EPA United States Environmental Protection Agency

Groundwater Remedy Completion Strategy

Moving Forward with the End in Mind

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1. Introduction

1.1 Purpose and Scope

Groundwater remediation is a component of more than 90 percent of active Superfund sites and achieving groundwater remedial action objectives (RAOs) can take years or even decades (EPA, 2013b). The purpose of this guidance is to help focus resources on the information and decisions needed to effectively complete groundwater remedies and to ensure that these remedies protect human health and the environment. This document presents a recommended "groundwater remedy completion strategy" for evaluating Superfund groundwater remedy performance and making decisions to help facilitate achievement of RAOs and associated cleanup levels. Figure 1 provides a graphical overview of the recommended groundwater strategy concept.

> A *Groundwater Remedy Completion Strategy* ("the strategy") is a recommended site-specific course of actions and decision making processes to achieve groundwater RAOs and associated cleanup levels using an updated conceptual site model, performance metrics and data derived from site-specific remedy evaluations.

EPA recommends that a completion strategy be developed for all CERCLA[1] Fund-, potentially responsible party-(PRP) and federal facility-lead groundwater remedies. It is important that the site team responsible for remedy implementation be involved in development of a site-specific groundwater remedy completion strategy. The make-up of the site team will depend on site-specific circumstances and typically includes the lead agency, support agency and if applicable PRP(s), tribe(s) and other site stakeholders. Typically the state representatives are involved, given their role in funding and long-term stewardship for Fund-lead sites. The recommended completion strategy approach generally should be useful throughout all phases of the cleanup – including remedy selection, remedial design/remedial action, long-term response action and operation and maintenance. A completion strategy can also help with review of the remedy performance and effectiveness as part of Five-Year Review evaluations. Development of a site-specific groundwater remedy completion strategy generally should occur as early as possible in the remedial process to maximize its potential usefulness.

This guidance should generally be considered at CERCLA sites with active and/or passive groundwater restoration remedies. Source control and plume containment actions are often critical to the success of aquifer restoration efforts, and this guidance may also help guide evaluation of these groundwater remedies. While this guidance focuses on groundwater restoration remedies, the recommended approach also may be useful for CERCLA remedial actions that do not include a groundwater restoration RAO.

Establishment of RAOs in the Superfund decision document[2] generally provides an important foundation for development of a site-specific strategy. RAOs normally specify "contaminants and media of concern, potential exposure pathways, and remedial goals" (40 CFR §300.430(e)(2)(i)). Also "when addressing groundwater contamination, the RAOs section of the Proposed Plan and ROD should clearly present the intended results of the remedial action" (EPA, 1999a). The decision document should include clearly-written RAOs that "provide a general description of what the cleanup will accomplish (*e.g.*, restoration of groundwater to drinking water levels)" (EPA, 1999a). The groundwater RAOs should also clearly state if the remedy objective is restoration and/or containment. Additional information on RAOs is included in Appendix 1.

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[1] The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provide the statutory and regulatory foundation for Superfund response actions.

[2] For purposes of this document, a Superfund decision document may be a Record of Decision (ROD), a ROD Amendment or an Explanation of Significant Differences (ESD).

This recommended groundwater remedy completion strategy is based upon existing Superfund law, regulations, policy and guidance. This consolidated information is intended to enhance the understanding, development and application of site-specific strategies by technical professionals who analyze groundwater data and managers who either review analyses or make decisions based upon them. Additional audiences who may find this document useful include other regulators and technical representatives of states, tribes, local governments, other federal agencies, PRPs and community members.

This guidance does not alter or supersede existing CERCLA guidance (including existing policy regarding RAOs or cleanup levels). While designed to promote a consistent national approach for implementing groundwater remedies to completion, the recommendations contained within this document are neither substitutions for CERCLA requirements or EPA's regulations, nor are they regulation themselves. EPA, federal, state, tribal and local decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance where appropriate. Any decisions regarding a particular facility will be made based on the applicable statutes and regulations. This document does not impose legally binding requirements on EPA, states, tribes or the regulated community, and may not apply to a particular situation based upon the circumstances. Furthermore, this document does not address groundwater classifications or groundwater use designations, and as such, provides no basis for addressing issues related to those classifications with states or tribes.

1.2 Background

The Superfund law, implementing regulations, policy and guidance provide the science-based technical foundation for Superfund groundwater response actions. Under CERCLA 121(d)(2)(A), groundwater response actions are governed in part by the following mandate established by Congress:

> ...Such remedial action shall require a level or standard of control which at least attains Maximum Contaminant Level Goals established under the Safe Drinking Water Act and water quality criteria established under section 304 or 303 of the Clean Water Act, where such goals or criteria are relevant and appropriate under the circumstances of the release or threatened release.

Furthermore, the NCP (40 CFR §300.430(a)(1)(iii)(F)) includes general expectations for purposes of groundwater restoration as follows:

> …EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. When restoration of ground water to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction.

This document complements existing EPA guidance for evaluation of groundwater remedies (EPA, 1993; EPA, 1994; EPA, 1996; EPA 1999b; EPA, 2000b; EPA, 2002; EPA, 2004b; EPA, 2005; EPA, 2008), the *Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration* (EPA, 2009), the *Groundwater Road Map* (EPA, 2011b) and *Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions* (EPA, 2013a). For these and other groundwater guidances, please refer to the Superfund groundwater website[3].

[3] http://www.epa.gov/superfund/health/conmedia/gwdocs/.

2. Elements of a Groundwater Remedy Completion Strategy

Key recommended steps for developing and implementing a site-specific groundwater completion strategy are described below. Figure 1 provides a graphic overview of the groundwater completion strategy process and Figures 2 and 3 provide greater process detail. Appendix 1 provides further detail on selected aspects[4].

Understand the Site Conditions. An important foundation for the development of a remedy completion strategy is an accurate and updated conceptual site model (CSM), including current site and remedy characteristics (EPA, 2011c). A site's existing CSM should be regularly re-evaluated and updated based on recent data collection and improved site knowledge. Understanding site-specific conditions related to groundwater contamination fate and transport is typically a dynamic process and usually evolves as the cleanup actions progress. Incorporation of recent site data into an updated CSM may help resolve any potential uncertainties regarding the remedy's effectiveness and current site conditions and may help identify key data gaps.

Design Site-Specific Remedy Evaluations. Site-specific remedy evaluation questions normally should help inform remedy operation, progress and attainment evaluations to ultimately make decisions regarding remedy implementation. Examples of recommended remedy evaluation questions include but are not limited to:

- Is the source remediation progressing as intended?
- Are the treatment units functioning as intended?
- Is the plume shrinking as anticipated?
- Do contaminants of concern (COC) concentration trends indicate that RAOs and cleanup levels are likely to be met in the expected timeframe discussed in the ROD?

