Dense non-aqueous phase liquids: Site remediation and redevelopment

Developing site strategy

Purpose

This Technical Guidance series provides guidance on the processes used to develop an effective strategy to manage sites contaminated with dense non-aqueous phase liquid (DNAPL). While the documents are written with DNAPL in mind, the fundamental principles can also be used to evaluate any site in order to develop and implement a remedial strategy. Each of the documents are applicable to sites regulated under the Minnesota Environmental Response and Liability Act (MERLA, Minn. Stat. § 115B.01 to 115B.24) and Resource Conservation and Recovery Act (RCRA) corrective action sites (Minn. R. ch. 7045 and Minn. Stat. § 116.07).

This page, Developing Dense Non-Aqueous Phase Liquids Site Strategy (DSS), describes the components of a DSS. It also provides a general overview of topics discussed further on the individual websites that comprise this guidance.

What is a DNAPL?

A DNAPL is a liquid that is both denser than water and is immiscible in water. When DNAPLs are released to the subsurface, the DNAPL initially remains separate from other phases (air and water). Over time, the contaminants that comprise the DNAPL may slowly change by dissolving into groundwater, reducing to simpler compounds, partitioning to soil, or volatilizing within the subsurface environment. More information regarding physical characteristics of a DNAPL and how it behaves in the subsurface is discussed on the DNAPL Properties and Characteristics website.

What is DNAPL Site Strategy (DSS)?

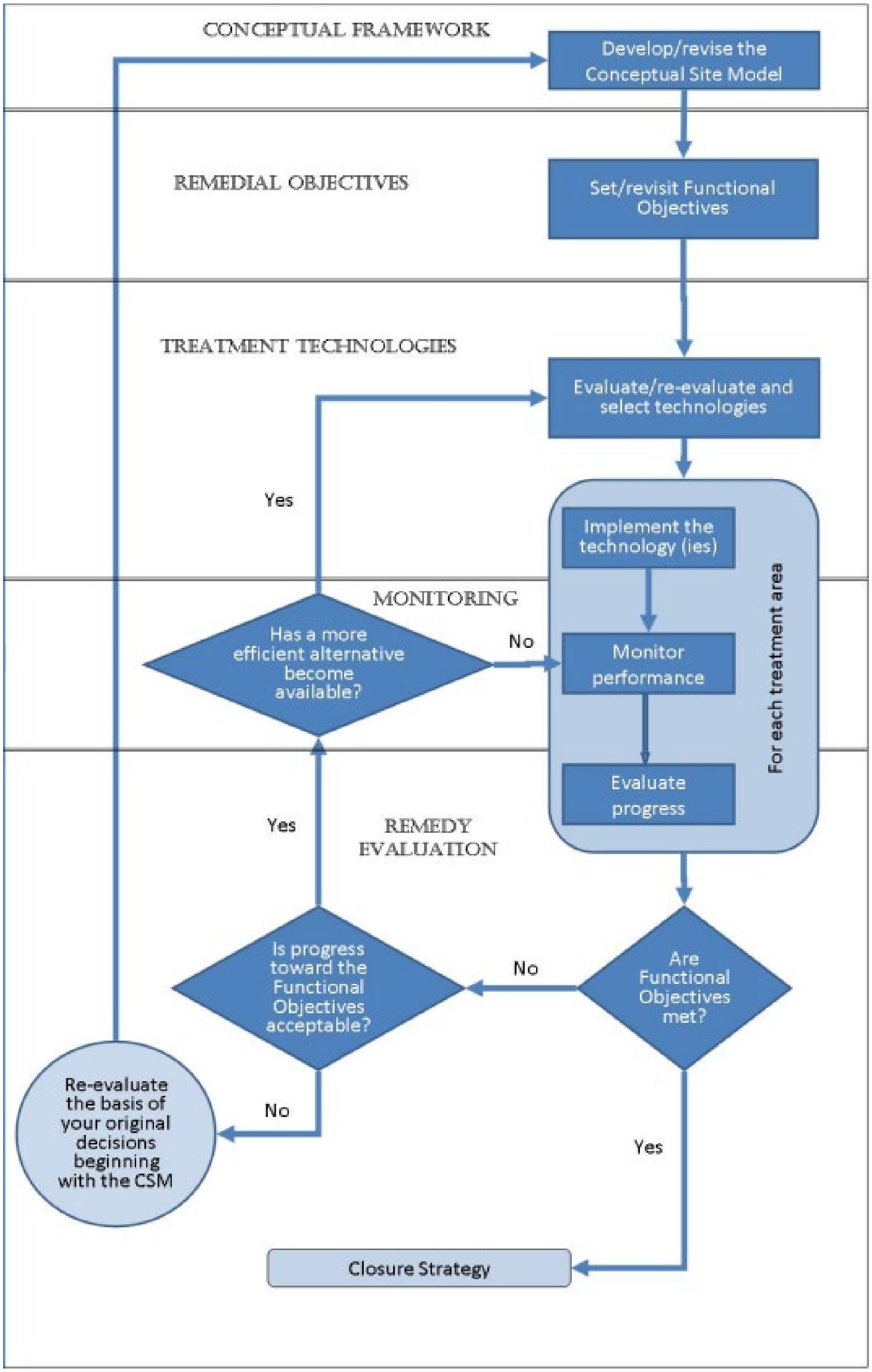
DSS is a practical framework for characterizing a DNAPL site, developing a detailed conceptual site model and developing an effective and efficient plan for meeting remedial objectives and assess progress toward meeting those objectives.

