DEPARTMENT OF LABOR AND EMPLOYMENT
Division of Oil and Public Safety
633 17th Street
Suite 500
Denver CO 80202-3660
(303) 318-8500; Fax (303) 318-8546

COLORADO DEPARTMENT OF LABOR AND EMPLOYMENT
DIVISION OF OIL AND PUBLIC SAFETY

PETROLEUM STORAGE TANK
OWNER/OPERATOR
GUIDANCE DOCUMENT

May 2005

TABLE OF CONTENTS

SECTION **PAGE**

1.0 Introduction 1
1.1 Definitions 2

2.0 Reporting Requirements for Petroleum Releases 5
2.1 Suspected Release 5
2.2 Confirming Releases 5

3.0 Site Classification and Response 6
3.1 Site Classification 6
3.2 Site Classification Checklist 7

4.0 Analytical Requirements 11
4.1 Chemicals of Concern (COCs) 11
4.2 Total Petroleum Hydrocarbon and Priority Polynuclear Aromatic Hydrocarbons 11
4.3 Additional Compounds 13
4.3.1 Fuel Additives 13
4.3.2 Hazardous Waste 13

5.0 Site Characterization 13
5.1 Free Product 13
5.2 Soil Sampling 13
5.2.1 Field Screening 13
5.2.2 Typical Soil Sampling Locations to Confirm the Presence of Contamination 14
5.2.3 Soil Samples Collected During Drilling or Direct Push Activities 14
5.2.4 Soil Samples Collected During Excavation 15
5.3 Soil Vapor Sampling 15
5.3.1 Field Screening 15
5.3.2 Samples 15
5.4 Groundwater Monitoring Wells 16
5.5 Groundwater Sampling 16
5.5.1 Excavation Groundwater 16
5.5.2 Groundwater Monitoring Well Purging 16
5.5.3 Groundwater Sample Collection 17
5.6 Definition of Extent of Contamination 17

6.0 Site Geology and Hydrogeology 17
6.1 Geology 17
6.1.1 Regional Geology of the Site Area 17
6.1.2 Site Geology 18
6.2 Hydrogeology 18
6.2.1 Regional Hydrogeology of the Site Area 18
6.2.2 Site Hydrogeology 18
7.0 Tier 1 Evaluation 19
7.1 Tier 1 RBSLs 20
7.2 Source Concentrations 21
7.3 Points of Exposure 22
7.4 Exposure Pathways 22
7.4.1 Groundwater - Direct Ingestion 22
7.4.2 Groundwater - To Indoor Air 23
7.4.3 Surficial - Ingestion, Dermal Contact, Inhalation of Particulates and Vapors 23
7.4.4 Subsurface Soil - To Indoor Air 23
7.4.5 Subsurface Soil - Leaching to Groundwater 23
7.5 Exposure Pathway Screening Criteria 23
7.6 Land Use 25
7.7 Polynuclear Aromatic Hydrocarbons (PAHs) 25

8.0 Tier 1A 28
8.1 Tier 1A Data Collection 28
8.1.1 Depth to Subsurface Soil Source 28
8.1.2 Depth to Groundwater 28
8.1.3 Thickness of Capillary Fringe 30
8.1.4 Thickness of Unsaturated Zone 30
8.1.5 Length of Source 30
8.1.6 Width of Source 30
8.1.7 Darcy Groundwater Velocity 31
8.1.8 Fraction of Organic Carbon (Foc) 31
8.1.9 Total Porosity of the Unsaturated Zone 31
8.1.10 Unsaturated Zone Water Content 31
8.1.11 Unsaturated Zone Air Content 31
8.1.12 Infiltration Rate 31
8.1.13 Soil Bulk Density 31
8.1.14 Distance to Point of Exposure in Groundwater 32
8.1.15 Effective Porosity of the Saturated Zone 32
8.2 Tier 1A Decision Process 32

9.0 Site Characterization Report (SCR) 32

10.0 Corrective Action Plan (CAP) 33
10.1 Confirmation Testing of Selected Corrected Action 34
10.1.1 Pilot Testing 34
10.1.2 Contaminant Transport Modeling 34

11.0 Tier 2 34
11.1 Tier 2 Models 34
11.2 Tier 2 Model Input Parameters 36
11.2.1 Depth to Top of Contamination 36
11.2.2 Thickness of Contamination 37
11.2.3 Residual Water Content 37
11.2.4 Van Genuchten's N 37
11.2.5 Thickness of Unsaturated Zone 37
11.2.6 Degradation Rate 37
11.2.7 Distance Downgradient and Crossgradient of POE 37
11.2.8 Well Screen Interval 37
11.2.9 Source Concentration 38
11.2.10 Molecular Weight of TPH Mixture 38
11.3 Tier 2 in the OPS Process 38

12.0 Tier 3 38

13.0 Monitoring 38

14.0 No Further Action 39

15.0 Flowchart 39

List of Tables

Table 3-1 Site Classification Checklist……..…..8
Table 7-1 Tier 1 Risk-Based Screening Levels (RBSLs)……..21
Table 7-2 Exposure Pathway Screening Criteria……...25
Table 7-3 Tier 1 for PAH Risk-Based Screening Levels (RBSLs)……28
Table 8-1 Tier 1A Input Parameters and Default Values……...30
Table 8-2 Typical Capillary Rise Values……...31
Table 11-1 Tier 2 Input Parameters (BP RISC)……...37

List of Appendices

Appendix A - Laboratory Analytical Methods and Petroleum Products

Appendix B - Procedures for Field Investigations and Site Assessments

Appendix C - Technical Background Document for RBCA Models

1.0 Introduction

The purpose of this guidance document is to assist owners and/or operators of regulated leaking storage tank facilities in conducting release investigations, performing initial response actions, preparing site characterization reports, and preparing and implementing corrective action plans. This document contains a summary of the necessary actions to be taken and information which should be gathered to determine the extent and degree of contamination which exists in soils, surface water and/or groundwater resulting from a leak, release, or spill associated with a regulated storage tank, associated piping, and/or dispenser systems. The guidance document is consistent with the OPS Storage Tank Regulations (7 CCR 1101-14), but does not supersede any of the regulations.

The OPS Storage Tank Regulations became effective on May 30, 2005, and apply to all releases occurring on or after that date. The OPS encourages owners/operators to re-evaluate existing assessment or corrective action projects under the current regulations.

The Colorado Department of Labor and Employment Division of Oil and Public Safety (OPS) has adopted a formal method of risk evaluation based on the American Society of Testing and Materials Standard E 1739-95, *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Site* (ASTM). This will facilitate improvements in the protection of human health and the environment as well as the service we provide to customers.

The standardized Colorado Risk-Based Corrective Action (RBCA) process incorporates established modeling techniques using current data on toxicological and chemical properties to estimate cleanup goals and predict contaminant fate and transport. RBCA utilizes a tiered approach, based on ASTM protocol, to set cleanup goals that are appropriate for each individual site. The initial Tier 1 site evaluation consists of comparing site concentrations of chemicals of concern (COCs) with a look-up table containing conservative, risk-based screening levels (RBSLs) for COCs in various media. If the site concentrations are below these Tier 1 RBSLs, no further site characterization or corrective action is required. Tier 1A and Tier 2 permit the incorporation of site specific model input parameters, which facilitates the development of cleanup goals that are custom tailored to the individual site.

Questions regarding this document may be answered by calling the OPS Storage Tank Remediation Program Technical Assistance Line at (303) 318-8547 from 8:00 A.M. to 5:00 P.M., Monday through Friday. You can visit the Division website at http://oil.cdle.state.co.us for access to this document, statutes, regulations, required report formats, and additional program related information.

1.1 Definitions

Attenuation is the reduction in concentrations of chemical(s) of concern in the environment with distance or time due to processes such as diffusion, dispersion, adsorption, chemical degradation, biodegradation, and other similar chemical, biological, or physical processes.

Capillary fringe is the zone immediately above the water table, where water is drawn upward by capillary attraction.

Chemicals of concern (COCs) are chemical compounds that have been identified for evaluation due to specific risks to human health and/or the environment.

Corrective action is the sequence of actions that include any or all of the following: interim remedial action, remediation, operation and maintenance, monitoring of progress, and termination of remedial action.

Crossgradient is in the direction of equal static head.

Downgradient is in the direction of maximum decreasing static head.

Effective porosity is the volume fraction of the soil (or rock) that is available to transport water. The effective porosity does not include isolated pore spaces.

Exposure pathway is the course that a chemical of concern takes from a source area to a point of exposure. An exposure pathway describes a unique mechanism by which a person or sensitive environment is assumed to be exposed to a chemical of concern. Each exposure pathway includes a source, an exposure route, and a point of exposure. If the exposure point differs from the source, transport or exposure media (e.g., air, water, dust) are also included. All exposure pathways are assumed to be complete unless an exposure pathway elimination criteria is demonstrated. Exposure pathway elimination criteria are listed in the Owner/Operator Guidance Document.

Fraction of organic carbon is the fraction by weight of total naturally occurring organic carbon in a soil sample.

Gradient is the slope of the water table in the direction of groundwater flow. This slope is typically expressed as a unit change in water table elevation per unit horizontal distance (e.g. ft/ft).

Hydraulic conductivity is the coefficient of proportionality describing the rate at which water can move through a permeable medium.

