# 6.0
# DEVELOPMENT AND VALIDATION OF CONCEPTUAL SITE MODEL

## 6.1 INTRODUCTION

This section discusses a systematic planning process for data collection activities for site characterization for Tier 1, 2, and 3 risk assessments. Environmental data used in the Missouri Risk-Based Corrective Action (MRBCA) process must be scientifically valid, defensible, and of known and documented quality. This can be achieved by the use of adequate quality assurance and quality control procedures throughout the entire process (from initial study planning through data usage). This section briefly discusses techniques used to collect the data, but references are cited to provide more detailed information about methodologies for the collection of data.

In the MRBCA process, data is used to:

- Develop and validate a conceptual site model,
- Delineate the extent of impacts in each media necessary to quantify the risk to receptors,
- Identify the maximum media-specific site concentrations,
- Identify the exposure domains for each complete receptor, route of exposure, and -exposure pathway,
- Estimate the representative concentration for each exposure domain,
- Develop a feasible risk management plan, if necessary, and
- Confirm the effectiveness of risk management alternatives.

It is extremely important that careful attention be paid to the data collection work plan preparation and implementation to ensure that the nature and extent of contamination is accurately characterized.

## 6.2 COMPONENTS OF CONCEPTUAL SITE MODEL

On a given project, different individuals may collect data over a long period of time. Therefore, it is important to compile the relevant data in a format that is easy to understand and use. A conceptual site model provides a convenient format to present an overall understanding of the site. A conceptual site model may be developed at the start of a project and refined and up-dated throughout the life of the site activities. A complete and detailed conceptual model is essential to making sound professional judgements about sampling design and for optimizing that design. It can help identify the pros and cons of various remediation activities or activity and use limitations. Finally, it is an important communication tool for regulators, remediating parties and stakeholders.

A conceptual site model can be prepared using available information for the site together with an applicable guidance document such as ***Guidance for the Data Quality Objectives Process*** (EPA QA/GW, August 2000) and ***Data Quality Objectives Process for Hazardous Waste Site Investigations*** (EPA QA/G-4HW, January 2000).

Key elements of the conceptual site model include:

1. The chemical release scenario, source(s), and chemicals of concern (COCs),
2. Spatial and temporal distribution of COCs in the various affected media,
3. Current and future land and groundwater use,
4. Description of any known existing or proposed land or water use restrictions,
5. Description of site stratigraphy, determination of the predominant vadose zone soil type, hydrogeology, meteorology, and surface water bodies that may potentially be affected by site COCs,
6. Remedial activities conducted to date, and
7. An exposure model that identifies the receptors and exposure pathways under current and future land use conditions.

To adequately characterize a site to determine risks, the following categories of data may be required:

- Site information, as defined in Section 6.3,
- Description and magnitude of the spill or release, as defined in Section 6.4,
- Adjacent land use, activity and use limitations, and receptor information, as defined in Section 6.5,
- Analysis of current and future groundwater use, as defined in Section 6.6,
- Vadose zone soil characteristics, as defined in Section 6.7,
- Characteristics of saturated zones, as defined in Section 6.8,
- Surface water body characteristics, as defined in Section 6.9,
- Ecological risk assessment, as defined in Section 6.11,
- Meteorology (such as rainfall, infiltration rate, evapotranspiration, wind speed and direction),
- Distribution of chemicals of concern in soil, as discussed in Section 6.12,
- Distribution of chemicals of concern in groundwater, as discussed in Section 6.13,
- Distribution of chemicals of concern in soil vapor, as discussed in Section 6.14, and
- Distribution of chemicals of concern in sediments and surface water bodies, as discussed in Section 6.15.

As part of the MRBCA evaluation, the remediating party must carefully review all the available data and identify any data gaps. A systematic planning process is used to develop a work plan to be approved by the department. To fill in data gaps, the work plan must include: (i) a sampling and analysis plan and (ii) a Quality Assurance Project Plan (QAPP) that meets *EPA Requirements for Quality Assurance Project Plans (EPA QA/R5)* along with *EPA Guidance for Quality Assurance Project Plans (EPA QA/G5)* (QAPPs can be site specific or activity specific). The objectives of the QAPP and the Sampling and Analysis Plan components of the work plan are to ensure that:

- The intended use of the data is clearly defined and understood to ensure that the collected data will be of adequate quality and quantity,
- All environmental data used to make risk assessment and risk management decisions is scientifically valid, defensible and of known quality,

- The specific location where samples will be collected, the handling requirements for the samples, and methods of analysis are clearly specified to avoid any confusion or ambiguity once the field work begins, and
- All data collected is consistent with the *Quality Management Plan* for the Missouri Department of Natural Resources, including historical sampling data that is used in support of decision-making regarding the need for further investigation or remediating. The *Quality Management Plan* is available on the department's website.

The remediating party can only use or develop target levels, calculate representative concentrations, prepare a risk assessment, and prepare a risk management plan after all the necessary data has been collected.

## 6.3 SITE INFORMATION

The term "site" refers to the areal extent of contamination where the spill or release occurred. Areas beyond the site that may be impacted by the site chemicals are referred to as the "off-site" areas.

The following information is necessary to complete an MRBCA conceptual site model:
- A site location map,
- A site map,
- Ground surface conditions,
- Location of utilities on and adjacent to the site,
- Surface water bodies,
- On-site and adjacent off-site groundwater use, and
- Local hydrogeology and aquifer characteristics.

A brief discussion of each of the above items is presented below. Relevant site information can be obtained by various means, including:
- Site visits,
- Deed search,
- Historical records and aerial photographs,
- Review of engineering drawings showing the layout of the site,
- Review of regional information,
- Review of files at the department related to the site or adjacent sites, and
- Contact with the city, municipality or other governing agencies to identify any existing land use requirements, such as zoning.

### 6.3.1 Site Location Map

A site location map must be prepared using United States Geological Survey (USGS) 7½ minute topographic maps as a base. The site location should be centered on the topographic map (cropping the maps as necessary), with the location clearly marked. Contour lines on the topographic map must be legible.

### 6.3.2 Site Map

A detailed map(s) of the site should show:

- Property boundaries,
- Layout of past and current site features such as containment or storage systems; process areas; transportation and delivery distribution systems; waste handling and storage areas, including associated components and piping runs; sumps; paved and unpaved areas; and buildings,
- Locations of area(s) of release,
- Locations of on-site monitoring wells (including those that have been abandoned, identified in some way but for which exact information is missing, or destroyed),
- Locations of water wells (public and private),
- Location of surface water features,
- Ecological or terrestrial sensitive features, and
- Locations of soil borings, soil vapor extraction wells, and soil excavation areas.

Multiple maps showing these features may be necessary.

Site maps must be drawn to scale and include a bar scale and a north arrow. In addition to the site map(s), a land use map is also required (refer to Section 6.5.1).

### 6.3.3 Ground Surface Conditions

Identify the portion of the site that is paved, unpaved or landscaped. Note the type, extent, date of installation, and general condition of the pavement. Describe the unpaved areas (for example, vegetated, gravel, or bare soil). Determine the direction in which the surface is sloping and note relevant topographic features (for example, swales, drainage, or detention ponds).

### 6.3.4 Location of Utilities On and Adjacent to the Site

Contaminated groundwater and vapors can flow preferentially into and through underground utility lines and conduits and thereby increase the probability of utility workers being exposed. Therefore, a thorough assessment of potential and actual migration and impacts of COCs to underground utilities must be performed. Utilities include cable, electrical and telephone lines, sanitary and storm sewers, and water and natural gas lines. A combination of site observations, knowledge of buried utilities, and discussions with utility representatives (or use of a one-call system) and the site owner should be used to determine the location of site utilities. At a minimum, the following must be performed:

- If explosive conditions are encountered, immediately inform the local fire department and the department Emergency Response Spill Line at (573) 634-2436.
- Locate all underground utility lines and conduits within the area of known or suspected soil and groundwater impact, both on- and off-site, where the release may have migrated or may migrate in the future.

Then, if available and if utilities are located in the area of contamination, the following information may be useful in the analysis:

- Direction of water flow in utility lines (potable water, storm water, and sewage).
- Location of the utility lines and conduits on a base map that shows the extent and thickness of non-aqueous phase liquid (NAPL), free product, if any, and soil and groundwater contamination.
- Depth of the utility lines and conduits relative to the depth of groundwater. Seasonal fluctuations of groundwater levels (relative to the depth of utilities) must be carefully evaluated. A cross-sectional diagram that illustrates the depth to groundwater and the locations and depths of the utility lines and conduits is recommended.
- Types of materials used for utility lines and conduits - for example, polyvinyl chloride (PVC), terra cotta, concrete or steel - and the type of backfill around the utilities.
- Any historical work completed on any of the utilities and if any contamination-related issues were identified at the time the work was performed.

### 6.3.5 On-site Groundwater Use

Current and former site owners and operators should be interviewed to determine whether any water well(s) is or was located on site. Any and all wells will need to be identified based on a search of local, state and federal records and databases and/or windshield or door-to-door surveys, as appropriate. The level of effort necessary will be especially critical for the department to make a determination whether the domestic use of groundwater pathway is complete or incomplete.

To the extent that such information is available, the remediating party must provide well construction details for all wells identified. Relevant construction details include the total depth of the well, casing depth, screened or open interval, static and/or pumping level, and the use of water from the well. If available, average well pumping rates and drawdown information also should be provided.

