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MEMORANDUM

SUBJECT: Technical Guides to Streamline Site Cleanup: Smart Scoping, Strategic Sampling and Data Management Best Practices

FROM: James E. Woolford, Director
Office of Superfund Remediation and Technology Innovation

TO: Superfund National Program Managers, Regions 1 – 10

PURPOSE

This memorandum's purpose is to transmit three technical guides: "Smart Scoping for Environmental Investigations," "Strategic Sampling Approaches Technical Guide" and "Best Practices for Data Management." The U.S. Environmental Protection Agency (EPA) developed these documents to assist environmental professionals in scoping, data management and strategic sampling activities at hazardous waste sites. EPA intends for the guides to strengthen Superfund site characterization activities to facilitate stronger site remedy decisions and improved remedy performance, among other objectives.

BACKGROUND

In the past six years, EPA's understanding of best management practices (BMPs) for site characterization has grown through implementation of the Agency's 2012 Superfund national optimization strategy, interaction with state and industry leaders, engagement in Lean processes and other relevant activities. The attached guides highlight these BMPs to help focus and streamline the site characterization process by presenting more efficient scoping, investigation and data management approaches. The streamlining of these activities may reduce both time and costs during the remedial investigation/feasibility study (RI/FS) and throughout the Superfund process.

In addition to bringing together lessons learned that help improve Superfund site characterization activities, the guides have been harmonized with the Agency's new Remedial Acquisition Framework. They also address several of the EPA's July 2017 Superfund Task Force Recommendations (https://www.epa.gov/sites/production/files/2017-07/documents/superfund_task_force_report.pdf), including:

- *Recommendation 3*: Broaden the Use of Adaptive Management at Superfund Sites
- *Recommendation 5*: Clarify Priorities for RI/FS Resources and Encourage Performing Interim/Early Actions During the RI/FS Process to Address Immediate Risks
- *Recommendation 8:* Reinforce Focused Scoping Which Closely Targets the Specific for Remediation and Identify and Use Best Management Practice in the RI/FS Stage

IMPLEMENTATION

The three documents are technical resources and do not mandate the adoption of the BMPs they highlight. Nonetheless, the Office of Superfund Remediation and Technology Innovation (OSRTI) strongly encourages remedial project managers and other staff who conduct and support Superfund cleanup activities to use these technical resources. The documents are available in SEMS at:

- "Data Management Tech Guide" (https://semspub.epa.gov/src/document/11/100001798)
- "Smart Scoping BMP Tech Guide" (https://semspub.epa.gov/src/document/11/100001799)
- "Strategic Sampling Tech Guide" (https://semspub.epa.gov/src/document/11/100001800)

Guide companions include classroom training through the CERCLA Education Center (https://trainex.org/) and 10-minute videos of each technical guide, the latter of which will be available through EPA's Legacy Learning Sharepoint site by the end of the calendar year. In addition, OSRTI has developed a variety of related materials, including Internet seminars on high-resolution site characterization that are accessible at the Hazardous Waste Cleanup Information (Clu-In) website (https://clu-in.org/characterization/technologies/hrsc). These Clu-In resources are available to EPA staff as well as contractors and other cleanup professionals across the hazardous waste site cleanup community. Site-specific technical support is also available by request.

Please contact me or have your staff contact Matthew Jefferson at Jefferson.matthew@epa.gov or at (703) 603-8892 or if you have any questions or concerns.

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EPA ID # 542-G-18-004

Section 1 - Introduction

This technical guide describes the use of "smart scoping" practices during any phase of a Superfund remedial investigation's project life cycle or in accordance with other similar federal, state or tribal regulatory authorities. Use of these practices can support the development of a robust conceptual site model (CSM), which, in turn, helps improve response action development, selection and implementation. Smart scoping integrates adaptive management and site characterization. Adaptive management is an approach the U.S. Environmental Protection Agency (EPA) is expanding to help ensure informed decision-making and the expenditure of limited resources go hand-in-hand throughout the remedial process.

Why is EPA Issuing this Technical Guide?

The U.S. Environmental Protection Agency (EPA) developed this guide to support achievement of the July 2017 Superfund Task Force goals. Two additional companion technical guides should be used in conjunction with this smart scoping technical guide:

- Strategic Sampling Approaches
- Best Practices for Data Management

The scoping process outlined in EPA's 1988 guidance for conducting a remedial investigation and feasibility study (RI/FS) still applies to Superfund sites. Smart scoping targets those parts of the scoping process that can help a site team develop a more robust and realistic CSM; it also highlights new approaches and tools to facilitate that development.

This technical guide's purpose is twofold. First, it broadly highlights the best practices related to scoping an environmental investigation. These best practices have been developed over many years of planning and implementing investigations. Second, it provides technical resources and references to support smart scoping activities.

How is this Technical Guide Organized?

Section 1 – Introduction: introduces smart scoping concepts and provides important definitions.

Section 2 – Focus on the Conceptual Site Model: discusses a robust and realistic CSM's elements and describes CSM development over the life cycle of the project. Section 2 also highlights the various CSM components. Each CSM component is important for the evaluation, selection, and successful implementation of remedial actions.

Section 3 – Focus on Scoping Best Practices: describes a set of EPA-identified best practices and discusses how these best practices can be used during scoping. Each best practice discussion includes a list of resources and references.

This section introduces smart scoping concepts and definitions.

What is Smart Scoping?

With the goal of developing and maintaining a robust CSM, smart scoping encourages both consideration of proven Superfund site strategies; and the upfront commitment of time and resources. It also anticipates the use of best practices or tried-and-true strategies for cleanup of sites with similar contamination profiles. Smart scoping highlights the importance of: (1) participation by and input from Remedial Project Managers (RPMs), technical experts, risk managers and other stakeholders; (2) establishing appropriate current and future land and groundwater resource use assumptions; (3) the appropriate design and use of human health and ecological risk assessments (including collection of appropriate information on natural or anthropogenic "background" and contaminant bioavailability); (4) leveraging in-house expertise (in lieu of contractor support); and (5) the appropriate use of early actions and adaptive management techniques.

What are the Benefits of Smart Scoping?

A robust and realistic CSM helps improve response action development, selection and implementation. Improved technical tools are now available that provide more comprehensive characterization of contamination sources and the environmental media those sources affect. In turn, comprehensive characterization provides greater opportunities for evaluating and selecting more targeted and cost-effective remedies.

Smart scoping can hasten response activity initiation. It calls for strong consideration of the value of shorter- and longer-term actions' ability to achieve risk reduction, and it results in data collection that supports those actions' timely selection and implementation. Smart scoping can facilitate the application of early removal or remedial actions at sites.

Smart scoping also reduces the need for additional characterization after response actions are selected and the comprehensive CSM it produces can reduce the need for more data.

Smart scoping results in strategic sampling designs that incorporate scientific and technical advancements in investigation technologies. These strategic sampling designs are discussed in EPA's companion technical guide "Strategic Sampling Approaches Technical Guide" (EPA 542-F-18-005).

What is a Robust and Realistic Conceptual Site Model?

By "robust," EPA means that the CSM: (1) incorporates all that is known about the site's current and potential future environmental conditions, and (2) evolves and matures over the project's life cycle. By "realistic," EPA means that the CSM is based on adequate data and reflects as closely as possible the true situation on the ground. A realistic CSM accurately portrays critical conditions which affect the success of response actions and at a scale that addresses heterogeneity.

Section 2 – Focus on the Conceptual Site Model

This section focuses on CSM development and describes CSM components. The CSM is a key communication tool for decision-makers, technical teams and stakeholder outreach.

The EPA identified six stages of the project life cycle CSM (see Highlight 1[1]). Each of these stages are representations of the CSM as it evolves through defined states of both maturity and purpose over a project's life cycle. Development of both the preliminary and the baseline CSM requires an initial compilation, synthesis and presentation of the CSM to managers, technical teams and stakeholders. Using existing data is key to developing a preliminary and baseline CSM.

Highlight 1. Project Life Cycle

Six Stages of the Project Life Cycle CSM

Key Points in the Development of a CSM

(1) **Preliminary CSM Stage –** Project milestone or deliverable based on existing data; developed prior to systematic planning to provide fundamental basis for planning effort.

(2) **Baseline CSM Stage –** Project milestone or deliverable used to document stakeholder consensus/divergence, identify data gaps, uncertainties, and needs; an outcome of systematic planning.

Key Points in the Evolution and Refinement of a CSM

(3) **Characterization CSM Stage –** Iterative improvement of CSM as new data become available during investigation efforts; supports technology selection and remedy decision making.

(4) **Design CSM Stage –** Iterative improvement of CSM during design of the remedy; supports development of remedy design basis and technical detail.

(5) **Remediation / Mitigation CSM Stage –** Iterative improvement of CSM during remedy implementation; supports remedy implementation and optimization efforts; provides documentation for attainment of cleanup objectives.

(6) **Post Remedy CSM Stage –** Comprehensive site physical, chemical, geologic, and hydrogeologic information of CSM supports reuse planning; documents institutional controls and waste left on site; and describes other key site attributes.

Develop and Use Project Life Cycle Conceptual Site Model

In July 2011, EPA developed and issued "Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model," to assist environmental professionals in developing realistic CSMs. As stated in the quick reference fact sheet:

The life cycle of a CSM mirrors the common progression of the environmental cleanup process where available information is used, or new information acquired, to support a change in focus for a project. The focus of a CSM may shift from characterization towards remedial technology evaluation and selection, and later, remedy optimization. As a project progresses, decisions, data needs, and personnel shift as well to meet the needs of a particular stage of a project and the associated technical requirements.

Maximize Use of Existing Data

The preliminary CSM considers all existing data, to the extent appropriate, from relevant sources, such as state and tribal partners, other federal agencies, local entities and facility records. The data serve as the planning foundation and are used to provide a comprehensive site overview. The preliminary CSM identifies all that is known about site conditions while also identifying data gaps that must be closed to assess risk and evaluate potential cleanup alternatives. The EPA recognizes there are significant opportunities to leverage existing data to develop more robust and realistic CSMs and to achieve remedial investigation cost savings. New tools for visualizing existing data gaps and to develop efficient data collection efforts to fill those gaps and are discussed in Section 3.

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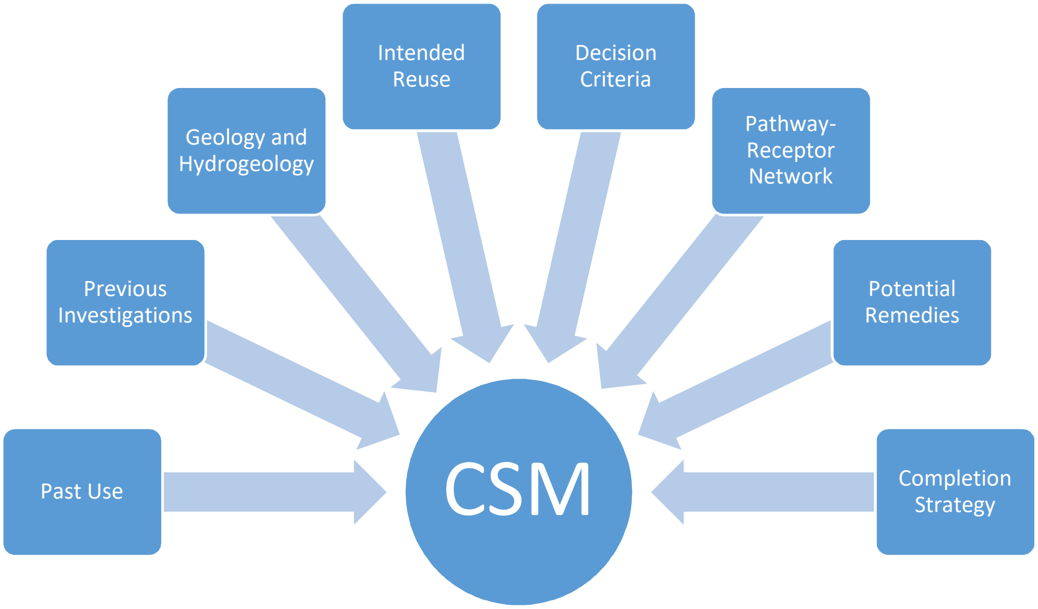
[1] EPA. 2011. Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model. https://www.epa.gov/remedytech/environmental-cleanup-best-management-practices-effective-use-project-life-cycle

Existing data can be leveraged and its usefulness maximized through the following steps:

- Collecting, evaluating, and organizing all existing data;
- Synthesizing existing data into a comprehensive CSM; and
- Visualizing existing data to better comprehend what is known and unknown about important site conditions.

Existing data from past investigations may inform the CSM, for example: (1) associated with the project in question or conducted at nearby sites, (2) at sites with similar contaminant profiles, and (3) at sites with similar environmental conditions, especially in relation to the subsurface geology and surface hydrology. Sufficient time should be given to scoping activities so that existing data can be collected, synthesized, and visualized as part of the planning process.

Highlight 2. Components of a Conceptual Site Model



Address All Conceptual Site Model Components

The EPA has identified physical, historical, programmatic, risk, and remedy data components that constitute a comprehensive CSM as it has gained experience implementing investigation and response activities (see Highlight 2[2]). A comprehensive CSM is not "one" thing, but is comprised of a number of important elements that should be considered to move the project forward to completion. A comprehensive CSM addresses eight components and several sub-elements within each component.

Each of these components can be informed by existing data. One well-known component of a CSM is the pathway-receptor network diagram that helps to identify all pathways by which contaminants may migrate from site sources to human and environmental receptors. While this diagram is likely the CSM's most recognized component, it is just one of several important components informing risk management.

The EPA has found that the most effective investigations use a comprehensive CSM that addresses all elements of the project. Many CSM components are related to and affected by each other. For example, the contaminant mass and distribution is greatly affected by the geology and hydrogeology component and relates to the pathway-receptor network, potential remedies, and decision criteria components.

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[2] EPA. 2016. Best Practices for Site Characterization Throughout the Remediation Process course. CERCLA Education Center.

Select Resources: CSM Development

- EPA. 2011. Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model. EPA 542-F-11-011. http://www.brownfieldstsc.org/pdfs/CSM_lifecycle_Fact_Sheet.pdf
- U.S. Army Corps of Engineers. Conceptual Site Models. EM 200-1-12. December 28, 2012. https://www.epa.gov/remedytech/environmental-cleanup-best-management-practices-effective-use-project-life-cycle
- American Society for Testing and Materials (ASTM). 2014. Standard Guide for Developing Conceptual Site Models for Contaminated Sites. E1689-95 (Reapproved 2014). https://www.astm.org/Standards/E1689.htm
- EPA. 2016. Innovations in Site Characterization Case Study: The Role of a Conceptual Site Model for Expedited Site Characterization Using the Triad Approach at the Poudre River Site, Fort Collins, Colorado. EPA 542-R-06-007. https://clu-in.org/download/char/poudre_river_case_study.pdf
- EPA. n.d. Conceptual Site Model Development. http://www.triadcentral.org/mgmt/splan/sitemodel/index.cfm
- EPA. 2006. Systematic Planning Using the Data Quality Objectives Process EPA/240/B-06/001. https://www.epa.gov/sites/production/files/documents/guidance_systematic_planning_dqo_process.pdf
- EPA. 2000. Soil Screening Guidance for Radionuclides, 2.1: Developing a Conceptual Site Model. EPA/540-R-00-007. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100MBXW.PDF?Dockey=P100MBXW.PDF
- EPA. 2016. CLU-IN. Key Optimization Components: Conceptual Site Model. Last Updated September 23, 2016. https://clu-in.org/optimization/components_csm.cfm
- EPA. n.d. Brownfields Road Map. Last Updated January 3, 2018. https://www.epa.gov/brownfields/brownfields-road-map
- EPA. 2008. Triad Issue Paper: Using Geophysical Tools to Develop the Conceptual Site Model. EPA 542-F-08-007. https://www.epa.gov/sites/production/files/2015-08/documents/issue-paper_triad-geophysics.pdf
- New Jersey Department of Environmental Protection, Site Remediation Program. 2011. Technical Guidance for Preparation and Submission of a Conceptual Site Model. http://www.nj.gov/dep/srp/guidance/srra/csm_tech_guidance.pdf

Past Uses

Past uses are evaluated to identify the contaminants of concern/contaminants of potential concern (COCs/COPCs), affected environmental media, potential release mechanisms, probable source area locations, historical releases' timing, the migration pathways, potentially responsible party (PRP) searches, current and former employee interviews, and potential receptors. A critical element is defining the contamination's location and nature of sources that continue to affect various media.

Questions about past uses of the site to be answered might include, but are not limited to:

- What are the contaminants associated with the site?
- Where were the contaminants stored, used, and disposed of?
- How long were the contaminants in use at the site?
- How were these contaminants released?
- When were the contaminants released?
- How many releases have occurred at the site?

Under CERCLA, the identification of contamination sources is important to the listing of sites on the National Priorities List and the investigation and remediation of all types of sites.

Select Resources: Past and Current Uses

- EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. OSWER Directive 9355.3-01. EPA 540/G-89/004. October.
- EPA. 2000. Abandoned Mine Site Characterization and Cleanup Handbook. EPA 910-B-00-001. August.
- EPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. OSWER Directive 9355.0-85. EPA-540-R-05-012. December.

Previous Investigations

Data from previous investigations are evaluated to estimate contaminant distributions in the environment and evaluate potentially complete pathway-receptor networks. Questions to be answered include:

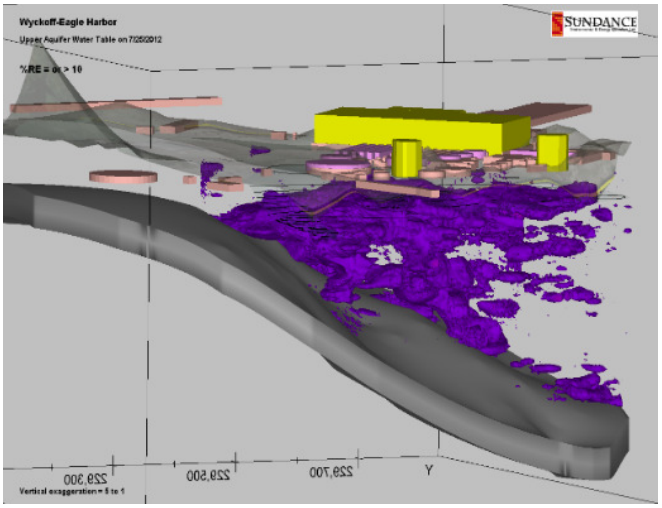
- What are the potential pathways of concern?
- What are the primary pathways for contamination that pose a threat to human health and the environment?
- What is the potential magnitude of the problem?
- What investigative tools and strategies have worked or failed?
- What remedies have been tried and with what success?
- What are potential critical data gaps?
- What are the perceived risks associated with the site?
- What are viable completion strategies?

