Conceptual Site Model (CSM) Development: Presampling

2.1 CSMs

A CSM describes the characteristics of a site and the processes by which potential contaminants may move from source(s) to receptor(s). CSMs facilitate site understanding and help organize site activities. CSMs are useful at every site.

CSM complexity will vary with site complexity, and the CSM should undergo revision as understanding of the site improves. A CSM can include text, maps, diagrams, and anything else useful in understanding the site.

ASTM (2003) describes six basic components of the CSM development process:

- Chemical identification – what potential contaminants (if any) are present in the soil, ground water, air, and other media at the site.
- Source identification – where did the potential contamination originate?
- Identification of potential contaminant migration pathways – how might potential contamination move from source(s) to receptor(s)?
- Background evaluation – a comparison of on-site chemical concentrations with those found in similar, nearby areas unaffected by site activities.[17]
- Receptor identification – who or what might the potential contamination affect?
- System boundary delineation – across what area should the CSM apply?

This section focuses on activities important in CSM development *prior to* sample collection – records review, site visit, sampling planning, data quality objectives, etc. However, it is important not to ignore data collected during any previous sampling events, provided those data are still relevant and usable.

[17] May not be applicable at all sites.

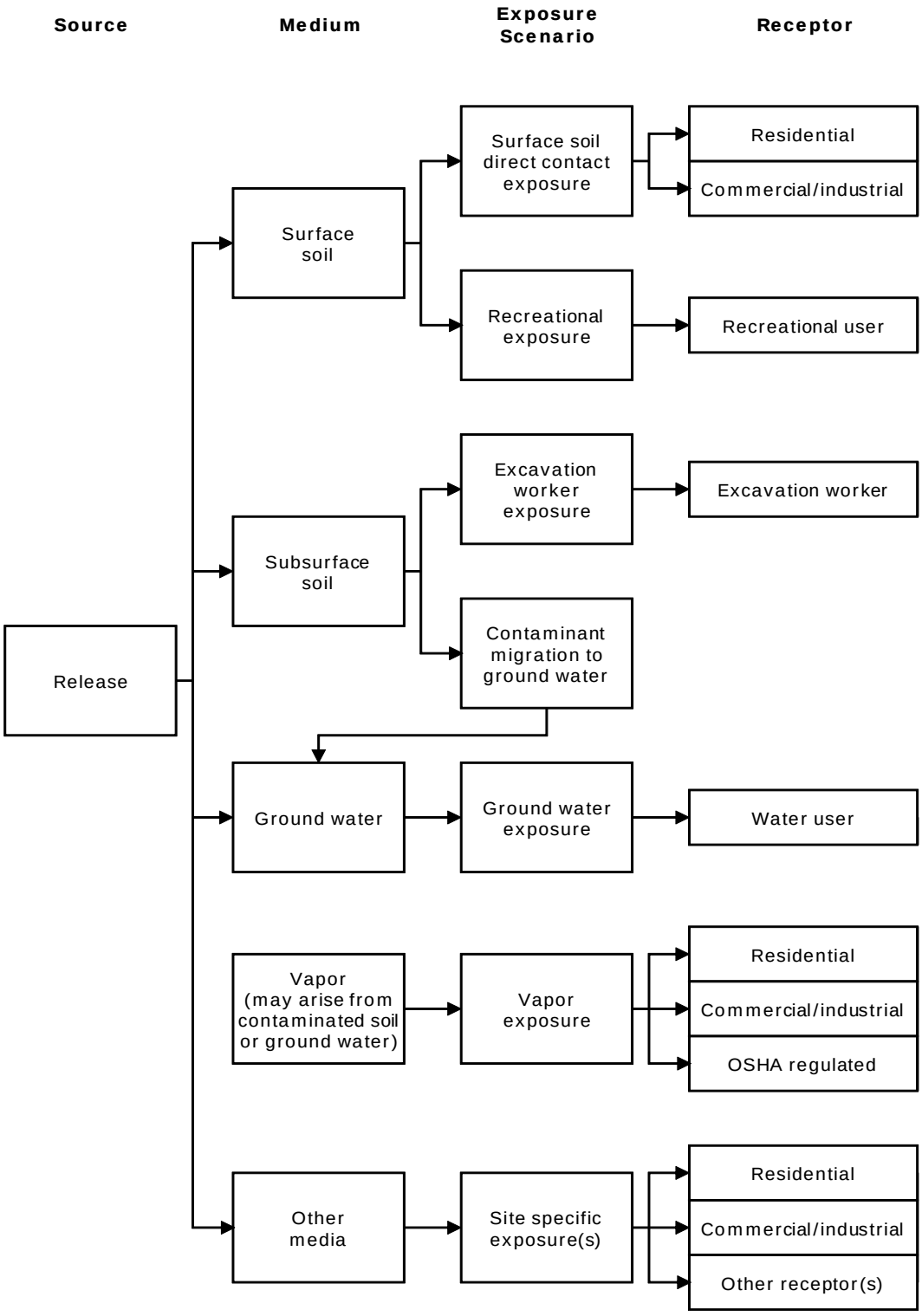
2.1.1 CSM Overview Diagram

Figure 2-A is an example of a CSM overview diagram. It traces possible pathways from source(s) through media and exposure scenarios to specific types of potential receptors.

CSM overview diagrams are a useful way of graphically depicting the CSM thought process. CSM overview diagrams can help investigators systematically plan investigations, isolate relevant exposure scenarios, evaluate potential risks to specific receptors, and guide selection of any necessary remedies. CSM diagrams also help evaluate the sufficiency of the investigation, risk evaluation, and remedy selection (if any).

There are many ways to draw CSM overview diagrams (U.S. EPA, 1996b); they need not conform to any particular format. It is entirely appropriate to tailor CSM overview diagrams to the characteristics of the site and investigation. As an investigation proceeds, modify the CSM and any accompanying CSM overview diagram to reflect newly acquired information – eliminating specific media and exposure scenarios, for example – to better focus on scenarios that are more important. Updates to the CSM should be included in the various investigative reports required by Indiana Department of Environmental Management (IDEM) remediation programs.

Figure 2-A: Example CSM Overview Diagram



2.2 Records Review

Records review includes collection and review of available site-specific information about the site and its surroundings, including local and regional conditions relevant to releases, migration, and receptors. The records review should also attempt to identify all past property uses and transfer dates. Other presampling guidance is available (ASTM, 2005). Potential information sources include, but are not limited to:

