Strategy for Demonstration of Attainment of Groundwater Cleanup Levels – 14618

Trevor Budge and Alaa Aly
INTERA Incorporated

ABSTRACT

The methodologies, criteria, and a strategy for 1) determining when active groundwater remediation can be ceased and 2) demonstrating that final groundwater cleanup levels have been attained as a result of active and passive remediation at contaminated sites at the U.S. Department of Energy Hanford Site are discussed. This excludes the monitoring requirements for solid waste management units or Resource Conservation and Recovery Act (RCRA) treatment, storage, and disposal facilities managed at the Hanford Site. The exact regulatory framework used to determine closure for a specific area is not discussed, however, the general strategy for approaching site closure is discussed to provide context to the processes, analyses, and data that are required, in general, by the various regulatory frameworks for demonstrating the attainment of cleanup levels in groundwater. The paper is organized into three sections. First, a brief background description provides focus for understanding groundwater remediation objectives and cleanup levels. This is followed by a review of the methods and criteria discussed in governing regulatory requirements and guidance documents. Lastly, the paper details a strategy for meeting these criteria for contaminated groundwater operable units (OUs), where active remedial actions have been implemented through an example calculation using hypothetical concentration observations at two wells.

INTRODUCTION

Decades ago, plutonium production operations at the U.S. Department of Energy Hanford Site left areas of groundwater contamination both on the Central Plateau and near the Columbia River. Remediation of groundwater contamination has been ongoing work at the Hanford Site since the mid-1990s. The cleanup objectives for groundwater are summarized in the remedial action objectives (RAOs) provided in the remedial investigation/feasibility study for several Hanford OUs (DOE/RL-2010-95, DOE/RL-2010-96, DOE/RL-2010-97, DOE/RL-2010-98, DOE/RL-2010-99). They are:

- Prevent unacceptable risk to human health from ingestion of and exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds, and
- Prevent unacceptable risk to human health and ecological exposure to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.

Remedial Action Objectives (RAOs) are to be achieved through institutional controls to prevent groundwater use, and reduction in concentration of contaminated groundwater through active remediation or enhanced- and natural-attenuation processes until concentrations fall below federal and state cleanup levels. The federal and state levels and risk-based thresholds for OU contaminants of concern (COCs) are developed based on Federal maximum concentration limits (MCL); the criteria and equations in the state of Washington Administrative Code (WAC) Model

Toxics Control Act (MTCA) Method B cleanup levels for potable groundwater (WAC 173-340-720[4][b][iii][A] and [B], and WAC 173-340-720[7][b]); and the Federal drinking water standards for radionuclides. Cleanup levels are provided for COCs in the decision documents prepared for each corresponding OU.

REGULATORY CLOSURE SUMMARY

Document DOE/RL-2007-20, Hanford Integrated Groundwater and Vadose Zone Management Plan, identifies that both Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and RCRA requirements and guidance are to be taken into consideration in determining a process for demonstrating cleanup of contaminated groundwater. This section summarizes the applicable regulatory information for determining cleanup of the groundwater has been achieved.

Compliance Monitoring

Compliance monitoring begins at a point of compliance when the remedial action is stopped. This monitoring includes gathering observational data that are used to determine whether a remedial action has achieved its goal(s), and groundwater at the compliance point can be declared clean. If the remedial action is pump-and-treat, all extraction wells influencing the point of compliance must cease extraction and injection prior to compliance monitoring. When in the case that bio-venting and/or bio-sparging is the remedial action, the air/nutrient injection must be terminated prior to the commencement of compliance monitoring. This differs from performance monitoring that occurs throughout the life cycle of the remedial action. Compliance monitoring wells are likely to be a subset of the performance monitoring well network or additional compliance wells might be needed beyond those used during the remedy performance monitoring period. Compliance monitoring must be conducted after the aquifer is no longer under the influence of active remedial activities. It is typically expected that some “rebound” of contaminant concentration will occur after termination of remedial activities. The compliance period is established to assess whether the contamination level and any “rebound” will remain below the clean-up level. The duration of the compliance period is ultimately site specific. However, federal regulations under RCRA (40 CFR 264.96) defines a three year compliance time period for sites involved in a “corrective action program”. Furthermore, in *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites* (EPA 540-G-88-003) section 2.4.2.3 the RCRA time frame may be applicable at Superfund sites. Based on the coexistence of RCRA and CERCLA sites at Hanford, planning for compliance monitoring is recommended for a time period of no less than three years. However, based on the site specific conditions the regulators and owner/operators may adjust this time frame through joint negotiation.