Every site-related document, regardless of its intended audience or purpose of creation, should be assessed for information that contributes to the CSM. Diligence in gathering and evaluating all data from previous investigations is essential to preparing a thorough CSM.

Select Resources: Previous Investigations

- EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. OSWER Directive 9355.3-01. EPA 540/G-89/004.
- EPA. n.d. Conceptual Site Model Checklist. https://triadcentral.clu-in.org/ref/ref/documents/CSM_Checklist.pdf
- EPA. n.d. Triad Central Web Resources. https://triadcentral.clu-in.org/index.cfm

Highlight 3. Detailed Site Subsurface



Geology and Hydrogeology

Based on investigative experience and other independent research into groundwater contamination, EPA has found that the nature of the geologic structure through which contaminants are moving has profound contaminant fate and transport effects. Highlight 3[3] shows an example of a detailed rendering of the subsurface for a site. Understanding the subsurface heterogeneity at a much higher resolution is critical for designing and implementing more effective and targeted response actions. Scoping activities that: (1) match the scale of the investigation to the scale of geologic heterogeneity expected in the subsurface and (2) define the three-dimensional structure through which groundwater and contaminants are moving can provide data necessary to evaluate and design a remedial strategy, possibly consisting of a combination of technologies. With sufficient resolution, site decisions and responses can be related to source treatment, plume management, and compliance monitoring to efficiently apply and monitor strategic and targeted remedial actions.

Select Resources: Geology and Hydrogeology

- EPA. Technical Support Project. Groundwater Forum. https://www.epa.gov/remedytech/technical-support-project-cleaning-contaminated-sites-ground-water-forum
- EPA. n.d. High-Resolution Characterization for Groundwater. Last Updated on September 23, 2016. https://clu-in.org/characterization/technologies/hrsc/
- EPA. 2017. A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models. EPA/600/R-17/293. https://semspub.epa.gov/work/HQ/100001009.pdf

Decision Criteria

Decision criteria are used to: (1) guide in-field decisions based on the real-time results of field methods, (2) characterize risk, and (3) determine the extent of cleanup. Field-based decision criteria are structured to ensure that the appropriate decision is made, compensating for any analytical method bias or imprecision. Site managers use risk-based screening criteria, such as criteria in EPA's Regional Screening Levels, Regional Removal Management Levels, Vapor Intrusion Screening Levels, and Superfund Chemical Data Matrix, to evaluate the level of contamination in various media. Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), both potential appropriate or relevant and appropriate requirements and calculated risk-based cleanup levels can be used to define the extent of remediation.

Select Resources: Decision Criteria

- EPA. Triad Central Web Resources. https://triadcentral.clu-in.org/index.cfm
- EPA. Regional Screening Levels (RSLs) – Generic Tables. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
- EPA. Regional Removal Management Levels for Chemicals (RMLs). Tables as of: May 2018. https://www.epa.gov/risk/regional-removal-management-levels-chemicals-rmls
- EPA. Vapor Intrusion Screening Level Calculator. https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-level-calculator
- EPA. Superfund Chemical Data Matrix (SCDM). https://www.epa.gov/superfund/superfund-chemical-data-matrix-scdm

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[3] EPA. Wyckoff Eagle Harbor Superfund Site Information. https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=1000612

Pathway-Receptor Network

Pathway-receptor network diagrams depict how contaminants may migrate from sources to receptors. This network diagram influences a CSM by ensuring all actual and potential pathways and receptors are evaluated during the human health and ecological risk assessments. The pathway-receptor network diagram is also used to determine related effects on project design and the sequencing of project activities. The most significant pathways should be addressed first, followed by those that pose less of a concern. Receptor networks can be complex. Chemical and receptor relationships can be less than obvious and drive development of more complex decision criteria. Therefore, it is important to discuss pathway-receptor networks and decision criteria early in the systematic planning process (SPP).

Select Resources: Pathway-Receptor Network

- EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. OSWER Directive 9355.3-01. EPA 540/G-89/004. October.
- EPA. n.d. Conceptual Site Model Checklist. https://triadcentral.clu-in.org/ref/ref/documents/CSM_Checklist.pdf
- EPA. 1989. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. December. https://www.epa.gov/sites/production/files/2015-09/documents/rags_a.pdf

Intended Reuse

The Superfund Task Force report identifies site reuse as a goal of the Superfund program and includes many recommendations to facilitate redevelopment. EPA's Superfund Redevelopment Initiative has shown the value of early consideration of reuse and facilitation of reuse planning at the local level. Bringing contaminated lands back into productive use is a major objective of all EPA's site cleanup programs. Evaluating and determining reuse of a contaminated site requires a significant lead-time and participation by stakeholder group(s). A site's ultimate reuse (whether open space, recreational, residential, commercial, or industrial or some combination) may be an important factor in determining the level of cleanup that will be required. Both the site type and contamination present may also influence available reuse options. Including reuse as a planning consideration from the beginning of the project life cycle helps ensure appropriate data are collected and developed to inform reuse decisions.

Select Resources: Superfund Redevelopment

- EPA. 1995. Land Use in CERCLA Remedy Selection Process, OSWER 9355.7-04. https://semspub.epa.gov/work/HQ/174935.pdf
- EPA. n.d. Superfund Redevelopment Program. Last Updated on January 9, 2018. https://www.epa.gov/superfund-redevelopment-initiative

Potential Response Alternatives

Scoping activities have traditionally focused on the data needed to conduct the baseline human health and ecological risk assessments and to define the nature and extent of contamination. While these are critical elements of the CSM, additional benefits may be gained by addressing data needed for evaluating and selecting early and long-term actions (see Highlight 4). Identifying and implementing early actions that achieve significant risk reduction and prevent further migration of contaminants (source control and remediation) is a cornerstone of all site remediation programs. Identification of sources of contamination involves several CSM components, including past use, previous investigations, geology and hydrogeology and pathway-receptor network.

Contaminants and mass distribution scenarios may have a limited set of potentially applicable remediation technologies. Once elements of risk and the need for remediation are considered, the data collection focus should be placed on understanding site physical features at appropriate scales and technical or programmatic elements that drive the applicability of these technologies. The EPA's adaptive management approach encourages leveraging experience by identifying potential technologies and ensuring data are collected to adequately evaluate them thus avoiding numerous rounds of data collection.

Highlight 4. Collecting Data to Evaluate Technologies

When planning for likely technology evaluations, parameters like total organic carbon or matrix properties such as hydraulic conductivity, may be collected more cost effectively earlier in the project life cycle.

Select Resources: Potential Remedies

- The EPA's CLU-IN website discusses many potential remedies and technologies. www.clu-in.org
- The Federal Remediation Technology Roundtable (FRTR) provides information on the application of potential technologies. www.frtr.gov
- The Interstate Technology and Regulatory Council (ITRC) provides technical information on the application of technologies. www.itrcweb.org
- The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ETSCP) provides cutting edge information on data collection techniques.
  https://www.serdp-estcp.org/

Completion Strategy

Scoping efforts often help identify completion strategies for several milestones tracked by EPA: (1) the project phase or a single operable unit, such as RI/FS, (2) completion of an operable unit as defined by the remedial action completion milestone, and (3) completion on a sitewide basis as defined by the construction completion milestone, site close out, and site deletion. Completion strategies for individual phases developed as part of the adaptive management approach should contribute to successful remedial action or risk management designs. While the regulatory program broadly defines requirements for site completion, the site team can develop a more detailed strategy for achieving completion. For example, EPA has issued guidance and a statistical tool for evaluating and documenting completion of groundwater restoration remedial actions. Smart scoping encourages early consideration of the data requirements for evaluating and documenting groundwater completion at sites which may need a groundwater restoration action.

Select Resources: Completion Strategy

- EPA. 2014. Groundwater Remedy Completion Strategy: Moving Forward with the End in Mind. OSWER Directive No. 9200.2-144. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100KM8X.PDF?Dockey=P100KM8X.PDF
- EPA. n.d. Groundwater Remedial Action Completion Webpage. Last Update on June 4, 2018. https://www.epa.gov/superfund/superfund-groundwater-groundwater-response-completion
- EPA. 2011. *Close Out Procedures for National Priorities List Sites*. OSWER Directive No. 9320.2-22. https://semspub.epa.gov/work/HQ/176076.pdf

Section 3 – Focus on Scoping Best Practices

The EPA has identified the following best practices for scoping environmental investigation and remediation programs:

- Project life cycle CSM (discussed in Section 2)
- Comprehensive team formation
- Systematic project planning
- Dynamic work strategies and adaptive management
- High-resolution and real-time measurement technologies
- Use of collaborative data and multiple lines of evidence
- Stakeholder outreach
- Demonstration of method applicability
- Data management and communication
- Three-dimensional visualization and analysis
- Optimization

Section 3 describes all but the first best practice listed above.

Form a Comprehensive Team

Successful investigations use a comprehensive team of multi-disciplinary technical professionals, regulatory staff and site stakeholders. The EPA encourages the use of in-house staff to provide technical support. Each comprehensive site team member should have a defined set of roles and responsibilities. A small group of multi-disciplinary technical staff will usually be responsible for developing and updating the comprehensive CSM. Regulatory staff and stakeholders are usually responsible for reviewing and commenting on approaches developed by the core technical team and data collection results. Regulatory staff and other stakeholders provide important information regarding reuse, decision criteria and site completion strategies. The SPP objective is to obtain site team consensus on the preliminary and baseline CSMs, the data gaps that need to be filled, and the data collection approaches to be used. Systematic project planning is discussed below in more detail. Depending on site-specific needs, a variety of disciplinary skills may potentially be required. Highlight 5 lists the typical types of disciplines that may be needed. The exact make-up of technical and project teams is expected to change over the project's life. For example, regulatory expertise may be critical at the outset, but become less important once key initial decisions are made.

Highlight 5. Typical Disciplines of Multi-Disciplinary Team

Geology – Hydrogeology – Geochemistry - Analytical Chemistry - Risk Assessment – Toxicology – Statistics - Geographical Information Systems (GIS) - Information Management - Soil and Sediment Science - Project Management - Environmental Safety and Health – Engineering – Biology – Ecology – Meteorology - Regulatory Expertise – Contracting – Community Involvement Expertise - Communications

Select Resources: Comprehensive Team Formation

- EPA. 2010. Best Management Practices: Use of Systematic Project Planning Under a Triad Approach for Site Assessment and Cleanup. https://clu-in.org/download/char/epa-542-f-10-010.pdf
- EPA. n.d. Multi-Disciplinary Technical Teams. http://www.triadcentral.org/mgmt/req/techteams/index.cfm

Conduct Systematic Project Planning

Systematic project planning is an efficient method for comprehensive planning, design, and implementation for all stages of hazardous waste site investigation and cleanup projects; it also supports adaptive management. Systematic project planning is a planning process that lays a scientifically defensible foundation for proposed project activities. It usually includes identification of key decisions to be made, the development of a CSM in support of decision-making, and an evaluation of decision uncertainty along with approaches for managing that uncertainty in the context of the CSM[4]. The EPA's *Best Management Practices: Use of Systematic Project Planning under a Triad Approach for Site Assessment and Cleanup*, September 2010, describes the SPP process. Systematic project planning is generally recognized to be common practice for all projects. For example, the data quality objectives process is used as a systematic planning tool for most EPA projects.[5] Such objectives focus on analytical methods and associated data quality, but systematic planning also involves planning for known decisions and identifying contingencies necessary to accommodate changes in project conditions through all key decision-making stages. Highlight 6[6] shows the SPP process. Systematic project planning is important for all types of investigations but is critical for planning and implementing the Triad Approach, which involves SPP, dynamic work strategies and real-time measurement technologies. This project planning approach places a strong emphasis on using a CSM as the basis for the planning of all project life cycle phases, from investigation through remediation (cleanup or mitigation) and site close out (regulatory satisfaction that site risks have been removed

Highlight 6. Systematic Project Planning Process

Preparation activities:

- Organize the project team of stakeholders and technical resources
- Summarize site information in a Preliminary CSM
- Research potential investigation and remedial technologies
- Submit Preliminary CSM and other information to SPP participants in advance of meeting

Meeting activities:

- Introduce and confirm roles and authorities of participants
- Define site reuse goals and project completion strategies
- Identify key site decisions, decision-making processes, tools and rules
- Create a Baseline CSM based on refinement of Preliminary CSM
- Use Baseline CSM to identify key data gaps
- Identify and quantify acceptable levels of uncertainty
- Identify real-time technologies and collaborative data needs
- Plan for real-time data management, assessment, visualization and communication
- Develop detailed dynamic work strategy outline, decision logic diagrams activity sequencing and contingencies plan

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[4] Definition of systematic project planning. (https://triadcentral.clu-in.org/gloss/dsp_glossterm.cfm?glossid=223

[5] EPA.2006.Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G4. EPA/240/B-06/001. February. https://www.epa.gov/sites/production/files/2015-06/documents/g4-final.pdf

[6] EPA. 2010. Best Management Practices: Use of Systematic Project Planning Under a Triad Approach for Site Assessment and Cleanup. September. https://clu-in.org/download/char/epa-542-f-10-010.pdf

or mitigated). The CSM is used during SPP to identify data needs, design the data collection approach, and drive the selection of appropriate data collection, analysis, and use methodologies.

Effective SPP has the following benefits:

- Building social capital among project stakeholders.
- Evaluating reuse options and completion strategies.
- Achieving stakeholder consensus on the CSM and data gaps.
- Identifying life cycle project data and resource needs to address all components of the CSM, especially the nature, extent and impact of sources.
- Identifying clear project objectives, timelines and other constraints.
- Developing the data collection strategy's basic elements and establishing performance metrics.
- Evaluating and planning for managing risk-related uncertainties.
- Other integral considerations, such as green remediation, sustainable reuse and environmental justice and community involvement.

Select Resources: Systematic Project Planning

- EPA. 2010. Best Management Practices: Use of Systematic Project Planning Under a Triad Approach for Site Assessment and Cleanup. https://clu-in.org/download/char/epa-542-f-10-010.pdf
- EPA. n.d. Triad Central. Use of Immunoassay Test Kits, Systematic Project Planning, and Dynamic Working Strategies to Facilitate Rapid Cleanup of the Wenatchee Tree Fruit Research and Extension Center Site, Wenatchee, Washington. Last Update on June 29, 2007. http://www.triadcentral.org/user/includes/dsp_profile.cfm?Project_ID=27
- EPA. n.d. Triad Central. Systematic Planning and Conceptual Site Model Case Study Basewide Hydrogeologic Characterization at Naval Air Weapons Station (NAWS) China Lake, Ridgecrest, CA. Last Update on October 22, 2004. http://www.triadcentral.org/user/includes/dsp_profile.cfm?Project_ID=4
- EPA. n.d. Triad Month Session 2: Triad Communications and Systematic Planning Sponsored by: U.S. EPA Technology Innovation and Field Services Division. https://clu-in.org/conf/tio/triad2_080609/
- US Navy. 2004. Triad's Systematic Planning Process. http://www.triadcentral.org/ref/doc/2_Adrianne.pdf
- US Army Corps of Engineers. 2006. Draft Systematic Planning Checklist—Implementing Systematic Project Planning. http://www.triadcentral.org/ref/ref/documents/Triad_Systematic_Planning_Checklist_Oct06_.pdf

Use Dynamic Work Strategies and Adaptive Management

Adaptive management through the design and implementation of dynamic work strategies applies to contaminated site characterization, remediation or monitoring (or a combination thereof) and includes built-in flexibility guided by a pre-approved decision logic.[7] As information is gathered, it is used to adapt the specific activities in real-time so that subsequent activities will best resolve remaining data and decision uncertainties. The goal is to evolve the CSM and complete remedial actions in as few mobilizations as feasible while providing flexibility for field teams and decision-makers to address site realities or unexpected features during these field activities. All planned work activities are described in written work planning documents appropriate to program

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[7] EPA. 2017. *Superfund Task Force Recommendation #3: Broaden the Use of Adaptive Management.* Office of Land and Emergency Management directive 9200.3-120. July 25. https://semspub.epa.gov/work/HQ/100001630.pdf

oversight. Dynamic field activities are typically driven by pre-approved decision logic. All scenarios or contingencies cannot be planned for and remaining project decisions are commonly addressed during field activities by remote project team stakeholders and decisions-makers using distance collaboration tools.

Dynamic work strategies are most commonly used in the form of adaptive data collection strategies. Data collection strategies can be "adaptive" in several different ways, one or all of which may be used in an adaptive data collection program. These include:

- <u>Adaptive Location Selection</u>: Refers to data collection programs where sampling location decisions are made in the field in response to real-time data collection results.
- <u>Adaptive Analytics Selection</u>: Refers to data collection programs where sample analysis decisions are made in the field in response to real-time measurement results.

Select Resources: Dynamic Work Strategies

- EPA. n.d. Triad Resource Center, Dynamic Work Strategies. http://www.triadcentral.org/mgmt/dwstrat/index.cfm
- EPA. 2009. CLU-IN. Triad Month Session 7: Dynamic Work Strategies Sponsored by: U.S. EPA Technology Innovation and Field Services Division. https://clu-in.org/conf/tio/triad7_082509/
- EPA. 2005. Use of Dynamic Work Strategies under a Triad Approach for Site Assessment and Cleanup—Technology Bulletin. https://nepis.epa.gov/Exe/ZyPDF.cgi/2000CYTM.PDF?Dockey=2000CYTM.PDF

Use High-Resolution and Real-Time Measurement Technologies

High-resolution site characterization (HRSC) includes investigation tools and strategies appropriate to the scale of heterogeneities in the subsurface that control contaminant distribution, transport and fate. The HRSC techniques provide the degree of detail necessary to understand exposure pathways, processes affecting the fate of contaminants, mass distribution and flux by phase and media, and how remediation or mitigation measures may affect the problem. Many HRSC techniques include real-time measurement technologies which refer to any data generation mechanism that supports real-time decision-making, including rapid turn-around from a fixed laboratory (using either quantitative or qualitative analytical methods) or field-based measurement technologies. Examples of real-time measurement technologies commonly used for HRSC approaches include:

- x-ray fluorescence (XRF)
- membrane interface probe (MIP)
- laser induced fluorescence (LIF)
- electrical conductivity meter
- hydraulic profiling tools
- forward-looking infrared technology
- passive samplers and flux meters
- bioassay and colorimetric test kits
- mobile laboratories
- surface and borehole geophysics

Real-time measurement technologies provide results quickly enough to influence data collection and field activities progress and to indicate where collaborative data collection can provide the greatest benefit.

