

**KANSAS RISK-BASED CORRECTIVE ACTION
FOR PETROLEUM STORAGE TANKS SITES
(KRBCA MANUAL)**
July, 2011



Kansas Department of Health and Environment

Bureau of Environmental Remediation

Storage Tank Section

SECTION 1.0 BACKGROUND AND INTRODUCTION

- 1.1 Introduction
- 1.2 Kansas Regulations Related to Corrective Action Process for Storage Tank Sites
- 1.3 Step-by-Step Description of the KRBCA Process
 - 1.3.1 Preliminary Release Investigation and Confirmation
 - 1.3.2 Emergency Action If Required
 - 1.3.3 Documentation of Release Investigation
 - 1.3.4 Determination of Site Rank
 - 1.3.5 Site Assessment
 - 1.3.6 Tier 2 Risk Evaluation
 - 1.3.7 Tier 3A Risk Evaluation
 - 1.3.8 Collection of Additional Data
 - 1.3.9 Tier 3B Risk Evaluation
 - 1.3.10 Tier 3C Risk Evaluation
 - 1.3.11 Development of a Corrective Action Plan

SECTION 2.0 THE KANSAS RBCA PROCESS

- 2.1 Introduction
- 2.2 Purpose and Applicability of This Document
- 2.3 Overview of the KRBCA Process
 - 2.3.1 Work Plan and Preliminary Planning
 - 2.3.2 Review of Existing Facility Information
 - 2.3.3 Performance of Receptor Survey
 - 2.3.4 Development of a Site Conceptual Exposure Model
- 2.4 Data Collection Activities
 - 2.4.1 Introduction
 - 2.4.2 Data Collection
 - 2.4.3 Monitoring Well Placement
 - 2.4.4 Data Evaluation and Refinement of the Conceptual Model
- 2.5 Recommended Laboratory Analytical Methods
 - 2.5.1 Introduction
 - 2.5.2 Laboratory Analytical Methods

SECTION 3.0 RISK-BASED EVALUATION: GENERAL CONSIDERATION

- 3.1 Introduction
- 3.2 Chemicals of Concern
- 3.3 Land Use
- 3.4 Receptors
- 3.5 Exposure Routes
- 3.6 Site Conceptual Exposure Models (SCEM)
 - 3.6.1 Development of Site Conceptual Exposure Models
 - 3.6.2 Point of Exposure
- 3.7 Calculation of Risk Based Target Levels
 - 3.7.1 Target Risk Level
 - 3.7.2 Quantitative Toxicity Factors
 - 3.7.3 Exposure Factors
 - 3.7.4 Fate and Transport Parameters
 - 3.7.5 Mathematical Models
- 3.8 Estimating Groundwater Compliance Well Concentration
- 3.9 Protection of Deeper Groundwater
- 3.10 Ecological Exposure
- 3.11 Estimating Impacts to Surface Waters
- 3.12 Management and Control of Nuisance Conditions or Conditions
- 3.13 Documentation of the KRBCA Evaluation
 - 3.13.1 Tier 2 and Tier 3A Evaluations
 - 3.13.2 Tier 3B evaluations
 - 3.13.3 Tier 3C Evaluations
- 3.14 Computational Aspects of KRBCA Evaluation

SECTION 4.0 TIER 2 EVALUATION

- 4.1 Overview
 - 4.1.1 Development of a Site Conceptual Exposure Model
 - 4.1.2 Selection of Relevant Tier 2 RBSL's
 - 4.1.3 Comparison of RBSL's with Maximum Site Concentration
 - 4.1.4 Selection of Next Course of Action

SECTION 5.0 TIER 3A EVALUATION

- 5.1 Site Characterization
- 5.2 Development of A Site Conceptual Exposure Model

- 5.3 Selection of Relevant Tier 3A Risk Based Screening Levels
- 5.4 Comparison of RBSLs with Site Concentrations
 - 5.4.1 Soils
 - 5.4.1.1 Surface Soil
 - 5.4.1.2 Subsurface Soil
 - 5.4.2 Groundwater
- 5.5 Selection of Next Course of Action

SECTION 6.0 TIER 3B EVALUATION

- 6.1 Development of A Site Conceptual Exposure Model
- 6.2 Input Parameters
- 6.3 Calculation of Tier 3B Levels
- 6.4 Calculation of Representative Concentration
- 6.5 Selection of The Next Course of Action

SECTION 7.0 TIER 3C EVALUATION

- 7.1 KDHE Policy on Conducting Tier 3C Evaluations

SECTION 8.0 REFERENCES

- 8.1 REFERENCES

APPENDICES

- Appendix A Models/Equations for Estimating Tier 3A and Tier 3B Target Levels within the KRBCA Process

TABLES

- Table 3-1 Chemicals of Concern for Different Product Releases
- Table 3-2 Chemical Specific Toxicity Parameters
- Table 3-3 Chemical Specific Fate and Transport Properties
- Table 3-4 Tier 2 and Tier 3A Default Exposure Factors
- Table 3-5 Tier 2 and Tier 3A Default Fate and Transport Parameters
- Table 4-1 Tier 2 Risk Based Screening Levels (from the RSK manual)
- Table 5-1(a) Tier 3A Risk-Based Screening Levels (RBSLs) for a Resident Child
- Table 5-1(b) Tier 3A Risk-Based Screening Levels (RBSLs) for a Resident Adult
- Table 5-1(c) Tier 3A Risk-Based Screening Levels (RBSLs) for a Commercial Worker
- Table 5-1(d) Tier 3A Risk-Based Screening Levels (RBSLs) for a Construction Worker
- Table 5-2 Tier 3A RBSLs for Soil Concentrations (for Leaching to Groundwater) for Different Distance to the Groundwater Exposure Point
- Table 5-3 Tier 3A Dilution Attenuation Factors

FIGURES

- Figure 1-1 Overview of KRBCA Process
- Figure 3-1 Site Conceptual Exposure Model - Current Conditions
- Figure 3-2 Site Conceptual Exposure Model - Future Conditions
- Figure 3-3 Schematic of Soil Leaching to Ground Water Pathway (Domenico's Model)

ATTACHMENTS

- Attachment 1 Corrective Action Policy Manual (CAP)

BACKGROUND AND INTRODUCTION**1.1 INTRODUCTION**

The Kansas Department of Health and Environment (KDHE) Storage Tank Section (STS) faces the task of regulating environmental cleanups of over 2,000 active petroleum storage tank sites. KDHE administers the Petroleum Storage Tank Release Trust Funds, which provide financial assistance for corrective action to eligible owners and operators (O/O) of Underground Storage Tanks (USTs) and Above ground Storage Tanks (ASTs). The approved remedial costs will be reimbursed as long as the requirements of the programs are met. This document in no way changes the requirements for competitive bidding and pre-approval of costs and work for sites participating in the reimbursement funds program. In addition to the sites which are eligible for and participating in the reimbursement fund programs, there are a number of sites where O/Os must or choose to perform remedial action using their own resources. The process described in this document is applicable to both reimbursable and non-reimbursable sites.

In 1992, KDHE STS began using a priority ranking system, based upon the risk a site poses to the public, to determine appropriate corrective action measures to be performed. Given limited resources, there is a clear need for a regulatory program that allows the efforts of responsible parties and of KDHE STS to be focused on those sites that pose unacceptable current and/or future risks. KDHE STS will continue to use the ranking system, but has developed Risk-Based Standards (RSK) and added a Risk-Based Corrective Action (RBCA) program for the assessment, remediation, and closure of leaking petroleum storage tank sites. The RBCA program will allow STS to establish remedial levels for sites based upon site circumstances rather than using generic numeric standards. This approach should reduce delays in closure of lower priority sites while continuing to provide remedial solutions that are equally protective of human health and the environment.

The Kansas STS RBCA program is based on the RSK standards developed by KDHE and the Risk based Corrective Action Applied at Petroleum Release Sites, Standard E 1739, issued by the American Society of Testing Materials (ASTM, 1995). This ASTM standard has been modified for consistency with the KDHE regulations and policies as well as the RSK document. The objectives of the program are to protect human health and the environment in the most practical and resource-effective manner, using a consistent and scientifically defensible decision-making process. All work under the program must be conducted in accordance with the KDHE Bureau of Environmental Remediation (BER) QA/QC Policy Manual, the Kansas Underground Storage Tanks Program Corrective Action Policy Manual, all local, state, and federal regulations.

This guidance document is not intended as a general guide to every aspect of the RBCA process. Prior experience or training will be necessary to correctly implement risk assessment as part of the overall process of site closure. It is hoped that, as environmental professionals and responsible parties gain experience with this approach, they will provide comments to KDHE STS. These comments will be evaluated in light of KDHE's experience to determine if it is in the best interests of the program and the people of the state of Kansas to modify the RBCA process. This guidance document will be updated and revised by KDHE to reflect any such modifications.

1.2 KANSAS REGULATIONS RELATED TO CORRECTIVE ACTION PROCESS FOR STORAGE TANK SITES

Kansas Administrative Regulations (K.A.R.) 28-48 Parts 1 and 2, requires that UST releases, and all AST releases that cause or threaten to cause soil or water contamination, be reported to KDHE. The Kansas Storage Tank Act was passed in May of 1989 to establish the Petroleum Storage Tank Trust Fund and provide KDHE with statutory authority to adopt federal UST regulations. In November 1990, K.A.R. 28-44-12 through 28-44-27 were promulgated. K.A.R. 28-44-24 adopts release reporting, investigation, and confirmation requirements contained in 40 CFR 280.50 through 280.53. K.A.R. 28-44-25 adopts the release response and corrective action requirements contained in 40CFR 280.60 through 280.67.

1.3 STEP BY STEP DESCRIPTION OF THE KS RBCA PROCESS

Figure 1-1 describes the KRBCA (Kansas Risk Based Corrective Action) process that includes a range of site-specific activities that begin with the first notice of a suspected release. This process continues until KDHE determines that the residual site-specific concentrations are protective of human health and the environment. Upon completion of this process, KDHE will issue a closure letter provided that (i) the KRBCA process has been correctly implemented, and (ii) the future use of the site is consistent with the assumptions used in the evaluation.

The KRBCA process integrates the elements of site characterization, exposure assessment, risk calculations, and risk management (including corrective action and risk communication) to determine site-specific chemical concentrations protective of human health and the environment. Each element of the process is important and has to be correctly applied for the adequate protection of human health and the environment.