Develop Performance Metrics and Collect Monitoring Data. Performance metrics should be selected to help generate information to inform the site-specific remedy evaluations. The site-specific metrics may include remedy performance criteria, hydrogeologic parameters or contaminant concentration trends, which can be used to evaluate remedy performance and measure progress. Examples of recommended performance metrics include effluent discharge concentrations, diagnostic parameters values (*e.g.*, dissolved oxygen levels) and contaminant concentrations trends in a monitoring well. A site-specific monitoring program generally should be developed, and updated as appropriate, to collect data to support metric evaluations.

Conduct Remedy Evaluations. Using the performance metrics and monitoring data, the remedy operation, progress and achievement of RAOs and cleanup levels should be assessed in a timely manner to address the remedy evaluation questions. As part of the remedy completion strategy, an attainment monitoring phase evaluation is recommended at each well after it has been determined that the groundwater remediation monitoring phase has been completed (EPA, 2013a).

Make Management Decisions. Based on the remedy evaluations, decisions should be made regarding next steps and any changes that may be appropriate. Depending on the significance of the changes, a ROD Amendment or ESD may be needed (EPA, 1999a). Remedy optimization or alternate response approaches may be warranted if performance indicates that the selected remedy is not performing or has the potential not to achieve groundwater RAOs and cleanup levels in a reasonable timeframe defined in the ROD.

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[4] Appendix 1 provides more information on several important components of an effective groundwater remedy completion strategy, including: (1) improving the current and comprehensive understanding of site characteristics; (2) developing definitive RAOs and associated cleanup levels and timeframes; and (3) improving the current understanding of other site actions related to the groundwater cleanup.

Remedy Evaluations normally should be conducted throughout the life cycle of the groundwater remedy to make decisions about remedy performance and progress toward attainment of RAOs and cleanup levels (*e.g.*, Are treatment units functioning as intended? Are the concentration trends as anticipated?). Evaluations should be conducted using site-specific performance metrics and site data.	*Performance Metrics* are site-specific remedy performance criteria, hydrogeologic parameters or contaminant concentration trends typically used to evaluate remedy performance and measure progress (*e.g.*, effluent discharge concentrations, contaminant concentrations trends in a monitoring well).

The remedy completion strategy approach is modeled on the EPA-endorsed Data Quality Objectives (DQO) process. The DQO process is designed to refine project information needs and focus monitoring efforts on collecting the appropriate type and amount of data so that data support key decisions (EPA, 2000a; EPA, 2004a; EPA, 2004b; EPA, 2006). This strategy is intended to provide a technical and scientific process for evaluating when sufficient data have been obtained to assess the likelihood that a groundwater remedy has or will achieve the RAOs and associated cleanup levels in a reasonable timeframe.

It is recommended that the completion strategy include a schedule for monitoring and evaluations to help ensure efficient and timely decision making. The schedule should reflect the dynamic and iterative nature of a groundwater strategy's implementation. With ongoing data collection, evaluation of the performance metrics and remedy assessment, the completion strategy process and findings should be updated periodically to facilitate open and transparent communications within the project team and external stakeholders (*i.e.,* state, federal, tribal, local and community site stakeholders).

It is recommended that the site-specific completion strategy be developed as early as possible in the Superfund process. Depending on the stage of cleanup when the strategy is first developed, it may be described in one or more site documents. There is intentional flexibility in how a site-specific strategy is developed. As appropriate, the strategy may be described conceptually as part of a remedy decision document. Development of the strategy as a component of the remedy design phase can help lay the foundation for effective remedy implementation. The strategy also may be described in more detail in the site operations and maintenance plan, monitoring reports and the five-year review. The completion strategy could take many forms, including a written report, a flow chart or a computer-based tool. It may be helpful to site team members and stakeholders to include active internet links to key site documents within the completion strategy. A stand-alone document may also be appropriate for describing a completion strategy. Consistent with the NCP's provisions regarding site records management, the completion strategy should be documented in the site file and the administrative record.

Development of a site-specific groundwater completion strategy can help a site team focus resources on gathering the most relevant data and other information to inform science-based site-specific decision making. While a modest level of effort may be needed to create and maintain the remedy-specific strategy, an increased focus on gathering data to support cleanup decisions generally should improve the overall time- and cost-efficiency of remedy completion.

The remedy completion strategy should be dynamic and as such should be re-evaluated and updated as the cleanup progresses and changes (if any) are made to the remedy, remedy operation and/or monitoring plans. The review frequency should reflect the level of site activity and rate of changing site conditions. It is recommended that the remedy completion strategy be evaluated at least concurrently with the five-year review and any remedy or monitoring optimization studies.

3. Understand the Site Conditions

As part of completion strategy development, it generally is important to have accurate knowledge of the historical site activities as well as a current and updated understanding of site conditions and response actions. This may include consideration of:

- A current CSM and associated data;
- EPA groundwater use designations and state groundwater classification;
- Site groundwater RAOs, the associated cleanup levels for all COCs and the area of attainment or point of compliance;
- Timeframe estimated to achieve cleanup;
- Groundwater cleanup response actions;
- Other site remedies for groundwater and other media including the status, goals and potential impact on the groundwater remedy; and
- Results of any remedy or monitoring optimizations or other site reviews.

Some of these factors (in particular the CSM) are likely to change often as the cleanup progresses. See Appendix 1 for further discussion of the CSM, RAOs and other technical foundations potentially relevant to development of site-specific groundwater completion strategies.

4. Design Site-specific Remedy Evaluations

Typically, a groundwater completion strategy describes how site groundwater remedial actions can be evaluated during implementation. A systematic approach can be used to develop the questions to evaluate groundwater remedy operation, as well as progress toward and achievement of RAOs and cleanup levels (EPA, 2000b; EPA, 2004a; EPA, 2004b; EPA, 2013a). Multiple lines of evidence usually strengthen the remedy evaluation conclusions. Figures 2 and 3 provide a graphical example of a recommended remedy evaluation.

The process of developing evaluation questions should serve to refine and focus the information needed to inform response action decision points. The recommended approach structure is intended to help the project team characterize the situation as well as identify in advance the information and data that should be useful for evaluation of the remedy with an appropriate level of confidence.

Remedy performance evaluations typically include the following categories:

- Remedy operation;
- Progress toward groundwater RAOs and associated cleanup levels; and
- Achievement of RAOs and cleanup levels.

Other factors, such as source remediation, hydrogeologic features and site changes independent of the remedy, generally are also important to consider at decision points. It is recommended that the evaluation questions be reviewed periodically to ensure they remain valid and appropriate. If remedy evaluation questions change, then it may also be appropriate to revise the performance metrics and the monitoring plan accordingly.

4.1 Design Remedy Operation Evaluations

This guidance recommends developing questions to evaluate remedy operation during implementation. These questions should consider all facets of the selected remediation approach that may impact the groundwater remedy performance and operation (EPA and USACE, 2005; EPA, 2008; EPA, 2012). Below are examples of questions that may be appropriate to ask concerning remedy operation:

- Are the groundwater well extraction rates and locations adequate to capture the contaminated groundwater?
- Are the treatment units functioning as intended?
- Are effluent levels/discharge performance levels being achieved?
- Is contaminated groundwater migration under control?
- Are there remedy optimization opportunities?
- Is the remedy operation and maintenance manual up-to-date?