When do you develop a DSS?

DSS should be developed at the beginning of a site investigation, while the site is being characterized and the Conceptual Site Model (CSM) is being developed. However, the concepts of DSS can be implemented at any stage of site investigation and/or site remediation, and they should be revised as new information becomes available. Questions to ask include:

- Is DNAPL present at the site? Is it likely to be present?
- Has the site been adequately characterized?
- What are the cleanup objectives?
- Is the site remedy effectively working to meet a cleanup objective? If not, what else should be done?
- Are there any technological improvements that could make the site remedy more effective?
- Is any new information available that changes the CSM?

Figure 1-2 from ITRC, 2011



DSS components

DSS components that lay out the process for an effective site management strategy (see figure 1-2 of ITRC, 2011) are:

- Develop a **conceptual site model** (CSM) based on knowledge of how and where the release occurred (if possible), reliable characterization and an understanding of subsurface conditions.
- **Conduct site characterization and investigation.**
- Set **remedial objectives** and performance metrics that are clear, concise, and measureable. These should be based upon realistic assumptions, as well as near-term and long-term expectations.
- Apply **treatment technologies** to optimize performance of remedial objectives.
- Conduct performance **monitoring** and **remedy re-evaluation** based on cleanup objectives, selected treatment technologies/approaches, and remedial performance goals. The DSS should be iterative, flexible, adaptive, and identify contingency actions when expectations are not met.

Conduct site characterization and monitoring

This portion of the DSS discusses the current state of the science with regard to investigation methods and tools used to characterize the origins of the release, geology, hydrogeology associated with DNAPL storage and transport in its various states. Monitoring results can also be used to confirm results of site characterization. Some key reminders for characterization are:

- Use an integrated method (see Triad resource website) for managing uncertainty by systematic planning, dynamic work strategies using real-time information, and real-time measurement technologies.
- Use High Resolution Site Characterization for DNAPL sites as it helps to discerns small-scale heterogeneities in soil that control contaminant transport.
- Use the Tool Selection Worksheet found in ITRC, 2015 to determine the best tools to aid in determining where to collect a sample. These tools can include gas chromatography (GC), membrane interface probe (MIP), laser induced fluorescence (LIF), cone penetration test (CPT), halogen specific detector (XSD), and hydraulic profiling.
- Use the site characterization steps and sampling guidelines in Fact Sheet 3 to obtain high quality results, develop, confirm, and refine the CSM and the attenuation mechanisms.
- Follow through with confirmation monitoring to confirm results are accurate and trends and ranges are properly characterized.

Conceptual site model development

Proper site characterization activities are essential for developing a CSM. A CSM is a reflection of the best interpretation of information collected at a site (ITRC, 2011). It conceptualizes the relationship between contaminant sources, site geology and hydrogeology, receptors, and provides a framework to collect and manage data necessary to support site decisions. CSMs need to be tailored for each site by a staff person that specializes in hydrogeology or environmental engineering. In addition, developing a CSM is an iterative process that needs to be updated continuously as new information is obtained. A CSM should:

- Provide information about the contaminant release (i.e., how, when, where, volume, and duration of occurrence).
- Contain a description of the geological and hydrogeological setting (including geologic and anthropogenic heterogeneities, lithologic structure, anisotropy, and heterogeneity). This should include utilities and utility backfill.
- Assess contaminant properties (e.g., physical, chemical, etc.).

