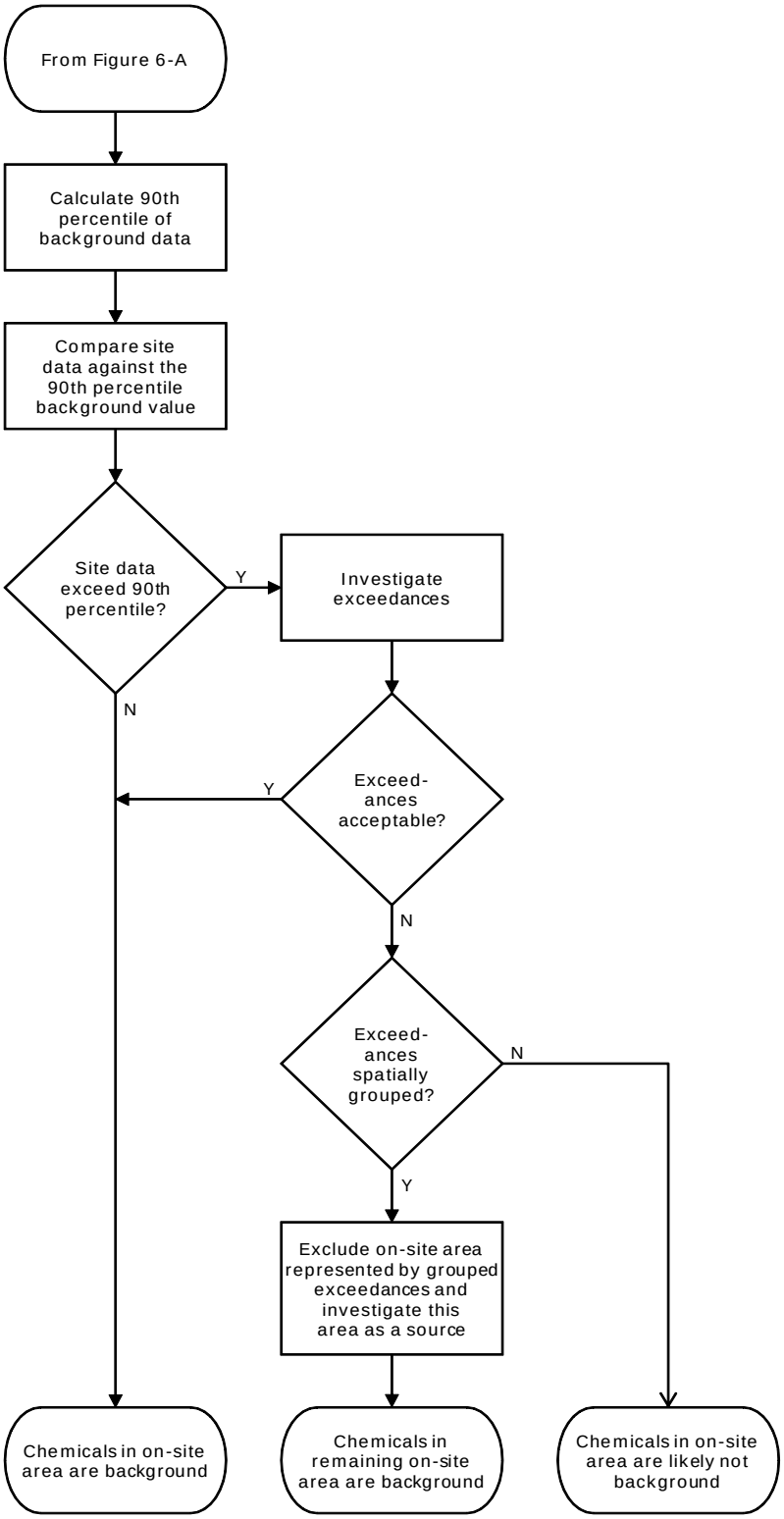
   Example: 2, 5, 7, 12, 14, 16, 20, 23, 25, 27, 29, 32

3. Calculate the concentration corresponding to the 10.8th position as the value of the 10th position plus 80% of the difference between the 10th and 11th values:

   27 + 0.8 x (29-27) = 27+0.8 x (2) = 27 + 1.6 = 28.6 ~ 29

Compare the 90th percentile concentration value (29, in the example) against each on-site data point.

