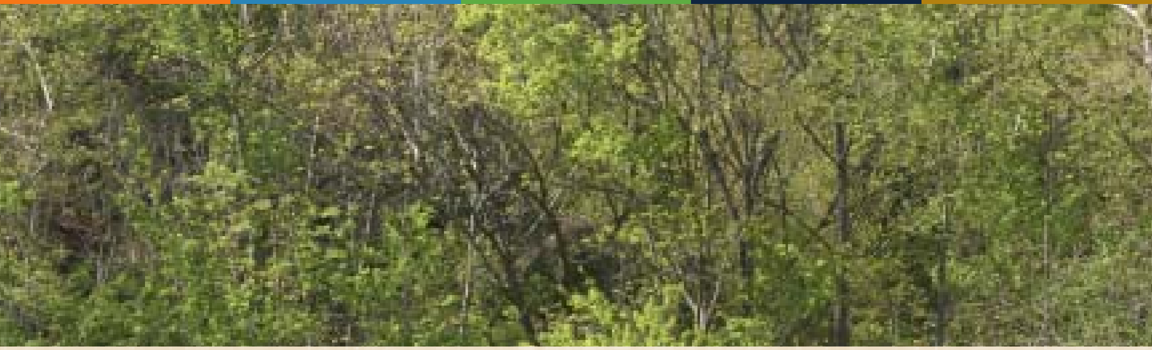
Technology Overview

Exit Strategy–Seeing the Forest Beyond the Trees

Second in a Series of Remediation Process Optimization Advanced Topics



March 2006

Prepared by
The Interstate Technology & Regulatory Council
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Disclaimer

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Exit Strategy—
Seeing the Forest Beyond the Trees

Introduction

This overview reviews the concept and advantages of Performance-Based Exit Strategies as one element of performance-based management (PBM) of environmental remediation projects. In 2004, the Interstate Technology and Regulatory Council (ITRC) Remediation Process Optimization (RPO) Team developed a technical regulatory guidance document titled, "*Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation.*" Based on feedback on the guidance and supplemental training, the RPO team identified the need for information on several additional PBM topics. This overview focuses on the role of the exit strategy in PBM of site remediation; reviews key elements of an exit strategy, discusses the benefits of preparing a transparent, flexible performance-based exit strategy, summarizes potential obstacles to developing, refining, and implementing a performance-based exit strategy, and considers the role of regulatory agencies in optimizing exit strategies.

Who We Are and the Intended Audience

The ITRC is a state-led coalition of regulators, industry experts, citizen stakeholders, academia, and federal partners that work to achieve regulatory acceptance of innovative environmental technologies. This coalition consists of 46 states and a network of some 7,500 people who work to break down barriers, reduce compliance costs, and make it easier to apply new technologies to solve environmental problems. ITRC helps maximize efficient use of state resources by creating a forum where innovative technology and process issues are explored. Together, the team members are building the environmental community's ability to expedite quality decision making while protecting human health and the environment.

This overview has the following intended audience who are involved in either remediation process (RPO) or PBM of hazardous site remediation projects:

- State and federal regulators
- Facility owners and operators
- Engineers and consultants
- Interested stakeholders

States and federal agencies play multiple roles in the RPO and PBM processes: as regulators, and as facility owners and operators when public funds are used to conduct site remediation work. As regulators, state and federal agencies are charged with protecting human health and the environment. Also, facility owners, private or public, have the greatest interest in achieving the goals of the specific site remediation project. In addition, the engineering and consulting community who guide and provide professional opinions to the owners must have a deep working knowledge of techniques that can ensure fast and effective site remediation. To understand PBM and be full participants in environmental remediation efforts, public stakeholders must not only understand technologies used at sites, but also the underlying technical basis that supports the decision-making process. This document is intended as a summary of performance-based exit strategies; however, users are encouraged to refer to the references provided at the end of the fact sheet for additional information.

This overview is part of a five fact booklet series: *Performance-based Management, Analysis of Above Ground Treatment Technologies, Exit Strategy Analysis, Data Management, Analysis and Visualization Techniques*, and *Life Cycle Cost Analysis*; each is an excellent resource for moving forward on their RPO and PBM projects. Public participation is emphasized during the response action planning process, through selection of the final remedy in the Decision Document (DD). Periodic remedy performance evaluations and DD modifications also generally are available for public review.

What is an Exit Strategy?