- Past investigative reports
- Site records pertaining to operational processes, chemical use, and waste storage and disposal practices
- Regulatory databases and files maintained by the United States Environmental Protection Agency (U.S. EPA), IDEM, and local health departments
- Aerial photographs, fire insurance maps, property tax or land title records, city directories, satellite imagery, and geographic information system maps
- Regional and site-specific geological information such as United States Geological Survey hydrologic and topographic maps and reports, Natural Resources Conservation Service Soil Surveys, and Indiana Geological Survey maps and reports
- Information on utilities, storm and sanitary sewers, water supply intakes, waste water treatment plants and disposal/discharge areas, and electrical transformers
- Regional ground water and surface water records from available sources, which may include Indiana Department of Natural Resources Water Well Records and logs for wells in the vicinity, and IDEM Office of Water Quality records on wellhead protection areas
- Interviews with current or past owners and employees, local fire and police departments, county health officials, and site neighbors
- Information on rare, threatened or endangered species, environmentally sensitive areas, or critical habitats near the site

2.3 Site Visit

The purpose of a site visit is to obtain information based on visual inspection of the site. Important site features include building locations and dimensions, potential contamination sources, and former or current operational or disposal areas. Potentially contaminated areas or receptors on surrounding properties and land use, particularly for nearby residential areas, are also important. Site visits should document:

- Whether the site is active or abandoned, and the general condition of site structures
- Presence, location, and identity of oils, chemicals or wastes stored on or disposed of on the property
- Whether storage tanks (including associated piping and fill or vent ports) or drums are present and, if so, whether there is evidence of leakage or releases
- Locations of potential indoor sources of contamination (e.g., chemical storage areas, maintenance areas, drains, sumps, oil/water separators, parts cleaners, etc.)
- Locations of exterior areas where contamination may occur (e.g., pits, ponds, lagoons, septic systems, etc.)
- Visible evidence of spills or leaks (e.g., stained floors or soils, stressed vegetation, etc.)
- Potential transport pathways that exist in areas where chemicals were used, treated, stored, transported, or disposed (e.g., cracked floors, drains, sumps, etc.)
- Conditions that exist at or near facility doors, bay exits, shipping docks, and pumping stations (e.g., French drains, ditches, sump pump outlets, etc.)
- Underground utilities
- Other features that may affect chemical migration
- *Specific* descriptions (retail, office, day care, residence, school, etc.) of surrounding land use and potential receptors, particularly for neighboring properties
- Whether and where on-site or off-site ecological or surface water impacts from site releases are evident or possible