Figure 6-B: Background Evaluation under Judgmental Sampling



6.4.6 Background in Soils: BTV Comparison to Systematic Samples

U.S. EPA's ProUCL software includes background comparison tools that are useful for comparing background sample sets to site samples collected under systematic sampling schemes. ProUCL applies several methodologies to each analysis and then recommends the appropriate statistic depending on the characteristics of the data. This capability helps to address the considerations discussed in Section 6.4.3.

Alternatively, the rest of this section provides an example procedure for comparing a background data set to site samples collected under systematic sampling schemes (Figure 6-C). IDEM will evaluate other approaches consistent with recent U.S. EPA guidance (U.S. EPA 2002, 2007).

Example Procedure:

When comparing the background data set to site samples collected under systematic sampling schemes, methods for calculating the BTV differ depending on whether the background data set contains nondetect values. For both methods the first step is to pool the background sample data (eight or more samples) and evaluate the data for the presence of outliers using the guidelines in Section 6.4.4. After addressing the disposition of potential outliers, evaluate the remaining results to determine whether they include any nondetect values.

For background sample sets that *do not* contain nondetect values, calculate the 95% UCL of the background data set using Hall's Bootstrap.[45] Use this UCL as the BTV, and compare it to the mean of the on-site samples for the area being evaluated. If the mean of the site samples is less than or equal to the BTV, the on-site contaminants are background. If the mean of the site samples is greater than the BTV, then the site samples may indicate contamination above background levels.

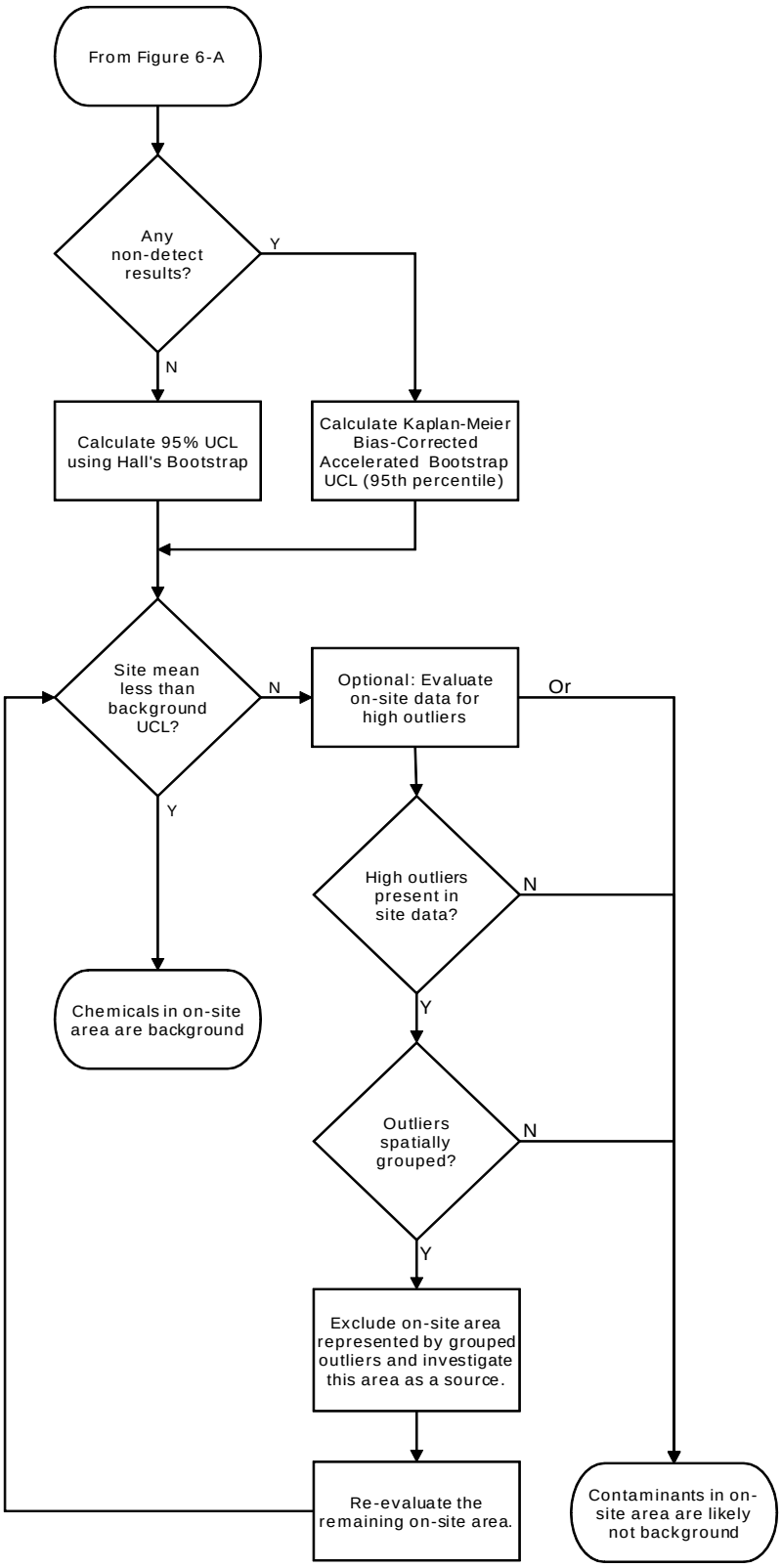
If the background data set *does* contain nondetect values, calculate its Kaplan-Meier Bias-Corrected Accelerated (BCA) Bootstrap UCL (at the 95th percentile).[45] As before, use this UCL as the BTV, and compare it to the mean of the on-site samples. If the mean does not exceed the BTV, it is reasonable to conclude that the on-site contaminants are background.