Analysis of site-specific remedy evaluations is discussed in Section 6.1.

4.2 Design Remedy Progress Evaluations

Typically, during remediation data are collected to monitor cleanup progress toward attainment of RAOs and associated cleanup levels in the expected timeframe. Below are example questions that may be included in the completion strategy to evaluate cleanup progress:

- Are there decreases in COC concentrations occurring in the contaminated groundwater and in a reasonable timeframe, as discussed in the ROD?
- Is there a reduction in mass discharge as measured in the extraction wells?
- Is the groundwater flow direction as expected and have temporal, seasonal, matrix diffusion or tidal influences been assessed and considered?
- Is the mass removal rate as expected?

- Are there potentially hazardous and/or mobile breakdown products present in sampling data?
- Is there evidence of attenuation, degradation and/or stabilization of COCs?
- Is the extent of contaminated groundwater shrinking in all three dimensions?
- Are there unacceptable impacts to receptors via water supply wells, surface water bodies, indoor air or other pathways?
- Do contaminant concentrations trends indicate that RAOs and cleanup levels are likely to be met in the expected timeframe discussed in the ROD?
- Are there opportunities for system or monitoring network optimization?

Evaluation of site-specific remedy progress considerations is discussed in Section 6.2.

4.3 Design Attainment Evaluations

As part of the completion strategy, an attainment evaluation is recommended at each well after it has been determined that the groundwater remediation phase is complete. During the attainment monitoring phase, monitoring well-specific conclusions should be used "to provide a scientific basis supporting the Agency's conclusion that the groundwater has met and will continue to meet cleanup levels for all COCs in the future" (EPA, 2013a). The attainment evaluation data set should reflect post remediation, or steady state, site conditions where remediation activities, if employed, are no longer influencing the groundwater in the well. Site-specific attainment evaluation questions for each well may include:

- Has the contaminant cleanup level for each COC been met?
- Will the groundwater continue to meet the contaminant cleanup level for each COC in the future?

Evaluation of attainment is discussed further in Section 6.3.

4.4 Evaluate Other Site Factors

In general, the success of groundwater response actions is related to the removal or containment of contaminant sources. However, groundwater remedy performance also may be affected by outside influences. Some examples of other factors that may be relevant include:

- Is source remediation to protect groundwater progressing as intended?
- Do data indicate that source containment and/or reduction continue to meet RAOs?
- Has the groundwater elevation or site flow regime changed due to drought, flood, off-site pumping or other circumstances?
- Is there a change in land use that impacts groundwater and/or the monitoring system?
- Are there changes in groundwater use or land use that may impact the treatment system or monitoring network?

Evaluation of other site factors as part of the completion strategy is discussed in Section 6.4.

5. Develop Performance Metrics and Collect Monitoring Data

The remedy operation, progress and attainment evaluation questions generally should be answered using site-specific performance metrics and monitoring data. Effective decision making is usually dependent upon quantifiable, transparent metrics and monitoring of remedy performance and progress.

5.1 Develop Performance Metrics

Performance metrics normally should include remedy performance criteria, contaminant concentration trends and hydrogeologic parameters used to evaluate the remedy performance and measure progress (EPA 1994; EPA, 2000a; EPA, 2004b; EPA 2011b). Performance metrics are typically objective, quantitative measurements (see also Figure 3). Since some remedies may require a long time to achieve completion, metrics may include interim measures of progress toward the RAOs and cleanup levels. Over the life of the remedy, the metrics may change as the remedy evolves.

Performance metrics may include the following:

- Remedy operation metrics (*e.g*., extraction rate, capture zone, effluent concentration, influent concentration trend, carbon usage rate);
- Progress metrics (*e.g.,* rates of reduction of contaminant volume and/or mass, COC trends, microbial populations); and
- Attainment metrics (*e.g.,* individual well COC concentration mean and confidence levels, individual well COC trends, overall COC trends).

Multiple metrics and the resulting lines of evidence generally can help strengthen the data and information used to support decision making throughout the remedy implementation process.

5.2 Develop or Update the Monitoring Plan

During remedy implementation, "groundwater sampling and monitoring data are typically collected to evaluate contaminant concentrations through time at appropriate locations" (EPA, 2011b). Monitoring usually includes system performance parameters, contaminant concentrations and hydrogeologic parameters. Consistent with existing Superfund guidance, the monitoring network should be evaluated during the remedial action and remedy operation to ensure sampling is at an appropriate frequency and spatial density to allow accurate evaluation of contaminant concentrations over time.

Long-term monitoring "…should involve repeated sampling over time in order to define the trends in the parameters of interest relative to clearly defined management interests" (EPA, 2004a). The monitoring well network should adequately delineate the lateral and vertical extent of contamination in the groundwater aquifer(s) and enable evaluations of contaminant concentrations and migration over time. Data should be collected to maximize efficient collection of an appropriate level of data to conduct evaluations.

Site monitoring plans generally should be reviewed regularly (at least at the same time as the five-year review) to ensure that sufficient data are being collected to support decision making. EPA and state representatives generally should work together to ensure continuity of groundwater monitoring during and after site transfer to the state (EPA, 2011a). The number and location of monitoring wells, monitoring parameters and frequency may change as the site progresses from characterization to long-term remedial action effectiveness monitoring to attainment monitoring (EPA, 2004a; EPA, 2004b; EPA and USACE, 2005; EPA, 2007).

Data over a period of several years are usually collected to gather information sufficient to accurately analyze trends or changes in contaminant concentrations, to assess capture of the contaminated groundwater and to evaluate cleanup progress. Data evaluation methods should be identified early to help ensure that adequate data can be collected to support analysis and decision making (EPA, 2008).

6. Conduct Remedy Evaluations

As operational and monitoring data are collected, these data should be examined by the project team to assess trends and patterns, to verify or update the CSM and to evaluate the performance metrics. Trend analysis often is an important remedy evaluation component. "Trend analysis evaluates data collected at specified intervals over a specified period in order to determine if conditions are changing over time, and if so, how they are changing (*i.e*., the magnitude and direction of the change" (EPA, 2004a). A typical key evaluation component is determining if concentrations are decreasing, increasing or if there is no trend. Data variability and uncertainty associated with the sample matrix, sampling techniques, aquifer heterogeneity, well construction and analytical methods also should be considered as part of the evaluation.

6.1 Evaluate Remedy Operation

The evaluation of engineering, operating and monitoring components of the remedy should indicate whether the system is functioning adequately to achieve the RAOs and associated cleanup levels and if remedy operation can be improved to reduce the remedial timeframe.

If data indicates that the remedy is meeting performance metrics as anticipated, then the system is generally considered to be operating adequately. While system operations may be adequate, it may be beneficial to consider remedial system and/or monitoring optimization (EPA and USACE, 2005; EPA, 2007; EPA, 2012). There may be opportunities to improve or optimize remedy efficiency to reduce costs and/or achieve cleanup levels more effectively.