Typical Evolution of Remedial Activities

A typical conceptual timeline for remediation progress for a site or a specific well is shown in Figure 1 (EPA/230-R-92-014, 1992). The groundwater contaminant concentration shown in the chart indicates the typical responses to each of these activities. Remediation activities at the Hanford Site are expected to follow a similar pattern. The focus of this paper is highlighted in Figure 1 where several milestones in the remediation process are shown in the figure including:

1) Start Remediation – Represents the point in time when active and/or passive remedial actions have been implemented.
2) Active and Passive Remediation with Performance Monitoring – Includes the period of time contaminant reduction due to remedial practices is monitored and/or optimized to ensure progress toward cleanup is being made.
3) End Remediation – The point in time when active and/or passive remediation is ceased. It is typically expected that some "rebound" of contaminant concentration will occur after termination of remedial activities.
4) Start Compliance Monitoring – This may or may not coincide with the end of step 3 depending on site specific conditions relating to the time for site conditions to return to pre-remedial action conditions. Compliance monitoring wells are likely to be a subset of the performance monitoring well network or additional compliance wells might be needed beyond those used during the remedy performance monitoring period.
5) End Compliance Monitoring, Declare Clean or Contaminated – Point in the process where statistical analysis of the data indicate the contamination level will or will not rise above the cleanup level. The type of analysis required by regulatory guidance for this declaration is the subject of this paper and is discussed in more detail in the subsequent sections.

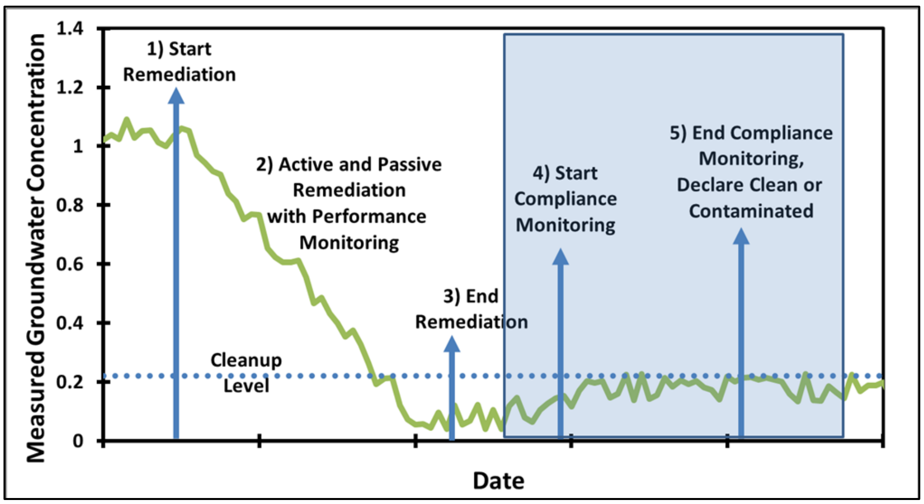

Figure 1. Typical timeline for meeting cleanup levels for a contaminated site (based on EPA/230-R-92-014).

Point of Compliance

The point of compliance is also referred to as the area of attainment in the CERCLA and RCRA guidance documents. The latter terminology reflects the expectation in both regulations that "remediation levels generally should be attained throughout the contaminated plume and beyond the edge of the waste management area when waste is left in place" as defined for CERCLA (OSWER 9283 1-33, 2009). The RCRA point of compliance has a separate definition found in 40 CFR 264.95 stating "the point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units." This appears to be a significant departure from the CERCLA definition. However, in the Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action (EPA 530-R-04-030, 2004) the expectation is expanded by the statement:

> "EPA believes the recommended throughout-the-plume/unit boundary point of compliance for final clean up goals is consistent with EPA's overarching goal of protecting human health and the environment by returning "usable" groundwater to its maximum beneficial use, where appropriate."

This statement places both the CERCLA and RCRA expectations for point of compliance at the same level. The throughout-the-plume approach to achieving remediation goals is mirrored based on the requirements found in MTCA (WAC 173-340-720 [8](b)) which states, "The standard point of compliance shall be established throughout the site from the uppermost level of saturated zone extending vertically to the lowest most depth which could potentially be affected by the site." Each of the regulations discusses the attainment of remediation goals throughout the site.

