Recommended Approach for Evaluating Completion of Groundwater Restoration Remedial Actions at a Groundwater Monitoring Well

The Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions, Office of Solid Waste and Emergency Response (OSWER) 9355.0-129 hereinafter referred to as "the groundwater restoration completion guidance", recommends evaluating contaminant of concern (COC) concentration levels on an individual well-by-well basis to assess whether aquifer restoration is complete. It states that, in general, EPA Regions should use monitoring well-specific conclusions to provide a technical and scientific basis supporting the Agency's conclusion that groundwater has met and will continue to meet COC cleanup levels to determine that a groundwater restoration remedial action is complete. The purpose of this document is to recommend well-specific factors for EPA Regions to consider in evaluating the groundwater in each monitoring well for purposes of the recommendations discussed in the groundwater restoration completion guidance.

The EPA Superfund program recognizes that a number of statistical references and tools are currently available to use to evaluate groundwater monitoring data. Many of these resources provide data analysis methodologies to discern data trends that can help determine whether cleanup levels have been achieved. The recommended approach in this guidance is designed to provide a resource for analysis of groundwater monitoring well data that can assist in the development of the monitoring plan, facilitate transparent decision-making throughout implementation of the groundwater restoration remedial action, and provide consistent documentation for making well-specific conclusions. Regardless of what statistical reference and tools site managers choose to use, it is recommended that the data analysis tool and methodologies be evaluated to assess whether they may provide the analysis on a well-specific basis consistent with the recommendations discussed in the Groundwater Restoration Completion Guidance.

> Examples will be referenced throughout the document to best illustrate the recommended approach presented in this document. The examples evaluate groundwater contaminant concentrations in an individual well over time. The COCs are trichloroethylene (TCE), 1,2 dichloroethene (DCE), and vinyl chloride (VC). The contaminant concentration tables can be found in Figure 1.

When evaluating whether a ground water restoration remedial action is completed, it is encouraged that EPA Regions continue to coordinate with states, tribes, responsible parties, and other stakeholders when determining the monitoring data to be collected and evaluated, as well as any statistical tools to be employed. This coordination should help ensure that all parties understand the data needs, level of effort, and costs associated with this evaluation.

In addition to this document, EPA has developed a statistical tool titled "Groundwater Statistics Tool" that may be used to evaluate groundwater monitoring data for individual COCs in a well. The tool was designed to be consistent with the approach recommended in this document. A link to the tool can be found on the following website: http://epa.gov/superfund/health/conmedia/gwdocs/remedial.htm.

Recommendations

Overview

It is recommended that Regions evaluate groundwater monitoring well data and other related subsurface information to make conclusions during the following two phases: the remediation monitoring phase, and the attainment monitoring phase.

As discussed in the Groundwater Restoration Completion Guidance, the remediation monitoring phase refers to the phase of the remedy where either active or passive remedial activities are being implemented to reach groundwater cleanup levels selected in a decision document. During this phase, groundwater sampling and monitoring data typically are collected to evaluate contaminant migration and changes in COC concentrations over time. The completion of this phase typically provides stakeholders a decision point for starting data collection and evaluation of the attainment monitoring phase. If an active treatment system is being employed at the site, the completion of this phase may also provide stakeholders with an opportunity to evaluate terminating the system, as appropriate, in the vicinity of the well or wells where groundwater restoration completion is being evaluated. If passive systems are being employed at the site, the data used to make the remediation phase completion conclusion may also be useful as part of the attainment phase evaluation since active systems are not being employed.

The remediation phase at a monitoring well typically is completed when the data collected and evaluated demonstrate that the groundwater has reached the cleanup levels for all COCs set forth in the record of decision (ROD). It is important to note that at any time during the groundwater remediation, conclusions may be made to remove certain COCs from the monitoring program because the data indicates that they have met their cleanup level before other, more recalcitrant COCs, in the well. This conclusion should be documented in a monitoring report and used, in conjunction with the current well data at the time of remedial action completion, to make the conclusion that all COCs have reached their cleanup levels in a monitoring well.

The attainment monitoring phase typically occurs after a Region determines that the remediation monitoring phase is complete. When the attainment monitoring phase begins, data typically are collected to first evaluate whether the well has reached steady-state conditions where active remediation activities, if employed, are no longer influencing the groundwater in the well. Once the groundwater is observed to have reached steady-state conditions, data should be collected and evaluated to confirm the attainment monitoring phase has been completed.

The attainment monitoring phase at a monitoring well typically is complete when contaminant-specific data provide a technical and scientific basis that:

(1) The contaminant cleanup level for each COC has been met; <u>and</u>
(2) The groundwater will continue to meet the contaminant cleanup level for each COC in the future.

By way of example for purposes of this guidance, Figure 2 provides an overview of COC data in a single well for TCE, 1,2 DCE, and VC. This figure shows the data set that will be used in this guidance document as an example to evaluate completion of both the remediation monitoring phase and the attainment monitoring phase.

Sample Frequency and Duration Considerations

The interval between sampling events (the sampling frequency) and the timeframe when data are collected generally should be based on site-specific groundwater flow conditions (such as hydraulic conductivity and gradient), seasonal variations, and other contributing factors. It may be appropriate to reevaluate the groundwater monitoring plan as the monitoring well data evaluation indicates that the remedial action is approaching cleanup levels for all COCs, particularly if a long sampling interval (such as one sampling event every 5 years) has been employed. Monitoring frequency generally should ensure that sufficient data are available for both the remediation monitoring phase and the attainment phase evaluations, and at the same time should avoid unnecessarily long timeframes between sampling events. Many sites use quarterly sampling for evaluating groundwater monitoring well data. The sampling frequency used typically should ensure a representative sample of the aquifer conditions, with the shortest sampling interval recommended being monthly (provided it is sufficient to document groundwater performance over time).

This document recommends a minimum number of data points to evaluate each phase. These recommended minimum numbers of data points are based on existing groundwater monitoring and statistical practices and are designed to ensure that decisions generally are made with sufficient supporting information (not using only a single sampling event). Completion of the remediation monitoring phase, in general, means that it is appropriate to begin attainment phase data collection and evaluation. Since the remediation monitoring phase is not the final decision point for completing the restoration remedial action in a given well, the determination may be made with a less robust data set using a visual or statistical (trend test or mean test) evaluation. Therefore, we recommend that a minimum of four data points be used for analyses during this phase. For most statistical tools, four data points normally should provide enough information to conduct a statistical analysis that produces results with sufficient statistical confidence.