If an identified well is not currently in use or likely to be used in the future, it should be closed in accordance with department requirements. Sections 256.603(1) and 256.637.4 RSMo of the Missouri Water Well Driller's Act provides information on abandoning and plugging wells under conditions of non-use, disrepair and hazardous conditions.

### 6.3.6 Local Hydrogeology and Aquifer Characteristics

Local hydrogeology, soil types and aquifer characteristics should be evaluated to determine the type and depth of aquifers in the area and whether they are confined, semi-confined or unconfined. This information can be found in published literature - especially United States Geological Survey (USGS) and the department's DGLS publications and in United States Department of Agriculture (USDA) soil surveys - and reports for any investigations conducted at adjacent or nearby release sites. General aquifer characteristics such as yield and total dissolved solids will help determine whether the domestic consumption exposure pathway is a concern. The remediating party should use regional information to better understand site-specific soil and groundwater conditions.

The Missouri Environmental Geology Atlas (MEGA), developed by the department in association with the Missouri Petroleum Storage Tank Insurance Fund, is a valuable, though not the only, source for regional hydrogeology and aquifer characteristics. The MEGA can be obtained for a nominal cost from DGLS by calling (573) 368-2101. Various USGS water resources reports are also available for selected areas in the state.

The review discussed above should also identify surface water bodies (lakes, rivers and streams, and wetlands), seeps, caves, sinkholes and springs located within a distance that is or could be affected by a release at the site. Water bodies must be identified on the area map discussed in 6.5.1. In karst areas, the department may require a larger search area.

## 6.4 DESCRIPTION AND MAGNITUDE OF SPILL OR RELEASE

Knowledge about the nature, location and magnitude of a release(s) is necessary to identify the:

- Soil and groundwater source(s) at the site,
- Chemicals of concern,
- Methods that will be used to analyze the samples, and
- Horizontal and vertical extent of soil and groundwater contamination.

The remediating party must collect as much of the following information as is available for each release that has occurred at the site:

- History of site activities related to the release,
- Location(s) and date(s) of spill(s) or release(s),
- Quantity of the release(s),
- Product(s) or chemical(s) released, and
- Interim response or corrective action measure(s) taken with respect to each release.

Release-related information can be obtained from a variety of sources, including:

- Review of historical aerial photographs or Sanborn fire insurance maps
- Review of product or waste inventory records,
- Interviews with past and current on-site employees,
- Review of the department's Hazardous Waste or Water Protection Program files,
- Review of USEPA files,
- Review of historic spill incident reports filed with the department,
- Review of permits, and
- Review of administrative or consent orders related to the site.

### 6.4.1 History of Activities at the Site

At many contaminated sites, one or more site investigations, monitoring events, system (such as tanks, pipelines, or lagoons) removal activities, or remediation activities may have taken place over an extended period of time.

Therefore, a key step in the MRBCA process is to develop a comprehensive chronology of historical events related to any chemical impacts. A chronology will help create a complete picture of the site activities and identify COC and data collection needs. The chronology should include information such as the dates, descriptions and results of:

- Installation, removal or upgrade of containment, process, delivery or waste systems,
- Remedial activities such as excavation and disposal of contaminated soil,
- Drilling, sampling and gauging of monitoring wells, and
- Collection of environmental media samples.

Interim response actions may have removed all or part of the COCs released at a site. Soil and groundwater data collected prior to the completion of these activities may not be representative of current conditions and should not be used in the calculation of current exposure and risk. At such sites, the remediating party must collect additional soil and groundwater concentration data representative of current conditions. However, data collected prior to the completion of interim action(s) may be used to guide decisions on additional data collection.

The intent of developing a site history is to clearly understand site activities in order to develop a conceptual site model that can be used to accurately assess any associated current and future risks.

### 6.4.2 Location and Date of Spill or Release

The identification of the location of a release helps define the source area(s). Likely release locations at contaminated sites include:

- Corroded or damaged containment or process system components,
- Piping, especially at pipe bends and joints and floor drains,
- Dispenser and delivery systems,
- Deposition near smoke stacks or air discharge points,
- Accidental releases at areas for receiving, delivering, or handling chemicals and wastes,
- Waste water lagoons and run-off basins,
- Waste storage and disposal areas, and
- Hazardous product materials storage areas.

A release may occur within the surficial soil. Surficial soil is the zone that a receptor could directly come into contact with and be exposed to COCs in the soil by ingestion, dermal contact, or inhalation of vapor and particulates. In the MRBCA process, for both residential and non-residential receptors, surficial soil is defined as from 0 to 3 feet below ground surface (bgs). Subsurface soil is defined as from 3 feet bgs to the water table. If the groundwater is less than 3 feet bgs, then the surficial soil extends to the depth of the water table and there is no subsurface soil for purposes of risk assessment.

During collection of surface soil samples where metals are a potential concern, it is important to collect data from the shallowest depth that can be practicably obtained, rather than choosing a random sampling interval in the 0-3 foot zone, or compositing samples across the entire zone. Simply using data from a 0-3 foot interval can dilute the concentration if contamination is not homogenous across the soil profile. These types of concerns should be addressed in the data collection work plan.

Based on the site chronology and operational history described in Section 6.4.1, the remediating party may be able to determine the location and date of the release(s). However, often the exact location and date of the release(s) cannot be known. In such cases, field screening, such as the use of a photoionization detector (PID), x-ray fluorescence (XRF) spectrophotometer, field bioassays, and/or collection of samples for laboratory analysis must be used to identify the likely location and extent (vertical and horizontal) of COCs in the soil and groundwater. Decisions regarding the use and application of field screening technologies and collection of samples must be based on site-specific conditions and chemicals. For example, PIDs may not be accurate for soils above a certain moisture content, and the PID does not detect all types of chemicals. Visual observations may be used to identify soil sample locations. This information is part of a sampling and analysis plan.

### 6.4.3 Quantity of Spill or Release

The MRBCA process does not necessarily require knowledge of the exact quantity of the released chemicals or wastes. Often this information is not known. However, having a general idea of the amount released can assist in assessing the potential extent and severity of a chemical impact. Approximate amounts may also be used to provide the basis for any chemical mass balance calculations.

### 6.4.4 Product(s) or Chemical(s) Released

The MRBCA process primarily focuses on developing risk-based target levels for individual chemicals. However, target levels may at times be developed for products or wastes that are mixtures of chemicals such as oil, gasoline, deicing agent, Stoddard solvent, polychlorinated biphenyls (PCBs), and polychlorinated dioxin. The remediating party must identify the COCs comprising such products or wastes. For chemicals related to petroleum product spills, refer to the most recent version of the ***Missouri Risk-Based Corrective Action (MRBCA) Process for Petroleum Storage Tanks***.

## 6.5 ADJACENT LAND USE, ACTIVITY AND USE LIMITATIONS, AND RECEPTOR INFORMATION

Land use information is used to identify the (i) location and type of potential receptors, (ii) exposure pathways by which the potential receptors may be exposed to the COCs, and (iii) presence of any site activity and use limitations (AULs) that may affect the completion of exposure pathways. This information is critical in developing a site exposure model. Specifically, the following information must be collected:

- Current land use and zoning,
- Potential future land use and zoning,
- Local ordinances, easements and restrictions that affect land or groundwater use,
- Quality and availability of potable water supplies,
- Off-site groundwater use, and
- Ecological receptor survey.

At a minimum, the department will require a land use and receptor survey covering the entire contaminated and potentially contaminated area.

### 6.5.1 Current Land Use

Knowledge of the uses of the site and nearby properties is necessary to define potential on-site and off-site receptors that may be exposed to the COCs. A visual, on-site land use reconnaissance survey within the area of impact must be conducted to avoid ambiguity about site uses. The survey must clearly identify the following: schools, hospitals, residences (apartments, condominiums, townhouses, and single-family homes), buildings with basements, day care centers, churches, nursing homes, and types of businesses. The survey must also identify surface water bodies, parks, recreational areas, wildlife sanctuaries, wetlands and agricultural areas. The results of the survey must be accurately documented on a land use map. Figure 6-1 is a sample land use map.

The land use map need not be drawn to an exact scale; in most cases, an approximate scale will suffice. However, a north arrow on the map is required.

### 6.5.2 Future Land Use

Future land use and receptors must be established, which are more difficult to determine than current land use and receptors. Unless future land use is known and can be documented (for example, by development plans or building permits), predictions of reasonably anticipated future use must be based on local zoning laws and surrounding land use patterns. As appropriate, zoning maps, aerial photographs, local planning offices, the U.S. Bureau of the Census, community master plans, changing land use patterns, and interviews with current property owners can provide information with which future land use can be predicted. Proximity to wetlands, critical habitat and other environmentally sensitive areas must also be considered in predicting future land uses.

### 6.5.3 Off-site Groundwater Use

A water well survey must be conducted to locate all public water supply wells within a one-mile radius of the site and all private water wells within a quarter-mile radius of the site. (The radial distances referenced above are minimum requirements. Relevant federal requirements or differences in COC mobility and/or hydrogeology at the specific site may necessitate well surveys of greater areal extent. ) A few of these wells may be known prior to the water well survey; others may be identified during the survey. The primary repository of well-related information is within DGLS, which maintains records of known pre-law wells and wells drilled in Missouri since enactment of the Water Well Driller's Act of 1985. Other information sources include the USGS, water system operators, and interviews with local residents.