- Describe the current state of the source zone:
    - Which phase the contamination is in (e.g., vapor, non-aqueous phase liquid (NAPL), dissolved, etc.).
    - Volume of contaminant in various geologic units.
    - Where mass is stored (e.g., low permeability zones v. high permeability zones).
    - Age of the contaminant mass and where any DNAPL is in its life cycle.
- Define current plume characteristics (e.g., direction and pathway of contaminant migration, consider transport phases and mechanisms such as advective flow and diffusion (see DNAPL Properties)).
- Quantify contaminant mass, transport, storage, and attenuation patterns.
- Assess ongoing contaminant exposure.
- Identify future potential exposures that may occur without intervention.
- Identify changes in future potential exposures that would occur in response to remedial actions.
- Collect sufficient information to select and design remedial actions.

Set remedial objectives

Remedial objectives need to include both short-term objectives (functional objectives) and long-term, ultimate objectives (absolute objectives) to achieve site goals. Functional objectives are steps/activities taken to achieve absolute objectives. Therefore, meeting all completed functional objectives results in attaining the absolute objectives. Well-designed remedial objectives will be specific, measurable, attainable, relevant, and time-bound (SMART) objectives. Specifically, SMART objectives:

- Protect human health and the environment.
- Specify the remedial objective to be achieved through a remedial action. The remedial objectives are concrete, detailed, and well defined.
- Measure whether or not the objectives are being met. Numbers, quantities, or comparisons are specified, and the uncertainty in key measurements is understood.
- Represent realistic technical expectations given site constraints (i.e., they are attainable).
- Have a clearly defined time allotted for achieving the objective. The timeframe is short enough to ensure accountability and is limited to a maximum of 20 years per ITRC guidance.
- Adhere to Applicable or Relevant and Appropriate Requirements (ARARs) and address non-promulgated guidance.
- Address all contaminant phases identified during the CSM development. The 14-compartment model is a useful tool to evaluate site conditions and to develop the CSM. See CSM Development.
- Are updated as previously unrecognized factors are identified and as treatment application/site monitoring occurs. This could include identifying a new receptor, identifying a new contaminant phase, addressing regulatory standards that have changed, assessment and application of new technologies, etc.

Select appropriate remedial technologies, apply, and evaluate treatment technologies

Historically, site managers have applied a single remedial technology for a site, thinking that it would be applicable over the entire remedial lifespan. This approach was based on an incomplete understanding of site conditions (e.g. having a complete site characterization, site changes based on remediation or natural attenuation, changes based on contaminant transport mechanisms, changes based on our understanding of DNAPL, etc.), as well as not realizing that multiple contaminant classes are often co-mingled in source areas and plumes. Consequently, this approach has often led to not meeting objectives as quickly and efficiently as possible.

Because the fundamental goal is to achieve remedial objectives as quickly and efficiently as possible, there has been a paradigm shift to accept that technologies should be combined over the remedial life cycle or at different locations within a plume or source area. The remedial approach should be:

- Adaptive and allow for modifications to transition between technologies based on evolving site conditions (see fact sheet 5 for information on "triggers" and transitions).
- Developed prior to implementing the remedial action rather than as a response to an underperforming remedy.
- Developed with coupled technologies into sequences, combinations, or treatment trains. Examples could include:
  - Source zone management with one approach (e.g., containment with a permeable reactive barrier or intensive in situ application) and plume management using another approach (e.g., bio in-situ remediation).
  - Any technology followed by monitored natural attenuation.

Conduct performance monitoring and remedy re-evaluation

Site monitoring should relate back to the SMART objectives identified above, and the remediation plan should be flexible enough to include new data as it is obtained. In addition, it should include deliberate reevaluation of the CSM, if remedy performance results indicate 1) the site isn't making adequate progress towards remedial objectives. Reevaluation of the CSM may include additional site characterization; and 2) the site has made progress but has not met the objectives). In that case, reevaluate site conditions and remedy performance. Consider application of different or additional technologies.