The attainment monitoring phase, however, is intended to provide data that are evaluated to help support a defensible determination that: a) the groundwater in the well has met the cleanup level for each COC; and b) provides assurance that the groundwater will continue to meet the COC cleanup level in the future. Since the Groundwater Remediation Completion guidance recommends that completion of the attainment monitoring phase be based on two lines of evidence, in general, a more robust data set using a visual or statistical (trend test and mean test) evaluation is typically used to make the final attainment determination. Therefore, it is recommended that a minimum of eight data points normally be used for analysis done during the attainment monitoring phase.

For both phases, the recommended minimum number of data points, regardless of the type of tool, should support the reliability of the tool and increase confidence in the results if statistical tools will be used for data evaluation. Although these minimum numbers of data points are recommended as a general matter, site conditions and the statistical tools, if utilized, may help establish the appropriate number of data points for the evaluation of both phases.

Data Collection and Analysis Considerations

In general, a statistical analysis can be useful for both phases to help provide sufficient and defensible data when analyzing whether the COCs will remain at or below the cleanup levels selected in the decision document. Although recommended as a general matter, there may be site-specific,

contaminant-specific, or data set-specific circumstances where statistical analysis may not be appropriate or necessary.

Below are some considerations to evaluate which statistical tools, if any, may be appropriate to use. Where a statistical analysis may be appropriate, this document references statistical guidance to provide the user of this document with a resource for the recommended statistical tools. In addition to statistics, it is recommended, throughout the performance of groundwater monitoring, that Regions continually evaluate the integrity of the well to help ensure the validity of the data to be used to conduct the analyses discussed in this document.

Non-detects

A non-detect sample result normally indicates a concentration between zero and either the practical quantification limit (PQL) or the reporting limit (RL). These limits typically are based on the particular sampling instrument and the analytical method used. The number of non-detect data points and how they are used can play a significant role in the statistics used for the data analysis. It is recommended that the same sampling methodology and analytic procedures be used for all data collection for a restoration remedial action so that any non-detects may be considered consistently. There may be cases where use of non-detects based on different sampling methodology or analytic procedures is unavoidable. In this situation, it should be noted that the variation in PQL or RL may alter the statistical analysis. Refer to *Nondetects and Data Analysis: Statistics for censored environmental data using Minitab and R* (Helsel, 2012)[1] and Chapter 15 of *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended tools that may be useful when evaluating and considering non-detects.

Duplicate Samples

In general, duplicate samples are more than one sample (generally two) collected by the same team or by another sampler or team at the same place, at the same time. Duplicate samples are generally collected and analyzed to estimate sampling and laboratory analysis precision. Although they are two separate samples, duplicate samples are not statistically independent and should not be treated as independent water quality samples. Therefore, for purposes of data evaluation and analysis, it is recommended that either the maximum concentration or the average concentration be used.

Outliers

A statistical outlier normally is a value originating from a different statistical population than the rest of the population. Outliers or observations not derived from the same population as the rest of the sample violate the basic statistical assumption of identically distributed measurements. Outliers may result, for example, from contaminated sampling equipment, well integrity issues, laboratory contamination of the sample, or errors in transcription of the data values. However, outliers may also be the result of a release, a change in historical background conditions, or actual environmental variability.

[1] EPA recommends the use of Helsel methods for the evaluation of nondetects in this document. *Nondetects and Data Analysis: Statistics for censored environmental data using Minitab and R* is drafted by the U.S. Geological Survey (USGS) and, as such, EPA recommends its use for the nondetect statistical tools. However, EPA does not support any policy positions associated with the USGS document for evaluating completion of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) groundwater restoration remedial actions.

If a statistical test identifies an observation as a statistical outlier, then the measurement should not be eliminated without a valid and defensible reason for the abnormal value. Outliers should be removed from a data set only under valid and documented reasons. If a valid reason exists for the outlier, this measurement may be removed from the data set. Refer to the discussion in Chapter 12 of *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended tools that may be useful when evaluating and considering outliers.

Data Distribution

In general, the normal or non-normal distribution of a data set will influence what types of statistical analysis may be appropriate to a given situation. A parametric (or linear) distribution of data normally allows for more straightforward data evaluation. A non-parametric (or random) distribution of data usually requires more complex data evaluation. The parametric or non-parametric distribution of data should be analyzed to ensure that the results are defensible and accurate. Refer to the discussion in Chapter 3, Section 2.4 of *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended statistic tool data distribution considerations.

Analysis Approach

The sampling and data analysis considerations discussed above generally should inform development of the monitoring plan and influence both the type of sample data and the most appropriate statistical tools used for the remediation monitoring and attainment monitoring phases.

Remediation Monitoring Phase

The remediation monitoring phase at a monitoring well typically is complete when the data demonstrate that the groundwater has reached cleanup levels established for all COCs in the ROD. In general, it is recommended that a minimum of four data points be used to make this conclusion. The number of data points needed may be more than four, depending on both data behavior and the types and confidence levels of statistics that may be desired.

Once the data have been collected, a non-statistical or visual review of the data may be appropriate. If the groundwater COC concentrations are all “non-detect” (the PQL or RL is below the cleanup level) or a combination of “non-detect” sampling results and all detected COC concentrations is below the cleanup level, a statistical analysis may not be needed to accurately conclude that the COC cleanup levels have been reached. If the non-statistical review shows that monitoring data for all COCs in the well are “non-detect,” all detected COC concentrations are below the cleanup level, or a combination of the two, it may be appropriate to conclude that the remediation phase is complete in the monitoring well based on a non-statistical or visual analysis of the data.

Groundwater monitoring data may not lend themselves to a non-statistical review for all COCs for many groundwater remedies. In this scenario, COC concentrations in groundwater may be present at detectable levels both above and below the cleanup level, or for some samples, results may be “non-detect” after initially reaching the cleanup levels. Therefore, it may be appropriate to use a statistical analysis on a groundwater monitoring well data set to conclude that the groundwater has reached the cleanup levels for these COCs in the monitoring well. We recommend using one of the following two statistical methods when making this determination:

1. Mean test; **<u>or</u>**
2. Trend test

The statistical method of choice is at the discretion of the user of the data. Furthermore, the behavior of the data for each COC should help inform which statistical method may be appropriate for groundwater that has multiple COC concentrations. Therefore, it typically is not necessary to use the same statistical method for all COCs.