A description of the KRBCA process is presented below:

1.3.1 Preliminary Release Investigation and Confirmation

Once a release or suspected release has been reported, a preliminary investigation and confirmation is conducted by an environmental consultant hired by the responsible party, or by KDHE staff. The investigation may be triggered by one or more of the following:

- Suspicion from non-environmental evidence;
 1. Tank or line tightness test failure
 2. Inventory shortage

- Suspicion from environmental evidence;
 1. Unexplained hydrocarbon odors on or off-site
 2. Unexplained surface water sheet down gradient of the property
 3. Sheen or free phase product on water in observation tube or vapor monitoring well installed for release detection in a UST basin

- Confirmed environmental contamination;
 1. Free product found below the ground surface
 2. Soil contaminant levels exceeding the Kansas Action Levels (KALs) listed in the RSK Manual incorporated in KRBCA as tier 2 levels (Attachments 1 & 2 of the KDHE Corrective Action Policy Manual.)
 3. Groundwater contaminate levels exceeding the Kansas Action Levels (KALs) listed in the RSK Manual incorporated in KRBCA as tier 2 levels (Attachments 1 & 2 of the KDHE Corrective Action Policy Manual).

As a follow-up on a reported release or complaint of a suspected release, KDHE staff may take one or more of the following actions:

1. Instruct the O/O, through a licensed contractor, to conduct a tightness test of the storage tank system
2. Instruct the O/O to submit inventory control or other applicable records for examination.
3. Conduct a site visit to perform a compliance inspection
4. Conduct a site visit to collect soil and/or water samples for field and/or laboratory analysis

1.3.2 Emergency Action If Appropriate

If KDHE STS staff determine that the site poses an immediate threat to the public, any action necessary to alleviate that threat will be conducted under the direction of KDHE. Impacted utilities and/or vapors in structures automatically deem the site an emergency. If the release was originally reported to one of the six KDHE District Offices, central office staff will be informed that a release has occurred. All emergency action will be coordinated between district and central office staff. Once the immediate threat has been mitigated, the site will be handled in the same manner as other non-emergency sites.

1.3.3 Documentation of Release Investigation

The KDHE representative will generate a Buried Tank Leak Assessment (BTLA) or Above Ground Tank Leak Assessment (ATLA) report documenting the activities performed to determine if a release has occurred, the results of these activities, and any measures taken to abate and mitigate a confirmed release. A copy of the BTLA/ATLA will be provided to the responsible party and to the KDHE STS central office staff. The BTLA/ATLA will indicate the status (active, closed, hold, monitor) assigned to the site by the District Office representative based on their initial assessment.

KDHE staff will give written notification to the tank O/O if contamination is confirmed. The notification will state if an investigation will be required to determine the degree and extent of contamination. This notification may be in the form of a copy of the BTLA/ATLA, with or without a cover letter. If an investigation is required (see 1.3.5 below), or if any costs were incurred that could be reimbursable under the Trust Fund Program, a KDHE representative will provide a Trust Fund

Application to the O/O. A copy of the BTLA/ATLA and any other relevant documents will be filed with the STS. A confirmed release must be documented in order to participate in the Trust Fund Programs.

1.3.4 Determination of Site Rank

STS staff rank the site to determine the order in which sites will be addressed. Initial corrective action procedures are also determined by a site's ranking score. Ultimate corrective action procedures will be determined, in large part, by KRBCA. The ranking process considers site-specific information in the BTLA/ATLA as well as information obtained from the following: nearby petroleum storage tank sites; the KDHE Bureau of Water (BOW) water well data base; scientific publications on regional and area geology and hydrogeology; observations on land use and history of land use in the area; and any other available relevant information. Those sites that appear to present the greatest risk to the public will be addressed first.

The KDHE STS's priority ranking system uses seven criteria (water use, site hydrologic characteristics, product released, public and private property risk, public utilities threatened or affected, and the degree and extent of contamination) to determine the potential risk to human health and the environment. A numeric value is assigned for each criterion, and the values for all criteria, except water use, are summed for a site-specific subtotal. The site subtotal is then multiplied by a water use factor between one and three. This factor is based on the number of public and/or domestic water supplies and lawn and garden wells within 1/4 mile of the site.

Depending on the site rank, the KDHE may direct the responsible party to conduct a site assessment or an investigation and remediation. The latter would typically be required at sites that are deemed to provide an unacceptable risk to human health and the environment.

1.3.5 Site Assessment

If required, an investigation may be conducted under one of the scenarios listed below.

- Participation in the Petroleum Storage Tank Release Trust Funds

If an application is submitted to the Petroleum Storage Tank Release Trust Fund reimbursement program and is approved, the investigation will be conducted as directed by Trust Fund staff in the KDHE central office. District Office staff will be consulted for information about the site and the area. Trust fund staff will keep the District Office staff informed of activities being conducted and the status of the investigation.

- Investigation Through the Federal Leaking Underground Storage Tank (LUST) Program

If the site is not eligible for participation in the Trust Fund, or no application is submitted, the investigation may be conducted under the federally funded LUST program under the direction of the LUST Program staff. Note that cost recovery is mandated under the LUST Fund Program.

District Office staff will be consulted for information about the site and the area. LUST Fund staff will keep the District Office staff informed of activities being conducted and the status of the investigation.

- **Investigation Without Financial Assistance**

The O/O may be required, or may choose, to conduct the investigation without funding assistance. The investigation and any subsequent activities will be performed as directed by District Office staff. District Office staff will coordinate all RSK and RBCA activities with central office staff and keep them informed of the status of the investigation. In order to maintain consistency in the application of RSK and RBCA throughout the state, central office staff will have authority for all RSK and RBCA program decisions.

In each case, the objective of site assessment remains the same, i.e., characterization of the source and soil and groundwater impacts, identification of receptors, assessment of flow direction etc. The specific activities conducted will be determined on a site-specific basis.

1.3.6 Tier 2 Evaluation

Tier 2 evaluation requires the comparison of maximum soil and groundwater concentrations with Tier 2 RBSLs included in Attachment 1 of the KDHE Corrective Action Policy Manual. Tier 2 evaluations are valid only for sites where indoor inhalation of vapors from soil or groundwater is not a complete pathway. For the COCs relevant to the STS, the Tier 2 RBSLs are presented in Section 4. Depending on the result of the comparison, the responsible party may request no further action from KDHE, adopt Tier 2 RBSLs as the cleanup levels and develop a corrective action work plan to achieve these levels, or proceed to a Tier 3A evaluation. Details of this step are discussed in Section 4.

1.3.7 Tier 3A Evaluation

Tier 3A will involve the development (or revision if one is already available) of a site conceptual exposure model to identify all the receptors and routes of exposure. For the complete routes of exposure, the responsible party should select the Tier 3A RBSLs from the tables referenced in Section 5. The RBSLs have to be compared with the representative site concentrations to determine the next course of action. This comparison may result in a request to KDHE for no further action, adoption of the RBSLs as cleanup goals and the development of a corrective action plan, or the performance of a Tier 3B evaluation. Details of a Tier 3A evaluation are presented in Section 5.

1.3.8 Collection of Additional Data

Tier 3B evaluation requires site-specific data related to soil, groundwater, receptors, land use and water use. As a part of this step, the responsible party should evaluate the available data and identify any data gaps. The responsible party should write a data acquisition plan to collect the necessary data and seek KDHE's approval prior to conducting the field work. The specific data to be collected will vary from site to site depending on the site conceptual exposure model and the available data. Upon completion of the data collection effort, the responsible party should write a brief report to document the field work

and use the data to complete a Tier 3B evaluation. Information about data collection is presented in Section 3.

1.3.9 Tier 3B Evaluation

Tier 3B evaluation involves the development of Tier 3B SSTLs as discussed in Section 6 of this guidance document. Tier 3B evaluation requires the use of the same models used in Tier 3A evaluation but allows the use of site-specific data. As part of the Tier 3B evaluation, the Tier 3B SSTLs are compared to the representative concentrations. Depending on the results of the comparison, the following three alternatives are possible:

- No further action if the site concentrations do not exceed the Tier 3B SSTL's,
- Adoption of Tier 3B SSTLs as cleanup levels and the development of a corrective action plan, or
- Request to perform Tier 3C evaluation.

Details of Tier 3B evaluation are presented in Section 6.

1.3.10 Tier 3C Evaluation

Within the KRBCA process, Tier 3C evaluation provides the most flexibility to the responsible party. Tier 3C will allow the use of any fate and transport model as long as it is technically defensible and reasonable. Due to the flexibility available in this evaluation, the responsible party may write a work plan and have it approved prior to initiating a Tier 3C evaluation. The work plan should clearly state the routes of exposure to be evaluated, chemicals of concern, fate and transport models used, input parameters, and other relevant information. It is anticipated that very few sites would actually go to a Tier 3C evaluation. After calculating the Tier 3C SSTLs, the responsible party should compare the representative concentration with these SSTLs. If the site concentrations are exceeded, the responsible party should adopt the Tier 3C SSTLs as the cleanup goals. Alternatively, if the representative concentrations do not exceed the target levels, the responsible party may request site closure. Details of this step are presented in Section 7.

1.3.11 Development and Implementation of a Corrective Action Plan

The responsible party will develop and implement a corrective action plan in a timely manner and in accordance with guidance provided by KDHE. A work plan should be developed and approved by KDHE before initiating the work. The objective of the plan should be to achieve the clean up goals established based on a Tier 2, Tier 3A or Tier 3B evaluation, in a timely and cost effective manner. During the implementation phase, sufficient data should be collected to demonstrate the effectiveness of the plan. Corrective action steps should be taken if performance does not meet the anticipated results. The specific data to be collected and the reporting requirements would vary with the specifics of the remedial option and should be clearly documented in the work plan.

2.1 INTRODUCTION

This chapter defines and outlines the site assessment protocol and requirements for implementing KRBCA process at confirmed petroleum storage tank release sites in Kansas. This guidance is subject to, and intended to be consistent with, the rule established under the Kansas Storage Tank Act and Kansas Administrative Regulations 28-44-12 through 28-44-29. This document emphasizes the collection of the data necessary to conduct appropriate RBCA evaluations. The investigation process outlined herein is intended to allow sufficient flexibility for an experienced consultant retained by the O/O to adequately address each release site. It is ultimately the responsibility of the O/O to complete the required corrective action.

2.2 PURPOSE AND APPLICABILITY OF THIS DOCUMENT

This risk based corrective action program establishes step-by-step procedures to determine:

- the type, quality, and quantity of data to be collected;
- the need for active remediation;
- site target cleanup levels;
- criteria for closure of petroleum storage tank release sites;
- the appropriateness of monitoring as a site management tool; and
- the appropriateness of natural attenuation as a site management tool.

This process shall be applicable to all petroleum storage tank release sites in Kansas regulated under the Kansas Storage Tank Act.

2.3 OVERVIEW OF THE KRBCA PROCESS

The Kansas STS RBCA process requires an assessment to evaluate the area which is or may be impacted by a release. The goal of the assessment is to obtain sufficient data to perform the tier-appropriate risk evaluation and determine clean up levels. The basic tasks necessary to achieve this goal are:

- identification of the nearest actual or potential receptor(s), all appropriate exposure pathways, and any immediate and long-term hazards to human health and the environment;
- identification of areas impacted by chemicals of concern (COC) and determination of the COC concentrations for all appropriate affected media;
- delineation of the horizontal and vertical extent of affected media;
- installation of appropriate well points where groundwater is impacted; and
- identification of any site conditions that could or do control or limit movement of COC through the affected media.

