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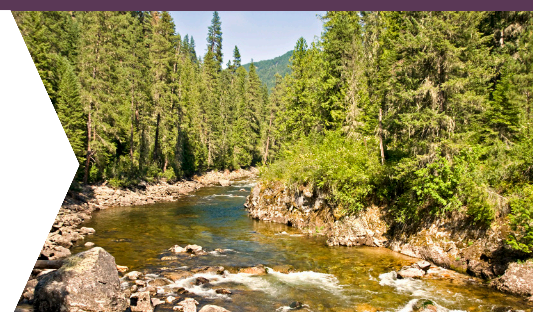
Expedited Exit and Remedy Optimization Strategies for Contaminated Sites

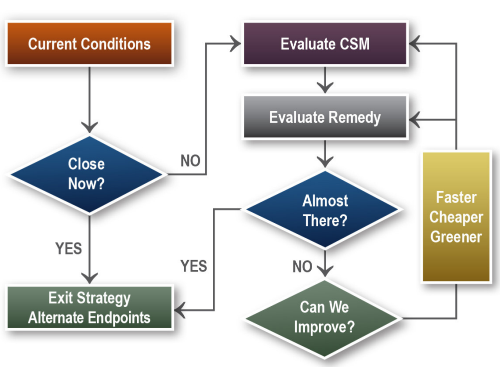


Contaminated sites often present significant technical challenges that can complicate the design and implementation of effective remedies. As a result, responsible parties are faced with ongoing and increasing remediation costs while seeing little progress towards achieving cleanup and making an exit. Even when a remedy initially shows high levels of effectiveness (perhaps in terms of contaminant mass removal), it can become less so over time while the costs of operating the remedy remain steady or even increase, making site closure or even a significant reduction in operation and management costs seem unachievable.

A careful review of site conditions, treatment objectives, and the remedy design and performance, coupled with technical expertise and a deep understanding of the applicable regulations can improve that outlook. There are a number of factors to consider in such a review, such as technological innovations and changes in risk assessments, site conditions, or a project's regulatory and economic context, that can have a positive impact on obtaining closure. In some cases, these factors could identify readily achievable remedial action objectives, while in others they could uncover the potential for improving the performance of existing remedial technologies or transitioning to more effective remedies while reducing costs and shortening the time to site closure. Although the opportunities and outcomes of these evaluations are unique to each site and the detailed procedures are adapted on a case-by-case basis, certain steps and processes can be applied to almost any site.

Woodard & Curran has developed a pragmatic strategy for expedited exit and remedy optimization (Figure 1). We begin with a deep understanding of current conditions to evaluate if closure options are available immediately, including alternative endpoints. If not, then our approach follows a path beginning with evaluation of the conceptual site model, the current remedy, and the monitoring program to determine if improvements can be made and result in a more efficient and effective remedy.

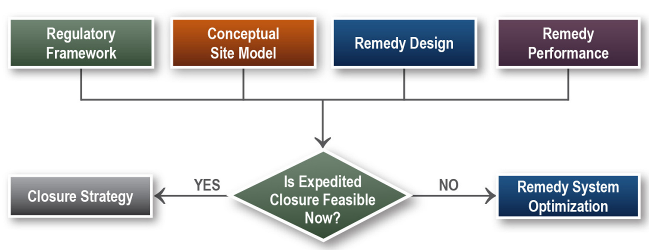
Figure 1: Overall Optimization Process



EVALUATE CURRENT CONDITIONS

The first step in developing an accelerated exit or remedial optimization strategy is evaluating the current site conditions. There are four primary components to evaluate here (Figure 2): the regulatory framework, the conceptual site model, the technical design of the existing remedy (or remedies), and the performance of those remedies.

Figure 2: Current Conditions Assessment



Regulatory framework key in defining remedial goals

Federal and state regulations often have different risk thresholds, enforceable cleanup standards, and procedures for agency approval of closure plans, among other differences. Furthermore, regulations can vary between different federal (e.g., RCRA or CERCLA) and state programs (e.g., a voluntary cleanup or state oversight program), making each project subject to a somewhat unique web of rules and requirements. Understanding the applicable regulatory framework is essential for determining the remediation objectives that must be achieved for site closure and exit. Furthermore, doing comprehensive research on the regulatory environment your project is subject to may help you discover an alternative regulatory program that could provide a more favorable setting for closure or optimization.