Mean Test

One recommended approach is the use of a statistical analysis to calculate the mean contaminant concentration from these data for the COC. Once the mean is calculated, confidence limits around the mean should be calculated to allow the user to account for uncertainty around the true mean. It is recommended that the upper confidence limit (UCL) be used to compare against the cleanup level instead of using the arithmetic mean. The lower confidence limit (LCL) generally should be appropriate for determining results that exceed the detection limits but should not be used for analysis of remediation phase completion. The use of the UCL value normally should account for uncertainty and provide confidence that the COC cleanup level has been reached. In general, the 95 percent UCL should be used as this recommended confidence limit. Refer to Chapter 21, Section 1.1 of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended statistical tools that can be useful for evaluating the mean and the UCL for parametric distributions. Refer to Chapter 21 and 22 of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended statistical tools that can be useful for evaluating the mean and the UCL for non-parametric distributions.

Trend Test

An alternative recommended approach is the use of a statistical analysis to calculate the time-dependent concentration trend for the COC. In general, the groundwater monitoring data should follow a normal distribution to employ trend statistics. If the data are not normally distributed, a data transformation may be appropriate to allow for the use of normal trend statistics. However, in some instances, it may be appropriate to use only nonparametric trend statistics. Once the trend is calculated, confidence limits around the trend line should be calculated to allow the user to account for variability within the data set. It is recommended that instead of using the trend line, the UCL on the trend line be used to compare against the cleanup level. The LCL on the trend line generally should not be used for this analysis. The UCL on the trend line accounts for uncertainty and provides confidence that the COC cleanup level has been reached. In general, the 95 percent UCL should be used as this recommended confidence limit. Refer to Chapter 10, Section 2, of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended data transformation tools. Refer to Chapter 21, Section 1.1 and Section 3.1, of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended statistical tools that may be useful when evaluating the trend and the UCL for parametric distributions. Refer to Chapter 21, Section 1.2 and Section 3.2, of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended statistical tools that may be useful when evaluating trend and the UCL for non-parametric distributions.

If the selected statistical method demonstrates that the UCL value is at or below the cleanup level for the COCs where a statistical analysis was used, then it may be appropriate to conclude that the remediation monitoring phase is complete.

Example

Figure 3 shows TCE, 1,2 DCE, and VC data collected during the remediation phase. When the data are inspected, the most recent data collected for all three contaminants show that the concentrations are approaching their specific clean up levels. Therefore, it may be an appropriate point to evaluate whether the remediation phase is complete.

TCE

From the inspection of the data in Figure 3, the TCE concentrations are rapidly approaching the cleanup level, with the last three samples concentrations below the cleanup level. Since the data indicate a more rapid decrease in concentrations, it may be appropriate to use the trend test to analyze if the cleanup level has been reached. Figure 4 shows the trend line and the UCL for the trend line for the TCE data using concentrations from samples 5 through 8. Evaluation of the UCL line in Figure 4 provides an indication that the TCE in the well has initially reached the cleanup level.

1,2 DCE

From an evaluation of the data in Figure 3, the 1,2 DCE concentrations are all below the cleanup level. Therefore, it may be appropriate to conclude that1,2 DCE has reached the cleanup level. In this circumstance, the use of statistics may not be necessary.

VC

From an evaluation of the data in Figure 3, the VC concentrations on the graph indicate that the VC concentrations in the well are near the cleanup level, with contaminant concentrations present at detectable levels both above and below the cleanup level. In this circumstance, it may be appropriate to use the mean test to evaluate whether the cleanup level has initially been met. When the first eight data points are put into the statistical tool, the UCL on the mean is 1.36 micrograms per liter (µg/L), which is below the cleanup level of 2 µg/L. The UCL on the mean provides a determination that the VC in the well has reached the cleanup level.

Based on both a nonstatistical (visual) and statistical evaluation for all COCs in the well, it may be appropriate to conclude that the remediation phase is complete in the well.

Groundwater monitoring should continue after the remediation monitoring phase is completed to verify that cleanup levels for each COC continue to remain at or below the cleanup level. (Refer to the **Attainment Monitoring Phase** discussion.) It is recommended that the site team evaluate the conceptual site model (CSM) and associated groundwater sampling program (frequency, locations, and parameters) to ensure that appropriate data are being and will continue to be collected for the **Attainment Monitoring Phase** evaluation.

Attainment Monitoring Phase

The Groundwater Restoration Completion Guidance recommends that well-specific conclusions be made throughout the lifetime of the remedial action; therefore, in some instances, it may be appropriate to conclude that the remediation phase is complete while an active system is being employed at the site. Since the attainment monitoring phase is intended to confirm that COC concentrations will remain at or below the cleanup level in the future, it is recommended that the attainment data set used to make these conclusions be limited to information collected after it has been demonstrated that groundwater in the well has reached post-remediation, steady-state, conditions. Therefore, it is recommended that Regions evaluate aquifer parameters within the well (i.e. water elevation stability) to determine if the groundwater has reached a steady-state and if it is being influenced by any ongoing site remediation activities. This evaluation should be carried out before the data set used to demonstrate completion of the attainment monitoring phase is collected.

Active System Considerations

Active systems generally involve physically extracting groundwater, injecting chemical/biological substrates into the groundwater system, heating the subsurface, and installing treatment barrier walls. In the case of active systems, changes in groundwater flow velocities, flow paths, or geochemistry typically can be induced when these technologies are employed. After the remediation phase is complete, it is recommended that the well be evaluated to decide if the groundwater in the well is influenced (physically or chemically) by the active system. If it is concluded that groundwater in the monitoring well is not influenced by the active system, contaminant concentrations should be evaluated to determine if the potential for rebound exists (e.g. increasing concentrations). If concentrations indicate that rebound may be occurring, then it generally is not appropriate to begin the attainment monitoring phase evaluation; instead, the Region should consider whether it is appropriate to continue monitoring or to re-start the active system.