2.3.1 Work Plan and Preliminary Planning

The success of a subsurface site investigation is directly related to the quality of pre-investigative planning. A risk assessment requires the identification of receptors, viable exposure pathways, and transport mechanisms; determination of current and potential future land use; delineation of chemical

source areas; and quantifying the maximum degree of contamination in all affected media. Preliminary planning includes preparation of a work plan. For Trust Fund sites, the work plan must be submitted to the KDHE and approved before conducting intrusive field activities. For other sites, it is recommended that a work plan be submitted to ensure that the investigation will meet the assessment requirements. At a minimum, the work plan must include a review of existing facility information, performance of a receptor survey, development of a site conceptual exposure model, and design of a scope of work for field activities. Development of the site conceptual model, or understanding of the site, requires the collection of all available background information and the performance of a receptor survey. It is essential that the site conceptual model be completed prior to conducting the site investigation and revised, if appropriate, following the receipt of data.

2.3.2 Review of Existing Facility Information

Regional Geology: Review local and regional geologic and/or hydrogeologic maps, nearby site assessments and/or investigation reports and any other pertinent publications. These should be used to determine general soil and lithologic characteristics, regional depth to bedrock, depth to groundwater, aquifer properties, groundwater gradient, and groundwater flow direction. Identify any aquifers and/or surface water bodies serving as sources of drinking water for the area. Identify and evaluate the use and/or potential use of the uppermost groundwater zone within 0.25 miles of the source of chemical release at the facility.

Land Use: Investigate and describe past, current, and potential future uses of the site. Identify potential source areas, migration pathways, and receptors. Determine past and current uses of adjacent properties to identify other potential sources of COC. If an off-site receptor is identified, assessment of the potential risk must anticipate future land use. Future land use assumptions should be based on current use, existing zoning, and development trends of adjacent properties. Document any ordinances preventing or influencing the future installation of water wells at the site or in the surrounding area such as groundwater protection areas. Identify the current predominant land use of the area as residential, recreational, agricultural, or undeveloped.

Source History: Knowledge of the tank system layout is critical to a complete investigation of the source area. Locate current and/or former tank systems and other potential sources such as spills or overflow incidents, both on and off-site. Inventory control records and tank tightness tests may provide valuable data in evaluating possible sources. Investigate any previous assessment work, such as tank removal data, previous site assessments, release investigations and/or remediation activities that may have been conducted on-site and on adjacent properties. The work plan must include a detailed site map of the facility, drafted to scale with a scale bar and north arrow. The map should show the locations of any current or past UST or AST systems, including all tanks, dispensers and piping, and locations and depths of all utilities on and adjacent to the site.

2.3.3 Performance of a Receptor Survey

Actual and potential receptors and exposure pathways are the justification for setting target cleanup levels, and it is of critical importance that they be identified. The receptor survey must include both a records search and a field survey. Water wells must be clearly presented on a vicinity map or a recent aerial photograph of appropriate scale.

Records Search: Obtain a water well records search report from the KDHE Bureau of Water (BOW), covering a minimum distance of 0.25 miles from the source of contamination. Additional sources of information on wells include local and county governments, Kansas Geologic Survey publications, United States Geologic Survey maps, and site visits.

Field Survey: A ground or door to door foot search for water wells must be made within a 500 foot radius of the source of contamination. The field survey must include, but not be limited, to the following:

- **Receptor Identification:** Find all water wells. Find all basements if the depth to groundwater is less than 25 ft below ground surface. Other sensitive receptors, such as surface water bodies, wildlife sanctuaries, and wetlands must also be identified during the field survey; and
- **Migration Pathway Identification:** Determine the location and depth of all subsurface utilities and structures, especially sanitary sewers, that may serve as preferential migration pathways for released COC.

If a receptor is identified, the potential for exposure or impact must be evaluated. When the receptor is off-site, the need for property access must be evaluated. For sites receiving financial assistance from the Trust Fund, written off-site access must be obtained prior to conducting any intrusive field activities, such as installing ground water probes or drilling. Immediate action should be taken to protect receptors known or suspected to be exposed to or impacted by COC. This action may include abatement measures, provision of an alternative water supply, relocation of residents, or any other action deemed appropriate for the specific circumstances.

2.3.4 Development of a Site Conceptual Exposure Model (SCEM)

The information obtained during the preliminary planning phase, together with the specified requirements for a Tier 2 or Tier 3A assessment, is used to develop an initial site conceptual exposure model (see also Section 3.6 and 4.1). The model is a general understanding, or working hypothesis, depicting the relationships between the chemical source areas, including impacted soils and groundwater and non-aqueous phase liquids; transport mechanisms, such as leaching, groundwater flow, and volatilization; receptors, such as residents, groundwater users, and surface waters; and exposure routes, such as inhalation, ingestion, and dermal contact. A conceptual exposure model of the site requires a basic understanding of the following characteristics:

- chemical concentrations and distributions;
- factors affecting chemical transport direction and rate; and
- the potential for chemicals to reach a receptor.

Risk assessment and corrective action decisions must take these characteristics into account. The conceptual model must be re-evaluated throughout the investigative process and modified if necessary to reflect known site conditions. The conceptual model must be described in written form and portrayed in a graphic or tabular format, with appropriate diagrams, maps, and/or cross sections.

2.4 DATA COLLECTION ACTIVITIES

2.4.1 Introduction

The scope of work is the plan derived from the conceptual model used to complete the site assessment, and is developed on a site-by-site basis. For Trust Fund sites, KDHE STS will evaluate individual site

requirements and determine the maximum number of monitoring wells to be installed at the site. The consultant will be responsible for determining the exact location of these wells within the limits specified in Section 2.4.3. For non-Trust Fund sites, the minimum number of wells is specified in Section 2.4.3, and the O/O will, with their consultant, determine the maximum number of wells to be installed. All soil borings and monitoring wells must be installed by a Kansas licensed water well contractor. All drilling activities must be conducted so as to minimize the potential for downward migration of contaminants. This includes the use of Hollow Stem Augers whenever possible.

To meet the minimum requirements of the RSK and RBCA assessment, the scope of work must emphasize characterizing the source area, determining the maximum concentrations of the COCs, and delineating the horizontal and vertical extent of COCs. The plan should include:

- appropriate sampling technology/tools and analytical methods;
- selecting locations for sampling point;
- obtaining off-site access, if necessary;
- evaluating the presence of NAPL and/or vapor-phase hydrocarbons; and
- surface water or groundwater receptors and determining waste management options.

The site investigation must be guided by the scope of work prepared during the preliminary planning phase, however, adjustments to the scope of work and modifications to the conceptual exposure model should be made as data is collected, analyzed, and evaluated during on-going site activities. It is imperative that the consultant performing the investigation remain flexible during the assessment procedure and evaluate all site information in the field to determine the next appropriate activity.

2.4.2 Data Collection

Sampling Technology/Tools: KDHE recognizes that both conventional and innovative sampling technologies can be used effectively during investigations. Site conditions will dictate the appropriate sampling technology/tools to be used. The assessment process is independent of the selected sampling technology. Permanent monitoring wells are required when groundwater is impacted. Temporary groundwater sampling points may be used to select locations for permanent monitoring wells, or to provide additional information. When determining the appropriate data collection method and sampling technologies/tool, the following should be considered:

- purpose and anticipated scope of the site assessment;
- anticipated geologic and hydrologic conditions
- known site features and layout;
- speed by which samples can be obtained;
- urgency of the need for data;
- advantage of using a combination of tools;
- capabilities, limitations, and cost of each tool;
- anticipated chemicals of concern and their concentrations; and
- disturbance to current site conditions or operations.

Field screening techniques should always be used during drilling to guide the subsurface assessment and assist in selection of soil samples to submit for laboratory analysis. All analytical reports submitted to KDHE must be performed by a laboratory certified by KDHE. Field screening equipment must be properly calibrated and be appropriate for the COCs at the site. Continuous profiling of the subsurface and soil vapor field screening should be conducted during drilling and continued until subsurface conditions are well understood or the total depth of drilling is reached. Soil samples should be collected at a minimum of every 5 feet of depth drilled to 50 feet, and every 10 feet of depth drilled below 50 feet.

As the complexity of subsurface conditions increases, the location of field screening data points and results become more important.

Geologic Descriptions: A continuous soil profile should be developed with detailed lithologic descriptions using the Unified Soil Classification System. Particular emphasis should be placed on characteristics such as zones of higher or lesser permeability that appear to control contaminant migration and distribution, changes in lithology, any observed correlation between soil vapor concentrations and lithologic zones, obvious areas of soil discoloration, fractures, and other lithologic characteristics. Soil boring logs must be submitted for each hole drilled at the site. The logs must denote depth correlated to changes in lithology (with lithologic descriptions), soil vapor analyses, occurrence of groundwater, total depth and any other pertinent data. When a monitoring well is installed, as-built diagrams with depth to groundwater denoted must be submitted for each well. Specific requirements for drilling logs and well construction diagrams for Trust Fund Investigations are included in the Limited Site Assessment Request for Proposal (LSA RFP). The KDHE STS encourages consultants performing non-Trust Fund investigations to follow these requirements.

Sample Selection for Chemicals of Concern in Soil: The vertical and horizontal extent of subsurface COC must be defined during the site assessment. At a minimum, discrete soil samples must be collected for laboratory analysis from the following:

- zone of greatest impact above the capillary fringe, based on field screening results; and
- immediately above the saturated zone and
- surficial (0-1 ft bgs) soil if exposure to surface soils is likely.

Additional samples may be necessary to fully characterize the soil COCs distribution and exposure potential for a Tier 3B or Tier 3C evaluation, or for the development of a remedial action plan. Additional information on the selection of soil samples for laboratory analysis is included in the LSA RFP.

Sample Selection for Physical Soil Properties: The sampling plan for measuring soil bulk density, specific gravity, and fractional organic carbon content should be adequate to determine average soil properties across the source area. Samples must also be representative of the soils through which the COCs migrate to reach groundwater. These parameters must be determined on samples not impacted by the release, particularly in the case of fractional organic carbon content. Consideration must be given to collecting additional samples if multiple lithologies are present which might affect transport of the COCs, or if COCs are encountered within multiple lithologies. Default values for physical soil properties must be used to complete a Tier 2 or Tier 3A evaluation. Site specific physical soil properties may be used in subsequent tier evaluations as input parameters for contaminant fate and transport models.

Sample Selection for Chemical of Concern in Surface Water: Appropriate samples should be collected when COCs migration is known or suspected to affect a surface water body. Sample selection should consist of sediment and/or water upstream, downstream, and/or radially from the discharge point(s).