An "exit strategy," also referred to as a "response completion plan," is a detailed, dynamic and succinct plan for accomplishing specific performance goals within a defined time period to assure protection of human health and the environment.

Exit Strategy Steps

1) Identify Risk or ARAR concern (include source, receptor, and pathway based upon updated conceptual site model (CSM))
   a) Identify remedial goal
   b) Identify proposed or current remedial method(s)
   c) Identify metrics (If a measurement is taken at any point, there should be a specific action logic associated with that measurement)
      i) Identify measurement parameters for closure / response complete
      ii) Identify measurement parameters for compliance monitoring / Milestones
      iii) Identify system operational parameters
   d) Identify contingent actions
      i) Based upon compliance monitoring
      ii) Based upon operational parameters
2) Identify next risk or ARAR concern

Decision documents (DDs) are the most common examples of environmental remediation response completion plans, in that they establish the following

- Environmental conditions that pose an unacceptable risk that requires remediation
- Remedial action objectives (RAOs) that must be met to mitigate the risk
- Means selected to achieve the objectives
- Metrics to be used to demonstrate success

A performance-based exit strategy focuses on performance (i.e., progress toward achieving RAOs) in order to routinely optimize the selected remedy and RAOs as information improves. Such exit strategies are dynamic and explicitly incorporate the flexibility needed to refine the strategy as site and technical knowledge improve over time, and emphasize assessment and optimization of remedy performance to assure timely, cost-efficient protection of human health. A performance-based exit strategy is based on sound scientific and technical understanding of site conditions and remediation technologies, and is iteratively validated and updated through routine review to take advantage of lessons learned. These exit strategies should be constructed using objective metrics and transparent decision logic to describe how progress toward achieving remedial action objectives (RAOs) will be measured and assured, and how "course corrections" will be implemented should the remedy fail to perform as expected.

Parties responsible for environmental remediation at federal or industrial facilities with multiple sites should develop an exit strategy for each site, as well as an overall comprehensive exit strategy for the entire facility. Depending on the maturity of the environmental program at a given site, exit strategies will reflect varying degrees of uncertainty. DDs are formal response completion plans, and as such, should incorporate all the elements of a defensible exit strategy, as described in the following subsection. Exit strategies for sites still in the remedial decision planning process necessarily will be more conceptual in nature. When the remedial decision is finalized, the exit strategy should be updated to reflect the RAOs, the remedial components, and the implementation plan.

As noted, stakeholder input is an important part of the response-decision planning process, which culminates in issuance of the DD. Therefore, good communication among stakeholders during remedy evaluation and selection is essential to establish common ground for dialogue so that expectations and concerns are identified and considered in the exit strategy

What Are Common Obstacles to Implementing a Performance-Based Exit Strategy?

Stakeholder disagreements regarding ARARs, RAOs, selected remedy, practicability constraints, costs, and the schedule to achieve the RAOs are generally resolved during the remedy planning process. Resolution of these issues is documented in the DD, which serves as the formal exit strategy for the site and requires consideration of public input and concurrence among decision-makers. Therefore, a well-planned, technically defensible exit strategy that has been agreed to by the facility owners/operators, regulators, and other stakeholders, should be implementable in an efficient and effective manner. A sound CSM, necessary and achievable RAOs, well-defined performance metrics and monitoring requirements, and a clear decision logic that is consistently applied during routine performance reviews will minimize implementation and optimization difficulties, and are recommended for any new exit strategy (DD).

Primary obstacles to executing an exit strategy generally can be traced to deficiencies in the strategy elements themselves, and are often encountered in attempting to execute poorly conceived or incomplete exit strategies. Many older DDs do not incorporate the elements of a flexible, performance-based strategy as defined herein, and rarely incorporate decision logic for dealing with unexpected conditions or poor performance. These older exit strategies need to be carefully evaluated during performance reviews, and the basis for recommended improvements must be clearly explained and well supported.