2.4 Land Use

Indiana Code (IC) 13-25-5-8.5(b) specifies that: *remediation objectives… shall be based on: (1) background levels of hazardous substances and petroleum that occur naturally on the site; or (2) an assessment of the risks… taking into consideration the… (A) Expected future use of the site. (B) Measurable risks to human health, natural resources or the environment based on the: (i) activities that take place; and (ii) environmental impact; on the site.*

Exposure assumptions and remediation objectives depend critically on current and future land use. Therefore, present and future uses of potentially impacted properties weigh heavily in the risk evaluation process.

Residential remediation objectives apply to any area that does or will contain occupied residences, associated property, and other areas where children may be present on a daily basis (e.g., **playgrounds**, schools, day care facilities, and similar areas or uses). IDEM's residential screening levels assume that residents, *including children*, undergo frequent and long-term exposure to potential contaminants – an assumption that generally results in the highest potential exposures and lowest screening levels.

Commercial/industrial remediation objectives apply to factories, warehouses, office buildings, and retail businesses. IDEM's commercial/industrial screening levels assume limited, adults-only exposure. If portions of a commercial/ industrial property have different exposures (e.g., a daycare facility within an office complex), remediation objectives should reflect those exposures.

Recreational remediation objectives apply to areas and facilities where leisure time activities take place. Examples include parks, trails, walkways, sports complexes, and open areas where people gather to enjoy recreational activities. Recreational remediation objectives are appropriate for this land use. However, residential objectives may be better suited to playground areas that present an opportunity for daily high soil contact rates for pre-school children.

Probable future land uses are important when evaluating remedial and closure strategies. Remediation objectives need only be as restrictive as appropriate for the intended use. If future land use is not consistent with intended land use at the time of closure, then the basis for closure may no longer be met and IDEM may require the responsible party to take further action. Local government planning resources (e.g., plan commission, comprehensive plan, etc.) are possible sources of information about potential future land use changes. U.S. EPA (1995b) contains additional guidance on considering future land use in the remedy selection process.

2.5 Geologic Setting

The geologic setting of a site provides the fundamental framework for understanding the distribution, migration, and fate of chemicals. Geologic materials influence the movement of chemicals from source to receptor over the ground surface, through the subsurface, and by ground water flow in aquifers. However, the subsurface environment is rarely homogeneous, and a thorough understanding of the complex relationships between its composition and structure is needed to understand the factors controlling the fate and transport of chemicals. A well developed CSM will sufficiently characterize the geologic setting, and allow identification and evaluation of all potential migration pathways.

The CSM should evaluate three fundamental components of the geologic setting:

Regional Landforms – Characterization of the major landforms (rivers, lakes, topography, karst, significant water withdrawals, land use, etc.) in the vicinity of a site provides a broad understanding of the geologic framework controlling chemical distribution and migration at a site. For example, topography drives surface runoff and regional ground water typically flows towards streams and rivers. This portion of the CSM can be developed from site records, site visits, and published literature on regional geology.

Subsurface Composition and Structure – While regional landforms provide an overview, subsurface investigation (soil borings, monitoring wells, geophysical investigations, soil analysis, etc.) provides a site-specific characterization of the subsurface and insight on the relationships between materials beneath and near the site. Investigative activities should provide detailed physical descriptions of unconsolidated and consolidated materials; determination of the thickness, depth, and horizontal extent of distinct geologic features (sand lenses, confining layers, bedrock topography, etc.); identification of natural and anthropogenic preferential pathways (sand stringers, utility corridors, karst, soil fractures, etc.), and the relationship of contaminant distribution to the site-specific geology.

Ground water Flow – Ground water flow is a complex and dynamic four-dimensional process. To understand the migration of dissolved contaminants, the CSM should characterize the flow direction(s), vertical and horizontal gradients, and velocities for each identified water-bearing unit within the subsurface. The variable nature of ground water flow dynamics is often sensitive to local and/or regional natural or anthropogenic changes (e.g., precipitation, flooding, pumping), and typically requires regular monitoring to characterize the magnitude and significance of changes in flow.