Sample Selection for Chemicals of Concern in Groundwater: If the vertical extent of subsurface impact extends to groundwater, temporary sampling points may be used to screen concentrations in groundwater and to assist in the selection of locations for permanent monitoring wells. A sufficient number of monitoring wells, as per KDHE's direction, should be installed to document COCs migration and groundwater flow. Well placement and design should consider:

- the concentration of COCs in the source area;

- the proximity to potential or impacted receptors;
- the occurrence of non-aqueous phase liquids (NAPLs) at the site;
- hydrologic conditions; and
- groundwater use.

2.4.3 Monitoring Well Placement

Unless directed otherwise by KDHE STS, under Tier 2 or Tier 3A, the O/O's consultant must drill and install a minimum of four (4) monitoring wells. All drilling activities must be conducted so as to minimize the potential for downward migration of contaminants. These wells shall be located as follows:

- one well must be installed in the location, usually at the source, where concentrations are expected to be highest;
- one well must be installed down gradient from the source of the release;
- one well must be installed in a location that will provide data to accurately determine the groundwater flow direction; and
- one well must be installed in an apparent up-gradient direction from any known potential source of release at the site.

These well locations may be modified to address site-specific conditions with prior approval from KDHE or at the direction of KDHE. The point of exposure (POE) well and the point of compliance (POC) well for the Tier 2 evaluations will be established based on site specific conditions.

If groundwater contamination is encountered, or if investigation beyond a Tier 2 evaluation is required, selection of additional sampling point locations for both soil and groundwater should consider the following:

- the source of release(s) or suspected area of major source(s) of COCs;
- the location of potential receptors;
- the physical characteristics of the surface and subsurface as determined through previous investigation or in the preliminary planning phase; and
- contingencies for possible future additional sampling points.

2.4.4 Data Evaluation and Refinement of the Conceptual Model

Data must be interpreted as it is collected during the field investigation. The assimilation and evaluation of soil and groundwater analytical results, subsurface geologic conditions, groundwater flow direction and/or other preferential migration pathways is necessary to ensure that adequate data is collected to completely assess the source area. This evaluation should resolve any data deficiencies and prevent additional unnecessary field mobilizations. Compilation of data into figures such as site maps and cross-sections is required to facilitate evaluation of the data and to refine the conceptual model.

Data collected during a site assessment, site investigation and/or other previous assessments or investigations may be adequate to perform the appropriate tier evaluation for the site. The requirements to complete a tier appropriate evaluation are:

- determination of actual or potential receptors, exposure pathways and both immediate and long-term hazards;
- identification of chemical source areas and maximum concentrations of all affected media;

- delineation of the vertical and horizontal extent of affected media exceeding tier appropriate health-based target levels;
- identification of site conditions which affect or limit chemical movement; and
- adequate tier appropriate monitoring wells when groundwater is affected.

Note that the KDHE STS, for purposes of KRBCA evaluations only, does not consider groundwater to be usable if yield is below 10 gallons per hour. If the water is being used, it will be considered usable regardless of flow. This criteria does not apply to risk based evaluations performed for any other program except the STS.

2.5 RECOMMENDED LABORATORY ANALYTICAL METHODS

2.5.1 Introduction

Qualitative field screening methods assist in the assessment process but cannot replace quantitative analytical methods. The purpose of the analysis will determine the selection of a qualitative or quantitative method. Numerous data points of a lower quality level may provide a better overall picture of site conditions than a few data points at a higher data quality level. A combination of data quality levels, with an appropriate number of data points at each level usually provides the best understanding of the site. Field screening methods may be sufficient to locate source areas, determine the selection of samples for laboratory analysis and/or placement of additional sampling points, and determine the extent of contamination in the subsurface. The relationship between field screening and analytical data is not necessarily linear and direct correlation may not be possible. Field screening methods must be augmented by KDHE-approved quantitative analytical methods.

2.5.2 Laboratory Analytical Methods

All quantitative sample analyses required by KDHE must be performed by a laboratory certified by KDHE. The LSA RFP includes an attachment that lists commonly used EPA analytical methods for the parameters that may be required. The method to be used for TPH will be specified in the Corrective Action Policy Manual (Attachment 1) for the sites not in the Trust Fund; note that KDHE does not certify for TPH methods at this time.

The physical properties of impacted soils affect fate and transport of the COC. In order to evaluate the potential for cross-media partitioning and chemical transport through the subsurface, soil samples should be collected for the following physical property analyses:

- dry bulk density of the unsaturated zone;
- porosity of the unsaturated zone;
- volumetric water content of the unsaturated zone;
- fraction of organic carbon content of the unsaturated zone;
- hydraulic conductivity of the saturated zone.

Soil samples collected to determine physical properties must be collected from a zone that is similar to the zone of probable chemical migration but located in an area that has not been impacted by any released substance. Every attempt must be made to obtain an undisturbed soil sample though the use of appropriate sampling tools such as a Shelby tube or split spoon sampler.

Dry Bulk Density (gm/cc)

ASTM Method D2937

This method involves collecting a core of a known volume of soil and transporting the core to the laboratory for measurement. Accurate measurement of bulk density requires weighing the know volume of soil, i.e. determining both the weight and volume of an undisturbed sample. A thin-walled sampler should be used to minimize disturbance of the soil sample during collection.

Porosity (cc/cc-soil)

No KDHE recommended Method

Many laboratories use dry bulk density and specific gravity data to determine porosity using the following derivation:

$$n = 1 - \frac{P_b}{P_s}$$

where,

- n = porosity (cc/cc)
- P_b = dry bulk density (gm of dry soil/cc of soil)
- P_s = specific gravity or particle density (gm/cc)

Specific gravity or particle density determined using ASTM Method D854.

Volumetric Water Content/Moisture Content (cc/cc):

ASTM Method D2216

This is a gravimetric oven drying method. Because the water content value used in most models is the volumetric water content, a conversion may be necessary and can be performed as follows:

$$O_{wv} = O_{wg} \times (P_b / P_l)$$

where,

- O_{wv} = volumetric water content (cc water / cc soil)
- O_{wg} = gravimetric water content (gm water /gm soil)
- P_b = dry bulk density (gm of dry soil/cc of soil)
- P_l = density of water (gm/cc)

Fraction Organic Carbon Content in Soil (g_c/g_s)

ASTM Method D2974

Results should be presented as Total Organic Matter and Total Organic Carbon. ASTM Method D2974 generally reports Total Organic Matter. The Total Organic Matter value must be divided by 1.724 to arrive at percent or Total Organic Carbon content.

Hydraulic Conductivity (cm/sec)

Aquifer Pumping Test

This method involves pumping groundwater at a steady rate from a well and measuring water level changes (aquifer response) over time in the pumped well and nearby observation wells. The rate of drawdown and recovery of water levels, once pumping has ceased, can be used to determine hydraulic conductivity. This test provides an estimate of the average conditions near the test and observation wells. Since this is a time consuming and “expensive” test, it is recommended primarily in situations where a pump and treat or an interceptor trench type remediation system is necessary.

ASTM Method D5084

This method is the “Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter” and should be used with undisturbed samples that are estimated to have a hydraulic conductivity of less than or equal to $1\text{E-}03$ cm/sec.

ASTM Method D2434

This method is the “Standard Test Method for Permeability of Granular Soils (Constant Head)” and should be used for soils with hydraulic conductivity greater than $1\text{E-}03$ cm/sec.

ASTM Method D422, Grain Size Distribution

Under certain circumstances KDHE may direct the O/O to use an alternative method for determining the hydraulic conductivity. One of these alternatives would be to perform a sieve test and estimate the hydraulic conductivity based on grain size distribution for the soil sample. Refer to “*Correlation of Permeability and Grain Size*” (Russell G. Shepherd, 1989).

EPA 9100.3, Slug or Bail-down Tests

Slug tests to determine hydraulic conductivity are not recommended where a monitoring well is installed such that the screened interval intersects the water table. The hydraulic characteristics of the sand pack in a well constructed in this manner can significantly influence the results of the tests because the initial results after a slug is added or removed from the well reflect the characteristics of the sand pack, not the formation. Where the screened interval of a monitoring well is submerged below the water table and intersects the lithology of concern, the well may be suitable for slug tests. However, under these circumstances the results should still be carefully reviewed.

RISK-BASED EVALUATION: GENERAL CONSIDERATIONS**3.1 INTRODUCTION**

A risk-based evaluation requires consideration of the relevant COCs and their properties, current and future land use, receptors, exposure pathways, target risk levels, target cleanup levels, and other factors. Several of these issues are common to all the Tiers and are discussed below.

3.2 CHEMICALS OF CONCERN

As mentioned in Section 1.1, KDHE Storage Tank Section is responsible for ensuring the cleanup of petroleum storage tank releases including, but not limited to, the following petroleum products:

Gasoline	Fuel Oil	Jet Fuel
Kerosene	Diesel	Used Oil

Each of these products is a complex mixture of numerous hydrocarbon compounds and additives, such as anti-knock agents, corrosion inhibitors, and anti-oxidants. No unique composition exists for any of these products. The actual composition of the product being addressed varies depending on the original source, age, temperature, and other factors and conditions. KDHE has identified a limited set of key components for each type of product that pose the majority of the risk associated with that product. These COCs will determine the scope of the KRBCA evaluation. Other chemicals may be added to the list as new data on toxicity becomes available.

The behavior of these products, and their toxic effects, depend on the physical and chemical properties of the individual constituents, their concentrations, and the characteristics, including the presence of other contaminants in the environment in which they are located. For some sites it may also be necessary to consider other constituents of the released product. In such situations, KDHE may require sampling for additional chemicals of concern.

Depending on the product spilled, it will be necessary to sample the soil and groundwater for the COCs identified in Table 3-1, and develop target levels for the specified COCs. The development of target levels is presented in Section 3.7. For Tier 2 and Tier 3A evaluations, risk based screening levels (RBSLs) have been calculated by KDHE and are discussed in Sections 4 through 7. For Tier 3B and Tier 3C evaluations, site specific target levels (SSTLs) will have to be developed for each COC and each complete route of exposure as discussed in Sections 6 and 7.

3.3 LAND USE

This section describes the role of land use in the KRBCA process. The KRBCA process is used to determine whether or not acceptable levels of risk exist at a petroleum storage tank release site for any current or likely future uses of the site and surrounding area. The use of a site and surrounding area affects the activities which occur on the site and also determines the potential for exposures consistent with these activities.

The terms “activity” and “use” describe site-specific attributes that affect exposure to human or environmental receptors. For the purpose of this document, “use” refers to the land itself, and is generally a broader term than “activity”. The terms residential, commercial and industrial describe site use. “Activity” describes actions which, when engaged in by a receptor at a site, could potentially affect the nature and types of exposure. Activities would include such actions as fishing, swimming and construction.

In order to adequately evaluate exposure, a risk assessment must identify and describe the activities and uses associated with the impacted site and the surrounding environment. Information about the current and foreseeable uses of the site is necessary to identify exposure points, exposure pathways, receptors, and to ensure that the risk assessment decisions are protective of future resources. The exposures to be considered in a human health or environmental risk assessment will depend upon the activities which could occur under the current and likely future uses of the land and groundwater at the site.