As discussed throughout this overview, there are several key elements of an exit strategy—any one of which can undermine the success of the strategy if it is not based on sound science and a comprehensive understanding of site conditions, risk assessment, statutory considerations, and technical/practicability constraints. Potential obstacles to efficient and effective exit strategy execution could include the following:

- If the CSM is inadequate to support the risk assessment, ARAR analysis, or remedy decision, the exit strategy may require modification as additional data become available
- If the RAOs are not necessary to protect human health and the environment, cost will be incurred on unnecessary actions
- If the RAOs are not achievable, the exit strategy cannot be successful
- If the remedy is impracticable or infeasible, the RAOs are unlikely to be achieved in a reasonable timeframe
- If performance metrics are unclear, or the performance monitoring plan is inadequate to provide appropriate evaluation data, the effective and efficiency of the exit strategy cannot be assessed, and optimization needs may go unrecognized—resulting in wasted resources and delayed protectiveness
- If performance assessment and contingency decision logic is not well-defined and agreed to by all stakeholders, expeditious implementation and optimization of the exit strategy is unlikely, and stakeholders may be disappointed in the outcome of the remedy and the time and cost to achieve protectiveness for optimizing and terminating a response action

Routine validation of the CSM and exposure assumptions, proper monitoring, periodic performance reviews, unambiguous metrics, transparent performance assessment, optimization, and contingency decision logic, and prompt communication of performance information to all stakeholders, as discussed in this fact sheet, will facilitate expeditious achievement of RAOs and site closure. Additional information on remedy optimization, monitoring requirements, and performance reviews is provided in the other fact sheets in this series, as well as in ITRC (ITRC 2004) and USEPA guidance documents.

What are the Key Elements of an Exit Strategy?

As a minimum, a defensible, performance-based exit strategy should summarize several key elements of the remedial decision and implementation process. These elements, listed below, are discussed in the following overview subsections.

What is a Conceptual Site Model?

The conceptual site model (CSM) is a summary of all available site-specific information related to contaminant sources and release mechanisms, affected media, contaminant transport and environmental fate, and receptor exposure. A CSM must be updated as data

Elements of a Performance-Based Exit Strategy

- A description of the environmental problem that warrants a response, which typically takes the form of a conceptual site model and results of a risk assessment
- The remediation action objectives (RAOs) that must be met to assure protection of human health and the environment, and the basis for selecting them
- The means (remedy) selected to achieve the RAOs
- Performance metrics and a performance monitoring plan to assess progress toward achieving the RAOs
- Decision logic for optimizing and terminating a response action, including the planned actions, performance metrics, decision points, conditions that will elicit alternative actions, alternative actions, and conditions required for site closeout

What is a Conceptual Site Model?

The conceptual site model is a summary of all available site-specific information related to contaminant sources and release mechanisms, affected media, contaminant transport and environmental fate, and receptor exposure. A CSM must be updated as data and knowledge are acquired, including changes in RAOs. This is crucial for assessing and optimizing remedy performance, and monitoring programs.

What are RAOs and How Are They Developed?

RAOs are the remediation objectives (or remediation completion criteria) that must be achieved to reduce risks and hazards to potential receptors to acceptable levels under reasonable exposure scenarios. Also, RAOs are defined by the nature of the problem being addressed, the scope of the action to be taken. Clearly defined and achievable RAOs are vital to efficient site remediation, and care must be taken to assure that only necessary and practicable remediation commitments are made. The current CSM, results of a risk evaluation, and consideration of statutory requirements form the basis for developing RAOs. RAOs thus should be

- selected based on the need to address unacceptable current or future risk and comply with (or justify waiver of) pertinent regulations,
- tailored to the specific environmental conditions and exposure scenarios requiring a response, and
- achievable in a reasonable timeframe for a reasonable cost

RAOs generally are expressed narratively, whereas media-specific cleanup goals or acceptable exposure concentrations typically are numeric. RAOs also often incorporate or reference the specific numeric cleanup goals. For example, an RAO might be to prevent exposure of onsite receptors to soil contaminants of concern at specific risk-based concentrations; these concentrations usually are developed based on acceptable cumulative risk levels and hazards.

The risk evaluation characterizes health risks to human and ecological receptors by evaluating exposures and contaminant toxicity in the context of the CSM (sources, affected media, receptor exposure points, and distribution, magnitude, mobility, and persistence of site-related contaminants). If site contaminants pose no unacceptable risk or hazard under current or predicted future site conditions, remedial actions—and therefore RAOs—are not required. If an action is warranted to reduce risk to acceptable levels, RAOs may achieve protectiveness through contaminant containment or treatment, and through receptor exposure controls.