The CSM should relate the above components of the geologic setting to the distribution of contaminants, to provide a clear understanding of the mechanisms controlling their migration through saturated and unsaturated media, and areas where saturation levels fluctuate. Such an understanding can be used to efficiently guide further investigative efforts; identify, evaluate, and eliminate exposure pathways; and evaluate the applicability of various remediation techniques.

2.6 Susceptible Areas

Susceptible areas are places in which standard risk assessment models and screening levels may not apply. Anyone performing a site inspection and/or records review should be familiar with these classifications and determine whether contamination from a release could affect susceptible areas.

Preferential pathways may have characteristics that allow potential contaminants to enter and move rapidly through a ground water system, often in unpredictable ways. These characteristics invalidate the assumptions of the soil-to-ground water partitioning model and vapor equations used to calculate screening levels. Examples of preferential pathways include **karst terrain**, mined areas, drainage tiles, utility lines, and other areas where fractures, anthropogenic features, or conduits enlarged by solution control ground water flow. Karst systems – common in southern Indiana - may transport contaminated soil as suspended load and deposit the soil within the system or along streams that receive water from an impacted karst system[18]. Because several endangered and/or threatened species occur in southern Indiana cave systems, karst terrain is also ecologically susceptible.

Wellhead protection areas (WHPAs) are defined zones that supply ground water to public wells. WHPA contamination poses a high probability of human exposure. Contact IDEM's Ground Water Section (Drinking Water Branch, Office of Water Quality at 317-234-5025) to determine whether a release lies within a WHPA. See Section 9.6.1 for guidance on evaluating risk in WHPAs.

Ecologically Susceptible Areas (ESAs) are special habitats that merit consideration of potential effects on non-human receptors. Examples include karst terrain; surface waters, including wetlands and riparian areas; parks, preserves, and other protected areas; and habitats used by endangered or threatened species, or species of special concern.[19]

Every investigation should include a **screening level ecological risk assessment -** a desktop review and site inspection to determine if ESAs exist at or near the site, and whether a release could affect them. If there are no ESAs within or near the site, and contaminants are not likely to affect ESAs beyond the site, then further ESA evaluation is not necessary.

Additional ecological risk assessment may be necessary if contaminants from the release could affect an ESA and may include, as appropriate, sampling and analysis of soil, sediments, surface water, ground water, and/or biota in ESAs, and in areas that might serve as pathways from the release to an ESA. Section 11 contains additional guidance on ecological risk evaluation. U.S. EPA (1997b, 1998a, 1999b, and 2003c) provides additional ecological risk assessment guidance.

[18] Receptor identification in karst terrain may require location of potentially impacted karst springs.
[19] Potential information sources include the Indiana Department of Natural Resources and the United States Fish and Wildlife Service (National Wetlands Inventory, Endangered/Threatened Species).

2.7 Planning Sampling and Quality Assurance Project Plans (QAPPs)

Careful planning is essential in executing environmental projects, and this is especially true with respect to the sample planning phase. A QAPP documents the sample planning process. QAPPs describe the decision making process, plans for data acquisition, quality criteria, and procedures for assessing investigation results. A site-specific QAPP prepared prior to collection of samples is an important part of every environmental project.

QAPPs define and describe:

- Data users
- Project goals, objectives, questions, or issues
- Decision(s) that the data will support
- The how, when, and where of project information generation
- Potential problems and corrective measures
- Projected type, quantity, and quality of data
- Data quality necessary to support the decision(s)
- Means of analyzing, assessing, and reporting data

The scope of QAPPs will generally increase with the complexity of the projects they support. New information and/or changes in project scope may also necessitate revisions to the QAPP.

A complete description of QAPPs and their components is beyond the scope of this document. U.S. EPA (1993, 1997e, 1999d, 2000c, 2001c, 2002c, 2002e, 2004d, 2005d, and 2006b) provides guidance on many aspects of QAPP development and implementation. IDEM's Leaking Underground Storage Tank Program has a generic QAPP that may prove useful during development of a site-specific QAPP. IDEM's Chemistry Services Section[20] also welcomes opportunities to review QAPPs prior to initiation of field work.