Industrial property is property currently zoned industrial by the local zoning authority.

Infiltration rate is the volume of water traveling through the unsaturated zone and reaching groundwater per unit time.

Lens as referred to in the Tier 2 model, is a horizontal unit of soil which can be assigned different soil properties (e.g. hydraulic conductivity and moisture content), and which is located between a petroleum vapor source and the ground surface or a building. The lens is typically used to estimate volatile chemical diffusion rates when there are units with variable moisture content above a vapor source.

Media are intervening substances through which something is transmitted or carried (e.g. soil, water, or air).

Point of compliance (POC) is a point or location some specified distance hydraulically downgradient of the activity being monitored for compliance.

Point of exposure (POE) is the location at which a person or sensitive environment is assumed to be exposed to a chemical of concern. POEs are: property boundaries, surficial soils, subsurface utilities, structures, groundwater wells, surface water, and sensitive environments.

Remediation means actions taken to reduce concentrations of chemicals of concern (including natural attenuation), or prevent migration of chemicals of concern to POEs. Remediation shall be implemented for sites where no further action is not appropriate.

Residential property is property currently zoned residential by the local zoning authority.

Residual water content is the fraction of water remaining in soil after gravity drainage.

Risk-based screening level(s) (RBSLs) are the risk-based corrective action target levels for chemical(s) of concern developed using the equations in ASTM E 1739 and the Domenico model.

Saturated zone is the subsurface zone which occurs below the water table. The soil pores are filled with water, and the moisture content equals the porosity.

Sensitive Environment is an area of particular environmental value where regulated petroleum contamination could pose a greater threat than in other less sensitive areas. Sensitive environments include: critical habitat for federally endangered or threatened species, national parks, national monuments, national recreation areas, national wildlife refuges; national forests, campgrounds; recreational areas, game management areas, wildlife management areas, designated federal wilderness areas, wetlands, wild and scenic rivers, state parks, state wildlife refuges, habitat designated for state endangered species, fishery resources, state designated natural areas, wellhead protection areas, classified groundwater areas, and county or municipal parks.

Site classification is a qualitative evaluation of a site based on known or readily available information to identify the need for interim remedial actions and further information gathering.

Site-specific target level(s) (SSTLs) are the risked-based remedial action target levels for chemical(s) of concern developed for a particular site under the Tier 2 evaluation.

Soil bulk density is the dry weight of soil per unit volume.

Source concentration is the highest concentration, in soil and/or groundwater and /or vapor, of the chemicals of concern.

Subsurface soils are all soils located at a depth of greater than one meter below the ground surface.

Surficial soils are all soils located from the ground surface to a depth of one meter below ground surface.

Tier 1 evaluation is a risk-based analysis, which includes a comparison of the highest levels of contamination remaining on the site with the Tier 1 RBSLs. Each completed exposure pathway must be evaluated. The completed exposure pathway with the lowest RBSLs for a given media will determine the cleanup goals for the site.

Tier 1A evaluation is a risk-based analysis to develop site-specific risk-based screening levels (SS-RBSLs) for complete exposure pathways utilizing the Tier 1 models and incorporating data collected from the site. The completed exposure pathway with the lowest SS-RBSLs will determine the cleanup goals for a given media at the site.

Tier 2 evaluation is a risk-based analysis to develop site-specific target levels (SSTLs) for complete exposure pathways utilizing saturated and unsaturated zone models such as API DSS VADSAT or BP RISC. Acceptable models for the unsaturated zone will be analytical, transient, capable of modeling one-dimensional dispersion and degradation, and calculating effective solubility for individual constituents in a mixture. Acceptable models for the saturated zone will be analytical or semi-analytical, transient, and simulate retardation, degradation, one-dimensional flow and three-dimensional dispersion. The Tier 2 evaluation incorporates data collected from the site. The completed exposure pathway with the lowest SSTLs for a given media will determine the cleanup goals for the site.

Total porosity is the volume of pore spaces divided by the total volume of soil.

Unsaturated zone is a subsurface zone which occurs above the water table. The soil pores are only partially filled with water, and the moisture content is less than the porosity.

Van Genuchten's N is a parameter, used in the Tier 2 models, to estimate long-term average moisture content in the unsaturated zone.

2.0 Reporting Requirements for Petroleum Releases

Colorado regulations require that any suspected or known release of a regulated substance must be reported to the OPS within 24 hours. The only exception to this requirement is a release known to be less than 25 gallons that can be completely cleaned up within 24 hours. If the owner/operator is unable to completely clean up the release within 24 hours, the OPS must be notified within the 24-hour time frame.

2.1 Suspected Release

If there is any reason to assume a release has occurred, including any of the following conditions, the OPS requires that a suspected release be reported within 24 hours:

- Stained soils.
- Soils with petroleum odors.
- Elevated readings of field monitoring instruments.
- Failure of any method of release detection (7 CCR 1101-14 (2-4-4), (2-4-5).
- Presence of known contamination on a downgradient property, with no obvious reason to suspect a release on that property (e.g., no petroleum storage or use on the property) and no obvious other source.

2.2 Confirming Releases

Colorado regulations require an owner/operator to confirm, within seven days, if a suspected release is an actual release. Once a suspected release has been confirmed the OPS must be notified within 24 hours. If a release is confirmed, the date that the release was initially suspected will become the official release date for all regulatory deadlines for that release.

Methods of confirming releases include:

- Laboratory analysis of suspect soils or water.
- Discovery of free product outside of the tank.

To report a release to the OPS, call (303) 318-8547 or FAX (303) 318-8546. The following information should be provided to the OPS when reporting a release:

- Site name and location including the zip code.
- Owner/Operator name and mailing address including the zip code.
- Site contact person name and phone number.
- Name and phone number of person reporting the release.
- Release date.
- Facility operating status.
- Comments concerning the release: type of product, cause of the release, amount of release and response actions.

If a situation exists which requires immediate emergency response on a weekend, or during a holiday, call the emergency response number at the Colorado Department of Public Health and Environment (CDPHE) at (303) 756-4455.

If the owner/operator suspects that the released substance may be classified as a hazardous waste, the CDPHE should be contacted regarding release reporting, investigation and remediation requirements.

The release reporting requirements discussed in this section are based upon Colorado Storage Tank Regulations. Note that the federal government, local government(s), and fire protection districts may have other, more stringent rules for reporting releases. It is the obligation of the owner/operator to determine these additional reporting requirements.

3.0 Site Classification and Response

3.1 Site Classification

In order to offer guidance in initial response and corrective actions, the OPS has developed a site classification system. This system is based upon the ASTM classification table, which has been modified to provide greater flexibility in classification and response actions.

Site classification is intended to be a dynamic process. Site classifications should be updated as more information becomes available regarding site specific conditions. Upon review of the Site Summary Form (SSF) and the Site Characterization Report (SCR) the OPS may determine that a different classification is warranted for the site and the owner/operator may be required to amend their classification. Sites will be reclassified, as necessary, subsequent to abatement, obtaining further assessment information, remedial actions, and quantifying the effects of natural attenuation.

There are five classifications, which are based on the immediacy and severity of the threat to human health and the environment. The classifications have been defined as follows:

- Class 1 - immediate threat to human health, safety or the environment.
- Class 2 and 2a - short term threat to human health, safety or the environment.
- (Class 2 = 0-6 months, Class 2a = 7 months-2 years)
- Class 3 - intermediate term threat to human health, safety or the environment. (>2 years)
- Class 4 - no demonstrable long term threat.

3.2 Site Classification Checklist

The OPS has created a checklist to guide owners/operators in responding to petroleum releases, based upon the threat to human health and the environment posed by these releases. An example of the Site Classification Checklist is presented below. The checklist suggests appropriate response actions that may be taken to mitigate threats to human health, safety, or the environment, which may exist at a site. To complete the following table, place a check in the Threat (T) box if the situation, designated by sub-class (SUB), exists at the site. If the threat does not exist, check the N box. If it is unknown whether the listed condition exists at the site, check the unknown (U) box. Check the Response (R) box if an appropriate response action has been completed for the existing condition at the site. If the response action has been completed and the threat no longer exists, the site classification will be the classification of the next most highly listed threat. The site will be classified by the first table where a threat box has been checked and an appropriate response has not been completed or where it is unknown whether or not the threat exists. However, complete the entire form and perform appropriate response actions for each condition which exists at the site, and submit the form as part of the Site Classification Form (due 45 days from the release). An updated form should additionally be submitted with the Site Characterization Report. Complete response actions in order of highest priority (1 being the highest).