The level of effort expended in a well survey depends on site-specific considerations. It can extend to searches of local, state and federal records and databases and windshield or door-to-door surveys. For example, in newly developed urban areas with a municipal water supply, a door-to-door survey might not be necessary. However, in rural areas where groundwater is the primary source of water or in older developed areas, a door-to-door survey may be needed. The level of effort for this task is especially critical if the department is to evaluate the domestic consumption pathway during the risk assessment process.

As in Section 6.3.4 for on-site wells, to the extent that such information is available, the remediating party must provide well construction details for all wells identified. Relevant construction details include the total depth of the well, casing depth, screened or open interval, static and/or pumping level, and the use of water from the well. If available, average well pumping rates and drawdown information also should be provided.

### 6.5.4 Ecological Receptor Survey

Ecological receptors include both specific species and general populations of flora and fauna and their habitats, including wetlands, surface water bodies, sensitive habitats, and threatened and endangered species. The Ecological Risk Assessment, Level 1, Checklist A (Appendix F), is a screening tool that must be completed for a Tier 1, Tier 2, or Tier 3 risk assessment. An Ecological Risk Assessment may also be required at the Default Target Level if certain COCs are present at a site (see Section 5.4). Accurate information on the checklist may require that the area around the site be visually surveyed for the specific ecological receptor criteria. The department will require that a visual survey be conducted if a checklist cannot be completed based on existing information.

Refer to Section 6.11 for further information regarding ecological risk assessment.

## 6.6 ANALYSIS OF CURRENT AND FUTURE GROUNDWATER USE

Impacts to groundwater and potential exposures via the domestic use of groundwater are of significant concern in Missouri because a large part of the state obtains drinking water from groundwater sources. The MRBCA process can be used in cases where groundwater has been contaminated or is likely to be contaminated by a site-specific release. The process has the following objectives:

- To protect all current and reasonably anticipated future uses of groundwater,
- To provide a rational basis for incorporating site-specific characteristics into the determination of groundwater target levels, and
- To facilitate the development of properties based on reasonable expectations for groundwater cleanup.

A key determination in developing risk-based groundwater target levels is if the groundwater domestic use pathway is complete under current or future conditions. The process used to make this determination is shown in Figure 6-2 and discussed below. The analysis of current and future groundwater domestic use must include all groundwater zones beneath or in the vicinity of the site that could potentially be (i) impacted by site-specific COCs, or (ii) targeted in the future for the installation of water use wells. For the purposes of this analysis, groundwater-bearing zones must be evaluated in a three dimensional context.

As a part of this step, other groundwater uses (for example, cooling water, irrigation, livestock watering, and industrial process water) must also be identified and documented.

### 6.6.1 Current Groundwater Use

The current groundwater domestic consumption pathway is considered complete if water use wells are located on or near the site and the wells may be impacted by site-specific chemical releases.

Whether a well may be impacted depends on the hydrogeological conditions, well construction and use of the well, including the following factors:

- Characteristics of soil and rock formations,
- Groundwater flow direction,
- Hydraulic conductivity,
- Distance to the well,
- The zone where the well is screened,
- Casing of the well,
- Zone(s) of influence and capture generated by well pumpage, and
- Biodegradability and other physical and chemical properties of the COCs.

If it is determined that any groundwater zone will not be impacted, then justification for this determination should be provided in any tiered risk assessment report and in the Risk Management Plan.

### 6.6.2 Future Groundwater Use

If an AUL is in place that eliminates the potential that the groundwater will serve as a future source of domestic water, the presence of the AUL will be considered along with other relevant site-specific domestic consumption factors. For early relief from consideration of this pathway, an ordinance that prohibits well drilling along with a Memorandum of Agreement with a governing body (discussed further in Section 11) can be used to justify an incomplete pathway.

If such controls are not in place and approved by the department, then a site-specific analysis of reasonably anticipated future use of groundwater must be conducted for each groundwater zone that potentially could be impacted by site contaminants.

For each zone, determining if the future groundwater use pathway is complete or likely to be complete is based on consideration of the following factors. All of these factors should be evaluated on a "weight of evidence" basis; the weight that a single factor will be given in determining the probability of future groundwater use will vary based on site-specific considerations, including the durability of any AULs.

**Evaluation of Activity and Use Limitations (AULs) for any particular zone:** If an AUL is in place that minimizes or eliminates the potential that a specified groundwater zone will serve as a future source of domestic water, the presence of the AUL will be considered along with other relevant site-specific domestic consumption factors for that zone.

With respect to the restrictions and construction standards of the Missouri Well Construction Rules (Chapter 256, RSMo, 10 CSR 23-3 and Section 11.3.4 of this guidance), including the designation of Sensitive and Special Areas established thereunder. These rules can be used to justify an incomplete future domestic consumption pathway for specific groundwater zones in specific designated areas of the state. However, the Missouri Well Construction Rules for Sensitive Areas do not prevent drilling, but rather prevent future use of contaminated specific groundwater zones by mandating special well construction requirements. If relying on these rules and special/sensitive areas for early relief from evaluation of the future domestic groundwater use pathway, a site-specific zone by zone analysis must be performed as these rules/designated areas do not constitute "blanket" early relief for all subsurface zones. Further, the department's acceptance of "early relief" from more detailed evaluation of the domestic groundwater use pathway is predicated on demonstrating that there is no current domestic use of groundwater from specific zones. Those seeking early relief must exercise due diligence in identifying any existing "grandfathered" domestic groundwater users that have wells constructed in zones that are now restricted by the Missouri Well Construction Rules. Groundwater is used for domestic purposes in many areas of the state where well installation is now restricted. In those situations, potential impacts to existing domestic use wells must be evaluated to determine if the domestic use pathway should be retained for further evaluation.

The degree to which AULs will affect the determination will depend on the attributes of the specific AUL. If the attributes of the AUL are not applicable to the situation, durable, or enforceable, a groundwater zone may remain a probable future domestic water source, despite the existence of the AUL.

If the AUL does not explicitly apply to a specific water-bearing zone and that zone meets each of the following criteria, a groundwater zone is considered to have a reasonably anticipated future use if:

- The zone is the highest quality groundwater resource (considering both yield and natural quality) in the hydrostratigraphic column.
- The zone has sufficient quality and yield to serve as a primary component of a public or private water supply.

- The zone has no widespread groundwater impacts associated with historic human activity in the vicinity of the site (excluding groundwater impacts associated with the specific site).

This information will form the basis for determining whether or not the domestic consumption pathway is carried forward for further evaluation in the risk-based process.

**Suitability for Use Determination:** For groundwater to be considered a viable domestic water supply source, it must meet appropriate total dissolved solids (TDS) and yield criteria.

<u>Total Dissolved Solids Criteria</u> – Groundwater containing less than 10,000 mg/L total dissolved solids is considered a potential source of domestic consumption.

<u>Yield Criteria</u> – Groundwater zones capable of producing a minimum of 1/4 gallon per minute or 360 gallons per day on a sustained basis have sufficient yield to serve as a potential source of domestic consumption. The yield of a bedrock aquifer should be based on the measured or calculated production of a 6-inch drilled well that penetrates the lesser of either the full saturated thickness of the aquifer or the uppermost 200 feet of the saturated zone. The yield of a low-yield, unconsolidated (glacial drift or alluvial) aquifer should be based on the measured or calculated production of a 3-foot-diameter, augered or bored well that penetrates the lesser of either the entire saturated thickness of the aquifer or the uppermost 50 feet of the saturated zone. Refer to Appendix G, "A Method for Determining If a Water Bearing Unit Should Be Considered an Aquifer," for further guidance on determining whether a particular zone should be considered as a potential domestic water source.

**Determination of Sole Source/Availability of Alternative Water Supplies:** If the groundwater zone being considered is the only viable source of water at or in the vicinity of the site, then the remediating party must assume that future domestic use is reasonable. This conclusion is irrespective of TDS or yield considerations, and this zone must be evaluated if it is likely to be impacted by COCs from the site. Determining the availability of alternative water supplies should include consideration of other groundwater zones, municipal water supply systems, and surface water sources.

**Reasonably Anticipated Future Use Determination:** The probability that a groundwater zone could be used as a future source of water for domestic consumption must be evaluated based on consideration of the following factors:

- Current groundwater use patterns in the vicinity of the site under evaluation,
- Suitability of use (TDS and yield criteria),
- Well location and construction requirements/restrictions,
- Availability of alternative water supplies,
- AULs,
- Urban development considerations for sites in areas of intensive historic industrial or commercial activity, having groundwater zones in hydraulic communication with

industrial or commercial surface activity, and located within metropolitan areas with a population of at least 70,000 in 1970, and
- Aquifer capacity limitations (ability to support a given density of production wells).

In metropolitan urban areas, common human activities often impact the uppermost-saturated zone. Due to these anthropogenic impacts, it may not be reasonable in some cases to consider the uppermost saturated zone as a domestic use water supply source. Examples include:
- Application of pesticides and fertilizers on household gardens,
- Leakage of waste from sewer pipes and septic tanks, and
- Infiltration of rain-dissolved chemicals that were present on the surface (oil from automobiles, etc.).