There is little ambiguity about current use, which can be observed and documented under actual circumstances. Future use, however, is hypothetical; it has not yet occurred, and may be changed or avoided by institutional controls or other means. Current uses and activities must be identified and evaluated relative to the protection of present receptors. Likely future uses and activities must be identified based on local zoning ordinances, current land use, knowledge of changing land use patterns, and any other relevant factors, and must protect against potential future exposures.

3.4 RECEPTORS

The objective of risk assessment is to quantify the adverse health effects of the COC on current as well as likely future receptors. For human health risk assessment, the receptors to be considered include persons who live within 500 feet of the site or 100 feet from the contaminant plume if the plume is greater than 500 feet in length and/or width. A distance of 500 feet is selected because historic data indicates that COC plumes at leaking petroleum storage tank sites do not usually exceed 500 feet. For residential receptors, risk to both adults and children should be evaluated. Risk to adults who work in the area as industrial or commercial workers should be evaluated. Additional, risks to construction workers should also be considered. Thus, the receptors of concern for human health risk assessment include:

Residential - Adult
Residential - Child

Commercial/Industrial Worker
Construction Worker

Each of these receptors may be exposed to site specific chemicals by several routes of exposure as discussed in Section 3.5.

3.5 EXPOSURE ROUTES

An adverse health effect cannot occur unless a receptor is exposed to a chemical. KDHE STS has identified the following as the most commonly encountered routes of exposure:

For surface soil (0 - 1 ft bgs)

- leaching to groundwater followed by potential ingestion of groundwater; and
- ingestion of soil, dermal contact with soil, and outdoor inhalation of volatile and particulate emissions.

Exposure by leaching to groundwater followed by potential ingestion of groundwater must always be evaluated. The other routes of exposure associated with surficial soil may not need to be evaluated *if* the site is paved *and* the pavement is likely to stay in good condition or surficial soils are not impacted.

For subsurface soil (1 ft bgs to water table)

- indoor inhalation of volatile emissions;
- leaching to groundwater followed by potential migration of groundwater; and

- ingestion of soil, inhalation of vapors and particulates from soil emissions, and dermal contact with soil (construction workers only).

For purposes of KRBCA, KDHE STS has assumed that construction workers will not be working at depths greater than 10 feet below ground surface, and therefore, only contaminated subsurface soil to 10 feet below ground surface needs to be evaluated as a route of exposure for construction workers. Note for the construction worker, no distinction is made between the surface and subsurface soil.

For groundwater:

- ingestion of water at the most reasonable point of exposure; and
- indoor inhalation of volatile emissions.

Indoor inhalation pathway may not be evaluated where the depth to groundwater or the top of the contaminated soil is more than 15 feet below the bottom of the structure and there is no separate phase product in the soil or above the water table. Each of these routes of exposure for soil and groundwater must be considered. Depending on land and groundwater use, some of these routes of exposure may be incomplete and need not be included in risk calculations.

Different receptors may be exposed by the same route of exposure. For example, a groundwater plume may have migrated below an on-site commercial building and an off-site residential building. Thus both the on-site commercial worker and the off-site resident are exposed by indoor inhalation. In this case the risk by indoor inhalation has to be evaluated for both receptors.

At sites where other routes are considered significant, such as the ingestion of produce grown in impacted soils, or exposure routes related to the use of impacted water for irrigation, the KDHE should be contacted for additional guidance.

3.6 SITE CONCEPTUAL EXPOSURE MODELS

For a Tier 2 and Tier 3 analysis, the user must conduct a qualitative evaluation to determine the mechanisms by which chemicals of concern will move from an affected source medium to the exposure point where contact with the receptor occurs. As discussed in Section 4, Tier 2 focuses on a few complete routes of exposure and is applicable to sites where only the selected routes of exposure are complete. If this migration or contact is not possible under current and likely future conditions, the site-specific chemicals cannot pose a risk. Factors that could prevent migration or contact are: engineering controls such as paving that prevents human contact with impacted soil, and owner imposed institutional controls such as deed restrictions that restrict activities that can be conducted on the property. This qualitative evaluation is facilitated by developing site conceptual exposure models as discussed below.

3.6.1 Development of Site Conceptual Exposure Models

Site Conceptual Exposure Models (SCEMs) identify the factors and their interactions that could result in the human uptake of harmful chemicals. These factors include the chemicals released from the source, the media of concern, and potential receptors. The SCEM identifies potential receptors, pathways by which chemicals migrate from the source to each receptor, and the routes of exposure associated with each pathway for each receptor.

The development of a SCEM is required for all the tiers. At most sites, two SCEMs should be developed; one for current site conditions and one for likely future site conditions. In some cases, additional SCEMs may be developed for short term current or future activities, during which different

receptors may be exposed for a short duration. An example of a likely future short-term activity would be the “future construction scenario” in which the construction worker would be the primary receptor.

By way of illustration, Figure 3-2 shows the SCEM for (future conditions) an inactive fenced gas station located in an area of mixed residential and commercial land use. Investigation revealed that the shallow water bearing zone is located at a depth of 8 feet, has very low yield and hence cannot be developed for use. Shallow impacted groundwater contamination has traveled off-site below residential property.

Because the site is located in a mixed land use area, the most conservative future use of the site is residential. The complete routes of exposure include:

On-Site Receptors: Residents

Current Conditions:

The site is vacant and fenced, hence there are no on-site receptors for current conditions.

Future Conditions:

- Indoor inhalation from groundwater
- Indoor inhalation from contaminated subsurface soil
- Dermal contact, ingestion of surface soil, and outdoor inhalation of vapors and particulates from surficial soil

Off-Site Receptors: Residents

Current & Future Conditions:

- indoor inhalation of vapors from groundwater

Additionally, the risk to construction worker from the following three pathways should be evaluated;

- Dermal contact, ingestion and outdoor inhalation of vapors from soil

Please note, the groundwater protection pathway is always complete. Therefore the leaching to groundwater from surficial and subsurface soils and point of compliance concentrations must also be evaluated.

If the property owner elects to use institutional controls, such as, the property will be used for commercial purposes only, KDHE STS will evaluate the risk assessment based on future on-site commercial use.

A SCEM must be presented in either graphical or tabular format. In either case the objective is to identify the complete pathways and routes of exposure.

It is important to document the evaluation of all source-pathway-receptor-route combinations. The rationale for combinations considered complete must be given. Combinations that are being eliminated must be clearly stated, and the rationale for eliminating them given. The final list of selected combinations should be clearly summarized. This will facilitate review by KDHE STS and any other interested party.

3.6.2 Point of Exposure

When developing the SCEM, it is important to specify the point of exposure (POE) for each receptor and for each route of exposure. The closer the point of exposure is to the site, the lower the risk based target concentrations will be.

For the groundwater pathway, the POE is the location or point, such as a drinking water well or spring, where the receptor comes in contact with the chemical of concern. The nearest current and likely future location of a drinking water well is determined based on site-specific conditions. For example, if a site is surrounded by a residential area, a neighbor could drill a drinking water well at the property boundary. In this situation the property boundary should be used as the potential point of exposure. If there is a wide, busy street located adjacent to the site, however, it is unlikely that a drinking water well would be drilled at the property boundary. The nearest POE for groundwater in that direction would then be a well located on the other side of the street. In no instance will the POE be located greater than 500 feet from the source.

The location of the critical or nearest POE at sites that do not meet the above descriptions will be based on site-specific considerations including but not limited to:

- any federal, state, county, city or municipal restrictions on drilling wells;
- water well completion details, e.g. depth of the screened interval in existing water wells relative to shallow water bearing vs. deeper aquifers, and well construction technique;
- existing drinking water well locations;
- structural features that might restrict future drilling of a drinking water well, such as a major highway or a building;
- the history of groundwater use in the site vicinity;
- the source of water, such as private or public water supplies, for the area;
- contact between groundwater and surface water bodies in the area; and
- lack of usable quantities of groundwater

The location of the POE must be established and agreed upon up front with KDHE to avoid unnecessary iterations in completion of the KRBCA evaluation. Acceptable concentrations at the point of exposure (i.e. the MCL values) are used to back calculate the acceptable soil concentrations at the source and acceptable concentrations in the compliance well (see Sections 3.7 and 3.8).

3.7 CALCULATION OF RISK BASED TARGET LEVELS

As part of the KRBCA evaluation, risk based target levels have to be developed (Tier 3B & 3C evaluation) for all the relevant receptors and complete routes of exposure. For example, at a site where the groundwater plume is located below a commercial building and has migrated off-site below residences, groundwater concentrations protective of indoor inhalation for an on-site commercial worker will be applicable for the on-site plume whereas concentrations protective of a resident will be applicable to the off-site plume.

For Tier 2 and Tier 3A evaluations, the RBSLs have been calculated by the KDHE for each of the COCs (refer to Sections 4 and 5), and relevant routes of exposure using conservative assumptions. These RBSLs are presented in Tables 4-1 and 5-1(a-d) respectively. Thus for Tiers 2 and 3A, the risk evaluator has to select RBSLs from these tables and compare them with representative concentrations for complete routes of exposure. For Tier 3B evaluations, SSTLs have to be calculated using the models used for developing the Tier 3A RBSLs using site-specific data. For Tier 3B evaluations, the O/O may use any publically available, technically defensible models based on a work-plan pre-approved by KDHE.

The calculation of RBSLs and SSTLs require quantitative values of (i) target risk, (ii) chemical specific toxicity factors, (iii) receptor-specific exposure factors, (iv) fate and transport parameters, (v) physical and chemical properties of the COCs, and (vi) mathematical models. Each of these factors is discussed below.

3.7.1 Target Risk Levels

A risk-based decision making process requires the specification of a target risk level for both carcinogenic and non-carcinogenic adverse health effects. For carcinogenic effects, the KDHE Storage Tank Section will use an individual excess lifetime cancer risk (IELCR) of 1×10^{-5} as the target risk for both current and future receptors. For non-carcinogenic effects, the acceptable level is a hazard quotient of unity (1) for current and future receptors.

The target risk level of 1×10^{-5} was selected in the KRBCA process for several reasons. Risk level of 1×10^{-5} is within the risk range for carcinogens (1×10^{-4} to 1×10^{-6}) generally used to evaluate CERCLA actions. The 1×10^{-5} level is protective based on the overall generally conservative nature of the exposure scenarios used in the KRBCA process and the underlying health criteria. Evidence is available that shows petroleum constituents in soil and groundwater are subject to natural attenuation processes which continue to reduce the concentrations of COC over time. At most UST sites the risk of exposure to unacceptable concentration levels (except for new releases) should reduce.

The KRBCA process utilizes one target risk level (1×10^{-5}), rather than a range, as an effort to streamline the decision making process and remain protective of human health and the environment. While the selection of one target risk level removes some of the flexibility of having a target risk range, utilizing one target risk level is a key component of streamlining the KRBCA process and providing a level of cleanup consistency in regards to risk level.