Table 3-1. Site Classification Checklist

CLASSIFICATION 1 - CURRENT THREAT TO HUMAN HEALTH , SAFETY, OR SENSITIVE ENVIRONMENT						
T	R	N	U	SUB	Threat	Response Action
				1.1	Explosive levels, or concentrations of vapors that could cause acute health effects, are present in a residence or other building.	*Evacuate occupants, begin emergency abatement measures such as subsurface ventilation, or building pressurization or free product removal*. *Notify local fire authority*.
				1.2	Explosive levels of vapors are present in subsurface utility system(s).	*Evacuate vicinity immediately, begin emergency abatement measures such as ventilation.*
				1.3	Free product is present in measurable quantities at ground surface, on surface water bodies, in utilities, or on surface water.	*Prevent further free product migration by appropriate containment measures, institute free product removal, restrict area access.*
				1.4	A water supply well, supply line, or surface intake is impacted** above action levels.	*Notify user(s) provide alternate water supply, control contaminated water and treat water at the point-of-use.*
				1.5	Ambient vapor/particulate concentrations of concern from an acute exposure or safety viewpoint.	*Install a vapor barrier*, *remove the source, or restrict access to affected area.*
				1.6	Surface water, storm water, or groundwater which is impacted** above action levels is discharging directly to a surface water body used for human drinking water or contact recreation, or a sensitive environment.	*Minimize extent of impact by containment measures, and implement habitat management to minimize exposures.*

CLASSIFICATION 2 - SHORT-TERM THREAT (0-6 MONTHS) TO HUMAN HEALTH, SAFETY, OR SENSITIVE ENVIRONMENT						
T	R	N	U	SUB	Threat	Response Action
				2.1	Explosive vapor levels, or concentrations that could cause acute health effects, may accumulate in a residence or other buildings within six months.	*Assess the potential for vapor migration through monitoring/modeling and remove source, if necessary, or install a vapor migration barrier.*
				2.2	Surficial soils impacted** above action levels, are exposed and less than 500 ft from public access, dwellings, parks, sensitive environment, playgrounds, day care centers, schools, or similar use facilities.	*Remove soils, cover area, or restrict access*.
				2.3	A water supply well producing from the affected groundwater is impacted** above action levels, or is located less than 120 ft* down-gradient of the known extent of contamination.	*Notify owner/user, evaluate need for point-of-use water treatment, hydraulic control, or alternative water supply.*
				2.4	Groundwater is impacted** above action levels and a water supply well producing from a different interval is within the known extent of contamination.	*Notify owner, monitor groundwater well quality and determine need for prevention of vertical migration to the supply well.*
				2.5	Surface water, storm water, or groundwater, impacted** above action levels, discharges within 500 ft of a surface water body used for human drinking water or contact recreation, or a sensitive environment.	*Begin containment measures. Restrict access to areas near discharge. Evaluate magnitude and impact to discharge area.*
				2.6	Free product, of any measurable thickness on groundwater is discovered.	*Prevent free product migration by appropriate containment measures. Begin free product removal immediately.*
				2.7	Groundwater impacted** above action levels is present offsite.	*Define extent and degree of contamination. Notify OPS of name and address of impacted parties.*

CLASSIFICATION 2a - INTERMEDIATE-TERM THREAT (7-24 MONTHS) TO HUMAN HEALTH, SAFETY, OR SENSITIVE ENVIRONMENT						
T	R	N	U	SUB	Threat	Response Action
				2a.1	Explosive vapor levels, or concentrations that could cause acute health effects may accumulate in a residence or other buildings within seven to twenty four months.	*Assess the potential for vapor migration, through monitoring/modeling and remove source, if necessary, or install a vapor migration barrier.*
				2a.2	Groundwater is impacted** above action levels and a water supply well producing from the impacted interval is located between 120 ft and 500 ft* down-gradient of the known extent of contamination.	*Notify owner/user, evaluate need for point-of-use water treatment, hydraulic control, or alternate water supply.*

CLASSIFICATION 3 - LONG-TERM THREAT (>2 YEARS) TO HUMAN HEALTH, SAFETY, OR SENSITIVE ENVIRONMENT						
T	R	N	U	SUB	Threat	Response Action
				3.1	Subsurface soils (> 3 ft bgs) are impacted** above action levels, and depth from impacted soils to the first groundwater is less than 50 ft.	*Define the extent of contamination. Monitor groundwater. Determine the potential for future contaminant migration to the groundwater.*
				3.2	Groundwater is impacted** above action levels onsite with the potential to migrate offsite.	*Define the extent of contamination. Monitor groundwater. Determine the potential for future contaminant migration to the groundwater at the property boundary.*
				3.3	Groundwater is impacted** above action levels, and water supply wells producing from the impacted interval are located between 500 ft and ½ mile* down gradient of the known extent of contamination.	*Define extent of contamination. Monitor the dissolved plume and evaluate the potential for future contaminant migration, for natural attenuation and the need for hydraulic control.*
				3.4	Surface water, storm water, or groundwater impacted** above action levels, discharges within 1500 ft of a surface water body used for human drinking water or contact recreation, or sensitive environment.	*Investigate potential impact on sensitive environment or surface water body, restrict access to area of discharge and evaluate the need for containment/controls measures.*

CLASSIFICATION 4 - NO DEMONSTRABLE LONG-TERM THREAT TO HUMAN HEALTH, SAFETY, OR SENSITIVE ENVIRONMENT						
T	R	N	U	SUB	Threat	Response Action
				4.1	Impacted** soils above action levels are located more than 3 ft bgs and are greater than 50 ft above the nearest groundwater.	*Monitor groundwater and evaluate effect of natural attenuation on leachate migration.*
				4.2	Groundwater is impacted** above action levels and water supply wells that do not produce from the impacted interval are located downgradient outside the known extent of contamination.	*Monitor groundwater and evaluate effect of natural attenuation on dissolved plume migration.*
				4.3	Surficial soils impacted** above action levels are exposed and greater than 500 ft from public access, dwellings, parks, sensitive environments, sensitive resources, playgrounds, day care centers, schools, or similar use facilities.	*Restrict access to affected soils.*

* These distances are based on conservative assumptions for groundwater flow velocity. These distances can be adjusted provided supporting documentation is submitted to and approved by the OPS.
******If the extent of contamination has not been defined the owner/operator must assume that all potential POEs are within the impacted area.

4.0 Analytical Requirements

The OPS has determined that certain chemical compounds contained in regulated substances pose risks to human health and the environment. These risks have been documented and substantiated during numerous studies conducted by governmental agencies, universities, and private industry. Based on this information, the OPS has selected chemicals of concern (COCs) and priority poly-nuclear aromatic hydrocarbons (PAHs) compounds found in total petroleum hydrocarbons (TPH).

4.1 Chemicals of Concern (COCs)

The following compounds have been selected as COCs:

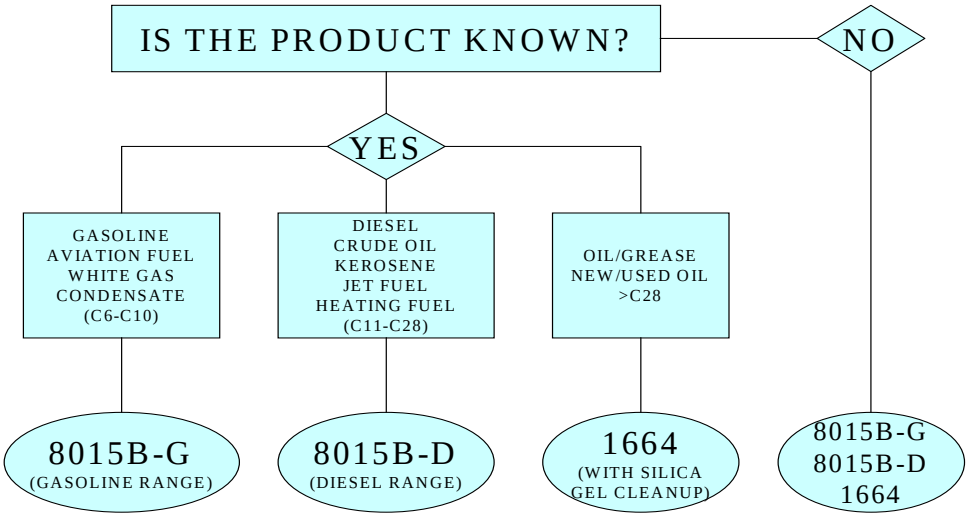
- Benzene
- Toluene
- Ethylbenzene
- Xylenes
- Methyl *tert*-Butyl Ether (MTBE)

Benzene was selected based on its carcinogenic, as well as toxic, properties. Toluene, ethylbenzene, and xylenes were selected based on their toxic properties. Collectively these compounds are typically referred to as BTEX and MTBE. All five compounds were selected because of their prevalence in regulated petroleum products, and their mobility in the subsurface. All samples collected are required to be analyzed for BTEX and MTBE. These compounds should be analyzed using EPA methods 8021or 602 as presented in SW-846, or an equivalent method approved by the OPS. EPA method 8260 may also be appropriate, especially in cases where a waste oil tank is/was present. Further information regarding the physical and chemical properties of the COCs, and laboratory analytical procedures is located in Appendix A. The RBSLs for these compounds are presented as Table 7-1.

4.2 Total Petroleum Hydrocarbon and Priority Polynuclear Aromatic Hydrocarbons

Total petroleum hydrocarbons (TPH) may contain polynuclear aromatic hydrocarbons (PAHs), many of which have toxic and carcinogenic properties. All samples collected are required to be analyzed for TPH. TPH should be analyzed using EPA methods 1664 or 8015B as presented in SW-846, or an equivalent method approved by the OPS. The following flow chart may be used to determine the appropriate analytical method based on the product type at the site.