**Probability of Impact Determination:** If a groundwater zone has a reasonably anticipated future use as a domestic water supply, the zone must be evaluated for the probability that the zone could be impacted by site COCs. The evaluation must consider the nature and extent of contamination at the site, site hydrogeology including the potential presence of karst features, contaminant fate and transport factors and mechanisms, and other pertinent variables. To evaluate potential site impacts to groundwater zones that could serve as future water supply sources, the potential impact must be evaluated at the nearest down-gradient location that could reasonably be considered for installation of a groundwater supply well. In the absence of durable AULs, the nearest location might be on the site itself.

## 6.7 VADOSE ZONE SOIL CHARACTERISTICS

Vadose zone soil is a medium through which COCs can migrate to groundwater and through which vapors can migrate upward to indoor and outdoor air. The following vadose zone parameters and their variability across the contaminated area significantly affect the movement of chemicals through vadose zone soil:
- Dry bulk density,
- Total porosity,
- Volumetric water content,
- Fractional organic carbon content,
- Thickness of vadose zone and depth to groundwater, and
- Thickness of capillary fringe.

The first four parameters - dry bulk density, porosity, water content, and fractional organic carbon content - are often collectively referred to as the soil geophysical or geotechnical parameters. Consideration should be given to preferential pathways. For example, desiccation cracks may provide a preferential pathway at sites where the primary soil type is clay.

For Tier 1 risk assessments, the department has assigned conservative default values to these parameters for three generic vadose zone soil types. Appendix O provides guidance on the determination of vadose zone soil types. As shown in Appendix E, Table E-5, these are:

- Soil type 1, representative of a sandy soil,
- Soil type 2, representative of a silty soil, and
- Soil type 3, representative of a clayey soil.

For Tier 2 and Tier 3 risk assessments, site-specific values based on data collected from the site or justified default parameters must be used.

If circumstances at a site are such that the geophysical properties cannot be determined because of sampling limitations, the remediating party must use appropriate conservative, justifiable literature values or values from samples collected in the field at nearby sites having very similar lithologic and geologic characteristics. If values cannot be found or do not exist, the remediating party should contact the department for further guidance.

Generally, collection of geophysical soil samples will require more than one boring or probe, depending on site conditions and recovery volumes. Ultimately the number of borings or probes necessary to obtain representative values of these parameters will be a site-specific decision of the driller and environmental consultant based on professional experience and judgment. The objective is to collect enough samples so that the results are representative of site-specific conditions. Fewer samples will be required at sites with relatively homogeneous vadose zone characteristics while more samples will be required if heterogeneous conditions exist.

In situations where undisturbed samples cannot practically be collected for the purposes of measuring dry bulk density, literature values may be used for this parameter. However disturbed samples must be collected and analyzed for fractional organic carbon, gravimetric water content, and particle density.

### 6.7.1 Thickness of Vadose Zone and Depth to Groundwater

The vadose zone is the uppermost layer of the earth and is conceptualized as a three-phase system consisting of solids, liquid and vapors. The thickness of the vadose zone can be determined based on information presented on boring logs and/or from measurements taken from monitoring wells or piezometers. It represents the distance from the ground surface to the depth at which the water table is encountered. For MRBCA evaluation, the capillary fringe thickness is not considered part of the vadose zone and is subtracted. Depth to groundwater is used to estimate vapor emissions from groundwater and to determine the vadose zone attenuation factor.

At sites where significant secondary porosity features are identified, the calculation of the dilution attenuation factor DAF should not be based on the assumption of granular media. Alternative methods to estimate the DAF and any alternative data needs must be proposed to the department. For sites where DAF cannot be accurately evaluated, the remediating party may propose alternative methods to evaluate the indoor inhalation pathway for department approval.

For sites where the water table fluctuates considerably, the available data must be evaluated to determine whether the fluctuations are seasonal or represent a consistent upward or downward regional trend. For sites with significant seasonal fluctuations, the average depth to groundwater and the average thickness of the vadose zone should be used in development of the overall conceptual site model and any related modeling efforts. Averages can be determined by groundwater level measurements obtained on at least a quarterly basis over one year. These averages should not; however, be used in the development of site-specific potentiometric maps, plans for well installation, or any other activities that require specific knowledge of fluctuations in groundwater flow direction(s). At sites with consistent, long-term (greater than one year) upward or downward water level trends that do not appear to represent seasonal fluctuations, the most recent data should be used to estimate the depth to groundwater and the thickness of the vadose zone.

At sites where the cleanup decision critically depends on the vadose zone thickness and/or depth to groundwater, and the depth to groundwater is known to fluctuate significantly, the department may request a sensitivity analysis. The analysis should be performed using different depths to groundwater and vadose zone thicknesses to assess the degree to which these parameters may affect the cleanup decision.

### 6.7.2 Dry Bulk Density

Dry bulk density is the dry weight of a soil sample divided by its field volume. An accurate measurement of dry bulk density requires determination of the dry weight and volume of an undisturbed sample. An undisturbed soil core sample may be collected using a Shelby™ tube, a thin-walled sampler, or an equivalent method. The sample must not be disturbed prior to laboratory analysis.

Dry bulk density is estimated using the American Society for Testing and Materials (ASTM) Method D2937, ***"Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method."*** At sites where multiple, widely differing soil types occur in the vadose zone, one sample must be collected from each distinct, predominant soil type. At such sites, the percentage of each soil type relative to the overall volume of the vadose zone should be considered in collecting samples and calculating bulk density. Where soil at a site is homogeneous or nearly so, a single sample for bulk density analysis may suffice.

### 6.7.3 Total Porosity

Total porosity is the ratio of the volume of voids to the volume of the soil sample. Many laboratories use dry bulk density and specific gravity of soil particles to calculate total porosity using the following:

$$n = 1 - \rho_b/\rho_s \tag{6-1}$$

where,

| | | |
|---|---|---|
| $n$ | = | porosity (cc/cc) |
| $\rho_b$ | = | dry bulk density (g/cc) |
| $\rho_s$ | = | specific gravity or particle density (g/cc). |

Thus, specific gravity and soil dry bulk density are needed to determine total porosity.

The ***"Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer,"*** ASTM Method D854, may be used to determine specific gravity. If specific gravity or particle density is not available, 2.65 g/cc can be assumed for most mineral soils. However, the use of this value must be justified.

If a site-specific total porosity value cannot be determined, literature values consistent with the site lithology may be used, provided the source(s) of the value(s) is cited and justified. Effective porosity is the amount of void space available for fluid flow. Various studies have identified that even in very fine clays, such as lacustrine deposits, the effective porosity is practically the same as total porosity (Fetter, 2001). Where the total and effective porosities differ significantly, the department may require a sensitivity analysis.

### 6.7.4 Volumetric Water Content/Moisture Content

Volumetric water content is the ratio of the volume of water to the volume of field or undisturbed soil. The ASTM Method D2216, **"Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soils and Rock by Mass,"** may be used to calculate this ratio. However, this is a gravimetric method that uses the mass of the sample, not the volume, to determine the ratio of water to soil. Therefore, to obtain the volumetric water content, the following conversion should be used:

$$\theta_{wv} = \theta_{wg} \times \frac{\rho_b}{\rho_l} \tag{6-2}$$

where,

| | | |
|---|---|---|
| $\theta_{wv}$ | = | volumetric water content (cc water/cc soil) |
| $\theta_{wg}$ | = | gravimetric water content, typically reported by the laboratory (g of water/g of soil) |
| $\rho_b$ | = | dry bulk density (g of dry soil/cc of soil) |
| $\rho_l$ | = | density of water (g/cc). |

Multiple samples from across the site at varying depths should be analyzed for water content to estimate a representative water content value for the vadose zone. Each soil sample analyzed for one or more of the applicable COCs must also be analyzed for water content (at sites where multiple samples from multiple depths are analyzed for COCs on a dry weight basis, additional samples solely for analysis of water content may not be necessary). In addition, water content values representative of each of the lithologic units that comprise the vadose zone must be determined. Because all soil COC concentration data must be reported on a dry weight basis, the water content for each soil sample must be compiled, reported and used as needed in calculating target levels.

### 6.7.5 Fractional Organic Carbon Content in Soil

Fractional organic carbon content is the weight of organic carbon in the soil divided by the weight of the soil and is expressed either as a ratio or as a percent. Organic carbon content must be determined using soil samples not impacted by petroleum or other anthropogenic chemicals. Therefore, a soil boring away from the contaminated area but within a soil type that is the same as, or very similar to, that found at the site must be drilled to determine fractional organic carbon content. At a screening level, one method of determining if certain anthropogenic chemicals have impacted the sample is to take a PID reading.

Samples representative of the vadose zone must be collected for fractional organic carbon content analysis. At sites where the vadose zone consists of several different soil types, each predominant soil type must be sampled. Multiple aliquots of soil samples from the same lithologic unit may be collected vertically from a boring and horizontally from different borings and composited in the field to create a single sample. While creating a composite sample, care should be taken not to combine samples collected from different lithologic units. Surficial soils typically have the highest organic carbon content, and care should be taken not to bias the samples by collecting too much surficial soil.

For sites where subsurface soil types vary significantly, soil samples from the vadose and saturated zones should be collected at two or more boring or probe points that represent the differing soil types. As appropriate, the resulting fractional organic carbon content can then be averaged to establish a fractional organic carbon content for each media. If the individual data are representative of significantly different volumes of soil, a weighted average is preferable to the arithmetic average.