Select Resources: High Resolution and Real-time Measurement Technologies

- FRTR provides information on the application and cost of measurement technologies. www.frtr.gov
- ITRC provides information on many characterization techniques and technologies. www.itrcweb.org
- The Triad Central website provides information and case studies on the Triad Approach. www.triadcentral.org

- EPA. n.d. High-Resolution Characterization for Groundwater. Last Updated on September 23, 2016. https://clu-in.org/characterization/technologies/hrsc/
- EPA. 2003. Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup. https://nepis.epa.gov/Exe/ZyPDF.cgi/10002O76.PDF?Dockey=10002O76.PDF

Use Collaborative Data Sets and Multiple Lines of Evidence

The term “collaborative data sets” refers to the use of more than one analytical or measurement technique to inform the contamination status of a site or area of concern. “Collaborative” indicates that the combination of two or more types of investigative results, each with different strengths and weaknesses, produces a better decision-making result than any used separately. The EPA promotes the use of a blend of real-time techniques with fixed-based laboratory methods to produce collaborative data sets. In addition, several field-deployable technologies can be used in combination to provide collaborative data sets.

Using multiple lines of evidence means that data from different measurement techniques provide results that converge and support similar conclusions. If the lines of evidence do not converge, then the site team will evaluate the reason and the original CSM assumptions and adjust to the actual conditions found in the field to resolve the inconsistency. Both convergence and divergence of multiple lines of evidence inform the project team and future investigative efforts. Examples of investigative multiple lines of evidence for determining relative hydraulic conductivity in the subsurface include lithologic logs, cone penetrometer testing, electrical conductivity readings and hydraulic profiling measurements. All four lines of evidence use different methods to give an indication of the relative hydraulic conductivity parameter. The EPA strongly encourages the use of multiple lines of evidence in many of its Superfund technical guides, including those related to vapor intrusion and monitored natural attenuation. Site teams can look for opportunities to develop strategic sampling designs that collect both collaborative data and multiple lines of evidence.

Select Resources: Collaborative Data and Multiple Lines of Evidence

- EPA. 2001. Current Perspectives in Site Remediation and Monitoring: Applying the Concept of Effective Data to Environmental Analyses for Contaminated Sites. https://clu-in.org/download/char/effective_data.pdf
- EPA. 2008. Demonstrations of Method Applicability under a Triad Approach for Site Assessment and Cleanup — Technology Bulletin. http://nepis.epa.gov/Exe/ZyPDF.cgi/P1001FR4.PDF?Dockey=P1001FR4.PDF
- EPA. 2015. Office of Solid Waste and Emergency Response (OSWER) Technical Guide for Assessing and Mitigating The Vapor Intrusion Pathway From Subsurface Vapor Sources To Indoor Air. https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf
- EPA. n.d. Use of a Conceptual Site Model and Collaborative Data Sets Involving ROSTTM and Other Field-based Measurement Technologies to Design and Implement Soil Vapor Extraction and Petroleum Product Extraction Systems at the Hartford Plume Site, Hartford, Illinois. Last Updated on December 31, 2007. http://www.triadcentral.org/user/includes/dsp_profile.cfm?Project_ID=31
- EPA. n.d. Triad Resources Center: Analytical, Data, and Decision Quality: http://www.triadcentral.org/mgmt/meas/key/quality/index.cfm
- ITRC. 2003. Technical and Regulatory Guidance for the Triad Approach: A New Paradigm for Environmental Project Management: http://www.itrcweb.org/Guidance/GetDocument?documentID=90
- ITRC. 2007. Vapor Intrusion Pathway: A Practical Guideline: http://www.itrcweb.org/documents/vi-1.pdf

Conduct Stakeholder Outreach

While stakeholder participation is necessary for all hazardous waste site remediation and closure efforts, stakeholders are key to the SPP process and play a particularly important role when using dynamic work strategies and adaptive site management. This importance is because using dynamic work strategies that are flexible and adaptable often defers significant sampling program decisions to field teams and remote decision makers.

Experience indicates that building “social capital” provides project benefits that flow from the trust, reciprocity, information sharing and cooperation associated with stakeholder networks. All stakeholders are important to project success, however, engaging core technical team’s key stakeholders, such as state, tribal and federal regulators is not only critically important to achieving consensus on the approach, strategies and tools employed but can serve to limit project management costs associated with data interpretation and document review. A collaborative approach to data collection design, execution and interpretation often results in a reduction of identified data gaps or disagreements about CSM elements. This more favorable outcome arises due to key stakeholders’ heavy investment in data collection design and to the majority of data interpretation occurring during dynamic field efforts. In this manner, shorter review times and fewer anticipated technical disagreements can reduce project management costs associated with stakeholder document review, comment and acceptance.

Successful deployment of a dynamic work strategy and an adaptive management approach requires stakeholder participation not just in concurring with work plans, but also potentially with decisions that are made in the field in response to site conditions and real-time results as they are encountered. It is recognized that some stakeholders may face resource challenges (particularly staff time) during dynamic field program planning and implementation; however, it is expected that efficiencies gained from reduced transaction costs during review and comment can help offset these resource expenditures. This participation level can have a positive impact on a characterization or remediation program’s ultimate outcome, since stakeholder data issues can be addressed while field work is underway. Many distance collaboration tools now exist to make engagement in the process easier and more resource friendly, including web portals, websites, file sharing services and video meetings.

Select Resources: Stakeholder Outreach and Engagement

- EPA. 2001. Stakeholder Involvement & Public Participation at the U.S. EPA: Lessons Learned, Barriers, & Innovative Approaches: https://www.epa.gov/sites/production/files/2015-09/documents/stakeholder-involvement-public-participation-at-epa.pdf
- EPA. 2013. Getting in Step: Engaging and Involving Stakeholders in Your Watershed 2nd Edition EPA841-B-11-001. https://cfpub.epa.gov/npstbx/files/stakeholderguide.pdf
- Federal Energy Regulatory Commission. 2001. Federal Energy Regulatory Commission Ideas for Better Stakeholder Involvement in the Interstate Natural Gas Pipeline Planning Pre-Filing Process. https://www.ferc.gov/legal/maj-ord-reg/land-docs/stakeholder.pdf
- Federal Emergency Management Agency. 2016. Guidance for Stakeholder Engagement. https://www.fema.gov/media-library-data/1470349382727-a25897d8ed8adfe0d99989d2b0c9a74c/SE_Discovery_Guidance_May_2016_508.pdf
- ITRC. 2001. Petroleum Vapor Intrusion Guidance- Community Engagement. http://www.itrcweb.org/PetroleumVI-Guidance/Content/7.%20Community%20Engagement.htm

- MDOT. 2009. Michigan Department of Transportation Guidelines for Stakeholder Outreach. https://www.michigan.gov/documents/mdot/MDOT_Guidelines_For_Stakeholder_Engagement_264850_7.pdf

Conduct Demonstrations of Method Applicability

A Demonstration of Method Applicability (DMA) is also called a "methods applicability study" or a "pilot study" to evaluate the investigative approach. The method involves proposed sampling or analytical methods pre-testing to evaluate site-specific performance. Such studies are recommended by EPA prior to finalizing the design of sampling and analyses plans for waste projects [SW-846 Section 2.1]. These studies can be designed to accomplish a variety of goals including:

- Initial evaluation of site-specific heterogeneities that will support further design of the data collection program:
  - Sampling design (how many samples to collect and where to collect them)
  - Sample support (what volume of sample to collect and with what collection tool)
  - Sample processing (also can be related to sample support issues)
  - Communicate heterogeneity issues to regulators and stakeholders
- Evaluation of analytical performance and planned decision logic on site-specific sample matrices:
  - Guides analytical method selection, establishes initial relationships and explores techniques for comparing collaborative data sets (statistical, qualitative, visual observation)
  - Determine whether and how to modify methods to improve performance and/or cost-effectiveness
- Develop initial method performance/QC criteria based on site-specific data needs:
  - During project implementation, both field and analytical QC results will be judged against these criteria to determine whether procedures are "in control" and meet defined project needs
  - Develop list of corrective actions to be taken if QC criteria exceeded
- Decision thresholds ("action levels" to guide decisions about soil or areas, and the routing of materials for final disposal)
- Develop contingency plans for tool or instrument failure
- Refine the data management plan to accommodate field data inputs (high resolution, direct sensing tools, spatial/location tools)
- Provide an initial look at CSM assumptions and elements affecting the sampling design
- Consider logistical issues, such as activity and media sequencing, drilling techniques/contingencies, load balance/staffing, and unitized costs

A DMA can also provide cost and performance information that can be used to optimize collaborative data collection using technologies for generating analytical data (or other information) both in the field and in an offsite location. Additionally, a DMA can offer stakeholders an understanding of a technology's site-specific performance while at the same time providing the basis to optimize deployment standard operating procedures. Demonstration of method applicability efforts are performed easily and affordably before mobilization, or as a field program's early component.

Select Resources: Demonstrations of Method Applicability

- EPA. 2008. Demonstrations of Method Applicability under a Triad Approach for Site Assessment and Cleanup — Technology Bulletin. https://clu-in.org/download/char/demonstrations_of_methods_applicability.pdf
- EPA. 2008. Demystifying the DMA (Demonstration of Method Applicability. https://clu-in.org/conf/tio/dma_072808/

- EPA. 2008. X-ray Fluorescence (XRF) Session 4: Demonstration of Method Applicability (DMA): https://clu-in.org/conf/tio/xrf_081408/
- EPA. 2003. Fort Lewis Agreed Order RI Demonstration of Method Applicability Sampling And Analysis Plan Addendum: http://www.triadcentral.org/user/doc/TPP-FortLewis-DMAMemo.pdf

Plan Carefully for Data Management and Communication

Data management and analysis is an important component of data collection for all environmental investigations. Some of the issues associated with data management are particularly relevant to dynamic work strategies and adaptive site management. They include:

- Timely dissemination of real-time data
- Balancing the needs for data review with the need for rapid data turn-around
- Data archiving requirements and management of direct sensing or other non-traditional data
- Broader uses of data sets

The EPA's new "Best Practices for Data Management Technical Guide," provides additional details on planning and implementing a data management plan. Data management best practices address the following aspects of data management: planning, collecting, analyzing, decision-making, storing, preserving and communicating. Actively planning for and managing data has many project benefits including:

- Quality control at the point of data generation
- Availability of real-time data to dynamically support a robust and realistic CSM
- Data is viewed as a deliverable - it can be reviewed or re-interpreted in response to the CSM rather than forced into a narrow context based on historical reports and interpretation
- Economies of scale for projects, sites, states, regions
- Data warehouse and interoperability - all site data available on demand and in electronic format to stakeholders and project partners

The EPA encourages the use of dynamic work strategies and real-time data collection; however, these approaches require site teams to evaluate and respond to data quickly. For many sites, data collection teams, decision makers, and stakeholders are geographically dispersed and sharing data in a timely manner can be a challenge. Several collaboration tools are available to communicate data among teams. Many of these tools can also be used as portals for teams to store and access information over the project life cycle. The EPA has found these communication tools particularly useful for sharing data visualization and CSM products.

A variety of publicly and commercially available software can assist with statistical data analysis, sampling design, modeling, visualization, risk assessment, optimization and more. Some examples of these tools can be found at https://clu-in.org/software/ and https://frtr.gov/decisionsupport/. Data results, findings and recommendations can be communicated to project team members and stakeholders using dedicated project websites, web meetings and collaboration pages. The EPA teams currently have access to a variety of these tools, such as Adobe Connect and SharePoint. Project teams are encouraged to plan for and utilize appropriate decision support and communication tools to maintain or achieve stakeholder consensus, remotely participate in dynamic field programs and data interpretation, and expedite review of documentation.

Select Resources: Data Management

- EPA. n.d. National Association of Remedial Project Managers - How To Plan Your Data. http://www.slideshare.net/EarthSoft/narpm-data-management-datasearles-pdf

- EPA. 2011. Data Management Plan Remedial Investigation/Feasibility Study Newtown Creek. https://semspub.epa.gov/work/02/162129.pdf
- Department of Energy. n.d. Suggested Elements for a Data Management Plan. Last Modified on: March 5, 2016. http://science.energy.gov/funding-opportunities/digital-data-management/suggested-elements-for-a-dmp/
- ITRC. 2006. Data Management, Analysis, And Visualization Techniques: http://www.itrcweb.org/GuidanceDocuments/RPO-5.pdf

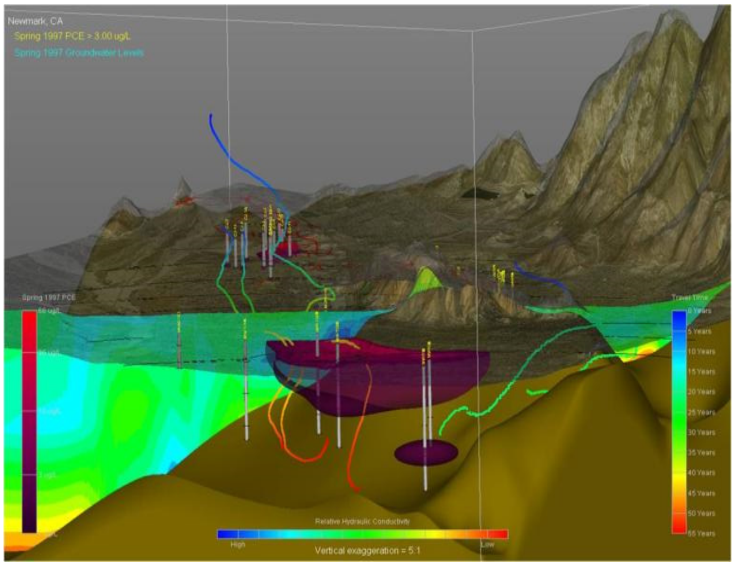
Consider Using Three-Dimensional Visualization and Analysis

The EPA has found that understanding subsurface heterogeneity at a much higher resolution is critical for evaluating contaminant fate and transport, and in designing and implementing more effective and targeted remedial actions. Obtaining a correct geologic interpretation is foundational to depicting the subsurface. Visualization software has been successfully used to perform three-dimensional visualization and analysis (3DVA) that integrates three important subsurface parameters - geology, hydrogeology, and contaminant chemistry - into a single spatially correct format. The EPA has used 3DVA successfully to better understand subsurface structure and characteristics and to reconcile technical CSM discrepancies.

Highlight 7[8] is an example of a three-dimensional visualization of important subsurface parameters. 3DVA provides advantages over two-dimensional data presentation and analyses tools for the following attributes of data analysis:

- Showing data with spatial accuracy
- Showing data at depth
- Showing data over time
- Quantifying mass and volume estimates
- Incorporating outlier data
- Integrating evaluations of collaborative data, maximizing the use of existing information potentially decreasing the need for additional data
- Interpreting and analyzing environmental data geostatistically
- Evaluating potential data gaps
- Quantifying spatial uncertainty and confidence

Highlight 7. Example 3DVA



Select Resources: 3DVA

- EPA. 2011. Use of Geostatistical 3-D Data Visualization/Analysis in Superfund Remedial Action Investigations. https://clu-in.org/conf/tio/3d_092311/
- ITRC. 2006. Data Management, Analysis, And Visualization Techniques. http://www.itrcweb.org/GuidanceDocuments/RPO-5.pdf

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[8] EPA. *Newmark Groundwater Contamination Site Information*. Last Updated on August 13, 2018. https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0902439

Optimize Investigations

The EPA has expanded its national optimization activities to include all Superfund remedial process stages. Investigation-stage optimization stresses the concepts this smart scoping technical guide presents and it encourages the use of a life cycle CSM and dynamic approaches that can be adapted in response to site conditions discovered as the investigation is underway. Optimization reviews provide an independent evaluation of site conditions, CSM components, system design, operating remedies, completion strategies and monitoring networks. The reviews result in the presentation of a series of findings and recommendations on technical and policy issues, cost efficiency, system protectiveness and progress towards completion. Project teams are encouraged to plan for the integration of optimization reviews and to take advantage of available technical resources.

Regardless of where a site is in the project life cycle, a team approach utilizing experienced technical staff who can invest time to help project teams update the CSM can result in source and plume management strategy development with measurable timeframes and targets. Armed with an improved understanding of the CSM and specific remediation objectives, project teams should be better positioned to measure progress and meet site goals.

Select Resources: Superfund Optimization

- EPA. Cleanup Optimization at Superfund Sites. Last Updated on June 4, 2018. https://www.epa.gov/superfund/cleanup-optimization-superfund-sites
- EPA. 2012. National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. OSWER 9200.3-75. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100GI85.PDF?Dockey=P100GI85.PDF
- EPA. n.d. Optimizing Site Cleanups. Last Updated on September 23, 2016. https://clu-in.org/optimization/
- EPA. 2010. Optimizing the Site Investigation Process: https://clu-in.org/consoil/prez/2010/Investigation-Process-Optimization-Slides.pdf
- ITRC. 2004. Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation. http://www.itrcweb.org/GuidanceDocuments/RPO-1.pdf

Disclaimer

The use of these best management practices may warrant site-specific decisions to be made with input from state, tribal, and/or local regulators and other oversight bodies. The document is neither a substitute for regulations or policies, nor is it a regulation or EPA guidance. In the event of a conflict between the discussion in this document and any statute, regulation or policy, this document would not be controlling and cannot be relied on to contradict or argue against any EPA position taken administratively or in court. It does not impose legally binding requirements on the EPA or the regulated community and might not apply to a particular situation based on the specific circumstances. This document does not modify or supersede any existing EPA guidance or affect the Agency's enforcement discretion in any way.

EPA ID# 542-F-18-005

Introduction

The purpose of this technical guide is to assist environmental professionals in identifying where strategic sampling approaches may benefit data collection activities at their project or site and what sampling approach may be most effective given site conditions.

Why is EPA Issuing this Technical Guide?

The U.S. Environmental Protection Agency (EPA) developed this guide to support achievement of the July 2017 Superfund Task Force goals. Two additional companion technical guides should be used in conjunction with this strategic sampling approaches technical guide:

- Smart Scoping for Environmental investigations
- Best Practices for Data Management

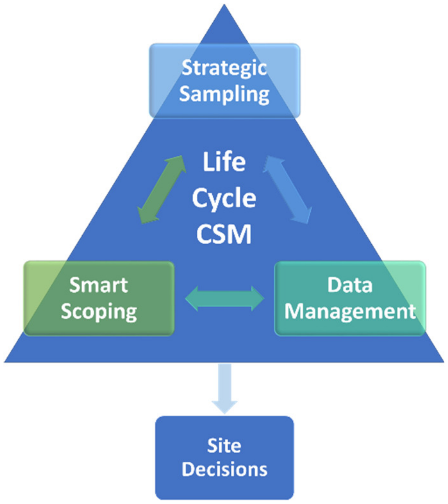
Section 1 of this guide defines the concept of strategic sampling approaches; describes the benefits of applying them; and explores opportunities for leveraging strategic sampling approaches during various phases of a project's life cycle.