However, no feasible monitoring plan can sample all locations and all times throughout the site. The use of monitoring wells at locations throughout the site monitored at a defined interval of time is a practical method for assessing the plume cleanup. Table 1 provides the references to monitoring well network guidance for each of the frameworks that may be applicable to the Hanford Site. Regulations are purposefully non-prescriptive with regard to development of monitoring well networks as site specific conditions will dominate the details of the process. However, general objectives that are common through all of the regulatory frameworks include: 1) evaluate the effectiveness of the remedial action, 2) evaluate contaminant migration, and 3) cleanup levels are typically met at all defined compliance wells.

Table 1. List of references for developing monitoring networks

Regulatory Framework	Reference
CERCLA	Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation, OSWER Directive No. 9355.4-28
RCRA	Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action, EPA 530-R-04-030
MTCA	WAC 173-340-410, 173-340-720, and 173-340-820

Objectives 1 and 2 deal primarily with the spatial characteristics and placement of monitoring wells throughout the site. Objective 3 involves how to determine compliance at individual wells across the site. Compliance at wells is determined on a well by well basis as described in the documents mentioned in Table 1. These objectives are discussed in more detail in the following sections.

Sub-Regions and Well Groups

Based on guidance discussed above each well defined as a compliance well must meet the closure criteria for the specified compliance monitoring period in order for a site to be closed. Therefore, the selection of compliance wells should be done in a manner that 1) assesses the remedial activities performance and 2) evaluates contaminant migration. Figure 2 shows a hypothetical compliance monitoring network for a fictional location. This figure illustrates some key strategies that should be considered when developing compliance networks at the Hanford site. Wells are placed throughout and downgradient of the plume. The compliance wells are assigned to a region of the hypothetical area based on the expected performance of the system and the contaminant distribution. Specifying compliance sub-regions for this location, termed focus area for this example, provides an opportunity to begin compliance monitoring for sub-regions when active remediation for the sub-region has ceased, but before the active remediation is terminated for the entire area. In Figure 2, once all compliance wells for the sub-region for focus area A or B are complete, the compliance monitoring period can begin for the respective focus area. The assignment of compliance wells to a focus area of within the site should be completed after analysis of observed data and numerical models by project scientists and engineers.

The assignments should reflect the most recent conceptual site models for what remedial actions are likely to effect the location of the compliance well (EPA 530-R-04-030). Figure 2b illustrates an example where after a period of time has passed, the assignment of a compliance well is shown to be more influenced by a different focus area B after initially being assigned to focus area A. Monitoring and sampling and analysis plans should address a process for changing the focus area assignment of compliance wells to another focus area if performance monitoring indicates the well is better assigned to a different focus area. Reassignment of wells to a different focus area is likely to require input from regulators to be completed.

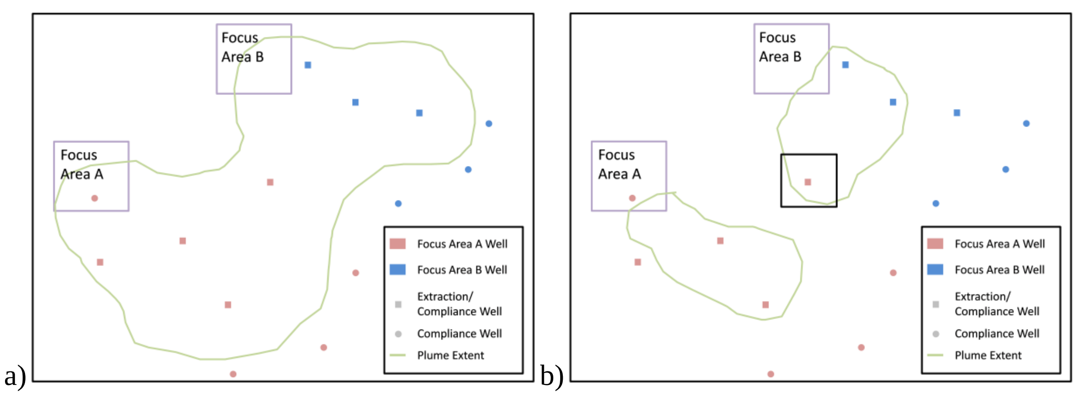

Figure 2. Hypothetical plume with compliance monitoring network: a) initial concentration at the time of implementation of the remedial activity; b) same plume after a period of pump-and-treat operations.