If the on-site mean exceeds the BTV for either method, investigators may want to evaluate *on-site* samples for high outliers using the guidelines in Section 6.4.4, or other appropriate methods. High outliers may indicate an area contaminated by site activities above background levels if they are spatially concentrated. If there are no outliers in the on-site samples or the outliers are not spatially grouped, then the entire evaluation area is likely contaminated above background levels. If there is an area of grouped outliers in the site data, it may be useful to exclude that area from the background evaluation, and focus further investigation or remediation efforts in that area. The remaining area can then be reevaluated for background. Calculate the mean of the remaining on-site data for comparison to the BTV.

The results of this comparison should be presented in the CSM along with the basis for any professional judgment and interpretation.

[45] ProUCL can perform this calculation. IDEM recommends using the latest version of ProUCL and selecting the maximum of 10,000 bootstrap operations for this calculation.

Figure 6-C: Background Evaluation under Systematic Sampling



6.4.7 Background in Soils: Small Background Sample Sets

Many small remediation sites have difficulty obtaining the requisite number of background samples for a statistical determination of a BTV - particularly given the necessity of collecting background samples from appropriate locations (Section 6.4.1). This section provides an example procedure for estimating the BTV from small background sample sets for comparison to on-site samples (Figure 6-D).

IDEM will evaluate alternative proposals consistent with recent U.S. EPA guidance (U.S. EPA 2002, 2007). Since the influence of a high outlier could be disproportionate in a small sample set, appropriate methods should have a conservative bias.

