NEBRASKA

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RISK-BASED CORRECTIVE ACTION (RBCA)
AT PETROLEUM RELEASE SITES:
TIER 1 / TIER 2 ASSESSMENTS & REPORTS

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ACL	Alternate Cleanup Level
ASTM	American Society for Testing and Materials
AST	Aboveground Storage Tank
BaP	Benzo(a)pyrene
BGL	Below Ground Level
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CERCLA	Comprehensive Environmental Recovery, Compensation, and Liability Act
CFR	Code of Federal Regulations
CGI	Combustible Gas Indicator
COC	Chemical of Concern
CP	Cathodic Protection
CRF	Concentration Reduction Factor
FID	Flame Ionization Detector
GC	Gas Chromatograph
HI	Hazard Index
HQ	Hazard Quotient
IELCR	Individual Excess Lifetime Cancer Risk
LAST	Leaking Aboveground Storage Tank
LEL	Lower Explosive Limit
LUST	Leaking Underground Storage Tank
LUT	Look-Up Table
MCL	Maximum Contaminant Level
MS	Mass Spectrometer
MTBE	Methyl tertiary Butyl Ether
NDEE	Nebraska Department of Environment and Energy
NELAP	National Environmental Laboratory Accreditation Program
PAH	Polynuclear Aromatic Hydrocarbon
PID	Photoionization Detector
POC	Point of Compliance
POE	Point of Exposure
PRS	Petroleum Remediation Section
QA/QC	Quality Assurance/Quality Control
RAC	Remedial Action Class
RAP	Remedial Action Plan
RBCA	Risk-Based Corrective Action
RBSL	Risk-Based Screening Level
RP	Responsible Party
SFM	State Fire Marshal (Nebraska)
SSTL	Site Specific Target Level
TEH	Total Extractable Hydrocarbons
USGS	United States Geological Survey
UST	Underground Storage Tanks
VRA	Voluntary Remedial Action
VOC	Volatile Organic Compound
WHPA	Wellhead Protection Area

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SECTION 1.0 – BACKGROUND & APPLICABILITY

The Petroleum Remediation Section (PRS) of the Nebraska Department of Environment and Energy (DEE or Department) has compiled this document for the purposes of conducting risk-based corrective action (RBCA) Tier 1 and Tier 2 site assessments and evaluations at petroleum release sites. It has been prepared in accordance with criteria contained in Nebraska Title 118 - Ground Water Quality Standards and Use Classification and Nebraska Title 126 -Rules and Regulations Pertaining to the Management of Wastes. Portions of this document are based on recommendations made by the Technical Advisory Committee created by the Nebraska Legislature, and information contained in the American Society for Testing and Materials (ASTM) Standard E-1739 Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (ASTM E-1739).

This document is intended to apply to all petroleum releases: those potentially eligible for reimbursement under Nebraska Title 200 -Rules and Regulations for Petroleum Release Remedial Action Reimbursement Fund, as well as those that are not (e.g., pipelines, transportation vessels). This guidance is not intended for investigations of petroleum wastes considered a hazardous waste in accordance with Nebraska Title 128 – Nebraska Hazardous Waste Regulations or a CERCLA-listed petroleum derivative identified in 40 CFR Part 302.

1.1 – TITLE 200 WORKPLAN APPROVAL & COSTS

Costs associated with remedial actions taken due to releases from petroleum leaking underground storage tanks (LUSTs) and leaking aboveground storage tanks (LASTs) are eligible for reimbursement consideration under Title 200. To secure reimbursement consideration for those releases where the Department has required remedial actions, the Department must first approve the responsible parties' (RP) workplans and review the associated cost estimates before any work is performed, unless expressly approved in other Department guidance documents. Performing remedial actions without first receiving approval from the Department may jeopardize Title 200 reimbursement eligibility for those actions.

For petroleum releases not eligible for Title 200, workplans may also be required by the Department.

For petroleum releases, this guidance document may be referenced in the workplan to serve as the description of the procedures that will be followed in the investigation. Any changes from the methods presented in this document must be highlighted and completely explained in the workplan, and they must receive the Department's approval before the investigation begins.

In the event that information specified in the workplan, or in any of the Department's guidance documents referenced by the workplan, is not collected during the assessment or included in the report, that report may be considered incomplete and may not be accepted by the Department. Costs incurred to correct an incomplete report may not be eligible for reimbursement.

The Department also has available the Voluntary Remedial Action (VRA) process whereby the RP does not have to wait for approval of a workplan and may be eligible for reimbursement under Title 200 at a later time. The RP can proceed with appropriate remedial actions following the Department's guidance documents and regulations if the Department has not yet required the RP to take remedial actions. Reimbursement will not occur until the Department requires and approves remedial actions at the site. The release, however, must first be reported to the Department in accordance with Title 126 to be considered eligible for Title 200 reimbursement.

For additional information regarding the Petroleum Remediation program, the VRA process, or RBCA in general, please view the Department's web page at http://dee.ne.gov, email us at NDEE.PetroleumRemediation@nebraska.gov, or call the Petroleum Remediation Section at 402/471-2186.

NOTE: The NDEE Petroleum Remediation Section is not the sole entity regulating the performance of remedial actions. All investigations, sampling, and other actions must be performed in accordance with the *Geologists Regulation Act* (Nebr. Rev. Stat. § 81-3501 to § 81-3541) and the *Engineers and Architects Regulation Act* (Nebr. Rev. Stat. § 81-3401 to § 81-3455). In addition, a license issued by the NDEE Water Well Standards and Contractors' Licensing Program is required for personnel installing water wells and pumps, or collecting samples or measurements from monitoring wells. All other Federal, State, and local laws must also be followed during the course of the RBCA process. Failure to do so may result in Title 200 reimbursement reductions. Table F-1 is a list of State Agencies and other contacts that may have jurisdiction.

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SECTION 2.0 – OVERVIEW OF NDEE'S RBCA PROCESS

2.1 – INTRODUCTION

The term Risk-Based Corrective Action (RBCA) refers to a consistent, methodical decision-making process used to assess actual or likely human and/or environmental risk of exposure to a chemical release and determine appropriate remedial actions in response to such releases. Petroleum releases vary considerably in their potential risk based on a number of variables, including, but not limited to, the type of petroleum product, amount of released product, duration of the release, extent of the release, site geology/hydrogeology, number and type of exposure pathways, and location of human receptors relative to the source. Potential remedial actions may run the gamut from long-term active cleanup to no action. In recognition of this fact, the Department has developed a tiered approach to its petroleum release corrective action process to cost effectively manage impacted sites and focus the finite resources on the more critical sites.

2.2 – GENERAL RBCA PROCESS

The Department's petroleum release RBCA process follows the general procedures outlined in the governing regulation, Title 118, Appendix B, Steps 6 – 12. Immediate threats from a release are to be mitigated before the site enters the RBCA process. The following steps (also depicted in the form of a flow chart in Figure 2-1) are included in the Department's RBCA process:

1. Pre-Investigation Site Visit *
2. Tier 1 Site Investigation *
3. Tier 1 Evaluation
4. Tier 2 Site Investigation *
5. Tier 2 Evaluation
6. Remedial Action Conceptual Plan
7. Preparation of Remedial Action Plan *
8. Implementation of Remedial Action Plan *
9. Review of Remedial Action Effectiveness
10. Public Notice and 30-day Comment Period for sites with groundwater impact
11. Abandonment of Monitoring Wells and Submittal of Abandonment Forms*
12. Site Closure *

Those steps marked with an asterisk (*) require Department review and approval of workplans and cost estimates prior to work being performed for Title 200 eligible releases. Workplans and cost estimates are not required for work performed under the VRA program, but they may be submitted for review as the Department's resources allow. Workplans without cost estimates may be required by the Department for non-Title 200 eligible releases.

The responses to discovery of free product, vapors in structures, or surface water impacts are not addressed as separate steps in the RBCA process, but are handled on a case-by-case basis. The unexpected discovery of any of these conditions must be reported to the Department as specified in Table 2-1. These reporting guidelines are in addition to the obligations of the responsible party to report releases according to Title 126.

Table 2-1. Notification of Unexpected Site Conditions at Petroleum Release Investigations

Condition	Notification Timeframe	Contact
Vapors in excess of 1% of the Lower Explosive Limit (LEL) in a building, utility conduit, or other structure Sheen on surface water	Immediate	• Local fire department. • State Fire Marshal's Office (see Appendix F). • DEE. During business hours, contact ANY project manager in the NDEE Petroleum Remediation Section at **402-471-2186.** At any other time, contact the Department's on-call personnel through the Nebraska State Patrol at **402-479-4921**.
Vapors below 1% of the LEL in a building, utility conduit, or other structure	Next business day	• Contact ANY NDEE Petroleum Remediation Section project manager at **402-471-2186.**
Presence of free product	Next business day	• DEE PRS project manager or the Petroleum Remediation Section at **402-471-2186.**

The presence of free product often modifies the Tier 1 or Tier 2 investigation requirements, as explained in Section 4.6. In such cases, a report incorporating all other Tier 1 or Tier 2 information, including that for the surface soil, soil leaching to groundwater, and inhalation of vapors from subsurface soil pathways, is still required. If necessary, a separate compliance date will be established for submittal of the information required for the suspended pathways.

The time required to complete the RBCA process depends on the amount of contamination present and the complexity of the investigation and, if necessary, remedial actions required. An uncomplicated site that requires only a Tier 1 investigation might achieve closure in five to seven months. If a Tier 2 investigation is required but subsequent remedial actions are not necessary, the process might take up to a year. The anticipated completion time for more complicated sites, or those requiring active remediation, is dependent on the specific site conditions and cannot be generally estimated.

2.3 – THE INVESTIGATION PROCESS

During the Tier 1 investigation, sufficient site data is gathered to establish land use (present and future) in the area around the release site; the location of potential points of exposure, human receptors and pathways; chemical of concern (COC) concentration data in soils and groundwater; and certain subsurface physical parameters. This information is used to generate a Site Conceptual Exposure Scenario and determine the appropriate risk-based screening levels (RBSLs) with which to compare the documented site COC concentrations. Data are collected to examine the potential risk of exposure to petroleum contaminants from the following exposure pathways:

- Dermal contact with, ingestion of, and outdoor inhalation through air of COCs from contaminated surface soils;
- Enclosed space inhalation of COCs from contaminated subsurface soils;
- Leaching of COCs from contaminated surface and subsurface soils to groundwater;
- Enclosed space inhalation of COCs from contaminated, shallow groundwater; and,
- Ingestion of COCs from contaminated groundwater.

The purpose of the Tier 2 investigation is to gather additional site COC concentration data and subsurface physical parameter information that is more detailed than that gathered during the Tier 1 investigation. This information is used to generate site-specific target levels (SSTLs) that are compared to representative site COC concentrations for the completed exposure pathways from Tier 1. All COCs and all complete routes of exposure will be evaluated during the Tier 2 phase.

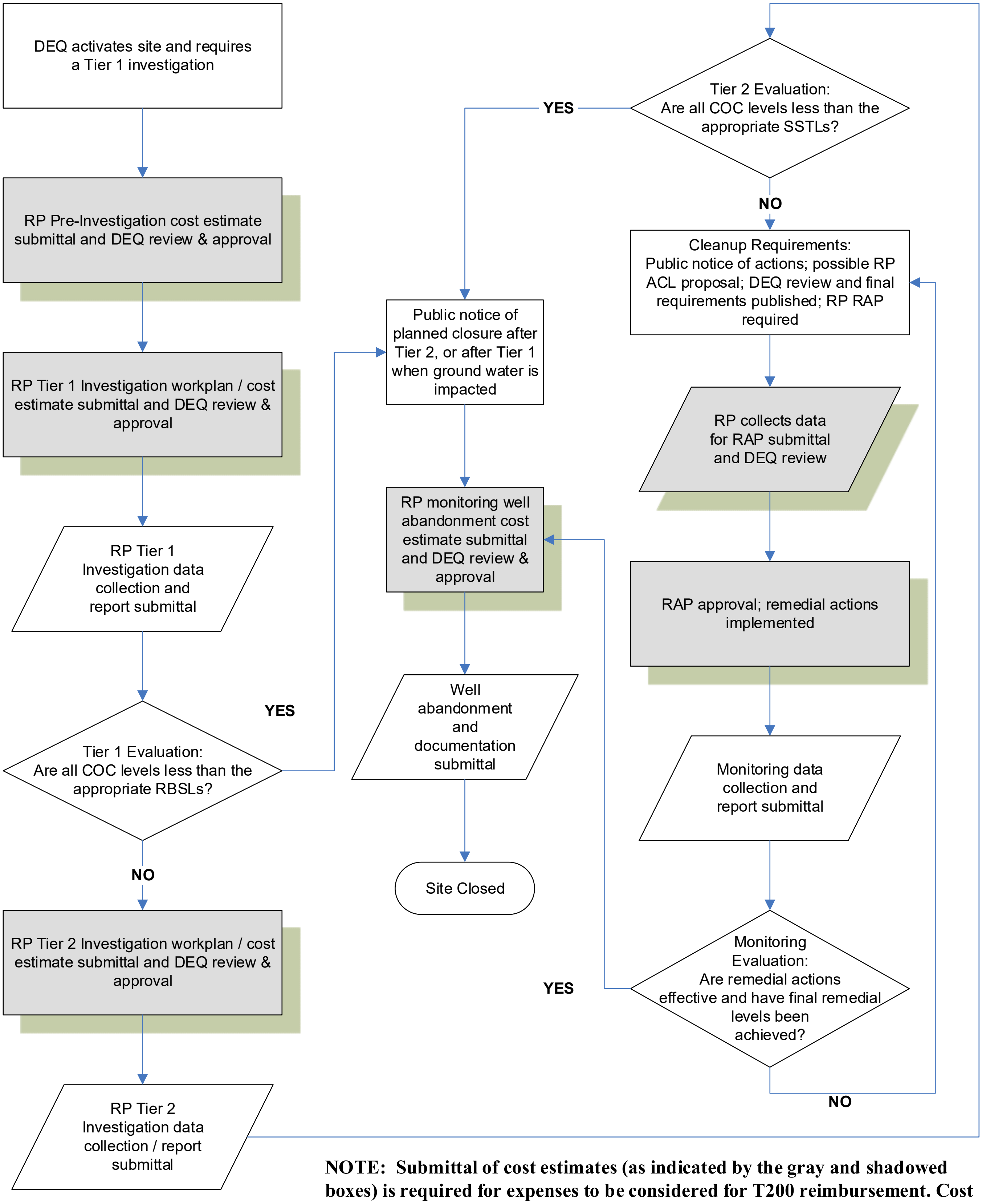
2.4 – CHARACTERISTICS OF TIERED PROCESS

As defined in ASTM E-1739, a Tier 1 evaluation is "a risk-based analysis to develop non-site-specific values for direct and indirect exposure pathways utilizing conservative exposure factors and fate and transport [models] for potential pathways and various property use categories ... Values established under Tier 1 will apply to all sites that fall into a particular category." ("Direct exposure" indicates that the point of exposure is at the source of the release; "indirect exposure" indicates the existence of an intervening medium of transport between the source and a point of exposure.)

A Tier 2 evaluation is a risk-based analysis applying the same exposure factors and models used for the Tier 1 evaluation but incorporating more site-specific data to develop site-specific target levels for all COCs and all complete exposure pathways.

Based on these definitions, certain general statements can be made when comparing the individual tiers. First, when proceeding from Tier 1 to Tier 2, the amount of data collected during the investigation phase increases. Additional work in the Tier 2 phase may include more complete soil sampling, additional groundwater sampling and/or subsurface physical/chemical parameter testing. Second, as more data is collected, the level of conservatism used in the evaluation of the data usually decreases. This means that the Tier 2 SSTLs will generally be greater than the Tier 1 RBSLs for the same site. However, the target risk or level of protection remains the same for both tiers.

Figure 2-1. Generalized NDEE RBCA Process Flow Chart



NOTE: Submittal of cost estimates (as indicated by the gray and shadowed boxes) is required for expenses to be considered for T200 reimbursement. Cost estimates are not required for releases that are ineligible for Title 200.

SECTION 3.0 – PRE-INVESTIGATION ASSESSMENT

3.1 – SITE ACTIVATION

Upon activating a petroleum release site for a RBCA Tier 1 investigation, the Department notifies the responsible party (RP) in writing of its requirements. For sites eligible for Title 200 reimbursement, the first of these requirements is the submittal of the Department's Tier 1 Pre-Investigation Assessment Work Plan Form, including a cost estimate to conduct a pre-investigation assessment as described in Section 3.2.1 below. Depending on the extent of the release, the Department may not require a pre-investigation assessment for non-Title 200 eligible releases. The Pre-Investigation Assessment Work Plan Form is to be submitted within the time schedule set by the Department.

3.2 – PRE-INVESTIGATION ASSESSMENT AND SITE VISIT

An assessment of the current site conditions is necessary for sites entering the RBCA process. Prior to conducting a RBCA Tier 1 site investigation, the Department requires that a pre-investigation assessment, including a site visit, be performed by the consultant. Work on the assessment must not begin until the Department has approved the Pre-Investigation Assessment Work Plan Form.

3.2.1 – Purpose of Pre-Investigation Assessment & Site Visit

The purpose of this assessment and site visit is to:

1. Conduct a file review and an on-site reconnaissance to determine the number and location of potential source areas, and potential complications for sampling the source areas.
2. Locate any water supply wells as described in Section 4.4.3.
3. Locate any surface water bodies within 1000 feet of the site.
4. Contact One-Call and conduct an on-site utilities survey (including UST leak detection and leak prevention equipment) as an aid in determining potential site complications.
5. Determine the appropriate sampling and/or drilling locations to obtain the required COC concentrations. Consultants must ensure that such potential monitoring well locations are accessible (landowner's permission as well as equipment access).
6. Prepare a site map (to scale) showing the following features. If any are not present, explain in the narrative.
    - potential source areas
    - selected sampling and/or drilling locations
    - water supply wells within 200 feet of the site
    - buildings within 200 feet of the site
    - basements within 200 feet of the site
    - utilities within 200 feet of the site
    - surface water bodies within 200 feet of the site
    - tank system (current and former) locations, including tanks, piping, dispensers, and leak detection and prevention equipment
    - area(s) of any surface staining
    - anticipated groundwater flow direction

NOTE: Selection of boring locations at facilities with any storage tanks (underground or aboveground) should be made with caution. Underground piping is typically non-metallic and may not be locatable. Steel tanks and piping may also be equipped with cathodic protection (CP). These CP systems may have wiring from the building to an anode bed surrounding the tanks and piping. "As-built" drawings are required to be kept at the tank location for location purposes prior to beginning any work. If you have any questions regarding these issues, please contact the State Fire Marshal's Fuel Safety Division at 402/471-9465. Also, please keep in mind that for any subsurface investigation, "One Call" procedures need to be followed for locating utility services.

Acquiring access to prospective drilling locations is a key purpose of the pre-investigation assessment and site visit.

Obtaining permission from property owners in advance helps ensure that field work can be completed quickly and efficiently, and every effort must be made to secure the necessary agreements before proceeding. If a property owner refuses to grant permission for access and no suitable alternative location is available, the PRS project manager should be contacted as soon as possible for assistance. The property owner's name, phone number, and the location of the property in question should be provided.

Payments to neighboring property owners for site access are generally not eligible for T200 reimbursement. When access is needed to railroad property, the railroad should be informed that the Department is requiring the remedial action because there are agreements in place to waive some of the fees. The PRS project manager should be contacted to discuss the specific situation.

Upon completion of the pre-investigation assessment, a Tier 1 Investigation Work Plan Form, the above referenced site diagram, and a proposed cost estimate for a complete Tier 1 site investigation are to be submitted to the PRS project manager for review.

3.2.2 – Location of Release Source Areas

Maximum COC concentrations are assumed to occur at the source areas. Therefore, the identification of source areas is of primary importance to the investigation. For the purposes of this document, source areas are determined as:

1. Areas surrounding documented points of leakage, such as holes in a tank or piping, leaking pipe joints as documented in a LUST/LAST removal/upgrade report, or overfills at other specific points such as dispensers or load out racks;
2. Visually discolored or stained surface and subsurface soils;
3. Elevated field screening levels and/or analytical sampling results compared to other areas documented during the tank removal/upgrade or following any other release event; and/or,
4. Any other known locations of a spill.

For service station sites where multiple holes are documented in one tank or in adjacent tanks, the tank area may be considered as one source area. In cases where an RP or their consultant believes the source area(s), as defined above, cannot be reasonably determined or believes the proximity of potential source areas may otherwise dictate a lesser number of sampling locations, the RP or their consultant should consult with the Department to select the appropriate number and location of sampling areas.

In cases where site conditions preclude investigation directly through a source area (e.g., a new building or building addition sitting over the former tank excavation location, concrete debris from tank removal disposed in former tank excavation, presence of utilities, lined secondary containment areas), the Department must be consulted to determine the appropriate number and location of sampling areas. Variables used in this discussion may include, but are not limited to, the degree of obstruction, expected groundwater flow direction and depth to groundwater. In extreme cases, the Department may consider alternatives to this document, such as sampling and monitoring of soil gas and/or indoor air.

See Figure 3-1 for examples of source area(s) selection for various petroleum release scenarios.

Figure 3-1. Example Selection of Source Areas for Various Petroleum Releases

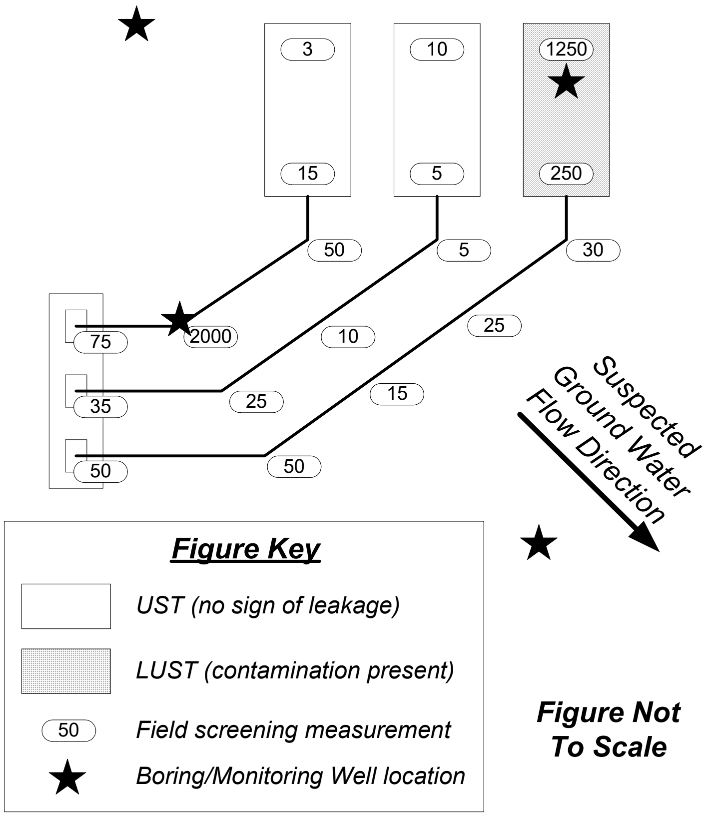


Figure 3-1a. This generalized LUST site layout (not to scale), based on a hypothetical Closure Assessment Report, provides an idealized example of determining potential source areas for monitoring well installation when conducting a RBCA Tier 1 investigation. The numbers along the product lines represent field screening measurements. The source areas are based on:

1) a documented point of leakage (corrosion holes) in one of the USTs, and

2) elevated field screening levels/laboratory analyses associated with a joint in the product piping.

Note the placement of an upgradient and downgradient monitoring well. The downgradient well should be downgradient from the point of highest source area contamination. The upgradient well should be located to best allow the groundwater flow direction to be determined.

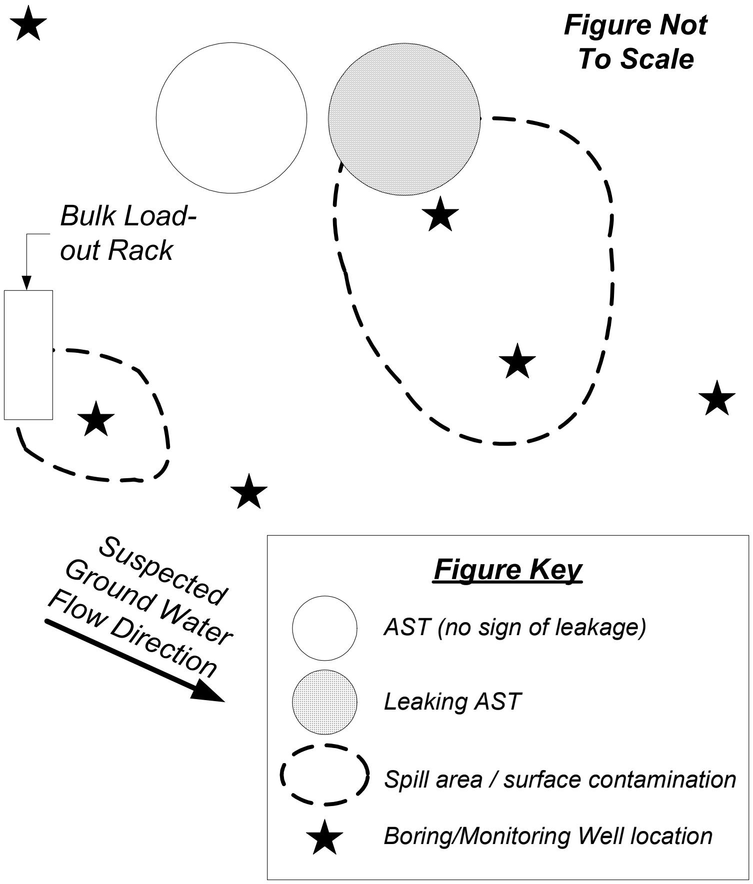


Figure 3-1b. Generalized AST release with no secondary containment around the ASTs. The actual number of source area borings (denoted by the stars within the spill area) will vary based on the size of the spill area and consultation with the Department. For such a surface release, low-lying areas where product may pool are likely candidates for boring placement. Also, this site contains a bulk load-out rack area where an unknown number of petroleum overfills have occurred and would need to be assessed during a Tier 1 investigation. Note the placement of an upgradient and down gradient monitoring well.

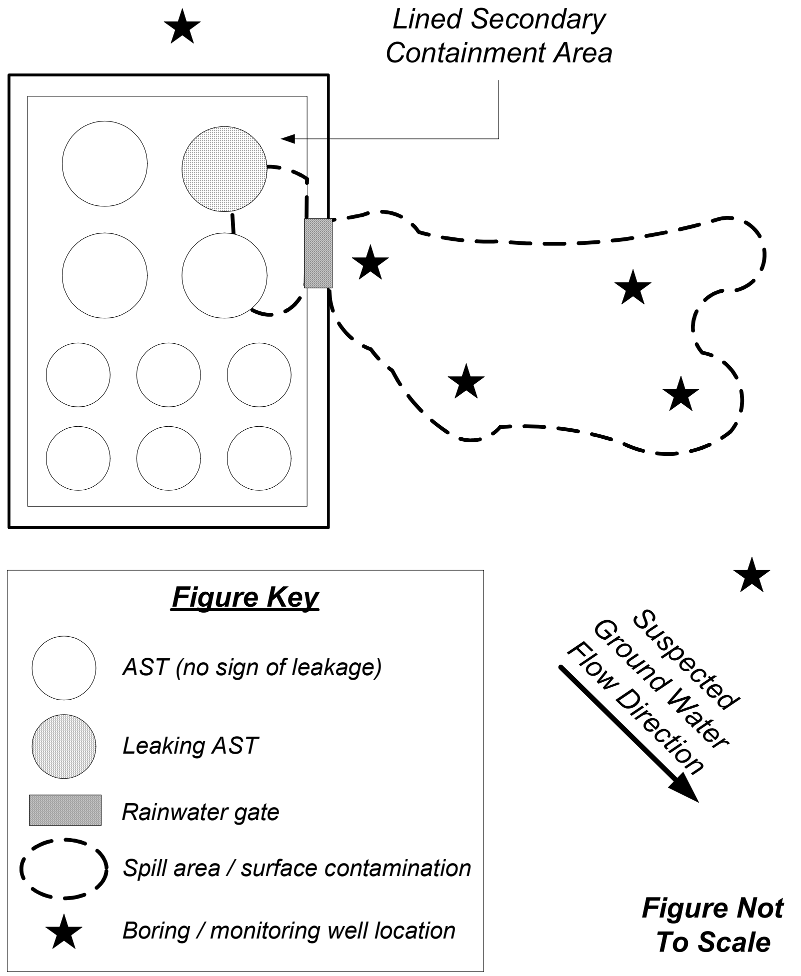


Figure 3-1c. Generalized AST bulk facility with lined secondary containment. To maintain the integrity of the liner, borings are generally not required within the secondary containment area. The actual number of source area borings/monitoring wells (denoted by the stars within the spill area) will vary based on the size of the spill area and consultation with the Department. For such a surface release, low-lying areas where product may pool are likely candidates for boring placement. Note the placement of an upgradient and down gradient monitoring well.

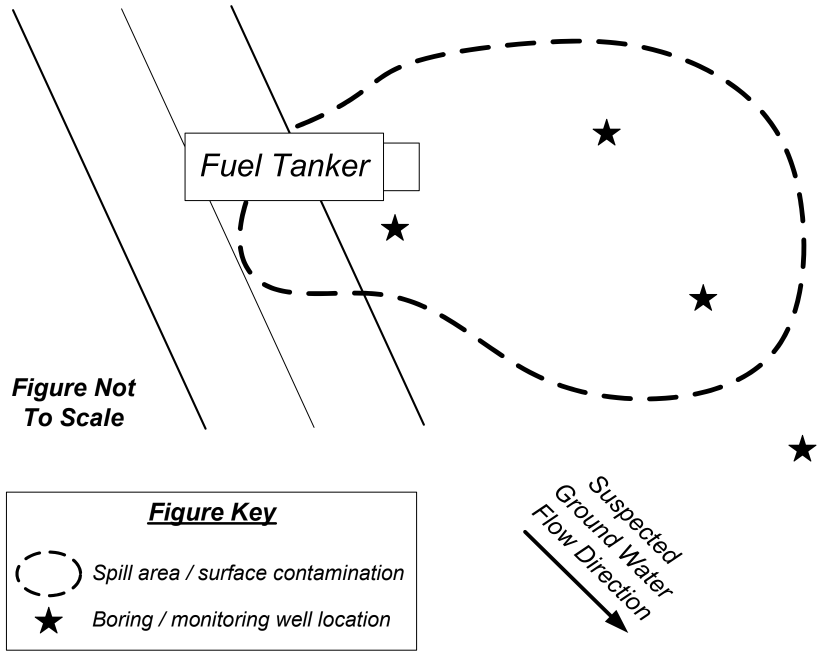


Figure 3-1d. Generalized transportation incident resulting in large volume petroleum release. This release would be ineligible for Title 200 reimbursement. The actual number of source area borings/monitoring wells (denoted by the stars within the spill area) will vary based on the size of the spill area, the surface sample analytical results, and consultation with the Department. For such a surface release, low-lying areas where product may pool are likely candidates for boring placement. An upgradient monitoring well is not needed unless there is reason to suspect that previous contamination may be present.

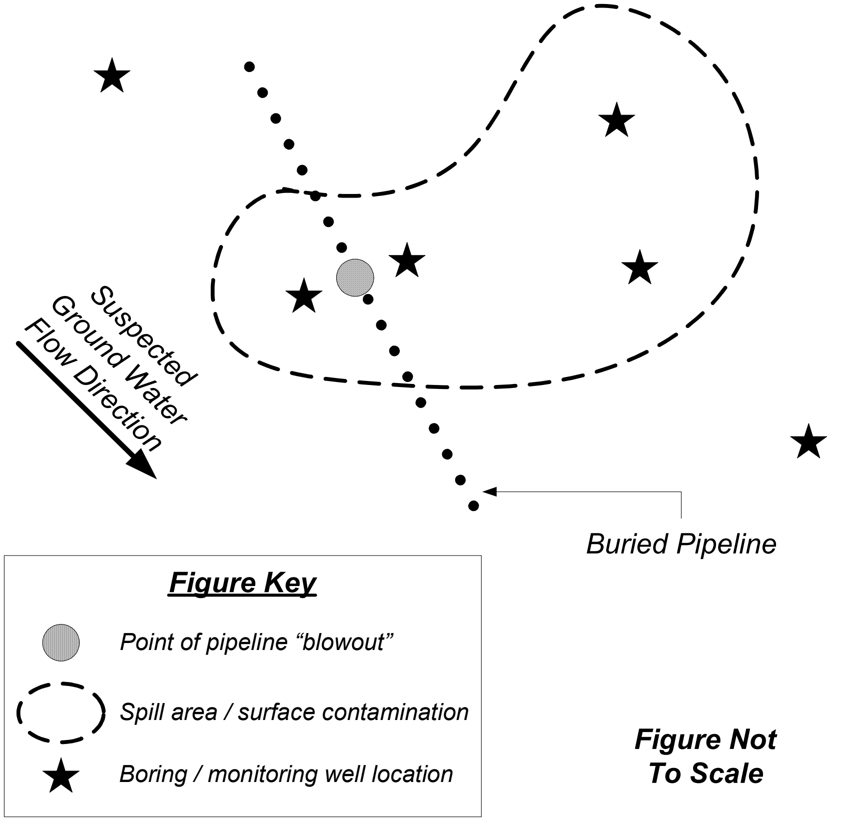


Figure 3-1e. Generalized high-volume pipeline "blowout" resulting in large volume petroleum release with an area of contaminated surface soils. This release would be ineligible for Title 200 reimbursement. The actual number of source area borings/monitoring wells (denoted by the stars within the spill area) will vary based on the size of the spill area and consultation with the Department. For such a surface release, low-lying areas where product may pool are likely candidates for boring placement. Upgradient and downgradient monitoring wells should be included.

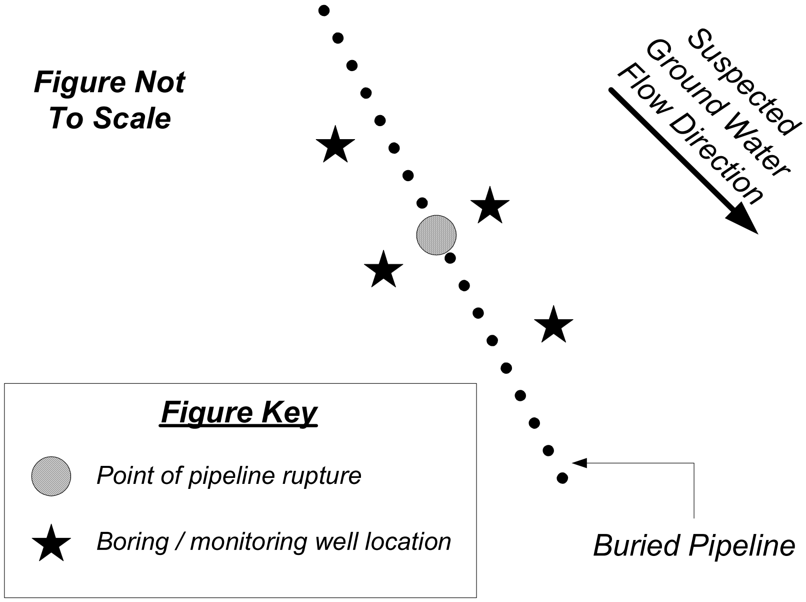


Figure 3-1f. Generalized high-volume pipeline release with limited or no contaminated surface soils. The immediate vicinity of the point of pipeline rupture would be considered the source area. A minimum of four borings/monitoring wells would be placed around the point of release, including upgradient, downgradient, and both cross-gradient locations. This release would be ineligible for Title 200 reimbursement.

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SECTION 4.0 – GENERAL RBCA SITE INVESTIGATION REQUIREMENTS

4.1 – INTRODUCTION

Section 4.0 provides guidance regarding information required for both Tier 1 and Tier 2 investigations. Such information includes selection of COCs, general site and area information, evaluation of groundwater and land use, water supply well information, free product requirements, general sampling requirements, and saturated zone characteristics.

If free product, a sheen on surface water, or petroleum vapor accumulations in structures or utility conduits are encountered at any time during the investigation, the Department must be contacted as specified in Table 2-1.