If it is determined that the well is not being influenced by an active system and there is no indication that rebound may be occurring, it may be appropriate to continue collecting data for purposes of evaluating the attainment monitoring phase. In this situation, it also may be appropriate to include data that was used to demonstrate completion of the remediation monitoring phase as part of the attainment monitoring phase evaluation.

If the well evaluation concludes that groundwater in the monitoring well is influenced by an active system, we recommend that Regions should evaluate the purpose of the system. If the system involves a permanent containment technology at the site, this information should be factored into the post-remediation condition analysis. If the active system is being employed for restoration, it is generally not appropriate to begin collecting data for the attainment monitoring phase evaluation. Post remediation conditions normally would be reached when the system operation has been modified and it may be concluded, through subsequent data collection and analysis, that the well is no longer influenced by the system. In this situation, in general, data used to evaluate completion of the remediation monitoring phase should not be used to evaluate completion of the attainment monitoring phase.

Passive System Considerations

Typically, the aquifer is not as perturbed for a passive system, such as monitored natural attenuation (MNA), as compared with an active system. Therefore, in this circumstance, additional well samples to

determine if the well has reached post-remediation conditions are generally not necessary. Instead, when it is concluded that the remediation phase is complete, it may be appropriate to include additional data used to support completion of the remediation monitoring phase as part of the attainment monitoring phase evaluation (for example, if the data set for the two phases overlaps).

Attainment Evaluation

After the data evaluation concludes that the monitoring well has reached post-remediation (steady-state) conditions, we recommend that Regions continue to collect and analyze data in order to evaluate whether the attainment monitoring phase is complete. The attainment monitoring phase completion evaluation should be conducted separately for each COC at each well.

The attainment monitoring phase at a monitoring well typically is completed when contaminant-specific data provide technical and scientific support indicating that:

(1) The contaminant cleanup level for each COC has been met; and
(2) The groundwater will continue to meet the contaminant cleanup level for each COC in the future.

It is recommended that the same data set be used to make both attainment monitoring phase conclusions discussed above for each COC. It is recommended that a minimum of eight data points be used in these analyses.

If all the COC monitoring data to be evaluated are "non-detect" and the PQL or RL is below the cleanup level, it may be appropriate for the Region to conclude that both the cleanup level has been met and that the groundwater will continue to meet the contaminant cleanup level for each COC in the future. In this situation, a statistical analysis of the groundwater monitoring data is generally not needed.

1. Evaluation of whether a cleanup level for each COC has been met

It is recommended that a statistical analysis be used to help calculate the UCL on the mean contaminant concentration from the data. The calculated UCL on the mean should be compared against the cleanup level for the COC. In some instances, a nonstatistical or visual review of the COC data may be sufficient to conclude that the cleanup level has been met. It may be sufficient if the groundwater COC concentrations are all "non-detect, the PQL/RL is below the cleanup level, or a combination of "non-detect" sampling results and all detected COC concentrations are below the cleanup level. Refer to the **Remediation Monitoring Phase** mean test discussion for addition information and recommended tools to calculate the COC mean and the UCL.

If the data analysis demonstrates that the UCL value is at or below the COC cleanup level, it generally is appropriate to conclude that the COC cleanup level has been met. The next recommended step is an evaluation of whether the groundwater will continue to meet the contaminant cleanup level for each COC in the future.

If the data analysis demonstrates that the UCL value is above the COC cleanup level, it is appropriate to conclude that the COC cleanup level has not been met. In this case, additional monitoring or remediation is generally warranted.

2. Evaluation of whether the groundwater will continue to meet the contaminant cleanup level for each COC in the future

It is recommended that a statistical analysis be used to help analyze the COC concentration trend over time. In particular, a trend analysis is recommended to provide additional support for concluding that future COC concentrations will remain at or below the COC cleanup level in the well.

In general, the groundwater monitoring data should follow a normal distribution to employ trend statistics. If the data are not normally distributed, using a data transformation may be appropriate to allow for the use of normal trend statistics. However, in some instances, it may be appropriate to use only nonparametric trend statistics. Refer to Chapter 10, Section 2, of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended data transformation tools. Refer to Chapter 21, Section 1.1, of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended parametric trend analysis tools. Refer to Chapter 21, Section 1.2, of the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (March 2009) for recommended non-parametric trend analysis tools.

If the trend line has a statistically significant zero or negative slope (steady state or decreasing), it may be appropriate to conclude that the contaminant concentrations for each COC in groundwater will remain at or below the cleanup level.

In general, if the trend line has a statistically significant positive slope (the concentration trend is increasing), a determination that the groundwater will continue to meet the contaminant cleanup level for each COC in the future may be premature. If the concentration trend is increasing, additional monitoring is recommended to evaluate the possibility of contaminant rebound for the COC in the aquifer. In this case, the attainment monitoring phase normally would not be complete.

If both the UCL value is at or below the COC cleanup level and the time-dependent trend line has a zero or statistically significant negative slope, it may be appropriate to conclude that the attainment monitoring phase has been completed for the COC being evaluated.

As the COC-specific attainment decisions are made, it is recommended that the decision, together with supporting data, be documented in a monitoring report.

Example

Figure 2 may be referenced to show data for TCE, 1,2 DCE, and VC collected after the remediation monitoring phase was deemed complete.

TCE

From inspection of the data in Figure 2, after the remediation phase has been completed, the TCE concentrations over the next two sampling events increased and exceeded the maximum contaminant level (MCL) of 5 µg/L. As can be seen from the data, after this temporary increase in TCE concentrations, subsequent data collected showed groundwater TCE concentrations at or below the cleanup level. In this circumstance, the attainment data analysis was conducted using all data collected after it was concluded that the remediation monitoring phase was complete (samples 9-18). After conducting a mean test, the UCL on the mean was 4.63 µg/L, which is below the cleanup level of 5 µg/L (see Figure 5 for the UCL on the mean). This statistical analysis supports a conclusion that the cleanup level for TCE continues to be met.

Figure 5 displays the data used for the attainment monitoring phase evaluation for TCE and shows the trend line for the data. The figure shows a decreasing slope of the trend line. This decreasing slope provides assurance that the groundwater will continue to meet the cleanup level in the future. Therefore, it may be concluded that the attainment monitoring phase is complete for TCE.