Fractional organic carbon content may be estimated using the Walkley Black Method (Page et al., 1982). However, some labs may not be familiar with this method. An alternative, though less preferred, method is ASTM Method D2974 ***(Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils).*** This method measures the organic matter content of a sample. When using Method D2974, the result must be divided by 1.724 to get fractional organic carbon content. If the laboratory results are reported as a percent, fractional organic carbon content is obtained by dividing the results by 100.

### 6.7.6 Thickness of Capillary Fringe

The capillary fringe is the zone immediately above the saturated zone where capillary attraction causes upward movement of water molecules from the saturated zone into the soil above. This zone is distinct in that it has characteristics of both the vadose and saturated zones. In a Tier 2 risk assessment, the thickness or height of the capillary fringe can be measured or an appropriately justified value used. Because accurate field measurement of the thickness of the capillary fringe can be difficult, literature values based on the soil type immediately above the water table may be used to assign a site-specific value for the capillary fringe thickness.

The thickness of the capillary fringe can significantly impact the concentrations in groundwater that are protective of indoor inhalation. Because this zone is not usually measured, the department may require that the remediating party estimate the most likely ranges of capillary zone thickness and depth to contamination and perform a sensitivity analysis. Most models used to perform this calculation assume the capillary fringe to be uncontaminated, which may not be accurate.

## 6.8 CHARACTERISTICS OF SATURATED ZONES

COCs may reach the water table by travelling vertically through the vadose zone. Vertical migration can be expected in the following conditions:

- When the matrix porosity of the subsurface medium of interest is conducive to vertical migration,
- When a natural or induced downward vertical gradient exists between shallow and deeper saturated zones,
- When vertically oriented secondary porosity features are present, or
- When non-aqueous phase liquids (NAPLs) are present. Typically the vertical migration of light NAPLs (LNAPLs) will stop at the water table, whereas the dense NAPLs (DNAPLs) will continue to move vertically downwards through the saturated zone.

Saturated zone characteristics that determine the rate, magnitude and direction of migration of COCs in groundwater include:

- Horizontal and vertical hydraulic conductivity,
- Hydraulic gradients (magnitude in both horizontal and vertical direction),
- Residual mass in capillary fringe,
- Saturated zone soil geophysical characteristics (fractional organic carbon content, total and effective porosity, and bulk density),
- Occurrence and rate of biodegradation and retardation due to other factors, such as sorption due to soil mineral oxide content, and
- pH and redox potential especially at sites where the COCs include metals.

Of the characteristics mentioned above, the properties typically having the greatest influence on COC migration are hydraulic conductivity and hydraulic gradient.

Early in the MRBCA process, various groundwater zones and the hydraulic inter-connection among them should have been identified. Qualitative and quantitative understanding of the above factors may be necessary for each of the zones.

When necessary, values of hydraulic conductivity, hydraulic gradient, effective porosity, and fractional organic carbon content must be used to estimate the theoretical advective migration velocity for the COCs in groundwater. The theoretical migration rate and extent of the groundwater plume should be compared with actual data to further validate the conceptual site model.

### 6.8.1 Hydraulic Conductivity

Reliable estimates of site-specific hydraulic conductivity can be obtained by field methods such as pump tests or slug tests. In the absence of these tests, literature values corresponding to the type of soil in the saturated zone may be used. When a literature value is used, adequate reference and justification for the value based on consideration of all predominant soil types comprising the saturated zone must be provided. Hydraulic conductivity may also be estimated based on the grain size distribution of the porous formation.

The hydraulic conductivity can vary significantly in the horizontal and vertical directions. When referring to hydraulic conductivity always indicate whether reference is to horizontal or vertical direction. Horizontal hydraulic conductivity and gradient should be used to calculate the horizontal velocity of water and vertical hydraulic conductivity and gradient should be used to estimate the vertical velocity of water.

### 6.8.2 Hydraulic Gradient

The magnitude and direction of the hydraulic gradient is estimated by comparing water levels measured in monitoring wells across a site. A contour map must be prepared, either manually or using a computer program, using field measured water level data corrected to elevations relative to, preferably, mean sea level, or other established datum. These contour maps can be used to estimate both the direction and magnitude of the horizontal hydraulic gradient. When drawing the contour maps, care should be taken to ensure that measurements from monitoring wells screened in the same interval or hydrologic unit are used. For sites where wells are screened in multiple zones, a contour map for each zone must be developed (data from wells screened in different zones should not be combined to draw one contour map). For sites that have seasonal variation in hydraulic gradient or predominant flow direction, estimates of the average hydraulic gradient for each season and each flow direction can be used in modeling efforts. However, these estimates should not be used in the preparation of potentiometric maps or other activities where specific knowledge of the range of fluctuation in the groundwater flow direction is necessary (for example, locating and installing downgradient monitoring wells).

At sites with multiple groundwater zones, vertical gradients must also be determined via a comparison of water levels in wells screened at different intervals. The department will consider exceptions to this requirement on a site-specific basis.

### 6.8.3 Saturated Zone Soil Characteristics

The saturated zone soil characteristics include fractional organic carbon content, porosity, and dry bulk density. These parameters are required to estimate the extent of the contamination, including the retardation factor that "slows" the movement of chemicals within the saturated zone. These parameters are also necessary when estimating future concentrations or performing contaminant mass balance calculations using models that include a finite source or biodecay. Section 6.7 discusses methods to measure these parameters.

### 6.8.4 Occurrence and Rate of Natural Attenuation/Biodegradation

The occurrence of natural attenuation may be evaluated at a site. Monitoring appropriate indicators (such as chemical concentrations, geochemical indicators, electron acceptors, microorganisms, or carbon dioxide) may be required when natural attenuation is proposed as a principal element of the risk management plan. Indicators of natural attenuation can be broadly classified into three groups: primary, secondary and tertiary lines of evidence. Data collected under each line of evidence is used to qualitatively evaluate the occurrence of natural attenuation/biodegradation.

The primary line of evidence is developed by demonstrating, via the evaluation of COC concentrations in groundwater, that reductions in chemical concentration or mass are occurring at a site. The primary line of evidence is best determined by:

- Plotting concentrations of COCs as a function of distance along the plume center line,
- Plotting concentrations of COCs in each well as a function of time,
- Comparing COC concentration contour maps at various times,
- Performing contaminant mass balance calculations, and
- As appropriate, generating three-dimensional depictions of plumes and their migration over time.

In performing the above analysis, other factors that could influence the data, such as seasonal water level or flow direction fluctuations, should be taken into account.

A secondary line of evidence is necessary when the primary line of evidence is insufficient, or when such information is necessary to design a remedial system (for example, the addition of oxygen). The secondary line of evidence involves measuring geochemical indicators such as dissolved oxygen, dissolved nitrates, manganese, ferrous iron, sulfate and methane. These indicators must be measured in at least three wells located along the plume center flow line. The wells must be located to represent conditions at:

- A background or upgradient location,
- An area within the plume near the source, and
- An area within the plume downgradient of the source.

Within the secondary line of evidence, measuring the degradation or breakdown products of COCs is another approach that can be used to demonstrate the occurrence of biodegradation. For example, natural degradation breaks down tetrachloroethylene (PCE) to trichloroethylene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride. However, degradation products may be more toxic than the parent compound. Thus, the risk from degradation products also must be evaluated as part of any monitored natural attenuation proposal.

Developing a tertiary line of evidence involves performing microbiological studies to identify and quantify microorganisms within and near the plume. A tertiary line of evidence is used in very rare cases.

The development of secondary and tertiary lines of evidence is not always necessary. However, at most sites, groundwater sampling data should be plotted to evaluate temporal trends. These trends can be used to determine whether the plume is expanding, stable or decreasing. The department will require that the groundwater plume be stable or decreasing prior to issuing a Letter of Completion.

## 6.9 SURFACE WATER BODY CHARACTERISTICS

The following data must be collected for a surface water body that may be impacted by site-related COCs:

- Distance to the surface water body,
- Likely location where COCs from the site would discharge into a surface water body,
- Flow direction and depth of any groundwater contamination plume(s) in relation to the water body,
- Lake or stream classification as found in 10 CSR 20-7.031, Table G and Table H respectively. Definitions for classifications can be found in 10 CSR 20-7.031(1)(F),
- Lake or pond acreage or stream 7Q10 flow rate,
- Determination of the beneficial uses of the lake or stream as found in 10 CSR 20-7.031, Table G and Table H respectively, and
- Water quality criteria based upon the beneficial uses of the lake or stream as found in 10 CSR 20-7.031, Table A. If a water quality criterion for a COC is not available, contact the department project manager. If necessary, the project manager can then coordinate with the Water Protection Program (WPP) for further guidance.

In addition, refer to Appendix E for information about developing soil and groundwater target levels that protect surface water beneficial uses.

## 6.10 DELINEATION OF IMPACTS

MRBCA evaluation requires the collection of sufficient data to delineate the impacts in various contaminated media, as discussed below.

### 6.10.1 Delineation of Impacts in Soil and Groundwater

Prior to the performance of a risk assessment, the remediating party must review the available data and determine if data of sufficient quality and quantity are available to delineate the extent of impacts in soil and groundwater. A variety of data are necessary, such as land use, water use, any activity and use limitations, site geology and hydrogeology, and analytical data for each contaminated media. The horizontal and vertical extent of soil and groundwater contamination must be delineated to the extent necessary to assess potential exposures to receptors and impacts to surface water bodies both on- and off-site.