While this target risk level is being utilized in the KRBCA process, other KDHE programs such as the RCRA or CERCLA programs may utilize a range of target risk levels. The use of any target risk level in risk based decision making within those programs must be acceptable to the respective KDHE program administrators.

Since there are a limited number of COCs at most regulated UST release sites and the KRBCA process uses conservative exposure values, the KDHE will not require the estimation of cumulative risk or the hazard index (sum of hazard quotients). Thus, the risk and hazard quotient from different chemicals will not be added. Likewise, risk and hazard quotients from different routes of exposure will not be added except for the routes of exposure associated with the surface soil.

For the ingestion of groundwater (shallow as well as deep), the above target risk and hazard quotient values are not required. Instead, the chemical-specific concentrations at the POE should not exceed the MCLs or health advisories (e.g. for MtBE). Concentrations at the POE can be determined either by site-specific sampling or by using a fate and transport model. If the concentrations currently exceed the MCL or are likely to exceed the MCL at the POE, compliance monitoring, at a minimum, will be required. For chemicals that do not have MCLs, target POE concentrations will be calculated assuming ingestion of water by an adult resident.

3.7.2 Quantitative Toxicity Factors

The toxicity of chemicals is quantified using slope factors (or potency value) for chemicals with carcinogenic adverse health effects. For chemicals that cause non-carcinogenic adverse health effects, toxicity is typically quantified by reference dose or reference concentrations. One of the most reliable

sources of information for toxicity factors is the U.S. EPA database called Integrated Risk Information System (IRIS).

Toxicity values for the COCs are presented in Table 3-2. The KDHE recommends that the most recent toxicity values recommended by the USEPA be used for KRBCA evaluations. As of the publication of this document, the values listed in Table 3-2 represent the most recent values and should be used for both Tier 2, Tier 3A and Tier 3B evaluations. Typically, these toxicity values will also be used for Tier 3C evaluations.

To check the current toxicity values, an KRBCA evaluator should consult the following sources in the order listed:

- state recommended values;
- Integrated Risk Information System (IRIS);
- Agency for Toxic Substance and Disease Registry (ATSDR);
- direct communication with the appropriate USEPA personnel, and
- review of literature by qualified professionals to develop toxicity factors. Consult the appropriate Regional U.S. EPA Office for specific recommendations.

3.7.3 Exposure Factors

Exposure factors describe the physiological and behavioral factors of the receptor. These include factors such as the body weight, body surface area, air inhalation rates, water ingestion rate, etc. Default exposure factors to be used for Tier 3A and Tier 3B evaluation are presented in Table 3-4. The exposure factors are typically estimated based on literature and site-specific measurements are not conducted. For a Tier 3C evaluation, site-specific values of the exposure factors, other than default values, may be used if they can be justified. An excellent source of information is the recently published U.S. EPA's *Exposure Factors Handbook Volume I - General Factors* (August 1997) and the companion document entitled *Socio-demographic Data Used for Identifying Potentially Highly Exposed Populations* (September 1999).

3.7.4 Fate and Transport Parameters

Fate and transport parameters are necessary to estimate the target levels for the indirect routes of exposure. These factors characterize the soil, groundwater, infiltration rate, and ventilation rates in buildings at a site. For Tier 2 and 3A evaluations, the KDHE has selected generic conservative default values that are listed in Table 3-5. For a Tier 3B evaluation, a combination of site-specific and generic values for these parameters may be used. However the value of each parameter used must be justified based on site-specific conditions. For Tier 3C evaluation, the specific fate and transport parameters required to compute the target levels will depend on the choice of models. A brief discussion of some of these parameters is presented below.

Indoor and Outdoor Inhalation: the fate and transport models used to estimate volatile emissions from soil and groundwater require information about the soils in the vadose zone, capillary fringe, and sub-foundation soils. The specific parameters required include:

- soil bulk density for the vadose zone and the capillary fringe;
- organic carbon content in the vadose zone and the capillary fringe;
- porosity in the vadose zone, capillary fringe, and soils in cracks;
- volumetric water content in the vadose zone, capillary fringe, and soils in cracks; and
- air content in the vadose zone, capillary fringe, and the soils in cracks.

The method used to measure these parameters is discussed in Section 2.5. It is important to note that the sum of the water content and the air content must equal the porosity.

Tier 3A assumes that the values of these properties in the vadose zone and the soil in cracks are identical. The organic carbon content and the porosity of the capillary fringe are assumed to be the same as in the vadose zone. Further, the water content in the capillary fringe is assumed to be 90% of the porosity.

The depth to groundwater should equal the sum of the thickness of the vadose zone and the capillary fringe. Where the depth to groundwater as measured in monitoring wells fluctuates, the average depth to groundwater should be used in the KRBCA calculations. The thickness of the capillary fringe depends on the soil grain size and is typically estimated based on literature values.

Several other parameters are required to estimate the risk based levels for indoor and outdoor inhalation. These include:

- enclosed space volume to infiltration area, typically equal to the height of the first floor,
- wind speed, and
- size of the surface soil source.

The air exchange rate in the building depends on the construction of the building. Default values listed in Table 3-5 may be used for Tier 3A as well as Tier 3B evaluation. Literature values may be obtained by researching architectural and building design publications.

Protection of Groundwater: Several fate and transport parameters are required to estimate the soil source concentration protective of the groundwater and to estimate the target compliance well concentration. These include:

- The areal dimensions of the soil source. Source dimensions include the length and width of the soil source as shown in Figure 3-3. These dimensions are estimated based on the site characterization data and should represent the most contaminated portion of the site. At sites where there are multiple sources, it may be appropriate to define more than one soil source. In the KRBCA process, it is conservatively assumed that the contaminants travel vertically downwards to the water table without any lateral dispersion. Therefore, the areal dimensions of the groundwater source are the same as the soil source dimensions. For Tier 3A and Tier 3B evaluation, the thickness of the groundwater source or the mixing zone thickness is assumed to be 200 cm. Analytical equations to estimate the thickness may be used for Tier 3C evaluation.
- Soil properties representative of the soil source include the organic carbon content, porosity, water content, and air content. The soil properties in the soil source zone may differ from those of the vadose zone. The KRBCA process assumes that values representative of the vadose zone are also representative of the soil source zone. For Tier 3A evaluation, the organic carbon content of the soil source and the saturated zone are assumed the same.
- Distance to the POE (section 3.6.2) and compliance well.

3.7.5 Mathematical Models

Two types of models or equations, namely (i) the uptake equations, and (ii) the fate and transport models are required to calculate the target levels. For Tier 3A and Tier 3B evaluations, the KDHE has selected

specific models and equations. These models have been programmed in the KRBCA Computational Software and were used to develop the Tier 3A target levels presented in Section 5. For Tier 3B evaluations, KDHE requires the use of these equations and models. The user is free to select any software that includes the parameters and models presented above. With the prior approval of the KDHE, a different set of models may be used for Tier 3C evaluations.

3.8 ESTIMATING COMPLIANCE WELL CONCENTRATION

The KDHE may require compliance well (CW) monitoring to confirm that the concentrations at the POE do not exceed the target levels in the groundwater or in a stream if applicable. Monitoring will be continued until the concentrations in the compliance wells stabilize below the calculated compliance well target levels.

The compliance well target concentrations can be estimated using the following relationship:

$$C_{CWtarget} = C_{EWtarget} \times (DAF_{POE} / DAF_{CW}) \quad (3.1)$$

where,

$C_{CWtarget}$ = Target concentration in compliance well (mg/L)

$C_{EWtarget}$ = Target concentration in the exposure well (groundwater standard) or in the water discharging to the stream (mg/L)

DAF_{POE} = Dilution attenuation factor for the distance from the source to the exposure well or the point where the plume discharges into the stream [(mg/L) / (mg/L)]

DAF_{CW} = Dilution attenuation factor to the compliance well from the source well [(mg/L) / (mg/L)]

In Equation 3-1, the DAFs represent the reduction in concentration as the chemical of concern travels from the source to the POE or the CW. This reduction in concentration is due to the combined effect of several factors including advection, diffusion, dispersion, dilution, adsorption, and biochemical processes. In general there are two ways to estimate the DAFs. First by using a fate and transport model that can predict the concentration at the POE or CW relative to the concentration at the source. Second, by calculating the ratio of the measured concentration at the source well and the POE or CW. The second method can be used only at sites where the plume is stable and sufficient groundwater monitoring data are available.

For Tier 3A evaluation, Table 5-3 lists the dilution attenuation factors (DAFs) that should be used to estimate the compliance point target concentration. Tier 3A DAFs were estimated using the Domenico's model (Appendix A). For Tier 3B and Tier 3C evaluation, site-specific DAFs may be calculated using site-specific data or a fate and transport model implemented using site-specific data.

An example calculation is presented below:

The compliance well target concentration for a POE at 500 feet from the source and the compliance well located at 300 feet from the source, i.e., 200 feet upgradient from the POE, is estimated as follows:

$$C_{CWtarget} = C_{EWtarget} \times (DAF_{500} / DAF_{300})$$

where,

$C_{CWtarget}$ = Target concentration in compliance well (mg/L)

$C_{EWtarget}$ = Target concentration in the exposure well (groundwater standard) or in the water discharging to the stream (mg/L)

DAF_{POE} = Dilution attenuation factor to the exposure well located at 500 feet from the source [(mg/L) / (mg/L)]

DAF_{CW} = Dilution attenuation factor to the compliance well located at 300 feet from the source [(mg/L) / (mg/L)]

For Benzene, using the DAF's from Table 5-3,

$$C_{CWtarget} = (.0005) \times (63.4 / 23.2)$$

The calculated target compliance well concentrations of 0.0137 mg/L will be used to establish compliance point monitoring requirements. Note target concentrations in a compliance well would typically exceed the target levels in an exposure well.

An identical procedure can be used to develop compliance well target concentrations for the protection of surface waters. At sites where the compliance well concentrations are exceeded, the KDHE may require continued monitoring or remediation until the concentrations stabilize below the calculated target level.

3.9 PROTECTION OF DEEPER GROUNDWATER

While performing KRBCA evaluations the potential impacts to deeper aquifers must also be evaluated. In some cases, qualitative evaluation based on the vertical flow gradients may be sufficient, however in other cases, quantitative evaluation of potential vertical migration of COCs may be necessary. Such cases will be evaluated under Tier 3C.

3.10 ECOLOGICAL EXPOSURE

Ecological exposures to wetlands, sensitive environments, or threatened and/or endangered species should be thoroughly evaluated. Where an ecological threat exists due to a release, an ecological evaluation should be performed as part of a Tier 3C evaluation. Note, within the KRBCA framework, protection of a stream, as discussed in Section 3.11 is considered independent of the ecological risk evaluation. Depending on the ecological risk issues at a site, KDHE may require a detailed work plan to evaluate ecological risks prior to the actual tier evaluation.