1,2 DCE

From a visual evaluation of the data in Figure 2, the 1,2 DCE concentrations after remediation monitoring phase has been completed continue to remain below the cleanup level. In addition, visual inspection of the data indicates that the concentrations are decreasing. A visual inspection confirms that the groundwater in the well continues to meet the cleanup level for this contaminant. In addition, a simple trend analysis indicates that the trend on the data is decreasing, which provides assurance that the groundwater will continue to meet the cleanup level in the future. Therefore, it may be appropriate to conclude that the groundwater restoration remedial action is complete for 1,2 DCE in the well being evaluated.

VC

From inspection of the data in Figure 2, after the remediation phase has been completed, the VC concentrations over the next eight sampling events are below the MCL of 2 µg/L. Since there was no rebound on increase in concentrations, it may be concluded that the groundwater is at steady state. In this circumstance, it may be appropriate to use some of the data from the completion analysis for the remediation monitoring phase in the attainment monitoring phase data set. Two data points (7 and 8) will be used as part of the attainment monitoring phase analysis. The attainment data analysis was conducted using data from sampling events 7-14. After conducting a mean test using eight data points, the UCL on the mean was 1.89 µg/L which is below the cleanup level of 2 µg/L (see Figure 6 for the UCL on the mean). This statistical analysis supports a conclusion that the cleanup level for VC continues to be met.

Figure 6 displays the data used for the attainment monitoring phase evaluation for VC and shows the trend line for the data. The figure shows a decreasing slope of the trend line. This decreasing slope provides assurance that the groundwater will continue to meet the cleanup level in the future. It may be appropriate to conclude that the attainment monitoring phase is complete for VC.

Based on the individual attainment monitoring phase analyses for all three contaminants, it may be appropriate to determine that the groundwater in the well has met the cleanup levels established in the ROD, for purposes of the recommendations discussed in the Groundwater Remediation Guidance.

Future Well Considerations

After the attainment monitoring phase is completed for all COCs at a well, Regions should consider the potential future use of the well. In some instances, it may be appropriate to continue monitoring the well, at appropriate intervals, to ensure the groundwater remedial action selected in the ROD continues to meet established cleanup levels. Similarly, it may be appropriate to continue monitoring the well, for the foreseeable future, to verify the performance of a groundwater or source containment remedy. If the well is no longer needed for monitoring, groundwater sampling typically may be terminated; in these situations, it also may be appropriate to decommission the well.

Conclusion

The recommendations in this attachment are intended to provide guidance regarding well-specific factors Regions should consider when evaluating whether CERCLA groundwater restoration remedial actions are complete, as discussed in the *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*. If the Region has any questions regarding the application of this approach or site-specific questions regarding completion of groundwater restoration remedial actions, they are encouraged to consult with the Office of Superfund Remediation and Technology Innovation (OSRTI) by contacting Kate Garufi at garufi.katherine@epa.gov, (703) 603-8827 or David Bartenfelder at bartenfelder.david@epa.gov, (703) 603-9047.

Figure 1: Example Well Groundwater Contaminant Data

Trichloroethylene		1,2 dichloroethylene		Vinyl Chloride	
Sampling Event	Conc. ug/L	Sampling Event	Conc. ug/L	Sampling Event	Conc. ug/L
1	93	1	30	1	0.15
2	82	2	37	2	0.21
3	52	3	49	3	0.41
4	19	4	52	4	0.82
5	6.1	5	56	5	1.1
6	4.2	6	64	6	1.3
7	2.8	7	60	7	2.1
8	1.8	8	58	8	1.7
9	4.3	9	48	9	1.8
10	6.1	10	42	10	1.9
11	4.6	11	28	11	1.8
12	4.5	12	27	12	1.7
13	5.3	13	14	13	1.7
14	3.9	14	12	14	1.6
15	3.3	15	11	15	1.6
16	2.1	16	10	16	1.3
17	1.4				
18	0.85				

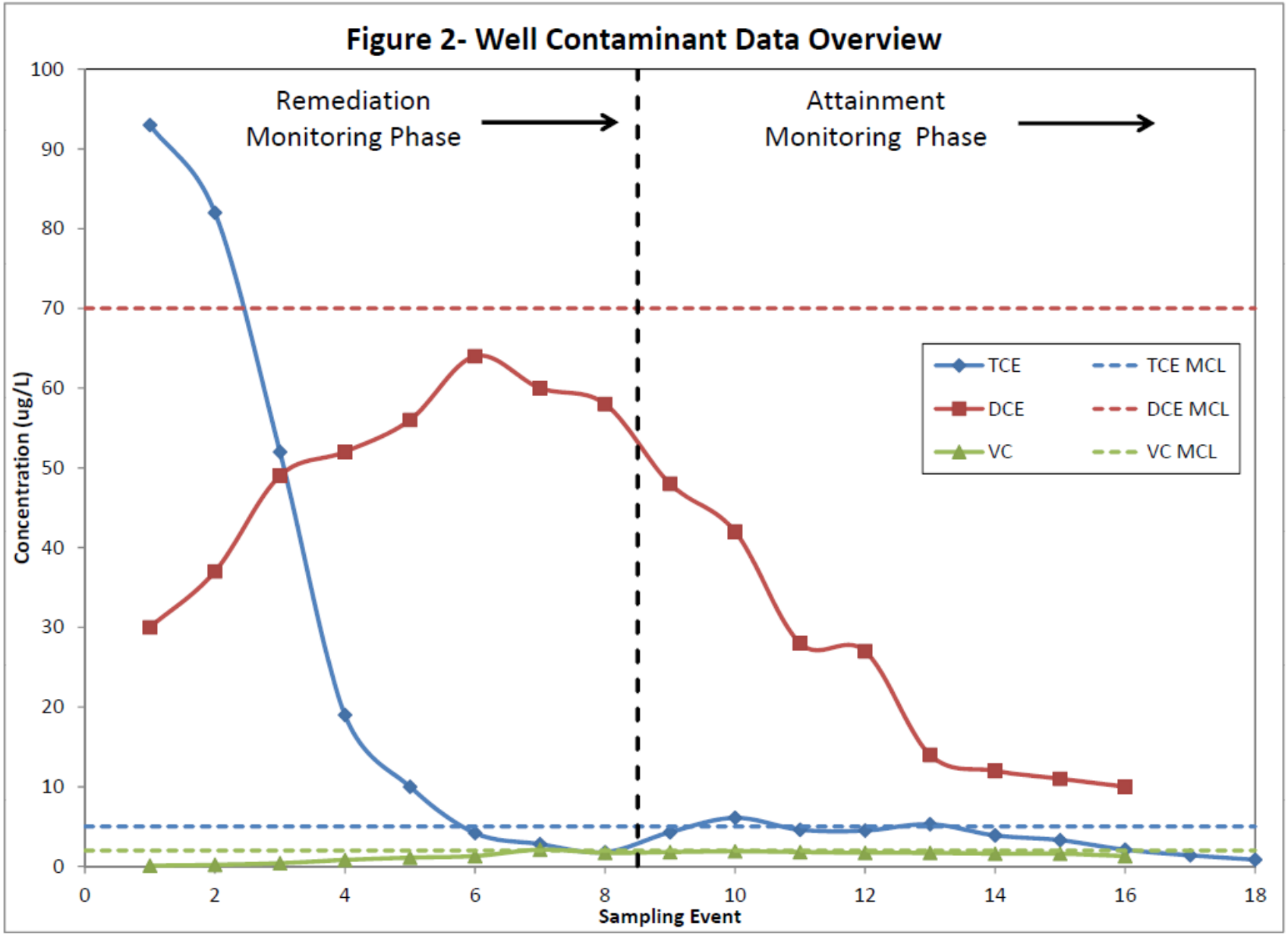
Figure 2- Well Contaminant Data Overview
Remediation Monitoring Phase
Attainment Monitoring Phase
TCE
TCE MCL
DCE
DCE MCL
VC
VC MCL
Concentration (ug/L)
Sampling Event
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18