Individual Well Compliance

Site closure requires the concentration of COCs to be below the cleanup level throughout each contaminant plume. While performance monitoring can employ statistical approaches to evaluate the plume as a whole, guidance from RCRA, CERCLA, and MTCA each specify compliance monitoring for closure must be accomplished at each well throughout the site. The strategy outlined in this paper focuses on determining compliance using data collected at an individual well. Each regulatory framework provides caveats to this requirement where site specific considerations warrant a different approach to compliance. Some examples include where contamination is left in place as a designated waste management area, where migration of the plume is extremely slow making it technically infeasible to recover, or where the plumes cover a large area with co-mingling sources. While, these situations may apply at certain locations at the Hanford Site, this paper will not go into detail about these site-specific situations. The focus of this strategy is how to determine when a single well is in compliance with cleanup levels and the data and analyses necessary to demonstrate this. Only by assessing individual well compliance can the goal of achieving compliance at the entire site be attained.

Compliance and Performance Optimization Tools

The costs associated with installation and operation of monitoring wells for performance or compliance are significant and persistent. EPA 542 R-05-003 outlines the methods used to optimize the location of wells, the temporal sampling, and methods of analysis to complete this work. The guidance emphasizes that the analysis and optimization of monitoring plans using statistical, analytical, and numerical modeling tools are essential to provide efficient designs of monitoring networks. When developing monitoring and compliance plans, numerical and statistical models should be utilized, with input from stakeholders and regulatory agencies, to ensure performance and compliance plans are developed in a manner that will provide robust monitoring and be efficient from a cost perspective.

CONSIDERATIONS NEAR THE COLUMBIA RIVER

MTCA (WAC 173-340-720 [6], [8](d and e)) provides guidance for groundwater cleanup near surface water bodies. In these cases MTCA requires that surface water cleanup levels be used for determining compliance in place of groundwater cleanup levels as a means to protect surface water bodies. Site specific evaluation of habitat and use of the surface water body should be considered for determining the cleanup levels as they will influence the timing and attainment of cleanup.

For properties abutting surface water, such as sites near the Columbia River at the Hanford Site, the point of compliance is defined as the location where groundwater flows into the surface water body (WAC 173-340-720 [6]). The standard acknowledges that monitoring locations are necessary to establish compliance and MTCA (WAC 173-340-720[8](e)) discusses the use of upland monitoring wells for compliance points with approval from the Washington Department of Ecology. Any use of upland wells must be placed as close as reasonably possible to the interface of the surface water and groundwater. Extensive monitoring along the Columbia River has been conducted using a specially designed piezometer, called an aquifer tube, installed near the surface water groundwater interface. While no statute specifically addresses the use of this type of apparatus for compliance, none expressly prohibits their use. When these locations provide a reasonable point of compliance and traditional well placement near these locations is not feasible their use should be considered.

MTCA guidance does not allow the use of a mixing zone calculation to determine compliance. But, there is allowance of alteration of the concentration based on natural attenuation (WAC

173-340-720 [8](e)). This allowance also must determine if natural processes may cause exceedance of the concentration levels of byproducts of the attenuation process. The method used for making this determination is not specified and requires approval from the regulatory agency.

Protecting Aquatic Habitat

The National Ambient Water Quality Criteria (NAWQC) and the State of Washington Water Quality Standard (WQS) are designed to be protective of aquatic life within receiving waters across the U.S. and the State of Washington, respectively. The NAWQC published by U.S. EPA serve as a source of toxicological data that states then use as the basis for promulgating state-specific enforceable standards. The criteria and standards have levels protective of exposure to ongoing ambient conditions that represents long-term continuous exposure (the criterion continuous concentration [CCC]) as well as short term exposure (the criterion maximum concentration [CMC]). Most of the criteria and standards are established by selecting a value that is protective of several classes of organisms that includes fish and benthic invertebrates among others. The final number is a statistical representation of concentration that may result in an effect to the tested organisms and an additional safety factor is applied. For some chemicals, mostly acute data are available and adjustments are made by applying an acute-chronic ratio established from available data.