If the remedy is not meeting or may not be able to meet the RAOs or performance metrics as expected, then this may indicate the need for an optimization review and/or revaluation of the existing remedy (EPA, 2012). Situations that may indicate that the system is not meeting the performance goals include, but are not limited to, the following:

- Operating conditions are outside the expected design range or specifications;
- Contaminant levels are not decreasing as anticipated;
- Plumes are expanding or migrating unexpectedly;
- Treatment efficiencies are not being met;
- Extraction/injection rates are not being met; or
- Discharge limitations have been exceeded.

Following evaluation, a decision should be made whether to consider changes or other adjustments to the selected remedy in order to improve remedy performance, as discussed in more detail in Section 7.

6.2 Evaluate Remedy Progress

Evaluation of the remedy performance metrics and monitoring data should indicate whether it is likely that the RAOs and cleanup levels will be achieved in a reasonable timeframe with the existing system. If contaminant concentrations are decreasing in a timely manner and other progress performance metrics are being achieved, then it is likely that the remedial approach is functioning as intended and the remedy is likely to achieve RAOs and cleanup levels in a reasonable timeframe as selected in the ROD. If this is the case, then it is generally recommended that remedy implementation continue.

If a well-by-well progress evaluation indicates that cleanup levels have initially been reached for all COCs, then it may be appropriate to conduct an evaluation of attainment (EPA, 2013a). See section 6.3 for further discussion of the attainment evaluation.

If monitoring data and analyses suggest that the remedy is not achieving sufficient progress toward achieving remedial objectives, then the remedy may need to be revisited. It is recommended that the project team evaluate whether:

- The remedial action may achieve RAOs and cleanup levels with modification to the selected remedy;
- The remedy is not likely to achieve RAOs and associated cleanup levels in the timeframe envisioned in the ROD;
- The remedy is not likely to achieve RAOs and associated cleanup levels in the timeframe envisioned in the ROD, but a new projected timeframe is still deemed reasonable; or
- The remedy is not likely to achieve RAOs and cleanup levels in any reasonable timeframe.

If the cleanup is not making sufficient progress toward implementing the ROD-selected remedy, then next steps may include:

- Conduct further investigation to refine understanding of the source, plume geometry and subsurface hydrogeology.
- Update the CSM.
- Optimize the remedy.
- Optimize the activities associated with long-term monitoring.
- Evaluate other cleanup technologies including innovative technologies and approaches.
- Implement the ROD contingency remedy[5]
- Revise the remedy decision.

Normally, any additional investigations should target information designed to effectively and efficiently inform next steps specifically and the overall decision making process. Additional investigations/evaluations may lead to a focused feasibility study (FFS) and a potential modification of the existing remedy. Depending on the significance of any modifications, a revised remedy decision document may be required (EPA, 1999a).

6.3 Evaluate Attainment of RAOs and Cleanup Levels

An attainment evaluation generally evaluates "contaminant of concern (COC) concentration levels on a well-by-well basis to assess whether aquifer restoration is complete" (EPA, 2013a). To the extent practicable, before an attainment evaluation is conducted at a well, operation of the active system in the vicinity of the monitoring well should be terminated. This termination allows for re-equilibration of the local hydrogeologic system and for the groundwater to reach steady state. Groundwater restoration remedial actions should generally be considered complete when well-specific monitoring data, provide a scientific basis to conclude that the groundwater has met and will continue to meet cleanup levels for all COCs in the future, in accordance with the decision document.

At the beginning of the attainment monitoring phase, it may be appropriate to review the monitoring plan, in particular the monitoring frequency and locations, to ensure an adequate amount of data will be collected to conduct the evaluation. The data from each monitoring well should be evaluated to confirm that the groundwater remedy continues to meet the cleanup levels for each COC and will continue to meet cleanup levels for all COCs in the future (EPA, 2013a).

[5] USEPA, "A Guide to Preparing Superfund Proposed Plans, Records of Decision, and other Remedy Selection Decision Documents" (OSWER 9200.1-23P, July 1999a). "Generally, an ESD will be required to invoke a contingency. However, if the contingency remedy or the criteria for its selection are not well-documented in the ROD, a ROD amendment may be required to invoke this cleanup option at a later point in time." (See page 8-3 to 8-4.)

"If the monitoring well-specific conclusions and other site information support a conclusion that the groundwater restoration remedial action is complete in accordance with the decision document(s), this determination typically is documented in the final close out report for the site" (EPA, 2013a).

If the attainment evaluation indicates that the RAOs and associated cleanup levels have not been attained throughout the contaminated aquifer, then the site team should evaluate what changes (if any) can be implemented to achieve the ROD-selected remedy (see Section 6.2 of this document). If, based on the remedy attainment evaluation, the region determines that the RAOs and cleanup levels are not likely to be attained, it is generally appropriate to consider other cleanup approaches as discussed in Section 7.

6.4 Evaluate Other Site Factors

In conjunction with the above remedy-specific evaluations, it may be appropriate to evaluate other site factors to fully assess whether a remedial action is likely to attain and maintain the RAOs and associated cleanup levels selected in the ROD. For example, if a previously unidentified contaminant source is discovered, this may require remedy re-evaluation (and potentially a revised decision document). These evaluations may be conducted in parallel with or separately from the remedy operation, progress and attainment evaluations discussed above.

7. Make Management Decisions

This section describes some of the key options to consider if it appears that a remedial action will not be able to achieve the groundwater RAOs and associated cleanup levels selected in the ROD. These factors may be considered at the same time as the Region and/or lead agency evaluates the selected remedy's protectiveness under the five-year review (EPA, 2001). Consideration of other cleanup approaches should involve the project team and state, federal, tribal, local and community site stakeholders. Consistent with CERCLA and the NCP, changes that significantly or fundamentally alter the selected remedy require an ESD or ROD Amendment (EPA, 1999a).

7.1 Consider Modification of RAOs and Other Remedial Alternatives

If remedy evaluations indicate that the selected remedy may not achieve the RAOs and cleanup levels in a reasonable timeframe, as selected in the decision document, then it may be appropriate to consider other remedial alternatives (EPA, 1999a; EPA, 2011b). If the site-specific remedy evaluations and review of the current updated "CSM indicate that the existing remedy will not achieve RAOs and associated cleanup levels, either the remedial technology or the comprehensive remedy generally should be modified" (EPA, 2011b). Modification of the remedy may involve the following activities as further described in EPA, 1993; EPA 1999a and EPA, 2011b:

- Evaluate the groundwater's restoration potential.
- Evaluate if the current RAOs and cleanup levels can be achieved with other technologies.
- Select an alternate remedial approach, and if necessary, modify the RAOs.
- Conduct technical impracticability (TI) evaluation.

If groundwater restoration or containment is still viable with a different technology or if the RAOs and associated cleanup levels need to be changed, then the selected remedy may need modification (EPA, 1999a).

Depending on the nature of the site data and data gaps, additional data gathering may be appropriate to support remedy evaluations and future decision making. For example, other treatment approaches or technologies may have become available since the current remedial action was selected[6]. Activities that may be considered to achieve the RAOs and associated cleanup levels in a reasonable timeframe, as selected in the ROD, include:

- Additional site investigation to address critical data gaps identified in the evaluations described above;
- Evaluation of additional source removal, containment or treatment;
- Optimization of existing remedial technology; or
- Selection of additional treatment approaches.