4.2 – NATURE OF THE RELEASE

4.2.1 – Product Released and Chemicals of Concern (COCs)

The petroleum products released to the environment are to be identified based on the spilled material reported to the Department, the documented presence of chemical components found in various petroleum products, and/or the available product storage history and points of leakage information documented in the Department's petroleum release file. This information is used to determine the appropriate COCs for which sampling must be performed during the site investigation.

This guidance is written to address releases of petroleum, petroleum distillates, petroleum additives, and waste oil. The COCs typically sampled for most petroleum releases are provided below in Table 4-1. To assess the overall degree of petroleum contamination at the site, a total gross hydrocarbons analysis will also be required for middle and heavy distillates.

Allowable laboratory analysis methods for these COCs are also provided in Table 4-1. The contracted laboratory must be able to achieve the minimum quantification levels that are found in Table 4-1. The Department has no lab certification program, but laboratory analysis of soil, groundwater and/or soil gas samples by laboratories certified by the National Environmental Laboratory Accreditation Program (NELAP) is recommended.

4.2.2 – Fuel/Waste Oil COCs and Alternative Use of TEH Analysis

RBCA requires that laboratory detection levels for COCs be below the potential target levels (i.e., the RBSLs and SSTLs). This is problematic for some of the polynuclear aromatic hydrocarbon (PAH) COCs, particularly benzo(a)pyrene which has a Maximum Contaminant Level (MCL) (and corresponding RBSL for the groundwater ingestion pathway) of 0.0002 mg/L.

In recognition of this potential dilemma, the Department has developed an alternative to a chemical-specific detection method for the specified PAHs. The alternate methodology takes a surrogate approach where TEH levels are used to estimate the on-site concentrations of the PAH COCs, based on a percentage of the COC in the original product. A more detailed discussion of this surrogate method can be found in Appendix A.

At the Tier 1 level, all PAHs are evaluated based on the TEH surrogate method. Therefore, the Department will not require chemical-specific analysis for the PAH COCs.

For the Tier 2 process, where SSTLs are developed, a somewhat different approach is taken. Based on the information provided in Appendix A, the PAH COC driving the evaluation of diesel fuel is naphthalene. For waste oil, it is benzo(a)pyrene (BaP). **For the evaluation of diesel fuel (and other middle distillates) at the Tier 2 level, the Department will require chemical-specific sampling for naphthalene**. This will allow for a more accurate evaluation of naphthalene and a more reasonable determination of appropriate SSTLs. For waste oil releases, the Department will still use the TEH surrogate method to establish SSTLs, and sampling for BaP is not necessary.

Table 4-1. Chemicals of Concern for Different Petroleum Product Releases

Chemical of Concern	Gasoline and JP-4	Diesel, #2 Fuel Oil, Kerosene, Other Jet Fuels	Heavy Distillates	Waste Oil	Acceptable Test Method(s)[1,2]	Minimum Quantification Level		
						Water (mg/L)	Soil (mg/kg)	Soil Gas[12] (mg/m^3)
ALKANES								
n-Hexane	X				8260 [3,6], OA-1 [4,6], TO-15[11]	0.050	0.100	550.0
AROMATICS								
Benzene	X	X		X	8260 [3,6], OA-1, TO-15[11]	0.005	0.005	4.0
Toluene	X	X		X	Same as Benzene	0.005	0.005	600.0
Ethylbenzene	X	X		X	Same as Benzene	0.005	0.005	1800.0
Xylenes	X	X		X	Same as Benzene	0.005	0.005	1300.0
OTHER VOLATILE ORGANIC COMPOUNDS (VOCs)								
MTBE	X				Same as Benzene [9]	0.020	0.020	70.0
POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) [7]								
Naphthalene		X	X	X	Tier 1: Test for TEH Tier 2: 8260 [3,6], OA-1, TO-15[11]	0.020	1.0	20.0
Pyrene		X	X	X	Test for TEH	N/A	N/A	N/A
Benzo(a)pyrene		X	X	X	Test for TEH	N/A	N/A	N/A
Total Extractable Hydrocarbons (TEH)		X	X	X	OA-2 [4,6,8], 8015B [3,6] (based on product type)	1.0	10.0	20.0
OTHER POTENTIAL ANALYTES[5]								
Ethanol					8260 [3,6] (water) 8015B [3,6], 8015C [3,6] (soil)			
Acetaldehyde					8315 [3,6]			
Formaldehyde					8315 [3,6]			

ABBREVIATIONS:

X:	COC to be analyzed
MTBE:	Methyl Tertiary-Butyl Ether
N/A:	Not Applicable; COC Screening Levels based on TEH Concentration

NOTES:

[1] The Department recommends consulting with a NELAP laboratory prior to collecting samples to determine its ability to analyze for the COCs.

[2] Other test methodologies not listed here may be appropriate for a specific COC. If an alternate methodology is desired, a prior written request must be submitted to the Department with appropriate supporting material.

[3] Methods promulgated by USEPA. Specific information regarding these methods can be found in EPA SW-846 Test Methods for Evaluating Solid Waste.

[4] The Iowa Hygienics Laboratory (IHL) methods OA-1 and OA-2 are not EPA promulgated methods, but the Department has approved them for use. Method OA-1 will analyze specifically for the BTEX compounds; Method OA-2 is to be used with the TEH surrogate method.

[5] The need to sample and analyze for these chemicals will be determined on a case-by-case basis as dictated by the product storage history and approved by the Department.

[6] The most current test method revision should be used for analysis. For method OA-1, your laboratory of preference must strictly adhere to the method as developed and written by the IHL, not a modified version of OA-1 unless approved by the IHL.

[7] Also refer to discussion in Section 4.2.2.

[8] When utilizing Method OA-2, request the laboratory to use the standard for those "heavy" petroleum products that were or may have been released, but not specifically mentioned in Table 4-1, such as naphtha, Stoddard solvent, motors oils, home heating and fuel oils, hydraulic oil, etc. Analysis for TEH(gasoline) is not required.

[9] The Department has approved the use of OA-1 and Method 8260 for volatile analysis. However, if MTBE is present in the sample (identified with the GC), we require that an MS (not an FID or PID) be used to quantify the MTBE. If MTBE is not present, the use of an MS is not necessary to quantify the remaining COC volatiles (benzene, toluene, ethylbenzene, total xylenes, n-hexane, and PAHs) that might be present in the sample.

[11] Method TO-15 is acceptable only for soil gas samples, not for water or soil.

[12] If the Department requires analysis of indoor air samples, the minimum quantification levels will be: n-hexane – 0.200; benzene – 0.0003; toluene – 0.100; ethylbenzene – 0.006; total xylenes – 0.18; MTBE – 0.0045; naphthalene – 0.0007. (all concentrations in mg/m^3)

4.3 – SITE INFORMATION

4.3.1 – Maps

Several maps depicting a variety of relationships between the release and the affected environment and potential receptors must be prepared for the investigation report. **Aerial photographs may be used as a base layer for, or submitted in addition to, a drafted map showing current features, but are not to be used as a substitute for any of the required maps.** General and specific map requirements are provided below.

4.3.1.1 General Map Requirements

Maps may be in 8.5- by 11-inch format or 11- by 17-inch format. All structures and other physical features depicted on the map must be based on current field information gathered during the pre-investigation site visit.

Maps are to be to scale and include:

1. north arrows;
2. the location of the permanent to semi-permanent benchmark used for site measurements and elevations;
3. numeric and bar scales; and,
4. a legend which includes the site name, Department spill file number, map title, map date and explanation of any symbols used.

4.3.1.2 Area Map

The Area Map is to be a general map showing the location of the facility within the bounds of the community or area in which it is found (e.g., from a USGS topographic map). In addition to the general map requirements listed above, this map must show the location of all water supply wells as designated under Section 4.4.3, all surface water bodies within 1000 feet, and all dwellings and sensitive population centers (see also Section 4.4.1) within 500 feet of the site’s source area(s).

4.3.1.3 Site Map

The Site Map is to be a larger scale map providing detail of the area within approximately 200 feet of the facility’s source area(s). In addition to the general map requirements listed above, this map must provide the location of all subsurface structures and utilities, any water supply wells, any surface water bodies, any dwellings and sensitive population centers, all sampling point locations (including vapor assessment locations) and the groundwater flow direction within this area (including groundwater elevation contours). The date of the groundwater elevation measurements used to determine the flow direction is to be included in the legend. If source area GPS coordinates are collected (see Section 4.3.4) the points at which the readings were taken should be clearly indicated on the site map.

4.3.1.4 Free Product Map

The Free Product Map, drawn to the same scale as the Site Map, is to provide details on the location, orientation, and apparent free product thickness of a free product plume. The Free Product Map is required only in instances where a measurable (≥ 0.01 feet) thickness of free product is present in one or more monitoring wells. In addition to the general map requirements listed above, this map must provide isopleths for plume thickness, the location of all buildings, subsurface structures and utilities, any water supply wells, any surface water bodies, any sensitive population centers, all sampling point locations (including vapor assessment locations), and the area groundwater flow direction.

4.3.1.5 Contaminant Plume Maps

Tier 1 Investigations: Because sampling locations are limited and the extent of contamination has not been defined, Contaminant Plume Maps are not required for Tier 1 investigations.

Tier 2 Investigations: Contaminant Plume Maps are to be provided for each media being investigated (i.e., groundwater, subsurface soils, soil gas) for each individual COC with concentrations exceeding the values presented in Table 4-2. If analytical results indicate that all concentrations of a COC are below the levels specified, no map should be submitted for that COC and media. Maps are to be drawn to the same scale as the Site Map and must provide details about the location, orientation, and quantitative sampling results of the COCs under investigation. Each map must include all analytical sampling results as well as isoconcentration lines for the lateral extent of the specific COC. Use dashed isoconcentration lines wherever data points are lacking and the information is inferred. In addition to the general map requirements listed above, these maps must provide the location of all buildings, subsurface structures and utilities, any water supply wells, any surface water bodies, any sensitive population centers, all sampling point locations (including vapor assessment locations) and the groundwater flow direction within this area.

Table 4-2. Minimum Concentrations for Contaminant Plume Maps

Contaminant of Concern	Media Affected		
	Groundwater (mg/L)	Subsurface Soil (mg/kg)	Soil Gas (mg/m^3)
Benzene	0.005	0.014	20.0
Toluene	1.0	8.510	3000.0
Ethylbenzene	0.700	4.370	9000.0
Xylenes	10.0	147.0	6500.0
n-Hexane	4.0	N/A[1]	2700.0
MTBE	0.020	0.022	350.0
Naphthalene	0.020	1.0	100.0
TEH (as Diesel fuel)	10.0	770.0	1200.0
TEH (as waste oil)	6.667	152,666.0	400.0

NOTES:

[1] Not Applicable; the target level is not exceeded for all possible saturated levels in soil.

4.3.2 – On-site Groundwater Use

Information is to be provided regarding groundwater use within the property boundaries of the release site. Documentation of this information is to include the number and use of any water supply wells, as well as any information regarding the construction and production capacities of the wells (depth, screened interval, diameter, etc.). If no on-site water supply wells exist, information is to be provided regarding the on-site water supply source.

4.3.3 – Regional Hydrogeology & Aquifer Characteristics

Information is to be provided regarding the regional hydrogeology and nature of the underlying aquifer. This information includes, but is not limited to, depth to groundwater, seasonal fluctuations, regional groundwater flow direction, controls over groundwater flow in the area (e.g., recharge areas, large expanses of paving, open drainage ditches, or nearby gaining or losing streams), subsurface sediment types, and aquifer thickness and aquifer parameters (e.g., hydraulic conductivity, transmissivity, storativity). Potential sources of this information include, but are not limited to, the USGS and the University of Nebraska Conservation and Survey Division.

4.3.4 – GPS Location

The Department requests that an accurate location for the site and each source area be determined using a Global Positioning System (GPS) receiver. Locations for individual monitoring wells may also be collected but are not required. The results are to be included on Tier 1 Report Form 3b or Tier 2 Report Form 1b in decimal degrees of latitude and longitude, reported to at least six decimal places (i.e., 99.123456). Supporting information to be provided on the form includes:

- The manufacturer and model number of the GPS receiver used.
- The datum used by the unit. The Department prefers either WGS84 (the typical manufacturers' default setting) or NAD83.
- The unit's WAAS (Wide Area Augmentation System) status: enabled (preferred), disabled, or N/A.
- The numerical accuracy of the location coordinates, if available. While the use of recreational-quality GPS units is adequate for site and source-area locations, the Department recommends using a unit that provides sub-meter accuracy if individual well locations are collected.
- A description of the point at which the coordinates were collected.

The location(s) where GPS readings were taken should also be included on the site map.

The location chosen for source area coordinates is to be as close as possible to the point of highest reported contamination within each identified source area. The general site location coordinates may be collected at either or both of the following locations:

- The intersection of the facility driveway with the closest public street, road, or highway
- Immediately outside the main office of the facility

When collecting the location coordinates, the Department recommends that the GPS unit be placed on a stationary surface and left in place for several minutes. Close proximity to trees, buildings, vehicles, and other objects should be avoided if possible as they may affect the quality of the received signal.

4.4 – ADJACENT LAND USE & RECEPTOR INFORMATION

The concept of risk-based investigations requires an understanding of the ideas of receptors and points of exposure. For the purposes of this document:

> "**Receptor**" refers to any humans potentially exposed acutely (short-term) or chronically (long-term) to any COCs from a petroleum release.
>
> "**Points of Exposure**" (POE) refers to the locations at which the receptor is potentially exposed, such as water wells or basements. POEs may be actual or hypothetical (future-use) locations, depending on groundwater use or the location of structures in the area.
>
> "**Ecological Exposure**" refers to locations where the COCs or free product from a petroleum release contact a lake, stream, wetland, or other surface water body with the potential to affect wildlife.

In order for the Department to evaluate the potential impacts to POEs and the consequential risk to humans, information must be collected about a variety of areas as described in the following sections.

4.4.1 – Current Land Use

Information regarding land use in the area around a petroleum release is needed for site evaluation and determination of the appropriate RBSLs and SSTLs. At the RBCA Tier 1 level, the Department classifies each release site as "Residential" or "Commercial" based on land use within a 500-foot radius of the site. "Residential," for the purposes of this document, refers to the presence of dwellings (e.g., houses, apartments) and/or sensitive population centers (e.g., schools, day care centers, hospitals, nursing homes). Sites that cannot be classified as residential, based on the preceding definition, are characterized as being in a "Commercial" setting.

At the RBCA Tier 2 level, on-site and off-site land use will be determined on a site-specific basis for properties directly or potentially affected by the petroleum release.

4.4.2 – Future Land Use

The potential for future changes in area land use must be considered during the data collection process. The current property owner is to be interviewed regarding planned development or land use changes that would affect the property's classification as residential or commercial. Any planned or proposed changes must be documented in the report.

4.4.3 – Water Well Survey

Information regarding the location and distance of water supply wells must be gathered. Water supply wells include municipal, domestic, irrigation, industrial, and agricultural water wells. This definition also includes sand points, hand-pumped wells, etc., used in activities such as, but not limited to, lawn irrigation or as a park water supply. The RP/consultant is to collect information on:

- all municipal wells within 2000 feet of the source area(s),
- domestic, irrigation, industrial, and agricultural wells within 1000 feet, and
- sand points and hand-pumped wells within 500 feet.

The information must include the owner of the well and, where available, the depth, screened interval, type and duration of use, and Nebraska Department of Natural Resources Registration number (see Appendix F for contact information).

Unregistered wells may be present. The local Water or Utility Superintendent must be contacted and asked about the presence and locations of unregistered domestic or other wells. The full name of the person contacted and the conversation date must be documented in the report. A visual survey of properties within 200 feet of the source (Tier 1) or within 200 feet of the maximum extent of soil contamination, free product, or dissolved contamination in groundwater (Tier 2) must also be conducted to verify the presence or absence of unregistered wells. Contact the property owner(s) if necessary. The unregistered well survey should be made in conjunction with the subsurface structures survey (Section 4.4.4).

At the Tier 1 level, all water supply wells described above are treated as potential points of exposure (POEs). At the Tier 2 level, only those water wells that influence or are threatened by the contaminant plume are considered potential POEs.

4.4.4 – Subsurface Structures

Identify the location and depth of all subsurface structures within 200 feet of the source (Tier 1) or within 200 feet of the maximum extent of soil contamination, free product, or dissolved contamination in groundwater (Tier 2). Subsurface structures include buildings with basements or crawl spaces, cellars, storm or sanitary sewer lines, utility conduits, or any other man-made space that might allow the accumulation of vapors from the release. Consult the local utility superintendent and conduct a visual survey of properties to verify the presence or absence of basements or other subgrade structures. Contact the property owner if necessary. The subsurface structures survey should be made in conjunction with the unregistered well survey (Section 4.4.3).

4.4.5 – Ecological Exposures Survey

Permanent surface water bodies within 1000 feet of the source (Tier 1) or within 1000 feet of the maximum extent of soil contamination, free product, or dissolved contamination in groundwater (Tier 2) are to be visually inspected for petroleum sheens possibly emanating from the source. Permanent surface water bodies refer to any river, stream, lake, pond, wetland, sand pit, quarry or similar water body which is likely to have water year-round or a significant portion of the year. All surface water bodies must be assessed for the presence of free product, petroleum sheen or petroleum contaminated seeps. When any of these situations are encountered on or in surface water, the PRS project manager must be contacted by the next business day. The need for additional assessment of these surface water bodies or other potential ecological exposures (e.g., endangered or threatened species considerations) will be determined by the Department.

4.5 – INSTALLATION, DEVELOPMENT, & ABANDONMENT OF MONITORING WELLS

4.5.1 – Monitoring Well Installation

All boring and monitoring well installation methods must adhere to the criteria described below. Monitoring wells are to be constructed as directed under Nebraska Title 178 – Environmental Health (administered by the Nebraska Department of Environment and Energy). Any regulatory variances from Title 178 must be approved by NDEE in advance and documented in the workplan and report.

4.5.1.1 General Installation Requirements

Monitoring wells must be a minimum of 2 inches in diameter. Screen length for all monitoring wells is not to exceed 10 feet without prior approval. Screens are to be commercially-slotted or continually-wrapped schedule 40 PVC. Monitoring wells should be constructed so that the anticipated static groundwater level intersects the midpoint of the screened interval. In cases where seasonal or other fluctuations of the groundwater table are anticipated, the range of expected fluctuations must be stated in the workplan. In those instances, the Department may approve a longer screen length or require the installation of additional monitoring wells to address the anticipated fluctuations.

In cases where utilities or other subsurface structures are present and the location cannot be reliably determined, the use of air knifing, potholing, or similar techniques may be appropriate. The NDEE project manager must be consulted for approval before beginning any such work.

NOTE: For the annular seal of wells screened at or above the groundwater table, the Department recommends the use of bentonite chips or a slurry containing cement. Wells screened below the water table should be sealed using bentonite granules or a cementaceous slurry. The use of a bentonite-only slurry is discouraged because it does not provide as many solids in the annular space.

4.5.1.2 Auger Drilling

A hollow stem auger is the preferred drilling method for environmental assessments. Solid stem augers may be used only for those monitor wells installed away from known source areas, when the material being drilled will maintain its integrity throughout the length of the boring without the aid of outside support, and **only** after Department approval. If there is any chance the borehole will distort (i.e., cave, heave, slough, etc.), solid stem augers are not to be used. Samples must be collected ahead of the drill string when either auger drilling method is used (see Section 4.7.2.2).

4.5.1.3 Direct Push

Direct push technologies can be used for Tier 1 investigations only if permanent monitoring wells can be constructed in compliance with Title 178. They are acceptable for Tier 2 investigations for soil vapor assessment (see Section 4.7.4), provided that analysis of vapors is performed in accordance with Section 6.3.1, or for soil and groundwater assessment, if they allow for the collection of all data required under this section and do not violate Title 178 requirements for any permanent monitoring wells.

4.5.1.4 Other Methods

Air rotary, mud rotary and/or cable tool drilling methods may be necessary in certain circumstances (e.g., excessive groundwater depth, near surface bedrock). However, such methods generally preclude the collection of soil samples as required by the Department. In such cases, either hollow stem augers will need to be used in conjunction with the alternate drilling method for subsurface soil sampling or the consultant must provide adequate evidence that the required and representative soil samples can be collected using the alternate drilling method. Contact the PRS project manager for approval of alternate drilling methods and additional requirements.

4.5.2 – Monitoring Well Development

Nebraska Title 178 requires that all cased water wells be developed. Monitoring wells are to be developed using a method that will maintain the integrity of the well materials. Well development is to continue until visibly clear water is discharged from the well or until indicator parameters (i.e., temperature, pH, conductivity) have stabilized. Any drilling method that involves the use of drilling fluids (e.g., mud rotary or head of water on hollow stem augers) must account for the volume of the fluid used when developing the well.

Sufficient time must be allowed following monitoring well installation and/or development in order for groundwater in the well to reach equilibrium conditions before groundwater samples for analytical analyses are collected. This time will vary based on site-specific conditions and will be at the discretion of the consultant. Well development does not suffice as a purging event.

4.5.3 – Purging of Monitoring Wells

4.5.3.1 Monitoring Wells in Sands or Gravels

Monitoring wells screened entirely or partially in sands or gravels and sampled for dissolved phase contaminants must be purged prior to sample collection, but should never be purged dry. Allowable purging methods are:

- pneumatic pumps;
- centrifugal pumps;
- positive displacement pumps;
- bailing (provided the bailer is gently lowered into groundwater)

The method used must minimize the agitation of formation water entering the well during the purging process. A minimum of three well volumes are to be removed, or the well is to be purged until the physical parameters of pH and conductivity stabilize within ±10% difference and temperature within ±1% for three consecutive readings. These physical parameters are to be measured after removing each well volume. The total water volume removed and field measurements are to be included in the assessment report.

If at any time during the purging process water levels in the well indicate that it is in danger of being purged dry, purging is to be halted. The failed purging attempt must be included in the investigation report, and for the current and any future sampling events the well is to be purged according to Section 4.5.3.2, below.

4.5.3.2 Monitoring Wells in Fine Grained Materials (clays, silts, or very fine sands)

Purging should be attempted prior to sampling unless the well has previously been identified as a low-yield well. If the purging attempt increases the turbidity of the water or water levels indicate that it is in danger of being purged dry, purging is to be halted and the failed purging attempt noted in the investigation report. Any well with a failed purging attempt will be treated thereafter as a low-yield well.

Low-yield wells, if the screened interval intersects the groundwater table, are at risk of being purged dry and are not to be purged at all. Low-yield wells screened completely below the groundwater table are to be purged of stagnant water only to the top of the screen. The method used must minimize the agitation of formation water entering the well and any fine-grained material within the well. The preferable method is to use low-flow pumps.

4.5.4 – Abandonment of Monitoring Wells

When monitoring wells are no longer needed for the site investigation or remedial activities, they must be abandoned in accordance with NDEE Title 178. For sites eligible for reimbursement under Title 200, a workplan and cost estimate must be submitted. The Department's approval is required before abandonment may take place.

4.5.4.1 Request to Retain Monitoring Wells for Subsequent Use

Once the Department determines that monitoring wells are no longer needed at a site, the responsible party or other property owner may request to retain one or more of the wells for their subsequent use. The request must be submitted in writing, identifying the well(s) in question by identification number and by designation on a copy of the site map and specifying the intended future use of the well(s). The Department will consider the request, but under no circumstances can a well be retained for a use that would constitute a new Point of Exposure resulting in a change to the site's RBSLs or SSTLs and leading to the need for additional remedial actions. If approved for well retention is granted by the Department, the Department of Natural Resources must be notified to transfer formal ownership of the well(s) to the new owner. A copy of the revised registration must be provided to the Department. The new owner will assume full responsibility for the security, maintenance, and eventual abandonment of the well(s).

4.6 – FREE PRODUCT ON GROUNDWATER

Free product will be defined as measurable (≥ 0.01 feet) petroleum product thickness that is present as a non-aqueous-phase liquid (but will not include a product sheen).

4.6.1 – Discovery of Free Product

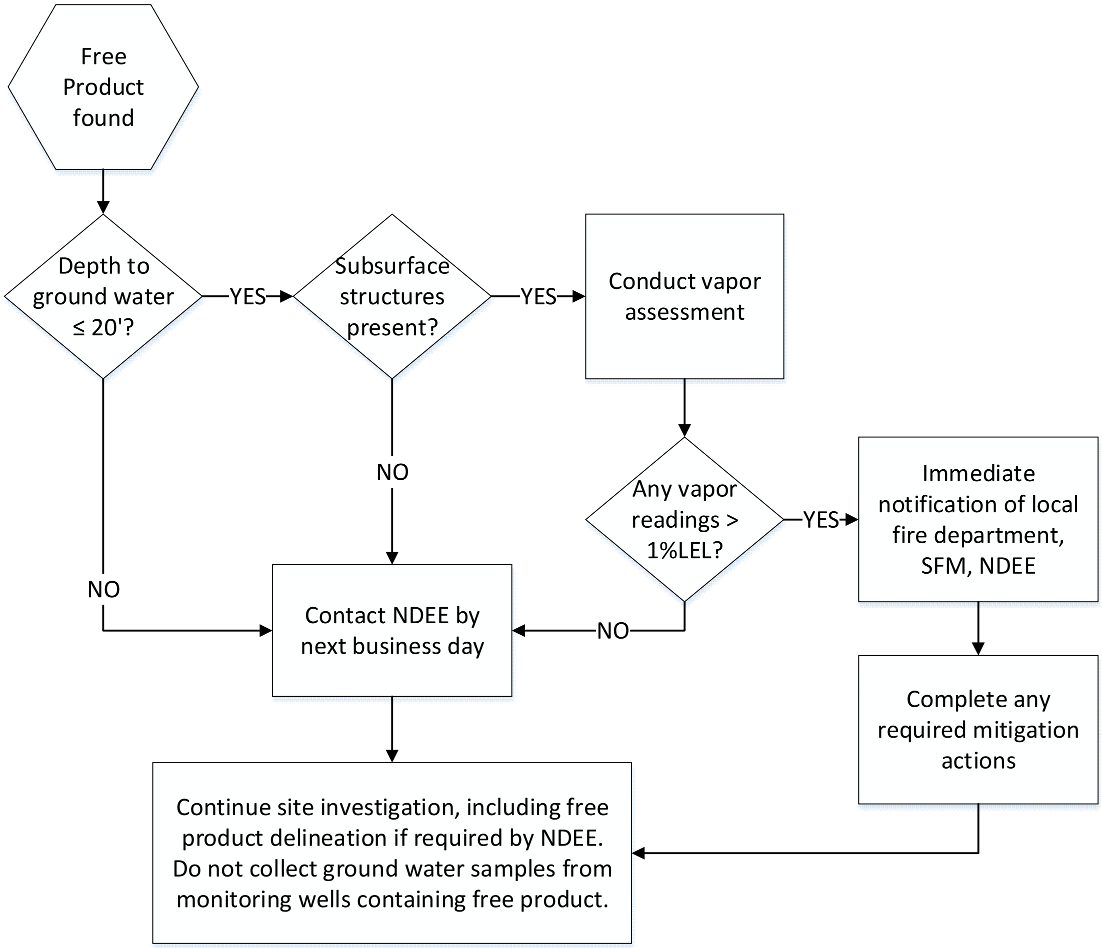
If free product is detected on groundwater during the site investigation, the Department must be notified, and additional actions are required depending on the site conditions:

- If the depth to groundwater is ≤ 20 feet below ground level (BGL) and subsurface structures (e.g., storm or sanitary sewers, buildings with basements or crawl spaces) are present, a vapor assessment must be conducted according to Section 4.7.4. The results are to be reported as specified in Table 2-1.
- If the depth to groundwater is greater than 20 feet BGL or no subsurface structures are present, the Department must be notified by the next business day. The site investigation can continue as planned with the exception that no groundwater samples should be collected for laboratory analysis from monitoring wells containing a measurable thickness of free product.

The free product response process is depicted as a flow chart in Figure 4-1.

Upon notification of the presence of free product, the Department may amend the Tier 1 or Tier 2 site assessment to include a subsurface investigation to assess the extent of the free product plume. The minimum data requirements for a free product assessment are provided in the following section, 4.6.2.

Figure 4-1. Free Product Response Process



4.6.2 – Minimum Free Product Assessment Data Requirements

- Items 1 - 5 of Section 5.1 (covering historical information, land use assessment, identification of petroleum product released and appropriate COCs, location and number of source areas, and potential POE information).
- Subsurface soil and surface soil (where applicable) samples must be collected, for analysis of the appropriate COCs. The actual number of samples to be analyzed is described in Section 5.2.1 (for subsurface soils) and Section 5.2.2 (for surface soils).
- The extent and magnitude of free product must be assessed by placing monitoring wells outward from the source areas in such a manner as to allow for the full lateral delineation of the free product plume and by measurement of apparent free product thickness in the wells. Results are to be depicted on a Free Product Map as detailed in Section 4.3.1.4.
- For sites with a depth to groundwater of 20 feet or less, on-site subsurface structures (including but not limited to storm and sanitary sewer lines, utility conduits, and basements) must be assessed for the presence of vapors. Subsurface utilities must be assessed for the presence of explosive vapors. Buildings directly above the free product plume must be assessed for the presence of **any** petroleum vapors using the procedure provided in Section 4.7.4.
- In instances where a water supply well is impacted or may be threatened, installation and groundwater sampling of a sentinel monitoring well(s) placed between the water supply well and the free product plume may be required by the PRS project manager. Several sentinel monitoring wells may be required and may be screened at varying depths.

4.7 – GENERAL SAMPLING REQUIREMENTS

4.7.1 – General Subsurface Advancement Methods

Methods of accessing subsurface soils and groundwater are discussed in Sections 4.5.1.2 through 4.5.1.4. Geoprobe or other direct push technologies are not allowed for Tier 1 investigations and may be applicable for only some Tier 2 pathways.

4.7.2 – Soil Sample Collection Methods

Methods to be used in the sample collection of subsurface soils are as follows:

4.7.2.1 Sampling of Surface Soils

Surface and near-surface soils represent a threat of dermal exposure or inhalation or ingestion of particulates. The appropriate sampling strategy depends on the source of the release and thus, the expected nature of the contamination:

1. For releases originating from **underground storage tank systems or buried piping** where surface soil contamination is present, surface soil samples are to be obtained from source-area borings at a depth between 0.5 and 3 feet BGL using split-barrel or thin-walled tubes as described in ASTM D 1586-84 Method for Penetration Test and Split-Barrel Sampling of Soils and ASTM D 1587-83 Practice for Thin-Walled Tube Sampling of Soils, or other similar methods as approved by the Department. Field screening of a portion of the sample is to be performed in accordance with Section 4.7.2.3. The portion of the cored sample used for laboratory analysis is to be collected in accordance with Section 4.7.2.4.

2. For **releases upon the surface of the land**, where contaminated surface soils are still present, one sample must be collected for laboratory analysis from each source area of 100 square feet or less, with a further sample collected for every additional 400 square feet of affected area (see Figure 3-1b). Samples must be collected from a depth between 0.5 and 3 feet BGL at points where the highest levels of contamination are measured, evident, or suspected within the affected area. In order to determine the area of contamination, field screening must be performed on a portion of the sample in accordance with Section 4.7.2.3 and another portion submitted for laboratory analysis in accordance with Section 4.7.2.4.

4.7.2.2 Continuous Sampling

Since one of the objectives in the sampling of a source area is to collect samples from what are suspected or perceived as the most contaminated portions of the boring, continuous sampling of all borings used to characterize soil contamination is required. Soil samples are to be collected using split-barrel or thin-walled tubes as specified in Section 4.7.2.1, Item 1. Field screening samples should be collected from all borings at a maximum interval of 5 feet.

All soil samples will be split into at least two different portions or aliquots at the time of sampling. One portion will be used for headspace screening and characterization. The other portion(s) will be transferred to and sealed in an appropriately prepared sample jar for possible laboratory analysis, and immediately placed on ice.

Tier 1 borings: Continuous sampling is required at all boring/monitoring well locations in identified source areas. In non-source boring/monitoring well locations, if evidence of contamination (field screening above 200 PID/FID response units) is detected in the first 25 feet, continuous sampling is required for the remainder of that boring and samples for laboratory analysis must be collected as for a known source-area boring.

Tier 2 borings: Continuous sampling will be required at downgradient and cross gradient locations to characterize the geology across the site in addition to the borings used to characterize soil contamination. Where a boring is continuously sampled solely for the purposes of describing the site geology, analytical samples are not required. This information will be used to construct geologic cross sections parallel and perpendicular to the groundwater flow direction. If evidence of contamination (field screening above 200 PID/FID response units) is detected in the first 25 feet during non-source-area drilling, continuous sampling is required for the remainder of that boring and samples for laboratory analysis must be collected as for a known source-area boring.

4.7.2.3 Field Screening

For consistency, only static headspace analysis for field screening of soil samples is to be used. Static headspace analysis must be performed using the following method:

1. Place the soil sample in a clean, wide-mouth glass jar with a screw-on, airtight lid. (Plastic bags are not allowed for field screening and laboratory analysis.)
2. Gently fill the jar one-half full with the soil sample.
3. Cover the mouth of the jar immediately with aluminum foil and secure the lid.
4. Place the jar in an environment above 60° F for 30 minutes.
5. Measure the contaminant level by removing the lid and puncturing the foil immediately with the instrument probe.
6. Record the highest level that the instrument registers.

Acceptable field instruments are Photoionization Detectors (PIDs), Flame Ionization Detectors (FIDs), and portable Gas Chromatographs (GCs). At a minimum, all field instruments are to be cleaned prior to use at each site and calibrated immediately before use and at regular intervals during use in accordance with the manufacturer's specifications.

4.7.2.4 Soil Sample Collection and Transport for Laboratory Analysis

The following procedure is to be used in collecting laboratory samples:

1. Prior to sampling, contact the laboratory for specific container requirements.
2. Quickly and gently place soil samples (do not compact soil) in the sample container, leaving as little headspace as possible.
3. Immediately seal containers with air-tight, Teflon-lined, screw-on lids.

To limit the loss of volatile organics during sample collection and shipping, a portion of each soil sample interval must be delivered to an appropriately prepared sample jar for possible laboratory analysis and immediately placed on ice. Once all field analyses have been performed, the appropriate number of samples, corresponding to the locations of highest contamination as documented by field screening, is to be submitted for laboratory analysis.

4.7.3 – Groundwater Sample Collection Methods

Any method used to collect groundwater samples must minimize agitation and avoid negative-displacement methods. Suction, airlift, inertial lift (Waterra ® or similar), or peristaltic pumps are not to be used to collect samples due to their agitative action and potential loss of volatile COCs. Acceptable sampling methods include the use of:

- gear-drive pumps
- helical rotor pumps
- pneumatic piston pumps (sealed drive gas)
- bladder pumps
- passive diffusion bag samplers (for wells totally screened below the water table where MTBE is not identified and a vertical gradient is not present in the aquifer)
- bailing (provided the bailer is gently lowered into groundwater)
- HydraSleeves®

Laboratory requirements for sample containers, methods of preservation, and sample holding times must be followed. These requirements may be COC-specific. The sampling method should always be included in workplans and investigation report narratives. Once the monitoring wells have been opened and allowed to equilibrate, wells are to be sampled from least contaminated to most contaminated. Groundwater samples are to be collected in the following order to minimize the loss of volatiles:

1. VOCs (BTEX, n-hexane, MTBE)
2. Total Extractable Hydrocarbons

4.7.4 – Air Sampling for Subsurface Structure Vapor Assessment

Initial vapor assessment of potentially impacted subsurface structures (e.g., on-site basements [including crawl spaces and similar structures] and on-site and proximate sanitary and storm sewers or utility conduits) is to be conducted using a photoionization detector (PID) or flame ionization detector (FID). If elevated levels of contamination are detected with the PID/FID, additional site screening is to be performed using a combustible gas indicator (CGI) or other explosimeter to determine the extent of the vapor impact. If explosive vapor concentrations are detected at a level >1% of the lower explosive limit (LEL) within a structure, as indicated by the explosimeter, the local fire department, State Fire Marshal's Office, and the Department must be contacted immediately as described in Table 2-1. These agencies will then determine the need for immediate mitigative actions. The location and depth of each structure showing evidence of vapor impact must be determined and included on the site map (Section 4.3.1.3).