ANALYTICAL METHODS FOR TPH



To identify sites where priority PAHs may pose a risk to human health and the environment, a threshold value of 500 mg/kg for TPH in soil has been established by the OPS. If TPH concentrations exceed the threshold value, and BTEX concentrations are below the site cleanup goal, then a sample taken from the location where the TPH concentration was the highest must be analyzed for the priority PAHs. The priority PAHs are listed below:

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)flouranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Chrysene
- Dibenzo(a,h)anthracene
- Flouranthene
- Flourene
- Indeno(1,2,3-c,d)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

Analysis for PAHs should be conducted using EPA method 8270 as presented in SW-846, or an equivalent method approved by the OPS. The RBSLs for these compounds are presented in Table 7-3 .

4.3 Additional Compounds

4.3.1 Fuel Additives

Ethylene dibromide (EDB) Dichloroethylene (DCE) and 1,2-Dichloroethane (DCA) are not currently considered to be COCs, however the OPS is currently performing a study to determine the prevalence of these fuel additives. If there is reason to suspect that EDB, DCE or DCA were used at the site, analyses should be performed. The recommended analyticals method for DCE, EDB, and DCA in soil or water are EPA 8021 and EPA 8260.

4.3.2 Hazardous Waste

If there is reason to suspect hazardous substances have been used at the site, appropriate analyses should be performed.

5.0 Site Characterization

5.1 Free Product

At sites where free product is present, the OPS must be notified within 24 hours of discovery. Free product must be removed to the full extent practicable and in a manner that minimizes the spread of contamination. The type, thickness, and total volume of free product removed should be noted. All free product removed must be disposed/treated in compliance with applicable regulations.

5.2 Soil Sampling

Soil samples should be collected to adequately characterize the horizontal and vertical extent of contamination and the subsurface soil profile within the area of contamination.

5.2.1 Field Screening

The OPS recommends that field screening instrumentation be used to determine the presence of volatile hydrocarbons in the soils in order to detect possible safety hazards associated with volatilization of hydrocarbons. Field screening data may also provide valuable guidance in selecting sample locations and depths. Soil samples collected from the area(s) exhibiting the highest screening levels should be analyzed by a laboratory to define source areas. Field screening should be performed according to the guidance set forth in Appendix B.

5.2.2 Typical Soil Sampling Locations to Confirm the Presence of Contamination

The OPS requires that soil samples for laboratory analysis be collected from the locations most likely to be contaminated. At a typical UST closure site samples must be collected from under the tanks, near the dispensers and along the dispensing lines, in areas where staining or odors are noted, and/or in areas with elevated field instrument readings. Although these factors may vary widely among sites, the following scenarios have been identified as occurring frequently, and recommended sampling locations have been defined:

- If site investigation activities are being performed in conjunction with the removal or closure in place of a petroleum storage system, the owner/operator must collect samples from directly beneath each end and the center of each tank, or from each end only if the tank capacity is less than 1000 gallons. Samples must also be collected from beneath each dispenser island and beneath any areas of piping which are suspected to have released petroleum product into the environment (e.g. joints, areas of damage or corrosion, etc.).

- If site investigation activities are being conducted due to failure of a tank tightness test, the owner/operator must collect a minimum of four samples, which bracket the tank on all sides and are collected from below the elevation of the base of the tank.

- If site investigation activities are being conducted due to failure of a line tightness test, the owner/operator must collect samples from beneath the associated dispenser island and from beneath any areas of piping which are suspected to have released petroleum product into the environment (e.g., joints, areas of damage or corrosion, etc.).

Justification for more or fewer samples or different sample locations based on tank size and/or site conditions should be provided to the OPS.

5.2.3 Soil Samples Collected During Drilling or Direct Push Activities

Soil samples collected during drilling or direct push activities should be screened at five foot intervals. The samples corresponding with the highest VOC reading and/or those samples collected directly above the water table should be submitted for laboratory analysis. For sample collection procedures see Appendix B.

Borehole lithologic logs and well construction diagrams should include the site name and address, boring number, date completed, surface elevation, depth, borehole diameter, initial and static water levels (if available), drilling method, sampling method, lithologic graphic (to scale), an indication of the intervals from which samples were obtained, results of VOC screening, and a geologic description and/or Unified Soil Classification System (USCS) class of each rock or soil type encountered including any staining or petroleum odors.

5.2.4 Soil Samples Collected During Excavation

If contaminated soil is removed from the site, one sample per hundred cubic yards of contaminated soil removed should be collected and analyzed. Additionally, samples should be collected to document soil conditions remaining on the site following excavation activities. Post excavation samples should be collected from beneath and/or adjacent to any areas from which contaminated soil has been removed.

Excavation lithologic logs should include the site name and address, excavation number, date completed, surface elevation, depth, dimensions, initial and static water levels (if applicable), excavation method, sampling method, lithologic graphic (to scale), an indication of the intervals from which samples were obtained, results of VOC screening, and a geologic description and/or Unified Soil Classification System (USCS) class of each rock or soil type encountered including any staining or petroleum odors.

5.3 Soil Vapor Sampling

Soil vapor sample collection is required only at sites where a structure is present within the influence of hydrocarbon impacted soils or groundwater, and the structure is not utilized as part of a business which dispenses petroleum products.

If soil vapor sample collection is required, then field screening should be conducted prior to the collection of discrete soil vapor samples as described below.

5.3.1 Field Screening

The OPS recommends that field screening instrumentation be used to determine the presence of VOCs in the soils in order to detect possible safety hazards associated with hydrocarbon vapors. Field screening data may provide valuable guidance in selecting sample locations and depths. Field screening samples should be taken adjacent to potential source areas, in and around subsurface utilities, and beneath or adjacent to building slabs or foundations. Soil vapor samples should be collected according to accepted industry practices (see Appendix B).

5.3.2 Samples

At a minimum, two discrete nested soil vapor samples should be collected for each potential source of contamination (e.g., soil or groundwater). One sample should be collected adjacent to the contamination source, and the second sample should be collected between the source and the potentially impacted structure. Additionally, preferential vapor migration pathways (e.g., utility trenches, paleochannels, etc.) should be considered for sampling, especially if the pathway connects the vapor source with the structure. For details on sampling protocol see Appendix B. Soil vapor samples should be analyzed for the appropriate COCs (see Appendix A).

5.4 Groundwater Monitoring Wells

Monitoring wells must be properly located and screened to characterize the magnitude and vertical and horizontal extent of contamination. Wells must be located upgradient of the contamination, within the contaminant plume, and downgradient of the defined extent of contamination. Additionally, consideration should be given to placing wells at property boundaries. These wells could later serve to confirm when cleanup goals are attained.

Point of compliance (POC) wells must be placed downgradient of the source area, beyond the limits of the defined extent of contamination, and between the defined extent of contamination and any points of exposure (POEs). POC wells must be spaced such that contaminant migration will be detected across the leading edge of the plume to insure that POEs are protected. If POEs have already been impacted above the defined extent of contamination, remediation must bring the POEs into compliance. During site characterization and remediation activities POC wells may be located beyond the property boundary. At the time No Further Action is requested, compliance must also be achieved at the property boundary (See Section 7.4.1 for exceptions).

Monitoring wells should be appropriately spaced to determine the hydraulic gradient at the site. Wells must be screened such that the screened interval will intercept the water table surface throughout the seasonal water cycle. Wells must also be properly developed to insure the maximum possible flow through the well. Details of well construction and development are presented in Appendix B.

5.5 Groundwater Sampling

Groundwater samples are obtained to define the nature and extent of the hydrocarbon plume and detect the presence of hydrocarbons in groundwater.

5.5.1 Excavation Groundwater

If groundwater is detected during excavation activities it must be sampled. If measurable free product is present on the groundwater, the OPS must be notified immediately.

5.5.2 Groundwater Monitoring Well Purging

Prior to sampling, wells should be purged properly to insure representative groundwater samples. Groundwater samples may be collected from monitoring wells, piezometers, etc. If, during well installation and development, it is apparent that proper purging and sampling procedures cannot be completed, then alternate sampling procedures may be considered (see Appendix B for purging and sampling techniques).

5.5.3 Groundwater Sample Collection

Prior to purging a well, a hydrocarbon/water interface device should be used to determine if free product is present and the thickness of free product, if applicable. If free product is detected, it should be removed and the well should not be sampled. Following purging and after the field parameters have stabilized, groundwater samples should be collected using the proper sampling procedures which are found in Appendix B.

5.6 Definition of Extent of Contamination

During site characterization activities, the extent of contamination associated with a release must be defined in both groundwater and soil. Groundwater must be defined to a level below the Colorado Department of Public Health and Environment, Water Quality Control Commission, Basic Standards for Ground Water (Regulation 41) Maximum Contaminant Levels (MCLs) for each chemical of concern found at the site. Soil must be defined to a level below the Tier 1 RBSLs for each chemical of concern found at the site for the subsurface soil leaching to groundwater pathway, and below the TPH threshold concentration (500 mg/kg).

6.0 Site Geology and Hydrogeology

Information concerning the geology and hydrogeology of a site is very important to the decision making process in the investigation and management of a release. As the owner/operator investigates and remediates a release, a variety of geologic and hydrogeologic information will be necessary. The appropriate Tier and completed exposure pathways for the site will determine what information should be collected for the site. Additional information may also be necessary for selected remediation techniques.