Section 2 of this guide describes eight strategic sampling approaches that can be used to improve data collection activities' effectiveness.

EPA recognizes that other sampling approaches may be developed and has designed this technical guide to allow for the inclusion of new approaches as they are developed.

Section 1 - What Are Strategic Sampling Approaches?

As applied in this guide, strategic sampling is broadly defined as the application of focused data collection across targeted areas of the conceptual site model (CSM) to provide the appropriate amount and type of information needed for decision-making. Strategic sampling throughout a project's life cycle may help inform the evaluation of remedial alternatives or a selected remedy's design, improve remedy performance, conserve resources, and optimize project schedules. In addition, strategic sampling approaches assist with source definition and identify unique contaminant migration pathways, such as the vapor intrusion pathway.



Improving Site Decisions

Evolving life cycle CSMs improve the efficiency of site characterization and cleanup and, ultimately, result in better, more defensible site decisions and improved remedy performance. **Smart scoping, data management,** and **strategic sampling** include best management practices that ensure CSMs evolve and improve the understanding of site conditions throughout the site cleanup process life cycle.

EPA encourages smart scoping to effectively plan for data collection and has outlined smart scoping concepts in the companion technical guide, "Smart Scoping for Environmental Investigations."

Role of the Conceptual Site Model

The key to planning a strategic sampling approach is to ensure that a CSM is based on existing data and other assumptions. EPA promotes the use of the project life cycle CSM to assist Superfund project teams, hazardous waste site cleanup managers and decision-makers throughout the investigation and cleanup life cycle stages.[1] As discussed above, the existing CSM informs strategic sampling approaches. Strategic sampling results from throughout the project life cycle help to inform and continually update the CSM.

What are the Benefits of Using Strategic Sampling Approaches?

In general, the benefits of strategic sampling approaches, whether in the remedial investigation, design, action, or long-term remedy operation phase, include:

1. Closing identified data gaps, thereby reducing project uncertainty;
2. Aligning data collection efforts with data needs for critical site decision-making;
3. Generating collaborative data sets across the project life cycle phases; and
4. Developing multiple lines of evidence to provide confidence when making decisions.

Benefits During Remedial Investigation/Feasibility Studies

Consideration of strategic sampling approaches during scoping of the remedial investigation/feasibility study (RI/FS) benefits the three primary objectives of the RI/FS: defining the extent of contamination, assessing risks and evaluating remedial technologies. Strategic sampling approaches provide more certainty regarding the identification of contaminant fate and transport and can provide an accurate footprint of contaminant sources and migration pathways. The risk assessment conducted as part of the RI/FS benefits from strategic sampling approaches because the risk assessment's needs are a primary scoping effort consideration to ensure all potential migration pathways, exposure routes and receptors are identified. Strategic sampling approaches also target early action opportunities to mitigate potential threats as well as the data needs for technology applications over the longer term, including targeted pilot studies.

Key Concept: Critical Factors for Strategic Sampling

- Thorough scoping and planning to identify key decisions, decision-makers, and site uncertainties
- Baseline or up-to date CSM
- Maximum use of state-of-practice analytical tools and sampling approaches
- Well-planned communications and data management and visualization

Benefits During Remedial Design and Remedial Action

Frequently, data collection activities are necessary during the design phase to address uncertainty related to site characterization, such as subsurface characterization, contaminant nature and extent, or contaminant partitioning to support the remedial design. Collection of these data may result in changes in site understanding, such as increased or decreased material volumes to be handled or treated, media contaminated at levels different than those described in the RI/FS, new treatment processes that become necessary to address contamination, or access and permitting issues that affect the remedy

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[1] EPA. 2011. Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model. EPA 542-F-011. July. https://www.epa.gov/sites/production/files/2015-04/documents/csm-life-cycle-fact-sheet-final.pdf

design. Identifying and addressing these changes before the remedy is designed will help ensure that the design can meet the requirements laid out in the record of decision (ROD).

Remedy decisions may select multiple technologies to address a problem, such as groundwater contamination. Each technology requires consideration of specific objectives to inform decisions regarding performance of the technology and when to transition from one technology to another. These performance objectives may include: mass discharge, diminishing return and others. Evaluating options and determining these goals early will facilitate strategic sampling decisions during the design and help establish data necessary for performance measurement during the remedy's implementation.

Finally, for some traditional source control remedies (such as soil or sediment excavation), confirmation sampling is critical to determining if a remedial action may be considered complete. In some instances, strategic sampling decisions may be made during the design investigation work to streamline or reduce the amount of sampling required at the remedial action's completion.

Benefits During Long-Term Remedy Operation

The benefits derived from the use of strategic sampling approaches during long-term remedy operation focus on evaluating how remedy implementation is moving the site toward completion in accordance with the site-specific completion strategy. It is recommended that the site-specific completion strategy be developed as early as possible in the Superfund process. There is intentional flexibility in how a site-specific strategy is developed and, depending on the cleanup stage when the strategy is first developed, it may be described in one or more site documents. A site-specific completion strategy's development 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.[2]

Document Organization

This document presents key concepts in separate call-out boxes, as appropriate, and includes highlights important points. In addition, each strategic sampling approach has: (1) a tool box for implementing the approach and (2) suggested resources and training to advance the reader's knowledge.

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[2] EPA. 2014. Groundwater Remedy Completion Strategy. OSWER No. 9200.2-144. May.

Section 2 – Strategic Sampling Approaches

This section describes eight strategic sampling approaches project managers and site teams can consider when conducting environmental investigations during any phase of a project's life cycle.

Section 2 is organized to provide a short description and resources for each of the following strategic sampling approaches:

- High-resolution site characterization in unconsolidated environments;
- High-resolution site characterization in fractured sedimentary rock environments;
- Incremental sampling;
- Contaminant source definition;
- Passive groundwater sampling;
- Passive sampling for surface water and sediment;
- Groundwater to surface water interaction; and
- Vapor intrusion.

New strategic sampling approaches will be added to this technical guide as they are developed.

The strategic sampling approaches described in this section address a variety of site complexities, such as heterogeneity associated with media and contaminant distributions, and interactions between contaminant phase and media. Several sampling techniques are highlighted, including high-resolution site characterization (HRSC), incremental sampling (IS) and passive methods. High-resolution site characterization and IS may address media and contaminant distribution heterogeneities whereas passive methods may provide valuable information on the groundwater to surface water interaction.

High-Resolution Site Characterization for Groundwater in Unconsolidated Environments

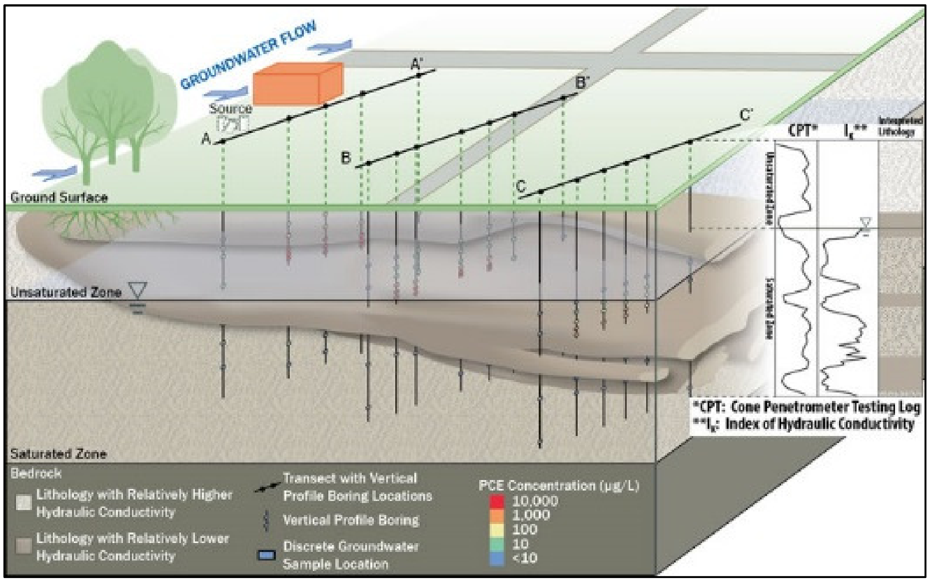
Consider this strategy if your site has:

- Contaminated groundwater in unconsolidated environments
- Stratified layers of varying soil type
- Non-aqueous phase liquids (LNAPL/DNAPL)
- Incomplete or generalized understanding of mass storage and transport in the CSM

Characterizing groundwater in unconsolidated environments can present challenges due to the high level of heterogeneity often found in sequences of gravel, sand, silt and clay. This heterogeneity not only creates uncertainty in the data and CSM when obtained with lower resolution techniques, but can often result in the existence of discrete zones of contaminant mass storage and transport. Heterogeneities that control contaminant storage and transport, such as thin layers of highly permeable sand and gravel, or thin silt and clay layers with low hydraulic conductivity, can be on the centimeter to meter scale and may be too small for conventional investigation strategies, such as monitoring wells, pump tests and slug tests to resolve. Detailed geologic, hydrogeologic and contaminant information is necessary to develop an accurate CSM to select and design remedial technologies matched to the scale of the spatial attributes of the subsurface problem. High-resolution site characterization offers an effective approach to resolve groundwater flow and contaminant concentrations at a detailed level.

Understanding the subsurface heterogeneity at a much higher resolution is critical for designing and implementing more effective and targeted remedial actions. Characterization activities that: (1) match the scale of the investigation to the scale of geologic heterogeneity expected in the subsurface and (2) define the three-dimensional (3D) structure through which groundwater and contaminants are moving can provide data necessary to evaluate and design a remedial strategy, possibly consisting of a combination of technologies. With sufficient resolution the site can be "compartmentalized" into areas of source treatment, plume management, and compliance monitoring to efficiently apply and monitor strategic and targeted remedial actions.

Highlight 1. Transect-based multi-level vertical profiling using direct push technology



High-resolution site characterization for groundwater in unconsolidated environments is comprised of a set of tools and approaches site managers can use to address the sample scale and sample spacing in 3D. Highlight 1 provides an example of transect-based, multi-level vertical profiling using direct push technology. Transects are oriented perpendicular to groundwater flow; vertical sampling for contaminant concentrations rely on direct sensing information for soil type and hydraulic conductivity to optimize sampling depth intervals. Data of this type can be collected over short, discrete intervals with specially designed tools that work with conventional drilling, direct sensing, direct push and hybrid techniques. Discrete samples can be analyzed in the field for contaminants in real time using handheld monitoring devices, field test kits or onsite laboratories. Continuous qualitative vertical contaminant profiles can be obtained using direct sensing tools, such as the membrane interface probe (MIP) or laser induced fluorescence (LIF) tools. A key component of the HRSC approach is dense data set integration and visualization to identify trends in aquifer material, physical and geochemical properties, contaminant phase and contaminant concentration, such as lower-concentration dissolved plumes and higher-concentration plume cores. Transects of vertical subsurface geologic, hydrologic and contaminant profiles oriented perpendicular to the hydraulic gradient's direction are used to generate two-dimensional (2D) cross-sections or more advanced 3D visualizations. Geostatistical data interpolation in 3D can further serve to estimate aquifer material properties like hydraulic conductivity and contaminant distribution in areas between data points.

While HRSC tools can provide valuable data for developing an accurate CSM, each has limitations on the subsurface conditions where it can be deployed and the type of data generated. For example, the MIP has delicate sensors that may be damaged in rocky, dense soils. Cone penetrometer testing (CPT) trucks are heavy, which may damage subsurface infrastructure. Subsurface sensors are subject to analytical detection limitations, and may provide relative concentration or permeability data that can be further verified by collaborative data and multiple lines of evidence. It is important to match the data gaps with the proper set of data collection tools to ensure the results will address the CSM data needs.

When using HRSC, the project team will need to consider each potential tool's applicability to site conditions and practical limitations. Planning and scoping field activities may require evaluation of site access and infrastructure, soil types, depth, and drilling platform and contingencies, in addition to the technical data needs to support an updated CSM.

Key Concept: Back Diffusion

The term "back diffusion" is the movement of contaminant mass out of low permeability units into higher permeability units by diffusion. In dual porosity systems, where low permeability units are in contact with higher permeability units, the low permeability units serve as sinks or storage areas for contaminant mass during the plume life's early stages. Large amounts of contaminant mass diffuse into the low permeability units when concentrations are high in the more permeable units. It is the diffusion of this mass stored in low permeability units back out into the higher permeability units that is referred to as back diffusion. This process serves as a long-term secondary source of contamination. These secondary sources are not limited to the original source area but are found throughout the plume's entire footprint. High-resolution site characterization defines areas where contaminant storage and back diffusion may be occurring.

EPA. 2016. Groundwater High-Resolution Site Characterization Course. CERCLA Education Center.

TOOL BOX
HIGH-RESOLUTION SITE CHARACTERIZATION FOR UNCONSOLIDATED ENVIRONMENTS

Field Analysis and Vertical Profiling

Geology and Hydrogeology Data
- Soil coring
- Cone penetrometer testing
- Electrical conductivity meter
- Hydraulic profiling tool
- Borehole flow meters
- Flow velocity sensor
- Point velocity probes
- Mini-piezometers
- Push-point samplers
- Thermal imaging with FLIR and DST

Qualitative Contaminant Data
- Membrane interface probe
- Laser induced fluorescence

Quantitative Contaminant Data
- Passive flux meters
- Polyethylene diffusion bags
- Mobile laboratory
- Fixed-based laboratory

Data Interpretation and Management
- Electronic lithologic logs
- Real-time instrumentation transfer
- Data base, such as Scribe
- QA/QC
- Decision logic to guide investigation
- CSM updates and distribution
- X, Y, and Z locational coordinates
- Data visualization, 2D and integrated 3DVA
- Data storage, EQuIS and WQX/STORET

Advancing Your Knowledge: Resources and Training

Resources:

- EPA's CLU-IN website contains a comprehensive set of HRSC resources in unconsolidated aquifers. www.clu-in.org/characterization/technologies/hrsc/
- This website contains references, case studies, and other resources for an investigation using the Triad Approach. HRSC is best implemented using the Triad Approach. www.triadcentral.org
- Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) are the Department of Defense's (DoD) environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. https://www.serdp-estcp.org/
- Highlight 1. See www.clu-in.org/characterization/technologies/hrsc/

Training:

- Groundwater High-Resolution Site Characterization, https://trainex.org/offeringslist.cfm?courseid=1389
- Best Management and Technical Practices for Site Assessment and Remediation, March 2015, CLU-IN Archived Webinar, https://clu-in.org/conf/tio/bmp/
- National Association of Remedial Project Managers Presents…Practical Applications and Methods of Optimization across the Superfund Pipeline, Parts 1 and 2, Spring 2013, https://clu-in.org/conf/tio/NARPMPresents18_050813/
- Triad Month, Sessions 1 – 7, August 2009, CLU-IN Archived Webinar, https://clu-in.org/conf/tio/triad1_080409/

High-Resolution Site Characterization for Fractured Sedimentary Rock Environments

Consider this strategy if your site has:

- Fractured sedimentary bedrock
- Fracture dominated flow
- LNAPL/DNAPL
- Plume stability concerns
- Incomplete CSM for fracture/matrix interaction flow

Fractured sedimentary rocks, such as sandstone and limestone, contain primary porosity created by the pore spaces between grains, and secondary porosity created by fractures that also allow fluids to move through the rock. Shale and siltstone are moderately impermeable to water flow through the matrix but may convey water through permeable fractures and along horizontal bedding planes. Finer grained sedimentary rocks, including shale and siltstone, have sufficient porosity to allow for contaminant diffusion into the matrix. Like back diffusion often encountered in unconsolidated heterogeneous media, dissolved contaminants that diffuse into the porous rock matrix can become a contaminant source zone if the concentration in the fractures falls below the contaminant concentrations in the rock matrix.

Investigations at fractured sedimentary rock sites must consider the interrelationship of the matrix and fractures in the CSM. To address these concerns, an integrated approach to characterizing the matrix and the fractures may be required. Rock-core material can be examined using a variety of visual logging and field examination techniques along with laboratory chemical, mineralogical and biological measurements. The borehole itself also provides opportunities for measurements during drilling and short- and long-term measurements within a completed unlined or lined borehole.

The HRSC strategy for fractured sedimentary rock focuses on identifying the permeable fractures and their associated flow characteristics, and determining contaminant phase and concentration in the fracture flow as well as the amount of sorbed contaminant in the rock matrix that may act as a long-term source. Packer testing, groundwater sampling, geophysics, acoustic and optical viewers, caliper logs, borehole flowmeters, and temperature logging are commonly used in fractured media; however, lining boreholes and limiting the time the boreholes are open in these settings are key strategies to limiting potential cross-contamination impacts that could be caused by the open borehole. Installation of borehole liners not only serve to limit potential connection of previously unconnected fractures but provide valuable fracture flow and contaminant distribution information during and after installation. Subsequently, within lined boreholes a variety of geophysics, temperature logging and vertical profiling techniques can be applied.