Example Procedure:

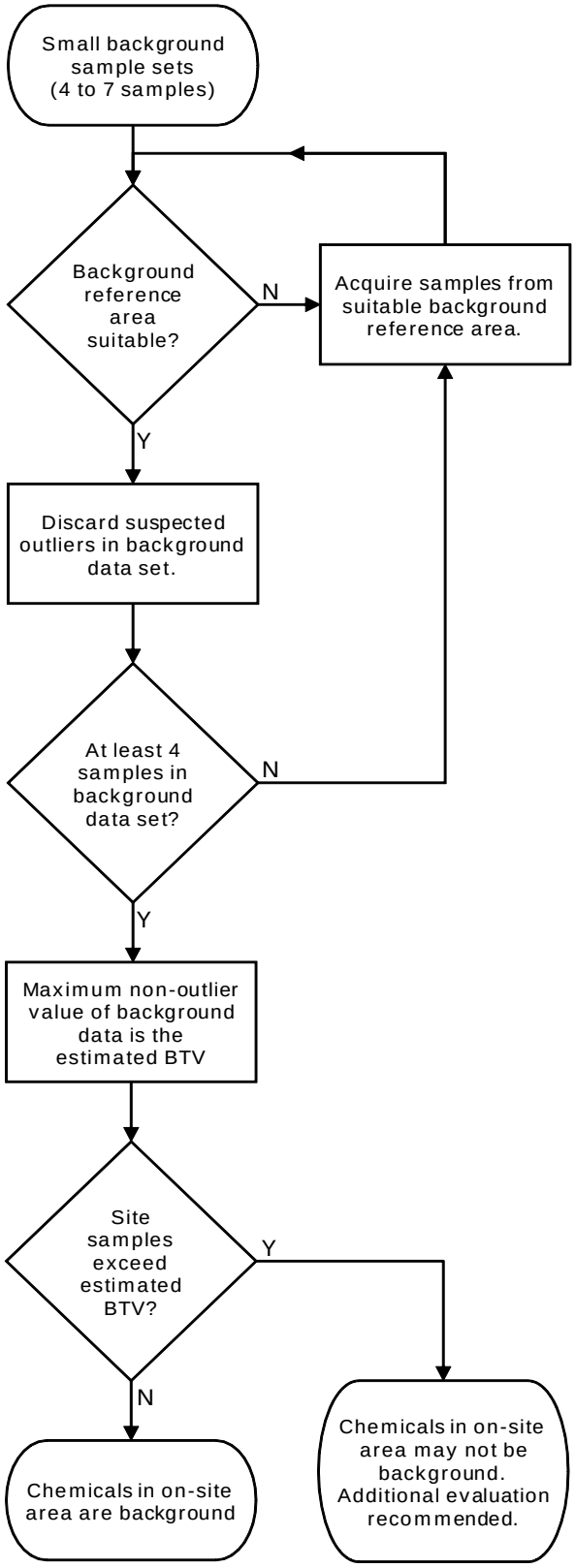
For data sets containing four to seven samples, IDEM recommends using professional judgment to evaluate the suitability of the background reference area and to evaluate suspected outliers. If the background reference area is suitable, an estimate of the BTV may be made from a background sample set with a minimum of four non-outlier values. If the background reference area is questionable or the background sample set contains fewer than four values it may be necessary to acquire additional background data. IDEM recommends using the procedures in Sections 6.4.5 or 6.4.6 when eight to ten or more samples can be obtained.

For small sample sets, the estimated BTV is the maximum value of the background sample set. The estimated BTV is compared point by point to the on-site samples. If the on-site sample(s) exceed the estimated BTV, the site may be a source, and it may be advantageous to acquire additional background data sufficient to calculate a BTV using the procedures in Section 6.4.5 or 6.4.6.

When using this procedure to determine a representative site-specific value for the fraction of organic carbon, pH, synthetic precipitation leaching procedure (SPLP) or other soil characteristic for use in calculating a site-specific closure level, the median value of the sample data should be used.

The results of this evaluation should be presented in the CSM along with the basis for any professional judgment and interpretation.

Figure 6-D: Background Evaluation Using Small Background Sample Sets



6.4.8 Background in Soils: Other Approaches

U.S. EPA (2007) identifies additional procedures for the BTV comparison to systematic site samples. This includes the use of two-sample hypothesis testing, and graphical methods to compare two or more populations. IDEM will evaluate such approaches for consistency with U.S. EPA guidance.