In making remedial decisions or risk management decisions regarding groundwater plumes migrating to surface water, the origins of the WQS and its relation to the site specific conditions at the Hanford Reach of the Columbia River should be considered. There are plumes of groundwater from the Hanford Site leading to the Columbia River that contain COC concentrations above both the acute and chronic WQS. The standards as recommended by EPA and written into state law are as follows: the four-day average can only exceed the chronic value once every three years and the one-hour average cannot exceed the acute value more than once every three years. However, there is no guidance as to how to determine the average or what frequency of sampling is required or allowed. Based on how the criteria were derived and how they are applied, there are options for establishing whether there are clear adverse effects to aquatic life occurring within the Hanford Reach of the Columbia River. One such option is to more fully research available toxicological data of Hexavalent Chromium as available information is greater than it was in 1980 when the Ambient Water Quality Criteria for Chromium (EPA 440/5-80-035, 1980) was published. This evaluation could also be combined with identification of the ecological exposure model for receptors within the Columbia River both in terms of the aquatic food web present and the areal extent, magnitude, repeatability, and seasonal timing of potential upwelling exposures. Together the updated toxicological data and exposure model could be used to identify a site-specific value that is protective of aquatic life relevant to the Hanford Reach and to be used in risk management decisions.

RECOMMENDED STATISTICAL METHODS

Two main elements are to be considered for compliance monitoring at individual wells. First, the timing of when to cease active remediation and second the statistical methods used to compare observed concentration measurements to the cleanup level to demonstrate compliance. These are discussed below.

Ceasing Remediation

Compliance monitoring must take place after active remediation has ceased. The timing for determining when to terminate active remediation is critical to overall project costs. If shutdown is too soon there is a possibility that contamination may rebound and rise above cleanup levels. If shutdown is continued past when the remediation is effective, the costs associated with continued operation and maintenance would rise higher than necessary, thus resulting in resources not being allocated where the maximum benefit to the environment is achieved at the Hanford Site as a whole. EPA/230-R-92-014 suggests using regression analysis on the observed concentration data as an aid for determining when to cease active remediation. The selected regression model should be checked to make sure residuals from the regression are normally distributed and have a constant variance (other regression methods and transformations can be employed to work with situations where these assumptions cannot be supported). A prediction based on the regression analysis estimated with confidence limits can be calculated in order to assess the likelihood that the concentration values will rebound.

The regression analysis methodologies mentioned in EPA/230-R-92-014 are only one method for making a determination to cease active remediation. Depending on the level of uncertainty associated with the decision to cease active remediation (e.g., shutdown/startup costs, rebound likelihood) more robust tools should be used to make this determination. Some of these include the use of fate and transport models, geostatistical analysis of water level and quality data in conjunction with expert analysis by professionals with working history of the site. These should be used in conjunction to make these decisions. Regression analysis provides a simple tool for quick estimation of well by well performance throughout the life of the remedial activities. Ideally, regression analysis should be used as a pre-cursor to more robust analysis using fate and transport models for major changes in remedial activities at the Hanford Site.

Compliance Comparison

EPA 530 R-09-007 Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities provides details of the recommended statistical analyses to be used for compliance assessment. Compliance involves comparing the observed concentration data to a cleanup level. The uncertainty in the observed mean is quantified by calculating the upper confidence limit about the mean. When the upper confidence limit falls and remains below the cleanup level for the duration of the compliance period the well is considered to be in compliance. MTCA (WAC 173-340-720[9](e)) contains three exceptions to the use of the UCL95 for calculating compliance. These include: 1) no single measurement is allowed to exceed two times the cleanup level, 2) no more than 10 percent of the measurements can exceed the cleanup level for a given sampling period, and 3) if more than 50 percent of the measurements are non-detect, the maximum concentration value will be used for comparison to the cleanup level.

Chapters 21 and 22 of EPA 530 R-09-007 provide the recommended methodology for calculating this value under the RCRA framework. MTCA (WAC 173-340-720[9]) provides the recommended statistical methods for the state of Washington. Both sets of guidelines recommend similar methods for calculating the upper confidence limit. Chapter 21 of EPA 530 R-09-007 recommends completing a regression analysis on the post-remedial action data for comparison to the cleanup level in addition to the UCL calculation on the data. Trend analysis can provide a “significant advantage” over prediction limits due to non-stationary behavior of the observed data overtime (EPA 530 R-09-007). Guidance on using trend analysis recommends checks including normality of residuals to verify that the trend analysis is an acceptable method. Based on these guidance documents, the recommended steps for comparing the observed data to the cleanup levels are as follows:

- Test data for normality
- Calculate the UCL
- Calculate UCL of the Trend Analysis
- Compare to the cleanup level

Methods for using a fixed time interval or a sequential time interval exist for calculating the UCL95 and are proposed in EPA/230-R-92-014. A quarterly monitoring cycle using the fixed interval coincides with guidance provided in EPA/530-R-09-007 and 40 CFR 264.99. For the purpose of this paper the fixed time interval for calculating a yearly average UCL95 is applied. All UCL95 calculations will utilize at least 8 concentration measurements in order to maintain statistical significance (EPA/530-R-09-007). If more than eight measurements exist for the current year then all points will be used. If less than eight measurements are available for the current year then the nearest measurements from the previous year(s) will be used until at least eight values are selected for use.