6.1 Geology

6.1.1 Regional Geology of the Site Area

Information regarding the regional geology of the site area can be obtained from maps and publications of the U.S. Geological Survey (USGS), the Colorado Geological Survey (CGS), and local governmental agencies (e.g., planning departments, agricultural extension offices). These documents may provide general area information such as: soil thicknesses, bedrock elevations, soil types, topography, and subsurface structural features. This information may be useful in planning site investigation activities.

6.1.2 Site Geology

The assessment of site geology should include data collected as a result of on-site investigative work. Data obtained from investigative work conducted at adjacent sites may be acceptable, as appropriate, to support findings or trends observed at a site. Observations related to excavation and drilling activities should be recorded on excavation or boring logs.

Site specific parameters associated with the geology of the site are required as part of a Site Characterization Report. Parameters measured in the field include soil type, soil structures and thickness of the unsaturated zone. Guidance on methods to collect site-specific geologic data is contained in Appendix B.

Additional parameters such as porosity, soil moisture, soil air content, Foc, and bulk density may be required to be collected at a site if a Tier 1A or Tier 2 evaluation is performed. More information concerning these additional parameters is contained in Sections 8.0 and 11.0.

6.2 Hydrogeology

6.2.1 Regional Hydrogeology of the Site Area

Information regarding the regional hydrogeology of the site area can be obtained from maps and publications of the U.S. Geological Survey (USGS), the State Engineer's Office, and local governmental agencies. These documents may provide general area information such as, groundwater surface elevations, saturated thickness, water well locations, and aquifer data. This information may be useful in planning site investigation activities and summarizing regional groundwater flow direction, climatological data for the site including, the average monthly precipitation, and to identify potential areas of local groundwater recharge or discharge (e.g. streams, springs, canals, dry wells, etc).

6.2.2 Site Hydrogeology

The assessment of site hydrogeology should include data collected as a result of on-site investigative work. Data obtained from investigative work conducted at adjacent sites may be acceptable, as appropriate, to support findings or trends observed at a site. Observations related to excavation and drilling activities should be recorded on excavation or boring logs.

The following parameters associated with the saturated zone are required as part of the site characterization report. During the Tier 1 evaluation only, these parameters may be estimated from literature sources. These parameters are required to be determined through on-site testing for Tier 1A and Tier 2 evaluations:

- Groundwater Elevation - At sites where groundwater is present, measurements for depth to the uppermost saturated zone (depth to water), depth to product, product thickness, and product elevation must be completed, and the corrected elevation of the groundwater in each of the wells calculated. If free product is present in a well, the water elevation must be corrected to account for the weight of product resting on the water surface. Relative product densities are provided in Appendix A.

- Hydraulic Gradient - At sites where groundwater is present, the hydraulic gradient should be obtained from static water elevation measurements of a minimum of three selected wells or piezometers completed in the hydrogeologic unit and appropriately spaced to create a planar configuration. The maximum slope of the plane is the groundwater flow direction. The maximum ratio of change in elevation per unit distance is the hydraulic gradient.

- Hydraulic Conductivity - Hydraulic conductivity is derived from water level measurements collected over time and/or distance following the placement of some stress on the aquifer. Methods of stressing the aquifer include rising and falling head slug tests and pumping tests. When selecting a testing method the aquifer material must be considered (e.g., slug testing in gravels is not usually effective

- Porosity - Porosity is obtained by collecting an undisturbed soil sample and submitting it to a laboratory for testing.

7.0 Tier 1 Evaluation

A Tier 1 evaluation is required to be performed for a site in order to identify the sources of contamination, potential points of exposure (POEs) to contamination, and any completed exposure pathways between the sources and the POEs. During the Tier 1 evaluation, a site specific cleanup level is determined for each media with a completed exposure pathway. It is possible that many of the exposure pathways will be found to be incomplete and eliminated from consideration during the Tier 1 evaluation. The extent of contamination, both in soils and groundwater should be determined at the site prior to the Tier 1 evaluation.

7.1 Tier 1 RBSLs

In Tier 1, the owner/operator compares site source concentrations to Tier 1 RBSLs contained in a look-up table (Table 7-1). A Tier 1 RBSL is listed for each chemical of concern in each of the exposure pathways considered. The methodology used to calculate Tier 1 RBSLs is based on the guidelines set forth in ASTM. The RBSLs were developed incorporating risk and exposure assessment practices as recommended by the United States Environmental Protection Agency (EPA) and Colorado specific data whenever appropriate. The Tier 1 RBSLs were developed using the EPA recommended target risk limit of $1x10^{-6}$, or Colorado Groundwater Standards, as appropriate. The model used to develop the Tier 1 RBSLs table is available at the Oil Inspection Section website http://oil.cdle.state.co/. Also additional information concerning the development of the Tier 1 RBSLs is available in Appendix C.

If the source concentrations are lower than the Tier 1 RBSLs for all completed pathways, and the TPH threshold has not been exceeded, a No Further Action Required designation may be requested. If the source concentrations exceed the Tier 1 RBSLs, the owner/operator may proceed to Tier 1A, or to a Corrective Action Plan (CAP), which may include proposed corrective actions and a Tier 2 evaluation.

Table 7-1. Tier 1 Risk-Based Screening Levels (RBSLs)
(The Tier 1 RBSL table is presented as Table 5.1 in the Storage Tank Regulations 7CCR 1101-14.)

Tier 1 Risk-Based Screening Levels (RBSLs)							
Media	**Exposure Pathway**	**Land Use**	**Benzene**	**Toluene**	**Ethyl-benzene**	**Xylenes**	**MTBE**
Surficial Soil [mg/kg]	Ingestion/ Dermal/ Inhalation	Residential	4.1	4,100	2,100	36,000	N/A
		Industrial	12	28,000	15,000	250,000	N/A
Subsurface Soil [mg/kg]	Leachate to Groundwater Ingestion	N/A	0.26	170	200	>Sat * or 2600 **	N/A
Soil Vapor [µg/m^3]	Indoor Air Inhalation	Residential	2,700	>VP	>VP	>VP	N/A
		Industrial	35,000	>VP	>VP	>VP	N/A
Groundwater [mg/l]	Indoor Air Inhalation	Residential	0.015	6.9	18	14	N/A
		Industrial	0.39	490	>Sol	>Sol	N/A
Groundwater [mg/l]	Groundwater Ingestion [MCLs]	N/A	0.005	1.0	0.7	1.4** to 10*	0.020

>VP denotes that even at a concentration equal to the vapor pressure of the chemical, a hazard quotient of 1 is not exceeded
>Sol denotes that even at a concentration equal to the solubility of the chemical, a hazard quotient of 1 is not exceeded
> Sat denotes that even at a concentration equal to the saturation of the chemical, a hazard quotient of 1 and a cancer risk of 1 $^{E-6}$ is not exceeded.
* This RBSL will be in effect for releases that occurred prior to September 14, 2004.
** This RBSL will be in effect for releases that occurred on or after September 14, 2004.

7.2 Source Concentrations

During the site assessment, samples are required to be collected from areas where the highest levels of contamination are most likely to exist. The highest concentrations detected are considered as the source concentrations unless any initial abatement has been performed. Following any initial abatement, the highest concentrations of COCs remaining on site will be considered as the source concentration.

7.3 Points of Exposure

The OPS defines POEs as the locations at which a receptor (person) is assumed to be exposed to a COC. They are as follows:

- Property boundaries are considered POEs because neither the OPS nor the owner/operator can control activities which could potentially occur beyond the property boundary (e.g., well installation, utility installation, building construction, etc.).

- Surficial soils are considered POEs to protect a receptor from exposure through dermal contact, inhalation, or ingestion.

- Utilities are considered POEs to protect a receptor from exposure to vapors in utility corridors.

- Structures (with or without a basement) are considered POEs.

- All Groundwater wells (excluding monitoring wells) are considered POEs.

- Surface water is considered a POE to protect a person from exposure through dermal contact, ingestion or inhalation.

- Sensitive environments where surface water is present will be treated as a Surface Water POE by the OPS. However, sensitive environments may be subject to more stringent regulation by the agencies directly involved in the management and preservation of these environments (e.g., National Park Service, Colorado Division of Wildlife, US Army Corps of Engineers, local governments, etc.).

7.4 Exposure Pathways

An exposure pathway is the path that a chemical of concern takes from the source to the POE. Each exposure pathway accounts for both the medium in which the source resides (e.g., subsurface soil) and the mode of transport to the POE (e.g., ingestion of groundwater impacted by leachate). The OPS considers the following to be exposure pathways.

7.4.1 Groundwater - Direct Ingestion

This exposure pathway is considered to insure that groundwater and surface water are protected to the MCLs.

Impacted groundwater may be allowed to remain at levels above the MCLs off-site in situations where groundwater has been designated as non-usable water by the Colorado Water Quality Control Commission (CWQCC). This designation is done directly by the CWQCC on a site by site basis. The CWQCC can be contacted at: (303) 692-3520.

Groundwater may be allowed to remain at levels above MCLs on-site, provided the contaminant plume is stable or diminishing within the property boundary (as demonstrated by four quarters of groundwater monitoring), there has been no impact to water supply wells, dissolved oxygen concentrations are higher outside of the defined plume, the groundwater flow velocity is less than 50 ft/year, and transport modeling results are consistent with site observations. In particular situations, such as where roadway right-of-ways are downgradient of the site and utilities have not been impacted, compliance samples may be collected up to 50 feet beyond the property boundary, upon approval of the OPS.