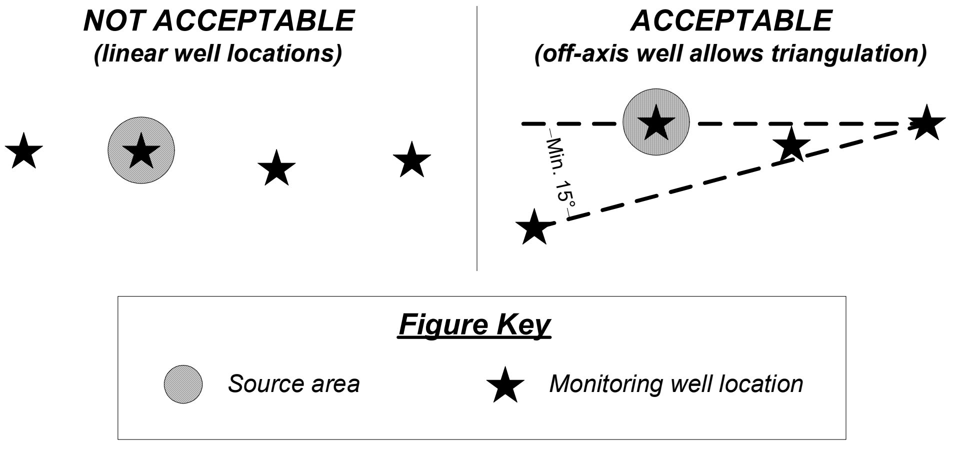
Table 2-1 provides a summary of notification requirements to be followed. If any vapor concentrations are detected within a building and do not represent an explosive hazard as described in the preceding paragraph, the Department must be contacted by the next business day. The Department will then determine what actions are needed in the immediate, short-term and long-term time frames to mitigate the vapor problem.

4.8 – SATURATED ZONE CHARACTERISTICS

4.8.1 – Groundwater Flow Direction

Accurate determination of the groundwater flow direction at the site is a critical part of both the Tier 1 and Tier 2 investigations. Monitoring well locations must be selected to avoid a linear or near-linear arrangement which might result in an erroneous concept of the flow direction. At least one well must be sited 15 degrees or more off-axis in order to allow for adequate triangulation and determination of a representative groundwater flow direction. See Figure 4-2 for examples.

Figure 4-2. Well Placement for Determining Groundwater Flow Direction



The linear well arrangement in the first example can result in an ambiguous groundwater flow direction. Placing at least one well off-axis as in the second example allows for triangulation and a more reliable determination of the groundwater flow direction.

4.8.2 – Hydraulic Conductivity

Site-specific values for hydraulic conductivity based on slug or pump tests will not be required for Tier 1 and Tier 2 investigations. Hydraulic conductivity values are to be selected from the values provided in Table 4-3, based on sediment type and other descriptive features (e.g., sorting) from the boring logs.

Table 4-3. Estimated Hydraulic Conductivity (K) Values from Particle Size Descriptions

Grain Size	Degree of Sorting			Silt Content		
	Poor	Moderate	Well	Slight	Moderate	Very
Clay and Silt						
Clay	0.7	----	----	----	----	----
Clay, silty	1.3	----	----	----	----	----
Silt, clayey	2.7	----	----	----	----	----
Silt	6.7	----	----	----	----	----
Silt, sandy	10.7	----	----	----	----	----
Sand and Gravel						
Very fine sand	13.4	20.1	26.7	22.7	18.7	13.4
VF to F sand	26.7	26.7	----	24.1	20.1	13.4
VF to M sand	36.1	----	----	32.1	26.7	20.7
VF to C sand	48.1	----	----	40.1	30.7	24.1
VF to VC sand	58.8	----	----	50.8	40.1	29.4
VF sand to F gravel	76.2	----	----	66.8	52.1	38.1
VF sand to M gravel	98.9	----	----	80.2	65.5	49.5
VF sand to C gravel	128.3	----	----	107	85.6	64.2
Fine sand	26.7	40.1	53.5	33.4	26.7	20.1
F to M sand	53.5	66.8	----	48.1	39.4	30.1
F to C sand	57.5	----	----	53.5	42.8	32.1
F to VC sand	70.2	----	----	60.2	47.5	34.8
F sand to F gravel	88.2	----	----	73.5	58.8	44.1
F sand to M gravel	113.6	----	----	93.6	74.9	56.8
F sand to C gravel	145.1	----	----	107	86.9	72.2
Medium sand	66.8	80.2	93.6	63.5	51.5	40.1
M to C sand	73.5	93.6	----	72.2	57.5	42.1
M to VC sand	84.2	----	----	73.5	60.8	48.8
M sand to F gravel	103.6	----	----	83.6	68.2	52.1
M sand to M gravel	131	----	----	113.6	81.6	65.5
M sand to C gravel	164.4	----	----	133.7	108.3	82.2
Coarse sand	80.2	107	133.7	93.6	73.5	53.5
C to VC sand	93.6	133.7	----	93.6	74.9	56.8
C sand to F gravel	116.3	----	----	107	87.6	68.2
C sand to M gravel	147.1	----	----	113.6	93.6	73.5
C sand to C gravel	184.5	----	----	133.7	99.6	92.2
Very coarse sand	107	147.1	187.2	113.6	93.6	73.5
VC sand to F gravel	133.7	213.9	----	120.3	103.6	86.9
VC sand to M gravel	169.8	----	----	147.1	123	98.9
VC sand to C gravel	207.2	----	----	160.4	131.7	103.6
Gravel						
Fine gravel	160.4	213.9	267.4	160.4	140.4	107
F to M gravel	200.5	334.2	----	200.5	167.1	133.7
F to C gravel	244.7	----	----	234	189.2	144.4
Medium gravel	240.6	320.9	401.1	240.6	200.5	160.4
M to C gravel	294.1	467.9		294.1	242.6	190.5
Coarse gravel	334.2	467.9	601.6	334.2	284.1	234

All values are expressed in feet/day.

Source: NDEE Wellhead Protection Program (modified from Reed and Piskin, UNL-CSD)

4.8.3 – Hydraulic Gradient

The hydraulic gradient is to be determined by taking the difference in hydraulic head (in feet) between two or more wells screened in the same aquifer aligned in the direction of groundwater flow and dividing by the distance (in feet) between the wells.

4.8.4 – Depth to Groundwater

The depth to groundwater is one of the factors used to determine the appropriate RBSLs and calculation of SSTLs for the following exposure pathways:

- Soil leaching to groundwater
- Intrusion of vapors to structure from contaminated groundwater

For estimating RBSLs and SSTLs for the intrusion of vapors from contaminated groundwater pathway, depth to groundwater must be measured from below the bottom of a basement or crawl space, if present, or from ground surface, if no basement or crawl space is present.

The thickness of the vadose zone is based on the depth below grade at which the groundwater interface is encountered. Depth to groundwater information must be collected as follows:

1. Reference elevations to a local or United States Geological Survey (USGS) benchmark. A local benchmark is any arbitrary, permanent, nearby feature or structure to which all subsequent elevation can be referenced over a number of years. The location of the selected benchmark must be identified on the site maps (Section 4.3.1.3). Measure the depth to water to within 0.01 foot from the top of the monitoring well casing.
2. Place a permanent mark on the well casing so all subsequent sampling events are measured from the same spot.
3. Take measurements with an interface probe or electronic measure tape (E-line).

Static water levels are dependent on site-specific conditions, including well construction, which could lead to aberrant groundwater level readings. The use of stick-up wellhead protectors and vented caps may greatly reduce the time needed to obtain true static water levels; however, vented caps are not to be used when the well is constructed in an area prone to flooding or surface drainage. All wells should be opened and adequate time allowed for water levels to stabilize prior to taking water level measurements. All water levels for the development of groundwater contour maps are to be obtained during a single measurement event. All water level measurements and the time (i.e., date, hour, minutes) they were taken are to be recorded and submitted as part of the assessment report.

4.8.5 – Groundwater Table Variations

Seasonal variations in water table depth and flow direction should be included, if known. This information may be gathered as either: 1) site specific data or 2) “areal” information based on past investigation and monitoring at other nearby release sites.

4.8.6 – Porosity

For Tier 1, values for soil porosity (symbolized as “n”) are either of two default values: sands/gravels (n = 0.30) or silts/clays (n = 0.35). The default porosity is determined based on the predominant sediment type in which a documented or potential POE (e.g., well screen, basement) is situated.

For Tier 2, porosity values are to be selected from the values provided in Table 6-2 (see Section 6.2.1).

4.8.7 – Calculated Groundwater Flow Velocity

For the Tier 1 and Tier 2 investigations, the general groundwater flow velocity is calculated in the report forms using the following equation:

$$\frac{K \times i}{n}$$

Where:
K is the hydraulic conductivity in feet per day
i is the hydraulic gradient (dimensionless)
n is the porosity of the saturated sediments

4.9 – QUALITY ASSURANCE/QUALITY CONTROL CONSIDERATIONS

Soil and groundwater samples should be collected carefully and consistently at all times. Soil for samples should be handled quickly and with as little disturbance as possible, and all water samples for volatile analysis should be checked for bubbles after sealing the sample container. If any bubbles are present, a new sample should be collected. To improve the overall quality and consistency of the data collected, the Department also requires that certain quality assurance/quality control (QA/QC) actions be taken during Tier 1 and Tier 2 investigations. A QA/QC program ensures that the quality of the data generated is sufficiently reliable for the RBCA process and that the results are representative, accurate, precise, and comparable.

If the following QA/QC samples are not collected and the results documented in the report, the chain-of-custody is broken, sample holding times are exceeded, or any other event occurs that may cast doubt on the quality of the data, the samples must be recollected. For Title 200 eligible releases, only costs associated with usable data can be eligible for reimbursement. If samples must be recollected due to a QA/QC issue, the costs associated with the first sampling event will most likely be ineligible for reimbursement.

QA/QC requirements and considerations apply to Tier 1 and Tier 2 investigations as well as any other sampling required by the Department, and include the following:

4.9.1 – "Blind" Duplicate Samples

No duplicate samples are required for soil or soil gas samples. One duplicate sample is required for every five monitoring wells or points sampled for groundwater. This means that one duplicate sample is required for five wells or less, two duplicates for six to ten wells, etc. The duplicate samples are to be collected from monitoring wells known or suspected to be contaminated. Sampling bottles must not be labeled as "duplicate." Duplicate samples are to be collected and analyzed for the same COCs as the original sample. Results must be provided in the designated Report Form.

4.9.2 – Field Blanks

No field blanks are required for soil or soil gas samples. The purpose of field blanks is to assess the potential contribution of airborne contaminants to groundwater samples. Ample field blanks are to be prepared. The sample container and preservation requirements are to comply with the laboratory requirements for the specific contaminants. Field blanks are to be analyzed for all applicable COCs for which groundwater samples are being collected, except for TEH or specific naphthalene samples. One field blank must be collected at the beginning of each day's sampling. One additional field blank is required whenever site conditions (e.g., when moving work efforts from a low-activity or low-traffic area like a residential area to a high-activity or high-traffic area like along a highway on the same site) and/or weather conditions change.

During the groundwater monitoring well sampling event, the field blank must be opened and exposed to ambient conditions for a period equal to the time from when the sample container is opened or the bailer or sampling pump first contains the actual sample (whichever is first) to when the sample vial/jar is closed, since this is when the groundwater sample and the interior of the sample container are exposed to the atmosphere. The amount of time the field blank was exposed to ambient conditions should be recorded on the QA/QC form. After closing the blank VOC vials, they should be inspected for bubbles and any problems noted on the chain-of-custody only. Results should be provided in the designated Report Form.

4.9.3 – Trip Blanks

No trip blanks are required for soil or soil gas samples. The purpose of the trip blank is to assess if sample bottle preparation, sample shipment, and laboratory handling and storage practices impact sample integrity. The blank groundwater sample(s) must be prepared by the laboratory or in the office prior to traveling to the site for the sampling event and must remain untouched while in the shipping container. The trip blank must be preserved as required by the laboratory and maintained under the same chain-of-custody as the other samples. One trip blank is required for each cooler used during the sampling event. Trip blanks are to be analyzed for all applicable COCs for which groundwater samples are being collected, except that no trip blanks are required for TEH or specific naphthalene samples. Results should be provided in the designated Report Form.

4.9.4 – Temperature Blanks / Thermometers

The purpose of a temperature blank is to ensure that samples have been maintained at a temperature of 4°C from the time of collection through their delivery to the laboratory. Temperature blanks may be provided by the laboratory, or the temperature may be measured in the field using a laboratory-grade thermometer prior to sealing the shipping container. If the samples are not delivered at 4°C (±2°C), the laboratory must note this on the chain-of-custody. Consequently, the Department may consider the data quality questionable. One temperature blank is required for each shipping container. Results should be provided in the designated Report Form.

4.9.5 – QA/QC Documents

The chain-of-custody record is to be started when the trip blank(s) are placed into the sample cooler. A copy of the chain-of-custody is to accompany each sampling event through delivery of the samples to laboratory. A copy of the chain-of-custody record is to be included in the investigation report. All samples must be maintained under the chain-of-custody. If the chain-of-custody is broken, samples must be recollected after informing the Department of the event. A site investigation report cannot be considered complete by the Department when the chain-of-custody has been broken.

Any reports which include laboratory analytical data must also contain the spiked-sample analysis results and chromatograms for all samples.

4.9.6 – Field Instrumentation Calibration

Field instruments are to be calibrated immediately before use and at regular intervals during use according to the manufacturer's specifications. Calibration intervals are to be included in the narrative section of the final report.

4.9.7 – Decontamination of Sampling Equipment

In addition to ensuring field instruments are cleaned and properly maintained, new or laboratory-cleaned sample containers must be used for the collection of each soil or groundwater sample. In addition, the following decontamination requirements apply to ancillary sampling equipment.

4.9.7.1 Soil Samples

The sample collection device (e.g., split-barrel or thin-walled tube), and any other instrument contacting the sample, must be decontaminated between each sample. At a minimum, decontamination is accomplished by washing the device with a laboratory-grade detergent (e.g., Alconox, Detergent 8) after removing all loose material, followed by two clean water rinses (final rinse of deionized water). The soil sample must be placed in a new or laboratory cleaned sample container. Auger stems are to be decontaminated (e.g., steamed-cleaned, scrubbed with a laboratory grade detergent) before drilling a new borehole.

4.9.7.2 Groundwater Samples

The order of sampling is to be from the least contaminated to most contaminated well (i.e., source areas). Any device used to purge (where applicable) or sample a monitoring well must be appropriately decontaminated prior to introduction into the well. At a minimum, such decontamination is accomplished by washing the device with a laboratory-grade detergent (e.g., Alconox, Detergent 8) after removing all loose material, followed by two clean water rinses (final rinse of deionized water). If a bailer is to be used to collect a water sample, it must be a new, disposable bailer or a laboratory cleaned, reusable bailer. New bailer line must be used for each well (unless Teflon-coated, allowing for decontamination). The water sample must be placed in a new or laboratory cleaned sample container.

Refer to ASTM Standard D 5088-90 Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites for additional information concerning the decontamination of drilling and sampling equipment exposed to other contaminants.

4.10 – DOCUMENTATION OF NEBRASKA RBCA INVESTIGATION

The information gathered for the RBCA investigation is to be documented and recorded on the forms provided by the Department for the particular RBCA Tier assessment. Examples of these Report Forms can be found in Appendix B (Tier 1) and Appendix C (Tier 2). Copies of these forms in Microsoft Excel format may be downloaded from the Department's web page (http://dee.ne.gov; see Publications/Forms) or are available on request by contacting a PRS project manager.

In addition to the Report Forms cited above, the following additional information is to be provided in the general formats discussed below.

4.10.1 – Maps

Maps as discussed in Section 4.3.1 are to be included in the investigation report.

4.10.2 – Boring/Monitoring Well Data

4.10.2.1 Licensing and Registration

Companies and individuals engaged in the installation, servicing, and sampling of monitoring or water wells in Nebraska are required to hold a license for that purpose, issued by the Nebraska Department of Environment and Energy (NDEE) Water Well Standards and Contractors' Licensing Program (see Appendix F). The requirements are contained in NDEE Title 178, which also sets forth the acceptable standards for well installation and construction.

Names and license numbers of personnel or subcontractors involved in installing or sampling wells during the investigation must be recorded on the appropriate Tier 1 or Tier 2 Report Form or included as part of any remediation or monitoring report.

If a regulatory variance from the Title 178 regulations is desired, the PRS project manager must first be contacted and agree to the proposal. The variance must then be obtained from NDEE prior to conducting the field work and a copy of the variance must be submitted with the workplan and report.

All monitoring wells must be registered with the Nebraska Department of Natural Resources (DNR). Contact information is available in Appendix F.

4.10.2.2 Boring Logs

Boring logs (or the results obtained from direct push technologies or other approved methods) are to include, at a minimum, the following information:

a) Consultant company name.
b) Project name.
c) Drilling contractor name (if other than consultant).
d) Names of personnel present from the consulting company and drilling contractor.
e) NDEE license numbers of all personnel involved in installing the boring.
f) Date and time drilling started and ended.
g) Boring identification number.
h) Surface elevation.
i) Boring location.
j) Drilling method.
k) Sediment description and classification (provide system used).
l) Sample collection depth intervals.
m) Field screening analysis results.
n) Total depth of boring.
o) Depth to water at time of drilling. Include date and time of measurement.
p) Stabilized depth to water. Include date and time of measurement.
q) Indicate if the boring was abandoned or completed as a permanent monitoring well.

4.10.2.3 Groundwater Monitoring Wells

Construction details for monitoring wells are to include the following minimum information:

a) Well identification number.
b) Installation date.
c) Top of casing elevation.
d) Ground level elevation.
e) Screen slot size.
f) Casing and screen material.
g) Length of screen (should never be >10 feet unless approved).
h) Screened interval depths.
i) Stabilized water level.
j) Gravel-pack material and interval.
k) Bentonite seal interval(s).
l) Bottom of well elevation.
m) Grout type and interval(s).
n) Consultant company name.
o) Drilling contractor name (if other than consultant).
p) Names of personnel present from the consulting company and drilling contractor.
q) NDEE license numbers of all personnel involved in installing the monitoring well.
r) DNR registration number, if available at the time of the report.
s) Lapsed development time.

4.10.2.4 Soil Vapor Monitoring Wells

Wells constructed as permanent vapor monitoring points that do not contact the water table are not regulated under Title 178 at the time of this writing. This situation may change in the near future, and the Department recommends consulting the NDEE if vapor monitoring wells are planned as part of an investigation. Such wells must, however, be registered with the Department of Natural Resources as soil vapor monitoring wells under the "Other" category.

If soil vapor monitoring wells are installed, the following minimum information must be provided in the report:

a) Well identification number.
b) Installation date.
c) Screen slot size.
d) Casing and screen material.
e) Length of screen.

f) Screened interval depths.
g) Bottom of well elevation.
h) Seal type and interval(s).
i) Consultant company name.
j) Drilling contractor name (if other than consultant).
k) Names of personnel present from the consulting company and drilling contractor.
l) DNR registration number, if available at the time of the report.

4.10.3 – Cross Sections

Cross sections are to be constructed using the results of the subsurface borings and must provide an understanding of the subsurface geology and clearly indicate known and inferred areas of contamination. Cross sections are required as follows:

- **Tier 1 Investigation** – No cross sections necessary.
- **Tier 2 Investigation** – A minimum of two views, including one parallel to and one perpendicular to the groundwater flow direction. The views should intersect the source area(s).

4.10.4 – Sampling Data

The following information, at a minimum, is to be noted in or provided as an appendix to the final report:

- Analytical method and version employed,
- All laboratory analysis sheets produced by the analytical laboratory, including chromatograms, and
- All chain-of-custody sheets generated.

Laboratory data may be provided in electronic form as described in Section 4.10.5.2, provided that a printed summary table is included in the report.

4.10.5 – Electronic Report Submittal

4.10.5.1 Reports via E-mail

All Tier 1 and Tier 2 investigation reports may be submitted electronically. The documents must be in PDF format, attached to an email sent to NDEE.ECMupload@nebraska.gov . The email subject must be in the format:
FACILITY ID# – PROGRAM (LST or RA) – PROGRAM ID (spill number) – BRIEF DOCUMENT DESCRIPTION
For example: **62076 – LST – 120194-GW-0830 – Tier 1**

You may copy the NDEE project manager on the email, but DO NOT send documents to the project manager only. **Electronic submittals will only be accepted if they are sent to the** NDEE.ECMupload@nebraska.gov **email address.** If you intend to also submit a paper copy of the document, please indicate this in the body of the email, and provide the email submission date on the paper document.

4.10.5.2 Reports on CD

To conserve paper and reduce the physical size of hard copy reports and to save printing and postage expenses, the following supporting information may be submitted in electronic form on a standard CD-R instead of being printed:

- Lab analytical data (provided that a printed summary table is included in the report).
- Pump test data.
- SVE, AS, or other pilot test data.
- Well registration and abandonment forms.

All other information, such as boring logs, well construction diagrams, maps, or photos, must be included in its entirety in the printed report.

Such electronic submittal is not a requirement. It is an option that is available, to be used at the consultant's discretion. Should any of the above information be submitted on CD, the following requirements apply:

- The CD must be labeled with the site name, NDEE spill number, NDEE IIS number, and report name and date. It must also be titled as an Appendix to the report.
- A table of contents must be included in the Appendix's position in the printed report, listing each of the files included on the CD.
- Files are to be in PDF format.
- Appropriate sections of the printed report are to contain a brief summary of the information, as well as references directing the reader to the CD for complete details. For example: *"Pilot test results indicate that SVE would be feasible at the site, with a minimum estimated radius of influence of 25 feet. Refer to the file SVE_TEST.PDF in Appendix E for full details."* If laboratory analytical results are provided on CD, a table summarizing the results for every well sampled must be included in the printed report.

The CD may be submitted as an unattached appendix or bound into the printed report.

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SECTION 5.0 – TIER 1 SITE INVESTIGATION

Prior to initiating a Tier 1 site investigation, the Department requires that a workplan, complete with the proposed sampling locations, and cost estimate be submitted for review for Title 200 eligible sites. A workplan, without a cost estimate, is required for sites not eligible for Title 200 reimbursement. Copies of any variances from regulations obtained from the Department or any other agency for environmental work related to the Tier 1 investigation must be included with the workplan. Any proposed changes from the methods presented in this document must be highlighted and explained. Access agreements should be secured with property owners for all planned and prospective drilling locations prior to mobilization for fieldwork. The RP is to proceed with the Tier 1 site investigation within the established time schedule once the Department's approval letter is received.

The following provides guidance regarding the information required to complete the requirements of a Tier 1 investigation. The Minimum Site Assessment Data Requirements section below provides a general outline of the required information. Detailed requirements for specific tasks in the site investigation are referenced as needed.

Direct push technologies are not to be used to collect data for a Tier 1 investigation. Title 178 does not currently allow the use of direct push to install the permanent monitoring wells that are required as part of the Tier 1 investigation.

5.1 – MINIMUM TIER 1 SITE ASSESSMENT DATA REQUIREMENTS

The minimum investigation data needs for a petroleum release Tier 1 site assessment are as follows:

1. Historical information, particularly of past releases and the results of any associated investigation(s), if any.
2. Identification, location, and number of source areas to be investigated. See Section 3.2.2.
3. Identification of petroleum product(s) released to the environment (for determining appropriate COCs; see Section 4.2).
4. An assessment of land use in the area of the release site. See Section 4.4.
5. Information regarding:
    - The location and distance of water supply wells as provided in Section 4.4.3;
    - The use of the water produced by each well and the potential for human access to it (faucets, sprinklers, etc.);
    - The location of permanent surface water bodies within 1000 feet of the source area(s), as described in Section 4.4.5; and,
    - The location of all structures, including all buildings (and depths of any associated basements) and subsurface utilities within 200 feet of the source area(s), as outlined in Section 4.4.4. It is especially important to ascertain if the buildings have subsurface structures (e.g., basements, crawl spaces, or cellars).

<u>NOTE</u>: It is only since 1993 that domestic water wells had to be registered with the State. Many domestic wells will not appear in the Nebraska Department of Natural Resources registered well database (see Appendix F). Consequently, it is very important that a house-to-house survey be conducted to determine if any domestic drinking water wells are located within 1000 feet of the source area(s). In addition, local water/utility superintendents are a useful source of such information.

6. The presence of free phase petroleum product on groundwater should be determined as described under Section 4.6.

<u>NOTE</u>: When free product is encountered on groundwater, certain site investigation requirements for Tier 1 groundwater sampling may be suspended until all free product issues have been resolved. In such an instance, the RP is still responsible for completing any unsuspended Tier 1 requirements as well as performing all actions and providing all information described in the <u>FREE PRODUCT ON GROUNDWATER</u> section (Section 4.6) by the Department's established compliance date.

7. Soil and groundwater samples must be collected for analysis of the appropriate COCs associated with the petroleum product(s) released to determine the on-site COC concentrations. Specific information regarding COCs and appropriate analytical methods are found in Section 4.2 and Table 4-1.
8. The actual number of samples to be obtained for laboratory analysis of the COCs is provided in Sections 5.2 (for soils) and 5.3 (for groundwater).

9. An evaluation of vertical migration of the dissolved plume must be made where a water supply well may be of sufficient or suspected proximity and/or pumping capacity to influence the dissolved product plume. At least one deeper monitoring well may be required for sites with a drinking water well located within 250 feet of the release source area (Section 5.3).
10. The depth to groundwater and its flow direction must be established, and the applicable saturated zone parameters (hydraulic conductivity, porosity, and gradient) must be determined in order to calculate groundwater flow velocity. See Section 4.8.
11. The names and addresses of groundwater users and landowners within 500 feet of the site must be provided if the location is in a rural or non-incorporated community setting.

5.2 – NUMBER OF SOIL SAMPLES

All source area borings are to be sampled as described in this section. In addition, if contaminated soils are discovered in the vadose zone while drilling outside of known source areas, the well is to be continuously sampled from that point and soil samples collected using the same guidelines.

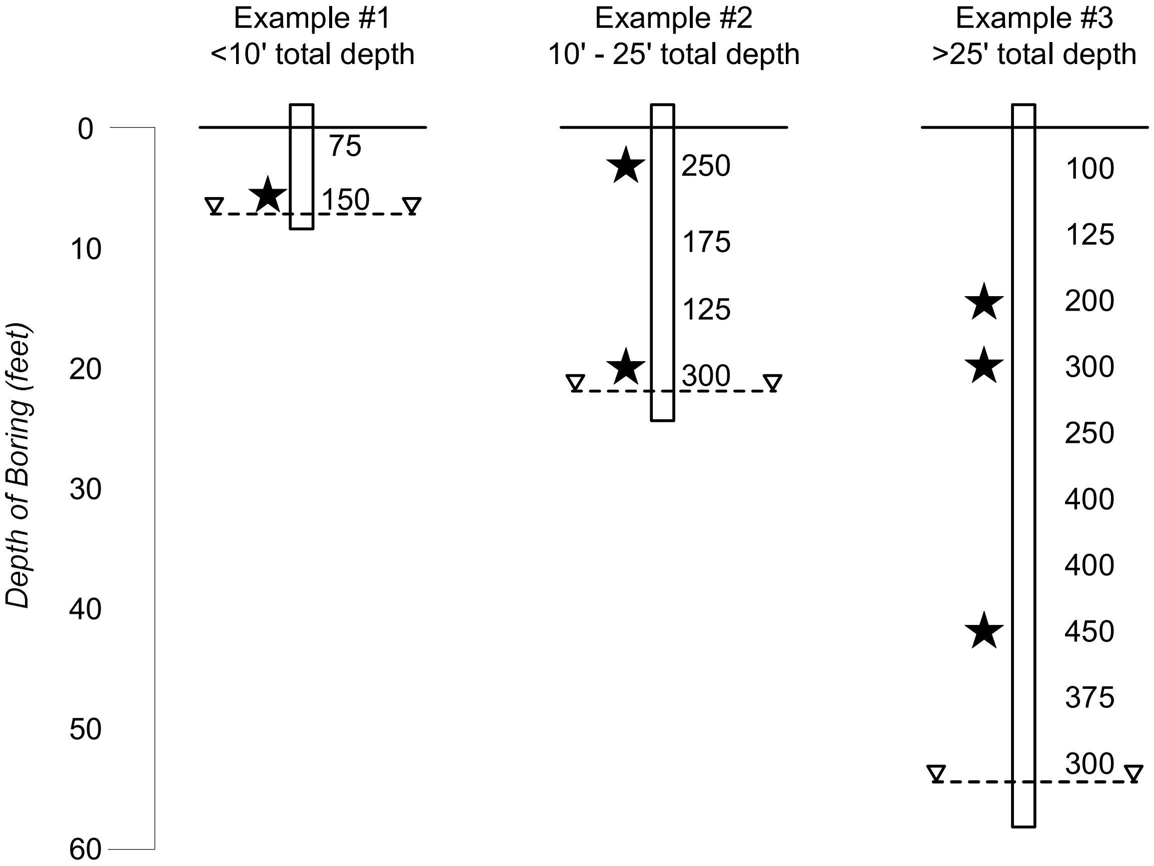
5.2.1 – Subsurface Soils

One to three subsurface soil samples from the vadose zone are to be analyzed from each applicable source boring/monitoring well, depending on the depth to groundwater.

- Where groundwater is <10 feet BGL, only one soil sample is required at the point where the highest level of contamination is measured by field instrumentation.
- Where groundwater is ≥10 feet, but ≤25 feet BGL, two subsurface soil samples must be collected at the points where the highest levels of contamination are measured by field instrumentation.
- Where groundwater is >25 feet BGL, two or three soil samples must be collected. Two soil samples must be obtained within the initial 25 feet BGL. For borings extending deeper than 25 feet, one additional soil sample is required **if** field instrumentation readings indicate a concentration greater than those identified in the first 25 feet of the boring. See Figure 5-1.

Should auger refusal (or near refusal) occur at depth before encountering groundwater, a soil sample is to be collected from the bottom of the boring for laboratory analysis and the results (with the collection depth) submitted in the Tier 1 investigation report. A decision concerning the use of an alternate drilling method will be made after the laboratory soil analysis results have been discussed with the Department.

Figure 5-1. Examples of Subsurface Soil Collection Points



This figure provides a visual explanation for determining the need to collect 2 or 3 subsurface soil samples from a boring. Factors involved in this decision are depth to groundwater and relative degree of contamination with depth. Field instrument readings are on the right side of the borings. Groundwater is indicated by the dashed lines. Approximate sampling depths are marked by the star symbols. Samples must always be collected from within the unsaturated zone, rather than at or below the groundwater table. In cases where an indicated sampling point is at the water table (Borings #1 and #2 in this example), the sample should be collected from just above the saturated sediments.

For Example #1, the groundwater depth is less than 10 feet BGL. A single soil sample is required from the point of highest observed contamination.

For Example #2, the depth to groundwater is less than 25 feet BGL, but greater than 10 feet BGL. In this circumstance, two soil samples would be required, since both samples would be used to evaluate the soil leaching to groundwater exposure pathway and the enclosed space inhalation from contaminated subsurface soils exposure pathway.

For Example #3, groundwater is in excess of 25 feet BGL and there is indication of higher contaminant levels at depth as evidenced by the elevated field instrument readings. Under these circumstances, three soil samples would be necessary. The two samples taken within the top 25 feet of the borehole would be used to evaluate the enclosed space inhalation from contaminated subsurface soils exposure pathway. A third sample from a perceived point of higher gross contamination at depth would be needed to adequately evaluate the soil leaching to groundwater pathway.

5.2.2 – Surface Soils

Surface soils are defined as those unsaturated materials located between 0 and 3 feet BGL. Where surface soil contamination is present (i.e., recognized from ground surface staining), soil samples are to be collected **within each** surface source area. For individual surface source areas of less than approximately 100 ft^2, one sample is to be collected. For source areas that exceed approximately 100 square feet (100 ft^2), one sample is required within the first 100 square feet, as well as one additional sample for every further 400 square feet of affected area, at different points of obvious contamination. Examples are provided in Figure 3-1. The surface soil sample(s) must be collected at points where the highest level of contamination is measured, evident or suspected. The Department will assess the need for additional surface soil sampling during its review. Surface soil samples are to be obtained from a depth between 0.5 and 3 feet BGL.

5.3 – NUMBER OF GROUNDWATER SAMPLES

The actual number of samples to be obtained for laboratory analysis is based on the following:

- One groundwater sample is to be collected from a single monitoring well located upgradient of the source area(s) to establish background water quality.
- One groundwater sample is collected from **each** source area.
- One groundwater sample is to be collected from a minimum of one monitoring well located downgradient of the source area where petroleum contamination of the greatest concentration is suspected.
- If a downgradient recharge area is present, or a water supply well is located within 250 feet of the site and may be of sufficient pumping capacity to influence the dissolved product plume, at least one sample is to be collected at depth to address the possibility of vertical contaminant migration. The monitoring well is to be located between the source and the well or recharge area. If more than one such POE is present (or depending on the site geology and the screened interval of the threatened well) multiple monitoring wells may be necessary. The depth of the screened interval of the well(s) must be presented in the workplan.

5.4 – TIER 1 WAIVER OF GROUNDWATER SAMPLING

Drilling to and sampling of groundwater may be waived if ***all*** the following conditions are met:

1. All potential source areas identified in the workplan are investigated.
2. Clear evidence from field screening analyses and other field observations indicates the probability or likelihood that contamination has not migrated from the source through the entire thickness of the vadose zone. (That is, field screening no longer detects contamination in the vadose zone.)
3. The unsaturated zone interval between the point where contamination is no longer detectable with field instrumentation and the estimated depth of groundwater at the site (based on regional information or past investigations in the area) is greater than 25 feet.
4. Two subsurface soil samples for laboratory analysis are collected from each boring: 1) at a minimum of five feet below the last indication of contamination and 2) at a minimum of 10 feet below the bottom of the previous sample interval. These two samples are in addition to the subsurface soil samples collected at the suspected points of highest contamination as described in Section 5.2.1.

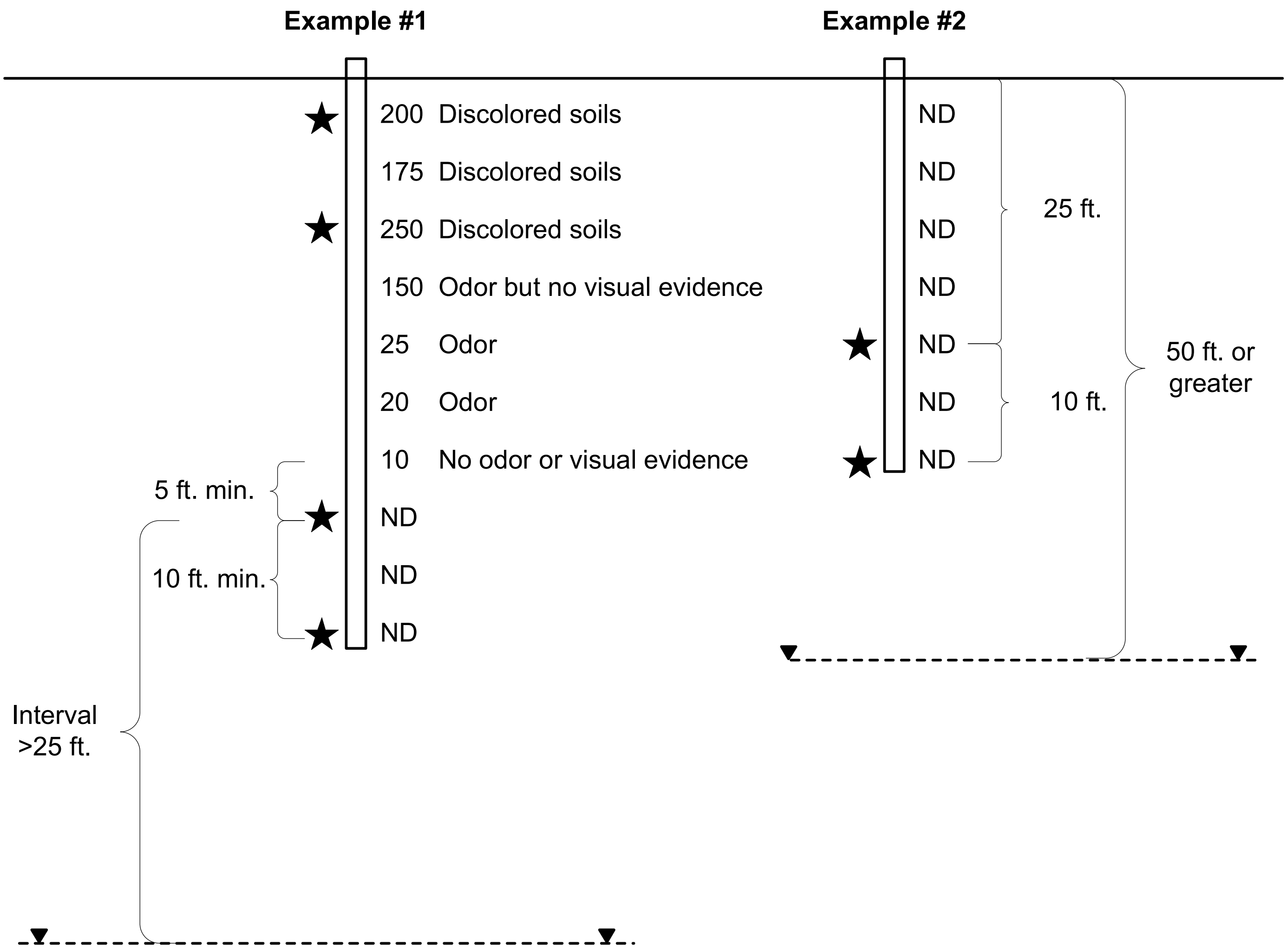
The groundwater sampling waiver may also apply to source area borings that do not encounter any soil contamination. Soil samples are required at 25 feet and 35 feet BGL, and the anticipated depth to groundwater must be 50 feet or greater.