All regulatory frameworks specify compliance monitoring must be completed once active remediation has ceased (WAC 173-340-720[9](c)(iv), EPA/230-R-92-014). Compliance monitoring continues throughout the compliance period that lasts at least three consecutive years (40 CFR 264.96(c)). The three-year period provides time to monitor the groundwater for what is termed “rebound” where it is possible that concentrations rise above the cleanup level after remediation has been terminated. Individual measurements may rise above the cleanup level; however, the individual measurements are not compared to the cleanup level. It is the UCL95 that is utilized for comparison to the cleanup level. When UCL95 for all compliance wells have remained below the cleanup level for the compliance period, the site may be considered for de-listing from the National Priority Listing (NPL).

EXAMPLE COMPLIANCE APPLICATION

The previous sections outlined regulatory guidance provided by the EPA and Washington State Department of Ecology through the RCRA, CERCLA, and the MTCA framework for determining compliance with cleanup levels. These guidance documents provide flexibility to deal with unique situations and challenges on a site by site basis. This section discusses the methods used for meeting the closure criteria regulations discussed in the previous section as it can be applied, in general, to wells at the Hanford Site. The example compliance calculation is documented in ECF-Hanford-13-0004, Rev.0 and is summarized below. The example uses hypothetical nitrate concentrations generated for illustration of the calculations.

This calculation is presented for illustration purposes only. The statistical software used for making the calculation, the R statistical software (R Core Team, 2012), is one of several possible software mentioned in recent guidance for performing statistical calculations (EPA 530 R-09-007, 2009). But, at this point, it is not approved for use for calculations released to the public at the Hanford Site. Therefore, this example is strictly illustrative and not meant to represent an official compliance calculation for either of these wells. Further, the calculations do not make any assumptions about whether these well locations are currently influenced by nearby extraction or injection wells. As explained above, full demonstration of compliance will require this determination to be made.

Calculation Using Hypothetical Data

Data generated to represent contaminant concentration at two monitor wells are shown in Figures 4 and 5. Vertical lines on the graph indicate the date active remediation was ceased in these wells, June 21, 2011 and June 1, 2009 respectively. The example makes two main calculations: 1) determining the time to cease remediation, and 2) compliance assessment of the concentration data. Each of these is discussed in the following sections.

Remediation Cessation

EPA/230-R-92-014 suggests using regression analysis on the observed concentration data as an aid for determining when to cease active remediation. Figure 3 and 4 show an example regression fit to nitrate data for hypothetical wells A and B respectively. In each case the best fit regression based on the R-squared parameter was an exponential regression fit. The exponential regression fit for Well A shows an estimate of approximately 10 mg/L or the cleanup level (for NO3-N) when pumping was ceased. The fit for Well B shown in Figure 4 indicates and estimated nitrate concentration of approximately 6 mg/L (expressed as NO3-N). In each case the concentration measurements collected post-termination of remediation indicate the cessation of remediation was warranted.

Compliance Assessment

To illustrate the methods used for assessing compliance to the cleanup levels a set of calculations was completed using hypothetical nitrate data. Figures 3 and 4 show nitrate data and regression and UCL95 analyses discussed in previous sections of this document. These analyses were preceded by normality tests on the data used for the compliance assessment. The Shapiro-Wilk normality test for Well A and B data (post-cessation of remediation) indicated p-values of 0.38 and 0.04 respectively. The null hypothesis for Well A was not rejected while the p-value for Well B is just at the level where the null hypothesis could be rejected. A lognormal test for Well B also provided p-value that rejected the null hypothesis. However, for the purpose of this illustrative example the data post-cessation of remediation for Well B is assumed to be normally distributed. Each of the plots shown for example wells shows a sequential UCL95 calculation using the previous 8 concentration measurements, a yearly calculation of the UCL95 calculation, a linear regression on the concentration data using the measurement point prior to cessation and all data collected post-cessation of remediation, and the UCL95 of the linear regression analysis.