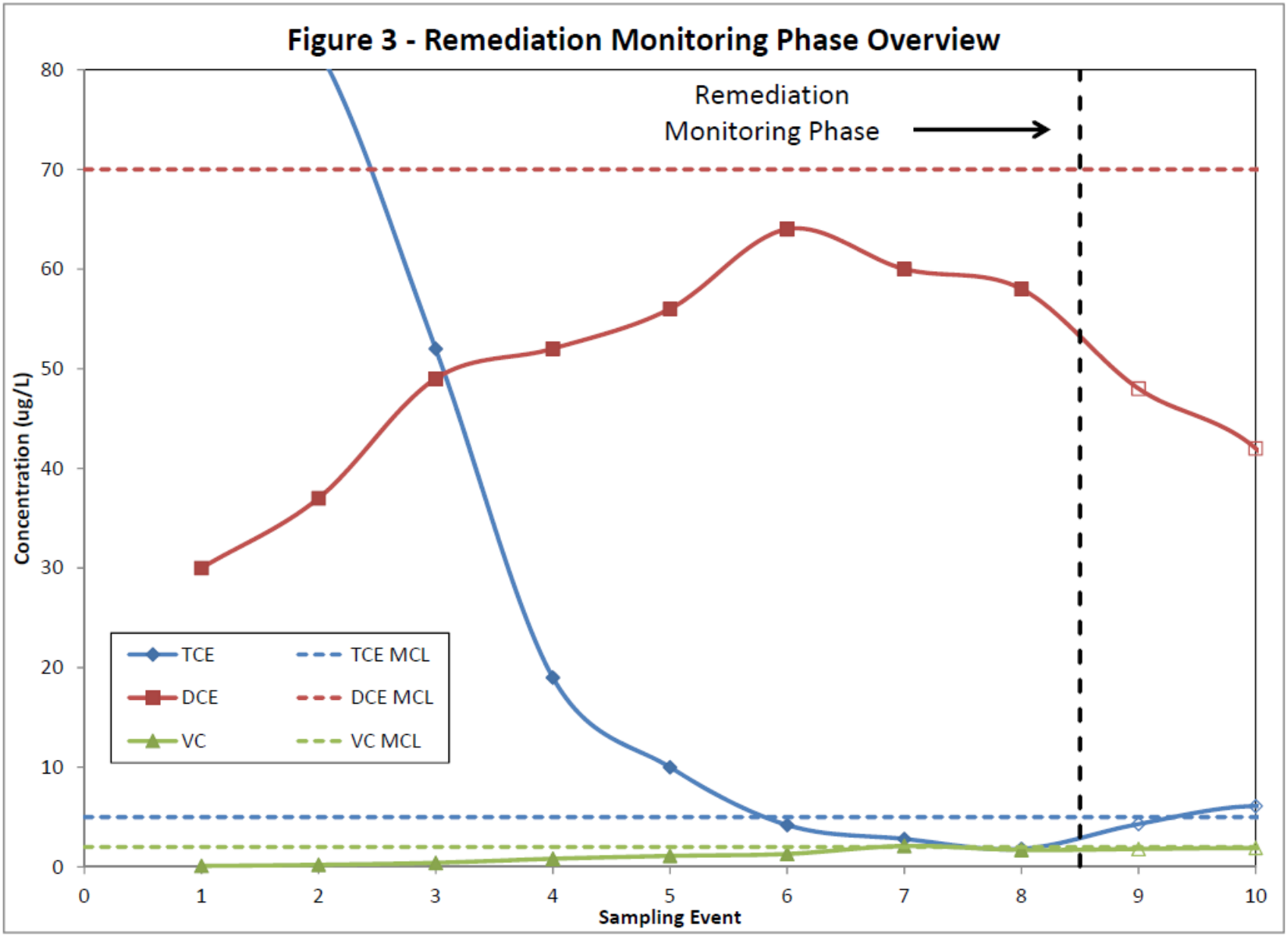
Figure 3 - Remediation Monitoring Phase Overview
Remediation
Monitoring Phase
Concentration (ug/L)
Sampling Event
TCE
TCE MCL
DCE
DCE MCL
VC
VC MCL
0
10
20
30
40
50
60
70
80
0
1
2
3
4
5
6
7
8
9
10