Figure 5-2 provides a visual explanation of these sampling requirements. Documentation that supports the contention that groundwater is at substantial depth (i.e., information from regional groundwater maps, past environmental reports) must be provided in the investigation report.

If multiple source areas are present, the possibility of groundwater sampling wavier is considered at each independently. In cases where at least one but not all source areas fulfill the waiver requirements, the PRS project manager should be contacted to discuss appropriate locations for installing the remaining non-source-area monitoring wells.

Should auger refusal (or near refusal) occur at depth before encountering groundwater, a soil sample is to be collected from the bottom of the boring for laboratory analysis and the results (with the collection depth) submitted in the Tier 1 investigation report. A decision concerning the use of an alternate drilling method will be made after the laboratory soil analysis results have been discussed with the Department.

Figure 5-2. Conditions for Discontinuing Borehole to Groundwater



This idealized figure (not to scale) illustrates the conditions under which drilling through a source area may be discontinued without completing the boring to groundwater during a RBCA Tier 1 investigation. Approximate sampling locations in the above examples are indicated by the star symbols.

Example #1: Visual, olfactory and field instrument evidence indicates no contamination is present at a point that is greater than 25 feet above the assumed level of groundwater. In addition to the subsurface soil samples necessary to evaluate those exposure pathways associated with subsurface soils (see Figure 5-1), two more subsurface soil samples for laboratory analysis are required for each source area investigated to confirm the field observations. The first sample is to be collected at a point 5 feet below the last indication of contamination, and the second is to be collected at a minimum of 10 feet below the bottom of the previous sample interval.

Example #2: No evidence of contamination is present at any point in the boring, and the anticipated depth to groundwater is at least 50 feet. Two soil samples for laboratory analysis are required, one at 25 feet BGL and the second at 35 feet BGL.

5.5 – TIER 1 REPORTING REQUIREMENTS

The Department has established a reporting format that the RP or their consultant is required to use for the submittal of the investigation results. The report format consists of Report Forms generated in Microsoft Excel for most of the required data. The Tier 1 Report Forms have been revised to incorporate the changes in this guidance document. The forms are presented in Appendix B. Copies of these forms in Microsoft Excel format may be downloaded from the Department's website (http://dee.ne.gov).

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SECTION 6.0 – TIER 2 SITE INVESTIGATION

The Tier 2 investigation involves only those exposure pathways where contaminant levels exceeded the Tier 1 RBSLs. These pathways will be identified by the Department when the Tier 2 investigation is requested. Soil and/or groundwater samples must be collected for analysis of the appropriate COCs associated with the petroleum product(s) released to determine the on-site COC concentrations. Specific information regarding COCs and appropriate analytical methods are found in Section 4.2 and Table 4-1.

Prior to initiating a Tier 2 site investigation, the Department requires that a workplan, complete with the proposed sampling locations, and cost estimate be submitted for review for Title 200 eligible sites. A workplan, without a cost estimate, is required for sites ineligible for Title 200. Copies of any variances from regulations obtained from the Department or any other agency for environmental work related to the Tier 2 investigation must be included with the workplan. Any proposed changes from the methods presented in this document must be highlighted and explained. The RP is to proceed with the Tier 2 site investigation within the established time schedule once the Department's approval letter is received.

Various methods can be used to collect the required Tier 2 data. Table 6-1 addresses the applicability of two of the most common techniques (auger drilling and direct push) for the various exposure pathways, as well as some alternative methods. Not all potentially applicable methods are listed in the table; the PRS project manager should be contacted to discuss the use of methods not specifically addressed in this guidance document.

Table 6-1. Common Data Collection Techniques for Tier 2 Investigations

Exposure Pathway	Conventional (Auger) Drilling Techniques	Direct Push Technologies (see NOTE below)	Other Methods (not inclusive)
Free Product delineation	Borings must be completed as permanent monitoring wells.	Only if permanent monitoring wells can be completed in compliance with Title 178	
Groundwater Ingestion	YES	Sample collection or permanent monitoring wells in compliance with Title 178	
Soil Leaching to Groundwater	YES	YES	
Inhalation of Vapors from Groundwater	Acceptable for groundwater sample collection.	Acceptable for groundwater or soil gas sample collection. Soil gas samples must be analyzed in accordance with Section 6.3.1.	Hand-installed subfloor soil gas sampling points.
Inhalation of Vapors from Contaminated Subsurface Soil	Acceptable for soil sample collection.	Acceptable for soil or soil gas sample collection. Soil gas samples must be analyzed in accordance with Section 6.3.1.	Hand-installed subfloor soil gas sampling points.
Surface Soil Contamination	N/A – There are no separate Tier 2 SSTLs for this pathway. If the Tier 1 RBSLs are exceeded, remedial actions will normally be required.	N/A – There are no separate Tier 2 SSTLs for this pathway. If the Tier 1 RBSLs are exceeded, remedial actions will normally be required.	

NOTE: If direct push techniques are used for Tier 2 sample collection only, the Department may require subsequent installation of permanent monitoring wells if the site requires remediation or additional monitoring.

Tier 2 investigations may require sampling locations on lands adjoining the source area property. To avoid unnecessary delays, prospective off-site locations should be identified and access permission obtained as early in the Tier 2 process as possible. If a property owner refuses to grant permission for access and no suitable alternative location is available, the PRS project manager should be contacted for assistance. The property owner's name, phone number, and the location of the property in question should be provided.

6.1 – MINIMUM TIER 2 SITE ASSESSMENT DATA REQUIREMENTS

The minimum investigation requirements needed for a Tier 2 site assessment are presented below for each of the exposure pathways. The Tier 2 investigation is to collect only that information necessary to evaluate specific pathways that failed the Tier 1 evaluation.

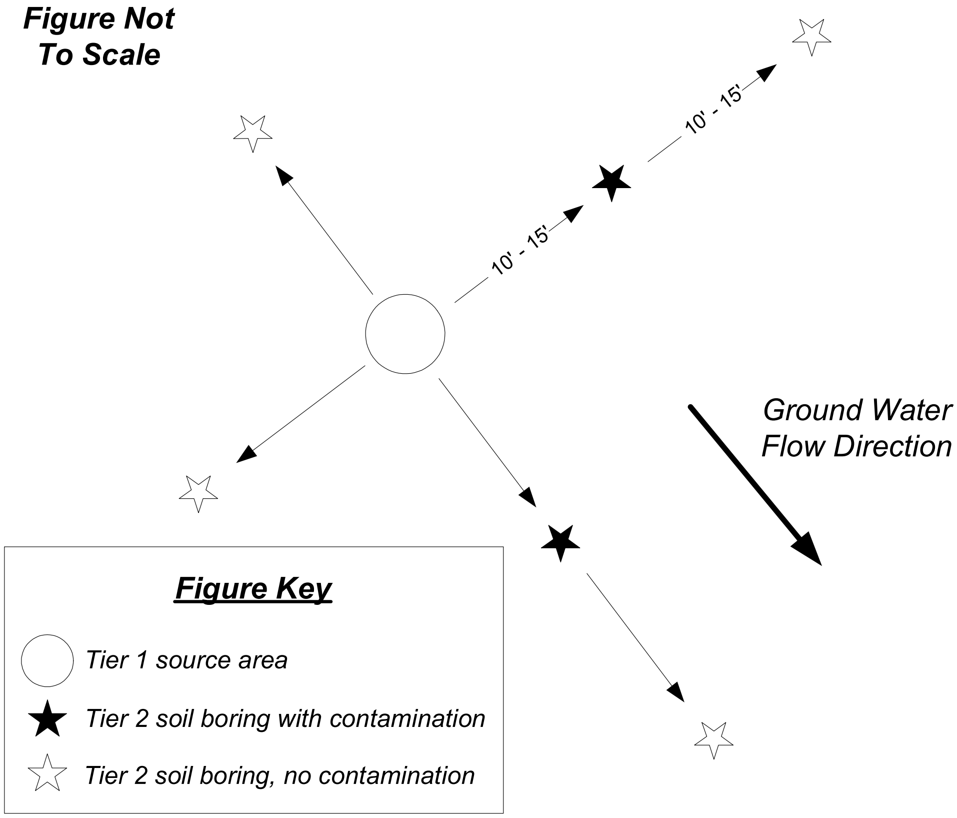
6.1.1 – Groundwater Ingestion Pathway

1. Monitoring points must be installed to collect groundwater samples for laboratory analysis of the COCs and relevant site-specific aquifer parameters. Monitoring points are to be placed in such a manner that the dissolved plume is delineated horizontally in all directions from the source area(s) to the specific COC levels found in Table 4-2.
2. All monitoring points, including those monitoring wells from the previous Tier 1 investigation, are to be sampled for the necessary COCs.
3. Where a water supply well (as determined during the Tier 1 investigation) may be of sufficient proximity and/or pumping capacity to influence the dissolved product plume, or potential on-site or downgradient recharge areas exist, it must be determined if vertical migration of the dissolved plume is occurring. The methods or means (e.g., multiple monitoring wells screened at different intervals) used to collect this information are to be included in the Tier 2 workplan. Boring logs and pump screen interval depth(s) for the water supply well are to be submitted if available. If pumping data or other well use information is available for the water supply well, it is also to be included in the investigation report.
4. Depth to groundwater is to be measured (after water levels have adequately stabilized) in all monitoring wells, including those installed during the Tier 1 as well as those installed as part of the Tier 2 investigation, for the purposes of determining the water table gradient and refining the groundwater flow direction established during Tier 1.

6.1.2 – Soil Leaching to Groundwater Pathway

1. The extent of source area subsurface soil contamination (i.e., "soil contaminant plume") in the vadose zone is to be closely delineated using soil samples collected from borings or direct push soil sampling technologies. Sampling points are to be concentrated around the source area(s) identified during the Tier 1 assessment. Where possible, sampling points are to be placed outward from the source area (at approximately 90-degree angles to each other; see Figure 6-1) at 10- to 15-foot intervals until no field evidence of source area soil contamination is found. Where such sampling is not possible, the Department is to be consulted for alternate sampling requirements. Sampling points are to be continuously sampled to determine the location(s) of maximum soil contamination and to accurately describe the site geology. Sampling of soils should be avoided in locations away from the source area where field evidence indicates contamination may only be associated with the capillary fringe.
2. All borings are to be sampled for the COCs and submitted for laboratory analysis. The number of samples to be collected is specified in Section 6.1.2a, below.
3. Soil samples are to be collected for determination of the following physical/chemical parameters: dry bulk density, and fractional organic carbon content (see Section 6.2). The number of samples to be collected is specified in Section 6.1.2b, below.

Figure 6-1. Idealized Placement of Tier 2 Soil Sampling Points



Idealized placement of sampling points around a source area for the Tier 2 investigation of the Soil Leaching to Groundwater or Intrusion of Vapors from Contaminated Subsurface Soils exposure pathways. Radial distance between sampling points should be approximately 10-15 feet.

6.1.2a Number of Soil Samples for COC Analysis

Where groundwater is less than 25 feet BGL, one sample per boring is to be collected at the identified point of maximum contamination. Where groundwater is greater than 25 feet BGL, two samples are to be collected: one sample within the first 25-foot interval and the second from between 25 feet BGL and the water table. Both samples are to be obtained from points of maximum evident contamination.

NOTE: The number of COC soil samples required from each boring for Tier 2 is different than for Tier 1. Be sure to refer to the correct section when planning or conducting investigations.

6.1.2b Number of Soil Samples for Chemical and Physical Parameter Analysis

One sample is to be collected for each parameter specified in Section 6.2.3 from each sediment type present at the site.

6.1.3 – Intrusion of Vapors to Structure from Contaminated Groundwater Pathway

This pathway concerns the migration of vapors from contaminated groundwater into structures. It may be assessed in either of two possible ways: using soil gas samples (preferred) or using groundwater samples.

Regardless of which option is chosen, all subsurface structures must be assessed for the presence of vapors as specified in Section 4.7.4. If vapors are detected in any buildings or other subsurface structures, the notification guidance outlined in Table 2-1 should be followed. The results of the vapor assessment must be submitted in the Tier 2 report.

6.1.3.1 Soil Gas Sampling Option

1. Monitoring points must be installed above the estimated capillary zone, in the following locations:
   - The source area(s), within three feet of the water table or saturated zone;
   - Adjacent to all on-site and the nearest off-site habitable structures, at a depth slightly less than the bottom of the building's footings, or three feet BGL, whichever is greater. If analysis results exceed the levels in Table 4-2 for any COC, install additional monitoring points to define the soil gas plume along the building (contact any NDEE project manager to determine locations, if necessary); and,
   - At least one location between the source area(s) and each structure, within three feet of the estimated capillary zone.
2. Soil gas samples must be collected from each monitoring point in accordance with Section 6.3.1.
3. A survey of structures within the contaminant plume must be performed, and a list of building owners (or owners' representatives), daytime telephone numbers, mailing addresses, and typical uses of space (e.g., residence, daycare, storage, etc.) must be provided in the Tier 2 Investigation Report. It is important to determine if the buildings have basements or similar subgrade structures.

6.1.3.2 Groundwater Sampling Option

1. Collect groundwater samples for laboratory analysis of the COCs. Monitoring points are to be located to delineate the dissolved plume COCs to the levels found in Table 4-2.
2. Soil samples must be collected above the estimated capillary zone for determination of the volumetric water content, dry bulk density, and fractional organic carbon content (see Section 6.2).
3. Depth to groundwater is to be measured in all monitoring wells (after water levels have adequately stabilized) for the purposes of determining the water table gradient and refining the groundwater flow direction established during Tier 1.
4. All monitoring points are to be sampled for the COCs and the samples submitted for the appropriate laboratory analysis.
5. A survey of structures within the contaminant plume must be performed, and a list of building owners (or owners' representatives), daytime telephone numbers, mailing addresses, and typical uses of space (e.g., residence, daycare, storage, etc.) must be provided in the Tier 2 Investigation Report. It is important to determine if the buildings have basements or similar structures.

6.1.4 – Intrusion of Vapors to Structure from Contaminated Subsurface Soils Pathway

This pathway concerns the migration of vapors from contaminated subsurface soils into structures. It may be assessed in either of two possible ways: using soil gas samples (preferred) or using soil samples.

Regardless of which option is chosen, all subsurface structures must be assessed for the presence of vapors as specified in Section 4.7.4. If vapors are detected in any buildings or other subsurface structures, the notification guidance outlined in Table 2-1 should be followed. The results of the vapor assessment must be submitted in the Tier 2 report.

6.1.4.1 Soil Gas Sampling Option

1. Monitoring points must be installed above the estimated capillary zone, in the following locations:
   - The source area(s), within the soil contaminant mass;
   - Adjacent to all on-site and the nearest off-site habitable structures, at a depth slightly less than the bottom of the building's footings, or three feet BGL, whichever is greater. If analysis results exceed the levels in Table 4-2 for any COC, install additional monitoring points to define the soil gas plume along the building (contact any NDEE project manager to determine locations, if necessary); and,
   - At least one location between the source area(s) and each structure, within the soil contaminant mass.
2. Soil gas samples must be collected from each monitoring point in accordance with Section 6.3.1.
3. A survey of structures within the contaminant plume must be performed, and a list of building owners

(or owners' representatives), daytime telephone numbers, mailing addresses, and typical uses of space (e.g., residence, daycare, storage, etc.) must be provided in the Tier 2 Investigation Report. It is important to determine if the buildings have basements or similar subgrade structures.

6.1.4.2 Soil Sampling Option

1. The extent of source area subsurface soil contamination (i.e., "soil contaminant plume") within the upper 25 feet of the vadose zone around the release area is to be closely delineated using soil borings. Borings are to be concentrated in the source area(s) identified in the Tier 1 assessment. Where possible, borings are to be placed around each source area (at approximately 90-degree angles to each other; see Figure 6-1) at 10- to 15-foot intervals outward until no field evidence of soil contamination is found. If habitable buildings are present over or near the soil contaminant plume, at least one boring is to be located as close as possible to each building, between the building and the source. Where such sampling is not possible, the Department is to be consulted for alternate sampling requirements. Borings are to be continuously sampled to determine the assumed or perceived location(s) of maximum soil contamination and to accurately describe the site geology.

2. Samples for the COCs are to be collected from all borings and submitted for laboratory analysis. The number of samples to be collected is specified in Section 6.1.4.1a, below.

3. Soil samples are also to be collected for determination of the following parameters: dry bulk density, fractional organic carbon content, and volumetric water content (see Section 6.2.). The number of samples to be collected is specified in Section 6.1.4.1b, below.

4. A survey of structures located over the soil contaminant plume must be performed, and a list of building owners (or owners' representatives), daytime telephone numbers, mailing addresses, and typical uses of space (e.g., residence, daycare, storage, etc.) must be provided in the Tier 2 Investigation Report. It is important to determine if the buildings have basements or similar subgrade structures.

6.1.4.2a Number of Soil Samples for COC Analysis

Two subsurface soil samples are to be analyzed from each sampling point. These samples are to be collected at the points where the highest level of contamination is measured by field instrumentation and are to be obtained within the initial 25 feet BGL or at points above the groundwater table, whichever is less.

NOTE: The requirements for this pathway are different than for the Soil Leaching to Groundwater pathway (Section 6.1.2a). Make sure that the samples collected satisfy the requirements of all applicable exposure pathways.

6.1.4.2b Number of Soil Samples for Chemical and Physical Parameter Analysis

One sample is to be collected for each parameter specified in Section 6.2.3 from each sediment type present at the site.

6.2 – VADOSE ZONE SOIL CHARACTERISTICS

Certain soil parameters or characteristics used in the Department's fate and transport equations are to be selected based on the predominant soil type or determined by sampling and laboratory analysis during the Tier 2 assessment. This section provides and discusses the parameters for which the Department requires site-specific information used in the calculation of the Tier 2 SSTLs.

NOTE: The boring location, depth, and sediment type from which each of the samples is collected for Sections 6.2.2 and 6.2.3 must be documented in the Tier 2 report.

6.2.1 – Soil Porosity

Porosity is a variable used in the Tier 2 fate and transport equations for all exposure pathways examined by the Department. Estimated values for soil porosity are to be selected from Table 6-2.

Table 6-2. Estimated Soil Porosity Values

Sediment Type	Porosity
Clay	0.42
Silt/Loess	0.47
Till, predominantly silt	0.34
Till, predominantly sand	0.31
Sand, fine	0.43
Sand, medium	0.39
Sand, coarse	0.39
Gravel, fine	0.34
Gravel, medium	0.32
Gravel, coarse	0.28

Source: Adapted from Todd (1980)

6.2.2 – Capillary Zone Thickness

The relatively greater percentage of pore water in the capillary zone, compared to that of the overlying vadose zone, has a limiting effect on the diffusion of contaminant vapors partitioning from a contaminant plume dissolved in groundwater. When examining the intrusion of vapors to a structure for the contaminated groundwater exposure pathway, information regarding the capillary zone thickness and its volumetric water content (see Section 6.2.3.2) must be obtained. Conservative estimated values for capillary zone thickness, based on predominant sediment type, are to be selected from Table 6-3.

Table 6-3. Estimated Capillary Zone Thickness

Sediment Type	Capillary Zone Thickness (cm)
Silt/Clay	105
Sand (fine)	42
Sand (medium to coarse)	13.5
v. coarse Sand to fine Gravel	2.5
Gravel (medium to coarse)	0

Source: Adapted from Todd (1980)

6.2.3 – Chemical and Physical Parameters

Site-specific values for soil dry bulk density, volumetric water content, and fractional organic carbon content in soil are required to calculate SSTLs for the following indirect exposure pathways:

- Soil leaching to groundwater
- Intrusion of vapors to structure from contaminated groundwater, except in cases where only the inhalation pathway is applicable and soil gas samples are collected instead of groundwater
- Intrusion of vapors to structure from contaminated subsurface soils, except in cases where only the inhalation pathway is applicable and soil gas samples are collected instead of subsurface soils

All samples for these parameters must be collected in the vadose zone. Specific requirements are provided below.

6.2.3.1 Dry Bulk Density

6.2.3.1a Number of Samples

The number of samples needed for the analysis of dry bulk density depends on the stratigraphy of the vadose zone. One representative sample is required for each sediment type encountered at the site (not from each individual boring). The Department recommends that these samples be collected from the boring for the down gradient monitoring well.

6.2.3.1b Sample Collection Methods

Samples obtained for dry bulk density analysis are to be collected using a thin-walled tube sampler for clay samples in general accordance with ASTM D-1587, a split-barrel sampler for sand samples in general accordance with ASTM D-4220, or some other method approved by the Department.

6.2.3.2 Volumetric Water Content

6.2.3.2a Number of Samples

One representative sample per site is required for each sediment type encountered within the vadose zone.

6.2.3.2b Sample Collection Methods

Samples obtained for volumetric water content analysis are to be collected using a thin-walled tube sampler for clay samples in general accordance with ASTM D-1587, a split-barrel sampler for sand samples in general accordance with ASTM D-4220, or some other method approved by the Department. Samples obtained for volumetric water content analysis are to be placed in a small glass jar and tested as described in ASTM Standard D-2216 or some similar method approved by the Department. Results are to represent a volumetric value. Laboratory results provided for gravimetric values are to be converted to and reported as volumetric values using the following relationship:

$$\theta_{wv} = \theta_{wg} \times \frac{\rho_s}{\rho_w}$$

where: θ_{wv} = volumetric water content (cm^3-water/cm^3-soil)
θ_{wg} = gravimetric water content (grams-water/grams-dry soil)
ρ_s = dry bulk soil density (grams-dry soil/cm^3-soil)
ρ_w = density of water (grams-water/cm^3-water) = 1

6.2.3.3 Fractional Organic Carbon Content in Soil

6.2.3.3a Number of Samples

The number of samples needed for the analysis of fractional organic carbon content is dependent on the sediment types present in the vadose zone. One representative sample per site is required for each sediment type within which contamination has been encountered; <u>however, the sample(s) must be obtained from uncontaminated soils to avoid analysis interference from organic carbon associated with the petroleum contamination</u>.

6.2.3.3b Sample Collection Methods

Samples obtained for fractional organic carbon content analysis are to be collected in a small glass jar and tested as described in ASTM Standard D-2974 or some similar method approved by the Department.

6.3 – DISTRIBUTION OF COCS IN SOIL GAS

At the Tier 2 level, soil gas sampling may be substituted for other media sampling (with the approval of the Department) for the following exposure pathways once the groundwater flow direction has been established:

- Intrusion of vapors to structure from contaminated groundwater (see Section 6.1.3.2).
- Intrusion of vapors to structure from contaminated subsurface soils (see Section 6.1.4.2).

The requirements for the number and location of sample points are presented in the referenced Sections.

6.3.1 – Soil Gas Sampling Point Installation

Soil gas sampling points may be temporary or permanent. Permanent monitoring points should be constructed with similar diameters, materials, surface seals, and screen lengths. Acceptable installation methods include:

- Direct push
- Auger drilling
- Hand-installed (generally limited to through-floor points inside buildings or other structures; specify in the workplan or contact the PRS Project Manager for approval)

6.3.2 – Soil Gas Sample Collection Methods

Soil gas samples are to be collected using the following criteria:

1. The sampling point is sufficiently sealed to prevent the introduction of ambient air into the sample;
2. The sample point is purged prior to sampling to ensure a representative sample of soil gas is collected (purging times and volumes to be included in investigation narrative);
3. The soil gas sample is to be collected and analyzed in the field using a gas chromatograph to avoid loss of volatiles in transport. NELAP certified analysis is recommended, but is not required. Chemicals of concern and minimum quantification levels are specified in Section 4.2 and Table 4-1. Any other analysis method will require the prior approval of the NDEE project manager.

The QA/QC documentation described in Section 4.9.5 is required, but no duplicate samples or field and trip blanks are necessary for soil gas samples. The-field analysis reports, company name, and analyst’s name must be submitted with the Tier 2 investigation report.

6.4 – TIER 2 REPORTING REQUIREMENTS

The Department has established a reporting format that the RP or their consultant must use to submit the investigation results. The report format consists of Report Forms generated in Microsoft Excel for most of the required data. The Tier 2 Report Forms have been revised to incorporate the changes in this guidance document. The forms are illustrated in Appendix C. Copies of these forms in Microsoft Excel format may be downloaded from the Department’s website (http://dee.ne.gov).

If any alternate methods from the procedures presented in this document were used in the investigation, they must be prominently noted in the report and an explanation provided. Cross sections, sampling data, and any other information in addition to that included in the Report Forms are to be provided in the general formats discussed under Section 4.10.

SECTION 7.0 – RISK-BASED EVALUATION: GENERAL CONSIDERATIONS

7.1 – INTRODUCTION

The Tier 1 and Tier 2 RBCA evaluations are performed by the Department using the assessment information collected by the responsible parties and their consultants. Sections 7.0, 8.0 and 9.0 of this document outline the procedures and parameters the Department uses for the evaluations.

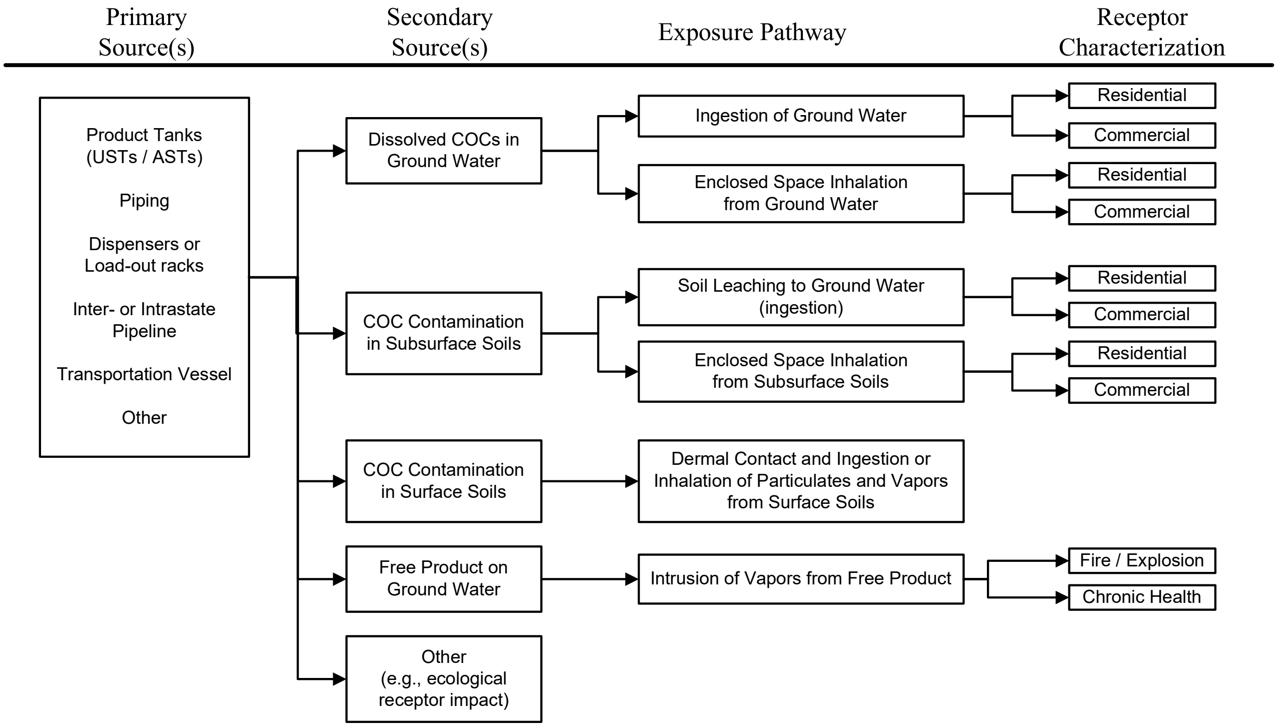
NOTE: While the Department may provide additional material (e.g., computational computer software) to interested parties, an RP and their consultant will only be responsible for providing the site data and information outlined in previous sections of the document and the Report Forms provided by the Department. Any evaluation of the site, other than that required by the Department, will not be eligible for Title 200 reimbursement consideration for those sites that are eligible for reimbursement.

After the appropriate site assessment data has been collected, it is used to evaluate the release based on risk considerations. The initial action is to develop a site-specific exposure scenario wherein several general factors (i.e., current and potential land use, receptors, points of exposure and potential routes of exposure) are examined to determine where any potential exposures are most likely to occur. Subsequently, target levels are determined for all complete exposure scenarios. At the Tier 1 level, this consists of comparing the COC levels encountered during the site assessment to initial RBSLs developed from non-site-specific criteria. At the Tier 2 level, this consists of comparing the COC levels encountered during the site assessment to SSTLs calculated using site-specific data. The need for initial abatement actions, monitoring and/or long-term active cleanup is determined by the Department.

7.2 – DEVELOPMENT OF SITE CONCEPTUAL EXPOSURE SCENARIO

A Site Conceptual Exposure Scenario for each release is developed using the information gathered during the investigation process to characterize the exposure pathways at risk due to the release. General factors to be examined during the development of the Site Conceptual Exposure Scenario include current and potential land use, receptors, points of exposure, and potential routes of exposure. The exposure scenario is displayed in graphical form in Figure 7-1.

Figure 7-1. Site conceptual exposure scenario



7.2.1 – Land Use

As discussed in Section 4.4, the Department classifies each site as "Residential" or "Commercial" based on land use within a 500-foot radius of the site. "Residential" refers to the presence of dwellings (e.g., houses, apartments) and/or sensitive population centers (e.g., schools, day care centers, hospitals, nursing homes). Sites that cannot be classified as residential are characterized as being in a "Commercial" setting. In addition, potential changes in future land use must be investigated.

7.2.2 – Receptors & Points of Exposure

"**Receptor**" refers to any humans potentially exposed to petroleum COCs.

"**Points of Exposure**" (POE) refers to the locations at which the receptor is potentially exposed, such as water wells or basements. Points of exposure may be actual or hypothetical (future-use) locations, depending on groundwater use or the location of structures in the area.

"**Ecological Exposure**" refers to locations where the COCs or free product from a petroleum release contact a lake, stream, wetland, or other surface water body with the potential to affect wildlife.

7.2.3 – Exposure Pathways of Concern

The Department examines petroleum releases to determine if the following exposure pathways are complete or incomplete:

- Dermal contact with, ingestion of, and outdoor inhalation of COCs emanating from contaminated surface soils;
- Enclosed space inhalation of COCs emanating from contaminated subsurface soils;
- Leaching of COCs from contaminated surface and subsurface soils to groundwater;
- Enclosed space inhalation of COCs emanating from contaminated, shallow groundwater; and,
- Ingestion of COCs from contaminated groundwater.

Surface soils are defined as those unsaturated materials located between 0 and 3 feet BGL. Subsurface soils are defined as those unsaturated materials located ≥3 feet BGL. For the enclosed space inhalation exposure pathway from shallow groundwater, "shallow" is defined as groundwater less than 15 feet below the base of a structure or 15 feet BGL where no structure is present. Idealized exposure pathways are illustrated in Figures 7-2 and 7-3.

For an exposure pathway to be considered complete, the following conditions must be met:

1. A source and mechanism must be present for petroleum COCs to be released into the environment;
2. A transport medium must be present (e.g., groundwater, soil gas) for the COCs to travel from the source to the POE (e.g., drinking water well, basement);
3. A potential POE (including potential future use) in contact with the medium must be documented (e.g., a drinking water well); and,
4. An exposure route or means for taking COCs into a human body must be possible (e.g., ingestion of water, inhalation of vapors).

In cases where an exposure pathway is not complete under both current and future conditions, that particular exposure pathway is not subject to a quantitative evaluation. All complete pathways are quantitatively evaluated but may be eliminated with use of appropriate engineering control(s) (e.g., abandoning an on-site water supply well), provided the appropriate control(s) are implemented and effective.