7.4.2 Groundwater - To Indoor Air

This pathway must be considered when groundwater is impacted above MCLs and a structure is present within the influence of hydrocarbon contamination. All structures within the influence of hydrocarbon contamination which are involved with dispensing petroleum products as part of regular operations are excluded.

7.4.3 Surficial - Ingestion, Dermal Contact, Inhalation of Particulates and Vapors

This pathway must be considered if soil is impacted above Tier 1 RBSLs for the surficial soil pathway, or above 500 mg/kg TPH, from ground surface to 1 meter below ground surface. If it appears that surficial soil to indoor air or surficial soil leaching to groundwater are completed pathways, these exposure pathways should additionally be considered and the subsurface RBSLs for these pathways be applied, as appropriate.

7.4.4 Subsurface Soil - To Indoor Air

This pathway must be considered if there are vapor concentrations in soil which exceed the Tier 1 RBSLs for soil contamination volatilizing to indoor air or TPH concentrations in soil greater than 500 mg/kg and a structure is present within the influence of hydrocarbon contamination. All structures within the influence of contamination which are involved with dispensing petroleum products as part of regular operations are excluded.

7.4.5 Subsurface Soil - Leaching to Groundwater

This pathway must be considered if soil contamination is present above Tier 1 RBSLs for the subsurface soil leaching to groundwater pathway or above 500 mg/kg TPH.

7.5 Exposure Pathway Screening Criteria

The responsible parties will complete an Exposure Pathway Screening Criteria (EPSC) checklist (Table 7-2) to determine which exposure pathways are complete at their site. Those pathways which are found to be incomplete can be eliminated from further evaluation, upon concurrence with the OPS. This checklist must be included in the SCR. In cases where more than one pathway is complete, the completed pathway with the most conservative Tier 1 RBSLs will determine the site cleanup goal for each media.

The EPSC checklist is intended to assist the owner/operator in identifying circumstances under which pathways can be automatically eliminated. If a ✓ mark is placed in the "yes" column adjacent to an exposure pathway, that pathway can be eliminated from further investigation. Owners/operators may also present other site specific circumstances that may eliminate certain pathways.

Table 7-2. Exposure Pathway Screening Criteria

Exposure Pathway Screening Criteria - Basis for Eliminating Pathways	Y	N
Groundwater (Ingestion):		
Impacted groundwater concentrations are below MCLs, or		
Impacted water-bearing unit is designated as "non-usable" by the CWQCC, or		
Groundwater plume is stable or diminishing within the property boundary (as demonstrated by four quarters of monitoring), and There is no impact to a water supply well, (active or inactive), and Dissolved oxygen concentrations are higher outside of the defined plume, and Groundwater flow velocity is <50 ft/year, and Transport modeling results are consistent with site observations.		
Groundwater (Enclosed Space Vapors):		
Impacted groundwater concentrations are below MCLs, or		
No existing structure is within the influence of the contamination, or		
There is an existing structure within the influence of the contamination, and the structure houses a business which dispenses petroleum products as part of its operation.		
Surficial Soils (Ingestion, Ambient Vapors, Particulates, Dermal Contact):		
Impacted soils concentrations below Tier 1 limits, or		
Impacted soils have been removed from the site.		
Subsurface Soils (Enclosed Space Vapors):		
Impacted soils are below Tier 1 limits, or		
No existing structure is within the influence of the contamination, or		
There is an existing structure within the influence of the contamination, and the structure houses a business which dispenses petroleum products as part of its operation.		
Subsurface Soils (Leaching to Groundwater):		
Impacted soils are below Tier 1 limits.		

7.6 Land Use

RBSLs have been established for both Residential and Industrial exposure pathways. RBSLs for commercial land uses have not been established because many of the municipalities in Colorado do not require re-zoning of commercial properties when the use changes to residential. Properties are classified Residential or Industrial as follows:

- Residential - Any property which could be developed or used for human residential occupation, without rezoning. Properties that are presently unzoned will be considered residential until the time they are zoned industrial.

- Industrial - Any property that must be rezoned prior to development or use for residential occupation.

If a party responsible for investigation and remediation of a petroleum release intends to utilize the Industrial RBSL in Tier 1 or industrial exposure parameters to develop Tier 1A or Tier 2 site specific target levels (SSTLs), all of the following conditions must be met:

- The subject property, and all properties currently or potentially impacted, must be zoned Industrial.

- The subject property, and all properties currently or potentially impacted, cannot be inhabited by a sensitive population (e.g., day care facilities, schools, nursing homes, etc.).

- The OPS must be included in the list of parties to be notified in the event of an application for re-zoning of the subject property and all properties currently or potentially impacted above Tier 1 residential RBSLs. This list must be maintained by the local governmental agency responsible for granting changes in zoning. The owner/operator must provide official documentation that this addition to the notification list has been performed.

7.7 Polynuclear Aromatic Hydrocarbons (PAHs)

In situations where TPH concentrations exceed the threshold value of 500 mg/kg and benzene, toluene, ethylbenzene, and xylene concentrations are below site cleanup goals, a sample collected from the source area should additionally be analyzed for the priority PAHs. The site source PAH concentrations should be compared to Tier 1 PAH RBSLs contained in a look-up table (Table 7-3). The Tier 1 PAH RBSL is listed for each priority PAH in each of the exposure pathways considered.

In situations where the contamination at the site is greater than 1 meter below ground surface and the Leachate to Groundwater Ingestion exposure pathway is complete, the clean-up goals for PAHs will be the Surficial Soil exposure pathway RBSLs if the Leachate to Groundwater Ingestion RBSLs are greater than saturation. The intent is to protect receptors, such as construction workers, who may come into direct contact with soil greater than 1 meter below ground surface.

The methodology used to calculate Tier 1 PAH RBSLs is based on the guidelines set forth in ASTM. More information is available concerning the development of the Tier 1 PAH RBSLs in Appendix C.

If the source concentrations are lower than the Tier 1 PAH RBSLs for all completed pathways a No Further Action Required designation may be requested. If the source concentrations exceed the Tier 1 PAH RBSLs, the owner/operator may proceed to Tier 1A, or to a Corrective Action Plan (CAP), which may include proposed corrective actions and a Tier 2 evaluation.

Table 7-3. Tier 1 for PAH Risk Based Screening Levels (RBSLs)

Tier 1 Risk-Based Screening Levels (RBSLs) - For the 16 Priority PAHs							
Media	**Surficial Soil [mg/kg]**		**Subsurface Soil [mg/kg]**		**Soil Vapor [µg/m^3]**	**Ground-water [mg/l]**	**Ground-water [mg/l]**
Complete Exposure Pathway	Ingestion/ Dermal/ Inhalation		Leachate to Groundwater Ingestion		Indoor Air Inhalation	Indoor Air Inhalation	Ground-water Ingestion [MCLs]
Land Use	Residential	Industrial	Res	Ind			
Acenaphthene	3,000	35,000	> Sat[1]	> Sat[1]	> VP[2]	> Sol[3]	0.420
Acenaphthylene[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	N/A
Anthracene	15,000	180,000	> Sat[1]	> Sat[1]	> VP[2]	> Sol[3]	2.1
Benzo(a)-anthracene	0.41	1.5	1.6	1.6	> VP[2]	> Sol[3]	4.8 E-6
Benzo(a)-pyrene	0.041	0.15	4.8** or > Sat[1]*	4.8** or > Sat[1]*	> VP[2]	> Sol[3]	4.8 E-6** or 2 E-4*
Benzo(b)-fluoranthene	0.41	1.5	4.5	4.5	> VP[2]	> Sol[3]	4.8 E-6
Benzo(g,h,i)-perylene[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	N/A
Benzo(k)-fluoranthene	4.1	15	4.4	4.4	> VP[2]	> Sol[3]	4.8 E-6
Chrysene	41	150	1.5	1.5	> VP[2]	> Sol[3]	4.8 E-6
Dibenzo(a,h)-anthra-cene	0.041	0.15	14	14	> VP[2]	> Sol[3]	4.8 E-6
Flouranthene	1,800	19,000	> Sat[1]	> Sat[1]	> VP[2]	> Sol[3]	0.280
Fluorene	2,000	23,000	> Sat[1]	> Sat[1]	> VP[2]	> Sol[3]	0.280
Indeno(1,2,3-CD) pyrene	0.41	1.5	> Sat[1]	> Sat[1]	> VP[2]	> Sol[3]	4.8 E-6
Naphthalene	2000	23,000	> Sat[1]	> Sat[1]	> VP[2]	28[4]	0.140
Phenanthrene[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	NTD[5]	N/A
Pyrene	1,500	18,000	> Sat[1]	> Sat[1]	> VP[2]	> Sol[3]	0.210

[1] > Sat denotes that even at a concentration equal to the saturation of the chemical, a hazard quotient of 1 and a cancer risk of 1 $^{E-6}$ is not exceeded.
[2] > VP denotes that even at a concentration equal to the vapor pressure of the chemical, a hazard quotient of 1 and a cancer risk of 1 $^{E-6}$ is not exceeded.
[3] > Sol denotes that even at a concentration equal to the solubility of the chemical, a hazard quotient of 1 and a cancer risk of 1 $^{E-6}$ is not exceeded.
[4] Industrial land use >Sol
[5] Health based risk levels for this compound are currently under development (NTD denotes no toxicological data).
* This RBSL will be in effect for releases that occurred prior to September 14, 2004.
** This RBSL will be in effect for releases that occurred on or after September 14, 2004.