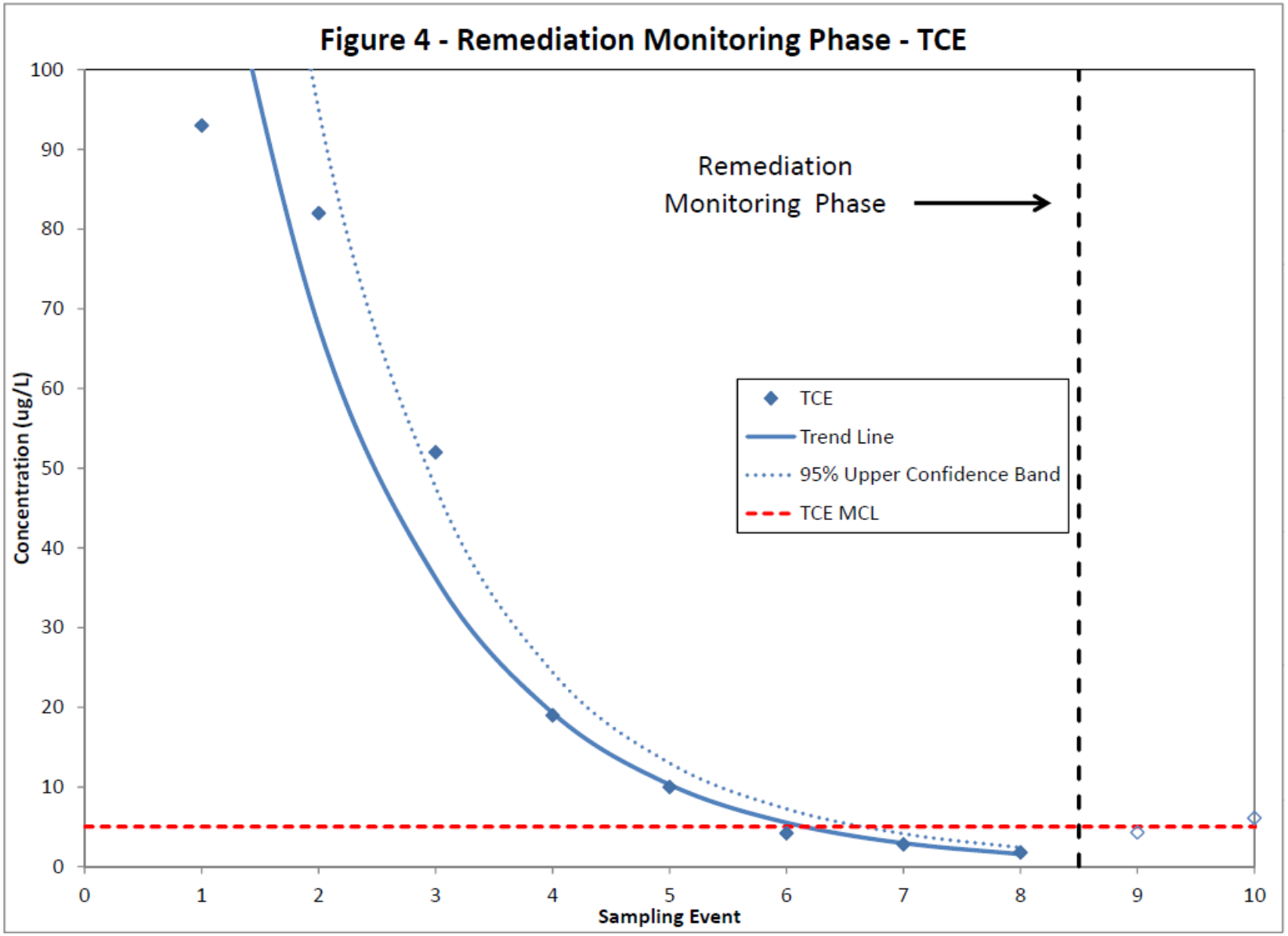
Figure 4 - Remediation Monitoring Phase - TCE
Remediation
Monitoring Phase
TCE
Trend Line
95% Upper Confidence Band
TCE MCL
Concentration (ug/L)
Sampling Event
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10

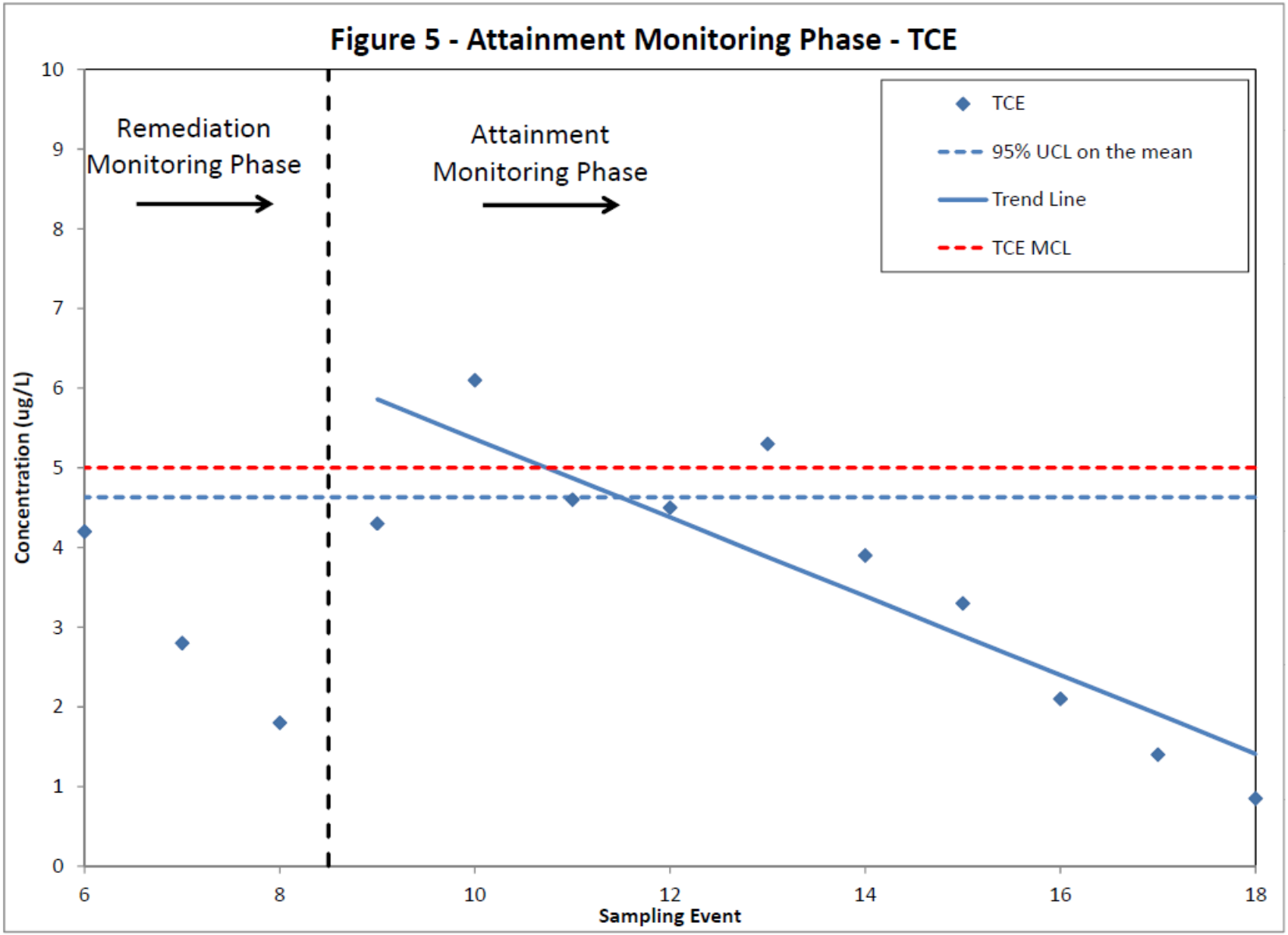
Figure 5 - Attainment Monitoring Phase - TCE
Remediation Monitoring Phase
Attainment Monitoring Phase
TCE
95% UCL on the mean
Trend Line
TCE MCL
Concentration (ug/L)
Sampling Event
0
1
2
3
4
5
6
7
8
9
10
6
8
10
12
14
16
18