RAO development also considers statutory requirements that may affect the scope, degree, or method of remediation. Under CERCLA-governed programs, ARARs must be identified and analyzed in the context of the current CSM. The applicability or relevance and appropriateness of various promulgated state and federal regulations to the specific site conditions (including contaminants, current and future land use, receptors, and physical and geochemical factors) must be evaluated, both initially during development of an exit strategy and periodically thereafter following remedy implementation. As the understanding of the available remedial or corrective action technologies and risks posed by site contaminants evolves, the ARARs for the site should be revisited. ARAR analysis requires an understanding of the intent of the regulations and statutes, the application of these requirements at similar sites, and the true current or potential exposures, as well as realistic performance goals that consider engineering and technical limitations of the selected remediation technology. ARAR analysis will involve team members that are familiar with current legal and regulatory developments, as well as those well versed in hydrogeology, geochemistry, and remediation technologies.

How is Remedy Performance Measured and Assured?

Execution of a performance-based exit strategy requires routine monitoring and comparison of observed site conditions to those predicted during the remedy planning process in order to assess the relative effectiveness and efficiency of the remedy. Most environmental regulatory frameworks require such routine performance assessments to assure protectiveness and to document when RAOs and closeout criteria have been met. For example, CERCLA mandates that remedy performance be reviewed at least every five years for sites that have not been cleared for unrestricted use or unrestricted receptor exposure. These reviews provide an opportunity to:

- Update site and technical information
- Monitor progress toward achieving strategy objectives
- Re-visit ARARs, RAOs, and the selected remedy in the context of updated information and performance monitoring data
- Apply lessons learned to optimize the exit strategy to achieve timely, costefficient, and reliable protection of human health and the environment

For performance reviews to be effective, appropriate evaluation metrics must be established, and performance monitoring data suitable to the metrics must be collected throughout the period of performance. Monitoring frequency and sampling locations needs to be clearly defined as well as how the data will be interpreted. The RAOs may specify that an average of the compliance points concentrations will be used to track performance, and verify cleanup attainment as long as any exceedances are not greater than a specified value.

Metrics

Metrics and, for phased exit strategies, interim milestones, are the yardsticks against which progress—and success or failure—are measured. Performance metrics should be objective and specific, and should represent stakeholder consensus so that the metrics are not subject to “second guessing” as the project team changes. Performance metrics typically fall into three general categories:

- Operational metrics for engineered systems (e.g., fluid extraction rates, treatment system efficiencies; discharge requirements)

- Risk-reduction metrics (e.g., plume stability or recession, product or soil removal, removal, and land-use controls)
- Response completion metrics or site closeout criteria (e.g., RAOs, confirmatory monitoring requirements)

Operational and risk-reduction metrics also may serve as the basis for contingency triggers for supplemental or alternate measures—including focused RPO evaluations—if these metrics are not met within prescribed constraints. For example, if an operational performance metric of 99-percent average removal efficiency is established for an air stripper, with the metric based on the monthly average of weekly influent and effluent measurements, deviation from this metric during any three consecutive monthly might be used to trigger addition of a carbon polishing unit as a contingent measure.

For phased remediation projects that include several steps between initial efforts and final site closure (e.g., initial removal actions or other interim remedies, phased implementation of the primary remedial action), interim metrics (milestones) should be developed to trigger the next phase of action. Also, there may be the stepwise optimization (scale down) of remedial actions and monitoring as risks are reduced (e.g., as a plume footprint diminishes or influent concentration trends become asymptotic). The exit strategy should identify these interim steps and provide clear decision logic that specifies what conditions must be met before proceeding with the next modification, expansion, or contraction of the remediation.

The basis for the decisions can be simple economic (e.g., when funding is available for additional remediation wells) or engineering considerations (e.g., treatment process effectiveness as a function of concentrations) for the timing and scope of the changes. In other cases, the milestones may include the attainment of specific concentration goals in the subsurface or in extracted ground water or soil vapor. Interim milestones also identify the targeted timeframes for attainment of these goals. Modeling may be used to develop the target concentrations and timeframes. Appropriate interim metrics and change milestones should be identified in the exit strategy, and should consider both subsurface (e.g., change from active remediation to natural attenuation) and aboveground systems (e.g., change from thermal treatment of offgas to carbon adsorption). The decision logic for making any changes should be reasonable, consistent with technical and regulatory constraints, and compatible with RAOs.

Furthermore, practicability constraints are an important consideration in developing exit strategy performance metrics and RAOs, and should be clearly defined and agreed upon by stakeholders during strategy development and refinement. Practicability constraints may include time, cost, accessibility, and technical limitations that are used to define what is reasonable and achievable within a reasonable timeframe for reasonable cost (e.g., cost/benefit considerations). Also see the ITRC Life-Cycle Cost Analysis Fact Sheet for more information on life-cycle cost and its potential application to site remediation projects.