8.0 Tier 1A

A Tier 1A evaluation is to be used as a simplified alternative to a Tier 2 evaluation for sites that do not meet Tier 1 RBSLs. Tier 1A allows the use of site specific data as input to the Tier 1 model (available at the Division of Oil and Public Safety website http://oil.cdle.state.co.us) for the development of potentially less stringent, but protective cleanup goals. OPS will not require the preparation of a CAP for sites that can be closed using Tier 1A criteria. Table 8-1 presents the Tier 1A input parameters that may be changed when conducting a Tier 1A evaluation. Also included in Table 8-1 are the applicable exposure pathways, as well as the default parameter values used to calculate the Tier 1 RBSLs presented in Table 7-1.

8.1 Tier 1A Data Collection

Tier 1A will be appropriate to use for those sites where it is believed the collection of site specific data will lead to a significantly different cleanup goal. If Tier 1A is to be utilized, site specific data must be collected and used to calculate Tier 1A Site Specific RBSLs (SS-RBSLs). Values for the following parameters may be derived from site-specific samples or data and subsequently utilized in the Tier 1A model. A description of the method of obtaining these data is presented below. For further information on input variables that can be modified in Tier 1A, see Appendix C, Section C.1.4.

8.1.1 Depth to Subsurface Soil Source

The value for this parameter is obtained by measuring the vertical distance between the ground surface and the depth where contamination above RBSLs was first detected.

8.1.2 Depth to Groundwater

This parameter is used for the groundwater to indoor air pathway and represents the vertical distance between the base of the potentially impacted structure and the top of the saturated interval.

Table 8-1. Tier 1A Input Parameters and Default Values
(Presented as Table 5-2 in 7 CCR 1101-14)

Parameters	Applicable Exposure Pathway(s)	Default Parameter Value
Depth to subsurface soil source	Soil vapor to indoor air	100 cm
Depth to groundwater	Groundwater to indoor air	380 cm
Thickness of the capillary fringe [1]	Groundwater to indoor air	5 cm
Thickness of the unsaturated zone [1]	Groundwater to indoor air	375 cm
Length of source	Soil leaching to groundwater Surficial soil[2]	1,000 cm
Width of source	Soil leaching to groundwater	1,000 cm
Darcy Groundwater velocity	Soil leaching to groundwater	1,800 cm/yr
Fraction of organic carbon	Soil leaching to groundwater Surficial soil[2] Soil vapor to indoor air[2]	0.009
Total porosity	Soil vapor to indoor air Groundwater to indoor air Surficial soil[2] Soil leaching to groundwater[2]	0.38
Unsaturated zone water content	Soil vapor to indoor air Groundwater to indoor air Surficial soil[2] Soil leaching to groundwater[2]	0.12
Unsaturated zone air content	Soil vapor to indoor air Groundwater to indoor air Surficial soil[2] Soil leaching to groundwater[2]	0.26
Infiltration rate	Soil leaching to groundwater	5 cm/yr
Soil bulk density	Surficial soil[2] Soil leaching to groundwater[2] Soil vapor to indoor air[2]	1.64
Distance to point of exposure in groundwater	Soil leaching to groundwater	1,000 cm
Effective porosity	Soil leaching to groundwater	0.25

[1] In order to change these parameters in Tier 1A, a soil sample must be collected from the unsaturated zone and a sieve analysis performed to estimate grain size.
[2] These pathways are only slightly affected by changes in the corresponding input parameter.

8.1.3 Thickness of Capillary Fringe

Capillary fringe is the zone immediately above the water table, where water is drawn upward by capillary attraction. This input parameter is only used for the groundwater to indoor air pathway. As it is very difficult to measure the capillary fringe, the OPS has developed a table of default values for the thickness of the capillary fringe based on soil type. To calculate a site-specific value for the capillary fringe thickness, a sieve analysis should be performed on a soil sample representative of the soil immediately above the water table. Table 8-2 presents typical capillary rise values (thickness) reported by Guyman (1994) as a function of soil type and grain size.

Table 8-2. Typical Capillary Rise Values

Unconsolidated Material	Grain Size (mm)	Capillary Rise (cm)
Fine Gravel	5 - 2	2.5
Very Coarse Sand	2 - 1	6.5
Coarse Sand	1 - 0.50	13.5
Medium Sand	0.50 - 0.20	24.6
Fine Sand	0.20 - 0.10	42.8
Silt (sample #1)	0.10 - 0.05	105.2
Silt (sample #2)	0.05 - 0.02	200.0

8.1.4 Thickness of Unsaturated Zone

This input parameter is only utilized for the groundwater to indoor air pathway and is determined by subtracting the thickness of the capillary fringe from the depth to groundwater.

8.1.5 Length of Source

The length of the source can be modified to reflect the measured length of contaminated soil parallel to the direction of groundwater flow (soil leaching to groundwater pathway) or wind (surficial soil vapor and particulate inhalation pathway).

8.1.6 Width of Source

The width of the source can be modified to reflect the measured length of contaminated soil perpendicular to the direction of groundwater flow (soil leaching to groundwater pathway).

8.1.7 Darcy Groundwater Velocity

The Darcy groundwater velocity is the product of the hydraulic gradient and the hydraulic conductivity. Hydraulic gradient is the slope of the water table in the direction of groundwater flow. This slope is typically expressed as a unit change in water table elevation per unit horizontal distance (e.g. ft/ft). Hydraulic conductivity is the coefficient of proportionality describing the rate at which water can move through a permeable medium. Hydraulic conductivity is estimated by aquifer testing (pumping test or slug test) in on-site wells.

8.1.8 Fraction of Organic Carbon (F_{oc})

Fraction of organic carbon is the fraction by weight of total naturally occurring organic carbon in a soil sample. The F_{oc} will be determined by laboratory analysis of samples collected from the site. These samples must be collected from the same soil unit as the predominant unit in the source area. These samples should be collected from outside of the area of contamination to obtain results representative of natural soil conditions.

8.1.9 Total Porosity of the Unsaturated Zone

Total porosity is the volume of pore spaces divided by the total volume of soil. This parameter represents the sum of the water and air content of a soil sample. It is calculated by laboratory analysis of an site-specific undisturbed soil sample that is representative of the soil medium.

8.1.10 Unsaturated Zone Water Content

The unsaturated zone water content should be measured in a laboratory from site-specific soil samples.

8.1.11 Unsaturated Zone Air Content

The unsaturated zone air content will be calculated by subtracting the water content from the measured total porosity.

8.1.12 Infiltration Rate

Infiltration rate is the volume of water traveling through the unsaturated zone and reaching groundwater per unit time. Infiltration rate is calculated by taking 10% of the average annual precipitation.

8.1.13 Soil Bulk Density

Soil bulk density is the dry weight of soil per unit volume.

8.1.14 Distance to Point of Exposure in Groundwater

This is the distance from the identified source to a POE.

8.1.15 Effective Porosity of the Saturated Zone

Effective porosity is the volume fraction of the soil (or rock) that is available to transport water.

8.2 Tier 1A Decision Process

If the source concentrations are lower than the Tier 1A SS-RBSLs for all completed pathways a No Further Action Required designation may be requested. If the source concentrations exceed the Tier 1A SS-RBSLs, the owner/operator will be required to prepare a CAP, which will include proposed corrective actions and/or a Tier 2 evaluation. The owner/operator will maintain the option of cleaning up to Tier 1 or 1A goals and will not be required to perform a Tier 2 evaluation. A proposal to proceed to Tier 2 may be included in the CAP.

9.0 Site Characterization Report (SCR)

The SCR must be completed on the form provided by the OPS and will be due 90 days from the release date (see section 2.2). The SCR includes detailed instructions including what information is required to be submitted. A complete SCR will include, identification of POEs, an updated Site Classification Checklist, land use criteria, identification of complete exposure pathways, determination of the full extent of contamination in soil and groundwater, and the hydrogeologic characteristics of the site and the surrounding area. The SCR will include a comparison of source concentrations with Tier 1 RBSLs.

If a Tier 1A evaluation was performed using site specific data input into the Tier 1 model then the Tier 1A table will also be included in the SCR with a comparison of the source concentrations and the Tier 1A SS-RBSLs. If contamination on site exceeds Tier 1 or Tier 1A levels, the owner/operator will be required to submit a CAP.

The SCR will also include a preliminary recommendation of remedial methods to be evaluated in the CAP. As with all reports the SCR must be submitted to the OPS in duplicate.

The owner/operator may submit a No Further Action Request Report (NFAR) in lieu of the SCR if no COCs have ever been detected as a result of the release at levels in excess of the Tier 1 RBSLs, and TPH has not been detected above 500 mg/Kg in soils. The NFAR must be submitted in duplicate on the approved form.

10.0 Corrective Action Plan (CAP)

A CAP must be submitted for all sites that do not meet Tier 1 RBSLs or approved Tier 1A SS-RBSLs. A CAP Modification must be submitted in duplicate on the form provided by the OPS. A completed CAP will include the following:

- An initial qualitative screening of the technological and economic feasibility of the most commonly used soil and groundwater remediation methods as applied to the site.