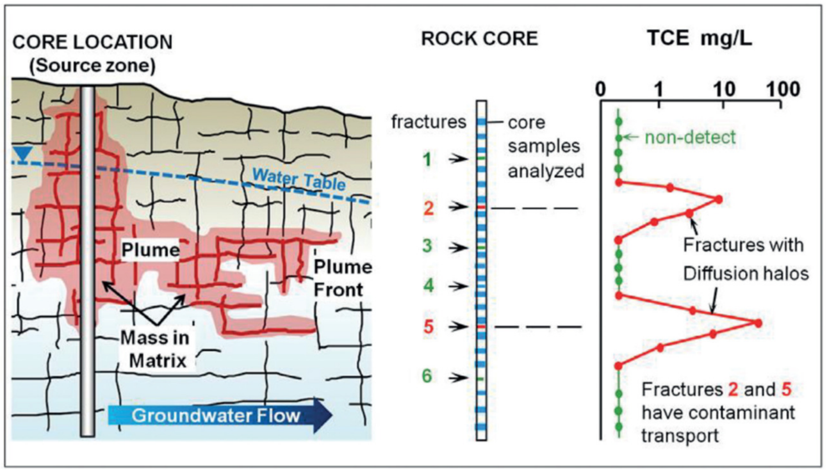
TOOL BOX
HIGH-RESOLUTION SITE CHARACTERIZATION FOR FRACTURED SEDIMENTARY ROCK ENVIRONMENTS

- Packer testing
- Borehole liners
- Groundwater sampling
- Multi-level groundwater sampling
- Geophysics
- Acoustic and optical viewers
- Caliper logs
- Borehole flowmeters
- Temperature logs
- Rock core sampling using microwave assisted extraction

The discrete fracture network (DFN) approach, described in the University of Guelph's G360 Centre for Applied Groundwater Research publication,[3] is one example of a comprehensive set of investigation tools used to delineate contaminant distributions and to understand contaminant transport and fate in both fracture networks and the rock matrix blocks between the fractures. The primary data collection components include comprehensive sampling of continuous rock core from strategically located holes for contaminant analysis, and open borehole tests, such as flexible liner hydraulic conductivity profiling, geophysical logging, hydraulic testing and use of multilevel monitoring systems to characterize fracture flow. These data are used to improve the CSM to reflect the source and plume characteristics. The CSM is then used as input to numerical groundwater flow and transport models to predict contaminant behavior. Remedial design is based on the contaminants' predicted behavior over the short- and long-term.

This type of approach is applicable to sites where contaminants are transported through fractures and are capable of diffusing into the rock matrix (see Highlight 2). Generally, this circumstance includes sites with sedimentary rocks (sandstone, limestone, dolomite) having rock matrix porosity generally in the range of 5-20 percent, not crystalline rocks, such as igneous or metamorphic rocks. Organic contaminants have been the most commonly studied species in DFN applications, but consideration may also be given to other contaminant types with the capacity of diffusing into pore spaces and becoming trapped. Sites with a history of releases of LNAPL and DNAPL are particularly well suited to sampling strategies that provide collaborative data and multiple lines of evidence because the complexities of NAPL fate and transport make reliance on a single line of evidence ill advised.

Highlight 2. Using Borehole, Fractures, and Rock Core



The limitations of a non-traditional approach to fractured sedimentary rock investigations are related to the site conditions described above, and the availability of project teams and vendors capable of delivering the high level of specialized services required to conduct the field work and analysis. Forming and using a comprehensive team is a best practice discussed in EPA's companion technical guide "Smart Scoping for Environmental Investigations," and an interdisciplinary team of geologist, geophysicists, hydrologists, engineers, and numerical modelers is required to develop and execute the plans. Specialty vendors, including diamond core drillers, labs capable of analyzing rock chips/cores, borehole geophysical services, and flexible borehole liner vendors, are necessary to execute the complex sampling strategy.

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[3] Parker, et al. 2012. Discrete Fracture Network Approach for Studying Contamination in Fractured Rock. AQUA mundi (2012) – AM06052: 101 – 116. December. http://www.acquesotterranee.it/sites/default/files/Am06052.pdf

The benefits of using the non-traditional approach over conventional fractured rock investigation methods are that the detailed knowledge of fracture and matrix interactions results in better prediction of flow and transport for remedial designs. The approach focuses on identifying and mapping fractures potentially storing or moving contaminant mass, nearby rock matrices with the potential for matrix diffusion, and the phase/flux of contaminant mass. A CSM constructed in this manner, for a site in remedial design for example, can focus on specific fractures that are most likely to transport contaminants and drive site risk, or may indicate that the plume is stationary and a combination of limited and targeted active remediation in conjunction with passive techniques may be most appropriate.

Contaminant flow in fractured sedimentary rock can be complicated and HRSC may employ many different tools, strategies, and visualization and modeling techniques. When planning and scoping, project managers are best served by expanded project teams, extensive stakeholder outreach, and taking the time required for integrating multiple data sets.

Advancing Your Knowledge: Resources and Training

Resources:

- EPA's CLU-IN website contains focused case studies classified under "Fractured Sedimentary Rock" and the "DFN Approach." www.clu-in.org
- DoD's SERDP and ESTCP are the Department's environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. https://www.serdp-estcp.org/
- Highlight 2. EPA. Groundwater High-Resolution Site Characterization Course. CERCLA Education Center. 2016.

Training:

- Groundwater High-Resolution Site Characterization, https://trainex.org/offeringslist.cfm?courseid=1389

Incremental Sampling

Consider this strategy if your site has:

- Contaminated shallow soil over large area
- Heterogeneous soil concentrations
- Release mechanisms with lower spatial correlation (aerial deposition versus a spill)
- Stable, non-volatile contaminants (such as metals, energetics and PAHs)
- High analytical costs expected due to known chemicals of concern

Traditional soil sampling methods do not always provide the accurate, reproducible and defensible data needed to make decisions about the volume and extent of cleanup because they do not account for contaminant heterogeneity in soil. Incremental sampling techniques include processing protocols that reduce variability, provide sampling results more representative of exposure scenarios, and provide higher density spatial coverage to reasonably assure adequate representation of the contamination present within a defined soil area or volume. To address the inherent variability due to matrix heterogeneity, IS involves collecting multiple soil increments of equal mass from locations throughout a defined soil sampling area and depth interval (known as a decision unit, DU) and combining the increments into a single field sample. The resulting field sample may be homogenized and processed such that it is representative of the defined DU and exposure mechanisms or assumptions. The IS strategy reduces data uncertainty from sample variability and soil heterogeneity, resulting in a more accurate delineation of the DU's volume of contaminated soil.

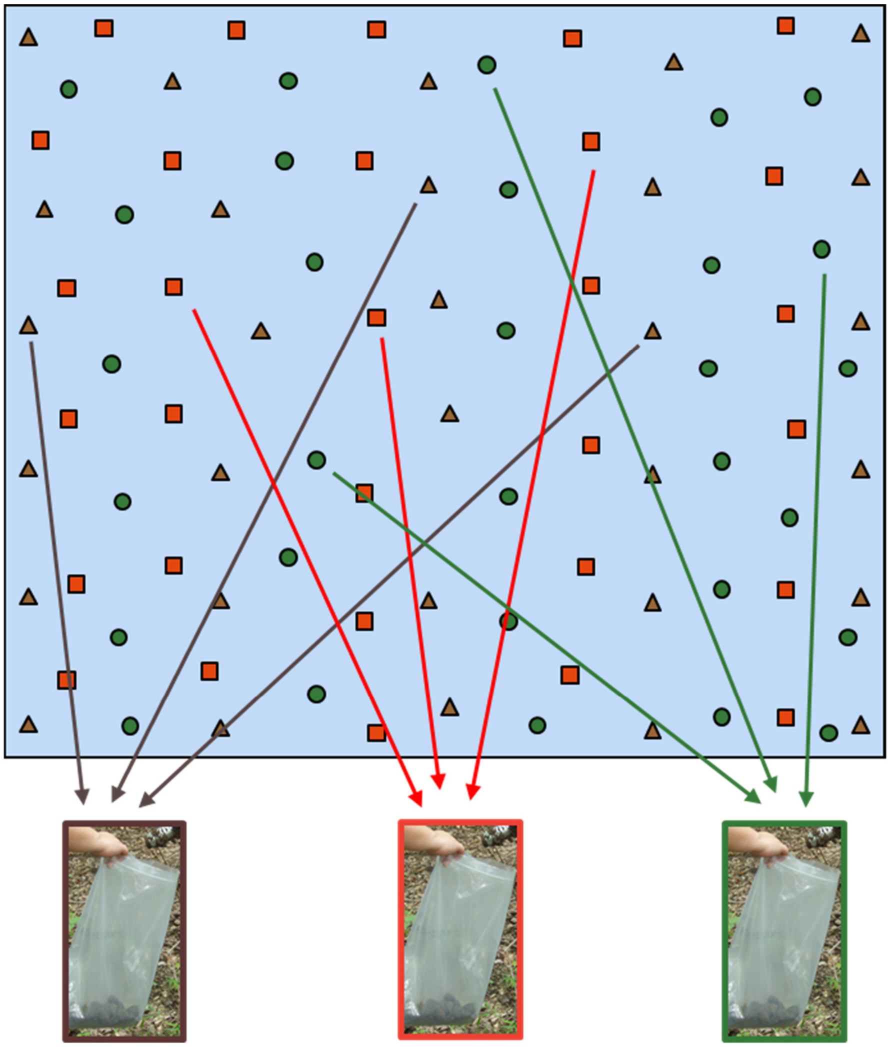
Key Concept: Compositing and Dilution

Some project stakeholders are concerned that potential areas of higher concentration within a DU (i.e., hot spots) will be diluted out when combined through the incremental sampling methodology (ISM) with increments of soil from less-contaminated portions of the DU. There are two concerns regarding hot spots: sampling density and defining the DU. Incremental sampling methodology effectively addresses compliance when action levels are based on the mean concentration within a DU. Concerns related to spatial resolution can be addressed only by changing the scale of the DU so that the it equals the hot spot's size. The chance that any single sampling event will include subareas of high and low concentration in the proper proportion is directly related to the number of samples collected within a DU. Incremental sampling methodology offers an advantage over other sampling designs because it accommodates large sample sizes. For this reason, while any individual sample collected in a hot spot is diluted within the larger group of samples, we are more likely to achieve an estimate of the mean that is representative of the true mean within the DU. This advantage of ISM addresses the concern of compliance with action levels but not the concern about spatial resolution. If the data quality objective includes the identification and delineation of small areas of elevated concentrations, ISM sampling can address this objective only by changing the scale of the DU so that it equals the size of the hot spot of concern.

http://www.itrcweb.org/ISM-1/8_5_1_2_Sampling_objectives_and_developing_the_decision_unit.html

Smart scoping is required to develop a site-specific sampling strategy for IS implementation. Project teams, including data users (risk assessors and design engineers), data quality managers, and sampling teams, identify the DU selection rationale and the increment volume and number to be collected. Decision unit size and volume are typically driven by applicable remediation strategies in source areas where contamination above cleanup standards is likely (smaller DUs) and exposure scenarios in areas where exceedances are less likely but risk management requires sampling to evaluate potential exposure (larger DUs). While there is no DU- required size and volume, DUs can range from smaller 10’x10’ grids with a depth of a few inches to larger ¼- 1-acre size with a 6-inch depth for some residential settings. Decision units can be regular in shape, such as a rectangle or square, or irregularly shaped, and those that are larger than one acre are typically only used for agricultural, recreational and industrial exposure scenarios.

Highlight 3. IS Replicate Samples in a Decision Unit



Highlight 3 shows how a DU is sampled in triplicate under IS. Each IS sample is made up of 30 increments, with all triangle locations representing the increments combined for the first IS sample, all square locations representing the increments for the second IS sample, and all circle locations representing the third IS sample increments. The three IS samples will each yield separate contaminant values. Using triplicate values or any series of replicates greater than three allows project teams the ability to calculate confidence limits on the mean. EPA has been combining IS with use of the x-ray fluorescence (XRF) instrument to conduct soil sampling for metals. EPA uses a high level of quality assurance and quality control (QA/QC) for sample preparation and analysis with the XRF to ensure data are of sufficient quality for decision-making. Sampling plans and quality assurance project plans (QAPP) developed for IS programs include detailed procedures for field sample collection and detailed instructions to field crews or laboratories for sample processing. Sample collection considers the type of tools used to collect soil samples as well as the procedures for collecting subsamples. Sample processing is an important part of the sampling design and may have a significant influence on the data. For example, small soil particles tend to have higher contaminant concentrations than larger particles, so soil sieving, grinding and disaggregation may need to be considered dependent on the soil material's characteristics. Sample processing may be completed in the field, begin in the field and finish in the lab, or all be done in the lab. All these considerations need to be addressed in the systematic planning and documented in the QAPP.

TOOL BOX
INCREMENTAL SAMPLING

- Decision unit selection – knowledge of site conditions, data quality objectives, statistical assistance
- Sample support – shape, orientation, and size
- Sample processing – grinding, drying, sub-sampling
- Mobile laboratory or fixed-based laboratory
- XRF instrument for specific contaminants

Advancing Your Knowledge: Resources and Training

Resources:

- The Interstate Technology and Regulatory Council (ITRC) developed a technical and regulatory guidance document, Incremental Sampling Methodology (ISM-1) http://www.itrcweb.org/Team/Public?teamID=11. The document provides users with a practical working knowledge of the methodology's concepts and principles, emphasizes the critical importance of clearly articulated sampling objectives, and provides a sound basis for adapting ISM to meet project goals and site-specific objectives. EPA and ITRC resources include additional references and case studies.
- EPA. 2013. The Roles of Project Managers and Laboratories in Maintaining the Representativeness of Incremental and Composite Soil Samples. OSWER Directive No. 9200.1-117FS. June. https://clu-in.org/download/char/RolesofPMsandLabsinSubsampling.pdf
- Highlight 3. EPA. Incremental Composite Soil Sampling course. CERCLA Education Center. June 2016.

Training:

- Soil Sampling and Decision Making Using Incremental Sampling Methodology, Parts 1 and 2, February and March 2015, CLU-IN Archived Webinar, https://clu-in.org/conf/itrc/ISM_020515/
- Incremental Composite Sampling Designs for Surface Soil Analyses, Modules 1 – 4, CLU-IN Archived Webinar, https://clu-in.org/conf/tio/ISM1_021612/
- XRF Training, Sessions 1 – 8, August 2008, CLU-IN Archived Webinar, https://clu-in.org/conf/tio/xrf_080408/

Contaminant Source Definition

Consider this strategy if your site has:

- Complex source (LNAPL/DNAPL, dispersed waste or source area, vadose zone source)
- Design that relies on source treatment or control
- Uncertainty in source footprint and heterogeneous/anisotropic aquifer conditions
- Incomplete CSM of the source – transport relationship

Strategic sampling designs for contaminant source definition focus on providing an accurate estimate of volumes and location in 3D space for application of both in situ and ex situ technologies. Two common reasons for cost or schedule challenges at many sites are the under-estimation of volume with related cost escalation in remedial action, and over- or under-estimation of the footprint for the application of in situ technologies. Both examples demonstrate the need for improved CSMs to ensure the design is appropriately sized to meet the remedial action objectives in the most cost effective and timely manner. Dense data sets help to focus treatment components.

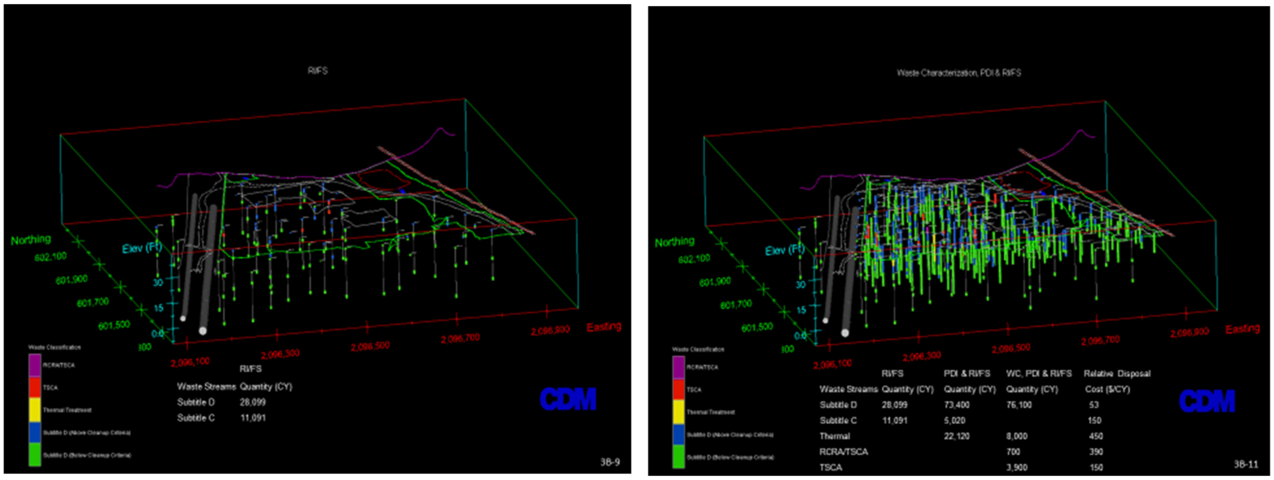
An accurate understanding of the CSM chemistry and hydrogeology is a critical factor in identifying cost-effective design alternatives and optimizing remedial design. Site managers can improve and expand the CSM by using collaborative data sets with a large volume of real-time data supported by a small volume of fixed lab data, and thoughtful development of DUs over which to measure contaminant levels. High-resolution site characterization techniques can be applied to source definition when the benefits outweigh the costs (return on investigation). Applying high-resolution tools can improve the delineation of the source footprint to optimize in situ remedies or to better segregate material for disposal. For LNAPL and DNAPL sources, high-resolution techniques aid in mapping mass storage versus transport zones so that more costly and aggressive methods are applied to the appropriate source areas, and plume management strategies effectively account for mass storage and transport zones.

Source areas that contain dispersed waste, such as surface soils contaminated by airborne lead deposition or subsurface contamination from multiple subsurface waste pits, can present uncertainty in estimating waste location and volume. High-resolution characterization tools, such as geophysical surveys or passive soil gas grids, coupled with the IS approach, can significantly reduce uncertainty in defining the source areas. Decision units and sample design can be selected based on the geophysical or soil gas signatures.

Using 3DVA to visualize the source area can be beneficial for developing a more realistic CSM. The dense data sets from HRSC match well with visualization tools and reflect high quality characterization in support of remedy selection, design, and optimization. Applying 3DVA improves communication among the design and construction team members by providing a consistent understanding of the site conditions.

When planning and scoping remedial design tasks, site managers consider the uncertainties in delineation of the source and apply the appropriate high-resolution data collection and analysis tools to reduce uncertainty.

Highlight 4. Comparative sampling densities using traditional approach versus HRSC



	RI/FS
Waste Streams	Quantity (CY)
Subtitle D	28,099
Subtitle C	11,091

	RI/FS	PDI & RI/FS	WC, PDI & RI/FS	Relative Disposal
Waste Streams	Quantity (CY)	Quantity (CY)	Quantity (CY)	Cost ($/CY)
Subtitle D	28,099	73,400	76,100	53
Subtitle C	11,091	5,020		150
Thermal		22,120	8,000	450
RCRA/TSCA			700	390
TSCA			3,900	150

Highlight 4 shows the value of HRSC for source definition at the Horseshoe Road Superfund site. The image on the left shows sampling density before HRSC and the image on the right shows sampling density using HRSC. The denser data set allowed better segregation of waste types and significantly reduced disposal costs.