[20] http://www.in.gov/idem/4673.htm

2.8 Choosing Areas to Sample

Sample areas depend on investigation objectives. Investigation objectives vary widely, and so will the sample areas necessary to pursue those objectives. Possible investigation objectives include:

- Find contaminated areas
- Evaluate exposure across a particular area
- Determine if receptor impacts exist
- Evaluate background levels
- Collect information needed for remedial system design
- Demonstrate achievement of remediation objectives in a given area

There are many other possibilities. Whatever the investigation objective(s), reports should include the rationale and supporting evidence for selection of specific sampling areas. Presampling investigations will usually provide enough information to guide initial selection of sample areas.

Note that different parts of a site may have different likely future exposures (e.g., paved parking, daycare, break area, factory floor, etc.). Separate sampling plans for each identifiable exposure area allow subsequent separate exposure evaluations in those areas, rather than using the same exposure assumptions across the entire site.

2.9 Identifying Potential Contaminants

Use information obtained during the presampling investigation to focus sampling efforts on specific **potential contaminants**.

When site-specific operating information is incomplete or unreliable, IDEM programs *may* specify pre-defined lists of potential contaminants. For example, the comprehensive list for Resource Conservation and Recovery Act Subtitle C sites may include Appendix VIII[21] (for soil) and Appendix IX[22] (for ground water). Less comprehensive lists, such as the Comprehensive Environmental Response, Compensation, and Liability Act target compound list or target analyte list may be appropriate if they include potential contaminants. See the *Remediation Program Guide* for more details on program-specific requirements. Ecological risk assessment may involve evaluation of different or additional potential contaminants than those relevant to human health risk assessment.

IDEM's Office of Land Quality Chemistry Services Section web page[23] includes lists of the most commonly encountered potential contaminants at several types of sites.

[21] Code of Federal Regulations (CFR) Title 40, Part 261
[22] CFR Title 40, Part 264
[23] http://www.in.gov/idem/4673.htm

2.10 Choosing Media to Sample

Appropriate sample media will depend on site characteristics and the exposure scenarios under evaluation. For example, a subsurface release may not warrant collection of surface soil samples. Conversely, a surficial release followed immediately by removal might achieve closure with only post-removal surficial soil samples. If site conditions suggest that contaminant migration through the soil column is unlikely (e.g., dense clay)[24], a site-specific investigation approach that minimizes or eliminates ground water sampling may be appropriate.

2.11 Sampling Design

There are many possible ways to place sample locations across a site. Although the *Remediation Closure Guide* confines discussion to two basic approaches, IDEM will evaluate alternative proposals on their merits. Whatever the approach, the number of samples necessary for an adequate investigation is site-specific.

Judgmental sampling uses professional judgment and existing site knowledge to place sample locations. Judgmental sampling works best at sites with known locations of potentially contaminated areas, receptors, or other indicators for sampling. In such cases, judgmental sampling may simplify sample placement.

Systematic sampling places samples at fixed intervals beginning from a random starting point (as along a drainage way, excavation wall, or perimeter) or according to a predefined pattern that distributes samples uniformly over an area. Systematic methods are suitable at any site, but are especially useful at sites where there is limited information about the distribution of potential contamination (e.g., fields, vacant lots, or sediment deposition zones).

It is appropriate to use the results of systematic samples to calculate exposure point concentrations (Section 7.2.3) *across* exposure areas. However, use of statistical methods to evaluate sites may require more samples than are necessary under judgmental approaches.

Sometimes it is useful to combine the two approaches. For example, judgmental sampling may identify specific areas of concern, followed by systematic sampling within those areas. The resulting exposure estimate may be more representative of on-site contamination than the original sample points.

U.S. EPA (2002d) offers information on numerous sampling designs, including: judgmental, simple random, stratified, ranked set, adaptive cluster, composite, systematic, and grid sampling methods. IDEM will consider proposals to use these sampling schemes and will evaluate such proposals on their merits.

[24] For example, naturally occurring homogeneous materials exhibiting low effective porosity and permeability (10^{-6} cm/sec or less), laterally continuous in extent, substantially thick (10 feet or greater), with no primary or secondary features such as fractures, joints, weathered zones, etc. that can serve as preferential pathways to ground water below.