The goal here includes understanding the applicable regulatory framework, along with associated cleanup objectives, program flexibility, and necessary procedures. This requires reviewing relevant documents, such as consent orders and other agreements, along with an assessment of the conceptual site model. Incorporating this as part of your exit and optimization strategies development, in addition to enabling you to possibly uncover more favorable regulatory programs, should also uncover recommendations for improving site management.

Identifying gaps in information through CSM review

The conceptual site model (CSM) is a representation of the physical, chemical, and biological processes and the interactions among them that reflect or influence the source, distribution, fate and transport, and risk associated with contaminants of concern (COCs). Nearly all aspects of site management — permitting, developing objectives, remedy design and implementation, monitoring, and ultimately closure — rely on an accurate and complete CSM. For example, uncertainties regarding what COCs are present, where the COCs are located, how much of a COC is present, COC transport pathways and rates, and COC transformation can lead to ineffective remedy design and performance. Remedies are initially designed and implemented based on the conditions at the outset of a project, but site conditions can evolve over time due to degradation and attenuation processes, transport, and remedial progress, which is why a remedy that may have initially performed very effectively may not always do so.

A regular evaluation of the CSM accuracy and completeness is important, including a detailed assessment of the COC mass and distribution, geologic and hydrogeologic characterization, fate and transport processes, and the risk associated with the COCs at relevant exposure points. This effort typically includes reviewing historical site investigation and characterization reports, risk assessments, modeling and remedy design reports, and monitoring data. Data gaps and recommendations for any additional investigation necessary to augment and update the CSM should become clear through this evaluation, providing a firmer foundation for remedy enhancements.

Adapting remedial approach based on technical design review

If you're looking for an optimization strategy, a remedy is most likely already in place. Remedies may include active systems (groundwater extraction and treatment, in-situ chemical oxidation or reduction, bioremediation), passive systems (monitored natural attenuation), or combinations of remedies. While the remedy was probably designed and implemented based upon a CSM, remedial technologies improve over time, and new, potentially more effective or less costly, alternatives may be available. As mentioned before, the conditions upon which a remedy was designed may also change over time, so a detailed review of existing remedies is an important element for formulating remedy optimization strategies.

The specific elements of this review depend upon the nature of the remedy, but generally include a detailed evaluation of the design basis, construction, and implementation of the existing remedy. It could also include an evaluation of system engineering (for example, the design of a groundwater treatment system), the characterization and modeling data upon which a design was based (groundwater extraction well capture zones or geochemical data such as redox conditions), and other elements of the remedy design (the estimated reagent radius of influence, well spacing and depth, reagent dosages for a reagent injection, etc.). The outcome of this assessment, along with an associated evaluation of the remedy's performance, will help form a basis for recommendations to improve upon the existing remedies or change them altogether.

Determining next steps based on remedy performance

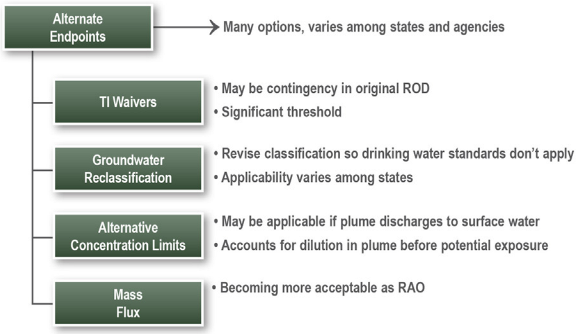
The last key element of the current conditions assessment is a performance evaluation of the existing remedy. The objective is to determine if a remedy is performing as designed. This is accomplished by reviewing periodic monitoring, treatment program report, or five-year review reports. Assimilating the information in these reports with the findings of the associated technical design review will help define a clear path forward for tweaking your remedial strategy as needed.