3.11 ESTIMATING IMPACTS TO SURFACE WATERS

Appropriate samples should be collected when COC migration is known or suspected to affect a surface water body. Sample collection may consist of sediment and/or water upstream, downstream, and/or radially from the discharge point. KDHE will determine the sampling plan on a site by site basis.

3.12 MANAGEMENT AND CONTROL OF NUISANCE CONDITIONS

The Tier 3A RBSLs and Tier 3B SSTLs are based on the protection of human health due to chronic exposure to the COC that are the most toxic constituents of petroleum products. Other constituents, however, may result in objectionable nuisance conditions. It is important to confirm that no nuisance conditions, such as odor, staining

of soil, or other visual impacts are present on-site. KDHE STS may deny site closure if such nuisance conditions exist, even if the site concentrations are below the RBSLs or SSTLs.

Nuisance conditions are difficult to define and measure. The presence of nuisance conditions will be determined on a site-by-site basis by KDHE, and will consider observations by KDHE staff, comments and complaints by neighbors or local officials, and any other applicable information.

3.13 DOCUMENTATION OF KRBCA EVALUATION

3.13.1 Tier 2, Tier 3A and 3B Evaluations

KDHE has developed a standardized reporting format for Tier 2, Tier 3A and Tier 3B RBCA evaluations. Tier 3B evaluations will be conducted using site-specific data to replace default values in the fate and transport models.

3.13.3 Tier 3C Evaluations

The documentation of Tier 3C KRBCA evaluations should be clear and precise. A discussion of each of the steps required to conduct the evaluation, as outlined in Section 6.0 of this guidance document, should be included. Emphasis should be placed on identifying the decisions made, and the justification for the decisions.

3.14 COMPUTATIONAL ASPECTS OF KRBCA EVALUATION

To develop the Tier 3A RBSLs presented in this document, KDHE used an excel based software developed by Risk Assessment & Management Group, Inc. This software will be used to develop Tier 3B SSTLs as well as to check the accuracy of calculations submitted to KDHE.

To develop the SSTLs, the responsible party or their consultant may choose any computational tool, subject to KDHE STS pre-approval. Tools must have been peer-reviewed, and justification for selection of the tool must be provided. A licensed copy of the tool and any related information must be provided if requested by KDHE. The report must state the computational tool chosen and give references documenting its successful use in similar situations. Alternatively, the O/O may purchase the KRBCA software from Risk Assessment and Management Group, Inc. (713-784-5151; asalhotra@ramgp.com).

Use and/or development of any software that has not been pre-approved will not be reimbursable under the Trust Fund program.

4.1 OVERVIEW

Tier 2 entails the comparison of site concentrations with the Tier 2 RBSL values developed by KDHE and presented in Table 4.1. The steps required to perform a Tier 2 evaluation include the following:

- Development of a site conceptual exposure model (SCEM)
- Selection of relevant Tier 2 RBSLs
- Comparison of the RBSLs with maximum site concentrations
- Selection of the next course of action

Each of these steps is discussed below.

4.1.1 Development of a Site Conceptual Exposure Model

The development of a SCEM has been discussed in Section 3.6. The SCEM must be developed for current and likely future site conditions, and will result in a matrix identifying complete pathways and routes of exposure. Each complete pathway and each route of exposure should be quantitatively addressed as discussed below. The complete pathways and routes of exposure should be clearly documented in the KRBCA report.

4.1.2 Selection of Relevant Tier 2 RBSLs

Table 4-1 lists the Tier 2 soil and groundwater target levels for the COCs. These values are identical to the Tier 2 values presented in Attachments 1 & 2 of the KDHE Corrective Action Policy Manual. The Tier 2 values were derived for the following routes of exposure for a commercial and residential receptor:

- ingestion of water;
- indoor inhalation of volatile emissions from indoor water use;
- dermal contact with water during bathing;
- Ingestion of soil;
- dermal contact with soil; and
- outdoor inhalation of soil.

For detailed discussion of the derivation of these values, refer to the March 1, 2003 RSK Manual.

If the SCEM developed in 4.1.1 includes any other routes of exposure (e.g. indoor inhalation of vapors from soil or ground water), then Tier 2 evaluation is not valid and the KRBCA process should proceed to Section 5.0. If no other routes of exposure are complete, Tier 2 target levels should be selected from Table 4-1. There are no RBSL's for Tier 3A for TPH in groundwater. If TPH in groundwater is the only COC to exceed Tier 2 levels the site cannot be automatically closed by performing a Tier 3A evaluation. The KDHE should be advised of this situation and consulted prior to performing a Tier 3A evaluation.

4.1.3 Comparison of RBSLs With Maximum Site Concentration

KDHE requires that the maximum soil or groundwater concentrations measured at the site be compared with the Tier 2 RBSLs. Depending on the results of the comparison, the responsible party should identify the next course of action as discussed in Section 4.1.4.

4.1.4 Selection of the Next Course of Action

The KDHE may issue a closure letter if the site concentrations:

- meet the criteria established in Section 4.1.2;
- no nuisance conditions exist at the site;
- separate phase product has been removed to the maximum extent practicable;
- the KDHE agrees with the overall Tier 2 evaluation; and
- historic data indicates that the plume is stable or decreasing.

If the site concentrations exceed the Tier 2 RBSL's, the following two alternatives are available:

Alternative 1: Remediation to Tier 2 Values. The O/O may elect to develop a corrective action plan to remediate the site to Tier 2 RBSLs. The corrective action plan must be approved by KDHE. The plan would have to meet the requirements of K.A.R 28-44-25 and the guidance presented in the Limited Site Assessment (Revision 6), 08/2001, Request for Proposal document.

Alternative 2: Selection of Tier 3A Analysis. The O/O conducts a Tier 3A evaluation. Details of the Tier 3A evaluation are discussed in Section 5.

The O/O should carefully review the site conditions and propose one of the two alternatives listed above. The selection of Alternative 1 or 2 will most likely be based on technical feasibility and cost-benefit considerations. For example, where the cost of cleanup is low (relative to the cost of additional analysis under Tier 3A evaluation), it may be most expeditious to adopt the Tier 2 RBSLs as the cleanup levels.

5.0 TIER 3A EVALUATION

The Tier 3A evaluation requires the comparison of site-specific representative soil and groundwater concentrations with the KDHE established Tier 3A RBSLs. A Tier 3A evaluation requires the following steps:

- Characterization and Prioritization of the site;
- Development of site conceptual exposure model;
- Selection of relevant RBSLs from the Tier 3A look-up table for the relevant COCs and complete routes of exposure;
- Comparison of the RBSLs with the site-specific representative concentrations for the completed pathways; and
- Recommendations for the next course of action.

5.1 SITE CHARACTERIZATION

A site characterization is necessary prior to the performance of a Tier 3A evaluation. Sufficient data related to land use, chemicals of concern, soil and groundwater impacts is necessary. Details of the site characterization step have been discussed in Section 2.

5.2 DEVELOPMENT OF A SITE CONCEPTUAL EXPOSURE MODEL

The development of a SCEM has been described in Section 3.6. This step includes the location of the nearest POE as per Section 3.6.2.

5.3 SELECTION OF RELEVANT TIER 3A RISK BASED SCREENING LEVELS

For each complete exposure pathway identified in the SCEM in Section 5.2 above, Tier 3A RBSLs should be selected for each COC from Table 5.1. As discussed in Section 3.7, these RBSLs were developed by KDHE using conservative input parameters and assumptions.

The Tier 3A target soil concentrations protective of groundwater depend on the distance to the POE from the source. For example, referring to Table 5-2, if the POE is 500 feet from the source, the allowable concentration of benzene in soil is 1.16 mg/kg. These target soil concentrations were developed assuming no attenuation in the unsaturated zone, and no bio-attenuation in the saturated zone.

5.4 COMPARISON OF RBSL'S WITH SITE CONCENTRATIONS

After Tier 3A target levels have been identified, they are compared with the representative concentrations provided no free product was present in the soils or groundwater. Depending on the site conditions, multiple representative concentrations may have to be developed for a site. For example, at a site where a groundwater plume exists below an onsite commercial building and has migrated off-site under a residential building, representative groundwater concentrations for on-site and off-site receptors would be different. The representative concentrations should be evaluated as follows:

5.4.1 Soils

For both surface and subsurface soils, the calculation of average concentration, which is the representative concentration, assumes the source area is adequately defined. Sample points used to calculate the average concentration cannot be < 25% of the maximum soil contamination detected. Representative soil concentrations protective of the groundwater pathway is the average of the soil data collected within the source area.

The soil data from the most recent investigation should be used. If recent (<4 years old) soil data has not been obtained, it may be appropriate to collect additional soil data and use the current soil data to

estimate the representative concentration. This data can be obtained through the implementation of a data acquisition plan approved by KDHE. Where only older (>4 years old) data is available, that data can be used, if there have been no additional releases since the data was collected. If a new release has occurred, soil assessment activity must be collected to adequately characterize the new release.

5.4.1.1 Surface Soil: The average concentration should be calculated based on the available surface soil concentration data. The Tier 3A RBSLs for surface soil should be compared with both the site-specific average and maximum surface soil concentrations. For the KDHE to consider closure at a site, the average concentration should not exceed the relevant Tier 3A target levels. Further, if the ratio of the maximum surface soil concentration exceeds the average concentration by a factor of 10, the KDHE may require further evaluation.

5.4.1.2 Subsurface Soil: The average subsurface concentration below or adjacent to current or proposed building should be calculated based on the available subsurface soil concentration data. The Tier 3A RBSLs for subsurface soil should be compared with both the site-specific average concentrations. For the KDHE to consider closure at a site, the average concentration should not exceed the relevant Tier 3A target levels. Further, if the ratio of the maximum subsurface soil concentration exceeds the average concentration by a factor of 10, the KDHE may require further evaluation.

5.4.2 Groundwater

Several representative groundwater concentrations may have to be estimated and/or calculated at a site. These could include (i) representative concentrations in the soil at the source area ii) representative concentrations in the groundwater at the source area, (iii) concentrations in the compliance wells, (iv) on-site representative concentrations to evaluate the protection of indoor inhalation, and (v) off-site representative concentrations to evaluate inhalation exposures to off-site receptors. Data from different monitoring wells may have to be used to evaluate each of these concentrations. Where the groundwater plume has been defined and several years of monitoring data are available, the averages using the recent two years data will be considered the representative groundwater concentrations for that well. The maximum concentration values from the recent two years of data for each COC detected in each well should also be identified. Concentrations used to calculate average groundwater contamination cannot be < 25% of the maximum contamination detected.

For comparing the compliance point groundwater concentrations with the back calculated compliance well concentrations, the average value from the two most recent years of data should be used as the representative concentration. This method will account for variation in concentrations due to seasonal fluctuations.

KRBCA evaluation can also be performed at sites where only minimal groundwater data (one or two sampling events) are available. However, subsequent to the evaluation, the KDHE may require additional monitoring data before issuing a final decision. If recent groundwater data has not been obtained, it may be appropriate to obtain additional data.