The key issue related to the delineation of impacts is the concentration levels to which impacts are defined. Several alternatives are available. Examples include but are not limited to: background levels, drinking water levels, generic screening levels, site-specific screening levels, or non-detect levels. The MRBCA guidance does not explicitly specify one-size-fits-all delineation concentrations for environmental media; instead, it uses "performance based" delineation criteria, as explained below.

Lateral and vertical impacts in soil and groundwater must be delineated to the extent required to determine:

- Potential exposure pathways to human and ecological receptors under current and reasonably anticipated future use conditions, and
- The extent of impacts above risk-based levels for corresponding potential exposure pathways.

For example,

- Delineation may be to non-residential levels on site at non-residential facilities, but if the plume extends off-site and surrounding land uses are residential, then delineation would be to residential levels,
- Delineate soil to the lower of levels protective of indoor inhalation or domestic use of groundwater target levels, depending on the complete exposure pathways, or
- Delineate to media transfer screening levels if volatile compounds are beneath or adjacent to existing buildings or planned future buildings would be located over contaminated areas.

The above use of performance criteria presents a dilemma in that the contaminated media must be sufficiently delineated to evaluate the risk at a site; however, risks cannot be accurately estimated until the site has been delineated. If AULs or engineering controls may be used as a component of the final remedy, delineation efforts will need to define areas over which these controls will be placed.

Thus, an iterative approach to delineation may be necessary unless the remediating party decides to delineate the site to very conservative concentrations such as background, DTLs/WQC, or non-detectable levels. If these very conservative delineation standards are not used, the following iterative approach is described for use. This approach may be more cost effective than delineating to very conservative levels, but it requires additional professional judgment and up front preparation. At sites where it is clear that active remediation is necessary, the remediating party may proceed with interim remedial measures and subsequently use confirmatory samples to delineate the extent of contamination. Thus, issues associated with contaminant delineation would not delay the implementation of remedial activities.

1. Prior to performing the site work, develop a preliminary conceptual site model, including the exposure model. The exposure model must consider receptors on site and on adjacent properties that may be exposed to contamination. This will require a determination of whether the domestic use of groundwater is or could be a complete pathway.

2. Based on the complete exposure pathways for soil and groundwater and the type of vadose zone soil, identify the applicable Tier 1 screening levels from the tables in Appendix B. In Tier 1 delineation, when cumulative site-wide risk appears to increase risk beyond acceptable levels, then the project manager should discuss this problem with the remediating party. At sites where it is clear that a Tier 2 risk assessment will be necessary and enough information is available about the site, it may be reasonable at this time for the remediating party to develop preliminary Tier 2 target levels. In developing any risk-based target levels, cumulative site-wide risk must be addressed.

3. After the delineation level for each COC has been established, the following field activities should be conducted:
   - Groundwater data from a direct push investigation may be used to screen the extent of impact prior to the installation of monitoring wells. The number and location of direct push screening points and monitoring wells is a very site-specific professional decision. Often, delineation will require multiple field mobilizations. For sites where sufficient groundwater data from monitoring wells indicates a shrinking plume, data from a direct push investigation could be used to delineate the downgradient extent of the plume. If used, direct push investigations should be conducted downgradient of the site source/release area until data indicates levels at or below the delineation level.
   - For sites where the available data indicates that the plume may be migrating, the remediating party must conduct sufficient investigations to determine the extent and rate of migration. It may be more cost effective to conduct a direct push investigation followed by the installation of a permanent delineation monitoring well(s). Wells must be monitored at a frequency and for a period of time sufficient to clearly demonstrate plume trends (expanding, stable, or shrinking) and that COC concentrations in the downgradient wells are below the delineation levels.
   - Upon preliminary completion of the site characterization, a check should be made to confirm that the assumptions used in the initial conceptual site model were accurate and that the delineation levels are appropriate.
   - For delineation of soil impacts, borings should be installed and soils sampled at increasing horizontal and vertical distances from the source area until the delineation levels are reached.

Chemical fate and transport modeling may be used as appropriate to aid in the placement of monitoring wells.

### 6.10.2 Delineation of Impacts in Other Media

In addition to the delineation of soil and groundwater impacts, impacts to other media, (for example, surface water, sediments, and air) must be evaluated. The number of samples, sample locations, delineation levels, and sampling methodologies will be based on site-specific considerations; hence the remediating party must receive the department's approval for the work plan prior to conducting fieldwork. For surface water and sediment sampling, the work plan must contain a strategy to determine background levels, location and concentration of site-related discharges to the surface water, and the extent of COC impacts. If air concentrations are to be measured, the work plan must contain a strategy to determine ambient background levels of the COCs.

Because the delineation process may be iterative, as part of the work plan report, the department will require documentation supported by site-specific data to confirm that the impacts have been delineated to the final risk-based target levels in all media.

## 6.11 ECOLOGICAL RISK ASSESSMENT

In the MRBCA process, site remediation must be protective of both human health and ecological receptors before a Letter of Completion can be issued. Ecological protection includes all non-human organisms and their habitats (ecological receptors). Therefore, exposure to ecological receptors must be considered and evaluated.

Section 5.4 discusses the process for determining if a COC may impact an ecological receptor at the Default Target Level. Within the tiered MRBCA process, ecological risk assessment has three levels:

- Level 1 is a qualitative screening evaluation comprised of Checklists A and B,
- Level 2 requires comparison of site-specific levels with applicable ecological standards, readily available in literature, and
- Level 3 allows for a site-specific evaluation.

A Level 2 and /or Level 3 evaluation is necessary only if ecological concerns persist beyond the Level 1 evaluation.

### 6.11.1 Level 1 Ecological Risk Assessment

A Level 1 ecological risk assessment must be performed at every Tier 1, 2, and 3 site to identify whether any ecological receptors or habitat exist at, adjacent to, or near the site. The evaluation, beginning with Ecological Risk Assessment Level 1 Checklist A (Appendix F), consists of seven questions. This checklist is a qualitative evaluation that can be completed by an experienced environmental professional who is not necessarily a trained biologist or ecologist. The checklist is designed such that, if the answer to all the questions is negative, no further ecological evaluation is necessary.

A positive answer to any one of the questions in Checklist A implies that a receptor or a habitat exists on or near the site and further evaluation is required. Therefore, a second checklist of seven questions, Ecological Risk Assessment Level 1 Checklist B, must then be completed. The second checklist determines if any pathways are complete for any of the receptor(s) identified in Checklist A. If the answer to all questions is negative, the conclusion is that, even though a receptor exists on or near the site, a complete pathway to the receptor(s) does not exist and, therefore, there are no ecological concerns at the site. If the answer to one or more of the seven questions is positive, a Level 2 ecological risk assessment may be necessary to determine whether contamination at the site poses an unacceptable risk to ecological receptors. A trained professional may be necessary to make these determinations.

### 6.11.2 Level 2 Ecological Risk Assessment

In a Level 2 ecological risk assessment, site-specific COC concentrations that may reach an environmental receptor are compared to Missouri's Water Quality Criteria or literature values when standards are not available. For site COCs listed in Table 5-1, the groundwater values listed are protective. Examples of additional sources, which may also be found at official websites, for these values include the following:

- Missouri's Water Quality Standards, 10 CSR 20-7.031, Table A – Criteria for Designated Uses. (Available at the Missouri Secretary of State's website),
- Ecotox Thresholds (ETs) as presented in ECO Update, US EPA, Office of Solid Waste and Emergency Response. Publication 9354.0-12FSI, EPA 540/F-95/038, PB95-963324. January 1996. Office of Emergency and Remedial Response Intermittent Bulletin Volume 3, Number 2,
- ORNL Values as presented in Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/R/Tm-96/R2. Suter II and C.L. Tsao. June,
- EPA Water Quality Standards –,
- TOXNET (National Institute of Health) –, and

National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Table (SQuiRTS) U.S. EPA, 2003. Ecological Screening Levels. Region 5 RCRA Corrective Action Branch.

If the comparison of representative, site-specific soil, groundwater, surface water or sediment values indicates that applicable values are exceeded, the remediating party may perform a Level 3 ecological risk assessment or use the applicable water quality criteria or literature values as cleanup goals. If the latter option is chosen, then at least one element of the Risk Management Plan must address remediation goals to protect ecological species.

### 6.11.3 Level 3 Ecological Risk Assessment

A Level 3 ecological risk assessment will include a detailed site-specific evaluation as per current USEPA guidance on performing risk assessment (for instance, ***EPA's April 1998, Guidelines for Ecological Risk Assessment, EPA/630/R-95/002F***). A Level 3 ecological risk assessment will require the development of a site-specific, detailed work plan and approval by the department prior to its implementation. As above, if a site-specific analysis determines that the risk to ecological species is still unacceptable, then at least one element of the risk management plan must address managing the risk to ecological species.

## 6.12 DISTRIBUTION OF CHEMICALS OF CONCERN IN SOIL

The objective of soil characterization is to (i) delineate the vertical and horizontal extent of site-related COCs to identify the exposure domains for each combination of receptor-pathway-complete exposure pathway, and (ii) estimate maximum and representative concentrations for each area of impact/exposure domain.

Data collected in areas that are clean (either because the samples were collected beyond the extent of impact or the remedial activities eliminated the COCs) are not appropriate for use in the calculation of representative concentrations. Use of such data may incorrectly underestimate the representative concentrations. Because of the significance of accurately estimating the representative concentrations for each exposure domain in the overall risk management decision, this concept is further discussed in Appendix C.