Depending on the regulatory framework used to close the site any one of these may be sufficient to demonstrate compliance with the cleanup level. When all of these indicate compliance, the argument is stronger that compliance with the cleanup level has been achieved. For example Well A shows that each of the UCL95 calculations and the linear trend of nitrate are below the cleanup level for a three-year period after the cessation of remediation. Similar results are shown in Figure 4 for Well B. Initially the UCL95 values hover just below the 10 mg/L cleanup level shown in the figure. Later values show improvement as each of the UCL95 values fall further below the cleanup level. Residuals for the trend analysis exhibited normal distributions with Shapiro-Wilk p-values of 0.8 and 0.25 for a critical point of 0.05 for Well B and Well A, respectively. This indicates that the trend analysis does not violate the assumptions of normal distributed data used to create the linear regression.

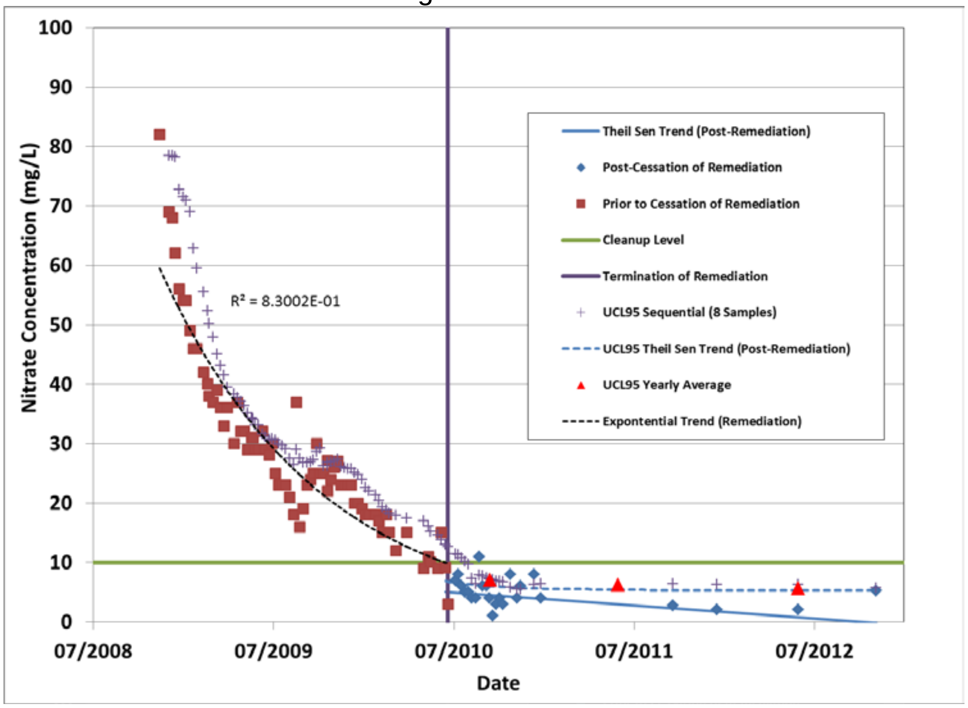

Figure 3. Hypothetical nitrate data for illustrative analysis as Well A showing both pre and post-cessation of remediation of groundwater.