DISCOVER ALTERNATIVE ENDPOINTS FOR A SMOOTH EXIT

Once the current conditions evaluation is complete, the next step is to draw a conclusion about whether an effective exit strategy can be proposed based upon your findings from all four key elements of the assessment. Traditionally, site closure was defined based upon achieving some type of unrestricted use or drinking water standard, or potentially a risk-based closure level. Today, however, alternative endpoints are becoming more widely accepted within the regulatory community.

There are a wide variety of possibilities for alternative endpoints, depending upon the regulatory framework, nature of the COC distribution and discharges, technical ability to achieve unrestricted use concentrations, availability of more effective remedial technologies, and other site characteristics. Examples of alternative endpoints (Figure 3) include technical impracticability waivers, alternative concentration limits, groundwater reclassification, or mass flux. Any alternative endpoint will typically require ongoing monitoring to ensure any wastes left in place above unrestricted use standards do not pose an unacceptable risk, and that human health and the environment remain protected. Such monitoring could include long-term groundwater monitoring, periodic site inspections, deed restrictions, and engineering controls. While alternative endpoints may not fully release a responsible party from future liabilities, they can result in significant cost savings and return impacted properties to productive use on a shorter timeline.

Figure 3: Alternative Endpoint Examples

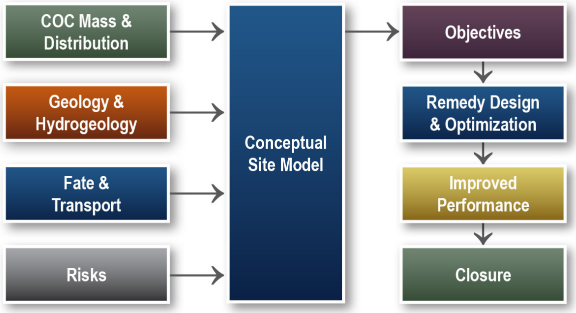


MAKING IMPACTFUL IMPROVEMENTS TO YOUR REMEDY

If a rapid exit or site closure are not reasonably achievable goals, the next step is to determine if an existing remedy can be optimized to improve performance or sustainability, reduce costs or the time required to achieve the remedial action objectives, or any combination of these metrics. The overall optimization process has four primary steps (Figure 4) that begin with an evaluation of the CSM. The CSM provides the overall basis for site management, including

Figure 4: Remedy Optimization Sequence

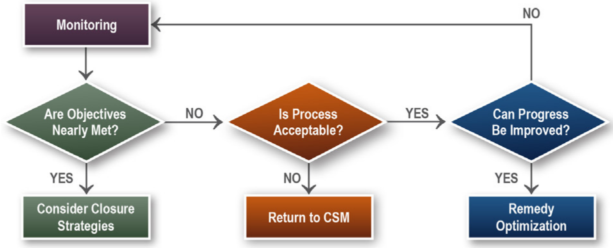
Figure 5: Central Importance of the CSM



remedial objectives, remedy design and optimization, performance, and ultimately site closure (Figure 5). The CSM is based upon multiple lines of information, including contaminant mass and distribution, geology and hydrogeology of the site, contaminant fate and transport, and the associated risks.

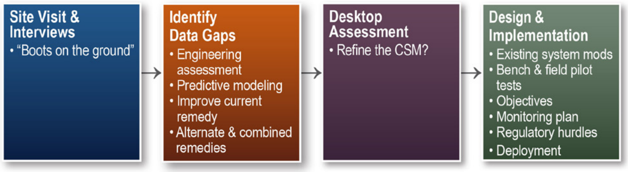
Remedy performance is based upon consideration of the monitoring data to evaluate if the remedy is performing as designed (Figure 6). If closure objectives are nearly met, then alternative endpoints may be considered (Figure 3). Otherwise, the monitoring data are evaluated to determine if interim objectives are being met or if remedy performance can be improved. If a remedy is not performing as designed, poor performance may be due to an incomplete or inaccurate CSM that resulted in an ineffective remedial design. However, if the CSM is reasonably complete and accurate, the remedy itself may not be well designed, or a change in site conditions could have affected the remedy's performance.