As noted in 6.4.2, the MRBCA process distinguishes between surficial soil and subsurface soil. A key difference between surface and subsurface soil is that, for surficial soil, the direct contact pathway (ingestion, dermal contact and outdoor inhalation of vapors and particulates) is considered complete for both the residential and non-residential receptors. For the subsurface soil, this pathway is considered incomplete except for the construction worker who may be involved in excavation activities below the surficial zone and hence may come in direct contact with subsurface soil. Thus, for the construction worker, no distinction is made between the surface and subsurface soil. In Tier 3 and based on site-specific exposure conditions, the depth of surface soil may be modified.

Because of the differences in exposure pathways for surface and subsurface soils, an adequate number of soil samples from each zone must be collected to meet the soil characterization objectives. Surficial soil (as well as subsurface soil) may include fill material - the distinction between surface and subsurface soil is one of depth rather than composition.

As previously indicated in Section 6.4.2, it is extremely important that careful attention be paid to the data collection work plan to ensure that the nature and extent of contamination is accurately characterized.

As discussed in Section 6.10.1, surficial and subsurface soil impacts should be delineated to the extent necessary to allow for assessment of risks to human health, public welfare and the environment. Delineation criteria are not a hard and fast number, but would depend on a number of site-specific factors. Typically the most conservative delineation criteria would be the lower of the levels protective of residential land use, background levels, or levels that could result in unacceptable contaminant transfers from soil to other media such as groundwater or air.

The number and locations of soil borings necessary to adequately delineate a site will vary from site to site depending on various factors; size of site, distribution of COCs, site hydrology and stratigraphy, exposure model, etc.

### 6.12.1 Logging of Soil and Groundwater Monitoring Well Boreholes

A qualified professional – either by or under the supervision of a Registered Geologist (R.G.) or Professional Engineer (P.E.) registered in Missouri - must log each soil boring to indicate depths correlating with changes in lithology (with lithologic descriptions), occurrence of groundwater, total depth, visual and olfactory observations, and other pertinent data such as a soil vapor screening reading. When a monitoring well is installed, as-built diagrams with depth to groundwater indicated must be submitted for each well. A continuous soil profile from soil borings should be developed with detailed lithologic descriptions. Particular emphasis should be placed on characteristics that may control chemical migration and distribution such as zones of higher or lower permeability, changes in lithology, correlation between soil vapor concentrations and different lithologic zones, obvious areas of soil discoloration, organic content, fractures, and other lithologic characteristics.

All boreholes and probes greater than 10 feet in depth must be abandoned in accordance with 10 CSR 23-4.080(6).

## 6.13 DISTRIBUTION OF CHEMICALS OF CONCERN IN GROUNDWATER

An adequate number of groundwater samples must be collected to:

1. Delineate the horizontal and vertical extent of dissolved groundwater COC plumes and non-aqueous phase liquids (NAPLs), and to identify the exposure domain for each receptor, pathway and exposure pathway combination,
2. Allow calculation of representative COC concentrations for each exposure domain, and
3. Determine the status of the plume (increasing, stable or shrinking).

### 6.13.1 Delineation of Groundwater Impacts

The delineation criteria for groundwater depend on whether the current and potential future domestic use of groundwater, or ecological receptor exposure if applicable, is a complete or incomplete pathway. .

Where the domestic use of groundwater pathway is complete, delineation criteria will be the lower of the following four criteria:

1. The Maximum Contaminant Levels (MCLs) (in the absence of MCLs, risk-based concentrations that assume ingestion of groundwater, dermal contact, and inhalation of vapors due to indoor water use),
2. Land use-dependent concentrations protective of indoor inhalation,
3. Concentrations for the protection of ecological receptors (when present), or
4. Non-domestic uses of groundwater when present.

Where the domestic use of groundwater pathway is determined to be incomplete, the delineation criteria will be based on other potentially complete pathways. Examples are: protection of indoor air due to volatilization of contaminants from the groundwater, exposures that may be encountered by subsurface construction workers, or the discharge of contaminated groundwater to surface water.

Tables in Appendix B provide:

- MCLs or calculated risk-based groundwater concentrations protective of ingestion, dermal contact, and inhalation due to indoor water use,
- Risk-based groundwater concentrations protective of indoor inhalation for resident and non-residential worker, and
- Risk-based groundwater concentrations protective of the construction worker.

Table 5-1 provides water quality criteria for chemicals for which the ecological protection values are lower than the MCLs or where no equivalent groundwater criteria exist in Missouri's Water Quality Standards.

### 6.13.2 Determination of Plume Stability

To assess plume stability, groundwater monitoring must be conducted for a period of time sufficient to show a reliably consistent trend in contaminant concentrations. Sampling and analysis of groundwater must be performed at a frequency and for parameters that are appropriate for site-specific conditions and are sufficient to enable assessment of contaminant trends, natural attenuation rates and seasonal or temporal variations in groundwater quality. Once cleanup levels are achieved, groundwater monitoring must continue for a period of time sufficient to ensure that residual subsurface contamination does not result in recontamination of groundwater above applicable MCLs or levels protective of other pathways, such as migration to surface water or indoor inhalation.

Groundwater monitoring for the purpose of evaluating plume stability must be conducted under a work plan approved by the department. Depending on site-specific data, statistical, graphical or other techniques may be used to demonstrate plume stability.

### 6.13.3 Groundwater Sampling

If groundwater has been contaminated by COCs, direct push sampling methods or temporary sampling points may be used to screen for groundwater contamination and to assist in determining the optimal location of monitoring wells. Monitoring wells must be installed in accordance with Missouri regulations, 10 CSR 23-4.010 through 10 CSR 23-4.080 and the following guidelines:

- An adequate number of monitoring wells must be installed to sufficiently delineate the horizontal and vertical extent of the dissolved and non-aqueous phase groundwater plume and the direction of groundwater flow.

- A sufficient number of monitoring wells must be installed to fully define the groundwater plume to levels protective of applicable exposure pathways.
- Well placement and design must consider the concentration of chemicals in the source area, the possible occurrence of both dense and light NAPLs at the site, presence of multiple water bearing zones, and groundwater flow direction.
- Well casing and screen materials must be compatible with the COCs to be monitored.
- Wells must be properly developed and the water level must be measured after installation.
- A land surveyor is the best qualified to conduct a site survey to establish well elevations and, by that, groundwater elevations. Accuracy should generally be to within plus or minus 0.01 foot relative to an established national geodetic vertical datum (NGVD) or some other appropriate datum. Based on the groundwater elevations, groundwater flow direction and gradient must be determined and plotted on a site map.
- Appropriate geographic coordinates must be identified and documented.

Groundwater samples must be collected in accordance with the approved work plan.

## 6.14 DISTRIBUTION OF CHEMICALS OF CONCERN IN THE VAPOR MIGRATION TO INDOOR AIR PATHWAY

For sites where soil or groundwater concentrations result in the exceedance of Tier 1 risk-based target levels for the vapor migration to indoor air pathway, additional tools and methodologies may be considered on a site-specific basis and implemented as appropriate. These methodologies include modeling, soil vapor monitoring, and/or foundation (crawlspace and subslab)/indoor air sampling. For further details, refer to Appendix H and relevant state and federal guidance, such as the most current version of USEPA's <u>Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils</u>. Soil vapor sampling and foundation/indoor air sampling methodologies would be included in a data collection work plan.

## 6.15 DISTRIBUTION OF CHEMICALS OF CONCERN IN SEDIMENTS AND SURFACE WATER BODIES

When site investigation data or modeling shows or suggests that COCs may have migrated to a surface water body, surface water samples should be collected. If surface drainage pathways are suspected of having been impacted by any site contaminants, sediment (and surface water, if present) from those pathways should also be sampled. Sediment analyses should include an analysis of sediment pore water to adequately characterize impacts in the hyporheic zone. Sampling must consider the representativeness of the samples with regard to the flow conditions. Water samples must be collected both upstream and downstream of each area where a discharge of contaminated groundwater is suspected.

If site investigation data shows or suggests that contaminated groundwater is discharging to surface water, sediment samples must be collected. The remediating party must compare the sediment sample data with sediment standards that are protective of human health and ecological receptors that can be obtained from literature or develop site-specific levels. The development of site-specific sediment standards would be considered a Tier 3 activity and would require a pre-approved work plan.

## 6.16 COLLECTION AND ANALYSES OF ENVIRONMENTAL SAMPLES

The remediating party must exercise extreme care in the collection of environmental samples. This guidance focuses on data necessary for the MRBCA evaluation; it does not identify specific field sampling techniques and laboratory analytical methods to be used. The remediating party must collect all environmental samples using appropriate methods.

The remediating party must document the details of collecting and analyzing the samples in the work plan and obtain the department's approval prior to collecting the data. Failure to do so may result in the collection of data not acceptable for MRBCA evaluation and additional sampling may be required.

## 6.17 INFORMATION SOURCES FOR DATA COLLECTION

The above sections present an overview of the data needed to develop the conceptual site model, and delineate releases for preparation of a risk-based evaluation. Whereas it is relatively easy to determine the categories of data required, it requires considerable judgment, knowledge and experience to determine the location and number of samples to be collected and analyzed and the sampling and analytical methodologies to be used in data collection.

The following selected references can assist the user in developing a comprehensive work plan, identifying data gaps, and planning and implementing fieldwork.