Monitoring

A monitoring program is intended to:

- Assure protection of potentially exposed populations
- Monitor changes in site conditions
- Assess the efficiency and effectiveness (performance) of the remedy at meeting RAOs
- Support decisions regarding the need to optimize the remedy
- Support site closeout

Monitoring programs should be routinely reviewed and optimized to assure that these objectives can be evaluated and that adequate and appropriate data are being collected at appropriate intervals. As remediation progresses and subsurface conditions change, the LTM program should be optimized. The exit strategy should address how the LTM program will change as the conditions change. While the LTM program likely will be reduced as performance metrics are met consistently, the exit strategy also must plan for monitoring program expansion in the event of unforeseen changes in site conditions that adversely affect remedy performance (e.g., a new source, recognition of an emerging contaminant of regulatory interest, changes in land use or climate, plume expansion, undesirable byproduct of remedial action). The basis for these changes should be documented in the DD and in remedial action planning documents (e.g., site Sampling and Analysis Plan, O&M Plan). Iterative assessment and optimization of the LTM program also should be performed to ensure that information required to document that closure criteria have been reliably met is well-defined and is being reported as the project progresses. If there is any ambiguity as to what is to be documented or why, a potential exists to overlook important information or to accumulate unnecessary data; both of which likely will have negative impacts on exit strategy cost and schedule. LTM program reviews can be implemented annually as part of the annual groundwater monitoring and O&M reporting, and can be conducted during RPO evaluations and periodic protectiveness reviews.

Example Exit Strategy

1) Risk-Petroleum at Site A – Private well near property boundary~1/4 mile to the NW, groundwater flow generally NW (see CSM pages 12-20 for locations of drinking water receptors)

a) Remedial goal-Source area groundwater below a concentration of 7 ppm benzene (see CSM page 19, and RA pages 70 -75 for fate and transport decisions)

b) Remedial method(s)-SVE/AS (see pilot test report)

c) Metrics

i) Response complete-When groundwater concentration is below 7 ppm benzene at MW-1 (source well) for four consecutive events

ii) Compliance monitoring-Quarterly for the first year and semi-annual thereafter at source MW-1, and sentinel wells MW-2 & MW-3 (located between source and receptor)

iii) SVE/AS system monitoring

(1) Injection point pressure

(2) Etc.

d) Contingencies

i) From compliance monitoring

(1) If concentration at MW-2 increases over 40% for two events, review of the SVE/AS system will be performed; alternative technologies may be considered (state what would support the decision to switch technologies)

(2) If concentration in MW-3 increases, additional remedial actions will be performed (state what they would be) or consideration will be given to relocating the private well

ii) Operational monitoring

(1) If the injection point pressure starts increasing past a specified point, jet injection wells

(2) If measurable progress towards the remedial goal is not documented by the groundwater monitoring program – system operation will terminate and be reviewed for optimization or an alternative strategy (identified here) will commence

2) Risk-Petroleum at Site A – Utilities …

Decision Logic for Optimization and Contingency Planning

During periodic remedy performance reviews, monitoring data are compiled and used to validate or update the CSM, the RAOs (including the ARAR analysis), and design and exposure assumptions. This updated information then is compared with expected conditions and the established performance metrics to assess ongoing protectiveness, progress toward RAOs, and overall remedy effectiveness and efficiency, to document success and to identify problems that may warrant corrective action. A performance-based exit strategy should "expect success, but plan for possible failure." Such exit strategies assure that most eventualities during remedial action implementation are readily managed by a pre-determined process that has stakeholder buy-in, and facilitate corrections that keep the strategy focused on end goal of costefficient protectiveness in a reasonable timeframe.

Simple "if (*a specified condition occurs*)–then (*a specified action will be taken*)" decision statements can be developed to identify how performance monitoring data will be used to assess performance, and which conditions are cause for concern. The degree of precision reflected in the decision logic may vary in various project documents. For instance, a generalized performance-assessment decision logic could be developed in the DD to reflect the principal metrics to be applied to the remedy (e.g., cost and time to achieve critical milestones, what would trigger the need for a contingency measure or scale-down of operational or monitoring requirements would occur). More detailed performance metrics/contingency triggers, and the process for invoking corrective action (e.g., optimization) could be detailed in the LTM and O&M plans. Stakeholder consensus should be sought during development of all remedy optimization and contingency measure decision logic.