TOOL BOX
CONTAMINANT SOURCE DEFINITION

- Direct push technologies
- Geophysics
- XRF
- Membrane interface probe
- Laser induced fluorescence
- Mobile laboratory or fixed-based laboratory
- High-resolution sampling strategy
- IS
- 3DVA

Advancing Your Knowledge: Resources and Training

Resources:

- EPA's CLU-IN website contains a comprehensive set of resources for HRSC in unconsolidated aquifers. High-resolution site characterization techniques are recommended for characterizing NAPL sources in the subsurface. www.clu-in.org/hrsc
- This ITRC document synthesizes the knowledge of DNAPL site characterization and remediation and provides guidance on characterization of contaminant distributions, hydrogeology, and attenuation processes. http://www.itrcweb.org/DNAPL-ISC_tools-selection/Content/1%20Introduction.htm
- SERDP and ESTCP are DoD's environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities.
  https://www.serdp-estcp.org/
- Highlight 4. Horseshoe Road Superfund Site information:
  https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0200781

Training:

- Remedial Design/Remedial Action Training, https://trainex.org/offeringslist.cfm?courseid=47
- Best Practices for Site Characterization Throughout the Remediation Process, https://trainex.org/offeringslist.cfm?courseid=1515
- Groundwater High-Resolution Site Characterization, https://trainex.org/offeringslist.cfm?courseid=1389
- ICS training webinar, https://clu-in.org/conf/tio/ISM1_021612/

Passive Groundwater Sampling

Consider this strategy if your site has:

- Contaminated groundwater in thin zones;
- Monitoring wells with long screen intervals and well-defined borehole flow dynamics
- Shallow groundwater adjacent to surface water
- Incomplete or generalized understanding of transport in the CSM

A passive groundwater sampler acquires a water sample from a discrete depth in a monitoring well or borehole without active pumping or purge techniques. Passive samplers use one of three different mechanisms to obtain concentration data:

- Direct well water sampling is performed using instantaneous grab sample devices.
- Diffusion samplers rely on the diffusion of analytes between the sampler fluid and groundwater or surface water to reach equilibrium.
- Integrating samplers sequester chemicals through trapping in a suitable medium, which can be a solvent, chemical reagent or a porous adsorbent.

All passive technologies rely on the sampling device being exposed to groundwater in ambient equilibrium during the sampler deployment period or the monitoring well water being in equilibrium with the formation water.

Passive sampling is a cost-effective HRSC method that can be used to collect contaminant data from multiple intervals in an existing well or borehole for shallow groundwater or groundwater and surface water interfaces. Monitoring wells with long-screen intervals (10 feet or greater), and wells screened in heterogeneous materials may have multiple flow zones that transport different amounts of contaminants at different hydraulic conductivities. Most passive samplers can be stacked to obtain samples at multiple depths, which allows vertical zones within a screened well interval to be sampled individually to give a better understanding of the contaminant concentrations at various depths. However, monitoring well or borehole flow dynamics must be well understood to successfully use passive sampling devices to define contaminant differences in distinct vertical flow zones. If vertical flow regimes in boreholes or depth integrated flow weighted averages across well screens exist then care must be taken to isolate specific zones using packers in open boreholes or other technologies for passive sampling techniques. The increased resolution of contaminant flow paths in aquifers supports a detailed CSM and leads to more efficient remedial design by identifying zones where contamination is greatest. Highlight 5 shows passive diffusion bags installed in series in a screened monitoring well whose borehole dynamics have been confirmed.

Highlight 5. Passive samplers in series

While each passive sampling method has unique advantages and limitations, one common consideration is that passive samplers must be exposed to the host environment for a time, and the resulting sample may represent the most recent exposure conditions if groundwater conditions fluctuate dramatically. Equilibrium may be reached within a few days or a few weeks depending on the nature of the contaminant and the sampling device. One advantage of passive samplers is that minimal equipment is required and little to no purge water is generated.

Passive groundwater samplers are relatively simple to deploy, and they are cost effective tools for groundwater monitoring in remote conditions. They can be used at any point in the process with proper planning to ensure quality controls and by conducting a method demonstration as necessary. In addition, there are many new passive samplers under development.

TOOL BOX
PASSIVE GROUNDWATER SAMPLING

- Devices that recover a grab sample
    - Two proprietary options are discussed
- Devices that rely on diffusion of the analytes to reach equilibrium between sampler and well water
    - Regenerated-Cellulose Dialysis Membrane Sampler
    - Nylon-Screen Passive Diffusion Samplers (NPSPDS)
    - Passive Vapor Diffusion Samplers (PVDs)
    - Peeper Samplers
    - Polyethylene Diffusion Bag Samplers (PDBs)
    - Rigid Porous Polyethylene Samplers (RPPS)
- Devices that rely on diffusion and sorption to accumulate analytes in the sampler
    - Semi-Permeable Membrane Devices (SPMDs)
    - Polar Organic Chemical Integrative Sampler (POCIS)
    - Passive In Situ Concentration Extraction Sampler (PISCES)
    - One proprietary option is discussed

http://www.itrcweb.org/GuidanceDocuments/DSP_4.pdf

Advancing Your Knowledge: Resources and Training

Resources:

- The Characterization and Monitoring section of EPA's CLU-IN website contains a discussion of the three generic forms of passive (no purge) samplers, and provides links to other references. The site also includes a table describing common analytes addressed by 15 different technologies. https://clu-in.org/characterization/
- ITRC developed a Technology Overview of Passive Sampler Technologies, which includes a comprehensive table of advantages, limitations, availability and cost of 13 different passive sampler technologies. https://www.itrcweb.org/GuidanceDocuments/DSP_4.pdf
- SERDP and ESTCP are the DoD's environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. https://www.serdp-estcp.org/
- Highlight 5. ITRC. Technical Overview of Passive Sampler Technologies. March 2006.

Training:

- Best Practices for Site Characterization Throughout the Remediation Process, https://trainex.org/offeringslist.cfm?courseid=1515
- Groundwater High-Resolution Site Characterization, https://trainex.org/offeringslist.cfm?courseid=1389

Passive Sampling for Surface Water and Sediment

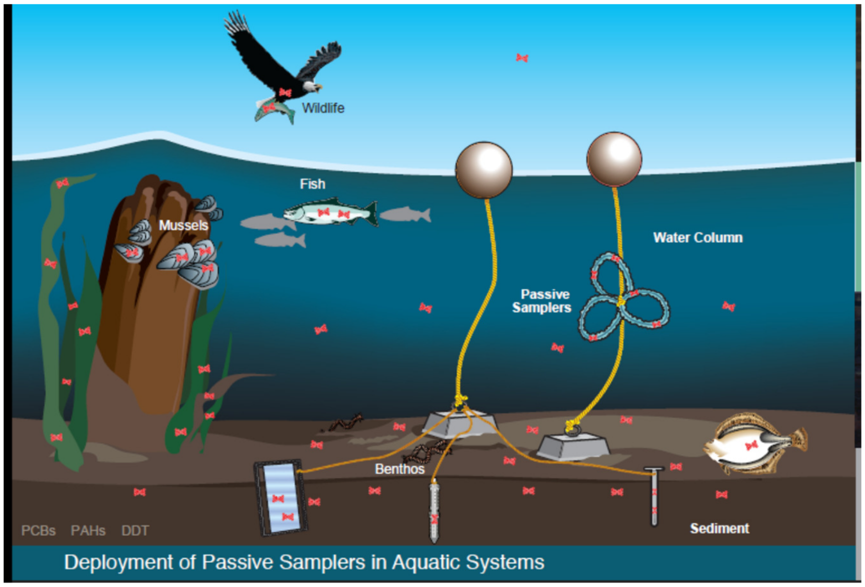
Sediment contamination is traditionally evaluated at Superfund sites using direct sampling of the sediment, pore water, and the adjacent surface water column. The underlying assumption of direct sample results is that all the contaminant is bioavailable. If the sediment concentrations indicate there may be a problem, then further bioavailability studies are sometimes conducted. Passive sampling methods for surface water and sediment can be used to quantify bioavailability based on the diffusion and subsequent partitioning of contaminants from sediment to a reference sampling media (pore water and surface water), which can reduce uncertainty in ecological risk assessment.

Consider this strategy if your site has:

- Sediment contamination
- Hydrophobic non-ionic contaminants (PCB, PAH, dioxins)
- CSM that includes sediment-surface water interaction
- Uncertainty regarding the bioavailability of contaminants
- Poor correlation between toxicity and bulk sediment chemistry

Passive sampling is a scientifically sound and cost-effective approach for monitoring contaminant concentrations in the water column and sediment interstitial waters, and it can provide information about the contaminant gradients between the sediment and the water. Passive samplers provide information on dissolved and bioavailable contaminant concentrations because the samplers serve as surrogates for organism bioaccumulation. The most common sediment contaminants are hydrophobic non-ionic contaminants including pesticides, polychlorinated biphenyls (PCBs), PAHs, and, to a lesser extent, dissolved-phase chlorinated hydrocarbons. Passive sampling methods for metals are not as advanced or established as methods for hydrophobic organic contaminants. Highlight 6 shows the deployment of passive samplers in an aquatic system.

Highlight 6. Deployment of passive samplers in aquatic systems



Passive samplers are commonly made of plastic polymer that is similar in hydrophobicity to many hydrophobic contaminants. Hydrophobic contaminants present in the dissolved phase will partition into the polymer, moving out of the water and dissolving into the polymer. Over time, the contaminants will accumulate in the sampler until they reach a state of concentration equilibrium with adjacent media. Passive samplers can be used for determining contaminant sources released from sediments to the water column in support of the CSM, and monitoring water column and interstitial water concentrations before, during and after remediation.

Sediment characterization is often complicated by the relatively rapid changes that can occur in sediment composition due to short-term temporal events (such as storms) that can cause sediment resuspension and movement. These changes can either result in an elevated or a reduced dissolved concentration in the water column that does not accurately reflect the site's long-term average concentration. Passive samplers provide time-averaged measurements, which more accurately reflect representative concentrations at a site rather than a snap-shot of conditions represented by traditional sampling. One disadvantage of passive samplers is that they are limited to only those compounds that can be captured in the sampling media, which may not include all site contaminants of concern. Additionally, regulators may require comparability tests prior to the use of passive samplers for certain sampling objectives.

When assessing sediment sites, site managers may consider the use of passive sediment and surface water samplers to better delineate the source areas, as well as to measure remedy effectiveness. Planning and scoping investigations with passive samplers typically require ecologists, chemists, and field staff input to ensure data collection can address CSM uncertainties.

TOOL BOX
PASSIVE SAMPLING FOR SURFACE WATER AND SEDIMENT

- Polyethylene samplers
- Polyoxymethylene samplers
- Solid phase micro-extraction samplers
- Methodology for translating measured concentrations in the passive sampler into dissolved concentrations around the passive sampler

Advancing Your Knowledge: Resources and Training

Resources:

- EPA has developed a guideline for using passive samplers to monitor organic contaminants at Superfund sediment sites https://clu-in.org/download/contaminantfocus/sediments/Sediments-Passive-Sampler-SAMS_3.pdf
- The SERDP and ESTCP are the DoD's environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. https://www.serdp-estcp.org/
- Highlight 6. EPA. https://clu-in.org/download/contaminantfocus/sediments/Sediments-Passive-Sampler-SAMS_3.pdf

Training:

- The Use of Passive Samplers to Monitor Organic Contaminants at Superfund Sediment Sites, August 2013, CLU-IN Archived Webinar, https://clu-in.org/conf/tio/passsamp_082613/
- RPM 201, Sediment Module, https://trainex.org/offeringslist.cfm?courseid=1374

Groundwater to Surface Water Interactions

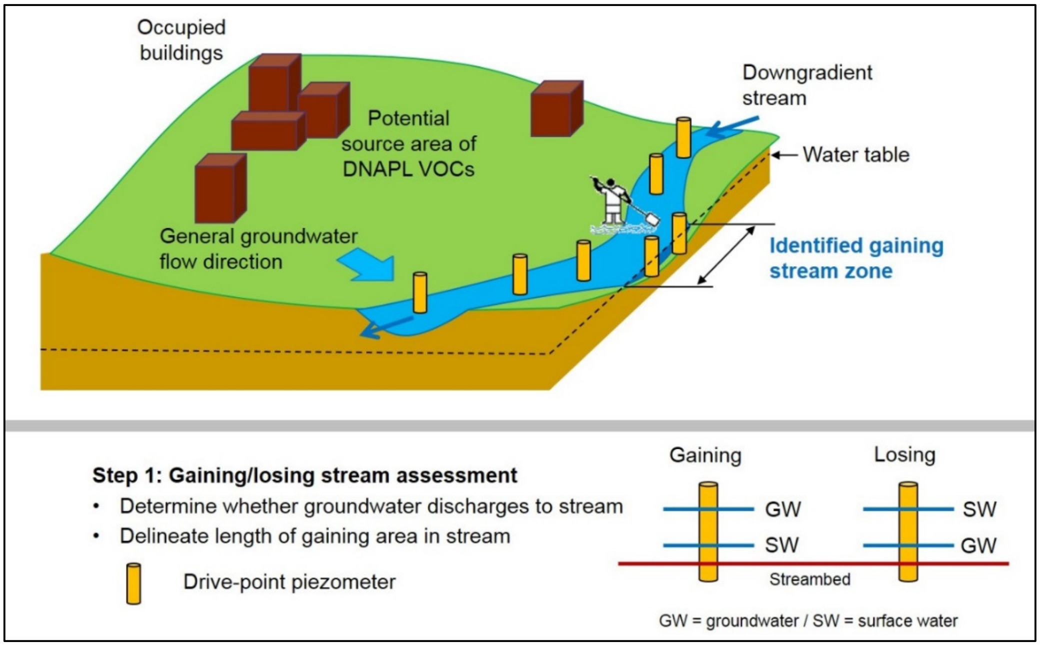
Consider this strategy if your site has:

- Surface water and groundwater present
- Potential for transport of contaminants from one media to the other
- Uncertainty in location of groundwater discharge points in surface water
- Incomplete CSM of the groundwater to surface water interaction

In hydrologic systems where groundwater and surface water are present, these media are connected by the groundwater and surface water transition zone. In some cases, groundwater discharges into the surface water, or the surface water may recharge the groundwater system. Understanding contaminant fate and transport in this zone is important because it represents the exchange of contaminants between media and the potential for ecological and human exposure. EPA is particularly interested in understanding the groundwater to surface water interaction because almost half of all Superfund sites have affected surface water.

Investigations of groundwater to surface water interactions are designed to evaluate both flow and chemical characteristics; specifically, understanding the location and magnitude of contaminant discharges to surface waters from groundwater plumes or from surface water to groundwater. The investigative and sampling strategy starts with a general reconnaissance of the area to identify groundwater discharge locations and evolves into a detailed and focused sampling of hydraulics, chemistry and biology. Highlight 7 depicts an example of an investigative strategy for evaluating groundwater to surface water interactions using groundwater and surface water elevations.

Highlight 7. Example of investigative strategy for groundwater – surface water interface



Potentiometric surface maps, developed from surface water- and groundwater-level data, are typically used to delineate discharge areas' general location. More specific methods, including seepage meters, thermal imaging, geophysical tools and quantitative dye tracer tests, may also be used to identify specific discharge locations. Temperature has been effectively used to map locations of groundwater to surface water discharge locations. Forward looking infrared cameras and distributed temperature sensors using fiber optic cables are techniques that can be used to map discharge at a variety of scales and optimize sediment, pore water and surface water sampling locations. This high-resolution, finer-scale analysis is important because recent studies have shown that significant discharge areas can be spatially complex, small and easily missed. Once the flow patterns have been established, the contaminants' flux can be evaluated.

While traditional investigation approaches using monitoring wells and depth-discrete surface water sampling are useful tools, HRSC techniques are also applicable for defining contaminant flux along the flow paths and at the suspected discharge points. High-resolution site characterization is critical in areas where contaminant flow may be at a very fine scale, such as in fractured rock or heterogeneous sediments. A large passive sampler network can be cost effectively deployed along stream banks and within the surface water body sediment to rapidly delineate the location and relative concentrations of contaminants discharging into surface water bodies.

TOOL BOX
GROUNDWATER TO SURFACE WATER INTERACTIONS

- HRSC techniques for groundwater component
- Passive flux meter
- Passive samplers
- Mini-piezometers
- Push point sampler
- Forward looking infrared camera
- Distributed temperature sensor
- Multi-level bundle piezometers
- Ground penetrating radar

The groundwater and surface water interface environment is complex, with flow across the sediment and water interface commonly changing direction and velocity, both temporally and spatially. The contaminant flux can change in magnitude and direction, with changes in both surface water temperature and stage; these changes require groundwater and surface water sample collections over time and during different flow conditions.

Developing an accurate and complete CSM of the groundwater and surface water interaction is a valuable tool when considering risk reduction options and remedial design. Discharge and flux information can aid in natural attenuation assessment, or the design and optimal placement of wall and curtain containment systems and engineered attenuation zones.

Advancing Your Knowledge: Resources and Training

Resources:

- EPA recommends the U.S. Geological Survey (USGS) document, Field techniques for estimating water fluxes between surface water and ground water, https://pubs.usgs.gov/tm/04d02/, as a practical compendium of methods for investigating the hydrologic characteristics of the groundwater/surface water zone.

- A joint publication EPA-USGS provides guidance on the application of passive samplers for delineating volatile organic compounds in groundwater discharge areas and nine case studies. https://pubs.usgs.gov/wri/wrir024186/pdf/wri024186.pdf
- The proceedings of EPA's Ground-Water/Surface-Water Interactions Workshop includes information on investigation methods and evaluation of the hydrological, chemical and ecological aspects of the zone. https://www.epa.gov/sites/production/files/2015-06/documents/gwsw_workshop.pdf
- Forward looking infrared camera, http://water.usgs.gov/ogw/bgas/thermal-cam/
- Distributed temperature sensor, http://water.usgs.gov/ogw/bgas/fiber-optics/
- The SERDP and ESTCP are the DoD's environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. https://www.serdp-estcp.org/
- Highlight 7. EPA. Best Practices for Site Characterization Throughout the Remediation Process course. CERCLA Education Center. 2016. https://trainex.org/offeringslist.cfm?courseid=1515&all=yes

Training:

- Best Practices for Site Characterization Throughout the Remediation Process, https://trainex.org/offeringslist.cfm?courseid=1515&all=yes
- A Rapid Multi-Scale Approach for Characterizing Groundwater/Surface Water Interactions and Evaluating Impacts on Contaminated Groundwater Discharge, NARPM 2014.