The relevant Tier 3A groundwater RBSLs should be compared with site-specific average and maximum groundwater concentrations. For a site to receive an closure, the average concentrations should be less than the RBSLs and none of the wells should have increasing concentrations. Thus an important requirement for a Tier 3A closure is that the plume must be stable or decreasing.

5.5 Selection of the Next Course of Action

The KDHE may issue a closure letter if:

- the site concentrations meet the criteria established in Section 5.4;
- no nuisance conditions exist at the site;

- free product has been removed to the maximum extent practicable;
- the KDHE agrees with the overall Tier 3A evaluation;
- the site-specific conditions in Section 5.4 are more conservative than those assumed for Tier 3A evaluation; and
- historic data indicates that the plume is stable or decreasing

If the site concentrations exceed the Tier 3A values, the following two alternatives are available:

Alternative 1: Remediation to Tier 3A Values: The O/O may elect to develop a corrective action plan to remediate the site to Tier 3A RBSLs. The corrective action plan would have to be approved by the KDHE. The plan would have to meet the requirements of K.A.R 28-44-25 and the guidance presented in the Remedial Design Plan (Revision 7), 07/1997, Request for Proposal document.

Alternative 2: Selection of Tier 3B Analysis: The Agency conducts a Tier 3B evaluation which may require the acquisition of additional data. A Tier 3B evaluation may also be necessary when the assumptions used in the Tier 3A evaluation are significantly different from the known or suspected site-specific conditions, and those conditions make the Tier 3A RBSLs less conservative. For values used to estimate the RBSLs, refer to Tables 3-2 to 3-5. For example, at sites where the depth to groundwater is less than the Tier 3A default depth of 300cm, it will be necessary to develop Tier 3B SSTLs using the site-specific depth to groundwater.

The O/O should carefully review the site conditions and propose one of the two alternatives listed above. The selection of Alternative 1 or 2 will most likely be based on technical feasibility and cost-benefit considerations. For example, where the cost of cleanup is low (relative to the cost of additional data collection and analysis under Tier 3B evaluation), it may be most expeditious to adopt the Tier 3A RBSLs as the cleanup levels.

This section provides details for a Tier 3B evaluation that may be conducted (i) when Tier 3A RBSLs are exceeded and it is not appropriate to remediate the site to Tier 3A RBSLs, or (ii) Tier 3A assumptions are sufficiently different from site-specific conditions, so that Tier 3A RBSLs will not be conservative. The Tier 3B evaluation is very similar to the Tier 3A evaluation in that it (i) is conservative, (ii) is broadly defined by KDHE but allows for some flexibility, (iii) uses conservative fate and transport algorithms (models), and (iv) uses default exposure factors.

The Tier 3B evaluation requires:

6.1 Development of Site Conceptual Exposure Models

The O/O should revise the SCEM if it has not already been developed and identify the complete exposure routes and pathways. All COCs and all complete routes of exposure should be evaluated under Tier 3B (even those that satisfy Tier 3A levels). Thus SCEM for Tier 3B will be very similar, and in most cases exactly the same, as the SCEM for the Tier 3A evaluation.

6.2 Input Parameters

For Tier 3B evaluation, KDHE requires the use of the same models and algorithms used to develop Tier 3A levels. Thus, the Tier 3B input parameter requirements are the same. The specific values to be used are presented below:

Exposure Factors: KDHE requires that the exposure factors remain the same for Tier 3A and Tier 3B evaluations. The specific values are listed in Table 3-4.

Physical and Chemical Properties: KDHE requires the physical and chemical properties remain the same for Tier 3A and Tier 3B evaluations. These are listed in Table 3-3, Chemical-Specific Fate & Transport Parameters.

Toxicity Values: KDHE requires that the current toxicity values promulgated by USEPA be used. These are the same values as for Tier 3A evaluation and are listed in Table 3-2.

Fate and Transport Parameters: KDHE allows that representative site-specific fate and transport parameters be used for Tier 3B evaluation. Tier 3A default values were tabulated in Table 3-5. At a minimum, the following site specific parameters must be used:

- depth to groundwater;
- depth to subsurface contaminated soil;
- size of soil source;
- soil properties including bulk density, porosity, water content, and organic carbon content; and
- groundwater velocity.

Where site-specific values are not available for a few parameters, professional judgment has to be used to determine whether to perform additional assessment or to use Tier 3A default values. If additional data is necessary, a work plan should be developed and approved by KDHE prior to performing the Tier 3B evaluation.

For fate and transport modeling, KDHE will allow the use of chemical specific biological decay rates based on site-specific evaluation of historic monitoring well data. If a decay rate is used, the O/O must clearly document the process used to estimate site-specific decay rates.

In cases where literature values are used, the half-life for any COC must not be less than 5 years, i.e., the first order decay rate should not exceed $(\ln 0.5)/5 = 0.139\text{yr}^{-1}$.

Target Risk: The target risk for Tier 3A and Tier 3B evaluation is the same. For details, refer to Section 3.7.1.

6.3 Calculation of Tier 3B Levels

The calculation of Tier 3B SSTLs should be performed by using the models presented in Appendix A and the input parameter values discussed above. The software used by KDHE to calculate the values may be purchased from the Risk Assessment & Management Group, Inc. (713-784-5151) or smatul@aol.com. Alternatively the owner/operator may use the equations to develop their own software. More information on how to obtain the specific software is available through KDHE.

KDHE is not dis-allowing the use of other appropriate software, but it requires that models and input parameters presented in this guidance document be used. If a KRBCA evaluator uses alternative tools, KDHE may require verification of the software.

6.4 Calculation of Representative Concentration

The representative soil and groundwater concentrations are calculated as for Tier 3A evaluation, see Section 3.7. These representative site concentrations are compared with the Tier 3B SSTLs and the next course of action determined as discussed in 6.5 below.

6.5 Selection of the Next Course of Action

After the completion of a Tier 3B evaluation, KDHE may issue a closed status if the following conditions are met:

- representative site concentrations do not exceed the Tier 3B levels and the maximum concentration in each media does not exceed the representative concentration in the source by a factor of 10;
- no nuisance conditions exist at the site;
- separate phase product has been removed to the maximum extent practicable;
- KDHE agrees with the Tier 3B evaluation and determines that additional confirmatory or compliance point monitoring is not necessary; and
- historic groundwater data indicates that the groundwater plume is stable or decreasing.

If the representative site concentrations exceed the Tier 3B levels, the following two alternatives are available:

Alternative 1: Remediation to Tier 3B levels. The O/O, with KDHE's concurrence, may elect to remediate the site to Tier 3B SSTLs. In this case the Tier 3B SSTLs become the cleanup goals. A Corrective Action Plan will be required for the site in accordance with K.A.R 28-44-25 and the guidance presented in the Remedial Design Plan (Revision 7), 07/1997, Request for Proposal document.

Alternative 2: Selection of Tier 3C Analysis. The O/O, with KDHE's concurrence, may opt to perform a Tier 3C analysis as per the guidance presented in Section 7.0. Note that only those complete routes of exposure that do not meet the Tier 3B requirements will have to be evaluated under Tier 3C.

7.1 KDHE Policy on Conducting Tier 3C Evaluations

Tier 3C is the most sophisticated and detailed site-specific analysis that can be conducted under the Kansas Risk-Based Corrective Action Program for petroleum storage tank releases. Tier 3C provides the most flexibility for developing site-specific target levels for estimating the site-specific risks. A Tier 3C analysis may, however, delay the overall process of site closure because of the high level of regulatory review and oversight that will be required.

Prior to conducting a Tier 3C analysis, the O/O, through their consultant, must submit a detailed work plan and discuss the specifics of the plan with KDHE. The work plan must be approved by KDHE before any recommendations resulting from the analysis will be considered. Tier 3C analysis is expected to vary significantly from site to site, so specific guidance cannot be provided in this document.

The cost of conducting a Tier 3C analysis may equal or exceed the cost of remediating a release to tier 3B levels. Although the Tier 3C analysis may show that further action is not necessary, it may also show that remediation or monitoring will be required. KDHE believes that reducing contaminant levels is a more appropriate use of limited resources than additional investigation. The Petroleum Storage Tank Release Trust Fund will not reimburse costs for conducting a Tier 3C analysis, unless specifically requested by the KDHE. The O/O may elect to conduct a Tier 3C analysis without financial assistance, and submit the results to KDHE for review. The O/O should keep in mind that demands on limited KDHE staff time are high, and review of Tier 3C reports is not considered a high priority.

KDHE upon review of a Tier 3C evaluation will then determine the most appropriate next action as described in Section 3.12 and shown in figure 1-1. Possible further actions include:

- site closure with no further action if the calculated risk is below KDHE acceptable level or if the Tier 3C target levels are below the representative site concentrations;
- remediation to Tier 3C levels which may require monitoring to confirm a declining plume; and
- monitoring.

KDHE will notify the O/O of the status of their site. Monitoring may be required following remediation, or as deemed appropriate for a specific site even if the site levels are below Tier 3C SSTLs.

8.1 REFERENCES

ATSDR. 1994. Toxicological Profile of Naphthalene. Draft Update. Public Health Service. U.S. Department of Health and Human Services.

Freeze A.A. and Cherry J.A. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, NJ 07632.

Lyman, W.J., F.W.F. Reehl, and D.H. Rosenblatt. 1990. Handbook of Chemical Property Estimation Methods. American Chemical Society. Washington, DC.

Shepherd, R.G. 1989. Correlations of Permeability and Grain Size. *Ground Water*. Vol 27, No. 5, pp. 633-638.

U. S. Environmental Protection Agency (EPA). 1991(a). Health Effects Assessment Summary Tables (HEAST). Office of Solid Waste and Emergency Response . OHEA ECAO-CIN-821. Washington, DC.

U. S. Environmental Protection Agency (EPA). 1989(a). Risk Assessment Guidance for Superfund, Vol. I. Human Health Evaluation Manual (Part A). EPA/540/1-89/002.

U. S. Environmental Protection Agency (EPA). 1989(b). Supplemental Risk Assessment Guidance for Superfund Program. EPA/901/5-89/001.

U. S. Environmental Protection Agency (EPA). 1991. Risk Assessment Guidance for Superfund, Vol. I. Human Health Evaluation Manual (Part B Development of Risk-Based Preliminary Remediation Guide).

U. S. Environmental Protection Agency (EPA). 1991(a). Health Effects Assessment Summary Tables (HEAST). Office of Solid Waste and Emergency Response . NTIS PB91-921100. Washington, DC.

U. S. Environmental Protection Agency (EPA). 1995. Health Effects Assessment Summary Tables (HEAST). Office of Solid Waste and Emergency Response . OHEA ECAO-CIN-821. Washington, DC.

U. S. Environmental Protection Agency (EPA). 1995. Integrated Risk Information System (IRIS).

U. S. Environmental Protection Agency (EPA). NWWA Technical Enforcement Guidance Document.