A flow diagram can be used to graphically present decision logic, and aids in consensus building due to the transparency of this format. Flow diagrams (Figure 1. shows an example) also are useful tools that lend themselves well to the performance evaluation and optimization process. In any long-term remediation effort, the potential exists for undesirable migration of the plume, persistent contaminant concentrations, or rebound of concentrations following cessation of active treatment or extraction systems. An appropriate exit strategy will include provisions for contingent actions in the event of such observations. When a remedy is failing to achieve RAOs, the underlying reason must be determined, and the RAOs, the means to achieve them, or both must be modified. Actions to improve the means could include remedial system optimization, replacement or supplementation of the selected remedy, or a technical impracticability evaluation. Any modification to RAOs should be based on a reassessment of the need to achieve specific objectives in order to be protective of human health and the environment, and the applicability or relevance and appropriateness of regulatory numeric criteria. For example, an RAO that specifies restoration of an otherwise nonpotable water-bearing unit to drinking water standards could be replaced with an RAO to prevent ingestion of the affected groundwater (e.g., by invoking state or county restrictions on installation of potable water wells in water-bearing units with poor water quality). The exit strategy, as documented in the DD, should be modified in the event that either remedial actions or RAOs are revised.

What is the Regulators' Role in Exit Strategy Optimization?

As noted at the beginning of this fact sheet, performance-based exit strategies must be flexible to take advantages of improving knowledge and lessons learned. Changes to the exit strategy are typically proposed due to a change in the understanding of site conditions. The change may be the discovery of a new source or a new receptor, historical monitoring trends that indicate a change in monitoring frequency, treatment systems which have not performed as well as expected, or promising new remedial techniques. Because a significant change to the exit strategy typically equates to a modification of the DD, regulatory review of the proposed modification is required. It is the regulators' task to ensure that the greater good of the community will be served by the proposed exit strategy change.

Before considering specific statutory requirements, an initial screening of the proposed change with the following questions can help put the decision into perspective and give a feel for the necessity of action.

- Does an immediate risk (unacceptable receptor exposure) exist, and if so, will the change eliminate it? When an immediate risk exists, an action should be taken to eliminate the exposure.
- Will the proposed change introduce new risks? As an example, a proposed remedial action could potentially release or accelerate migration of contaminants into other media, where they may be more difficult to treat or contain.
- Will the proposed change result in expedited or more cost-effective attainment of RAOs? The benefits (risk-reduction) associated with a proposed change should be weighed against cost and schedule impacts.

By considering the performance issues reflected in the preceding questions, the reviewer can optimize the decision process and focus attention on effective and efficient protection of human health and the environment. A performance-based exit strategy provides a flexible framework within which evolving site conditions and technical understanding can be applied to reduce uncertainties and to plan for the unexpected, while meeting the responsibilities of sound environmental management and efficient use of resources.

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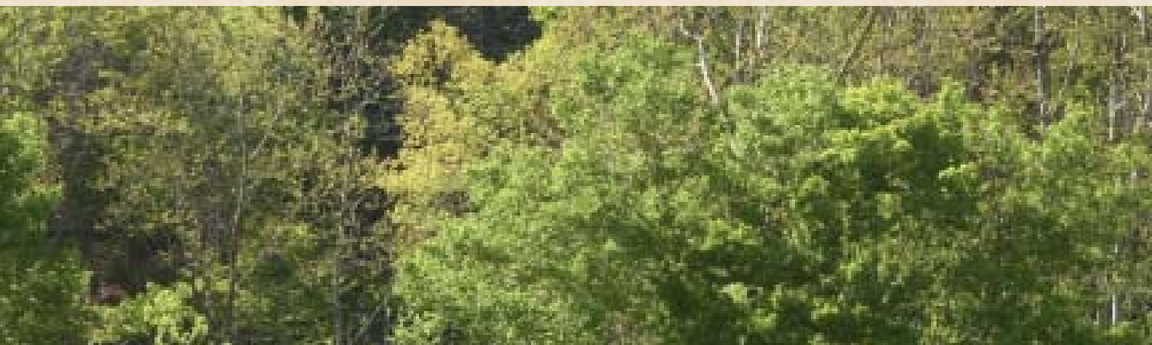

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