Figure 7-2. Idealized Illustration of Groundwater Ingestion and Soil Leaching to Groundwater Exposure Pathways

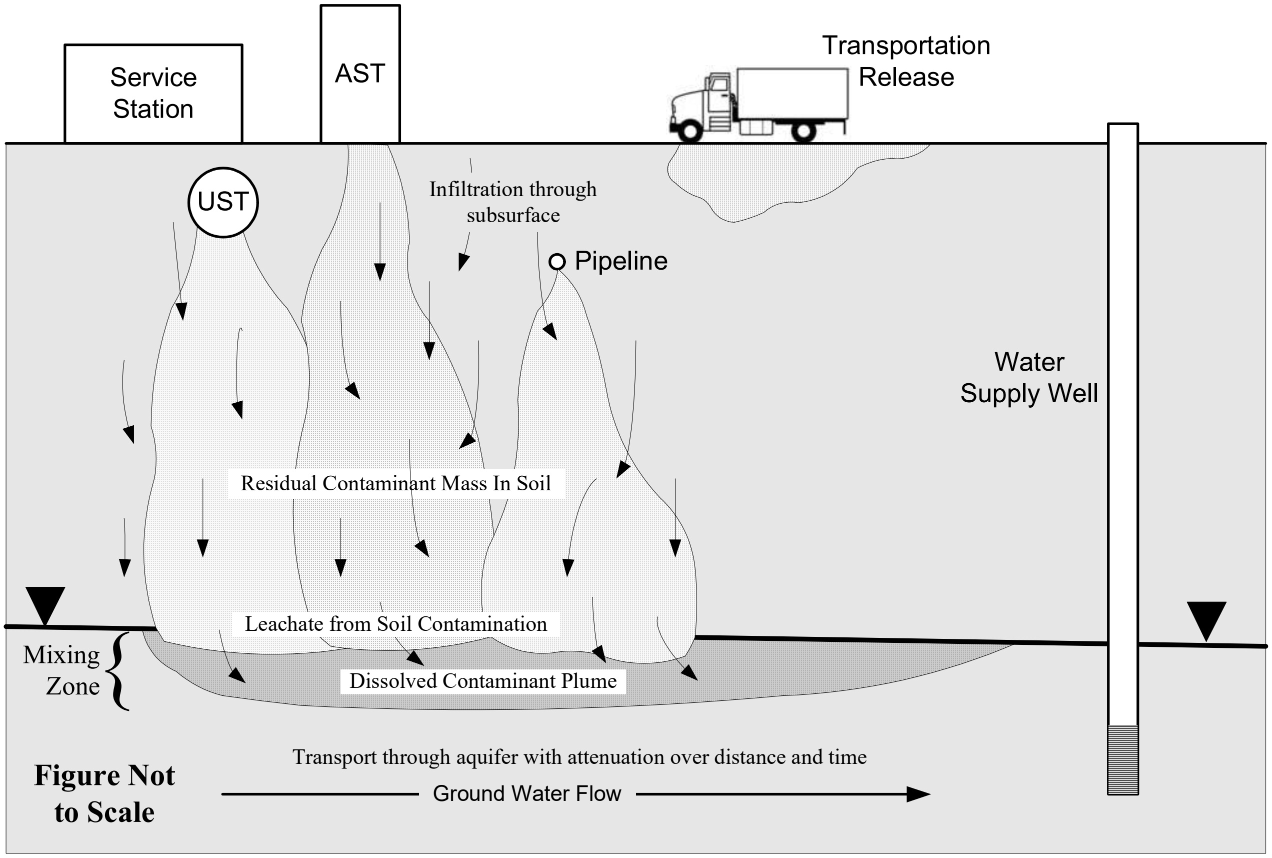
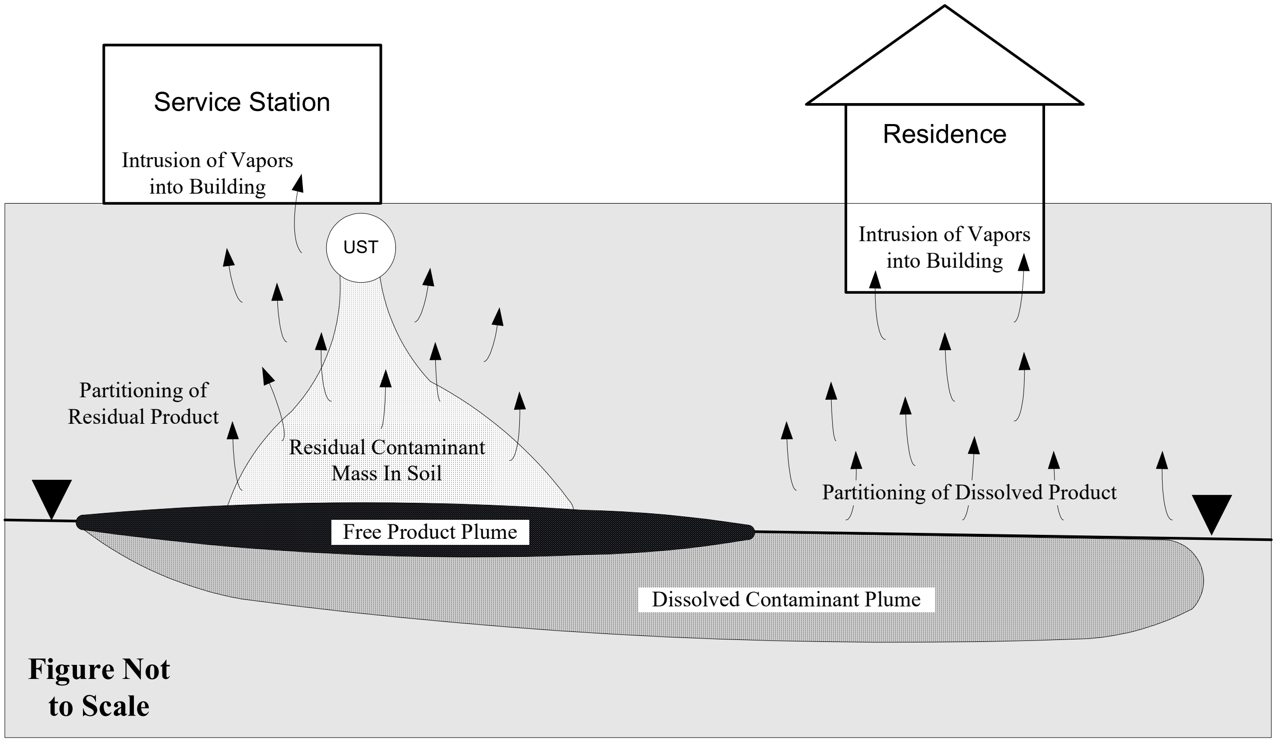


Figure 7-3. Idealized Illustration of Enclosed Space Inhalation Exposure Pathways



7.3 – CALCULATION OF TARGET LEVELS

"Target levels" refer to either the Tier 1 RBSLs or the Tier 2 SSTLs to which the contamination levels found during the site assessment are compared. Requirements for developing the target levels include:

- Allowable concentrations at a POE for groundwater or surface water protection
- Target risk limits
- COC-specific physical and chemical properties
- COC-specific quantitative toxicity factors
- Human exposure factors
- Fate and transport parameters
- Mathematical models

7.3.1 – Allowable Concentration

The groundwater ingestion and ecological exposure pathways have regulations in place (Title 118 for groundwater, Title 117 for surface water) which prescribe the maximum contaminant levels (MCLs) allowable for certain COCs at points of exposure. These MCLs are the basis for the groundwater ingestion, soil leaching to groundwater, and ecological exposure scenarios.

7.3.2 – Target Risk Limit

The target risk limit is the starting point for development of the RBSLs and SSTLs. It represents the maximum level of individual risk that will be permitted by the Department when calculating an allowable or acceptable chronic intake of a COC into the human body.

The Department's approach varies the target risk limits depending on the nature of the potential exposure. For RAC-1 sites that involve the potential ingestion of contaminated groundwater, or for sites where inhalation of vapors or ingestion of contaminated soil is a present and ongoing concern, the most stringent target risk limits should be used. For sites that involve contamination of groundwater categorized as RAC-2 or have the potential for inhalation concerns with no current building or structure present, slightly lower target risk limits are used. This difference allows the Department to appropriately address cases of varying exposure likelihood and consequence.

For definitions and a more detailed explanation of Remedial Action Classes, see Section 7.4.1.

7.3.2.1 Carcinogenic Effects

MCLs, or an equivalent concentration selected by the Department when an MCL has not been promulgated for a particular COC, are used to calculate the appropriate target levels for carcinogens for pathways involving the chronic ingestion of groundwater classified as RAC-1. Values for Individual Excess Lifetime Cancer Risk (IELCR) are used for all other situations involving carcinogenic effects. Table 7-1 summarizes the applicable target risk limits for the various pathway/RAC combinations.

Table 7-1. Target Risk Limits for Carcinogenic Effects

Exposure Pathway	Target Risk Limit
Groundwater Ingestion (RAC-1)	MCL
Soil Leaching to Groundwater (RAC-1)	MCL
Inhalation from soil or groundwater (structure present)	IELCR = 10^{-6}
Dermal contact/soil ingestion	IELCR = 10^{-6}
Groundwater Ingestion (RAC-2)	IELCR = 10^{-5}
Soil Leaching to Groundwater (RAC-2)	IELCR = 10^{-5}
Inhalation from soil or groundwater (no structure present)	IELCR = 10^{-5}

7.3.2.2 Non-carcinogenic Effects

MCLs, or an equivalent concentration selected by the Department when an MCL has not been promulgated for a particular COC, are used to calculate the appropriate target levels for non-carcinogens for both pathways involving the chronic ingestion of groundwater classified as RAC-1. Hazard Indices (HI) are used for all other situations involving non-carcinogenic COCs. Table 7-2 summarizes the applicable target risk limits for the various pathway/RAC combinations.

Table 7-2. Target Risk Limits for Non-Carcinogenic Effects

Exposure Pathway	Target Risk Limit
Groundwater Ingestion (RAC-1)	MCL
Soil Leaching to Groundwater (RAC-1)	MCL
Inhalation (structure present)	HI = 1
Dermal contact/soil ingestion	HI = 1
Groundwater Ingestion (RAC-2)	HI = 10
Soil Leaching to Groundwater (RAC-2)	HI = 10
Inhalation (no structure present)	HI = 10

7.3.2.3 Additive effects

Carcinogens. Additivity of cancer risk is not explicitly considered at either the Tier 1 or Tier 2 level for several reasons. First, the listed NDEE carcinogenic COCs (benzene, ethylbenzene, naphthalene, and benzo(a)pyrene (BaP)) each affect different parts of the body. Second, it is assumed that the number of exposure pathways that may be considered complete is limited at any particular site. Third, the conservative assumptions used in the generation of the target levels are assumed to provide a margin of safety in this regard. Lastly, target levels calculated using an MCL (as for the groundwater ingestion pathway) are not readily comparable to target levels when calculated using a specific IELCR (as for the enclosed space inhalation pathways).

Non-carcinogens. The HI represents the sum of all Hazard Quotients (HQs) for each COC affecting the same target organs and causing the same adverse health effect. For the purposes of the Tier 1 and Tier 2 assessments, benzene, toluene, ethylbenzene, and total xylenes are considered to have additive health effects. While the carcinogenic effects of benzene and ethylbenzene outweigh their non-carcinogenic effects (meaning the target levels for these COCs are based on their carcinogenic effects), their additive effect in combination with toluene and total xylenes must be considered.

In Tier 1, a cumulative HI = 1 (or =10 for RAC-2 releases or where no structure is present for inhalation concerns) for additive effects of the BTEX compounds is established by assigning an HQ = 0.25 (or =2.5) to each individual compound. In Tier 2, additivity is addressed by totaling the cumulative risk for each individual BTEX component using the ratio between the actual site concentrations and the appropriate SSTLs for each exposure pathway. That is, SSTLs for each BTEX component are calculated using an HQ = 1, and the ratio between the representative concentration and the calculated SSTL is determined. If the sum of the BTEX ratios is ≤1, the BTEX contamination is considered to pose an acceptable risk from exposure.

7.3.3 – COC Physical & Chemical Parameters

Appendix D, Table D-1 provides the pertinent physical and chemical properties used to establish or calculate the appropriate target level for each COC.

7.3.4 – COC Quantitative Toxicity Factors

Appendix D, Table D-2 provides the quantitative toxicity factors used to establish or calculate the appropriate target level for each COC.

7.3.5 – Human Exposure Factors

The applicable exposure factors (e.g., body weight, exposure duration) and the values used to calculate the appropriate target level for a residential and commercial receptor are provided in Appendix D, Table D-3.

7.3.6 – Fate & Transport Parameters

Appendix D, Table D-4 provides the pertinent data parameters and default values used in the fate and transport models and to determine the appropriate target level for each COC. General comments concerning these parameters include:

- Unless otherwise noted in this section, default values are taken directly from the ASTM E-1739 Standard Appendix.
- Values for the calculation of source area (30 feet by 30 feet) are based on a review of tank removal reports and are reflective of a typical service station where 3-4 tanks are located in a single excavation.
- Default values for the saturated hydraulic conductivity, hydraulic gradient, total porosity of the saturated zone, infiltration rate, and fractional organic carbon content vary between Tier 1 lookup tables.
- Thickness of the mixing zone (default: 5 feet) is based on the general monitoring well construction practice for petroleum releases of screening a well with the groundwater/unsaturated zone interface at the mid-point of the well screen length (commonly 10 feet).
- The unsaturated zone concentration reduction factor (CRF) varies with depth to groundwater. The possible values of 1 and 2 are empirical depending on the depth to groundwater.

7.3.7 – Mathematical Models

Mathematical equations are used to model the fate and transport of contaminants in the environment and the human uptake of contaminants because of chronic exposure. Fate and transport models calculate the reduction in COC concentrations as COCs move from the source to the POE; data inputs include various soil and aquifer parameters and the physical and chemical properties of the COCs. Uptake models estimate the quantities of COCs ingested, inhaled, or absorbed by humans as a result of chronic contact with COCs at the POE; data inputs include the physical and chemical properties of the COCs and representative physiological values for adults and children.

The equations used in the calculation of the Tier 1 RBSLs and Tier 2 SSTLs are summarized in Appendix E. Default values for input into these equations are discussed in Section 7.3.6 and provided in Appendix D. Chemical-specific data are also provided in Appendix D. The models used are:

- Domenico and Summers models for back-calculating allowable dissolved COC concentrations in groundwater from a POE and allowable soil leachate concentrations from those groundwater concentrations.
- Farmer's model for calculating soil and groundwater concentrations protective of indoor inhalation.
- USEPA's model (1991) for estimating outdoor inhalation from surface soils.
- USEPA's models (1991) for estimating uptake.

7.4 – PROTECTION OF GROUNDWATER

The following is provided from Nebraska Title 118 – *Ground Water Quality Standards and Use Classification*, Appendix B – Remedial Action Protocol for Petroleum Releases, Step 7:

> "Most ground water in the principal aquifer (closest underlying major aquifer) is of drinkable quality and is used by nearly all Nebraskans as drinking water. Water of drinking water quality is usually suitable for all other beneficial uses. For these reasons, protecting ground water for drinking water use is most important and normally protects it for all uses."

In addition to the protection of groundwater itself, consideration must also be given to residual contamination in soils as a source of continued groundwater contamination. Considerations to be made for the protection of groundwater are provided below.

7.4.1 – Remedial Action Classes (RACs)

Protection of groundwater as a drinking water source under Title 118 directly relates to the Remedial Action Class (RAC) established for the release by the Department. The RAC categories are not intended to represent a groundwater classification system, but rather a pollution release-ranking scheme. It gives the Department a method to determine the importance of remedial action based on the use of the groundwater. RACs are determined by:

- The location of drinking water wells in the area of the release;
- Potential future drinking water use considerations; and,
- The degree of groundwater contamination encountered during the Tier 1 and Tier 2 investigations

A RAC is defined for pollution occurrences in three types of groundwater (or overlying soils) depending on the degree (or potential) of use of the groundwater as drinking water. The extent of remedial action required will differ depending, in part, on the RAC of the contaminated (or likely to be contaminated) groundwater. (Note that the RAC assigned is determined from the condition of the groundwater prior to the occurrence of pollution. The Department will do this based on information submitted by the RP in the RBCA Tier 1 and Tier 2 site investigations and other available information.) Below are definitions of the three RAC categories followed by some further explanation. (Definitions of Classes GA, GB, GC and GC(R) can be found in Title 118, Chapter 7 and Appendix B. Class GA waters also include designated Wellhead Protection Areas [WHPAs].)

RAC-1. This category includes groundwaters of Class GA (groundwater used or proposed to be used for a public drinking water source) and a portion of Class GB (groundwater currently being used as a private drinking water source), and groundwater within a designated WHPA. In addition, RAC-1 shall be automatically assigned anytime a public or private drinking water supply well has been polluted. RAC-1 will usually receive the most extensive remedial action measures.

RAC-2. This category includes groundwaters of Class GB (except for the portion of Class GB placed in RAC-1; i.e., groundwater with the potential to be used as public or private drinking water source) and Class GC(R) (groundwater resources where the Department determines that restoration or cleanup may be appropriate).

RAC-3. This category includes, but is not limited to, groundwaters of Class GC (except for Class GC(R) which was placed in RAC-2; i.e., groundwater not currently used and has little or no potential to be used as a public or private drinking water source). RAC-3 will usually receive the least extensive remedial action measures.

RAC-1 is the category of highest rank; it represents that groundwater being used for drinking water and that groundwater intended to be used in a public drinking water supply. Therefore, RAC-1 occurrences will normally receive the most conservative RBCA target levels and most extensive remedial action measures.

RAC-2 occurrences involve groundwater currently not used as drinking water but that has a reasonable potential to be used in the future. Potential use exists if the groundwater is located in a highly populated area or is part of a regional, high-yielding aquifer, or if otherwise justified. The RAC-2 category also includes groundwater with prior contamination that may be treated easily or cost-effectively to drinking water quality.

RAC-3 pollution occurrences are of lowest importance if the groundwater involved is not used, or not likely to be used, as drinking water. Generally, remedial action measures will be least extensive for this category since the future use of such groundwater as a drinking water supply is improbable. Justification for assigning occurrences to RAC-3 is based on a combination of factors, including:

- The water is of such poor natural quality that it is unfit for human consumption.
- Insufficient yield may limit or exclude the groundwater being used for drinking water.
- Historical contamination may have contaminated the groundwater to a point that it is not suitable for consumption [see NRS § 81-1505(2)(d)]. This historical contamination may now be uneconomical to treat.
- Past and present intensive land use may also be a reason why groundwater could be unusable as drinking water. This includes areas of concentrated industrial development or densely populated areas where groundwater is likely to be contaminated or will not be used as drinking water.

7.4.2 – Location and Type of Water Supply Wells

Water supply wells must be located and documented during the Tier 1 site investigation in accordance with Sections 4.3.2 and 4.4.3. Water supply wells include municipal, domestic, irrigation, industrial or any other well from which water is withdrawn for beneficial purposes. Water supply wells do not include monitoring wells or recovery wells used for corrective actions.

At the Tier 1 level, all water supply wells documented in accordance with Sections 4.3.2 and 4.4.3 are treated as potential POEs (see also, Section 7.4.4, Step 1). At the Tier 2 level, only those wells that may be impacted by the contaminant plume are considered potential POEs. This determination is based on the orientation and extent of the contaminant plume, along with consideration of the effects of any pumping wells on the contaminant plume.

In defining a RAC, Title 118 only refers to drinking water supply wells, or groundwater used or capable of being used as drinking water. This emphasis on drinking water creates a potential dilemma in the RBCA process where RAC-2 designation is assigned to a site (and correspondingly higher target levels are used compared to a RAC-1 situation); consequently, a nearby non-drinking water well (e.g., irrigation well, industrial well) may not receive the appropriate protection. Therefore, in the RBCA evaluation process, drinking and non-drinking water wells will be examined separately. To remain protective of beneficial groundwater use for a non-drinking water supply well, target levels are set at ten times the level for a drinking water supply well, given the same site characteristics.

7.4.3 – Location of Compliance Wells

A point of compliance (POC) is a location within a source area or between a source area and the potential POEs where the concentrations of COCs must be at or below the determined target levels. For Tier 1, the borings/monitoring wells located within the source area(s) are the compliance point(s) for subsurface soil and groundwater. At Tier 2, additional compliance points are set at select locations between the source area(s) and a potential POE for which individual SSTLs are calculated. These wells are located to monitor and assess the dynamics of the contaminant plume. They will also help to assess the validity of the fate and transport equations used by the Department and to ensure that groundwater concentrations are decreasing (see also Section 7.4.4, Step 3).

7.4.4 – Calculation of Target Levels Protective of Groundwater

Target levels for soils and water that are protective of groundwater and water supply wells (i.e., POEs) in the area are determined as provided below. The key steps in these calculations include:

1. Identification of POEs;
2. Target concentrations at a POE;
3. Identification of appropriate POCs (see Section 7.4.3);
4. Target concentrations at a POC; and,
5. Target concentrations in the source soils.

7.4.4.1 Identification of POEs

The identification of POEs is based on: 1) the RAC of the release and 2) the existence and type of water supply wells (drinking vs. non-drinking wells) near the site. For RAC-1 releases, the POE of most concern is the closest of the following:

- Municipal wells within 1000 feet,
- Domestic, irrigation and industrial wells within 500 feet,
- Sand points and hand-pump wells within 500 feet, and
- A hypothetical POE at 750 feet where the RAC-1 designation is based on the presence of a Wellhead Protection Area (WHPA).

Where a non-drinking water well (e.g., irrigation or industrial well) in a RAC-1 area is closer to a source area than a drinking water well, an evaluation must be made of both the non-drinking water well and the nearest drinking water well. The more conservative target level will be established as the allowable COC concentrations.

For RAC-2 releases, a hypothetical drinking water well located at 500 feet from the source area is considered a POE.

For the Tier 2 evaluation, only those water supply wells that are downgradient, or other wells of sufficient proximity and/or pumping capacity to influence the migration of the contaminant plume, are considered potential POEs.

7.4.4.2 Target Concentrations at a POE

Allowable COC target concentrations at a POE in the Tier 1 and Tier 2 evaluations vary based on the RAC designation of the release. The levels for RAC-1 releases in both tiers are based on MCLs (or other levels) for the individual COC. Where a non-drinking water well is in closer proximity to a source area than a drinking water well in a RAC-1 situation, allowable target levels at the well are calculated at ten times the RAC-1 allowable level.

The allowable target concentrations at a POE for a RAC-2 release in a Tier 1 evaluation are calculated assuming ingestion of water with the following target risk limits:

- Carcinogens: IELCR = 10^{-5}
- Non-carcinogens: HQ for BTEX = 2.5; for others = 10

For a RAC-2 release in a Tier 2 evaluation, the HQ for BTEX = 10, and is based on the sum of the ratios of the representative site concentrations to the allowable intake concentration of the individual BTEX constituents.

Table 7-3 provides the allowable COC concentrations at a POE for various groundwater uses.

Table 7-3. Allowable COC Target Concentrations (mg/L) at a POE

Chemical of Concern	RAC-1	Non-Drinking Well	RAC-2
Benzene	0.005	0.050	0.015
Toluene	1.000	10.000	18.25
Ethylbenzene	0.700	7.000	9.13
Xylenes	10.000	100.000	182.50
n-Hexane	4.000	40.000	13.00
MTBE	0.020	0.200	0.47
Naphthalene	0.020	0.200	7.30
TEH (as diesel)	10.000	100.00	11.67
TEH (as waste oil)	6.660	66.600	38.80

In both RAC-1 and RAC-2 sites, soil and POC target concentrations must be protective of the identified POEs. For RAC-3 sites, the groundwater ingestion pathway is considered incomplete; however, the inhalation exposure pathways and free product concerns must be considered.

7.4.4.3 Target Concentrations at a POC and Source Soils

The Department establishes target levels for POCs and source area soils by back-calculating allowable contaminant levels in groundwater from a POE to the source area(s) and/or other compliance wells. In Tier 1, the target levels are RBSLs established using non-site-specific criteria; at Tier 2, the Department calculates the SSTLs for each appropriate compliance well or location. The specific equations used to calculate compliance well target levels are provided in Appendix E.

7.4.5 – Protection of Deeper Groundwater

In areas where surface recharge and/or a water supply well(s) may be contributing to the vertical migration of a groundwater contaminant plume, compliance wells screened at appropriate depths may be required by the Department to assess the vertical migration of the plume.

7.5 – PROTECTION OF INDOOR AIR QUALITY

To protect against the possibility of chronic health effects, indoor inhalation pathways are evaluated at every site during the Tier 1 investigation. If contaminant concentrations indicate, the pathways are examined in greater detail during the Tier 2. Target levels for groundwater, soil, and soil gas are determined using the following steps:

1. Identification of POEs;
2. Target concentrations at a POE;
3. Target concentrations in soil gas, soils, and/or groundwater.

Details of the calculation process are provided below.

7.5.1 – Identification of POEs

Any habitable structure situated above or adjacent to contaminated subsurface soils or groundwater is considered a POE. In cases where more than one POE is present, an evaluation of each POE will be made. The most conservative target level will be used for the remainder of the calculations.

If no habitable structures are currently present and no evidence of suitable construction restrictions are presented, the Department will assume that such a structure could be built. The hypothetical structure will be considered the POE.

7.5.2 – Target Concentrations at a POE

Allowable COC concentrations at a POE in the Tier 1 and Tier 2 evaluations vary based on the characteristics of the POE. The primary distinctions are made between sites with existing structures and those that do not currently have a structure present. The allowable target concentrations are calculated using the following target risk limits for sites with existing structures:

- Carcinogens: IELCR = 1 x 10^{-6}
- Non-carcinogens: HQ for BTEX = 0.25, for others = 1.0

If no structure is present, the following target risk limits are used:

- Carcinogens: IELCR = 1 x 10^{-5}
- Non-carcinogens: HQ for BTEX = 2.5, for others = 10

A secondary consideration is the type of structure present or anticipated. Commercial structures are considered to be occupied by adults for limited periods of time, while Residential buildings are assumed to be continuously inhabited by both adults and children. The physical and chemical parameters listed in Appendix D are used in conjunction with the equations presented in Appendix E to determine the appropriate target concentrations.

For Tier 2 evaluations, the default values listed in Appendix D may be replaced with site-specific values determined during the investigation.

7.5.3 – Target Concentrations in Soil Gas, Soils, and/or Groundwater

The POE target concentrations are the allowable levels inside the structure. The target concentrations in soil gas, soil, or groundwater are determined by back-calculating from the POE target concentrations using the parameters listed in Appendix D and the equations in Appendix E. Soil gas target levels are determined first, and the soil and groundwater target concentrations are then calculated from those values. All calculations assume equilibrium conditions.

7.6 – PROTECTION FROM CONTAMINATED SURFACE SOILS

Potential exposures relating to contaminated surface soils involve dermal contact as well as the ingestion and inhalation of particulates. The physical and chemical parameters listed in Appendix D are used in conjunction with the equations presented in Appendix E to determine the RBSLs. The outdoor exposure to contaminated surface soils pathway is only evaluated at the Tier 1 level. If site concentrations exceed the Tier 1 RBSLs, surface soil cleanup will be required.

7.7 – PROTECTION OF SURFACE WATER, WETLANDS, AND ECOLOGY

Where surface waters or wetlands are threatened or have been impacted by a petroleum release, the Department will determine the appropriate mitigation measures to be taken on a case-by-case basis. Such measures may include free product recovery from the surface water, mitigating the continued discharge to the surface water body, or additional ecological assessment of the release. At a minimum, all pertinent Department surface water quality standards, as detailed in Nebraska Title 117 – Nebraska Surface Water Quality Standards, must be met for the impacted water body.

In instances where ecological exposures of threatened and endangered species habitat may be present or possible, the Department, in consultation with the Nebraska Game & Parks Commission, will determine the appropriate actions to be taken to mitigate the exposure. The extent of the assessment will be determined on a case-by-case basis.

7.8 – REPRESENTATIVE CONTAMINANT CONCENTRATIONS

In evaluating individual exposure pathways, the applicable RBSLs or SSTLs are compared to representative concentrations based on the analytical samples collected during the site investigation. To determine the representative site COC concentrations, the Department differentiates between *maximum* COC concentrations versus *average* COC concentrations.

7.8.1 – Representative Groundwater Concentrations

7.8.1.1. Groundwater Ingestion Pathway

For the groundwater ingestion pathway, maximum COC concentrations are used. The fate and transport model used for this exposure pathway incorporates natural attenuation processes between two discrete points (i.e., between a water supply well and a source area). Because this model essentially deals with plume attenuation dominated in a single dimension (i.e., the direction of groundwater flow), maximum COC concentrations are best used for the evaluation.

7.8.1.2. Enclosed Space Inhalation from Contaminated Groundwater Pathway

For evaluating the enclosed space inhalation pathways from contaminated groundwater (and subsurface soils; see Section 7.8.2.2), the model used to calculate the appropriate RBSLs or SSTLs is based on the emission and diffusion of COCs over three dimensions. Because this model considers effects of area and depth for calculating contaminant emissions into a structure, it has been determined that averaging COC concentration levels is an appropriate means of establishing a representative contaminant concentration for these exposure pathways. The average contaminant concentration is calculated from samples with detectable levels of contamination taken immediately upgradient and surrounding the building. Samples that show non-detectable levels are not used to calculate the average concentration. Where no building is present, all groundwater samples with detectable levels of contamination are used for calculating the average, assuming a building could be located on top of these locations.

7.8.2 – Representative Subsurface Soil Concentrations

7.8.2.1. Soil Leaching to Groundwater Pathway

Because petroleum, both in non-aqueous and dissolved phase, is leached from contaminated soils to groundwater, which in turn greatly impacts the groundwater ingestion pathway, the maximum subsurface soil COC concentration levels are used for evaluation.

7.8.2.2. Enclosed Space Inhalation from Contaminated Subsurface Soils Pathway

Like the inhalation from contaminated groundwater exposure pathway, the Department uses the average of COC concentration levels to determine a representative contaminant concentration for this pathway. The average contaminant concentration is calculated from samples with detectable levels of contamination. Samples that show non-detectable levels are not used to calculate the average concentration.

Because soil samples may be obtained from variable depths within the vadose zone, an associated, average sample depth is needed as well. For the evaluation, the average depth of subsurface soil contamination is based on the following relationship (Salhotra, 2002, pers. com.):

$$d_{avg} = \frac{C_1 + C_2 + C_3 + \dots + C_n}{\left(\frac{C_1}{d_1} + \frac{C_2}{d_2} + \frac{C_3}{d_3} + \dots + \frac{C_n}{d_n} \right)}$$

where: d_{avg} is the average depth to the contaminant mass (in feet)
C_n is the concentration of the n^{th} sample (in mg-contaminant/kg-soil), and
d_n is the depth from which the n^{th} sample was obtained (in feet).

7.8.3 – Representative Surface Soil Concentrations

When multiple surface soil samples have been collected, the maximum concentration is considered representative of the COC concentration levels for the dermal contact with, ingestion of, and inhalation (through outdoor air) of COCs from contaminated surface soils.

7.8.4 – Representative Soil Gas Concentrations

The Department will use the average of soil vapor concentrations from sampling points located in close proximity to existing structures as the representative concentration. If no existing structures are present, the average of all soil vapor concentrations will be used. Samples with a concentration below the detection limit will not be used in calculating the average.

7.8.5 – Representative Indoor Air Concentrations

The Department will determine methods for determining appropriate representative concentrations for indoor air samples on a case-by-case basis.

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SECTION 8.0 – TIER 1 EVALUATION

8.1 – STEP 1: DEVELOPMENT OF SITE CONCEPTUAL EXPOSURE SCENARIO

Using the information gathered from the Tier 1 site assessment pertaining to land use, groundwater use, receptors and POEs, a site-specific Site Conceptual Exposure Scenario (see Figure 7-1) can be created to determine the complete exposure pathways.

To determine whether an exposure pathway may be considered complete or incomplete, the evaluation flowchart in Figure 7-1 is used to follow the release from its point(s) of leakage to the current or future point(s) of exposure. This provides a graphical representation of site conditions and potential exposure pathway impacts for evaluation. Provided below are pathway-specific criteria to be used to determine whether a pathway is complete.

8.1.1 – Groundwater Ingestion

The groundwater ingestion exposure pathway is considered incomplete if any of the following conditions are met:

- Groundwater has not been impacted and is not likely to be impacted.
- It has been demonstrated that contamination is limited to the overlying source areas, as detailed in Section 5.4.
- The release has received a RAC-3 designation, although free product must still be considered.

8.1.2 – Soil Leaching to Groundwater

The soil leaching to groundwater exposure pathway is considered incomplete if subsurface soils (≥ 3' BGL) have not been impacted or the release has received a RAC-3 designation. Free product must still be considered.

8.1.3 – Intrusion of Vapors to Structure from Contaminated Groundwater

The intrusion of vapors to a structure from contaminated groundwater exposure pathway is considered incomplete if any of the following conditions are met:

- Groundwater has not been impacted.
- Groundwater is demonstrated to be greater than 15 feet below floor level of a basement, crawl space or similar subsurface structure.
- Groundwater is demonstrated to be greater than 15 feet below floor level of a building with no basement, crawl space or similar structure.
- Groundwater is demonstrated to be greater than 15 feet below ground level where no building is present.

The depth to groundwater is based on the shallowest depth encountered during the investigation, or the highest known groundwater fluctuation.

8.1.4 – Intrusion of Vapors to Structure from Contaminated Subsurface Soils

The intrusion of vapors to a structure from contaminated subsurface soils exposure pathway is considered incomplete if any of the following conditions are met:

- Subsurface soils have not been impacted.
- The average depth of subsurface soil contamination is demonstrated to be greater than 15 feet below floor level of a basement, crawl space or similar subsurface structure.
- The average depth of subsurface soil contamination is demonstrated to be greater than 15 feet below floor level of a building with no basement, crawl space or similar structure.
- The average depth of subsurface soil contamination is demonstrated to be greater than 15 feet below ground level where no building is present.

8.2 – STEP 2: SELECTION OF RELEVANT TIER 1 RBSLS

For those exposure pathways that are complete or potentially complete, representative contaminant concentrations are compared to the Tier 1 RBSLs. To account for the considerable variability of sediment characteristics, aquifer properties and depth to groundwater across Nebraska, the RBCA Tier 1 RBSLs have been developed for several different site conditions. The site conditions include the following:

- Land use scenarios (i.e., residential or commercial);
- Two default hydrogeological scenarios (see Table 8-1 below);
- RAC designation;
- Proximity of water supply wells;
- Thickness of the vadose zone; and,
- Presence/absence of on-site/off-site structures (e.g., buildings with or without basements)

The default hydrogeological scenarios are characterized by the factors provided in Table 8-1.

Table 8-1. Applicable Factors for Tier 1 Default Hydrogeological Scenarios

Factor	**Hydrogeology 1** (Darcy Velocity < 0.1 ft/day)	**Hydrogeology 2** (Darcy Velocity ≥ 0.1 ft/day)
Darcy velocity (cm/year)	111.25	11125
Porosity in vadose zone	0.35	0.30
Organic carbon content (g-C/g-soil)	0.01	0.005
Infiltration rate (cm/year)	3.8	7.6

The factors under the Hydrogeology 1 scenario are representative of a less permeable soil than that of Hydrogeology 2. Consequently, sites with predominantly silty and clayey soils would be assumed to fall under Hydrogeology 1 and sandy soils under Hydrogeology 2. Under Tier 1, the soils in the vadose zone and in the saturated zone are assumed to be homogeneous and have the same hydrogeological characteristics.

As part of the Tier 1 evaluation, the hydrogeological scenario to be utilized must be determined. The determination is based on the groundwater Darcy velocity at the site. If the Darcy velocity is <0.1 feet/day (36.5 feet/year or 1112.5 cm/year), the site falls under Hydrogeology 1. The site falls under Hydrogeology 2 if the Darcy velocity is ≥ 0.1 feet/day.

The RBSLs calculated using these scenarios are provided in the Look-Up Tables in Section 8.3.

8.3 – STEP 3. COMPARISON OF RBSLS WITH REPRESENTATIVE CONCENTRATIONS

The appropriate RBSLs are selected from the Look-Up Tables for each complete or potentially complete exposure pathway and compared to the appropriate representative contaminant concentrations. The calculation of representative concentrations (maximum or average) for each pathway is discussed in Section 7.8.

The following Look-Up Tables are available:

GROUNDWATER INGESTION

Representative concentrations are the maximum reported groundwater concentrations for each COC.

- Table 8-2. Groundwater Flow Rate ≥0.1 feet/day
- Table 8-3. Groundwater Flow Rate <0.1 feet/day

SOIL LEACHING TO GROUNDWATER

Representative concentrations are the maximum reported soil concentrations for each COC.

- Table 8-4. Groundwater Flow Rate ≥0.1 feet/day
- Table 8-5. Groundwater Flow Rate <0.1 feet/day

ENCLOSED SPACE INHALATION

Representative concentrations are average concentrations for each COC.

- Table 8-6. Residential Exposure; Building Present
- Table 8-7. Residential Exposure; No Building Present
- Table 8-8. Commercial Exposure; Building Present
- Table 8-9. Commercial Exposure; No Building Present

DERMAL CONTACT, INHALATION & INGESTION OF SURFACE SOILS

Representative concentrations are the maximum reported surface soil concentrations for each COC.

- Table 8-10. Allowable Contaminant Concentrations in Surficial Soils

SURFACE WATER OR ECOLOGICAL EXPOSURE

Representative concentrations are the maximum reported soil and/or groundwater concentrations for each COC.

- Table 8-11. Surface Water Impact from Contaminated Groundwater
- Table 8-12. Surface Water Impact from Contaminated Soil Leaching to Groundwater

Table 8-2. Groundwater Ingestion Exposure Pathway
Groundwater Flow Rate ≥ 0.1 feet/day

Table 2A - Drinking Water Wells (municipal, domestic, hand-pump)

Remedial Action Class	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
RAC-1	0	0.005	1.000	0.700	10.000	4.000	0.020	10.000	6.666
	250	0.174	50.400	26.100	> Sol	> Sol	0.692	700.000	> Sol
	500	0.699	285.000	112.000	> Sol	> Sol	2.750	5200.000	> Sol
	750 or [750]	1.590	> Sol	> Sol	> Sol	> Sol	6.230	> Sol	> Sol
RAC-2	[500]	2.170	> Sol	> Sol	> Sol	> Sol	65.200	> Sol	> Sol

Table 2B - Non-Drinking Water Wells (irrigation, industrial, other)

	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
For use when only a non-potable well is present	0	0.050	10.000	7.000	100.000	> Sol	0.200	100.000	66.666
	250	1.740	504.000	> Sol	> Sol	> Sol	6.920	7000.000	> Sol
	500	6.999	> Sol	> Sol	> Sol	> Sol	27.500	> Sol	> Sol
	750 or [750]	15.900	> Sol	> Sol	> Sol	> Sol	62.300	> Sol	> Sol

NOTES:

1) All RBSL concentrations are expressed in mg/L.
2) RBSLs used for both residential and commercial land uses.
3) **[750]**: Distance from source to a hypothetical well for a RAC-1 release in a Wellhead Protection Area
4) **[500]**: Distance from source to a hypothetical future well in a RAC-2 release.
5) **> Sol**: The target level is not exceeded for all possible dissolved concentrations.