Vapor Intrusion

Consider this strategy if your site has:

- Subsurface source of vapor-forming chemicals underneath or near buildings
- Potential pathway for VOC inhalation exposure
- Incomplete analysis of vapor intrusion pathway in CSM

Vapor intrusion is the migration of hazardous vapor from a subsurface contaminant source (groundwater, soil or conduit) into an overlying structure. Contaminants that typically lead to vapor intrusion include chlorinated hydrocarbons, petroleum hydrocarbons, and both halogenated and non-halogenated volatile organic compounds. Vapor intrusion pathways are generally assessed by collecting and evaluating multiple lines of evidence through groundwater sampling, soil gas sampling, passive soil gas surveys, sub-slab sampling and indoor air sampling. A complete vapor intrusion pathway indicates that there is an opportunity for human exposure.

EPA recommends that the potential for human health risk from vapor intrusion be evaluated throughout the project life cycle. There are different scenarios for vapor intrusion depending on characteristics of the source, subsurface conditions and vapor migration, building susceptibility, lifestyle factors, and regional climate. For these reasons, every site (and every building) will not warrant the same vapor intrusion assessment approach. The best practice is to develop a strategic sampling program as early as possible in the cleanup life cycle to ensure the remedial design addresses the vapor intrusion pathway.

EPA recognizes two general levels of vapor intrusion assessments; each can be approached strategically:

- *Preliminary assessments* are conducted utilizing available and readily ascertainable information to develop an initial understanding of the human health risk potential
  - Typically performed as part of an initial site assessment
  - Strategy is to focus on data that help define inclusion zones
- *Detailed investigations* are generally recommended when the preliminary analysis indicates that subsurface contamination with vapor-forming chemicals may be present underlying or near buildings (buildings are within an inclusion zone)
  - Typically performed as part of the site investigation stage but can be done at any time
  - Strategy is to prioritize other lines of evidence necessary to complete detailed investigations
  - Account for spatial/temporal variations

Certain sites with long-term contaminated groundwater cleanups underway may be evaluated for vapor intrusion during periodic reviews.

Sampling programs for vapor intrusion can be invasive to structure occupants, and will require somewhat extensive community outreach efforts. Additionally, due to the highly site-specific nature of vapor risk, an accurate CSM that incorporates all aspects of the scenarios stated above is needed to successfully conduct the assessment. Temporal and spatial variability of sampling data can span at least an order-of-magnitude and often more, and individual lines of evidence may be inconsistent with other lines of evidence. Assessment of multiple lines of evidence may result in decisions based on professional judgement. A well-formulated strategic sampling approach should identify the buildings that will require mitigation, with mitigation strategies only implemented at the buildings that exceed risk thresholds.

TOOL BOX
VAPOR INTRUSION

- Building assessment
- Vapor source assessment
- Indoor air sampling
    - Evacuated canisters
    - Sorbent samplers – active and passive
- Outdoor air sampling
    - Use methods akin to indoor air sampling
- Sub-slab soil gas sampling
    - Sampling probe(s)
    - Evacuated canisters
- Groundwater characterization and monitoring
    - HRSC
    - Monitoring well network

Advancing Your Knowledge: Resources and Training

Resources:

- In June 2015, EPA released a final vapor intrusion technical guide that describes a recommended framework for assessing vapor intrusion. This comprehensive guide provides EPA's current technical recommendations based on the most current understanding of vapor intrusion into indoor air from subsurface vapor sources. https://clu-in.org/download/issues/vi/VI-Tech-Guide-2015.pdf
- The ITRC Vapor Intrusion Pathway Guidance is a practical, easy-to-read, how-to guideline for assessing the vapor intrusion pathway and includes a companion guide that describes six different, yet common, hypothetical vapor intrusion scenarios and the investigation approaches that might be followed. https://clu-in.org/download/contaminantfocus/vi/ITRC%20VI-1.pdf
- The SERDP and ESTCP are the DoD's environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. https://www.serdp-estcp.org/
- Additional resources may be found on the CLU-IN Issues: Vapor Intrusion (provides many links/guidance documents): https://clu-in.org/issues/default.focus/sec/Vapor_Intrusion/cat/Overview/

Training:

- RPM 201, Vapor Intrusion module, https://trainex.org/offeringslist.cfm?courseid=1374
- Vapor Intrusion 2014 Update, NARPM 2014.

Disclaimer

The use of these best management practices may require site-specific decisions to be made with input from state, tribal, and/or local regulators and other oversight bodies. The document is neither a substitute for regulations or policies, nor is it a regulation or EPA guidance document itself. In the event of a conflict between the discussion in this document and any statute, regulation or policy, this document would not be controlling and cannot be relied on to contradict or argue against any EPA position taken administratively or in court. It does not impose legally binding requirements on the EPA or the regulated community and might not apply to a particular situation based on the specific circumstances. This document does not modify or supersede any existing EPA guidance document or affect the Agency’s enforcement discretion in any way

EPA ID # 542-F-18-003

Section 1 - Introduction

This technical guide provides best practices for efficiently managing the large amount of data generated throughout the data life cycle. Thorough, up-front remedial investigation and feasibility study (RI/FS) planning and scoping combined with decision support tools and visualization can help reduce RI/FS cost and provide a more complete conceptual site model (CSM) earlier in the process. In addition, data management plays an important role in adaptive management application during the RI/FS and remedial design and action.

Why is EPA Issuing this technical guide?

The U.S. Environmental Protection Agency (EPA) developed this guide to support achievement of the July 2017 Superfund Task Force goals. Two additional companion technical guides should be used in conjunction with this data management technical guide:

- Smart Scoping for Environmental Investigations
- Strategic Sampling Approaches

This section defines the data life cycle approach and describes the benefits a comprehensive data life cycle management approach can accrue.

What is the “Data Life Cycle” Management Approach?

The Superfund program collects, reviews and works with large volumes of sampling, monitoring and environmental data that are used for decisions at different scales. For example, site-specific Superfund data developed by EPA, potentially responsible parties, states, tribes, federal agencies and others can include:

- Geologic and hydrogeologic data;
- Geospatial data (Geographic Information System [GIS] and location data);
- Chemical characteristics;
- Physical characteristics; and
- Monitoring and remediation system performance data.

In addition, EPA recognizes that regulatory information and other non-technical data are used to develop a CSM and support Superfund decisions. These data may include applicable or relevant and appropriate requirements (ARARs), future site use, population characteristics, site maps, models, exposure points, potential remedies and decision criteria. All these data are important to at least one Superfund process stage and, taken together, form the basis of an effective site management approach.

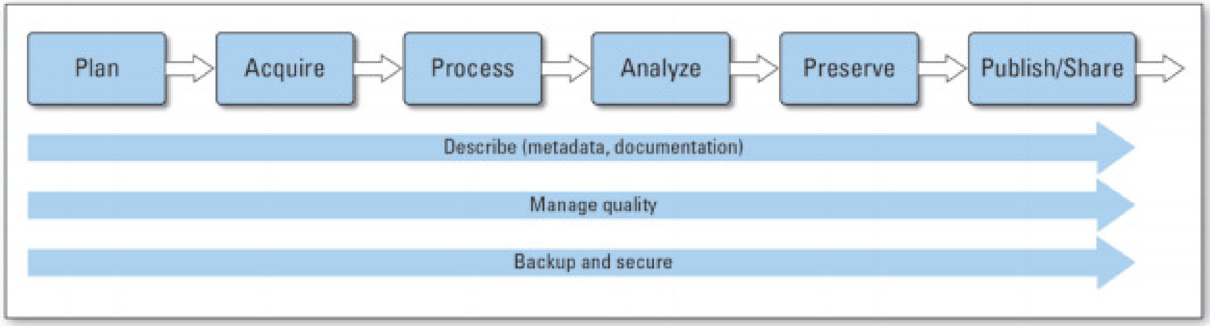
Therefore, approaching data collection and management in a deliberate and comprehensive fashion throughout the project "life cycle" should enhance the ultimate effectiveness, efficiency and defensibility of EPA's response action. Data life cycle management is potentially useful in any complex, data-intensive management process. For example, the U.S. Geological Survey (USGS) uses a data life cycle model across its programs, as illustrated in Highlight 1.[1] The model shows that throughout the data life cycle, cross-cutting program elements are necessary to ensure the data are usable for the intended purpose. First, the data must be described and documented in sufficient detail so that other data users can evaluate the results' validity and determine the data's usefulness and applicability for specific decision-making.

How is this Technical Guide Organized?

Section 1 introduces and defines the data life cycle and information flow, and describes the benefits of managing the data as part of comprehensive data management system.

Section 2 describes best practices for elements of the Superfund data life cycle. EPA recognizes that new tools and resources may be developed and has designed this document to allow for revision as one-page substitutions and additions.

Highlight 1. U.S. Geological Society Science Data Lifecycle Model



The second cross-cutting element addresses the importance of documenting data quality assurance measures at the project's inception and as data are generated. This element is particularly important when the data set contains qualitative or semi-quantitative data. The third element, data backup and security, is necessary to prevent physical data loss due to hardware or software failure, natural disasters or human error.

The concept of a data life cycle includes the individual actions, operations, or processes that must be undertaken at different stages to manage all data types, and help to ensure timely, comprehensive, and secure data management.

What is Active Data Management?

Active data management is part of a comprehensive approach that tries to minimize the time between when data requirements are set, data are collected, and when and how data are managed and made available. Active data management can improve information quality. The Superfund remedial program has traditionally used reports to exchange information. While such reports are necessary for project

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[1] Faundeen, J.L., Burley, T.E., Carlino, J.A., Govoni, D.L., Henkel, H.S., Holl, S.L., Hutchison, V.B., Martín, Elizabeth, Montgomery, E.T., Ladino, C.C., Tessler, Steven, and Zolly, L.S., 2013, The United States Geological Survey Science Data Lifecycle Model: U.S. Geological Survey Open-File Report 2013–1265, 4 p., *http://dx.doi.org/10.3133/ofr20131265*

documentation, the data's usability can be diminished when managed and stored solely in the report format. For example, answering simple questions regarding a site requires additional labor costs and can require exhaustive literature searches. Also, key information can get lost in appendices and attachments. Active data management considers the "data" as the deliverable while reports serve to document data collection and, to some extent, interpret the data. The approach seeks to provide on-demand access to all site data in electronic format and reduce challenges associated with program data transition (such as removal to remedial, states to EPA, remedial project manager to remedial project manager, and potentially responsible party to EPA). This improved data interoperability can serve to limit project management costs when EPA, states, tribes, other federal agencies, and other stakeholders are reviewing and interpreting data. Management cost savings accrue because, unlike lengthy document development and comment and response, data interoperability gives all parties access to the same information, which, in turn, supports collaborative interpretation and use. Further, active data management can provide the ability to leverage nationally developed tools and provide economies of scale allowing project teams to forego re-collection of existing information or re-creation of a new data management approach at every site.

What are the Benefits of a Comprehensive Data Management Approach?

The benefits of managing the data life cycle in a comprehensive manner are:

1) Overall data quality improvement to support decision-making due to consistent content and a format that reduces data entry errors;

2) Clear data collection guidelines, processing and storage, which eliminates the cost of recollecting samples, and can preserve the integrity and availability of older information as inputs to the CSM;

3) A better understanding of data quality and any limitations when analyzing and making decisions; and

4) Improved accessibility to data in electronic format, which supports real-time interpretation and optimization of collaboratively collected data as well as use of decision support tools (such as statistical analysis, visualization, and modeling) while field crews are mobilized.

A comprehensive data management approach ensures the use of a common data platform and data consistency, accessibility, integration and versatility.

Common Data Platform. One tool to facilitate a comprehensive data management approach is a single, centralized data system. A common data transfer and storage platform provides for easy data transmission among data partners and users. A common data platform facilitates quicker decision-making because users can focus on the data content, not format. EPA regions may have regional data management plans that provide high-level minimum data requirements. Project teams are encouraged to develop data management plans at the project- and field-levels to address specialty data sets, such as those from direct sensing tools. Such plans ensure alignment of data management goals with data quality objectives (DQOs). Advanced visualization techniques requiring large data sets are often obtained from different data collection teams. A comprehensive approach to data management ensures that data collection produces a consistent data set to enhance understanding and communication of an evolving CSM. A consistent approach for collecting, processing and analyzing data facilitates the decision-making team's data transfer and integration, and allows for more effective sharing among data partners, users and project stakeholders.

Data consistency. Throughout the project life cycle, different contractors and EPA staff may be assigned to a project. A comprehensive data management approach helps ensure the team has consistent data throughout the project life cycle. Data may be generated in several phases and sometimes over many years. As additional data are generated and new interpretation tools are developed, previous site data should be readily available to the team for re-examination particularly in light of new developments or findings regarding the CSM. For example, groundwater quality data collected early in the remedial investigation (RI) can be used as a baseline to evaluate changes in mass flux or performance of a treatment system. However, to make the comparison, the older data need to be in a usable format with a clear understanding of the data's quality and usability. Changes in data elements, such as sampling methods, analytical methods, detection and reporting limits, and target analytes can be expected to change over the life of many projects. A consistent and well-documented approach to capturing, processing, storing and using data can significantly improve project teams' ability to use that data for decision-making and risk management.

Data accessibility. A comprehensive data management approach provides increased accessibility to project team members. Data are available in a consistent electronic format, often in near real time, allowing real-time interpretation and optimization of collaborative data collection, use of decision support tools (such as statistics, visualization and modeling) while crews are mobilized, and rapid evolution of the CSM to support dynamic field activities. The metadata that informs analytical results and spatial information is also captured, managed and available to support site decision-making.

Data Integration. A benefit of the comprehensive data management approach that includes regional-, site-, and field-level data management plans is that other secondary data sources, such as hydrogeologic features, precipitation, water quality, and population information, are easily integrated with the site-specific data. This data integration allows project teams to easily adjust the data assessment scale appropriately for risk management, remedial design, remedial action, community involvement or other project needs.

Data Versatility. During the post-record of decision (post-ROD) phase, site conditions may change and new information may emerge during the remedy's design, construction and evaluation, including sampling and analysis to confirm achievement of cleanup levels and remedial action objectives. To address these likely changes, EPA encourages the use of adaptive management, which provides a systematic process for planning for and responding to field conditions. Adapting the management approach and developing new solutions can require the examination of large volumes of existing data. Data life cycle management assures the data are readily available in a format that enhances project teams' and managers' ability to reliably adapt to changing site conditions.

Section 2 – Best Practices

This section describes best practices for data life cycle elements that project managers and site teams can consider during any phase of a project's life cycle. Section 2 is organized to provide best practices for each of the following data life cycle elements:

- Planning for Data Collection and Processing
- Collecting Data
- Processing Data
- Storing Data
- Making Decisions Using Data
- Communicating Data

Best Practices for Planning for Data Collection and Processing

Systematic project planning (SPP) is EPA's preferred process for building a consensus vision for conducting environmental investigation and remediation. It is a planning process that lays a scientifically defensible foundation for proposed project activities and usually includes key decision identification, CSM development in support of decision-making, and an evaluation of decision uncertainty along with approaches for managing that uncertainty in the context of the CSM.[2] The SPP is key to adaptive management. Applying SPP ensures that the project team will have adequate data to make decisions while avoiding generation of large volumes of data that do not enhance site understanding. An early SPP activity that is best conducted before data collection begins is preparation of a data management plan. A documented approach to data management, summarized in the data management plan, establishes the data management procedures throughout the data life cycle. The data planning process should follow a process that is transparent, objective and documented.

When conducting systematic planning, it is especially important to pay close attention to the following concepts:

1) Develop a comprehensive CSM so that the project team understands existing data and data needed to fill identified data gaps. A comprehensive CSM also helps prepare for the unexpected in the field. Understand analytical and spatial data needs but also plan to capture and manage important metadata electronically.
2) Engage stakeholders and end data users to ensure data collected will not only meet DQOs but will provide an appropriate data set for multiple end uses, such as risk assessment, risk management, feasibility analysis, remedy design, state/tribal review and communication with local officials and community members.
3) Exercise data tool outputs and field procedures with a data management plan and data management tools to fully understand the data that will be generated, including how that data

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[2] Definition of systematic project planning. https://triadcentral.clu-in.org/gloss/dsp_glossterm.cfm?glossid=223.

will be obtained; provided; and processed, stored and used. These factors have implications for data format, decision support tool inputs, processing procedures and more.

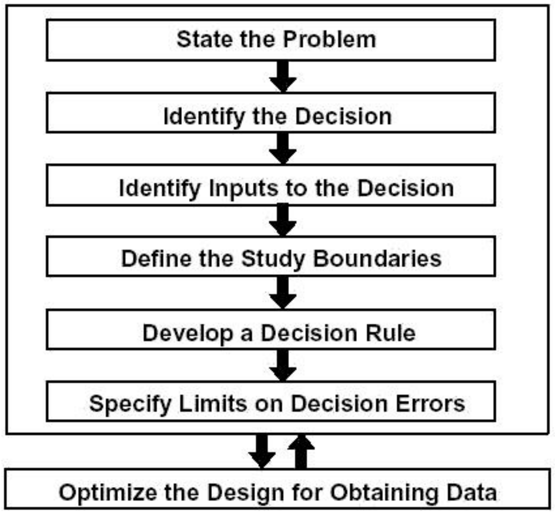
4) Automate data management activities where appropriate and check data quality at the point of generation.

5) Designate a data management professional for your site, project and field effort as part of your team.

6) Leverage existing tools to gain efficiency and economies of scale. Many have sufficient flexibility to accommodate field, site and regional data management needs.

When considering the data needs and data collection activities to support decision-making, project teams use the DQO process to align the data approach with the intended project decisions (Highlight 2). The EPA's "Systematic Planning Using the Data Quality Objectives Process" (EPA/240/B-06/001*)* explains the DQO process at an agency-wide, cross-program level. Since the nature of data and decision-making varies greatly among EPA program offices, agency-level DQO guidance is necessarily non-specific. The Intergovernmental Data Quality Task Force prepared a template quality assurance project plan (QAPP) that applies the DQO process specifically to cleanup investigations. The "Uniform Federal Policy for Quality Assurance Project Plans" template is a series of worksheets that improve data quality and project outcomes by prompting the user to develop the information and quality control procedures that fulfill the DQO process. Housed on Superfund's Federal Facilities website, the template is supported by a manual, training materials and other tools that assist in the DQO process' application at hazardous waste sites. In addition to aiding QAPP writers, the standardized worksheet format speeds QAPP approval staff's review.[3]

Highlight 2. DQO Process.



The intent of data collection should be more than informing the project team of next steps. Systematic project planning defines the project's direction, DQOs help to answer how the project team might arrive there, and data management ensures information can be used to make those decisions.