- The owner/operator must demonstrate the technological feasibility of a minimum of three alternative methods of addressing both soil and groundwater contamination. Each of these methods must be protective of human health, safety, and the environment. The technological feasibility of each proposed method will be presented on OPS summary forms. If applicable, a proposal to conduct a Tier 2 evaluation can be substituted for one of the soil and groundwater remediation methods. If a Tier 2 evaluation is proposed, the CAP will include an explanation of site conditions that justify the suitability of this site for Tier 2.

- The owner/operator must demonstrate the economic feasibility of the three alternative methods of addressing both soil and groundwater contamination evaluated in the technical feasibility analysis. The economic feasibility of each proposed method will be presented in the Corrective Action Plan on OPS summary forms. The Tier 2 economic feasibility analysis will require an estimate of costs for data collection, modeling, and cleaning up to Tier 2 SSTLs.

- A remedial design which includes the results of pilot testing

- A plan for the implementation of the CAP. The plan will include a summary of the overall remediation strategy and various details of the remediation system designed such as a description of the equipment to be used and the proposed placement of materials.

- In all cases where contaminated soils have impacted or have the potential to impact groundwater, a groundwater monitoring plan must be prepared. This plan should include a description of the upgradient sample point, the downgradient POCs, the frequency and duration of the monitoring plan, and the laboratory analyses.

- A plan for system monitoring, maintenance, and reporting.

- The CAP must be implemented within 90 days of the CAP approval or within the time schedule presented in the approved CAP. If any deviations from the approved CAP are necessary, due to unforeseen conditions, then a CAP amendment must be submitted to the OPS.

Design features for in-situ remediation methods are described in EPA 510-B-95-007 *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites, A Guide for Corrective Action Plan Reviewers*, May 1995.

10.1 Confirmation Testing of Selected Corrected Action

10.1.1 Pilot Testing

Pilot testing is required to be conducted to assess whether or not the remediation method selected is technologically feasible. Data from another site may be substituted only in the instances where another site is in close proximity and the geologic and hydrologic conditions are similar. Appendix B, Section 6.0 includes information on pilot testing. The results of the pilot test will be presented in the Corrective Action Plan on OPS summary forms.

10.1.2 Contaminant Transport Modeling

Contaminant transport modeling is required to be conducted for sites where remediation through natural attenuation is proposed as the remedial alternative. At a minimum, the model used should be able to predict estimated travel time from the contaminant source to a POE, and account for processes such as advection, adsorption, and biodegradation. In addition to calculating the predicted travel time, it will be necessary to validate the modeling results with a minimum of four consecutive quarters of groundwater (or soil) monitoring data.

11.0 Tier 2

11.1 Tier 2 Models

The purpose of Tier 2 is to allow for the use of site-specific data as input for more sophisticated predictive models. Generally in Tier 2, the models calculate site-specific target levels (SSTLs) which are less stringent than Tier 1 RBSLs or Tier 1A SS-RBSLs, but equivalently protective. There will be rare cases, however, when site conditions warrant more stringent cleanup goals than those achieved by using the Tier 1 RBSLs. In those cases Tier 2 SSTLs may actually be more conservative than Tier 1 RBSLs.

The significant differences between Tier 1 and Tier 2 models are as follows:

- In Tier 1 models, the contaminant source is assumed to be constant (non-decreasing) over time whereas the models in Tier 2 can account for a finite source.

- In Tier 1 the source is assumed to be in direct contact with the water table whereas Tier 2 allows for a vertical separation between the bottom of the source and the groundwater table.

- Tier 2 models allow for biodegradation in the unsaturated and saturated zones.

Acceptable models for the unsaturated zone will be analytical, transient, capable of modeling one-dimensional dispersion and degradation, and calculating effective solubility for individual constituents in a mixture. Acceptable models for the saturated zone will be analytical or semi-analytical, transient, and simulate retardation, degradation, one-dimensional flow and three-dimensional dispersion. Examples of two models which are acceptable are:

- BP Unsaturated Zone and Saturated Zone Model
- API/DSS VADSAT

The BP Unsaturated Zone and Saturated Zone Model and API/DSS VADSAT models are based on nearly identical methods and equations, and generate essentially identical results. These models have straightforward data requirements, the ability to handle residual levels of contamination, and are user friendly. Detailed summaries of these models are provided in Appendix C. The models can be obtained from the following sources:

BP RISC

Streamline Groundwater Applications
520 Chicopee Row
Groton, MA 01450
Tel: (978) 772-4622
Fax: (978) 772-0595
www.groundwatersoftware.com

API/DSS

American Petroleum Institute (API)
1220 L Street NW
Washington DC 20005
Contact: Sue Covello
(202) 682-8319
www.api.org

11.2 Tier 2 Model Input Parameters

The following table (Table 11-1) lists the input parameters for which site specific data can be collected in Tier 2. The table lists input parameters for the BP Risc model, which the OPS will be using to duplicate Tier 2 SSTLs submitted by owners/operators. Although all of the models will require similar data, there may be variations in input requirements. It is the owner/operator's responsibility to insure that input parameters are appropriate for the model selected.

Table 11-1 Tier 2 Input Parameters (BP Risc)

Tier 2 Input Parameters (BP Risc)	
Source Parameters	
Depth to top of contamination	Width of source
Length of source	Thickness of contamination
Unsaturated Zone Properties	
Soil bulk density	Saturated conductivity
Total porosity of the unsaturated zone	Infiltration rate
Residual water content	Van Genuchten's N
Fraction of organic carbon	Thickness of unsaturated zone
Gradient	Degradation rate (for each chemical)
Aquifer Properties	
Effective porosity of saturated zone	Soil bulk density
Hydraulic conductivity	Hydraulic gradient
Fraction of organic carbon	Degradation rate (for each chemical)
Point of Exposure Location	
Distance downgradient	Well screen interval
Distance crossgradient	
Lens parameters (if applicable)	
Total porosity	Van Genuchten's N
Residual water content	Thickness
Saturated conductivity	
Source Concentration Parameters	
Source concentration(s)	TPH Mixture

Values for the above parameters may be derived from site-specific samples or data and subsequently utilized in the Tier 2 model. A description of the method of obtaining the data not previously provided in Section 8 (Tier 1A) is presented below.

11.2.1 Depth to Top of Contamination

The value for this parameter is obtained by measuring the vertical distance between the ground

surface and the depth where contamination was detected.

11.2.2 Thickness of Contamination

The value for this parameter is obtained by measuring the vertical interval where contamination above RBSLs was detected.

11.2.3 Residual Water Content

Residual water content is the water naturally remaining in soil after drainage. The residual water content should be measured in a laboratory from site-specific soil samples.

11.2.4 Van Genuchten's N

Van Genuchten's N is a parameter, used in the Tier 2 models, to estimate long-term average moisture content in the unsaturated zone.

11.2.5 Thickness of Unsaturated Zone

This parameter is the vertical distance from the ground surface to the water table.

11.2.6 Degradation Rate

The site specific degradation rate is calculated from the measured half-life of the contaminant in days.

11.2.7 Distance Downgradient and Crossgradient of POE

These parameters equal the maximum distances along the upgradient to downgradient axis to a given POE and the distance of the POE from the axis and perpendicular to it.

11.2.8 Well Screen Interval

This parameter is the distance above and below the water table the well screen extends. This is directly measured in the field or obtained from well installation logs.

11.2.9 Source Concentration

The source concentration is the highest level of contamination remaining as a result of the release. This is obtained from the laboratory analysis of samples collected from those areas identified as having the highest potential for contamination.

11.2.10 Molecular Weight of TPH Mixture

This may be determined by laboratory analysis of product samples collected from the site.

11.3 Tier 2 in the OPS Process

In order to conduct a Tier 2 evaluation it is necessary to demonstrate that the costs for this evaluation (and potential cleanup) are less than the costs of cleaning up to Tier 1 or Tier 1A levels. These costs include those associated with the collection of additional site specific data, additional analyses and modeling, and the cost of corrective actions that would be necessary to attain the SSTLs. If a Tier 2 analysis is selected, this information must be included in the CAP that will be due 150 days following the release.

12.0 Tier 3

Tier 3 analysis is currently under consideration by the OPS.

13.0 Monitoring

After the remediation has been performed or a decision has been made not to perform remediation, the OPS may require groundwater monitoring of the site. The purpose of monitoring is to insure that the assumptions used in developing the recommended corrective action were correct. Generally this monitoring will be on a quarterly basis. The OPS uses monitoring to insure that contamination left in place is not migrating or causing adverse effects that were not previously noted. Monitoring reports must be submitted on the standard report format developed by OPS. As with all reports, they must be submitted in duplicate to the OPS.

14.0 No Further Action

When soil and groundwater have been remediated to, or demonstrated to be at levels below all applicable RBSLs at the POEs, the OPS may issue a No Further Action letter for the site. This letter states the site has met OPS requirements and does not currently pose a risk to human health, or the environment. This letter does not release the owner/operator from liability, if site conditions change, and/or future risks resulting from this release become apparent.

15.0 Flowchart

The attached flowchart depicts the process an owner/operator must follow from the discovery of the release to the request for closure.

State of Colorado
Dept. of Labor& Employment
Oil Inspection Section
RBCA Process Flow Chart

DATE: December 10, 1998