It may be appropriate to prepare a FFS to evaluate and document consideration of new remedial alternatives (EPA, 1988a). The FFS may consider many activities, including but not limited to remedy optimization, alternative treatment technologies and a change from an active to a passive remedy or other remedial approaches (*e.g.*, greater reliance on institutional controls to ensure protectiveness if alternative response actions by themselves are not expected to achieve RAOs and associated cleanup levels in a reasonable timeframe).

7.2 Consider the Need for a Technical Impracticability Waiver

In some circumstances, remedy operation, progress or attainment evaluations may indicate that the current RAOs and associated applicable or relevant and appropriate requirements (ARAR)-based cleanup levels

[6] For more on green and sustainable cleanups, see http://www.epa.gov/oswer/greenercleanups/index.html.

selected in the ROD are not likely to be achieved, even after optimization and consideration of other cleanup approaches. In such a situation, it may be appropriate to modify the groundwater restoration RAOs and explore whether a TI waiver should be considered (EPA, 1993).

CERCLA section 121(d)(2) requires that on-site remedial actions meet ARARs. CERCLA section 121(d)(4) also provides that ARARs may be waived in certain limited circumstances, as long as the cleanup also assures protection of human health and the environment. Pursuant to CERCLA section 121(d)(4), “technical impracticability” is one of the six possible statutory ARARs waivers. “A decision to propose or invoke a TI waiver can be made at any time during the remedial process, but must be included in a remedy selection decision document” (EPA, 1999a); in addition,

> EPA’s goal of restoring contaminated groundwater within a reasonable timeframe at Superfund sites will be modified where complete restoration is found to be technically impracticable. In such cases, EPA will select an alternative remedial strategy that is technically practicable from an engineering perspective, protective of human health and the environment, and satisfies the statutory and regulatory requirements of Superfund (EPA, 1993).

EPA has issued guidance on considering TI waivers (EPA, 1993) and on documenting TI waivers (EPA, 1999a). Furthermore, as discussed in Section 4.4 of EPA’s 2011 *Groundwater Road Map:*

> Determinations of technical impracticability are made by EPA based on site-specific information evaluated when reviewing restoration potential (see step 4.1). The TI evaluation documents the results of this evaluation. The TI evaluation generally should include the following components: (1) specific ARARs (e.g., media cleanup levels) for which TI waiver determinations are sought, (2) spatial area over which the TI waiver decision will apply, (3) current CSM, (4) the results of the evaluation of restoration potential of the site, (5) estimates of the costs of the existing remedy and proposed alternative remedial strategy, and (6) any additional information EPA deems necessary. *A TI decision* [including the alternative remedial strategy], *must be incorporated into a Superfund ROD or be incorporated into a modification or amendment to an original document*” [EPA, 1993]. A modification to a signed ROD invoking a TI ARAR waiver generally is accomplished through a ROD amendment, since an ARAR waiver usually constitutes a fundamental change in the remedy. In addition to the TI waiver, the decision document should incorporate all components of the alternative remedial strategy.

Data and information providing support for the lead agency’s determination that a TI waiver of ARARs is appropriate should be provided in a stand-alone TI evaluation, an FFS, or other appropriate technical document. The TI evaluation should be summarized in the proposed plan describing the proposed waiver.

A TI waiver may be a valid remedial approach where the lead agency determines it is appropriate and there is sufficient data and information included in the administrative record to support the determination.

> The Superfund program remains committed to restoring groundwater to beneficial use consistent with CERCLA and the NCP, and bring human exposures under control. TI waiver determinations are a recognized part of EPA’s remedial strategy, and they may be appropriate depending on-site specific conditions, as discussed in the 1993 TI guidance (EPA, 2011d).

In 2011, EPA issued a summary of TI waivers finalized at Superfund National Priorities List sites between 1988 and 2009. During this period, EPA issued 88 TI waivers and 79 of these waivers applied to the groundwater media (EPA, 2011d).

8.0 Conclusions

Groundwater remediation can be a lengthy process. As discussed in this guidance, a groundwater remedy completion strategy is a recommended process for evaluating groundwater remedy performance to help maximize performance, timeliness and cost efficiency, and to guide lead agency decision-making to ensure remedial actions protect human health and the environment. The decision points, performance metrics and monitoring that typically are addressed in a remedy completion strategy can help assess remedy performance and evaluate whether the remedial action is working as anticipated or if the remedy selected in the decision document may need to be modified in order to achieve RAOs and associated cleanup levels. Consideration of a completion strategy generally may be appropriate throughout the cleanup process, and should help focus resources on evaluating the remedy selected, its operation and progress toward achieving the RAOs and associated cleanup levels in a reasonable timeframe.

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Appendix 1 - Recommended Technical Foundations for Site-Specific Completion Strategy Development

An effective groundwater remedy completion strategy generally should be based upon "technical foundations" which normally include: (1) improving the current and comprehensive understanding of the site characteristics; (2) developing definitive RAOs and associated cleanup levels and timeframes; and (3) improving the current understanding of other site actions related to groundwater cleanup. This appendix describes these technical aspects in more detail.

Update or Verify the Conceptual Site Model

A current understanding of subsurface structure and processes as depicted in a current CSM is important for development of a groundwater completion strategy. The CSM should be an iterative, "living representation" of a site that summarizes and helps project teams visualize and understand available information (EPA, 2011c). The CSM "synthesizes data acquired from historical research, site characterization, and remediation system operation…the CSM, like any theory or hypothesis, is a dynamic tool that should be tested and refined throughout the life of the project" (EPA, 1993). The CSM also is designed to foster consistent site understanding among the members of the project team and site stakeholders.

CSMs generally should build upon findings from past site investigations, historic and current site operations and intended site reuse. The CSM is "a three-dimensional 'picture' of site conditions that illustrates contaminant sources, release mechanisms, exposure pathways, migration routes, and potential human and ecological receptors. The CSM documents current and potential future site conditions and is supported by maps, cross sections, and site diagrams that illustrate what is known about human and ecological exposure through contaminant release and migration to potential receptors" (EPA, 1999a). As appropriate, a component or outcome of the CSM may be identification of uncertainties and data gaps.

The level of effort to develop the CSM should roughly correlate with the site maturity, site complexity and the extent of site characterization. Technical teams are encouraged to use the CSM in a framework that evolves and continues to incorporate new information as the project characterization and remediation progresses[7]. A life-cycle CSM is essential to identify the need for additional information to minimize the data gaps that may be impeding an understanding of why a remedy may not be performing as anticipated.

"Analyses of the data collected should focus on the development or refinement of the conceptual site model by presenting and analyzing data on source characteristics, the nature and extent of contamination, the contaminated transport pathways and fate, and the effects on human health and the environment" (EPA, 1988a). The improved site understanding that can emerge from an updated CSM can help the project team understand and evaluate remedy progress.