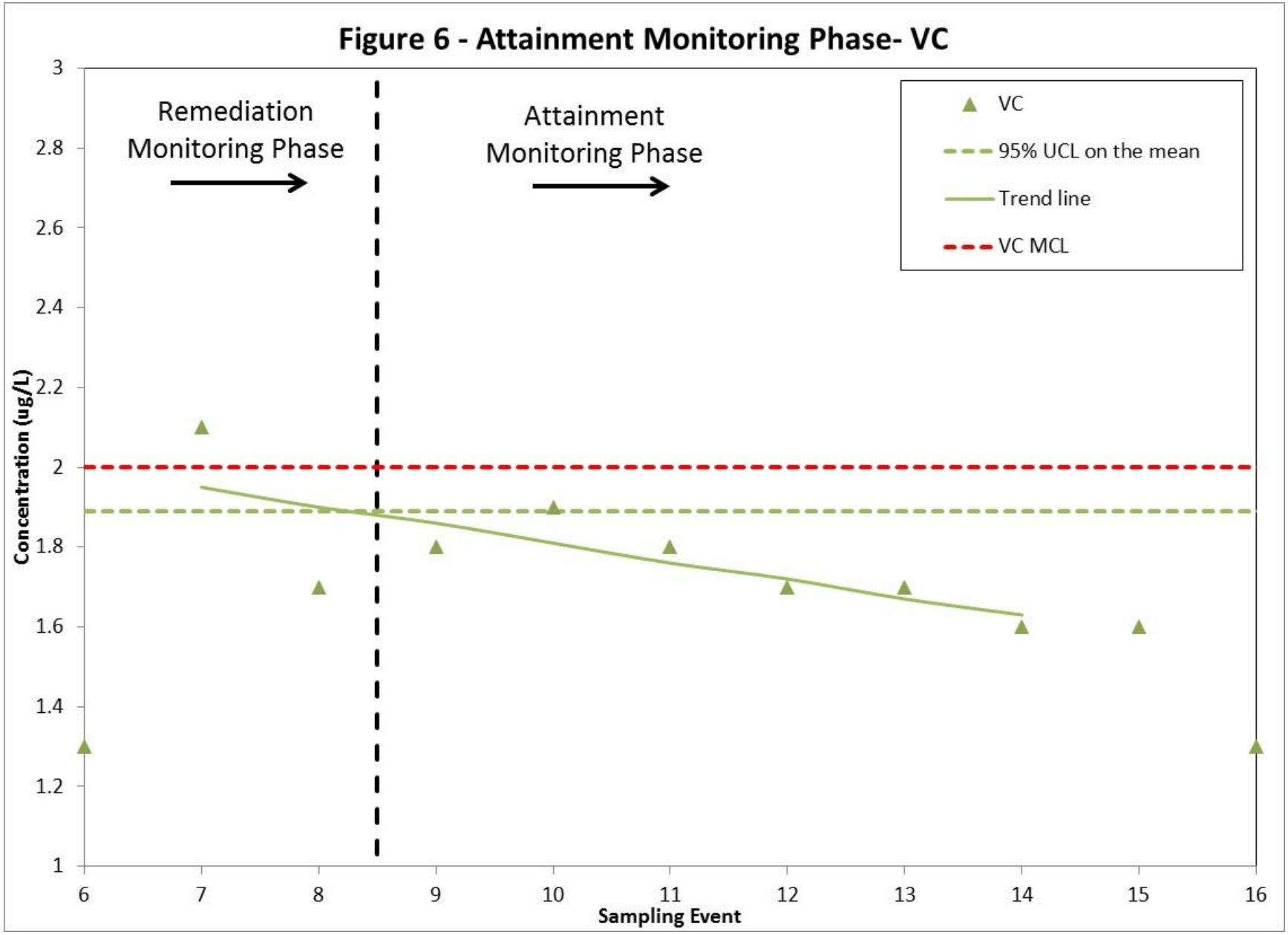
Figure 6 - Attainment Monitoring Phase- VC
Remediation Monitoring Phase
Attainment Monitoring Phase
VC
95% UCL on the mean
Trend line
VC MCL
Concentration (ug/L)
Sampling Event
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
6
7
8
9
10
11
12
13
14
15
16