Background values from literature sources or from studies completed for other remediation sites may be useful for evaluating background in soils in some cases. Proposals including such studies should present the information in the context of the CSM and document that the study provides a representative background reference. Background values from studies not in close proximity to the site under investigation may not be suitable for direct application to a site.

6.5 Background in Ground Water

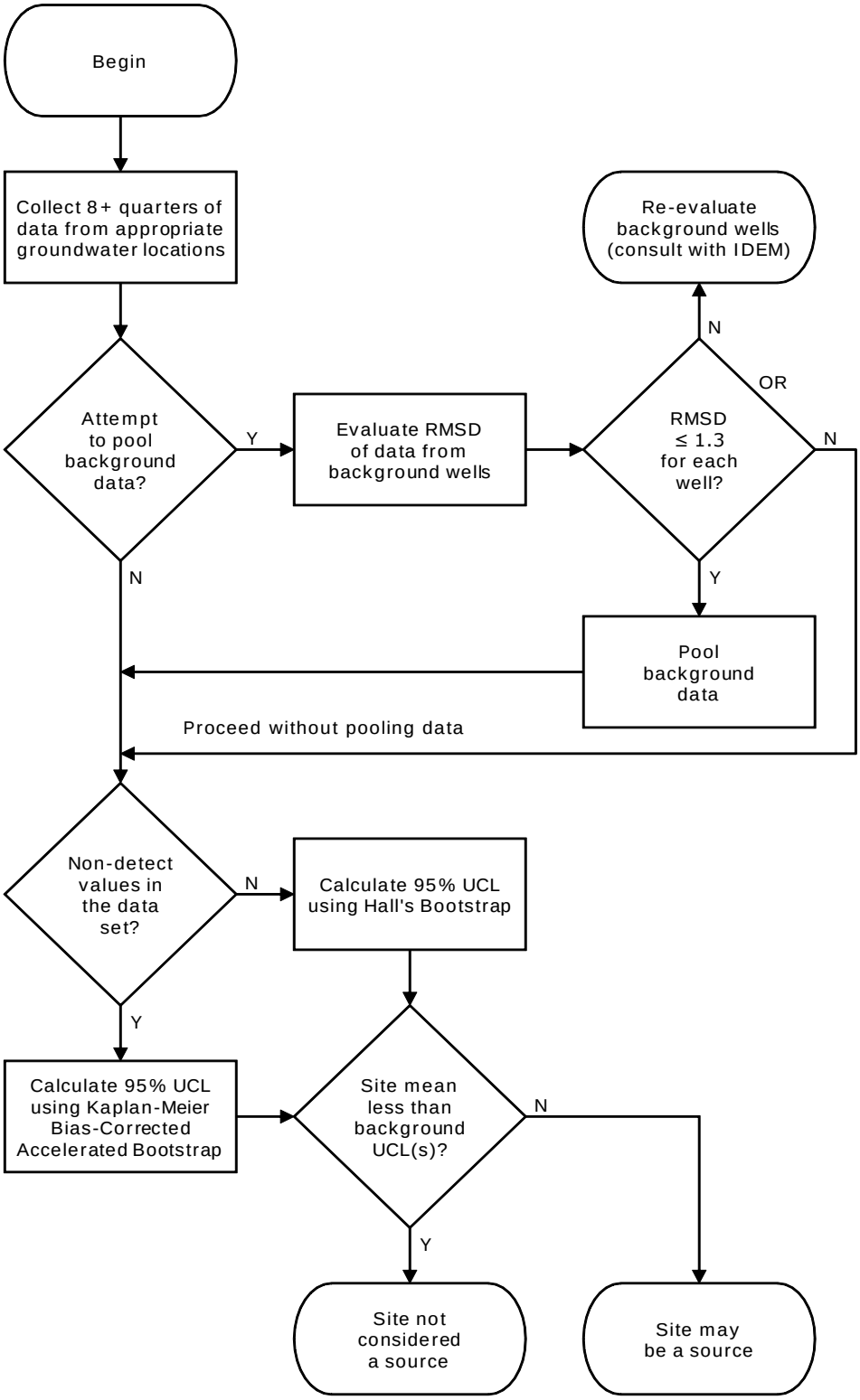
Figure 6-E illustrates a procedure for evaluating background in ground water. Appropriate ground water background sampling points are typically upgradient of, and hydraulically connected to, the site. The suitability of the location of the background sampling point should be based on the following hydrogeologic assumptions:

- The ground water background samples come from areas unaffected by site releases
- The upgradient and downgradient well samples are drawn from the same aquifer and the wells are screened at essentially the same hydrostratigraphic position. The fate and transport characteristics of ground water contaminants likely will differ in each aquifer, resulting in unique concentration patterns.
- The ground water flows in a definable pathway from upgradient to downgradient wells beneath the area under investigation. Undefined or incorrectly defined flow paths may invalidate statistical comparisons.
- The ground water flow moves at a sufficient velocity beneath the site, so that the same ground water observed at upgradient well locations is subsequently monitored at downgradient wells over the course of the evaluation.
- The time between sampling events and velocity of the ground water flow is sufficient to ensure collection of independent samples.

To minimize sampling variability, collect all ground water samples using the same or similar sampling equipment and methods. Because ground water moves, background evaluations in ground water take more time than soil evaluations. Sampling over time also allows for evaluation of fluctuations in contaminant concentrations caused by climate and rainfall. Collect a minimum of eight quarterly samples from each well used in the evaluation.

When using more than one background well it is necessary to evaluate the distribution of the background data. This may be accomplished by evaluating the root mean squared deviation (RMSD) of each background well using Equation 6-B.

Figure 6-E: Ground Water Background Evaluation



Equation 6-B: Root Mean Squared Deviation

$$RMSD = \sqrt{\frac{\sum_{i=1}^{n}(C_{ai} - C_{wi})^2}{N}}$$

where:

C_{wi} = the contaminant concentration for a given sampling event in the well currently under evaluation

C_{ai} = the average concentration of the contaminant in those background wells not currently under evaluation. For example: if there are four background wells, and well 2 is currently under evaluation, this value is the average of the contaminant concentrations in wells 1, 3, and 4; and

N = the total number of background wells.

If the RMSD values are ≤ 1.3 for *each* background well, it is acceptable to pool the background well data. If an RMSD value is greater than 1.3 for any background well, then either proceed without pooling the data, or re-evaluate the background wells. Depending on site conditions, there may be several options for re-evaluating background wells. Consultation with IDEM regarding suitable options is recommended.

If the background data set (pooled or not) contains nondetect values, use the Kaplan-Meier Bias-Corrected Accelerated (BCA) Bootstrap method to calculate a UCL at the 95th percentile level.[46] Otherwise, calculate the 95th percentile UCL using Hall's Bootstrap.[46] Compare the appropriate UCL(s) derived from the background data to the mean contaminant concentration in each of the downgradient wells. If the mean of contaminant concentrations from on-site wells is less than or equal to the background UCL(s), the site is probably not a source. Otherwise, IDEM may consider the site a source.

6.6 Off-site Sources

There is no standard approach to demonstrating that contamination arises from an off-site source. Each demonstration is inherently site-specific and IDEM will evaluate each demonstration on its merits. However, IDEM expects that successful demonstrations will typically employ the CSM approach and multiple lines of evidence (LOEs). An off-site source demonstration should characterize the contamination that is attributed to an off-site source; characterize any temporal variation in concentrations; and identify the particular locations where contamination is coming onto the subject property. Suitable LOEs might include ground water concentration gradients, surface and/or ground water flow direction, suspected source operating history, surface or subsurface soil sample results, prevailing wind direction, etc.

[46] ProUCL can perform this calculation.