- Missouri Department of Natural Resources, Quality Management Plan for Missouri Department of Natural Resources (Refer to most current version).

- EPA, 1998, EPA Requirements for QAPPs for Environmental Data Operations. EPA QA/R-5, USEPA, Quality Assurance Division, Washington, D.C.

- EPA, 1998. Guidance for Data Quality Assessment: Practical Methods for Data Analysis, EPA QA/G-9, QA97 update, Office of Research and Development, EPA/600/R-96/084, Washington, D.C.

- EPA, 1997. Expedited Site Assessment Tools for Underground Storage Tank Sites, EPA/510B-97-001, Office of Solid Waste and Emergency Response, Washington, D.C.

- ASTM, 1995. Standard Guide for Developing Conceptual Site Models for Contaminated Sites: E 1689-95.

- EPA, 1994. Guidance for the Data Quality Objectives Process, EPA QA/G-4, Office of Research and Development, EPA/600/R-96/055, Washington, D.C.

- EPA, 1993. Data Quality Objectives Process for Superfund, Interim Final Guidance, EPA/540-R-93-071, Office of Solid Waste and Emergency Response, Washington, D.C.

- EPA, 1992. Guidance for Data Usability in Risk Assessment, Part A, Office of Solid Waste and Emergency Response, 92857-09A, Office of Emergency and Remedial Response, Washington, D.C.

- EPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, OSWER-9335.3-01, Office of Solid Waste and Emergency Response, Washington, D.C.

- EPA, 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document Draft, OSWER-9950.1, Office of Solid Waste and Emergency Response, Washington, D.C.

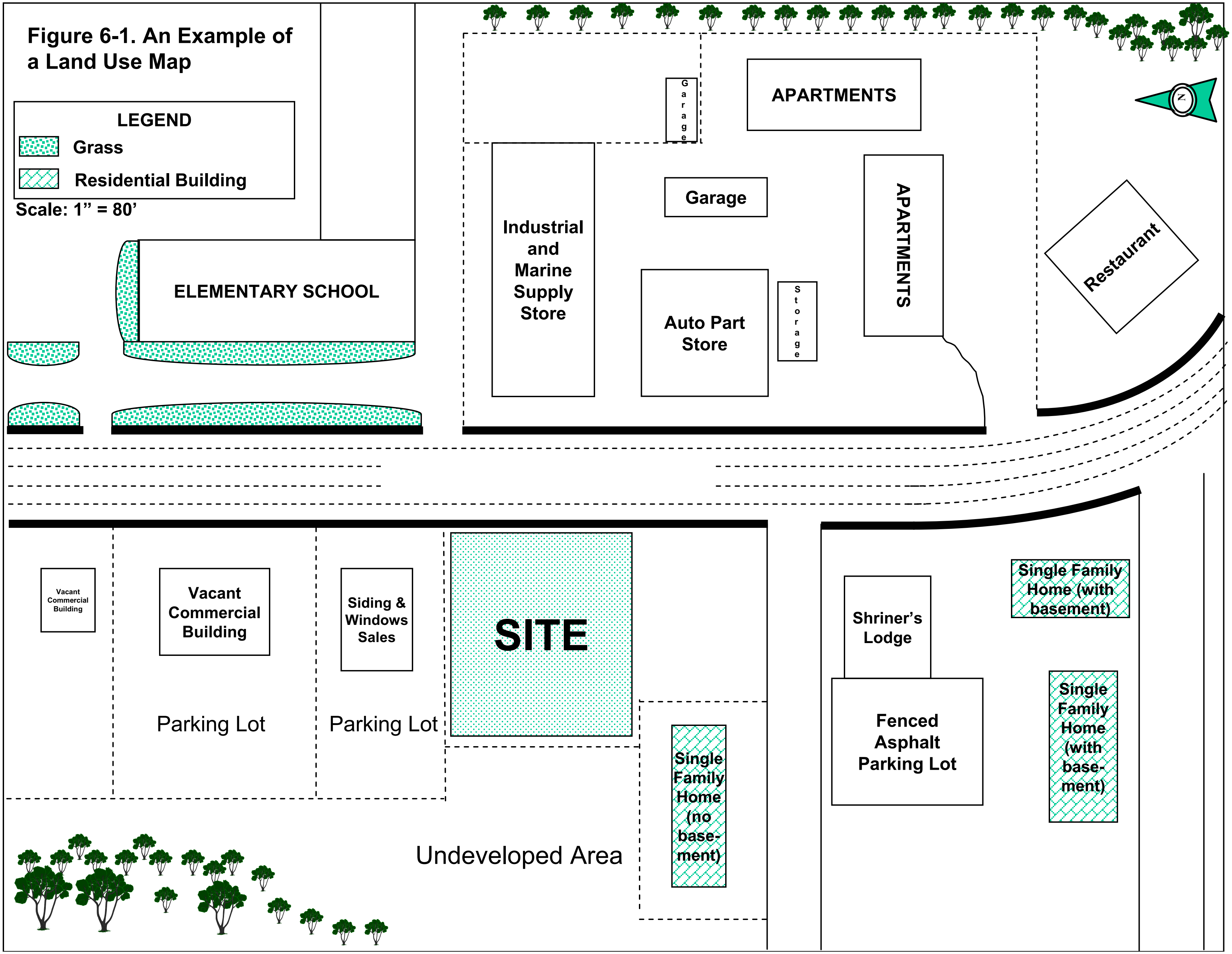


Figure 6-1. An Example of a Land Use Map

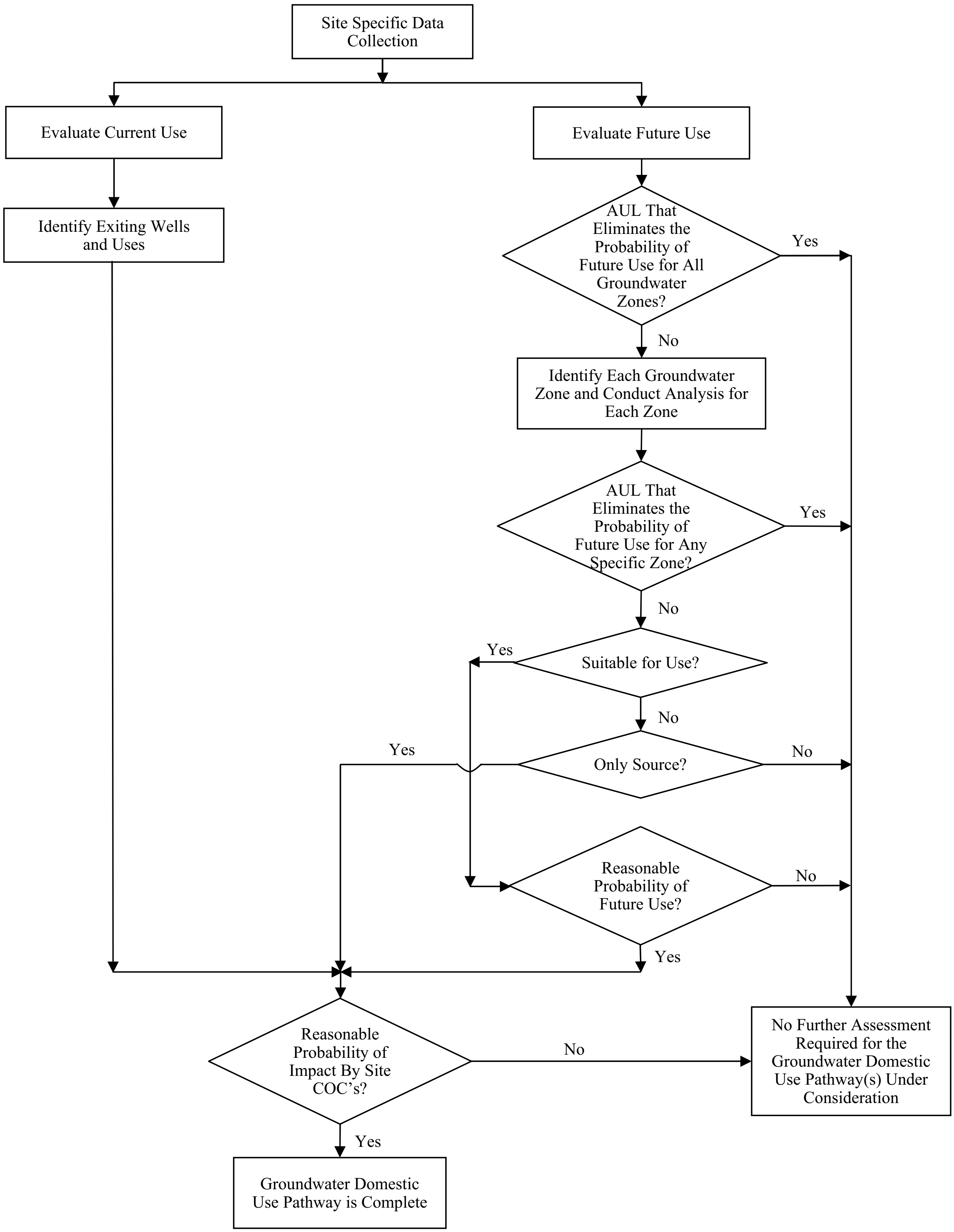


**Figure 6-2. Domestic Consumption of Groundwater Exposure Pathway Analysis**