Identify Groundwater Remedial Action Objectives, Associated Cleanup Levels and Timeframe

Groundwater RAOs generally provide a solid foundation for effective remedy implementation, development of the groundwater completion strategy and ultimately site completion. "RAOs provide a general description of what the cleanup will accomplish (*e.g.,* restoration of groundwater to drinking water levels)" (EPA, 1999a). The basis and rationale for RAOs (*e.g.*, current and reasonably anticipated future land use and potential beneficial ground-water use) are typically developed as part of the feasibility study. Consistent with CERCLA,

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[7] The importance of a life cycle CSM that can be used as a project management and decision making tool is further discussed in EPA, 2011c. Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Model. OSWER Directive 542-F-11-011 - see http://www.epa.gov/tio/download/remed/csm-life-cycle-fact-sheet-final.pdf.

the NCP and Superfund guidance documents, site decision documents (ROD, ROD Amendment or ESD) should describe the groundwater RAOs and cleanup levels (EPA, 1999a; EPA, 2009; EPA, 2011).

Depending on site conditions, multiple RAOs may be appropriate for groundwater remedies. “RAOs and associated cleanup levels should be easily identified and “clearly present the intended results of the remedial action” (EPA, 1999a). “A range of RAOs may be applicable to ground-water [*sic*] remedy decisions. Some of these objectives may be achievable in a relatively short timeframe (*e.g*., exposure control, plume containment), while other objectives may require a much longer timeframe (*e.g*., restoration)” (EPA, 1999a). In addition to groundwater RAOs, it may also be appropriate to include RAOs for other media (*e.g.*, soils, sediment, and surface water).

The basic foundation for groundwater RAOs generally includes one or more of the following:

- *“Prevent exposure to contaminated groundwater, above acceptable risk levels.*
- *Prevent or minimize further migration of the contaminant plume (source control).*
- *Prevent or minimize further migration of contaminants from source materials to groundwater (source control).*
- *Return groundwater to its expected beneficial uses wherever practicable (aquifer restoration)”* (EPA, 1999a).

“Basic RAO structures are generally used as a starting point for RAO development and should be modified to include site-specific exposure scenarios and more specificity” (EPA, 2011b). The groundwater RAOs should state if the remedy objective is restoration or containment. Commonly used terms in groundwater RAOs are restore, prevent and minimize. Definitions of these terms are provided in the glossary of this document. The use of these terms as defined in the glossary is encouraged to promote consistency in the development of RAOs.

Groundwater remedies will often have a restoration RAO based on the NCP expectation that groundwater will be restored to its beneficial use within a reasonable timeframe.[8] If there is a waste management unit or a Technical Impracticability Waiver, then inclusion of a containment RAO will be appropriate. In cases where there are both groundwater restoration and containment RAOs, the decision document should clearly identify the applicable portion of the aquifers.

In addition to RAOs, proposed and final decision documents should include “cleanup levels for each medium (i.e., contaminant specific remediation goals), basis for cleanup levels, and risk at cleanup levels (if appropriate)” (EPA, 1999a.)[9] Cleanup levels should be identified for each COC. In many cases, ARARs, for example MCLs for groundwater are generally the cleanup level or measurable remedy endpoint” (EPA, 1999a). “Final cleanup levels establish acceptable contaminant-specific exposure levels that are protective of human health and the environment (EPA, 1999a). "Groundwater cleanup levels are established based on promulgated standards (*e.g*., federal or state MCLs or non-zero MCLGs), or other standards to be found to be ARARs, or risk-based levels (*e.g.,* for contaminants when there are no standards that define protectiveness)” (EPA, 2009). This measure is crucial in determining when an RAO has been achieved to allow the Agency to move the site to completion.

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[8] *“EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site. When restoration of ground water to beneficial uses is not practicable, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated ground water, and evaluate further risk reduction” 40 CFR 300.430(a)(1)(iii)(F).*

[9] Interim decisions may be issued and are followed by a final ROD which identifies the final ARARs and cleanup levels (EPA, 1999a).

Understand Site Actions Related to Groundwater Cleanup

The site team should understand past, ongoing and future site activities related to the groundwater contaminants and groundwater cleanup. Information is typically available from the remedial investigation/feasibility study, remedy decision documents, five-year review reports and other site related documents. Other activities or conditions at the site (*e.g.*, source control actions) that may impact the groundwater remedy and long-term operation and maintenance of the remedy should also be considered (EPA, 1988a; EPA 1999a; EPA 2001; EPA 2005; EPA, 2011b; EPA, 2012).

Groundwater Remedy

The site-specific strategy developed by the lead agency typically should note if the groundwater remedy actions are phased, interim or final and whether the response action's goal is restoration and/or containment of the groundwater[10]. The status of the remedy implementation, timeframe and anticipated next phases, if applicable, should be described.

Other Remedy Components

In addition to the selected groundwater remedy, other media information may also be important to consider. For example, early actions taken to control sources, exposure and/or contaminant migration should be identified. Superfund site cleanups may include remedial actions that address other media such as source areas, surface water, soil, sediment and air. Examples of other cleanup components that may influence the groundwater remedy include removal actions, source remediation activities (*e.g.*, excavation and off-site disposal, NAPL recovery, soil vapor extraction and/or destruction), source containment features (*e.g.*, landfill cap, subsurface barriers) and institutional controls. Depending on the site, it may also be important to consider impacts from flooding, drought and climate change. The completion strategy should briefly summarize site-related activities impacting the groundwater remedy and influencing the groundwater remedy completion strategy decision points. The discussion should include the implementation status and anticipated next phases of remedy implementation.

Operation and Maintenance (O&M) and Long-term Monitoring

During groundwater remedy implementation, operational and monitoring data should be regularly collected to evaluate and monitor progress toward attainment of RAOs and associated cleanup levels as well as evaluating the efficiency of the system (EPA, 2004a, EPA, 2005; EPA, 2011a).

Optimization Reviews (if conducted to date)

Periodic optimization reviews can improve the operation and efficiency of groundwater remedies. Optimization of remedy performance considers improvements to operational parameters (*e.g.*, flow rate, well locations); treatment components and other remedy elements related to ensuring efficacy of the groundwater remedy (EPA and USACE, 2005; EPA, 2007; EPA, 2012). Long-term monitoring optimization considers whether the monitoring network is sufficient to provide the appropriate data to evaluate remedy progress, protectiveness and attainment of RAOs and cleanup levels.

If remedy engineering performance or monitoring optimization efforts have been previously conducted for the groundwater remedy, the outcomes and findings should be considered during development of the site-specific groundwater remedy completion strategy. The nature of the evaluations, findings and any outcomes should

[10] Groundwater remedy features that should be briefly described include, but are not limited to, the following: in situ/ex situ treatment components; monitored natural attenuation components; groundwater-related institutional controls; and groundwater monitoring.

be considered as these may provide additional information supportive of the strategy. The results of previous optimization reviews can help inform and frame the utility of any subsequent optimization reviews that may be part of the strategy.