Table 8-3. Groundwater Ingestion Exposure Pathway
Groundwater Flow Rate < 0.1 feet/day

Table 3A - Drinking Water Wells (municipal, domestic, hand-pump)

Remedial Action Class	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
RAC-1	0	0.005	1.000	0.700	10.000	4.000	0.020	10.000	6.666
	250	1.240	> Sol	> Sol	> Sol	> Sol	1.670	> Sol	> Sol
	500	22.500	> Sol	> Sol	> Sol	> Sol	14.300	> Sol	> Sol
	750 or [750]	184.000	> Sol	> Sol	> Sol	> Sol	64.100	> Sol	> Sol
RAC-2	[500]	69.700	> Sol	> Sol	> Sol	> Sol	338.000	> Sol	> Sol

Table 3B - Non-Drinking Water Wells (irrigation, industrial, other)

	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
For use when only a non-potable well is present	0	0.050	10.000	7.000	100.000	> Sol	0.200	100.000	66.666
	250	12.400	> Sol	> Sol	> Sol	> Sol	16.700	> Sol	> Sol
	500	225.000	> Sol	> Sol	> Sol	> Sol	143.000	> Sol	> Sol
	750 or [750]	> Sol	> Sol	> Sol	> Sol	> Sol	641.000	> Sol	> Sol

NOTES:

1) All RBSL concentrations are expressed in mg/L.
2) RBSLs used for both residential and commercial land uses.
3) **[750]**: Distance from source to a hypothetical well for a RAC-1 release in a Wellhead Protection Area
4) **[500]**: Distance from source to a hypothetical future well in a RAC-2 release.
5) **> Sol**: The target level is not exceeded for all possible dissolved levels.

Table 8-4. Soil Leaching to Groundwater Exposure Pathway
Groundwater Flow Rate ≥ 0.1 feet/day

Table 4A - Unsaturated zone thickness 0-50 feet

Well Type	Remedial Action Class	Distance from Source (ft)	CHEMICALS OF CONCERN							
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
Drinking Water Well	RAC-1	0	0.337	187.000	> Sat	> Sat	> Sat	0.602	16,100.000	> Sat
		250	11.700	> Sat	> Sat	> Sat	> Sat	20.800	> Sat	> Sat
		500	47.100	> Sat	> Sat	> Sat	> Sat	83.000	> Sat	> Sat
		750 or [750]	107.000	> Sat	> Sat	> Sat	> Sat	188.000	> Sat	> Sat
	RAC-2	[500]	146.000	> Sat	> Sat	> Sat	> Sat	1,960.000	> Sat	> Sat
Non-Drinking Water Well ONLY Present	RAC-1 or RAC-2	0	3.370	> Sat	> Sat	> Sat	> Sat	6.020	> Sat	> Sat
		250	117.000	> Sat	> Sat	> Sat	> Sat	208.000	> Sat	> Sat
	RAC-1 only	500	471.000	> Sat	> Sat	> Sat	> Sat	830.000	> Sat	> Sat
		750	> Sat	> Sat	> Sat	> Sat	> Sat	1,880.000	> Sat	> Sat

Table 4B - Unsaturated zone thickness >50 feet

Well Type	Remedial Action Class	Distance from Source (ft)	CHEMICALS OF CONCERN							
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
Drinking Water Well	RAC-1	0	0.673	375.000	> Sat	> Sat	> Sat	1.200	32,000.000	> Sat
		250	23.500	> Sat	> Sat	> Sat	> Sat	41.700	> Sat	> Sat
		500	94.100	> Sat	> Sat	> Sat	> Sat	166.000	> Sat	> Sat
		750 or [750]	215.000	> Sat	> Sat	> Sat	> Sat	375.000	> Sat	> Sat
	RAC-2	[500]	292.000	> Sat	> Sat	> Sat	> Sat	3,930.000	> Sat	> Sat
Non-Drinking Water Well ONLY Present	RAC-1 or RAC-2	0	6.730	> Sat	> Sat	> Sat	> Sat	12.000	> Sat	> Sat
		250	235.000	> Sat	> Sat	> Sat	> Sat	417.000	> Sat	> Sat
	RAC-1 only	500	> Sat	> Sat	> Sat	> Sat	> Sat	1,660.000	> Sat	> Sat
		750	> Sat	> Sat	> Sat	> Sat	> Sat	3,750.000	> Sat	> Sat

NOTES:

1) All RBSL concentrations are expressed in mg/kg.
2) RBSLs used for both residential and commercial land uses.
3) **[750]**: Distance from source to a hypothetical well for a RAC-1 release in a Wellhead Protection Area
4) **[500]**: Distance from source to a hypothetical future well in a RAC-2 release.
5) **> Sat**: The target level is not exceeded for all possible saturated levels in soil.

Table 8-5. Soil Leaching to Groundwater Exposure Pathway
Groundwater Flow Rate < 0.1 feet/day

Table 5A - Unsaturated zone thickness 0-50 feet

Well Type	Remedial Action Class	Distance from Source (ft)	CHEMICALS OF CONCERN							
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
Drinking Water Well	RAC-1	0	0.014	8.5100	4.370	147.000	> Sat	0.022	770.000	152,666.000
		250	3.430	> Sat	> Sat	> Sat	> Sat	1.820	> Sat	> Sat
		500	62.400	> Sat	> Sat	> Sat	> Sat	15.600	> Sat	> Sat
		750 or [750]	510.000	> Sat	> Sat	> Sat	> Sat	69.800	> Sat	> Sat
	RAC-2	[500]	193.000	> Sat	> Sat	> Sat	> Sat	368.000	> Sat	> Sat
Non-Drinking Water Well ONLY Present	RAC-1 or RAC-2	0	0.139	85.100	43.700	> Sat	> Sat	0.218	7,700.000	> Sat
		250	34.300	> Sat	> Sat	> Sat	> Sat	18.200	> Sat	> Sat
	RAC-1 only	500	624.000	> Sat	> Sat	> Sat	> Sat	156.000	> Sat	> Sat
		750	> Sat	> Sat	> Sat	> Sat	> Sat	698.000	> Sat	> Sat

Table 5B - Unsaturated zone thickness >50 feet

Well Type	Remedial Action Class	Distance from Source (ft)	CHEMICALS OF CONCERN							
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
Drinking Water Well	RAC-1	0	0.027	17.000	8.740	294.000	> Sat	0.043	1,535.000	305,000.000
		250	6.850	> Sat	> Sat	> Sat	> Sat	3.640	> Sat	> Sat
		500	125.000	> Sat	> Sat	> Sat	> Sat	31.100	> Sat	> Sat
		750 or [750]	> Sat	> Sat	> Sat	> Sat	> Sat	140.000	> Sat	> Sat
	RAC-2	[500]	387.000	> Sat	> Sat	> Sat	> Sat	736.000	> Sat	> Sat
Non-Drinking Water Well ONLY Present	RAC-1 or RAC-2	0	0.277	170.000	87.400	> Sat	> Sat	0.435	15,350.000	> Sat
		250	68.500	> Sat	> Sat	> Sat	> Sat	36.400	> Sat	> Sat
	RAC-1 only	500	> Sat	> Sat	> Sat	> Sat	> Sat	311.000	> Sat	> Sat
		750	> Sat	> Sat	> Sat	> Sat	> Sat	1,400.000	> Sat	> Sat

NOTES:

1) All RBSL concentrations are expressed in mg/kg.
2) RBSLs used for both residential and commercial land uses.
3) **[750]**: Distance from source to a hypothetical well for a RAC-1 release in a Wellhead Protection Area
4) **[500]**: Distance from source to a hypothetical future well in a RAC-2 release.
5) **> Sat**: The target level is not exceeded for all possible saturated levels in soil.

Table 8-6. Enclosed Space Vapor Inhalation Exposure Pathways
Residential Exposure; Building Present

Media	Subsurface Sediments	Vertical Interval between Contamination and Structure	CHEMICALS OF CONCERN						
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel oil)
Ground Water	Sands	< 3 feet	4.830	> Sol	> Sol	> Sol	5.770	391.000	> Sol
		3 – 6 feet	8.880	> Sol	> Sol	> Sol	10.400	797.000	> Sol
		> 6 feet	9.770	> Sol	> Sol	> Sol	11.200	953.000	> Sol
	Silts/Clays	< 3 feet	0.553	73.900	> Sol	137.000	0.528	88.100	6,500.000
		3 – 6 feet	1.460	195.000	> Sol	> Sol	1.380	241.000	> Sol
		> 6 feet	2.030	271.000	> Sol	> Sol	1.920	341.000	> Sol
Subsurface Soils	Sands	< 3 feet	0.008	2.950	5.120	9.260	0.167	0.622	2,390.000
		3 – 6 feet	0.241	89.400	> Sat	> Sat	5.060	18.900	72,500.000
		> 6 feet	0.485	180.000	> Sat	> Sat	10.200	38.000	> Sat
	Silts/Clays	< 3 feet	0.008	3.610	6.120	11.600	0.166	0.607	3,085.000
		3 – 6 feet	0.268	110.000	> Sat	352.000	5.050	18.400	93,500.000
		> 6 feet	0.539	220.000	> Sat	> Sat	10.100	37.000	188,000.000

NOTES:

1) All RBSL concentrations in mg/L for groundwater or mg/kg for soil.
2) RBSLs for volatilization hazards from all contaminants of concern are based on a structure within the source area.
3) These pathways are to be considered incomplete for releases of waste oil, as all determined RBSLs for this product are greater than the highest expected concentration in pure product.
4) **> Sol**: The target level is not exceeded for all possible dissolved levels.
5) **> Sat**: The target level is not exceeded for all possible saturated levels in soil.
6) RBSLs for benzene soil contamination in contact with an enclosed space may be below detection limits for most approved laboratory methods. This exposure pathway shall be considered incomplete if soil analytical results are non-detect at laboratory detection limits acceptable to the Department. The Department will provide guidance on acceptable detection limits at a later date.

Table 8-7. Enclosed Space Vapor Inhalation Exposure Pathways
Residential Exposure; No Building Present

Media	Subsurface Sediments	Vertical Interval between Contamination and Structure	CHEMICALS OF CONCERN						
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel oil)
Ground Water	Sands	< 3 feet	48.300	> Sol	> Sol	> Sol	> Sol	3,910.000	> Sol
		3 – 6 feet	88.800	> Sol	> Sol	> Sol	> Sol	7,970.000	> Sol
		> 6 feet	97.700	> Sol	> Sol	> Sol	> Sol	9,530.000	> Sol
	Silts/Clays	< 3 feet	5.530	> Sol	> Sol	> Sol	5.280	881.000	> Sol
		3 – 6 feet	14.600	> Sol	> Sol	> Sol	> Sol	2,410.000	> Sol
		> 6 feet	20.300	> Sol	> Sol	> Sol	> Sol	3,410.000	> Sol
Subsurface Soils	Sands	< 3 feet	0.079	29.500	51.200	92.600	1.670	6.220	23,950.000
		3 – 6 feet	2.410	> Sat	> Sat	> Sat	50.600	189.000	> Sat
		> 6 feet	4.850	> Sat	> Sat	> Sat	> Sat	380.000	> Sat
	Silts/Clays	< 3 feet	0.083	36.100	61.200	116.000	1.670	6.070	30,850.000
		3 – 6 feet	2.680	> Sat	> Sat	> Sat	50.500	184.000	> Sat
		> 6 feet	5.390	> Sat	> Sat	> Sat	102.000	370.000	> Sat

NOTES:

1) All RBSL concentrations in mg/L for groundwater or mg/kg for soil.
2) RBSLs for volatilization hazards from all contaminants of concern are based on future land use considerations.
3) These pathways are to be considered incomplete for releases of waste oil, as all determined RBSLs for this product are greater than the highest expected concentration in pure product.
4) **> Sol**: The selected risk level is not exceeded for all possible dissolved levels.
5) **> Sat**: The selected target level is not exceeded for all possible saturated levels in soil.

Table 8-8. Enclosed Space Vapor Inhalation Exposure Pathways
Commercial Exposure; Building Present

Media	Subsurface Sediments	Vertical Interval between Contamination and Structure	CHEMICALS OF CONCERN						
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel oil)
Ground Water	Sands	< 3 feet	48.300	> Sol	> Sol	> Sol	> Sol	3,910.000	> Sol
		3 – 6 feet	88.800	> Sol	> Sol	> Sol	> Sol	7,970.000	> Sol
		> 6 feet	97.700	> Sol	> Sol	> Sol	> Sol	9,530.000	> Sol
	Silts/Clays	< 3 feet	5.530	> Sol	> Sol	> Sol	5.280	881.000	> Sol
		3 – 6 feet	14.600	> Sol	> Sol	> Sol	> Sol	2,410.000	> Sol
		> 6 feet	20.300	> Sol	> Sol	> Sol	> Sol	3,410.000	> Sol
Subsurface Soils	Sands	< 3 feet	0.079	29.500	51.200	92.600	1.670	6.220	23,950.000
		3 – 6 feet	2.410	> Sat	> Sat	> Sat	50.600	189.000	> Sat
		> 6 feet	4.850	> Sat	> Sat	> Sat	> Sat	380.000	> Sat
	Silts/Clays	< 3 feet	0.083	36.100	61.200	116.000	1.670	6.070	30,850.000
		3 – 6 feet	2.680	> Sat	> Sat	> Sat	50.500	184.000	> Sat
		> 6 feet	5.390	> Sat	> Sat	> Sat	102.000	370.000	> Sat

NOTES:

1) All RBSL concentrations in mg/L for groundwater or mg/kg for soil.
2) RBSLs for volatilization hazards from all contaminants of concern are based on a structure within the source area.
3) These pathways are to be considered incomplete for releases of waste oil, as all determined RBSLs for this product are greater than the highest expected concentration in pure product.
4) **> Sol**: The selected risk level is not exceeded for all possible dissolved levels.
5) **> Sat**: The selected target level is not exceeded for all possible saturated levels in soil.
6) RBSLs for benzene soil contamination in contact with an enclosed space may be below detection limits for most approved laboratory methods. This exposure pathway shall be considered incomplete if soil analytical results are non-detect at laboratory detection limits acceptable to the Department. The Department will provide guidance on acceptable detection limits at a later date.

Table 8-9. Enclosed Space Vapor Inhalation Exposure Pathways Commercial Exposure; No Building Present

Media	Subsurface Sediments	Vertical Interval between Contamination and Structure	CHEMICALS OF CONCERN						
			Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel oil)
Ground Water	Sands	< 3 feet	182.000	> Sol	> Sol	> Sol	> Sol	14,700.000	> Sol
		3 – 6 feet	334.000	> Sol	> Sol	> Sol	> Sol	30,000.000	> Sol
		> 6 feet	368.000	> Sol	> Sol	> Sol	> Sol	35,800.000	> Sol
	Silts/Clays	< 3 feet	20.800	> Sol	> Sol	> Sol	> Sol	3,320.000	> Sol
		3 – 6 feet	54.900	> Sol	> Sol	> Sol	> Sol	9,060.000	> Sol
		> 6 feet	76.500	> Sol	> Sol	> Sol	> Sol	12,800.000	> Sol
Subsurface Soils	Sands	< 3 feet	0.299	21.400	> Sat	> Sat	12.100	23.400	> Sat
		3 – 6 feet	9.080	> Sat	> Sat	> Sat	> Sat	710.000	> Sat
		> 6 feet	18.300	> Sat	> Sat	> Sat	> Sat	1,430.000	> Sat
	Silts/Clays	< 3 feet	0.332	263.000	> Sat	> Sat	12.100	22.800	> Sat
		3 – 6 feet	10.100	> Sat	> Sat	> Sat	> Sat	693.000	> Sat
		> 6 feet	20.300	> Sat	> Sat	> Sat	> Sat	1,390.000	> Sat

NOTES:

1) All RBSL concentrations in mg/L for groundwater or mg/kg for soil.
2) RBSLs for volatilization hazards from all contaminants of concern are based on future land use considerations.
3) These pathways are to be considered incomplete for releases of waste oil, as all determined RBSLs for this product are greater than the highest expected concentration in pure product.
4) **> Sol**: The selected risk level is not exceeded for all possible dissolved levels.
5) **> Sat**: The selected target level is not exceeded for all possible saturated levels in soil.

Table 8-10. Exposures from Contaminated Surface Soils

Chemical of Concern	RBSL (mg/kg)
Benzene	**3.63**
Toluene	**>Sat**
Ethylbenzene	**>Sat**
Xylenes	**>Sat**
n-Hexane	**>Sat**
MTBE	**102**
TEH (as Diesel)	**9520**
TEH (as Waste Oil)	**3173**

NOTES:

1) The fate and transport model used to determine the RBSLs related to exposures from contaminated surface soils combines effects from dermal contact with, ingestion of and inhalation through outdoor air of COCs emanating from these soils.
2) >Sat: The selected target level is not exceeded for all possible saturated levels in soil.

Table 8-11. Surface Water Impact from Contaminated Groundwater

Darcy Flow Velocity	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
< 0.1 feet/day	0	0.712	200.000	29.000	> Sol	> Sol	1.000	10.000	> Sol
	250	176.000	> Sol	> Sol	> Sol	> Sol	83.560	22.451	> Sol
	500	> Sol	> Sol	> Sol	> Sol	> Sol	715.000	88.760	> Sol
	750	> Sol	> Sol	> Sol	> Sol	> Sol	3202.000	3047.000	> Sol
> 0.1 feet/day	0	0.712	200.000	29.000	> Sol	> Sol	1.000	10.000	> Sol
	250	24.807	> Sol	> Sol	> Sol	> Sol	34.571	22.451	> Sol
	500	99.526	> Sol	> Sol	> Sol	> Sol	138.000	88.760	> Sol
	750	227.000	> Sol	> Sol	> Sol	> Sol	311.000	3047.000	> Sol

NOTES:

1) All RBSL concentrations in mg/L.
2) **> Sol**: The target level is not exceeded for all possible dissolved levels.

Table 8-12. Surface Water Impact from Contaminated Soils Leaching to Groundwater

Table 12A - Unsaturated zone thickness 0-50 feet

Subsurface Sediments	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
Silts/Clays	0	1.972	> Sat	> Sat	> Sat	> Sat	1.088	23,814	> Sat
	250	488.000	> Sat	> Sat	> Sat	> Sat	90.915	> Sat	> Sat
	500	> Sat	> Sat	> Sat	> Sat	> Sat	778.000	> Sat	> Sat
	750	> Sat	> Sat	> Sat	> Sat	> Sat	3485.000	> Sat	> Sat
Sands	0	47.914	> Sat	> Sat	> Sat	> Sat	30.110	498,518	> Sat
	250	> Sat	> Sat	> Sat	> Sat	> Sat	1041.000	> Sat	> Sat
	500	> Sat	> Sat	> Sat	> Sat	> Sat	4144.000	> Sat	> Sat
	750	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat

Table 12A - Unsaturated zone thickness > 50 feet

Subsurface Sediments	Distance from Source (ft)	CHEMICALS OF CONCERN							
		Benzene	Toluene	Ethylbenzene	Xylenes	n-Hexane	MTBE	TEH (as diesel fuel)	TEH (as waste oil)
Silts/Clays	0	3.945	> Sat	> Sat	> Sat	> Sat	2.176	47,629	> Sat
	250	> Sat	> Sat	> Sat	> Sat	> Sat	182.000	> Sat	> Sat
	500	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat
	750	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat
Sands	0	95.827	> Sat	> Sat	> Sat	> Sat	60.219	997,036	> Sat
	250	> Sat	> Sat	> Sat	> Sat	> Sat	2082.000	> Sat	> Sat
	500	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat
	750	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat	> Sat

NOTES:

1) All RBSL concentrations in mg/kg.
2) > Sat: The target level is not exceeded for all possible saturated levels in soil.

8.4 – STEP 4. SELECTION OF NEXT COURSE OF ACTION

The possible outcomes of the Tier 1 evaluation are as follows:

- Site closure;
- Removal/treatment of contaminated surface soils to meet Tier 1 levels (see NDEE Environmental Guidance Document 06-205: Management of Petroleum Contaminated Materials for disposal direction);
- Tier 2 investigation and assessment; and/or
- Implementation of remedial actions.

Details of actions that may be required are expressed below:

- If the concentrations for all COCs are less than the RBSLs for all applicable exposure pathways, then no additional actions will normally be required by the Department.
- Where the representative concentrations are at or above any of the RBSLs, other than those concerning the surficial soils pathways, an additional Tier 2 investigation and evaluation will normally be required by the Department for those exposure pathways for which the RBSLs are exceeded.
- For the dermal contact/ingestion/inhalation of surface soil contamination exposure pathways only, if the contaminant concentrations for all COCs are less than the RBSLs, then no additional actions will normally be required by the Department. If the maximum contaminant concentrations are greater than the RBSLs for any COCs, the Department will normally require active remediation to address the pathway(s) levels (see NDEE Environmental Guidance Document 06-205: Management of Petroleum Contaminated Materials for disposal direction).

SECTION 9.0 – TIER 2 EVALUATION

9.1 – STEP 1: IDENTIFICATION OF DATA NEEDS AND COLLECTION OF DATA

When a site is required to proceed with a Tier 2 assessment, additional contaminant and site data are needed. This information is used in the calculation of Tier 2 SSTLs. The information to be collected is dependent on the exposure pathway(s) being investigated. The data requirements are discussed in Section 6.0.

9.2 – STEP 2: DEVELOPMENT OF SITE CONCEPTUAL EXPOSURE SCENARIO

Under the Tier 1 evaluation, a Site Conceptual Exposure Scenario was developed to identify the complete exposure pathways. This scenario must be revised for the Tier 2 evaluation. In most cases, the Site Conceptual Exposure Scenario for Tier 2 will be the same as for Tier 1.

9.3 – STEP 3: INPUT PARAMETERS FOR TIER 2 SSTLS

The Tier 2 assessment requires the use of the same models as the Tier 1 assessment. However, site-specific fate and transport parameter values are used to calculate Tier 2 SSTLs, whereas Tier 1 RBSLs were generated using non-site-specific default values.

9.3.1 – Physical & Chemical Properties of COCs

The Department uses the same default values for the calculation of Tier 2 SSTLs as used for the generation of Tier 1 RBSLs; values can be found in Table D-1, Appendix D.

9.3.2 – Exposure Factors

The Department uses the same default values for residential and commercial exposure factors in Tier 2 as used in Tier 1; values can be found in Table D-3, Appendix D.

9.3.3 – Toxicity Values & Target Risk Limits

The Department uses the same default toxicity values and target risk limits for carcinogenic and noncarcinogenic health effects in Tier 2 as in Tier 1; values can be found in Table D-2, Appendix D.

9.3.4 – Fate & Transport Parameters

The Department allows the use of representative site-specific values for fate and transport parameters for Tier 2 that were not allowed at the Tier 1 level. These variables are labeled as “Site-Specific” under the “Tier 2 Value” column in Table D-4, Appendix D.

9.4 – STEP 4: CALCULATION OF TIER 2 SSTLS

Tier 2 SSTLs are calculated by the Department for selected POCs using computational software developed by the Department.

9.5 – STEP 5: CALCULATION OF REPRESENTATIVE CONCENTRATIONS

The SSTLs are compared to the representative contaminant concentrations discussed in Section 7.8. The representative concentrations are either the maximum or average contaminant concentrations, depending on the exposure pathway being examined.

9.6 – STEP 6: SELECTION OF THE NEXT COURSE OF ACTION

The possible outcomes of the Tier 2 evaluation are as follows:

- Site closure.
- RP notified of SSTLs and remedial actions required.
- Monitoring for a finite period to verify representative contaminant concentrations.

Details of actions that may be required are expressed below:

- If the representative concentrations for all COCs are less than the SSTLs for the applicable exposure pathways, then no additional actions would normally be required by the Department.
- Where the representative site concentrations are above any of the SSTLs for an exposure pathway, active cleanup to the SSTLs will normally be required. Remedial actions will proceed as detailed in Title 118 Appendix B, Steps 9 – 11.
- The use of engineered controls may be considered to eliminate actual or potential exposures.

SECTION 10.0 – REFERENCES

American Society for Testing and Materials, E 1739-95 – Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, 1995.

Domenico, P. A., and Schwartz, F. W., Physical and Chemical Hydrogeology. John Wiley and Sons, New York, 1990.

Nebraska Department of Environment and Energy, Title 117 – Nebraska Surface Water Quality Standards.

Nebraska Department of Environment and Energy, Title 118 – Ground Water Quality Standards and Use Classification.

Nebraska Department of Environment and Energy, Title 126 – Rules and Regulations Pertaining to the Management of Wastes.

Nebraska Department of Environment and Energy, Title 200 – Rules and Regulations for Petroleum Release Remedial Action Reimbursement Fund.

Nebraska Department of Environment and Energy, Regulation & Licensure, Title 178 NAC 12 – Water Well Construction, Pump Installation and Water Well Decommissioning Standards.

Reed and Piskin, unknown date, unpublished University of Nebraska-Lincoln Conservation and Survey Division report.

Salhotra, A. M., personal communication, February 26, 2002.

Todd, D. K, Ground Water Hydrology, John Wiley & Sons, New York, 1980

United States Environmental Protection Agency, Integrated Risk Information System (IRIS) database.

United States Environmental Protection Agency, EPA 600/8-89/043 – Exposure Factors Handbook, July 1989.

United States Environmental Protection Agency Office of Water, EPA 822-B-96-002 – Drinking Water Regulations and Health Advisories, February 1999.

United States Environmental Protection Agency Office of Remediation and Emergency Response, Publication 9285.7-01B – Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), December 1991.

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SECTION 11.0 – GLOSSARY

applicable exposure factors - data used to calculate some allowable intake concentration of a chemical of concern into the body, including such factors as body weight, exposure duration, ingestion rate, etc.

biodecay – see biodegradation

biodegradation - the reduction in total mass and concentration of chemicals of concern due to the biological processes by bacteria in the environment.

chemical of concern (COC) - specific constituent of petroleum that the Department has identified for evaluation due to its toxicological effects.

commercial - refers to land use or exposure factors under conditions that cannot be defined as "residential" where receptors are potentially exposed to COCs.

direct exposure pathway - exposure pathway where the point of exposure is in the source area, without a release to any other medium (e.g., dermal contact with contaminated surface soils).

enclosed space - structure (e.g., residence with basement) of limited access allowing for the potential collection and concentration of contaminant vapors in the structure's breathing space.

exposure pathway - the course a chemical of concern travels from the source area(s) of a release to a potentially exposed receptor, comprised of a release source (e.g., LUST), a transport medium or media (e.g., groundwater), a point of exposure (e.g., a water well) and an exposure route (e.g., ingestion of contaminated groundwater).

fate and transport model - an estimate of contaminant concentration with time and distance based on a quantitative estimate of chemical mobility and persistence, developed using pre-set or site-specific information in conjunction with analysis of transport mechanisms such as advection, dispersion, and diffusion and/or a quantitative estimate of biodegradation processes.

free product - measurable (≥ 0.01 feet) petroleum product that is present as a non-aqueous phase liquid (i.e., liquid not dissolved in groundwater).

habitable – intended for human occupancy as a residence or workplace.

Hazard Index (HI) - the sum of two or more hazard quotients for multiple chemicals of concern or multiple exposure pathways, or both.

Hazard Quotient (HQ) - the ratio of the level of exposure of a chemical of concern over a specified time period to a reference dose for that chemical of concern derived for a similar period of time.

indirect exposure pathway - an exposure pathway with at least one intermediate release to any media between the source area and point of exposure (e.g., ingestion of contaminated groundwater at a water well, generated from contaminated soils located in the upgradient direction of groundwater flow).

Individual Excess Lifetime Cancer Risk (IELCR) - the target risk level for a carcinogenic chemical of concern (as in 10^{-6}) used to quantify risk in the RBCA process or establish risk-based screening levels.

Look-Up Table (LUT) - table containing Tier 1 RBSLs used for comparison to contaminant concentrations found during the Tier 1 site assessment.

monitoring well – a water well installed in accordance with Nebraska NDEE Title 178 within or straddling the groundwater table for the purpose of collecting groundwater samples for analysis.

monitoring (sampling) point – either a monitoring well, borehole, or similar structure (e.g., direct push boring, soil gas point) used for the collection of various environmental media (i.e., groundwater, soil, soil gas) for analysis.

natural attenuation - the reduction in total mass and concentration of chemicals of concern with distance and time due to processes such as biodegradation, diffusion, dispersion, and absorption.

non-aqueous-phase liquid (NAPL) - see free product.

point of compliance (POC) - location between a source area and a potential point of exposure where concentrations of chemicals of concern must be at or below the determined target levels in the media of concern.

point of exposure (POE) - point at which a chemical of concern may come into contact with or be taken into an actual or potential receptor.

receptor - any human who is or may be adversely affected by a petroleum release.

recharge area – area where there is a downward component to hydraulic head and infiltrating water travels into deeper levels of the aquifer.

Remedial Action Class (RAC) - one of three pollution occurrences defined for categories of groundwater (or overlying soils) in Nebraska, dependent on the degree (or potential) of use of groundwater as drinking water, and further defined in NDEE Title 118 - Ground Water Quality Standards and Use Classification.

residential - refers to land use or exposure factors used to describe or characterize receptors that are potentially exposed to COCs in at least one of the following environments: residences, ground-level or basement apartments, or other similar domiciles, and sensitive population centers, including but not limited to daycare centers, schools, hospitals, or nursing homes.

risk assessment - an analysis of the potential for adverse health effects caused by a chemical of concern, used to determine the need and type of remedial action and/or to develop site-specific cleanup levels.

risk-based corrective action (RBCA) - a streamlined approach to petroleum release corrective actions in which exposure and risk assessment practices are integrated with traditional corrective actions to ensure that appropriate and cost-effective remedies are selected that are protective of human health and the environment.

risk-based screening level (RBSL) - initial corrective action target concentration for a chemical of concern for the first tier of risk assessment, calculated from simple and conservative fate and transport models and pre-set site conditions.

site-specific target level (SSTL) - corrective action target concentration or final cleanup level for a chemical of concern developed during the second tier of risk assessment, calculated from the same fate and transport models used to develop an RBSL, using site-specific information.

soil gas - vapors or gases present in the unsaturated pore space of vadose zone sediments and materials. Constituents of interest for RBCA primarily include petroleum vapors, but may also include oxygen, carbon dioxide, methane, or other chemicals.

source area - either the location of liquid or residual petroleum hydrocarbons from a point source release or the location of the highest soil and groundwater contaminant concentration of the chemicals of concern as determined by the site assessment.

structures, subsurface – enclosed manmade spaces located partially or wholly below ground level. Includes utility conduits, such as storm or sanitary sewers, as well as basements, crawl spaces, or other habitable structures.

subsurface soils - those unconsolidated materials located within the unsaturated zone at a depth greater than three feet below ground level.

surface soils - those unconsolidated materials located within the unsaturated zone at a depth between zero and three feet below ground level.

target risk limit - level of concern used in exposure equations for carcinogens (e.g., a 10^{-6} IELCR) or non-carcinogens (e.g., a HI=1) to calculate an allowable intake of a chemical of concern into the body.

Tier 1 assessment - a risk-based analysis to develop non-site-specific values (RBSLs) for direct and indirect exposure pathways utilizing conservative factors and fate and transport models for various potential exposure pathways, where the values will apply to all releases that fall within specific categories.

Tier 2 assessment - a risk-based analysis applying the direct exposure factors established under a Tier 1 evaluation at the point(s) of exposure developed for a specific site and development of SSTLs for potential indirect exposure pathways at a POE based on site-specific conditions.

vapor - the gaseous state of a substance that is liquid or solid at standard temperature and pressure

APPENDICES

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Appendix A:

PAH Evaluation Using Total Hydrocarbons Analysis

SURROGATE METHOD FOR THE CONVERSION OF PAH RBSLS TO THE DEFAULT TEH VALUES

Due to potential difficulties with achieving the minimum quantification levels required by the Department for the polycyclic aromatic hydrocarbons (PAH) chemicals of concern (naphthalene, pyrene and benzo(a)pyrene), the Department developed an alternate method for the Tier 1 site screening of these chemicals using a Total Extractable Hydrocarbon (TEH) analysis method. In this surrogate method, default TEH risk-based screening levels (RBSLs) are developed based on the chemical-specific RBSLs and the assumed concentration of the chemical in the original product.

DIESEL FUEL

It is assumed here that diesel fuel contains the PAH chemicals of concern in the following percentages (by weight):

Naphthalene	**0.2%**
Pyrene	**0.001%**
Benzo(a)pyrene	**0.001%**

TEH values for each chemical-specific RBSL were calculated by dividing the RBSL by the percentage of the chemical in the product, providing a relative TEH level for the chemical concentration. For each exposure pathway, the lowest TEH value calculated was chosen as the default “TEH as Diesel” RBSL found in the Tier 1 Look-Up Tables.

The TEH values calculated for each chemical-specific RBSL are found in the accompanying tables in this appendix. The values used in the Tier 1 Look-Up Tables are shown in bold typeface.

WASTE OIL

It is assumed here that waste oil contains the PAH chemicals of concern in the following percentages (by weight):

Naphthalene	**0.0%**
Pyrene	**0.0%**
Benzo(a)pyrene	**0.003%**

Since benzo(a)pyrene (BaP) is the only PAH chemical of concern typically associated with waste oil, TEH values were calculated by dividing the BaP RBSL, where applicable, by the percentage of BaP in the product, providing a relative TEH level for BaP. For each applicable exposure pathway of concern, this TEH value was used as the default “TEH as Waste Oil” RBSL found in the Tier 1 Look-Up Tables.

The TEH values calculated for each BaP RBSL are found in the accompanying tables in this appendix, indicated by the bold typeface.

Table A-1. PAH as TEH Values: Groundwater Ingestion Exposure Pathway

		Tier 1 RBSLs			Default TEH as Diesel			Default TEH as Waste Oil		
	(ft)	Naphthalene	Pyrene	BaP	Naphthalene	Pyrene	BaP	Naphthalene	Pyrene	BaP
Sands										
RAC-1	0	0.02	0.02	0.0002	10.0	2000.0	20.0			6.66
	250	1.40	> Sol	> Sol	700.0					
	500	10.40	> Sol	> Sol	5200.0					
	750	> Sol	> Sol	> Sol						
RAC-2	[500]	> Sol	> Sol	> Sol						
Silts / Clays										
RAC-1	0	0.02	0.02	0.0002	10.0	2000.0	20.0			6.66
	250	> Sol	> Sol	> Sol						
RAC-2	[500]	> Sol	> Sol	> Sol						

Notes:
1) Values provided in milligrams per liter (mg/L) or approximately parts per million (ppm)
2) BaP: Benzo(a) pyrene
3) > Sol: The selected target level is not exceeded for all possible dissolved levels

Table A-2. PAH as TEH Values: Soil Leaching to Groundwater Exposure Pathway

GROUNDWATER 0-50 FT.

		Tier 1 RBSLs			Default TEH as Diesel			Default TEH as Waste Oil		
	(ft)	Naphthalene	Pyrene	BaP	Naphthalene	Pyrene	BaP	Naphthalene	Pyrene	BaP
Sands										
RAC-1	0	32.2	> Sat	> Sat	16100.0					
	250	> Sat	> Sat	> Sat						
RAC-2	[500]	> Sat	> Sat	> Sat						
Silts / Clays										
RAC-1	0	1.54	> Sat	4.58	770.0		460,000			152,226
	250	> Sat	> Sat	> Sat						
RAC-2	[500]	> Sat	> Sat	> Sat						

GROUNDWATER >50 FT.