Figure 6: Remedy Performance Evaluation



Once the CSM and remedy performance are evaluated, enabling you to better pinpoint why a remedy isn't as effective as it could be, a four-step remedy optimization strategy begins with a site visit and interviews with operators,

Figure 7: Remedy Optimization Strategy Steps



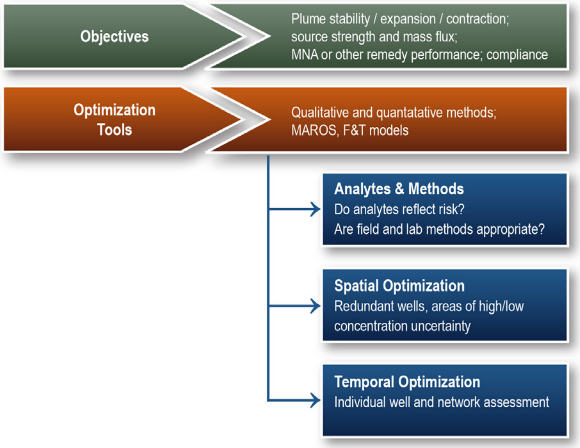
stakeholders, and other key people (Figure 7). A boots-on-the-ground approach provides insight to the conditions that are not visible on paper and an opportunity to interview project staff with experience at the site. Once the site visit is complete, the CSM assessment can be revisited, data gaps filled in, and any additional investigation completed.

Once any data gaps are addressed, the next step is a desktop analysis of the remedial design and consideration of improvement options. Additional modeling and design efforts might also be necessary to effectively evaluate improvements to existing remedies and conduct cost-benefit analyses of alternative remedies. In some cases, the outcome is an improvement to an existing remedy; for example, an adjustment to groundwater extraction rates, or an additional phase of reagent injection may be all that is required to get a remedy on track. In other instances, deploying a completely new remedy may be justified. A new remedy may not involve a complete redesign and construction or any increase in costs; for example, the data may indicate that a groundwater extraction and treatment system is no longer effectively removing contaminant mass, in which case a transition to a monitored natural attenuation remedy (with typically significantly lower operating costs) may be justified. In other cases, technological advances since the initial remedy was deployed may justify utilizing new remedies that are more effective, less costly, or more sustainable.

The final step is identifying any potential hurdles to implementing the optimization recommendations. This could include actions like overcoming regulatory concerns or ensuring compliance with regulatory requirements and confirming that any implemented system modifications are operating as designed.

A final aspect to consider is optimizing monitoring plans (Figure 8). Monitoring plans often represent a significant ongoing operational expense, yet often have room for improvement due to the same factors as remedies. The important questions are if the existing network, sampling frequency, and analyte list are appropriate for a specific site and set of remedial action objectives. Identifying optimization opportunities requires first clearly identifying the monitoring objectives. Once those have been specifically defined, the monitoring plan can be evaluated both qualitatively and quantitatively. Qualitative approaches may be as simple as ensuring that a source-strength monitoring well is indeed installed in the source area. Quantitative approaches include software optimization tools such as MAROS to assess monitoring data in a way that informs your long-term approach and justifies actions, such as modifying a sampling frequency or eliminating redundant monitoring locations.

Figure 8: Is the Monitoring Strategy Effective



SUMMARY

Contaminated site management may seem to carry spiraling costs with no end in sight. The context in which a remedial action is applied may in many respects change over time. The regulatory environment, the technological innovations, the site conditions upon which a remedy was designed, and the business situation may all evolve over time and may provide opportunities for improving your remedy or expediting your exit strategy. The general process outlined here for identifying and capitalizing on those opportunities can be applied to most sites, but every site has unique characteristics, challenges, and concerns. Working with an experienced team to conduct a detailed evaluation of closure possibilities or a remedial optimization effort can provide concrete benefits, potentially resulting in earlier site exit or improved effectiveness as reflected in reduced costs, increased sustainability, and shorter timeframes to completion.

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