Other Site Factors

Other site factors may affect groundwater remedy components and cleanup progress. These normally will be site-specific and could include current site and surrounding land uses as well as reasonably anticipated future land uses. Examples of other factors that may impact the groundwater remedy include public, domestic, irrigation and other water supply wells; water applied for landscaping, irrigation or other purposes; subsurface injection or drainage; nearby construction projects; extreme weather events such as floods and droughts; and others.

Appendix 2 - Glossary

For purposes of this guidance, the following terms are defined as follows:

Applicable or Relevant and Appropriate Requirements (ARAR): As defined in the NCP (40 CFR §300.5), the term "applicable requirements"

> means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

The term "relevant and appropriate requirements"

> means those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not 'applicable' to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

Attainment: An outcome that occurs at each monitoring well and is determined complete "when contaminant-specific data provide a scientific basis that: 1) the contaminant cleanup level for each COC has been met; and 2) the groundwater will continue to meet the cleanup level for each COC in the future" (EPA, 2013a).

Cleanup Levels: "Final cleanup levels establish acceptable contaminant-specific exposure levels that are protective of human health and the environment. They are not formally determined until the site remedy is ready to be selected and are established in the ROD. In the ROD, it is preferable to use the term "remediation level" or "cleanup level" rather than "remediation goal" in order to make clear that the Selected Remedy establishes binding requirements" (EPA, 1999a).

Conceptual Site Model (CSM): "An iterative, 'living representation' of a site that summarizes and helps project teams visualize and understand available information" (EPA, 2011c).

Feasibility Study (FS): As defined in the NCP (40 CFR §300.5):

> *Feasibility study* (FS) means a study undertaken by the lead agency to develop and evaluate options for remedial action. The FS emphasizes data analysis and is generally performed concurrently and in an interactive fashion with the remedial investigation (RI), using data gathered during the RI. The RI data are used to define the objectives of the response action, to develop remedial action alternatives, and to undertake an initial screening, and detailed analysis of the alternatives. The term also refers to a report that describes the results of the study.

Focused Feasibility Study (FFS): A feasibility study "under which fewer alternative options would be studied…consistent with the NCP (see § 300.430(e)(1))" (NCP Preamble at 55 FR 8793).

Groundwater Remedy Completion Strategy: A recommended site-specific course of actions and decision making processes to achieve groundwater RAOs and associated cleanup levels using an updated conceptual site model, performance metrics and data derived from site-specific remedy evaluations.

Long-term Monitoring Optimization (LTMO): Efforts to "improve the cost-effectiveness of long-term monitoring by assuring that monitoring achieves its objectives with an appropriate level of effort" (EPA and USACE, 2005).

Maximum Contaminant Level (MCL): Drinking water standards established under the Safe Drinking Water Act which as ARARs typically represent cleanup levels at CERCLA sites. "MCLs are set at levels that are protective of human health, and are set as close to MCLGs as is feasible taking into account available treatment technologies and the costs to large public water systems." Consistent with CERCLA and the NCP, MCLs typically are relevant and appropriate when establishing cleanup levels for contaminated groundwater that is or may be used as drinking water (EPA, 1988b).

Maximum Contaminant Level Goals (MCLG): "Strictly health-based levels established under the Safe Drinking Water Act that do not take cost or feasibility into account. As health goals, MCLGs are established at levels at which no known or anticipated adverse effects on the health of persons occur and which allow an adequate margin of safety" (EPA, 1988b).

Minimize: A term that can be used in RAOs to describe curtailing the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment [from CERCLA Section 101(24)].

Monitored Natural Attenuation (MNA): Typically physical or biological processes (unassisted by human intervention) that will "attain cleanup levels (or other remedial action objectives) in a timeframe that is reasonable when compared to the cleanup timeframes of the other alternatives and when compared to the timeframe of the anticipated resource use" (EPA, 1999b).

Operation and Maintenance (O&M): "(A)ctivities required to maintain the effectiveness and integrity of a remedy; in the case of Fund-financed measures to restore groundwater or surface water, O&M refers to the continued operation of such measures beyond the LTRA (long-term response action) period until cleanup levels are achieved" (EPA, 2011a).

Optimization: "Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase" (EPA, 2012).

Performance Metrics: Site-specific remedy performance criteria, hydrogeologic parameters or contaminant concentration trends typically used to evaluate remedy performance and measure progress (*e.g.*, effluent discharge concentrations, contaminant concentrations trends in a monitoring well).

Prevent: A term that may be used in RAOs to describe stopping the release of hazardous substances, pollutants or contaminants so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment (from CERCLA Section 101(24)).

Reasonable Timeframe: The time period "to return usable ground waters to their beneficial uses wherever practicable…given the particular circumstances of the site" (40 CFR 300.430(a)(1)(iii)(F)).

Record of Decision (ROD): As described in EPA's 1999 ROD guidance**:** "The ROD documents the remedial action plan for a site or operable unit and serves the following three basic functions: (1) it certifies that the remedy selection process was carried out in accordance with CERCLA and, to the extent practicable, with the NCP; (2) it describes the technical parameters of the remedy, specifying the methods selected to protect human health and the environment including treatment, engineering, and institutional controls components, as well as cleanup levels; and (3) it provides the public with a consolidated summary of information about the site and the chosen remedy, including the rationale behind the selection" (EPA, 1999a).

Remedial Action Objectives (RAOs): RAOs specify "contaminants and media of concern, potential exposure pathways, and remedial goals" (40 CFR 300.430(e)(2)(i)). Consistent with the NCP, "RAOs are designed to provide a general description of what the cleanup will accomplish (*e.g.*, restoration of groundwater to drinking water levels)" (EPA, 1999a).

Remedy Evaluations: Normally conducted throughout the life cycle of the groundwater remedy to make decisions about remedy performance and progress toward attainment of RAOs and cleanup levels (*e.g.*, Are treatment units functioning as intended? Are the concentration trends as anticipated?). Evaluations should be conducted using site-specific performance metrics and site data.

Restoration: A term used to describe reduction of concentrations of COCs identified in the ROD to levels that ensure protectiveness of human health and the environment, consistent with Superfund or RCRA Corrective Action programs. For groundwater currently or potentially used for drinking water purposes, these levels may be MCLs or non-zero MCLGs established under the SDWA; state MCLs or other cleanup requirements; or risk-based levels for compounds not covered by specific state or federal MCLs or MCLGs. Other cleanup levels may be appropriate for groundwater used or potentially used for non-drinking purposes (EPA, 1993).

Restore: A term used to describe "returning usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site" (40 CFR 300.430(a)(1)(iii)(F)).

Technical Impracticability (TI): An ARAR waiver that may be authorized under CERCLA. The TI waiver may be appropriate when compliance with an ARAR specified in a ROD "is technically impracticable from an engineering perspective" (40 CFR 300.430(f)(2)(ii)(C)(3)).