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1) [3] U.S. EPA (2012) Intergovernmental Data Quality Task Force, Uniform Federal Policy for Implementing Environmental Quality Systems: Evaluating, Assessing and Documenting Environmental Data Collection/Use and Technology Programs, March. https://www.epa.gov/fedfac/assuring-quality-federal-cleanups and https://www.epa.gov/sites/production/files/documents/ufp_qapp_worksheets.pdf

Best Practices for Collecting Data

During the RI/FS stage, many different data types are collected. It is beyond this guides scope' to address the best practices for numerous techniques and tools that could be used. When considering sampling strategies to address CSM data gaps, project teams should develop an understanding of the data generated by each, and consider the following best practices:

1) **Identify the levels of quality needed.** The levels of quality (such as precision and accuracy) needed for each technique should be established before data collection. Identify the measurement units and develop measurement metrics to ensure the right types of data are collected. Using collaborative data sets and multiple lines of evidence can improve the site team's understanding of conditions even when the quality of a single instrument or data collection method alone may not be sufficient. Consider quality in the context of all collaborative data streams and lines of evidence; assess where variability is coming from (such as sample design, sample processing, extraction, or analytical). Improve quality by directly addressing the variability source this assessment identifies. For example, under EPA's recommended incremental sampling design, potential variability is addressed through the collection of triplicate samples and seven additional analyses.

2) **Assess reliability of data sources.** All data sources' reliability, including direct instrument measurement, should be assessed. Reliability can relate to the ruggedness of the physical instruments used to collect the data and the ability to perform under all anticipated field conditions, or, the consistency of the readings generated by the technique. For example, cone penetrometer testing logs present soil lithology based on unbiased physical measurements, whereas borehole logs may be subject to the logger's interpretation and experience. If permeable zone correlation is the primary driver for collecting lithology information, then hole-to-hole consistency in soil type interpretation is critical, and interpretation of permeability by different loggers can be problematic. Standardizing core descriptions of non-aqueous phased liquid in planning documents, taking physical core measurements such as grain size and permeability, and logging boreholes using consistent methods such as the unified soil classification system are techniques that help to limit variability associated with multiple professionals providing bore log descriptions.

3) **Consider data quality.** Transcription and electronic recording and download errors can affect data quality. Manual data collection is subject to random transcription errors during collection when recording readings from instruments. Scale factors, correction factors, calibration, instrument stabilization, and field conditions may generate systematic error in electronic files. Mislabeling data files for download is another source of systematic error. Taking clear and detailed field notes of data transfer activities should help identify and correct these errors. In addition, creating valid values lists and using them to automatically flag errors and performing data audits are ways to check and ensure data quality. Conducting a demonstration of method applicability for field techniques not only provides an opportunity to understand sampling design, sample preparation, and instrument performance for a given site matrix, but it also allows project teams to optimize all the procedures that may impact data quality.

4) **Verify each manual data entry and transfer**. Quality control begins with ensuring the initial recording of a data point accurately reflects the measurement or condition. Ensure that field teams

are trained, and systems (valid values lists, data audits) are in place to verify initial data collection quality.

5) **Establish standard systems for identifying locations and sample media types**. A unique numbering system for sample locations and sample types should reduce the likelihood of mislabeling and improve data review and management efficiency. Consider the following practical tips:

   - Check existing databases and the CSM information to see what sample or well identification descriptions (ID) have already been used so as not to duplicate an existing numbering system. When multiple contractors, parties and regulatory agencies are working on a site, it can be easy to duplicate sample or well IDs.
   - Be careful as to how much information a sample ID contains. For data sorting and filtering, it is better to add fields to the database that describe individual sample points, such as depth, rather than to capture this information with the sample ID. In addition, the use of too many characters in a sample ID increases the potential for transcription errors.
   - Limit the amount of interpretation field crews must make with regard to sample IDs. The following example illustrates why field crew interpretation should be limited:
     - At a recent field effort using incremental sampling in combination with x-ray fluorescence, the QAPP for the demonstration of method applicability (DMA) required the field crews to collect composite and incremental soil samples at four depth horizons:
       - Depth 1: 0-1 inches (bare soil) or 0-2 inches (vegetated soil)
       - Depth 2: 1-6 inches (bare soil) or 2-6 inches (vegetated soil)
       - Depth 3: 6-12 inches
       - Depth 4: 12-18 inches
     - The field crews struggled with determining whether a sample was from “bare” or “vegetated” soil and which depth horizon to use. In addition, the sample IDs included this depth-specific nuance, and the top two intervals’ sample IDs were mislabeled and had transcription errors. In this case, the DMA was a valuable tool in correcting these problems before the full sampling effort’s initiation. The improved methodology will consider the top interval to be 0-1 inches regardless of vegetation, and the QAPP will specify and stress to the field crew that, for lawns or vegetated soil, the 0-1-inch interval starts at the root mass base.

6) **Use electronic data forms.** Using consistent data formats and software from project initiation to completion improves data collection efficiency and consistency. Scribe is an EPA software tool used to collect and manage environmental data. It can import electronic data deliverable (EDD) files, including analytical laboratory EDD files and locational data EDD files, such as GPS data. Scribe outputs include labels for collected samples, electronic and hardcopy chain-of-custody generation, and analytical laboratory result data reports. Scribe users may manage, query and view data, and

can export electronic data for use with GIS tools and in reports. The EPA strongly prefers Scribe's use for Superfund data collection and management, but the Agency also supports the concurrent use of other commercially available software that can enhance data integration and visualization. Using standard software for data collection and management: ensures all pertinent data are collected and recorded in a consistent and repeatable manner; assists in seamlessly transferring information among stakeholders; and minimizes the likelihood of transcription errors.

7) **Track metadata**. Metadata includes information on a data resource's content, such as the data source, limitations, access and use restrictions, data quality, and contact information. These descriptive fields help a user decide if a data set is appropriate for their proposed use. Many electronic data systems contain metadata fields where these data can be entered but few data management strategies plan for how that data will be managed. Field logbooks can capture some of this information but are generally not formatted to capture all pertinent metadata in a consistent format; further, retrieving and interpreting that information months or years after a field effort can be challenging.

8) **Require accurate geospatial information.** Accurate geospatial location information is essential to site data interpretation. Collect GIS-compatible data, when appropriate. A GIS platform provides a standard base for communicating, transferring and interpreting all data types. Ensure that the coordinate system used for the GIS is geo-referenced to the site, not a stand-alone coordinate system. Check the accuracy of the site attributes to make sure the data represent the most current site configuration. Distribute GIS files to data partners to facilitate data transfer and interpretation. A GIS system generally relies on high accuracy x and y coordinates to locate a sample on the earth's surface. Data interpretation, however, is critically affected by the accuracy and maintenance of the depth or z coordinate. Accurate geospatial information must therefore include high accuracy surface elevation, sample depth, well screen depth, depth within a well screen, and other critical vertical information. Depth information should be in separate fields within the database. For additional resources on ensuring accuracy of geospatial information please see the following website: https://www.epa.gov/geospatial/geospatial-policies-and-standards

9) **Use and verify electronic data delivery of laboratory data.** Superfund projects often utilize multiple analytical laboratories to analyze field samples and report data. The site team should follow EPA requirements to ensure the analytical laboratory has expertise in the requested analysis, and can provide quality data in the required EDD format to support project decisions. Analytical laboratories should have access to relevant portions of the project QAPP, and may be asked to aid in developing DQOs for the project. Upfront communication with the analytical laboratories is key to ensuring the laboratories can deliver the required data in a consistent and compatible format. The EPA strongly recommends the use of Scribe-compatible EDD file formats. The staged electronic data deliverable (SEDD) is a uniform, Scribe-compatible format developed by the federal government for electronic delivery of analytical data, which can improve the efficiency of analytical laboratory data delivery, review, storage, and retrieval. Using a consistent EDD format, such as SEDD, can make the data review and evaluation most cost-effective and efficient by reducing transcription errors and automating portions of the data review process. At minimum, analytical laboratories should deliver data in a Scribe-compatible format that is consistent with historical data requirements and other

software being used for site data management. Several EPA regions have adopted additional requirements for analytical laboratory EDD submissions to ensure laboratory data are consistently reported and can be assessed against EPA data quality requirements.

For more information on SEDD, please see the following website:
https://www.epa.gov/clp/staged-electronic-data-deliverable-sedd

For more information on EPA's EDD submission process in Superfund please see the following website:
https://www.epa.gov/superfund/epa-superfund-electronic-data-submission-multi-regions-edd

Best Practices for Processing Data

Many data types require processing prior to use to ensure they are ready for integration and analysis. According to the USGS Science Lifecycle Model, processing includes various activities associated with preparation of new or previously collected data inputs. Data processing should entail definition of data elements; integration of disparate datasets; extraction, transformation, and load operations; and application of calibrations to prepare the data for analysis. The most common example of these practices are fixed laboratory chemical analysis data. The laboratory follows rigorous quality control procedures and provides users with information to assess data quality; however, the user is responsible for independently determining the quality of the data set through a formal data validation process. Data from direct reading instruments and field methods can also be subjected to review through data quality checks developed by the project quality assurance team. Some data may need to have correction factors applied or converted to standard units prior to use. Environmental data sets are often disparate and processing includes considerations for CSM integration. For example, direct sensing data from an electrical conductivity meter should be integrated with both relative hydraulic conductivity data from hydraulic profiling and lithologic logs from soil borings to provide cross-checks on each other and to determine if these multiple lines of evidence converge. In addition, collaborative data sets (such as x-ray fluorescence [XRF] data and laboratory data measuring the same contaminant) can be used to improve spatial information even if statistical correlations between the two data sets are poor. Processing involves not only preparing data for integration and analysis but also determining how disparate data sets will be used to inform the CSM.

As data are exchanged and transferred from their initial source to databases or other intermediate platforms, errors and incomplete exchanges can occur. A best practice is to verify the data transfer or import to ensure the original data's integrity. Determine if spot checks or 100 percent checking of the data are necessary based on the limits for decision errors identified in the DQO analysis.

Best Practices for Storing Data

The application of dynamic work strategies in Superfund investigations involves collecting a large volume of data, interpreting the data in real time, and making real-time decisions. A robust system for data storage and long-term preservation is necessary to ensure the data are available, complete, and accurate during the project life cycle. A data storage strategy is part of the SPP and includes a detailed discussion of data management procedures, equipment (software and hardware), lines of communication, reporting formats, and time frames for implementing data storage activities. Data planning assists the project team to adequately assess costs and resource needs associated with data management.

Many electronic database systems are available to store data on a temporary (field) or permanent basis. Scribe and Scribe.net are data management systems developed by EPA and used to provide site-specific, flexible data collection, management, and exchange. Additional information on field-oriented data management using these and other tools is available in EPA Triad Central Technology Bulletin Management and Interpretation of Data Under a Triad Approach (EPA 542-F-07-001), https://www.epa.gov/remedytech/management-and-interpretation-data-under-triad-approach-technology-bulletin. Ruggedness, acceptable data content, and ease of use are important considerations for selecting field data storage systems. Database systems should be scalable (able to accommodate both small and large amounts of data) and transportable (easily moved).

The agency's regional offices have adopted a variety of data management systems for storing site-level data. Two common platforms used for data storage in the regions. One, WQX/STORET is EPA's water quality storage system, and the second, EQuIS, is a commercial data management and decision support system for soil, water, air, geotechnical, and other environmental data types. Some data storage solutions have electronic data checker tools to assess data quality and manage submission and export formats. In addition, some have modules to simplify field data collection and manage large-volume sensor data collection activities. It is important to work with regional data management specialists and the appropriate EPA program office to identify applicable policy and requirements during the project planning phase.

The advantages of comprehensive data storage systems are that data can be organized for easy retrieval and use, and the data are in a single, secure location. Some data storage systems use proprietary or license-based software, such as ArcGIS and EQuIS, and team access may require software ownership. Many data systems have free software to allow stakeholders to view, but not manipulate data. Ensuring a data management system's long-term integrity is part of the planning process and includes methods for securing databases and managing users' rights to upload or change data. For additional information on maintaining data security from electronic tampering, preventing loss of electronic data quality while in electronic storage, and unauthorized release of electronic data or personally identifiable information, please see EPA's privacy policy found on this website: https://www.epa.gov/irmpoli8/epas-privacy-policy-personally-identifiable-information-and-privacy-act-information

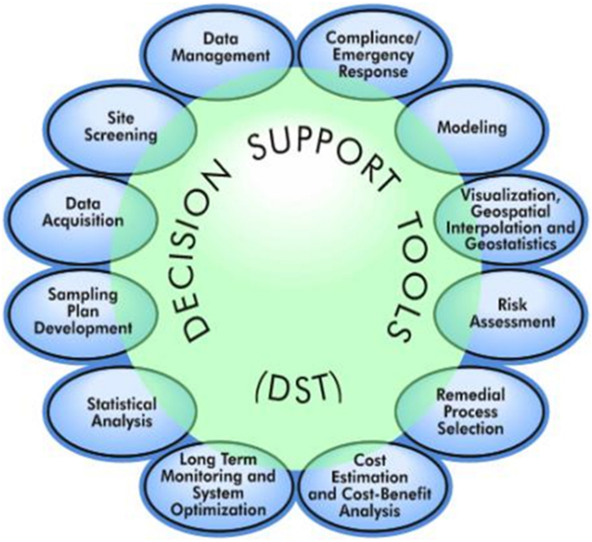
Best Practices for Making Decisions Using Data

Decision-making for contaminated sites usually involves integration of different data sets from many technical areas. Systematic project planning incorporates decision logic flow diagrams to guide the field decision-making process. Using collaborative data sets and multiple lines of evidence further strengthens data interpretation while providing increased confidence in CSM development. Where collaborative data support each other and multiple lines of evidence converge, the project team has increased confidence in interpreting that data or CSM component. Conversely, instances where collaborative data sets or lines of evidence diverge or lead to different conclusions may indicate the presence of data gaps, inconsistent spatial scales, or the need to update a CSM component to account for differences.

Decision support tools (DSTs) are interactive software tools that use data. These tools can be used by decision-makers throughout the project life cycle to help answer questions, solve problems, and support or refute conclusions. They can be incorporated into a structured decision-making process for environmental site cleanup (Highlight 3). Individual tools may integrate data from many different technologies including GIS, global positioning system (GPS), databases, and visualization tools. Using DSTs is a best practice to provide a transparent, standardized, reproducible approach to data analysis that can incorporate and quantify uncertainty in the data sets and decisions.

The DSTs can be used to support specific project tasks such as statistical data evaluation, sampling design (visual sampling plan) or groundwater sampling optimization (monitoring and remediation optimization system software), or multiple functions required for data acquisition, spatial data management, contaminant modeling, and cost estimating (spatial analysis and decision assistance software). Detailed analysis of several DSTs' attributes and applications can be found in the DST matrix on the Federal Remediation Technology Roundtable website: http://www.frtr.gov/decisionsupport/index.htm.

Highlight 3. Examples of Decision Support Tools.



The EPA has found that utilizing high-resolution site characterization tools and strategies along with visualizing those results can lead to a better understanding of the CSM and more effective and targeted remedial actions. Further, these tools and approaches can be combined to expedite field investigations and drive dynamic work strategies as well as facilitate timely and collaborative data by stakeholders. Recent Superfund pilot projects and institutionalization of EPA's optimization program have shown these approaches can expedite project schedules; reduce transaction costs for data sharing among stakeholders; and lead to a transparent, fast, and collaborative approach to site decision-making.

Visualization technology (for example, three-dimensional visualization and analysis or 3DVA) is a valuable decision support mechanism that integrates geology, hydrogeology, and contaminant chemistry data into a single spatially correct visual model. Geostatistical algorithms within these software packages can further help teams to interpret data or interpolate between data points. It is important to note however, that these geostatistical interpolations must be performed by qualified professionals and are subject to further refinement based on collaborative data, other lines of evidence and professional judgment of key technical team members. For example, geologic interpretations can be supplemented with environmental sequence stratigraphy as described in Best Practices for Environmental Site Management: A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models published in EPA's groundwater issue from September 2017, EPA /600/R-17/293, https://semspub.epa.gov/work/HQ/100001009.pdf. Visualization capabilities in

DSTs allow the user to rapidly assimilate new field data and display information to support dynamic field decision-making.

The use of DSTs and visualization tools are best practices and support implementing adaptive management throughout the project life cycle. By applying the appropriate DSTs and viewing the most current data and interpretations, stakeholders can evaluate options and develop data collection contingencies and identify logical sequencing of field investigation tasks. Stakeholders can make decisions in real-time and adapt sampling strategies to reflect the most current CSM, potentially saving time and resources.

Best Practices for Communicating Data

The EPA encourages the use of dynamic work strategies and real-time data collection; however, these approaches require project teams to evaluate and respond to data quickly. For many sites data collection teams, decision-makers, and stakeholders are geographically dispersed and timely data sharing can be a challenge. Several collaboration tools are available to communicate data among teams. Many of these tools can also be used as portals for teams to store and access information over the project life cycle. The EPA has found these communication tools particularly useful for sharing data visualization and CSM products. Examples of data communication tools include:

- Project- and site-oriented websites where team members can quickly and securely share information, such as EPA on-scene coordinators' website and SharePoint sites.
- Custom, project-specific websites and databases, developed by the regions for storing data, visualizing and exchanging information with stakeholders.
- Virtual meeting tools or commercial web conferencing (Adobe Connect, Skype, Go To Meeting, Meeting Place) allow teams to review and discuss information as if they were in the same physical space.

More data evaluation and storage tools are becoming available, and project teams can use SPP to identify the data communication tools and procedures to be used throughout the data life cycle. In general, dynamic and expedited field efforts require timely stakeholder data evaluation and decision-making along with a resource commitment to meet timely data review demands and real-time decision making. In many cases geographically dispersed project teams are at an advantage for this project type. For example, during a recent Superfund preliminary design investigation, the project team used direct sensing tools to rapidly characterize the contaminant distribution and subsurface geology and hydrogeology at a West Coast site. At the end of each day, the field data were uploaded to a project team website and an East Coast visualization expert would download the data and update the CSM thereby assuring the project team's ability to view the data the next morning. With the updated information the technical team would meet remotely to discuss and plan future activities. The result was a completion of field activities, interpretation of data, generation of a report, and move to remedy design in weeks versus months.

Conclusion

Approaching data collection and management in a deliberate and comprehensive fashion throughout the project "life cycle" should enhance the ultimate effectiveness, efficiency, and defensibility of EPA's response action. Applying best practices to data management activities increases the data's usefulness and allows the use of new data interpretation tools and programs.

Disclaimer

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