		Tier 1 RBSLs			Default TEH as Diesel			Default TEH as Waste Oil		
	(ft)	Naphthalene	Pyrene	BaP	Naphthalene	Pyrene	BaP	Naphthalene	Pyrene	BaP
Sands										
RAC-1	0	64.4	> Sat	> Sat	32,000					
	250	> Sat	> Sat	> Sat						
RAC-2	[500]	> Sat	> Sat	> Sat						
Silts / Clays										
RAC-1	0	3.07	> Sat	9.15	1,535		919,000			305,000
	250	> Sat	> Sat	> Sat						
RAC-2	[500]	> Sat	> Sat	> Sat						

Notes:
1) Values provided in milligrams per kilogram (mg/kg) = parts per million (ppm)
2) BaP: Benzo(a) pyrene
3) > Sat: The selected target level is not exceeded for all possible saturated levels in soil

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Appendix B:

Tier 1 Report Forms

NEBRASKA

DEPT. OF ENVIRONMENT AND ENERGY

RBCA Tier 1 Site Investigation Report Forms for Petroleum Release Sites

(For Use by Consultants)

FACILITY NAME:	
LOCATION:	
NDEE SPILL NO.:	
NDEE IIS NO.:	
CONSULTANT PROJECT NO.:	
CONSULTANT:	
COMPLETION DATE:	
PREPARED BY:	
REVIEWED BY:	

NDEE RBCA TIER 1 REPORT FORMS

TABLE OF CONTENTS

Form No.	Description		Check box if included
FORMS FOR USE BY RP/CONSULTANT			
1.	Executive Summary		☐
2.	Basic Information:	2a. Facility/File	☐
		2b. Consultant and Licensing	☐
3.	Release:	3a. Characterization and History	☐
		3b. Source Area GPS Coordinates	☐
4.	Land Use		☐
5.	Water Use:	5a. Ground Water and Surface Water Use	☐
		5b. Water Supply Well Location Information	☐
6.	Enclosed Spaces		☐
7.	Instructions for Investigation Narrative		☐
8.	Site Stratigraphy and Hydrogeology		☐
9.	Surface Soil (0-3 ft bgl) Analytical Data Summary		☐
10.	Subsurface Soil (>3 ft bgl) Analytical Data Summary		☐
11.	Ground Water	11a. Analytic Data Summary	☐
		11b. QA/QC Sample Data Summary	☐
12.	Free Product		☐
13.	References and Protocols		☐
ATTACHMENTS			
	All maps submitted must include a bar scale, legend, north arrow, location of all known soil borings and monitoring wells, and date of map, where appropriate.		
1.	Topographic Map		☐
2.	Area Map		☐
3.	Site Map		☐
4.	Free Product Map		☐
5.	Boring Logs		☐
6.	Monitoring Well		☐
7.	Laboratory Analysis		☐
8.	Geologic Cross		☐
9.	Well Survey		☐

OTHER ATTACHMENTS:

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 1**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

EXECUTIVE SUMMARY

Facility or file name:						
Current facility name (if different from above):						
Facility address or site location:						
Status of fuel storage/distribution:	☐ Active		☐ Inactive		☐ NA	
Is surface soil contamination present?	☐ Yes		☐ No			
Are subsurface soils impacted?	☐ Yes		☐ No			
Is ground water impacted?	☐ Yes		☐ No		☐ NA	
Has the source(s) of release been identified?	☐ Yes		☐ No			
Was free product detected during the Tier 1 investigation?	☐ Yes	☐ No				
If yes, was the free product plume fully delineated?	☐ Yes	☐ No				
Were vapors detected in any on-site subsurface structures?	☐ Yes	☐ No				
Has surface water been impacted by the release?	☐ Yes	☐ No				
Were emergency actions initiated?	☐ Yes	☐ No				
Average depth of contamination in subsurface soils:	________ ft			________ cm		
Shallowest depth to ground water:	________ ft			☐ Not measured		
Average depth to ground water:	________ ft			☐ Not measured		
Distance to nearest drinking water supply well:	________ ft	☐ municipal		☐ domestic		
Distance to nearest non-potable water supply well:	________ ft		type:			
Distance to nearest downgradient water supply well:	________ ft	☐ municipal		☐ domestic		
Is there evidence of vertical migration of the contaminant plume?	☐ Yes	☐ No		☐ NA		

Statement of Completion & Responsible Party/Consultant Signature Block

The consultant representative acknowledges that this report meets the minimum requirements for a Tier 1 investigation at this petroleum release site, as specified in the Department's *Risk-Based Corrective Action (RBCA) at Petroleum Release Sites: Tier 1/Tier 2 Assessments and Reports Guidance Document* . Any procedures that differ from the guidance document specifications are noted in the report, were approved by the Department and are accompanied by appropriate documentation. The responsible party acknowledges that they have read (or discussed with their consultant), this site investigation report and are aware of their responsibility for the timely submission to the Department.

Consultant Representative Signature Date

Responsible Party Signature Date

ADDITIONAL NOTES

Recommended attachments: None.

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 2a**

FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

FACILITY/FILE INFORMATION

Facility or file name:

Facility address or site location:

County:

Legal Location (¼, ¼, ¼, Sec, T, R):

Responsible Party:

Responsible Party mailing address:

Responsible Party phone number:

Property owner:

Property owner mailing address:

Property owner phone number:

Other contacts:

ADDITIONAL NOTES

Recommended attachments: Topographic map

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 2b**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

CONSULTANT AND LICENSING INFORMATION

Consulting Firm:

Consulting Firm mailing address:

Consulting Firm Project Manager:

Consultant phone numbers:

Nebraska Department of Health & Human Services Water Well Licenses

List all personnel and subcontractors involved in installing or sampling wells during this investigation.

License No.	*License Type*	*Personnel/Subcontractor Name*

ADDITIONAL NOTES

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 3a**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

RELEASE CHARACTERIZATION

PETROLEUM RELEASE HISTORY

NDEE Spill Number	Location/Source	Product/Quantity

SOURCE(S) OF RELEASE (Check all that apply)

- ☐ Surface Spills
- ☐ Load Out Racks (includes overfills)
- ☐ Piping
- ☐ Dispenser Islands (includes vessel overfills)
- ☐ USTs (includes UST overfills)
- ☐ ASTs (includes AST overfills)
- ☐ Transportation Vessels
- ☐ Interstate/Intrastate Pipelines
- ☐ Unknown
- ☐ Other (specify)

SUBSTANCE(S) RELEASED (Check all that apply)

- ☐ Gasoline
- ☐ Diesel/#2 Fuel Oil
- ☐ Used Oil
- ☐ AV Gas
- ☐ Jet Fuel: **JP**
- ☐ Kerosene
- ☐ Other Fuel Oil/Heavy Distillate (specify)

Other product (specify)

SUMMARY OF RELEASE

			(Provide explanatory notes below)
Has the source(s) of release been identified?	☐ YES	☐ NO	
Has the release been abated?	☐ YES	☐ NO	
Were emergency actions initiated?	☐ YES	☐ NO	
Are surface soils impacted?	☐ YES	☐ NO	
Are subsurface soils impacted?	☐ YES	☐ NO	
Is ground water impacted?	☐ YES	☐ NO	☐ Not sampled, drilled out of contamination
Were vapors detected in any utilities?	☐ YES	☐ NO	
Were vapors detected in any on-site subsurface structures?	☐ YES	☐ NO	
Is surface water impacted?	☐ YES	☐ NO	
Has a sensitive habitat/resource been impacted?	☐ YES	☐ NO	

ADDITIONAL NOTES

Recommended attachments: None.

NDEE RBCA TIER 1 REPORT **Tier 1 Investigation Form - 3b**

FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

GPS LOCATIONS

GPS Manufacturer & Model:

Reference Datum: ☐ WG S 84 ☐ NAD 83 ☐ Unknown or Other:

WAAS Status: ☐ Enabled ☐ Disabled ☐ N/A or Unknown

Source Area Locations:

Take readings as near as possible to the point of highest contamination in each identified source area.

Latitude	Longitude	Accuracy	(ft)	(m)	Point Description

General Facility Locations:

Preferred locations are the intersection of the facility driveway and closest public street and/or the facility office entrance.

Latitude	Longitude	Accuracy	(ft)	(m)	Point Description

Coordinate Converters

These are provided for your convenience. Enter only readings in decimal degrees in the tables above.

Degrees	*Minutes*	*Seconds*	*Decimal Degrees*
			- - - - -
			- - - - -

Degrees	*Decimal Minutes*	*Decimal Degrees*
		- - - - -
		- - - - -

ADDITIONAL NOTES

Recommended attachments: Show GPS reading locations on Site Map.

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 3b**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

GPS LOCATIONS

GPS Manufacturer & Model:

Reference Datum: ☐ WG S 84 ☐ NAD 83 ☐ Unknown or Other:

WAAS Status: ☐ Enabled ☐ Disabled ☐ N/A or Unknown

Monitoring Well Locations (Optional):

The use of GPS units with sub-meter accuracy is recommended for determining monitoring well locations.

Latitude	Longitude	Accuracy	(ft)	(m)	Point Description

Coordinate Converters

These are provided for your convenience. Enter only readings in decimal degrees in the tables above.

Degrees	*Minutes*	*Seconds*	*Decimal Degrees*
			- - - - -
			- - - - -

Degrees	*Decimal Minutes*	*Decimal Degrees*
		- - - - -
		- - - - -

ADDITIONAL NOTES

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 4**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

LAND USE

☐ Currently operating as a service station or petroleum bulk facility. If not, site currently used as:

☐ Tanks temporarily out of service ☐ Tanks permanently out of service

Current On-site Land Use		Future On-site Land Use	
Residential	☐	Residential	☐
Commercial	☐	Commercial	☐

Comments: *Justify the choice for future land use.*

Off-site Land Use (within 500 feet - at a minimum, state whether residential, agricultural, commercial, or sensitive population center)

North:
Northeast:
Northwest:
South:
Southeast:
Southwest:
West:
East:

ADDITIONAL POINT OF EXPOSURE SURVEY

	Distance (feet)	Direction
Nearest residential site (≤500 ft):		
Nearest commercial site (≤500 ft):		
Nearest habitable building (≤500 ft):		
Nearest ecologically sensitive area, e.g., wetland (≤1000 ft):		
Nearest school, hospital, day care, retirement home, etc. (≤500 ft):		

ADDITIONAL NOTES

Recommended attachments: Site map with detailed land use in the vicinity of the site, Area map.

NDEE RBCA TIER 1 REPORT		Tier 1 Investigation Form 5a
FACILITY NAME:	NDEE SPILL NO.:	NDEE IIS NO.:
CONSULTANT:	COMPLETION DATE: 00-Jan-00	PREPARED BY:

GROUND WATER AND SURFACE WATER USE

Ground Water - Current Use

Well Designation	Well Type/Use	Distance (ft)	Direction

Surface Water - Current Use

Surface Water Type	Beneficial Use	Distance (ft)	Direction

Ground Water & Surface Water - Future Use

Are the RP, current property owner (if different than RP), adjacent landowners, and/or local municipal authorities aware of potential future ground and/or surface water use development within the next five years?

Ground Water
☐ Yes ☐ No

Surface Water
☐ Yes ☐ No

If yes, provide the following information. Include contact information in Notes below and/or Form 5b.

Location	Type of New Use

NOTES: 1) Justify choice of future ground water use; also indicate if water supply well may have some influence over vertical migration of plume.
2) Justify choice for future surface water use and type of water body.

Recommended attachments: Area map with well and surface water locations.

NDEE RBCA TIER 1 REPORT

Tier 1 Investigation Form - 5b

FACILITY NAME:

NDEE SPILL NO.:

NDEE IIS NO.:

CONSULTANT:

COMPLETION DATE:

PREPARED BY:

WATER SUPPLY WELL LOCATION INFORMATION

List all wells located within the distances for the categories requested.

Well Designation	Physical Location/Address	Well Owner	Well Owner Mailing Address

Municipal Water/Utilities Superintendent: Telephone Number:

Third Party Contact for Future Ground Water Use: Telephone Number:

NOTES:

Provide location information of all water supply wells documented in Report Form 5a on area map.

Well location may be street property address or legal description.

Use well designation as map label. Include well locations on site map.

Recommended Attachment(s): Well logs and installation information.

NDEE RBCA TIER 1 REPORT **Tier 1 Investigation Form - 6**

FACILITY NAME:

CONSULTANT:

NDEE SPILL NO.:

NDEE IIS NO.:

COMPLETION DATE:

PREPARED BY:

ENCLOSED SPACES

☐ *NO ENCLOSED SPACES ASSOCIATED WITH RELEASE LOCATION*

ON-SITE SUBSURFACE UTILITIES

Indicate which of the following utilities currently act as conduits or are potentially liable to become conduits under the columns entitled "Impacted by release," and "Potentially Impacted by Release," respectively.

	Depth [feet]	Construction material	Fill Material	Flow direction	Impacted by release	Potentially impacted by release
☐ Sanitary sewer						
☐ Covered storm sewer						
☐ Water line						
☐ Gas line						
☐ Electric line						
☐ Telephone line						
Other:						
☐						
☐						

ON-SITE & ADJACENT PROPERTY (within 200 ft) BUILDINGS

Building Location	Direction *(Cross, Down, Upgradient)*	Distance from source area(s)	Use	Basement or other subgrade present? (e.g. crawl space, daylight room)	
				Type of structure	Depth (ft bgl)

VAPOR ASSESSMENT

Subsurface Structure Screened	Location	PID/FID (ppm)	CGI (%LEL)

Recommended attachments: Site map with locations of utilities, tanks and ancillary equipment, and vapor sampling locations.

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 7**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

INSTRUCTIONS FOR INVESTIGATION NARRATIVE

Note: The reporter may use a format of their choosing for the following narrative information, with the provision that all the minimum information requirements listed below are provided under the following headings and in the order outlined. Place the narrative behind a copy of this Investigation Form in the Tier 1 Report.

I. Brief history of any abatement/remedial actions taken prior to initiating the Tier 1 investigation

II. Summary of site characteristics
    A. Site Location
    B. General site topography, geology, and hydrogeology

III. Summary of drilling activities
    A. Date/method/equipment
    B. Drilling order of boreholes
    C. Drilling complications (e.g., auger failure or refusal, site recently modified), if any
    D. Description of materials drilled through and evidence of contamination
    E. Monitoring well installation
        - depth of wells
        - screened interval
        - filter pack and grout materials
        - type of well head protection
        - well development methodology, duration, estimated water removed
        - other information
    F. Monitoring well location information
        - nature and location of permanent benchmark to which wells are referenced (designate on site map)
        - method (e.g., stadia, measuring wheel, tape) and measurements (in tabular format) used to reference wells to benchmark
    G. Other information related to drilling activities (e.g., start/stop times for drilling & well installation)

IV. Direct push technologies
    A. Date/method/equipment
    B. Order of probe locations
    C. Description of materials drilled through and evidence of contamination
    D. Other information related to direct push activities (e.g., start/stop times, media investigated)

V. Summary of sampling activities
    A. Soil sampling
        - method of sample collection
        - method/protocol used for head space analysis
        - method/protocol used for laboratory sample preparation
    B. Ground water sampling
        - purging method/protocol/criteria (includes rationale for not purging, if applicable)
        - sample collection method/protocol
        - order of well sampling (Note: sample least contaminated to most contaminated)
    C. Drinking water supply well/system sampling
        - location of sampling point (e.g., directly from well, outdoor tap, indoor tap)
        - purging method/protocol/criteria
        - sample collection method/protocol
    D. QA/QC considerations
        - steps taken to limit cross-contamination between sampling locations
        - number/type/location of duplicates/blanks
        - decontamination protocol and other measures taken to minimize cross-contamination

VI. Other information
    A. Rationale for variances from approved work plan or RBCA guidance document
    B. Contact information (i.e., names, phone numbers, affiliations) for people providing information gathered during investigation

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 8**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

SITE STRATIGRAPHY AND HYDROGEOLOGY

STRATIGRAPHY OF THE SITE

Depth [feet]	Unified Soil Classification	Type of Soil

Predominant soil type:

Depth [feet]	Type of Bedrock & Geological Formation (where applicable) (discuss rock properties and features, e.g., fractures)

HYDROGEOLOGY OF THE SATURATED IMPACTED ZONE

Range of ground water fluctuation, (if known): ____ ft Source: ____

Average depth to water table/static water level: ____ ft

Flow direction: ____

Hydraulic gradient (i): ____ ft/ft MWs used: ____

Hydraulic conductivity (K): ____ ft/day for: ____

Porosity (n) [0.30 for sands, 0.35 for silts/clays] ____

Seepage velocity (K x i/n) [calculated]: ____ ft/day ____ cm/year

ADDITIONAL NOTES

Recommended attachments: Relevant cross-sections and soil boring logs.

NDEE RBCA TIER 1 REPORT **Tier 1 Investigation Form - 9**

FACILITY NAME: **NDEE SPILL NO.:** **NDEE IIS NO.:**

CONSULTANT: **COMPLETION DATE:** **PREPARED BY:**

ANALYTICAL DATA SUMMARY FOR SURFACE SOIL (Soil sample depth between 0-3 feet bgl; All concentrations in mg/kg)

☐ **NOT APPLICABLE FOR THIS SITE**

Sample No.						Arithmetic Average	Maximum	Ratio (Max. / Avg) *
Sampling Date								
Sample Depth (ft)								
VOLATILE ORGANIC CHEMICALS ANALYSES								
Benzene								
Toluene								
Ethylbenzene								
Xylenes (total)								
n-Hexane								
Methyl-tert-butyl-ether (MTBE)								
TOTAL EXTRACTABLE HYDROCARBONS ANALYSES								
TEH (as diesel)								
TEH (as waste oil)								
TEH (as kerosene)								
TEH as								
TEH as								
TEH as								
OTHER ANALYTES								

NOTE:

Provide any laboratory analytical data sheets not previously submitted to the Department.

Non-detects can be expressed as ND, BDL, etc.

*** : If the ratio is high (for example >10) there may be a "hot spot" and additional investigation/evaluation may be warranted. In such circumstances, contact the Department.**

Recommended Attachments: Site map showing location(s) of surface soil sample(s), chemical concentration maps, laboratory analysis reports, and chain of custody.

NDEE RBCA TIER 1 REPORT

Tier 1 Investigation Form - 10

FACILITY NAME:
NDEE SPILL NO.:
NDEE IIS NO.:
CONSULTANT:
COMPLETION DATE:
PREPARED BY:

ANALYTICAL DATA SUMMARY FOR SUBSURFACE SOIL (Soil sample depth greater than 3 ft bgl; All concentrations in mg/kg.)

MW / SB No.													Arithmetic Average	Maximum	Ratio (Max. / Avg) *
Sampling Date															
Sample Depth (ft)															
VOLATILE ORGANIC CHEMICALS ANALYSES															
Benzene															
Toluene															
Ethylbenzene															
Xylenes (total)															
n-Hexane															
Methyl-tert-butyl-ether (MTBE)															
TOTAL EXTRACTABLE HYDROCARBONS ANALYSES															
TEH (as diesel)															
TEH (as waste oil)															
TEH (as kerosene)															
TEH as															
TEH as															
TEH as															
OTHER ANALYTES															

NOTE:

Provide any laboratory analytical data sheets not previously submitted to the Department. Add additional sheets as needed.

Non-detects can be expressed as ND, BDL, etc.

*** : If the ratio is high (for example >10) there may be a "hot spot" and additional investigation/evaluation may be warranted. In such circumstances, contact the Department.**

Recommended Attachments: Site map showing location(s) of subsurface soil sample(s), chemical concentration maps, laboratory analysis report(s), chain of custody, and boring logs.

NDEE RBCA TIER 1 REPORT **Tier 1 Investigation Form - 11a**

FACILITY NAME:
NDEE SPILL NO.:
NDEE IIS NO.:

CONSULTANT:
COMPLETION DATE:
PREPARED BY:

ANALYTICAL DATA SUMMARY FOR GROUND WATER (All concentrations in mg/L)

☐ NOT APPLICABLE FOR THIS SITE

Monitoring Well Number								**Arithmetic Average**	**Maximum**	**Ratio (Max. / Avg) ***
Installation Date										
Screen Interval (feet below datum)										
Water Level (feet below datum)										
Last Sampling Event										
VOLATILE ORGANIC CHEMICALS ANALYSES										
Benzene										
Toluene										
Ethylbenzene										
Xylenes (total)										
n-Hexane										
Methyl-tert-butyl-ether (MTBE)										
TOTAL EXTRACTABLE HYDROCARBON ANALYSIS										
TEH (as diesel)										
TEH (as waste oil)										
TEH (as kerosene)										
TEH as										
TEH as										
TEH as										
OTHER ANALYTES										

NOTE: Provide any laboratory analytical data sheets not previously submitted to the Department. Add additional sheets as needed.

* : If the ratio is high (for example >10) there may be a "hot spot" and additional investigation/evaluation may be warranted. In such circumstances, contact the Department.

Recommended Attachment: Site map showing location(s) of monitoring well(s), chemical concentration maps, laboratory analysis report(s), chain of custody, boring logs, and monitoring well schematics.

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 11b**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

ANALYTICAL DATA SUMMARY FOR QA/QC WATER SAMPLES (All concentrations in mg/L)

☐ **NOT APPLICABLE FOR THIS SITE**

Type of QA/QC Water Sample	**Blind Duplicates**		**Field Blanks**		**Trip Blanks**	
Sample Designation						
Sample Date						
Field Blank Exposure Time (min)						
VOLATILE ORGANIC CHEMICALS ANALYSES						
Benzene						
Toluene						
Ethylbenzene						
Xylenes (total)						
n-Hexane						
Methyl-tert-butyl-ether (MTBE)						
TOTAL EXTRACTABLE HYDROCARBON ANALYSIS						
TEH (as diesel)						
TEH (as waste oil)						
TEH (as kerosene)						
TEH as						
TEH as						
TEH as						
OTHER ANALYTES						

TEMPERATURE BLANKS	**Cooler ID**	**Pre-Delivery Temp. (°C)**	**Laboratory Temp (°C)**	**Cooler ID**	**Pre-Delivery Temp. (°C)**	**Laboratory Temp (°C)**

NOTE: Provide any laboratory analytical data sheets not previously submitted to the Department.
Recommended Attachment: Laboratory analysis report(s) and chain of custody.

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 12**

FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

FREE PRODUCT

Is free product present at the site? ☐ YES ☐ NO

(Note if NO, proceed to the next report form)

Has free product been found in any utility? ☐ YES ☐ NO

Has the free product plume been delineated? ☐ YES ☐ NO

Shallowest depth to free product:

Type of free product released:

Number of monitoring wells currently at the site:

List the monitoring wells containing free product:

Specify the well ID and maximum free product thickness:

feet Date:

VAPOR ASSESSMENT

Place vapor assessment information in Tier 1 Investigation Form - 6.

REMEDIATION

Has free product removal been initiated? ☐ YES ☐ NO

If YES, specify method of removal (bailer, pump, etc.)?

Frequency of removal (continuously, weekly, etc.):

Total number of recovery events to date:

Total amount of purge-water recovered:

Total amount of free product recovered:

Date of latest free product report submittal:

ADDITIONAL NOTES

Recommended attachments: Free product thickness maps as appropriate. Place narrative detailing free product effort in Form - 7.

NDEE RBCA TIER 1 REPORT	**Tier 1 Investigation Form - 13**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

REFERENCES AND PROTOCOLS

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Appendix C:

Tier 2 Report Forms

NEBRASKA

DEPT. OF ENVIRONMENT AND ENERGY

RBCA Tier 2 Site Investigation Report Forms for Petroleum Release Sites

(For Use by Consultants)

FACILITY NAME:	
LOCATION:	
NDEE SPILL NO.:	
NDEE IIS NO.:	
CONSULTANT PROJECT NO.:	
CONSULTANT:	
COMPLETION DATE:	
PREPARED BY:	
REVIEWED BY:	

NDEE RBCA TIER 2 REPORT FORMS

TABLE OF CONTENTS

FORMS FOR USE BY RP/CONSULTANT

Form No.	Description		Check box if included
1.	Basic Information:	1. Executive Summary	☐
		1a. Consultant and Licensing	☐
		1b. GPS Locations	☐
2.	Instructions for Tier 2 Investigation Narrative		☐
3.	Site Stratigraphy and Hydrogeology		☐
4.	Site-Specific Vadose Zone Parameters		☐
5.	Subsurface Soil (>3 ft bgl) Analytical Data Summary		☐
6.	Ground Water:	6a. Analytical Data Summary	☐
		6b. QA/QC Sample Data Summary	☐
7.	Soil Gas Analytical Data Summary		☐
8.	References and Protocols		☐

ATTACHMENTS

All maps submitted must include a bar scale, legend, north arrow, location of all known soil boring and monitoring wells, and date of map, where appropriate.

Attachment No.	Description	Check box if included
1.	Area Map	☐
2.	Site Map	☐
3.	Contaminant Plume	☐
4.	Free Product Map	☐
5.	Boring Logs	☐
6.	Monitoring Well	☐
7.	Laboratory Analysis	☐
8.	Geologic cross-sections	☐
9.	Well Survey	☐

OTHER ATTACHMENTS:

NDEE RBCA TIER 2 REPORT **Tier 2 Investigation Form - 1**

FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

EXECUTIVE SUMMARY

Facility or file name:			
Current facility name (if different from above):			
Facility address or site location:			
Status of fuel storage/distribution:	☐ Active	☐ Inactive	☐ NA
Was surface soil remediated after the Tier 1 investigation?	☐ Yes	☐ No	
This Tier 2 investigation pertains to:			
Ground Water Ingestion Pathway	☐ Yes	☐ No	
Soil Leaching to Ground Water Pathway	☐ Yes	☐ No	
Enclosed Space Inhalation from Soils Pathway	☐ Yes	☐ No	
Enclosed Space Inhalation from Gound Water Pathway	☐ Yes	☐ No	
Was free product detected during the Tier 1 investigation?	☐ Yes	☐ No	
If yes, was the free product removed prior to Tier 2 investigation?	☐ Yes	☐ No	
Were vapors detected in any utilities?	☐ Yes	☐ No	
Has surface water been impacted by the release?	☐ Yes	☐ No	
Average depth of contamination in subsurface soils:	________ ft	________ cm	☐ NA
Shallowest depth to ground water:	________ ft	☐ NA	
Average depth to ground water:	________ ft	☐ NA	
Distance to nearest drinking water supply well:	________ ft	☐ NA	
Distance to nearest non-potable water supply well:	________ ft	☐ NA	
Distance to nearest downgradient water supply well:	________ ft	☐ NA	
Is there evidence of vertical migration of the contaminant plume?	☐ Yes	☐ No	☐ NA

Statement of Completion & Responsible Party/Consultant Signature Block

The consultant representative acknowledges that this report meets the minimum requirements for a Tier 2 investigation at this petroleum release site, as specified in the Department's Risk-Based Corrective Action (RBCA) at Petroleum Release Sites: Tier 1/Tier 2 Assessments and Reports Guidance Document. Any procedures that differ from the guidance document specifications are noted in the report, were approved by the Department and are accompanied by appropriate documentation. The responsible party acknowledges that they have read (or discussed with their consultant), this site investigation report and are aware of their responsibility for the timely submission to the Department.

Consultant Representative Signature Date

Responsible Party Signature Date

ADDITIONAL NOTES

Recommended attachments: None.

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 1a**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

CONSULTANT AND LICENSING INFORMATION

Consulting Firm:

Consulting Firm mailing address:

Consulting Firm Project Manager:

Consultant phone numbers:

Nebraska Department of Health & Human Services Water Well Licenses

List all personnel and subcontractors involved in installing or sampling wells during this investigation.

License No.	*License Type*	*Personnel/Subcontractor Name*

ADDITIONAL NOTES

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 1b**

FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

GPS LOCATIONS

GPS Manufacturer & Model:

Reference Datum: ☐ WG S 84 ☐ NAD 83 ☐ Unknown or Other:

WAAS Status: ☐ Enabled ☐ Disabled ☐ N/A or Unknown

Source Area Locations:

Take readings as near as possible to the point of highest contamination in each identified source area.

Latitude	Longitude	Accuracy	(ft)	(m)	Point Description

General Facility Locations:

Preferred locations are the intersection of the facility driveway and closest public street and/or the facility office entrance.

Latitude	Longitude	Accuracy	(ft)	(m)	Point Description

Coordinate Converters

These are provided for your convenience. Enter only readings in decimal degrees in the tables above.

Degrees	*Minutes*	*Seconds*	*Decimal Degrees*
			- - - - -
			- - - - -

Degrees	*Decimal Minutes*	*Decimal Degrees*
		- - - - -
		- - - - -

ADDITIONAL NOTES

Recommended attachments: Show GPS reading locations on Site Map.

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 1b**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

GPS LOCATIONS

GPS Manufacturer & Model:

Reference Datum: ☐ WG S 84 ☐ NAD 83 ☐ Unknown or Other:

WAAS Status: ☐ Enabled ☐ Disabled ☐ N/A or Unknown

Monitoring Well Locations (Optional):

The use of GPS units with sub-meter accuracy is recommended for determining monitoring well locations.

Latitude	Longitude	Accuracy	(ft)	(m)	Point Description

Coordinate Converters

These are provided for your convenience. Enter only readings in decimal degrees in the tables above.

Degrees	*Minutes*	*Seconds*	*Decimal Degrees*
			- - - - -
			- - - - -

Degrees	*Decimal Minutes*	*Decimal Degrees*
		- - - - -
		- - - - -

ADDITIONAL NOTES

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 2**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE: 00-Jan-00	**PREPARED BY:**

INSTRUCTIONS FOR INVESTIGATION NARRATIVE

Note: The reporter may use a format of their choosing for the following narrative information, with the provision that all the minimum information requirements listed below, as it pertains to the exposure pathways investigated, are provided under the following headings and in the order outlined. Place the narrative behind a copy of this investigation form in the Tier 1 report.

I. Brief history of any abatement/remedial actions taken prior to initiating the Tier 2 investigation

II. Summary of site characteristics
  A. Site Location
  B. General site topography, geology, and hydrogeology

III. Summary of drilling activities
  A. Date/method/equipment
  B. Drilling order of boreholes
  C. Drilling complications (e.g., auger failure or refusal, site recently modified), if any
  D. Description of materials drilled through and evidence of contamination
  E. Monitoring well installation
    - depth of wells
    - screened interval
    - filter pack and grout materials
    - type of well head protection
    - well development methodology, duration, estimated water removed
    - other information
  F. Monitoring well location information
    - nature & location of permanent benchmark to which wells are referenced (designate on site map)
    - method (e.g., stadia, measuring wheel, tape) and measurements (in tabular format) used to reference wells to benchmark
  G. Other information related to drilling activities (e.g., start/stop times for drilling & well installation)

IV. Direct push technologies
  A. Date/method/equipment
  B. Order of probe locations
  C. Description of materials drilled through and evidence of contamination
  D. Other information related to direct push activities (e.g., start/stop times, media investigated)

V. Summary of sampling activities
  A. Soil sampling
    - method of sample collection
    - method/protocol used for head space analysis
    - method/protocol used for laboratory sample preparation
  B. Ground water sampling
    - purging method/protocol/criteria (includes rationale for not purging, if applicable)
    - sample collection method/protocol
    - order of well sampling (Note: sample least contaminated to most contaminated)
  C. Drinking water supply well/system sampling
    - location of sampling point (e.g., directly from well, outdoor tap, indoor tap)
    - purging method/protocol/criteria
    - sample collection method/protocol
  D. Soil vapor sampling
    - sample point installation (e.g., probe rod, vapor monitoring well)
    - purging method/protocol/criteria
    - sample collection method/protocol
  E. QA/QC considerations
    - steps taken to limit cross-contamination between sampling locations
    - number/type/location of duplicates/blanks
    - decontamination protocol and other measures taken to minimize cross-contamination

VI. Other information
  A. Rationale for variances from approved work plan or RBCA guidance document
  B. Contact information (i.e., names, phone numbers, affiliations) for people providing information gathered during investigation

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 3**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

SITE STRATIGRAPHY AND HYDROGEOLOGY (Based on Tier 2 investigation)

STRATIGRAPHY OF THE SITE

Depth [feet]	Unified Soil Classification	Type of Soil

Predominant soil type:

Depth [feet]	Type of Bedrock & Geological Formation (where applicable) (discuss rock properties and features, e.g. fractures)

HYDROGEOLOGY OF THE IMPACTED SATURATED ZONE

Type of aquifer? (Justify under "Additional Notes") ☐ Confined ☐ Unconfined ☐ Perched

Range of ground water fluctuation, (if known): ft Source:

Average depth to water table/static water level: ft

Flow direction:

Hydraulic gradient (i): ft/ft MWs used:

Hydraulic conductivity (K): ft/day for:

Porosity (n):

Seepage velocity (K x i/n) [calculated]: ft/day cm/year

ADDITIONAL NOTES

Recommended attachments: Relevant cross-sections, soil boring logs, and laboratory/field sheets providing vadose zone characteristics.

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 4**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

SITE-SPECIFIC VADOSE ZONE PARAMETERS (Based on Tier 2 investigation)

DRY BULK DENSITY

Unit Interval [ft bgl]	Sediment Type	Value [g/cm^3]	ASTM Test Method

POROSITY

NOTE: Values for porosity may be estimated using Table 6-2 of the NDEE RBCA Guidance Document.

Unit Interval [ft bgl]	Sediment Type	Value [cm^3/cm^3]

VOLUMETRIC WATER CONTENT

Unit Interval [ft bgl]	Sediment Type	Value [cm^3/cm^3]	ASTM Test Method

FRACTIONAL ORGANIC CARBON CONTENT

Unit Interval (ft bgl)	Sediment Type	Value [g-C/g-soil]	ASTM Test Method

ADDITIONAL NOTES

Recommended attachments: Relevant cross-sections, soil boring logs, and laboratory/field sheets providing vadose zone characteristics.

NDEE RBCA TIER 2 REPORT **Tier 2 Investigation Form - 5**

FACILITY NAME:	**NDEE SPILL NO.:**	**NDEE IIS NO.:**
CONSULTANT:	**COMPLETION DATE:**	**PREPARED BY:**

ANALYTICAL DATA SUMMARY FOR SUBSURFACE SOIL (Based on Tier 2 investigation; soil sample depth greater than 3 feet bgl. All concentrations in mg/kg)

☐ **NOT APPLICABLE FOR THIS SITE**

MW / SB No.													**Arithmetic Average**	**Maximum**	**Ratio (Max. / Avg.) ***
Sampling Date															
Sample Depth (ft)															
VOLATILE ORGANIC CHEMICALS ANALYSES															
Benzene															
Toluene															
Ethylbenzene															
Xylenes (mixed)															
n-Hexane															
Methyl-tert-butyl-ether (MTBE)															
Naphthalene															
TOTAL EXTRACTABLE HYDROCARBONS ANALYSES															
TEH (as diesel)															
TEH (as waste oil)															
TEH (as kerosene)															
TEH as															
TEH as															
TEH as															
OTHER ANALYTES															

NOTE:

Provide any laboratory analytical datasheets not previously submitted to the Department. Add additional sheets as needed.

Non-detects can be expressed as ND, BDL, etc.

*** : If the ratio is high (for example >10) there may be a "hot spot" and additional investigation/evaluation may be warranted. In such circumstances, contact the Department.**

Recommended Attachments: Site map showing location(s) of subsurface soil sample(s), chemical concentration maps, laboratory analysis report(s), chain of custody, and boring logs.

NDEE RBCA TIER 2 REPORT **Tier 2 Investigation Form - 6a**

FACILITY NAME:
NDEE SPILL NO.:
NDEE IIS NO.:
CONSULTANT:
COMPLETION DATE:
PREPARED BY:

ANALYTICAL DATA SUMMARY FOR GROUND WATER (Based on Tier 2 investigation; All concentrations in mg/L)

☐ **NOT APPLICABLE FOR THIS SITE**

Monitoring Well Number								**Arithmetic Average**	**Maximum**	**Ratio (Max. / Avg.) ***
Installation Date										
Screen Interval (feet below datum)										
Water Level (feet below datum)										
Last Sampling Event										
VOLATILE ORGANIC CHEMICALS ANALYSES										
Benzene										
Toluene										
Ethylbenzene										
Xylenes										
n-Hexane										
Methyl-tert-butyl-ether (MTBE)										
Naphthalene										
TOTAL EXTRACTABLE HYDROCARBONS ANALYSES										
TEH (as diesel)										
TEH (as waste oil)										
TEH (as kerosene)										
TEH as										
TEH as										
TEH as										
OTHER ANALYTES										

NOTE: Provide any laboratory analytical datasheets not previously submitted to the Department. Add additional sheets as needed.

*** : If the ratio is high (for example >10) there may be a "hot spot" and additional investigation/evaluation may be warranted. In such circumstances, contact the Department.**

Recommended Attachment: Site map showing location(s) of monitoring well(s), chemical concentration maps, laboratory analysis report(s), chain of custody, and boring logs.