Figure 1: Overview of Groundwater Remedy Completion Strategy

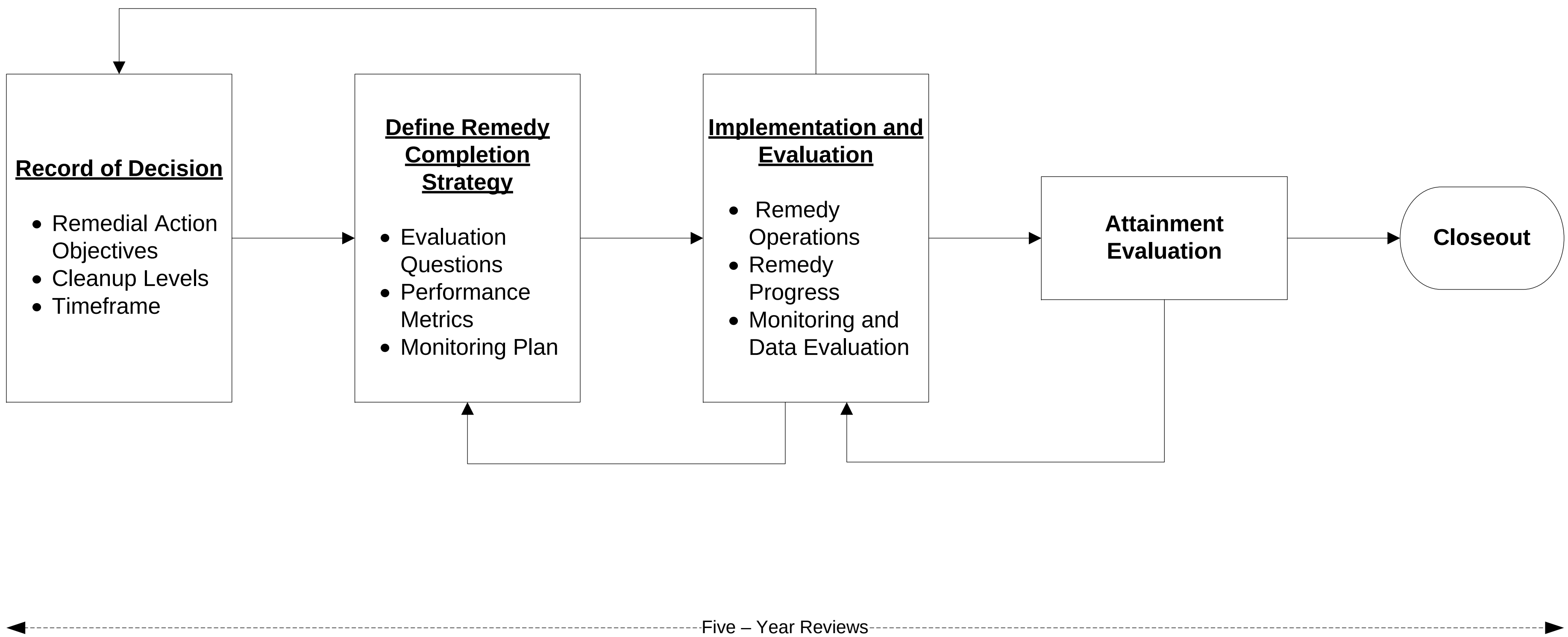
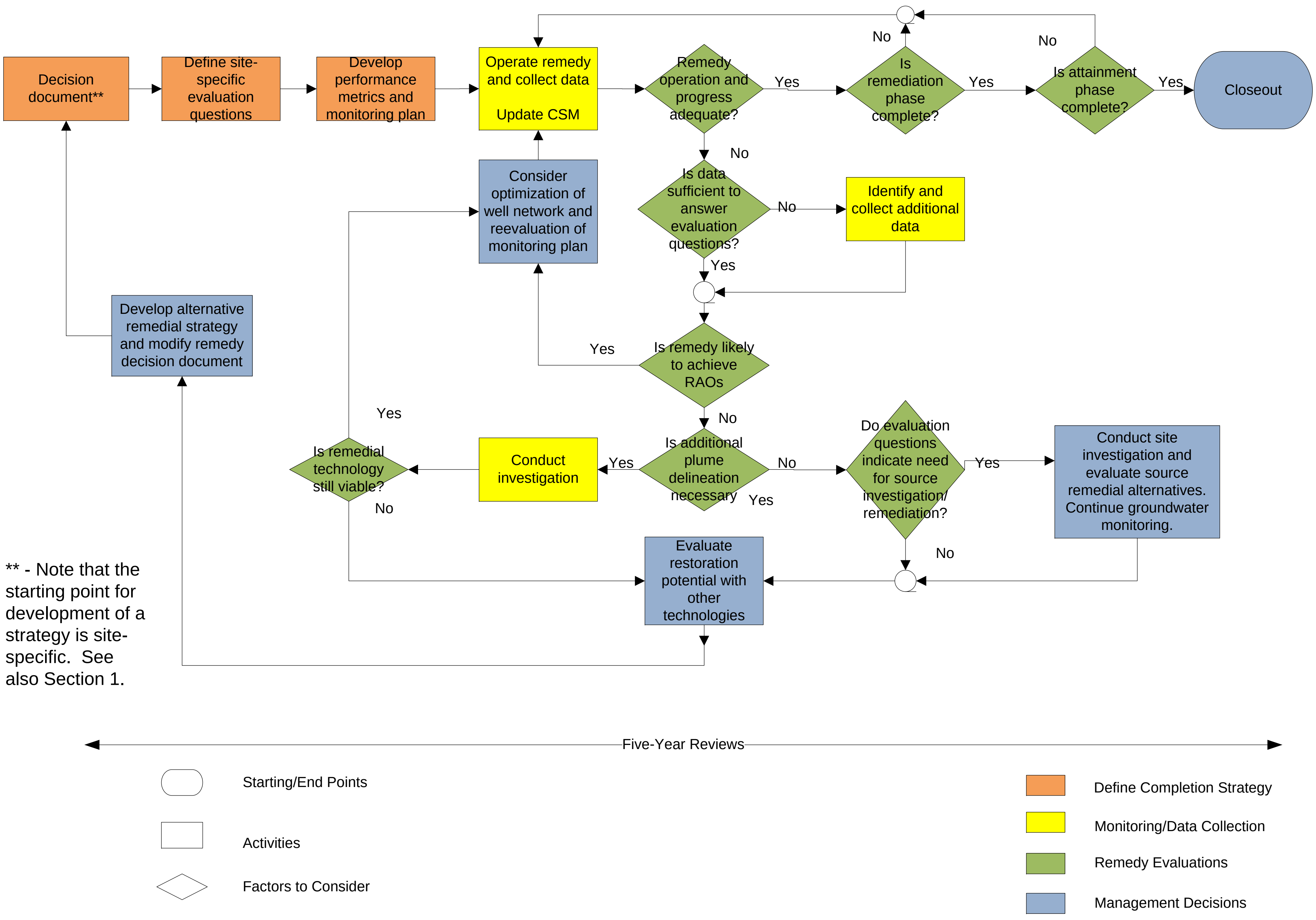


Figure 2: Groundwater Remedy Completion Strategy Implementation



** - Note that the starting point for development of a strategy is site-specific. See also Section 1.

Figure 3: EXAMPLE OF A REMEDY EVALUATION STRUCTURE