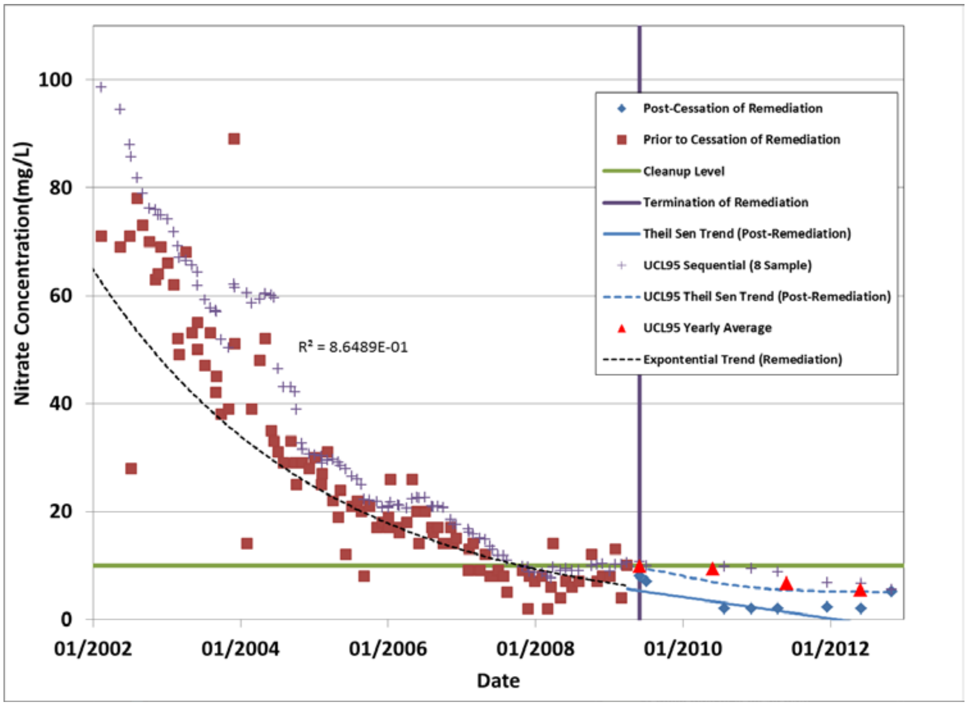

Figure 4. Hypothetical nitrate data for illustrative analysis as Well B showing both pre and post-cessation of remediation of groundwater.

CONCLUSIONS

Federal and state guidance allows multiple lines of evidence to be used to demonstrate compliance throughout remedy implementation. The outlined methods are in line with guidance and appear to be implementable at the Hanford Site. During implementation, other decisions will have to be made to determine which cleanup values are used at different monitor well locations. It would be expected to use the more stringent of surface (ambient) water quality levels or drinking water levels for wells located near the river. For wells that are within a reasonable distance inland, drinking water levels can be used as cleanup values. The cleanup values and specifics with regard to well locations and compliance monitoring must be addressed and detailed in decision documents (i.e., records of decision, remedial designs, performance monitoring plans, sampling-and-analysis plans, and permits) that are developed for each application.

REFERENCES

1. Comprehensive Environmental Response, Compensation, and Liability Act, 1980, Public law 96-150, as amended 95 Stat. 2767, 42 USC 9601 et seq.
2. 40 CFR 264, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.” U.S. Environmental Protection Agency, Code of Federal Regulations.
3. Resource Conservation and Recovery Act, 1976, Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq.
4. DOE/RL-2007-20, 2007, Hanford Integrated Groundwater and Vadose Zone Management Plan, DOE/RL-2007-20, Rev. 0, U.S. Department of Energy, Richland, Washington

5. DOE/RL-2010-95, 2010, Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units, Rev. 0, U.S. Department of Energy, Richland, Washington
6. DOE/RL-2010-96, 2010, Remedial Investigation/Feasibility Study for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units, Rev. 0, U.S. Department of Energy, Richland, Washington
7. DOE/RL-2010-97, 2010, Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units, Rev. 0, U.S. Department of Energy, Richland, Washington
8. DOE/RL-2010-98, 2010, Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units, Rev. 0, U.S. Department of Energy, Richland, Washington
9. DOE/RL-2010-99, 2010, Remedial Investigation/Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units, Rev. 0, U.S. Department of Energy, Richland, Washington
10. EPA/230-R-92-014, 1992, Methods for Evaluating the Attainment of Cleanup Standards. U.S. Environmental Protection Agency, Washington, D.C.
11. EPA 440/5 80 035, 1980, Ambient Water Quality Criteria for Chromium, U.S. Environmental Protection Agency, Washington, D.C.
12. EPA 530-R-04-030, 2004, Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action, U.S. Environmental Protection Agency, Washington, D.C.
13. EPA 530 R-09-007, 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, U.S. Environmental Protection Agency, Washington, D.C.
14. EPA 540-G-88-003, 1988, Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, U.S. Environmental Protection Agency, Washington, D.C.
15. EPA 542-R-05-003, 2005, Roadmap to Long-Term Monitoring Optimization, , U.S. Environmental Protection Agency, Washington, D.C.
16. OSWER Directive 9283 1-33, 2009, Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration, Office of Solid Waste Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.
17. OSWER Directive No. 9355.4-28, Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation, Office of Solid Waste Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.
18. R Core Team , 2012, R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.
19. WAC 173-340, “Model Toxics Control Act—Cleanup,” Washington Administrative Code, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340
    173-340-410, “Compliance Monitoring Requirements”
    173-340-720, “Groundwater Cleanup Standards”
    173-340-820, “Sampling and Analysis Plans”