NDEE RBCA TIER 2 REPORT		**Tier 2 Investigation Form - 6b**
FACILITY NAME:	**NDEE SPILL NO.:**	**NDEE IIS NO.:**
CONSULTANT:	**COMPLETION DATE:**	**PREPARED BY:**

ANALYTICAL DATA SUMMARY FOR WATER QA/QC SAMPLES (Based on Tier 2 investigation; All concentrations in mg/L)

☐ NOT APPLICABLE FOR THIS SITE

Type of QA/QC Water Sample	Blind Duplicates			Field Blanks			Trip Blanks		
Sample Designation									
Sample Date									
Field Blank Exposure Time (min)									
VOLATILE ORGANIC CHEMICALS ANALYSES									
Benzene									
Toluene									
Ethylbenzene									
Xylenes									
n-Hexane									
Methyl-tert-butyl-ether (MTBE)									
Naphthalene									
TOTAL EXTRACTABLE HYDROCARBONS ANALYSES									
TEH (as diesel)									
TEH (as waste oil)									
TEH (as kerosene)									
TEH as									
TEH as									
TEH as									
OTHER ANALYTES									

TEMPERATURE BLANKS	Cooler ID	Pre-Delivery Temp. (°C)	Laboratory Temp. (°C)	Cooler ID	Pre-Delivery Temp. (°C)	Laboratory Temp. (°C)	Cooler ID	Pre-Delivery Temp. (°C)	Laboratory Temp. (°C)

NOTE: Provide any laboratory analytical datasheets not previously submitted to the Department. Add additional sheets as needed.

Recommended Attachment: Laboratory analysis report(s) and chain of custody.

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 7**

FACILITY NAME:	**NDEE SPILL NO.:**	**NDEE IIS NO.:**
CONSULTANT:	**COMPLETION DATE:**	**PREPARED BY:**

ANALYTICAL DATA SUMMARY FOR SOIL GAS SAMPLES (Based on Tier 2 investigation; All concentrations in mg/m^3)

☐ **NOT APPLICABLE FOR THIS SITE**

Sample No.										**Arithmetic Average**	**Maximum**	**Ratio (Max. / Avg.) ***
Sampling Date												
Sample Depth (ft)												
VOLATILE ORGANIC CHEMICALS ANALYSES												
Benzene												
Toluene												
Ethylbenzene												
Xylenes												
n-Hexane												
Methyl-tert-butyl-ether (MTBE)												
Naphthalene												
TOTAL EXTRACTABLE HYDROCARBONS ANALYSES												
TEH (as diesel)												
TEH (as waste oil)												
TEH (as kerosene)												
TEH as												
TEH as												
TEH as												
OTHER ANALYTES												

NOTE:

Provide any laboratory analytical datasheets not previously submitted to the Department.
Non-detects can be expressed as ND, BDL, etc.

*** : If the ratio is high (for example >10) there may be a "hot spot" and additional investigation/evaluation may be warranted. In such circumstances, contact the Department.**

Recommended Attachments: Site map showing location(s) of soil gas sample(s), chemical concentration maps, laboratory analysis report(s), chain of custody, and boring logs.

NDEE RBCA TIER 2 REPORT	**Tier 2 Investigation Form - 8**
FACILITY NAME:	**CONSULTANT:**
NDEE SPILL NO.:	**NDEE IIS NO.:**
COMPLETION DATE:	**PREPARED BY:**

REFERENCES AND PROTOCOLS

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Appendix D:

Target Level Default Data

Table D-1. Physical / Chemical Properties of Chemicals of Concern

CHEMICALS OF CONCERN	Molecular Weight[1] (g/g-mol)	Water Solubility[2] S (mg/L)	Henry's Law Constant[2] H (L-water/L-air)	Carbon-Water Partitioning Coeff.[2] Koc (mL-water /g-org.C)	Soil-Water Partition Coefficient[3] Kd [(mg/g-soil)/(mg/mL-water)]	Diffusion Coefficient[2]		Half-Life[2] (days)	Decay Rate[4] (days-1)
						Air (cm^2/s)	Water (cm^2/s)		
Benzene	78.1	1.75E+03	2.20E-01	3.80E+01	$K_{oc} * f_{oc}$	9.30E-02	1.10E-05	7300	9.49E-05
Toluene	92.1	5.35E+02	2.60E-01	1.35E+02	$K_{oc} * f_{oc}$	8.50E-02	9.40E-06	630	1.10E-03
Ethylbenzene	106	1.52E+02	3.20E-01	9.55E+01	$K_{oc} * f_{oc}$	7.60E-02	8.50E-06	2280	3.04E-04
Xylenes (mixed)	106	1.98E+02	2.90E-01	2.40E+02	$K_{oc} * f_{oc}$	7.20E-02	8.50E-06	3650	1.90E-04
n-Hexane	86.2	1.30E+01	3.14E+01	4.79E+02	$K_{oc} * f_{oc}$	2.00E-01	7.77E-06	3650	1.90E-04
Methyl-tert-butyl-ether (MTBE)	88.1	4.80E+04	2.20E-02	1.23E+01	$K_{oc} * f_{oc}$	8.06E-02	6.10E-06	10000	6.93E-05
Naphthalene	128	3.10E+01	4.90E-02	1.30E+03	$K_{oc} * f_{oc}$	7.20E-02	9.40E-06	2580	2.69E-04
Benzo(a)pyrene	252	3.80E-03	5.80E-08	3.89E+05	$K_{oc} * f_{oc}$	5.00E-02	5.80E-06	10600	6.54E-05
Pyrene	202	1.32E-01	5.10E-06	3.80E+04	$K_{oc} * f_{oc}$	5.70E-02	4.56E-06	3650	1.90E-04
TEH (as Diesel)	N/A	1.00E+06	N/A	N/A	$K_{oc} * f_{oc}$	N/A	N/A	N/A	N/A
TEH (as Waste Oil)	N/A	1.00E+06	N/A	N/A	$K_{oc} * f_{oc}$	N/A	N/A	N/A	N/A

Notes:

1) Source: MERCK Index
2) Source: Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, ASTM 1739-95
3) Calculated value for the Soil-Water Partitioning Coefficient where $K_d = K_{oc} * f_{oc}$ (fractional organic carbon content)
4) Calculated value for Decay Rate where λ = inverse of Half-Life

N/A = Not Applicable

Table D-2. Toxicity Parameters of Chemicals of Concern

CHEMICALS OF CONCERN	Slope Factor		Reference Dose		Oral RA Factor (RAFo)	Dermal RA Factor (RAFd)
	Oral (SFo) [kg-day/mg]	Inh. (SFi) [kg-day/mg]	Oral (RfDo) (mg/kg-day)	Inh. (RfDi) (mg/kg-day)		
Benzene	0.055[a]	0.0273[a]	0.003[b]	0.0017[b]	1	0.5
Toluene	N/A	N/A	0.2	0.114	1	0.5
Ethylbenzene	N/A	N/A	0.1	0.29	1	0.5
Xylenes (mixed)	N/A	N/A	2	0.2	1	0.5
n-Hexane	N/A	N/A	0.06	0.057	1	0.5
Methyl-tert-butyl-ether (MTBE)	0.0018	0.0018	N/A	0.86	1	0.5
Naphthalene	N/A	N/A	0.02	0.00086	1	0.05
Benzo(a)pyrene	7.3	3.1	N/A	N/A	1	0.05
Pyrene	N/A	N/A	0.03	0.03	1	0.05
TEH (as Diesel)	N/A	N/A	N/A	N/A	N/A	N/A
TEH (as Waste Oil)	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

a) Value provided is the most conservative of the range provided in the USEPA IRIS Database.

b) Reference doses for benzene applicable for addressing additivity concerns for BTEX compounds.

N/A = Not Applicable

Table D-3 Applicable Exposure Factors

Parameter	Symbol	Unit	Value
Averaging time for carcinogen	ATc	year	70
Averaging time for non-carcinogen	ATnc	year	=ED
Body weight:			
Resident child	BW	kg	15
Resident adult	BW	kg	70
Commercial worker	BW	kg	70
Exposure duration:			
Resident child	ED	year	6
Resident adult	ED	year	30
Commercial worker	ED	year	25
Exposure frequency:			
Resident child	EF	day/year	350
Resident adult	EF	day/year	350
Commercial worker	EF	day/year	250
Soil ingestion rate:			
Resident child	IRs	mg/day	200
Resident adult	IRs	mg/day	50
Commercial worker	IRs	mg/day	50
Groundwater ingestion rate:			
Resident child	IRw	L/day	1
Resident adult	IRw	L/day	2
Commercial worker	IRw	L/day	1
Hourly indoor inhalation rate:			
Resident child	IRai	m3/hr	0.417
Resident adult	IRai	m3/hr	0.84
Commercial worker	IRai	m3/hr	1.5
Exposure time for hourly indoor inhalation:			
Resident child	ETin	hr/day	24
Resident adult	ETin	hr/day	24
Commercial worker	ETin	hr/day	10

Parameter	Symbol	Unit	Value
Indoor Inhalation Rate:			
Resident Child	IRa	m3/day	15
Resident Adult	IRa	m3/day	20
Commercial Worker	IRa	m3/day	20
Hourly outdoor inhalation rate:			
Resident child	IRao	m3/hr	1
Resident adult	IRao	m3/hr	0.84
Commercial worker	IRao	m3/hr	1.5
Exposure time for hourly outdoor inhalation:			
Resident child	ETout	hr/day	10
Resident adult	ETout	hr/day	10
Commercial worker	ETout	hr/day	10
Outdoor Inhalation Rate:			
Resident Child	IRa	m3/day	20
Resident Adult	IRa	m3/day	20
Commercial Worker	IRa	m3/day	20
Skin surface area:			
Resident child	SA	cm2/day	2500
Resident adult	SA	cm2/day	3160
Commercial worker	SA	cm2/day	5000
Soil to skin adherence factor:			
Resident child	M	mg/cm2	0.5
Resident adult	M	mg/cm2	0.5
Commercial worker	M	mg/cm3	0.5
Target risk limit	TR	--	variable[1]
Target Hazard Quotient	THQ	--	variable[1]

Notes:

1) Depends on site characteristics. See Section 7.3.

Table D-4 Fate and Transport Parameters

Parameter	Symbol	Unit	Tier 1 Default Values Hydrogeology 1 (Silt/Clay)	Tier 1 Default Values Hydrogeology 2 (Sand/Gravel)	Tier 2 Value
Soil parameters:					
Length of soil source area parallel to wind direction	W_a	cm	914.4	914.4	914
Vertical separation between building foundation and the average soil contamination depth	L_s	cm	3	3	Site-Specific
Lower depth of surficial soil zone	d	cm	91.44	91.44	91.44
Thickness of capillary fringe	h_{cap}	cm	3	3	Site-Specific
Thickness of vadose zone	h_v	cm	102	102	Site-Specific
Dry soil bulk density in the vadose zone	ξ_s	g/cm^3	1.7	1.7	Site-Specific
Fractional organic carbon content (vadose zone)	f_{oc}	g-C/g-soil	0.01	0.005	Site-Specific
Total soil porosity in the vadose zone	ξ_T	cm^3/cm^3-soil	0.35	0.3	Site-Specific
Volumetric water content in capillary fringe	ξ_{wcap}	cm^3/cm^3	0.32	0.27	Site-Specific
Volumetric water content in vadose zone	ξ_{ws}	cm^3/cm^3	0.1	0.1	Site-Specific
Volumetric air content in capillary fringe	ξ_{acap}	cm^3/cm^3	0.03	0.03	Site-Specific
Volumetric air content in vadose zone	ξ_{as}	cm^3/cm^3	0.25	0.2	Site-Specific
Soil-vapor parameters					
Vertical separation between the building foundation and the soil-vapor sampling point	$L_{s\text{-}v}$	cm	91.44	91.44	Site-Specific
Groundwater parameters:					
Depth to groundwater	L_{gw}	cm	105	105	Site-Specific
Width of groundwater source perpendicular to GW flow direction	W_y	cm	914.4	914.4	914.4
Length of groundwater source parallel to GW flow direction	W_x	cm	914.4	914.4	914.4
Dry soil bulk density in the saturated zone	ξ_{ss}	g/cm^3	1.7	1.7	Site-Specific
Fractional organic carbon content (saturated zone)	f_{ocs}	g-C/g-soil	0.01	0.005	Site-Specific
Total soil porosity in the saturated zone	ξ_{TS}	cm^3/cm^3-soil	0.35	0.3	Site-Specific
Hydraulic conductivity in the saturated zone	K	cm/year	22250	2225000	Site-Specific
Hydraulic gradient	i	--	0.005	0.005	Site-Specific
Groundwater Darcy velocity	U_{gw}	cm/year	111	11125	Site-Specific
Groundwater mixing zone thickness	ξ_{gw}	cm	152.4	152.4	152.4
Infiltration rate	ξ	cm/year	3.8	7.6	Site-Specific
Ambient air parameters:					
Breathing zone height	ξ_a	cm	200	200	200
Wind speed within the breathing zone	Ua	cm/s	225	225	225
Enclosed space parameters:					
Enclosed space air exchange rate:					
Residential	N	day^{-1}	12	12	12
Commercial	N	day^{-1}	20	20	20
Height of enclosed space:					
Residential and commercial	h	cm	240	240	240
Fraction of cracks in foundation/walls through which diffusion occurs:					
Residential and commercial	f	cm^2/cm^2	0.001	0.001	0.001
Particulate emission rate:					
Residential and commercial	P_e	g/cm^2sec	6.90E-14	6.90E-14	6.90E-14
Averaging time for vapor flux:					
Resident child	ξ	sec	1.89E+08	1.89E+08	1.89E+08
Resident adult	ξ	sec	9.46E+08	9.46E+08	9.46E+08
Commercial worker	ξ	sec	7.88E+08	7.88E+08	7.88E+08

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Appendix E:

Fate & Transport Equations

Table E-1. Allowable Groundwater Concentrations for a POE

For a RAC-1 release, the allowable groundwater concentration at a drinking water point of exposure (C_{poe}) is equal to the COC-specific MCL or some other standard selected by the Department for a COC not having an MCL. For non-drinking water wells, the allowable concentration is equal to 10 times the MCL or other selected standard.

For a RAC-2 release, C_{poe} is equal to a calculated risk-based target level for water ingestion based on the following:

Carcinogenic effects

$$RBTL_{gw} = \frac{TR \times BW \times AT_c \times 365}{IR_w \times ED \times EF \times SF_o}$$

Non-carcinogenic effects

$$RBTL_{gw} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_o}{IR_w \times ED \times EF}$$

where:

$RBTL_{gw}$ = Risk-based target level for groundwater ingestion [mg/L]
TR = Target risk or the increased chance of developing cancer over a lifetime due to exposure to a COC [-]
THQ = Target Hazard Quotient for individual non-carcinogenic constituents [-]
BW = Body weight [kg]
AT_c = Averaging time for a carcinogen [years]
AT_{nc} = Averaging time for a non-carcinogen [years]
IR_w = Water ingestion rate [L/day]
ED = Exposure duration [years]
EF = Exposure frequency [days/year]
SF_o = Chemical-specific oral cancer slope or potency factor $[mg/(kg\text{-}day)]^{-1}$
RfD_o = Chemical-specific oral reference dose [mg/(kg-day)]

Table E-2. Groundwater Concentration at a Source and a POC Protective of Drinking Water

Concentration in groundwater at the source: $C_{gw,source} = C_{poe} \times CRF_{sat,poe}$

Concentration in groundwater at a point of compliance: $C_{gw,poc} = C_{poe} \times \frac{CRF_{sat,poe}}{CRF_{sat,poc}}$

where:

$C_{gw,source}$ = RBSL calculated in the source area [mg/L]

$CRF_{sat,poe}$ = Concentration reduction factor in the saturated zone between a source area and a point of exposure [(mg/L)/(mg/L)]

$CRF_{sat,poc}$ = Concentration reduction factor in the saturated zone between a source area and a point of compliance [(mg/L)/(mg/L)]

C_{poe} = Allowable contaminant concentration at the point of exposure [mg/L]

The CRF_{sat} is estimated using a simplified version of **Domenico's model*** that assumes (i) an infinite source; (ii) uniform, one-dimensional flow; (iii) first-order biodecay; and (iv) the receptor location directly downgradient from the source. The specific form of Domenico's model used is:

$$\frac{C(x)}{C_o} = \exp\left\langle \frac{x}{2\alpha_x} \times \left(1 - \sqrt{1 + \frac{4\lambda\alpha_x}{v}}\right)\right\rangle \times erf\left(\frac{W_y}{4\sqrt{\alpha_y x}}\right) \times erf\left(\frac{\delta_{gw}}{2\sqrt{\alpha_z x}}\right)$$

where:

C = Dissolved-phase concentration [mg/L]

C_o = Dissolved-phase concentration at the source (x=y=z=0) [mg/L]

v = Retarded seepage velocity for a chemical [cm/day]

= Darcy Velocity / (Retardation Factor x Total Porosity)

λ = Overall first-order decay rate [day^{-1}]

α_x = Longitudinal dispersivity = x/10 [cm]

α_y = Lateral dispersivity = x/30 [cm]

α_z = Vertical dispersivity = x/100 [cm]

x, y, z = Spatial coordinates [cm]

x = Distance along the center line from the downgradient edge of the dissolved-plume source zone or source well [cm]

W_y = Width of source area perpendicular to groundwater flow [cm]

δ_{gw} = Groundwater mixing zone thickness [cm]

Retarded seepage velocity: $v = \dfrac{K \times i}{R \times \Theta_{TS}}$

where:

K = Hydraulic conductivity [cm/year]
i = Hydraulic gradient [--]
R = Retardation factor [--]
Θ_{TS} = Total porosity in the unsaturated zone [cm^3-voids/cm^3-soil]

Retardation factor: $R = 1 + \dfrac{\rho_{ss} \times K_{ds}}{\Theta_{TS}}$

where:

ρ_{ss} = Dry bulk density of soil in the saturated zone [g/cm^3]
K_{ds} = Soil-water partition coefficient in the saturated zone [cm^3-water/g-soil] = f_{ocs} x K_{oc}
    F_{ocs} = Fractional organic carbon content in the saturated zone soil [g-C/g-soil]
    K_{oc} = Carbon-water partition coefficient [cm^3-water/g-c]
Θ_{TS} = Total porosity in the saturated zone [cm^3-voids/cm^3-soil]

If a particular chemical is assumed not to biodecay (i.e., λ=0), $\dfrac{C(x)}{C_o}$ is equal to the result of the error function.

Please note that the CRF_{sat} is actually equal to $\dfrac{C_o}{C(x)}$.

**Source: Domenico, P.A. and Schwartz, F.W., Physical and Chemical Hydrogeology, John Wiley and Sons, New York, 1990 (Equation 17.21)*

Table E-3. Soil Concentration Protective of Drinking Water

Allowable soil concentration: $C_{soil} = C_{poe} \times CRF_{sat,poe} \times CRF_{mix} \times CRF_{unsat} \times ECF$

where:

C_{soil} = Allowable source soil concentration [mg/kg]
C_{poe} = Allowable groundwater concentration at the point of exposure [mg/L]
$CRF_{sat,poe}$ = Concentration reduction factor in the saturated zone [(mg/L)/(mg/L)]
CRF_{mix} = Concentration reduction factor in the mixing zone [(mg/L)/(mg/L)]
CRF_{unsat} = Concentration reduction factor in the unsaturated zone [(mg/L)/(mg/L)]
ECF = Equilibrium conversion factor [(mg/kg-soil)/(mg/L-water)]

Concentration reduction in the mixing zone: $CRF_{mix} = 1 + \frac{U_{gw} \times \delta_{gw}}{IW_x}$

where:

U_{gw} = Groundwater Darcy Velocity [cm/year]
= Hydraulic conductivity [cm/year] x Hydraulic gradient [--]
δ_{gw} = Groundwater mixing zone thickness [cm]
I = Infiltration rate of water through soil [cm/year]
W_x = Length of source area parallel to groundwater flow [cm]

Concentration reduction in the unsaturated zone is empirically estimated in Tier 1:

CRF_{unsat} = 1 for depth to groundwater ≤ 50 feet
CRF_{unsat} = 2 for depth to groundwater > 50 feet

Equilibrium conversion factor: $ECF = \frac{\rho_s \times K_d + \Theta_{ws} + \Theta_{as} \times H}{\rho_s}$

where:

ρs = Dry bulk density of soil [g/cm^3]
K_d = Soil-water partition coefficient [cm^3-water/g-soil] = f_{ocs} x K_{oc}
  F_{ocs} = Fractional organic carbon content [g-C/g-soil]
  K_{oc} = Carbon-water partition coefficient [cm^3-water/g-c]
Θ_{ws} = Volumetric water content in the vadose zone [cm^3/cm^3]
Θ_{as} = Volumetric air content in the soil [cm^3/cm^3]
H = Henry's Law coefficient [(mg/L-water)/(mg/L-air)]

Table E-4. Allowable Enclosed Space Breathing Zone COC Concentrations for Indoor Inhalation

To calculate allowable subsurface soil and groundwater RBSLs protective of the enclosed space inhalation pathways of concern, target levels for contaminant concentrations within the enclosed space breathing zone must first be determined. These target levels are calculated based on the following:

Carcinogenic effects

$$RBTL_{ai} = \frac{TR \times BW \times AT_c \times 365}{IR_i \times ET_i \times ED \times EF \times SF_i}$$

Non-carcinogenic effects

$$RBTL_{ai} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_i}{IR_i \times ET_i \times ED \times EF}$$

where:

$RBTL_{ai}$ = Risk-based target level for indoor air [mg/m^3]

TR = Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical of concern [--]

THQ = Target Hazard Quotient for individual non-carcinogenic constituents [-]

BW = Body weight [kg]

AT_c = Averaging time for a carcinogen [years]

AT_{nc} = Averaging time for a non-carcinogen [years]

IR_i = Indoor inhalation rate [m^3/hour]

ET_i = Exposure time for indoor inhalation [hours/day]

ED = Exposure duration [years]

EF = Exposure frequency [days/year]

SF_i = Chemical-specific inhalation cancer slope or potency factor [$mg/(kg\text{-}day)]^{-1}$

RfD_i = Chemical-specific inhalation reference dose [mg/(kg-day)]

Table E-5. Soil Gas Concentrations Protective of Indoor Inhalation

Once $RBTL_{ai}$ has been determined (see Table E-4), this value is used to calculate an allowable soil vapor gas concentration outside the enclosed indoor space in source-zone soils, at a non-source-zone soil-vapor sampling point, and at the groundwater table, using the following relationships:

Soil source:

$$C_{v,s} = RBTL_{ai} \times 10^{-3} \times \left(\frac{h \times N \times L_s}{f \times 86400 \times D_s^{eff}} + 1 \right)$$

Vapor sampling point:

$$C_{v,v} = RBTL_{ai} \times 10^{-3} \times \left(\frac{h \times N \times L_{s,v}}{f \times 86400 \times D_s^{eff}} + 1 \right)$$

At the groundwater table:

$$C_{v,gw} = RBTL_{ai} \times 10^{-3} \times \left(\frac{h \times N \times L_{gw}}{f \times 86400 \times D_w^{eff}} + 1 \right)$$

where:

$C_{v,s}$ = Vapor concentration in subsurface source soil [mg/L]
$C_{v,v}$ = Vapor concentration in subsurface soil where the soil vapor sample is collected [mg/L]
H = Height of the indoor space [cm]
N = Volume of air changes per day [day^{-1}]
L_s = Depth to chemical in soil [cm]
$L_{s,v}$ = Depth to soil-vapor sampling point [cm]
L_{gw} = Depth to the groundwater table [cm]
f = Fraction of the floor area through which diffusion occurs [--]
D_s^{eff} = Chemical-specific effective diffusion coefficient in vadose zone soils [cm^2/s]
D_w^{eff} = Chemical-specific effective diffusion coefficient between the groundwater table and a structure [cm^2/s]
$RBTL_{ai}$ = Risk-based target level for indoor air [mg/m^3]
86400 = Conversion factor from days to seconds
10^{-3} = Conversion factor from mg/m^3 to mg/L

Table E-6. Calculation of Effective Diffusivities

Chemical-specific effective diffusion coefficients in vadose zone soils, at the groundwater table, and in capillary zone soils are calculated using the following relationships:

Vadose soils:

$$D_s^{eff} = D_a \times \frac{\Theta_{as}^{3.33}}{\Theta_T^2} + D_w \times \frac{1}{H} \times \frac{\Theta_{ws}^{3.33}}{\Theta_T^2}$$

At the groundwater table:

$$D = \frac{L_{gw}}{\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}}$$

Capillary zone soils:

$$D_{cap}^{eff} = D_a \times \frac{\Theta_{acap}^{3.33}}{\Theta_T^2} + D_w \times \frac{1}{H} \times \frac{\Theta_{wcap}^{3.33}}{\Theta_T^2}$$

where:

D_a = Chemical-specific diffusion coefficient in air [cm^2/s]
D_w = Chemical-specific diffusion coefficient in water [cm^2/s]
D_s^{eff} = Effective diffusivity in vadose zone soils [cm^2/s]
D_w^{eff} = Effective diffusivity above the groundwater table [cm^2/s]
D_{cap}^{eff} = Effective diffusivity in capillary zone soils [cm^2/s]
Θ_T = Total soil porosity in the impacted zone [cm^3/cm^3-soil]
Θ_{as} = Volumetric air content in the vadose zone [cm^3-air/cm^3-soil]
Θ_{ws} = Volumetric water content in the vadose zone [cm^3-water/cm^3-soil]
Θ_{acap} = Volumetric air content in the capillary zone [cm^3-air/cm^3-soil]
Θ_{wcap} = Volumetric water content in the capillary zone [cm^3-water/cm^3-soil]
H = Henry's Law coefficient [(mg/L-water)/(mg/L-air)]
L_{gw} = Depth to the groundwater table [cm]
h_{cap} = Capillary zone thickness [cm]
h_v = Vadose zone thickness [cm]
= $L_{gw} - h_{cap}$

Table E-7. Groundwater & Subsurface Soil Contaminant Concentrations Protective of Indoor Inhalation

For groundwater: $$RBSL_{winh} = \frac{C_{v,gw}}{H}$$

where:

$RBSL_{winh}$ = Allowable concentration in groundwater protective of indoor inhalation [mg/L]

$C_{v,gw}$ = Vapor concentration above the groundwater table [mg/L]

H = Henry's Law coefficient [(mg/L-water)/(mg/L-air)]

For subsurface soils: $$RBSL_{\mathrm{sinh}} = \frac{C_{v,s}}{H} \times ECF$$

where:

$RBSL_{sinh}$ = Allowable concentration in groundwater protective of indoor inhalation [mg/L]

$C_{v,s}$ = Vapor concentration above the groundwater table [mg/L]

H = Henry's Law coefficient [(mg/L-water)/(mg/L-air)]

ECF = Equilibrium conversion factor [(mg/kg-soil)/(mg/L-water)], as presented in Table E-3

Table E-8. Surface Soil Contaminant Concentrations Protective of Outdoor Inhalation, Dermal Contact, and Ingestion of Vapors and Particulates

RBSLs for contaminated surface soils are determined using the following models:

Carcinogenic effects:

$$RBTL_{ss} = \frac{TR \times BW \times AT_c \times 365}{EF \times ED \times \left[\left(SF_o \times 10^{-6} \times \left(IR_s \times RAF_o + SA \times M \times RAF_d\right)\right) + \left(SF_i \times IR_o \times ET_o \times \left(VF_{ss} + VF_p\right)\right)\right]}$$

Non-carcinogenic effects:

$$RBTL_{ss} = \frac{THQ \times BW \times AT_{nc} \times 365}{EF \times ED \times \left[\frac{10^{-6} \times \left(IR_s \times RAF_o + SA \times M \times RAF_d\right)}{RfD_o} + \frac{IR_o \times ET_o \times \left(VF_{ss} \times VF_p\right)}{RfD_i}\right]}$$

where:

TR = Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical of concern [--]

THQ = Target Hazard Quotient for individual non-carcinogenic constituents [--]

BW = Body weight [kg]

AT_c = Averaging time for a carcinogen [years]

AT_{nc} = Averaging time for a non-carcinogen [years]

ED = Exposure duration [years]

EF = Exposure frequency [days/year]

IR_s = Soil ingestion rate [mg/day]

RAF_o = Oral relative absorption factor [--]

RAF_d = Dermal relative absorption factor [--]

SA = Skin surface area [cm^2/day]

M = Soil-to-skin adherence factor [mg/cm^2]

IR_o = Outdoor inhalation rate [m^3/hour]

ET_o = Exposure time for outdoor inhalation [hours/day]

SF_o = Chemical-specific oral cancer slope or potency factor [mg/(kg-day)]$^{-1}$

SF_i = Chemical-specific inhalation cancer slope or potency factor [mg/(kg-day)]$^{-1}$

RfD_o = Chemical-specific oral reference dose [mg/(kg-day)]

RfD_i = Chemical-specific inhalation reference dose [mg/(kg-day)]

VF_p = Volatilization factor of particulates [(mg/m^3-air)/(mg/kg-soil)]

VF_{ss} = Volatilization factor of particulates [(mg/m^3-air)/(mg/kg-soil)]

10^{-6} = Conversion factor from milligrams to kilograms

Table E-9. Calculation of Volatilization Factors from Surface Soil

To calculate **VF_{ss}**, the volatilization factor from surface soils, use:

$$VF_{ss} = \frac{2 \times W_a \times \rho_s}{U_a \times \delta_a} \times \sqrt{10^3 \times \frac{D_s^{eff} \times H}{\pi \times \tau \times \left[\Theta_{ws} + \left(K_d \times \rho_s\right) + \left(H \times \Theta_{as}\right)\right]}}$$

OR

$$VF_{ss} = \frac{W_a \times \rho_s \times d}{U_a \times \delta_a \times \tau} \times 10^3$$

NOTE: Use the smaller of the two results.

where:

W_a = Width of source area parallel to wind flow direction [cm]
ρs = Dry bulk density of soil [g/cm^3]
U_a = Wind speed within breathing zone [cm/s]
δ_a = Breathing zone height [cm]
D_s^{eff} = Effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s]
H = Henry's Law coefficient [(mg/L-water)/(mg/L-air)]
Θ_{as} = Volumetric air content in the soil [cm^3/cm^3]
Θ_{ws} = Volumetric water content in the vadose zone [cm^3/cm^3]
K_d = Soil-water partition coefficient [cm^3-water/g-soil] = f_{ocs} x K_{oc}
    F_{ocs} = Fractional organic carbon content [g-C/g-soil]
    K_{oc} = Carbon-water partition coefficient [cm^3-water/g-c]
τ = Averaging time for vapor flux [s] = ED(years) x 365(days/year) x 86400(sec/day)
d = Depth to base of surficial soil zone [cm]
10^3 = Conversion factor from [m^3-g] to [cm^3-kg]

To calculate VF_p, the volatilization factor of particulates, use:

$$VF_p = \frac{P_e \times W_a}{U_a \times \delta_a} \times 10^3$$

where:

P_e = Particulate emission rate [g-soil/cm^2-sec]
W_a = Width of source area parallel to wind flow direction [cm]
U_a = Wind speed within breathing zone [cm/s]
δ_a = Breathing zone height [cm]
10^3 = Conversion factor from [m^3-g] to [cm^3-kg]

Table E-10. Soil Saturation Level

In some instances, the calculated RBSL for an exposure pathway of concern involving surface or subsurface soils may be greater than the maximum contaminant concentration that could be expected for the specified exposure scenario, even if free phase product is present in the soil. The soil concentration at which equilibrated vapor and dissolved pore-water phases become saturated, C_s^{sat}, is described by the following:

$$C_s^{sat} = \frac{S}{\rho_s} \times \left[H \times \Theta_{as} + \Theta_{ws} + K_d \times \rho_s \right]$$

where:

S = Pure component solubility in water {mg/L-water]

ρ_s = Dry soil bulk density [g-soil/cm^3-soil]

H = Henry's Law coefficient [(mg/L-water)/(mg/L-air)]

Θ_{as} = Volumetric air content in the vadose zone [cm^3-air/cm^3-soil]

Θ_{ws} = Volumetric water content in the vadose zone [cm3-water/cm3-soil]

K_d = Soil-water partition coefficient [cm^3-water/g-soil] = f_{oc} x K_{oc}

  f_{oc} =Fractional organic carbon content [g-Carbon/g-soil]

  K_{oc} =Carbon-water partition coefficient [cm^3-water/g-Carbon]

Table E-11. Saturated Vapor Concentration

$$C_v^{sat} = \frac{P_v \times MW \times 10^3}{R \times T}$$

where:

C_v^{sat} = Saturated vapor concentration [mg/L-air]

P_v = Saturated vapor pressure [atm]

MW = Molecular weight [g/g-mol]

R = Ideal gas constant [L-atm/g-mol-K]

T = Temperature [K]

10^3 = Conversion factor [mg/g]

Appendix F:

Associated State Agency and Other Authority Contact List

Table F-1. Associated State Agency and Other Authorities Contact List

Authority	Area of Concern	Contact Information
Nebraska Department of Environment and Energy		
Petroleum Remediation Section	Petroleum release investigations and remedial actions	402-471-2186
Waste Management Section	Petroleum-contaminated soils disposal	402-471-4210
NPDES Permits Unit	NPDES discharge permitting	402-471-4220
Air Quality Permitting Section	Construction permitting for SVE or air stripping remedial systems	402-471-2189
Water Well Standards and Contractors' Licensing Program	Water well construction requirements and professional licenses http://deq.ne.gov/NDEQProg.nsf/OnWeb/WWS	402-471-4982
General NDEE	Reporting of spills per Neb. Title 126 https://dee.ne.gov	402-471-2186 402-479-2121 (24-hour contact)
Nebraska State Fire Marshal		
Fuels Division	UST system installation, removals, inspections, fire/explosion threats https://sfm.nebraska.gov	402-471-9465
Nebraska Department of Natural Resources		
Water Administration Division	Monitoring well registration requirements, registered well locations https://dnr.nebraska.gov	402-471-2363
Nebraska Department of Roads		
Maintenance Support	Right-of-way access	402-479-4656
Nebraska Board of Geologists		
Nebraska Board of Geologists	Certification and licensure of geologists performing work in Nebraska. https://nebog.nebraska.gov	402-471-8383
Nebraska Board of Engineers and Architects		
Nebraska Board of Engineers and Architects	Certification and licensure of engineers performing work in Nebraska. https://ea.nebraska.gov	402-471-2021
Nebraska Natural Resource District Offices		
NE Association of Resources Districts	Water production well permitting in Groundwater Management areas www.nrdnet.org , nard@nrdnet.org	402-471-7670 877-777-6273
Central Platte NRD		308-385-6282 (Grand Island)
Lewis & Clark NRD		402-254-6758 (Hartington)
Little Blue NRD		402-364-2145 (Davenport)
Lower Big Blue NRD		402-228-3402 (Beatrice)
Lower Elkhorn NRD		402-371-7313 (Norfolk)

Authority	Area of Concern	Contact Information
Lower Loup NRD		308-728-3221 (Ord)
Lower Niobrara NRD		402-775-2343 (Butte)
Lower Platte North NRD		402-443-4675 (Wahoo)
Lower Platte South NRD		402-476-2729 (Lincoln)
Lower Republican NRD		308-928-2182 (Alma)
Middle Niobrara NRD		402-376-3241 (Valentine)
Middle Republican NRD		308-367-4281 (Curtis)
Nemaha NRD		402-335-3325 (Tecumseh)
North Platte NRD		308-632-2749 (Gering)
Papio-Missouri River NRD		402-444-6222 (Omaha)
South Platte NRD		308-254-2377 (Sidney)
Tri-Basin NRD		308-995-6688 (Holdrege)
Twin Platte NRD		308-535-8080 (North Platte)
Upper Big Blue NRD		402-362-6601 (York)
Upper Elkhorn NRD		402-336-3867 (O’Neill)
Upper Loup NRD		308-645-2250 (Thedford)
Upper Niobrara-White NRD		308-432-6190 (Chadron)
Upper Republican NRD		888-883-9066 (Imperial)
United States Environmental Protection Agency		
Region VII Spill Prevention, Containment, & Countermeasures (SPCC)	Petroleum storage secondary containment	913-551-7247
Region VII Spill Line	Spill reporting	913-281-0991
General Region VII	Main office / general questions www.epa.gov/region7/index.htm	800-223-0425
National Response Center	Reporting of petroleum spills >10,000 gallons to land or any quantity to navigable waters www.nrc.uscg.mil/	800-424-8802